Groundwater Response Action Plan
Lockheed Martin Middle River Complex
2323 Eastern Boulevard
Middle River, Maryland

Prepared for:

Lockheed Martin Corporation

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(CD ATTACHED)

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ACRONYMS

AIChE	American Institute of Chemical Engineers
ARARs	Applicable or Relevant and Appropriate Requirements
ARD	anaerobic reductive-dechlorination
AWQC	Ambient Water Quality Criteria
bgs	below ground surface
CERCLA	(federal) Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
cis-1,2-DCE	cis-1,2-dichloroethene
CO_2	carbon dioxide
COC	chemical(s) of concern
COMAR	Code of Maryland Regulations
CSF	cancer-slope factor
CWA	(federal) Clean Water Act
Cv	flow coefficient
DHC	dehalococcoides
DNAPL	dense non-aqueous-phase liquid
DO	Dissolved oxygen
DP	differential pressure
DPT	direct-push technology
EOS®	Emulsified Oil Substrate
EPA	United States Environmental Protection Agency
ERH	electric-resistance heating
GAC	granular activated carbon
gpm	gallons per minute
GRA	general response action
HDPE	high-density polyethylene
hp	horsepower
IC	institutional control
ILCR	individual lifetime-cancer risk
ISCO	*in situ* chemical oxidation
J&E	Johnson and Ettinger
LCA	Life cycle assessment
LDRs	Land Disposal Restrictions

Lockheed Martin	Lockheed Martin Corporation
MCL	maximum contaminant level
MDE	Maryland Department of the Environment
µg/L	microgram(s) per liter
mg/L	milligram(s) per liter
MMBTU	million British Thermal Units
MNA	monitored natural attenuation
MRAS	Middle River Aircraft Systems
MRC	Middle River Complex
MSDS	material safety data sheet
msl	mean sea level
MS2	Maritime Systems & Sensors
mV	milliVolt
NCP	*National Oil and Hazardous Substances Pollution Contingency Plan*
NEPA	National Environmental Policy Act
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
OCP	Oil Control Program
ORP	oxidation-reduction potential
OSHA	(federal) Occupational Safety and Health Administration
P&ID	piping and instrumentation diagram
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PM10	Particulate matter
POTW	publicly owned treatment works
PPE	personal protective equipment
PRB	Permeable reactive barrier
psi	pounds per square inch
PVC	polyvinyl chloride
RAO	response action objective
RAP	response action plan
RBC	risk-based concentration
RCRA	(federal) Resource Conservation and Recovery Act
REC	Recognized Environmental Condition
RfD	reference dose
RME	reasonable maximum exposure
rpm	revolutions per minute
scfm	standard cubic feet per minute

SO_x	sulfur oxides
SPLP	Synthetic Precipitation Leaching Procedure
SSO	site safety officer
S.U.	standard units
SVE	Soil vapor extraction
TBC	to be considered
TCA	total cost analysis
TCE	trichloroethene
Tetra Tech	Tetra Tech, Inc.
TOC	total organic carbon
TRACI	Tool for the Reduction of Chemical and other Environmental Impacts
UIC	underground injection control
USACE	United States Army Corps of Engineers
USLCI	U.S. Life Cycle Inventory
USC	United States Code
UST	underground storage tank
VCP	Voluntary Cleanup Program
VFD	variable-frequency drive
ViM	Vapor Intrusion Model
VOC	volatile organic compound

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GLOSSARY

1,4-dioxane—A clear, flammable volatile organic compound mainly used as an industrial solvent or solvent stabilizer in a variety of manufacturing processes, including electronics, metal finishing, fabric cleaning, pharmaceuticals, herbicides, pesticides, antifreeze, and paper. It is also found in household products such as detergents, shampoos, body lotions, dishwashing soap, and cosmetics. It does not break down naturally in the environment, so it tends to linger in soil and groundwater for a very long time.

adsorb, adsorption—A chemical process whereby water-borne contaminants adhere or bond to solid particles, effectively removing the contaminants from water; also referred to as *sorbing* or *sorption*.

anaerobic reductive dechlorination (ARD)—A natural breakdown or treatment process in which anaerobic bacteria (i.e., bacteria that do not require oxygen) remove chlorine from chlorinated compounds (such as trichloroethene). Once all possible chlorine atoms are taken away, a chemical called "ethene" is formed, which is not harmful to human health or the environment.

Applicable or Relevant and Appropriate Requirements (ARARs)—Environmental cleanup standards and requirements (federal and state laws and regulations) that must be attained during cleanup operations and maintained at project completion (a directive of the federal Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]).

aquifer—An underground layer of rock, sand, silt, or clay that contains sufficient water to serve as a source of groundwater for wells and springs. A *surficial aquifer* refers to the uppermost aquifer at a given location (i.e., closest to the ground surface).

bioaugmentation—A treatment technology in which specialized bacteria that consume organic compounds are added to the subsurface (i.e., under the ground).

biodegradation—A natural process whereby naturally occurring bacteria decompose or break down contaminants or chemicals.

biostimulation—A treatment technology in which chemicals and/or nutrients are added to the subsurface to increase the activity of naturally occurring bacteria that consume organic compounds.

bulk density—A soil property defined as the mass of a soil sample divided by the volume of the soil and its pore spaces (open spaces between sediment particles, or "bubbles" and cracks in rock) and void spaces. The bulk density of a soil can change depending on the degree of compaction. More compaction results in a higher bulk density value.

chemical(s) of concern (COC)—Chemicals identified by a regulatory agency (such as the United States Environmental Protection Agency [EPA] or a state environmental agency) found at a site at concentrations higher than what is considered safe, and which must be cleaned up and/or monitored.

chitin—A protective covering; a tough semitransparent substance that forms part of the protective outer casing of some insects and other arthropods and the cell walls of some fungi. Chitin has many industrial uses, including as an additive to thicken and stabilize foods and pharmaceuticals and as a binder in dyes, fabrics, and adhesives. Industrial separation membranes and ion exchange resins can also be made from chitin.

coagulation—In wastewater treatment, the promotion of the settling of fine suspended particles by the addition of chemicals.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)—Commonly called Superfund, a federal law passed in 1980 and modified in 1986 by the Superfund Amendments and Reauthorization Act (SARA). Among other things, this addresses the remediation of hazardous substance disposal sites.

containment—A technology or design that prevents the movement of contaminants from a site but does not necessarily treat or remove the contaminants.

dechlorination—The breakdown process of a chlorinated organic compound that contaminates soil and groundwater. This process removes chlorine atoms from the chemical during biological degradation. For example, the complete dechlorination of trichloroethene (TCE) creates ethene.

dehalococcoides—An important microbe in *in situ* biodegradation. It is necessary to biodegrade trichloroethene to ethene, an environmentally benign compound.

dense non-aqueous phase liquids (DNAPL)—An accumulation of liquid chemicals, such as solvents, in the ground that are more dense than water, tend to sink, and tend to adsorb (i.e., cling to) to rock, soil, and pore spaces in aquifers. DNAPLs are difficult to remove and can be an ongoing source of groundwater contamination.

drawdown—A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer by pumping groundwater from wells. The drawdown is the vertical distance between the original water level and the new water level in the well.

effective porosity—A measure of the pore spaces (open spaces between sediment particles, or "bubbles" and cracks in rock) that are interconnected in the subsurface, effectively allowing fluids to flow through the rock or sediment. Some of the groundwater will cling to the sediment or rock surfaces and not drain because some of the pores are not interconnected; thus, "effective porosity" is less than the "total porosity."

***ex situ*—**Away from the original location or place where pollutants are found; in this report, *ex situ* means on-site and at the surface, but not in place. For example, an *ex situ* treatment of contaminated soil or groundwater would remove (through pumping or digging, for example) the soil or groundwater from where it was found and subject it to a treatment process. (See also *in situ*, below.)

fines—Very small solid particles that slowly settle out of water.

flocculation—In wastewater treatment, the formation of clusters of fine suspended particles to improve settling, using gentle mixing. This step typically follows coagulation.

fraction of organic carbon—The measure of the total weight of organic carbon in a soil sample relative to the total weight of the soil sample.

groundwater—Water beneath the ground surface that fills open spaces between particles such as sand, soil, and gravel, or that fills cracks, fractures, and voids in rock.

hydraulic conductivity—The rate at which water can move through a permeable medium, such as an aquifer.

hydraulic gradient—The slope of the water table (in an unconfined aquifer) or potentiometric surface (in a confined aquifer) that controls the general direction of where groundwater flows (e.g., groundwater flows from high elevations to lower elevations).

***in situ*—**In this report, *in situ* means on-site and in place. For example, an *in situ* treatment of contaminated soil or groundwater would treat these media in place, without removing the soil or groundwater to send it through a treatment process.

***in situ* bioremediation—**A treatment technology in which chemicals and/or nutrients are added to groundwater *in situ* (as opposed to extracted groundwater) to increase the activity of naturally occurring bacteria that consume and degrade organic compounds. Bioaugmentation is often included if the naturally occurring bacteria are not present in sufficient quantity to break down the compounds.

***in situ* chemical oxidation (ISCO)—**A treatment technology in which chemicals are added to groundwater *in situ* (as opposed to extracted groundwater) to destroy site contaminants via oxidation.

Land use controls—Engineered and non-engineered (administrative) controls formulated and enforced to regulate current and future land use options. Engineered controls include fencing and signage. Non-engineered controls typically consist of administrative restrictions that prohibit certain types of development and/or groundwater use.

leachability—The relative tendency of chemicals (in this case, primarily metals) to be transferred from soil to groundwater based on the groundwater conditions.

maximum contaminant level (MCL)—The maximum concentration level that EPA considers safe for human consumption of a chemical in drinking water.

model—A model in this report is a numerical (i.e., mathematical) simulation of environmental conditions and processes. Groundwater flow and contaminant fate (i.e., endpoints) and transport (i.e., migration) were modeled for this report, but models can also simulate air circulation and other environmental phenomena. The model is first calibrated to ensure that it accurately represents known environmental conditions and other factors before then predicting, through simulation of various scenarios, future conditions, such as contaminant concentrations (in environmental media) over time.

model domain—The project area and subsurface units represented within the fate and transport model.

***National Oil and Hazardous Substances Pollution Contingency Plan* (NCP)—**A federal plan that determines the party or parties that will respond and how they will respond to a spill or release, or threat of release, of oil or a hazardous substance. It establishes a National Response Team, headed by EPA, and outlines requirements for accident reporting, spill containment, and cleanup.

natural attenuation—Naturally occurring reductions in contaminant concentrations in the absence of active cleanup methods. Such reductions can occur through biological degradation, volatilization, and/or dilution, as well as through other processes.

permeable reactive barrier—Reactive materials placed in the subsurface (by trenching or drilling) to catch contaminated groundwater and change contaminants, as they pass through the barrier, into less harmful, environmentally acceptable products.

plume—A body of contaminated groundwater moving away from its source. The movement of contaminants is influenced by such factors as local groundwater flow patterns, aquifer characteristics (such as pH, mineral content, geologic characteristics, and other factors), and the nature and type of contaminant that is moving through the groundwater.

potentiometric surface—The imaginary surface of an aquifer representing the level to which water will rise in a well installed within that aquifer. The water table represents the potentiometric surface of an unconfined aquifer, whereas the potentiometric surface of a confined aquifer (one capped by a less permeable layer) may rise above the actual top of the aquifer.

pumping test—A test to determine groundwater or well characteristics that involves removing/pumping groundwater from a well or other extraction point and measuring the resultant drop in water levels.

response action—The process of correcting and/or cleaning up environmental contamination. This process is governed by various federal and state laws, regulations, and other requirements. A response action is an action or series of actions to reduce, isolate, or remove contamination from an environmental medium (e.g., soil, air, groundwater, surface water), with the goal of preventing exposure of people or animals to that contamination and reducing its impact to the environment.

response action objectives (RAOs)—Cleanup objectives specifying contaminants to be cleaned up, the level of cleanup, the area of cleanup, and the time required to achieve cleanup adequate to protect human health and the environment.

residual—A modeling term that represents the difference between model-computed and field-measured values for various environmental conditions or phenomena (such as hydraulic head or groundwater flow rate).

retardation—A chemical and physical reaction in the subsurface that changes the average speed of movement of some kinds of contaminant plumes, so that the plume travels much slower than groundwater. Retardation is primarily due to adsorption (i.e., adhering) of contaminants to soil

and natural organic material that effectively holds back (i.e., retards) contaminants, limiting their ability to move at the same speed as the groundwater.

slug test, also known as **single-well permeability tests—**A test to determine hydraulic conductivity that involves the sudden addition or removal of a known volume (typically a large cylinder) from a well and measuring the resultant change in water level.

soil-water partition coefficient—A measure of how much a chemical clings (sorbs) to soil versus how much dissolves in the surrounding water. Expressed as a ratio of "the amount of chemical that adsorbs to soil solids" to "the amount that dissolves in water" (expressed in liters per kilogram [L/kg]).

sorb, sorption—A chemical process whereby water-borne contaminants adhere or bond to solid particles, effectively removing the contaminants from water; also referred to as *adsorption*.

specific yield—The ratio of the volume of water an aquifer will yield (give up) to the volume of rock or sediment when it is allowed to drain under the force of gravity. The specific yield is a property of unconfined aquifers.

storativity—The amount of water an aquifer releases from (or takes into) storage (per unit area per unit change in hydraulic head), for example, when water is pumped from a well.

steady-state model—A model of an aquifer system that is in equilibrium (or in balance) with respect to groundwater flowing into and out of the model areas of interest. In a steady-state model simulation, the groundwater head and flux conditions do not change over time.

stratigraphy—The study and classification of rock layers using their physical and geochemical characteristics and geologic age.

subsurface utilities—Pipe and/or conduit buried in the ground and currently or formerly used in facility operations. This may include storm drains, sanitary sewer pipes, fire water pipes, fuel piping, electrical or telephone lines, etc.

total porosity—A measure of the total volume of pore spaces (open spaces between sediment particles, or "bubbles" and cracks in rock) in the subsurface that can contain groundwater. Some groundwater will cling to sediment or rock surfaces and not drain (because some pores are dead ends), in which case the "total porosity" will be greater than the "effective porosity."

transient model (time-dependent**)—**A model of an aquifer system that is not in equilibrium with respect to groundwater flowing into and out of the model area of interest. In a transient-state model simulation, groundwater head and flux conditions change over time.

trichloroethene (also known as **TCE** or **trichloroethylene)—**A nonflammable, colorless liquid chemical with a slightly sweet odor commonly used as an industrial solvent and metal degreaser. Trichloroethene has been used for decades and is still used in many household and consumer products such as typewriter correction fluid, paint removers, adhesives, spot removers, etc.

vapor intrusion—The movement (migration) of chemical vapors from the ground into basements and overlying buildings.

volatile organic compounds (VOCs)—A group of chemicals (organic compounds) that will vaporize or evaporate into the atmosphere at room temperature. They often have a sharp smell and can come from many products, such as office equipment, adhesives, carpeting, upholstery, paints, petroleum products, solvents, and cleaning products. Trichloroethene is an example of a VOC.

zero-valent iron—A type of pure iron, typically in the form of small particles, used to construct subsurface reactive walls to treat and reduce contaminant levels in groundwater.

Executive Summary

Environmental stewardship of our activities is an important aspect of Lockheed Martin Corporation's commitment to the communities in which we operate. Accordingly, the Corporation has assumed responsibility for the assessment and cleanup of environmental impacts for the Lockheed Martin Middle River Complex located at 2323 Eastern Boulevard in Middle River, Maryland. Tetra Tech, Inc. has prepared this *Groundwater Response Action Plan—Lockheed Martin Middle River Complex* for Lockheed Martin Corporation in accordance with the requirements of the Maryland Department of the Environment's Voluntary Cleanup Program (Section 7-508 of the Environment Article, *Annotated Code of Maryland*). It provides relevant background information necessary to evaluate response action alternatives for site groundwater and to provide details on the implementation of the selected alternative. The long-term goal for the site is to receive a Certificate of Completion from the Maryland Department of the Environment under a Tier 1B (Residential Restricted) future land use and restriction category. Response actions for soil throughout the Middle River Complex are presented in separate Soil Response Action Plans. Evaluation of sediment impact in nearby surface water bodies is being addressed under a separate regulatory framework.

The Middle River Complex comprises approximately 160 acres, including 12 main buildings, an active industrial area and yard, perimeter parking lots, an athletic field, a vacant concrete lot, a trailer and parts storage lot, and various grassy spaces along its perimeter. This *Response Action Plan—Lockheed Martin Middle River Complex* primarily addresses groundwater contamination in areas outside of the active industrial area at the Middle River Complex. Groundwater in the industrial area will be addressed upon completion of delineation of contamination in that area, or if the property's use changes in the future. Implementing the selected groundwater response action before delineation in the active industrial area will expedite cleanup of the accessible areas of the site and allow more options for use of a large portion of the site in a timely manner.

Nature and Extent of Groundwater Contamination

Environmental contamination at the Middle River Complex was identified in the 1980s. Since that time, more than 150 groundwater monitoring wells have been installed and sampled at the site as part of ongoing investigations. The results of these investigations show that groundwater at several areas beneath the site contains various volatile organic compounds, 1,4-dioxane, and metals above the Maryland Department of the Environment's Generic Numeric Cleanup Standards for Groundwater. Section 2.2.1 of the *Response Action Plan* provides more data on groundwater contamination at the Middle River Complex. Following is a summary of the nature and extent of contamination at the Middle River Complex:

- The primary volatile organic compound in site groundwater and addressed in this *Response Action Plan* is trichloroethene, found primarily in two areas: one in the western portion of the site and one in the eastern portion.

- The western trichloroethene area is the smaller of the two and contains lesser concentrations than the eastern area, with a maximum trichloroethene concentration of 2,800 micrograms per liter. The primary suspected source of trichloroethene contamination in this area is a solvent spill from a waste oil tank located north of Tilley Chemical. A possible secondary trichloroethene source in this area is the wastewater treatment plant that was located south of Tilley Chemical and Chesapeake Park Plaza. The size and timing of any releases or spills from these possible sources are unknown.

- The eastern area is larger, and has maximum trichloroethene concentrations of 3,900 micrograms per liter in the northern portion and 19,000 micrograms per liter in the southern portion; the data suggest that these are two distinct sources. In the northern portion, a solvent spill likely occurred south of Building C, possibly related to past handling and storage practices; current data indicate that this did not occur under the Building C basement. In the southern portion, a solvent spill likely occurred southeast of former Building D, near the former location of the fuel storage tanks and the location of the current water storage tank. The size and timing of any spills are unknown.

- Benzene has been observed in several areas throughout the site, including small localized detections and areas co-located with the eastern and western trichloroethene areas. The maximum benzene concentration detected is 150 micrograms per liter.

- The compound 1,4-dioxane is found primarily in the area of the western trichloroethene areas, with a maximum detected concentration of 360 micrograms per liter.

- Several metals at the site exceed Maryland Department of the Environment Generic Numeric Cleanup Standards for Groundwater. A detailed evaluation was conducted to better understand the source and possible effects of these metals, especially beryllium, nickel, and cobalt (see Section 2.2.3). That evaluation determined that these metals in groundwater are naturally occurring and do not contribute significantly to site risk; therefore, targeted remediation of metals in groundwater is not necessary.

Exposure Assessment

An exposure assessment was completed for the site (Section 4) to predict human health and ecological risks associated with exposure to site contaminants under current and future exposure scenarios. This exposure assessment concludes that regulatorily unacceptable risk at this site can be mitigated via land use controls, which can effectively control or eliminate exposure to the constituents detected in groundwater, until constituent concentrations are reduced to levels that permit removal of some or all of the land use controls. Therefore, active remediation is not required to reduce risk provided that land use controls are implemented. However, Lockheed Martin Corporation is choosing to go beyond the risk-elimination requirements and will conduct active remediation at the site.

These land use controls will be established by the Maryland Department of the Environment in their Block-specific Certificates of Completion which are anticipated to be issued following submittal and execution of soil Response Action Plans for each tax block.

Response Action Objectives

To obtain a Certificate of Completion under a Tier 1B (Residential Restricted) future land use and restriction category (see Section 5), the following goal was set: mitigate human health and ecological risks. Lockheed Martin set an additional goal of reducing contaminants. The following response action objectives (see Section 5.2) were developed based on these goals:

Response action objective	Description
1	Conduct active remediation with the objective of reducing the mass of trichloroethene in the subsurface of the active remediation areas and reducing the mass of trichloroethene daughter products, including primarily cis-1,2-dichloroethene and vinyl chloride
2	Prevent human exposure (including showering, drinking, and irrigation) to groundwater containing concentrations of site-related chemicals of concern greater than drinking water standards (i.e., greater than Maryland Department of the Environment Generic Numeric Standards for Groundwater).
3	Prevent discharge of groundwater with chemicals of concern causing regulatorily unacceptable human health and ecological risks in the sediments or surface water of Dark Head Cove and Cow Pen Creek.
4	Prevent off-site migration to adjacent properties of site-related chemicals of concern in groundwater at levels that exceed drinking water standards.
5	Prevent exposure of industrial workers, construction workers, and future residents to site-related volatile organic compounds due to vapor intrusion from groundwater into buildings at levels that would cause regulatorily unacceptable cumulative risk, with an Individual Lifetime Cancer Risk greater than 1×10^{-5} or a cumulative hazard index greater than 1.0 for non-carcinogenic volatile organic compounds.

Response Action Alternatives

After identifying the response action objectives, response action alternatives for groundwater were identified and evaluated (see Sections 6.2 and 6.3). Initially, 25 process options were considered, separated into seven general response action categories. The general response action categories include "no action," "limited action," "containment," "collection," "*in situ* treatment," "*ex situ* treatment," and "discharge/disposal" (see Table 6-5 for more information). A detailed screening of process options was conducted and the remaining options were combined into an initial list of 14 remedial alternatives to be further evaluated. Following this evaluation, the final three response action alternatives were retained:

- ***Alternative 1:*** Groundwater and vapor extraction in high concentration areas and land use controls.
- ***Alternative 2:*** *in situ* bioremediation in high concentration areas with groundwater and vapor extraction via wells and land use controls.
- ***Alternative 3:*** *in situ* bioremediation in high concentration areas and land use controls.

A detailed evaluation was performed on each alternative according to the following criteria (see Sections 6.3.3.1 through 6.3.3.3):

- overall protection of human health and the environment
- compliance with applicable or relevant and appropriate requirements
- long-term effectiveness and permanence
- reduction of toxicity, mobility, or volume of contaminants through treatment
- short-term effectiveness
- implementability
- life-cycle impacts
- cost

These alternatives were then compared qualitatively and quantitatively to each other based on these same criteria (see Section 6.4).

Selected Response Action

For Lockheed Martin Corporation, success depends on how well we recognize and fulfill our responsibilities to the environment, to a safe workplace, to stewardship of scarce natural resources, and to our customers and shareholders. All of these responsibilities were considered in

selecting the response action for the Middle River Complex. This evaluation led to selection of Alternative 3 (*in situ* bioremediation in high concentration areas and land use controls) as the groundwater response action for the Middle River Complex. This alternative will reduce the mass of trichloroethene primarily through *in situ* bioremediation in the three trichloroethene high concentration areas at the site (the western trichloroethene area and the northern and southern portions of the eastern trichloroethene area), meeting Response Action Objective 1.

Appropriate utility locating and injection testing will be completed to safeguard against migration of injected amendment away from the targeted injection areas. Groundwater monitoring will be implemented as part of this remedy to determine concentration trends outside of active treatment areas. Following active remediation, groundwater monitoring will be expanded to include the treatment areas. Land use controls will mitigate potential site risks and be used to ensure that Response Action Objectives 2 through 5 will be met. These controls may include prohibitions on site groundwater use and other requirements that will address potential vapor intrusion. A detailed description and conceptual design of the selected alternative are provided in Section 8.

A Block-specific Certificate of Completion will be sought from Maryland Department of the Environment subsequent to completion of the soil response action in each Block. In these Certificates, the Maryland Department of the Environment will establish the land use controls for the site.

Schedule

A schedule of the response action implementation is presented in Section 10. Major activities include:

- response action design completed—fall 2012
- well and piping installation—summer 2013
- response action implementation—2013-2016

Communication and Community Relations

Lockheed Martin Corporation is committed to its partnership with the Middle River community and to maintaining a high level of community outreach and communication as work progresses. The Corporation has and will continue to invest in the environmental, health, and economic needs of the community. Lockheed Martin Corporation will also provide remediation program updates to the Civic Association Leadership and, upon request, will attend Civic Association meetings to provide updates and answer questions. Lockheed Martin Corporation will also hold a Community Relations Availability Session before the response action begins. Lockheed Martin Corporation remains committed to two-way communication with the community to ensure that questions are answered and issues and concerns are addressed in a timely manner.

Section 1
Introduction

1.1 PURPOSE OF THE RESPONSE ACTION PLAN

On behalf of Lockheed Martin Corporation (Lockheed Martin), Tetra Tech, Inc. (Tetra Tech) has prepared this *Response Action Plan* (RAP) for groundwater at the Lockheed Martin Middle River Complex (MRC) in Middle River, Maryland. The location of MRC is shown in Figure 1-1. This RAP was prepared in accordance with the requirements of the Maryland Department of the Environment (MDE) Voluntary Cleanup Program (VCP) (see Section 7-508 of the Environment Article, *Annotated Code of Maryland*). A Draft RAP was submitted to the MDE in April 2011; MDE comments on the document were received on July 13, 2011. Lockheed Martin's responses to those comments are included in Appendix A and the responses are incorporated into this RAP.

The purpose of the RAP is to provide the background, supporting documentation, and framework (i.e., goals, performance evaluation criteria, and schedule) for remediation of groundwater at MRC. It details the response action objectives, selection of remedial technologies, and implementation of the response actions. The response actions and goals detailed in this RAP are based on current and historical site data derived from groundwater investigations, pilot studies, and groundwater modeling, which are detailed in Sections 2 and 3. This groundwater RAP addresses one component of the cleanup program for this facility proposed for completion under the VCP (see Section 1.2).

1.2 SCOPE

The MRC consists of multiple parcels of land designated as "tax blocks" ("blocks" herein). Figure 1-2 shows the locations of these blocks. The currently operating facilities are in Block I. Surrounding Block I are the external Blocks A, B, D, E, F, G, and H, which are owned by Lockheed Martin and used for an office building or parking or are leased for use by others, as described below:

- *Block A*—Lockheed Martin operations building and associated parking

- *Block B*—Lockheed Martin parking and open space (formerly an athletic field)
- *Block D*—Leased space
- *Block E*—Leased parking in a portion of the block; also contains a large above-ground water tank, which is part of the site fire suppression system for the Martin State Airport
- *Block F*—Open space
- *Block G*—Leased space
- *Block H*—Lockheed Martin parking

The groundwater investigation in these external blocks is complete. Groundwater investigation in Block I is ongoing; therefore, the response action for the groundwater in the active areas of Block I will be addressed via a separate RAP. Lockheed Martin is submitting this RAP before completion of delineation in the active industrial area to expedite cleanup of the accessible areas of the site and allow more options for use of a large portion of the site in a timely manner.

The complete response action for the MRC under the VCP will address soil and groundwater with chemical of concern (COC) concentrations with the potential to cause regulatorily unacceptable risk to human health and the environment if exposure to the COC is not mitigated. The groundwater response action presented in this RAP addresses remediation to meet the response action objectives established for groundwater at the MRC. This groundwater RAP is comprehensive for all tax blocks at the MRC (and the areas between those blocks), except for areas of Block I that are largely inaccessible due to ongoing operations at the site. As stated above, these areas will be addressed in a separate RAP.

The response actions for soil in Blocks B, D, E, F, G, and H are described in separate soil RAPs. Block A requires no response action and remediation of soil in Block B has been completed. Development of a response action for soil and groundwater in Block I (the active industrial facilities) is deferred until these industrial activities cease and Block I can be completely characterized. Together, this groundwater RAP, any subsequent groundwater RAP addressing Block I, and the soil RAPs for the six tax blocks constitute the complete response action plan for the MRC under the VCP. Evaluation of sediment impact in Cow Pen Creek and Dark Head Cove is being addressed under a separate regulatory framework. A Certificate of Completion will be sought upon execution of the soil cleanup being conducted under the separate soil RAPs.

1.3 ORGANIZATION

The RAP is organized as follows:

Section 1—Introduction: Presents the purpose, scope, and organization of the RAP.

Section 2—MRC Overview: Briefly describes the MRC and its site history, environmental investigations and results, nature and extent of contamination, and a summary of the proposed groundwater response actions.

Section 3—Overview of Pilot Studies and Groundwater Modeling: Summarizes pilot studies and groundwater modeling performed in support of the groundwater remedial design.

Section 4—Exposure Assessment: Presents the current and potential future land use, environmental media of concern, and describes possible exposure pathways.

Section 5—Cleanup Criteria: Presents cleanup criteria, cleanup goals, response action objectives, and information associated with attainment of cleanup goals.

Section 6—Response Action Alternative Evaluation and Selection: Presents the screening of technologies and process options, the development and analysis of alternatives, a comparative analysis of alternatives, and describes the alternative selected to clean up the site.

Section 7—Performance Evaluation Criteria and Contingency Measures for the Selected Response Action: Presents the criteria for evaluation of the selected technology and the criteria required to obtain a Certificate of Completion.

Section 8—Proposed Response Actions: Presents the plan for all work necessary to perform the proposed response action.

Section 9—Permits, Notifications, and Contingencies: Presents local, state, and federal laws and regulations that prescribe the permits and approvals required to implement the MDE-approved RAP.

Section 10—Implementation Schedule: Presents the detailed schedule for all work necessary to implement the MDE-approved RAP.

Section 11—Administrative Requirements: Presents the administrative documents required to implement the MDE-approved RAP.

Section 12—References: Lists references and citations used in compiling this RAP.

Appendices:

Appendix A—MDE Comments on Draft RAP and Lockheed Martin Responses

Appendix B—Database of MRC Groundwater Data

Appendix C—Metals Leachability in Aquifer Materials Report

Appendix D—Generalized Cross-Sections

Appendix E—Interim ISCO Pilot Study Report

Appendix F—Enhanced Anaerobic Reductive Dechlorination Pilot Study Report

Appendix G—Groundwater Modeling Report

Appendix H—Vapor Intrusion Calculations and Surface Water Concentration Modeling

Appendix I—2010 Sediment and Pore Water Sampling Results

Appendix J—Detailed Evaluation of Groundwater Treatment Technologies and Process Options

Appendix K—Life Cycle Assessment Information

Appendix L—Total Cost Analysis Information

Appendix M—Soil Management Plan

Appendix N—*Criterium Decision Plus* Results

Appendix O—Response Action Equipment Information

Appendix P—Permit List

Appendix Q—Administrative Requirements

Figure 1-1

Figure 1-2

Section 2
Middle River Complex Overview

2.1 MIDDLE RIVER COMPLEX BACKGROUND

The Middle River Complex (MRC), part of the Chesapeake Industrial Park, is located at 2323 Eastern Boulevard in Middle River, Maryland, approximately 11.5 miles northeast of downtown Baltimore. The MRC comprises approximately 160 acres containing 12 main buildings, an active industrial area and yard, perimeter parking lots, an athletic field, a concrete-covered vacant lot, a trailer and parts storage lot (leased for use by others), and numerous grassy spaces along its perimeter. The MRC is bounded by Eastern Boulevard (Route 150) to the north, Dark Head Cove to the south, Cow Pen Creek to the west, and Martin State Airport to the east. The MRC location is shown in Figure 1-1. Figure 2-1 is an MRC layout map. Lockheed Martin Corporation's (Lockheed Martin's) primary activities at the site include operating Maritime Systems & Sensor (MS2), a subsidiary of Lockheed Martin that fabricates, assembles, tests, and otherwise supports vertical launch systems; other activities include facility and building management and maintenance. The primary tenant is Middle River Aircraft Systems (MRAS), a subsidiary of General Electric that designs, manufactures, fabricates, tests, overhauls, repairs, and maintains aeronautical structures, parts, and components for military and commercial applications.

2.1.1 Middle River Complex History

In 1929, the Glenn L. Martin Company, a predecessor entity of Lockheed Martin, acquired a large parcel of undeveloped land in Middle River, Maryland to manufacture aircraft for the United States government and commercial clients. In the early 1960s, the Glenn L. Martin Company merged with American-Marietta Company to form Martin Marietta Corporation. Around 1975, the adjacent airport (Martin State Airport), totaling approximately 750 acres, was transferred to the State of Maryland. In the mid 1990s, Martin Marietta Corporation merged with Lockheed Corporation to form Lockheed Martin Corporation. Shortly after the merger, General

Electric acquired most of Lockheed Martin's aeronautical business in Middle River and began operating at the MRC as MRAS.

2.1.2 Middle River Complex Characteristics

2.1.2.1 Current and Surrounding Land Use

The MRC is an industrial facility surrounded primarily by commercial, industrial, and residential developments. Six facilities are adjacent to the MRC, comprising the remaining portion of the Chesapeake Industrial Park. These include Tilley Chemical Company, Inc. (a food- and pharmaceutical-chemical distributor), North American Electric, Inc. (an industrial and commercial electrical-contractor), Johnson and Towers (a heavy-duty diesel equipment, truck, and boat repair and maintenance company), Poly Seal Corp. (a flexible packaging producer), Exxon (a gasoline filling station and convenience store), and the Middle River Post Office. Residential developments are on the opposite shores of Cow Pen Creek, Dark Head Cove, and Dark Head Creek and north of Eastern Boulevard (Route 150). Martin State Airport is to the east.

2.1.2.2 Physiography

The MRC is in the western shore of the Coastal Plain Physiographic Province, which is generally characterized by low relief. Topography at the MRC slopes gently, ranging from sea level to 32 feet above mean sea level (msl) (Cassell, 1977). The topography slopes from Eastern Boulevard to the southwest and south toward Cow Pen Creek and Dark Head Cove.

2.1.2.3 Hydrology

The MRC is approximately 3.2 miles upstream of Chesapeake Bay, at the confluence of Cow Pen Creek and Dark Head Cove. Both surface water bodies discharge into Dark Head Creek, a tributary to Middle River, which discharges into Chesapeake Bay. The MRC has no perennial surface water bodies. Excluding areas immediately adjacent to Cow Pen Creek and Dark Head Cove, surface water runoff discharges from the facility via storm sewer outfalls south of Parking Lots 6 and former Building D to the south (discharging to Dark Head Cove), and west of Lots 2 and 3 to the west (discharging to Cow Pen Creek). These outfalls are shown in Figure 2-1. Lockheed Martin maintains a Maryland National Pollution Discharge Elimination System (NPDES) permit (State Discharge Permit No.: 00-DP-0298, NPDES No.: MD0002852), issued by the Maryland Department of the Environment (MDE) Industrial Discharge Permits Division,

Water Management Administration. The permit covers storm water discharge from the entire property rather than from individual tenants.

2.1.2.4 Soils

Soils underlying the MRC have been mapped by the U.S. Department of Agriculture Soil Conservation Service as Mattapex-Urban Land Complex and Sassafras-Urban Land Complex. Mattapex-Urban Land soils consist of well-drained silty soils, the original texture of which has been disturbed, graded over, or otherwise altered. Sassafras-Urban Land soils consist of well-drained sandy soils, the original texture of which has been disturbed, graded over, or otherwise altered. Site characterization studies indicate that fine-grained (e.g., primarily silt and clay with some fine-grained sand) soils with low permeabilities make up most soils at the MRC.

2.1.2.5 Regional Geology and Hydrogeology

The MRC is on the Western Shore of Chesapeake Bay, situated in the westernmost portion of the Coastal Plain Physiographic Province. Geologic mapping of Baltimore County shows that the site is underlain by the Potomac Group, a lower Cretaceous age inter-bedded gravel, sand, silt, and clay unit ranging from 0–800 feet thick. The Potomac Group at the site consists of the following three stratigraphic units (from the top down, and thus from the youngest to oldest): the Patapsco Formation, the Arundel Clay, and the Patuxent Formation. Potomac Group sediments were deposited in a river delta environment (Hansen, 1969).

The Patapsco Formation, the most shallow formation and location of the site-related contamination, is the formation of primary interest in this RAP. It is composed primarily of silty sands, fine-grained to medium-grained sands, silty clays, clayey silts, and plastic clay characteristic of back swamps and floodplain deposits. The Arundel Clay is composed of dark gray and maroon lignitic-clays ranging between 25–200 feet thick beneath the site. The Arundel Clay acts as an impermeable barrier to the downward movement of any constituents found in the overlying groundwater. Below the Arundel Clay is the Patuxent Formation. It is a multi-aquifer unit, due to various inter-bedded sand and silt/clay layers and the rapid changes in deposited material types over short distances (Glaser, 1969).

2.2 PREVIOUS INVESTIGATIONS

Since 1988, various investigations have been conducted at the MRC to determine the extent of groundwater and soil contamination at the site. Table 2-1 outlines the investigations related to site groundwater. The primary findings of these investigations as they relate to this groundwater *Response Action Plan* (RAP) are included in Sections 2.2.1 through 2.2.3. This includes a summary of the groundwater concentrations for selected organic and inorganic compounds, followed by a summary of the geologic and hydrogeologic conditions at the MRC, and a discussion of the metals leachability testing conducted on site soil.

2.2.1 Summary of Groundwater Conditions

In May and June 2010, 96 of the on-site groundwater monitoring wells were sampled for volatile organic compounds (VOCs), 1,4-dioxane, metals (filtered and total), and/or natural attenuation parameters; these are the latest data available from a site-wide sampling event. The 2010 monitoring round also included groundwater depth measurements at all accessible wells and surface water elevation measurements in Cow Pen Creek and Dark Head Cove. These data are used below, along with data from 2005, 2007, 2008, and 2009, to describe current groundwater conditions. The well designations A, B, and C used below correspond to the following well depths:

- *"A" designation*—These are water table wells, generally 15–20 feet below ground surface (bgs), in the areas addressed in this RAP. In the northern area of the site with a greater depth to groundwater, these wells are up to 40 feet deep.
- *"B" designation*—These wells are considered the intermediate portion of the surficial aquifer and generally have a total depth of 30–35 feet bgs.
- *"C" designation*—These wells have total depths ranging from 55–75 feet bgs.
- *"D" designation*—These are considered deep wells, are installed to the top of the Arundel Clay, and have total depths ranging from 184–214 feet bgs.

A statistical summary of the groundwater sample chemical analyses for the 2010 sampling event is presented in Table 2-2. This is intended to provide an overview of the site data and indicate which compounds are most often detected at the site and which compounds have the highest relative concentrations. A complete database containing all site groundwater laboratory data is included on the CD included as Appendix A.

2.2.1.1 Organic Compounds

Results from the 2010 sampling confirm the presence of trichloroethene (TCE) in groundwater in several areas throughout the central and southern portions of the MRC; benzene was detected in sporadic locations at relatively low concentrations. Consistent with the 2009, 2008, 2007, and 2005 results, the 2010 analytical data show that TCE and benzene are in groundwater at concentrations exceeding the MDE groundwater standard for drinking water (5 micrograms per liter [µg/L] for each). Contoured concentrations of TCE and benzene from the May–June 2010 groundwater monitoring event are shown in Figures 2-2 and 2-3, respectively.

Trichloroethene, a commonly used industrial solvent and metal degreaser, was detected in shallow groundwater in 2010 at several areas at concentrations ranging from 0.32–19,000 µg/L (Figure 2-2). Trichloroethene is by far the most prevalent site contaminant that exceeds MDE standards. Further, TCE degradation daughter products (dichloroethenes, vinyl chloride, etc.) are typically co-located with TCE. Therefore, the distribution of TCE was evaluated to provide an overview of the primary VOC groundwater contamination at the MRC. TCE contamination is primarily in two areas: the western and eastern areas.

Western TCE area—As shown in Figure 2-2, the second largest contiguous area of TCE groundwater contamination at the site extends from MW21, near the site of a former 2,000-gallon waste oil underground storage tank (UST), to MW12 (near Cow Pen Creek). The maximum reported 2010 concentrations of TCE in this area are 2,800 µg/L at well MW14B (in the center of the area near Chesapeake Park Plaza) and 1,600 µg/L at well MW12A (in the southernmost portion of the area near Cow Pen Creek). Contamination in this area extends to a maximum depth of 35 feet bgs (see Section 2.2.2).

Eastern TCE area—As shown in Figure 2-2, the largest contiguous area and highest concentrations of TCE groundwater contamination extend southeastward from MW60, at the southern end of Building C to well MW37, near Dark Head Cove. Two high concentration areas (greater than 1,000 µg/L) are apparent from the data: just south of Building C and south of the former Building D, near the above ground water tank. The maximum TCE concentration detected in 2010 in the northern portion of this eastern area was 3,900 µg/L at MW60B; concentrations of approximately 10,000 µg/L were found in the area just south of MW60 before *in situ* pilot testing was conducted in that area (see Section 3). In the southern portion of the area,

the highest concentration was observed at MW74B, south of the former Building D location, near the on-site water tank. The TCE concentration at this location was 19,000 µg/L. These high concentrations indicate the possible presence of dense non-aqueous phase liquids (i.e., residual solvent product) and two distinct contaminant source areas.

Figure 2-2 shows that the maximum concentrations of TCE reported for wells MW74B and MW60B are in the intermediate portion of the surficial aquifer. These wells are screened from 20–30 feet bgs. Contamination in this area extends to a maximum depth of approximately 35 feet bgs (see Section 2.2.2). The sources of this contamination have not been identified, but may originate from the south end of the Building C basement (although source material was not found during an investigation of soil beneath the Building C basement), or possibly from spillage of material handled near MW60B and MW74B, respectively.

Other TCE areas—As shown in Figure 2-2, TCE was also detected at concentrations exceeding the groundwater standard in the western portion of the facility in wells MW50A (19 µg/L), MW53A (270 µg/L), MW16A (5.5 µg/L), and MW90B (310 µg/L). Trichloroethene concentrations below MDE standards at nearby wells indicate that these are smaller contaminated areas, and have lower concentrations than the eastern and western TCE areas. Sources of the TCE detections at MW16A, MW53A, MW50A, and MW90B are unknown and are being further investigated as part of the continuing Block I investigation.

A TCE concentration of 1,500 µg/L was also observed at MW88A, near the northeast corner of Building C, in the active industrial area of the site, following that well's installation in 2008. TCE was detected at 440 µg/L at this location in the 2010 site wide sampling event. A subsequent investigation in that area has shown that the TCE has not moved significantly from this area. Due to current access restrictions in this area caused by ongoing site operations, TCE contamination near MW88A will be addressed in a separate RAP. Additional TCE contamination was also observed in the eastern portion of the MRC at well MW25A (100 µg/L).

Benzene—Benzene, a constituent of petroleum-based fuels, was detected in shallow groundwater in several areas, at concentrations ranging from 0.33–150 µg/L (Figure 2-3). Overall, concentrations of benzene reported in 2010 are less than those reported in 2005 and have been steadily decreasing.

***1,4-Dioxane*—**The compound 1,4-dioxane has been detected in several wells in the western TCE area, but has historically been detected in the eastern TCE area at only one well, and at a low concentration. The distribution of 1,4-dioxane for the 2010 sampling event is shown in Figure 2-4. In 2010, 1,4-dioxane was detected at concentrations ranging from 0.96–360 µg/L. The highest concentration was reported at MW14B.

***Other volatile organic compounds*—**One well (MW-43A) in the southwest corner of Block E contained high concentrations of VOCs, including 1,2,3-trichlorobenzene (2,000 µg/L), 1,2,4-trichlorobenzene (11,000 µg/L), 1,4-dichlorobenzene (570 µg/L), and 1,2-dichlorobenzene (450 µg/L). These compounds are not observed at high concentrations at any other site locations. Historically, chlorobenzenes were used in conjunction with polychlorinated biphenyls (PCBs) in dielectric fluid for transformers. This source of chlorobenzenes at this location is consistent with the detection of elevated PCBs in the soil in the southwest area of Block E, and is further supported by the detection of both chlorobenzenes and PCBs in a small area of non-aqueous phase product encountered at 8 feet bgs in this area of Block E. Due to the very limited area of groundwater contamination due to this source, this contamination is being investigated in conjunction with Block E soil and will be addressed as part of the response actions for the Block E soil.

***Deep groundwater investigation*—**A deep groundwater investigation was conducted in 2010. One well north/upgradient of the contaminated areas of the site (MW93D) and three wells south/downgradient of contaminated areas (MW94D, MW95D, and MW96D) were installed (Figure 2-2). Total well depths for this program range from 189–214 feet bgs. Well screens were installed at the base of the surficial aquifer and above a thick clay sequence interpreted to be the regionally extensive Arundel Clay. Groundwater flow direction at this depth is generally south-southeast. Groundwater samples from these wells indicate no site-related contamination. Low concentrations of VOCs associated with potable water used in drilling were detected in initial well sampling, but not at levels exceeding the MDE Generic Numeric Standards for Groundwater (i.e., Maryland drinking water standards). These compounds were not detected in the second sampling event. More information on the MRC deep groundwater investigation can be found in the *Deep Groundwater Investigation Report* (Tetra Tech, 2010b).

***Off-site wells*—**In 2007, nine multi-level off-site monitoring wells with 24 discrete screened intervals (Figure 2-2) were installed across Cow Pen Creek and Dark Head Cove. Well locations

and depths were designed to monitor groundwater in the general direction of flow identified at the two primary areas containing TCE in groundwater. In 2007 and 2010, groundwater samples were collected from these wells and analyzed for VOCs and 1,4-dioxane; all results were below the MDE Generic Numeric Standards for Groundwater (i.e., Maryland drinking water standards). More information on off-site groundwater sampling at the MRC can be found in the *Groundwater Monitoring Report May–June 2010* (Tetra Tech, 2010c).

2.2.1.2 Inorganic Compounds

The most recent comprehensive sampling of metals at the site was in 2008. Concentrations of metals above MDE standards were found throughout the MRC. Table 2-3 summarizes metals exceeding MDE groundwater standards in the 2008 sampling event. See Section 2.2.3 for more information on testing conducted to determine the source of these metals.

As seen in Table 2-3, concentrations of 12 metals exceed groundwater standards in one or more groundwater samples. Concentrations of manganese, iron, and nickel exceed standards most frequently (45–83%), in both total and filtered samples, with maximum concentrations of these metals exceeding the standards by more than two orders of magnitude (i.e., greater than 100 times). Concentrations of beryllium and vanadium exceed the standard in approximately one in four samples (17–26% of samples), with maximum concentrations of 263 and 218 µg/L, respectively, exceeding the groundwater standards by more than an order of magnitude (more than 10 times).

Concentrations of the remaining metals, such as arsenic, cadmium, chromium, copper, lead, mercury, and zinc exceed standards in less than 10% of samples, ranging from one exceedance each for cadmium and mercury to eight for zinc. Maximum concentrations of these metals are less than one order of magnitude (i.e., less than 10 times) above the groundwater standard, and the maximum levels of cadmium and mercury only slightly exceed standards. Concentrations exceeding groundwater standards for these seven metals are co-located with high concentrations of other metals such as manganese, iron, and nickel. Filtered (dissolved) mercury concentrations did not exceed the standard. Although Maryland has no standard for cobalt, cobalt concentrations exceeded the EPA Risk-Based Concentration (RBC) of 11 µg/L for tap water in 85% of the samples collected.

Groundwater distributions of beryllium, cobalt, and nickel are shown in Figures 2-5 through 2-7, respectively. These metals were selected because they exceed standards over a wide area of the site and significantly exceed standards in various locations. Values selected for contouring represent the higher concentrations of the total- and dissolved-metal analyses to provide a conservative representation. For a given well cluster, the A, B, or C well with the highest concentration was selected for these figures, as indicated by the appropriate well label. The groundwater standard (e.g., 4 µg/L for beryllium) (or the tap water RBC, in the case of cobalt) is represented in the figures by the contours with the lowest values.

As shown in Figures 2-5 through 2-7, the highest concentrations of metals are in the northwest and center portions of the site, primarily in wells with very low pH groundwater (a map showing the relative pH values for groundwater wells is included in Appendix C). Possible causes of the low pH are detailed in Appendix C and include the rainwater collection and discharge processes that concentrate low pH (4.3–4.7) rainwater from the roofs of the operation buildings and other impervious areas into the areas south of Buildings A, B, and C. No other known site activities that would cause low pH conditions over this large of an area have been identified. Additionally, as the groundwater flows to areas of higher pH, metals concentrations decrease. Well MW67A, in the western portion of the site and upgradient of suspected operational areas, contains high concentrations of nickel (13,100 µg/L), cobalt (6,810 µg/L), and relatively high concentrations of beryllium (244 µg/L); because the well is upgradient of the activities, it is unlikely that these concentrations were caused by the industrial activities.

2.2.2 MRC Geology and Hydrogeology

Data collected as part of the groundwater investigations indicate a complex stratigraphy of predominantly clay, silty clay, silt, and clayey silt, with smaller more permeable zones of silty sand and sand beneath the site. The northern portion of the site is generally comprised of thick, very low hydraulic conductivity clays, with increasing amounts of higher hydraulic conductivity material in the southern area of the site near the surface water. Lithologic data from site investigations were used to construct geologic cross-sections for the MRC. These cross-sections were simplified to differentiate between lower (less than 0.01 feet per day) and higher (greater than or equal to one foot per day) hydraulic conductivity soil. Fence diagrams showing multiple cross-sections, and individual cross-sections for the two primary areas of TCE contamination are

presented in Figures 2-8, 2-9, and 2-10, respectively. The complete set of cross-sections is in Appendix D.

For the purposes of this groundwater RAP, the stratigraphy in the two major TCE areas is discussed below. Soil borings advanced in the eastern TCE area indicate that the subsurface stratigraphy varies slightly, moving from north to south. In the northern portion, near MW60, multiple layers of low hydraulic conductivity material extend from the ground surface to a depth of approximately 30 feet bgs. These are underlain by a thicker layer of higher hydraulic conductivity material. Wells installed in this deeper zone (e.g., MW27C, screened at approximately 60–70 feet bgs, and MW92C, screened at approximately 45–55 feet bgs) do not contain TCE concentrations above Maryland drinking water standards. Therefore, the bulk of contamination in this area likely extends to a maximum of approximately 35 feet bgs.

Most of the shallow soils (to 15 feet bgs) in the southeastern portion of the MRC, near MW74, are of lower hydraulic conductivity. Soils between 15 feet bgs and 30–35 feet bgs are of higher hydraulic conductivity (slightly less than one foot per day). These soils are underlain by another layer of lower hydraulic conductivity soil ranging from 4–10 feet thick. The significant majority of the contamination in this area, based on data from below this layer, likewise appears to extend to a maximum depth of approximately 35 feet bgs.

Stratigraphy in the western TCE area also changes from north to south. At MW21 and MW14 (in the northern and central portion of the area), a significant amount of lower hydraulic conductivity material extends from the ground surface to 12–15 feet bgs. Below that is a higher hydraulic conductivity zone from approximately 20–30 feet bgs, underlain by a thick, low hydraulic conductivity zone. In the southern portion of the area, near MW12 and Cow Pen Creek, the upper low hydraulic conductivity zones to the north pinch out, and a higher hydraulic conductivity zone extends from the ground surface to a depth of approximately 20 feet bgs. Stratigraphy and groundwater data indicate that the significant majority of the contamination extends to a maximum depth of approximately 35 feet bgs in this area as well. Table 2-4 presents the June 2010 groundwater level measurements and computed elevations for the MRC. Figures 2-11 and 2-12 show the June 2010 groundwater elevation contour maps for the upper (“A” and “B”) and lower (“C”) wells. Groundwater generally flows from higher to lower elevation, perpendicular to the contours shown.

Depths to groundwater for the upper wells range from less than one foot below grade at MW10A, MW15A, and MW40A, to more than 20 feet bgs at MW67A. Depth to groundwater in the lower wells ranges from less than one foot at MW12C to slightly more than 13 feet at MW27C. The June 2010 groundwater flow figure is similar to previous years. As shown in Figure 2-11, shallow groundwater follows site topography and flows radially from the hydraulically upgradient northern–central portion of the MRC (near Eastern Boulevard and immediately south of Buildings A, B, and C). Groundwater flows from these areas primarily to the southeast, south, and southwest toward Dark Head Cove and Cow Pen Creek.

Single-well hydraulic conductivity tests (slug tests) were conducted in 28 wells selected to represent variability across the site with the following results:

- Low average hydraulic conductivities were reported for the shallow wells, ranging from 0.0027 feet per day at MW57 to 1.25 feet per day at MW66A. The geometric mean hydraulic conductivity for the shallow wells is 0.07 feet per day. These results are consistent with published hydraulic conductivity of sand and silt mixtures (Spitz and Moreno, 1996; Halford and Kuniansky, 2002), which were noted in borings for these locations.

- Except for MW27B, the hydraulic conductivity values of the intermediate wells are more consistent across the site than those of the shallow wells, with a geometric mean of 0.22 feet per day and an arithmetic average of 0.48 feet per day. The hydraulic conductivity of the intermediate wells (“B” wells) is consistent with published lower values for clean sand or typical values of sand and silt mixtures.

- Except for well MW37C, hydraulic conductivities for the deep wells range from 0.35–9.16 feet per day. The average hydraulic conductivity of the deeper wells is 3.82 feet per day.

Step drawdown tests and 72-hour constant-rate pumping tests were also conducted on four site wells: MW70A, MW70B, MW74A, and MW74B. Groundwater was pumped at the following rates during the 72-hour tests:

- MW70A—0.375 gallons per minute (gpm)
- MW70B—0.75 gpm
- MW74A—0.12 gpm
- MW74B—0.30 gpm

Groundwater levels were monitored in the pumping wells and several nearby monitoring wells; groundwater level responses were generally limited to monitoring wells nearest the pumping wells, due to the low hydraulic conductivity of site soil. Test results indicate that:

- hydraulic conductivity for the upper surficial aquifer (represented by wells MW70A and MW74A) ranges from 2.35–2.98 feet per day

- hydraulic conductivity for the intermediate surficial aquifer (represented by wells MW70B and MW74B) ranges from 0.31–0.71 feet per day

2.2.3 Metals Leachability in Site Soil

As discussed above, concentrations of various metals in groundwater exceed MDE standards for drinking water in various areas of the site. To better understand the source(s) and possible effects of beryllium, nickel, and cobalt detected in site groundwater, the leachability of metals from site soil was evaluated. These metals were studied because they were detected throughout the MRC and, at various locations, had concentrations well above applicable screening standards. The Metals Leachability in Aquifer Materials Report is included as Appendix C. To complete the leachability study, 111 subsurface soil samples were collected from five hollow stem auger soil borings advanced in areas near current and historical plant operations and in areas away from those operations (i.e., background locations). A subset of these samples was then analyzed for metals leachability at various pH and oxidation-reduction potential (ORP) levels, using a modified Synthetic Precipitation Leaching Procedure (SPLP).

The evaluation results show that these metals are most likely naturally occurring and that two predominant mechanisms are likely responsible for releasing beryllium, nickel, and cobalt from site aquifer materials. The primary mechanism is the release of metals from soil at low pH values, due to desorption from soils and dissolution of iron and manganese hydroxide bound to the soil. The second mechanism results from the release of metals when iron and manganese oxyhydroxides are solubilized in low oxygen and low ORP conditions; this mechanism is significantly less prevalent at the MRC. These mechanisms are significant in evaluating the source of these metals in groundwater at the site as follows:

- low pH conditions observed in areas of the site are likely the major cause of elevated beryllium, cobalt, and nickel concentrations in site groundwater. Metals are also present in the soil throughout the MRC and can be released from samples collected near plant operations and those collected from locations outside of these areas (i.e., background areas)

- beryllium, cobalt, and nickel at the site were detected in soil in areas of plant operations at concentrations consistent with those collected outside of operational areas. Mobilization of these elements from samples from both operations and background

locations occurs under low pH or low ORP conditions. Therefore, these metals are deemed naturally occurring.

Additionally, few receptors exist for metals in groundwater:

- site groundwater is not used for drinking water
- metals do not contribute to vapor intrusion risk
- elevated metals concentrations decrease as pH increases nearer the surface water bodies and groundwater model analyses predict a very low flux of groundwater to surface water (this has been confirmed by sampling of pore water below the surface water bodies). These factors result in an extremely low rate of metals transport from groundwater to surface water, and thus no identified human health or ecological risk in surface water or sediment is posed by the studied metals

In summary, the studied metals in groundwater occur naturally and do not contribute significantly to site risk at the levels detected. Although not all metals were studied in this detail, similar conclusions for other metals can likely be drawn. Therefore, metals are not considered chemicals of concern (COC) at the MRC.

2.3 CONCEPTUAL SITE MODEL

This section provides a conceptual model for groundwater at the MRC, including primary site groundwater contaminants and locations, suspected contaminant sources, geologic considerations, and plume stability. TCE is the primary site contaminant. TCE daughter products (including cis-1,2-dichloroethene [cis-1,2-DCE] and vinyl chloride), benzene, 1,4-dioxane, and chlorobenzenes are present in site groundwater at lower concentrations and/or over a significantly smaller areal extent. There are three areas at the site contain TCE concentrations above 1,000 μg/L. The maximum depth of groundwater contamination in each of these locations is 35 feet bgs. Possible sources of this contamination are as follows:

- In the western TCE area (maximum TCE concentration 2,800 μg/L), the primary suspected source of TCE contamination is a solvent spill from a waste oil tank located north of Tilley Chemical; the size and timing of this release are unknown. A possible secondary source of TCE in this area is the wastewater treatment plant that was located south of Tilley Chemical and Chesapeake Park Plaza; the size and timing of any release from this possible source are unknown.
- In the eastern TCE area (maximum TCE concentration 3,900 μg/L), a solvent spill likely occurred south of Building C, possibly related to past handling and storage practices; available data from the groundwater monitoring wells, a limited soil investigation under Building C, and from the operation of the sub-slab depressurization system at Building C

indicate that this did not occur under the Building C basement. The size and timing of any release or spill are unknown.

- Also in the eastern TCE area (maximum TCE concentration 19,000 μg/L), a solvent spill likely occurred southeast of former Building D, in the former location of the fuel storage tanks and the current location of the water storage tank. The size and timing of any spill are unknown.

Various other site spills and releases (size and timing unknown) have resulted in smaller areas of TCE and benzene contamination in groundwater; only very low concentrations of these compounds has been detected in site soil. Releases from transformer use and storage at the location of former Building D are suspected of being the cause of chlorobenzene concentrations identified at MW43A; additional investigations and cleanup of this contamination will be addressed as part of the Block E soil remediation.

Stratigraphic logging of soils beneath the MRC have identified a complex, heterogeneous stratigraphy. Underlying soils exhibit low hydraulic conductivity and are composed primarily of clay and silty clay. Groundwater flow across the site is extremely slow, on the order of a few feet per year.

Long-term groundwater TCE trends are not available due to the relatively recent nature of the site investigation. However, the size, shape, and maximum concentrations of the TCE areas have generally remained relatively stable over the short period since the beginning of this investigation, except for sampling events following the *in situ* pilot studies and groundwater pumping tests. Current plume shapes and groundwater modeling indicate a flow component toward the surface water bodies, producing a contaminant flux to those bodies. Groundwater and surface water modeling indicate that this flux is quite small, and does not constitute a human health or ecological risk in either Cow Pen Creek or Dark Head Cove. Metals are in site groundwater above drinking water standards. Significant study of three of the primary metals at the site was completed. Based on the results of this testing and site conditions detailed in Section 2.2.3, metals are not considered a COC in groundwater at the MRC.

2.4 SUMMARY OF PROPOSED RESPONSE ACTIONS

This section briefly describes the proposed groundwater response actions at the MRC (detailed in Section 8 of this RAP), including the following components:

- *in situ* bioremediation in the western and eastern TCE areas, with a goal of achieving reduction in TCE mass. Monitored natural attenuation will be performed as part of the remedy, if necessary, to confirm continued mass removal following active remediation. Groundwater monitoring is also included.

- land use controls to prevent exposure of current and future site users to regulatorily unacceptable risk

The proposed response action primarily addresses the TCE contamination in the areas outside current industrial operations. Investigations are ongoing in areas of current industrial operations. Additional response actions would be addressed in a separate RAP.

Table 2-1
MRC Historical Groundwater Investigations
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Investigation	Year	General scope	Reference
Chromium investigation	1988	Hexavalent chromium sampled at six locations	Earth Engineering and Science, Inc., 1988
Phase I environmental site investigation	2003	13 Recognized Environmental Conditions (RECs) identified at the MRC	Earth Tech, 2003
Phase II investigation	2003	Groundwater and soil sampling at 13 RECs and geophysics at seven RECs	Tetra Tech, February, 2004a
Historical survey	2004	18 additional RECs identified	Tetra Tech, August 2004b
Site-wide Phase II investigation	2004	Groundwater and soil sampling at 31 RECs, geophysical survey at five locations, radiological survey at one location	Tetra Tech, April 2004a
Site-wide groundwater investigation	2005 and 2006	Installation and sampling of wells at various depths and hydraulic testing	Tetra Tech, May 2006
Building C Basement investigation	2006	Soil and groundwater sampling	Tetra Tech, May 2006
Site-wide groundwater investigation	2007	Membrane interface probe investigation, soil boring installation (with soil and groundwater sample collection), metals leachability testing, monitoring well installation and sampling, and hydraulic conductivity testing (slug tests and pump tests)	Tetra Tech, August 2008
Groundwater monitoring	2008, 2009, and 2010	Site groundwater well sampling	Tetra Tech, May 2009a, January 2010a, September 2010b
Block I Phase II site investigation	2008 and 2009	Block I area soil and groundwater investigation	Tetra Tech, July 2009b
Deep groundwater investigation	2009	Installation and sampling of four deep groundwater wells	Tetra Tech, 2010b

Table 2-2

Statistical Summary of Groundwater Sample Organic Chemical Analyses, May-June 2010
Lockheed Martin Middle River Complex, Middle River, Maryland
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Chemical	MDE Groundwater Criteria	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Sample of Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
		Number	Percent								
VOLATILES (ug/L)											
1,1,1-TRICHLOROETHANE	200	5/125	4%	0.22	160	0.23 J	1.3 J	MRC-EXT06-060410, MRC-MW71A-062310	1.88	0.774	8.90
1,1,2-TRICHLOROTRIFLUOROETHANE	NA	1/125	1%	0.28	200	0.56 J	0.56 J	MRC-MW71A-062310	2.35	0.560	11.2
1,1-DICHLOROETHANE	90	33/125	26%	0.15	110	0.22 J	49 J	MRC-MW14B-062210	2.77	6.60	8.12
1,1-DICHLOROETHENE	7	35/125	28%	0.19	140	0.33 J	780	MRC-MW14B-062210	14.9	49.0	75.1
1,2,3-TRICHLOROBENZENE	NA	2/125	2%	0.17	120	16	2000	MRC-MW43A-060210	17.1	1008	178
1,2,3-TRIMETHYLBENZENE	NA	1/125	1%	0.0059	4.2	1.1 J	1.1 J	MRC-MW17A-060310	0.069	1.10	0.267
1,2,4-TRICHLOROBENZENE	70	3/125	2%	0.15	110	0.47 J	11000	MRC-MW43A-060210	89.0	3697	980
1,2,4-TRIMETHYLBENZENE	NA	2/125	2%	0.12	86	2.1 J	3.8	MRC-MW50A-062410	1.05	2.95	4.82
1,2-DICHLOROBENZENE	600	2/125	2%	0.13	93	4.3	450 J	MRC-MW43A-060210	4.44	227	40.3
1,2-DICHLOROETHANE	5	1/125	1%	0.22	160	0.59 J	0.59 J	MRC-MW15A-062210	1.85	0.590	8.90
1,3-DICHLOROBENZENE	1.8	4/125	3%	0.14	100	0.2 J	22	MRC-MW36A-060310	1.35	5.73	5.90
1,4-DICHLOROBENZENE	75	3/125	2%	0.13	93	1.3 J	570	MRC-MW43A-060210	5.56	199	50.9
2-BUTANONE	700	3/125	2%	0.57	410	0.82 J	1.5 J	MRC-MW93D-061010	4.78	1.24	22.8
4-ISOPROPYLTOLUENE	NA	1/125	1%	0.12	86	0.51 J	0.51 J	MRC-MW50A-062410	1.01	0.510	4.81
4-METHYL-2-PENTANONE	630	1/125	1%	0.32	230	0.67 J	0.67 J	MRC-MW93D-061010	2.69	0.670	12.9
ACETONE	550	30/125	24%	1.1	790	1.9 J	26 J	MRC-MW17A-060310	15.8	9.31	43.9
BENZENE	5	6/125	5%	0.13	93	0.33 J	150	MRC-MW17A-060310	2.67	33.5	14.5
BROMODICHLOROMETHANE	80	2/125	2%	0.15	110	0.23 J	0.31	MRC-MW95D-061110	1.30	1.38	6.10
CARBON DISULFIDE	100	3/125	2%	0.13	93	0.28 J	6.9	MRC-MW92C-061410	1.15	2.63	5.23
CARBON TETRACHLORIDE	5	3/125	2%	0.13	93	0.22 J	13	MRC-MW34B-061710	1.21	5.17	5.32
CHLOROBENZENE	100	3/125	2%	0.15	110	1.1 J	37	MRC-MW36A-060310	1.57	13.1	6.88
CHLORODIBROMOMETHANE	NA	1/125	2%	0.18	130	0.37 J	0.37 J	MRC-MW95D-061110	1.52	0.390	7.25
CHLOROETHANE	3.6	1/125	1%	0.29	210	0.73 J	0.73 J	MRC-MW92C-061410	2.42	0.730	11.6
CHLOROFORM	80	22/125	18%	0.16	110	0.17 J	19	MRC-MW95D-061110	1.93	3.45	6.77
CHLOROMETHANE	19	18/125	14%	0.3	210	0.3 J	1.3	MRC-MW73A-060410	2.54	0.454	11.8
CIS-1,2-DICHLOROETHENE	70	50/125	40%	0.17	85	0.28 J	1200	MRC-OW2I-060810	41.6	104	176
DICHLORODIFLUOROMETHANE	NA	1/125	1%	0.31	220	1.7	1.7	MRC-MW02A-060110	2.62	1.70	12.5
ETHANE	NA	5/14	36%	0.26	1.3	0.27 J	0.85	MRC-MW24A-060810	0.291	0.478	0.236
ETHENE	NA	2/14	14%	0.31	0.31	2.3 J	28	MRC-MW81B-061610	2.30	15.2	7.42
ETHYLBENZENE	700	2/125	2%	0.17	120	11	34	MRC-MW17A-060310	1.77	22.5	7.39

Table 2-2

Statistical Summary of Groundwater Sample Organic Chemical Analyses, May-June 2010
Lockheed Martin Middle River Complex, Middle River, Maryland
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Chemical	MDE Groundwater Criteria	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Sample of Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
		Number	Percent								
ISOPROPYLBENZENE	66	4/125	3%	0.13	93	0.44 J	14 J	MRC-MW21B-061410	1.21	4.29	5.33
M+P-XYLENES	NA	2/125	2%	0.24	170	13	14	MRC-MW50A-062410	2.21	13.5	9.66
METHANE	NA	13/14	93%	0.1	0.1	0.13 J	810	MRC-MW21A-061710	165	178	257
METHYL TERT-BUTYL ETHER	20	12/125	10%	0.17	120	0.21 J	170	MRC-MW79B-060310	3.97	27.1	18.3
METHYLENE CHLORIDE	5	3/125	2%	0.33	240	0.42 J	40 J	MRC-MW14B-062210	3.41	15.6	14.2
NAPHTHALENE	0.65	1/125	1%	0.24	170	38 J	38 J	MRC-MW69B-062110	2.32	38.0	10.1
N-PROPYLBENZENE	NA	2/125	2%	0.14	100	1.5	3.3 J	MRC-MW17A-060310	1.20	2.40	5.60
O-XYLENE	NA	9/125	7%	0.14	100	0.37 J	4.2	MRC-MW50A-062410	1.23	0.977	5.60
SEC-BUTYLBENZENE	NA	2/125	2%	0.13	93	0.57 J	1.5 J	MRC-MW24A-060810	1.11	1.04	5.21
TERTIARY-BUTYL ALCOHOL	NA	3/3	100%	-	-	31 L	93 L	MRC-MW24A-060810	61.7	61.7	NA
TETRACHLOROETHENE	5	5/125	4%	0.29	210	0.56 J	8.7 J	MRC-MW48A-061410	2.55	3.97	11.6
TOLUENE	1000	6/125	5%	0.13	93	0.21 J	12	MRC-MW17A-060310	1.21	2.48	5.30
TOTAL XYLENES	10000	9/125	7%	0.28	200	0.37 J	18	MRC-MW50A-062410	2.61	3.99	11.3
TRANS-1,2-DICHLOROETHENE	100	10/125	8%	0.19	140	0.39 J	56	MRC-OW2I-060810	2.28	9.33	9.20
TRICHLOROETHENE	5	62/125	50%	0.17	85	0.32 J	19000	MRC-MW74B-060710	326	662	1803
TRICHLOROFLUOROMETHANE	NA	2/125	2%	0.21	150	1.1	8.1 J	MRC-MW02A-060110	1.81	4.60	8.30
VINYL CHLORIDE	2	21/125	17%	0.22	160	0.22 J	390	MRC-OW2I-060810	9.31	46.0	43.9
SEMIVOLATILES (ug/L)											
1,4-DIOXANE	NA	23/72	32%	0.49	0.49	0.96 J	360	MRC-MW14B-062210	9.95	30.6	46.2
BUTYL BENZYL PHTHALATE	NA	2/4	50%	0.8	0.8	1.1	1.1	MRC-MW93D-061010, MRC-MW94D-061010	0.750	1.10	0.404

Footnotes:

For non-detects, 1/2 sample quantitation limit was used as a proxy concentration.

1/2 the detection limit was used for B qualified data.

NA - Not applicable/available.

126 wells sampled (122 surficial aquifer wells and 4 deep aquifer wells) one well was sampled twice (MRC-MW07A).

125 VOCs, 103 metals, 72 1,4‑dioxane, 4 (deep wells) SVOCs and dissolved metals, 24 hexavalent chromium, and 14 NAA parameters.

MDE - Maryland Department of the Environment, June 2008.

Table 2-3

Summary of Metals Exceeding Maryland Groundwater Standards, July-August 2008
Lockheed Martin Middle River Complex, Middle River, Maryland

Analyte	MDE Groundwater Standard[1] (ug/L)	Total Metals Samples			Filtered Metals Samples		
		Detections Exceeding Standards		Maximum Concentration	Detections Exceeding Standards		Maximum Concentration
		(Quantity)	(Percent)[2]	(ug/L)	(Quantity)	(Percent)	(ug/L)
Manganese	73	90	83%	43,900	88	81%	42,600
Iron	2600	61	56%	270,000	54	50%	286,000
Nickel	73	51	47%	12,900	49	45%	13,100
Beryllium	4	28	26%	263	23	21%	290
Vanadium	3.7	19	17%	218	4	4%	51.6
Zinc	1100	8	7%	20,700	8	7%	21,000
Arsenic	10	5	5%	36	1	1%	37
Lead	15	3	3%	94.4	1	1%	18.8
Chromium	100	2	2%	298	1	1%	308
Copper	1300	2	2%	2,850	2	2%	3,160
Cadmium	5	1	1%	8.7	1	1%	9.3
Mercury	2	1	1%	4.6	0	0%	0.28

1 MDE Soil and Groundwater Standards, Interim Final, March 2008.
2 Total numbers of samples for each metals analyses is 109.
ug/L = Micrograms per liter (i.e., parts per billion)

Table 2-4

Groundwater Depths and Elevations - June 2010
Lockheed Martin Middle River Complex, Middle River, Maryland

Well ID	Elevation Top of Well Casing-2010 Feet (NGVD 1988)	Elevation Ground-2010 Feet (NGVD 1988)	Screen Depth Top Feet (bgs)	Screen Depth Midpoint (1) Feet (bgs)	Screen Depth Bottom Feet (Below Grade)	Screen Elevation Top Feet (NGVD 1988)	Screen Elevation Midpoint Feet (NGVD 1988)	Screen Elevation Bottom Feet (NGVD 1988)	Depth to Groundwater 6/30/2010 Feet Top of Casing	Groundwater Elevation 6/30/2010 Feet (NGVD 1988)
MRC-MW01A	33.63	33.76	18	23	28	15.63	10.63	5.63	14.98	18.65
MRC-MW02A	28.35	28.99	17	22	27	11.35	6.35	1.35	9.10	19.25
MRC-MW03A	28.17	28.61	4	9	14	24.17	19.17	14.17	4.24	23.93
MRC-MW04A	24.26	24.42	4	9	14	20.26	15.26	10.26	3.80	20.46
MRC-EXT-MW04	34.22	32.66	--	--	--	NA	NA	NA	DRY	NA
MRC-MW05A	35.15	35.49	24	29	34	11.15	6.15	1.15	NM	NA
MRC-MW06A	31.82	32.07	23	28	33	8.82	3.82	-1.18	8.74	23.08
MRC-EXT-MW06	31.63	29.58	--	--	--	NA	NA	NA	11.41	20.22
MRC-MW07A	33.39	33.70	12	17	22	21.39	16.39	11.39	12.14	21.25
MRC-MW08A	9.70	9.87	3	8	13	6.70	1.70	-3.30	0.00	9.70
MRC-MW09A	8.26	7.72	4	9	14	4.26	-0.74	-5.74	2.90	5.36
MRC-MW10A	9.52	9.64	3	8	13	6.52	1.52	-3.48	0.20	9.32
MRC-MW11A	11.90	12.21	3	8	13	8.90	3.90	-1.10	3.79	8.11
MRC-MW11C	11.45	13.41	63	68	73	-51.55	-56.55	-61.55	2.21	9.24
MRC-MW12A	9.29	9.67	4	9	14	5.29	0.29	-4.71	2.55	6.74
MRC-MW12B	9.56	9.87	20	25	30	-10.44	-15.44	-20.44	3.99	5.57
MRC-MW12C	9.83	9.98	65	70	75	-55.17	-60.17	-65.17	0.60	9.23
MRC-MW13A	10.31	10.37	4	9	14	6.31	1.31	-3.69	4.77	5.54
MRC-MW14A	16.67	16.86	3	8.55	13	13.67	8.12	3.67	5.39	11.28
MRC-MW14B	15.88	16.06	20	25	30	-4.12	-9.12	-14.12	5.76	10.12
MRC-MW14C	15.88	16.02	65	70	75	-49.12	-54.12	-59.12	6.61	9.27
MRC-MW15A	16.80	17.01	3	8	13	13.80	8.80	3.80	0.00	16.80
MRC-MW16A	18.89	19.42	3	10.33	13	15.89	8.56	5.89	5.07	13.82
MRC-MW17A	32.59	33.06	9	14	19	23.59	18.59	13.59	7.09	25.50
MRC-MW18A	32.46	32.88	16	21.3	26	16.46	11.16	6.46	4.86	27.60
MRC-MW19A	36.36	36.90	8	13	18	28.36	23.36	18.36	11.86	24.50
MRC-MW20A	36.18	36.45	15	20	25	21.18	16.18	11.18	11.02	25.16
MRC-MW21A	32.70	33.09	6	11	16	26.70	21.70	16.70	4.97	27.73
MRC-MW21B	32.91	33.15	24	29	34	8.91	3.91	-1.09	11.23	21.68
MRC-MW22A	31.58	32.05	30	35	40	1.58	-3.42	-8.42	16.46	15.12
MRC-MW22B	31.04	31.24	27	32	37	4.04	-0.96	-5.96	0.00	31.04
MRC-MW23A	25.37	25.64	12	17	22	13.37	8.37	3.37	NA	NA
MRC-MW24A	20.77	21.31	10	15	20	10.77	5.77	0.77	7.92	12.85
MRC-MW25A	26.71	27.23	20	25	30	6.71	1.71	-3.29	12.81	13.90
MRC-MW26A	22.90	23.40	13	18	23	9.90	4.90	-0.10	10.19	12.71

Table 2-4

Groundwater Depths and Elevations - June 2010
Lockheed Martin Middle River Complex, Middle River, Maryland

Well ID	Elevation Top of Well Casing-2010 Feet (NGVD 1988)	Elevation Ground-2010 Feet (NGVD 1988)	Screen Depth Top Feet (bgs)	Screen Depth Midpoint (1) Feet (bgs)	Screen Depth Bottom Feet (Below Grade)	Screen Elevation Top Feet (NGVD 1988)	Screen Elevation Midpoint Feet (NGVD 1988)	Screen Elevation Bottom Feet (NGVD 1988)	Depth to Groundwater 6/30/2010 Feet Top of Casing	Groundwater Elevation 6/30/2010 Feet (NGVD 1988)
MRC-MW27A	20.76	21.07	8.5	14	19	12.26	6.76	2.26	9.81	10.95
MRC-MW27B	20.90	21.24	40	45	50	-19.10	-24.10	-29.10	23.65	-2.75
MRC-MW27C	21.35	21.62	68	73	78	-46.65	-51.65	-56.65	13.67	7.68
MRC-MW28A	17.45	17.83	9	14	19	8.45	3.45	-1.55	7.94	9.51
MRC-MW29A	13.97	14.36	5	10	15	8.97	3.97	-1.04	5.60	8.37
MRC-MW30A	11.14	11.28	4	9	14	7.14	2.14	-2.87	1.77	9.37
MRC-MW31A	11.00	11.12	4	9	14	7.00	2.00	-3.00	3.85	7.15
MRC-MW32A	11.01	11.23	4	9	14	7.01	2.01	-2.99	4.58	6.43
MRC-MW33A	11.08	11.19	4	9	14	7.08	2.08	-2.92	3.39	7.69
MRC-MW34A	10.88	11.13	4	9	14	6.88	1.88	-3.12	5.04	5.84
MRC-MW34B	10.84	11.20	20	25	30	-9.16	-14.16	-19.16	4.92	5.92
MRC-MW34C	10.80	11.21	45	50	55	-34.20	-39.20	-44.20	4.21	6.59
MRC-MW35A	8.39	8.87	3	8	13	5.39	0.39	-4.61	3.25	5.14
MRC-MW36A	9.72	10.15	8.5	13.5	18.5	1.22	-3.78	-8.78	7.42	2.30
MRC-MW37A	10.50	10.79	7	12.05	17	3.50	-1.55	-6.50	8.25	2.25
MRC-MW37B	7.36	7.64	24	29	34	-16.64	-21.64	-26.64	5.97	1.39
MRC-MW37C	7.45	7.58	60	65	70	-52.55	-57.55	-62.55	6.04	1.41
MRC-MW38A	8.07	8.13	4	9.6	14	4.07	-1.53	-5.93	6.26	1.81
MRC-MW38B	8.18	8.13	21	23.5	26	-12.82	-15.32	-17.82	NA	NA
MRC-MW39A	4.78	4.88	4	9	14	0.78	-4.22	-9.22	2.22	2.56
MRC-MW40A	4.50	4.74	5	10	15	-0.50	-5.50	-10.50	0.00	4.50
MRC-MW41A	27.52	27.82	6	12.7	16	21.52	14.87	11.52	9.06	18.46
MRC-MW42A	28.21	28.48	9	15.2	19	19.21	13.04	9.21	9.60	18.61
MRC-MW43A	11.01	11.34	3.5	8.5	13.5	7.51	2.51	-2.49	2.34	8.67
MRC-MW44A	10.64	11.11	3	8	13	7.64	2.64	-2.36	2.04	8.60
MRC-MW45A	4.64	5.15	3	9.72	13	1.64	-5.08	-8.36	12.89	-8.25
MRC-MW46A	6.40	6.54	3	8.8	13	3.40	-2.40	-6.60	5.41	0.99
MRC-MW47A	10.75	10.86	5	10	15	5.75	0.75	-4.25	3.47	7.28
MRC-MW48A	24.76	25.09	11	16	21	13.76	8.76	3.76	8.01	16.75
MRC-MW49A	31.47	31.47	12	17	22	19.47	14.47	9.47	12.43	19.04
MRC-MW50A	30.15	30.72	16	21	26	14.15	9.15	4.15	14.89	15.26
MRC-MW51A	21.88	22.09	3	8	13	18.88	13.88	8.88	2.60	19.28
MRC-MW52A	20.32	20.55	3	8	13	17.32	12.32	7.32	6.19	14.13
MRC-MW53A	18.59	18.79	3	8	13	15.59	10.59	5.59	5.17	13.42
MRC-MW53B	18.41	18.74	39	44	49	-20.59	-25.59	-30.59		NA

Table 2-4

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Well ID	Elevation Top of Well Casing-2010 Feet (NGVD 1988)	Elevation Ground-2010 Feet (NGVD 1988)	Screen Depth Top Feet (bgs)	Screen Depth Midpoint (1) Feet (bgs)	Screen Depth Bottom Feet (Below Grade)	Screen Elevation Top Feet (NGVD 1988)	Screen Elevation Midpoint Feet (NGVD 1988)	Screen Elevation Bottom Feet (NGVD 1988)	Depth to Groundwater 6/30/2010 Feet Top of Casing	Groundwater Elevation 6/30/2010 Feet (NGVD 1988)
MRC-MW54A	17.05	17.14	7	12	17	10.05	5.05	0.05	4.06	12.99
MRC-MW55A	38.35	38.70	12	17	22	26.35	21.35	16.35	12.69	25.66
MRC-MW56A	35.94	36.18	2.5	7.5	12.5	33.44	28.44	23.44	6.18	29.76
MRC-MW57A	36.49	36.96	2	7	12	34.49	29.49	24.49	8.46	28.03
MRC-MW58A	35.03	35.55	8	13	18	27.03	22.03	17.03	4.06	30.97
MRC-MW59A	34.11	34.47	2	7	12	32.11	27.11	22.11	9.63	24.48
MRC-MW60A	31.26	31.63	12	17	22	19.26	14.26	9.26	13.95	17.31
MRC-MW60B	30.06	30.82	22	27	32	8.06	3.06	-1.94	12.66	17.40
MRC-MW61A	24.16	26.05	4	9	14	20.16	15.16	10.16	6.11	18.05
MRC-MW62A	10.62	11.27	3	8	13	7.62	2.62	-2.38	1.66	8.96
MRC-MW62C	10.89	11.17	55	60	65	-44.12	-49.12	-54.12	3.46	7.43
MRC-MW63A	16.20	16.40	4	9	14	12.20	7.20	2.20	8.72	7.48
MRC-MW64A	30.88	31.40	6	11	16	24.88	19.88	14.88	6.75	24.13
MRC-MW65A	14.76	14.99	8	13	18	6.76	1.76	-3.24	6.50	8.26
MRC-MW66A	14.99	15.10	9	14	19	5.99	0.99	-4.01	7.74	7.25
MRC-MW67A	36.67	36.92	22	30	37	14.67	7.17	-0.33	20.82	15.85
MRC-MW68A	36.28	37.04	18	28	38	18.28	8.28	-1.72	12.91	23.37
MRC-MW69A	27.63	27.92	7	12	17	20.63	15.63	10.63	9.57	18.06
MRC-MW69B	27.85	27.90	25	33	40	2.85	-4.65	-12.15	12.48	15.37
MRC-MW70A	14.69	14.95	4	9	14	10.69	5.69	0.69	4.18	10.51
MRC-MW70B	14.44	14.63	20	25	30	-5.56	-10.56	-15.56	4.71	9.73
MRC-MW71A	16.90	17.29	4	9	14	12.90	7.90	2.90	2.20	14.70
MRC-MW71B	16.94	17.13	20	25	30	-3.06	-8.06	-13.06	5.22	11.72
MRC-MW72A	11.12	11.45	4	9	14	7.12	2.12	-2.88	6.80	4.32
MRC-MW72B	10.79	10.95	25	30	35	-14.21	-19.21	-24.21	6.92	3.87
MRC-MW73A	10.46	10.74	7	12	17	3.46	-1.55	-6.55	7.39	3.07
MRC-MW73B	10.28	10.44	24	29	34	-13.73	-18.73	-23.73	7.66	2.62
MRC-MW74A	11.18	11.69	8	13	18	3.18	-1.83	-6.83	8.19	2.99
MRC-MW74B	10.88	11.15	22	27	32	-11.12	-16.12	-21.12	8.40	2.48
MRC-MW74C	11.05	11.41	45	50	55	-33.45	-38.45	-43.45	8.78	2.27
MRC-MW75A	29.00	29.37	11.5	16.5	21.5	17.50	12.50	7.50	9.10	19.90
MRC-MW76A	28.42	28.70	9	14	19	19.42	14.42	9.42	10.79	17.63
MRC-MW76B	28.24	28.97	24	29	34	4.24	-0.76	-5.76	10.49	17.75
MRC-MW77A	23.06	23.87	7	12	17	16.06	11.06	6.06	NA	NA
MRC-MW78B	24.30	24.60	24	29	34	0.30	-4.70	-9.70	8.11	16.19

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Well ID	Elevation Top of Well Casing-2010 Feet (NGVD 1988)	Elevation Ground-2010 Feet (NGVD 1988)	Screen Depth Top Feet (bgs)	Screen Depth Midpoint (1) Feet (bgs)	Screen Depth Bottom Feet (Below Grade)	Screen Elevation Top Feet (NGVD 1988)	Screen Elevation Midpoint Feet (NGVD 1988)	Screen Elevation Bottom Feet (NGVD 1988)	Depth to Groundwater 6/30/2010 Feet Top of Casing	Groundwater Elevation 6/30/2010 Feet (NGVD 1988)
MRC-MW79B	19.14	19.65	27	32	37	-7.86	-12.86	-17.86	10.49	8.65
MRC-MW80A	32.82	33.23	4	9	14	28.82	23.82	18.82	7.82	25.00
MRC-MW80B	32.66	32.90	23	28	33	9.66	4.66	-0.34	12.17	20.49
MRC-MW81A	27.34	27.56	9	13.5	18	18.34	13.84	9.34	NA	NA
MRC-MW81B	25.96	27.00	22	27	32	3.96	-1.04	-6.04	9.29	16.67
MRC-MW82A	23.88	24.16	20	25	30	3.88	-1.12	-6.12	5.20	18.68
MRC-MW83A	20.14	20.42	24	29	34	-3.86	-8.86	-13.86	1.19	18.95
MRC-MW84A	20.20	20.69	20	25	30	0.20	-4.80	-9.80	1.45	18.75
MRC-MW85A	18.66	19.06	30	35	40	-11.35	-16.35	-21.35	5.33	13.33
MRC-MW86A	23.62	24.18	6	11	16	17.62	12.62	7.62	5.14	18.48
MRC-MW86B	23.72	24.18	24.5	29.5	34.5	-0.78	-5.78	-10.78	5.10	18.62
MRC-MW87A	26.64	27.06	6	11	16	20.64	15.64	10.64	11.66	14.98
MRC-MW87B	26.72	27.06	24.5	29.5	34.5	2.22	-2.78	-7.78	12.01	14.71
MRC-MW88A	24.47	24.78	10	20	30	14.47	4.47	-5.54	6.20	18.27
MRC-MW88B	24.40	24.68	48	53	58	-23.61	-28.61	-33.61	6.32	18.08
MRC-MW90B	21.67	21.88	30	35	40	-8.33	-13.33	-18.33	7.71	13.96
MRC-MW91A	36.85	36.75	10	15	20	26.85	21.85	16.85	9.32	27.53
MRC-MW91B	36.54	36.75	60	65	70	-23.46	-28.46	-33.46	19.60	16.94
MRC-MW91C	36.21	36.75	60	65	70	-23.79	-28.79	-33.79	NA	NA
MRC-MW92C	25.31	25.87	64.5	69.5	74.5	-39.19	-44.19	-49.19	25.43	-0.12
MRC-MW93A	32.05	32.29	4	9	14	28.05	23.05	18.05	NA	NA
MRC-MW93B	31.97	32.29	65	70	75	-33.03	-38.03	-43.03	NA	NA
MRC-MW93D	25.06	25.26	179	184	189	-153.94	-158.94	-163.94	9.80	15.26
MRC-MW94B	25.28	25.29	41.5	46.5	51.5	-16.22	-21.22	-26.22	NA	NA
MRC-MW94D	23.01	23.12	186	191	196	-162.99	-167.99	-172.99	11.82	11.19
MRC-MW95B	24.04	24.31	45	50	55	-20.96	-25.96	-30.96	NA	NA
MRC-MW95D	9.99	10.02	204	209	214	-194.01	-199.01	-204.01	1.82	8.17
MRC-MW96D	6.44	6.35	179	184	189	-172.56	-177.56	-182.56	0.00	6.44

MRC-MW23A - buried and cannot be located in the field.
NA - Not available.
NGVD = National Geodetic Vertical Datum.

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Figure 2-1

Figure 2-2

Figure 2-3

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Figure 2-5

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Section 3
Overview of Pilot Studies and Groundwater Modeling

In addition to the site investigations described in Section 2, two *in situ* pilot studies were conducted at the Middle River Complex (MRC) and groundwater flow and transport modeling was performed to evaluate potential remediation technologies. The first pilot study used *in situ* chemical oxidation (ISCO), a process that injects chemicals into the subsurface to react with and destroy trichloroethene (TCE) and other contaminants found at the site. The second study used enhanced anaerobic reductive dechlorination (ARD), a process in which a substrate is injected into the subsurface to enhance natural biological processes that break down site contaminants into harmless byproducts. This section summarizes those tests and the groundwater modeling. Complete pilot study reports are in Appendices E and F. Groundwater modeling provided estimates of groundwater recovery rates and cleanup times for various remedial alternatives. The Groundwater Modeling Report is in Appendix G.

3.1 ISCO PILOT STUDY

Tetra Tech conducted an ISCO pilot study in 2008 to determine whether this process could be applied successfully to the TCE areas to significantly and permanently reduce chlorinated volatile organic compound (VOC) concentrations in the saturated zone at the site. An Interim ISCO Pilot Study Report, prepared in 2009, is in Appendix E, providing more detail regarding the design, implementation, and results of the ISCO pilot study. The objectives of the ISCO pilot study were to:

- determine the effectiveness of ISCO in reducing chlorinated VOC concentrations at the site using sodium persulfate, both with and without hydrogen peroxide activation
- determine the hydraulic capacity of the pilot study area subsurface to accept the required injection volumes of the oxidant via direct-push (DPT) injections

- determine the extent of "rebound" of chlorinated VOC concentrations following oxidant injection

Bench-scale studies—CDM conducted bench-scale studies, using soil and groundwater collected from the ISCO pilot study area, to help determine the pilot study parameters. The effectiveness of the destruction of COC and the oxidant volume required to destroy the contaminants were tested with several different oxidants, including potassium permanganate, activated sodium persulfate (using hydrogen peroxide, sodium hydroxide, and iron as activators), and unactivated sodium persulfate. The following conclusions were derived from the bench-scale studies:

- Sodium persulfate with hydrogen peroxide activation resulted in the greatest rates of contaminant oxidation, but also resulted in the greatest oxidant consumption, which could lead to greater costs and a smaller radius of influence in a full-scale application. This formulation was recommended for testing in the field due to its success in treating the contaminants.

- Unactivated sodium persulfate was effective in treating trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), benzene, and 1,4-dioxane and resulted in the lowest oxidant consumption. Lower oxidant consumption could lead to lower costs and greater radius of influence in a full-scale application. This oxidant was also recommended for testing in the field due to its success and potential to significantly reduce overall remediation costs.

- Potassium permanganate was capable of TCE and cis-1,2-DCE oxidation. It was not very effective at oxidizing benzene and was not recommended for field testing.

Pilot study—Tetra Tech, Inc. (Tetra Tech) conducted the ISCO pilot study in the western TCE area, which contains 1,4-dioxane as well as TCE. Nested observation wells were installed in three locations in the central portion of the western TCE area to facilitate pilot testing. Activated and unactivated sodium persulfate were injected via DPT equipment. Two different methods of liquid injection were tested, due to the low hydraulic conductivity soil in the pilot study area: standard injection through DPT rods and use of pressure-pulse technology in conjunction with injection through DPT rods. The pressure-pulse technology was tested to determine if the injection rates and area of influence would improve with this technology. More information on the pressure pulse technology is in Appendix E.

Tetra Tech completed the oxidant injections in the pilot study area in the western TCE area from June 17–20, 2008. Oxidant injection took place through DPT rods both with and without the use of pressure-pulse technology and with and without the use of hydrogen peroxide as an activator. Injections were completed at nine separate locations. Injections were completed at moderate

pressure, ranging from 20–40 pounds per square inch (psi). At this pressure, most of the liquid was injected into the water column, but small quantities of injected reagent were also observed at the ground surface and at nearby monitoring wells.

Groundwater sampling associated with the pilot study included pre-injection baseline sampling and three post-injection sampling rounds. In the second post-sampling round, conducted two months following injection, average TCE and cis-1,2-DCE concentrations in the monitored wells showed reductions of 76% and 54%, respectively, from baseline concentrations. Similarly, the concentration of 1,4-dioxane showed a reduction of 69% from the baseline concentration. Data from the first two post-injection sampling rounds are detailed in the Interim in situ Chemical Oxidation Pilot Study Report included in Appendix E.

The third and final performance sampling event was conducted subsequent to preparation of the report in Appendix E. Table 3-1 presents sampling results from the baseline event and the three post-injection events. Results from the final performance monitoring of this sampling event indicate that:

- chlorinated VOCs and 1,4-dioxane concentrations in OW-4I remained relatively constant since the second round of sampling, showing overall decreases of 59% for TCE and 29% for 1,4-dioxane

- TCE and cis-1,2-DCE concentrations in OW-6I rebounded more significantly since showing substantial reductions in the first round of sampling, resulting in overall decreases of 14% for TCE; 1,4-dioxane reductions remained high, at 73%

- the greatest contaminant reductions were initially observed at MW-14B, but TCE and 1,4-dioxane concentrations both rebounded by an order of magnitude during the final sampling event. At this location, overall TCE and 1,4-dioxane reductions were 30% and 24%, respectively

The TCE and 1,4-dioxane increases observed during the final sampling event (and those seen in OW-6I during the previous event) are generally accompanied by a decrease in the oxidation reduction potential conditions from initial post-injection sampling events. This may indicate that untreated water from outside the pilot test area had migrated to these wells over the six month period since the injection. Another possible explanation is that contaminants diffused from lower hydraulic conductivity clays to groundwater, as equilibrium was re-established in the aquifer. The rebound observed is common following application of one ISCO injection. Accordingly, full-scale implementation of ISCO would include multiple injections and possibly other injection

strategies to account for the rebound observed during pilot study testing and to meet cleanup goals.

Increases in beryllium, cobalt, and nickel concentrations were observed in all sampled wells (except for cobalt and nickel at OW-5S). Metals concentrations increased substantially at MW-14B, presumably in response to the significant increase in oxidation-reduction potential (ORP) and decrease in pH caused by the chemical injection. The beryllium concentration increased approximately two orders of magnitude (from 1.8–290 μg/L), cobalt approximately one order of magnitude (from 49.4–1020 μg/L), and nickel approximately one order of magnitude (from 109–1880 μg/L).

Concentrations observed were substantially higher than their Maryland Department of the Environment (MDE) drinking water standards and U.S. Environmental Protection Agency (EPA) risk-based concentrations (RBC), and are among the highest observed on site. Additional sampling of these wells shows that the metals concentrations moderated as groundwater ORP and pH returned to pre-injection levels. Site-wide sampling also completed during this period indicates that these increases were highly localized in the pilot test area. The pilot test area is well outside facility process areas; therefore, the high metals concentrations leached from the soil at the pilot test location, considered in conjunction with the results of the metals leachability testing, provide additional evidence that high metals concentrations throughout the site are naturally occurring, and will be present in groundwater whenever appropriate geochemical conditions occur. If these conditions are created artificially via ISCO injections, and metals concentrations and/or mobility is increased as an unintended consequence, ISCO application could pose a net negative result, even if TCE concentrations are reduced.

High iron concentrations were also observed in the pilot study area wells during performance monitoring. Iron concentrations range from 51.5–232 micrograms per liter (mg/L) in OW-4I, OW-6I, and MW14B, which are greater than most iron concentrations throughout the site. Although iron data are not available from the background sampling round, the consistently high iron concentrations in the observation wells seems to indicate that iron is entering the dissolved phase, based on the change in geochemical conditions. MW14B followed a similar pattern for iron as it did for the other metals, with a spike to 270 mg/L following injection, then a reduction to 61 mg/L as geochemical conditions moderated. These significant increases, if they persist,

would be expected to cause negative side effects if ISCO were to be conducted as part of the selected response action. With the appropriate injection strategy, including multiple injections, ISCO could significantly reduce TCE concentrations at the site. However, the accompanying increases in groundwater metals concentrations may make full-scale implementation untenable, especially closer to the site boundaries.

3.2 ENHANCED ANAEROBIC REDUCTIVE DECHLORINATION PILOT STUDY

Tetra Tech conducted an enhanced ARD pilot study in 2008 to determine whether enhanced ARD could be applied successfully to the areas of high TCE concentration and significantly and permanently reduce VOC concentrations in the saturated zone of the site. ARD is the primary biological degradation process by which chlorinated VOCs are transformed into innocuous compounds such as carbon dioxide, ethene, ethane, and chloride. In the presence of a suitable electron donor (e.g., hydrogen), the appropriate naturally present or added microbial consortia, and favorable geochemical conditions, a hydrogen atom can replace a chlorine atom on a chlorinated ethene molecule. Hydrogen is typically generated when organic carbon is fermented. In this case, the ARD would be enhanced by the addition of organic carbon from a source such as lactate or vegetable oil that is injected in the subsurface.

The pilot study was conducted approximately 120 feet south of Building C in an area used as a vehicle access ramp to the rear of this building. An Enhanced Anaerobic Reductive Dechlorination Pilot Study Report, prepared in 2009, describing the design, implementation, and results of the ARD pilot study is in Appendix F. The objectives of the enhanced ARD pilot study were to:

- determine the effectiveness of enhanced ARD in creating reducing conditions in the subsurface and reducing VOC concentrations throughout the site using Emulsified Oil Substrate (EOS®) without pH buffering or biostimulation

- determine the effectiveness of hydraulic fracturing to promote the distribution of amendments in the subsurface. In the study, hydraulic fracturing was applied to the soil before injection of amendment into the subsurface; this involved injecting a mixture of water and sand at high pressure at various depths to open channels to allow for easier injection of the amendment (no contaminants are introduced to the subsurface by this process). Detailed information on hydraulic fracturing is in Appendix F.

***Bench-scale studies*—**CDM conducted bench-scale studies using soil and groundwater collected from throughout the site (including samples from low and neutral pH areas of the eastern TCE area) to help determine the parameters for the field-scale pilot study. The destruction of chemicals of concern was tested with several different substrates, including:

- EOS® 598
- EOS® 598B42 (including vitamin B12)
- sodium lactate
- whey

Each substrate was tested with and without addition of a microbial culture (Shaw SDC-9™). In all tests (except for the sterile and negative control tests), significant biodegradation of TCE and its daughter products was observed. Significant formation of ethene was also observed, indicating that complete reduction was occurring, even in low pH environments, without introduction of the microbial culture. These results led to the decision that enhanced ARD would be field tested without the use of a pH buffer or the addition of a microbial culture. EOS® 598B42 (supplied by EOS® Remediation) was chosen as the substrate to be field tested due to the rapid reduction of TCE and formation of ethene observed in the bench-scale study using this substrate. The vitamin B12 supplement provides additional nutrients to support the growth of microbes known to support complete destruction of TCE to ethene.

***Pilot study*—**Following the bench-scale tests, Tetra Tech conducted a field-scale pilot test of enhanced ARD in the eastern TCE area. Three sets of nested observation wells were installed in the northern portion of the study area in December 2007 to facilitate pilot testing. Enhanced ARD was tested using injection of EOS® 598B42 via fractures emplaced in the subsurface by hydraulic fracturing, as discussed above. Monitoring associated with the pilot study included baseline monitoring before injection and performance monitoring conducted approximately one month, three months, and six months following injection.

Injection of EOS® 598B42 (without the addition of a pH buffer or a microbial consortium) in the northern portion of the eastern TCE area effectively established reducing conditions, dechlorination from TCE to ethene, and growth of a significant population of dehalococcoides (DHC) and other important biological parameters such as desulfuromonas, dehalobacter, bvcA reductase, and vinyl chloride reductase. Reducing conditions were maintained and ARD continued in the observation wells for at least six months. The radius of influence established by

the injection method used was conservatively estimated at 20 feet. Results of groundwater sampling associated with this pilot study are in Table 3-2.

Significant complications arose during the pilot study that may preclude full-scale implementation of fracturing technology at the MRC. In one case, a shallow fracture began just below the water table (10 feet in the pilot study area) emplaced with an orientation greater than 45 degrees from the horizontal and came within a few feet of the ground surface. Fractures diverging significantly from the horizontal, such as this one, would cause additional problems in areas where fractures would have to be placed closer to the ground surface to address areas with shallower groundwater contamination (for example, the southern portion of the eastern TCE area). Moreover, injected water and EOS® infiltrated into the site storm water system and were released to the nearby surface water, indicating that active and inactive utilities throughout the MRC would significantly complicate the use of hydraulic fracturing and any type of liquid injection at the site.

3.3 GROUNDWATER MODELING

Groundwater flow and transport modeling was conducted to help guide remediation planning. The full modeling report is in Appendix G. The numerical groundwater flow model was initially constructed based on a conceptual model developed using hydrogeological data, including site geology, hydrogeologic parameters, and surrounding surface water features. The model was then calibrated to groundwater level data collected during groundwater monitoring events in 2008 and 2009, to data from groundwater pumping tests conducted in 2007, and to data collected via level recorders installed in 2009 in select monitoring wells and at surface water locations.

The groundwater contaminant transport model was developed based on the current contaminant profile at the site and checked via initializing particles in the model at the potential release locations (as determined during the site investigations). A 10-year half-life for the natural degradation of TCE was assumed based on a range of values from approximately one to 13 years noted in the scientific literature for anaerobic conditions (Aronson and Howard, 1977; Wiedemeier, et al., 1999). This was considered a relatively conservative value (see Appendix G for more information).

Following calibration, the groundwater flow and transport model was used to simulate various remediation scenarios to help guide the conceptual design and effectiveness evaluations.

Groundwater modeling addressed important remediation system design considerations, such as extraction and injection well locations, depths, pumping rates required to hydraulically contain the two major areas of TCE contamination, injection rates achievable with acceptable groundwater mounding and pressure responses, and time to reach specific concentrations (important for decisions related to the implementation/discontinuation of active remediation). The model analysis focused on the two major TCE areas at the site: the western and eastern TCE areas.

Hydraulic containment systems were simulated for both TCE areas. Total pumping rates required to maintain hydraulic control were very low, less than 2 gallons per minute (gpm) for the western area and less than 3 gpm for the eastern area. Groundwater containment at these low flow rates reflects the generally low hydraulic conductivity of the aquifer at the MRC.

More aggressive scenarios were also simulated, including additional pumping wells for focused source recovery, and incorporation of the anticipated results of various source treatment scenarios, such as *in situ* bioremediation and electric-resistance heating. In general, adding wells did not significantly increase the overall groundwater recovery rate, and varying degrees of source reduction did not significantly affect the time required to reach drinking water standards. The time to reach drinking water standards exceeded 90 years in all simulations.

Additional simulations were performed for the southeastern TCE area to indicate expected general performance of injection scenarios (for the application of an *in situ* treatment technology). For injection scenarios, the model grid detail was increased substantially in the southeastern TCE area so that relatively dense networks of injection wells could be simulated with sufficient accuracy. Predictive simulations of selected injection well system designs and various operational modes were conducted to study the viability of injection and the effect of injection both with and without local groundwater extraction. The results of these simulations provided significant foundational information to facilitate selection of the recommended remedial alternative.

The contaminant transport model was also used to assist in the estimation of the current mass of TCE and 1,4-dioxane in the areas being simulated, using groundwater TCE and 1,4-dioxane concentrations and data on total organic carbon and bulk density from soil samples collected at the site, literature values for the partitioning coefficients for these compounds, and porosity estimates. As shown in Appendix G, the estimated current mass of TCE in the eastern TCE area

is approximately 113 pounds, and the estimated current mass of TCE is approximately 34 pounds in the western TCE area; therefore, the total estimated TCE mass in the areas being simulated is approximately 150 pounds. The total estimated mass of 1,4-dioxane in the simulated area is less than 3 pounds. The groundwater model was also used to calculate the mass of TCE in the locations proposed for active remediation (i.e., areas with TCE concentrations greater than 1,000 μg/L) in the eastern and western TCE areas. These calculations indicated that approximately 70 pounds of TCE are present in the eastern areas and 20 pounds of TCE are present in the western area.

The mass flux of contaminants to surface water was also simulated over a 100 year period. Under a scenario that included no active treatment, a total of approximately 7.5 pounds of TCE and 1.9 pounds of 1,4-dioxane were discharged to the surface water over the 100 year period. The maximum annual discharge of TCE to surface water from the western TCE area (to Cow Pen Creek) was 0.2 pounds in Year 8 and the maximum discharge of TCE to surface water from the eastern TCE area (to Dark Head Cove) was 0.03 pounds in Year 55. The effect of mass flux on surface water contaminant concentrations is in Section 4.

Once the three final alternatives were selected (Section 6), modeling simulations were run for each option. The results of those simulations are discussed in greater detail in the individual alternative descriptions. The groundwater modeling report is in Appendix G.

Table 3-1

In Situ Chemical Oxidation Pilot Study Data
Lockhed Martin Middle River Complex, Middle River, MD

Observation Well	Sampling Round	TCE µg/L	DCE µg/L	VC µg/L	1,4-Dioxane µg/L	Beryllium µg/L	Cobalt µg/L	Nickel µg/L	pH S.U.	ORP mV	DO ppm
OW4S	Baseline	ND	ND	ND	ND	ND	7.3	6.6	6.14	12	0.00
	Round 1	14	5.1	ND	3.3	--	--	--	5.58	248	12.01
	Round 2	1.7	2.1	ND	ND	--	--	--	5.80	54	0.00
	Round 3	1.5	0.63	ND	ND	0.12	48.5	17.5	4.72	6	4.73
	% Reduction	Increase	Increase	No Change	No Change	--	--	--	--	--	--
OW4I	Baseline	1520	399	2	100	5.4	66.8	116	5.62	15	0.00
	Round 1	790	200	ND	56	--	--	--	5.51	20	0.31
	Round 2	600	160	ND	70	--	--	--	5.50	14	0.00
	Round 3	630	180	ND	71	12.3	93.3	180	4.33	10	4.73
	% Reduction	59%	55%	Complete	29%	--	--	--	--	--	--
OW5S	Baseline	3	3	ND	ND	1.4	110	24.6	5.95	67	0.00
	Round 1	10	0.92	ND	2	--	--	--	2.84	490	19.99
	Round 2	3.7	2	ND	ND	--	--	--	5.40	279	1.70
	Round 3	1.6	1.8	ND	ND	2.2	61.9	22.5	4.57	63	4.94
	% Reduction	47%	40%	No Change	No Change	--	--	--	--	--	--
OW5I	Baseline	268	68	1	87	0.9 J	47.5	44.8	5.82	4	0.11
	Round 1	--	--	--	--	--	--	--	--	--	--
	Round 2	--	--	--	--	--	--	--	--	--	--
	Round 3	--	--	--	--	--	--	--	--	--	--
	% Reduction	--	--	--	--	--	--	--	--	--	--
OW6S	Baseline	2	1.4	ND	0.8	1.2	46.9	22.5	5.78	76	0.00
	Round 1	ND	ND	ND	ND	--	--	--	2.32	652	19.99
	Round 2	3	2	ND	ND	--	--	--	2.88	487	15.67
	Round 3	3.4	3.4	ND	ND	4.5	105	40.5	3.92	311	7.00
	% Reduction	Increase	Increase	No Change	Complete	--	--	--	--	--	--
OW6I	Baseline	832	166	1	166	ND	28.3	41.2	5.22	-12	2.25
	Round 1	30	4.1	ND	6.9	--	--	--	2.46	660	19.99
	Round 2	540	100	ND	42	--	--	--	4.65	184	6.17
	Round 3	720	140	ND	44	0.42	141	201	4.32	66	5.93
	% Reduction	14%	16%	No Change	73%	--	--	--	--	--	--
MW14B	Baseline	3300	ND	ND	158	1.8	49.4	109	5.35	123	0.00
	Round 1	210	3.1	ND	4.2	290	1020	1880	2.36	705	19.99
	Round 2	230	4.2	ND	19				2.60	647	0.72
	Round 3	2300	47	ND	120	54	180	412	2.91	406	4.03
	% Reduction	30%	Increase	No Change	24%	--	--	--	--	--	--

TCE - Trichloroethene
DCE - cis-1,2-Dichloroethene
VC - Vinyl Chloride

ORP - Oxidation Reduction Potential
DO - Dissolved Oxygen
µg/L - Micrograms per Liter

S.U. - Standard Units
mV - millivolts
ppm - Parts per Million

-- - Not analyzed or not applicable

Table 3-2

Anaerobic Reductiove Dechlorination Pilot Study Data
Lockhed Martin Middle River Complex, Middle River, MD

Observation Well	Sampling Round	TCE µg/L	DCE µg/L	VC µg/L	Total CVOC µ–mol/L	Beryllium µg/L	Cobalt µg/L	Nickel µg/L
OW1I	Baseline	7390	1730	178	76.9	0.9 J	87.5	34.5
	Baseline - 2 *	--	--	--		--	--	--
	Round 1	2800	740	68	30.0	0.43	21.8	11.4
	Round 2	7700	1800	210	80.5	--	--	--
	Round 3	4100	1600	120 J	49.6	0.58 B	41.1	12.3
OW1D	Baseline	9370	1740	81	90.6	ND	29.8	16.7
	Baseline - 2 *	--	--	--		--	--	--
	Round 1	8500	1600	170	83.9	--	--	--
	Round 2	7800	880	ND	68.4	--	--	--
	Round 3	150	790	ND	9.3	0.37 B	12.2	18.8
OW2I	Baseline	9940	3420	211	114.3	5.7	235	136
	Baseline - 2 *	--	--	--	--	--	--	--
	Round 1	2800	3300	170	58.1	--	--	--
	Round 2	250	9200	760	109.0	--	--	--
	Round 3	39	53	16	1.1	0.46 B	32.4	35.1
OW2D	Baseline	12200	1190	23	105.5	0.1 J	22.5	19.5
	Baseline - 2 *	--	--	--		--	--	--
	Round 1	6600	3800	510	97.6	0.37	10.2	8.8
	Round 2	2400	4200	1100	79.2	--	--	--
	Round 3	60	1600	1100	34.6	0.29 B	16.8	19.4
OW3I	Baseline	932	253	23	10.1	0.1 J	22.5	19.5
	Baseline - 2 *	--	--	--		--	--	--
	Round 1	1500	330	32	15.3	0.83	74.9	47.4
	Round 2	53	1700	46	18.7	--	--	--
	Round 3	2.3 J	140	7.2	1.6	0.38 B	1.6	0.88 B
OW3D	Baseline	2320	331	28	21.5	0.07 J	25.0	22.9
	Baseline - 2 *	--	--	--		--	--	--
	Round 1	3000	2800	45	52.4	0.32	51.4	9.9
	Round 2	ND (140)	4000	75	42.5	--	--	--
	Round 3	ND (83)	2700	440	34.9	0.65 B	17.6	4.4

Table 3-2

Anaerobic Reductiove Dechlorination Pilot Study Data
Lockhed Martin Middle River Complex, Middle River, MD

Observation Well	Sampling Round	Iron µg/L	TOC mg/L	Methane µg/L	Ethene µg/L	Chloride mg/L	Sulfate mg/L	pH S.U.
OW1I	Baseline	--	3.0	3530	9.5	60.8	11.1	5.88
	Baseline - 2 *	--	--	--	--	--	--	5.34
	Round 1	--	4	1200	3.5	--	17.2	5.89
	Round 2	--	3	590	1.7	73.5	9.5	--
	Round 3	7080	5	1200	5.9	172	14.5	6.02
OW1D	Baseline	--	3.1	634	80.4	60.2	43.1	6.74
	Baseline - 2 *	--	--	--	--	--	--	5.66
	Round 1	--	3.0	3300	7.0	--	7.6	5.39
	Round 2	--	8	55	ND	32.2	2.7	--
	Round 3	14700	4	22	0.57	148	11.9	6.40
OW2I	Baseline	--	3.1	3390	9.2	83.0	43.3	5.39
	Baseline - 2 *	--	--	--	--	--	--	4.83
	Round 1	--	310	3400	3.7	--	1.3	5.58
	Round 2	--	100	850	60	97.9	0.4	--
	Round 3	8700	38	1200	290	169	4.6	6.60
OW2D	Baseline	--	5.7	350	27.5	48.8	15.1	6.26
	Baseline - 2 *	--	--	--	--	--	--	5.71
	Round 1	--	24	490	89.0	--	17.2	5.62
	Round 2	--	8	193	43	48.6	ND	--
	Round 3	85200	8	1400	290	462	0.20 B	6.61
OW3I	Baseline	--	1.7	990	4.0	39.1	37.3	6.33
	Baseline - 2 *	--	--	--	--	--	--	5.46
	Round 1	--	75	2500	5.1	--	0.5	5.51
	Round 2	--	41	2100	ND	50.6	0.2	--
	Round 3	12800	13	5700	4.3 J	158	6.1	7.01
OW3D	Baseline	--	2.1	1190	15.1	41.5	75.0	6.62
	Baseline - 2 *	--	--	--	--	--	--	5.96
	Round 1	--	120	1400	11.0	--	0.3	5.54
	Round 2	--	140	2100	3.6	2.0	ND	--
	Round 3	149000	11	7100	11	862	ND	7.27

Table 3-2

Anaerobic Reductiove Dechlorination Pilot Study Data
Lockhed Martin Middle River Complex, Middle River, MD

Observation Well	Sampling Round	ORP	DO	DHC
		mV	ppm	Cells/mL
OW1I	Baseline	37	2.54	--
	Baseline - 2 *	57	1.72	0.265
	Round 1	25	2.74	--
	Round 2	41	0.00	--
	Round 3	75	5.12	4.9
OW1D	Baseline	-15	2.65	--
	Baseline - 2 *	-13	2.84	<0.25
	Round 1	48	2.70	--
	Round 2	-36	0.00	--
	Round 3	-103	4.81	58.9
OW2I	Baseline	162	0.00	--
	Baseline - 2 *	153	1.92	--
	Round 1	-83	0.00	--
	Round 2	-111	0.00	--
	Round 3	-84	5.46	--
OW2D	Baseline	-30	0.58	--
	Baseline - 2 *	-49	1.58	--
	Round 1	-122	1.01	--
	Round 2	-88	0.00	--
	Round 3	-118	4.71	--
OW3I	Baseline	67	0.58	--
	Baseline - 2 *	117	1.88	7.41
	Round 1	-80	0.00	--
	Round 2	-66	0.00	--
	Round 3	-167	4.28	80.9
OW3D	Baseline	-40	0.21	--
	Baseline - 2 *	-18	1.71	0.055
	Round 1	-156	0.00	--
	Round 2	-163	0.00	--
	Round 3	-163	4.68	31400

* This data was collected one week prior to the injections.
TCE - Trichloroethene
DCE - cis-1,2-Dichloroethene
VC - Vinyl Chloride
TOC - Total Organic Carbon
ORP - Oxidation Reduction Potential
DO - Dissolved Oxygen
mg/L - Milligrams per Liter
µg/L - Micrograms per Liter
S.U. - Standard Units
mV - millivolts
ppm - Parts per Million
DHC - Dehalococcoides
-- - Not analyzed or not applicable

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Section 4
Exposure Assessment

4.1 CURRENT AND FUTURE LAND USE

An exposure assessment for the Middle River Complex (MRC) was conducted following the Maryland Department of the Environment's (MDE's) Voluntary Cleanup Program (VCP) land use definitions. The assessment includes an evaluation of potentially exposed populations and environmental receptors (to groundwater contaminants of concern) based on current and future land use and possible exposure pathways. The VCP requires applicants to choose a land use and restriction category based on the planned future use of the property. A Certificate of Completion issued for a property is contingent on future use of the property as defined by the VCP. Currently, the MRC is considered Tier 3 Industrial. The VCP defines this land use category as follows:

> "Industrial property to be used by workers over the age of 18, adult workers and construction workers, and other potential expected users. Industrial purposes allow access to the property at a frequency and duration consistent with a typical business day."

Groundwater is not currently used for drinking water, irrigation, or industrial processes at the MRC. This *Response Action Plan* (RAP) provides an evaluation of groundwater response action technologies at the MRC in terms of what would be required to achieve a Tier 1B Residential (Restricted) land use and restriction category. The VCP defines this land use and restriction category as follows:

> "Property usage that allows exposure and access by all populations including infant, children, elderly, and infirmed populations. The "B (Restricted)" classification indicates that one or more land use controls (LUCs) are imposed as a condition of residential use of the property."

Remediation of groundwater to drinking water standards is not feasible in a reasonable time (less than 90 years) at this site due to the areal extent of contamination and low hydraulic conductivity of the soil matrix. Therefore, long-term land use controls, designed to prevent exposures that cause regulatorily unacceptable risk, would be required.

4.2 POTENTIAL EXPOSURE PATHWAYS

Possible exposure pathways at the site associated with groundwater containing concentrations of organic compounds above drinking water standards (MDE Generic Numeric Groundwater Standards) were identified to determine groundwater cleanup goals (Section 5) and appropriate remedial measures and land use controls. These possible pathways are as follows:

- direct exposure (dermal, inhalation, ingestion) for current site users and future residents, from activities including showering, drinking, irrigation (current and future use)
- exposure to volatile organic compounds (VOCs) via vapor intrusion (current industrial)
- exposure to VOCs via vapor intrusion (future residential)
- current and future exposure to sediments and surface water in Dark Head Cove and Cow Pen Creek that have been affected by site groundwater
- current and future exposure of construction workers to site groundwater
- current and future exposure of off-site receptors to groundwater with concentrations above drinking water standards

The goal of the selected response action is to most effectively eliminate regulatorily unacceptable risk associated with any of these pathways. The methods for achieving this goal for each pathway are detailed below.

Land use controls are required to eliminate the risk associated with some of the pathways described below. The MDE will document land use controls and related environmental covenants applicable to the MRC property in the applicable Certificates of Completion, which will be issued upon successful completion of soil remediation in each Block. Each Certificate of Completion will be filed in the local land use records and will pass to subsequent property owners as part of the deed documentation (i.e., "travels with the land"). The MDE regards all land use controls to exist in perpetuity unless the related environmental covenants are eliminated or modified by mutual consent of the stakeholders. The MDE will present certain environmental covenants as part of the Certificate of Completion documentation. The environmental covenants will provide stakeholders with legal standing for their enforcement of the covenants. The MDE will determine final disposition of any land use controls. Elimination or modification of any land use control may require a re-application to the VCP.

Direct exposure—The site risk assessment indicates that concentrations of certain chemicals detected in groundwater in some areas of the MRC would preclude the use of this groundwater

by any future residents. The risk characterization for residential use of MRC groundwater resulted in theoretical cancer risk estimates for the reasonable maximum exposure (RME) case in excess of MDE's upper end threshold of 1×10^{-5} (i.e., a one in 100,000 probability of cancer) and also of United States Environmental Protection Agency's (EPA's) target risk range of 1×10^{-6} to 1×10^{-4} (i.e., a one-in-a-million to one in 10,000 probability of cancer).

Chemicals in groundwater contributing to hypothetical residents' risk primarily include trichloroethene (TCE), vinyl chloride, tetrachloroethene (PCE), benzene, and, in some locations, arsenic (although arsenic concentrations do not exceed MDE Generic Numeric Cleanup Standards for groundwater). Hypothetical future residential exposures to groundwater at the site resulted in theoretical noncancer hazard index estimates exceeding 1.0 at many locations; this is considered an unacceptable noncancer risk. The main chemicals contributing to noncancer risk in groundwater are TCE, benzene, and metals.

No exposure to site groundwater exists at present. Future groundwater use for drinking, showering, or irrigation is considered highly unlikely due to low recovery rates, low pH in many portions of the site, and high concentrations of naturally occurring metals, especially iron. However, it is likely that the MDE will establish land use controls that prevent use of groundwater as part of the MRC Certificates of Completion, which are anticipated to be issued following submittal and execution of soil RAPs for each tax block. Based on the establishment of appropriate land use controls to eliminate this potential pathway, and to remain consistent with current Baltimore County practice, it is expected that current and future property owners will be prohibited from recovering and/or using groundwater.

Exposure to VOCs via vapor intrusion (current industrial use)—A significant indoor air and sub-slab vapor sampling program has been conducted in the active facilities at the MRC. This program has been established to protect current industrial workers at the site. Some samples have exceeded established conservative concentration thresholds. In these cases, sub-slab depressurization systems have been installed to draw air from below the foundation before it can migrate to indoor air and thereby eliminate the sub-surface to indoor air vapor pathway and reduce VOC concentrations in indoor air. Vapors are then treated via activated carbon and clean air is discharged to the atmosphere. Details on vapor intrusion sampling and sub-slab depressurization system operation are available in several documents, including:

- Remedial Action Progress Report #4, Sub-Slab Depressurization Systems—Buildings A and C (Tetra Tech, December 2009)

- Vapor Intrusion Investigation and Sub-Slab Depressurization System Operation, February 2010 Sampling Report (Tetra Tech, August 2010)

The Vapor Intrusion Model (ViM) and the Johnson and Ettinger Model (EPA, 2004) were run to determine groundwater concentrations that may lead to indoor air concentrations that exceed the current conservative benchmarks. Site data such as depth to water, soil conditions near the active facilities, and correlations between site sub-slab soil vapor concentrations and indoor air concentrations were entered into the models.

Two hundred runs of the ViM were executed, with a 10% variation in both directions for each input parameter's value to produce the results shown in Table 4-1; this table shows the groundwater concentrations that would protect indoor air concentrations in the 95th percentile of the runs. As shown in the table, protective concentrations calculated using ViM are lower than those predicted by the Johnson and Ettinger model. The results of the ViM will be used, to be conservative; therefore, a TCE concentration of 4,800 micrograms per liter (µg/L) or lower in groundwater near the active facilities would protect indoor air. Much of the site is available for industrial use without vapor intrusion controls, because only very small portions of the eastern TCE area exceed these values. See Appendix H for vapor intrusion modeling details.

As part of this process, a comprehensive Vapor Management Plan is being developed for the active portions of the facility to provide a more systematic methodology for sample collection and set protocols for starting and discontinuing operation of the sub-slab depressurization systems. This plan will be submitted under separate cover. Any information in that document affecting the vapor intrusion model results presented in this *Response Action Plan* (RAP) will be considered in the response action design phase. In summary, this pathway has been eliminated for the current industrial facilities. Land use controls will likely be established by the MDE to require a vapor monitoring and mitigation protocol for any future industrial activities at the MRC.

Exposure to VOCs via vapor intrusion (future residential use)—Using inputs similar to those described above, the ViM and Johnson and Ettinger model were also used to determine the groundwater concentration at which vapor intrusion may cause regulatorily unacceptable risk for residents of hypothetical future housing constructed without allowance for vapor mitigation.

Again, the ViM model yields lower results than the Johnson and Ettinger model, as shown in Table 4-2. To be conservative, the results of the ViM will be used; therefore, a TCE concentration of 35 µg/L or lower in groundwater near the future residences would protect indoor air.

Current groundwater concentrations are greater than these values; therefore, groundwater would be expected to contribute to regulatorily unacceptable risk to future site residents if proper vapor mitigation measures were not taken for dwellings near the TCE areas. This pathway will likely be eliminated via land use controls established by the MDE, including a combination of a requirement for vapor barriers and/or venting systems on any residences built in certain areas of the site. The calculations in this section are based on standard assumptions for residential units; if the property is transferred and residential development becomes a potential land use, the actual building location and construction will be used to update these calculations and develop updated protective groundwater concentrations for these compounds.

Because no VOCs have been detected on off-site properties, there is no off-site vapor intrusion risk.

More information on the specific land use controls that will likely be established for the selected alternative is presented in Section 8.

Exposure to sediments and surface water in Dark Head Cove and Cow Pen Creek (current and future use)—As discussed in Section 3, extensive groundwater modeling has been conducted to determine the groundwater and contaminant flow patterns at this site. Modeled scenarios include active remediation and monitored natural attenuation (MNA) and predict the mass of contaminants discharged to Dark Head Cove and Cow Pen Creek. For example, for a no action or MNA scenario, the total mass of TCE discharged to the surface water was calculated as just 7.5 pounds over a 100 year period. The maximum yearly flux to the surface water is predicted to be just 0.03 pounds for the eastern TCE area and 0.2 pounds for the western TCE area. Surface water modeling using these parameters results in a maximum modeled TCE concentration in surface water well below the relevant Maryland standard for TCE of 300 µg/L for surface water bodies not used for drinking water (*Code of Maryland Regulations* 26.08.03.02-2). This modeled result is also less than the federal Ambient Water Quality Standard of 30 µg/L for such surface water bodies. Even with a significantly overestimated discharge rate of one pound per year (a five-times overestimate of modeled

discharge), the maximum concentration in surface water is calculated to be less than 10 µg/L, which is also well below the relevant standards. Therefore, this risk pathway is not a concern even without active site remediation. Surface water quality modeling calculations are in Appendix H.

To confirm the results of the surface water modeling, sediment and sediment pore water samples were collected from locations where groundwater discharge from the eastern and western TCE areas to surface water would be expected. Pore water samples were collected from five locations in Dark Head Cove and three in Cow Pen Creek. TCE was detected in one sample, cis-1,2-dichloroethene (cis-1,2-DCE) was detected in two samples, and vinyl chloride was detected in one sample; all detections were less than 1 µg/L, which is consistent with the modeling results and significantly less than the federal and Maryland Ambient Water Quality Standards. These results confirm the lack of significant impact to the surface water bodies caused by on-site TCE contamination. A figure showing sampling locations and tables showing the analytical results for the samples collected are in Appendix I.

Sediment samples from multiple locations and depths were collected and submitted for VOC analysis, including 41 samples from the top layer of sediment (0–6 inches below the sediment/water interface), 10 samples from 6–18 inches below the interface, and 10 samples from 18–30 inches below the interface. Trichloroethene was not detected in any of these samples. In one sample, cis-1,2-DCE was detected at a concentration of 2 µg/kg, well below its associated screening levels. These sediment and pore water samples were collected in 2010 as part of a comprehensive sediment sampling program. A complete description of the sampling program and results will be submitted under separate cover.

Exposure of construction workers to site groundwater (current and future use)—The estimated risks posed to an unprotected construction worker encountering groundwater exceed the regulatorily acceptable risk ranges, but only at a few locations within the highest TCE concentration areas at the site. The primary concern is exposure to TCE, and the pathway of greatest risk contribution is inhalation. Using a conservative estimated exposure of four hours per day over a 30 day period, a groundwater TCE concentration of approximately 2,600 µg/L would be expected to cause potentially unacceptable risk without engineering controls. These risks can be mitigated via appropriate engineering controls and personal protective equipment as detailed in a site-specific health and safety plan developed prior to conducting intrusive work at the MRC.

Exposure of off-site receptors to groundwater with COC concentrations above drinking water standards (current and future use)—As described in Section 2.2.1, an off-site groundwater monitoring well network (24 wells installed to various depths at 9 locations) was sampled in 2007 and 2010. The well network was installed across Cow Pen Creek and Dark Head Cove from the MRC and was designed to monitor the potential off-site migration of contaminated groundwater. No exceedances of MDE Generic Numeric Groundwater Standards for VOCs or 1,4-dioxane were found in any of these wells. At this time, no off-site receptors appear to be exposed to these constituents.

Groundwater modeling, which indicates that these wells will not be affected by site contaminants, will be verified through continued groundwater monitoring to ensure that this pathway remains incomplete. In summary, all of the pathways listed above are either not complete pathways to receptors or can be eliminated via a program of land use controls. Therefore, the primary purpose of any active remediation recommended for this site would be to reduce contaminant mass.

Table 4-1
Groundwater Concentration Protective of Indoor Air (µg/L)—Current Industrial Use
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Model	Percentile	Groundwater concentration protective of indoor air (µg/L)		
		TCE	Vinyl chloride	Benzene
ViM	95th	4,800	650	3,200
J&E	NA	9,505	1,558	3,639

Table 4-2
Groundwater Concentration Protective of Indoor Air (µg/L)—Future Residential Use
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Model	Percentile	Groundwater concentration protective of indoor air (µg/L)		
		TCE	Vinyl chloride	Benzene
ViM	95th	35	7	2
J&E	NA	289	16	82

Section 5
Cleanup Criteria

5.1 CLEANUP CRITERIA

Cleanup goals must satisfy the requirements of the Maryland Department of the Environment's (MDE's) Voluntary Cleanup Program (VCP) and be consistent with the requirements of the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) (40 *Code of Federal Regulations* [CFR] Part 400.430), promulgated under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The VCP defines a need for response action at sites with a cancer risk of 1×10^{-5} (i.e., a one in 100,000 probability of cancer) or greater, or a hazard index of 1.0 or greater. In this case, because this *Response Action Plan* evaluates response actions based on a Tier 1B Residential (Restricted) criterion, Lockheed Martin Corporation (Lockheed Martin) recommends a risk-based response action. As discussed in Section 1, volatile organic compounds (VOCs) in various areas of the current industrial operations (Block I) will be addressed in a separate response action plan (RAP); additional investigation and monitoring in these areas is ongoing.

5.2 CLEANUP GOALS AND RESPONSE ACTION OBJECTIVES

***Organics*—**Concentrations of VOCs and 1,4-dioxane exceed drinking water standards (see MDE's Generic Numeric Groundwater Cleanup Standards) at various site locations; however, as discussed in Section 4, risks associated with these VOCs can be mitigated via land use controls to prevent use of groundwater that will likely be established by the Maryland Department of the Environment (MDE) as part of the Certificates of Completion for the MRC. Implementation of land use controls would eliminate regulatorily unacceptable risks associated with existing site groundwater contamination, so the primary goal of active remediation at the site will be to reduce trichloroethene (TCE) mass at the Middle River Complex (MRC). In a low permeability, heterogeneous aquifer such as that present at the MRC, achieving contaminant reduction is difficult. These subsurface conditions would significantly hinder recovery of contaminant mass via groundwater and/or vapor extraction and distribution of amendments for the purpose of *in situ* remediation. However, TCE mass reduction is considered achievable based on current

knowledge of site hydrogeology and contaminant distribution. TCE mass reduction would significantly reduce the potential for vapor intrusion and increase the potential for natural attenuation to meet more stringent milestones over time.

Groundwater modeling indicates that an estimated 90 pounds of TCE are currently in the areas proposed for active remediation (i.e., areas containing TCE concentrations greater than 1,000 µg/L). The mass of cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride were calculated based on the ratio of TCE to its daughter products in site groundwater. Before remediation, the initial TCE mass will be recalculated using results from the baseline sampling event, which will incorporate analytical results from existing wells and those installed to monitor response action progress. Mass removal will be measured by the results of post-remediation performance monitoring of these same wells.

As mentioned, mass removal is a difficult objective considering the low hydraulic conductivity soil and extremely low groundwater flow rates at this site. Therefore, following the active remediation described in Section 8, groundwater will be extensively monitored to determine remediation effectiveness. Performance evaluation criteria are in Section 7.1. In addition to mass removal, other site remediation milestones will be associated with the land use controls in the various Blocks. For example, it is likely that the Certificate of Completion issued by the MDE will allow for cycling of the operation of the sub-slab depressurization systems between active and passive mode, as warranted based on actual indoor air and system monitoring data. Vapor mitigation requirements for future industrial development may be based on the reduction of TCE concentrations in groundwater to below 4,800 micrograms per liter (µg/L) (Appendix H).

Similarly, the requirements for vapor mitigation on residential development may be based on reduction of TCE concentrations to below approximately 35 µg/L (Appendix H).

As stated in Section 4.2, the MDE regards all land use controls to exist in perpetuity and these land use controls could only be eliminated or modified by mutual consent of the stakeholders.

Inorganics—As stated in Section 2.2.1.2, screening of metals concentrations against MDE Generic Numeric Cleanup Standards for Groundwater indicates metals concentrations at the site are above screening levels. However, an analysis in the Metals Leachability in Aquifer Materials Report (Appendix C) indicates that the primary metals are likely naturally occurring in site soil.

Metals leachability testing (see Section 2.2.3 and Appendix C) indicates that metals in site groundwater are naturally present in soil; in some areas they are solubilized by low pH conditions and are then detected in site groundwater.

In bench-scale and pilot testing, increases in nickel, cobalt, and beryllium concentrations were observed when pH values decreased. These metals are not major contributors to site risk under probable site use scenarios. The Metals Leachability in Aquifer Materials Report contains the following statement:

> "Because it is presumed that they are naturally occurring and there are no receptors (drinking water or vapor intrusion), the treatment of metals would not effectively reduce risk at the site."

Therefore, metals in groundwater at the MRC are not chemicals of concern (COC), and their remediation is not necessary.

Response action objectives—Response action objectives (RAOs) are contaminant- and medium-specific goals that define the objectives of response actions that will protect human health and the environment. RAOs specify the COC (Table 6-1), potential exposure routes and receptors, and regulatorily acceptable contaminant levels for the site. Development of RAOs must consider Applicable or Relevant and Appropriate Requirements (ARARs). RAOs for groundwater were developed that consider a range of treatment and containment alternatives to meet the cleanup goals presented above. The following RAOs were developed for groundwater at MRC:

Response action objective	Description
1	Conduct active remediation with the objective of reducing the mass of TCE in the subsurface of the active remediation areas and reducing the mass of TCE daughter products, including primarily cis-1,2-DCE and vinyl chloride.
2	Prevent human exposure (including showering, drinking, and irrigation) to groundwater containing concentrations of site-related COC greater than drinking water standards (i.e., greater than MDE Generic Numeric Standards for Groundwater).
3	Prevent discharge of groundwater with COC causing regulatorily unacceptable human health and ecological risks in the sediments or surface water of Dark Head Cove and Cow Pen Creek.
4	Prevent off-site migration to adjacent properties of site-related COC in groundwater at levels that exceed drinking water standards.
5	Prevent exposure of industrial workers, construction workers, and future residents to site-related VOCs due to vapor intrusion from groundwater into buildings or through intrusive site activities at levels that would cause regulatorily unacceptable cumulative risk, with an Individual Lifetime Cancer Risk greater than 1×10^{-5} or a cumulative hazard index greater than 1.0 for non-carcinogenic VOCs.

5.3 ATTAINMENT OF CLEANUP GOALS

This RAP evaluates remedial alternatives based on achieving Tier 1B (Residential Restricted) conditions for organic compounds in MRC groundwater through land use controls (for risk mitigation) and active remediation (for contaminant mass reduction). Following active remediation and a post-remediation period of groundwater monitoring, a limited groundwater monitoring program (including monitoring for VOCs, 1,4-dioxane, and metals) would continue at the site. Land use controls will be established in the Certificates of Completion to be issued by MDE following submittal and execution of soil RAPs for each Block.

Section 6
Response Action Alternative Evaluation and Selection

6.1 INTRODUCTION

The selected technologies and land use controls for the proposed groundwater response actions are discussed in this section, as required by the Maryland Department of the Environment's (MDE's) Voluntary Cleanup Program (VCP) guidance (MDE, 2006). The *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) (40 *Code of Federal Regulations* [CFR] Part 400.430), promulgated under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), guides the selection of remedial technologies. This section describes the identification, screening, and evaluation of potential technologies and process options; the preliminary screening and detailed evaluation of these technologies and process options; selection of representative process options; development and detailed analysis of alternatives; comparative analysis of alternatives; and identification of the proposed alternative.

Technology identification and screening is based on the following steps:

- development of cleanup goals (Section 5)
- development of response action objectives (RAOs) (Section 5)
- identification of Applicable or Relevant and Appropriate Requirements (ARARs) (Section 6)
- identification of chemicals of concern (COC) (Section 6)
- identification of general response actions (GRAs) (Section 6)

6.1.1 Applicable or Relevant and Appropriate Requirements

The ARARs in this *Response Action Plan* (RAP) are based on the risk-based cleanup goals for organic contaminants in Section 5, as follows:

- any standard, requirement, criterion, or limitation under federal, Maryland, county, or municipal environmental law

- any promulgated standard, requirement, criterion, or limitation under a state environmental or facility-siting law that is either more stringent than the associated federal standard, requirement, criterion, or limitation, or is relevant for consideration or application in the absence of federal or Maryland environmental law

Other criteria that are nonpromulgated, nonenforceable guidelines or criteria that may be useful in developing a response action or necessary to determine what protects human health and/or the environment will be considered. Examples include United States Environmental Protection Agency (EPA) drinking water health advisories, reference doses (RfDs), cancer slope factors (CSFs), and certain MDE standards.

One of the primary concerns in developing response action alternatives for contaminated sites is the degree of human health and environmental protection offered by a given remedy. CERCLA Section 121 requires that primary consideration be given to response alternatives that attain or exceed ARARs. The purpose of this requirement is to make CERCLA response actions consistent with other pertinent federal and state environmental requirements.

The NCP identifies the following three categories of ARARs [40 CFR Section 300.400 (g)]:

- *Chemical-specific*—Health-risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Examples include maximum contaminant levels (MCLs) and federal Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC). Table 6-2 lists federal and Maryland chemical-specific ARARs. These ARAR criteria offer some medium-specific guidance on regulatorily "acceptable" or "permissible" concentrations of contaminants.

- Location-specific—Restricts actions or contaminant concentrations in certain environmentally sensitive areas. Examples of these areas (regulated under various federal laws) include floodplains, wetlands, and locations where endangered species or historically significant cultural resources are present. Table 6-3 presents a list of federal and Maryland location-specific ARARs and "to be considered" (TBC) criteria. These ARARs and TBC criteria restrict contaminant concentrations or activities solely on the basis of the particular characteristics or location of a site.

- Action-specific—Technology- or activity-based requirements, limitations on actions, or conditions involving special substances that control or restrict response action. Examples of action-specific ARARs include wastewater discharge standards, performance or design standards, or controls or restrictions on particular types of activities. Table 6-4 lists federal and Maryland action-specific ARARs and TBCs.

6.1.2 Chemicals of Concern (COC)

COC in groundwater at the MRC are those organic contaminants detected at concentrations that exceed Maryland's Numeric Generic Cleanup Standards. Although these standards are not necessarily the site cleanup goals, they are expected to be the trigger for the MDE to establish land use controls at this site. The COC and the frequency of their detection and maximum concentrations are summarized in Table 6-1. The distribution of representative organic compounds in site groundwater is presented in Figures 2-2, 2-3, and 2-4 for trichloroethene (TCE), benzene, and 1,4-dioxane, respectively. As detailed in Section 2, metals are not considered COC at the MRC.

6.1.3 General Response Actions (GRAs)

GRAs are broadly defined response approaches that may attain RAOs. GRAs describe categories of actions that could be implemented to satisfy or address a component of an RAO for the site. Response action alternatives will be developed using the following GRAs individually or in combination to meet the RAOs for contaminated groundwater at the MRC. The following GRAs were considered for groundwater at the MRC:

- no action
- TCE area containment
- *ex situ* treatment
- discharge/disposal
- limited action: land use controls and groundwater monitoring
- collection (of high concentration groundwater and vapor)
- *in situ* treatment

6.2 SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

The primary objective of this phase of the RAP is to identify and screen an appropriate range of technologies and process options that will then be used to develop response action alternatives using the following steps:

- identification and preliminary screening of technologies and process options
- detailed evaluation of technologies and process options that pass preliminary screening
- selection of representative process options

Various technologies and process options were identified for each GRA and screened based on the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988). Table 6-5 summarizes the preliminary screening of technologies and process options applicable to site groundwater conditions at the MRC. It presents the general response actions, identifies the technologies and process options, briefly describes the process options, and provides screening comments.

Technologies and process options (to address groundwater contamination at the MRC) retained after the preliminary screening were evaluated by the criteria of effectiveness, implementability, and cost, as described in Appendix J and summarized below:

- ***Effectiveness***
  - protection of human health and environment; reduction in toxicity, mobility, or volume; and permanence of solution
  - potential for the technology to address the estimated areas or volumes of contaminated media
  - potential for the technology to meet the cleanup goals identified in the RAOs
  - technical reliability (innovative versus proven) with respect to contaminants and site conditions
- ***Implementability***
  - overall technical feasibility at the site
  - availability of vendors, mobile units, storage and disposal services, etc.
  - administrative feasibility
  - special long-term maintenance and operation requirements
- ***Cost (qualitative)***
  - capital cost
  - operation and maintenance costs

The technologies and process options that passed the initial screening and detailed evaluation (provided in Table 6-6) were then selected for the next step in remedial alternative selection: developing groundwater response action alternatives.

6.3 DEVELOPMENT AND DETAILED ANALYSIS OF ALTERNATIVES

This section discusses the development of the groundwater response action alternatives from the process options retained above and describes the conceptual designs for the selected short list of alternatives. A two-step process for identifying and evaluating alternatives was used for this RAP. First, an initial list of 14 potential response action alternatives was developed from the process options retained during the preliminary screening and detailed evaluation. Advantages and disadvantages of each were identified and the alternatives' capital and operating costs were estimated. The initial list of 14 options was then screened, resulting in three remedial alternatives for further evaluation. Several important assumptions and design considerations were used to develop these alternatives:

- Contaminant mass removal is the primary consideration in selecting the active portion of the groundwater response action. Contaminant mass removal will, over time, reduce the need for vapor mitigation at the site and may reduce the time required to attain groundwater drinking water quality standards.

- The overall site risk and exposure pathways analysis indicates that land use controls without an active groundwater response action will protect human health and the environment at the MRC. Likely land use controls, to be established by the MDE, would restrict the use of site groundwater and provide a framework for monitoring and/or mitigation of contaminated vapor in areas where risk from vapor intrusion to existing or future buildings may exist.

- Industrial activity continues and a significant network of active and inactive underground utilities remains in the Block I (operating) area of the site; investigation of this area is ongoing. Therefore, remediation in Block I will be limited to certain accessible areas and will not include some areas near existing operations.

- The following definitions were used in developing response action alternatives for this site. The areas referred to below are based on the TCE isoconcentration contours from the 2010 sampling event (Figure 2-2):

    - "source area" treatment includes only areas with TCE concentrations greater than 5,000 micrograms per liter (μg/L) (these are in the eastern TCE areas only)

    - "high concentration area" treatment includes accessible areas within the 1,000 μg/L contour in the southern and northern portions of the eastern TCE area and in the western TCE area

    - "area-wide" treatment assumes that the active treatment would extend to a location halfway between the 1,000 μg/l and 100 μg/l contours in each area

- Hydraulic containment includes groundwater recovery trenches installed parallel to the surface water shorelines and are intended to restrict groundwater migration.

- Groundwater extraction includes groundwater recovery trenches installed parallel to the surface water shorelines or groundwater wells in the downgradient portions of the high TCE concentration areas and are intended to both restrict COC movement and extract COC mass.

- High concentration area groundwater extraction includes wells installed in accessible areas within the 1,000 g/L contour. These wells will also include the potential for employing vacuum-enhanced groundwater extraction to increase groundwater flow rates, remove some contaminant mass from the source area(s) following depression of the water table, and somewhat mitigate vapor intrusion in the operating plant areas.

- Groundwater extraction rates for containment and high concentration source area pumping are based on hydraulic testing and groundwater modeling. The groundwater model was calibrated to field conditions.

- We assume that discharge to the publicly owned treatment works (POTW) will be allowed. During initial operation of a groundwater extraction and treatment system, discharge to the POTW is preferable to discharge to surface water until concentrations in extracted groundwater decrease and become more predictable.

6.3.1 Screening of Initial Alternatives

Fourteen alternatives were developed from the technologies and process options retained in Section 6.2. Each alternative includes groundwater monitoring; options with active treatment include monitored natural attenuation (MNA) in treatment areas, if necessary, for continued mass removal following active remediation; and, options with groundwater treatment also include *ex situ* treatment and discharge to the POTW. Land use controls are also a component of each alternative; these controls are considered necessary to meet the RAOs for the Middle River Complex groundwater and will be established by the MDE as part of their Certificate of Completion for each Block at the site.

The 14 alternatives are as follows:

- ***Alternative A****:* MNA and land use controls

- ***Alternative B:*** Hydraulic containment with land use controls

- ***Alternative C:*** Groundwater and vapor extraction in high concentration areas (above 1,000 μg/L TCE) and land use controls

- ***Alternative D1:*** *in situ* bioremediation in high concentration areas (above 1,000 μg/L TCE) with groundwater and vapor extraction via trenches and land use controls

- ***Alternative D2:*** *in situ* bioremediation in high concentration areas (above 1,000 μg/L TCE) with groundwater and vapor extraction via wells and land use controls

- ***Alternative D3:*** *in situ* bioremediation in high concentration areas (above 1,000 μg/L TCE) and land use controls

- ***Alternative D4:*** *in situ* chemical oxidation in high concentration areas (above 1,000 μg/L TCE) with groundwater and vapor extraction via wells and land use controls

- ***Alternative E1:*** Area-wide *in situ* bioremediation with groundwater and vapor extraction via wells and land use controls

- ***Alternative E2:*** Area-wide *in situ* bioremediation and land use controls

- ***Alternative E3:*** Area-wide *in situ* chemical oxidation with groundwater and vapor extraction via wells and land use controls

- ***Alternative F1:*** Source area (above 5,000 μg/L TCE) *in situ* bioremediation with groundwater and vapor extraction via wells and land use controls

- ***Alternative F2:*** Source area (above 5,000 μg/L TCE) *in situ* bioremediation and land use controls

- ***Alternative F3****:* Source area (above 5,000 μg/L TCE) *in situ* chemical oxidation with groundwater and vapor extraction via wells and land use controls

- ***Alternative G:*** Electric resistance heating (ERH) (in the southern portion of the eastern TCE area) and *in situ* bioremediation with groundwater and vapor extraction via wells in high concentration areas (above 1,000 μg/L TCE) and land use controls

A description of the components of these options is provided in Table 6-7, along with a list of the alternatives' general advantages and disadvantages, and the approximate capital and operating costs of each. Based on the analysis of the remediation goals, advantages, disadvantages, and costs, the following alternatives were eliminated:

- ***Alternative A:*** Although this alternative would protect human health and the environment through implementation of land use controls, it does not remove significant contaminant mass and would not meet RAO 1 in a timely fashion. Therefore, Alternative A was removed from consideration.

- ***Alternative B:*** Similarly, this alternative would protect human health and the environment through implementation of land use controls, but would not provide mass removal in a reasonable time frame and would not meet RAO 1 in a timely fashion. Therefore, Alternative B was removed from consideration.

- ***Alternative D1:*** Alternative D1 is very similar to Alternative D2 in that it includes *in situ* bioremediation as the primary remedial technology for treatment in high concentration areas. The major difference is that trenches would be used for groundwater recovery in

D1, as opposed to wells being used in Alternative D2. Wells would be more effective, due to a substantial number of disadvantages with recovery trenches, including: issues with constructability (due to the required depths of the trenches); proximity to surface water and underground utilities in the installation area; difficulties in maintaining the trenches (especially considering the potential for clogging based on the high concentration of dissolved metals in the groundwater); and the roadway and storage tank in the southern portion of the eastern TCE area that would prevent installation of the trench near the high concentration area. Therefore, Alternative D1 was removed from consideration.

- ***Alternatives D4, E3, and F3:*** These alternatives include *in situ* chemical oxidation (ISCO) injections to treat contaminated areas of the site. Pilot testing at the site (see Section 3) indicates that ISCO poses several potential issues. First, solubilization of metals from site soils caused high concentrations of metals in groundwater in the injection area in the pilot tests. Although these effects moderated over time, migration of these metals toward surface water or to a groundwater treatment system could pose issues in a full-scale application. Introduction of large quantities of sulfates to the aquifer (via sodium persulfate injection) could also cause problems with the aquifer geochemistry, surface water (as the treated water migrates toward surface water), and groundwater treatment, if used. ISCO reagents are not persistent in the subsurface, so active treatment of groundwater contamination is limited to a short time period during and immediately following injection. In the pilot study, groundwater contaminant concentrations quickly rebounded following reductions observed immediately after injection. Therefore, alternatives that include ISCO were removed from consideration.

- ***Alternatives E1 and E2:*** These alternatives are similar to Alternatives D1 and D2 in that they use *in situ* bioremediation as the primary source of contaminant mass reduction. Alternatives E1 and E2 include area-wide remediation; in this scenario, injections are conducted for the entire area inside the 1,000 μg/L TCE isoconcentration contour and in approximately half of the area between the 1,000 μg/L and 100 μg/L concentration contours. The areas containing less than 1,000 μg/L of TCE contain a relatively small percentage of the mass of TCE at the site. Treatment of this additional area provides no additional risk reduction and only a minimum of mass reduction, at substantial additional cost. Therefore, Alternatives E1 and E2 were removed from consideration.

- ***Alternatives F1 and F2:*** These alternatives are similar to Alternatives D1, D2, and E1 in that they use *in situ* bioremediation as the primary source of contaminant mass reduction. Alternatives F1 and F2 focus on source area remediation (that is, active injections in all areas with concentrations of TCE greater than 5,000 μg/L). In this way, they provide a lower-cost alternative that still addresses the most contaminated areas of the site. The portions of the eastern TCE area with 1,000–5,000 μg/L of TCE represent a relatively large percentage of the TCE mass and are not addressed under these alternatives. Under this scenario, the western TCE area, which includes significant TCE mass, would not be treated because no concentrations of TCE above 5,000 μg/L have been identified in that area. Alternatives F1 and F2 were removed from consideration because they do not address a significant portion of the TCE mass in the eastern area and do not address the western TCE area at all.

- ***Alternative G:*** This alternative calls for ERH treatment in the high concentration areas. Although ERH would be effective in accessible areas, site utilities and surface features limit its application area. ERH is also an expensive option, with significant energy use. Alternative G was removed from consideration for these reasons.

Therefore, Alternatives C, D2, and D3 *(renumbered hereafter as Alternatives 1, 2 and 3 for clarity)* were carried forward for further evaluation:

- ***Alternative 1:*** Groundwater and vapor extraction in high concentration areas and land use controls
- ***Alternative 2:*** *in situ* bioremediation in high concentration areas with groundwater and vapor extraction via wells and land use controls
- ***Alternative 3:*** *in situ* bioremediation in high concentration areas and land use controls

6.3.2 Description and Detailed Analysis of Alternatives

This section describes the conceptual design of each alternative, followed by a detailed analysis using the nine NCP criteria set forth in 40 CFR Part 300, plus the added criterion of life cycle impacts. The evaluation criteria are discussed below.

6.3.2.1 Evaluation Criteria

Conceptual designs were developed for the three alternatives and each was evaluated against the nine CERCLA criteria from 40 CFR Part 300.430 and a tenth criterion, life cycle impacts. The evaluation criteria are described below:

- overall protection of human health and the environment
- long-term effectiveness and permanence
- short-term effectiveness
- life cycle impacts
- state acceptance
- compliance with ARARs
- reduction of toxicity, mobility, or volume through treatment
- implementability
- cost
- community acceptance

Overall protection of human health and the environment—Alternatives must be assessed for adequate protection of human health and environment (both short- and long-term) from regulatorily unacceptable risks posed by COC in MRC groundwater by eliminating, reducing, or controlling exposure to COC. Evaluation of this criterion includes the assessment of other

evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)— Alternatives must be assessed to determine whether they would attain ARARs under federal environmental laws and state environmental or facility siting laws. If one or more applicable regulations cannot be complied with, a waiver will be invoked. Grounds for invoking a waiver are as follows:

- the alternative will attain a standard of performance equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach; or,
- a state requirement has not been consistently applied or the state has not demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other response actions in the state

Long-term effectiveness and permanence—Alternatives must be assessed for the long-term effectiveness and permanence they offer, along with the degree of certainty that the alternative will succeed. Other considerations include, as appropriate, the magnitude of residual risk (e.g., risks posed by untreated waste or treatment residuals) and the adequacy and reliability of controls (e.g., controls needed to manage untreated waste or treatment residuals).

Reduction of toxicity, mobility, or volume through treatment—The degree to which an alternative employs recycling or treatment that reduces the toxicity, mobility, or volume of the waste must be assessed, including how the treatment and associated reduction addresses principal site risks.

Short-term effectiveness—The short-term effects of the alternative must be assessed considering the following:

- short-term risks that might be posed to the community during implementation
- potential effects on workers during the response action and the effectiveness and reliability of protective measures
- potential environmental effects of the response action and the effectiveness and reliability of mitigation measures during implementation
- time until protection is achieved

Implementability—The ease or difficulty of implementing the alternatives must be assessed by considering technical feasibility, administrative feasibility, and availability of services and materials.

Life cycle impacts—Two software tools, *SimaPro* and *SiteWise*, were used to analyze the life cycle environmental effects of the three remedial alternatives. The same inputs from the conceptual design of each alternative were used for both of these tools.

SimaPro—SimaPro is a systematic life cycle assessment (LCA) model that captures resource consumption, energy use, and emissions throughout the life of a product or process. This technique recognizes the interconnections of the elements in a system and enables identification of environmental contamination attributable to specific components and processes.

The concept of LCA was applied to the conceptual design of the three remedial alternatives in this RAP using *SimaPro* v.7.2 life cycle assessment software. The installation, operation, monitoring, and decommissioning phases were analyzed for each remediation alternative over 30 years. LCA is a "cradle-to-grave" impact assessment for all items consumed on site for each alternative. Inventory items, including heavy equipment, construction materials, treatment chemicals, and energy use, were modeled in *SimaPro*, which allows environmental loads to be attributed to system components, processes, and/or phases. The study does not model the contaminants associated with the site, nor does it account for the efficiency of the remediation systems.

Ecoinvent v.2.2 and the U.S. Life Cycle Inventory (USLCI) databases were used to create the inventories in *SimaPro*. The Tool for the Reduction of Chemical and other Environmental Impacts (TRACI) and ReCiPe2008 life cycle impact assessment methodologies were used to assess the potential environmental burdens of each alternative. TRACI is a tool developed by EPA to support life cycle assessment, pollution prevention, sustainability metrics, and process design. Impact categories assessed in TRACI include global warming, acidification, smog, ozone depletion, carcinogens, noncarcinogens, respiratory effects, eutrophication, and ecotoxicity. ReCiPe2008 offers three different perspectives; the "hierarchist" perspective, which is based on the most common policy principles, was used to assess 18 different impact categories. These categories include climate change, human toxicity, and fossil fuel depletion. The *SimaPro* information is in Appendix K.

The output of *SimaPro* includes normalized endpoint values (unitless) for the life cycle impacts described for Alternatives 1, 2, and 3. In this analysis, higher values indicate more environmental impact, and are therefore less desirable. These values are useful for comparing the three alternatives (refer to slide 78 of Appendix K, Life Cycle Impact Assessment: Alternatives Comparison *ReCiPe* 2008 Endpoint Normalization by Impact Category) because they facilitate the understanding of the relative environmental burden by impact category.

SiteWise—*SiteWise* is a spreadsheet-based tool developed by the U.S. Navy, U.S. Army Corps of Engineers, and Batelle Memorial Institute. It provides a model for assessing the environmental footprint of remedial alternatives in terms of a consistent set of metrics, including greenhouse gas emissions, particulate emissions, and energy usage. The components of Alternatives 1, 2, and 3 were divided into four modules (representing the remedial phases of most response actions) and their environmental footprint was then calculated; these are then combined to determine each alternative's total footprint, which can then be compared among the set of alternatives. *SiteWise* can also be used to determine the primary footprint contributors of each alternative. The *SiteWise* information is in Appendix K.

Cost—The concept of Total Cost Assessment (TCA) was developed in 1991 by Tellus Institute for the EPA and the New Jersey Department of Environmental Protection. It is based on methods and programs developed by General Electric Corporation to better select and justify waste management investment decisions that are environmentally sound and which reduce long-term liabilities. The American Institute of Chemical Engineers (AIChE) developed a full methodology around the TCA concept.

The AIChE methodology is the basis of the TCA performed for Alternatives 1, 2, and 3. TCA considers the costs associated with implementing a program, including direct costs associated with implementation and environmental and health costs, risks and liabilities, and costs borne by others. The cost categories considered in the Middle River TCA for the groundwater remediation alternatives are as follows:

- **I—Direct costs** (recurring and non-recurring), including:
  - Remediation design
  - Remediation construction, including capital, labor, material, and waste disposal

- Operating, maintenance, and monitoring
- Decommissioning and disposal upon remedy completion

- **II—Indirect costs** (recurring and non-recurring) expended by Lockheed Martin to manage and support the remediation program.

- **III—Future and contingent liability costs**, including:
  - Fines and penalties
  - Natural Resource Damage Assessments under CERCLA
  - Property damage
  - Disposal or recycling facility failures
  - Future development under land use controls
  - Currently unknown issues:
    - Unknown contamination in the remediation area or under the operating manufacturing facilities
    - Future releases to groundwater
    - Effect of future modification or demolition of manufacturing facilities, including changes in groundwater flow and contaminant release
    - Emerging contaminants

- **IV—Internal intangible costs**, including:
  - Community relations
  - Regulatory relations
  - Corporate image
  - Customer loyalty
  - Worker wellness and morale

- **V—External costs** (borne by society), including:
  - Environmental deterioration
  - Resource depletion
  - Protection of future residents and workers.

TCA, as applied in this groundwater RAP, includes quantitative estimates of Category I and II costs and qualitative assessments of Category III, IV, and V costs. Qualitative assessments are generally included in the other CERCLA evaluation criteria. Cost analysis results are in Appendix L.

State acceptance—MDE will review the proposed RAP and inform Lockheed Martin in writing, on or before the end of a 75-day review period, whether the RAP has been approved or rejected. If the proposed RAP is rejected, MDE will state the modifications necessary to receive approval. This criterion is not included as part of this evaluation because it requires MDE review of the RAP.

Community acceptance—Lockheed Martin is committed to its partnership with the community in regard to the environmental activities at the MRC and is currently developing materials to present the contents of this groundwater RAP to the public. Lockheed Martin will also provide program remediation updates and attend Civic Association meetings upon request. Input from the community will be an important consideration in the implementation of the response action at the MRC. However, because community review of the RAP has not yet occurred, this criterion is not included in this evaluation at this time.

Relative importance of criteria—Among the 10 evaluation criteria, the following are considered *threshold criteria*:

- overall protection of human health and the environment
- compliance with ARARs

Threshold criteria must be satisfied for an alternative to be eligible for selection. Among the remaining criteria, the following six are considered the primary *balancing criteria*. *Balancing criteria* weigh the relative merits of alternatives in terms of the following:

- long-term effectiveness and permanence
- short-term effectiveness
- life cycle impacts
- reduction of toxicity, mobility, or volume
- implementability
- cost

The remaining two of the 10 criteria (state and community acceptance) are *modifying criteria* that must be considered during response action selection. These last two modifying criteria can only be evaluated after MDE and the community have reviewed the proposed RAP. Therefore,

this RAP addresses only eight of the 10 evaluation criteria. The remaining two will be addressed through the RAP review, comment, and approval process.

6.3.3 Detailed Analysis of Alternatives

6.3.3.1 Alternative 1: Groundwater and Vapor Extraction in High Concentration Areas and Land Use Controls

Description of Alternative 1

Alternative 1 has four major components: (1) groundwater and vapor collection, (2) *ex situ* treatment of groundwater and vapors, (3) discharge, and (4) land use controls. Figure 6-1 provides a plan view of the locations of the components described below.

Component 1: Groundwater collection and vapor recovery—The groundwater collection and vapor recovery components of this option include:

- six groundwater/vapor recovery wells installed in the southwestern TCE high concentration area. The extraction wells would be spaced approximately 100 feet apart.
- four groundwater/vapor recovery wells installed in the northern TCE high concentration area
- five groundwater/vapor recovery wells installed in the southeastern TCE high concentration area

This component of Alternative 1 includes 15 wells that could be used to extract both groundwater and vapors. The number and spacing of the extraction wells are based on the hydraulic capture determined via pumping simulations conducted using the groundwater model. These recovery wells would be six inches in diameter and installed to a depth of approximately 30–35 feet bgs. Groundwater would be recovered using variable speed electric submersible pumps in combination with in-well level transducers. The pumps would be set to maintain a constant pre-determined liquid level in the wells to reduce aeration and metals precipitation. Figure 6-2 provides a schematic of a typical recovery well. The addition of vapor recovery capabilities to the high concentration area wells provides the following advantages:

- application of a vacuum to the wells can moderately increase the rate of groundwater flow
- vapor recovery can remove additional contaminant mass in the high concentration areas as groundwater drawdown exposes previously saturated soils containing adsorbed-phase (i.e., non-aqueous phase) volatile organic compounds (VOCs)
- vapor extraction, especially in areas near the operating facility, may help mitigate vapor intrusion

The pumping rate per extraction well is assumed to be approximately 1 gallon per minute (gpm), based on groundwater modeling and application of conservative safety factors, with a total maximum flow from all wells of 15 gpm assumed. The estimated vapor flow under a sustained vacuum of 150 inches of water is approximately 15 standard cubic feet per minute (scfm) per well, with a total vapor flow rate from all wells of approximately 200 scfm. However, the selected vacuum blower would have to be capable of generating up to 500 scfm of flow to accommodate unanticipated flows and future system growth.

This component will also include groundwater monitoring to determine groundwater concentration trends, to determine the effectiveness of the remedy, and to ensure that there is no regulatorily unacceptable risk at the site. The current monitoring well network might be augmented by additional wells in the treatment areas. The likely monitoring parameters would be VOCs, 1,4-dioxane, and metals. More information on the monitoring protocol will be presented in Section 8 for the selected alternative and further developed as part of the remedial design for the site.

Additionally, MNA may be used in the treatment area, if necessary, for continued mass removal following active remediation. MNA is a technique for monitoring or testing the progress of natural attenuation processes that can degrade contaminants in groundwater. It is often used with other remediation processes as a finishing option; in this case, natural processes can then mitigate any remaining pollution; regular groundwater monitoring can verify such reductions. A quantifiable TCE reduction goal will be established for the selected alternative and presented in Section 7. MNA would be used to treat contamination inside the active remediation areas as a finishing option, if required to meet the specific quantitative remedial goal for the selected alternative.

Component 2: ex situ treatment—Recovered groundwater and vapors would be conveyed via underground piping to a common treatment system between the eastern and western TCE areas (Figure 6-1). Piping would be routed to minimize road and railroad track crossings to avoid existing subsurface utilities (to the extent possible) and to limit the system's effect on future site use. All underground piping carrying contaminated groundwater would be high-density polyethylene (HDPE) pipe.

Once conveyed to the treatment system building, treatment via multiple unit processes would be required before discharging the treated water. The treatment system would be designed to treat a maximum continuous flow rate of approximately 25 gpm, to allow for future system expansion to other areas. Metals would have to be removed from the groundwater stream before organic constituents can be removed. This is necessary to prevent fouling the downstream treatment units (primarily due to the high iron and manganese concentrations expected in the recovered groundwater) and to meet potential discharge limitations. Following metals removal, the organic compounds (primarily TCE and its daughter products) would be treated. Finally, the pH would be adjusted as necessary to meet discharge limitations. The treatment process flow diagram is shown in Figure 6-3. The treatment process shown includes the required process if surface water discharge via a National Pollutant Discharge Elimination System (NPDES) permit is required. If discharge to the POTW is allowed, the treatment system could be significantly less complicated, as noted below. The treatment train would consist of the following major components:

- Aeration and pH adjustment (using sodium hydroxide) to precipitate metals from solution: the capability to use stronger oxidizers (such as hydrogen peroxide, oxygen, and ozone) would be included if additional metals removal proves necessary. An inclined plate clarifier would remove solids from the water stream. A polymer would also be added to allow the particles to coagulate/flocculate, for easier removal. With discharge to the POTW, the primary purpose of the metals removal would be to reduce the precipitation of metals during air stripping (because the metals discharge limitations would be much higher for the POTW than for surface water discharge). Removal of metals to these concentrations could be accomplished via aeration and pH adjustment; stronger oxidizers would not be required and chemical use would be expected to be reduced.

- following clarification, the pH of the water stream would be adjusted and the water stream treated using a shallow tray air stripper to remove VOCs

- after passing through the air stripper, the water stream would pass through cartridge filters to remove any remaining suspended solids

- liquid-phase granular activated carbon (GAC) would provide a final VOC polishing step. Treatment via liquid-phase GAC would not be required for POTW discharge.

- sludge would be accumulated in and partially thickened in a sludge holding tank. Sludge may be further thickened using gravity cloth filtration. Sludge generation would be expected to be reduced (due to the reduced chemical use) if treated water is discharged to the POTW.

- the vapor recovery system would consist of a vacuum blower and a knock-out tank to separate water from the recovered vapor stream (for transfer to, and treatment in, the groundwater treatment system)

- vapor-phase activated carbon would treat vapors recovered from the soil vapor extraction (SVE) system and the air stripper exhaust.

Treatment system components would be housed in a dedicated building, as shown in Figure 6-1. The arrangement of treatment system equipment in the building is shown in Figure 6-4. The extraction system's primary purpose is contaminant mass removal. It would operate intermittently and ultimately cease, as mass removal rates and contaminant concentrations decrease and significant contamination rebound following intermittent shutdown decreases.

Component 3: Discharge—Thickened sludge would be collected and sampled for the parameters required by the state and the designated Lockheed Martin-approved disposal facility and then disposed of off-site. Initial calculations of the monthly volume of sludge that would be produced (2,000 gallons) indicate that using a filter press to dewater the thickened sludge is not cost effective; we therefore propose that thickened sludge be removed from the site via vacuum truck and properly disposed of.

Treated groundwater would initially be discharged to the Baltimore County sanitary sewer system and treated at the City of Baltimore Back River Wastewater Treatment Plant.

Discharge from the groundwater treatment system would be pumped and tied into an existing sanitary sewer near the proposed treatment building. Discharge to the sanitary sewer would be metered and routinely sampled to comply with Baltimore County industrial wastewater discharge standards.

After the extraction and treatment system has operated for one to two years, extraction flow rates, groundwater concentrations, and treated water concentrations would be well established. If at that time the data indicate that the surface water discharge parameters could be met in an economical manner, plant operation data would then be used to apply for an NPDES permit to discharge to Dark Head Cove. The application would include developing an MDE-approved estuary model to calculate effluent limitations and to field calibrate the model. Treated water would be discharged to Dark Head Cove through a submerged multiple diffuser outfall. Discharge would be metered and routinely sampled to comply with the NPDES permit.

Component 4: Land use controls—Land use controls would be established by the MDE as part of the Certificate of Completion issued for each Block. The following land use controls are likely to be included in the Certificate of Completion:

- Prohibition of the use of groundwater beneath the property for any purpose.
- A requirement for the implementation of sub-slab soil vapor mitigation technology beneath all buildings where the potential for soil vapor intrusion to indoor air exists.

Detailed Analysis of Alternative 1

Overall protection of human health and environment—Alternative 1 would protect human health and the environment. Active groundwater and vapor extraction in the high concentration areas would reduce contaminant mass at the site and land use controls would eliminate regulatorily unacceptable risk. Groundwater monitoring will be used to determine contaminant trends, determine the effectiveness of the remedy, and to confirm that there is no regulatorily unacceptable risk at the site.

Compliance with ARARs—Alternative 1 would, over time, achieve the cleanup goals established in Section 5. Location-specific and action-specific ARARs that require compliance include the following:

- Resource Conservation and Recovery Act (RCRA) regulations, including Identification and Listing of Hazardous Wastes and Land Disposal Restrictions (LDRs)
- Occupational Health and Safety Administration (OSHA) regulations
- Maryland Hazardous Waste Management System regulations
- Maryland regulation of water supply, sewage disposal, and solid waste

- Maryland General Permit for Construction Activity
- Maryland Oil Control Program (OCP)

Long-term effectiveness and permanence—Alternative 1 offers long-term effectiveness because regulatorily unacceptable risk from site groundwater would be eliminated via land use controls and the groundwater and vapor extraction system would reduce contaminant mass. The groundwater model analysis indicates that it would take more than 90 years to reach drinking water standards throughout the site. Approximately 30 years would be needed to reach concentrations lower than those calculated to cause unacceptable risk via vapor intrusion in a residential scenario.

Reduction of toxicity, mobility, and volume through treatment—Alternative 1 would permanently and irreversibly reduce the mobility, toxicity, and volume of the organic contaminants in the environment over an extended period via mass removal and natural attenuation. In some cases this would be via contaminant transfer to other media through the *ex situ* treatment system rather than through destruction.

Short-term effectiveness—Construction associated with this alternative would pose insignificant risk to the surrounding community and on-site workers. During installation of the groundwater extraction and treatment system, the primary risk to the community would be from inhalation of the minimal amount of dust (and potential odor and organic vapor) generated during installation of piping trenches, wells, and soil borings. This risk would be mitigated through implementation of dust and vapor suppression measures. Throughout system operation, samples would be collected and maintenance performed to confirm that no hazardous substances are discharged to the environment. The groundwater extraction system would operate for approximately 15 years; if necessary, this would be followed by MNA to meet the project goals. Intrusive construction work, such as installation of piping, vaults, and foundations, may expose workers to contaminated groundwater and associated vapors. Monitoring and appropriate personal protective equipment would eliminate risk to workers.

Implementability—Designing and implementing each of the Alternative 1 components poses technical and administrative challenges, particularly the installation of an extensive piping and power/signal cable trench network throughout the operating facility, as well as operating the groundwater treatment system. However, personnel and equipment to design and implement the

proposed actions are readily available, and time to coordinate with stakeholders and to obtain the necessary permits can be built into the schedule. Identification and field location of utilities and other features that may interfere with construction will also be required during the design process and before intrusive construction work begins. With these considerations, Alternative 1 is implementable.

Life cycle impacts—*SimaPro* provides the following normalized values for major endpoints:

- climate change: human health—293
- particulate matter formation—105
- fossil fuel depletion—487

The following environmental effects were estimated using *SiteWise*:

- greenhouse gas emissions—2,250 tons (carbon dioxide [CO_2] equivalent)
- nitrogen oxides (NO_x) emissions—2.8 tons
- sulfur oxides (SO_x) emissions—7.5 tons
- particulate matter (PM10) emissions—0.07 tons
- total energy used—40,000 million British Thermal Units (MMBTUs)

Cost—The following costs for Alternative 1 were estimated via the TCA process:

- design and construction—$2,300,000
- 15-year operational period, 30–year long-term monitoring, and decommissioning—$4,800,000
- total cost—$7,100,000
- net present value cost—$4,700,000

6.3.3.2 Alternative 2: *in situ* Bioremediation in High Concentration Areas with Groundwater and Vapor Extraction via Wells and Land Use Controls

Description of Alternative 2

Alternative 2 consists of five major components: (1) *in situ* bioremediation, (2) groundwater and vapor collection via extraction wells (3) *ex situ* treatment of groundwater, (4) discharge, and

(5) land use controls. Figure 6-5 provides a plan view of the locations of the components described below.

Component 1: in situ bioremediation—Biological treatment would include injection of a carbon substrate (and de-chlorinating cultures and pH buffering solutions, if required) into the subsurface to enhance natural biodegradation of COC. Specifically, enhanced anaerobic reductive dechlorination (ARD) would treat the portions of the site contaminated with TCE and other chlorinated compounds noted in Section 5. ARD is the primary biological degradation process by which chlorinated VOCs are transformed into innocuous compounds such as carbon dioxide, ethene, ethane, and chloride. In the presence of a suitable electron donor (e.g., hydrogen), the appropriate naturally-present or added microbial population, and favorable geochemical conditions, a hydrogen atom can replace a chlorine atom on a chlorinated ethene molecule. Hydrogen is typically generated when organic carbon is fermented. In this case, the organic carbon would come from an injected carbon substrate such as lactate or vegetable oil.

Lactate is a soluble substrate and electron donor that dissolves in water and is typically used quickly by microorganisms. An advantage of soluble substrates is that delivery and distribution are more easily achieved in a heterogeneous environment, and the injection from a given point can cover a larger area than is the case with non-soluble slow-release substrates. Vegetable oil is a slow-release substrate and electron donor that slowly releases fatty acids into groundwater, which in turn are metabolized and used by microbes for ARD. Many of these substrates persist for months or years before being exhausted.

Appropriate microbial populations are required to facilitate ARD. Baseline and performance ARD pilot test sampling of groundwater indicate that appropriate species (particularly dehalococcoides) appear to be present in sufficient quantities to support complete ARD of chlorinated VOCs into non-toxic end products such as ethane and ethene. The results from the enhanced ARD pilot study also indicate that a pH buffering amendment (such as sodium bicarbonate) is not required to facilitate ARD processes. However, especially during the early stages of implementation, aquifer biological and geochemical parameters should be monitored to evaluate whether the necessary populations are flourishing and geochemical conditions do not limit ARD processes. This evaluation suggests that de-chlorinating cultures and/or pH buffering solutions could be added to the subsurface with the electron donor in subsequent injection events.

Under Alternative 2, biological amendment would be introduced into the subsurface using rows of injection wells connected by the underground conveyance piping to a central treatment plant building where biological amendment and pumping equipment would be located. Therefore, the central treatment plant building would be used for both *in situ* remediation system components and for the aboveground groundwater treatment process equipment. The conveyance piping to a central treatment plant would be co-located with piping for the groundwater extraction system. The bioremediation system would be designed based on the following criteria:

- Biological amendment would be injected using rows of injection wells installed perpendicular to the direction of groundwater flow. Injected amendment would be carried

between rows of injection wells by groundwater flow that has been slightly enhanced by pumping from downgradient extraction wells.

- Injection well locations and injection quantities are based on a goal of having a substrate concentration of 100 milligrams per liter (mg/L) or greater over at least 50% of the TCE biological treatment area following the initial injection event.

- Groundwater was modeled to simulate various injection scenarios (see Appendix G) in the southeastern TCE area, including groundwater extraction from the three planned wells in that area. Modeling indicates that injection of 3,000 gallons of fluid (1% substrate) at each of 25 injection locations would be adequate to meet the distribution goal.

- Groundwater was also modeled to estimate an achievable flow rate that does not cause groundwater mounding in excess of two feet or develop pressure heads greater than 10 feet in the injection zone. Mounding and pressure heads must be monitored and controlled during injection for two primary reasons. First, excessive mounding may be indicative of transfer of substrate from the injection zone to the water table. Second, excessive mounding may result in transfer of substrate to the ground surface or interception and transport of the substrate by utilities.

- Modeling results for the southeastern TCE area were used to estimate the area with greater than 100 mg/L of substrate in the other two TCE high concentration areas, assuming the same injection rate per well and similar transport from the wells. These calculations suggest that the injection scenario presented in this design would provide adequate distribution in these two areas as well.

- The slow groundwater movement at the site will minimize the possibility of migration of the amendment toward nearby surface water and will allow the amendment to remain in the treatment areas for a long duration, maximizing the effectiveness of the high concentration area treatment.

The bioremediation system components would be based on the above design criteria and installed as follows (see Figure 6-5):

- *Southwestern area:* Four rows of injection wells spaced 50–70 feet apart; 20–25 feet spacing between injection wells in a row; total of 40 injection wells; three downgradient extraction wells spaced 75 feet apart; two separate amendment lines from the central treatment plant location.

- *Southeastern area:* Four rows of injection wells spaced 50–60 feet apart; 20–25 feet spacing between injection wells in a row; total of 25 injection wells; three downgradient extraction wells spaced 75 feet apart; one amendment line from the treatment plant central location.

- *Northern area:* Three rows of injection wells with 12 injection wells (irregularly spaced due to obstacles); two downgradient extraction wells spaced 70 feet apart; one amendment line from the treatment plant central location.

Injection wells would be constructed of two-inch diameter Schedule 40 polyvinyl chloride (PVC) to a depth of approximately 30–35 feet bgs and screened from approximately 15-35 feet bgs. The design of a typical injection well is shown in Figure 6-6. The injected fluid would be a combination of dilution water and an appropriate substrate. The preliminary substrate recommended in this RAP is LactOil™ from JRW Remediation. This substrate is a combination of a slow-release soy vegetable oil (45%) and a fast-release soluble ethyl lactate (35%). The formulation is a stable microemulsion (generally an oil droplet size of less than 1 micron, -68V Zeta potential) that is completely miscible with water.

The substrate would be metered into the dilution water stream at the central treatment plant and injected over approximately two weeks (Figure 6-7). Injection rates would be maintained at a sufficiently low level to avoid development of mounding and pressure heads exceeding the limits described above. We estimate that approximately 3,000 gallons of fluid (de-oxygenated water with substrate) can be injected into each injection well over the two week period to obtain an adequate distribution of these amendments. Water will be de-oxygenated by an in-line membrane contactor.

These injection volumes total approximately 230,000 gallons of fluid during each event. The substrate (LactOil™) would be diluted to approximately 1% before injection; therefore, approximately 30 gallons (250 pounds) of substrate would be added at each location. This equates to approximately 2,200 gallons (19,000 pounds) of injected substrate per event. Additionally, microbial inoculum may be added at each injection well to supplement the naturally occurring microbes at the site. Injection parameters in each TCE area are summarized in Table 6-8.

Estimates from groundwater modeling indicate that an estimated continuous flow of 0.15 gpm can be injected at each well; this would be confirmed during the initial injection event. Assuming 0.15 gpm flow for each well, approximately two weeks of continuous injection would be required. Based on the groundwater contaminant concentrations and distribution, the low permeability nature of the subsurface, the site geochemical conditions, and experience at similar sites, it is expected that three injection events will be required. The actual number of injection events would be determined based on the remedy performance. The frequency of injection events would depend on factors such as VOC trends, the presence of an electron donor(s) in the formation, aquifer reduction state (based primarily on dissolved oxygen and oxidation-reduction potential readings), pH, and other parameters.

The existing groundwater flow velocity at the MRC is very slow (an estimated 1–10 feet per year). This would be increased only slightly by groundwater extraction from the downgradient extraction wells as described below. The groundwater monitoring and MNA portions of this component are similar to those described for Alternative 1.

Component 2: Groundwater collection—The primary purposes of this component of Alternative 2 are to:

- increase groundwater flow in the areas of the bioremediation injection wells to expedite and control distribution of injected amendments in the subsurface
- maintain hydraulic control of the injected amendment and COC during bioremediation
- provide limited additional removal of COC mass via pumping

- provide contingency capability to immediately recover and treat groundwater and amendment should the injections push substrate outside of the treatment area

In the southwestern and southeastern areas, this component would consist of three recovery wells in each area installed directly downgradient of the last row of injection wells, as shown in Figure 6-5. In the northern area, two recovery wells would be installed. Therefore, eight recovery wells would be installed for this alternative. Recovery wells would be installed to a depth of approximately 30–35 feet bgs and be six-inches in diameter. The design of the extraction wells is similar to those in Alternative 1 (see Figure 6-2). Groundwater modeling predicts that the total flow from these wells necessary to maintain a groundwater elevation of two-feet below mean sea level (msl) and maintain hydraulic control would be less than 0.5 gpm. Therefore, the total modeled flow for this alternative would be less than 4 gpm.

The system may operate intermittently (based on the results of the injections) because the primary purpose of the recovery system is to help distribute the amendment and provide groundwater flow control during bioremediation. System operation would be discontinued following confirmation that the injections are not causing any ongoing migration (from the injection area) of regulatorily unacceptable levels of substrate and/or site contaminants; this is estimated to be a maximum of two years following completion of the injections.

Component 3: ex situ treatment—The *ex situ* treatment system is similar to the version described in Alternative 1, with the following primary differences:

- The vapor extraction and treatment component of the system proposed under Alternative 2 is identical to that described in Alternative 1. However, vapor flows are expected to be lower as compared to Alternative 1.

- The total system flow rate required is reduced under Alternative 2 to approximately 4 gpm. To provide a safety factor and allow for future expansion, the treatment system would be designed for a maximum flow of 25 gpm.

- The system includes appropriate components to store, mix, and deliver amendment to the injection wells.

The *ex situ* treatment system components are shown in Figure 6-8 (process flow diagram) and Figure 6-9 (treatment equipment layout).

Component 4: Discharge—This component is similar to its Alternative 1 counterpart except that lower groundwater flow rates and associated sludge generation rates are expected.

Component 5: Land use controls—This component is similar to its Alternative 1 counterpart.

Detailed Analysis of Alternative 2

Overall protection of human health and environment—Alternative 2 would protect human health and the environment. *In situ* bioremediation in the high concentration areas would reduce contaminant mass at the site and land use controls would eliminate regulatorily unacceptable risk.

Groundwater monitoring will be used to determine contaminant trends, determine the effectiveness of the remedy, and to ensure that there is no regulatorily unacceptable risk at the site.

Compliance with ARARs—Alternative 2 would, over time, achieve the cleanup goals established in Section 5. The location-specific and action-specific ARARs that would have to be complied with include the following:

- RCRA regulations including Identification and Listing of Hazardous Wastes and LDRs
- OSHA regulations
- Maryland Hazardous Waste Management System regulations
- Maryland regulation of water supply, sewage disposal, and solid waste
- Maryland General Permit for Construction Activity
- Maryland OCP

Long-term effectiveness and permanence—Alternative 2 would be effective in the long-term because regulatorily unacceptable risk from site groundwater would be eliminated via land use controls and contaminant mass would be reduced primarily via *in situ* bioremediation. The groundwater model analysis indicates that approximately 90 years would be required to reach the final drinking water standards throughout the site. Approximately 25 years would be needed to reach concentrations lower than those calculated to cause unacceptable risk via vapor intrusion in a residential scenario.

Reduction of toxicity, mobility, and volume through treatment—Alternative 2 would permanently and irreversibly reduce the mobility, toxicity, and volume of the organic contaminants in the environment via mass reduction.

Short-term effectiveness—Construction associated with this alternative would pose insignificant risk to the surrounding community and on-site workers. During installation of the groundwater extraction and treatment system, the primary risk to the community would be from inhalation of the minimal amount of dust (and potential odor and organic vapor) generated during installation of the piping trenches, wells, and soil borings. This risk would be mitigated by implementation of dust and vapor suppression measures.

Intrusive construction work, such as installation of piping, vaults, and foundations, may expose workers to contaminated groundwater and associated vapors. Monitoring and appropriate personal protective equipment would eliminate risk to workers. Throughout system operation, monitoring and maintenance would be performed to ensure that no hazardous substances are discharged to the environment. Bioremediation would need to continue for approximately four years (i.e., three injection events). The groundwater extraction system would need to operate for approximately seven years.

Implementability—Designing and implementing each of the Alternative 2 components presents technical and administrative challenges, specifically during the installation of an extensive piping and power signal/cable trench network throughout the operating facility and operation of the groundwater treatment system. Significant technical challenges are posed by injecting amendment into low hydraulic conductivity soil, and in the presence of underground utilities which can provide preferential flow pathways that quickly convey the amendment away from the treatment zones. Of particular concern are preferential flow pathways that could convey injected substrate to the storm drainage system and to Cow Pen Creek or Dark Head Cove.

Identification and field location of utilities in the areas of construction and injection would also be required during the design process and before intrusive construction work begins. This is necessary to identify utilities that may interfere with construction and to identify potential pathways that could divert injected substrate away from the remediation zones and to surface water. Personnel and equipment required to design and implement the proposed actions are available, and time to coordinate with stakeholders and obtain necessary permits can be built into the schedule. With the considerations outlined above, Alternative 2 is implementable.

Life cycle impacts—*SimaPro* provides the following normalized values for major endpoints:

- climate change: human health—232
- particulate matter formation—85
- fossil fuel depletion—382

The following environmental impacts were estimated using *SiteWise*:

- greenhouse gas emissions—1,110 tons (CO_2 equivalent)
- NOx emissions—1.5 tons

- SOx emissions—4.4 tons
- PM10 emissions—0.08 tons
- total energy used—20,250 MMBTUs

Cost—The following costs for Alternative 2 were estimated via the TCA process:

- design, construction, and injections—$4,300,000
- 30–year long-term monitoring and decommissioning—$3,600,000
- total cost—$7,900,000
- net present worth cost—$6,000,000

6.3.3.3 Alternative 3: *in situ* Bioremediation, MNA, and Land Use Controls

Description of Alternative 3

Alternative 3 is similar to Alternative 2 except groundwater recovery would not be performed and *ex situ* groundwater treatment is not required. Because groundwater extraction is not a component of this alternative, additional injection wells are required to achieve the substrate distribution goal. Alternative 3 consists of two major components: (1) *in situ* bioremediation and (2) land use controls. Figure 6-10 provides a plan view of the locations of the components described below:

> *Component 1: in situ bioremediation*—This component is similar to its counterpart in Alternative 2 except that no groundwater extraction is performed to help distribute the injected substrate. Thus, following active injection, natural groundwater flow would be relied upon to distribute the injected substrate throughout the areas of high VOC concentrations. Similar to Alternative 2, the biological amendment would be introduced into the subsurface using rows of injection wells connected by the underground conveyance piping. However, because Alternative 3 does not require a central groundwater treatment facility, the injection infrastructure would be decentralized. Each high concentration area (southeastern, southwestern, and northern) would have a separate small building housing biological amendment mixing and pumping equipment. This approach would eliminate construction of an underground piping network to a central location, as would be used in Alternative 2. The design basis for this alternative is very similar to that of Alternative 2, except that significantly more injection wells are proposed. The bioremediation system components would be installed as shown in Figure 6-10 based on the design criteria shown in Table 6-9 and the results of the groundwater modeling simulations of injection-only scenarios:
>
> - *Southwestern area:* Nine rows of injection wells spaced approximately 40 feet apart; 20 feet spacing between injection wells in a row; total of 79 injection wells

- *Southeastern area:* Seven rows of injection wells spaced 40 feet apart; 20 feet spacing between injection wells in a row; total of 52 injection wells

- *Northern area:* Four rows of injection wells with 17 injection wells (irregular spacing due to obstacles

As compared to Alternative 2, Alternative 3 would require installation of approximately twice as many injection wells, twice the volume of injection fluid, and twice the mass of substrate. The distribution area of the injected amendment would be similar to that of Alternative 2. The design of a typical injection well would be the same as in Alternative 2 (Figure 6-6). The injected fluid make-up would also be similar to Alternative 2.

We assume that a continuous flow of 0.15 gpm can be injected at each well; however, to reduce the potential for groundwater mounding and excessive pressure heads in the injection zone, groundwater modeling indicates that only half the wells can be used for injection at a given time. Therefore, the injection event would probably take about a month. As in Alternative 2, injection rate control and monitoring of water table mounding and injection zone pressure heads would be required to limit the water table mound to approximately two-feet and pressure heads to approximately 10 feet.

Based on the groundwater contaminant concentrations and distribution, the low permeability nature of the subsurface, the site geochemical conditions, and experience at similar sites, it is expected that three injection events will be required. The actual number of injection events would be determined based on the remedy performance. The frequency of injection events would depend on such factors as VOC trends, electron donor presence in the formation, aquifer geochemistry (based primarily on dissolved oxygen and oxidation-reduction potential readings), pH, and other parameters. Also similar to Alternative 2, the slow groundwater movement at the site will minimize the possibility of migration of the amendment toward nearby surface water and will allow the amendment to remain in the treatment areas for a long duration, maximizing the effectiveness of the high concentration area treatment.

The bioremediation system flow diagram for Alternative 3 is presented in Figures 6-11, 6-12, and 6-13. The layout of the aboveground injection equipment (located in a small building) would be similar for each of the high concentration areas. A typical aboveground injection equipment layout is shown in Figure 6-14. More details on the design of the selected alternative, including provisions for injections in the areas of utilities, are included in Section 8. The groundwater monitoring and MNA portions of this component are similar to those described for Alternatives 1 and 2.

Component 2: Land use controls—This component is similar to its counterpart in Alternatives 1 and 2.

Detailed Analysis of Alternative 3

Overall protection of human health and environment—Alternative 3 would protect human health and the environment. *In situ* bioremediation in the high concentration areas would reduce contaminant mass at the site and land use controls would eliminate regulatorily unacceptable

risk. Groundwater monitoring will be used to determine contaminant trends, determine the effectiveness of the remedy, and to ensure that there is no regulatorily unacceptable risk at the site.

Compliance with ARARs—Alternative 3 would, over time, achieve the cleanup goals established in Section 5. The location-specific and action-specific ARARs that would, in particular, have to be complied with include:

- RCRA regulations including Identification and Listing of Hazardous Wastes and LDRs
- OSHA regulations
- Maryland Hazardous Waste Management System regulations
- Maryland regulation of water supply, sewage disposal, and solid waste
- Maryland General Permit for Construction Activity
- Maryland OCP

Long-term effectiveness and permanence—Alternative 3 offers long-term effectiveness because regulatorily unacceptable risk from site groundwater would be eliminated via land use controls and mass reduction would be accomplished primarily via *in situ* bioremediation. Analysis using the groundwater model indicates that approximately 90 years would be required to reach the final drinking water standards throughout the MRC. Approximately 25 years would be needed to reach concentrations lower than those calculated to cause unacceptable risk via vapor intrusion in a residential scenario.

Reduction of toxicity, mobility, and volume through treatment—Alternative 3 would permanently and irreversibly reduce the mobility, toxicity, and volume of the organic contaminants in the environment over an extended period via mass removal and natural attenuation.

Short-term effectiveness—Construction associated with this alternative would pose insignificant risk to the surrounding community and on-site workers. During installation of the bioremediation system, the primary risk to the community would be from inhalation of the limited amount of dust (and potential odor and organic vapor) generated during installation of piping trenches, wells, and soil borings. This risk would be mitigated by implementation of dust and vapor suppression measures.

Intrusive construction work, such as installation of piping, vaults, and foundations, may expose workers to contaminated groundwater and associated vapors. Monitoring and appropriate personal protective equipment would eliminate risk to workers. Implementation of Alternative 3 entails less intrusive work than the other two alternatives. Throughout system operation, samples would be collected and maintenance performed to ensure that no hazardous substances are discharged to the environment. Bioremediation would take approximately four years (i.e., three injection events).

Implementability—Designing and implementing each of the Alternative 3 components presents technical and administrative challenges, specifically during the installation of wells and piping, especially in the area of active industrial operations. Significant technical challenges are posed by injecting amendment into low hydraulic conductivity soil, and in the presence of underground utilities which can provide preferential flow pathways that quickly convey the amendment away from the treatment zones. Of particular concern are preferential flow pathways that could convey injected substrate to the storm drainage system and to Cow Pen Creek or Dark head Cove.

Identification and field location of utilities in the areas of construction and injection would also be required during the design process and before intrusive construction work begins. This is necessary to identify utilities that may interfere with construction and to identify potential pathways that could divert injected substrate away from the remediation zones and to surface water. Personnel and equipment required to design and implement the proposed actions are available, and time to coordinate with stakeholders and obtain necessary permits can be built into the schedule. With the considerations outlined above, Alternative 3 is implementable.

Life cycle impacts—*SimaPro* provides the following normalized values for major endpoints:

- climate change: human health—50
- particulate matter formation—20
- fossil fuel depletion—86

The following environmental impacts were estimated using *SiteWise*:

- greenhouse gas emissions—310 tons (CO_2 equivalent)
- NOx emissions—0.7 tons
- SOx emissions—0.1 tons

- PM10 emissions—0.06 tons
- total energy used—4,700 MMBTUs

Cost—The following costs for Alternative 3 were estimated via the TCA process:

- design, construction, and injections—$2,900,000
- 30–year long-term monitoring and decommissioning—$2,600,000
- total—$5,500,000
- net present worth cost—$4,000,000

6.4 COMPARATIVE ANALYSIS OF ALTERNATIVES AND PROPOSED ALTERNATIVE

Two methods were used to compare the three groundwater response action alternatives: a qualitative analysis and a quantitative analysis. Both use the same evaluation criteria: the seven CERCLA criteria plus an eighth criterion: the life cycle impacts of each alternative. As discussed above, this evaluation did not consider the state acceptance or community acceptance criteria; these will be evaluated through input from the community and MDE following submittal of this RAP. Table 6-10 summarizes the qualitative analysis. *Criterium Decision Plus* decision-tool software was used for the quantitative analysis.

Criterium Decision Plus software allows the criteria for making a decision to be given relative weights and ranks. The software then processes that data to calculate a score for each alternative. The eight evaluation criteria for the MRC were entered and individually assigned relative weights; these weights represented the relative importance of each criterion. The process continued as sub-criteria were added to the eight primary criteria and relative weights were assigned. As a final step, relative rankings, on a scale of 0–100 were assigned to each criterion and/or sub-criterion for each alternative. The weightings, rankings, and results of this analysis are summarized in Table 6-11 and presented in Appendix M. In *Criterium Decision Plus*, higher scores indicate that the alternative is more highly ranked in that category.

All three alternatives evaluated meet the threshold criteria (overall protection of human health and the environment and compliance with ARARs) equally well; therefore, the six balancing criteria (see Section 6.3.2.1) were used to differentiate the alternatives and determine the preferred alternative:

- *Long-term effectiveness and permanence*—The alternatives featuring *in situ* remedies (Alternatives 2 and 3) are ranked higher in this category because they would require a reduced period to meet RAOs (TCE mass reduction in the active remediation areas) and would have a lower residual risk due to this faster cleanup time.

- *Short-term effectiveness*—The results of this category are mixed.

    - Alternative 3 is ranked highest in the category of protecting remediation workers because the amount of fieldwork (specifically, piping trench installation and system maintenance) is significantly less than the fieldwork needed for Alternatives 1 and 2.

    - All alternatives are equally protective of the community.

    - Alternative 3 ranks highest in minimizing environmental impact because groundwater extraction and treatment are not included. Upsets, overflows, or line breaks in the extraction and treatment system are considered the most likely source of releases to the environment.

- *Reduction of toxicity, mobility, or volume by treatment*—Alternatives 2 and 3 rank highest due to the expected effectiveness and timeliness of the contaminant reductions achieved. These site remedies reduce contaminants to innocuous byproducts, rather than merely transferring contaminants to another medium as in the *ex situ* treatment scenario in Alternative 1.

- *Implementability*—Alternative 3 ranks highest in this category because trenches would not have to be installed in the operating plant area and disruptions to plant operations would be relatively minor.

- *Life cycle impacts*—Alternative 3 ranks highest in the life cycle analysis categories, followed by Alternative 2.

- *Cost*—Alternative 3 ranks highest (lowest cost) in this category, followed by Alternative 1.

The *Criterium Decision Plus* scoring is as follows (higher scores indicate that the alternative is more highly ranked):

- *Alternative 1*—0.48

- *Alternative 2*—0.53

- *Alternative 3*—0.64

In the qualitative analysis, Alternative 3 was chosen for several reasons. Most importantly, it protects human health and the environment and complies with the ARARs. The relatively short period required for active remediation to meet the project goals is another advantage of this alternative. In the final comparison of the top two alternatives (Alternatives 2 and 3), the limited

benefit of adding groundwater extraction to the response action does not justify the additional life cycle impacts and cost associated with Alternative 2. Thus, Alternative 3 was selected as the proposed groundwater response action at the MRC, based on both the qualitative and quantitative analyses.

Table 6-1

Statistical Summary of COC Chemical Analyses, May-June 2010
Lockheed Martin Middle River Complex, Middle River, Maryland

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Minimum Detected	Maximum Detected	Well of Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent								
VOLATILES (ug/L)										
1,1-DICHLOROETHENE	35/125	28%	0.19	140	0.33 J	780	MRC-MW14B	14.9	49.0	75.1
BENZENE	6/125	5%	0.13	93	0.33 J	150	MRC-MW17A	2.67	33.5	14.5
CARBON TETRACHLORIDE	3/125	2%	0.13	93	0.22 J	13	MRC-MW34B	1.21	5.17	5.32
CHLOROFORM	22/125	18%	0.16	110	0.17 J	19	MRC-MW95D	1.93	3.45	6.77
CHLOROMETHANE	18/125	14%	0.3	210	0.3 J	1.3	MRC-MW73A	2.54	0.454	11.8
CIS-1,2-DICHLOROETHENE	50/125	40%	0.17	85	0.28 J	1200	MRC-OW2I	41.6	104	176
ETHYLBENZENE	2/125	2%	0.17	120	11	34	MRC-MW17A	1.77	22.5	7.39
METHYL TERT-BUTYL ETHER	12/125	10%	0.17	120	0.21 J	170	MRC-MW79B	3.97	27.1	18.3
NAPHTHALENE	1/125	1%	0.24	170	38 J	38 J	MRC-MW69B	2.32	38.0	10.1
TETRACHLOROETHENE	5/125	4%	0.29	210	0.56 J	8.7 J	MRC-MW48A	2.55	3.97	11.6
TRICHLOROETHENE	62/125	50%	0.17	85	0.32 J	19000	MRC-MW74B	326	662	1803
VINYL CHLORIDE	21/125	17%	0.22	160	0.22 J	390	MRC-OW2I	9.31	46.0	43.9
SEMIVOLATILES (ug/L)										
1,4-DIOXANE	23/72	32%	0.49	0.49	0.96 J	360	MRC-MW14B	9.95	30.6	46.2

Footnotes:

For non-detects, 1/2 sample quantitation limit was used as a proxy concentration.

1/2 the detection limit was used for B qualified data.

NA - Not applicable, there are an insufficient number of samples to calculate statistics.

Table 6-2

Chemical-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
Safe Drinking Water Act (SWDA) Regulations, Maximum Contaminant Levels (MCLs)	40 Code of Federal Regulations (CFR) Part 141, Subparts B and G	Relevant and Appropriate	Establishes enforceable standards for potable water for specific contaminants that have been determined to adversely affect human health.	Would be used as protective levels for groundwater or surface waters that are current or potential drinking water sources.
Cancer Slope Factors (CSFs)	NA	To Be Considered	CSFs are guidance values used to evaluate the potential carcinogenic hazard caused by exposure to contaminants.	CSFs would be considered for development of human health protection preliminary remediation goals (PRGs) for groundwater at this site.
Reference Doses (RfDs)	NA	To Be Considered	RfDs are guidance values used to evaluate the potential non-carcinogenic hazard caused by exposure to contaminants.	RfDs would be considered for development of human health protection PRGs for groundwater at this site.
State				
Cleanup Standards for Soil and Groundwater	Maryland Annotated Code 7-508	To Be Considered	This guidance document presents the approach and supporting documentation used to develop numeric cleanup standards for hazardous substances in soil and groundwater in the State of Maryland.	These non-promulgated standards would be used in determining cleanup goals for groundwater.

Table 6-3

Location-Specific ARARs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
National Environmental Policy Act (NEPA) Regulations, Floodplain Management, Executive Order 11988	40 CFR Part 6, Appendix A	Applicable	Appendix A describes the policy for carrying out the Executive Order regarding floodplains. If no practicable alternative exists to performing cleanup in a floodplain, potential harm must be mitigated and actions taken to preserve the beneficial value of the floodplain.	Remedial actions may take place in a floodplain, so alternatives would be considered that would reduce the risk of flood loss and restore and preserve the floodplain.
Coastal Zone Management Act	16 United States Code (U.S.C.) Parts 1451 et. seq.	Applicable	Requires that any actions must be conducted in a manner consistent with state-approved management programs.	The site is located in a coastal zone management area: therefore, applicable coastal zone management requirements need to be addressed.
State				
Coastal Zone Management Program	Maryland Executive Order 01.01.1978.05 Coastal Zone Management	To be considered	Maryland's Coastal Program is based on existing state laws and policies designed to protect coastal and marine resources.	The site is located in a coastal zone management area: therefore, applicable coastal zone management requirements need to be addressed.

Table 6-4

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
Resource Conservation and Recovery Act (RCRA) Regulations, Identification and Listing of Hazardous Wastes	40 Code of Federal Regulations (CFR) Part 261, subparts A, B, C, and D	Potentially Applicable	Defines the listed and characteristic hazardous wastes subject to RCRA. Appendix II contains the Toxicity Characteristic Leaching Procedure (TCLP).	These regulations would apply when determining whether or not a solid waste is hazardous, either by being listed or by exhibiting a hazardous characteristic, as described in the regulations.
RCRA Regulations, Contingency Plan and Emergency Procedures	40 CFR 264, Subpart D	Potentially Relevant and Appropriate	Outlines requirements for emergency procedures to be followed in case of an emergency.	The administrative requirements established in this rule would be met for response actions involving the management of hazardous waste.
RCRA Regulations, Preparedness and Prevention	40 CFR Part 264, Subpart C	Potentially Relevant and Appropriate	Outlines requirements for safety equipment and spill control for hazardous waste facilities. Facilities must be designed, maintained, constructed, and operated to minimize the possibility of an unplanned release that could threaten human health or the environment.	Safety and communication equipment would be incorporated into all aspects of the response action process, and local authorities would be familiarized with site operations.

Table 6-4

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
RCRA Regulations, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDFs).	40 CFR Part 264	Potentially Relevant and Appropriate	Establishes minimum national standards defining the acceptable management of hazardous wastes for owners and operators of facilities that treat, store, or dispose of hazardous wastes.	If response actions involve management of RCRA wastes at an off-site TSDF or if RCRA wastes are treated or managed on site, the requirements of this rule would be followed.
RCRA Regulations, Use and Management of Containers	40 CFR Part 264, Subpart I	Potentially Relevant and Appropriate	Sets standards for the storage of containers of hazardous waste.	This requirement would apply if a response action alternative involves the storage of a hazardous waste (i.e., contaminated soil or groundwater) in containers prior to treatment or disposal.
Clean Water Act (CWA), Section 402, National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122-125, 131	Potentially Applicable	These standards govern discharge of water into surface waters. Regulated discharges must meet ambient water quality criteria.	Extracted groundwater would be treated as required prior to discharge.
Underground Injection Control Program	40 CFR 144 Subparts A, B, E, and G	Potentially Applicable	Assures that underground injection will not endanger drinking water sources.	These regulations would apply to remedial actions involve underground injection, such as an electron donor for bioremediation and an oxidizer for in-situ chemical oxidation.

Table 6-4

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State				
Maryland Hazardous Waste Management System	Code of Maryland Regulations (COMAR) Title 26, Subtitle 13, 02- Identification; 03 - Generators; 04 - Transporters; 05 - TSDFs	Potentially Applicable	Requires hazardous waste generators to ship their hazardous waste to a facility permitted to accept it or, with the appropriate permits, treat it themselves. Requires use of a certified hauler to ship hazardous waste off site, and shipment must be accompanied by a manifest. Requires compliance with regulations on the storage of the waste and specifies procedures to prevent the occurrence of circumstances that would threaten human health or the environment.	These regulations would apply if waste on site was deemed hazardous and was to be treated on site or stored, transported, or disposed properly.
Maryland General Permit for Construction Activity	Title 26, Subtitle 17 of COMAR 01 – E&S Control	Potentially Relevant and Appropriate	Establishes requirements for stormwater management and erosion and sediment control at construction sites.	Response actions involving excavation would require submittal of an erosion and sediment control plan and a stormwater management plan.
Underground Injection Control	COMAR Title 26, Subtitle 8, 01 - Underground Injection Control	Potentially Applicable	Establishes a State Underground Injection Control Program consistent with federal requirements to preserve the quality of the groundwater of the state.	These regulations would apply to remedial actions involve underground injection, such as an electron donor for bioremediation and an oxidizer for in-situ chemical oxidation.
Ground Water Quality Standards	COMAR Title 26, Subtitle 8, 02.09 - Ground Water Quality Standards	Applicable	For the purpose of controlling the pollution of the ground waters of the State, aquifer types are identified and ground water quality standards are established.	These standards would be used to determine which cleanup standards to apply to groundwater.

Table 6-4

Action-Specific ARARs and TBCs
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Maryland Pollutant Discharge Elimination System	COMAR Title 26, Subtitle 8, 02 - Water Quality; 03 - Discharge Limitations; 04.02 - Discharge Permit Limits; 08 - Pretreatment Requirements to POTWs	Potentially Applicable	These standards govern discharge of water into surface waters and POTWs. Regulated discharges must meet ambient water quality criteria.	Extracted groundwater would be treated as required prior to discharge.
Well Standards	COMAR Title 26, Subtitle 4, 04 - Well Construction	Applicable	Identifies the standards and specification that must be followed for the installation of all wells.	Applies to wells installed for monitoring, groundwater treatment, and/or extraction.
Toxic Air Pollutants	COMAR Title 26, Subtitle 11, 15 - Toxic Air Pollutants; 16.06 - Class I Toxic Air Pollutants	Potentially Applicable	Prohibits emissions which result or will result in violation of any provisions of federal NESHAP regulations.	Control of emissions during treatment of groundwater would be implemented.

Table 6-5

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
No Action	None	Not Applicable	No activities conducted at the Middle River Complex (MRC) to address contamination. Biodegradation of contaminants may occur through natural attenuation processes, but would not be verified.	Eliminate. This option does not meet response action objectives (RAOs) and has been eliminated from consideration.
Limited Action	Land Use Controls (LUCs)	Land use controls	Engineered and non-engineered (administrative) controls formulated and enforced to regulate current and future land use options.	Retain. Alone, would not be suitable to meet cleanup goals in a reasonable timeframe; however, would be protective of human health and the environment and will be required to obtain a Tier 1B Ceritifcate of Completion.
	Monitoring and Monitored Natural Attenuation	Groundwater Sampling	Sampling and analysis of groundwater to evaluate the effectiveness of site treatment and the progress of natural attenuation following active remediation.	Retain. Alone, would not be suitable to meet cleanup goals in a reasonable timeframe; however, will be required in conjunction with an active remedy during and after active remediation.
Containment	Barrier	Groundwater Extraction	Use of extraction wells or trenches to prevent migration of groundwater to surrounding surface water bodies.	Retain. The technology would be used to prevent contaminant migration to off-site receptors. Based on the site geology and geochemistry; pumping from wells is the option retained.

Table 6-5

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
Containment (Cont.)	Barrier	Permeable Barrier	Use of a permeable reactive barrier (PRB) containing zero valent iron to prevent migration of groundwater to surrounding surface water bodies.	Eliminate. Use of groundwater extraction is the preferred containment remedy due to implementation concerns with a PRB.
Collection	Groundwater and Vapor Extraction	Pumping and Vapor Extraction via Wells	Extraction of groundwater and vapor via pumping wells placed within the groundwater plumes for source removal.	Retain. Groundwater and vapor extraction could be used to reduce contaminant mass.
Ex Situ Treatment	Biological	Aerobic/ Anaerobic	Natural degradation of organic chemicals of concern (COCs) via microorganisms in an aerobic (oxygen-rich) or anaerobic (oxygen-deficient) environment.	Eliminate. Volatile organic compounds (VOCs) are more readily treated by air stripping and/or granular activated carbon (GAC). Would not be effective for metals. Effectiveness on 1,4-dioxane is uncertain.
	Physical	Filtration	Separation of suspended solids from water via entrapment in a bed of granular media or membrane.	Retain. May be useful in combination with other ex-situ treatment options.
		Air Stripping	Contact of water with an air stream to remove VOCs.	Retain. Proven treatment method for VOC removal.
		GAC Adsorption	Separation of dissolved contaminants from water or air streams via adsorption onto GAC.	Retain. Proven treatment method for VOC removal from contaminated groundwater and air stripper off-gas. Would not be effective on metals.

Table 6-5

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
Ex Situ Treatment (Cont.)	Physical	Solvent Extraction	Separation of contaminants from a solution by contact with an immiscible liquid with a higher affinity for the COCs.	Eliminate. Not proven to be cost-effective for VOC removal.
		Sedimentation	Separation of solids from water via gravity settling.	Retain. May be needed for incidental removal of iron and manganese.
	Chemical	Coagulation/ Flocculation	Use of chemicals to neutralize surface charges and promote attraction of colloidal particles to facilitate settling.	Retain. May be needed for metals removal and incidental removal of iron and manganese.
		Chemical Precipitation	Use of reagents to convert soluble compounds into insoluble compounds.	Retain. pH adjustment and chemical addition required to precipitate dissolved metals.
		Ion Exchange	Removal of dissolved ions through exchange with similarly charged ions held on the active sites of a synthetic resin that is contacted with the liquid to be treated.	Eliminate. Will not be required as a polishing step to meet discharge requirements.
		Advanced Oxidation	Use of oxidizers such as ozone, hydrogen peroxide, or potassium permanganate to break down certain organic compounds.	Eliminate. Low concentrations of 1,4-dioxane do not require treatment.

Table 6-5

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
In Situ Treatment	Biological	Enhanced Anaerobic Reductive Dechlorination	Injection of substrates and/or bioamendments to create conditions suitable for reductive dechlorination.	Retain. Shown to be effective at the site for reducing trichloroethene (TCE) and other VOC mass.
		Enhanced Co-Metabolic Biodegradation	Creation of an aerobic subsurface environment and degrading 1,4-dioxane in the presence of another substrate, and not as the primary growth substrate.	Eliminate. Specific treatment of 1,4-dioxane is not required.
		Enhanced Biodegradation via Oxygen Addition	Inject oxygen and/or bioamendments to create conditions suitable for biodegradation of petroleum consitituents.	Eliminate. Limited effectiveness at low petroleum constituent concentrations present at the MRC.
	Chemical	Oxidation via Oxidant Addition	Destroy contaminants via oxidation using an oxidant injected into the aquifer	Retain. Pilot testing showed that this technology can reduce contaminant concentrations. Rebounding concentrations at the end of the test indicated that multiple injections will be required to reach remediation goals.
	Thermal	Electric Resistance Heating	Volatilization of organic COCs through groundwater and soil heating with electrodes in combination with vacuum extraction of volatilized material.	Retain. Could be effective for small, high concentration areas at the site.

Table 6-5

Preliminary Screening of Technologies and Process Options
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response Action Technology	Process Option	Description	Screening Comment
Discharge/ Disposal	Surface Discharge	Direct Discharge	Discharge of treated water to surface water. Includes disposal of sludge generated by the groundwater treatment process.	Retain. Treatment of other constituents, such as other metals, may be required to meet effluent limitation requirements.
		Indirect Discharge	Discharge of collected/treated water to local publicly-owned treatment works (POTW). Includes disposal of sludge generated by the groundwater treatment process.	Retain. Treatment of other constituents, such as metals, may be required to meet effluent limitation requirements. POTW may have flow rate and influent limitations.
		Off-Site Treatment Facility	Treatment and disposal of water at an off-site treatment works.	Eliminate. Separate facility not available. Large volume of water would be too costly to transport by tanker.
	Subsurface Discharge	Reinjection	Use of injection wells, spray irrigation, or infiltration for discharge of treated groundwater underground.	Eliminate. Continuous reinjection would be difficult due to the heterogenous, low permeability soil at the site.

Table 6-6

Technologies and Process Options for Groundwater Response Actions
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

General Response Action	Response	Process Option
Limited Action	Land Use Controls	Land use controls
	Monitoring/Monitored Natural Attenuation	Groundwater Sampling
Containment	Barrier	Groundwater Extraction
Collection	Groundwater and/or	Groundwater and Vapor Extraction via Wells or Trenches
Ex Situ Treatment	Physical	Filtration
		Air Stripping
		GAC Adsorption
		Sedimentation
	Chemical	Chemical Precipitation
		Coagulation/Flocculation
In Situ Treatment	Biological	Enhanced Anaerobic Reductive Dechlorination (ARD)
	Chemical	*In Situ* Chemical Oxidation (ISCO)
	Thermal	Electrical Resistance Heating (ERH)
Discharge/Disposal	Surface Discharge (Treated Water) and Sludge Disposal	Direct Discharge – with National Pollution Discharge Elimination (NPDES) permit; with off-site sludge disposal
		Indirect Discharge – through publicly owned treatment works (POTW); with off-site sludge disposal

Table 6-7

Initial Screening of Response Alternatives
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Alternative	Description	Major Advantage	Major Disadvantage	Capital/ Injection Cost	Total LTM Cost	Total Cost
Alternative A: MNA and land use controls	No active remediation.	Low cost and impact.	Does not provide significant mass reduction.	NA	$2,200,000	$2,200,000
Alternative B: Hydraulic containment and land use controls	GW recovery and treatment via 8 extraction wells in 3 areas.	Eliminates groundwater migration.	Does not provide significant mass reduction.	$2,000,000	$10,200,000	$12,200,000
Alternative C: GW and vapor extraction in high concentration areas, land use controls	GW and soil vapor recovery and treatment via 15 extraction wells in 3 areas.	Provides effective mass removal using an established technology. No injections; therefore, limited risk.	Long operating period.	$2,300,000	$4,800,000	$7,100,000
Alternative D1: In situ bio in high concentration areas with GW and vapor extraction via trenches, land use controls	GW and vapor extraction and in-situ bio in 3 high concentration areas (1,000 ug/L contour).	Proven technologies address majority of site contaminant mass.	Trenches are difficult to install/operate.	$4,500,000	$3,600,000	$8,100,000
Alternative D2: In situ bio in high concentration areas with GW and vapor extraction via wells, land use controls	GW and vapor extraction and in-situ bio in 3 high concentration areas.	Proven technologies address majority of site contaminant mass.	Risk associated with subsurface injections.	$4,300,000	$3,600,000	$7,900,000
Alternative D3: In situ bioremediation in high concentration areas, land use controls	In-situ bio in 3 high concentration areas. Injection from separate location at each area	Proven technology addresses majority of site contaminant mass.	Risk associated with subsurface injections.	$2,900,000	$2,600,000	$5,500,000
Alternative D4: ISCO in high concentration areas with GW and vapor extraction via wells, land use controls	GW and vapor extraction and ISCO in 3 high concentration areas. Assumed that ISCO is applied similar to bio	Proven technologies address majority of site contaminant mass.	ISCO not as effective in site pilot testing.	$4,800,000	$3,600,000	$8,400,000
Alternative E1: Area-wide in situ bio with GW and vapor extraction via wells, land use controls	GW and vapor extraction and in-situ bio in 1,000 ug/L contour + 50% of 100 ug/L contour	Proven technologies address significant majority of site contaminant mass.	Large area of lower concentration treatment makes this alternative only slightly more effective in reducing mass while being significantly more costly.	$6,500,000	$4,100,000	$10,600,000

Table 6-7

Initial Screening of Response Alternatives
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Alternative	Description	Major Advantage	Major Disadvantage	Capital/ Injection Cost	Total LTM Cost	Total Cost
Alternative E2: Area-wide in situ bio, land use controls	In-situ bio in 1,000 ug/L contour + 50% of 100 ug/L contour.	Proven technology addresses significant majority of site contaminant mass.	Large area of lower concentration treatment makes this alternative only slightly more effective in reducing mass while being significantly more costly.	$6,000,000	$2,600,000	$8,600,000
Alternative E3: Area-wide ISCO with GW and vapor extraction via wells, land use controls	GW and vapors extraction and in-situ bio in 1,000 ug/L contour + 50% of 100 ug/L contour. Assumed that ISCO is applied similar to bio.	Proven technologies address significant majority of site contaminant mass.	ISCO not as effective in site pilot testing.	$7,300,000	$4,100,000	$11,400,000
Alternative F1: In situ bio in source areas with GW and vapor extraction via wells, land use controls	GW and vapor extraction and in-situ bio in 3 source areas (5,000 ug/L countour)	Proven technologies address areas of highest site contaminant mass; lower cost.	Does not address western TCE area.	$1,000,000	$3,400,000	$4,400,000
Alternative F2: In situ bio in source areas, land use controls	In-situ bio in 3 source areas. Injection from separate location at each area.	Proven technology addresses areas of highest site contaminant mass; lower cost.	Does not address western TCE area.	$1,500,000	$2,200,000	$3,700,000
Alternative F3: ISCO in source areas with GW and vapor extraction via wells, land use controls	GW and vapor extraction and ISCO in 3 source areas. Assumed that ISCO is applied similar to bio.	Proven technologies address areas of highest site contaminant mass; lower cost.	ISCO not as effective in site pilot testing.	$2,500,000	$3,400,000	$5,900,000
Alternative G: ERH (in the southeastern TCE area) and in situ bio in high concentration areas with GW and vapor extraction via wells, land use controls	ERH (in the southern portion of the eastern TCE area = 1/3 acre) GW and vapor extraction and in-situ bio in 3 high concentration areas.	Aggressive treatment expected to be effective in mass removal.	Significant cost and life cycle impacts while being only slightly more effective than other alternatives.	$8,100,000	$3,400,000	$11,500,000

Table 6-8

Alternative 2 TCE Area Injection Parameters
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Area	TCE area (square feet)	Number of injection points	Area with substrate > 100 ppm (sq feet)	% of TCE area with substrate > 100 ppm	Injection volume (gallons)	Injection volume as % of total pore volume	Mass of substrate (pounds)
Southwestern TCE area	65000	40	32550	50%	120000	4.9%	10000
Northern TCE area	21000	12	9800	47%	36000	4.6%	3000
Southeastern TCE area	33000	25	20340	62%	75000	6.1%	6250
TOTAL	**119000**	**77**	**62690**	**53%**	**231000**	**5.2%**	**19250**

Table 6-9

Alternative 3 TCE Area Injection Parameters
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Area	TCE area (square feet)	Number of injection points	Area with substrate > 100 ppm (sq feet)	% of TCE area with substrate > 100 ppm	Injection volume (gallons)	Injection volume as % of total pore volume	Mass of Substrate (pounds)
Southwestern TCE area	65000	79	33500	52%	237000	9.7%	20000
Northern TCE area	21000	17	13900	66%	51000	6.5%	6000
Southeastern TCE area	33000	52	22100	67%	156000	12.6%	12500
TOTAL	**119000**	**148**	**69500**	**58%**	**444000**	**9.9%**	**30500**

Table 6-10

Comparative Analysis of Alternatives
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland
Page 1 of 2

Evaluation Criterion	Alternative 1: Groundwater and Vapor Monitoring in High Concentation Areas, and Institutional Controls	Alternative 2: *In Situ* Bioremediation with Groundwater and Vapor Extraction via Wells and Institutional Controls	Alternative 3: *In Situ* Bioremediation, and Institutional Controls
Overall Protection of Human Health and Environment	Protective via institutional controls.	Protective via institutional controls.	Protective via institutional controls.
Compliance with ARARs	Would comply	Would comply	Would comply
Long-Term Effectiveness and Permanence	Effective – will meet RAOs in 15 years	Effective will meet RAOs in 5 years	Effective – will meet RAOs in 5 years
Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment	Permanent reductions in toxicity, mobility, and volume of contaminants from the subsurface; some contaminant transfer rather than destruction in *ex situ* treatment.	Permanent and timely reductions in toxicity, mobility, and volume of contaminants from the subsurface via bioremediation.	Permanent and timely reductions in toxicity, mobility, and volume of contaminants from the subsurface via bioremediation.
Short-Term Effectiveness	Would be effective. Minimum potential for short-term risks.	Would be effective. Minimum potential for short-term risks. Some risk of material release.	Would be effective. Lowest potential for short-term risks to site workers. Slightly higher risk of material release than Alternative 2 (would be managed in the design and implementation phases).
Implementability	Complications in design and implementation (trenching through the operating facility, and operating a groundwater treatment system).	Complications in design and implementation (subsurface injection, trenching through the operating facility, and operating a groundwater treatment system).	Complications in design and implementation (subsurface injection), but easiest to implement due to reduced amount of infrastructure and groundwater treatment system operation.

Table 6-10

Comparative Analysis of Alternatives
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Evaluation Criterion	Alternative 1: Groundwater and Vapor Monitoring in High Concentation Areas, and Institutional Controls	Alternative 2: In Situ Bioremediation with Groundwater and Vapor Extraction via Wells and Institutional Controls	Alternative 3: In Situ Bioremediation, and Institutional Controls
Life Cycle Impacts	Greatest life cycle impacts.	Moderate life cycle impacts.	Lowest life cycle impacts.
Cost – Capital/Injection and 30-year O&M/LTM cost	Capital – $2,300,000 O&M/LTM – $4,800,000 Total - $7,100,000	Capital/Injection – $4,300,000 O&M/LTM - $3,600,000 Total - $7,900,000	Capital/Injection – $2,900,000 O&M/LTM - $2,600,000 Total - $5,500,000

ARARs Applicable or Relevant and Appropriate Requirements.
RAOs Response action objective.
O&M Operation and maintenance.
LTM Long term monitoring.

Table 6-11

Criteria Weighting and Ranking
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, MD

Weighting						Ranking			
Weights	***Criteria***	***Weights***	***Sub-Criteria 1***	***Weights***	***Sub-Criteria 2***	***Criteria/Sub-Criteria***	**Alternative 1**	**Alternative 2**	**Alternative 3**
75	Overall Protection of Human Health and Environment	50	Groundwater Receptors			Groundwater Receptors	50	50	50
		75	Surface Water Receptors			Surface Water Receptors	50	50	50
		50	Benthic Receptors			Benthic Receptors	50	50	50
		75	Air - Soil Vapor Intrusion			Air - Soil Vapor Intrusion	50	50	50
50	Long Term Effectiveness and Permanence	75	Time to Achieve RAOs			Time to Achieve RAOs	50	75	75
		75	Minimize Residual Risk			Minimize Residual Risk	50	75	75
50	Compliance with ARARs					Compliance with ARARs	50	50	50
75	Reduction of Toxicity, Mobility and Volume thru Treatment	75	Permanent Reduction of Groundwater Contamination			Permanent Reduction of Groundwater Contamination	50	75	75
75	Short Term Effectiveness	75	Protect Workers	75	Protect Remediation Workers	Protect Remediation Workers	50	50	75
				75	Protect Plant Workers	Protect Plant Workers	50	50	50
		75	Protect Community			Protect Community	50	50	50
		75	Minimize Environmental Impacts			Minimize Environmental Impacts	50	40	60
75	Implementabilty	75	Feasibility	75	Technical	Technical	75	40	75
				50	Administrative	Administrative	50	50	50
		75	Minimum Interference with Plant Operations			Minimum Interference with Plant Operations	40	40	75
50	Life-Cycle Impacts					Life-Cycle Impacts	30	40	75
50	Cost	50	Capital	75	Total Cost	Total Cost	50	40	75
				50	Volatility	Volatility	50	30	50
		50	OMM	75	Total Cost	Total Cost	30	50	75
				50	Volatility	Volatility	50	40	50
						TOTAL SCORE	**0.48**	**0.53**	**0.65**

Insert tables Table 6-1 thru Table 6-11

Insert Figures 6-1 thru Figure 6-14

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Section 7
Performance Evaluation Criteria and Contingency Measures for the Selected Response Action

7.1 PURPOSE

Several important items must be considered in the implementation and evaluation of the selected response action (Alternative 3: *in situ* bioremediation and land use controls). Implementation will therefore entail a significant amount of groundwater monitoring to evaluate the effectiveness of each component of the response action. Performance evaluation criteria include:

- For the *in situ* bioremediation component, the initial evaluation criterion will be the ability to inject an adequate volume of dilute substrate into the subsurface at acceptable pressures (generally, 10 feet of pressure head or less) without groundwater mounding greater than approximately two feet. If the achievable injection rate considering these parameters is less than 0.05 gallons per minute (gpm), the feasibility of injecting the required volumes will be re-evaluated. The injection rate will be determined during initial injection testing.

- During initial testing and the first round of substrate injection, another major evaluation criterion will be the areas affected by the injection; that is, those areas exhibiting a total organic carbon (TOC) concentration of 100 milligrams per liter (mg/L) at intervals of one, three, six, and nine months following injection. The goal for the initial injection is for 50–75% of the active trichloroethene (TCE) treatment areas to have TOC concentrations greater than 100 mg/L. The results of groundwater modeling indicate that this should be achievable with the current injection plan.

- The reduction in the concentrations of TCE and its daughter products is also a major evaluation criterion. To allow this evaluation, a quantitative goal for the remediation is required. As discussed earlier, the low permeability and complex stratigraphy at the Middle River Complex (MRC) create a challenging setting for contaminant mass reduction. However, based on the current understanding of the site and experience with *in situ* bioremediation at similar sites, the goal for the MRC response action will be to reduce TCE mass in the active remediation areas by 70%. This provides and aggressive and achievable target for the design and implementation of the response action.

Groundwater modeling indicates that an estimated 90 pounds of TCE are currently in the areas proposed for active remediation (i.e., areas containing TCE concentrations greater than 1,000 micrograms per liter [µg/L]). The mass of cis-1,2-dichloroethene (cis-1,2-DCE) and vinyl chloride were calculated based on the ratio of TCE to its daughter products in site groundwater (Table 7-1). Before remediation, the initial TCE mass will be recalculated using results from the baseline sampling event, which will incorporate analytical results from existing wells and those installed to monitor response action progress. Mass removal will be measured by the results of post-remediation performance monitoring of these same wells. For all mass calculations (baseline and performance monitoring), these data will be input into the groundwater model; the same assumptions that were used to develop the above estimate of TCE contaminant mass will then be used to determine the TCE mass at that time.

The results of groundwater monitoring following each injection event will be compared against this goal. This evaluation will be based on a calculation of the initial TCE mass (considering a baseline round of sampling of existing monitoring wells and newly installed performance monitoring wells) and the TCE mass from post-injection sampling events, as calculated through the use of the groundwater model. Although the reduction of daughter products is not part of the remediation goal, additional modifications to the injection protocol (pH adjustment, bioaugmentation, etc.) may be considered to address residual cis-1,2-DCE and vinyl chloride concentrations following attainment of the goal for TCE reduction.

- In addition to the primary criteria outlined above, several other criteria will be evaluated for the *in situ* bioremediation component. The oxidation-reduction potential (ORP) and dissolved oxygen content of the groundwater will be monitored to determine if the conditions are adequately reducing for anaerobic reductive dechlorination (ARD); targets will be ORP of -50 milliVolt (mV) or less and dissolved oxygen concentrations of 1 mg/L or less. Additionally, the populations of dehalococcoides (DHC) and the necessary functional genes will be monitored; the target concentration of DHC will be 10,000 cells per liter or greater.

- The monitored natural attenuation (MNA) component of the response action will only be instituted if the TCE mass reduction has been effective but has not reached the TCE mass removal goal as detailed in Section 8.2.6. MNA will be evaluated based on groundwater monitoring data from inside the active treatment areas. Groundwater concentration trends and geochemical data for wells containing TCE will be analyzed to determine the rates at which MNA is occurring and to provide timely estimates on when the TCE mass reduction goal will be met.

- Land use controls will be inspected, on a schedule established by the MDE in the Certificate of Completion for each Block, to ensure that they are being properly implemented. As stated in Section 4.2, each Certificate of Completion will be filed in the local land use records and will pass to subsequent property owners as part of the deed documentation (i.e., “travels with the land”). If one or more of the land use controls is not being properly implemented, this would indicate that the implementation protocol and awareness program would have to be reinforced or re-evaluated.

Groundwater monitoring data (for organic and geochemical parameters) will be evaluated continuously as they become available to optimize response action effectiveness. Formal evaluations of the entire response option will be conducted every three years or when site conditions change significantly (e.g., a change in property use). A conceptual sampling program to allow evaluation of the criteria stated above for the proposed response action appears in Section 8.

7.2 CONTINGENCY MEASURES

Several contingency measures must be built into the design and implementation of the remedial alternative, including:

- If the evaluation criteria for amendment distribution or TCE mass reduction in the treatment area are not met, then one or more of the following contingency measures could be implemented:
  - adjusting substrate injection rates and volumes
  - increasing the mass of substrate injection
  - injection of de-chlorinating bacteria cultures and/or pH buffering solutions
  - installation of additional injection wells in one or more of the TCE areas. This may include additional rows of injection wells.
  - use of temporary groundwater extraction during and immediately after the injections. Groundwater recovery has been shown (through groundwater modeling) to have a slight effect on substrate distribution; this could be maximized through pumping in the injection area. Recovered water would be treated and discharged, recirculated through the injection wells, or disposed of off-site. Each of these alternatives raises significant issues with implementation and permitting, which would be resolved as part of the contingency, as required.

- If groundwater monitoring shows that groundwater concentrations of TCE or its daughter products are consistently increasing over a wide area outside of the currently proposed active remediation areas over the course of the injections and are potentially causing site risks, the injection areas could be expanded. If groundwater monitoring shows that benzene and/or 1,4-dioxane concentrations are consistently increasing and causing site risk, additional *in situ* remediation of those compounds (bioremediation and chemical oxidation, respectively) would be considered.

- If the land use controls are not being effectively implemented, the implementation plan will be revised to increase inspections and/or expand the awareness program.

The need for contingency measures will be evaluated continuously based on data received, and formally every three years or when site conditions change significantly.

Table 7-1
Groundwater Model TCE Mass Results
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

TCE Area	Mass of TCE pounds (lbs)	Mass of cis-1,2-DCE (lbs)	Mass of Vinyl Chloride (lbs)	Total Mass (lbs)
Eastern TCE active remediation areas	70	10	5	85
Western TCE active remediation area	20	10	0	30
TOTAL	**90**	**20**	**5**	**115**

Section 8
Proposed Response Actions

8.1 INTRODUCTION

This section presents the conceptual design for the proposed response action for groundwater at the Middle River Complex (MRC), Alternative 3: *in situ* bioremediation and land use controls. A site plan presenting the layout of the response action preliminary design is presented in Figure 8-1. A summary of the conceptual design for the proposed response action appears below. This proposed conceptual design may be altered in the course of a more detailed design process and in response to any additional information obtained before implementation.

A final response action design will be developed following approval of the *Response Action Plan* (RAP). The design will provide the final design basis for the response actions, details on the areas and volumes to be treated, final locations and design for the injection locations, and details on flow rates, piping locations, and unit processes for the injected solution preparation, distribution, and injection system. The final design will also detail the remedial performance sampling protocol for each treatment area, including groundwater monitoring. The final design will also incorporate information from the site utility identification detailed in Section 8.2.6. The schedule for implementation of the response action is in Section 10.

8.2 *IN SITU* BIOREMEDIATION

The proposed groundwater response action for this site focuses on three areas with high concentrations of trichloroethene (TCE) in groundwater: the southeastern area, the southwestern area, and the northern area (Figure 8-1). Biological amendment will be introduced into the subsurface in these areas using rows of injection wells connected by underground conveyance piping to an injection equipment building in each area, as described below. After active remediation is completed, the injection wells and infrastructure will be removed.

As discussed in the soil RAPs submitted under separate cover, portions of the southeastern and southwestern treatment areas are located in areas containing soil contamination that will be

addressed as part of the soil response actions. The groundwater wells and infrastructure associated with this groundwater RAP will be installed prior to completion of the soil response actions. To prevent damage to this infrastructure during the soil response actions, soil sampling and removal in these areas will take place prior to the installation of the infrastructure. The plan for management of this soil is discussed in Appendix N.

8.2.1 Injection Well Spacing and Locations

Determining the proper spacing between injection wells is a major factor in designing an adequate amendments distribution system for *in situ* bioremediation. The most conservative design uses a dense array of injection wells and injects an amendment volume approximately equal to the entire pore volume of the treatment area. However, for the MRC, this approach would lead to extremely high injection volumes (i.e., millions of gallons) and likely significant contaminant displacement. This approach also ignores the heterogeneous nature of the shallow saturated zone where the TCE contamination is present.

The geology in the proposed injection interval (generally 15–35 feet below ground surface) consists of layers of low hydraulic conductivity silt and silty sand interspersed with somewhat higher hydraulic conductivity silty sand layers. This heterogeneous geology is further complicated by buried utilities and associated bedding and backfill. As a result, the injected solution will not spread uniformly from each injection point but will instead travel preferentially through more permeable or hydraulically accessible layers. In practice, the injected solution will generally travel longer distances through these thin layers of higher hydraulic conductivity material as compared to injection in a homogeneous formation, where the injected solution would be distributed radially, forming a cylinder around each injection well.

The proposed injection system allows the injected amendment volume and rate to be varied in response to the effectiveness of the amendment distribution. The amendment distribution system will be designed such that injection can be performed over long periods (if necessary) without constant operator involvement.

Injection locations, volumes, and rates can be varied over a wide range to achieve the desired amendments distribution and avoid unwanted effects (such as contaminated groundwater displacement and preferential channeling of the injected amendments). The basis of the injection

system design and the resulting injection parameters are in Sections 6.3.3.2 and 6.3.3.3. The proposed injection parameters for the selected alternative are summarized in Table 8-1.

A low injection rate will limit groundwater mounding and contaminant displacement caused by the injection. The preliminary design injection rate, determined through groundwater model simulations, is 0.15 gallons per minute (gpm) per injection well. To minimize groundwater mounding during injection, we anticipate that injection will be conducted at 50% of the injection wells at any given time. Therefore, approximately 30 days will be required to inject the estimated amendment volume at each of the high concentration areas. The injection will start at a low flow (e.g., 0.05 gpm per well) and slowly increase to the design level of 0.15 gpm per well, while groundwater mounding and pressure heads are monitored.

8.2.2 Substrate Selection

Carbon substrates available for enhanced bioremediation of chlorinated hydrocarbons fall into two general categories: soluble and slow-release electron donors. Soluble electron donor substrates dissolve in water and include lactate, ethanol, and other short-chain hydrocarbons. Advantages of soluble electron donors are that delivery and distribution are more easily achieved in a heterogeneous environment, application from a given point can cover a larger area than slow-release electron donors can, and these donors tend to break down and establish favorable geochemical conditions more quickly than slow-release donors. These advantages are expected to be helpful at this site due to its varied geologic environment. The disadvantage of soluble electron donors is that they are generally consumed by microorganisms in three to six months.

Slow-release electron donors include hydrogen-releasing compounds, vegetable oil, and chitin. These compounds slowly release fatty acids into the groundwater, which in turn are metabolized by microbes in an anaerobic reductive dechlorination process. Many of these substrates persist for months or years before being exhausted. Emulsified vegetable oils that have been engineered to exhibit enhanced transport properties while slowly releasing carbon are commercially available. An added benefit of these oils is that they can preferentially partition contaminants from the dissolved phase into the oil.

Substrate formulations containing both soluble and slow-release electron donors are also now available. These are preferable because they combine the advantages of both approaches. The substrate recommended for the MRC bioremediation is LactOil™ from JRW Remediation

(see Appendix O). It is a combination of a slow-release soy vegetable oil (45%) and a fast-release soluble ethyl-lactate (35%), with the remaining 20% being water. The formulation is a stable microemulsion (generally less than 1 micron, -68V Zeta potential) that is completely miscible with water. The selected substrate formulation offers the following advantages:

- it contains a significant portion of both soluble and slow-release substrate, offering the advantages of both compounds
- it is a stable microemulsion with a long shelf-life that will not require on-site preparation
- it is completely miscible with water and can be transferred into the dilution water stream using conventional metering pumps
- the small size (generally less than 1 micron) and stable nature of the microemulsion will allow the vegetable oil portion to travel greater distances from a release point as compared to non-emulsified vegetable oil

The selected injection approach (a system of semi-permanent injection wells and an automated substrate injection system) will allow the use of different types of substrate (if warranted) without equipment modification.

8.2.3 Injection Wells and Distribution Piping

The injection wells will be constructed of two-inch diameter polyvinyl chloride (PVC) solid casing and well screen (0.006-inch slot) and will be screened from approximately five feet below the top of the groundwater table to near the bottom of the contaminated zone. These screen intervals were selected to limit the intrusion of the injected fluid into the vadose zone and to reduce channeling and daylighting of the injected fluid. Therefore, a typical injection well screened interval would be from 15–35 feet below ground surface. Screen intervals for individual injection wells will be selected according to groundwater table elevations, the vertical distribution of targeted contaminants, and the depth to the low hydraulic conductivity clayey layer in a particular location. A good grout seal will be emplaced above the screened interval to prevent vertical flow of injected amendment through the annular space of the injection well to the surface.

Each injection well will have a ⅜-inch flexible-tubing connection to one-inch piping header with a ¼-inch flow-regulating metering valve. A ¼-inch air-relief valve will be installed at the top of the well casing in an 18-inch diameter wellhead. The selected flow-regulating metering valve will have 20 turns to full opening, allowing injection flow metering from approximately 0.025–2 gpm

per injection well. The valve manufacturer's curve and the measured pressure differential across a valve will determine injection flow at each well (see Appendix O). Depth to water in the injection well (if the water level is below the wellhead flange) can also be estimated by measuring a negative pressure at the downstream end of the metering valve. Design details of the injection wells are presented in Figure 8-2.

Injection wells will be connected to the injection equipment in several clusters to allow greater flexibility in the injection process. The bioremediation system injection piping details in each high concentration area are summarized as follows:

- *Southwestern area*—Nine rows of injection wells with 79 injection wells. Seven separate 1-inch high-density polyethylene (HDPE) injection lines will connect the injection well clusters, as shown in Figure 8-3.

- *Southeastern area*—Seven rows of injection wells with 52 injection wells. Seven separate 1-inch HDPE injection lines will connect the injection well clusters, as shown in Figure 8-4.

- *Northern area*—Four rows of injection wells with 17 injection wells (with irregular spacing due to obstacles). Three separate 1-inch HDPE injection lines will connect the injection well clusters, as shown in Figure 8-5.

The design of the substrate injection distribution piping and controls will allow any number of injection wells to operate at any given time at the desired injection flow rates. Distribution piping will be made of 1-inch HDPE, SDR 11 piping with a 230 pounds per square inch (psi) pressure rating. It will be installed underground in a 12-inch wide trench at a depth of approximately two feet below grade (Figure 8-2). Trench width can be further reduced if a trenching machine (e.g., a "Ditch-Witch") is used. The HDPE piping will be surrounded by sand bedding, as shown in Figure 8-2. The specifics of piping installation in each of the high concentration areas are discussed below:

- *Southwestern high concentration area*—Most of the injection wells and distribution piping in the southwestern area will be in an open area between Chesapeake Park Plaza and Cow Pen Creek. Complicating the well and piping installation are a concrete pad extending across the southwest end of the planned injection area and apparently abandoned outfalls to Cow Pen Creek in that same area. Injection well cluster #1 (14 wells) will be installed on the north side of Chesapeake Park Plaza, necessitating a road crossing and an access agreement with Tilley Chemical Company. Another (minor) roadway crossing will be required to connect five wells in injection well cluster #2, north of the main open area. A sanitary sewer line along Chesapeake Park Plaza Drive (Figure 8-3) will also have to be crossed, but it is probably deeper than the injection lines'

trench depth. Refer to Figure 8-3 for the distribution piping and underground utility details for the southwestern high concentration area.

- *Southeastern high concentration area*—All of the injection wells and the distribution piping in the southeastern area will be in the area within the 90-degree turn of Chesapeake Park Plaza. The groundwater remediation system in this area has no road crossings. However, a storm water line, a fuel oil line, and possibly a fire water line will have to be crossed. Refer to Figure 8-4 for the distribution piping and underground utility details.

- *Northern high concentration area*—The northern area is the smallest of three high concentration areas, but it is the most complicated in terms of injection wells and distribution piping installation. There are numerous obstacles, including aboveground structures, railroad, and underground utilities. The injection piping will have to cross a storm water line, fire water lines, a domestic water line, possible additional unidentified lines, and a bermed railroad track. The injection well locations and distribution piping route presented in Figure 8-5 are preliminary and subject to change based on actual site conditions.

HDPE piping will be joined by means of electrical-fusion thermal welding. HDPE piping material was selected over PVC to reduce the number of joints and to provide an overall greater degree of reliability, due to its superior mechanical properties.

It is possible that contaminated soil will be encountered during the installation of the injection wells and distribution piping at the site. The soil will be handled and disposed of according to the appropriate regulations and Lockheed Martin policy. More detail on the soil handling and disposal protocol will be included in the Work Plan associated with these activities.

8.2.4 Injection Process and Equipment

The injection and solution preparation processes and equipment will be similar for each of the high concentration areas, although equipment sizes and capacities for the northern area can be reduced, since fewer injection wells will be installed in this area. Small prefabricated buildings will house the process equipment and store the substrate in the three high concentration areas.

8.2.4.1 Amendments Solution Preparation Approach

The injected solution will mainly consist of a substrate diluted in water to a 1% concentration. Therefore, dilution water will represent the major portion of the injected solution (approximately 99%). Significant total injection volumes are anticipated: approximately 240,000 gallons, 160,000 gallons, and 50,000 gallons are estimated as a base case for each injection for the southwestern, southeastern, and northern areas, respectively.

Potable water typically contains significant residual disinfectants (e.g., chlorine and chloramines) and dissolved oxygen levels, which can negatively affect anaerobic degradation. Therefore, potable water will be treated by removing residual disinfectants and dissolved oxygen before using it for amendment injection.

Removing residual disinfectant is relatively simple using granular activated carbon. Carbon use and vessel size for the required water volumes will be modest and treatment cost will be low. However, removing dissolved oxygen is more complex. A batch process was initially considered, which would remove dissolved oxygen by adding a small amount of substrate into potable water stored in several frac tanks. Dissolved oxygen would be consumed after several days' residence. However, this approach poses significant logistical challenges and cost for the required injection volumes and may be unsuitable if larger injection volumes are later required.

The selected process for removing dissolved oxygen is based on a membrane contactor that removes dissolved gases (such as oxygen) using an in-line cartridge, similar to a filter cartridge. The selected technology (Liqui-Cel® membrane contactors; see Appendix O) allows gas to be transferred from an aqueous stream without dispersion. The membrane contactors contain thousands of Celgard® microporous-polypropylene hollow fibers knitted into an array wound around a distribution tube. The aqueous stream will not penetrate the pores because the hollow-fiber membrane is hydrophobic. The gas/liquid interface is immobilized at the pore by applying a higher pressure to the aqueous stream relative to the gas stream.

This approach allows continuous preparation of the solution water without an operator's presence and avoids storing large amounts of potable water at injection locations. Moreover, because of the continuous nature of this process, overall injection volumes can generally be increased with no significant cost increase. An added benefit of a membrane contactor is its ability to remove dissolved oxygen to very low levels, allowing direct injection of de-chlorinating cultures to the injection manifold of the equipment buildings.

A preferred source of potable water for preparing the injection solution would be a connection to a fire water line or a domestic water line near the equipment building in each source area. Such lines are present in the southeastern and northern areas. A fire-water line in the southwestern area is at some distance from the equipment building, so whether it can be used is unclear. If a potable water connection line is not available, potable water can be transported and stored in one or

several frac tanks. The solution preparation equipment in each building will be designed so that either a pressurized water line or a water storage tank can be used as a source of solution water.

8.2.4.2 Process Summary

This section describes process equipment sizing and sequence. The maximum continuous capacities of the injection systems for the different areas are shown in Table 8-2. These maximum capacities significantly exceed the anticipated injection rates described in Section 8.2.1 and will allow for future system expansion if required.

Below is a description of the solution water preparation and injection process. Refer to the process and instrumentation diagram in Figure 8-6 for process details and equipment nomenclature. Refer to Appendix O for the equipment manufacturers' information.

- *Untreated water inlet*—Untreated potable water will enter the equipment building from an outside pressurized water line or a storage tank. A one-inch manual shut-off valve (V-1) and an electrically actuated one-inch ball valve (MV-1) with a spring return will be installed at the inlet. The actuated valve MV-1 will be interlocked with the high pressure switches (HPS-1 with ~20 psi set-point and HPS-2 with ~70 psi set-point) to shut down the water supply if an alarm is triggered.

- *Pressure booster pump*—A pressure booster pump (P-1) will provide a pressure reserve independent of the inlet water line pressure. An estimated discharge pressure up to 20 psi may be required at the maximum capacities needed for the entire process. However, the actual flows and pressures will vary within a wide range depending on the selected injection mode. Therefore, the booster pump will be equipped with a variable-frequency drive (VFD) for flexibility in selecting flows and discharge pressures. Regenerative turbine pumps are recommended for this application. The pump P-1 will be interlocked with the high pressure switches (HPS-1 and HPS-2) to shut down if an alarm is triggered. Pressure boosting will probably not be required if a potable water line with sufficient pressure is used. In this case, the pressure boosting pump (P-1) will be deactivated and bypassed (open valve V-10, close valve V-2) until such time that pressure boosting is required.

- *Flow-regulating and pressure-limiting valves*—After the booster pump (P-1), fluid will pass through an adjustable flow regulating valve (FRV-1). This valve can be adjusted to a desirable set-point within a wide range of flow. The flow rate will then be maintained at the set point regardless of changes in inlet pressure. A pressure reducing valve (PRV-1) will be installed at the outlet of the flow regulating valve. The purpose of this valve is to keep the fluid pressure below the working pressure rating of the downstream process equipment. The set point of the pressure limiting valve (PRV-1) will be approximately 70 psi, which is 35–50% lower than the maximum working pressures of the downstream process equipment (LGAC-1, ORC-1, PF-1).

- *Granular activated carbon*—At the next step, the water stream will be treated by granular activated carbon (LGAC-1) to remove residual chlorine and chloramines (if present). GAC treatment for chlorine is usually selected based on 3–5 gpm of flow per cubic foot of activated carbon. Chloramines are more difficult to remove, so GAC treatment is usually sized based on 0.5 gpm of flow per cubic foot of activated carbon. The GAC vessels are sized conservatively to allow both chlorine and chloramine removal (40 cubic feet of activated carbon for the southwestern and southeastern area systems and 18 cubic feet of activated carbon for the northern area system). The GAC vessel will have a recirculation wetting loop (valve V-9) to settle carbon dust during startup.

- *Dissolved oxygen removal package*—The final step in preparing the solution water is to remove dissolved oxygen. The dissolved oxygen removal package will consist of a membrane contactor, an inlet particulate filter (less than 5 microns) to remove carbon dust from the stream, and a vacuum pump. An optional nitrogen source can be used in addition to a vacuum pump if the outlet dissolved oxygen concentration must be below 0.5 mg/L. The selected membrane contactor (Liqui-Cell®, model 4×13 Extra-Flow) is 4.5-inches in diameter and 20-inches tall with ¾-inch connections on the side for liquid (inlet and outlet on each end) and ¾-inch connections for vacuum/nitrogen. Refer to the "4×13 Extra-Product Data Sheet" in Appendix O for dimensions and operational data.

- *Substrate and dehalococcoides (DHC) cultures injection*—The substrate will be introduced directly into the one-inch PVC line at the effluent of the dissolved oxygen removal contactor and before the distribution manifold of the injection wells. A metering pump (e.g., solenoid diaphragm type) with a sufficient flow and pressure range to supply the required substrate quantities will be used (MP-1). The metering pump (MP-1) will discharge into a ¼-inch substrate injection line with a check valve and a shut-off valve connected to the main one-inch PVC line via a reducing tee (see Figure 8-1). The DHC cultures injection line will be similarly constructed, but the cultures will be displaced from the shipping container using an inert gas (e.g., argon); this will require an operator on site. A static mixer (SM-1) will be installed downstream of the substrate and DHC cultures injection points.

- *Distribution manifold*—The injection solution fluid will pass through a turbine-type electronic flow meter-totalizer (FMT-1) and a check valve (CV-3), and the stream will then be split into several branches leading to different injection well clusters (seven for both the southwestern and southeastern areas and three for northern area). Each well cluster line will have a mechanical flow meter-totalizer (C_-FMT), a check valve (C_CV), and shutoff valves.

- *Injection wells instrumentation*—Each injection well will have a ⅜-inch flexible tubing connection to a one-inch piping header with a ¼-inch flow-regulating metering valve. A ¼-inch air-relief valve will be installed at the top of the well casing in an 18-inch diameter wellhead. The selected flow-regulating metering-valve will have 20 turns to full opening, allowing injection flow metering from approximately 0.025–2 gpm per injection well. The valve manufacturer's curve (valve flow coefficient versus number of turns) and the measured pressure differential across a valve will determine injection flow at each well.

The characteristics and sizes of the major equipment items are summarized in Table 8-3. Below are two examples of the system's operational settings for the southwestern area (79 injection wells). The granular activated carbon unit is assumed to be wetted with all equipment ready for operation:

1. Startup or pilot test injection at low flow: injecting into 50% of the wells at 0.05 gpm per injection well. Total injection flow: 0.05 gpm/well ×40 wells=2 gpm

    - Adjust flow-regulating valve FRV-1 to 2 gpm
    - Open the metering needle valves (NMV-_) at the injection wellheads for two complete turns
    - Determine the valve flow coefficient (Cv) for two turns (valve manufacturer curve, Appendix O). For two turns: Cv=0.022
    - Begin the injection process (open MV-1, V-1 through V-6). Pressure boosting will probably not be required at such low flow. Therefore, deactivate and bypass the booster pump P-1 (open V-10, close V-2)
    - Measure differential pressures (DP) across metering needle valves (NMV-_) using differential pressure gauges at the wellheads (DPG-_). The pressure differential at 0.05-gpm flow should be 5 psi. The following equation calculates the expected differential pressure with water as fluid: $DP=(Flow / Cv)^2$.
    - If necessary, adjust each metering needle valve (NMV-_) to 5 psi differential pressure
    - Verify that the total injection flow is 2 gpm (FMT-1). If necessary, adjust the flow-regulating valve FRV-1 to obtain 2 gpm.
    - The substrate dosage to obtain a 1% concentration in the injected solution would be 1.2 gallons per hour

2. Anticipated injection mode: injecting into 50% of the wells at 0.15 gpm per injection well. Injection wil occur in one area at a time. Total injection flow: 0.15 gpm/well×40 wells=6 gpm.

    - Adjust flow-regulating valve FRV-1 to 6 gpm
    - Open the metering needle valves (NMV-_) at the injection wellheads for five complete turns
    - Determine the valve Cv for five turns (valve manufacturer curve; see Appendix O). For five turns: Cv=0.05
    - Begin the injection process (open MV-1, V-1 through V-6). If pressure boosting is required, activate the booster pump P-1 (close V-10, open V-2)

- Measure DP across the metering needle valves (NMV-_) using differential pressure gauges at the wellheads (DPG-_). The pressure differential at 0.15-gpm flow should be 9 psi.

- If necessary, adjust each metering needle valve (NMV-_) to 9 psi differential pressure

- Verify that the total injection flow is 6 gpm (FMT-1). If necessary, adjust the flow-regulating valve FRV-1 to obtain 6 gpm

- The substrate dosage to obtain a 1% concentration in the injected solution would be 3.6 gallons per hour

8.2.5 Groundwater Monitoring and Monitored Natural Attenuation

In addition to sampling associated with the *in situ* bioremediation, periodic groundwater monitoring will be conducted at the MRC. Initially, the monitoring will primarily include sampling wells at the MRC outside of the active treatment areas. This will help determine the concentration trends of site chemicals of concern (COC) and ensure that there is no regulatorily unacceptable risk at the site. Sampling parameters will include volatile organic compounds (VOCs), 1,4-dioxane, and metals at appropriate wells.

The current program of annual monitoring includes approximately 100 on-site wells and 24 off-site wells. The design of the groundwater monitoring event will include a total of approximately 40 on-site wells (not including performance monitoring wells) and 24 off-site wells and will focus on wells near the surface water and those containing low concentrations of organic contaminants, primarily TCE and benzene. As with the performance monitoring plan described in Section 8.2.6, the well and analyte lists will be optimized after each monitoring event to ensure that the sampling program is efficient.

These data will be analyzed to determine if the areas of groundwater contamination are expanding or contracting and if contaminant concentrations (TCE, benzene, and 1,4-dioxane in the low concentration areas, primarily) are increasing, decreasing, or remaining steady. These data, along with the performance monitoring data, will also be used to update and re-calibrate the groundwater model, if necessary. The model would then be used to provide updated predictions of future contaminant concentrations and the time needed to meet certain contaminant concentration thresholds. Groundwater monitoring will continue until a Tier 1B Certificate of Completion is received from the Maryland Department of the Environment (MDE).

Groundwater monitoring will be expanded to the active treatment areas following achievement of the TCE mass reduction goal. Following active remediation, monitored natural attenuation (MNA) sampling may be instituted in the active treatment areas and would include approximately 15 of the performance monitoring wells to determine COC trends and geochemical parameters in these wells. The potential scenario for instituting MNA in the active treatment areas is presented in items 13 and 15 in Section 8.2.6. MNA sampling would continue until the TCE mass removal goal was met.

8.2.6 Implementation Plan Summary

Implementation of the *in situ* bioremediation component of the selected response action will entail the following steps:

1. *Complete the utilities investigation for the three injection areas.* This will include an extensive paper study of the catalogued site drawings to identify current and former subsurface utilities in these areas. A field investigation will also be conducted, including a variety of geophysical and utility location methods and follow up direct inspections of utilities where necessary. The investigation will determine the locations, depths, and use (current or former) of all subsurface utilities in the injection area. A work plan for these activities will be submitted separately. This information will be transferred to the injection design drawings, and the following actions may be taken:

    a. Adjusting the injection well locations based on the location and elevation of utilities, potentially eliminating areas from active treatment based on the presence of utilities

    b. Abandoning unused utilities, such as storm drains, if possible

    c. Temporarily plugging storm drains and re-routing storm water during injection activities

    d. Planning to monitor, during operation, for substrate presence at possible preferential pathways and critical receptors.

2. *Perform numerical groundwater model flow and transport simulations of injections in the southwestern and northern TCE areas.* Injections in these areas were not explicitly simulated before completion of this RAP; these simulations will be used to confirm or adjust the conceptual designs for injections in these areas.

3. *Investigate and remove soil, as appropriate, from the southeastern and southwestern areas as described in the soil management plan in Appendix N.*

4. *Install 148 injection wells and 21 monitoring wells.* Continuous geological logging will be conducted at 30 injection wells to obtain more complete data on soil heterogeneities in the injection areas. Monitoring wells are shown in Figure 8-3 (eight wells in the southwestern area), Figure 8-4 (eight wells in the southeastern area), and Figure 8-5 (five

wells in the northern area). Twelve of the monitoring wells will be constructed of two-inch diameter PVC and be screened from 20–30 feet below ground surface. The wells downgradient of each injection area (SWMW-7, SEMW-7, and NMW-4) will be screened from 10–30 below ground surface (bgs) to provide a more comprehensive view of substrate or contaminants that may be migrating from the injection areas. At one location in each area, two nested wells (SWMW-5S/I, SEMW-5S/I, and NMW-2S/I), with screened intervals of approximately 10–15 feet bgs and 25–30 feet bgs, will be installed to provide more information on the difference in pressure head between the injection depth and the water table, and to determine the effect of the substrate injection on the aquifer near the top of the water table.

5. *Complete piping construction and injection well connections*. Install underground piping in shallow and narrow trenches to limit environmental impact, limit disturbances to site operations, and reduce channeling. Install wellheads.

6. *Erect injection equipment buildings and install process equipment*.

7. *Conduct baseline performance monitoring sampling.* Sample 21 new monitoring wells and existing monitoring wells MW12A, MW12B, MW14B, MW60A, MW60B, MW81B, MW74A, MW74B, and MW72B. Institute the groundwater monitoring program in areas outside of the active remediation areas.

8. *Perform test injections using water (with chlorine and dissolved oxygen removed) and dye tracer.* Injection equipment will be tested and operating procedures will be developed during testing. Start the injection slowly and build to the design injection rates. Measure groundwater table mounding and pressure heads in the injection interval. Visually examine and track utilities, outfalls, and channels for the injected solution. Use field instrumentation to detect small quantities of tracer in utilities and outfalls. The tracer used will be inert and environmentally-safe. This tracer test will encompass an entire injection cycle (i.e., the full design volume will be injected, with tracer, into each area). Monitoring of tracer will also be completed in the months following testing and continuing through amendment injection until the tracer can no longer be detected. If tracer is detected in locations that indicate discharge to the environment, adjustments such as modifying injection rate or changing injection locations would be made.

9. *Refine acceptable injection rates and volumes* based on tracer testing results.

10. *Perform the first round of injection.* Start slowly and build up to design injection rates. Significant monitoring will be conducted during injections (injection rates and pressures, groundwater mounding, pressure head in the injection interval, field groundwater quality parameters, visual monitoring of utilities, channels, and outfalls).

11. *Monitor performance one, three, six, and 12 months following the injection* at the new performance monitoring wells and the existing wells listed above. Sampling parameters include VOCs and MNA parameters, as follows:

    a. VOCs, including TCE, cis-1,2-dichlorethene (cis-1,2-DCE), and vinyl chloride

    b. biodegradation byproducts and end products (e.g., ferrous iron, sulfide, nitrite, nitrogen, and the dissolved gases ethane, ethane, and methane)

c. electron acceptors (e.g., sulfate, nitrate, ferric iron)

d. general water quality parameters and biogeochemical indicators (e.g., total organic carbon, alkalinity, chlorides)

e. organic fatty acids (an indicator of substrate presence)

f. genetic material (DHC and functional genes to determine the presence of microorganisms capable of degrading TCE to ethene)

g. field parameters (e.g., oxidation-reduction potential, dissolved oxygen, pH, temperature, specific conductance)

This list of parameters is comprehensive. Not all wells will be sampled for all parameters. The performance monitoring plan will be developed during the final design phase and will be optimized after each event to determine if adjustments to the sampling protocol should be made.

12. *Evaluate remedy performance.* The criteria for evaluation of the response action are outlined in Section 7. The evaluation will determine if any of the following adjustments are required:

    a. adjustments to the injection wells/injection rates to limit preferential channeling (utilities, outfalls, channels) and maximize distribution

    b. addition of DHC and/or pH buffering to the subsequent injection

    c. addition of injection wells to improve distribution

    d. addition of localized groundwater extraction in the treatment areas to enhance substrate distribution and/or limit displacement of contamination or injected fluid

    e. optimize performance sampling by eliminating unnecessary wells and analytes

13. *Perform the second injection event* based on the remedy evaluation phase recommendations and conclusions.

14. *Repeat performance monitoring and evaluation*. If the TCE mass reduction goal is met following this injection, groundwater monitoring will be established in this area. If the data indicate that MNA will be sufficient to achieve the goal within three years, injection activities will be discontinued and MNA initiated in the treatment areas. If the response objectives have not been met or concentrations rebound during the groundwater monitoring or MNA phase and the mass removal goal is no longer met, a third injection event would be conducted. The evaluation will also be used to determine if any of the adjustments listed in step 11 are required; it will also determine if the scope of the third injection can be decreased to concentrate on remaining “hot spots” only.

15. *Perform the third injection event* (this event may be over a smaller area than the others, based on performance sampling results), as required to meet project goals. Three injection events are expected to meet project goals. If the initial two injections show

limited or no success (for example, less than 40% reductions in TCE mass or less than 50% of the injection area with a total organic carbon (TOC) concentration of greater than 100 mg/L), some contingencies may be incorporated into the third injection event.

16. *Repeat performance monitoring and remedy evaluation.* Based on current data, it is likely that active remediation will be complete and groundwater monitoring will be initiated in the remediation areas following the third injection event. The evaluation of the path forward after the third injection event will include:

    a. A review of the TCE mass reduction: if the TCE reduction has met the goal of 70% within the injection areas, the injections will be discontinued and groundwater monitoring initiated in the injection areas (or additional remedial actions may be performed to address residual cis-1,2-DCE and vinyl chloride concentrations). If TCE reduction is less than 50%, additional injections, injection with contingencies, and/or alternative remedial options will be considered. If TCE mass reduction is between 50–70%, the following options will be considered: a fourth full-scale injection; targeted injections in hot spot areas; injections with contingencies; or MNA.

    b. The decision on the next action if the TCE reductions are between 50–70% will be primarily based on TCE concentration trends in performance monitoring wells, relative concentrations of cis-1,2-DCE and vinyl chloride, geochemical conditions in the aquifer (pH, oxidation-reduction potential [ORP], dissolved oxygen, etc.), microbial populations in the aquifer, other indicators of successful bioremediation (chloride, ethene, and ethane), and the success in distribution of amendment in the three previous injection events.

8.3 LAND USE CONTROLS

The MDE will document land use controls applicable to the MRC property in the applicable Certificates of Completion, which will be issued upon successful completion of soil remediation in each Block. Each Certificate of Completion will be filed in the local land use records and will pass to subsequent property owners as part of the deed documentation. The MDE regards all land use controls to exist in perpetuity unless the related environmental covenants are eliminated or modified by mutual consent of the stakeholders. The MDE will present certain environmental covenants as part of the Certificate of Completion documentation. The environmental covenants will provide stakeholders with legal standing for their enforcement of the covenants. The MDE will determine final disposition of any land use controls. Elimination or modification of any land use control may require that a re-application to the VCP.

These land use controls may include:

- Prohibition of the use of groundwater beneath the property for any purpose.
- Requirements for the implementation of sub-slab soil vapor mitigation technology

beneath all buildings where and to the extent the potential for soil vapor intrusion to indoor air exists. For new-footprint buildings, the vapor mitigation system may, for example, consist of slotted PVC tubing arranged in such a manner as to passively exhaust soil vapors from beneath the building slab to the atmosphere. Any passive vent system would be required to be readily convertible to an active remedial system, if necessary. Other acceptable remedial alternatives exist. Regardless of remedial choice, indoor air would need to be tested prior to occupancy and concentrations of any detected contaminant must not exceed the applicable indoor air standards.

These land use controls will apply to the entire Block at which they are applied, and not to smaller portions of the Block, as agreed upon by the Department and Lockheed Martin.

8.4 REPORTING REQUIREMENTS

Semi-annual reports will be submitted to MDE throughout the active portion of the response action detailing the progress of the groundwater response action. Following active remediation and during groundwater monitoring or MNA activities, reports will be submitted annually. The reports will include the following:

- a description of activities during the reporting period
- a summary of remedial progress including analytical results from *in situ* bioremediation performance monitoring
- estimates of TCE mass reductions during the reporting period and throughout the life of the response action
- injection information, including volumes of water and substrate injected, wells used, etc.
- results of site groundwater monitoring
- a summary of updates to the groundwater model
- results of inspections regarding land use controls and any proposed changes to those land use controls.
- a summary of upcoming activities, including groundwater monitoring and response action optimization

Other reports may be required by the regulatory agencies; for example, periodic reports may be required for the underground injection control permit. These reports will be prepared and submitted, as required.

Table 8-1
Proposed Injection Parameters for Selected Alternative
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

Area	TCE area (square feet)	Number of injection points	Area with substrate >100 ppm (square feet)	% of TCE area with substrate >100 ppm	Injection volume per location (gallons)	Injection volume (gallons)	Injection volume as % of total pore volume	Substrate mass (pounds)
Southwestern TCE area	65000	79	33500	52%	3000	237000	9.7%	20000
Northern TCE area	21000	17	13900	66%	3000	51000	6.5%	6000
Southeastern TCE area	33000	52	22100	67%	3000	156000	12.6%	12500
TOTAL	**119000**	**148**	**69500**	**58%**	**3000**	**444000**	**9.9%**	**30500**

Table 8-2
Maximum Injection Capacity by TCE Area
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

High Concentration Area	Number of injection wells	Maximum continuous injection capacity (gpm)	Maximum rate per injection well with wells operated simultaneously (gpm)
Southwestern	79	15	0.2
Southeastern	52	15	0.3
Northern	17	5	0.3

Table 8-3
Major Equipment Summary Table
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland
Page 1 of 2

P&ID* symbol	Description	Manufacturer/model	Sizes/capacities		
			Southwestern area	Southeastern area	Northern area
MV1	Electrical actuated ball valve, spring return on fail	Not specified	1 inch	1 inch	1 inch
FRV1	Adjustable set-point flow-regulating valve	W. A. Kates, Flo-Miser series	FM50 for 1–10 gpm range FM75 for 3–30 gpm range	FM50 for 1–10 gpm range FM75 for 3–30 gpm range	FM50 for 1–10 gpm range FM38 for 0.3–3 gpm range
P1	Booster pump, regenerative-turbine type, closed coupled	MTH Pump, E41 series, closed-coupled with 3-phase motor	model E41M, 2 hp**, 3450 rpm***: 75 psi @ 15 gpm; 1750 rpm: 60 psi @ 2 gpm.	model E41M, 2 hp, 3450 rpm: 75 psi @ 15 gpm; 1750 rpm: 60 psi @ 2 gpm.	model E41D, 1 hp, 3450 rpm: 85 psi @ 5 gpm; 1750 rpm: 70 psi @ 1 gpm.
LGAC1	Liquid phase carbon vessel, fiberglass	Siemens, PG series	model PG1100, 1100 lbs of carbon, 65 gpm max flow	model PG1100, 1100 lbs of carbon, 65 gpm max flow	model PG500, 500 lbs of carbon, 35 gpm max flow
PF1	Particulate filter, <5 microns	Not specified	1 inch	1 inch	1 inch
ORC-1	Oxygen removal membrane contactor	Liqui-Cell® Extra-Flow series	Model 4×13 Extra-Flow cartridge, 15 gpm max	Model 4×13 Extra-Flow cartridge, 15 gpm max	Model 4×13 Extra-Flow cartridge, 15 gpm max
VP-1	Vacuum pump—part of oxygen removal package	Not specified	2 hp	2 hp	1 hp
MP-1	Substrate metering pump	LMI series, solenoid diaphragm	4 gallons per hour capacity, 100 psi maximum pressure	4 gallons per hour capacity, 100 psi maximum pressure	2 gallons per hour capacity, 100 psi maximum pressure
FMT-1	Flow meter totalizer	Digital, turbine, local display	2–20 gpm range, ¾" FNPT connections, brass	2–20 gpm range, ¾" FNPT connections, brass	1–10 gpm range, ½" FNPT connections, brass

Table 8-3
Major Equipment Summary Table
Groundwater Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland
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P&ID* symbol	Description	Manufacturer/model	Sizes/capacities		
			Southwestern area	Southeastern area	Northern area
NMV_	Flow-regulating needle-valve at wellheads	20-turns needle valve, ¼" FNPT, 0.025–2 gpm flow range	Hoke series 2300, model 2335FY	Hoke series 2300, model 2335FY	Hoke series 2300, model 2335FY
DPT_	Differential pressure gauge at wellheads	Not specified	0–25 psi range	0–25 psi range	0–25 psi range

**piping and instrumentation diagram*

*** horsepower*

**** revolutions per minute*

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Figure 8-1

Figure 8-2

Figure 8-3

Figure 8-4

Figure 8-5

Figure 8-6

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Section 9
Permits, Notifications, and Contingencies

9.1 INTRODUCTION

This section describes the permits that will be required for the proposed response actions and the required notifications and contingencies if unexpected conditions are encountered during implementation of the *Response Action Plan* (RAP).

9.2 PERMITS

Lockheed Martin will meet all federal, state, and local permitting requirements for the proposed groundwater response action described in Section 8. Permitting requirements for the proposed response action relate to installation of infrastructure and *in situ* groundwater treatment, as determined by a review of United States Environmental Protection Agency (EPA), Maryland Department of the Environment (MDE), and Baltimore County Department of Environmental Protection and Natural Resources Groundwater Management requirements. A list of permit requirements with contact information and review periods is included in Appendix P. Permits that may potentially be required to install the response action described in Section 8 include:

- A Baltimore County grading permit for any land disturbance and grading that disturbs greater than 5,000 square feet or more than 100 cubic yards of fill material will probably be required. Grading plans will be submitted to Baltimore County for review and approval.

- As a condition of receiving a grading permit, a storm water management plan will be submitted to Baltimore County for review and approval. The storm water management plan will be prepared in accordance with the *Maryland Storm Water Design Manual, Volumes I and II* (MDE, 2000), including the 2009 revisions and subsequent supplements.

- An erosion and sediment control plan will be submitted to Baltimore County to be reviewed by the Baltimore County Soil Conservation District. It will be prepared in accordance with the 1994 *Maryland Standards and Specifications for Soil Erosion and Sediment Control* (MDE, 1994); draft standards and specifications published in early 2010 will also be considered. Baltimore County will coordinate review of these plans with the Critical Areas Commission.

- A joint application will be submitted to MDE, since the project will disturb land within the Chesapeake Bay Critical Area. This information is circulated to various offices within MDE, including tidal and non-tidal wetlands divisions, and to the U.S. Army Corp of Engineers (USACE).

- MDE and Baltimore County well construction permits.

- Baltimore County building permits for the three injection enclosures.

- Injecting chemicals into groundwater is regulated by MDE's Underground Injection Control (UIC) Program. Any injection wells used for the proposed response action would be classified as Class V wells, defined as shallow wells used to place a variety of fluids below the land surface, including wells used to inject chemicals for *in situ* groundwater treatment. Information on the proposed nature and type of injection well operation(s) will be submitted to MDE's Groundwater Permits Division. MDE will then determine whether the injection wells would be authorized by rule, whether an individual permit will be required, and/or whether additional information and/or operational requirements will be needed to comply with state regulations.

- If adjustments or contingences to the initial system are required, additional permits may be required.

- Permits will be required for installation of piping across Chesapeake Park Plaza, a county road.

- An access agreement must be reached with Tilley Chemical Company to install injection wells and infrastructure on their property.

- North American Electric must be notified and informed of the nature of the injection activities occurring adjacent to their property.

- Lockheed Martin Properties, Inc. (LMCPI) must be kept informed of work progress and schedule. Potable water must be obtained at locations, volumes, and rates approved by LMCPI.

9.3 NOTIFICATIONS

MDE will be notified immediately of any previously undiscovered contamination, changes in the RAP schedule, and citations from regulatory entities related to health and safety practices associated with implementation of the proposed response action. They will also be notified of any discharges to the environment.

9.4 CONTINGENCIES

Potential contingency measures to be implemented if the response actions fail to meet their evaluation criteria are detailed in Section 7.2.

Section 10
Implementation Schedule

A projected sequence of events for this project, including the expected completion schedule of various milestones, appears below (all dates below, except for Items 1 and 2) are estimated and subject to change:

1. Submit draft *Response Action Plan* (RAP) to the Maryland Department of the Environment (MDE) (April 2011)
2. Submit final RAP (August 2012)
3. Complete 90% system design (September 2012)
4. Complete 100% system design (November 2012)
5. Obtain required permits (December 2012)
6. Mobilize to install the infrastructure for the response action (March 2013)
7. Complete baseline sampling to allow comparison with remedial performance monitoring (April 2013)
8. Complete installation of infrastructure for the response action (July 2013)
9. Initial injection testing (September – October 2013)
10. First round of substrate injection (December 2013 – February 2014)
11. Performance sampling (November 2013 – October 2014)
12. Second round of substrate injection (December 2014 – February 2015)
13. Performance sampling (November 2014 – October 2015)
14. Determine the path forward based on the results of the response action: additional injections, system modifications/contingencies, additional monitoring, and/or a request for a Tier 1B Certificate of Completion

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Section 11
Administrative Requirements

11.1 INTRODUCTION

The Maryland Department of the Environment's (MDE's) Voluntary Cleanup Program (VCP) stipulates several administrative requirements that applicants must comply with. Administrative requirements include a written agreement, zoning certification, performance bond or other security, and health and safety plan requirements. These administrative requirements are described below.

11.2 WRITTEN AGREEMENT

A written agreement is provided in Appendix Q, in compliance with Section 7-508 of the Environment Article, *Annotated Code of Maryland*. The written agreement stipulates that if the *Response Action Plan* (RAP) is approved, the applicant agrees, subject to the withdrawal provisions set forth in Section 7-512 of the Environment Article, to comply with the RAP provisions.

11.3 ZONING CERTIFICATION

A zoning certification is in Appendix Q, in compliance with Section 7-508 of the Environment Article, *Annotated Code of Maryland*. Section 7-508 requires that RAPs include a certified written statement that the property meets all applicable county and municipal zoning requirements.

11.4 PERFORMANCE BOND OR OTHER SECURITY

Lockheed Martin Corporation will obtain a bond before proceeding with the active remedies associated with this RAP. The purpose of the bond is to secure and stabilize the site, if necessary. The value and details of this bond will be determined as part of final design activities.

11.5 HEALTH AND SAFETY PLAN

A project-specific health and safety plan will be prepared and submitted to MDE before implementation of the MDE-approved RAP. The health and safety plan will address each planned response action activity performed by workers engaged in hazardous waste site activities. The project-specific health and safety plan will reference applicable regulations that may apply to response action activities. At a minimum, the plan will contain the required elements specified in 29 CFR Parts 1910.120 and 1926.65, as well as other regulatory and Lockheed Martin requirements that apply to the activities to be performed. At a minimum, the project-specific health and safety plan will address the following (29 *Code of Federal Regulations* [CFR] Part 1910 citations in parentheses):

- health and safety personnel requirements and responsibilities [29 CFR Part 1910.120(b)(4)(iv)]
- pertinent site information [29 CFR Part 1910.120(b)(4)(iv)]
- scope of work [29 CFR Part 1910.120(b)(4)(iv)]
- a safety and health risk or hazard analysis for each planned site activity [29 CFR Part 1910.120(b)(4)(iv)]
- training requirements [29 CFR Part 1910.120(e)]
- personal protective equipment (PPE) requirements for each planned site activity [29 CFR Part 1910.120(c)(5)]
- medical surveillance requirements [29 CFR Part 1910.120(h)(1)(i)]
- air monitoring and sampling requirements
- site control measures [29 CFR Part 1910.120(d)]
- decontamination procedures [29 CFR Part 1910.120(k)(1)]
- an emergency response plan [29 CFR Part 1910.120(l)(1)]
- confined-space entry procedures (29 CFR Part 1910.146)
- spill containment [29 CFR Part 1910.120(j)(1)(viii)]
- recordkeeping [29 CFR Part 1910.120(f)(8)]

The health and safety plan will present information to adequately address appropriate hazard recognition and evaluation and control for potential hazards that may be anticipated for the specific activities planned. The project-specific health and safety plan is subject to review and possible revision, as appropriate. Possible factors that could warrant revision of the plan include a change in the scope of work or a change resulting from the evaluation of data collected throughout implementation of the response action. The site safety officer (SSO) assigned to the response action (with assistance from project management, as appropriate) will implement the appropriate portions of the project-specific health and safety plan. The SSO will be on site during all intrusive activities. Specific health and safety program implementation elements are summarized below.

11.5.1 Training and Medical Surveillance

All personnel who participate in on-site work with the potential for exposure to hazardous waste-related safety or health hazards will be current participants in health and safety training and medical surveillance programs, in accordance with regulatory requirements. In general, the employee training and medical requirements specified in federal Occupational Safety and Health Administration (OSHA) hazardous waste regulations are regarded as minimum requirements. At a minimum, employees who will or may participate in any on-site activities that may involve potential exposures to hazardous waste-related safety or health hazards must first satisfy the following health and safety training requirements:

- 40-hour introductory hazardous waste general worker training [29 CFR Part 1910.120(e)(3)(i)]
- on their first assignment, an additional 24 hours of activity under the direction of a trained, experienced supervisor [29 CFR Part 1910.120(e)(3)(i)]
- supervisors must also complete an additional eight hours of management/supervisory health and safety training [29 CFR Part 1910.120(e)(4)]
- eight hours of annual health and safety refresher training for all general workers and supervisors [29 CFR Part 1910.120(e)(8)]
- project-specific training before the start of any intrusive on-site activities

Additional health and safety training requirements may also be specified in the project-specific health and safety plan, depending on the nature of the planned activities (e.g., confined-space entry training, fall protection training, excavation safety training, etc.).

11.5.2 On-Site Health and Safety Functions

The SSO will be responsible for ensuring that all requirements specified in the health and safety plan are adequately performed and documented. This commonly includes activities such as the following:

- conducting and documenting on-site health and safety training
- implementing a project-specific hazard communication program (e.g., chemical inventory, material safety data sheets [MSDSs], chemical container labeling, etc.)
- implementing other project-specific health and safety programs that may be relevant based on the response action scope of work and the nature of planned activities (e.g., hearing conservation program, confined-space entry program, respiratory protection program, etc.)
- performing and documenting equipment inspections for equipment to be used on site
- calibration and use of air monitoring (e.g., organic vapor meters, particulate meters, etc.) and air sampling devices
- ensuring that specified PPE is used appropriately
- overseeing personnel and equipment decontamination
- coordinating with appropriate on- and off-site contacts and agencies and managing the emergency response plan, when/as appropriate
- other duties as specified in the health and safety plan.

Section 12
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APPENDIX A—MDE COMMENTS ON DRAFT RAP AND LOCKHEED MARTIN RESPONSES

Lockheed Martin Corporation
6801 Rockledge Drive, MP: CCT 246
Bethesda, MD 20817
Telephone 301-548-2209

LOCKHEED MARTIN

March 1, 2012

VIA HAND DELIVERY

Mr. Jim Carroll
Voluntary Cleanup Program
Maryland Department of the Environment
1800 Washington Boulevard, Suite 625
Baltimore, Maryland 21230

Transmittal: Responses to July 13, 2011, VCP Comments regarding the DRAFT Groundwater Response Action Plan (RAP), dated April 29th, 2011, Middle River Complex (MRC)

Dear Mr. Carroll:

Lockheed Martin is grateful for the VCP comments received regarding the DRAFT Groundwater (RAP). Please find attached one hard copy of the comment-responses document. The subject comment-responses are being submitted for formal consideration by the Maryland Department of Environment (MDE) under the Voluntary Cleanup Program (VCP). No public comments were received during the public comment period. Lockheed Martin is presently preparing a proposed Final version of the Groundwater RAP document.

Please let me know if you have any questions. My office phone is (301) 548-2209.

Sincerely,

Thomas D. Blackman
Project Lead, Environmental Remediation

Attachment
cc: via email
Christine Kline, Lockheed Martin
Norman Varney, Lockheed Martin
Mike Martin, Tetra Tech
Dale Truskett, Lockheed Martin

VOLUNTARY CLEANUP PROGRAM

LOCKHEED MARTIN / MIDDLE RIVER COMPLEX
2323 EASTERN BOULEVARD
MIDDLE RIVER, MARYLAND

RESPONSES TO THE VCP COMMENTS OF JULY 13, 2011, REGARDING THE DRAFT GROUNDWATER RESPONSE ACTION PLAN DATED APRIL 29, 2011

Note: The MDE's comments are reproduced in "**bold**" font type, followed by Lockheed Martin's responses in "regular" font type.

GENERAL COMMENTS

1) The Maryland Department of the Environment ("Department") acknowledges that the Lockheed Martin Corporation ("Lockheed") has voluntarily developed a remedial strategy for groundwater at the Middle River Complex ("MRC") as a part of the corporate due diligence policy. The Department accepts the assumptions and calculations regarding the geological and hydrogeological criteria which form a basis for the remedial strategy at the MRC, as presented in the April 29, 2011 draft Response Action Plan ("RAP"). The Department understands that Lockheed will perform sufficient confirmatory sampling to validate the effectiveness of the proposed groundwater remedies.

Regardless of whether Lockheed meets the corporate remedial goals set forth in the RAP, the Department will require a prohibition on the use of groundwater beneath the property for any purpose. This requirement will be included in the certificate of completion ("COC") as a land use control ("LUC").

Since the Department will address groundwater contamination via LUCs, and since Lockheed has voluntarily developed the remedial strategy for groundwater as a part of its corporate due diligence policy, the Department will focus on mitigation of the soil vapor to indoor air exposure pathway and the appropriate institutional and engineering LUCs that will mitigate such risk.

Response: Lockheed Martin notes the Department's acceptance of the criteria which form the basis of the remedial strategy and the Department's acknowledgement of the remedial strategy. Only minor changes, based on later specific comments, will be made to the portions of the document that address the selection of the remedial strategy.

Lockheed Martin also notes that the Department (and not Lockheed Martin) sets forth the required LUCs in the Certificate of Completion. The RAP will be modified to reflect this; specific changes are referenced as part of the responses to subsequent comments.

2) Throughout the RAP, references to land use controls are confusing and do not represent the Department's perspective. The paragraphs below clarify the Department's concept of land use controls, the applicability of these controls to the MRC remedial efforts, the method whereby the controls are administered, certain aspects of the administrative relationship between property lessor and lessee, and the role of OSHA requirements pertaining to on-site field work.

The Department recommends that the April 29, 2011 draft RAP should be revised so as to place less emphasis on Lockheed's involvement with and determination of land use controls, and to create a

perspective that is consistent with the Department's requirements. The Department welcomes in-house meetings and/or telephone conference calls with Lockheed and consultants to ensure that the concepts of land use controls are adequately represented.

For reference purposes, the following few paragraphs are excerpted from a June 8, 2011 email that the Department forwarded to Lockheed's consultant, and was intended to clarify the distinctions between institutional and engineering controls.

As referenced in the Department's Certificate of Completion ("COC") document, "Land use controls" means any restriction or control that serves to protect human health and the environment by limiting use of or exposure to any portion of the property, including water resources. These controls may include:

- **Engineering Controls: remedial actions directed toward containing or controlling the migration of contaminants through the environment. These include, but are not limited to, storm water conveyance systems, slurry walls, liner systems, hard caps, landscape caps, leachate collection systems, pump and treat systems, groundwater recovery systems, soil vapor mitigation systems, indoor (sub-slab) soil vapor treatment systems, groundwater treatment systems.**

- **Institutional Controls: legal or administrative tools designed to prevent or reduce human exposure to remaining contamination and to prevent activities that may result in increased exposure to or spread of such contamination. These include, but are not limited to, prohibition on the use of groundwater beneath the property for any reason, restriction on future land use category (i. e. residential, nonresidential), HOA management of land maintenance, no-dig without prior Department notice restriction, soil/fill excavation and disposal restrictions, cap maintenance requirements, landscape maintenance requirements."**

Response: The RAP will be modified to recognize the Department's role in establishing and administering the LUCs at the site. This affects many Sections of the RAP, including 4.2, 5.2, 5.3, 6.1.2, 6.3, 6.3.1, 6.3.3.1, 6.3.3.2, 6.3.3.3, 7.1, 7.2, and 7.3. The most significant changes are in Sections 4.2 (which first discusses the LUCs in detail with regard to the elimination of risk pathways) and 8.3 (which describes the role of LUCs in the recommended remedy).

In Section 4.2, the description of the use of LUCs in eliminating the first pathway discussed (direct exposure) will be modified to read as follows:

- "*No exposure to site groundwater exists at present. Future groundwater use for drinking, showering, or irrigation is considered highly unlikely due to low recovery rates, low pH in many portions of the site, and high concentrations of naturally occurring metals, especially iron. However, it is likely that the MDE will establish LUCs that prevent use of groundwater as part of the Certificates of Completion for the MRC which are anticipated to be issued following submittal and execution of soil RAPs for each tax block. Based on the establishment of appropriate LUCs to eliminate this potential pathway, and to remain consistent with current Baltimore County practice, it is expected that current and future property owners will be prohibited from recovering and/or using groundwater.*"

Note: per Specific Comment 1 below, the more general term "land use controls (LUCs)" is substituted for the more specific terms "institutional controls" and "engineering controls" in all responses.

Section 8.3 will be modified to read as follows:

"As discussed throughout this RAP, the MDE is likely to require LUCs in addition to the active remedy described above. These LUCs, to be determined by the MDE and established as part of the Block-specific Certificates of Completion, may include:

- *"Prohibition of the use of groundwater beneath the property for any purpose.*

- *"Requirements for the implementation of sub-slab soil vapor mitigation technology beneath all buildings where and to the extent the potential for soil vapor intrusion to indoor air exists. For new-footprint buildings, the vapor mitigation system may, for example, consist of slotted PVC tubing arranged in such a manner as to passively exhaust soil vapors from beneath the building slab to the atmosphere. Any passive vent system would be required to be readily convertible to an active remedial system, if necessary. Other acceptable remedial alternatives exist. Regardless of remedial choice, indoor air would need to be tested prior to occupancy and concentrations of any detected contaminant must not exceed the MDE's applicable indoor air standards."*

Note: Other referenced sections of the RAP will also be modified; the changes to the two sections above are meant to be representative of the overall changes to the document.

Also note that LUCs will remain a component of the alternatives and will be included in the alternative titles. This is being done because the LUCs are required for the alternatives to be protective. The text throughout the alternative descriptions/comparisons and the recommended alternative description will be modified to clearly state that the LUCs are established by the MDE.

3) Lockheed has requested a residential future use for Blocks A, B, D, E, F, G, and H. Since certain land use restrictions will apply, the referenced Blocks will be designated as land use "lB". According to Lockheed, Block I may be retained for non-residential future use ("2B" land use designation). The VCP has not yet received an application for Block I.

The Department will determine which land use controls are appropriate for the property. Land use controls will be itemized on the COC documents, and the following are the controls most relevant to implementation of the groundwater RAP.

- **The Department will prohibit the use of groundwater beneath the property for any purpose.**

- **The Department will require the implementation of sub-slab soil vapor mitigation technology beneath all buildings where the potential for soil vapor intrusion to indoor air exists. For new-footprint buildings, the vapor mitigation system may, for example, consist of slotted pvc tubing arranged in such a manner as to passively exhaust soil vapors from beneath the building slab to the atmosphere. If Lockheed elects to utilize such an alternative, the vent system must be readily convertible to an active remedial system, if necessary. Other acceptable remedial alternatives exist. Regardless of remedial choice, indoor air must be tested prior to occupancy and concentrations of any detected contaminant must not exceed the Department's applicable indoor air standards.**

Since LUCs are a part of the COC, they are permanent and may not be modified or negotiated, such as between property owner and lessee or between property owner and developer. Note that land use controls will apply to the entire area of property described in each application. Since Lockheed has elected to submit a separate application for each property Block, the land use controls will apply to the entire Block, and not to smaller portions of the Block. Since the COC is filed in the local land records and passes to subsequent property owners (i.e. "travels with the land"), all land use controls exist in perpetuity unless eliminated by mutual consent of the parties, as may be enabled by an environmental

covenant. If any property owner elects to lease portions of the property to a third party, the Department will hold the property owner responsible for any violation of the COC land use requirements, or other environmental regulatory infractions. Lease agreements between the property owner and any lessee must be consistent with requirements set forth in the COC document, and the lease will exist solely between the property owner and the lessee.

Response: See response to General Comment 2 above. Additionally, Lockheed Martin would request a change to the following phrase from the comment above: ***"the land use controls will apply to the entire Block, and not to smaller portions of the Block"***.

Lockheed Martin requests that the phrase be changed to: *"the land use controls will apply to the entire Block, and not to smaller portions of the Block, except to the extent that only smaller portions of the Block are appropriately the subject of LUCs, as agreed upon by the Department and Lockheed Martin."*

Note: Lockheed Martin had submitted a VCP application for Block I. We have attached (**Appendix "A"**) the Department's letter accepting Block I into the VCP (dated 11/20/07).

4) On-site construction activity will be guided by the site-specific Health and Safety Plan (HASP). The HASP should include a section regarding the mitigation of exposure to on-site environmental-based contamination (e.g. TCE, benzene, etc. in groundwater and soil vapors) and describe the appropriate precautions to the construction worker so as to minimize or eliminate the exposure pathway(s). Since environmental-based exposure will be addressed in the HASP, COC-based institutional/engineering controls during construction activity are not appropriate (refer to Specific Comment #3, below).

Response: References to appropriate precautions for on-site construction work will not be listed as LUCs (this reference has been removed in the revised Section 8.3, above).

The relevant portion of Section 4.2 will be modified to read as follows:

"Exposure of construction workers to site groundwater (current and future use)—*The estimated risks posed to an unprotected construction worker encountering groundwater exceed the regulatorily acceptable risk ranges, but only at a few locations within the highest TCE concentration areas at the site. The primary concern is exposure to TCE, and the pathway of greatest risk contribution is inhalation. Using an estimated exposure of four hours per day over a 30 day period, a groundwater TCE concentration of approximately 2,600 g/L would be expected to cause potentially unacceptable risk without engineering controls; to the extent that actual construction activity and associated procedures and personal protective equipment would be designed to reduce or eliminate this exposure to workers, the risk is overestimated.*

Other uncertainties associated with the construction worker risk estimates also bias the model toward overestimating actual risks. Thus, although in some isolated areas groundwater may pose a health hazard to a construction worker, these risks can be mitigated via appropriate engineering controls and personal protective equipment as detailed in a site-specific health and safety plan developed prior to conducting intrusive work at the MRC."

SPECIFIC COMMENTS

1) Omit reference to the terms "institutional control(s)" and "engineering control(s)" and replace them with the more generic term "land use control(s)" throughout the document.

Response: As stated above, the more general term "land use controls (LUCs)" will be substituted for the more specific terms "institutional controls" and "engineering controls"

2) Section 4.2, "Potential Exposure Pathways", pg. 4-4: The referenced "Vapor Management Plan" should be submitted to the Department as a RAP Amendment and should be prepared for both non-residential and residential properties.

Response: The referenced Vapor-Intrusion Management Plan was submitted to the Department on December 22, 2010. This document addresses only the existing industrial buildings at the MRC and will be updated periodically based on data obtained and/or changes in regulations; updated plans will be submitted to the MDE upon completion. The first update of the plan is scheduled for 2012.

Although Lockheed Martin did apply for residential use of Tax Blocks A, B, D, E, F, G, and H, there are no current plans to develop the properties as residential. The 2012 updated Vapor-Intrusion Management Plan will include acknowledgement of this potential future use. If residential plans for the Blocks are developed in the future, the Vapor-Intrusion Management Plan will be updated with specific information regarding the vapor sampling and mitigation associated with residential properties.

3) Section 4.2, pg. 4-6: The paragraphs that discuss exposure of construction workers to site groundwater should be revised per the VCP general comments, above.

Response: See the response to General Comment 4, above.

4) Section 5.2, "Cleanup Goals and Response Action Objectives", pg. 5-2: Note that the Department will consider sub-slab depressurization systems as permanent equipment, and as such may be converted from active systems to passive systems, or vice versa. Institutional controls prohibiting the use of groundwater beneath the property for any purpose will exist permanently, and will be documented in the COC.

Response: Noted. The Section will be revised to note that it is expected that the MDE's Certificate of Completion will allow for sub-slab depressurization systems to be cycled between active and passive operation based on the site data, and that groundwater use restrictions are expected to continue permanently.

5) Section 8.1, "Introduction", pg. 8-1: A revised RAP or RAP Amendment may be necessary if the final response action design significantly differs from the April 29, 2011 draft RAP that was submitted to the Department.

Response: Noted.

6) Section 8.2.3, "Injection Wells and Distribution Piping", pg. 8-5: Discuss the appropriate sampling and soil disposal contingency measures if trenching, boring, etc. encounters contaminated soil.

Response: Text will be added to this section to discuss the soil management measures in general. Specific requirements will be included in the Work Plan developed for implementation of the remedy.

7) Section 8.2.5, "Groundwater Monitoring and Monitored Natural Attenuation", pg. 8-11 : Note that the Department intends to issue a COC to the property owner upon successful completion of the soil remediation within each property Block. Lockheed may then proceed with voluntary long-term implementation and monitoring according to internal corporate due-diligence goals.

Response: The text in this section will be modified to reflect the fact that the Certificate of Completion will be issued based on the implementation of the soil program and not on the basis of progress achieved in the groundwater program. This change will also affect other sections of the RAP, including the Executive Summary, 1.2, 5.2, 5.3, 8.2.6, 8.3 (as noted above), 8.4, and 10.

8) Section 8.3, "Institutional Controls", pg. 8-16: This section is confusing and should be eliminated, or rewritten in the context of suggestions presented in the General Comments and Specific Comments sections.

Response: Refer to the response in General Comment 2.

9) Section 8.4, "Reporting Requirements", pg. 8-17: The Department suggests semi-annual reporting during the active stages of remediation and annual reporting during the monitoring stages. Monthly reporting is appropriate during the groundwater equipment installation, pilot testing, and system start-up stages.

Response: The Department's suggestion will be incorporated into Section 8.4.

----------End of Comment-Response----------

ADDITIONAL CLARIFICATION

As part of the implementation of the groundwater remedy presented in the RAP, Lockheed Martin now intends to also remediate the soil underlying the infrastructure associated with the groundwater injection system in Tax Blocks E and G. The intent will be to remediate soils to a specified lateral and vertical boundary as part of the site preparation for construction of the groundwater remediation infrastructure including injection wells, conveyance piping, and the equipment building. Lockheed Martin will include documentation depicting the area of interest and the proposed remedial interim action approach as an appendix to the next submittal of the Groundwater RAP.

APPENDIX "A"

A copy of MDE's letter accepting Parcel 964, Tax Block I into the VCP (dated 11/20/07).

MARYLAND DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard • Baltimore MD 21230
MDE 410-537-3000 • 1-800-633-6101

Martin O'Malley
Governor

Anthony G. Brown
Lieutenant Governor

Shari T. Wilson
Secretary

Robert M. Summers, Ph.D.
Deputy Secretary

November 20, 2007

Kenneth H. Measheey, Vice President, Energy, Environmental, Safety and Health
Lockheed Martin Corporation
6801 Rockledge Boulevard
Bethesda, Maryland 20817

Re: Voluntary Cleanup Program Application
Chesapeake Park Plaza – Parcel 964, Block I
Baltimore, Maryland 21220

Dear Mr. Measheey:

The Voluntary Cleanup Program ("VCP") of the Maryland Department of the Environment ("Department") has completed a review and evaluation of the application package submitted by the Lockheed Martin Corporation for the Chesapeake Park Plaza – Parcel 964, Block I property, located at 2323 Eastern Boulevard in Middle River, Baltimore County, Maryland. The application and property have been accepted for participation in the VCP and the Department confirms the responsible person status of the Lockheed Martin Corporation for this property pursuant to Title 7, Subtitle 5 of the Environment Article, Annotated Code of Maryland.

The Department has also determined that a proposed response action plan ("RAP") should be developed, approved by the Department and implemented to address potential risks identified in the human health risk assessment and Final Indoor Air Quality Investigation submitted as part of the VCP application package. Please contact Richelle Hanson or Gary Schold, the project managers, to discuss development of the proposed RAP and the expected date for submitting the proposed RAP to the Department for review and approval.

A summary of the requirements for the proposed RAP are enclosed and can also be found in Section 7-508 of the Environment Article. Upon submission of the proposed RAP to the Department for review and approval, you must initiate an opportunity for public participation by posting a sign on the property and publishing a notice in a daily or weekly newspaper of general circulation in the geographic area where the participating property is located. Both notices for the proposed RAP must include the date and location of the public informational meeting and must be approved by the Department prior to publication and posting. A summary of the public participation requirements, as well as a template for the public notice in the newspaper and the sign on the property, have also been enclosed.

Upon satisfactory implementation and completion of the provisions in the approved RAP, the Department will issue a Certificate of Completion that must be recorded in the land records of Baltimore County within 30 days following receipt.

In accordance with the provisions of Section 7-506(g)(1) of the Environment Article, you are requested to inform the Department in writing, within 30 days of receipt of this letter, whether the Lockheed Martin Corporation intends to proceed in the VCP. If the Department does not receive the notice of your intent to proceed in the VCP within the 30-day period, the application for participation in the Voluntary Cleanup Program shall be deemed withdrawn pursuant to Section 7-506(g)(2) of the Environment Article.

If you have any questions regarding the development of the proposed RAP or other aspects of the program, please contact Ms. Hanson, Mr. Schold or me at 410-537-3493.

Sincerely,

Mark A. Mank, Section Head
Voluntary Cleanup/Brownfields Program

MAM: rah
Enclosures
cc: Mr. Michael Martin, Tetra Tech
Ms. Tina Armstrong, Lockheed Martin Corporation
Mr. Horacio Tablada
Mr. James R. Carroll
Ms. Richelle A. Hanson
Mr. Gary Schold

Lockheed Martin Corporation
6801 Rockledge Drive Bethesda, MD 20817
Telephone 301-214-9958 Fax 301-214-9502

LOCKHEED MARTIN

Transmitted by Overnight Mail

Mr. James W. Metz

December 13, 2007

Chief, Voluntary Cleanup Division
Environmental Restoration and Redevelopment Program
Maryland Department of the Environment
1800 Washington Blvd. Ste. 625
Baltimore, MD 21230

Re: Middle River Complex VCP Application Notice of Intent to Proceed
Parcel 964, Block I

Dear Mr. Metz:

In reference to the Maryland Department of the Environment's (MDE) acceptance of the Chesapeake Park Plaza, Parcel 964, Block I property into the Voluntary Cleanup Program (VCP), this letter serves as Lockheed Martin Corporation's Notice of Intent to Proceed with the program in accordance with the provisions of Section 7-506(g)(1) of the Environment Article, Annotated Code of Maryland. Lockheed Martin Corporation is developing a Response Action Plan that will meet the requirements described in Section 7-508 of the Environment Article, including the opportunity for public participation.

Please let me know if you have any questions about this Notice of Intent at (301) 214-9958.

Sincerely,

Thomas D. Blackman
Project Lead, Environmental Remediation

Attachment: MDE Letter to Lockheed Martin dated 11-20-07, Acceptance of Block I Application
BET 101
cc: Via Email

Brad Owens, Lockheed Martin	Mr. Horacio Tablada, MDE
Christine Kline, Lockheed Martin	Mr. James R. Carroll, MDE
Mary Morningstar, Lockheed Martin	Ms. Richelle Hanson, MDE
Mike Martin, Tetra Tech	Mr. Gary Schold, MDE

APPENDIX B—DATABASE OF MRC GROUNDWATER DATA

(CD ATTACHED)

APPENDIX C—METALS LEACHABILITY IN AQUIFER MATERIALS REPORT

Metals Leachability in Aquifer Materials
Lockheed Martin Corporation
Middle River Complex
Baltimore, Maryland

Prepared in Collaboration with Tetra Tech NUS, Inc.

September 15, 2009

Report

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Section 1
Introduction

This report describes the work conducted as described in the *Metals Leachability in Groundwater and Aquifer Material* Statement of Work/Technical and Functional requirements for the Lockheed Martin Corporation Middle River Complex (MRC) in Baltimore, Maryland.

1.1 Background

Site investigation efforts conducted at the MRC have identified impacts to groundwater associated with historic plant activities. These impacts have mainly resulted from organic compounds such as TCE. However, groundwater sampling programs have also detected elevated levels of beryllium, nickel, and cobalt. The objective of this work is to better understand the source and leachability of these metals in the subsurface in sufficient detail to update the site conceptual model for the site.

The following Section 1.2 describes the geochemistry of beryllium, cobalt, and nickel.

1.2 Beryllium, Cobalt, and Nickel Geochemistry

1.2.1 Beryllium

Beryllium Aqueous Species

Beryllium (Be) occurs in only one oxidation state in natural waters, +2. Be exists predominantly as positively charged ions (cations) below a pH of about 8.2, a neutral ion between pH 8.2 and 9.6, and as a negatively charged species (anions) above pH 9.6, as shown in Figure 1-1.

Beryllium also forms relatively strong aqueous complexes with fluoride (BeF^+), particularly at low pH (EPRI 1984). Therefore, significant concentrations of dissolved fluoride can increase the mobility of beryllium in the water.

Beryllium Pure Phase Minerals

The only important pure phase beryllium mineral that occurs in natural waters is beryllium hydroxide ($Be(OH)_2$). The beta form (β-$Be(OH)_2$) has fast precipitation kinetics and is believed to be an important control on beryllium concentrations in natural waters (EPRI 1984). Aldahan et al. (1999) found that in their experiments, aqueous beryllium was controlled by adsorption onto minerals below a pH of about 6 su and by precipitation of beryllium hydroxide at pH values of about 6 or greater. Figure 1-2 shows that at a relatively low total beryllium concentration (50 µg/L), beryllium hydroxide is predicted to form from solution above a pH of about 6.2 su.

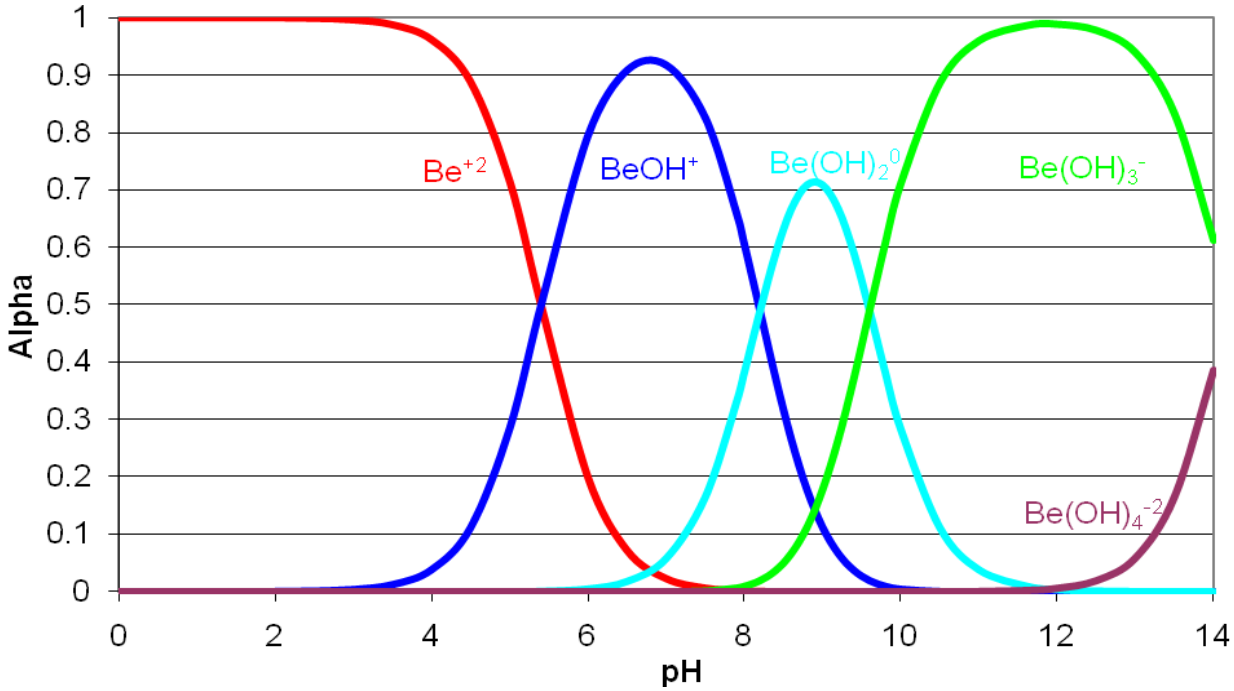

Figure 1-1. Beryllium Speciation as a Function of pH (alpha is the fraction of the total dissolved beryllium consisting of the given species).

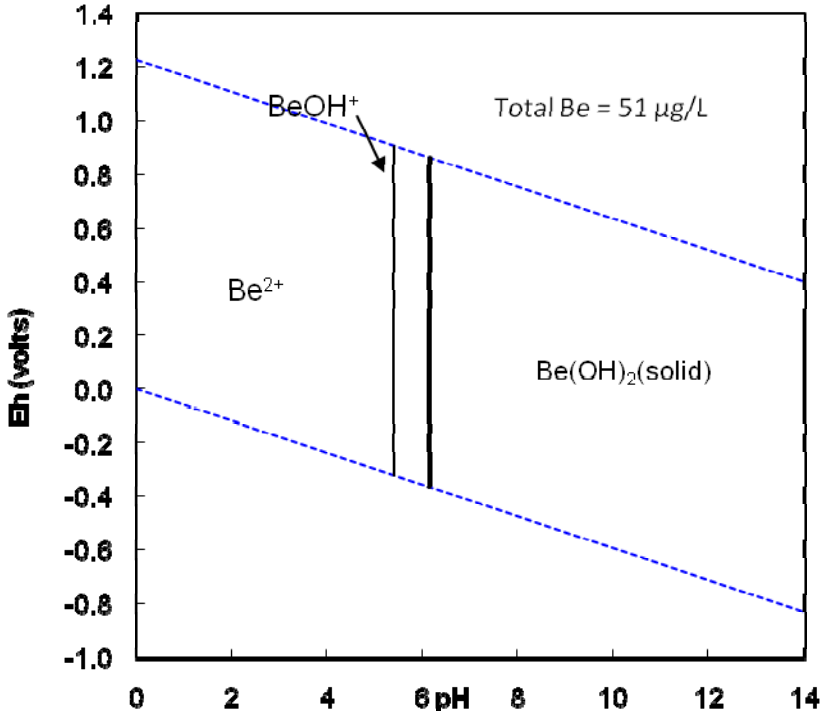

Figure 1-2. Eh-pH Diagram for System Be-O-H at 25°C and 1 atm.

At the higher pH values typical of natural waters (6-8 su), aqueous beryllium concentrations would be low (0.002 – 50 µg/L) due to the precipitation of beryllium hydroxide. A summary of the solubility of beryllium hydroxide at various pH values is shown in Table 1-1.

Table 1-1 Summary of $Be(OH)_2$ Solubility vs. pH

pH	Solubility[1] (mg/L as Be)
4	238
5	2.38
6	0.0238
7	0.00024
8	0.000002

[1] Taking into account hydroxide complexes and activity effects assuming an ionic strength of 4×10^{-3} M. Thermodynamic data from Smith and Martel (1976).

Beryllium Solid-Solution Phases

Beryllium has not been shown to form solid-solution phases in natural waters, at least according to the sparse literature available for the element. However, Be is probably coprecipitated with iron oxyhydroxides as are most divalent ions such as the transition metals.

Beryllium Adsorption

Be adsorbs to solid surfaces due partly to interactions between the negatively charged ions and a positively charged surface, or vice versa. Therefore, $Be(OH)_3^-$ and $Be(OH)_4^{-2}$ adsorption tends to be favored for solid materials that are positively charged, while Be^{+2} and $BeOH^+$ adsorption onto negatively charged surfaces is favored. The surface charge of the material depends on the type of solid, the pH of the water, and the concentration of other anions in solution.

At low pH values, the water and mineral surfaces have higher concentrations of hydronium ion (H_3O^+) which imparts a positive charge to the surface. As the pH increases, the hydronium ion concentration decreases relative to the hydroxide ion (OH^-) concentration in both the water and the solid materials within the water. At a specific threshold pH value called the pH of the zero-point-of-charge (ZPC), the surface charge transitions from positive to neutral to negative. The pH of the ZPC is different for different materials, as shown in Table 1-2.

Table 1-2 pH of the Zero-Point-of-Charge (pH_{ZPC}) for Various Minerals[1]

Material	Formula	pH_{ZPC}
Magnetite	Fe_3O_4	6.5
Goethite	FeOOH	7.8
Hematite	Fe_2O_3	6.7
Amorphous Ferric hydroxide	$Fe(OH)_3$	8.5
Aluminum Hydroxide	γ-AlOOH	8.2
Aluminum Hydroxide	Ά-$Al(OH)_3$	5.0
Amorphous Silica	SiO_2	2.0
Manganese Dioxide	δ-MnO_2	2.8
Albite	$NaAlSi_3O_8$	2.0
Montmorillonite Clay	$Na_{0.2}Ca_{0.1}Al_2Si_4O_{10}(OH)_2 \cdot 10\ H_2O$	2.5
Kaolinite Clay	$Al_2Si_2O_5(OH)_4$	4.6

[1] Data from Stumm and Morgan (1981)

The materials with a higher pH_{ZPC} are able to maintain a positive charge at a higher pH than for materials with a lower pH_{ZPC}. Of the materials listed in Table 1-2, amorphous ferric hydroxide is the best anion adsorbent at higher pH values (below 8.5), while manganese dioxide and clays are the best cation adsorbents over most of the pH range of natural waters. By comparing the pH_{ZPC} values in Table 1-2 with the ion distributions in Figure 1-1, the optimum pH windows for Be adsorption can be determined. Over the pH range of most natural waters, beryllium exists predominantly as a cation and would tend to adsorb to negatively charged surfaces, such as manganese dioxides, clays, and silica.

The degree to which a dissolved constituent adsorbs to a surface can be expressed using a number of models, the most simple of which is the distribution coefficient model, which is given by:

$$K_d = C_{Solid}/C_{soln} \qquad (1\text{-}1)$$

Where:

K_d = the distribution coefficient (l/kg)

C_{solid} = the concentration of the adsorbed constituent in the solid at equilibrium (mg/kg)

C_{soln} = the concentration of the adsorbed constituent in solution at equilibrium (mg/L)

Based on equation 1-1, high K_d values correspond to a high degree of adsorption (low mobility) relative to low K_d values (relatively high mobility). A summary of K_d values for adsorption of beryllium onto various materials is presented in Table 1-3.

Table 1-3 K_d Values for Adsorption of Be Onto Biotite and Albite Under Different Conditions (After Aldahan et al. 1999)

Mineral	Grain size (µm)	Kd (L/kg)			
		pH 2	pH 4	pH 6*	pH 7*
Biotite	20-63	189	175	380	1700
	63-124	93	155	210	2400
Albite	20-63	6	39	20	400
	63-124	25	26	50	300

*Corrected for precipitation of $Be(OH)_2$ (s)

As shown in Table 1-3, Aldahan et al. (1999) found that beryllium adsorption onto biotite and albite increased with increasing pH, which is consistent with the adsorption of a cation onto an increasingly negative surface charge as the pH increases. The results also indicated that the K_d was greater for adsorption onto finer particle sizes.

Coulombic adsorption of Be cations onto the positively charged surface of amorphous ferric hydroxide would not occur. However, like the adsorption of many transition metal ions (copper, zinc, cobalt, nickel, etc.) specific adsorption (bonding of the ions to atoms on the surface of the mineral) is likely.

Column studies cited in EPRI (1984) indicated that beryllium was less mobile within a solid waste than zinc, cadmium, nickel, or mercury, and that only copper and lead were less mobile. Other studies cited in EPRI (1984) indicated that calcareous soils high in layer lattice silicates (i.e., clays and micas) were the most effective for Be adsorption, but the adsorption mechanism (coulombic vs. specific) had not been investigated.

1.2.2 Cobalt

Cobalt (Co) occurs in only one oxidation state in natural waters, +2. Cobalt can have an oxidation state of 0 or +3 in solid phases, but in aqueous solution only the +2 oxidation state is stable. Co exists predominantly as a positively charged ion (cation) up to a pH of 9.8, a neutral species between pH 9.8 and 12.7, and a negatively charged species above pH 12.7, as shown in Figure 1-3.

Cobalt Pure Phase Minerals

Most pure phase cobalt minerals are very soluble and are only present at very high aqueous concentrations of cobalt. Cobalt hydroxide forms only at high pH values (>9 su), as shown in Figure 1-4.

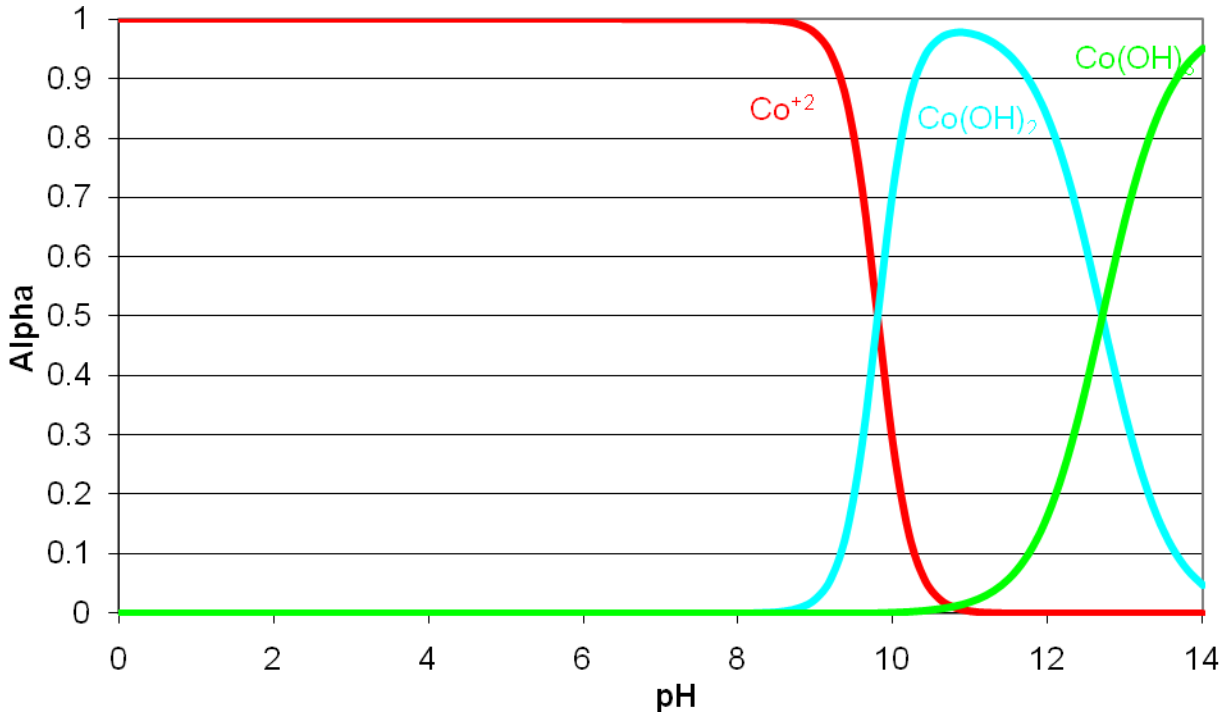

Figure 1-3. Cobalt Speciation as a Function of pH (alpha is the fraction of the total dissolved cobalt consisting of the given species).

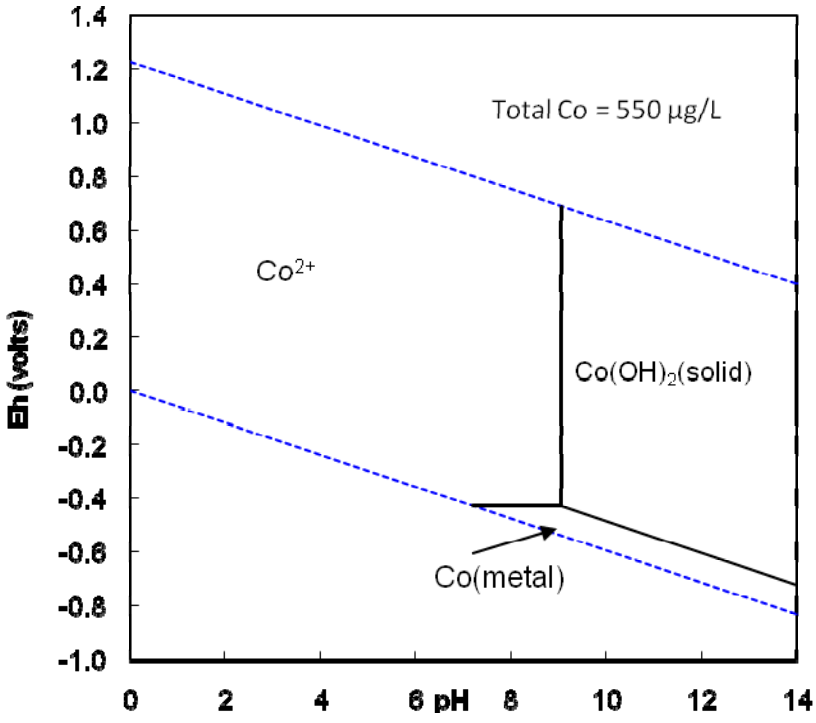

Figure 1-4. Eh-pH Diagram for System Co-O-H at 25°C and 1 atm. Thermodynamic data from Smith and Martel (1976).

Therefore, cobalt hydroxide is probably not an important control on aqueous cobalt concentrations, because the vast majority of natural waters have pH values below pH 9 su.

When moderate alkalinity is present in the water, a cobalt carbonate phase called sphaerocobaltite can occur. Figure 1-5 is an Eh-pH diagram showing the cobalt carbonate stability field.

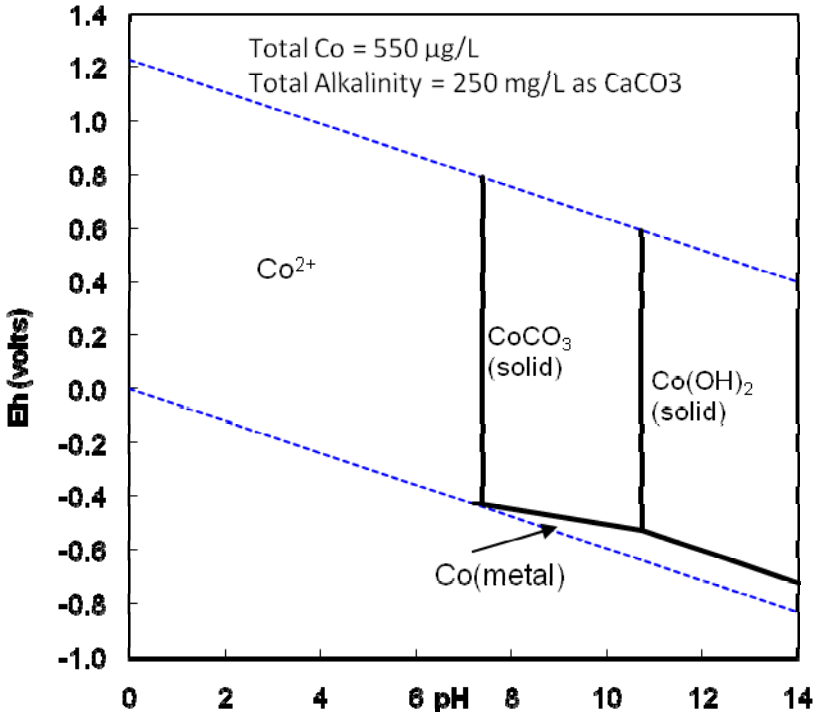

Figure 1-5. Eh-pH Diagram for System Co-C-O-H at 25°C and 1 atm. Thermodynamic data from Smith and Martel (1976).

Cobalt carbonate is predicted to form at a pH of 7.4 su under moderate alkalinity (250 mg/L) and a cobalt concentration of 550 µg/L.

Thompson et al. (1999) conducted an experiment in which suspensions of kaolinite clay were equilibrated with a pH 4.2 solution containing millimolar concentrations of cobalt (1 millimole of Co = 58 mg/L). After 24 hours, the solutions were adjusted to pH 7.8 using sodium hydroxide and allowed to equilibrate for several months. During the low pH interval, the kaolinite partially dissolved, releasing silicon and aluminum into solution. Following the pH adjustment to pH 7.8 su, a cobalt aluminum hydroxysilicate called hydrotalcite formed ($Co_6Al_2(OH)_{16}(H_3SiO_4)_2$). Apparently, high cobalt concentrations and a specific sequence of pH adjustment (low pH followed by high pH in the presence of kaolinite) are required to form this phase.

Cobalt Solid-Solution Phases

Cobalt is known to substitute into at least three phases:

- Iron oxyhydroxide
- Manganese oxides
- Calcite

Iron Oxyhydroxide

Cobalt has often been found associated with iron oxyhydroxides (Rae and Parker 1993, Whiting and Olsen 1997a and 1997b, etc.). However, it is not always clear if cobalt is adsorbed onto the surfaces of the iron oxyhydroxide grains or is coprecipitated.

A reasonable coprecipitation reaction in which Co^{+2} substitutes for Fe^{+3} would be as follows:

$$2x\ Fe^{+3} + 3\text{-}3x\ Co^{+2} + 6\ OH^- \rightarrow Fe_{2x}Co_{3\text{-}3x}(OH)_6\ (s) \qquad (1\text{-}2)$$

Where "x" is the fraction of iron in the phase. As a result of reaction (1-2), cobalt can coprecipitate from solution due to the oxidation of ferrous iron (Fe^{+2}) to ferric iron (Fe^{+3}) and/or an increase in the pH. In reality, equation (1-2) is likely to be much more complex, with other cations such as aluminum (Al^{+3}), and divalent metals (i.e., Pb^{+2}, Zn^{+2}, Cu^{+2}, Ni^{+2}, etc.) substituting for iron, and anions such as arsenate (AsO_4^{-3}), chloride (Cl^-), and phosphate (PO_4^{-3}) substituting for hydroxide. In mine impacted waters where the pH is low and sulfate concentrations are high (>1,500 mg/L), significant sulfate substitution can occur, resulting in a schwertmannite or jarosite type hydroxysulfate coprecipitate. The phases are typically amorphous (no crystal structure) when first formed, but tend to crystallize (and become less soluble) over time.

Manganese Oxides

Whiting and Olsen (1997a and 1997b) performed electron microprobe analyses on stream sediments impacted by cobalt mining and found that the manganese oxide precipitates contained 4.4 to 9.0 percent cobalt. Brooks et al. (1998) suggest that Co^{+2} is oxidized to Co^{+3} by Mn^{+3} and Mn^{+4} in the manganese oxide resulting in incorporation of the cobalt into the crystal structure of the mineral.

Calcite

Katsikopoulos et al. (2008) found that cobalt can substitute into calcite at concentrations up to 33 mole percent. Cobalt substitutes for calcium within the calcite structure despite a size difference of about 25 percent between the two ions. The cobalt substituted phase, $(Co, Ca)CO_3$, is called cobaltoan calcite. The degree of substitution of cobalt into calcite depends mainly on the Co/Ca ratio in solution, with the higher ratios resulting in greater substitution of Co into the solid.

Cobalt Adsorption

Co adsorbs to solid surfaces due partly to interactions between the positively charged ion (Co^{+2}) and a negatively charged surface. Therefore, Co adsorption tends to be favored for solid materials that are negatively charged. The surface charge of the material depends on the type of solid, the pH of the water, and the concentration of other ions in solution.

At low pH values, the water and mineral surfaces have higher concentrations of hydronium ion (H_3O^+), which imparts a positive charge to the surface. As the pH increases, the hydronium ion concentration decreases relative to the hydroxide ion (OH^-) concentration in both the water and the solid materials within the water. At a specific threshold pH value called the pH of the zero-point-of-charge (ZPC), the surface charge transitions from positive to neutral to negative. Once the surface charge becomes negative, adsorption of the positively charged cobalt ions become more prevalent. The pH of the ZPC is different for different materials, as shown in Table 1-2.

The materials with a lower pH_{ZPC} are able to maintain a negative charge at lower pH values than for materials with a higher pH_{ZPC}. Therefore, minerals such as clays, manganese dioxide, and amorphous silica would be predicted to be effective adsorbents. Cobalt adsorption onto manganese dioxide (Hasany and Qureshi 1981, Brooks et al. 1998), iron oxyhydroxide (Ardizzone and Formaro 1983, Brooks and Herman 1998, Brooks et al. 1998, Angove 1999), clays (Thompson et al. 1999, Kara et al. 2003) and silica (Brooks et al. 1998) have been observed in the laboratory. Brooks et al. (1998) found that cobalt is adsorbed to a greater extent onto manganese oxide (hausmanite) than onto iron oxyhydroxide or silica and is also more difficult to desorb.

Based on equation (1-1), high K_d values correspond to a high degree of adsorption (low mobility) relative to low K_d values (relatively high mobility). A summary of K_d values for adsorption of cobalt onto various materials is presented in Table 1-4.

Table 1-4 Summary of Distribution Coefficient (K_d) Values for Cobalt.

Adsorbent	Kd (L/kg)	Notes	Source
MnO_2	25-300	K_d values measured at pH 3. Specific Adsorption at pH>3	Hasany and Qureshi, 1981
Sand Soil	0.07-9,000	Based on 33 observations	Thibault et al., 1990
Silt Soil	100-9,700	Based on 23 observations	
Clay Soil	20-14,000	Based on 15 observations	

The large range in K_d values is due to the differences in the adsorbents (mineral composition, grain size, concentration of adsorbent, etc.) and the leaching solutions (pH, oxidation-reduction potential, other ions in solution, etc.). In general, adsorption of cobalt is favored at pH values greater than 3, on finer grained soils, and in the

absence of ligands that can complex cobalt, such as citrate, EDTA, oxalate, ascorbate, etc. (Brooks and Herman 1998, Brooks et al. 1998, Kara et al. 2003).

1.2.3 Nickel

Nickel (Ni) occurs in only one oxidation state in natural waters, +2. Ni exists predominantly as a positively charged ion (cation) up to a pH of 9.5, a neutral species between pH 9.5 and 11.0, and a negatively charged species above pH 11.0, as shown in Figure 1-6.

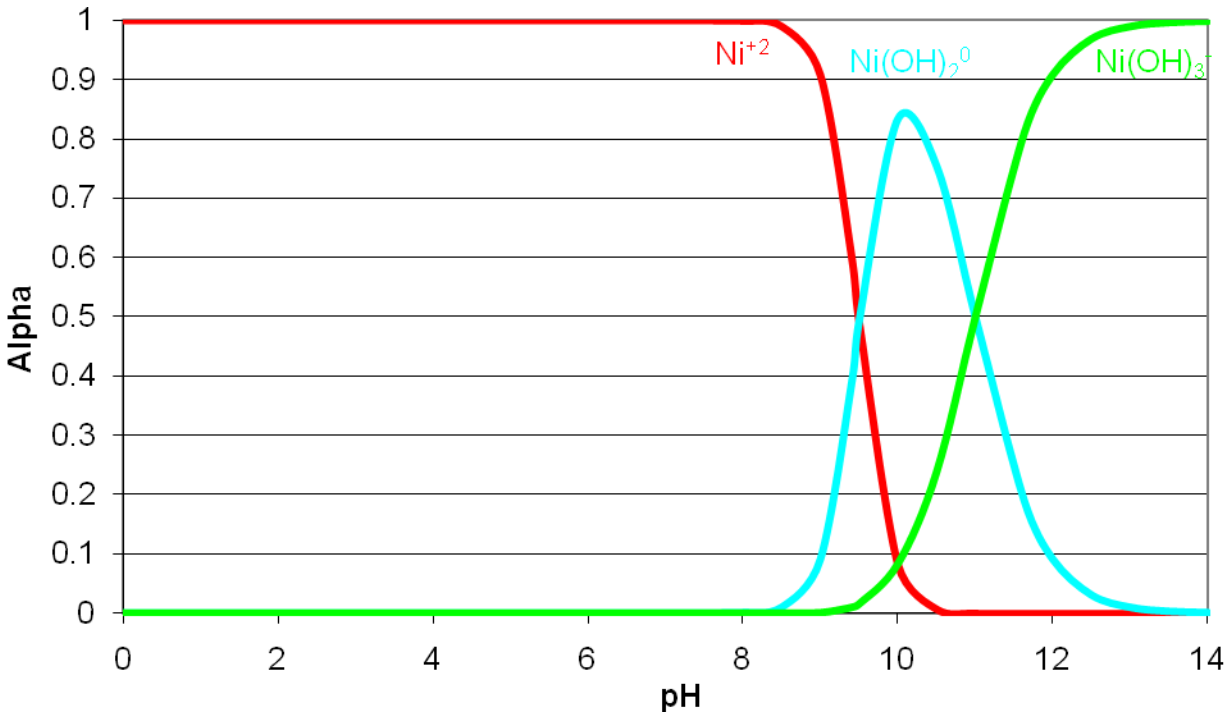

Figure 1-6. Nickel Speciation as a Function of pH (alpha is the fraction of the total dissolved nickel consisting of the given species).

The +3 oxidation state of Ni may be stable in the natural environment under high pH and very high Eh (highly oxidizing) conditions, but Ni^{+3} solid phases have not been identified in natural soil environments.

Nickel Pure Phase Minerals

Most pure phase nickel minerals are very soluble and are only present at very high aqueous concentrations of nickel. Nickel hydroxide forms only at high pH values (>8 su), as shown in Figure 1-7.

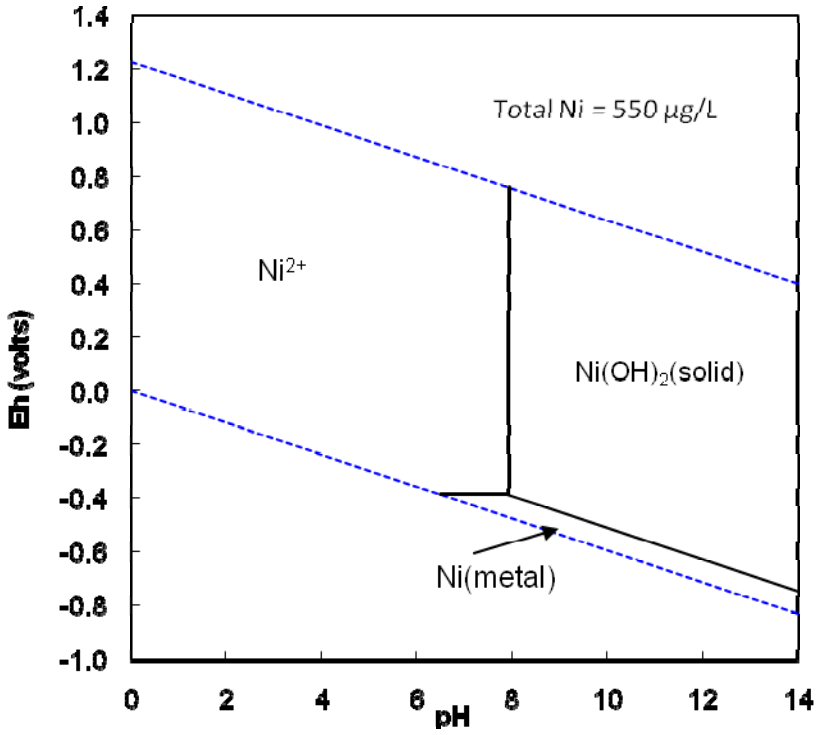

Figure 1-7. Eh-pH Diagram for System Ni-O-H at 25°C and 1 atm. Thermodynamic data from Ball et al. (1980).

Therefore, nickel hydroxide is probably not an important control on aqueous cobalt concentrations, as the vast majority of natural waters have pH values below pH 8 su.

Other Ni^{+2} solids can be postulated as controlling phases in the soil environment. The Ni^{+2} oxide NiO(solid), known as bunsenite, has a stability region with nearly identical shape as $Ni(OH)_2$(solid), but with a slightly smaller size. Thus, bunsenite and is not as stable as $Ni(OH)_2$(solid) and will not tend to form in natural soil environments.

Nickel carbonate is a possible phase based on the stability data reported by Grauer (1994) (cited in Lakshtanov and Stipp, 2007). An Eh-pH diagram for the Ni-C-O-H system is shown in Figure 1-8. Under moderate alkalinity (250 mg/L as $CaCO_3$) and at nickel concentrations of 550 µg/L, nickel carbonate is predicted to form at a pH of 6.76 su.

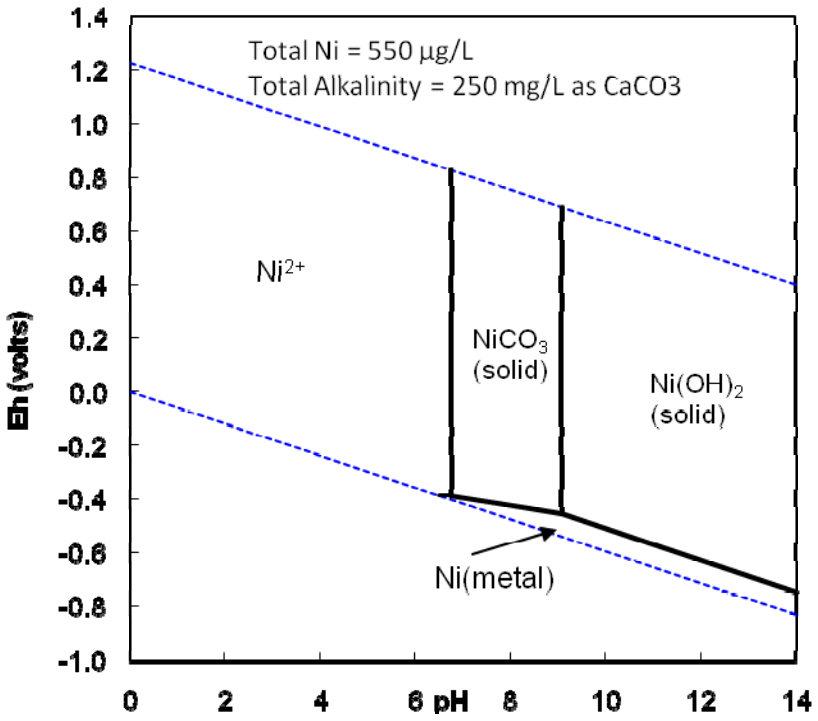

Figure 1-8. Eh-pH Diagram for System Ni-C-O-H at 25°C and 1 atm. Thermodynamic data from Grauer (1994).

Lin et al. (1998) performed x-ray diffraction analyses on the precipitate formed when a Ni-bearing solution was treated with lime. The precipitate was found to consist of $Ni(OH)_2$ (solid) and nickel hydroxycarbonate phases, but the x-ray lines for $NiCO_3$ were not present. In nature, the minerals theophrastite ($Ni(OH)_2$) and the nickel hydroxycarbonate, zaratite ($Ni_3(CO_3)(OH)_4 \cdot 4H_2O$) often occur together and are difficult to separate, suggesting that they have similar solubilities (Lin et al. 1998). As no thermodynamic data are currently available for nickel hydroxycarbonate, it is not possible to show the conditions under which the phase is stable. However, based on the fact that nickel hydroxycarbonates and hydroxides occur in nature and the experimental work of Lin et al. (1998), the hydroxycarbonate and hydroxide phases are likely a more important control on aqueous nickel concentrations than the pure nickel carbonate.

$NiFe_2O_4$(solid) is another possible Ni^{+2} controlling phase that should have a similarly shaped and even larger stability region than $Ni(OH)_2$(solid). Although $NiFe_2O_4$(solid) is a possible Ni-controlling phase, it is unlikely to be stable in the natural soil environment because it is probably restricted to high temperature systems.

Nickel Solid-Solution Phases

Nickel is known to substitute into at least two phases:

- Iron oxyhydroxide
- Calcite

Iron Oxyhydroxide

Nickel has often been found associated with iron oxyhydroxides (Theis and Richter 1980, Sadiq and Zaidi 1981, and others). However, it is not always clear if nickel is adsorbed onto the surfaces of the iron oxyhydroxide grains or is coprecipitated.

A reasonable coprecipitation reaction in which Ni^{+2} substitutes for Fe^{+3} would be as follows:

$$2x\ Fe^{+3} + 3\text{-}3x\ Ni^{+2} + 6\ OH^- \rightarrow Fe_{2x}Ni_{3\text{-}3x}(OH)_6\ (s) \qquad (1\text{-}3)$$

Where "x" is the fraction of iron in the phase. As a result of reaction (1-3), cobalt can coprecipitate from solution due to the oxidation of ferrous iron (Fe^{+2}) to ferric iron (Fe^{+3}) and/or an increase in the pH. In reality, equation (1-3) is likely to be much more complex, with other cations such as aluminum (Al^{+3}), and divalent metals (i.e., Pb^{+2}, Zn^{+2}, Cu^{+2}, Co^{+2}, etc.) substituting for iron, and anions such as arsenate (AsO_4^{-3}), chloride (Cl^-), and phosphate (PO_4^{-3}) substituting for hydroxide. In mine impacted waters where the pH is low and sulfate concentrations are high (>1,500 mg/L), significant sulfate substitution can occur, resulting in a schwertmannite or jarosite type hydroxysulfate coprecipitate. The phases are typically amorphous (no crystal structure) when first formed, but tend to crystallize (and become less soluble) over time.

Lin et al. (1998) found that nickel coprecipitates with ferric iron, with the minimum residual aqueous nickel concentrations occurring at pH 8-9 su.

Calcite

Lakshtanov and Stipp (2007) found that nickel can substitute into calcite and that within calcareous environments (i.e., carbonate aquifers), this substitution can be an important control on aqueous nickel concentrations. The degree of substitution of nickel into calcite depends mainly on the Ni/Ca ratio in solution, with the higher ratios resulting in greater substitution of Ni into the solid.

Nickel Adsorption

Ni adsorbs to solid surfaces due partly to interactions between the positively charged ion (Ni^{+2}) and a negatively charged surface. Therefore, Ni adsorption tends to be favored for solid materials that are negatively charged. The surface charge of the material depends on the type of solid, the pH of the water, and the concentration of other ions in solution.

As previously discussed, at low pH values, the water and mineral surfaces have higher concentrations of hydronium ion (H_3O^+), which imparts a positive charge to the surface. As the pH increases, the hydronium ion concentration decreases relative to the hydroxide ion (OH^-) concentration in both the water and the solid materials within the water. At a specific threshold pH value called the pH of the zero-point-of-charge (ZPC), the surface charge transitions from positive to neutral to negative. Once the surface charge becomes negative, adsorption of the positively charged nickel ions becomes more prevalent.

A summary of K_d values for nickel are presented in Table 1-5.

Table 1-5 Summary of Distribution Coefficient (K_d) Values for Nickel

Adsorbent	K_d (L/kg)	Notes	Source
Sand Soil	60-3,600	Based on 11 observations	Thibault et al. 1990
Clay Soil	305-2,467	Based on 10 observations	
Sandy Sediments	3-45	Based on 7 observations	Hassan et al. 1996

The large range in K_d values is due to the differences in the adsorbents (mineral composition, grain size, concentration of adsorbent, etc.) and the leaching solutions (pH, oxidation-reduction potential, other ions in solution, etc.).

Hassan et al. (1996) found that for sandy sediments, the K_d dependence on pH could be described by the following empirical relationship:

$$\text{Log } K_d = 0.29287(\text{pH}) - 0.24148$$

In general, adsorption of nickel is favored at pH values greater than 3, on finer grained soils, and in the absence of ligands that can complex nickel, such as EDTA and tartrate (Lin et al. 1998).

1.3 Sample Collection

Samples of the aquifer material (soils or sediments) were collected at five locations. Locations were selected to represent both background areas (MW70A/B and MW72A/B) and areas near the plant operations (MW60A/B, MW75A, and MW76A/B). The samples were collected via hollow stem auger drilling. The borings were completed as monitoring wells. Groundwater samples were collected from each well and analyzed. Boring logs, sample depths, sample ID, and sample descriptions are provided in Appendix A. Table 1-6 summaries the rationale for location selection and provide the laboratory results for the groundwater.

Table 1-6 Groundwater Data and Locations Selection Rationale

	Well	Be (µg/l)	Co (µg/l)	Ni (µg/l)	pH (su)	ORP[1] (mv)	Rationale
Background	MW70A	0.26	46.5	52	6.06	-74	Located in SW plume; little or no metals impact observed in this area in previous sampling. Outside of plant operations.
	MW70B	0.048	39.3	49.1	6.78	-162	
	MW72A	0.097	2.6	3.7	5.87	112	Located in SE plume; little or no metals impact observed in this area in previous sampling. Outside of plant operations.
	MW72B	0.61	10.4	9.3	5.14	313	
Plant Operations (Block I)	MW60A	0.74	58.8	63.4	5.48	74	Center of site; near Building C operations.
	MW60B	0.4	24.8	46.1	6.00	39	
	MW75A	0.34	67.5	130	5.50	88	Near NW corner of Building A; area of high metals impact in surrounding wells.
	MW76A	13.1	433	390	5.39	149	Center of site; near Building C operations.

[1] Uncorrected for the reference electrode

1.4 Report Organization

This Report contains the following sections:

- Section 1: Introduction
- Section 2: Methodology
- Section 3: Results
- Section 4: Data Interpretation and Conclusions

Section 2
Methodology

A total of 111 subsurface soil samples were collected from the five soil borings and shipped to the CDM Denver laboratory. The soil samples were checked in versus the chain-of-custody. The samples were transferred to disposable drying pans and allowed to air dry overnight. After air drying, the samples were well mixed and split through a 1/2-inch riffle splitter. One-half of the sample was reserved for leaching tests and a 25 gram portion was ground to less that 60 mesh and analyzed by X-ray fluorescence (XRF). An initial soil pH measurement was determined on each of the samples using a 2:1 mL per gram ratio (mL of deionized water per gram of soil). Results are provided in Section 3.

2.1 XRF Analysis

XRF analysis was conducted with a Spectrace TX-5000 EDXRF spectrometer. The TX-5000 utilizes a Si (Li) detector rated at 155 eV resolution (Mn K-alpha) and 50 KV, 1 mA Rh target X-ray tube. Transmission filters were used to optimize excitation conditions for analytes with emission lines in a limited spectral range. Spectra acquisition, processing, and analysis were microprocessor (software) controlled. Spectra and X-ray intensity data obtained for each sample were archived in electronic format.

2.1.1 Calibration

The XRF instrument was calibrated for the analytes and matrix elements by defining spectral regions of interest (ROI) using pure compounds of the elements as references. Spectra for a set of calibration samples were then obtained and ROI intensities determined. Mathematical models were used to relate intensities to analyte concentrations and/or correction factors.

Energy calibration is required to monitor and/or correct instrumental drift. The procedure entails periodic acquisition of a reference spectrum (copper) and shifting of the spectrum to account for drift due to changes in environmental conditions. For this investigation, energy calibration was performed prior to the start of each 16-sample run.

The set of reference standards for XRF calibration was selected to include both specific analytes plus any matrix elements present in the soil samples that would produce spectral responses. Selection was based on quantitative and/or qualitative analyses of over 50,000 soil samples in the CDM Denver laboratory. Examination of spectra and analytical data for soil samples collected during this investigation confirmed that the set of reference standards adequately represented analyte and matrix elements.

Conditions under which sample spectra were acquired were established based on optimizing for the primary element of concern. The TX-5000 instrument was calibrated in the Denver laboratory using a Fundamental Parameters model and two

National Institute of Standards and Technology (NIST) Standards (2710 and 2711, both Montana Soil).

The XRF results for all the samples are provided in Section 3.

2.2 Selection of Samples for ICP-AES/ICP-MS Analysis

After completion of the XRF analyses, a sub-set of all samples analyzed by XRF were selected for additional evaluation by ICP analytical methods. The rational for the selection of these samples is presented in Table 2-1. The samples were selected based on the concentrations of nickel and cobalt from the XRF results and the type of soil. Soils with potentially higher permeabilities were selected because these zones would correspond to the most groundwater flow. However, most of the materials were silty sandy clay; therefore, materials representative of these zones with the higher metal concentrations were selected. Samples from all five locations (both plant and background) were selected. Because beryllium does not respond on the XRF equipment, it was analyzed by ICP-AES methods.

The ground, homogenized samples analyzed by XRF were transmitted to Test America for analysis of total metals using digestion method 3050B (nitric acid/ hydrogen peroxide) and SW-846 method 6020 (ICP-MS) for cobalt and nickel and SW-846 method 6010B (ICP-AES) for iron and beryllium. Results are provided in Section 3.

Table 2-1 Justification for ICP-AES/ICP-MS Analysis Submittal

Sample IDs	Sample Depth (ft)	Rationale and Sample Description
MW-60B-0607	6 - 7	High Ni, Co and Fe concentration; Moist silty sandy clay, sand is very fine
MW-60B-0708	7 - 8	
MW-60B-1516	15 - 16	High Co concentration; Moist brown very fine silty clayey sand
MW-60B-1718	17 - 18	High Ni, Co and Fe concentration; Moist silty sandy clay
MW-60B-2021	20 - 21	
MW-60B-2122	21 - 22	
MW-60B-2728	27 -28	High Ni concentration
MW-70B-1112	11 - 12	High Ni and Co concentration in 11-12', high Ni, Co and Fe in 16-17'; Moist brown silty sandy clay
MW-70B-1617	16 -17	
MW-70B-1718	17 - 18	High Ni and Co concentration; Silty clay
MW-70B-2021	20 - 21	High Ni and Fe concentration; Moist reddish silty clay
MW-70B-2324	23 - 24	High Ni concentration; Wet red silty clay with fine sand
MW-70B-2526	25 -26	
MW-72B-1718	17 - 18	High Ni, Co, and Fe concentration; Moist red brown silty sand
MW-72B-1819	18 - 19	High Ni and Co concentration; Moist red silty clay
MW-72B-1920	19 - 20	
MW-72B-2627	26 - 17	High Ni, Co and Fe concentration; Wet reddish silty clayey sand, very fine increase clay with depth
MW-72B-3132	31 - 32	
MW-72B-3233	32 - 33	High Ni and Fe concentration; Silty sandy clay some yellow brown discoloration
MW-75A-1112	11 - 12	High Ni and Co concentration; Silty sand with silty clay at bottom
MW-75A-1415	14 - 15	High Ni, Co and Fe concentration in the 14-15; high Ni and Co in the 15-16'; Silty sand w/clay
MW-75A-1516	15 - 16	
MW-75A-1819	18 - 19	High Ni, Co, and Fe concentration; Red clay (dry)
MW-75A-2223	22 - 23	High Ni, Co and Fe concentration; Red clay (softening, dry)

Table 2-1 Justification for ICP-AES/ICP-MS Analysis Submittal

MW-75A-2324	23 – 24	
MW-76B-2627	26 - 27	High Ni, Co and Fe concentration; Moist silty sand clay
MW-76B-2728	27 - 28	
MW-76B-3435	34 - 35	High Ni and Co concentration; Moist silty sand clay with very fine sand

2.3 Selection of Samples for Leachability Studies

After completion of the XRF and ICP-AES and ICP-MS analyses, a sub-set of all samples analyzed were selected for the leachability study. The rational for the selection of these samples is presented in Table 2-2. The samples were selected based on nickel, cobalt, and beryllium concentrations; soil type; and location (both background and plant locations). A modified SPLP (Synthetic Precipitation Leaching Procedure, SW-846 method 1312) was used to evaluate the leachability of the metals. The liquid to solid ratio was adjusted to approximately 4:1 (100 mL de-ionized water and 25 grams of sediment) and variable pH values were selected. The 4:1 ratio is less than the specified 20:1 ratio in method 1312. However, the 4:1 is more representative of groundwater leaching conditions. Actual in situ conditions are still lower than 4:1; however, the selected ratio allows for easier experimental conditions (mixing and water volume). During the tests, the pH was adjusted to four pH values to cover the range of pH conditions observed at the site (pH values of 4, 5, 6, and 7). A sample blank was prepared using 25 grams of sand and 100 grams of de-ionized water. The pH values were obtained by adjusting the initial slurry (soil-water mixture) pH with varying concentrations of sodium hydroxide and hydrochloric acid. The Eh or ORP (oxidation-reduction potential) was then recorded and the samples were placed on the rotary tumbler. An additional pH adjustment was performed after 48-hours and the samples were returned to the rotary tumbler. After an additional 24 hours of tumbling, the samples were removed and the Eh and pH values were recorded. The leachate (water phase) was then filtered with 0.45 µm membrane filter and sent to Test America for total metals analysis (Be, Co, Ni and Fe). Results are provided and discussed in Section 3.

Table 2-2 Justification for Leachate Study

Sample IDs	Justification	Ni (mg/kg)	Be (mg/kg)	Co (mg/kg)	Fe (mg/kg)
MW-60B-0607	High Be concentration; Moist silty sandy clay, sand is very fine	21	1.3	14	21,000
MW-60B-1718	High Be concentration; Moist silty sandy clay	22	3.5	7.8	21,000
MW-70B-1112	High Ni and Co, mid Be concentrations; Moist brown silty sandy clay	29	1.2	17	15,000
MW-70B-2021	High Be concentration; Moist reddish silty clay	18	2.3	7.6	24,000
MW-70B-2526	High Ni and Co concentrations; Wet red silty clay with fine sand	62	0.27	27	3,800
MW-72B-1718	High Be concentration; Moist red brown silty sand	10	0.5	3.7	18,000
MW-72B-3233	High Be concentration; Silty sandy clay some yellow brown discoloration	30	2	10	48,000

Table 2-2 Justification for Leachate Study

Sample IDs	Justification	Ni (mg/kg)	Be (mg/kg)	Co (mg/kg)	Fe (mg/kg)
MW-75A-1415	High Be concentration; Silty sand with clay	16	1.5	8.8	29,000
MW-75A-2223	High Be concentration; Red clay (dry)	30	2.3	11	53,000
MW-76B-2728	High Be concentration; Moist silty sand clay	22	3.5	11	37,000

Section 3
Results

3.1 XRF and Initial Soil pH Values

The results of the XRF analyses conducted by the CDM Denver laboratory are provided in Appendix B. Table 3-1 summarizes the concentrations for iron, nickel, and cobalt. Because beryllium does not respond well on the XRF, it was not included in the XRF analysis. Table 3-1 also provides the results of the initial soil pH measurements. Values of nickel and cobalt below the instrument detection limit are signified with a "U" and the detection limit is provided in parenthesis. The concentrations of nickel ranged from <3 to 39 mg/kg. The concentrations of cobalt ranged from <3 to 16.5 mg/kg. The concentrations of iron and manganese ranged from 6,888 to 99,902 mg/kg and 23 to 2,425 mg/kg, respectively. As previously discussed, samples were selected for additional elemental analyses using ICP-AES and ICP-MS based on the XRF concentrations, soil type and sample location. The XRF results for all of the elements measured are provided in Appendix B.

3.2 ICP Results

As previously discussed in Section 2, 28 samples were selected for ICP-AES and ICP-MS analyses for iron, nickel, cobalt, and beryllium. Table 3-2 presents results of the total metals analysis produced by Test America. The iron, nickel, and cobalt results are comparable to the XRF results. The concentrations of iron ranged from 600 to 62,139 mg/kg. The concentrations of nickel, cobalt, and beryllium ranged from 4.4 to 62 mg/kg, 1.7 to 27 mg/kg, and 0.27 to 3.5 mg/kg, respectively. As previously discussed, 10 samples were selected for the leaching tests. The samples were selected based on metal concentrations, soil type, and location (both background and plant).

Table 3-1 Results of XRF Analysis

Sample ID	Iron (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)	Cobalt (mg/kg)	pH (su)
MW-60B-0001	4445	154	11.569	(1.577)U	6.7
MW-60B-0102	36921	758	(4.261)U	8.905	6.7
MW-60B-0203	3842	96	(3.438)U	(1.675)U	6.7
MW-60B-0304	4868	55	(2.84)U	(0.609)U	6.6
MW-60B-0405	6991	23	(5.334)U	3.122	6.6
MW-60B-0506	7628	106	(6.736)U	(1.786)U	6.6
MW-60B-0607	32323	279	19.624	8.886	6.6
MW-60B-0708	21581	322	17.301	7.183	6.6
MW-60B-0809	26204	70	13.455	9.4	6.4
MW-60B-0910	25245	128	12.932	7.227	6.3
MW-60B-1011	18790	165	8.998	6.567	6.2
MW-60B-1112	16901	186	8.476	3.922	6
MW-60B-1213	24694	314	13.721	5.208	5.7
MW-60B-1314	30314	1511	16.869	9.441	5.7
MW-60B-1415	14980	105	14.668	3.175	5.7
MW-60B-1516	20442	168	(5.997)U	6.366	5.6
MW-60B-1617	38385	919	21.699	8.042	5.6
MW-60B-1718	32976	430	22.465	10.845	5.3
MW-60B-1819	39288	427	17.82	10.001	5.2
MW-60B-1920	40366	467	19.329	9.8	5.2

Table 3-1 Results of XRF Analysis

Sample ID	Iron (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)	Cobalt (mg/kg)	pH (su)
MW-60B-2021	43376	586	21.842	8.054	5.1
MW-60B-2122	48655	463	22.117	8.163	5.1
MW-60B-2425	37353	331	18.263	5.27	5
MW-60B-2526	34051	379	13.893	6.131	4.7
MW-60B-2627	51343	805	17.295	11.846	4.9
MW-60B-2728	62139	1243	25.14	12.227	4.8
MW-60B-2829	87579	2105	(7.794)U	12.003	4.8
MW-60B-2930	81364	1882	17.356	10.639	4.7
MW-60B-3031	36402	707	13.011	5.513	4.8
MW-60B-3132	99902	2425	(9.915)U	12.503	4.8
MW-75A-0203	24364	176	8.864	8.299	6.4
MW-75A-0304	28870	249	20.575	7.104	6.4
MW-75A-0405	23943	242	13.56	7.343	6.3
MW-75A-0506	22062	237	17.689	6.252	6.4
MW-75A-0607	22147	218	12.99	7.499	6.4
MW-75A-0708	23172	203	10.012	7.874	6.4
MW-75A-0809	21964	232	(7.372)U	(3.5)U	6.4
MW-75A-0910	16549	210	(4.976)U	3.791	6.4
MW-75A-1011	22334	957	(3.445)U	4.044	6.4
MW-75A-1112	20102	809	15.628	6.964	6.3
MW-75A-1213	23496	1005	8.404	7.02	6.3
MW-75A-1314	21978	601	(5.373)U	6.611	6.3
MW-75A-1415	51880	474	25.473	12.053	6.2
MW-75A-1516	30960	636	16.612	9.703	6
MW-75A-1617	51086	286	22.823	8.131	5.9
MW-75A-1718	51970	227	22.912	12.671	5.8
MW-75A-1819	53633	275	26.984	12.239	5.4
MW-75A-1920	52032	322	22.006	11.801	5.3
MW-75A-2021	42722	197	20.908	7.497	5.1
MW-75A-2122	53463	341	19.497	7.804	4.9
MW-75A-2223	82131	320	32.454	13.126	5
MW-75A-2324	96961	474	39.123	13.504	5
MW-72B-1617	26728	104	8.838	6.425	6.2
MW-72B-1718	30998	190	11.877	8.804	6.3
MW-72B-1819	16477	106	10.298	7.635	6
MW-72B-1920	17212	144	10.256	4.749	6
MW-72B-2021	22160	260	(5.277)U	6.848	5.9
MW-72B-2122	22801	181	7.618	7.806	5.6
MW-72B-2223	24299	110	15.251	6.945	5.4
MW-72B-2324	21264	176	12.007	7.112	5
MW-72B-2425	25245	395	13.372	9.624	5.3
MW-72B-2526	6888	125	U	3.16	5.1
MW-72B-2627	23204	163	15.046	6.655	5.1
MW-72B-2728	13911	182	(4.27)U	(1.342)U	5.2
MW-72B-2829	12456	204	7.169	4.806	5.2
MW-72B-2930	14958	129	8.346	3.734	5
MW-72B-3031	29096	268	9.975	7.299	5.1
MW-72B-3132	84788	545	15.575	16.517	5.1
MW-72B-3233	68117	223	15.139	12.643	5
MW-72B-3334	41184	152	10.816	8.616	5
MW-70B-0001	28855	402	11.931	8.21	4.6
MW-70B-0102	26351	368	(5.63)U	5.432	4.6
MW-70B-0203	25422	253	14.546	6.69	4.5
MW-70B-0304	31997	392	8.945	11.172	4.6
MW-70B-0405	41297	182	11.633	9.029	4.8
MW-70B-0506	22192	198	12.358	7.127	4.3

Table 3-1 Results of XRF Analysis

Sample ID	Iron (mg/kg)	Manganese (mg/kg)	Nickel (mg/kg)	Cobalt (mg/kg)	pH (su)
MW-70B-0607	37829	238	(6.988)U	8.778	4.3
MW-70B-0708	46383	189	9.179	11.679	4.3
MW-70B-0809	13505	84	12.261	(2.75)U	4.2
MW-70B-0910	18860	144	30.179	7.174	4
MW-70B-1011	27846	399	15.858	7.33	4.1
MW-70B-1112	22778	282	21.254	5.483	4
MW-70B-1213	28689	248	12.401	6.209	4
MW-70B-1314	55292	392	19.813	10.618	4.1
MW-70B-1415	30798	196	15.296	8.132	4.2
MW-70B-1516	49216	346	19.839	9.847	4.3
MW-70B-1617	42170	275	20.816	10.75	4.4
MW-70B-1718	42960	299	18.49	11.908	4.3
MW-70B-1819	36309	329	(4.196)U	9.877	4.4
MW-70B-1920	31462	233	9.358	5.709	4.4
MW-70B-2021	34463	241	15.458	8.748	4.4
MW-70B-2122	34628	127	9.55	9.412	4.4
MW-70B-2223	23420	61	15.65	6.642	4.3
MW-70B-2324	19098	164	12.924	3.761	4.2
MW-70B-2425	11365	187	(7.26)U	(2.289)U	4
MW-70B-2526	8152	37	10.901	3.612	4
MW-70B-2627	9615	110	(6.97)U	(2.307)U	4.1
MW-70B-2728	8343	88	(6.67)U	(2.008)U	4
MW-70B-2829	8893	181	(7.053)U	3.446	4.1
MW-70B-2930	8118	30	7.869	(0.818)U	4
MW-76B-2627	52580	631	29.556	11.615	5.1
MW-76B-2728	53909	644	23.36	10.685	5
MW-76B-2829	78356	1725	(9.876)U	13.854	5
MW-76B-2930	51660	788	(8.276)U	8.825	4.9
MW-76B-3031	24004	310	14.903	5.007	5.1
MW-76B-3132	23878	212	12.349	5.069	5.1
MW-76B-3233	42396	657	11.181	7.315	5.1
MW-76B-3334	44878	686	(7.972)U	9.306	5
MW-76B-3435	43315	786	23.341	8.836	5

Table 3-2 Total Metals Analysis of ICP-AES and ICP-MS Analysis

		Parameter			
Sample ID	Method	Fe (mg/kg)	Ni (mg/kg)	Co (mg/kg)	Be (mg/kg)
MW-60B-0607	6010B/6020	21000	21	14	1.3
MW-60B-0708	6010B/6020	14000	18	10	1.1
MW-60B-1516	6010B/6020	13000	13	5	1.2
MW-60B-1718	6010B/6020	21000	22	7.8	3.5
MW-60B-2021	6010B/6020	28000	21	9.1	3.1
MW-60B-2122	6010B/6020	29000	21	8.7	1.7
MW-60B-2728	6010B/6020	62139	25	12.2	1.7
MW-70B-1112	6010B/6020	15000	29	17	1.2
MW-70B-1617	6010B/6020	22000	15	6.8	1.9
MW-70B-1718	6010B/6020	28000	14	5.8	2.5
MW-70B-2021	6010B/6020	24000	18	7.6	2.3
MW-70B-2324	6010B/6020	11000	12	4.9	0.88
MW-70B-2526	6010B/6020	3800	62	27	0.27
MW-72B-1718	6010B/6020	18000	10	3.7	0.5
MW-72B-1819	6010B/6020	8500	5.1	2	0.35
MW-72B-1920	6010B/6020	8700	4.4	1.7	0.37
MW-72B-2627	6010B/6020	12000	6.9	3.7	0.47

Table 3-2 Total Metals Analysis of ICP-AES and ICP-MS Analysis

Sample ID	Method	Parameter			
		Fe (mg/kg)	Ni (mg/kg)	Co (mg/kg)	Be (mg/kg)
MW-72B-3132	6010B/6020	51000	13	9.1	2.2
MW-72B-3233	6010B/6020	48000	30	10	2
MW-75A-1112	6010B/6020	11000	11	12	0.97
MW-75A-1415	6010B/6020	29000	16	8.8	1.5
MW-75A-1516	6010B/6020	19000	14	11	1.3
MW-75A-1819	6010B/6020	34000	24	9.3	1.7
MW-75A-2223	6010B/6020	53000	30	11	2.3
MW-75A-2324	6010B/6020	600	29	11	0.05
MW-76B-2627	6010B/6020	29000	22	9.4	2.8
MW-76B-2728	6010B/6020	37000	22	11	3.5
MW-76B-3435	6010B/6020	4900	21	14	0.51

3.3 Comparison of XRF and ICP Results

As discussed, the soil samples were analyzed by using both XRF and ICP methods. All 111 soil samples collected were analyzed by XRF and a total of 28 of the original soil samples analyzed by XRF were analyzed by Test America by either ICP-AES or ICP-MS. Table 3-3 presents the results of an RPD analysis performed an all samples analyzed by XRF and ICP-AES or ICP-MS. The average RPD for iron was 29 percent, cobalt was 23 percent, and nickel was 17 percent. The RPDs get larger as the results reported get near the detection limit. In general, the elevated results for nickel and cobalt showed good agreement between the XRF and the ICP-AES and ICP-MS results. Elevated iron results analyzed by XRF did not agree as well with the results produced by ICP-AES.

Table 3-3 Results of RPD Analysis

Parameter	Method	Sample ID			
		MW-60B-0607	**MW-60B-0708**	**MW-60B-1516**	**MW-60B-1718**
Fe (mg/kg)	XRF	32323.406	21580.836	20441.809	32976.48
	6010B	21000	14000	13000	21000
	%RPD	**21**	**21**	**22**	**22**
Ni (mg/kg)	XRF	19.624	17.301	5.99	22.465
	6010B	21	18	13	22
	%RPD	**3**	**2**	**37**	**1**
Co (mg/kg)	XRF	8.886	7.183	6.366	10.845
	6010B	14	10	5	7.8
	%RPD	**22**	**16**	**12**	**16**
Parameter	Method	Sample ID			
		MW-60B-2021	MW-60B-2122	MW-70B-1112	MW-70B-1617
Fe (mg/kg)	XRF	43376.379	48654.781	22778.393	42170.258
	6010B	28000	29000	15000	22000
	%RPD	**22**	**25**	**21**	**31**
Ni (mg/kg)	XRF	21.842	22.117	21.254	20.816
	6010B	21	21	29	15
	%RPD	**2**	**3**	**15**	**16**
Co (mg/kg)	XRF	8.054	8.163	5.483	10.75
	6010B	9.1	8.7	17	6.8
	%RPD	**6**	**3**	**51**	**23**
Parameter	Method	Sample ID			
		MW-70B-1718	MW-70B-2021	MW-70B-2324	MW-70B-2526
Fe (mg/kg)	XRF	42960.148	34463.414	19097.91	8151.909

Table 3-3 Results of RPD Analysis

		Sample ID			
	6010B	28000	24000	11000	3800
	%RPD	**21**	**18**	**27**	**36**
Ni (mg/kg)	XRF	18.49	15.458	12.924	10.901
	6010B	14	18	12	62
	%RPD	**14**	**8**	**4**	**70**
Co (mg/kg)	XRF	11.908	8.748	3.761	3.612
	6010B	5.8	7.6	4.9	27
	%RPD	**34**	**7**	**13**	**76**
Parameter	Method	Sample ID			
		MW-72B-1718	MW-72B-1819	MW-72B-1920	MW-72B-2627
Fe (mg/kg)	XRF	30997.648	16476.656	17212.203	23204.094
	6010B	18000	8500	8700	12000
	%RPD	**27**	**32**	**33**	**32**
Ni (mg/kg)	XRF	11.877	10.298	10.256	15.046
	6010B	10	5.1	4.4	6.9
	%RPD	**9**	**34**	**40**	**37**
Co (mg/kg)	XRF	8.804	7.635	4.749	6.655
	6010B	3.7	2	1.7	3.7
	%RPD	**41**	**58**	**47**	**29**
Parameter	Method	Sample ID			
		MW-72B-3132	MW-72B-3233	MW-70B-1112	MW-70B-1617
Fe (mg/kg)	XRF	84787.953	68116.75	22778.393	42170.258
	6010B	51000	48000	15000	22000
		MW-72B-3132	MW-72B-3233	MW-70B-1112	MW-70B-1617
	%RPD	**25**	**17**	**21**	**31**
Ni (mg/kg)	XRF	15.575	15.139	21.254	20.816
	6010B	13	30	29	15
	%RPD	**9**	**33**	**15**	**16**
Co (mg/kg)	XRF	16.517	12.643	5.483	10.75
	6010B	9.1	10	17	6.8
	%RPD	**29**	**12**	**51**	**23**
Parameter	Method	Sample ID			
		MW-72B-3132	MW-72B-3233	MW-75A-1112	MW-75A-1415
Fe (mg/kg)	XRF	84787.953	68116.75	20101.543	51880.008
	6010B	51000	48000	11000	29000
	%RPD	**25**	**17**	**29**	**28**
Ni (mg/kg)	XRF	15.575	15.139	15.628	25.473
	6010B	13	30	11	16
	%RPD	**9**	**33**	**17**	**23**
Co (mg/kg)	XRF	16.517	12.643	6.964	12.053
	6010B	9.1	10	12	8.8
	%RPD	**29**	**12**	**27**	**16**
Parameter	Method	Sample ID			
		MW-75A-1516	MW-75A-1819	MW-75A-2223	MW-75A-2324
Fe (mg/kg)	XRF	30959.982	53633.402	82131.078	96960.641
	6010B	19000	34000	53000	600
	%RPD	**24**	**22**	**22**	**99**
Ni (mg/kg)	XRF	16.612	26.984	32.454	39.123
	6010B	14	24	30	29
	%RPD	**9**	**6**	**4**	**15**
Co (mg/kg)	XRF	9.703	12.239	13.126	13.504
	6010B	11	9.3	11	11
	%RPD	**6**	**14**	**9**	**10**
Parameter	Method	Sample ID			
		MW-76B-2627	MW-76B-2728	MW-76B-3435	MW-60B-2728
Fe (mg/kg)	XRF	52580.262	53909.023	43315.285	62139.453

Table 3-3 Results of RPD Analysis

		Sample ID			
	6010B	29000	37000	4900	36000
	%RPD	**29**	**19**	**80**	**27**
Ni (mg/kg)	XRF	29.556	23.36	23.341	25.14
	6010B	22	22	21	8.8
	%RPD	**15**	**3**	**5**	**48**
Co (mg/kg)	XRF	11.615	10.685	8.836	12.227
	6010B	9.4	11	14	5
	%RPD	**11**	**1**	**23**	**42**

3.4 Leaching Test Results

As previously discussed in Section 2, ten samples were leached at various pH conditions. The resulting leachate (water) samples were then sent for laboratory analyses at Test America. Table 3-4 presents results of the analyses produced by Test America. Sample mass, Eh and pH measurements are provided in Appendix C. As shown, some of the data are qualified. A "B" qualifier indicates that the result is estimated and reported below the reporting limit, "J" indicates the value was estimated due to low level blank contamination of iron in the method blank below the reporting limit and "L" indicates that the serial dilution of the digestate in the analytical batch indicate a chemical or physical interferences are present. These values should be used with caution given the qualifier. None of the qualifiers effect the overall conclusions.

Table 3-4 Results of Leachability Study Analysis

Well Sample #	Targeted pH	Be (µg/L)	Co (µg/L)	Ni (µg/L)	Fe (µg/L)	Final pH (su)	Final Eh (mv)
MW-60B-0607 (6 -7 feet)	4	51	55	49	<200	4.11	N/A
	5	43	53	31	<200	5.05	300.1
	6	4.3	7.4	10	<200	5.97	291
	7	<2	1.7B	3.9B	<200	6.96	360.4
MW-60B-2021 (20 - 21 feet)	4	36	71	550	<200	4.11	333.6
	5	2.1	7.6	60	350J	5.04	332.9
	6	1.5B	1.3B	6.3	<200	6.07	328.1
	7	<2	0.59B	1.4B	240J	7.06	305.2
MW-70B-1112 (11 -12 feet)	4	1.2 B	30	41	910J	4.07	476.6
	5	<2	3.4	6.8	840B	4.99	388.5
	6	7.9	62	100	56000J	5.96	313.8
	7	16	140	230	110000J	6.98	280.5
MW-70B-2021 (20 - 21 feet)	4	1.1B	0.94B	2.8B	69B,J	3.96	420.1
	4 (duplicate)	2	1.1B	1.7B	45B,J	3.99	393.5
	5	2	0.63B	2.1B	670J	5.1	387.7
	6	10	9.4	42	67000J	5.95	336.7
	7	12	13	58	82000J	6.97	297
MW-70B-2526 (25 - 26 feet)	4	1.2B	17	23	120B,J	4.17	455.8
	5	14	1.6B	2.6B	86B,J	4.98	349.3
	6	<2	0.78B	1.7B	860J	6.04	314
	7	<2	1.4B	3.4B	2800L	6.98	341
	7 (duplicate)	<2	7	12	4400L	7.02	294
MW-72B-1718 (17 - 18 feet)	4	2.5	2.5	3.2B	<200L	4.11	371.3
	5	<2	0.41B	1.3B	<200L	5.06	357.4
	6	<2	0.33B	0.74B	<200L	5.97	299.1
	7	<2	0.41B	1.4B	<200L	6.96	269.9
MW-72B-3233	4	<2	15	22	<200L	3.81	395.2

Table 3-4 Results of Leachability Study Analysis

Well Sample # (32 - 33 feet)	Targeted pH	Be (µg/L)	Co (µg/L)	Ni (µg/L)	Fe (µg/L)	Final pH (su)	Final Eh (mv)
	5	<2	2.4	3.5B	<200L	4.95	339
	6	<2	0.17B	<4	<200L	5.96	332.5
	7	<2	0.21	<4	<200L	6.91	320.4
MW-75A-1415 (14 - 15 feet)	4	28	150	140	<200L	3.98	263.3
	5	45	56	63	<200	4.97	244.7
	6	3	9.7	12	<200	5.96	247.7
	7	<2	1.2B	3.1B	60B	7.19	179.1
MW-75A-2223 (22 - 23 feet)	4	1.4B	42	110	<200	4.1	402.2
	5	<2	1.7B	4.6	<200	4.93	366.4
	6	<2	0.47B	1.5B	610	5.92	334.1
	7	0	0	0	0	7.05	312.1
MW-76B-2728 (27 - 28 feet)	4	15	13	56	<200	3.98	389.3
	5	<2	0.61B	2.7B	<200	4.9	351.5
	6	<2	0.4B	1B	<200	5.96	328.1
	7	<2	0.31B	1.1B	76B	7.01	316.8
Blank	4	3.4	0.68B	5.2	79B	4.08	422.3

Section 4
Data Interpretation and Conclusions

4.1 Aquifer Sediment Concentrations

In order to evaluate the results of the leaching tests, the results of the XRF and ICP laboratory analyses of the soils were compared to see if any correlations exist that may suggest the phases in which beryllium, cobalt, and nickel, are contained. Figure 4-1 shows that beryllium concentrations correlate fairly well with iron concentrations, especially at low concentrations.

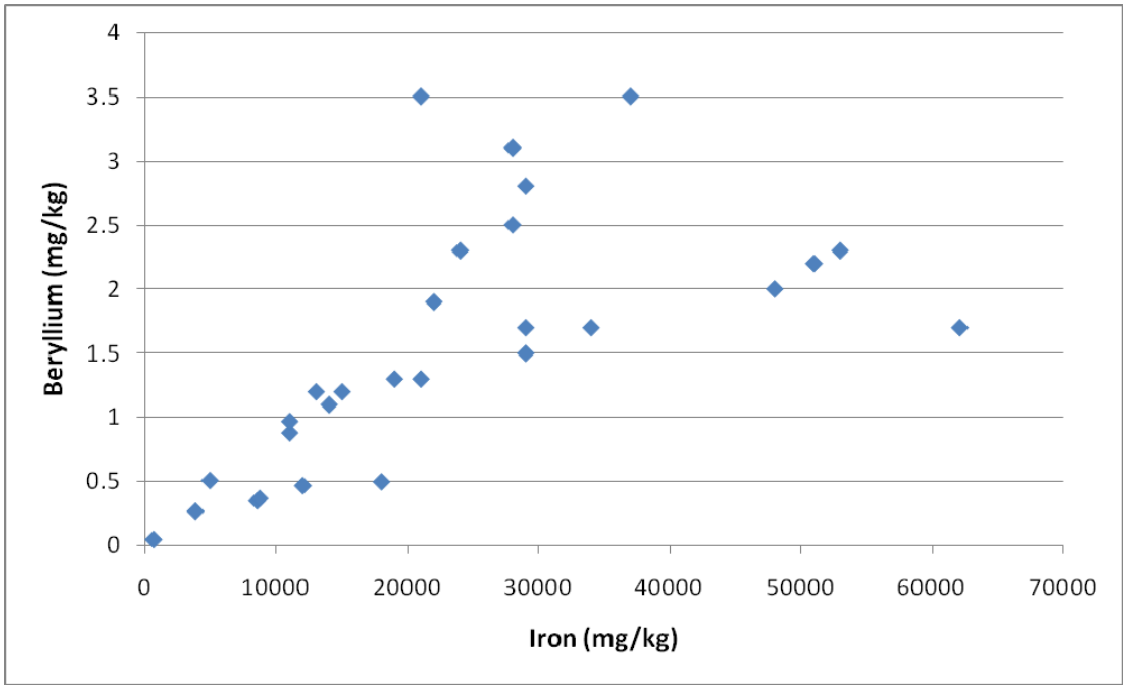

Figure 4-1. Variation of Beryllium Concentrations (ICP) in the Aquifer Sediment vs. Iron Concentrations (ICP) in the Sediment.

As discussed previously in Section 1, iron oxyhydroxide tend to coprecipitate transition metal ions and probably beryllium as well. However, given the fairly reducing conditions within some zones of the aquifer, reduced iron phases such as green rusts may also be present as the host phase for the beryllium within the aquifer sediments.

The cobalt and nickel concentrations within the aquifer sediments did not correlate, suggesting that an iron phase is not the dominate host for these metals. The correlation of cobalt and nickel was no better for manganese; however, when the iron and manganese concentrations were summed, a correlation was observed (see Figures 4-2 and 4-3). The correlations suggest that cobalt and nickel are hosted by both iron and manganese phases. The most likely phases are iron oxyhydroxides and manganese oxides.

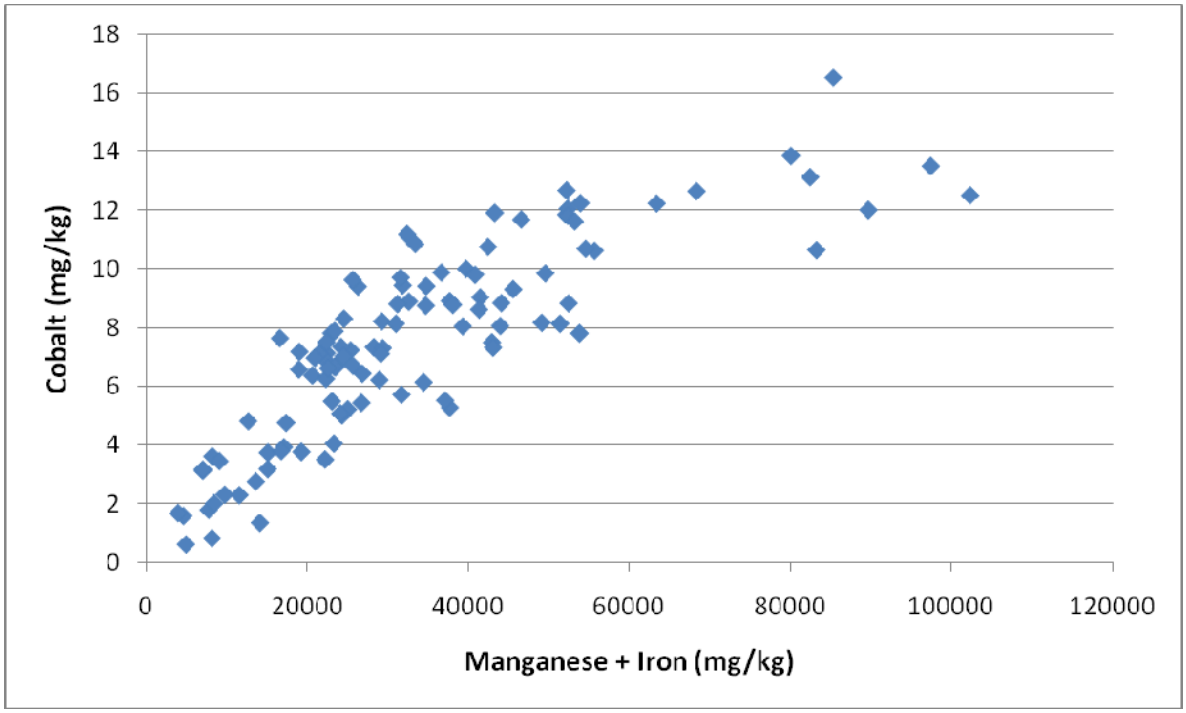

Figure 4-2. Variation of Cobalt Concentrations (XRF) in the Aquifer Sediment vs. the Sum of the Manganese and Iron Concentrations (XRF) in the Sediment.

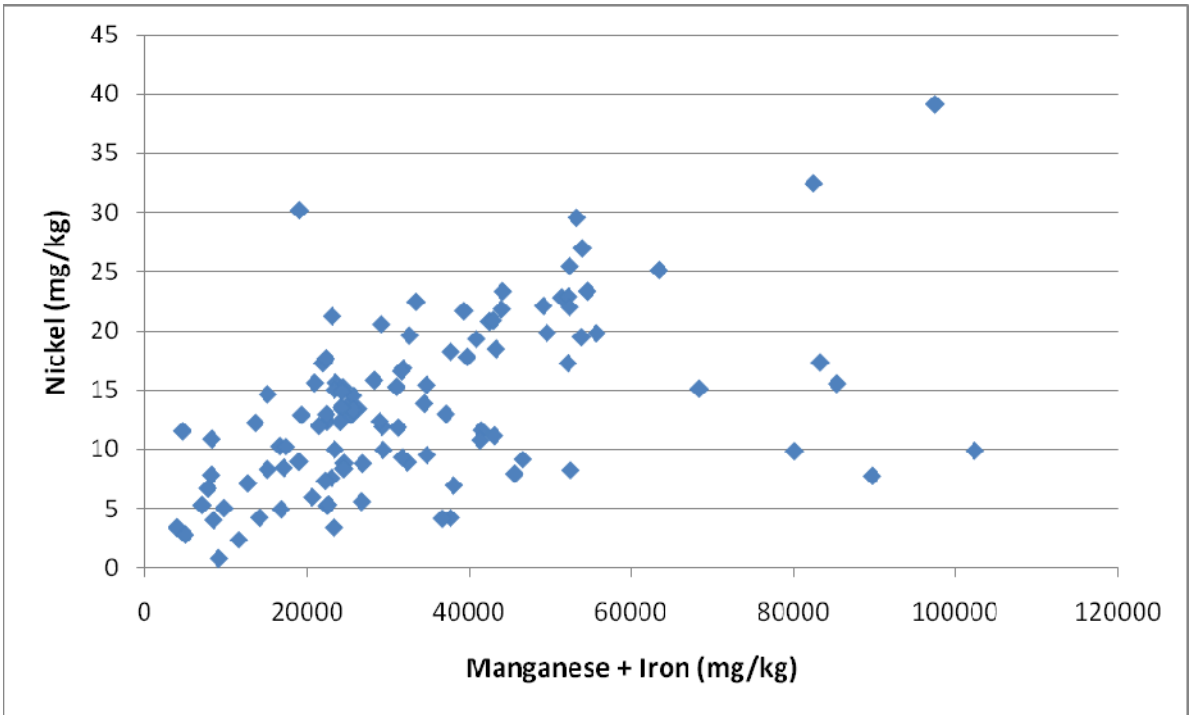

Figure 4-3. Variation of Nickel Concentrations (XRF) in the Aquifer Sediment vs. the Sum of the Manganese and Iron Concentrations (XRF) in the Sediment.

4.2 Comparison of Metal Concentrations to Literature Values

Several literature sources are available that provide metal concentrations in soils and sediments. USGS Professional Paper (H. Shacklette and J. Boerngen, 1984) provides the following values (mg/kg) for soils in the eastern United States:

Metal	Range	Arithmetic Mean
Be	<1-7	0.85
Co	<0.3-70	9.2
Ni	<5-700	18

Lindsay (W. Lindsay, 1979) provides the following values (mg/kg) for soils compiled from many sources:

Metal	Range	Arithmetic Mean
Be	0.1-40	6
Co	1-40	8
Ni	5-500	40

Typical site concentrations of these metals outside plant operations (MW70 and MW72, see Table 1-6) ranged from 0.3 to 2.5 mg/kg for Be, <2 to 16 mg/kg for Co, and <4 to 30 mg/kg for Ni. Concentrations at other locations on the site were very similar with the maximum observed concentrations being only slightly higher (3.5 mg/kg for Be, 16.5 mg/kg for Co, and 39 mg/kg for Ni). Overall the site concentrations for these metals are variable but consistent with literature values. This variability reflexes the complex geology and multiple lithologic units at the site.

4.3 Leaching Results

A total of 10 samples were selected for evaluation: MW-60B-0607, MW-60B-2021, MW-70B-1112, MW-70B-2021, MW-70B-2526, MW-72B-1718, MW-72B-3233, MW-75A-1415, MW-75A-2223, and MW-76B-2728.

Figures 4-5 through 4-14 provide the chemical concentrations of iron, cobalt, beryllium, and nickel as a function of pH. The pH values used to construct these figures were obtained from the measured pH in the solution after adjusting the solution pH midway through the testing. The solution was at this pH value for a majority of the test. The pH in the solutions tends to change back to the starting pH value in the soil as a result of the buffering capacity in the soils. Two conditions or mechanisms can release nickel, cobalt, and beryllium into solution: low pH values or high Eh values. Both of these conditions result in leaching of the host phases, typically iron and manganese phases. Low pH conditions also result in desorption of the metals. However, large quantities of iron were leached in only selected samples (MW-70B-2021 and MW-70B-2526). Small quantities of iron were released into the leachate for MW-60B-0607, MW-60B-2021, MW-72B-1718, and MW-72B-3233. This low concentration of iron is due to the relatively oxidizing conditions at these locations. In

addition, the host phase may not always be iron phases. Other potential host metal containing phases such as manganese were not measured in the aqueous samples to enable evaluation of the manganese leaching. However, as previously discussed, the concentrations of iron in the soil sample are typically 100 to 1,000 times higher than the manganese concentration; therefore, iron phases are anticipated to be the most important host phase for the beryllium, cobalt, and nickel.

The aquifer sediment correlations suggest that the beryllium is contained mainly within iron phases, while the cobalt and nickel are within both iron and manganese phases. However, within the batches it is possible that pure phase beryllium hydroxide is formed within the pH 7 solutions, as shown in Figure 4-4 (points on the right side of the saturation line). The predicted supersaturation of beryllium may be due to complexation by humic substances, which was not accounted for in the solubility calculations.

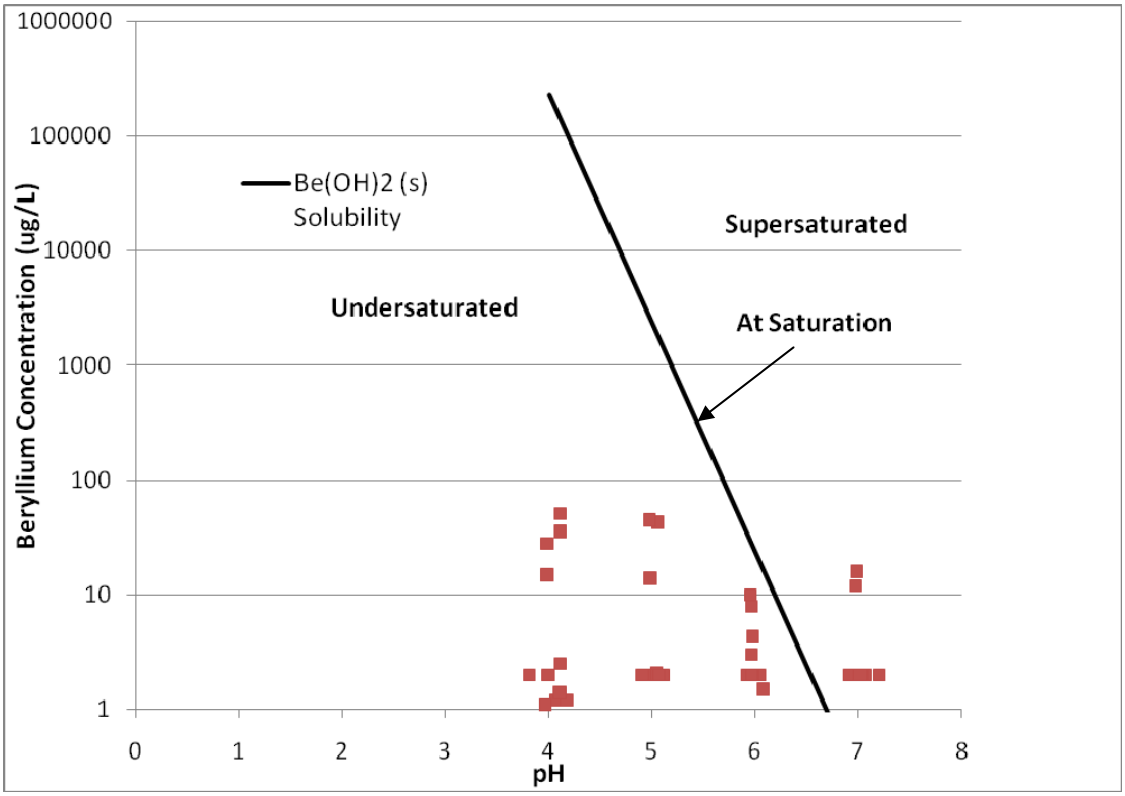

Figure 4-4. Berylium hydroxide solubility vs pH. Leach solutions are shown (red squares).

The following paragraphs provide a discussion of the results for each sample.

4.3.1 MW-60B (Plant Location – Near Center of Site)

Figure 4-5 presents the results of the leaching study for sample MW-60-0607 (6 to 7 feet) and Figure 4-6 presents results for MW-60-2021 (20 – 21 feet). The concentration values for iron on the figures are presented in mg/L while the concentration values for cobalt, nickel, and beryllium are presented in µg/L. As presented in the figures, the solubility of cobalt, nickel, and beryllium increased significantly with a decrease in pH at this location. The concentration of nickel was the highest (550 µg/L) at a pH value of 4.11 for the sample collected from a depth of 20 to 21 feet (MW60B-2021). The concentrations for beryllium and cobalt were similar at the targeted pH value of 4 su for both samples. The low pH value of 4 su was not maintained in the sample from 6 to 7 feet during the entire test due to neutralizing materials in the sample. The pH in the groundwater at these locations was measured at 6.00 su. Only small quantities of iron (<200 µg/L to 350 µg/L) were leached from these samples. Initial soil pH values were 6.6 su at 6-7 feet and 5.1 su at 20 – 21 feet.

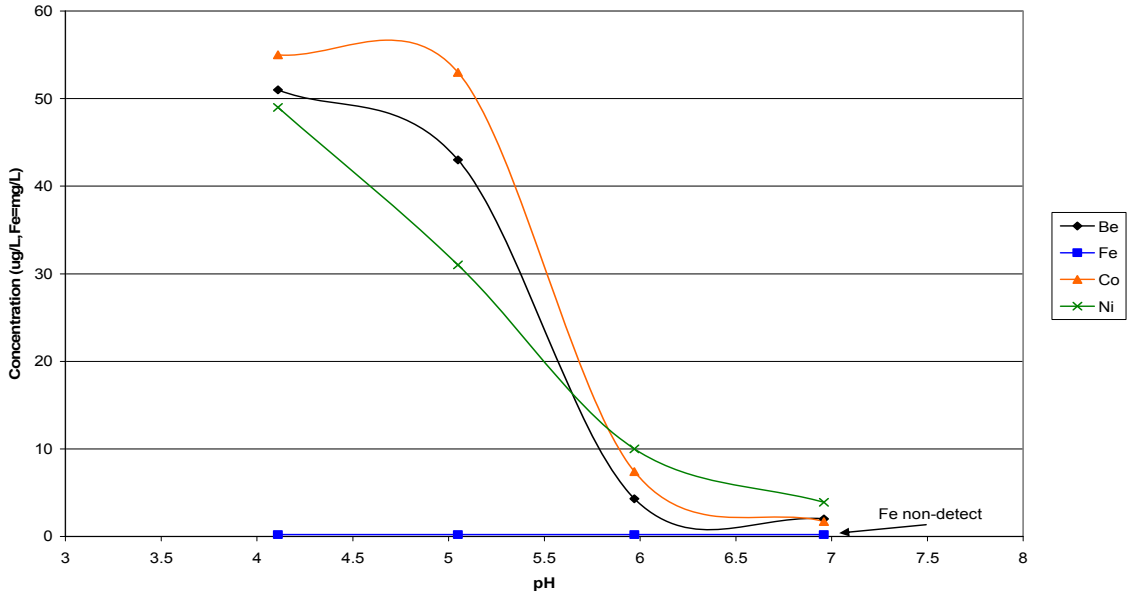

Figure 4-5. Leach Test Concentrations vs. pH: MW-60B-0607

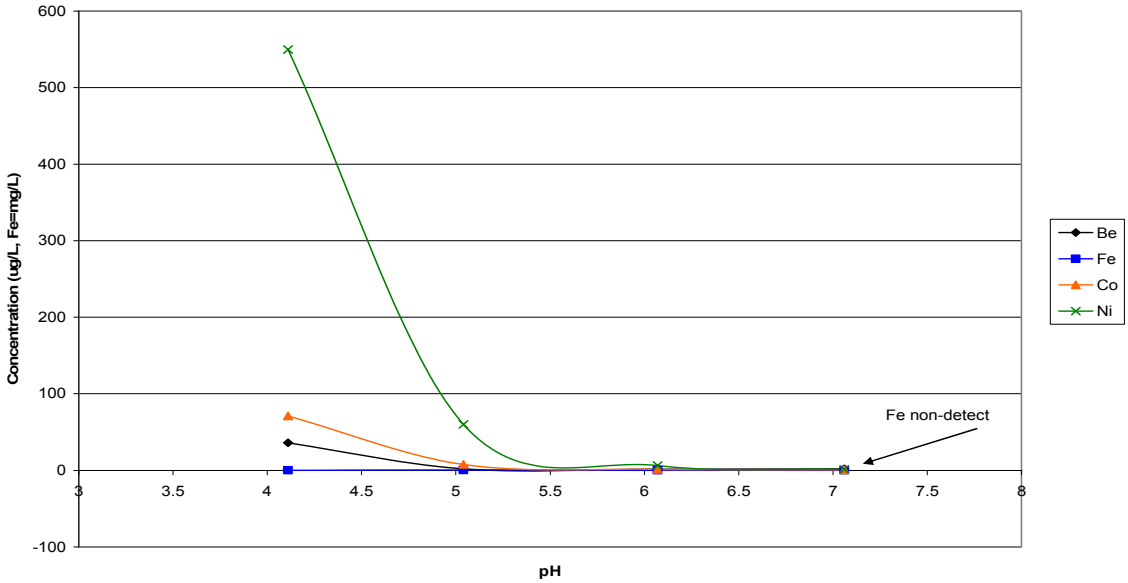

Figure 4-6. Leach Test Concentrations vs. pH: MW-60B-2021

4.3.2 MW-70B (Background Location – In Southwest Plume)

Figure 4-7, Figure 4-8, and Figure 4-9 presents the results of the leaching tests for samples collected from MW-70 at 11 to 12 feet, 20 to 21 feet, and 25 to 26 feet, respectively. As presented in the figures, the solubility of cobalt, nickel, beryllium, and iron increased significantly with an increase in pH in the sample from 11 to 12 feet and 20 to 21 feet. Iron concentrations also increased significantly with an increase in pH in these samples (up to 110,000 µg/L in sample MW70B-1112 at a pH value of 6.63).The nickel, cobalt and beryllium are apparently contained in the iron (and potentially the manganese) matrix and are released when the iron becomes soluble. Amorphous iron oxyhydroxides (e.g., present as coating on particle surfaces) have large adsorption capacities and typically adsorb other metals present in solution. These iron oxyhydroxides become more soluble under reducing conditions (decreased Eh values). Manganese oxides behave in a similar manner. During the tests, the Eh values did decrease substantially at the higher pH values; however, the value is not low enough to solubilize the iron oxyhydroxides (based on theoretical thermodynamic calculations). The field measured Eh (ORP) of the groundwater at this location is -162 mv. This is the lowest Eh measured in the wells where the samples were collected and is low enough to solubilize the iron oxyhydroxides. Initial soil pH values from depth intervals were 4.0 su at 11-12 feet, 4.4 su at 20-21 feet, and 5.1 su at 32-33 feet. The field measured pH value in the groundwater at this location is 6.78 su. Another possibility is that humic substances present within the aquifer sediments were solubilized as the pH was increased from ~4 to 7 su. Sodium hydroxide is used to extract humic material from soil. The sodium hydroxide added during the leaching tests may have been sufficient to leach humic matter, which when solubilized is an effective complexing agent for iron.

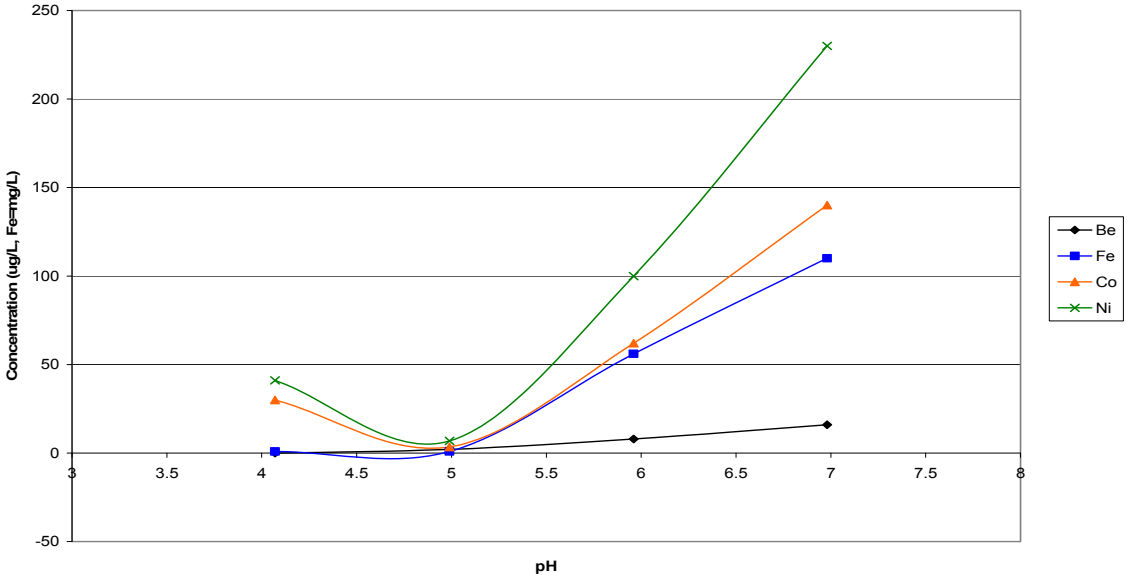

Figure 4-7. Leach Test Concentrations vs. pH: MW-70B-1112

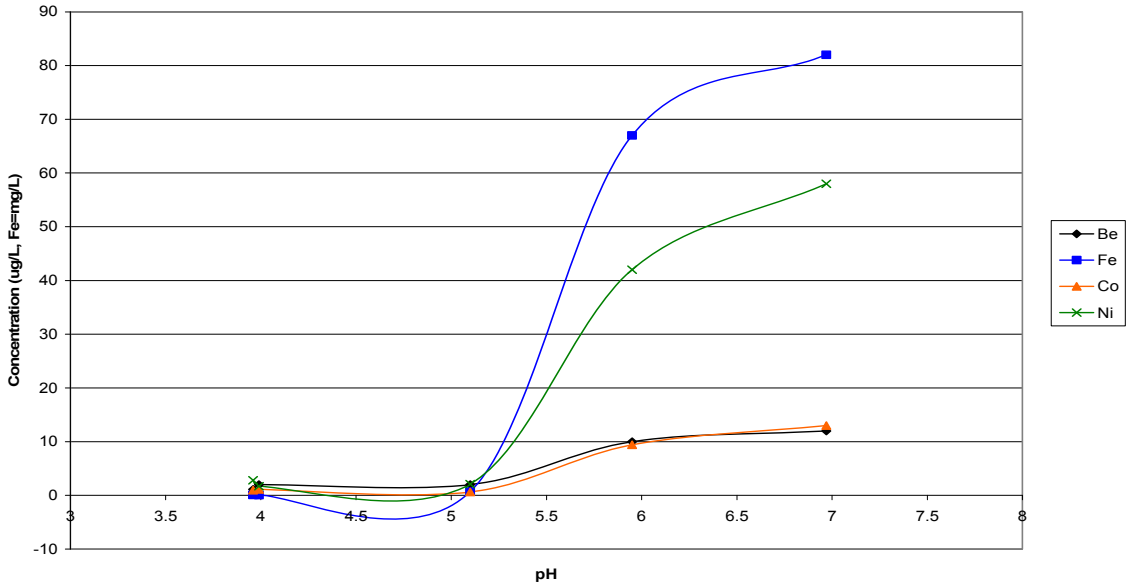

Figure 4-8. Leach Test Concentrations vs. pH: MW-70B-2021

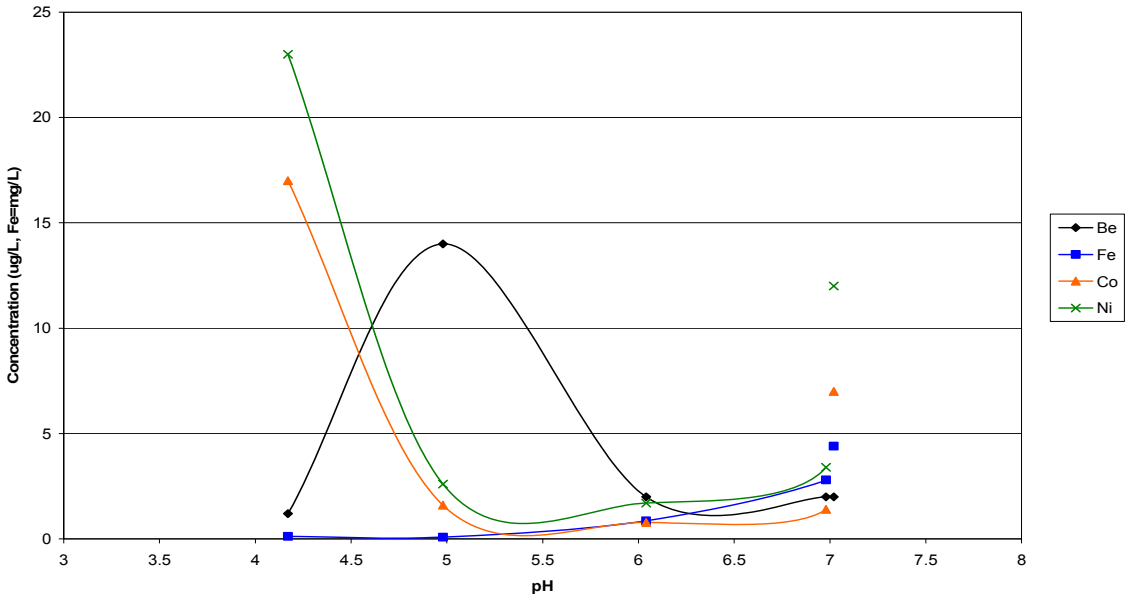

Figure 4-9. Leach Test Concentrations vs. pH: MW-70B-2526

4.3.3 MW-72B (Background Location – In Southeast Plume)

Figure 4-10 and Figure 4-11 present the results of the leaching tests for samples collected from MW-72B at 17 to 18 feet, and 32 to 33 feet, respectively. As presented in the figures, the solubility of cobalt, nickel, and beryllium increased with a decrease in pH. However, the resulting concentrations at the low pH values were relatively low compared to the concentrations at either high pH values in samples from MW70B or low pH values in samples from MW60B. The highest observed value was for nickel at a concentration of 22 µg/L. No iron was leached above the detection limit (200 µg/L). Initial soil pH values from these two depth intervals were 6.3 su at 17 to 18 feet and 5.0 su at 22 – 23 feet. The field measured pH in the groundwater was 5.14 su and the measured Eh (ORP) was 313 mv.

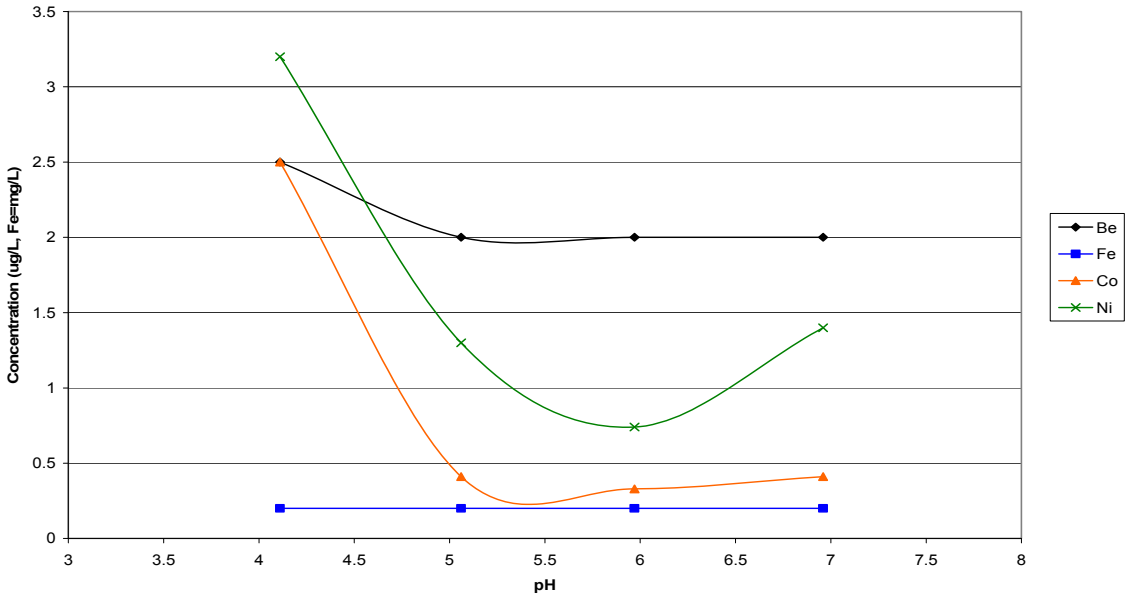

Figure 4-10. Leach Test Concentrations vs. pH: MW-72B-1718

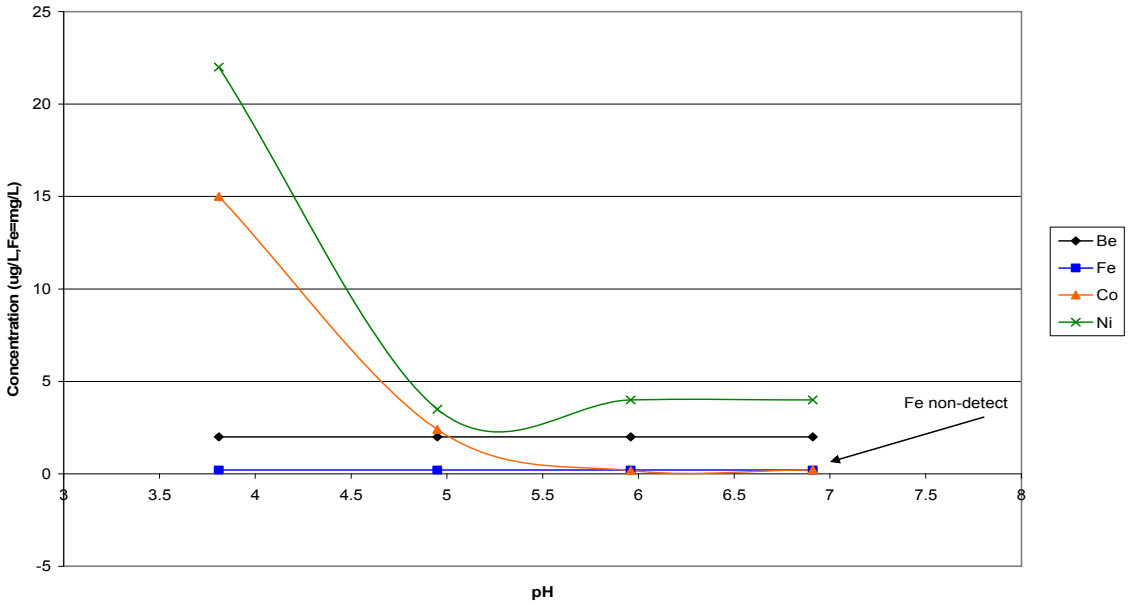

Figure 4-11. Leach Test Concentrations vs. pH: MW-72B-3233

4.3.4 MW-75A (Plant Location – Northwest Corner of Building A)

Figure 4-12 and Figure 4-13 present the results of the leaching tests for samples collected from MW-75A at 14 to 15 feet and 22 to 23 feet, respectively. As presented in the figures, the solubility of cobalt, nickel, and beryllium increased significantly with a decrease in pH. The resulting concentrations are much higher than MW72, but still less than the concentrations from samples collected at MW60B and MW70B. Only small quantities of iron were leached during these tests. Initial soil pH values from theses two depth intervals were 6.2 su at 14 to 15 feet and 5.0 su at 27 – 28 feet. The groundwater collected from this location has a pH value of 5.50 su and an Eh (ORP) of 88 mv.

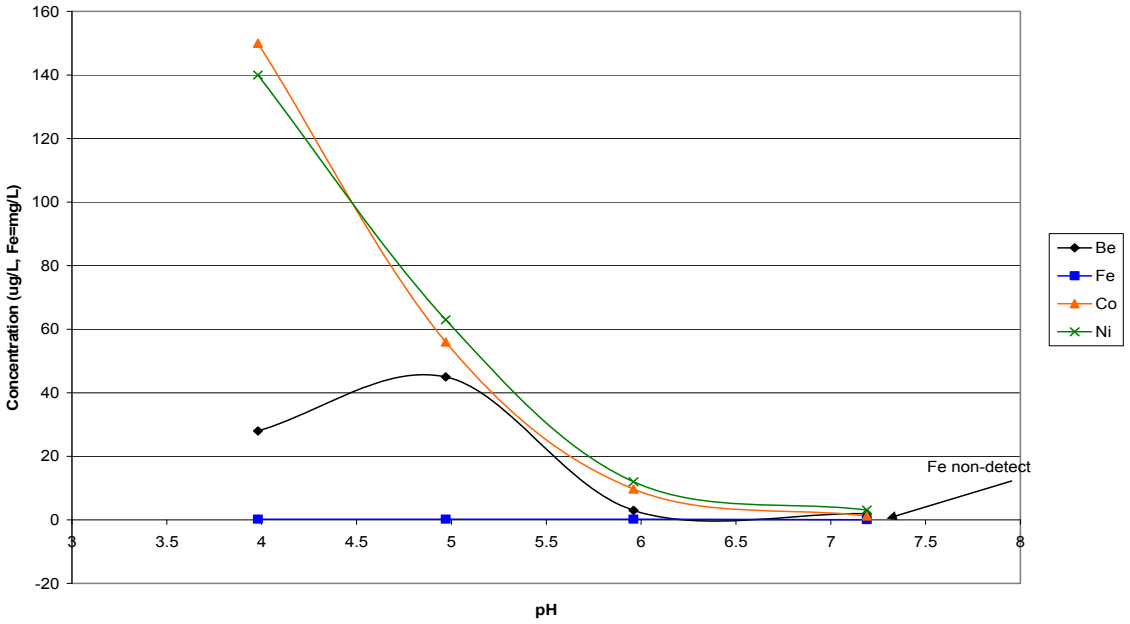

Figure 4-12. Leach Test Concentrations vs. pH: MW-75A-1415

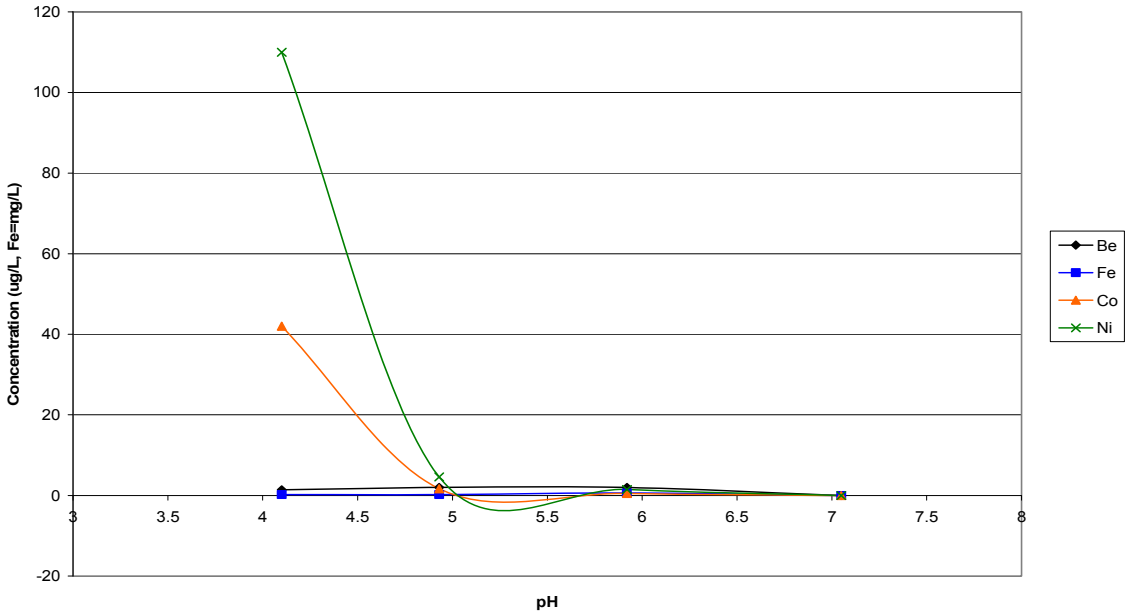

Figure 4-13. Leach Test Concentrations vs. pH: MW-75A-2223

4.3.5 MW-76B (Plant Location – Center of Site)

Figure 4-14 presents the results of the leaching test for samples collected from MW-75B at 27 to 28 feet. As presented in the figure, the solubility of cobalt, nickel and beryllium increased with a decrease in pH. The increase was more than at MW70B but less than at the other locations. Only small quantities of iron were released during the tests. Initial soil pH value from this depth interval was 5.0 su. The groundwater collected from this locations had a pH of 5.90 su and a Eh (ORP) of 24 mv.

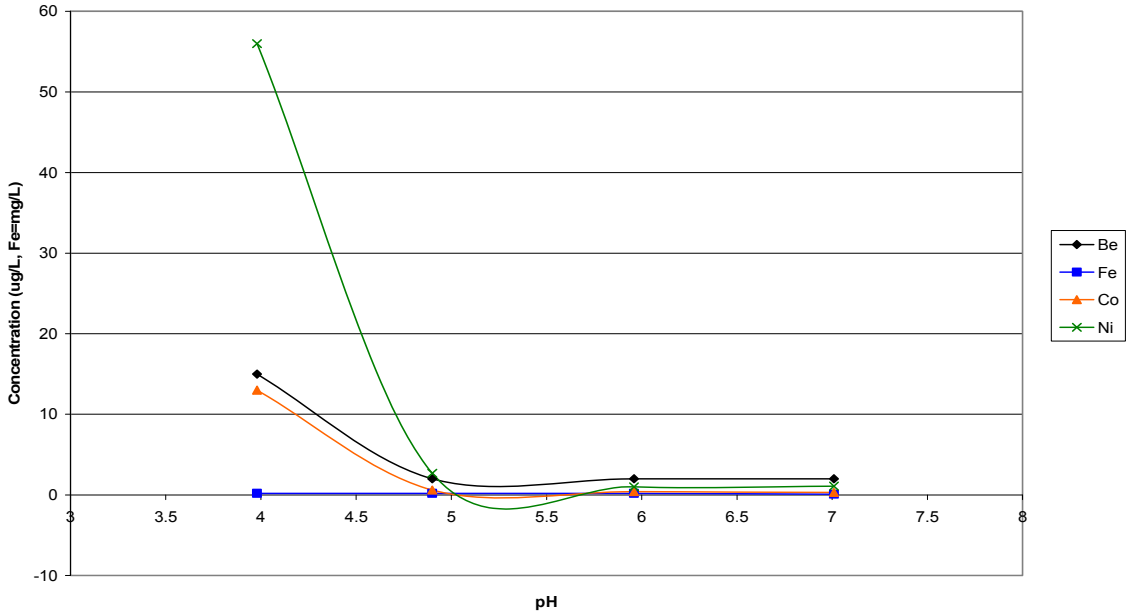

Figure 4-14. Leach Test Concentrations vs. pH: MW-76B-2728

4.4 Conclusions

As previously discussed, two mechanisms release nickel, cobalt and beryllium from the site aquifer materials. The major mechanism occurring at the site is release of metals at low pH values (due to desorption from sediment and dissolution of iron and manganese oxyhydroxides). Significant increases in the concentrations of nickel, cobalt, and beryllium are observed when pH values decrease to values of 4 su. At these locations, the conditions are relatively oxidizing and only very small quantities of iron are released from the aquifer materials at the low pH values. If pH values decreased further (below about 3.5 su), the iron oxyhydroxides would become soluble and additional metals may be released. The second mechanism occurring at the site is release of metals when iron and manganese oxyhydroxides are solubilized when reducing conditions exist. This occurs only at more reducing (less oxidizing) conditions and higher pH values (possibly due to complexation by humic substances). As shown, metals can be released from both background aquifer material and from samples collected near plant operations.

The beryllium, cobalt, and nickel at the site are present in the aquifer sediments at concentrations consistent with background. Mobilization of these elements occurs when the host phases are dissolved, typically under low pH or low Eh conditions. The Eh-pH conditions at the site are extremely variable, with pH values ranging from 4 to over 12 su, while the Eh ranges from about 100 to about 900 mv. Figure 4-15 is an Eh-pH diagram for iron, with the site data plotted. Most of the points plot along the iron hydroxide (Fe(OH)3)-ferrous iron (Fe+2) field boundaries, indicating that iron hydroxide is at equilibrium.

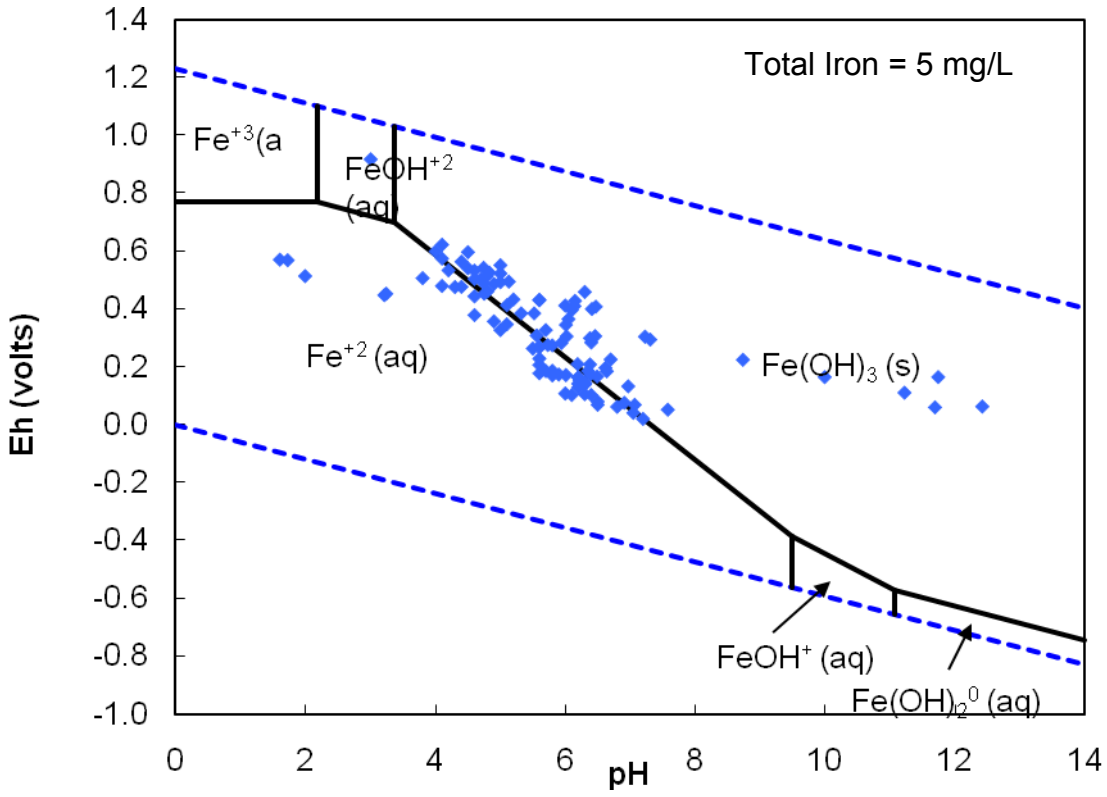

Figure 4-15 Eh-pH diagram for the Fe-O-H System at 25°C and 1 atm pressure. The groundwater data are shown (blue diamonds) straddling the iron hydroxide field boundary.

Changes in pH and oxidation-reduction conditions will result in dissolution or precipitation of iron solid phases. The sediment analyses indicate that beryllium, cobalt, and nickel are all contained with iron and manganese minerals, most likely iron hydroxide. Water with different Eh or pH conditions from the natural groundwater would cause iron hydroxide to either dissolve or precipitate to maintain equilibrium. For example, a low pH water would tend to dissolve iron hydroxide and the beryllium, cobalt, and nickel present as trace constituents. The reaction is as follows:

$Fe(OH)_3$ (s) [with Be, Co, and Ni] + $3H^+$ (aq) [from low pH water] → Fe^{+3} (aq) + $3H_2O$

The ferric iron ion (Fe^{+3}) produced results in a higher Eh, such that the data tend to "trend" along the ferric hydroxide-ferrous iron phase boundary. Release of high pH water would result in precipitation of ferric hydroxide (the reverse of the above reaction) which would cause the Eh to decrease (the points trend in the other direction along the phase boundary line). However, high pH water could also dissolve organic matter which would effectively complex the iron. Organic complexing may explain the presence of the points within the ferric hydroxide field (at high pH values > 8 su), which normally would suggest super-saturation with

respect to ferric hydroxide (a condition unlikely to occur within an aquifer). These points may also be the result of control by another phase, such as manganese oxide, as a linear trend with a lower slope can also be observed in Figure 4-15 (points with pH values of > 8 su).

The cobalt and nickel contained within manganese oxides would dissolve under low pH conditions, as follows:

MnO_2 (s) [with Co and Ni] + $4H^+$ (aq) → Mn^{+4} (aq) + $2H_2O$

Low pH groundwaters are wide spread in localized areas across the site; however, no consistent pattern is observed. As previously discussed, the low pH waters that have apparently resulted in the mobilization of the beryllium, cobalt, and nickel naturally present within the aquifer sediments at the site. The low pH conditions are the major cause of the elevated beryllium, cobalt and nickel concentrations observed in the groundwater across the site. The sources of the low pH waters are not specifically known, but are probably not natural. Reduced oxidation-reduction conditions can also cause mobilization of the metals. Reducing conditions can be caused by anthropogenic releases of organic compounds (e.g., TCE and petroleum products). However, the observed low Eh conditions at the site do not directly correspond to the high TCE concentrations. The lower Eh locations may naturally reflect the variable lithologic materials present at the site. In some areas of low pH and low Eh conditions at the site, no elevated concentrations of beryllium, cobalt, or nickel are observed. This reflects the geology and hydrogeology of the site. The lithology of the subsurface at the site is complex, consisting of silty and clayey layers with discontinuous layers and lenses of more permeable units (i.e. sandy materials). This results in different solid phase materials with different concentrations of beryllium, cobalt, and nickel.

4.5 Considerations for Site Remediation

As stated in Section 4.3, the metals leachability testing indicated that the beryllium, cobalt, and nickel concentrations in the aquifer sediments appeared to be consistent with background and are mobilized to the groundwater by contact with low pH groundwater. The source of the low pH groundwater has not been specifically traced to site operations and release points. Several factors should be considered when analyzing the source of this low pH and potential remedial actions for the metals and/or low site pH:

- The conclusions of this report were borne out during site pilot testing. In the western plume, sodium persulfate (activated with hydrogen peroxide) was injected into the aquifer in order to oxidize site contaminants. This led to a significant drop in pH (to less than 3 su) and dramatic increases in the concentrations of beryllium, cobalt, and nickel in the groundwater in the injection area, as predicted in the laboratory testing. Wells outside of the immediate area of injection also showed significant increases, creating a "plume" of high metals concentrations where it was not previously present. As the pH moderated following the test, metals concentrations decreased. The

test was done in an area of historically low metals concentrations and moderate pH. No known source of these metals is present in the area and concentrations of metals between this area and plant operations are historically low. Therefore, the metals present in the aquifer sediments in this area would be expected to be naturally occurring. Their release via the reduction in pH provides tangible field evidence of the mechanism shown in the laboratory and concluded to be occurring throughout the site. A table showing the pH and metals concentrations of the wells associated with this test and a map showing the well locations is included in Appendix D. Maps from 2007 and 2008 groundwater sampling, also included in Appendix D, show the significant increase in groundwater beryllium concentrations in this area following the 2008 injections (see the area of MW14 and MW71).

- Although the creation of reducing conditions in site groundwater was reported as another potential mechanism for the increase of groundwater metals concentrations, an increase in concentrations was not observed with the creation of these conditions during the in-situ anaerobic reductive dechlorination test conducted in the eastern plume.

- Historically, plant operations may have released low pH process water into the subsurface, but no evidence of this has been found. Currently, no process wastewater is known to be directly released to the subsurface. If the source of the low pH was historical operations, areas with observed low pH would be more localized than observed, and the pH would be expected to moderate over time as groundwater with higher pH flowed in to the area. A sketch showing the relative pH in site wells is included in Appendix D.

- The low pH groundwater is present in a widespread area of the site including areas of historic site operations and areas outside of the historical operations. Considering the low permeability soil, the widespread nature of the low pH would not be suspected from the release of low pH process water from a small number of sources. Therefore, potential sources of the widespread nature of the low pH conditions were investigated. One potential source is the infiltration of rainwater in the areas immediately surrounding the industrial buildings. A site investigation indicated that the rainwater from the building rooftops is collected in the gutter system and discharged to the subsurface just outside the buildings. Additionally, the storm water throughout this area infiltrates through cracks and joints in the pavement and concrete and through the small grassy areas present. Groundwater level measurements support this; a significant groundwater mound is present south of Buildings A, B, and C (see groundwater contour map, Appendix D). Various sources (the National Atmospheric Deposition Program and United States Geologic Survey) indicate that rainwater in this area has a pH of 4.3 to 4.7 (Appendix D). With the significant amounts of rainwater infiltration and low groundwater flow rates from the area (due to the site's low hydraulic

conductivity) this rainwater may contribute to the low pH in the groundwater surrounding the site buildings.

- High metals concentrations are primarily confined to the center of the site and beryllium, cobalt, and nickel are not contaminants of concern in the site sediments and surface water. Because it is presumed that they are naturally occurring and there are no receptors (drinking water, surface water, sediments, or vapor intrusion), the treatment of the metals would not effectively reduce risk at the site. In two locations near the surface water, metals concentrations are above standards (MW08 and MW12). Groundwater containment via groundwater extraction is part of the expected remedy at MW12 to address the volatile organic compound plume in that area and would concurrently address the metals in this area. Metals concentrations at MW08 should continue to be monitored with the potential for extending the groundwater extraction system to that area if it appears that surface water and/or sediments in Cow Pen Creek are being impacted.

Based on the information presented in this report, the recommended path forward regarding metals in groundwater at this site includes:

- Continued monitoring of pH and groundwater metals concentrations throughout this site. Concentration and pH trends will be developed as more data becomes available.

- Additional investigation to confirm that no low pH waste water is being discharged to the subsurface through site operations.

- Groundwater extraction in the vicinity MW12 as part of the volatile organic compound remedial action.

- Monitoring at MW08 to confirm that metals concentrations are not increasing and the surface water and sediments at the site are not being impacted by metals in the site groundwater. If conditions changed significantly, expansion of the groundwater extraction system to this area should be considered.

- Future in-situ remedies should not include significant reduction in groundwater pH. If in-situ chemical oxidation is utilized, an activator that increases or maintains the site pH, such as sodium hydroxide, should be utilized in lieu of hydrogen peroxide.

Section 5
References

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Appendix A
Sample Description and Soil Boring Logs

1730 - 1200
Rig setup
SB ttings
PLds
& development
GA & B

1240

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: ~~MW-75A~~
PROJECT NUMBER: 112C01883
DRILLING COMPANY:
DRILLING RIG:

BORING No.: MW-75A
DATE: 10/11/07
GEOLOGIST:
DRILLER:

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
	0	asphalt											
	0.5												
	2	3 5	15/24		Stiff	Red	Silt (ML) trace clay, dry, floury						PID 0
							Black staining, some odor						
							2.5YR 4/4						
	4	2 4 5 6	14/24		Stiff		Silty Clay w/ some f. sand dry - brown, some staining 2.5YR 4/4						0
	6	3 5 6 5	12/24		Soft		Silty clay - grey/brn red/ olive brn moist, soft, low/med plastic						0
	8	2 2 2 5	9/24		Soft		Silty clay transitions to Silty Sand (SM) med sorting, fine, slightly moist 10YR 4/3 brown						0
		25											
	10	5 4	20/24		Soft		Silty Sand as above w/ silty clay at bottom 10YR 6/3 pale brown (SM to CL)						0
	12	4 4 5 5	5/24		soft		low recov - Silty clay - Clay inc w/ depth as above 10YR 6/3						

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): [ ]

Remarks:

Converted to Well: Yes _____ No _____ Well I.D. #: _____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LMC@MRC
PROJECT NUMBER:
DRILLING COMPANY:
DRILLING RIG:

BORING No.: MW-75A
DATE: 10/11/07
GEOLOGIST:
DRILLER:

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
	14		20/24		soft		moist/slightly wet silty sand w/ clay - clay increases w/ depth low to med plasticity pale brown 10YR 6/3						
	16	7 7 8 9	23/24	hard	soft		Clay (CL) - red, dry, hard, some silt sharp contact @ ~14.5 from 10YR 6/3 SM low to med plasticity to 2.5YR 4/6 CL						
	18	7 12 15 16			stiff		Dry red clay as above 2.5YR 4/6 silty - mottling (trace) white gray 2.5Y 8/1 & olive yellow 2.5Y 6/6						
	20	5 14 16 18			same		as above (all clay - red & dense) dry						
	22	4 6 8 9					as above dry slight softening w/ depth stiff to med						
1400	24	6 9 14 18					as above dry slight softening						

* When rock coring, enter rock brokeness.
** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Remarks:

Drilling Area Background (ppm):

Converted to Well: Yes ____ No ____ Well I.D. #:

well set @ 21.5' bgs
10' screen
1' sand below screen bottom
sand to 8' Bentonite to 5' grout to 1.5'

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112IL00998
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)

BORING No.: MW-70B
DATE: 10/16/07
GEOLOGIST: CHARLIE MARINO
DRILLER: PETE HARPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		# SAMPLED BY			DRY	BROWN/REDDISH BROWN							
		HAND			SILTY, CLAYEY, SAND.								
0-2					SAND IS V. FINE-FINE			SC		0.1			
					GRAINED.								
		3 7											
4'		11 9	6"		SAME AS ABOVE			SC		0.0			
		6 4			MOIST, LT BROWN/GRAY, SILTY,								
6'		4 10	12"		SANDY, CLAY, MED. PLASTICITY.			CL		0.0			
					SAND IS V. FINE GRAINED								
		10 10											
8'		12 11	12"		SAME AS ABOVE			CL		0.0			
		4 5			SAME AS ABOVE TO			CL		0.0			
10'		10 6	16"		9.5'								
					WET BROWN SILTY, CLAYEY								
					SAND, V. FINE - FINE GRAINED			SC		0.0			
					9.5' - 10.0'								

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Remarks: _____

Drilling Area Background (ppm): _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112L00998
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)
BORING No.: MW-70B
DATE: 10/16/07
GEOLOGIST: CHARLIE WARING
DRILLER: PETE HAMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		3/4			MOIST, BROWN, SILTY, SANDY,								
		5/6	14"		CLAY. MED PLASTICITY,								
12'					SAND IS V. FINE - FINE			CL		0.0			
					GRAINED.								
		5/5											
14'		7/7	12"		SAME AS ABOVE			CL		0.0			
		3/5			SAME AS ABOVE								
16'		7/7	18"					CL					
					INCREASED SAND CONTENT					0.0			
					WITH DEPTH.								
		7/9			SAME AS ABOVE TO 17.5'			CL		0.0			
18'		13/15	20"										
					WET REDDISH BROWN SILTY, CLAYEY								
					SAND, V. FINE - FINE GRAINED			SC		0.0			
					17.5 - 18.0'								
		3/4			WET REDDISH-BROWN, SILTY,								
20'		4/6	16"		CLAYEY, SAND. V. FINE - FINE			SC		0.0			
					GRAINED.								

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): ____

Remarks: ____

Converted to Well: Yes ____ No ____ Well I.D. #: ____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112IC00998
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)
BORING No.: MW-70B
DATE: 10/16/07
GEOLOGIST: CHARLIE WARLND
DRILLER: PETE HAMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		6/6			SAME AS ABOVE 20.0-21.5			SC		0.0			
22'		9/12	16"										
					MOIST REDDISH-BROWN, SILTY, SANDY,								
					CLAY, MED PLASTICITY, SAND IS			CL		0.0			
					V. FINE-FINE GRAINED 21.5-22.0								
		8/5											
24'		6/10	14"		WET REDDISH-BROWN, SILTY,								
					CLAYEY, SAND. V.-FINE-FINE					0.0			
					GRAINED.			SC					
		10/15											
26	-	22/34	24"		SAME AS ABOVE			SC					
										0.6			
		2/2											
28'		5/6	20"		SAME AS ABOVE			SC					
										11.2			
		5/7											
30'		15/11			SAME AS ABOVE			SC		6.2			

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): ____

Remarks: ____

Converted to Well: Yes ____ No ____ Well I.D. #: ____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112IC00958
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)

BORING No.: MW-72B
DATE: 10/10/07
GEOLOGIST: CHARLIE WARWD
DRILLER: PETE HAMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		20/18			MOIST REDDISH-BROWN SILTY								
16'-18'		11/10	6"		SAND. VI FINE-MED GRAINED								
								SM	0.0				
		4/3			WET REDDISH-BROWN SILTY,								
20		3/3	16"		CLAYEY, SAND. V. FINE TO								
					MED GRAINED.			SC	0.0				
		2/3											
22'		3/4			SAME AS ABOVE.								
			18"		INCREASED CLAY CONTENT			SC	0.0				
					WITH DEPTH								
		7/5											
24'		7/6	0"		NO RECOVERY								
		3/4			WET REDDISH-BROWN SILTY,								
26'		2/2	20"		CLAYEY SAND V. FINE - MED			SC	0.0				
					GRAINED.								

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Remarks:

Drilling Area Background (ppm):

Converted to Well: Yes _____ No _____ Well I.D. #: _____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN [redacted]
PROJECT NUMBER: 112 IC 00598
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)

BORING No.: MW-72B
DATE: 10/10/00
GEOLOGIST: CHARLIE WARWD
DRILLER: PETE HUMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		4 3			WET REDDISH-BROWN TO TAN								
		3 2			SILTY, CLAYEY SAND, V. FINE			SC		0.0			
28'			16"		TO MED SIZED GRAINS.								
		2 2											
		2 2	20"		SAME AS ABOVE			SC		0.0			
30'													
		1 2											
32'		3 4	22"		SAME AS ABOVE								
					INCREASED CLAY			SC		2.5			
					CONTENT WITH DEPTH								
		3 3			MOIST REDDISH BROWN SILTY								
34'		9 13	0"		SANDY CLAY, MED. PLASTICITY,								
					SAND IS V. FINE - FINE GRAINED,			CL		0.1			
					SOME YELLOWISH-BROWN								
					DISCOLORATIONS								

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): [ ]

Remarks: _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112IC00598
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)

BORING No.: MW 608
DATE: 10/8/07
GEOLOGIST: CHARLIE WARING
DRILLER: PETE HAMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
					0.0'- 0.5'		ASPHAULT.						
0-2'		SAMPLED BY HAND			0.5'- 2.0'		GRAVEL / SAND FILL. DRY, BROWN FINE TO MED SAND	SP		0.4			
		9/5			MOIST TAN/GRAY SAND.								
4'		5/3	13"		FINE - MED GRAINED.			SP		0.3			
		10/50/3			SAME AS ABOVE TO 4'8". CONCRETE @ 4'8".			SP					
6'			3"							0.3			
		20/25			MOIST BROWN SILTY, SANDY CLAY. MED PLASTICITY								
8'		10/14	4"		SAND IS VERY FINE - FINE GRAINED			CL		0.7			
		11/9											
10'		11/12	12"		SAME AS ABOVE			CL		0.8			

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Remarks: _____

Drilling Area Background (ppm): _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112L00698
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)
BORING No.: MW-608
DATE: 10/8/07
GEOLOGIST: CHARLIE WARNE
DRILLER: PETE HAMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		7/11			MOIST	BROWN	SILTY, CLAYEY						
12'		11/7	8"		SAND.	VERY	FINE TO	SP		0.4			
					FINE GRAINED.								
		6/3			MOIST	BROWN	SILTY, SANDY,						
14		3/3	14"		CLAY.	MED	PLASTICITY.	SAND IS					
					V. FINE-FINE	GRAINED.	SOME	CL		0.3			
					BLACK	ORGANIC	STAINING.						
		2/5			SAME AS	ABOVE	TO 15.5'	CL					
16'		9/15	12"		MOIST	BROWN	V. FINE-FINE			0.3			
					SILTY,	CLAYEY	SAND TO 16.0'	SP					
		6/9			SAME AS	ABOVE	TO 16.5'	SP					
18'		8/8	18"		16.5'-18.0'	MOIST	REDDISH-BROWN						
					SILTY,	SANDY,	CLAY. MED. PLASTICITY.			0.3			
					SAND IS	V. FINE-	FINE GRAINED						
		3/5											
20'		6/7	16"		SAME AS	ABOVE		CL		0.0			

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): ____

Remarks: ____

Converted to Well: Yes ____ No ____ Well I.D. #: ____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112IC 00998
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)
BORING No.: MW-76B
DATE: 10/4/07
GEOLOGIST: CHARLIE WARING
DRILLER: PETE HAMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		21/18											
	20-~~22~~'	16/24	0"				NO RECOVERY						
		5/8					MOIST BROWNISH-RED						
		8/15					SILTY, SANDY, CLAY. MED						
	24'		16"				PLASTICITY. SAND IS V. FINE	CL		>2000			
							TO FINE GRAINED.						
		6/8					MOIST BROWNISH-RED, SILTY,						
	26'	6/8	14"				SANDY CLAY. MED PLASTICITY						
							SAND IS VERY FINE-FINE	CL		0.0			
							GRAINED. CLAY CONTENT						
							INCREASES WITH DEPTH						
		4/6					MOIST BROWNISH-RED,						
	28'	7/9	16"				SILTY, SANDY CLAY, MED.						
							PLASTICITY. SAND IS VERY	CL		0.0			
							FINE-FINE GRAINED.						
		10/9											
	30'	10/10	16"				SAME AS ABOVE	CL		0.0			

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0.0

Remarks: _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: LOCKHEED MARTIN
PROJECT NUMBER: 112 IC 00998
DRILLING COMPANY: SUMMIT
DRILLING RIG: ATV (HSA)
BORING No.: MW-76B
DATE: 10/4/07
GEOLOGIST: CHARLIE WARWD
DRILLER: PETE HUMPSON

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		5/6											
		7/9			SAME AS ABOVE								
32'			18"					CL		0.0			
		5/9											
34'		11/14	3"		SAME AS ABOVE			CL		0.0			
		6/9			MOIST REDDISH BROWN								
35'			3"		SILTY CLAY. MED PLASTICITY								
					SOME VERY FINE- FINE			CL		0.0			
					GRAINED SAND.								

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0.0

Remarks:

Converted to Well: Yes X No _____ Well I.D. #: MW-76B

SET 2" WELL @ 34'. 10' SCREEN, 24' RISER. SAND TO 22' BGS, BENTONITE TO 19' BGS. GROUT TO 2' BGS.

Appendix B
XRF Results

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Calcium (mg/kg)		Titanium (mg/kg)		Vanadium (mg/kg)		Chromium (mg/kg)		Manganese (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-01	MW-60B-0001	3437.905		5819.667		70.266	U	4.755	U	154.351	
CDM-MR-02	MW-60B-0102	33725.22		5034.796		65.695	U	28.788	U	757.68	
CDM-MR-03	MW-60B-0203	2144.903		6612.306		65.695	U	7.127	U	96.419	
CDM-MR-04	MW-60B-0304	1227.575	U	6748.555		7.209	U	21.103	U	55.141	U
CDM-MR-05	MW-60B-0405	2898.914		5958.576		84.928	U	40	U	23.467	U
CDM-MR-06	MW-60B-0506	1771.524	U	5825.217		31.446	U	38.231	U	106.349	
CDM-MR-07	MW-60B-0607	3066.112		5391.24		106.334	U	9.083	U	279.397	
CDM-MR-08	MW-60B-0708	1514.753	U	5220.802		92.815	U	7.252	U	322.255	
CDM-MR-09	MW-60B-0809	3157.692		5683.705		19.305	U	26.204	U	69.61	U
CDM-MR-10	MW-60B-0910	2661.344		5831.04		68.586	U	35.643	U	128.127	
CDM-MR-11	MW-60B-1011	1072.336	U	5605.183		24.096	U	28.946	U	164.972	
CDM-MR-12	MW-60B-1112	1820.665		5206.456		84.897	U	28.946	U	186.332	
CDM-MR-13	MW-60B-1213	380.344	U	6968.194		28.023	U	41.915	U	313.889	
CDM-MR-14	MW-60B-1314	980.138	U	6511.791		17.216	U	37.114	U	1510.521	
CDM-MR-15	MW-60B-1415	819.433	U	5873.364		22.102	U	42.118	U	105.387	
CDM-MR-16	MW-60B-1516	456.955	U	5288.976		48.795	U	5.21	U	167.774	
CDM-MR-17	MW-60B-1617	0.372	U	4684.54		29.344	U	30.759	U	919.391	
CDM-MR-18	MW-60B-1718	456.955	U	5084.175		65.695	U	38.644	U	430.435	
CDM-MR-19	MW-60B-1819	38.51	U	4809.346		116.61		7.499	U	427.477	
CDM-MR-20	MW-60B-1920	1182.387	U	4547.605		65.607	U	92.729		467.166	
CDM-MR-21	MW-60B-2021	938.868	U	4690.78		29.197	U	28.946	U	585.739	
CDM-MR-22	MW-60B-2122	456.955	U	4421.406		121.784		28.946	U	463.495	
CDM-MR-25	MW-60B-2425	374.518	U	5213.725		35.288	U	39.992	U	330.936	
CDM-MR-26	MW-60B-2526	1329.251	U	5406.479		50.264	U	28.946	U	379.311	
CDM-MR-27	MW-60B-2627	920.288	U	5908.252		160.87		2.164	U	804.912	
CDM-MR-28	MW-60B-2728	334.583	U	5138.916		120.332		28.946	U	1242.818	
CDM-MR-29	MW-60B-2829	722.83	U	5415.937		114.465	U	28.946	U	2104.734	
CDM-MR-30	MW-60B-2930	469.184	U	5153.09		86.489	U	74.047	U	1881.635	
CDM-MR-31	MW-60B-3031	456.955	U	5270.991		86.176	U	14.137	U	707.28	
CDM-MR-32	MW-60B-3132	1563.804	U	4813.61		173.691		28.946	U	2424.662	
CDM-MR-33	MW-70B-0001	2387.884		4738.78		10.875	U	28.946	U	402.201	
CDM-MR-34	MW-70B-0102	187.75	U	5465.055		3.628	U	28.946	U	367.856	
CDM-MR-35	MW-70B-0203	1063.163	U	2575.673		65.103	U	28.946	U	253.151	
CDM-MR-36	MW-70B-0304	1824.094		4081.456		51.812	U	28.946	U	391.864	
CDM-MR-37	MW-70B-0405	456.955	U	5682.705		24.984	U	1.726	U	181.528	

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Calcium (mg/kg)		Titanium (mg/kg)		Vanadium (mg/kg)		Chromium (mg/kg)		Manganese (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-38	MW-70B-0506	1308.686	U	6305.069		109.812		20.419	U	198.18	
CDM-MR-39	MW-70B-0607	1037.51	U	6408.221		17.87	U	2.017	U	238.37	
CDM-MR-40	MW-70B-0708	456.955	U	6313.349		54.741	U	28.946	U	189.285	
CDM-MR-41	MW-70B-0809	456.955	U	5910.968		13.715	U	39.297	U	84.198	U
CDM-MR-42	MW-70B-0910	238.719	U	6399.322		65.695	U	54.601	U	143.704	
CDM-MR-43	MW-70B-1011	382.653	U	6465.235		69.983	U	64.843		398.575	
CDM-MR-44	MW-70B-1112	918.568	U	6543.278		65.695	U	28.946	U	281.959	
CDM-MR-45	MW-70B-1213	1719.329	U	6210.603		78.848	U	28.946	U	247.719	
CDM-MR-46	MW-70B-1314	1289.819	U	6242.889		54.768	U	51.072	U	392.378	
CDM-MR-47	MW-70B-1415	632.577	U	5193.878		65.695	U	18.943	U	195.675	
CDM-MR-48	MW-70B-1516	288.494	U	5287.695		40.65	U	50.76	U	345.581	
CDM-MR-49	MW-70B-1617	1414.142	U	5865.564		77.212	U	8.733	U	274.698	
CDM-MR-50	MW-70B-1718	645.34	U	6078.926		35.356	U	28.946	U	299.37	
CDM-MR-51	MW-70B-1819	354.708	U	6911.015		29.644	U	18.256	U	329.145	
CDM-MR-52	MW-70B-1920	902.415	U	6036.339		44.699	U	19.003	U	232.638	
CDM-MR-53	MW-70B-2021	97.898	U	5963.951		64.258	U	28.946	U	241.023	
CDM-MR-54	MW-70B-2122	356.505	U	6286.396		22.445	U	80.153		127.106	
CDM-MR-55	MW-70B-2223	1782.133		6489.003		2.972	U	14.504	U	60.502	U
CDM-MR-56	MW-70B-2324	456.955	U	6350.07		55.664	U	9.327	U	164.048	
CDM-MR-57	MW-70B-2425	1060.926	U	4955.75		65.695	U	14.753	U	187.021	
CDM-MR-58	MW-70B-2526	45.1	U	3552.31		89.245	U	39.278	U	36.519	U
CDM-MR-59	MW-70B-2627	59.45	U	4076.378		47.914	U	28.946	U	109.981	
CDM-MR-60	MW-70B-2728	343.535	U	3197.385		11.406	U	2.138	U	87.609	
CDM-MR-61	MW-70B-2829	456.955	U	4817.377		66.854	U	28.946	U	181.336	
CDM-MR-62	MW-70B-2930	1097.458	U	4276.194		127.454		21.186	U	30.156	U
CDM-MR-63	MW-72B-1617	2349.066		3839.751		47.025	U	44.679	U	104.386	U
CDM-MR-64	MW-72B-1718	1131.845	U	4123.944		121.104		13.903	U	190.175	
CDM-MR-65	MW-72B-1819	618.572	U	4732.121		62.732	U	72.796		106.163	
CDM-MR-66	MW-72B-1920	456.955	U	4415.494		24.102	U	29.902	U	143.662	
CDM-MR-67	MW-72B-2021	2493.799		5346.861		65.695	U	32.351	U	260.051	
CDM-MR-68	MW-72B-2122	1876.669		5740.357		49.569	U	25.15	U	181.465	
CDM-MR-69	MW-72B-2223	672.278	U	5623.252		114.346		7.2	U	110.477	
CDM-MR-70	MW-72B-2324	1763.854		4978.063		94.808	U	30.079	U	176.34	
CDM-MR-71	MW-72B-2425	593.993	U	4634.977		56.191	U	4.941	U	394.511	
CDM-MR-72	MW-72B-2526	450.852	U	3223.187		40.629	U	28.946	U	125.133	

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Calcium (mg/kg)		Titanium (mg/kg)		Vanadium (mg/kg)		Chromium (mg/kg)		Manganese (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-73	MW-72B-2627	1663.592	U	5525.937		65.695	U	60.316	U	162.695	
CDM-MR-74	MW-72B-2728	2654.284		4347.285		65.695	U	25.357	U	182.45	
CDM-MR-74	MW-72B-2829	941.525	U	2553.019		24.776	U	4.548	U	204.216	
CDM-MR-76	MW-72B-2930	728.461	U	3780.406		105.255		28.946	U	129.177	
CDM-MR-77	MW-72B-3031	456.955	U	4664.81		22.462	U	25.577	U	267.814	
CDM-MR-78	MW-72B-3132	802.216	U	5045.861		45.833	U	16.294	U	545.469	
CDM-MR-79	MW-72B-3233	296.29	U	4630.788		164.724		28.946	U	223.253	
CDM-MR-80	MW-72B-3334	456.955	U	4918.366		104.996	U	19.059	U	151.96	
CDM-MR-81	MW-75A-0203	2148.493		5727.638		96.025	U	28.946	U	175.542	
CDM-MR-82	MW-75A-0304	1883.503		5919.041		74.256	U	52.981	U	249.118	
CDM-MR-83	MW-75A-0405	1828.614		6014.268		48.957	U	28.946	U	242.292	
CDM-MR-84	MW-75A-0506	4635.127		6111.629		76.715	U	3.272	U	237.015	
CDM-MR-85	MW-75A-0607	2462.638		6018.039		29.613	U	28.946	U	218.402	
CDM-MR-86	MW-75A-0708	904.177	U	5868.084		68.459	U	33.594	U	203.445	
CDM-MR-87	MW-75A-0809	1164.733	U	5032.729		50.143	U	28.946	U	232.338	
CDM-MR-88	MW-75A-0910	710.489	U	4814.029		72.004	U	28.946	U	210.336	
CDM-MR-89	MW-75A-1011	12645.69		6260.665		101.778	U	8.389	U	957.02	
CDM-MR-90	MW-75A-1112	14495.17		5659.722		129.336		35.972	U	808.618	
CDM-MR-91	MW-75A-1213	14958.82		6725.645		0.058	U	31.917	U	1004.962	
CDM-MR-92	MW-75A-1314	10418.08		6064.34		17.401	U	90.723		601.102	
CDM-MR-93	MW-75A-1415	4379.817		5771.949		13.469	U	49.351	U	473.791	
CDM-MR-94	MW-75A-1516	12603.41		5795.353		41.894	U	26.287	U	635.675	
CDM-MR-95	MW-75A-1617	654.26	U	6020.396		151.794		73.891		286.044	
CDM-MR-96	MW-75A-1718	554.862	U	5482.612		102.002	U	15.355	U	226.786	
CDM-MR-97	MW-75A-1819	456.955	U	5844.04		44.021	U	23.935	U	274.826	
CDM-MR-99	MW-75A-1920	324.648	U	5339.715		183.784		14.62	U	321.739	
CDM-MRR-98	MW-75A-2021	833.627	U	5868.158		65.001	U	54.114	U	197.331	
CDM-MR-100	MW-75A-2122	773.325	U	6453.998		95.536	U	28.946	U	340.904	
CDM-MR-101	MW-75A-2223	456.955	U	6248.584		116.92	U	70.233	U	319.538	
CDM-MR-102	MW-75A-2324	456.955	U	5891.386		89.561	U	28.946	U	474.355	
CDM-MR-103	MW-76B-2627	547.52	U	6155.184		42.215	U	74.938	U	631.183	
CDM-MR-104	MW-76B-2728	456.955	U	5142.13		72.164	U	28.946	U	643.8	
CDM-MR-105	MW-76B-2829	3132.616		5981.402		42.054	U	42.883	U	1725.051	
CDM-MR-106	MW-76B-2930	688.789	U	5828.512		65.695	U	26.642	U	788.488	
CDM-MR-107	MW-76B-3031	30.635	U	5208.454		133.512		28.946	U	310.175	

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Calcium (mg/kg)		Titanium (mg/kg)		Vanadium (mg/kg)		Chromium (mg/kg)		Manganese (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-108	MW-76B-3132	456.955	U	5554.777		86.225	U	21.894	U	212.012	
CDM-MR-109	MW-76B-3233	3833.528		6181.211		65.695	U	42.553	U	657.22	
CDM-MR-110	MW-76B-3334	3807.354		4950.742		65.695	U	9.142	U	686.056	
CDM-MR-111	MW-76B-3435	1093.284	U	6373.537		18.853	U	28.946	U	786.369	

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Iron (mg/kg)		Nickel (mg/kg)		Copper (mg/kg)		Zinc (mg/kg)		Arsenic (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-01	MW-60B-0001	4444.792		11.569		19.907		17.412		7.48	
CDM-MR-02	MW-60B-0102	36920.81		4.261	U	33.618		29.635		1.071	U
CDM-MR-03	MW-60B-0203	3841.925		3.438	U	23.869		11.263		4.349	
CDM-MR-04	MW-60B-0304	4868.051		2.84	U	13.963	U	9.059	U	4.658	
CDM-MR-05	MW-60B-0405	6990.862		5.334	U	18.473		8.233	U	1.071	U
CDM-MR-06	MW-60B-0506	7628.295		6.736	U	18.058		6.423	U	1.071	U
CDM-MR-07	MW-60B-0607	32323.41		19.624		54.848		92.125		1.071	U
CDM-MR-08	MW-60B-0708	21580.84		17.301		34.502		84.315		1.808	U
CDM-MR-09	MW-60B-0809	26203.94		13.455		20.995		41.191		3.176	
CDM-MR-10	MW-60B-0910	25245.37		12.932		27.238		41.845		4.128	
CDM-MR-11	MW-60B-1011	18790.18		8.998		13.943	U	18.818		0.003	U
CDM-MR-12	MW-60B-1112	16901.19		8.476		11.005	U	29.928		1.071	U
CDM-MR-13	MW-60B-1213	24694.43		13.721		22.822		92.379		3.06	U
CDM-MR-14	MW-60B-1314	30313.72		16.869		19.856		86.066		1.071	U
CDM-MR-15	MW-60B-1415	14980.44		14.668		32.175		33.865		6.896	
CDM-MR-16	MW-60B-1516	20441.81		5.997	U	26.128		55.567		3.555	
CDM-MR-17	MW-60B-1617	38385.29		21.699		32.823		72.415		1.739	U
CDM-MR-18	MW-60B-1718	32976.48		22.465		24.334		63.144		1.071	U
CDM-MR-19	MW-60B-1819	39288.25		17.82		37.556		62.492		2.708	U
CDM-MR-20	MW-60B-1920	40365.97		19.329		24.05		76.948		2.118	U
CDM-MR-21	MW-60B-2021	43376.38		21.842		27.597		84.53		1.071	U
CDM-MR-22	MW-60B-2122	48654.78		22.117		19.285		72.096		3.537	
CDM-MR-25	MW-60B-2425	37353.29		18.263		22.501		35.151		3.228	
CDM-MR-26	MW-60B-2526	34051.32		13.893		41.087		41.568		1.071	U
CDM-MR-27	MW-60B-2627	51342.93		17.295		31.623		62.625		1.071	U
CDM-MR-28	MW-60B-2728	62139.45		25.14		16.911	U	60.087		4.616	
CDM-MR-29	MW-60B-2829	87579.25		7.794	U	31.152		86.344		1.071	U
CDM-MR-30	MW-60B-2930	81363.69		17.356		24.936		77.977		2.901	U
CDM-MR-31	MW-60B-3031	36402.3		13.011		17.375	U	33.256		4.429	
CDM-MR-32	MW-60B-3132	99901.6		9.915	U	20.9	U	81.469		2.059	U
CDM-MR-33	MW-70B-0001	28854.98		11.931		30.692		80.266		1.071	U
CDM-MR-34	MW-70B-0102	26351.01		5.63	U	42.722		98.899		1.071	U
CDM-MR-35	MW-70B-0203	25421.69		14.546		22.336		25.509		5.383	
CDM-MR-36	MW-70B-0304	31996.52		8.945		24.356		29.417		8.272	
CDM-MR-37	MW-70B-0405	41297.13		11.633		21.207		25.711		0.883	U

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Iron (mg/kg)		Nickel (mg/kg)		Copper (mg/kg)		Zinc (mg/kg)		Arsenic (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-38	MW-70B-0506	22191.7		12.358		18.191		14.076		1.071	U
CDM-MR-39	MW-70B-0607	37829.25		6.988	U	36.938		14.878		1.071	U
CDM-MR-40	MW-70B-0708	46383		9.179		28.487		7.135	U	7.921	
CDM-MR-41	MW-70B-0809	13504.87		12.261		11.207	U	38.12		2.636	U
CDM-MR-42	MW-70B-0910	18859.88		30.179		36.897		55.465		1.071	U
CDM-MR-43	MW-70B-1011	27846.37		15.858		29.894		39.662		1.071	U
CDM-MR-44	MW-70B-1112	22778.39		21.254		38.97		46.825		6.33	
CDM-MR-45	MW-70B-1213	28689.17		12.401		24.132		38.46		2.779	U
CDM-MR-46	MW-70B-1314	55292.25		19.813		33.687		60.67		11.537	
CDM-MR-47	MW-70B-1415	30798.13		15.296		22.366		36.678		2.223	U
CDM-MR-48	MW-70B-1516	49216.44		19.839		15.947	U	58.734		10.067	
CDM-MR-49	MW-70B-1617	42170.26		20.816		38.909		43.223		7.888	
CDM-MR-50	MW-70B-1718	42960.15		18.49		9.055	U	45.636		1.071	U
CDM-MR-51	MW-70B-1819	36308.67		4.196	U	30.571		26.213		2.195	U
CDM-MR-52	MW-70B-1920	31462.23		9.358		25.652		37.447		1.071	U
CDM-MR-53	MW-70B-2021	34463.41		15.458		32.896		29.993		1.446	U
CDM-MR-54	MW-70B-2122	34628.49		9.55		28.013		36.343		1.071	U
CDM-MR-55	MW-70B-2223	23420.32		15.65		19.113		53.996		2.017	U
CDM-MR-56	MW-70B-2324	19097.91		12.924		20.846		30.177		2.589	U
CDM-MR-57	MW-70B-2425	11364.87		2.404	U	23.723		41.293		2.271	U
CDM-MR-58	MW-70B-2526	8151.909		10.901		11.991	U	49.073		2.279	U
CDM-MR-59	MW-70B-2627	9614.74		5.072	U	11.616	U	18.631		2.39	
CDM-MR-60	MW-70B-2728	8343.491		4.071	U	8.897	U	16.741		1.071	U
CDM-MR-61	MW-70B-2829	8892.746		0.847	U	12.792	U	7.825	U	1.47	U
CDM-MR-62	MW-70B-2930	8117.979		7.869		36.899		12.39		1.071	U
CDM-MR-63	MW-72B-1617	26727.6		8.838		5.811	U	15.133		1.071	U
CDM-MR-64	MW-72B-1718	30997.65		11.877		23.525		27.838		1.071	U
CDM-MR-65	MW-72B-1819	16476.66		10.298		19.663		31.67		1.071	U
CDM-MR-66	MW-72B-1920	17212.2		10.256		19.516		12.776		1.071	U
CDM-MR-67	MW-72B-2021	22160.17		5.277	U	15.454	U	23.984		1.071	U
CDM-MR-68	MW-72B-2122	22800.6		7.618		15.012	U	36.817		0.512	U
CDM-MR-69	MW-72B-2223	24298.85		15.251		18.884		25.559		2.269	U
CDM-MR-70	MW-72B-2324	21263.84		12.007		21.343		22.19		1.071	U
CDM-MR-71	MW-72B-2425	25245.26		13.372		31.331		18.057		1.558	U
CDM-MR-72	MW-72B-2526	6888.25				11.887	U	8.249	U	0.733	U

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Iron (mg/kg)		Nickel (mg/kg)		Copper (mg/kg)		Zinc (mg/kg)		Arsenic (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-73	MW-72B-2627	23204.09		15.046		15.48	U	50.168		7.436	
CDM-MR-74	MW-72B-2728	13910.55		4.27	U	8.55	U	43.213		7.565	
CDM-MR-74	MW-72B-2829	12456.09		7.169		9.79	U	6.431	U	1.071	U
CDM-MR-76	MW-72B-2930	14957.63		8.346		4.837	U	15.582		2.134	U
CDM-MR-77	MW-72B-3031	29095.53		9.975		25.459		20.419		1.963	U
CDM-MR-78	MW-72B-3132	84787.95		15.575		49.446		51.556		3.222	U
CDM-MR-79	MW-72B-3233	68116.75		15.139		24.777		56.981		1.071	U
CDM-MR-80	MW-72B-3334	41184.49		10.816		28.564		40.419		6.249	
CDM-MR-81	MW-75A-0203	24363.83		8.864		23.147		34.561		5.194	
CDM-MR-82	MW-75A-0304	28869.69		20.575		36.524		47.28		1.071	U
CDM-MR-83	MW-75A-0405	23943.27		13.56		33.673		35.521		1.071	U
CDM-MR-84	MW-75A-0506	22061.82		17.689		25.804		23.357		2.478	U
CDM-MR-85	MW-75A-0607	22147.48		12.99		16.862	U	39.478		1.071	U
CDM-MR-86	MW-75A-0708	23172.03		10.012		38.73		28.965		4.855	
CDM-MR-87	MW-75A-0809	21963.52		7.372	U	23.06		38.517		5.772	
CDM-MR-88	MW-75A-0910	16549.2		4.976	U	10.919	U	29.152		0.52	U
CDM-MR-89	MW-75A-1011	22333.96		3.445	U	42.764		47.073		1.071	U
CDM-MR-90	MW-75A-1112	20101.54		15.628		15.168	U	51.595		6.249	
CDM-MR-91	MW-75A-1213	23495.75		8.404		17.067		50.051		4.186	
CDM-MR-92	MW-75A-1314	21977.82		5.373	U	36.799		41.183		0.44	U
CDM-MR-93	MW-75A-1415	51880.01		25.473		49.221		57.45		9.988	
CDM-MR-94	MW-75A-1516	30959.98		16.612		29.29		53.548		2.713	U
CDM-MR-95	MW-75A-1617	51085.57		22.823		26.578		54.757		6.015	
CDM-MR-96	MW-75A-1718	51970.37		22.912		23.613		59.294		4.961	
CDM-MR-97	MW-75A-1819	53633.4		26.984		26.533		66.562		1.071	U
CDM-MR-99	MW-75A-1920	52032.4		22.006		49.465		80.595		6.437	
CDM-MRR-98	MW-75A-2021	42721.79		20.908		20.926		49.28		1.071	U
CDM-MR-100	MW-75A-2122	53462.96		19.497		44.269		65.567		6.164	
CDM-MR-101	MW-75A-2223	82131.08		32.454		64.748		109.201		5.561	
CDM-MR-102	MW-75A-2324	96960.64		39.123		52.691		153.361		13.352	
CDM-MR-103	MW-76B-2627	52580.26		29.556		8.073	U	95.725		7.357	
CDM-MR-104	MW-76B-2728	53909.02		23.36		33.902		92.851		6.167	
CDM-MR-105	MW-76B-2829	78355.88		9.876	U	30.156		84.636		0.537	U
CDM-MR-106	MW-76B-2930	51659.54		8.276	U	36.796		44.399		1.071	U
CDM-MR-107	MW-76B-3031	24004.02		14.903		27.447		37.212		1.071	U

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Iron (mg/kg)		Nickel (mg/kg)		Copper (mg/kg)		Zinc (mg/kg)		Arsenic (mg/kg)	
		Result	Detect	Result	Detect	Result	Detect	Result	Detect	Result	Detect
CDM-MR-108	MW-76B-3132	23878.12		12.349		29.26		41.986		4.135	
CDM-MR-109	MW-76B-3233	42395.66		11.181		34.964		62.761		8.518	
CDM-MR-110	MW-76B-3334	44877.7		7.972	U	24.201		97.194		1.071	U
CDM-MR-111	MW-76B-3435	43315.29		23.341		26.168		64.162		1.071	U

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Lead (mg/kg)		Cobalt (mg/kg)	
		Result	Detect	Result	Detect
CDM-MR-01	MW-60B-0001	6.778	U	1.577	U
CDM-MR-02	MW-60B-0102	18.322		8.905	
CDM-MR-03	MW-60B-0203	19.237		1.675	U
CDM-MR-04	MW-60B-0304	9.239		0.609	U
CDM-MR-05	MW-60B-0405	5.811	U	3.122	
CDM-MR-06	MW-60B-0506	10.597		1.786	U
CDM-MR-07	MW-60B-0607	15.303		8.886	
CDM-MR-08	MW-60B-0708	13.882		7.183	
CDM-MR-09	MW-60B-0809	16.824		9.4	
CDM-MR-10	MW-60B-0910	14.664		7.227	
CDM-MR-11	MW-60B-1011	14.19		6.567	
CDM-MR-12	MW-60B-1112	4.546	U	3.922	
CDM-MR-13	MW-60B-1213	20.125		5.208	
CDM-MR-14	MW-60B-1314	19.775		9.441	
CDM-MR-15	MW-60B-1415	14.036		3.175	
CDM-MR-16	MW-60B-1516	5.661	U	6.366	
CDM-MR-17	MW-60B-1617	6.922	U	8.042	
CDM-MR-18	MW-60B-1718	8.283		10.845	
CDM-MR-19	MW-60B-1819	9.793		10.001	
CDM-MR-20	MW-60B-1920	8.736		9.8	
CDM-MR-21	MW-60B-2021	13.672		8.054	
CDM-MR-22	MW-60B-2122	12.396		8.163	
CDM-MR-25	MW-60B-2425	14.696		5.27	
CDM-MR-26	MW-60B-2526	8.179		6.131	
CDM-MR-27	MW-60B-2627	11.415		11.846	
CDM-MR-28	MW-60B-2728	9.647		12.227	
CDM-MR-29	MW-60B-2829	4.821	U	12.003	
CDM-MR-30	MW-60B-2930	3.971	U	10.639	
CDM-MR-31	MW-60B-3031	7.828		5.513	
CDM-MR-32	MW-60B-3132	9.318		12.503	
CDM-MR-33	MW-70B-0001	36.431		8.21	
CDM-MR-34	MW-70B-0102	47.445		5.432	
CDM-MR-35	MW-70B-0203	9.538		6.69	
CDM-MR-36	MW-70B-0304	14.35		11.172	
CDM-MR-37	MW-70B-0405	13.584		9.029	

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Lead (mg/kg)		Cobalt (mg/kg)	
		Result	Detect	Result	Detect
CDM-MR-38	MW-70B-0506	20.684		7.127	
CDM-MR-39	MW-70B-0607	12.977		8.778	
CDM-MR-40	MW-70B-0708	12.608		11.679	
CDM-MR-41	MW-70B-0809	14.526		2.75	U
CDM-MR-42	MW-70B-0910	15.675		7.174	
CDM-MR-43	MW-70B-1011	14.492		7.33	
CDM-MR-44	MW-70B-1112	10.731		5.483	
CDM-MR-45	MW-70B-1213	20.144		6.209	
CDM-MR-46	MW-70B-1314	20.733		10.618	
CDM-MR-47	MW-70B-1415	14.978		8.132	
CDM-MR-48	MW-70B-1516	11.586		9.847	
CDM-MR-49	MW-70B-1617	14.515		10.75	
CDM-MR-50	MW-70B-1718	7.814	U	11.908	
CDM-MR-51	MW-70B-1819	16.222		9.877	
CDM-MR-52	MW-70B-1920	20.157		5.709	
CDM-MR-53	MW-70B-2021	23.192		8.748	
CDM-MR-54	MW-70B-2122	10.39		9.412	
CDM-MR-55	MW-70B-2223	8.365		6.642	
CDM-MR-56	MW-70B-2324	9.563		3.761	
CDM-MR-57	MW-70B-2425	8.241		2.289	U
CDM-MR-58	MW-70B-2526	6.982		3.612	
CDM-MR-59	MW-70B-2627	4.819	U	2.307	U
CDM-MR-60	MW-70B-2728	11.673		2.008	U
CDM-MR-61	MW-70B-2829	2.519	U	3.446	
CDM-MR-62	MW-70B-2930	2.991	U	0.818	U
CDM-MR-63	MW-72B-1617	12.184		6.425	
CDM-MR-64	MW-72B-1718	4.616	U	8.804	
CDM-MR-65	MW-72B-1819	10.246		7.635	
CDM-MR-66	MW-72B-1920	13.856		4.749	
CDM-MR-67	MW-72B-2021	13.221		6.848	
CDM-MR-68	MW-72B-2122	5.066	U	7.806	
CDM-MR-69	MW-72B-2223	10.281		6.945	
CDM-MR-70	MW-72B-2324	18.952		7.112	
CDM-MR-71	MW-72B-2425	11.049		9.624	
CDM-MR-72	MW-72B-2526	3.433	U	3.16	

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Lead (mg/kg)		Cobalt (mg/kg)	
		Result	Detect	Result	Detect
CDM-MR-73	MW-72B-2627	25.647		6.655	
CDM-MR-74	MW-72B-2728	23.227		1.342	U
CDM-MR-74	MW-72B-2829	6.705		4.806	
CDM-MR-76	MW-72B-2930	6.903		3.734	
CDM-MR-77	MW-72B-3031	7.239		7.299	
CDM-MR-78	MW-72B-3132	9.146	U	16.517	
CDM-MR-79	MW-72B-3233	9.647		12.643	
CDM-MR-80	MW-72B-3334	30.903		8.616	
CDM-MR-81	MW-75A-0203	14.307		8.299	
CDM-MR-82	MW-75A-0304	16.954		7.104	
CDM-MR-83	MW-75A-0405	10.079		7.343	
CDM-MR-84	MW-75A-0506	11.71		6.252	
CDM-MR-85	MW-75A-0607	14.821		7.499	
CDM-MR-86	MW-75A-0708	15.037		7.874	
CDM-MR-87	MW-75A-0809	2.781	U	3.5	U
CDM-MR-88	MW-75A-0910	9.397		3.791	
CDM-MR-89	MW-75A-1011	26.116		4.044	
CDM-MR-90	MW-75A-1112	18.919		6.964	
CDM-MR-91	MW-75A-1213	19.815		7.02	
CDM-MR-92	MW-75A-1314	14.128		6.611	
CDM-MR-93	MW-75A-1415	18.465		12.053	
CDM-MR-94	MW-75A-1516	18.12		9.703	
CDM-MR-95	MW-75A-1617	16.379		8.131	
CDM-MR-96	MW-75A-1718	20.61		12.671	
CDM-MR-97	MW-75A-1819	24.832		12.239	
CDM-MR-99	MW-75A-1920	18.827		11.801	
CDM-MRR-98	MW-75A-2021	19.874		7.497	
CDM-MR-100	MW-75A-2122	29.268		7.804	
CDM-MR-101	MW-75A-2223	47.741		13.126	
CDM-MR-102	MW-75A-2324	42.296		13.504	
CDM-MR-103	MW-76B-2627	3.584	U	11.615	
CDM-MR-104	MW-76B-2728	17.931		10.685	
CDM-MR-105	MW-76B-2829	15.19		13.854	
CDM-MR-106	MW-76B-2930	10.973		8.825	
CDM-MR-107	MW-76B-3031	8.476		5.007	

Appendix B
XRF Results

CDM Sample ID	Sample IDs	Lead (mg/kg)		Cobalt (mg/kg)	
		Result	Detect	Result	Detect
CDM-MR-108	MW-76B-3132	6.241	U	5.069	
CDM-MR-109	MW-76B-3233	19.239		7.315	
CDM-MR-110	MW-76B-3334	8.891		9.306	
CDM-MR-111	MW-76B-3435	13.568		8.836	

Appendix C
Complete Data Sheets From Leaching Tests

Appendix C
Complete Data Sheets From leaching Study

Well Sample #	Sample ID	Soil Mass (g) 1/23/2008	Water Mass (g) 1/23/2008	Initial Eh 1/23/2008	Initial pH 1/23/2008	Adjusted pH 1/23/2008	Initial pH 1/25/2008	Adjusted pH 1/25/2008	Final pH 1/28/2008	Final Eh 1/28/2008
MW-60B-0607	CDM-MR-07-4	9.1	38	440	6.76	4.03	7.06	4.11	6.13	N/A
	CDM-MR-07-5	9.7	40	438.6	6.69	5.09	7.45	5.05	6.68	300.1
	CDM-MR-07-6	9.7	40.8	429.3	6.57	6.03	7.35	5.97	7.19	291
	CDM-MR-07-7	9.8	42.1	425.3	6.38	7	7.53	6.96	7.8	360.4
MW-60B-2021	CDM-MR-21-4	25.5	101.6	416	9.16	4.05	4.11	N/A	4.11	333.6
	CDM-MR-21-5	27.7	101	302.4	5.17	4.97	4.45	5.04	5.28	332.9
	CDM-MR-21-6	25.3	102.6	370.8	4.83	5.99	4.85	6.07	6.65	328.1
	CDM-MR-21-7	26.3	100.7	416.2	4.96	4.1	4.45	7.06	6.9	305.2
MW-70B-1112	CDM-MR-44-4	25.2	106.5	463	4.06	N/A	4.07	N/A	4.07	476.6
	CDM-MR-44-5	25.4	106.9	463.2	4.07	5.12	3.86	4.99	5.22	388.5
	CDM-MR-44-6	25.1	101.8	468	3.87	6.03	4.16	5.96	5.94	313.8
	CDM-MR-44-7	25.7	101.5	478	3.87	7	5.09	6.98	6.63	280.5
MW-70B-2021	CDM-MR-53-4	25.9	100.5	439.3	4.65	3.9	3.49	3.96	4.38	420.1
	CDM-MR-53-4 Dup	26.6	106.7	485.3	4.21	4.06	3.74	3.99	4.52	393.5
	CDM-MR-53-5	25.2	103.4	450.9	4.24	5.01	4.26	5.1	5.18	387.7
	CDM-MR-53-6	25.4	100.6	454.6	4.3	5.93	4.02	5.95	5.87	336.7
	CDM-MR-53-7	25.4	100.8	465	4.35	6.93	5.18	6.97	6.93	297
MW-70B-2526	CDM-MR-58-4	25	101.8	513.6	3.69	4.17	4.08	N/A	4.08	455.8
	CDM-MR-58-5	25.4	101.5	506.9	3.87	4.97	4.73	4.98	5.34	349.3
	CDM-MR-58-6	27.3	102.2	515.6	3.75	6.17	4.02	6.04	6.28	314
	CDM-MR-58-7	25.4	109.2	499	3.82	7.13	5.56	6.98	6.77	341
	CDM-MR-58-7 Dup	25.5	101.4	485.3	3.95	6.98	5.56	7.02	6.73	294
MW-72B-1718	CDM-MR-64-4	27.1	100.8	450.4	6.27	4.06	5.05	4.11	5	371.3
	CDM-MR-64-5	25.1	104.5	446.5	6.3	5.02	5.71	5.06	5.82	357.4
	CDM-MR-64-6	25.1	101.2	465.9	6.19	N/A	6.38	5.97	7.81	299.1
	CDM-MR-64-7	26.4	101.1	461.4	6.3	6.84	5.52	6.96	7.23	269.9
MW-72B-3233	CDM-MR-79-4	25.2	101.9	437.1	4.97	3.81	4.1	N/A	4.1	395.2
	CDM-MR-79-5	25.6	104	447.2	4.77	4.89	4.46	4.95	5.42	339
	CDM-MR-79-6	25.1	101	449.7	4.5	5.82	4.68	5.96	6.15	332.5
	CDM-MR-79-7	37.5	150	447.6	5	6.9	5.44	6.91	6.94	320.4
MW-75A-1415	CDM-MR-93-4	25.6	103.6	449.5	6.13	4.01	6.55	3.98	5.92	263.3
	CDM-MR-93-5	25.8	103.5	450.8	6.11	4.89	6.71	4.97	6.5	244.7
	CDM-MR-93-6	25.5	102.2	444.1	6.1	N/A	6.94	5.96	6.98	247.7
	CDM-MR-93-7	25.6	100.5	445.5	6.18	7.19	7.12	N/A	7.12	179.1
MW-75A-2223	CDM-MR-101-4	11.8	47.8	452.5	4.72	4.1	4.16	N/A	4.16	402.2
	CDM-MR-101-5	12.1	47.9	444.3	4.9	N/A	4.85	4.93	5.25	366004
	CDM-MR-101-6	13	49.5	454.4	4.63	5.97	4.86	5.92	6.15	334.1
	CDM-MR-101-7	12.1	48.7	453.8	4.7	7	5.3	7.05	7	312.1
MW-76B-2728	CDM-MR-104-4	26.8	101.3	430.2	5.02	4.02	4.27	3.98	4.84	389.3
	CDM-MR-104-5	25.5	101.3	442.2	4.77	4.9	5.06	N/A	5.06	351.5
	CDM-MR-104-6	25.5	100.4	443.6	4.68	5.83	5.11	5.96	6.1	328.1
	CDM-MR-104-7	25.5	102.2	444.8	4.88	7.02	5.57	7.01	6.9	316.8
Blank		26.8	103	188.9	10.19	4.11	8.07	4.08	5.75	422.3

Appendix D
Back-Up for Site Remediation Considerations

TABLE 1

IN-SITU CHEMICAL OXIDATION PILOT STUDY DATA
LOCKHEED MARTIN MIDDLE RIVER COMPLEX, MIDDLE RIVER, MARYLAND

Observation Well	Sampling Round	TCE µg/L	DCE µg/L	VC µg/L	1,4-Dioxane µg/L	Beryllium µg/L	Cobalt µg/L	Nickel µg/L	pH S.U.	ORP mV	DO ppm
OW4S	Baseline	ND	ND	ND	ND	ND	7.3	6.6	6.14	12	0.00
	Round 1	14	5.1	ND	3.3				5.58	248	12.01
	Round 2	1.7	2.1	ND	ND				5.80	54	0.00
	Round 3	1.5	0.63	ND	ND	0.12	48.5	17.5	4.72	6	4.73
	% Reduction	Increase	Increase	No Change	No Change						
OW4I	Baseline	1520	399	2	100	5.4	66.8	116	5.62	15	0.00
	Round 1	790	200	ND	56				5.51	20	0.31
	Round 2	600	160	ND	70				5.50	14	0.00
	Round 3	630	180	ND	71	12.3	93.3	180	4.33	10	4.73
	% Reduction	59%	55%	Complete	29%						
OW5S	Baseline	3	3	ND	ND	1.4	110	24.6	5.95	67	0.00
	Round 1	10	0.92	ND	2				2.84	490	19.99
	Round 2	3.7	2	ND	ND				5.40	279	1.70
	Round 3	1.6	1.8	ND	ND	2.2	61.9	22.5	4.57	63	4.94
	% Reduction	47%	40%	No Change	No Change						
OW5I	Baseline	268	68	1	87	0.9 J	47.5	44.8	5.82	4	0.11
	Round 1										
	Round 2										
	Round 3										
	% Reduction										
OW6S	Baseline	2	1.4	ND	0.8	1.2	46.9	22.5	5.78	76	0.00
	Round 1	ND	ND	ND	ND				2.32	652	19.99
	Round 2	3	2	ND	ND				2.88	487	15.67
	Round 3	3.4	3.4	ND	ND	4.5	105	40.5	3.92	311	7.00
	% Reduction	Increase	Increase	No Change	Complete						
OW6I	Baseline	832	166	1	166	ND	28.3	41.2	5.22	-12	2.25
	Round 1	30	4.1	ND	6.9				2.46	660	19.99
	Round 2	540	100	ND	42				4.65	184	6.17
	Round 3	720	140	ND	44	0.42	141	201	4.32	66	5.93
	% Reduction	14%	16%	No Change	73%						
MW14B	Baseline	3300	ND	ND	158	1.8	49.4	109	5.35	123	0.00
	Round 1	210	3.1	ND	4.2	290	1020	1880	2.36	705	19.99
	Round 2	230	4.2	ND	19				2.60	647	0.72
	Round 3	2300	47	ND	120	54	180	412	2.91	406	4.03
	% Reduction	30%	Increase	No Change	24%						

TCE - Trichloroethene
DCE - cis-1,2-Dichloroethene
VC - Vinyl Chloride
ORP - Oxidation Reduction Potential
DO - Dissolved Oxygen
µg/L - Micrograms per Liter
S.U. - Standard Units
mV - millivolts
ppm - Parts per Million

MRC-MW03A 24.23
MRC-MW01A 20.14
MRC-MW02A 20.84
MRC-MW05A 21.85
MRC-MW06A 18.08
MRC-MW68A 20.04
MRC-MW67A 15.70
MRC-MW49A 19.25
EXT-MW04 NM
MRC-MW50A 16.32
MRC-MW51A 18.20
MRC-MW75A 19.16
MRC-MW52A 15.44
MRC-MW41A 18.83
MRC-MW69A 16.68
MRC-MW53A 14.49
MRC-MW64A 24.60
MRC-MW17A 27.35
MRC-MW08A 11.46
MRC-MW54A 14.68
MRC-MW18A 28.60
MRC-MW58A 28.28
MRC-MW19A 30.64
MRC-MW20A 26.35
MRC-MW07A NM
MRC-MW16A 18.89
MRC-MW09A 5.87
MRC-MW80A 25.80
MRC-MW21A 30.84
MRC-MW22A 17.36
EXT-MW06 22.84
MRC-MW15A 18.36
MRC-MW10A 11.31
MRC-MW71A 14.85
MRC-MW14A 13.67
MRC-OW4S NM
MRC-OW5S-I NM
MRC-OW6S-I NM
MRC-MW70A 11.47
MRC-PZ02A NM
MRC-MW11A 11.19
MRC-MW63A 12.94
MRC-MW12A 9.83
MRC-MW13A 9.79
MRC-MW65A 10.62
MRC-MW66A 9.10
MRC-MW47A 8.98
MRC-MW45A 1.94
MRC-MW46A 1.48
MRC-MW59A 25.61
MRC-MW42A 19.40
MRC-MW25A 15.58
MRC-MW55A 25.45
MRC-MW57A 28.89
MRC-MW56A 30.38
MRC-OW3S-I NM
MRC-MW76A 16.77
MRC-MW60A 25.12
MRC-OW1S-I NM
MRC-81A 17.40
MRC-OW2S-I NM
MRC-MW48A 17.84
MRC-MW23A 17.72
MRC-MW24A 14.60
MRC-MW26A 14.04
MRC-MW27A 12.60
MRC-MW28A 11.04
MRC-MW29A 9.97
MRC-MW30A 11.59
MRC-MW31A 9.15
MRC-MW32A 8.34
MRC-MW33A 10.00
MRC-MW34A 7.82
MRC-MW35A 6.14
MRC-MW40A 6.24
MRC-MW39A 5.40
MRC-MW04A 22.60
MRC-MW61A 19.17
MRC-MW62A 11.29
MRC-MW44A NM
MRC-MW43A 11.28
MRC-MW72A 4.35
MRC-MW73A 2.81
MRC-MW74A 2.44
MRC-PZ01A NM
MRC-MW37A 3.43
MRC-MW36A 3.46
MRC-MW37B 2.35
MRC-MW38A 3.10

20 15 10 25 20 15 10 5 20 15 10 5

Cow Pen Creek

Dark Head Cove

FIGURE 4-1 GROUNDWATER CONTOURS OF THE UPPER SURFICIAL AQUIFER, OCTOBER 2008

Legend

- GROUNDWATER MONITORING WELL
- SURFACE WATER
- GROUNDWATER CONTOUR — CONTOUR INTERVAL = 5 FEET
- INFERRED
- 15.23 WATER LEVEL, FEET (MSL)
- NM NOT MEASURED

LMC Middle River Complex
Middle River, Maryland

0 100 200 Feet

N

DATE MODIFIED: 11/25/08

CREATED BY: MP

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\Middle River GW Contours of Upper Surfacial Aquifer Oct 08.mxd) 11/25/2008

Map Document: (K:\GProject\middle_river\Maps\Middle River Beryllium Distribution in GW_Oct_Nov_2007.mxd) 7/10/2008 -- 11:03:25 AM

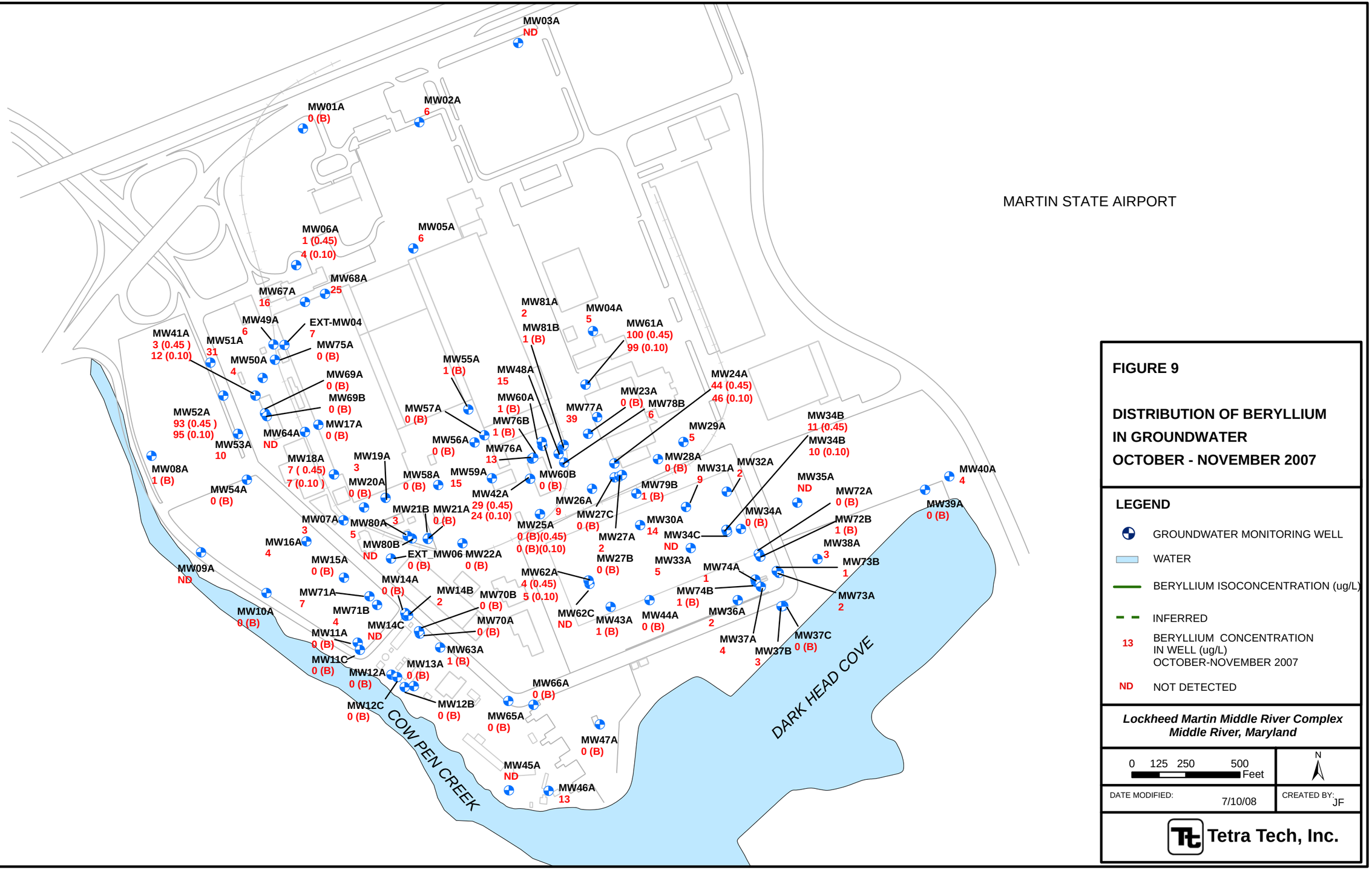


FIGURE 9

DISTRIBUTION OF BERYLLIUM IN GROUNDWATER OCTOBER - NOVEMBER 2007

LEGEND

- GROUNDWATER MONITORING WELL
- WATER
- BERYLLIUM ISOCONCENTRATION (ug/L)
- INFERRED
- 13 — BERYLLIUM CONCENTRATION IN WELL (ug/L) OCTOBER-NOVEMBER 2007
- ND — NOT DETECTED

Lockheed Martin Middle River Complex
Middle River, Maryland

0 125 250 500 Feet

N

DATE MODIFIED: 7/10/08

CREATED BY: JF

Tetra Tech, Inc.

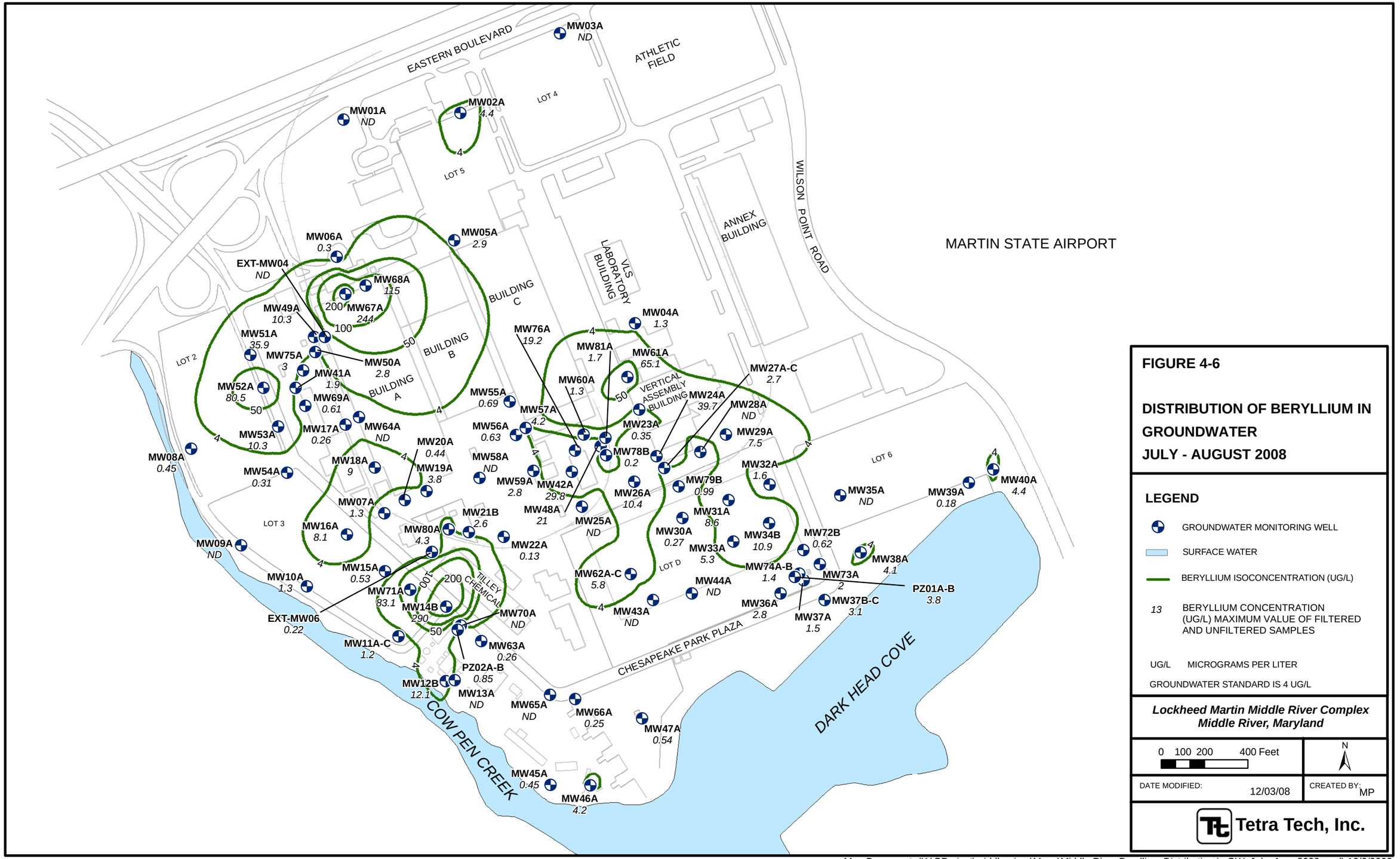


FIGURE 4-6

DISTRIBUTION OF BERYLLIUM IN GROUNDWATER
JULY - AUGUST 2008

LEGEND

- GROUNDWATER MONITORING WELL
- SURFACE WATER
- BERYLLIUM ISOCONCENTRATION (UG/L)
- 13 BERYLLIUM CONCENTRATION (UG/L) MAXIMUM VALUE OF FILTERED AND UNFILTERED SAMPLES

UG/L MICROGRAMS PER LITER

GROUNDWATER STANDARD IS 4 UG/L

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 12/03/08

CREATED BY: MP

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\Middle River Beryllium Distribution in GW_July_Aug_2008.mxd) 12/3/2008

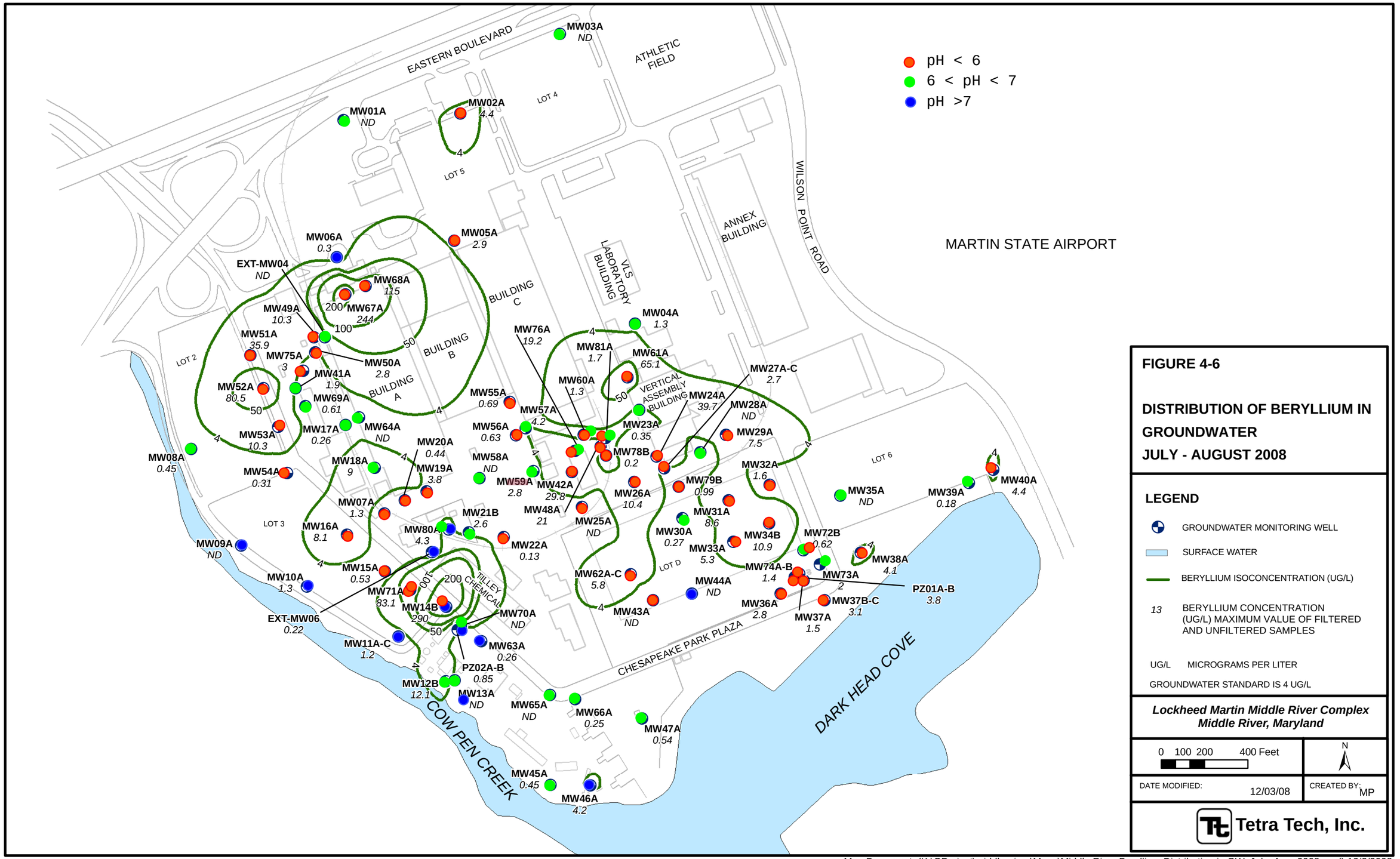


FIGURE 4-6

DISTRIBUTION OF BERYLLIUM IN GROUNDWATER
JULY - AUGUST 2008

LEGEND

- GROUNDWATER MONITORING WELL
- SURFACE WATER
- BERYLLIUM ISOCONCENTRATION (UG/L)
- 13 BERYLLIUM CONCENTRATION (UG/L) MAXIMUM VALUE OF FILTERED AND UNFILTERED SAMPLES

UG/L MICROGRAMS PER LITER

GROUNDWATER STANDARD IS 4 UG/L

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 12/03/08

CREATED BY: MP

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\Middle River Beryllium Distribution in GW_July_Aug_2008.mxd) 12/3/2008

National Atmospheric Deposition Program/National Trends Network
2007 Annual & Seasonal Data Summary for Site MD99
Part 1: Summary of Sample Validity and Completeness Criteria

(Printed 11/13/2008)

Site Identification	
Site Name	Beltsville
Site ID	MD99
State	MD
County	Prince Georges
Operating Agency	University of Maryland-CBL
Sponsoring Agency	Maryland DNR
Latitude	39.028
Longitude	-76.8171
Elevation	46 m

Sample Validity for Annual Period	
Number of samples	51
Valid Samples	39
with precipitation	36
with full chemistry**	35
without chemistry	1
without precipitation	3
Invalid Samples	12
with precipitation	12
missing precipitation data	0

Summary Period Information

	Annual	Winter*	Spring*	Summer	Fall
First summary period day	01/03/2007	11/28/2006	02/27/2007	05/29/2007	08/28/2007
Last summary period day	01/03/2008	02/27/2007	05/29/2007	08/28/2007	11/27/2007
Summary period duration	365	91	91	91	91
Number of samples	51	12	13	13	13
Measured precipitation (cm)	82.1	15.8	23.6	19.4	21.6
Valid samples with full chemistry**	35	9	5	11	9
Valid field pH measurements	--	--	--	--	--

NADP/NTN Completeness Criteria

	Annual	Winter*	Spring*	Summer	Fall
1.Summary period with valid samples (%)	75	75	46	85	92
2.Summary period with precip coverage (%)	100	100	100	100	100
3.Measured precipitation with valid samples (%)	79	64	61	91	98
4.Collector efficiency (%)	104	99	106	105	103
Precip with full chemistry and valid field pH (%)	--	--	--	--	--

* = Data do not meet NADP/NTN Completeness Criteria for this period.

** = Valid samples for which all Laboratory Chemical measurements were made (The ONLY samples described by the percentile distributions in the Statistical Summary of Precipitation Chemistry for Valid Samples).

*** = Measured precipitation for sample periods during which precipitation occurred and for which complete valid laboratory chemistry . data are available

National Atmospheric Deposition Program/National Trends Network
2007 Annual & Seasonal Data Summary for Site MD99
Part 2: Statistical Summary of Precipitation Chemistry for Valid Samples

Precipitation-Weighted Mean Concentrations

	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	H(lab)	H(fld)	pH(lab)	pH(fld)
	mg/L											
Annual	0.113	0.035	0.018	0.095	0.275	1.183	0.232	1.887	3.63E-02	--	4.44	--
Winter*	0.063	0.026	0.015	0.206	0.173	0.963	0.410	1.168	2.71E-02	--	4.57	--
Spring*	0.099	0.030	0.027	0.195	0.390	1.132	0.358	2.082	3.26E-02	--	4.49	--
Summer	0.219	0.081	0.019	0.064	0.442	1.844	0.228	2.965	5.45E-02	--	4.26	--
Fall	0.057	0.009	0.014	0.036	0.111	0.623	0.093	1.070	2.22E-02	--	4.65	--

Deposition

	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	H(lab)	H(fld)	pH(lab)	pH(fld)
	kg/ha											
Annual	0.927	0.287	0.148	0.780	2.257	9.708	1.904	15.485	2.98E-01	--	--	--
Winter*	0.099	0.041	0.024	0.325	0.273	1.520	0.647	1.843	4.28E-02	--	--	--
Spring*	0.234	0.071	0.064	0.460	0.920	2.671	0.845	4.913	7.69E-02	--	--	--
Summer	0.426	0.157	0.037	0.124	0.859	3.583	0.443	5.762	1.06E-01	--	--	--
Fall	0.123	0.019	0.030	0.078	0.240	1.346	0.201	2.312	4.79E-02	--	--	--

Weekly Sample Concentrations

	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	H(lab)	H(fld)	pH(lab)	pH(fld)
	mg/L											
Minimum value	0.019	0.004	0.006	0.020	0.007	0.317	0.059	0.689	8.13E-04	--	3.77	--
Percentile 10	0.041	0.010	0.008	0.030	0.074	0.564	0.091	0.936	1.65E-02	--	4.02	--
Percentile 25	0.086	0.018	0.011	0.038	0.128	1.020	0.137	1.546	2.69E-02	--	4.11	--
Percentile 50	0.148	0.029	0.020	0.089	0.329	1.629	0.249	2.078	4.79E-02	--	4.32	--
Percentile 75	0.349	0.060	0.034	0.188	0.609	2.447	0.457	3.893	7.76E-02	--	4.57	--
Percentile 90	0.528	0.100	0.061	0.337	0.787	4.329	0.604	5.379	9.60E-02	--	4.78	--
Maximum value	1.685	0.789	0.142	0.442	1.900	10.581	1.029	10.320	1.70E-01	--	6.09	--
Arithmetic mean	0.261	0.065	0.024	0.123	0.410	2.136	0.308	2.900	5.46E-02	--	4.26	--
Arith. std dev	0.322	0.136	0.019	0.100	0.369	1.951	0.217	2.019	3.40E-02	--	--	--
Below detection	0	0	0	0	0	0	0	0	--	--	--	--

Other Parameters

	Measured Precipitation*** mm	Conductivity uS/cm	Equivalence Ratios SO4/NO3	SO4+NO3/H	Cation/Anion
Minimum value	0.51	8.2	0.61	1.12	0.92
Percentile 10	1.17	11.3	0.77	1.28	0.94
Percentile 25	2.03	16.4	1.42	1.34	0.96
Percentile 50	8.64	24.7	2.07	1.57	0.99
Percentile 75	25.40	41.1	2.71	1.90	1.01
Percentile 90	40.08	53.2	3.27	2.38	1.05
Maximum value	156.53	96.4	4.51	117.36	1.19

Annual and Seasonal Equivalence Ratios

	SO4/NO3	SO4+NO3/H	Cation/Anion
Annual	2.06	1.61	1.00
Winter*	1.57	1.47	1.00
Spring*	2.38	1.89	0.99
Summer	2.08	1.68	1.02
Fall	2.22	1.46	0.97

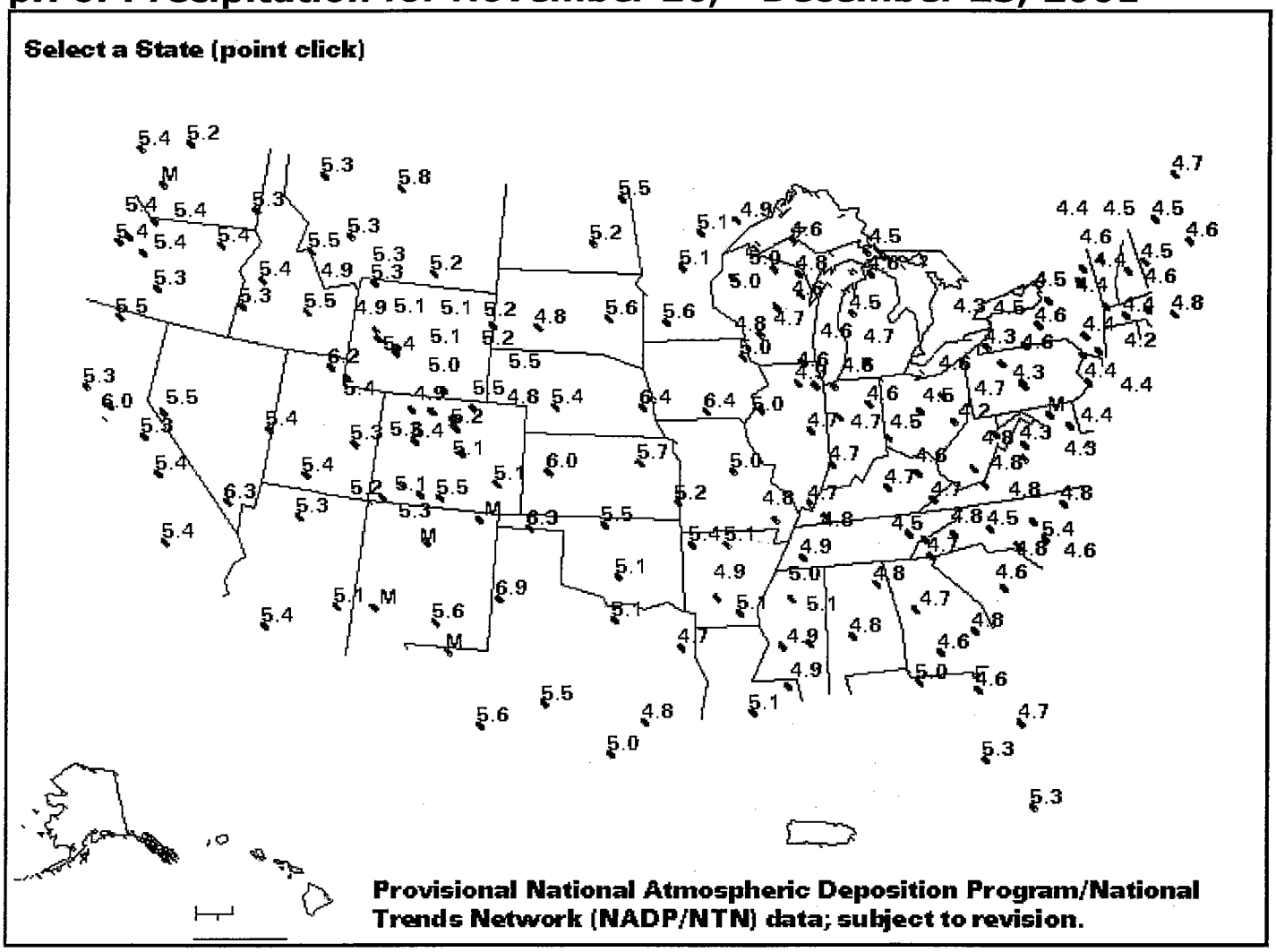
Please see page 1 for footnotes.

USGS

National Water Conditions

U.S. Geological Survey
Environment Canada Climate Information Branch

pH of Precipitation for November 26, - December 23, 2001

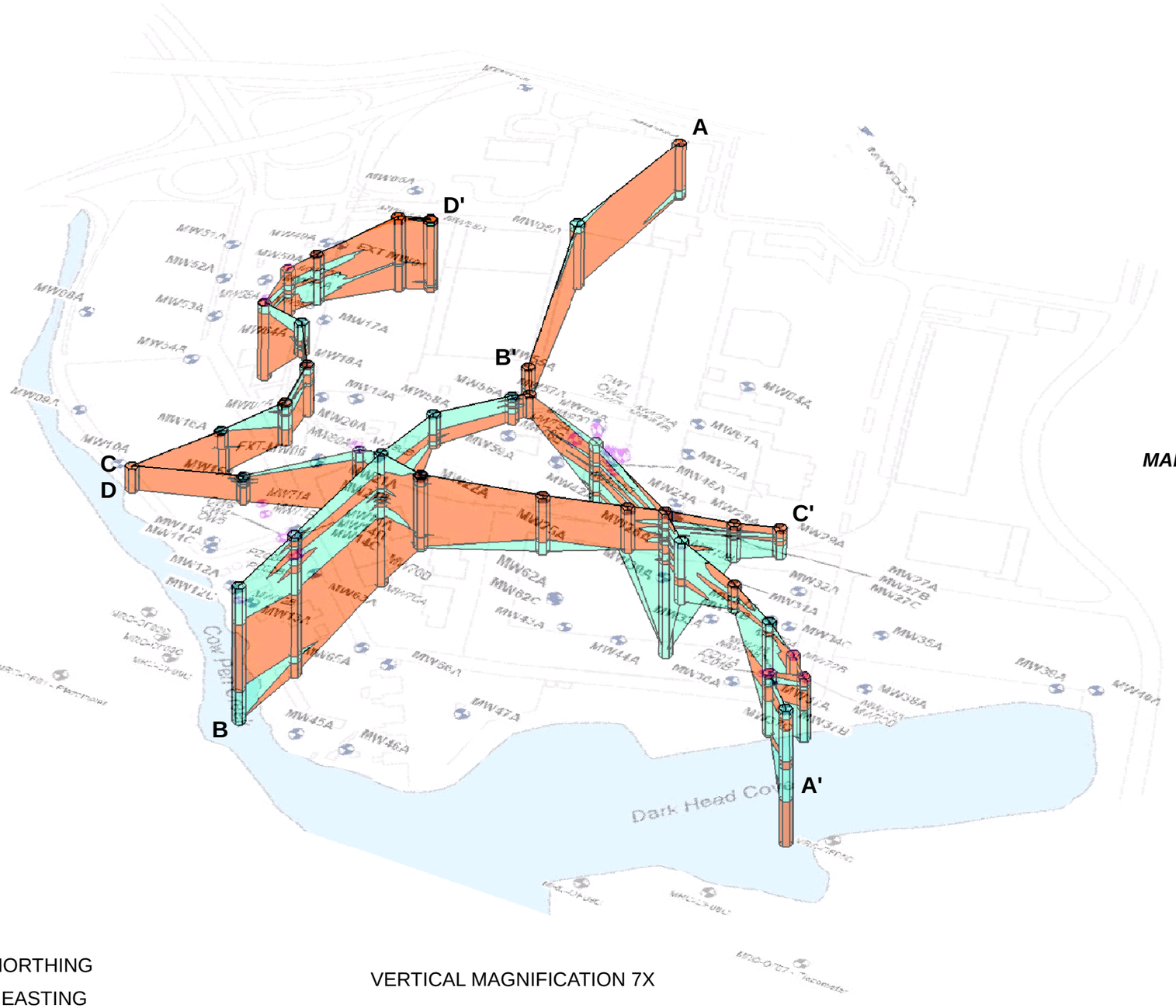


Current pH data shown on the map (● 4.9) are precipitation-weighted means caculated from preliminary laboratory results provided by the NADP/NTN Central Analytical Laboratory at the Illinois State Water Survey and are subject to change. The 190 points (●) shown on this map represent all sites which were in operation during the reporting period.A notation of **D** instead of a pH value at a site indicates that there was no precipitation; a notation of **M** indicates that data for the site did not meet preliminary screening criteria for this provisional report.

A list of the approximately 190 sites comprising the total Network and additional data for the sites are available from the NADP/NTN Coordination Office, Illinois State Water Survey, 2204 Griffith Drive, Champaign, IL 61880.

APPENDIX D—GENERALIZED CROSS-SECTIONS

P:\GIS\MIDDLE_RIVER\MAPDOCS\MXD\FENCE.MXD 06/19/08 JEE



NORTHING
EASTING

VERTICAL MAGNIFICATION 7X

MARTIN STATE AIRPORT

Legend

Hydrogeologic Unit

- High Permeability (>= 1ft/d)
- Low Permeability (< 0.01 ft/d)

Tetra Tech NUS, Inc.

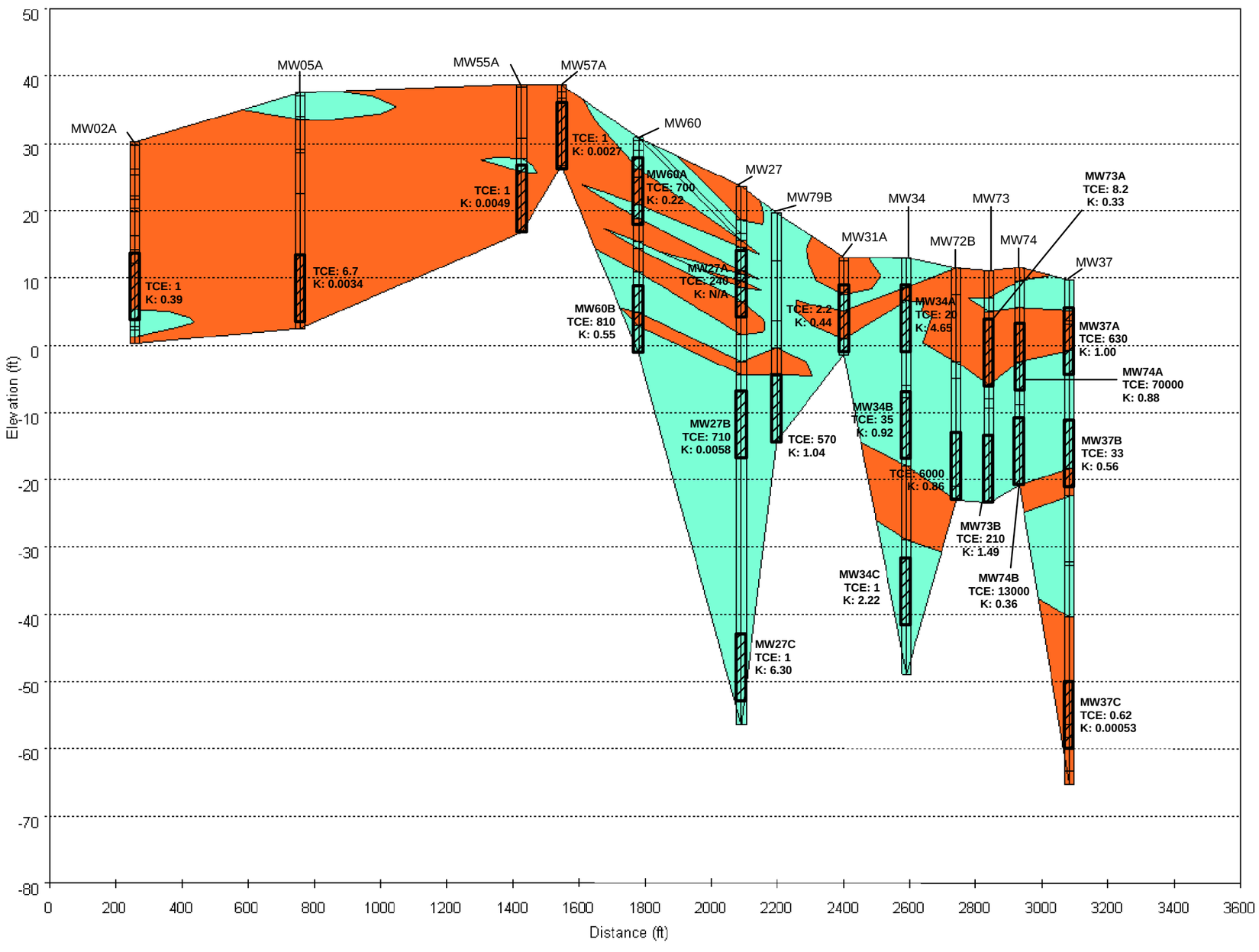
FENCE DIAGRAM
LOCKHEED MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

FILE	SCALE
FENCE.MXD	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE NO.	0 / _____

P:\GIS\MIDDLE_RIVER\MAPDOCS\MXD\CROSS_SECTION_AA.MXD 06/19/08 JEE

A

A'



Legend

Well Screen

TCE Trichloroethene Concentrations (ug/L)

K Hydraulic Conductivity (ft/day)

Hydrogeologic Unit

High Permeability (>= 1ft/d)

Low Permeability (< 0.01 ft/d)

Tetra Tech NUS, Inc.

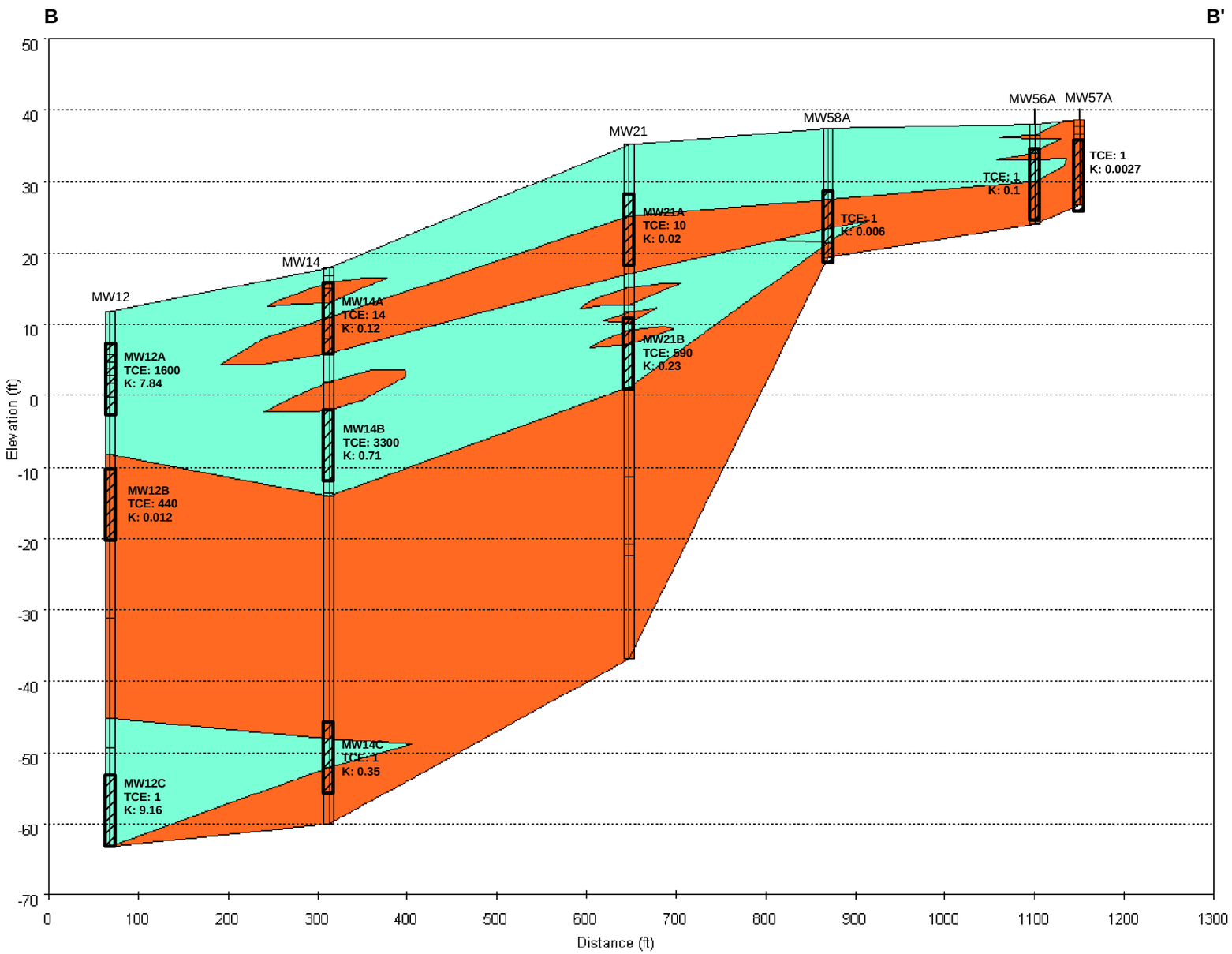
GEOLOGIC CROSS-SECTION A-A'
LOCKHEED MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

FILE	SCALE
CROSS_SECTION_AA.MXD	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE NO.	0 / _____

P:\GIS\MIDDLE_RIVER\MAPDOCS\MXD\CROSS_SECTION_BB.MXD 06/19/08 JEE

B

B'



Legend

Well Screen

TCE Trichloroethene Concentrations (ug/L)

K Hydraulic Conductivity (ft/day)

Hydrogeologic Unit

High Permeability (>= 1ft/d)

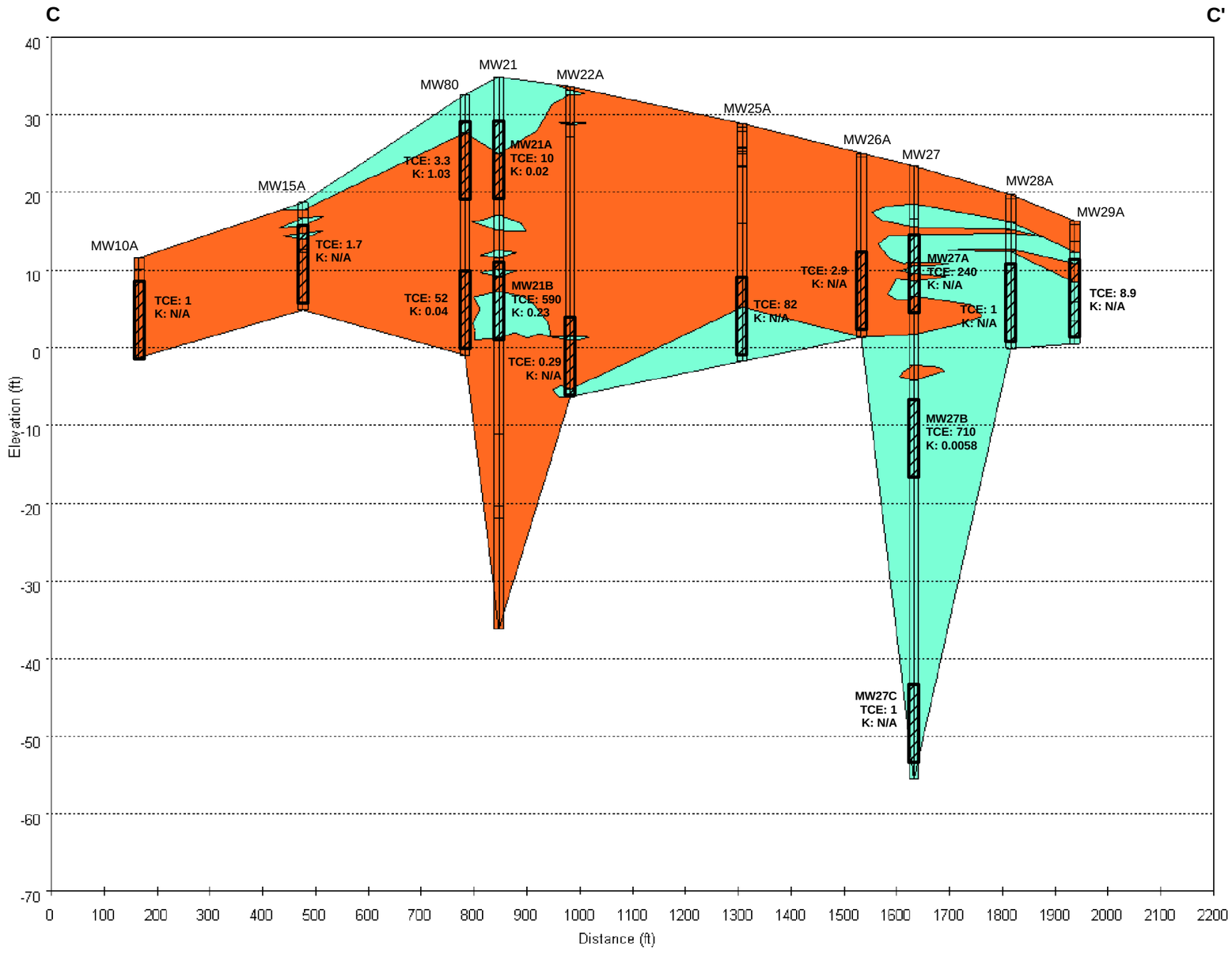
Low Permeability (< 0.01 ft/d)

Tetra Tech NUS, Inc.

GEOLOGIC CROSS-SECTION B-B'
LOCKHEED MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

FILE	SCALE
CROSS_SECTION_BB.MXD	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE NO.	0

P:\GIS\MIDDLE_RIVER\MAPDOCS\MXD\CROSS_SECTION_CC.MXD 06/19/08 JEE



Legend

Well Screen

TCE Trichloroethene Concentrations (ug/L)
K Hydraulic Conductivity (ft/day)

Hydrogeologic Unit

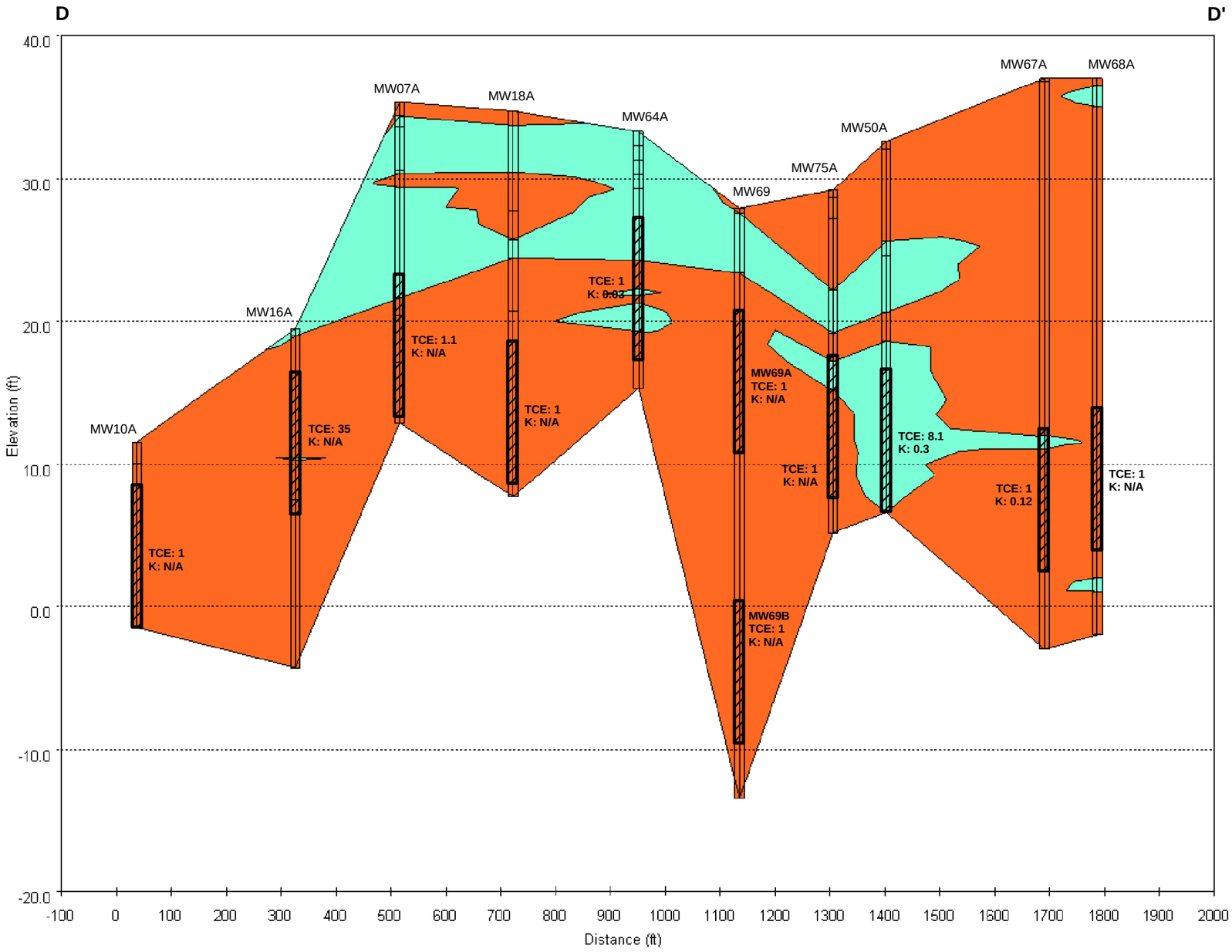
High Permeability (>= 1ft/d)
Low Permeability (< 0.01 ft/d)

Tetra Tech NUS, Inc.

GEOLOGIC CROSS-SECTION C-C'
LOCKHEED MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

FILE	SCALE
CROSS_SECTION_CC.MXD	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE NO.	0 / _____

P:\GIS\MIDDLE_RIVER\MAPDOCS\MXD\CROSS_SECTION_DD.MXD 06/19/08 JEE



Legend

- Well Screen
- **TCE** Trichloroethene Concentrations (ug/L)
- **K** Hydraulic Conductivity (ft/day)

Hydrogeologic Unit

- High Permeability (>= 1ft/d)
- Low Permeability (< 0.01 ft/d)

Tetra Tech NUS, Inc.

GEOLOGIC CROSS-SECTION D-D'
LOCKHEED MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

FILE	SCALE
CROSS_SECTION_DD.MXD	AS NOTED
FIGURE NUMBER	REV / DATE
FIGURE NO.	0 / _____

APPENDIX E—INTERIM ISCO PILOT–STUDY REPORT

Interim ISCO Pilot Study Report
Lockheed Martin Middle River Complex
2323 Eastern Boulevard
Middle River, Maryland

Prepared for:

Lockheed Martin Corporation

Prepared by:

Tetra Tech, Inc.

_____

Michael Martin
Project Manager, P.G.

_____

Christopher Pike
Project Engineer, P.E.

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Section 1
Introduction

On behalf of Lockheed Martin Corporation (Lockheed Martin), Tetra Tech has prepared the following interim report for the in-situ chemical oxidation (ISCO) pilot study conducted at the Lockheed Martin Middle River Complex (MRC) located in Middle River, Maryland. The pilot study was conducted to determine whether ISCO can be applied successfully to the areas of concern and significantly and permanently reduce the volatile organic compound (VOC) concentrations within the saturated zone of the site.

The objectives of the ISCO pilot study are:

- Determine the effectiveness of ISCO in reducing VOC concentrations at the site utilizing sodium persulfate (Klozur™ from FMC, Inc.) with and without activation via hydrogen peroxide.
- Determine the capacity of the pilot study area subsurface to accept the required injection volumes of the sodium persulfate and hydrogen peroxide solutions via direct push technology (DPT) injections.
- Determine the extent of "rebound" of VOC concentrations following oxidant injection.

To address the above objectives, the following activities were conducted:

- Installation of observation wells.
- Baseline sampling.
- Testing of pressure pulse equipment utilizing potable water injections.
- Injection of sodium persulfate solution (Klozur™ from FMC, Inc.) at multiple locations near the observation wells in the central portion of the western plume.
- Injection of sodium persulfate solution and hydrogen peroxide activator at other locations near the observation wells.
- Performance monitoring.
- Reporting.

This interim ISCO pilot test report is organized as follows:

- Section 2 – Site Background: Presents a brief description of site history, subsurface conditions, and previous investigations.
- Section 3 – ISCO Pilot Study Field Implementation: Presents a description of the field activities employed.

- Section 4 – ISCO Pilot Study Interim Sampling Results: Presents a comparison of the results of the baseline sampling and the first two rounds of pilot study performance sampling.
- Section 5 – References: Cites references used to compile this report.

Section 2
Site Background

2.1 MRC BACKGROUND

The MRC, which is part of the Chesapeake Industrial Park, is located at 2323 Eastern Boulevard in Middle River, Maryland, approximately 11.5 miles northeast of downtown Baltimore. The MRC comprises approximately 161 acres including 12 main buildings, an active industrial area and yard, perimeter parking lots, an athletic field, a concrete-covered vacant lot, a trailer and parts storage lot, and numerous grass-covered green spaces along its perimeter. The MRC is bounded by Eastern Boulevard (Route 150) to the north, Dark Head Cove to the south, Cow Pen Creek to the west, and Martin State Airport to the east. A MRC layout map is presented as Figure 2-1 and site monitoring well locations are shown in Figure 2-2.

Currently, Lockheed Martin's primary activities at the MRC include facility and building management and maintenance. There are two main tenants at MRC: Middle River Aircraft Systems (MRAS), a subsidiary of General Electric, that conducts design, manufacturing, fabrication, testing, overhaul, repair, and maintenance of aeronautical structures, parts, and components for military and commercial applications; and Maritime Systems & Sensors – Littoral Ships & Systems (MS2-LS&S), that conducts fabrication, assembly, testing and support of vertical launch systems.

2.1.1 MRC History

In 1929, the Glenn L. Martin Company (GLM), a predecessor of Lockheed Martin, acquired a large parcel of land in Middle River, Maryland to conduct aircraft manufacturing for the United States government and commercial clients. Prior to the acquisition, the MRC was reportedly undeveloped land. In the early 1960s, GLM merged with American-Marietta Company, forming Martin Marietta Corporation. Around 1975, the adjacent western airport (Martin State Airport),

totaling approximately 750 acres, was transferred to the State of Maryland. In the mid-1990s, Martin Marietta Corporation merged with Lockheed, forming Lockheed Martin Corporation, with its principal subsidiary specializing in construction and testing of new ordnance for United States Government and commercial clients. Shortly following the merger, General Electric acquired the majority of Lockheed Martin's aeronautical business in Middle River, which began to function as MRAS.

2.1.2 MRC Characteristics

2.1.2.1 Current and Surrounding Land Use

The MRC is an industrial facility, and the area surrounding the property primarily consists of commercial, industrial, and residential establishments. Six facilities, comprising the remaining portion of the Chesapeake Industrial Park, are adjacent to MRC. These facilities include Tilley Chemical Company, Inc., a food and pharmaceutical chemical distributor; North American Electric, Inc., an industrial and commercial electrical contractor; Johnson and Towers, a heavy duty automotive and boat repair and maintenance company; Poly-Seal Corp., a company that produces flexible packaging; Exxon, a gasoline fill station and convenience store; and the Middle River Post Office. Residential developments are present on the opposite shores of Cow Pen Creek, Dark Head Cove, and Dark Head Creek and north of Eastern Boulevard (Route 150).

2.1.2.2 Physiography

The MRC is located within the Western Shore of the Coastal Plain Physiographic Province, which is generally characterized by low relief. The topography of the MRC is gently sloping, ranging from sea level to 32 feet above mean sea level (msl) (Cassell, July 1977). The topography slopes from Eastern Boulevard to the southwest and south towards Cow Pen Creek and Dark Head Cove.

2.1.2.3 Hydrology

The MRC is located at the junction of Cow Pen Creek and Dark Head Cove. Both surface water bodies discharge into Dark Head Creek, a tributary to Middle River, which is a tributary to

Chesapeake Bay. The MRC is approximately 3.24 miles (17,100 feet) upstream of Chesapeake Bay.

No surface water bodies are present within the MRC. Excluding areas immediately adjacent to Cow Pen Creek and Dark Head Creek, surface water runoff discharges from the facility via storm drains. Lockheed Martin maintains a State of Maryland National Pollution Discharge Elimination System (NPDES) permit (State Discharge Permit No.: 00-DP-0298, NPDES No.: MD0002852), issued by Maryland Department of the Environment (MDE) Industrial Discharge Permits Division, Water Management Administration. The permit covers stormwater discharge from the entire property rather than individual tenants.

2.1.2.4 Soils

Soils underlying MRC have been mapped as Mattapex-Urban Land Complex and Sassafras-Urban Land Complex by the United States Department of Agriculture Soil Conservation Service. Mattapex-Urban Land soils consist of deep, well-drained silty soils whose original texture has been disturbed, graded over, or otherwise altered. Sassafras-Urban Land soils consist of deep, well-drained sandy soils whose original texture has been disturbed, graded over, or otherwise altered. Site characterization studies indicate that fine-grained (e.g., silt and clay) soils with low permeabilities make up the majority of soils at the MRC.

2.1.2.5 Regional Geology

Based on geologic mapping of Baltimore County, the MRC is underlain by the Potomac Group, a Cretaceous-age interbedded gravel, sand, silt, and clay unit ranging in thickness from 0 to 800 feet. The Potomac Group is composed of three units: the Raritan and Patapsco Formations, the Arundel Clay, and the Patuxent Formation. The Raritan and Patapsco Formations range up to 400 feet thick and are composed of a gray, brown, and red variegated silt and clay unit with lenses of sand and few gravels. The Arundel Clay is composed of dark gray and maroon lignitic clays and ranges in thickness from 25 to 200 feet. The Patuxent Formation is described as a white or light gray to orange brown, moderately sorted sand unit with quartz gravels, silts, and clays and ranges up to 250 feet in thickness.

Lithologic logging of the soils beneath the MRC identified a very heterogeneous stratigraphy. The underlying soils are composed primarily of silty sands, fine-grained to medium-grained sands, silty clays, clayey silts, and plastic clay, with the primary lithology being clay to silty clay. Areas along the waterfront have historically been back-filled to their present elevation. Soils obtained from fill areas were similar in appearance and composition to soils considered to be native to the MRC.

2.1.2.6 Regional Hydrogeology

Sand and gravel zones within the unconsolidated surficial deposits, when present, may form an unconfined or water table aquifer system (Bennett and Meyer, 1952). The water table at MRC generally conforms to the shape of the land surface, with the highest water levels in the interior land areas and the lowest levels at approximately the surface water elevations along the shoreline.

The Patuxent Formation is the most important water-bearing formation in the Baltimore area. Industrial wells in the southeastern part of the area, specifically Curtis Bay and Sparrows Point, yield from 500 to 900 gallons per minute (gpm). Transmissivities and coefficients of storage in confined portions of the aquifer in these industrialized areas average about 50,000 gallons per day per foot (g/d/ft) and 0.00026, respectively. The Patapsco Formation is also an important water-bearing formation in industrialized Baltimore, where it is separated by clay into a lower and an upper aquifer. The lower aquifer yields as much as 500 to 750 gpm to industrial wells, and a transmissivity of 25,000 g/d/ft has been estimated. The upper aquifer yields quantities of water similar to industrial wells, and because it has a greater thickness than the lower aquifer, it likely has a higher overall transmissivity.

2.2 SUMMARY OF DATA FROM THE ISCO PILOT STUDY AREA

This section provides data from previous investigations that apply directly to the area of the ISCO pilot study, primarily from the 2005 Site-Wide Groundwater Investigation and the field investigations that took place at MRC in late 2007 and early 2008. More information on the 2005 activities can be found in the Site-Wide Groundwater Investigation Report (Tetra Tech, 2006) and

information on the recent investigations will be presented in the Groundwater Response Action Plan, scheduled for submittal in 2011.

The ISCO pilot test location is shown in Figure 2-3.

2.2.1 ISCO Pilot Study Area Characteristics

The ISCO pilot study was conducted in the western trichloroethene (TCE) plume, which is the second largest contiguous area of TCE groundwater contamination and extends from MW21, which is located near REC #9 (Former 2,000 Gallon Waste Oil underground storage tank [UST]), to MW12, located near Cow Pen Creek. The maximum reported concentrations of TCE in the plume are 3,300 micrograms per liter (µg/L) at well MW14B in the central portion of the plume and 1,600 µg/L at well MW12A in the southernmost portion of the plume near Cow Pen Creek. Groundwater TCE, 1,4-dioxane, and benzene iso-concentration contours are shown on Figure 2-4.

High concentrations of TCE reported for wells MW14B and MW21B indicate that TCE has migrated to the base of the upper surficial aquifer. In these areas, residual TCE may be trapped in silt and sand lenses between the clay-rich zones and/or may be adsorbed to organic material and clays. The suspected source for the western TCE plume is a former waste oil tank (i.e., REC #9) located near well MW21A. An emerging chemical of interest, 1,4-dioxane, was detected in several wells in the western TCE plume.

Nested observation wells were installed in three locations in the central portion of the western TCE plume to facilitate pilot testing. OW4S, OW5S, and OW6S were installed with a screened interval of 5 feet below ground surface (bgs) to 15 feet bgs; OW4I, OW5I, and OW6I were installed with a screened interval of 20 feet bgs to 25 feet bgs. In general, the "S" wells were installed in a low permeability clay or silty clay and the "I" wells were installed in a higher permeability sandy clay; boring logs and well installation diagrams for these wells are included in Appendix A. Observation well locations are shown on Figure 2-5.

As part of the baseline sampling associated with the pilot testing, groundwater samples were collected from these observation wells following installation and prior to chemical injection.

Concentrations of VOCs were low in the "S" wells, with TCE ranging from less than the detection limit to 3 µg/L. Concentrations were significantly higher in the "I" wells, with TCE ranging from 268 to 1,520 µg/L. A similar pattern was observed in the 1,4-dioxane concentrations, with a maximum of 0.8 µg/L in the "S" wells and a range of 87 to 166 µg/L in the "I" wells.

Concentrations of metals above MDE screening standards are found in the groundwater throughout the MRC. The effect of the pilot study injections on the metals concentrations is an important consideration. Therefore, the groundwater samples from the observation wells were analyzed for metals. Three of the metals found to exceed MDE standards in multiple locations are beryllium, cobalt, and nickel. Maximum concentrations of beryllium, cobalt, and nickel in the observation wells associated with this area are 5.4 µg/L, 110 µg/L, and 116 µg/L, respectively, all above the MDE screening standards.

Table 2-1 provides selected organic and inorganic compound concentrations and geochemical data observed during baseline sampling of the observation wells.

2.2.2 Bench-Scale Testing

In order to assist in determining the parameters for the pilot study, bench-scale studies were conducted by CDM, Inc. using soil and groundwater collected from the ISCO pilot study area. A brief summary of the testing is included in this section; complete data from the tests are included in the pilot test work plan (Tetra Tech, 2008).

Testing was conducted on samples from throughout the site, including samples from low and neutral pH areas of the eastern plume and low and neutral pH areas of the western plume. The destruction of COCs and the oxidant demand of the media were tested with several different oxidants including potassium permanganate, activated sodium persulfate (utilizing hydrogen peroxide, sodium hydroxide, and iron as activators), and unactivated persulfate. The following is a summary of the testing results provided by CDM, Inc.:

Eastern Neutral pH Test

- All oxidants were capable of rapidly oxidizing TCE and DCE at the 1 percent and 5 percent concentrations.
- Sodium hydroxide-activated persulfate oxidized TCE and DCE at the slowest rate.
- Unactivated persulfate was effective at oxidizing TCE and DCE.
- Unactivated persulfate also resulted in the lowest oxidant consumption.
- Low pH was observed in the iron- and hydrogen peroxide-activated persulfate tests.

Eastern Low pH Test

- All oxidants were capable of rapidly oxidizing TCE and cis-1,2-dichloroethene (DCE) at the 5 percent concentration. The 1 percent concentration was less effective. Sodium persulfate activated with hydrogen peroxide and potassium permanganate were generally the most effective.
- Unactivated persulfate was capable of oxidizing TCE and DCE albeit at slower rates.
- Unactivated persulfate also resulted in the lowest oxidant consumption.
- Low pH was observed in the hydrogen peroxide activated persulfate tests.
- Benzene was effectively treated by hydrogen peroxide, with and without activation. Permanganate was not effective in treating benzene.

Western Neutral pH Test

- All oxidants were capable of rapidly oxidizing TCE and 1,4-dioxane at the 1 percent and 5 percent concentrations with the possible exception of sodium hydroxide activated persulfate. The ability of permanganate to rapidly oxidize 1,4-dioxane is unexpected and previously unobserved in the scientific literature.
- Unactivated persulfate was effective at oxidizing TCE and 1,4-dioxane.
- Unactivated persulfate resulted in the lowest oxidant consumption.
- Low pH was observed in the iron- and hydrogen peroxide-activated persulfate tests.

Western Low pH Test

- All oxidants were capable of rapidly oxidizing TCE and 1,4-dioxane at the 1 percent and 5 percent concentrations with the possible exception of hydrogen peroxide activated persulfate (TCE and 1,4-dioxane) and 1 percent permanganate (1,4-dioxane only).
- Unactivated persulfate was effective at oxidizing TCE and 1,4-dioxane.
- Unactivated persulfate resulted in the lowest oxidant consumption.
- Low pH was observed in the iron- and hydrogen peroxide-activated persulfate tests.

General Conclusions and Recommendations

- Persulfate with hydrogen peroxide activation resulted in the greatest rates of contaminant oxidation but also resulted in the greatest amounts of oxidant consumption. This greater consumption may lead to greater costs and smaller radius of influence in a full-scale application. Due to its success in treating the contaminants, this formulation will be tested in the field.

- Unactivated persulfate was effective in treating TCE, DCE, benzene, and 1,4-dioxane and resulted in the lowest amounts of oxidant consumption. The lower oxidant consumption may lead to lower costs and greater radius of influence in a full-scale application. Due to its success and potential to significantly reduce overall remediation costs, this oxidant will be tested in the field.
- Permanganate was capable of TCE and DCE oxidation. It was not very effective at benzene oxidation. Unexpectedly, it was capable of 1,4-dioxane oxidation which should be confirmed. Due to the experimental nature of using this oxidant for 1,4-dioxane treatment, it will not be tested in the field.

TABLE 2-1

IN-SITU CHEMICAL OXIDATION PILOT STUDY DATA
LOCKHEED MARTIN MIDDLE RIVER COMPLEX, MIDDLE RIVER, MARYLAND

Observation Well	Sampling Round	TCE µg/L	DCE µg/L	VC µg/L	1,4-Dioxane µg/L	Beryllium µg/L	Cobalt µg/L	Nickel µg/L	pH S.U.	ORP mV	DO ppm
OW4S	Baseline	ND	ND	ND	ND	ND	7.3	6.6	6.14	12	0.00
	Round 1	14	5.1	ND	3.3				5.58	248	12.01
	Round 2	1.7	2.1	ND	ND				5.80	54	0.00
	% Reduction	Increase	Increase	No Change	No Change						
OW4I	Baseline	1520	399	2	100	5.4	66.8	116	5.62	15	0.00
	Round 1	790	200	ND	56				5.51	20	0.31
	Round 2	600	160	ND	70				5.50	14	0.00
	% Reduction	61%	58%	Complete	30%						
OW5S	Baseline	3	2	ND	ND	1.4	110	24.6	5.95	67	0.00
	Round 1	10	0.92	ND	2				2.84	490	19.99
	Round 2	3.7	2	ND	ND				5.40	279	1.70
	% Reduction	Increase	No Change	No Change	No Change						
OW5I	Baseline	268	68	1	87	0.9 J	47.5	44.8	5.82	4	0.11
	Round 1										
	Round 2										
	% Reduction										
OW6S	Baseline	2	1.4	ND	0.8	1.2	46.9	22.5	5.78	76	0.00
	Round 1	ND	ND	ND	ND				2.32	652	19.99
	Round 2	3	2	ND	ND				2.88	487	15.67
	% Reduction	Increase	Increase	No Change	Complete						
OW6I	Baseline	832	166	1	166	ND	28.3	41.2	5.22	-12	2.25
	Round 1	30	4.1	ND	6.9				2.46	660	19.99
	Round 2	540	100	ND	42				4.65	184	6.17
	% Reduction	35%	40%	No Change	75%						
MW14B	Baseline	3300	ND	ND	158	1.8	49.4	109	5.35	123	0.00
	Round 1	210	3.1	ND	4.2				2.36	705	19.99
	Round 2	230	4.2	ND	19				2.60	647	0.72
	% Reduction	93%	Increase	No Change	88%						

TCE - Trichloroethene
DCE - cis-1,2-Dichloroethene
VC - Vinyl Chloride
ORP - Oxidation Reduction Potential
DO - Dissolved Oxygen
µg/L - Micrograms per Liter
S.U. - Standard Units
mV - millivolts
ppm - Parts per Million



FIGURE 2-1

MIDDLE RIVER COMPLEX LAYOUT MAP

LEGEND

OUTFALL 004 NPDES PERMITTED OUTFALL

STORMWATER AND FLOW DIRECTION

PRE-1950 SHORELINE

EXISTING STRUCTURE

FORMER STRUCTURE

REC LOCATION (APPROXIMATE)

Lockheed Martin Middle River Complex
Middle River, Maryland

0 200 400

N

DATE MODITFIED 4/02/07

CREATED BY LR

Tetra Tech Inc.

filename: k:\gproject\middle_river\cad\newfolder\2003SiteLocationMapFigure2_16Jan07.dwg

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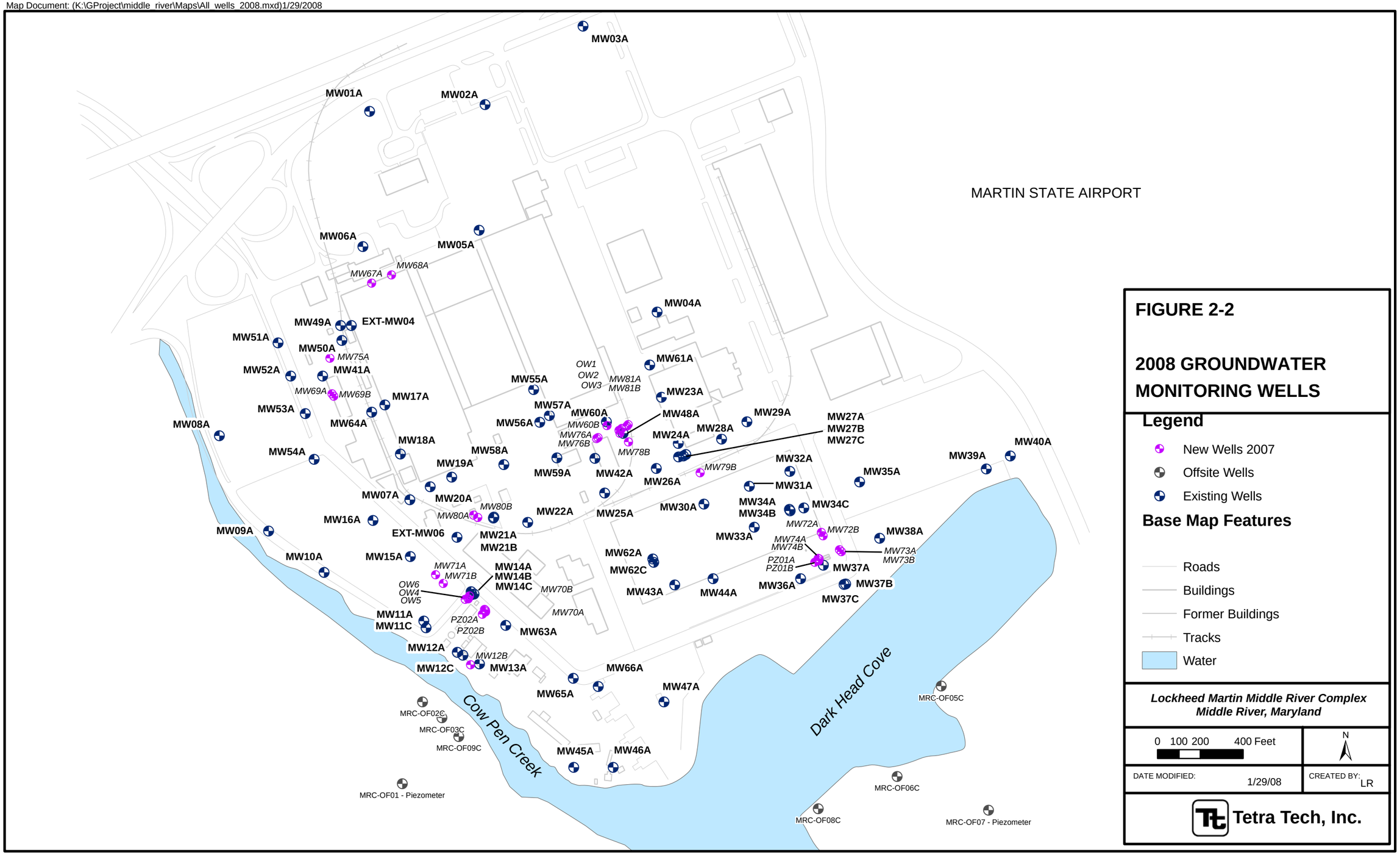

FIGURE 2-2

2008 GROUNDWATER MONITORING WELLS

Legend

- New Wells 2007
- Offsite Wells
- Existing Wells

Base Map Features

- Roads
- Buildings
- Former Buildings
- Tracks
- Water

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 1/29/08

CREATED BY: LR

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\All_wells_2008.mxd)1/29/2008

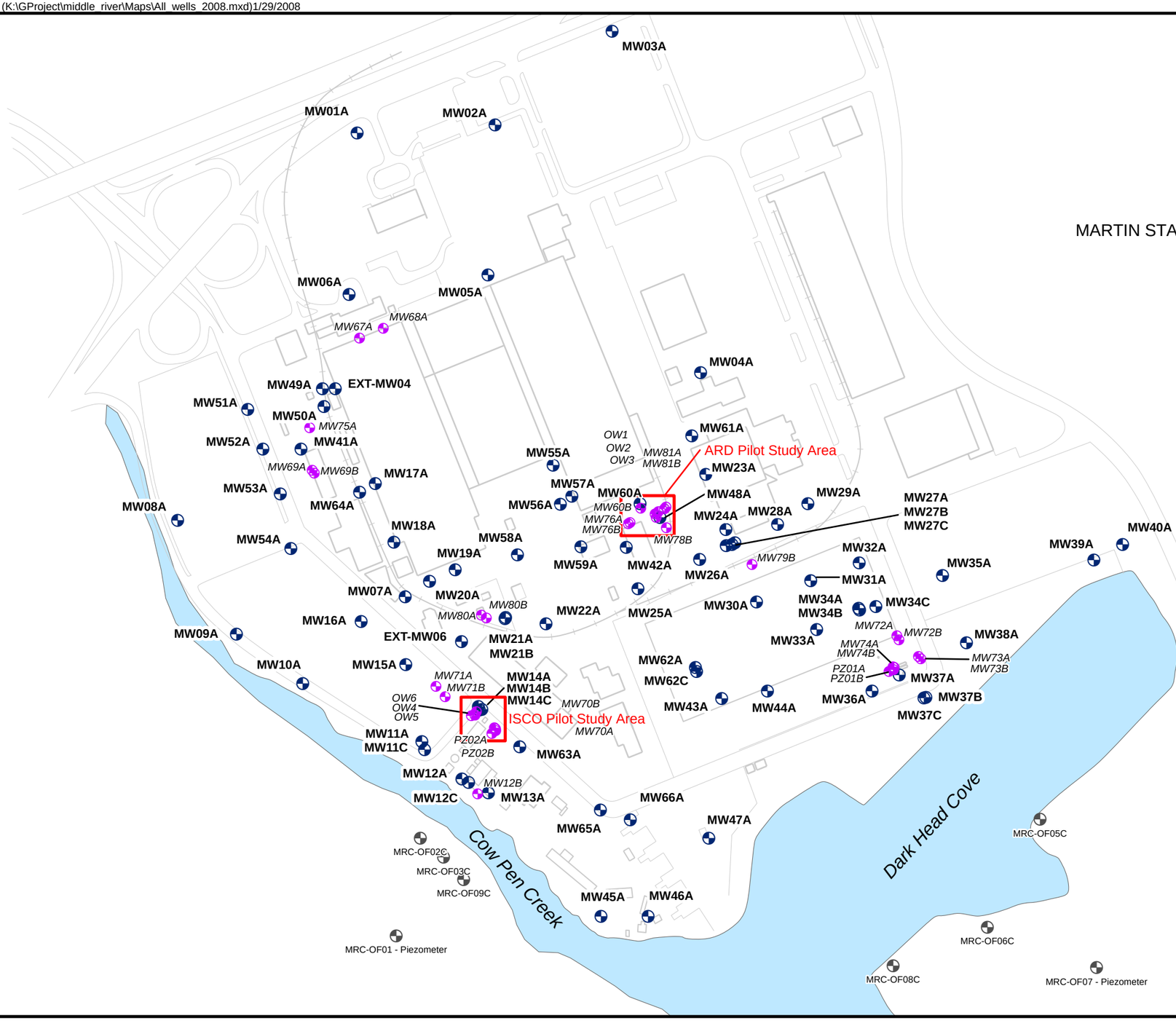

FIGURE 2-3

PILOT STUDY LOCATIONS

Legend

- New Wells 2007
- Offsite Wells
- Existing Wells

Base Map Features

- Roads
- Buildings
- Former Buildings
- Tracks
- Water

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 1/29/08

CREATED BY: LR

Tetra Tech, Inc.

MARTIN STATE AIRPORT

MW03A
MW01A
MW02A
MW05A
MW06A
MW67A
MW68A
MW49A
EXT-MW04
MW50A
MW51A
MW41A
MW75A
MW69A
MW52A
MW69B
MW53A
MW17A
MW64A
MW08A
MW19A
MW18A
MW58A
MW59A
MW54A
MW42A
MW20A
MW21A
MW07A
MW80A
MW21B
MW16A
MW80B
MW22A
EXT_MW06
MW09A
MW15A
MW14A
MW14B
MW71A
MW70A
MW71B
MW70B
MW10A
MW11A
MW14C
MW63A
MW11C
MW12A
MW13A
MW12C
MW12B
MW04A
MW81B
MW81A
MW55A
MW48A
MW61A
MW23A
MW78B
MW60A
MW57A
MW77A
MW76A
MW29A
MW56A
MW27A
MW76B
MW24A
MW60B
MW28A
MW26A
MW79B
MW31A
MW32A
MW27C
MW34B
MW25A
MW30A
MW34A
MW27B
MW34C
MW35A
MW72A
MW72B
MW33A
MW38A
MW74A
MW73A
MW62A
MW74B
MW73B
MW62C
MW43A
MW44A
MW36A
MW37C
MW37A
MW37B
MW65A
MW66A
MW47A
MW45A
MW46A
MW40A
MW39A
COW PEN CREEK
DARK HEAD COVE

FIGURE 2-4

DISTRIBUTION OF TCE, BENZENE AND 1,4 DIOXANE IN GROUNDWATER OCTOBER - NOVEMBER 2007

LEGEND

- GROUNDWATER MONITORING WELL
- WATER
- TRICHLOROETHENE ISOCONCENTRATION (ug/L)
- INFERRED
- BENZENE ISOCONCENTRATION (ug/L)
- INFERRED
- 1,4 DIOXANE ISOCONCENTRATION (ug/L)
- INFERRED

Lockheed Martin Middle River Complex
Middle River, Maryland

0 165 330 660 Feet

N

DATE MODIFIED: 2/4/08

CREATED BY: JF

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\Middle River TCE Benzene Dioxane Distribution in GW_Oct_Nov_2007.mxd) 2/13/2008 -- 3:30:16 PM

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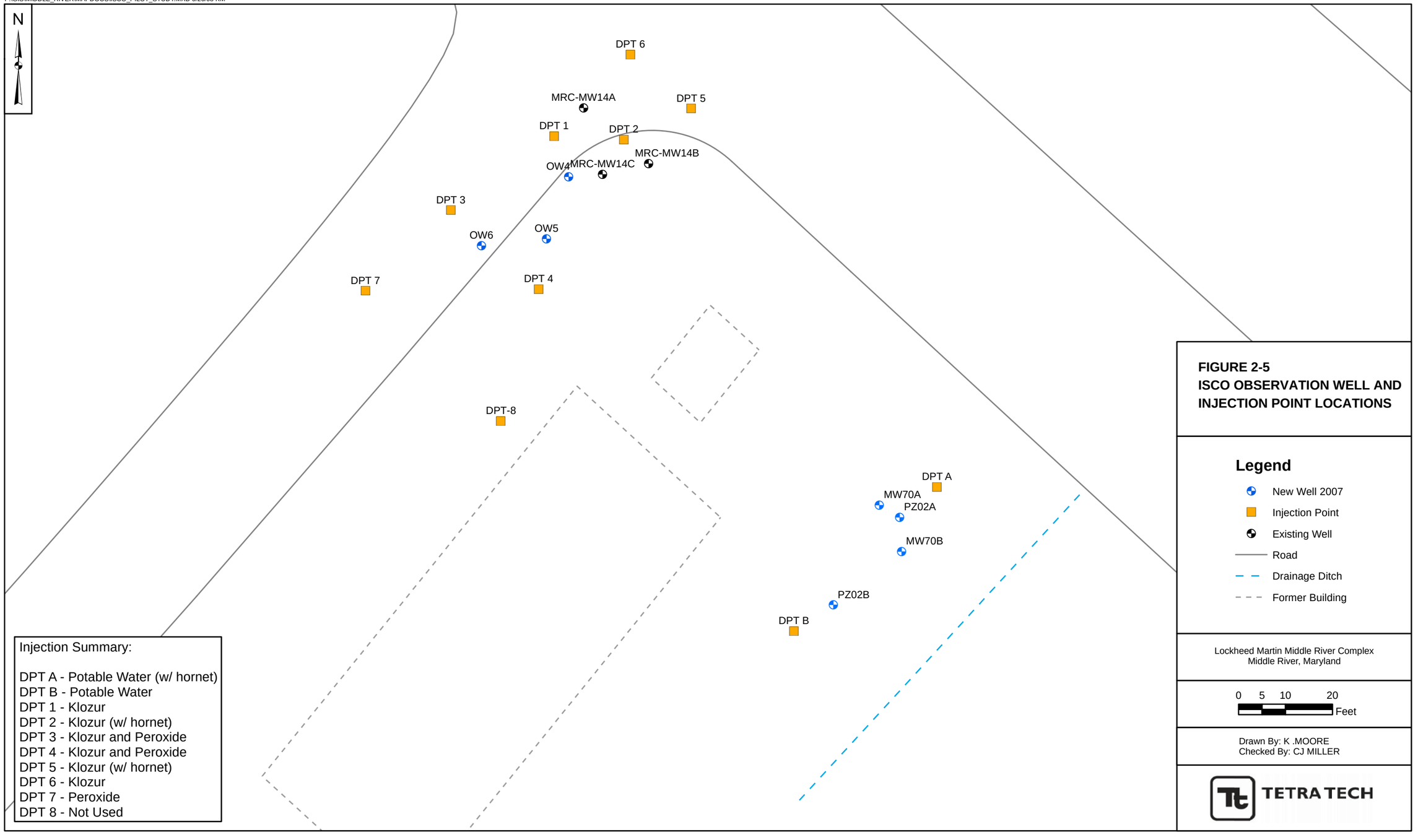

Injection Summary:

DPT A - Potable Water (w/ hornet)
DPT B - Potable Water
DPT 1 - Klozur
DPT 2 - Klozur (w/ hornet)
DPT 3 - Klozur and Peroxide
DPT 4 - Klozur and Peroxide
DPT 5 - Klozur (w/ hornet)
DPT 6 - Klozur
DPT 7 - Peroxide
DPT 8 - Not Used

FIGURE 2-5
ISCO OBSERVATION WELL AND INJECTION POINT LOCATIONS

Legend

- New Well 2007
- Injection Point
- Existing Well
- Road
- Drainage Ditch
- Former Building

Lockheed Martin Middle River Complex
Middle River, Maryland

0 5 10 20
Feet

Drawn By: K .MOORE
Checked By: CJ MILLER

TETRA TECH

Section 3
ISCO Pilot Study Field Implementation

To obtain the data required for design of remedial actions, Tetra Tech conducted an in-situ pilot study in the western TCE plume, which contains 1,4-dioxane as well as TCE. ISCO was tested using injection of activated and unactivated sodium persulfate via direct push technology (DPT) equipment. Sampling associated with the pilot study included baseline sampling prior to injection, and sampling rounds conducted approximately two weeks and two months following injection. Additional sampling will be conducted from various depth intervals in the pilot study area via DPT and an additional round of groundwater sampling will be conducted approximately 6 months after injection. The results of these final two sampling events will be included in a subsequent pilot study report.

3.1 BASELINE SAMPLING

As detailed in Section 2.0, a total of 6 observation wells were installed in the pilot study area during field activities completed in late 2007 and early 2008. Wells OW4S, 4I; OW5S, 5I; and OW-6S, 6I were installed in the western plume to facilitate completion of the ISCO pilot study at this site. Due to its proximity to the pilot study area, MW14B was also included in the pilot study evaluation; data from MW14B generated during the most recent site-wide round of groundwater sampling was utilized as its baseline data.

The observation well locations are shown in Figures 3-1.

Following installation, these wells were sampled and analyzed for VOCs, 1,4-dioxane, and metals. This data is presented in Section 2.0.

Additionally, the following field parameters were measured from groundwater in the 6 observation wells and MW14B: pH, temperature, oxidation reduction potential (ORP), dissolved oxygen (DO), and conductivity.

Field sampling logs are included in Appendix B and laboratory analytical reports are included in Appendix C.

3.2 IN-SITU CHEMICAL OXIDATION PILOT STUDY

This ISCO pilot study was designed to determine the following:

- Injection volumes and areas of influence of liquid injection through DPT rods.
- The effect on those parameters when pressure pulse technology is utilized.
- The effectiveness of unactivated sodium persulfate in treating VOCs and 1,4-dioxane in the subsurface.
- The effectiveness of sodium persulfate activated with hydrogen peroxide in treating VOCs and 1,4-dioxane in the subsurface.
- "Rebound" effects of VOC and 1,4-dioxane concentrations associated with utilizing chemical oxidation.

The ISCO pilot study consisted of sub-surface injection of an oxidant with the goal of destroying VOCs and 1,4-dioxane in the pilot study area. Based on the results of the ISCO bench-scale testing, both activated and unactivated sodium persulfate were tested. Due to the low permeability soil present in the pilot study area, two different methods of liquid injection were tested, standard injection through DPT rods and use of pressure pulse technology in conjunction with injection through DPT rods to potentially increase the injection rates and area of influence.

The first phase of the testing included potable water injection to obtain injection parameters for traditional DPT injection and injection using the pressure pulse technology and the second phase consisted of the oxidant injection.

3.2.1 Pressure Pulse Technology Testing

On June 16 and 17, 2008, the Hornet apparatus, from Wavefront Technologies (Wavefront), was field tested in conjunction with DPT injection to determine the operating parameters for the remainder of the test. Representatives of Wavefront were present on site to assist Tetra Tech and the DPT/injection subcontractor (Vironex, Inc.) in use of the technology. In order to perform the test, the following activities were performed:

A boring (DPT A) was installed to a depth of 35 feet bgs using DPT methods. Potable water was injected through the DPT rods with the Hornet apparatus installed at the top of the rods and used to control the flow via pressure pulse technology. The rods were then gradually raised and flow rates and required injection pressures recorded for various depth intervals. As the rods were raised to approximately 8 feet bgs, careful observation was conducted to determine if "daylighting" of liquid was occurring. Injection proceeded from 35 feet bgs to 4 feet bgs with no daylighting. A total of 276 gallons of potable water was injected at an average flow rate of 3.7 gallons per minute (gpm) at a pressure of 21 pounds per square inch (psi). During injection, groundwater levels in MW70A and MW70B and piezometers PZ-02A and -02B were monitored to determine the effect of the injection on local groundwater elevations.

A second boring (DPT B) was installed to 35 feet using similar DPT methods. Potable water was then injected using standard methods through a hose installed within the DPT rods. The injections were stopped at a depth of approximately 8 feet due to water levels above the top of casing (TOC) in the nearby monitoring wells and piezometers. A total of 183 gallons of potable water was injected at an average flow rate of 2.7 gpm at an average pressure of 42 psi.

The following observations were made in the field regarding use of the Hornet tool:

- As the rods are raised and it is necessary to change out the rods, the Hornet tool must be removed from the DPT rods. This is both time consuming and a potential safety concern when strong oxidants are used. It is necessary to relieve the pressure from the rods and flush with potable water prior to removing the Hornet tool.
- Standard DPT rods can be damaged through the use of oxidant injections directly through the rods, as required when using the pressure pulse tool.
- Advantages to injection through a hose installed inside the rods (not possible using pressure pulse technology) included: the time constraints and safety concerns detailed

above are not applicable, and damage to the rods from the oxidants is significantly reduced due to limited contact.

- The Hornet tool appeared to provide quicker response at greater distances from the injection location. This indicates that the area effected can be increased using the tool, but also that the tool may increase creation of preferential flow pathways in the subsurface.
- When daylighting occurred, substantially more activity (bubbling, churning, etc.) was observed when the tool was activated compared to when it was not.

Locations of the pressure pulse technology test borings are presented on Figure 3-1; a summary of the injection quantities and pressures is provided in Table 3-1. Information on the Hornet pressure pulse equipment is presented in the pilot test work plan (Tetra Tech, 2008). A field report prepared by Vironex, Inc., which includes data from the Hornet potable water testing activities, is included in Appendix D.

3.2.2 Oxidant Injection

Between June 17 and June 20, 2008, Tetra Tech completed the injection of sodium persulfate in the pilot study area located in the western TCE plume. The oxidant injection took place through DPT rods both with and without the use of pressure pulse technology and with and without the use of hydrogen peroxide as an activator. A total of nine separate injections were completed, as summarized in Table 3-1 and shown on Figure 2-5.

At location DPT-1, a 20 percent solution of sodium persulfate (Klozur^{TM} from FMC, Inc.) was injected via standard DPT methods from a depth of 35 feet bgs to 8 feet bgs.

At location DPT-2, a 20 percent Klozur^{TM} solution was injected from 35 feet bgs to 18 feet bgs using the Hornet tool. Daylighting of the chemical around the borehole was observed, so injection was ceased at that time. Location DPT-5, located nearby, was then added to the plan and injection proceeded there via the same methods from a depth of 27 feet bgs to a depth of 6 feet bgs.

Points DPT-3a and DPT-3b were co-located. Standard DPT injection of Klozur^{TM} solution at DPT-3a and an approximately 10 percent hydrogen peroxide solution at DPT-3b were completed.

Similar injections were completed at DPT-4a and DPT-4b, which were also co-located.

Injection of Klozur™ solution from 20 feet bgs to 11 feet bgs at DPT-6 and injection of hydrogen peroxide solution from 35 feet bgs to 11 feet bgs at DPT-7 were completed to inject the remaining chemical.

As planned, a total of 1,900 pounds of Klozur™ was injected; due to daylighting of chemical and reactions at the surface, only three of the four drums of 35 percent hydrogen peroxide delivered to the site were injected. Throughout the field activities, injection flow rates and pressures were controlled to prevent significant daylighting and resultant process and safety issues; average flow rates ranged from 1.6 to 3.3 gpm and average pressures ranged from 20 to 43 psi.

Due to the difficulty in completing further injections into the pilot study area without significant daylighting and surfacing of oxidant out of the monitoring wells with resultant reactions, it was decided that the fourth drum of peroxide would not be injected.

Following the injection at each location, field parameters (depth to water, pH, DO, ORP, temperature, turbidity, conductivity and total dissolved solids [TDS]) were measured at the wells in the pilot study area to determine the area of influence of each injection. These data are summarized in Table 3-2.

The data indicate that the oxidant injection had a significant effect on the majority of pilot test observation wells; however, OW4B was not affected in the same manner as the other wells. OW4B is located approximately 9 feet from DPT-1, a location where persulfate only was injected without use of the Hornet tool. Field data from the test indicate that there was only a very slight effect on the field parameters at the well during the injection, despite a significant increase in water level. This indicated that although the injection was proceeding at an adequate rate, there was a limited radius of influence. The observation wells are closely spaced and the boring logs are similar, so any variations in geology do not appear to account for the difference in influence at this well.

When the persulfate was added using the Hornet tool at DPT-2, located a similar distance from MW14B, the DO and ORP increased significantly and chemical was observed in the well. This may indicate that influence was observed at a greater distance when the tool was employed.

The effect of the injections at DPT-3 and DPT-4 without the Hornet tool was different than that observed for DPT-1. At DPT-3, as injection progressed, a significant increase in DO and ORP was observed at OW6B, located approximately 10 feet from the injection well. At DPT-4, response was observed at OW5A and 5B, located a similar distance away. Therefore, it appears that in some cases, the injection without using the Hornet can provide significant areas of influence as well.

During the subsequent hydrogen peroxide injections, all performed without the Hornet tool, effects were observed throughout the study area, including more than 60 feet from the injection locations. The groundwater in all of the "B" wells reached the top of casing and bubbling reactions were seen at the wells (except OW4B) and the locations of DPT-3 and DPT-5. As the injections ended, it appeared that injection of additional material into the study area was not feasible without significant upwelling.

In general, although influence is observed a certain distance from an injection point, it is not necessarily true that the entire cylinder around the well is being effected. To obtain an effect throughout the entire thickness of the aquifer, ideally the volume of injected liquid would equal a significant percentage of the cylinder being influenced. For this test, the goal was to reach a 1 percent concentration of persulfate in the study area groundwater. A manufacturer-recommended concentration of 20 percent persulfate was utilized (concentrations of 10 to 20 percent are common; because we were not sure of possible injection volumes achievable in this tight matrix, the more conservative value was used). That translates to approximately 5 percent of one pore volume injected. When the diluted hydrogen peroxide is considered, a total of approximately 8 percent of a pore volume was injected.

As injection proceeded, it became apparent that without allowing a significant time period for the aquifer to come back to equilibrium, the volume injected approached the maximum that could be effectively added to the matrix. The water level in the "B" wells was to the top of casing, and with

the reactions from the peroxide addition, water and chemical were bubbling out the top of the well casings. Water level increases were seen at MW70, approximately 85 feet from the injection location. Interestingly, the water level increases were not as significant in the shallow wells. It appeared that a low permeability layer in the shallow zone was acting as a semi-confining layer, and the water was finding the path of least resistance out of the ground via the observation wells and previous DPT borings, and also effecting water levels in wells located a significant distance away.

Attempting to inject a volume equivalent to a significant percentage of the effected cylinder would have required up to 6 times the injection volume used (for 50 percent of the pore volume). This is unrealistic in a short term test as it would have caused a tremendous amount of upwelling as well as increased the chance of spreading the contamination laterally.

One important point on Hornet injection: although the distance effected during the injections increased, the total volume injected was similar to the quantities for the non-Hornet points. This indicates that the Hornet may have created preferential flow paths and actually decreased the percentage of a pore volume injected in the area influenced.

3.3 POST-INJECTION PERFORMANCE MONITORING

Following injection activities, the period of post-injection monitoring began. Two rounds of post-injection monitoring have been completed; one additional round is planned.

The first round of post-injection performance monitoring was completed on June 30 and July 1, 2008, approximately two weeks after injections were initiated. Samples were collected from 6 wells: OW4S, OW4I, OW5S, OW6S, OW6I, and MW14B. During the sampling activities, it was observed that OW5I contained silt nearly to the top of the well casing. The silt was too thick to remove via pumping or bailing and it was assumed that the well construction was compromised. Consideration was given to either attempting to rehabilitate the well through removal of the silt via vacuum truck, or abandoning the well and re-installing another nearby. However, it was determined that adequate data would be available from the other test wells and rehabilitation or re-installation of OW5I would not be required.

The groundwater samples from each well were analyzed for VOCs and 1,4-dioxane. Additionally, the following field parameters were measured: pH, temperature, ORP, DO, and conductivity.

The second round of post-injection performance monitoring was completed on August 11 and 12, 2008. The sampling protocol was the same for this event.

A third round of post-injection performance monitoring was conducted in November 2008, but the results are not included in this Interim Report. The following table summarizes the overall sampling approach:

Sampling Summary

Parameter	Baseline	2 Weeks	2 Months	6 Months
VOCs	7	6	6	6
1,4-Dioxane	7	6	6	6
Metals (plus Na)	7	0	0	6
Field Parameters	7	6	6	6

Low-flow well purging and sample collection, documentation, sample handling and nomenclature, equipment decontamination, waste management, and the utility clearance requirements for this work followed the protocol from the On-Site Remedial Design Work Plan for MRC (Tetra Tech, 2007).

Additionally, a DPT sampling event to determine the effectiveness of the injections at several depths will be completed. During this event, groundwater samples will be collected from depths of 10, 15, 20, 25, and 30 feet bgs from three locations in the pilot study area. Samples from these intervals will be measured for the field parameters and laboratory analyzed for VOCs and sulfate (if adequate groundwater can be be collected).

TABLE 3-1

IN-SITU CHEMICAL OXIDATION INJECTION SUMMARY
LOCKHHED MARTIN MIDDLE RIVER COMPLEX, MIDDLE RIVER, MARYLAND

Injection Location	Chemical Injected	Injection Method	Depth Interval (ft bgs)	Quantity (Gallons)	Avg Flow (gpm)	Avg Pressure (psi)	Comments
DPT-A	Potable Water	DPT/Hornet	35' - 4'	276	3.7	21	
DPT-B	Potable Water	DPT	35' - 8'	183	2.7	42	
DPT-1	20% Klozur	DPT	35' - 8'	239	2.1	23	
DPT-2	20% Klozur	DPT/Hornet	35' - 18'	85	1.9	25	Injection ceased due to surfacing around borehole (DPT-5 added)
DPT-3a	20% Klozur	DPT	35' - 8'	218	3.3	43	These points were co-located
DPT-3b	~10% Hydrogen Peroxide	DPT	35' - 17'	226	1.6	26	
DPT-4a	20% Klozur	DPT	35' - 7'	228	3.0	27	These points were co-located
DPT-4b	~10% Hydrogen Peroxide	DPT	35' - 9'	210	2.1	24	
DPT-5	20% Klozur	DPT/Hornet	27' - 6'	166	2.2	20	Added to complete injection in the vicinity of DPT-2
DPT-6	20% Klozur	DPT	20' - 11'	45	3.3	34	Added to inject remaining Klozur
DPT-7	~10% Hydrogen Peroxide	DPT	35' - 11'	175	1.9	31	Added to complete injection of third peroxide drum
DPT-8	Not Utilized						

TABLE 3-2

ISCO PILOT STUDY FIELD DATA SUMMARY
LOCKHEED MARTIN MIDDLE RIVER COMPLEX, MIDDLE RIVER, MARYLAND

Baseline (6/17/08)
Collected prior to any chemical injections.
Baseline for Test #1

Well ID	pH	Conductivity	Turbidity	Dissolved Oxygen	Temperature	Total Dissoved Solids	Oxidation-Reduction Potential
MW-14A	5.78	1.75	23.50	4.04	20.80	1.30	43
MW-14B	5.36	0.43	26.90	0.00	17.60	0.28	98
OW-4S	6.05	1.82	6.00	6.83	18.50	1.20	22
OW-4I	5.09	0.49	30.60	0.00	16.00	0.32	45
OW-5S	5.81	2.12	5.90	0.66	17.80	1.40	71
OW-5I	5.70	6.48	294.00	3.60	16.80	0.40	21
OW-6S	5.57	1.96	23.30	0.00	18.00	1.20	110
OW-6I	5.87	0.28	38.30	0.25	17.00	0.18	NA

Test #1 (6/18/08)
Sodium Permanganate injection at DP-03 using DPT only
Post Injection Results

Well ID	pH	Conductivity	Turbidity	Dissolved Oxygen	Temperature	Total Dissoved Solids	Oxidation-Reduction Potential
MW-14A	5.63	1.53	6.40	1.52	19.20	1.00	113
MW-14B	5.51	0.35	12.90	0.13	15.50	0.23	96
OW-4S	6.08	2.40	12.00	0.00	15.90	1.50	20
OW-4I	5.65	0.52	14.30	0.25	15.60	0.33	55
OW-5S	5.94	2.36	6.90	0.00	16.70	1.50	44
OW-5I	5.83	0.59	19.10	0.08	15.70	0.38	10
OW-6S	2.62	67.50	55.70	>19.9	17.10	40.00	800
OW-6I	2.44	60.30	164.00	>19.9	16.20	36.00	758

Test #2 (6/18/08):
Baseline for Sodium Permanganate injection at DP-01 using DPT only.
Baseline for Test #2

Well ID	pH	Conductivity	Turbidity	Dissolved Oxygen	Temperature	Total Dissoved Solids	Oxidation-Reduction Potential
MW-14A	5.63	1.53	6.40	1.52	19.20	1.00	113
MW-14B	5.51	0.35	12.90	0.13	15.50	0.23	96
OW-4S	6.08	2.40	12.00	0.00	15.90	1.50	20
OW-4I	5.65	0.52	14.30	0.25	15.60	0.33	55
OW-5S	5.94	2.36	6.90	0.00	16.70	1.50	44
OW-5I	5.83	0.59	19.10	0.08	15.70	0.38	10
OW-6S	2.62	67.50	55.70	>19.9	17.10	40.00	800
OW-6I	2.44	60.30	164.00	>19.9	16.20	36.00	758

Test #2 (6/18/08)
Post Persulfate injection at DP-01 using DPT only.
Post Injection results for Test #2

Well ID	pH	Conductivity	Turbidity	Dissolved Oxygen	Temperature	Total Dissoved Solids	Oxidation-Reduction Potential
MW-14A	5.62	4.09	41.40	1.12	18.90	2.50	61
MW-14B	4.81	0.45	10.60	0.94	17.10	0.29	129
OW-4S	6.13	2.19	8.40	0.04	18.10	1.00	18
OW-4I	5.46	0.90	14.00	0.20	16.40	0.30	54
OW-5S	5.94	2.56	10.70	4.70	16.20	1.60	55
OW-5I	5.81	0.60	49.10	8.57	16.30	0.40	28
OW-6S	2.53	65.60	49.40	>19.9	16.80	39.00	816
OW-6I	2.40	55.90	115.00	>19.9	17.10	33.00	801

TABLE 3-2

ISCO PILOT STUDY FIELD DATA SUMMARY
LOCKHEED MARTIN MIDDLE RIVER COMPLEX, MIDDLE RIVER, MARYLAND

Test #3 (6/18/08) Hornet Test with persulfate at DP-02. Baseline for Test #3							
Well ID	**pH**	**Conductivity**	**Turbidity**	**Dissolved Oxygen**	**Temperature**	**Total Dissoved Solids**	**Oxidation-Reduction Potential**
MW-14A	5.62	4.09	41.40	1.12	18.90	2.50	61
MW-14B	4.81	0.45	10.60	0.94	17.10	0.29	129
OW-4S	6.13	2.19	8.40	0.04	18.10	1.00	18
OW-4I	5.46	0.90	14.00	0.20	16.40	0.30	54
OW-5S	5.94	2.56	10.70	4.70	16.20	1.60	55
OW-5I	5.81	0.60	49.10	8.57	16.30	0.40	28
OW-6S	2.53	65.60	49.40	>19.9	16.80	39.00	816
OW-6I	2.40	55.90	115.00	>19.9	17.10	33.00	801

Test #3 (6/18/08) Hornet Test with persulfate at DP-02. Post Injection Results for Test #3							
Well ID	**pH**	**Conductivity**	**Turbidity**	**Dissolved Oxygen**	**Temperature**	**Total Dissoved Solids**	**Oxidation-Reduction Potential**
MW-14A	5.68	1.58	3.30	6.31	19.10	1.00	64
MW-14B	Chemical in well as identified during baseline readings so did not resample.						
OW-4S	6.10	2.43	14.00	9.74	16.60	1.60	-1
OW-4I	5.46	0.15	24.60	15.17	16.10	0.40	59
OW-5S	5.93	2.38	10.80	5.94	15.90	1.50	25
OW-5I	5.91	0.58	25.30	9.96	16.10	0.37	-11
OW-6S	Chemical in well as identified during baseline readings so did not resample.						
OW-6I	Chemical in well as identified during baseline readings so did not resample.						

Test #4 (6/19/08) DPT injection with persulfate at DP-04. Baseline							
Well ID	**pH**	**Conductivity**	**Turbidity**	**Dissolved Oxygen**	**Temperature**	**Total Dissoved Solids**	**Oxidation-Reduction Potential**
MW-14A	5.56	1.91	6.40	1.74	19.40	1.20	60
MW-14B	Chemical in well as identified during baseline readings so did not resample.						
OW-4S	5.99	2.76	6.40	0.00	16.70	1.80	-34
OW-4I	5.35	0.90	17.70	0.00	15.80	0.60	33
OW-5S	5.77	2.73	7.50	0.00	16.10	1.70	6
OW-5I	5.58	0.57	24.40	0.02	16.00	0.37	-14
OW-6S	Chemical in well as identified during baseline readings so did not resample.						
OW-6I	Chemical in well as identified during baseline readings so did not resample.						

Test #4 (6/20/08) DPT Test with persulfate at DP-04. Post Injection Results							
Well ID	**pH**	**Conductivity**	**Turbidity**	**Dissolved Oxygen**	**Temperature**	**Total Dissoved Solids**	**Oxidation-Reduction Potential**
MW-14A	5.64	1.95	4.20	3.31	19.50	1.20	48
MW-14B	Chemical in well as identified during baseline readings so did not resample.						
OW-4S	5.92	37.10	10.40	4.43	16.80	999.00	12
OW-4I	5.12	0.55	58.40	4.91	17.10	0.35	129
OW-5S	2.63	7.29	999.00	>19.9	17.70	4.60	613
OW-5I	3.17	0.78	999.00	0.00	17.10	0.48	444
OW-6S	Chemical in well as identified during baseline readings so did not resample.						
OW-6I	Chemical in well as identified during baseline readings so did not resample.						

Section 4
ISCO Pilot Study Interim Sampling Results

This section provides a summary of the pilot study data from the first two rounds of performance sampling.

4.1 FIRST ROUND OF PERFORMANCE SAMPLING

As stated in Section 3, wells OW4S, 4I, 5S, 6S, and 6I and MW14B were sampled on June 30 and 31, approximately two weeks after the ISCO injections took place. A summary of the analytical results for TCE, DCE, and vinyl chloride and key field parameters (pH, ORP, and DO) are included in Table 2-1. In general, the data show the following:

- The field data indicated that pH was sharply reduced and ORP and DO significantly increased at four of the six wells (OW5S, OW6S, OW6I, and MW14B). At these four wells, pH levels were less than 3 standard units (SU), ORP was 490 millivolts (mV) or greater, and DO was recorded as the highest value on the instrument – 19.99 parts per million (ppm). In the bench-scale testing conducted prior to the pilot study, it was shown that the sodium persulfate alone did not reduce the pH of the groundwater; the pH was only significantly reduced when the persulfate was activated with hydrogen peroxide. However, field data from the pilot study showed that persulfate alone reduced the groundwater pH significantly.
- OW4S showed a significant increase in DO and ORP with only a minimal decrease in pH. OW4I showed only slight increases in pH and ORP and decrease in pH. The well was only slightly influenced, if at all, by either persulfate or peroxide. During peroxide injection, reactions (in the form of bubbling groundwater at the surface) were observed in many of the observation wells. However, although there was a rise in water level at OW4S and 4I, there was no indication of vigorous chemical reactions.
- Because the concentrations in the "S" wells started out at quite low levels, the analytical data from those wells cannot be usefully compared to the baseline data.

- The two "I" wells with the significant increases in ORP and DO (and decreases in pH) showed significant reduction in VOCs and 1,4-dioxane concentrations – all 94 percent or greater.
    - OW6I
        - TCE – 96 percent reduction
        - DCE – 97 percent reduction
        - 1,4-dioxane – 96 percent reduction
    - MW14B
        - TCE – 94 percent reduction
        - 1,4-dioxane – 97 percent reduction
- OW4I, which showed significantly less response in the field parameters, had significantly lower, but still measureable, reductions in COC concentrations – approximately 50 percent:
    - OW4I
        - TCE – 48 percent reduction
        - DCE – 50 percent reduction
        - 1,4-dioxane – 44 percent reduction

4.2 SECOND ROUND OF PERFORMANCE SAMPLING

The second round of post-injection performance sampling occurred approximately two months after injection and included sampling of the same wells and parameters as the first round. Each of the three wells showing measurable decreases in VOC and 1,4-dioxane concentrations in the first round of post-injection sampling (OW4I, OW6I, and MW14B) had differing trends in the second sampling round. It appears that the change in COC concentrations between the first and second rounds of post-injection monitoring was correlated to the changes in the field parameters at each well, as described below.

OW4I, which exhibited the lowest concentration reductions in the first round (approximately 50 percent) showed continued decreases of VOC concentrations, but a slight increase in 1,4-dioxane concentrations from the initial event. TCE and DCE concentrations showed reductions of 61 percent and 58 percent, respectively, from baseline concentrations. The concentration of 1,4-dioxane showed a reduction of 30 percent from the baseline concentration. Despite the reductions in contaminant concentrations, little or no effect from the oxidant injection on the field parameters was observed.

Concentrations in MW14B changed only slightly. TCE increased from 210 µg/L in the first round to 230 µg/L in the second round of post-injection sampling; the overall decrease from baseline was 93 percent. Similar slight increases between the first and second post-injection events were observed in DCE and 1,4-dioxane concentrations. Overall, the 1,4-dioxane concentration was reduced by 88 percent between the baseline and second post-injection monitoring events. The field parameters in this well continued to show a significant effect from the oxidant injection; pH was 2.6 SU and ORP was 647 mV.

Significant rebound was observed in the VOC and 1,4-dioxane concentrations at OW6I. Although the concentrations of TCE, DCE, and 1,4-dioxane concentrations were still lower than baseline conditions (35 percent, 40 percent, and 75 percent, respectively) these reductions were much lower than observed following the first round of sampling (96 percent, 97 percent, and 96 percent, respectively). Field parameters in this well continued to show the effects of the oxidant addition, but had moved closer to baseline conditions. The pH was 4.65 SU, ORP was 184 mV, and the DO was 6.17 ppm.

Section 5
References

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2. Cassell, J.R., Drainage Area Map – Existing Storm Water Drains, Chesapeake Park Plaza/Dark Head Cove Road; Sheet A1 of 7; July 20, 1977.

3. Reinhardt, J., Geologic Map of the Middle River Quadrangle, Maryland, Maryland Geological Survey, Baltimore, Maryland. 1977.

4. Tetra Tech, Inc., 2004 Phase II Environmental Site Assessment, Middle River Complex, February 28, 2005.

5. Tetra Tech, Inc., Historical Research Report, Lockheed Martin Middle River Complex. August, 2004.

6. Tetra Tech, May 2006. Site Characterization Report, Revision 1.0, Lockheed Martin Middle River Complex.

7. Tetra Tech, September 2007. On-Site Remedial Design Studies Work Plan, Lockheed Martin Middle River Complex.

8. Tetra Tech, April 2008. Groundwater Response Action Plan, Lockheed Martin Middle River Complex.

9. Tetra Tech, May 2008. On-Site Pilot Scale Studies Work Plan, Lockheed Martin Middle River Complex.

APPENDIX A

OBSERVATION WELL BORING LOGS/ WELL COMPLETION DIAGRAMS

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57
BORING No.: OW-4
DATE: 11-27-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
	0												
0915		3/3				orange	Silty clay		moist	~~0.5~~			
S-1	2	4/4	1.2/2.0	1' pellets	med. dm stiff					0.5	0	0	0
0925		3/10				brown	Sandy clay		moist				
S-2	4	28/26	1.6/2.0	3' Sand	hard	orange	Silty clay		moist	3.0	0	0	0
0935		5/19				orange	Silty sand		wet				
S-3	6	26/29	1.2/2.0		hard	orange	Silty sandy clay		Rounded pebbles	2.5	0	0	0
1009		3/12											
S-4	8	20/19	1.5/2.0		hard	orange	Silty clay		wet	0.8	0	0	0
1021		6/8				orange	Sandy clay		wet				
S-5	10	10/11	1.3/2.0		very stiff	brown	clay		wet	2.8	0	0	0
1030		3/3											
S-6	12	4/5	1.6/2.0		stiff	orange brown	clay		wet	1.8	0	0	0
1039		8/8											
S-7	14	10/11	1.2/2.0		very stiff	orange brown	Silty clay		Rounded pebbles	1.4	0	0	0
1045		6/7											
S-8	16	8/10	1.9/2.0	15' Sand	very stiff	orange	Sandy clay		moist	1.4	0	0	0
1052		6/7		16' pellets									
S-9	18	9/11	1.8/2.0		very stiff	orange brown	silty sandy clay		wet	2.1	0	0	0
1057		3/5		18' Sand									
S-10	20	5/7	2.0/2.6	20'	stiff	org brown	Sandy clay		wet	0.6	0	0	0
1112		4/5											
S-11	22	8/11	1.1/2.0		very stiff					2.2	0	0	0
1115		4/5				orange brown	Sandy clay		wet				
S-12	24	6/9	2.0/2.0		very stiff					2.9	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 3 2 nested wells

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-4A , OW-4B

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-4
DATE: 11-27-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
1119		7/6				orange brown	Sandy clay		wet. medium rnd.	29.7	0	0	0
S-13	20	10/12			very stiff								
1126		7/7				orange brown	Sandy clay		wet medium rnd.	6.4	0	0	0
S-14	25	11/14			very stiff								
1139		11/12				orange brown	clayey sand		wet medium rnd.	7.2	0	0	0
S-16	30	18/20		30	hard								

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 2 nested wells.

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-4A, OW-4B

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: ATV B-57

BORING No.: OW-5
DATE: 11-28-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
S	0	2/3				brown	sandy silt						
S-1 1055	2	5/5	1.2/2.0		stiff	brown	silty clay			20+	0	0	0
		7/6		1' pellets		orange	sand		rounded pebbles				
S-2 1101	4	12/13	1.4/2.0	3' sand	very stiff	brown	sandy clay			45.1	0	0	0
		7/7				orange	sand		1" interbed of				
S-3 1110	6	6/11	1.4/2.0	5'	very stiff				fine sand @ 5'6'	25.1	0	0	0
		6/5				brown	silty clay		trace sand				
S-4 1119	8	7/11	1.6/2.0		very stiff	orange	sandy clay			5.8	0	0	0
		2/3											
S-5 1125	10	3/5	2.0/2.0		medium stiff	orange	sandy clayey silt		moist	10.0	0	0	0
		2/3				brown orange	silty clay		moist some sand leases				
S-6 1139	12	5/7	2.0/2.0		stiff					0	0	0	0
		9/6				orange	clayey silt		moist sparse rounded pebbles				
S-7 1152	14	7/11	2.0/2.0		very stiff	reddish brown	clay			0	0	0	0
		6/7				brown	sandy clay		moist rounded medium sand				
S-8 1203	16	9/12	2.0/2.0	15' sand 16' pellets	very stiff	red brown	clay			0	0	0	0
		6/9											
S-9 1214	18	11/11	2.0/2.0		very stiff	red brown	sandy silty clay		moist, med. rnd. sand	0	0	0	0
		5/8		18' sand 20									
S-10 1240	20	11/12	2.0/2.0		very stiff	red brown	clay		moist	3.4	0	0.5	0
		9/12											
S-11 1255	22	13/15	2.0/2.0		very stiff	red brown	silty sandy clay		moist, fine to med. sand	2.4	0	0	0
		6/7											
S-12 1310	24	9/14	2.0/2.0		very stiff	red brown	clay			5.1	0	0	0
		6/10											

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 2 nested wells flush mount.

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-5A, OW-5B

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-5
DATE: 11-28-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
S-13 1339	26	15/16 6/12	20/2.0		very stiff	red brown	Silty clay		moist	8.9	0	0	0
						red brown	Silty Sandy clay		Saturated, fine sand				
S-14 1350	28	15/19 9/10	2.0/2.0		hard	red brown	Silty clay		moist	19.6	0	0	0
S-15 1405		15/30	20/2.0	~30'	hard				moist	19.6	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 2 nested wells

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-5A, OW-5B

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: ATV B-57

BORING No.: OW-6
DATE: 11-29-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
	0	1 / 3				yellow brown	Silty Clay		with organics, moist				
S-1		5 / 5	1.0/2.0										
0945	2	~~4 / 14~~		1' pellets	stiff	yellow brown	clay		with sparse angular pebbles, moist	0	0	0	0
		4 / 14											
S-2	4	14 / 28	2.0/2.0	3' sand	hard	orange	Silty Sand		Med. Rounded sand	0	0	0	0
0955		20 / 45					Sandy clay		Moist				
S-3	6	47 / 50	1.7/2.0	5'	hard	orange	Sand, trace silt		well rounded, wet	1.3	0	0	0
1012		15 / 11				orange	Sand, med to coarse		sparse pebbles				
S-4	8	12 / 9	2.0/2.0		very stiff	orange	Silt		wet	0.5	0	0	0
1035		5 / 4											
S-5	10	9 / 8	2.0/2.0		very stiff	orange	Sandy clay		trace Rnd pebbles med. Rnd sand, wet	0.1	0	0	0
1106		5 / 3											
S-6	12	5 / 7	1.8/2.0		stiff	green	Clay		plant organics, wet	1.0	0	0	0
1113		6 / 9				orange	Sandy clay		saturated, Med. Rnd.				
S-7	14	9 / 11	2.0/2.0		very stiff	brown	Silty clay		wet	0.8	0	0	0
1125		6 / 12											
S-8	16	14 / 16	2.0/2.0	15' sand	very stiff	Red	Clay		moist	1.9	0	0	0
1138		4 / 5		16' pellets									
S-9	18	6 / 7	2.0/2.0		stiff	mottled	Sandy clay		saturated, med. Rnd	1.5	0	0	0
1147		5 / 7		18' sand 20'									
S-10	20	4 / 5	2.0/2.0		stiff	mottled	Silty sand		saturated	4.2	0	0	0
1209		4 / 6											
S-11	22	9 / 15			very stiff	mottled	Sandy clay		saturated, Med Rnd	2.8	0	0	0
1220		4 / 8											
1227 S-12	24	11 / 13			very stiff	red brown	~~Sand~~ clayey Sand		saturated fine to med.	1.5	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Remarks: 2 nested wells. Flush mount

Drilling Area Background (ppm): 0

Converted to Well: Yes ✓ No ____ Well I.D. #: OW-6A, OW-6B

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IL01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-6
DATE: 11-29-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
		7/11											
S-13 1225	26	12/14	2.0/20		very stiff	reddish brown	silty clay, trace sand		wet med. grnd sand, wet	2.1			
		12/12							1" sand lens @ 27'				
S-14	28	14/23	2.0/20		hard	brown	sandy clay		wet Med to coarse, grnd.	3.7			
		4/5											
S-15	30	8/12	1.2/2.0	30'	very stiff	brown	sand		wet fine to medium, sand	27.0			

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 2 nested wells

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-6A, OW-6B

APPENDIX B

FIELD SAMPLING LOGS

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW4A-081208
Sample Location: OW4A
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 8-12-08	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Time: 1052								
Method: Geo pump	Slightly	5.8	0.22	20.9	11	0.00	0.1	54

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 8-12-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC			See Low Flow Purge Data Sheet					
Total Well Depth (TD):								
Static Water Level (WL): 4.20								
One Casing Volume(gal/L):								
Start Purge (hrs): 0950								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml Vials	
~~Total metals~~	~~None~~	~~1 - 500 ml Poly~~	
~~Diss metals~~	~~None~~	~~1 - 500 ml Poly~~	
1,4 Dioxane	4°C	2 - 1L Ambers	

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:
—	—

Signature(s):

Walter

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Complex
PROJECT NUMBER:

WELL ID.: OW-4A-082108
DATE: 8-21-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. S/M (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0950	4.20	—	—	—	—	—	—	—	—	Init. level, no odor
0952	4.25	250	5.7	0.25	120	1.40	19.3	118	0.1	Slightly cloudy
0957	4.30	250	5.7	0.24	80	0.00	19.6	67	0.1	" " "
1002	4.35	250	5.7	0.24	100	0.00	20.1	57	0.1	" " "
1007	4.35	220	5.7	0.23	80	0.00	20.5	57	0.1	" " "
1012	4.35	220	5.8	0.22	50	0.00	20.6	61	0.1	" " "
1017	4.35	220	5.8	0.22	40	0.00	20.7	62	0.1	" " "
1022	4.35	220	5.8	0.22	33	0.00	20.7	60	0.1	" " "
1027	4.37	220	5.8	0.22	28	0.00	20.8	59	0.1	" " "
1032	4.37	220	5.8	0.22	15	0.00	20.8	58	0.1	" " "
1037	4.37	220	5.8	0.22	12	0.00	20.8	56	0.1	" " "
1042	4.37	220	5.8	0.22	11	0.00	20.9	55	0.1	" " "
1047	4.37	220	5.8	0.22	11	0.00	20.9	54	0.1	" " "
			Well Parameters Stabilized							
			Sampling Begins							

SIGNATURE(S): Wade

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 11

Sample ID No.: OW4B-081208
Sample Location: OW4B
Sampled By: MP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

SAMPLING DATA:

Date: 8-12-08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Time: 1209								
Method: Geo Pump	Cloudy	5.5	88	18.8	60	0.00	0.0	ORP 14

PURGE DATA:

Date: 8-12-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo Pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC			See Low Flow Purge Data Sheet					
Total Well Depth (TD):								
Static Water Level (WL): 5.00								
One Casing Volume(gal/L):								
Start Purge (hrs): 1113								
End Purge (hrs): 1204								
Total Purge Time (min): 51								
Total Vol. Purged (gal/L): 2.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml Vials	✓
~~TAL metals~~	~~HNO3~~	~~1 - 500 ml Poly~~	✓
~~Diss metals~~	~~HNO3~~	~~1 - 500 ml Poly~~	✓
1,4 Dioxane	ICE	2 - 1L Amber	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:
~~MS/MSD~~	

Signature(s): Mark E B

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW4B-081208
DATE: 8-12-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. ~~(mS/cm)~~ mS/m	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1113	5.00	—	—	—	—	—	—	—	—	
1114	5.20	300	5.5	83	50	1.39	18.3	36	0.0	Initial, no odor
1119	7.05	130	5.2	78	100	0.00	18.0	39	0.0	Slightly cloudy
1124	7.55	130	5.1	76	70	0.00	19.0	42	0.0	" " "
1129	8.10	130	5.2	74	40	0.00	19.0	37	0.0	" " "
1134	8.60	130	5.3	72	39	0.00	19.0	24	0.0	" " "
1139	8.95	130	5.4	71	40	0.00	19.0	17	0.0	" " "
1144	9.40	130	5.5	72	45	0.00	18.7	13	0.0	" " "
1149	9.80	130	5.5	73	45	0.00	18.6	11	0.0	" " "
1154	10.10	100	5.5	89	60	0.00	19.1	13	0.0	" " "
1159	10.20	100	5.5	87	60	0.00	19.6	12	0.0	" " "
1204	10.30	100	5.5	88	60	0.00	18.8	14	0.0	" " "
			Well	Parameters Stabilized						
				Sampling Begins						

SIGNATURE(S): Walt Z

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 5A - 081308
Sample Location: OW 5A
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 8-13-08								
Time: 1355								
Method: Geo pump	Slighty	5.4	0.23	21.8	19	1.70	0.1	Orp 279

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 8-13-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge						
Total Well Depth (TD):								
Static Water Level (WL): 3.80			Data Sheet					
One Casing Volume(gal/L):								
Start Purge (hrs): 1259								
End Purge (hrs): 1350								
Total Purge Time (min): 51								
Total Vol. Purged (gal/L): 4.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml Vials	✓
1,4 Dioxane	ICE	2 - 1L Ambers	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s): Walt [illegible]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River ~~Complex~~ WELL ID.: ONSA-081308
PROJECT NUMBER: DATE: 8-13-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. ~~mS/cm~~ SPC (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1259	3.80	—	—	—	—	—	—	—	—	Initial, no odor
1300	4.10	250	5.1	0.23	160	1.01	20.9	429	0.1	Slightly cloudy
1305	4.15	250	5.1	0.23	80	0.92	20.9	410	0.1	" " "
1310	4.15	250	5.1	0.23	~~98~~	0.98	21.3	358	0.1	" " "
1315	4.15	250	5.1	0.22	70	1.30	21.5	311	0.1	" " "
1320	4.15	250	5.3	0.22	45	1.32	21.5	282	0.1	" " "
1325	4.35	250	5.4	0.22	29	1.34	21.7	268	0.1	" " "
1330	4.36	240	5.4	0.22	23	1.38	21.7	265	0.1	" " "
1335	4.40	240	5.4	0.23	19	1.58	21.8	272	0.1	" " "
1340	4.45	240	5.4	0.23	19	1.69	21.8	275	0.1	" " "
1345	4.45	240	5.4	0.23	19	1.73	21.8	278	0.1	" " "
1350	4.45	240	5.4	0.23	19	1.70	21.8	279	0.1	" " "
			Well Parameters Stabilized							
			Sampling Begins							

SIGNATURE(S): Watt

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Page ___ of ___

Project Site Name: MRC
Project No.: _____

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type: _____
[] QA Sample Type: _____

Sample ID No.: MRC-OW6A-081308
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: _____
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 8/13/08	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 1110	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Method: Low Flow Pump	—	2.88	0.29	22.0	45	15.67	0.1	487

PURGE DATA:

Date: 8/13/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow Pump								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 11.55								
Static Water Level (WL): 3.4								
One Casing Volume(gal/L): 1.39								
Start Purge (hrs): 1015								
End Purge (hrs): 1130								
Total Purge Time (min): 75mm								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40mL vials	8/13/08
1,4 - Dioxane	—	2 - 34oz amber glass bottles	8/13/08

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC
PROJECT NUMBER:

WELL ID.: MRC-OW6A-081308
DATE: 8/13/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1015	3.4	—	—	—	—	—	—	—	—	Static WL; Begin Purge
1020	3.55	140	2.86	0.250	850	15.55	21.5	479	0.1	
1025	3.60	140	2.88	0.240	650	13.80	21.6	480	0.1	
1030	3.62	140	2.94	0.225	450	14.18	21.8	477	0.1	
1035	3.63	140	2.94	0.222	310	14.06	21.8	478	0.1	
1040	3.63	140	2.93	0.221	220	14.94	22.0	480	0.1	
1045	3.65	140	2.91	0.230	170	14.88	21.9	483	0.1	
1050	3.66	140	2.88	0.223	140	15.12	21.9	484	0.1	
1055	3.67	140	2.90	0.216	100	15.05	21.9	483	0.1	
1100	3.68	140	2.92	0.213	70	15.53	22.0	482	0.1	
1105	3.69	140	2.91	0.215	50	15.27	22.1	481	0.1	
1110	3.69	140	2.88	0.219	45	15.69	22.0	487	0.1	Sample
1130	3.69	—	—	—	—	—	—	—	—	Final WL; End Purge

SIGNATURE(S): David L. Mathews

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Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: MRC
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: MRC-GW63-081308
Sample Location: MRC
Sampled By: DLM
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 8/13/08	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 1345	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Method: Low Flow Pump	—	4.65	0.304	19.1	15	6.17	0.2	184

PURGE DATA:

Date: 8/13/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow-Pump								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 27.3'								
Static Water Level (WL): 4.8'								
One Casing Volume(gal/L): 3.83								
Start Purge (hrs): 1300								
End Purge (hrs): 1403								
Total Purge Time (min): 63 min								
Total Vol. Purged (gal/L): 2gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3-40mL vials	8/13/08
1,4-Dioxane	—	2-34oz amber glass bottles	8/13/08

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

Dawn L. Markley

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC
PROJECT NUMBER:

WELL ID.: MRC-OW6B-081308
DATE: 8/13/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1300	4.8'	—	—	—	—	—	—	—	—	Static WL; Start Purge
1310	5.32'	200	4.31	0.339	7.7	18.67	19.4	223	0.2	
1315	5.38'	200	4.44	0.336	9.4	9.06	18.9	210	0.2	
1320	5.44'	200	4.49	0.331	15	7.71	18.7	204	0.2	
1325	5.44'	200	4.51	0.327	15	7.10	18.8	201	0.2	
1330	5.5'	200	4.52	0.320	15	6.53	18.8	199	0.2	
1335	5.5'	200	4.54	0.316	15	6.38	18.6	194	0.2	
1340	5.41	200	4.61	0.308	15	6.26	19.0	185	0.2	
1345	5.40	200	4.65	0.304	15	6.17	19.1	184	0.2	Sample
1403	5.40	—	—	—	—	—	—	—	—	Final WL; End Purge

SIGNATURE(S): Shawn L. Madden

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Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: MRC-MW14B-080813
Sample Location: MW14B
Sampled By: MP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 8-13-08	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 1052	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	MP
Method: Geo pump	Cloudy	2.6	0.60	17.7	>999	0.72	0.3	647

PURGE DATA:

Date: 8-13-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material								
Type: 2" PVC			SEE	Low	Flow	Purge		
Total Well Depth (TD):								
Static Water Level (WL): 6.40			Data	Sheet				
One Casing Volume(gal/L):								
Start Purge (hrs): 1001								
End Purge (hrs): 1047								
Total Purge Time (min): 46								
Total Vol. Purged (gal/L): 2.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml Vials	
1,4 Dioxane	ICE	2 - 1L Ambers	

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD | Duplicate ID No.:

Signature(s):

Walter R

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: MRC-MW14B-081308
DATE: 8-13-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1001	6.40	—	—	—	—	—	—	—	—	Initial, no data
1002	6.60	190	2.7	0.58	>999	4.33	17.2	614	0.3	Tank water
1007	6.20	180	2.6	0.59	>999	4.54	17.2	624	0.3	" " "
1012	6.20	190	2.6	0.59	>999	3.89	17.1	631	0.3	" " "
1017	6.20	190	2.6	0.59	>999	2.93	17.2	633	0.3	" " "
1022	6.20	190	2.6	0.59	>999	1.60	17.2	637	0.3	" " "
1027	6.20	190	2.6	0.60	>999	0.80	17.3	640	0.3	" " "
1032	6.20	190	2.6	0.60	>999	0.69	17.4	641	0.3	" " "
1037	6.20	190	2.6	0.60	>999	0.69	17.5	640	0.3	" " "
1042	6.20	190	2.6	0.60	>999	0.76	17.7	645	0.3	" " "
1047	6.20	190	2.6	0.60	>999	0.72	17.7	647	0.3	" " "
			Well Stabilized							
			Sampling Begins							

SIGNATURE(S): Walt Lp

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112IC01597

Sample ID No.: OW4A-063008
Sample Location: OW4A-063008
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 6.30.08 / Time: 1032 / Method: Geo pump	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
	Slighty	5.58	3.15	19.5	13.4	12.01	0.2	248

PURGE DATA:

Date: 6.30.08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge						
Total Well Depth (TD): 14.80								
Static Water Level (WL): 4.50		Data	Sheet					
One Casing Volume(gal/L): 1.8								
Start Purge (hrs): 0930								
End Purge (hrs): 1027								
Total Vol. Purged (gal/L): 4.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
1,4 Dioxins	ICE	2 - 1L Ambers	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD — Duplicate ID No.:

Signature(s): MP

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle Raven Center
PROJECT NUMBER: 112IC05597

WELL ID.: OW44 - 063008
DATE: 6-30-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0930	4.50	220	—	—	—	—	—	—	—	Initial, LT Brown no odor
0932	4.55	220	5.27	7.80	310	19.99	18.5	250	0.2	
0937	4.60	220	5.19	3.86	227	19.89	18.8	268	0.2	
0942	4.63	220	5.25	3.22	115	19.99	18.8	273	0.2	
0947	4.66	220	5.39	3.63	57.4	19.89	18.9	262	0.2	
0952	4.70	220	5.43	3.42	33.0	19.32	19.1	255	0.2	
0957	4.73	220	5.43	3.31	32.3	17.64	19.1	253	0.2	
1002	4.76	220	5.45	3.24	22.2	16.18	19.1	253	0.2	
1007	4.81	220	5.48	3.17	17.4	14.80	19.2	251	0.2	
1012	4.85	220	5.52	3.16	14.4	13.64	19.3	250	0.2	
1017	4.91	220	5.56	3.14	13.8	12.07	19.3	249	0.2	
1022	4.95	220	5.57	3.14	13.1	12.15	19.4	248	0.2	
1027	4.97	220	5.58	3.15	13.4	12.01	19.5	248	0.2	
	←		Well Parameters stabilize						→	
	←		Sampling begins						→	

SIGNATURE(S): Walt Pe

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112IC01597

Sample ID No.: OW4B-063008
Sample Location: OW4B
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 6-30-08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Time: 1224								
Method: Geo pump	Slighty	5.51	0.93	18.6	26.2	0.31	0.0	20

PURGE DATA:

Date: 6-30-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge						
Total Well Depth (TD):		Data Sheet						
Static Water Level (WL): 5.70								
One Casing Volume(gal/L):								
Start Purge (hrs): 1047								
End Purge (hrs): 1219								
Total Purge Time (min): 90								
Total Vol. Purged (gal/L): 4.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
1,4 Dioxins	ICE	2 - 1L Ambers	✓

OBSERVATIONS / NOTES:

Circle If Applicable:
MS/MSD
Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Complex
PROJECT NUMBER: 112EC01597
WELL ID.: OW4B-063008
DATE: 6-30-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1047	5.70	—	—	—	—	—	—	—	—	Initial, no odor
1049	6.40	230	5.43	1.04	50.6	0.00	18.1	34	0.0	Slightly cloudy
1054	7.60	230	5.41	0.94	13.2	0.00	17.6	26	0.0	
1059	8.15	140	5.42	99.9	14.6	0.00	18.1	23	4.0	
1104	8.75	140	5.44	99.9	27.4	0.00	18.1	20	4.0	
1109	9.22	140	5.45	99.9	26.8	0.00	17.9	20	4.0	
1114	9.65	140	5.44	99.9	23.5	0.00	17.6	20	4.0	
1119	9.95	120	5.44	99.9	19.9	0.00	18.1	20	4.0	
1124	10.25	120	5.45	99.9	20.1	0.00	18.1	19	4.0	
1129	10.50	120	5.46	99.9	24.4	0.00	18.2	20	4.0	
1134	10.68	100	5.47	99.9	23.3	0.00	18.3	19	4.0	
1139	10.82	100	5.48	99.9	26.1	0.00	18.2	18	4.0	
1144	10.92	100	5.49	99.9	23.4	0.00	18.0	19	4.0	
1149	11.10	100	5.51	20.2	25.2	0.38	18.6	18	0.9	
1154	11.16	100	5.52	1.40	23.7	0.45	18.4	18	0.2	
1159	11.20	100	5.52	1.30	25.0	0.45	18.3	18	0.1	
1204	11.25	100	5.49	1.15	27.0	0.38	18.1	20	0.0	
1209	11.30	100	5.50	0.95	25.9	0.31	18.3	20	0.0	
1214	11.35	100	5.51	0.92	26.0	0.30	18.4	20	0.0	
1219	11.40	100	5.51	0.93	26.2	0.31	18.6	20	0.0	
			Well Parameters Stabilize							
			Sampling begins							

SIGNATURE(S): Wab

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112IC01557

Sample ID No.: OW5A-063008
Sample Location: OW5A
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 6-30-08 / Time: 1454 / Method: Geo pump	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
	Cloudy	2.84	4.45	18.7	>999	0.2	0.2	590

PURGE DATA:

Date: 6-30-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge Data Sheet						
Total Well Depth (TD): 12.80								
Static Water Level (WL): 4.00								
One Casing Volume(gal/L): 1.5								
Start Purge (hrs): 1342								
End Purge (hrs): 1449								
Total Purge Time (min): 67								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
44 Dioxins	ICE	2 - 1L Ambers	✓

OBSERVATIONS / NOTES:

Circle if Applicable:
MS/MSD
Duplicate ID No.:

Signature(s):
Walt E Pz

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Centery
PROJECT NUMBER: 112IC01597

WELL ID.: OW5A - 063008
DATE: 6-30-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1342	4.00	250	—	—	—	—	—	—	—	Initial Groundwater
1344	4.30	250	2.25	4.01	> 999	19.99	19.5	549	0.2	Cloudy water
1349	4.50	250	2.68	3.92	> 999	19.99	19.8	569	0.2	
1354	4.70	250	2.70	3.94	> 999	19.99	19.4	573	0.2	
1359	4.80	250	2.70	4.01	> 999	19.99	18.7	575	0.2	
1404	4.85	250	2.71	3.98	> 999	19.99	18.8	579	0.2	
1409	4.95	250	2.72	4.00	> 999	19.99	18.9	581	0.2	
1414	5.00	250	2.74	4.04	> 999	19.99	18.7	583	0.2	
1419	5.00	250	2.78	4.10	> 999	19.99	18.3	582	0.2	
1424	5.00	250	2.80	4.16	> 999	19.99	18.8	584	0.2	
1429	5.00	250	2.81	4.22	> 999	19.99	18.7	585	0.2	
1434	5.00	250	2.82	4.35	> 999	19.99	18.7	587	0.2	
1439	5.00	250	2.83	4.48	> 999	19.99	18.7	588	0.2	
1444	5.00	250	2.84	4.54	> 999	19.99	18.7	589	0.2	
1449	5.00	250	2.84	4.65	> 999	19.99	18.7	590	0.2	
	← 3 well volume collected →									
	← Sampling begins →									

SIGNATURE(S): Walter

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112IC01557

Sample ID No.: OW6A-070108
Sample Location: OW6A
Sampled By: VP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 7-1-08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Time: 1403								
Method: Geo Pump	Slightly	2.32	11.5	22.7	43.9	19.99	0.7	652

PURGE DATA:

Date: 7-1-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge Data Sheet						
Total Well Depth (TD):								
Static Water Level (WL): 3.75'								
One Casing Volume(gal/L): 1.7								
Start Purge (hrs): 1312								
End Purge (hrs): 1358								
Total Purge Time (min): 46								
Total Vol. Purged (gal/L): 3.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
1,4 Dioxane	Ice	2 - 1L Ambers	✓

OBSERVATIONS / NOTES:

Circle If Applicable:

MS/MSD | Duplicate ID No.:

Signature(s):

VP

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112801597

WELL ID.: OW6A - 070108
DATE: 7-1-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1312	3.75	~~220~~	—	—	—	—	—	—	—	Initial, no odor
1313	4.00	220	2.31	12.6	> 999	19.99	23.1	602	0.7	Cloudy water
1318	4.10	220	2.27	12.5	232	19.99	22.1	619	0.7	Slightly Cloudy
1323	4.20	220	2.26	12.1	136	19.99	21.7	632	0.7	
1328	4.25	220	2.26	12.0	73.1	19.99	21.6	639	0.7	
1333	4.30	220	2.27	11.9	65.0	19.99	21.5	640	0.7	
1338	4.35	220	2.28	11.7	52.7	19.99	21.9	632	0.7	
1343	4.35	200	2.30	11.6	39.4	19.99	22.5	644	0.7	
1348	4.35	200	2.31	11.5	43.9	19.99	22.4	652	0.7	
1353	4.35	200	2.31	11.5	40.8	19.99	22.1	657	0.7	
1358	4.35	200	2.32	11.5	43.7	19.99	22.7	652	0.7	

SIGNATURE(S): _____

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112G01557

Sample ID No.: OW6B-063008
Sample Location: OW6B
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 6-30-08	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Time: 1620								
Method: Geo pump	Slightly	2.46	7.03	17.4	39.0	19.99	0.4	66

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 6-30-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge Data Sheet						
Total Well Depth (TD): 27.00								
Static Water Level (WL): 5.30								
One Casing Volume(gal/L): 3.7								
Start Purge (hrs): 1524								
End Purge (hrs): 1615								
Total Vol. Purged (gal/L): 4.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3-40 ml VOA	✓
1,4 Dioxins	ICE	2-1L Ambers	✓

OBSERVATIONS / NOTES:

Circle if Applicable:
MS/MSD
Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112IC01592
WELL ID.: OWGB-063008
DATE: 6-30-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1524	5.30	—	—	—	—	—	—	—	—	Initial, no odor
1525	5.67	230	2.46	7.41	885	19.99	17.7	645	0.4	Cloudy water
1530	6.25	160	2.43	7.27	75	19.99	17.6	650	0.4	Slighty Cloudy
1535	6.55	160	2.43	7.25	35.7	19.99	17.6	652	0.4	
1540	6.76	160	2.43	7.26	31.2	19.99	17.5	654	0.4	
1545	6.90	160	2.45	7.22	34.6	19.99	17.5	656	0.4	
1550	6.90	150	2.45	7.20	42.3	19.99	17.5	658	0.4	
1555	6.90	150	2.45	7.19	33.4	19.99	17.4	659	0.4	
1600	6.90	150	2.45	7.14	39.0	19.99	17.4	660	0.4	
1605	6.90	150	2.45	7.11	39.0	19.99	17.4	660	0.4	
1610	6.90	150	2.46	7.06	39.9	19.99	17.5	660	0.4	
1615	6.90	150	2.46	7.03	39.0	19.99	17.4	660	0.4	
			Well Parameters Stabilized							
			Sampling begins							

SIGNATURE(S): Walt & R

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC
Project No.: 112200597

Sample ID No.: MRC-MW14B-070108
Sample Location: MW14B
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 7-1-08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Time: 1041								
Method: Geo pump	Cloudy	2.36	14.9	16.6	>999	15.99	0.9	705

PURGE DATA:

Date: 7-1-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0-0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge Data Sheet						
Total Well Depth (TD):								
Static Water Level (WL): 6.55								
One Casing Volume(gal/L):								
Start Purge (hrs): 0935								
End Purge (hrs): 1036								
Total Purge Time (min): 61								
Total Vol. Purged (gal): 4.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
1,4 Dioxane	ICE	2 - 1L Ambers	✓

OBSERVATIONS / NOTES:

Circle if Applicable:
MS/MSD
Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112SC01597
WELL ID.: MRC-MW14B-070108
DATE: 7-1-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0935	6.55	—	—	—	—	—	—	—	—	Initial Brown water
0936	6.91	210	2.31	15.4	>999	19.99	17.4	660	0.9	Cloudy water
0941	7.02	210	2.38	15.1	>999	19.99	17.2	672	0.9	
0946	7.15	210	2.34	15.7	>999	19.99	16.7	626	0.9	
0951	7.19	210	2.34	15.3	>999	19.99	16.7	680	0.9	
0956	7.20	210	2.35	15.0	>999	19.99	16.8	682	0.9	
1001	7.20	210	2.35	14.9	>999	19.99	16.7	685	0.9	
1006	7.20	210	2.35	14.9	>999	19.99	16.7	688	0.9	
1011	7.20	210	2.36	14.9	>999	19.99	16.7	690	0.9	
1016	7.20	210	2.36	14.9	>999	19.99	16.7	694	0.9	
1021	7.25	210	2.36	14.9	>999	19.99	16.7	696	0.9	
1026	7.25	210	2.36	14.9	>999	19.99	16.6	700	0.9	
1031	7.25	210	2.36	14.9	>999	19.99	16.7	701	0.9	
1036	7.25	210	2.36	14.9	>999	19.99	16.7	705	0.9	
			Well parameters Stabilized							
			Sampling begins							

SIGNATURE(S): Nat

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW4A-060408
Sample Location: OW4A
Sampled By: MP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: / Time: / Method:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other

PURGE DATA:

Date: 6.4.08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 15.0		See Low Flow Purge						
Static Water Level (WL): 2.60								
One Casing Volume(gal/L): 2.1		Data Sheet						
Start Purge (hrs): 1013								
End Purge (hrs): 1050								
Total Purge Time (min): 37								
Total Vol. Purged (gal/L): 1.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

15.00 − 2.60 = 12.40

12.40 × .17

8680
12400
2.1080

Circle if Applicable:

MS/MSD | Duplicate ID No.:

Signature(s):

Mike R

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC
PROJECT NUMBER:

WELL ID.: 4 OW&A - 060408
DATE: 6-4-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1013	2.60									
1015	2.90	180	6.09	24.9	103.3	0.14	17.2	30	~~3.0~~ 1.8	Initial, No odor
1020	2.70	180	6.11	3.84	34.6	0.30	16.8	13	0.2	Cloudy With Small Red Iron Particles
1025	2.70	180	6.09	2.54	34.1	0.04	17.4	10	0.1	Slightly Cloudy
1030	2.70	180	6.11	2.49	19.5	0.00	17.7	10	0.1	" " "
1035	2.70	180	6.11	2.54	15.0	0.00	17.7	10	0.1	" " "
1040	2.70	180	6.12	2.53	9.57	0.00	17.5	10	0.1	Clear water
1045	2.70	180	6.13	2.48	9.00	0.00	17.6	10	0.1	" " "
1050	2.70	180	6.14	2.47	8.65	0.00	17.7	12	0.1	" " "

SIGNATURE(S): Wall

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW4B-060408
Sample Location: OW 4B
Sampled By: MP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: / Time: / Method:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 6.4.08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 30.0		See Low Flow Purge						
Static Water Level (WL): 4.65								
One Casing Volume(gal/L):		Data	Sheet					
Start Purge (hrs): 1056								
End Purge (hrs): 1158								
Total Purge Time (min): 62								
Total Vol. Purged (gal/L): 2.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

Nate

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC
PROJECT NUMBER:

WELL ID.: OW4B-060408
DATE: 6-4-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1056	4.65	—	—	—	—	—	—	—	—	Initial, no odor
1058	5.50	190	5.61	0.546	152	0.43	16.7	30	0.0	Cloudy water
1103	5.61	180	5.61	7.96	111	0.44	16.6	18	0.3	" " "
1108	6.75	190	5.61	3.85	72.7	0.00	16.6	16	0.2	Slightly Cloudy
1113	7.05	190	5.61	3.44	56.7	0.09	16.9	16	0.2	" " "
1118	7.23	150	5.62	2.16	63.5	0.05	17.1	15	0.1	" " "
1123	7.55	150	5.64	1.47	99.3	0.13	17.4	14	0.1	" " "
1128	7.75	150	5.64	1.16	100	0.09	17.9	14	0.1	" " "
1133	7.90	100	5.64	1.02	123	0.08	18.0	13	0.0	Cloudy water
1138	8.05	100	5.64	0.90	111	0.00	18.0	14	0.0	" " "
1143	8.15	100	5.63	0.90	155	0.00	19.0	13	0.0	" " "
1148	8.30	100	5.63	0.90	192	0.00	17.5	14	0.0	" " "
1153	8.45	100	5.62	0.90	187	0.00	17.4	15	0.0	" " "
1158	8.60	100	5.62	0.90	183	0.00	17.4	15	0.0	" " "

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

Sample ID No.: JWEA-060408
Sample Location:
Sampled By:
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: / Time: / Method:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 6-4-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 14.80		See Low Flow Purge Data Sheet						
Static Water Level (WL): 2.15								
One Casing Volume(gal/L): 2.2								
Start Purge (hrs): 1255								
End Purge (hrs): 1357								
Total Purge Time (min): 62								
Total Vol. Purged (gal/L): 2.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

Walt

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:
WELL ID.: OW5A-060408
DATE: 6-4-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1255	2.15	—	—	—	—	—	—	—	—	Initial, no odor
1257	2.30	200	5.86	99.9	96.0	0.00	17.8	54	4.0	Slightly cloudy
1302	2.30	200	5.81	99.9	53.0	0.06	17.8	53	4.0	" " "
1307	2.30	200	5.79	99.9	37.7	0.03	17.8	54	4.0	" " "
1312	2.30	200	5.78	90.7	22.7	0.00	17.8	57	4.0	" " "
1317	2.30	200	5.78	59.4	13.3	0.00	17.9	61	4.0	" " "
1322	2.30	200	5.81	47.0	9.09	0.00	17.8	61	2.9	Clear water
1327	2.30	200	5.86	20.6	4.25	0.00	17.8	59	1.2	" " "
1332	2.30	200	5.92	23.1	4.12	0.00	17.9	58	1.4	" " "
1337	2.30	200	5.95	4.72	2.53	0.00	17.9	56	0.3	" " "
1342	2.30	200	5.98	2.92	3.25	0.00	17.9	57	0.1	" " "
1347	2.30	200	5.98	2.23	3.00	0.00	18.0	62	0.1	" " "
1352	2.30	200	5.97	2.23	3.05	0.00	18.0	65	0.1	" " "
1357	2.30	200	5.95	2.21	3.17	0.00	17.9	67	0.1	" " "

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

Sample ID No.: OW5B-060408
Sample Location: OW2B
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: / Time: / Method:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 6-4-08								
Method: Geo Pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 18.70			See Low flow Purge					
Static Water Level (WL): 3.80								
One Casing Volume(gal/L):			Data Sheet					
Start Purge (hrs): 1401								
End Purge (hrs): 1503								
Total Purge Time (min): 62								
Total Vol. Purged (gal/L): 3.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: 5 OWSB-060408
DATE: 6-4-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1401	3.80	—	—	—	—	—	—	—	—	Initial, no odor
1403	4.80	200	4.73	0.523	28.8	6.70	16.4	264	0.0	Slightly cloudy w/ small particles
1408	5.30	200	4.36	0.493	26.9	5.89	17.4	312	0.0	" " "
1413	5.75	200	4.67	0.490	20.2	5.78	17.5	202	0.0	" " "
1418	5.95	150	5.53	0.588	65.0	4.65	17.6	53	0.0	" " "
1423	6.15	150	5.78	0.784	97.6	1.97	17.6	18	0.0	" " "
1428	6.30	150	5.85	0.730	150.0	0.83	17.4	18	0.0	" " "
1433	6.45	100	5.86	0.718	195	3.37	17.7	11	0.0	" " "
1438	6.60	100	5.79	0.700	135	0.60	17.4	14	0.0	Cloudy water
1443	6.75	100	5.81	0.686	117	4.53	17.6	12	0.0	" " "
1448	6.90	100	5.82	0.679	142	4.55	17.6	14	0.0	" " "
1453	6.90	100	5.81	99.9	128	0.08	17.4	8	4.0	" " "
1458	6.95	100	5.82	99.9	124	0.09	17.3	6	4.0	" " "
1503	7.00	100	5.82	99.9	126	0.11	17.3	4	4.0	" " "

SIGNATURE(S): Walt

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Condea
Project No.:

Sample ID No.: OWGA-060508
Sample Location: OWGA
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: / Time: / Method:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other

PURGE DATA:

Date: 6-5-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo Pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 15.00		See	Low	Flow	Purge			
Static Water Level (WL): 1.00								
One Casing Volume(gal/L): 2.4		Data		Sheet				
Start Purge (hrs): 0936								
End Purge (hrs): 1118								
Total Purge Time (min): 102								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

Mab

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW6A - 060508
DATE: 6-5-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0936	1.00	—	—	—	—	—	—	—	—	
0938	1.00	200	5.94	37.9	151	0.00	16.6	77	4.0	Initial, no odor
0943	1.00	200	5.93	51.4	103	0.19	16.6	66	2.9	Cloudy water w/ small particles
0948	1.00	200	5.91	99.9	74.1	0.02	16.8	106	4.0	Slightly cloudy w/ small particles
0953	1.00	200	5.91	99.9	46.9	0.01	16.9	65	4.0	" " "
0958	1.00	200	5.86	99.9	62.5	0.00	17.0	66	4.0	" " "
1003	1.00	200	5.69	69.3	78.5	0.00	16.9	81	4.0	" " "
1008	1.00	200	5.60	73.5	70.0	0.00	17.0	83	3.0	" " "
1013	1.00	200	5.63	90.0	65.9	0.00	17.1	80	2.8	" " "
1018	1.00	200	5.66	88.9	40.5	0.00	17.0	80	2.0	" " "
1023	1.00	200	5.68	94.6	32.6	0.00	17.1	81	0.3	" " "
1033	1.00	200	5.70	99.9	25.0	0.00	17.2	80	0.2	" " "
1043	1.00	200	5.74	1.69	20.5	0.00	17.2	79	0.1	" " "
1048	1.00	200	5.76	2.14	7.81	0.00	17.2	77	0.1	Clear water
1053	1.00	200	5.77	1.96	6.50	0.00	17.3	77	0.1	" " "
1058	1.00	200	5.78	1.75	4.42	0.00	17.2	77	0.1	" " "
1103	1.00	200	5.79	1.66	2.91	0.00	17.2	76	0.1	" " "
1108	1.00	200	5.79	1.61	2.79	0.00	17.2	76	0.1	" " "
1113	1.00	200	5.78	1.58	2.62	0.00	17.2	76	0.1	" " "
1118	1.00	200	5.78	1.58	2.62	0.00	17.3	76	0.1	" " "

SIGNATURE(S): Nate

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OWGB-060508
Sample Location: OWGB
Sampled By:
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: / Time: / Method:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other

PURGE DATA:

Date: 6-5-08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 28.80		See Low Flow Purge						
Static Water Level (WL): 3.80								
One Casing Volume(gal/L):								
Start Purge (hrs): 1225		Data Sheet						
End Purge (hrs): 1332								
Total Purge Time (min): 67								
Total Vol. Purged (gal/L): 4.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW68-060508
DATE: 6-5-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1225	3.80	—	—	—	—	—	—	—	—	Initial, no odor
1227	4.25	200	5.85	0.311	81.5	1.46	18.0	-21	0.0	Slightly cloudy
1232	4.90	200	5.61	0.270	71.6	7.20	17.2	-2	0.0	" " "
1237	4.85	150	5.40	0.268	72.6	7.02	17.3	9	0.0	" " "
1242	4.90	150	5.33	0.261	103.6	7.46	17.4	13	0.0	" " "
1247	5.00	150	5.34	0.256	118	2.56	17.2	15	0.0	Cloudy/clear
1252	5.05	150	5.37	0.252	113	5.84	17.3	11	0.0	" " "
1257	5.08	150	5.43	0.252	146	5.22	17.1	8	0.0	" " "
1302	5.10	150	5.51	0.253	121	4.51	17.2	5	0.0	" " "
1307	5.15	150	5.60	0.255	130	4.28	17.3	-1	0.0	" " "
1312	5.15	150	5.72	0.257	132	3.45	17.3	-6	0.0	" " "
1317	5.20	150	5.81	0.259	119	2.86	17.2	-10	0.0	" " "
1322	5.20	150	5.85	0.259	123	2.50	17.3	-11	0.0	" " "
1327	5.20	150	5.87	0.260	121	2.35	17.3	-12	0.0	" " "
1332	5.22	150	5.88	0.261	125	2.25	17.3	-12	0.0	" " "

SIGNATURE(S): [signature]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: middle river center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 4s - 012108
Sample Location: OW 4s
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-21-08								
Time: 1031								
Method: Geo pump	clear	6.19	0.504	10.4	4.32	1.04	0.2	66

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-21-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC	See Low Flow Purge Data							
Total Well Depth (TD): 15.00								
Static Water Level (WL): 2.15	Sheet							
One Casing Volume(gal/L): 2.2								
Start Purge (hrs): 0920								
End Purge (hrs): 1026								
Total Purge Time (min): 66								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml VOA	✓
Total PP metals	HNO3	1 - 500 ml Poly	✓
Diss PP metals	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Ambers	✓
RSK 175 methane/Ethene/Ethane	HCl	2 - 40 ml VOA	✓
Chloride, Nitrate/Nitrite	ICE	1 - 250 ml Poly	✓
TOC	HCl	1 - 125 ml Amber	✓

OBSERVATIONS / NOTES:

15.00 − 2.15 = 12.85

12.85 × .17 = 18995 + 12850 = 2.1895

Ferrous Iron 1 mg 1108
Hydrogen Sulfide 0.0 1115

Circle if Applicable:

MS/MSD —

Duplicate ID No.:

Signature(s): Walter

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW45-012108
DATE: 1-21-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0920	2.15	—	—	—	—	—	—	—	—	Init. field parameters
0921	2.60	190	5.85	0.269	72.6	0.19	10.1	65	0.1	Slightly Cloudy
0926	2.60	190	5.92	0.340	71.4	0.00	10.2	60	0.2	" " "
0931	2.60	190	5.96	0.523	57.3	0.00	10.4	57	0.3	" " "
0941	2.60	190	6.03	0.715	41.4	0.47	10.4	56	0.4	" " "
0951	2.60	190	6.15	0.742	21.9	0.87	10.3	58	0.4	" " "
1001	2.60	190	6.16	0.745	12.1	0.87	10.3	61	0.4	" " "
1006	2.60	190	6.17	0.743	10.4	0.95	10.4	62	0.4	Clear water
1011	2.60	190	6.17	0.745	7.01	1.02	10.4	63	0.3	" " "
1016	2.60	190	6.17	0.505	2.55	1.03	10.4	64	0.3	" " "
1021	2.60	190	6.18	0.503	4.22	1.06	10.4	65	0.2	" " "
1026	2.60	190	6.19	0.504	4.32	1.04	10.4	66	0.2	" " "

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 4I - 012608
Sample Location: OW 4I
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-21-08								
Time: 1312								
Method: Geo pump		5.12	0.148	14.1	33.0	0.00	0.1	120

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-21-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 30.00		See	Low	Flow	Purge			
Static Water Level (WL): 4.50								
One Casing Volume(gal/L): 4.3								
Start Purge (hrs): 1116								
End Purge (hrs): 1307		Data	Sheet					
Total Purge Time (min): 110								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs			

OBSERVATIONS / NOTES:

$$\begin{array}{r} 2\cancel{3}^{9}0.00 \\ -\ 4.50 \\ \hline 25.50 \end{array} \qquad \begin{array}{r} {}^{3}25^{3}.50 \\ \times\ .17 \\ \hline 17850 \\ 25500 \\ \hline 4.3350 \end{array}$$

Ferrous Iron 2.5 mg 1358
Hydrogen Sulfide 0.0 1400

Circle if Applicable:

MS/MSD	Duplicate ID No.:
—	

Signature(s): [signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Constr
PROJECT NUMBER:

WELL ID.: OW4I-012108
DATE: 1-21-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1116	4.50	—	—	—	—	—	—	—	—	Initial pre purge
1117	5.40	190	5.45	79.1	220	6.66	13.3	53	0.0	Cloudy water
1122	6.30	190	5.44	93.0	248	0.00	13.4	53	0.0	" " "
1127	7.25	190	5.26	0.223	247	0.00	13.5	87	0.1	" " "
1132	8.20	180	3.87	0.185	77.8	0.00	14.4	330	0.1	" " "
1147	9.45	140	4.28	0.141	55.4	0.00	13.4	253	0.1	Slightly cloudy
1157	10.05	140	4.77	0.185	73.7	0.00	13.6	183	0.1	" " "
1207	11.60	140	4.84	0.183	52.4	0.00	13.6	174	0.1	" " "
1217	11.00	140	4.90	0.172	49.6	0.00	14.0	163	0.1	" " "
1227	11.40	140	4.96	0.165	47.4	0.00	14.1	151	0.1	" " "
1237	11.80	140	4.98	0.157	45.8	0.00	14.1	147	0.1	" " "
1242	11.90	140	5.00	0.154	38.3	0.00	14.3	145	0.1	" " "
1247	12.05	140	5.01	0.150	34.3	0.00	14.2	142	0.1	" " "
1252	12.20	140	5.03	0.149	31.0	0.00	14.3	139	0.1	" " "
1257	12.21	110	5.11	0.149	33.0	0.00	14.3	123	0.1	" " "
1302	12.23	110	5.12	0.148	32.0	0.00	14.2	122	0.1	" " "
1307	12.25	110	5.12	0.148	33.0	0.00	14.1	120	0.1	" " "

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 5s - 012108
Sample Location: OW 5s
Sampled By: wp
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-21-08								
Time: 1619								ORP
Method: Geo pump	Clear	5.67	0.465	9.9	4.00	0.00	0.2	131

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-21-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material								
Type: 2" PVC		See Low Flow Purge Data						
Total Well Depth (TD): 15.00								
Static Water Level (WL): 1.95								
One Casing Volume(gal/L): 2.2		Sheet						
Start Purge (hrs): 1512								
End Purge (hrs): 1614								
Total Purge Time (min): 62								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml VOA	✓
Total PP metals	HNO3	1 - 500 ml Poly	✓
Diss PP metals	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Amber	✓
RSK-175	HCl	2 - 40 ml VOA	✓
TOC	HCl	1 - 250 ml Amber	✓
Chloride, Nitrate, Nitrite	ICE	1 - 125 ml Poly	✓

OBSERVATIONS / NOTES:

15.00 − 1.95 = 13.05

13.05 × .17 = 19135 + 13050 = 22195

Ferrous Iron 2.5 mg 1620
Hydrogen Sulfide 0.0 1623

Circle if Applicable:

MS/MSD —

Duplicate ID No.:

Signature(s): Wat

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW 55 - 012108
DATE: 1-21-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1512	1.75	—	—	—	—	—	—	—	—	Initial, no odor
1514	2.20	240	5.54	0.297	40.2	0.71	10.3	122	0.2	Slightly cloudy
1519	2.26	240	5.60	0.683	36.0	0.00	10.2	123	0.3	" " "
1524	2.20	240	5.63	0.661	36.3	0.31	10.1	122	0.4	" " "
1534	2.25	240	5.67	0.521	24.3	0.07	9.9	122	0.3	" " "
1544	2.25	240	5.66	0.523	16.6	0.00	9.9	125	0.3	" " "
1554	2.25	240	5.66	0.493	11.1	0.00	9.9	128	0.2	" " "
1559	2.25	240	5.66	0.453	9.84	0.00	9.8	129	0.2	Clear water
1604	2.25	240	5.67	0.417	7.15	0.00	10.0	129	0.2	" " "
1609	2.25	240	5.67	0.416	4.25	0.00	9.9	130	0.2	" " "
1614	2.25	240	5.67	0.415	4.00	0.00	9.9	131	0.2	" " "

SIGNATURE(S): [signature]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OWSI-012308
Sample Location: OWSI
Sampled By: VP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-23-08	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	Vap
Time: 1210								
Method: Geo pump	Cloudy	5.83	56.6	13.1	401	0.00	0.0	22

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-23-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 18.90		See Low Flow Purge Data Sheet						
Static Water Level (WL): 3.20								
One Casing Volume(gal/L): 2.7								
Start Purge (hrs): 0944								
End Purge (hrs): 1205								
Total Purge Time (min): 136								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml vom	✓
Total RP metals	HNO3	1 - 500 ml Poly	✓
Diss RP metals	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Amber	✓
RSK-175	HCl	2 - 40 ml vom	✓
TOC	HCl	1 - 250 ml Amber	✓
Chloride, Nitrate, Nitrite	ICE	1 - 125 ml Poly	✓

OBSERVATIONS / NOTES:

18.90
3.20
15.70

315.70
x .17
10990
15700
2.6690

Ferrous Iron 2.5 mg 1215
Hydrogen Sulfide 0.0 1220

Circle if Applicable:
MS/MSD
Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW5I-012308
DATE: 1-23-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0944	3.20									
0945	3.90	170	5.61	55.3	>999	0.71	12.6	66	0.0	
0950	4.50	170	5.68	57.0	>999	0.04	12.5	60	0.0	
0955	5.52	170	5.68	57.3	>999	0.00	12.5	58	0.0	
1000	7.10	170	5.68	58.0	>999	0.00	12.5	57	0.0	
1015	7.10	130	5.77	65.1	>999	0.00	12.3	41	0.0	
1025	7.20	130	5.78	65.0	>999	0.00	12.6	36	0.0	
1035	7.40	130	5.78	64.1	>999	0.00	12.7	34	0.0	
1045	7.65	130	5.79	62.0	894	0.00	12.8	32	0.0	
1055	7.80	130	5.79	61.0	603	0.00	12.8	31	0.0	
1105	7.95	130	5.79	59.0	665	0.00	13.2	29	0.0	
1115	8.15	130	5.81	59.5	567	0.00	13.0	27	0.0	
1125	8.35	130	5.82	57.9	490	0.00	13.1	26	0.0	
1135	8.55	130	5.79	56.7	436	0.00	13.3	27	0.0	
1145	8.70	130	5.82	57.1	399	0.00	13.3	24	0.0	
1155	8.85	130	5.82	56.9	398	0.00	13.3	24	0.0	
1200	8.80	130	5.83	56.6	400	0.00	13.1	23	0.0	
1205	8.80	130	5.83	56.6	401	0.00	13.1	22	0.0	

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 6s - 012508
Sample Location: OW 6s
Sampled By: LP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-25-08								
Time: 1018								
Method: Geo pump	clear	6.22	0.157	10.4	8.33	0.00	0.1	108

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-25-08								
Method: Geo Pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 15.00		See	Low	Flow	Purge			
Static Water Level (WL): 2.20								
One Casing Volume(gal/L): 2.2								
Start Purge (hrs): 0831		Data	Sheet					
End Purge (hrs): 1013								
Total Purge Time (min): 100								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2x2 40 ml VOA	4
Total PP metal	HNO3	2x1 500 ml Poly	2
Diss PP metal	HNO3	2x1 500 ml Poly	2
1,4 Dioxane	ICE	2x2 1L Ambers	4
RSK-175	HCl	2x2 40 ml VOA	4
TOC	HCl	2x1 125 ml Amber	2
Chloride, Nitrate, Nitrite	ICE	2x1 250 ml poly	2

OBSERVATIONS / NOTES:

15.00 − 2.20 = 12.80

12.80 × .17 = 18960 + 12800 = 21760

Ferrous Iron 2.5 mg/L 1105
Hydrogen Sulfide 0.0 mg/L 1110

Circle if Applicable:

MS/MSD —

Duplicate ID No.: OW - Dup - 012508

Signature(s): [signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Michelle River Center
PROJECT NUMBER:

WELL ID.: OW 6S - 012508
DATE: 1-25-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0831	2.20	—	—	—	—	—	—	—	—	Initial, no odor
0833	2.33	150	6.00	0.162	440	0.79	10.4	120	0.1	Cloudy water
0838	2.30	150	6.08	0.160	275	0.59	10.2	112	0.1	" " "
0843	2.30	150	6.13	0.159	211	0.41	10.2	108	0.1	" " "
0853	2.30	150	6.17	0.157	161	0.18	10.5	103	0.1	" " "
0903	2.30	150	6.20	0.157	124	0.12	10.6	102	0.1	" " "
0913	2.33	150	6.21	0.157	94.5	0.12	10.6	102	0.1	Slightly cloudy
0923	2.33	150	6.22	0.157	57.8	0.06	10.6	103	0.1	" " "
0933	2.33	150	6.22	0.158	30.8	0.00	10.6	105	0.1	" " "
0943	2.33	150	6.22	0.157	18.7	0.00	10.6	106	0.1	" " "
0953	2.33	150	6.22	0.158	15.1	0.00	10.5	107	0.1	" " "
1003 ~~[illegible]~~	2.33	150	6.22	0.158	10.0	0.00	10.5	108	0.1	" " "
1008	2.33	150	6.22	0.157	10.0	0.00	10.4	108	0.1	" " "
1013	2.33	150	6.22	0.157	8.33	0.00	10.4	108	0.1	

SIGNATURE(S): [signature]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 6I-012308
Sample Location: OW 6I
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other orp
Date: 1-23-08								
Time: 1621								
Method: Geo pump	Slightly	5.76	31.8	13.8	27.2	0.00	0.0	39

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-23-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 30.00		See Low Flow Purge						
Static Water Level (WL): 4.20								
One Casing Volume(gal/L): 4.4								
Start Purge (hrs): 1440		Data Sheet						
End Purge (hrs): 1616								
Total Purge Time (min): 96								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml VOA	✓
Total PP metal	HNO3	1 - 500 ml Poly	✓
Diss PP metal	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Ambers	✓
RSK-175	HCl	2 - 40 ml VOA	✓
TOC	HCl	1 - 250 ml Amber	✓
Chloride, nitrate, nitrite	ICE	1 - 125 Poly	✓

OBSERVATIONS / NOTES:

$$\begin{array}{r} 30.00 \\ -\ 4.20 \\ \hline 25.80 \end{array} \qquad \begin{array}{r} 25.80 \\ \times\ .17 \\ \hline 18060 \\ 25800 \\ \hline 4.3860 \end{array}$$

Ferrous Iron 2.5 mg

Hydrogen Sulfide 0.0

Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s): [signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: middle River Center
PROJECT NUMBER:

WELL ID.: [redacted] OWGI-01230S
DATE: 1-22-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1440	4.20	—	—	—	—	—	—	—	—	Initial, no odor
1441	4.65	280	5.84	23.5	543	2.08	14.5	59	0.0	Cloudy water
1446	5.40	280	5.76	23.3	789	0.00	14.2	55	0.0	" " "
1451	5.40	190	5.73	22.4	760	0.00	13.7	54	0.0	" " "
1501	5.40	190	5.73	22.7	439	0.04	13.8	49	0.0	" " "
1511	5.60	190	5.74	24.5	263	0.00	13.5	43	0.0	" " "
1521	5.65	190	5.74	25.8	156	0.00	13.9	41	0.0	" " "
1531	5.74	190	5.74	26.8	82.5	0.00	14.0	39	0.0	Slightly cloudy
1541	5.75	190	5.75	27.6	60.5	0.00	14.0	39	0.0	" " "
1551	5.75	190	5.74	28.1	46.3	0.00	14.0	38	0.0	" " "
1601	5.75	190	5.75	28.6	35.6	0.00	14.0	38	0.0	" " "
1606	5.75	190	5.76	29.8	28.6	0.00	14.0	38	0.0	" " "
1611	5.75	190	5.75	30.8	26.1	0.00	13.9	39	0.0	" " "
1616	5.75	190	5.76	31.8	27.2	0.00	13.8	39	0.0	" " "

SIGNATURE(S): [signature]

APPENDIX C

LABORATORY ANALYTICAL RESULTS

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Tetra Tech NUS Inc

Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

Client Sample ID: TB-081208

Sample #: 001 Date Sampled: 08/12/08 07:30 Date Received: 08/14/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
Acetone	**6.0**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	ND	5.0	ug/L	SW846 8260B	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
Carbon disulfide	ND	1.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	ND	1.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	

(Continued on next page)

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: TB-081208					
Sample #: 001 Date Sampled: 08/12/08 07:30 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	ND	1.0	ug/L	SW846 8260B	
Chloromethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloroethane	**0.64 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	**3.5**	**1.0**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	**0.41 J**	**1.0**	**ug/L**	**SW846 8260B**	

(Continued on next page)

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: TB-081208					
Sample #: 001 Date Sampled: 08/12/08 07:30 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	
Client Sample ID: OW4A-081208					
Sample #: 002 Date Sampled: 08/12/08 10:52 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	**2.0 J**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	ND	5.0	ug/L	SW846 8260B	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
Carbon disulfide	ND	1.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**2.1**	**1.0**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

(Continued on next page)

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

Client Sample ID: OW4A-081208
Sample #: 002 Date Sampled: 08/12/08 10:52 Date Received: 08/14/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Volatile Organics by GC/MS				Reviewed
2-Hexanone	ND	5.0	ug/L	SW846 8260B
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B
Naphthalene	ND	1.0	ug/L	SW846 8260B
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B
Styrene	ND	1.0	ug/L	SW846 8260B
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B
Vinyl acetate	ND	2.0	ug/L	SW846 8260B
o-Xylene	ND	1.0	ug/L	SW846 8260B
Xylenes (total)	ND	2.0	ug/L	SW846 8260B
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B
Benzene	ND	1.0	ug/L	SW846 8260B
Bromoform	ND	1.0	ug/L	SW846 8260B
Bromomethane	ND	1.0	ug/L	SW846 8260B
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B
Chlorobenzene	ND	1.0	ug/L	SW846 8260B
Chloroethane	ND	1.0	ug/L	SW846 8260B
Chloroform	**0.47 J**	**1.0**	**ug/L**	**SW846 8260B**
Chloromethane	ND	1.0	ug/L	SW846 8260B
1,1-Dichloroethane	**1.1**	**1.0**	**ug/L**	**SW846 8260B**
1,2-Dichloroethane	ND	1.0	ug/L	SW846 8260B
1,1-Dichloroethene	**0.66 J**	**1.0**	**ug/L**	**SW846 8260B**
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW4A-081208					
Sample #: 002 Date Sampled: 08/12/08 10:52 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	ND	1.0	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	**1.7**	**1.0**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	
J Estimated result. Result is less than RL.					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	ND	1.0	ug/L	SW846 8270C	
Client Sample ID: OW4B-081208					
Sample #: 003 Date Sampled: 08/12/08 12:09 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	ND	120	ug/L	SW846 8260B	
Bromobenzene	ND	25	ug/L	SW846 8260B	
Bromochloromethane	ND	25	ug/L	SW846 8260B	
Bromodichloromethane	ND	25	ug/L	SW846 8260B	
2-Butanone	ND	120	ug/L	SW846 8260B	
n-Butylbenzene	ND	25	ug/L	SW846 8260B	
sec-Butylbenzene	ND	25	ug/L	SW846 8260B	
tert-Butylbenzene	ND	25	ug/L	SW846 8260B	
Carbon disulfide	ND	25	ug/L	SW846 8260B	
Dibromochloromethane	ND	25	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	50	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	120	ug/L	SW846 8260B	
2-Chlorotoluene	ND	25	ug/L	SW846 8260B	
4-Chlorotoluene	ND	25	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	25	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW4B-081208					
Sample #: 003 Date Sampled: 08/12/08 12:09 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Dibromomethane	ND	25	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	25	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	25	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	25	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	25	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**160**	**25**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	25	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	25	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	25	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	25	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	25	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	25	ug/L	SW846 8260B	
2-Hexanone	ND	120	ug/L	SW846 8260B	
Isopropylbenzene	ND	25	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	25	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	500	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	120	ug/L	SW846 8260B	
Naphthalene	ND	25	ug/L	SW846 8260B	
n-Propylbenzene	ND	25	ug/L	SW846 8260B	
Styrene	ND	25	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	25	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	25	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	25	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	25	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	25	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	25	ug/L	SW846 8260B	
Vinyl acetate	ND	50	ug/L	SW846 8260B	
o-Xylene	ND	25	ug/L	SW846 8260B	
Xylenes (total)	ND	50	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	120	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	50	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	120	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	120	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	120	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	120	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW4B-081208					
Sample #: 003 Date Sampled: 08/12/08 12:09 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Benzene	ND	25	ug/L	SW846 8260B	
Bromoform	ND	25	ug/L	SW846 8260B	
Bromomethane	ND	25	ug/L	SW846 8260B	
Carbon tetrachloride	ND	25	ug/L	SW846 8260B	
Chlorobenzene	ND	25	ug/L	SW846 8260B	
Chloroethane	ND	25	ug/L	SW846 8260B	
Chloroform	ND	25	ug/L	SW846 8260B	
Chloromethane	ND	25	ug/L	SW846 8260B	
1,1-Dichloroethane	**71**	**25**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	ND	25	ug/L	SW846 8260B	
1,1-Dichloroethene	**250**	**25**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	25	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	25	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	25	ug/L	SW846 8260B	
Ethylbenzene	ND	25	ug/L	SW846 8260B	
Methylene chloride	**13 J**	**25**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	ND	25	ug/L	SW846 8260B	
Tetrachloroethene	ND	25	ug/L	SW846 8260B	
Toluene	ND	25	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**36**	**25**	**ug/L**	**SW846 8260B**	
Trichloroethene	**600**	**25**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	25	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**70**	**2.5**	**ug/L**	**SW846 8270C**	
Client Sample ID: MRC-MW14B-081308					
Sample #: 004 Date Sampled: 08/13/08 10:52 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	**19 J**	**45**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	9.1	ug/L	SW846 8260B	
Bromochloromethane	**3.5 J**	**9.1**	**ug/L**	**SW846 8260B**	
Bromodichloromethane	ND	9.1	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: MRC-MW14B-081308					
Sample #: 004 Date Sampled: 08/13/08 10:52 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
2-Butanone	ND	45	ug/L	SW846 8260B	
n-Butylbenzene	ND	9.1	ug/L	SW846 8260B	
sec-Butylbenzene	ND	9.1	ug/L	SW846 8260B	
tert-Butylbenzene	ND	9.1	ug/L	SW846 8260B	
Carbon disulfide	ND	9.1	ug/L	SW846 8260B	
Dibromochloromethane	ND	9.1	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	18	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	45	ug/L	SW846 8260B	
2-Chlorotoluene	ND	9.1	ug/L	SW846 8260B	
4-Chlorotoluene	ND	9.1	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	9.1	ug/L	SW846 8260B	
Dibromomethane	ND	9.1	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	9.1	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	9.1	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	9.1	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	9.1	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**4.2 J**	**9.1**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	9.1	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	9.1	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	9.1	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	9.1	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	9.1	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	9.1	ug/L	SW846 8260B	
2-Hexanone	ND	45	ug/L	SW846 8260B	
Isopropylbenzene	ND	9.1	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	9.1	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	180	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	45	ug/L	SW846 8260B	
Naphthalene	ND	9.1	ug/L	SW846 8260B	
n-Propylbenzene	ND	9.1	ug/L	SW846 8260B	
Styrene	ND	9.1	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	**22**	**9.1**	**ug/L**	**SW846 8260B**	
1,2,3-Trichlorobenzene	ND	9.1	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	9.1	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	9.1	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: MRC-MW14B-081308					
Sample #: 004 Date Sampled: 08/13/08 10:52 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,1,2-Trichloro-1,2,2-trifluoroethane	**6.4 J**	**9.1**	**ug/L**	**SW846 8260B**	
1,2,4-Trimethylbenzene	ND	9.1	ug/L	SW846 8260B	
Vinyl acetate	ND	18	ug/L	SW846 8260B	
o-Xylene	ND	9.1	ug/L	SW846 8260B	
Xylenes (total)	ND	18	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	45	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	18	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	45	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	45	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	45	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	45	ug/L	SW846 8260B	
Benzene	ND	9.1	ug/L	SW846 8260B	
Bromoform	ND	9.1	ug/L	SW846 8260B	
Bromomethane	ND	9.1	ug/L	SW846 8260B	
Carbon tetrachloride	ND	9.1	ug/L	SW846 8260B	
Chlorobenzene	ND	9.1	ug/L	SW846 8260B	
Chloroethane	ND	9.1	ug/L	SW846 8260B	
Chloroform	**38**	**9.1**	**ug/L**	**SW846 8260B**	
Chloromethane	**49**	**9.1**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethane	**34**	**9.1**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	**3.7 J**	**9.1**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	**5.4 J**	**9.1**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	9.1	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	9.1	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	9.1	ug/L	SW846 8260B	
Ethylbenzene	ND	9.1	ug/L	SW846 8260B	
Methylene chloride	**48**	**9.1**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	**20**	**9.1**	**ug/L**	**SW846 8260B**	
Tetrachloroethene	ND	9.1	ug/L	SW846 8260B	
Toluene	ND	9.1	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**25**	**9.1**	**ug/L**	**SW846 8260B**	
Trichloroethene	**230**	**9.1**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	9.1	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: MRC-MW14B-081308					
Sample #: 004 Date Sampled: 08/13/08 10:52 Date Received: 08/14/08 Matrix: WATER					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**19**	**1.0**	**ug/L**	**SW846 8270C**	
Client Sample ID: OW6A-081308					
Sample #: 005 Date Sampled: 08/13/08 11:10 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**2.0**	**1.0**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	**0.31 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B	
Acetone	**31**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	**2.2 J**	**5.0**	**ug/L**	**SW846 8260B**	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

Client Sample ID: OW6A-081308

Sample #: 005 Date Sampled: 08/13/08 11:10 Date Received: 08/14/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
Carbon disulfide	**0.29 J**	**1.0**	**ug/L**	**SW846 8260B**	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	ND	1.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	**2.0**	**1.0**	**ug/L**	**SW846 8260B**	
Chloromethane	**8.0**	**1.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethane	**1.8**	**1.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethene	**0.21 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW6A-081308					
Sample #: 005 Date Sampled: 08/13/08 11:10 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	**0.65 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	**22**	**1.0**	**ug/L**	**SW846 8260B**	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	**3.0**	**1.0**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	ND	1.0	ug/L	SW846 8270C	
Client Sample ID: OW6B-081308					
Sample #: 006 Date Sampled: 08/13/08 13:45 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	ND	120	ug/L	SW846 8260B	
Bromobenzene	ND	25	ug/L	SW846 8260B	
Bromochloromethane	ND	25	ug/L	SW846 8260B	
Bromodichloromethane	ND	25	ug/L	SW846 8260B	
2-Butanone	ND	120	ug/L	SW846 8260B	
n-Butylbenzene	ND	25	ug/L	SW846 8260B	
sec-Butylbenzene	ND	25	ug/L	SW846 8260B	
tert-Butylbenzene	ND	25	ug/L	SW846 8260B	
Carbon disulfide	ND	25	ug/L	SW846 8260B	
Dibromochloromethane	ND	25	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	50	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	120	ug/L	SW846 8260B	
2-Chlorotoluene	ND	25	ug/L	SW846 8260B	
4-Chlorotoluene	ND	25	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	25	ug/L	SW846 8260B	
Dibromomethane	ND	25	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	25	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

Client Sample ID: OW6B-081308
Sample #: 006 Date Sampled: 08/13/08 13:45 Date Received: 08/14/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
1,3-Dichlorobenzene	ND	25	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	25	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	25	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**100**	**25**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	25	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	25	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	25	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	25	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	25	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	25	ug/L	SW846 8260B	
2-Hexanone	ND	120	ug/L	SW846 8260B	
Isopropylbenzene	ND	25	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	25	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	500	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	120	ug/L	SW846 8260B	
Naphthalene	ND	25	ug/L	SW846 8260B	
n-Propylbenzene	ND	25	ug/L	SW846 8260B	
Styrene	ND	25	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	25	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	25	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	25	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	25	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	25	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	25	ug/L	SW846 8260B	
Vinyl acetate	ND	50	ug/L	SW846 8260B	
o-Xylene	ND	25	ug/L	SW846 8260B	
Xylenes (total)	ND	50	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	120	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	50	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	120	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	120	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	120	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	120	ug/L	SW846 8260B	
Benzene	ND	25	ug/L	SW846 8260B	
Bromoform	ND	25	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW6B-081308					
Sample #: 006 Date Sampled: 08/13/08 13:45 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Bromomethane	ND	25	ug/L	SW846 8260B	
Carbon tetrachloride	ND	25	ug/L	SW846 8260B	
Chlorobenzene	ND	25	ug/L	SW846 8260B	
Chloroethane	ND	25	ug/L	SW846 8260B	
Chloroform	**10 J**	**25**	**ug/L**	**SW846 8260B**	
Chloromethane	ND	25	ug/L	SW846 8260B	
1,1-Dichloroethane	**35**	**25**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	ND	25	ug/L	SW846 8260B	
1,1-Dichloroethene	**170**	**25**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	25	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	25	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	25	ug/L	SW846 8260B	
Ethylbenzene	ND	25	ug/L	SW846 8260B	
Methylene chloride	**18 J**	**25**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	ND	25	ug/L	SW846 8260B	
Tetrachloroethene	ND	25	ug/L	SW846 8260B	
Toluene	ND	25	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**14 J**	**25**	**ug/L**	**SW846 8260B**	
Trichloroethene	**540**	**25**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	25	ug/L	SW846 8260B	
J Estimated result. Result is less than RL.					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**42**	**1.0**	**ug/L**	**SW846 8270C**	
Client Sample ID: OW5A-081308					
Sample #: 007 Date Sampled: 08/13/08 13:55 Date Received: 08/14/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	**5.7**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	**0.81 J**	**5.0**	**ug/L**	**SW846 8260B**	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	

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The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Client Sample ID: OW5A-081308

Sample #: 007 Date Sampled: 08/13/08 13:55 Date Received: 08/14/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
Carbon disulfide	ND	1.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**2.0**	**1.0**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	ND	1.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

Client Sample ID: OW5A-081308
Sample #: 007 Date Sampled: 08/13/08 13:55 Date Received: 08/14/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	**0.72 J**	**1.0**	**ug/L**	**SW846 8260B**	
Chloromethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethane	**1.4**	**1.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethene	**0.54 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	ND	1.0	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**0.33 J**	**1.0**	**ug/L**	**SW846 8260B**	
Trichloroethene	**3.7**	**1.0**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H140238 MIDDLE RIVER CENTER **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW5A-081308					
Sample #: 007 Date Sampled: 08/13/08 13:55 Date Received: 08/14/08 Matrix: WATER					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	ND	1.0	ug/L	SW846 8270C	

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: TB-081108

Sample #: 001 Date Sampled: 08/11/08 07:30 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
Acetone	**8.8**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	ND	5.0	ug/L	SW846 8260B	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
Carbon disulfide	ND	1.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	ND	1.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: TB-081108

Sample #: 001 Date Sampled: 08/11/08 07:30 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	ND	1.0	ug/L	SW846 8260B	
Chloromethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloroethane	**0.95 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	**5.1**	**1.0**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	**0.72 J**	**1.0**	**ug/L**	**SW846 8260B**	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: TB-081108						
Sample #: 001 Date Sampled: 08/11/08 07:30 Date Received: 08/12/08 Matrix: WATER						
Volatile Organics by GC/MS						Reviewed
Vinyl chloride		ND	1.0	ug/L	SW846 8260B	
J Estimated result. Result is less than RL.						
Client Sample ID: DMW-24I-081108						
Sample #: 002 Date Sampled: 08/11/08 11:45 Date Received: 08/12/08 Matrix: WATER						
Mercury in Liquid Waste (Manual Cold-Vapor)						Reviewed
Mercury		ND	0.20	ug/L	SW846 7470A	
Mercury	Dissolved	ND	0.20	ug/L	SW846 7470A	
ICP-MS (6020)						Reviewed
Silver	Dissolved	ND	1.0	ug/L	SW846 6020	
Arsenic	**Dissolved**	**2.6 B**	**5.0**	**ug/L**	**SW846 6020**	
Barium	**Dissolved**	**22.1**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium	**Dissolved**	**2.2**	**1.0**	**ug/L**	**SW846 6020**	
Cadmium	**Dissolved**	**0.23 B**	**1.0**	**ug/L**	**SW846 6020**	
Cobalt	**Dissolved**	**35.0**	**1.0**	**ug/L**	**SW846 6020**	
Chromium	**Dissolved**	**2.7**	**2.0**	**ug/L**	**SW846 6020**	
Copper	**Dissolved**	**6.8**	**2.0**	**ug/L**	**SW846 6020**	
Iron	**Dissolved**	**5050**	**50.0**	**ug/L**	**SW846 6020**	
Manganese	**Dissolved**	**748**	**1.0**	**ug/L**	**SW846 6020**	
Molybdenum	Dissolved	ND	2.0	ug/L	SW846 6020	
Nickel	**Dissolved**	**9.5**	**2.0**	**ug/L**	**SW846 6020**	
Lead	**Dissolved**	**0.36 B**	**1.0**	**ug/L**	**SW846 6020**	
Antimony	**Dissolved**	**0.054 B**	**2.0**	**ug/L**	**SW846 6020**	
Selenium	**Dissolved**	**3.2 B**	**5.0**	**ug/L**	**SW846 6020**	
Thallium	Dissolved	ND	1.0	ug/L	SW846 6020	
Vanadium	Dissolved	ND	20.0	ug/L	SW846 6020	
Zinc	**Dissolved**	**28.6**	**20.0**	**ug/L**	**SW846 6020**	
Silver		ND	1.0	ug/L	SW846 6020	
Arsenic		**2.9 B**	**5.0**	**ug/L**	**SW846 6020**	
Barium		**22.3**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium		**2.4**	**1.0**	**ug/L**	**SW846 6020**	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: DMW-24I-081108				
Sample #: 002 Date Sampled: 08/11/08 11:45 Date Received: 08/12/08 Matrix: WATER				
Cadmium	**0.24 B**	**1.0**	**ug/L**	**SW846 6020**
Cobalt	**35.3**	**1.0**	**ug/L**	**SW846 6020**
Chromium	**4.6**	**2.0**	**ug/L**	**SW846 6020**
Copper	**16.1**	**2.0**	**ug/L**	**SW846 6020**
Iron	**6210**	**50.0**	**ug/L**	**SW846 6020**
Manganese	**654**	**1.0**	**ug/L**	**SW846 6020**
Molybdenum	**0.14 B**	**2.0**	**ug/L**	**SW846 6020**
Nickel	**9.7**	**2.0**	**ug/L**	**SW846 6020**
Lead	**0.60 B**	**1.0**	**ug/L**	**SW846 6020**
Antimony	**0.15 B**	**2.0**	**ug/L**	**SW846 6020**
Selenium	**3.2 B**	**5.0**	**ug/L**	**SW846 6020**
Thallium	ND	1.0	ug/L	SW846 6020
Vanadium	**1.3 B**	**20.0**	**ug/L**	**SW846 6020**
Zinc	**28.3**	**20.0**	**ug/L**	**SW846 6020**

B Estimated result. Result is less than RL.

Volatile Organics by GC/MS					Reviewed
Acetone	**8.0 J**	**12**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	2.5	ug/L	SW846 8260B	
Bromochloromethane	ND	2.5	ug/L	SW846 8260B	
Bromodichloromethane	ND	2.5	ug/L	SW846 8260B	
2-Butanone	ND	12	ug/L	SW846 8260B	
n-Butylbenzene	ND	2.5	ug/L	SW846 8260B	
sec-Butylbenzene	ND	2.5	ug/L	SW846 8260B	
tert-Butylbenzene	ND	2.5	ug/L	SW846 8260B	
Carbon disulfide	ND	2.5	ug/L	SW846 8260B	
Dibromochloromethane	ND	2.5	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	5.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	12	ug/L	SW846 8260B	
2-Chlorotoluene	ND	2.5	ug/L	SW846 8260B	
4-Chlorotoluene	ND	2.5	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	2.5	ug/L	SW846 8260B	
Dibromomethane	ND	2.5	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	2.5	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	2.5	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: DMW-24I-081108					
Sample #: 002 Date Sampled: 08/11/08 11:45 Date Received: 08/12/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,4-Dichlorobenzene	ND	2.5	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	2.5	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	ND	2.5	ug/L	SW846 8260B	
trans-1,2-Dichloroethene	ND	2.5	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	2.5	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	2.5	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	2.5	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	2.5	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	2.5	ug/L	SW846 8260B	
2-Hexanone	ND	12	ug/L	SW846 8260B	
Isopropylbenzene	ND	2.5	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	2.5	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	50	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	12	ug/L	SW846 8260B	
Naphthalene	ND	2.5	ug/L	SW846 8260B	
n-Propylbenzene	ND	2.5	ug/L	SW846 8260B	
Styrene	ND	2.5	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	2.5	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	2.5	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	2.5	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	2.5	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	2.5	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	2.5	ug/L	SW846 8260B	
Vinyl acetate	ND	5.0	ug/L	SW846 8260B	
o-Xylene	ND	2.5	ug/L	SW846 8260B	
Xylenes (total)	ND	5.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	12	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	5.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	12	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	12	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	12	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	12	ug/L	SW846 8260B	
Benzene	ND	2.5	ug/L	SW846 8260B	
Bromoform	ND	2.5	ug/L	SW846 8260B	
Bromomethane	ND	2.5	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: DMW-24I-081108					
Sample #: 002 Date Sampled: 08/11/08 11:45 Date Received: 08/12/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Carbon tetrachloride	ND	2.5	ug/L	SW846 8260B	
Chlorobenzene	ND	2.5	ug/L	SW846 8260B	
Chloroethane	ND	2.5	ug/L	SW846 8260B	
Chloroform	**0.44 J**	**2.5**	**ug/L**	**SW846 8260B**	
Chloromethane	ND	2.5	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	2.5	ug/L	SW846 8260B	
1,2-Dichloroethane	ND	2.5	ug/L	SW846 8260B	
1,1-Dichloroethene	ND	2.5	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	2.5	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	2.5	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	2.5	ug/L	SW846 8260B	
Ethylbenzene	ND	2.5	ug/L	SW846 8260B	
Methylene chloride	ND	2.5	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	2.5	ug/L	SW846 8260B	
Tetrachloroethene	ND	2.5	ug/L	SW846 8260B	
Toluene	ND	2.5	ug/L	SW846 8260B	
1,1,1-Trichloroethane	ND	2.5	ug/L	SW846 8260B	
Trichloroethene	**56**	**2.5**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	2.5	ug/L	SW846 8260B	
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	ND	1.0	ug/L	SW846 8270C	
Inorganic Analysis					Reviewed
Hexavalent Chromium	ND	0.02	mg/L	SW846 7196A	
Client Sample ID: DMW-11S-081108					
Sample #: 003 Date Sampled: 08/11/08 12:06 Date Received: 08/12/08 Matrix: WATER					
Mercury in Liquid Waste (Manual Cold-Vapor)					Reviewed
Mercury	ND	0.20	ug/L	SW846 7470A	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: DMW-11S-081108						
Sample #: 003 Date Sampled: 08/11/08 12:06 Date Received: 08/12/08 Matrix: WATER						
Mercury	Dissolved	ND	0.20	ug/L	SW846 7470A	
ICP-MS (6020)						Reviewed
Silver	Dissolved	ND	1.0	ug/L	SW846 6020	
Arsenic	**Dissolved**	**4.4 B**	**5.0**	**ug/L**	**SW846 6020**	
Barium	**Dissolved**	**40.1**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium	**Dissolved**	**0.055 B**	**1.0**	**ug/L**	**SW846 6020**	
Cadmium	Dissolved	ND	1.0	ug/L	SW846 6020	
Cobalt	**Dissolved**	**18.3**	**1.0**	**ug/L**	**SW846 6020**	
Chromium	**Dissolved**	**0.32 B**	**2.0**	**ug/L**	**SW846 6020**	
Copper	**Dissolved**	**0.97 B**	**2.0**	**ug/L**	**SW846 6020**	
Iron	**Dissolved**	**14700**	**50.0**	**ug/L**	**SW846 6020**	
Manganese	**Dissolved**	**1020**	**1.0**	**ug/L**	**SW846 6020**	
Molybdenum	Dissolved	ND	2.0	ug/L	SW846 6020	
Nickel	**Dissolved**	**7.3**	**2.0**	**ug/L**	**SW846 6020**	
Lead	**Dissolved**	**0.72 B**	**1.0**	**ug/L**	**SW846 6020**	
Antimony	**Dissolved**	**0.15 B**	**2.0**	**ug/L**	**SW846 6020**	
Selenium	**Dissolved**	**1.2 B**	**5.0**	**ug/L**	**SW846 6020**	
Thallium	Dissolved	ND	1.0	ug/L	SW846 6020	
Vanadium	Dissolved	ND	20.0	ug/L	SW846 6020	
Zinc	**Dissolved**	**42.8**	**20.0**	**ug/L**	**SW846 6020**	
Silver		ND	1.0	ug/L	SW846 6020	
Arsenic		**4.3 B**	**5.0**	**ug/L**	**SW846 6020**	
Barium		**40.8**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium		**0.069 B**	**1.0**	**ug/L**	**SW846 6020**	
Cadmium		**0.010 B**	**1.0**	**ug/L**	**SW846 6020**	
Cobalt		**18.7**	**1.0**	**ug/L**	**SW846 6020**	
Chromium		**0.50 B**	**2.0**	**ug/L**	**SW846 6020**	
Copper		**7.7**	**2.0**	**ug/L**	**SW846 6020**	
Iron		**15100**	**50.0**	**ug/L**	**SW846 6020**	
Manganese		**960**	**1.0**	**ug/L**	**SW846 6020**	
Molybdenum		ND	2.0	ug/L	SW846 6020	
Nickel		**7.7**	**2.0**	**ug/L**	**SW846 6020**	
Lead		**1.1**	**1.0**	**ug/L**	**SW846 6020**	
Antimony		**0.20 B**	**2.0**	**ug/L**	**SW846 6020**	
Selenium		**1.2 B**	**5.0**	**ug/L**	**SW846 6020**	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: DMW-11S-081108				
Sample #: 003 Date Sampled: 08/11/08 12:06 Date Received: 08/12/08 Matrix: WATER				
Thallium	ND	1.0	ug/L	SW846 6020
Vanadium	ND	20.0	ug/L	SW846 6020
Zinc	**44.5**	**20.0**	**ug/L**	**SW846 6020**

B Estimated result. Result is less than RL.

Volatile Organics by GC/MS					Reviewed
Acetone	ND	8300	ug/L	SW846 8260B	
Bromobenzene	ND	1700	ug/L	SW846 8260B	
Bromochloromethane	ND	1700	ug/L	SW846 8260B	
Bromodichloromethane	ND	1700	ug/L	SW846 8260B	
2-Butanone	ND	8300	ug/L	SW846 8260B	
n-Butylbenzene	ND	1700	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1700	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1700	ug/L	SW846 8260B	
Carbon disulfide	ND	1700	ug/L	SW846 8260B	
Dibromochloromethane	ND	1700	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	3300	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	8300	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1700	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1700	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1700	ug/L	SW846 8260B	
Dibromomethane	ND	1700	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1700	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1700	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1700	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1700	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**36000**	**1700**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	1700	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1700	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1700	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1700	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1700	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1700	ug/L	SW846 8260B	
2-Hexanone	ND	8300	ug/L	SW846 8260B	
Isopropylbenzene	ND	1700	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: DMW-11S-081108
Sample #: 003 Date Sampled: 08/11/08 12:06 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
p-Isopropyltoluene	ND	1700	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	33000	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	8300	ug/L	SW846 8260B	
Naphthalene	ND	1700	ug/L	SW846 8260B	
n-Propylbenzene	ND	1700	ug/L	SW846 8260B	
Styrene	ND	1700	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1700	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	1700	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1700	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1700	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1700	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1700	ug/L	SW846 8260B	
Vinyl acetate	ND	3300	ug/L	SW846 8260B	
o-Xylene	ND	1700	ug/L	SW846 8260B	
Xylenes (total)	ND	3300	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	8300	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	3300	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	8300	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	8300	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	8300	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	8300	ug/L	SW846 8260B	
Benzene	ND	1700	ug/L	SW846 8260B	
Bromoform	ND	1700	ug/L	SW846 8260B	
Bromomethane	ND	1700	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1700	ug/L	SW846 8260B	
Chlorobenzene	ND	1700	ug/L	SW846 8260B	
Chloroethane	ND	1700	ug/L	SW846 8260B	
Chloroform	**1000 J**	**1700**	**ug/L**	**SW846 8260B**	
Chloromethane	ND	1700	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	1700	ug/L	SW846 8260B	
1,2-Dichloroethane	ND	1700	ug/L	SW846 8260B	
1,1-Dichloroethene	ND	1700	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	1700	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1700	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1700	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: DMW-11S-081108					
Sample #: 003 Date Sampled: 08/11/08 12:06 Date Received: 08/12/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Ethylbenzene		ND	1700	ug/L	SW846 8260B
Methylene chloride		ND	1700	ug/L	SW846 8260B
1,1,2,2-Tetrachloroethane		ND	1700	ug/L	SW846 8260B
Tetrachloroethene		ND	1700	ug/L	SW846 8260B
Toluene		**1200 J**	**1700**	**ug/L**	**SW846 8260B**
1,1,1-Trichloroethane		ND	1700	ug/L	SW846 8260B
Trichloroethene		**29000**	**1700**	**ug/L**	**SW846 8260B**
Vinyl chloride		**3300**	**1700**	**ug/L**	**SW846 8260B**
J Estimated result. Result is less than RL.					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane		**4.6**	**1.0**	**ug/L**	**SW846 8270C**
Inorganic Analysis					Reviewed
Hexavalent Chromium		ND	0.02	mg/L	SW846 7196A
Client Sample ID: DMW-24S-081108					
Sample #: 004 Date Sampled: 08/11/08 13:20 Date Received: 08/12/08 Matrix: WATER					
Mercury in Liquid Waste (Manual Cold-Vapor)					Reviewed
Mercury		ND	0.20	ug/L	SW846 7470A
Mercury	Dissolved	ND	0.20	ug/L	SW846 7470A
ICP-MS (6020)					Reviewed
Silver	Dissolved	ND	1.0	ug/L	SW846 6020
Arsenic	**Dissolved**	**36.0**	**5.0**	**ug/L**	**SW846 6020**
Barium	**Dissolved**	**18.9**	**1.0**	**ug/L**	**SW846 6020**
Beryllium	**Dissolved**	**6.2**	**1.0**	**ug/L**	**SW846 6020**
Cadmium	**Dissolved**	**3.1**	**1.0**	**ug/L**	**SW846 6020**
Cobalt	**Dissolved**	**410**	**1.0**	**ug/L**	**SW846 6020**
Chromium	**Dissolved**	**12.2**	**2.0**	**ug/L**	**SW846 6020**

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: DMW-24S-081108					
Sample #: 004 Date Sampled: 08/11/08 13:20 Date Received: 08/12/08 Matrix: WATER					
Copper	**Dissolved**	**156**	**2.0**	**ug/L**	**SW846 6020**
Iron	**Dissolved**	**87700**	**50.0**	**ug/L**	**SW846 6020**
Manganese	**Dissolved**	**2930**	**1.0**	**ug/L**	**SW846 6020**
Molybdenum	Dissolved	ND	2.0	ug/L	SW846 6020
Nickel	**Dissolved**	**542**	**2.0**	**ug/L**	**SW846 6020**
Lead	**Dissolved**	**1.3**	**1.0**	**ug/L**	**SW846 6020**
Antimony	**Dissolved**	**0.059 B**	**2.0**	**ug/L**	**SW846 6020**
Selenium	**Dissolved**	**48.3**	**5.0**	**ug/L**	**SW846 6020**
Thallium	**Dissolved**	**0.26 B**	**1.0**	**ug/L**	**SW846 6020**
Vanadium	**Dissolved**	**82.4**	**20.0**	**ug/L**	**SW846 6020**
Zinc	**Dissolved**	**1810**	**20.0**	**ug/L**	**SW846 6020**
Silver		**0.0050 B**	**1.0**	**ug/L**	**SW846 6020**
Arsenic		**36.7**	**5.0**	**ug/L**	**SW846 6020**
Barium		**18.9**	**1.0**	**ug/L**	**SW846 6020**
Beryllium		**5.9**	**1.0**	**ug/L**	**SW846 6020**
Cadmium		**3.1**	**1.0**	**ug/L**	**SW846 6020**
Cobalt		**404**	**1.0**	**ug/L**	**SW846 6020**
Chromium		**12.3**	**2.0**	**ug/L**	**SW846 6020**
Copper		**162**	**2.0**	**ug/L**	**SW846 6020**
Iron		**86200**	**50.0**	**ug/L**	**SW846 6020**
Manganese		**2960**	**1.0**	**ug/L**	**SW846 6020**
Molybdenum		ND	2.0	ug/L	SW846 6020
Nickel		**530**	**2.0**	**ug/L**	**SW846 6020**
Lead		**1.3**	**1.0**	**ug/L**	**SW846 6020**
Antimony		**0.046 B**	**2.0**	**ug/L**	**SW846 6020**
Selenium		**47.2**	**5.0**	**ug/L**	**SW846 6020**
Thallium		**0.29 B**	**1.0**	**ug/L**	**SW846 6020**
Vanadium		**81.8**	**20.0**	**ug/L**	**SW846 6020**
Zinc		**1780**	**20.0**	**ug/L**	**SW846 6020**

B Estimated result. Result is less than RL.

Volatile Organics by GC/MS						Reviewed
Acetone		**1.2 J**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene		ND	1.0	ug/L	SW846 8260B	
Bromochloromethane		ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane		ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: DMW-24S-081108
Sample #: 004 Date Sampled: 08/11/08 13:20 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
2-Butanone	ND	5.0	ug/L	SW846 8260B	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
Carbon disulfide	ND	1.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	ND	1.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: DMW-24S-081108
Sample #: 004 Date Sampled: 08/11/08 13:20 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	**0.18 J**	**1.0**	**ug/L**	**SW846 8260B**	
Chloromethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	ND	1.0	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	ND	1.0	ug/L	SW846 8260B	
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: DMW-24S-081108						
Sample #: 004 Date Sampled: 08/11/08 13:20 Date Received: 08/12/08 Matrix: WATER						
Semivolatile Organic Compounds by GC/MS						Reviewed
1,4-Dioxane		ND	1.0	ug/L	SW846 8270C	
Inorganic Analysis						Reviewed
Hexavalent Chromium		ND	0.02	mg/L	SW846 7196A	
Client Sample ID: DMW-11I-081108						
Sample #: 005 Date Sampled: 08/11/08 13:26 Date Received: 08/12/08 Matrix: WATER						
Mercury in Liquid Waste (Manual Cold-Vapor)						Reviewed
Mercury		**1.8**	**0.20**	**ug/L**	**SW846 7470A**	
Mercury	Dissolved	ND	0.20	ug/L	SW846 7470A	
ICP-MS (6020)						Reviewed
Silver	Dissolved	ND	1.0	ug/L	SW846 6020	
Arsenic	**Dissolved**	**0.71 B**	**5.0**	**ug/L**	**SW846 6020**	
Barium	**Dissolved**	**2.9**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium	**Dissolved**	**0.017 B**	**1.0**	**ug/L**	**SW846 6020**	
Cadmium	**Dissolved**	**0.040 B**	**1.0**	**ug/L**	**SW846 6020**	
Cobalt	**Dissolved**	**0.80 B**	**1.0**	**ug/L**	**SW846 6020**	
Chromium	Dissolved	ND	2.0	ug/L	SW846 6020	
Copper	**Dissolved**	**4.9**	**2.0**	**ug/L**	**SW846 6020**	
Iron	**Dissolved**	**79.3**	**50.0**	**ug/L**	**SW846 6020**	
Manganese	**Dissolved**	**21.6**	**1.0**	**ug/L**	**SW846 6020**	
Molybdenum	**Dissolved**	**0.34 B**	**2.0**	**ug/L**	**SW846 6020**	
Nickel	**Dissolved**	**1.8 B**	**2.0**	**ug/L**	**SW846 6020**	
Lead	**Dissolved**	**0.49 B**	**1.0**	**ug/L**	**SW846 6020**	
Antimony	Dissolved	ND	2.0	ug/L	SW846 6020	
Selenium	Dissolved	ND	5.0	ug/L	SW846 6020	
Thallium	Dissolved	ND	1.0	ug/L	SW846 6020	
Vanadium	Dissolved	ND	20.0	ug/L	SW846 6020	
Zinc	**Dissolved**	**19.1 B**	**20.0**	**ug/L**	**SW846 6020**	
Silver		ND	1.0	ug/L	SW846 6020	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: DMW-11I-081108				
Sample #: 005 Date Sampled: 08/11/08 13:26 Date Received: 08/12/08 Matrix: WATER				
Arsenic	**0.92 B**	**5.0**	**ug/L**	**SW846 6020**
Barium	**5.5**	**1.0**	**ug/L**	**SW846 6020**
Beryllium	**0.042 B**	**1.0**	**ug/L**	**SW846 6020**
Cadmium	**0.011 B**	**1.0**	**ug/L**	**SW846 6020**
Cobalt	**0.76 B**	**1.0**	**ug/L**	**SW846 6020**
Chromium	**1.7 B**	**2.0**	**ug/L**	**SW846 6020**
Copper	**5.5**	**2.0**	**ug/L**	**SW846 6020**
Iron	**355**	**50.0**	**ug/L**	**SW846 6020**
Manganese	**21.0**	**1.0**	**ug/L**	**SW846 6020**
Molybdenum	**0.56 B**	**2.0**	**ug/L**	**SW846 6020**
Nickel	**1.7 B**	**2.0**	**ug/L**	**SW846 6020**
Lead	**1.0**	**1.0**	**ug/L**	**SW846 6020**
Antimony	ND	2.0	ug/L	SW846 6020
Selenium	ND	5.0	ug/L	SW846 6020
Thallium	ND	1.0	ug/L	SW846 6020
Vanadium	**2.1 B**	**20.0**	**ug/L**	**SW846 6020**
Zinc	**15.9 B**	**20.0**	**ug/L**	**SW846 6020**

B Estimated result. Result is less than RL.

Volatile Organics by GC/MS				Reviewed
Acetone	**1.9 J**	**5.0**	**ug/L**	**SW846 8260B**
Bromobenzene	ND	1.0	ug/L	SW846 8260B
Bromochloromethane	ND	1.0	ug/L	SW846 8260B
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B
2-Butanone	**0.66 J**	**5.0**	**ug/L**	**SW846 8260B**
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B
Carbon disulfide	ND	1.0	ug/L	SW846 8260B
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: DMW-11I-081108				
Sample #: 005 Date Sampled: 08/11/08 13:26 Date Received: 08/12/08 Matrix: WATER				
Volatile Organics by GC/MS				Reviewed
Dibromomethane	ND	1.0	ug/L	SW846 8260B
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B
cis-1,2-Dichloroethene	**0.77 J**	**1.0**	**ug/L**	**SW846 8260B**
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B
2-Hexanone	ND	5.0	ug/L	SW846 8260B
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B
Naphthalene	ND	1.0	ug/L	SW846 8260B
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B
Styrene	ND	1.0	ug/L	SW846 8260B
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B
Vinyl acetate	ND	2.0	ug/L	SW846 8260B
o-Xylene	ND	1.0	ug/L	SW846 8260B
Xylenes (total)	ND	2.0	ug/L	SW846 8260B
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: DMW-11I-081108

Sample #: 005 Date Sampled: 08/11/08 13:26 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	ND	1.0	ug/L	SW846 8260B	
Chloromethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	ND	1.0	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	**0.44 J**	**1.0**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	ND	1.0	ug/L	SW846 8270C	
Inorganic Analysis					Reviewed
Hexavalent Chromium	ND	0.02	mg/L	SW846 7196A	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: MW-3-081108						
Sample #: 006 Date Sampled: 08/11/08 16:09 Date Received: 08/12/08 Matrix: WATER						
Mercury in Liquid Waste (Manual Cold-Vapor)						Reviewed
Mercury		ND	0.20	ug/L	SW846 7470A	
Mercury	Dissolved	ND	0.20	ug/L	SW846 7470A	
ICP-MS (6020)						Reviewed
Silver	Dissolved	ND	1.0	ug/L	SW846 6020	
Arsenic	**Dissolved**	**1.4 B**	**5.0**	**ug/L**	**SW846 6020**	
Barium	**Dissolved**	**35.2**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium	Dissolved	ND	1.0	ug/L	SW846 6020	
Cadmium	Dissolved	ND	1.0	ug/L	SW846 6020	
Cobalt	**Dissolved**	**0.83 B**	**1.0**	**ug/L**	**SW846 6020**	
Chromium	**Dissolved**	**1.5 B**	**2.0**	**ug/L**	**SW846 6020**	
Copper	**Dissolved**	**0.20 B**	**2.0**	**ug/L**	**SW846 6020**	
Iron	**Dissolved**	**6900**	**50.0**	**ug/L**	**SW846 6020**	
Manganese	**Dissolved**	**139**	**1.0**	**ug/L**	**SW846 6020**	
Molybdenum	Dissolved	ND	2.0	ug/L	SW846 6020	
Nickel	**Dissolved**	**0.74 B**	**2.0**	**ug/L**	**SW846 6020**	
Lead	**Dissolved**	**0.072 B**	**1.0**	**ug/L**	**SW846 6020**	
Antimony	**Dissolved**	**0.059 B**	**2.0**	**ug/L**	**SW846 6020**	
Selenium	**Dissolved**	**0.24 B**	**5.0**	**ug/L**	**SW846 6020**	
Thallium	Dissolved	ND	1.0	ug/L	SW846 6020	
Vanadium	**Dissolved**	**3.5 B**	**20.0**	**ug/L**	**SW846 6020**	
Zinc	**Dissolved**	**11.8 B**	**20.0**	**ug/L**	**SW846 6020**	
Silver		ND	1.0	ug/L	SW846 6020	
Arsenic		**1.5 B**	**5.0**	**ug/L**	**SW846 6020**	
Barium		**33.9**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium		ND	1.0	ug/L	SW846 6020	
Cadmium		**0.032 B**	**1.0**	**ug/L**	**SW846 6020**	
Cobalt		**0.86 B**	**1.0**	**ug/L**	**SW846 6020**	
Chromium		**1.9 B**	**2.0**	**ug/L**	**SW846 6020**	
Copper		**2.8**	**2.0**	**ug/L**	**SW846 6020**	
Iron		**6740**	**50.0**	**ug/L**	**SW846 6020**	
Manganese		**131**	**1.0**	**ug/L**	**SW846 6020**	
Molybdenum		ND	2.0	ug/L	SW846 6020	
Nickel		**1.1 B**	**2.0**	**ug/L**	**SW846 6020**	
Lead		**0.62 B**	**1.0**	**ug/L**	**SW846 6020**	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: MW-3-081108				
Sample #: 006 Date Sampled: 08/11/08 16:09 Date Received: 08/12/08 Matrix: WATER				
Antimony	**0.081 B**	**2.0**	**ug/L**	**SW846 6020**
Selenium	ND	5.0	ug/L	SW846 6020
Thallium	ND	1.0	ug/L	SW846 6020
Vanadium	**4.3 B**	**20.0**	**ug/L**	**SW846 6020**
Zinc	**19.7 B**	**20.0**	**ug/L**	**SW846 6020**

B Estimated result. Result is less than RL.

Volatile Organics by GC/MS				Reviewed
Acetone	**3.4 J**	**12**	**ug/L**	**SW846 8260B**
Bromobenzene	ND	2.5	ug/L	SW846 8260B
Bromochloromethane	ND	2.5	ug/L	SW846 8260B
Bromodichloromethane	ND	2.5	ug/L	SW846 8260B
2-Butanone	ND	12	ug/L	SW846 8260B
n-Butylbenzene	ND	2.5	ug/L	SW846 8260B
sec-Butylbenzene	ND	2.5	ug/L	SW846 8260B
tert-Butylbenzene	ND	2.5	ug/L	SW846 8260B
Carbon disulfide	ND	2.5	ug/L	SW846 8260B
Dibromochloromethane	ND	2.5	ug/L	SW846 8260B
1,2-Dibromo-3-chloro-propane	ND	5.0	ug/L	SW846 8260B
2-Chloroethyl vinyl ether	ND	12	ug/L	SW846 8260B
2-Chlorotoluene	ND	2.5	ug/L	SW846 8260B
4-Chlorotoluene	ND	2.5	ug/L	SW846 8260B
1,2-Dibromoethane	ND	2.5	ug/L	SW846 8260B
Dibromomethane	ND	2.5	ug/L	SW846 8260B
1,2-Dichlorobenzene	ND	2.5	ug/L	SW846 8260B
1,3-Dichlorobenzene	ND	2.5	ug/L	SW846 8260B
1,4-Dichlorobenzene	ND	2.5	ug/L	SW846 8260B
Dichlorodifluoromethane	ND	2.5	ug/L	SW846 8260B
cis-1,2-Dichloroethene	**61**	**2.5**	**ug/L**	**SW846 8260B**
trans-1,2-Dichloroethene	ND	2.5	ug/L	SW846 8260B
1,3-Dichloropropane	ND	2.5	ug/L	SW846 8260B
2,2-Dichloropropane	ND	2.5	ug/L	SW846 8260B
1,1-Dichloropropene	ND	2.5	ug/L	SW846 8260B
Trichlorofluoromethane	ND	2.5	ug/L	SW846 8260B
Hexachlorobutadiene	ND	2.5	ug/L	SW846 8260B

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: MW-3-081108

Sample #: 006 Date Sampled: 08/11/08 16:09 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
2-Hexanone	ND	12	ug/L	SW846 8260B	
Isopropylbenzene	ND	2.5	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	2.5	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	50	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	12	ug/L	SW846 8260B	
Naphthalene	ND	2.5	ug/L	SW846 8260B	
n-Propylbenzene	ND	2.5	ug/L	SW846 8260B	
Styrene	ND	2.5	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	2.5	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	2.5	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	2.5	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	2.5	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	2.5	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	2.5	ug/L	SW846 8260B	
Vinyl acetate	ND	5.0	ug/L	SW846 8260B	
o-Xylene	ND	2.5	ug/L	SW846 8260B	
Xylenes (total)	ND	5.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	12	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	5.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	12	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	12	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	12	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	12	ug/L	SW846 8260B	
Benzene	ND	2.5	ug/L	SW846 8260B	
Bromoform	ND	2.5	ug/L	SW846 8260B	
Bromomethane	ND	2.5	ug/L	SW846 8260B	
Carbon tetrachloride	ND	2.5	ug/L	SW846 8260B	
Chlorobenzene	ND	2.5	ug/L	SW846 8260B	
Chloroethane	ND	2.5	ug/L	SW846 8260B	
Chloroform	ND	2.5	ug/L	SW846 8260B	
Chloromethane	ND	2.5	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	2.5	ug/L	SW846 8260B	
1,2-Dichloroethane	ND	2.5	ug/L	SW846 8260B	
1,1-Dichloroethene	ND	2.5	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	2.5	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: MW-3-081108						
Sample #: 006 Date Sampled: 08/11/08 16:09 Date Received: 08/12/08 Matrix: WATER						
Volatile Organics by GC/MS						Reviewed
cis-1,3-Dichloropropene		ND	2.5	ug/L	SW846 8260B	
trans-1,3-Dichloropropene		ND	2.5	ug/L	SW846 8260B	
Ethylbenzene		ND	2.5	ug/L	SW846 8260B	
Methylene chloride		ND	2.5	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane		ND	2.5	ug/L	SW846 8260B	
Tetrachloroethene		ND	2.5	ug/L	SW846 8260B	
Toluene		ND	2.5	ug/L	SW846 8260B	
1,1,1-Trichloroethane		ND	2.5	ug/L	SW846 8260B	
Trichloroethene		**1.2 J**	**2.5**	**ug/L**	**SW846 8260B**	
Vinyl chloride		**16**	**2.5**	**ug/L**	**SW846 8260B**	
Semivolatile Organic Compounds by GC/MS						Reviewed
1,4-Dioxane		ND	1.0	ug/L	SW846 8270C	
Inorganic Analysis						Reviewed
Hexavalent Chromium		ND	0.02	mg/L	SW846 7196A	
Client Sample ID: DMW-23S-081108						
Sample #: 007 Date Sampled: 08/11/08 16:10 Date Received: 08/12/08 Matrix: WATER						
Mercury in Liquid Waste (Manual Cold-Vapor)						Reviewed
Mercury		ND	0.20	ug/L	SW846 7470A	
Mercury	Dissolved	ND	0.20	ug/L	SW846 7470A	
ICP-MS (6020)						Reviewed
Silver	Dissolved	ND	1.0	ug/L	SW846 6020	
Arsenic	**Dissolved**	**10.7**	**5.0**	**ug/L**	**SW846 6020**	
Barium	**Dissolved**	**112**	**1.0**	**ug/L**	**SW846 6020**	
Beryllium	Dissolved	ND	1.0	ug/L	SW846 6020	
Cadmium	Dissolved	ND	1.0	ug/L	SW846 6020	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER		RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD
Client Sample ID: DMW-23S-081108					
Sample #: 007 Date Sampled: 08/11/08 16:10 Date Received: 08/12/08 Matrix: WATER					
Cobalt	**Dissolved**	**4.2**	**1.0**	**ug/L**	**SW846 6020**
Chromium	**Dissolved**	**2.1**	**2.0**	**ug/L**	**SW846 6020**
Copper	**Dissolved**	**0.28 B**	**2.0**	**ug/L**	**SW846 6020**
Iron	**Dissolved**	**33300**	**50.0**	**ug/L**	**SW846 6020**
Manganese	**Dissolved**	**1500**	**1.0**	**ug/L**	**SW846 6020**
Molybdenum	**Dissolved**	**2.0**	**2.0**	**ug/L**	**SW846 6020**
Nickel	**Dissolved**	**2.6**	**2.0**	**ug/L**	**SW846 6020**
Lead	**Dissolved**	**0.043 B**	**1.0**	**ug/L**	**SW846 6020**
Antimony	**Dissolved**	**0.047 B**	**2.0**	**ug/L**	**SW846 6020**
Selenium	**Dissolved**	**0.41 B**	**5.0**	**ug/L**	**SW846 6020**
Thallium	Dissolved	ND	1.0	ug/L	SW846 6020
Vanadium	**Dissolved**	**0.79 B**	**20.0**	**ug/L**	**SW846 6020**
Zinc	**Dissolved**	**3.3 B**	**20.0**	**ug/L**	**SW846 6020**
Silver		ND	1.0	ug/L	SW846 6020
Arsenic		**12.0**	**5.0**	**ug/L**	**SW846 6020**
Barium		**123**	**1.0**	**ug/L**	**SW846 6020**
Beryllium		ND	1.0	ug/L	SW846 6020
Cadmium		**0.31 B**	**1.0**	**ug/L**	**SW846 6020**
Cobalt		**4.8**	**1.0**	**ug/L**	**SW846 6020**
Chromium		**3.9**	**2.0**	**ug/L**	**SW846 6020**
Copper		**1.1 B**	**2.0**	**ug/L**	**SW846 6020**
Iron		**38000**	**50.0**	**ug/L**	**SW846 6020**
Manganese		**1780**	**1.0**	**ug/L**	**SW846 6020**
Molybdenum		**3.9**	**2.0**	**ug/L**	**SW846 6020**
Nickel		**3.4**	**2.0**	**ug/L**	**SW846 6020**
Lead		**0.45 B**	**1.0**	**ug/L**	**SW846 6020**
Antimony		**0.32 B**	**2.0**	**ug/L**	**SW846 6020**
Selenium		**0.42 B**	**5.0**	**ug/L**	**SW846 6020**
Thallium		ND	1.0	ug/L	SW846 6020
Vanadium		**1.2 B**	**20.0**	**ug/L**	**SW846 6020**
Zinc		**4.7 B**	**20.0**	**ug/L**	**SW846 6020**

B Estimated result. Result is less than RL.

					Reviewed
Volatile Organics by GC/MS					
Acetone	**3.1 J**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: DMW-23S-081108					
Sample #: 007 Date Sampled: 08/11/08 16:10 Date Received: 08/12/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	**1.4 J**	**5.0**	**ug/L**	**SW846 8260B**	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	**0.39 J**	**1.0**	**ug/L**	**SW846 8260B**	
tert-Butylbenzene	**0.42 J**	**1.0**	**ug/L**	**SW846 8260B**	
Carbon disulfide	**0.55 J**	**1.0**	**ug/L**	**SW846 8260B**	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	**0.42 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**0.85 J**	**1.0**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	**0.32 J**	**1.0**	**ug/L**	**SW846 8260B**	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	**0.31 J**	**1.0**	**ug/L**	**SW846 8260B**	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

Client Sample ID: DMW-23S-081108

Sample #: 007 Date Sampled: 08/11/08 16:10 Date Received: 08/12/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	**0.11 J**	**5.0**	**ug/L**	**SW846 8260B**	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	**4.2**	**1.0**	**ug/L**	**SW846 8260B**	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	**0.31 J**	**1.0**	**ug/L**	**SW846 8260B**	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	ND	1.0	ug/L	SW846 8260B	
Chloromethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloroethane	**0.58 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	ND	1.0	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	ND	1.0	ug/L	SW846 8260B	
Vinyl chloride	**5.6**	**1.0**	**ug/L**	**SW846 8260B**	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8H120110 MARTIN STATE AIRPORT **Date Reported:** 9/02/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: DMW-23S-081108					
Sample #: 007 Date Sampled: 08/11/08 16:10 Date Received: 08/12/08 Matrix: WATER					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**7.3**	**1.0**	**ug/L**	**SW846 8270C**	
Inorganic Analysis					Reviewed
Hexavalent Chromium	ND	0.02	mg/L	SW846 7196A	

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: TB-063008					
Sample #: 001 Date Sampled: 06/30/08 07:30 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	ND	5.0	ug/L	SW846 8260B	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	ND	5.0	ug/L	SW846 8260B	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
Carbon disulfide	ND	1.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
trans-1,2-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	ND	1.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: TB-063008					
Sample #: 001 Date Sampled: 06/30/08 07:30 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	ND	1.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	ND	1.0	ug/L	SW846 8260B	
Chloroform	ND	1.0	ug/L	SW846 8260B	
Chloromethane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloroethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloroethane	**0.25 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	ND	1.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	**1.2**	**1.0**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	**0.46 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,1,1-Trichloroethane	ND	1.0	ug/L	SW846 8260B	
Trichloroethene	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: TB-063008					
Sample #: 001 Date Sampled: 06/30/08 07:30 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	
Client Sample ID: OW4A-063008					
Sample #: 002 Date Sampled: 06/30/08 10:32 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,4-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**5.1**	**1.0**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	**0.51 J**	**1.0**	**ug/L**	**SW846 8260B**	
Acetone	**19**	**5.0**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.0	ug/L	SW846 8260B	
Bromochloromethane	ND	1.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	1.0	ug/L	SW846 8260B	
2-Butanone	**1.5 J**	**5.0**	**ug/L**	**SW846 8260B**	
n-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.0	ug/L	SW846 8260B	
Carbon disulfide	ND	1.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	5.0	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.0	ug/L	SW846 8260B	
Dibromomethane	ND	1.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.0	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

The results shown below may still require additional laboratory review and are subject to change. Actions taken based on these results are the responsibility of the data user.

Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

Client Sample ID: OW4A-063008
Sample #: 002 Date Sampled: 06/30/08 10:32 Date Received: 07/02/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
2-Hexanone	ND	5.0	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.0	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	20	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	5.0	ug/L	SW846 8260B	
Naphthalene	ND	1.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.0	ug/L	SW846 8260B	
Styrene	ND	1.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	1.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	1.0	ug/L	SW846 8260B	
Vinyl acetate	ND	2.0	ug/L	SW846 8260B	
o-Xylene	ND	1.0	ug/L	SW846 8260B	
Xylenes (total)	ND	2.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	5.0	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	5.0	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	5.0	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	5.0	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	5.0	ug/L	SW846 8260B	
Benzene	ND	1.0	ug/L	SW846 8260B	
Bromoform	ND	1.0	ug/L	SW846 8260B	
Bromomethane	**0.49 J**	**1.0**	**ug/L**	**SW846 8260B**	
Carbon tetrachloride	ND	1.0	ug/L	SW846 8260B	
Chlorobenzene	ND	1.0	ug/L	SW846 8260B	
Chloroethane	**0.34 J**	**1.0**	**ug/L**	**SW846 8260B**	
Chloroform	ND	1.0	ug/L	SW846 8260B	
Chloromethane	**6.6**	**1.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethane	**2.8**	**1.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	**0.29 J**	**1.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	**1.1**	**1.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	1.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW4A-063008					
Sample #: 002 Date Sampled: 06/30/08 10:32 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
cis-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.0	ug/L	SW846 8260B	
Ethylbenzene	ND	1.0	ug/L	SW846 8260B	
Methylene chloride	ND	1.0	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	1.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	1.0	ug/L	SW846 8260B	
Toluene	ND	1.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**0.77 J**	**1.0**	**ug/L**	**SW846 8260B**	
Trichloroethene	**14**	**1.0**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	1.0	ug/L	SW846 8260B	
J Estimated result. Result is less than RL.					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**3.3 J**	**10**	**ug/L**	**SW846 8270C**	
J Estimated result. Result is less than RL.					
Client Sample ID: OW4B-063008					
Sample #: 003 Date Sampled: 06/30/08 12:24 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,4-Dichlorobenzene	ND	22	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	22	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**200**	**22**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	22	ug/L	SW846 8260B	
Acetone	ND	110	ug/L	SW846 8260B	
Bromobenzene	ND	22	ug/L	SW846 8260B	
Bromochloromethane	ND	22	ug/L	SW846 8260B	
Bromodichloromethane	ND	22	ug/L	SW846 8260B	
2-Butanone	ND	110	ug/L	SW846 8260B	
n-Butylbenzene	ND	22	ug/L	SW846 8260B	
sec-Butylbenzene	ND	22	ug/L	SW846 8260B	
tert-Butylbenzene	ND	22	ug/L	SW846 8260B	
Carbon disulfide	ND	22	ug/L	SW846 8260B	
Dibromochloromethane	ND	22	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW4B-063008					
Sample #: 003 Date Sampled: 06/30/08 12:24 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,2-Dibromo-3-chloro-propane	ND	44	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	110	ug/L	SW846 8260B	
2-Chlorotoluene	ND	22	ug/L	SW846 8260B	
4-Chlorotoluene	ND	22	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	22	ug/L	SW846 8260B	
Dibromomethane	ND	22	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	22	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	22	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	22	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	22	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	22	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	22	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	22	ug/L	SW846 8260B	
2-Hexanone	ND	110	ug/L	SW846 8260B	
Isopropylbenzene	ND	22	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	22	ug/L	SW846 8260B	
tert-Butyl alcohol	**87 J**	**440**	**ug/L**	**SW846 8260B**	
4-Methyl-2-pentanone	ND	110	ug/L	SW846 8260B	
Naphthalene	ND	22	ug/L	SW846 8260B	
n-Propylbenzene	ND	22	ug/L	SW846 8260B	
Styrene	ND	22	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	22	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	22	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	22	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	22	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	22	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	22	ug/L	SW846 8260B	
Vinyl acetate	ND	44	ug/L	SW846 8260B	
o-Xylene	ND	22	ug/L	SW846 8260B	
Xylenes (total)	ND	44	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	110	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	44	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	110	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	110	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW4B-063008					
Sample #: 003 Date Sampled: 06/30/08 12:24 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Ethyl-t-Butyl Ether (ETBE)	ND	110	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	110	ug/L	SW846 8260B	
Benzene	ND	22	ug/L	SW846 8260B	
Bromoform	ND	22	ug/L	SW846 8260B	
Bromomethane	ND	22	ug/L	SW846 8260B	
Carbon tetrachloride	ND	22	ug/L	SW846 8260B	
Chlorobenzene	ND	22	ug/L	SW846 8260B	
Chloroethane	ND	22	ug/L	SW846 8260B	
Chloroform	ND	22	ug/L	SW846 8260B	
Chloromethane	ND	22	ug/L	SW846 8260B	
1,1-Dichloroethane	**77**	**22**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	ND	22	ug/L	SW846 8260B	
1,1-Dichloroethene	**380**	**22**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	22	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	22	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	22	ug/L	SW846 8260B	
Ethylbenzene	ND	22	ug/L	SW846 8260B	
Methylene chloride	ND	22	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	22	ug/L	SW846 8260B	
Tetrachloroethene	ND	22	ug/L	SW846 8260B	
Toluene	ND	22	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**41**	**22**	**ug/L**	**SW846 8260B**	
Trichloroethene	**790**	**22**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	22	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**56**	**20**	**ug/L**	**SW846 8270C**	

Client Sample ID: OW5A-063008
Sample #: 004 Date Sampled: 06/30/08 14:54 Date Received: 07/02/08 Matrix: WATER

Volatile Organics by GC/MS					Reviewed
Acetone	**140**	**10**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	2.0	ug/L	SW846 8260B	

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PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW5A-063008					
Sample #: 004 Date Sampled: 06/30/08 14:54 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Bromochloromethane	ND	2.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	2.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	2.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**0.92 J**	**2.0**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	2.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	2.0	ug/L	SW846 8260B	
2-Butanone	**7.3 J**	**10**	**ug/L**	**SW846 8260B**	
n-Butylbenzene	ND	2.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	2.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	2.0	ug/L	SW846 8260B	
Carbon disulfide	**1.2 J**	**2.0**	**ug/L**	**SW846 8260B**	
Dibromochloromethane	ND	2.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	4.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	10	ug/L	SW846 8260B	
2-Chlorotoluene	ND	2.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	2.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	2.0	ug/L	SW846 8260B	
Dibromomethane	ND	2.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	2.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	2.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	2.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	2.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	2.0	ug/L	SW846 8260B	
Trichlorofluoromethane	**0.66 J**	**2.0**	**ug/L**	**SW846 8260B**	
Hexachlorobutadiene	ND	2.0	ug/L	SW846 8260B	
2-Hexanone	ND	10	ug/L	SW846 8260B	
Isopropylbenzene	ND	2.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	2.0	ug/L	SW846 8260B	
tert-Butyl alcohol	**7.8 J**	**40**	**ug/L**	**SW846 8260B**	
4-Methyl-2-pentanone	ND	10	ug/L	SW846 8260B	
Naphthalene	ND	2.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	2.0	ug/L	SW846 8260B	
Styrene	ND	2.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	2.0	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	2.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	2.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW5A-063008					
Sample #: 004 Date Sampled: 06/30/08 14:54 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,2,3-Trichloropropane	ND	2.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	**1.0 J**	**2.0**	**ug/L**	**SW846 8260B**	
1,2,4-Trimethylbenzene	ND	2.0	ug/L	SW846 8260B	
Vinyl acetate	ND	4.0	ug/L	SW846 8260B	
o-Xylene	ND	2.0	ug/L	SW846 8260B	
Xylenes (total)	ND	4.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	10	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	4.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	10	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	10	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	10	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	10	ug/L	SW846 8260B	
Benzene	ND	2.0	ug/L	SW846 8260B	
Bromoform	ND	2.0	ug/L	SW846 8260B	
Bromomethane	ND	2.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	2.0	ug/L	SW846 8260B	
Chlorobenzene	ND	2.0	ug/L	SW846 8260B	
Chloroethane	ND	2.0	ug/L	SW846 8260B	
Chloroform	**2.6**	**2.0**	**ug/L**	**SW846 8260B**	
Chloromethane	**7.0**	**2.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethane	**26**	**2.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	**1.7 J**	**2.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	ND	2.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	2.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	2.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	2.0	ug/L	SW846 8260B	
Ethylbenzene	ND	2.0	ug/L	SW846 8260B	
Methylene chloride	ND	2.0	ug/L	SW846 8260B	
1,1,2,2-Tetrachloroethane	ND	2.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	2.0	ug/L	SW846 8260B	
Toluene	**0.89 J**	**2.0**	**ug/L**	**SW846 8260B**	
1,1,1-Trichloroethane	**18**	**2.0**	**ug/L**	**SW846 8260B**	
Trichloroethene	**10**	**2.0**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	2.0	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW5A-063008					
Sample #: 004 Date Sampled: 06/30/08 14:54 Date Received: 07/02/08 Matrix: WATER					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**2.0 J**	**10**	**ug/L**	**SW846 8270C**	
J Estimated result. Result is less than RL.					
Client Sample ID: OW6B-063008					
Sample #: 005 Date Sampled: 06/30/08 16:20 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	**68**	**7.2**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	1.4	ug/L	SW846 8260B	
Bromochloromethane	ND	1.4	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	1.4	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	1.4	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**4.1**	**1.4**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	1.4	ug/L	SW846 8260B	
Bromodichloromethane	**0.24 J**	**1.4**	**ug/L**	**SW846 8260B**	
2-Butanone	**3.6 J**	**7.2**	**ug/L**	**SW846 8260B**	
n-Butylbenzene	ND	1.4	ug/L	SW846 8260B	
sec-Butylbenzene	ND	1.4	ug/L	SW846 8260B	
tert-Butylbenzene	ND	1.4	ug/L	SW846 8260B	
Carbon disulfide	**0.47 J**	**1.4**	**ug/L**	**SW846 8260B**	
Dibromochloromethane	ND	1.4	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	2.9	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	7.2	ug/L	SW846 8260B	
2-Chlorotoluene	ND	1.4	ug/L	SW846 8260B	
4-Chlorotoluene	ND	1.4	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	1.4	ug/L	SW846 8260B	
Dibromomethane	ND	1.4	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	1.4	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	1.4	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	1.4	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	1.4	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	1.4	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	1.4	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	1.4	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW6B-063008					
Sample #: 005 Date Sampled: 06/30/08 16:20 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
2-Hexanone	ND	7.2	ug/L	SW846 8260B	
Isopropylbenzene	ND	1.4	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	1.4	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	29	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	7.2	ug/L	SW846 8260B	
Naphthalene	ND	1.4	ug/L	SW846 8260B	
n-Propylbenzene	ND	1.4	ug/L	SW846 8260B	
Styrene	ND	1.4	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	1.4	ug/L	SW846 8260B	
1,2,3-Trichlorobenzene	ND	1.4	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	1.4	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	1.4	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	**0.57 J**	**1.4**	**ug/L**	**SW846 8260B**	
1,2,4-Trimethylbenzene	ND	1.4	ug/L	SW846 8260B	
Vinyl acetate	ND	2.9	ug/L	SW846 8260B	
o-Xylene	ND	1.4	ug/L	SW846 8260B	
Xylenes (total)	ND	2.9	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	7.2	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	2.9	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	7.2	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	7.2	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	7.2	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	7.2	ug/L	SW846 8260B	
Benzene	ND	1.4	ug/L	SW846 8260B	
Bromoform	ND	1.4	ug/L	SW846 8260B	
Bromomethane	ND	1.4	ug/L	SW846 8260B	
Carbon tetrachloride	**5.0**	**1.4**	**ug/L**	**SW846 8260B**	
Chlorobenzene	ND	1.4	ug/L	SW846 8260B	
Chloroethane	ND	1.4	ug/L	SW846 8260B	
Chloroform	**13**	**1.4**	**ug/L**	**SW846 8260B**	
Chloromethane	**22**	**1.4**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethane	**25**	**1.4**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	**1.8**	**1.4**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	**1.5**	**1.4**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	1.4	ug/L	SW846 8260B	

(Continued on next page)

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW6B-063008					
Sample #: 005 Date Sampled: 06/30/08 16:20 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
cis-1,3-Dichloropropene	ND	1.4	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	1.4	ug/L	SW846 8260B	
Ethylbenzene	ND	1.4	ug/L	SW846 8260B	
Methylene chloride	**6.4**	**1.4**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	**0.46 J**	**1.4**	**ug/L**	**SW846 8260B**	
Tetrachloroethene	ND	1.4	ug/L	SW846 8260B	
Toluene	ND	1.4	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**11**	**1.4**	**ug/L**	**SW846 8260B**	
Trichloroethene	**30**	**1.4**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	1.4	ug/L	SW846 8260B	
J Estimated result. Result is less than RL.					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**6.9 J**	**10**	**ug/L**	**SW846 8270C**	
J Estimated result. Result is less than RL.					
Client Sample ID: MRC-MW14B-070108					
Sample #: 006 Date Sampled: 07/01/08 10:41 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Acetone	**45**	**36**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	7.1	ug/L	SW846 8260B	
Bromochloromethane	ND	7.1	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	7.1	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	7.1	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	**3.1 J**	**7.1**	**ug/L**	**SW846 8260B**	
trans-1,2-Dichloroethene	ND	7.1	ug/L	SW846 8260B	
Bromodichloromethane	ND	7.1	ug/L	SW846 8260B	
2-Butanone	ND	36	ug/L	SW846 8260B	
n-Butylbenzene	ND	7.1	ug/L	SW846 8260B	
sec-Butylbenzene	ND	7.1	ug/L	SW846 8260B	
tert-Butylbenzene	ND	7.1	ug/L	SW846 8260B	
Carbon disulfide	**4.8 J**	**7.1**	**ug/L**	**SW846 8260B**	
Dibromochloromethane	ND	7.1	ug/L	SW846 8260B	

(Continued on next page)

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: MRC-MW14B-070108					
Sample #: 006 Date Sampled: 07/01/08 10:41 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,2-Dibromo-3-chloro-propane	ND	14	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	36	ug/L	SW846 8260B	
2-Chlorotoluene	ND	7.1	ug/L	SW846 8260B	
4-Chlorotoluene	ND	7.1	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	7.1	ug/L	SW846 8260B	
Dibromomethane	ND	7.1	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	7.1	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	7.1	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	7.1	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	7.1	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	7.1	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	7.1	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	7.1	ug/L	SW846 8260B	
2-Hexanone	ND	36	ug/L	SW846 8260B	
Isopropylbenzene	ND	7.1	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	7.1	ug/L	SW846 8260B	
tert-Butyl alcohol	ND	140	ug/L	SW846 8260B	
4-Methyl-2-pentanone	ND	36	ug/L	SW846 8260B	
Naphthalene	ND	7.1	ug/L	SW846 8260B	
n-Propylbenzene	ND	7.1	ug/L	SW846 8260B	
Styrene	ND	7.1	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	**5.8 J**	**7.1**	**ug/L**	**SW846 8260B**	
1,2,3-Trichlorobenzene	ND	7.1	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	7.1	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	7.1	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	**3.5 J**	**7.1**	**ug/L**	**SW846 8260B**	
1,2,4-Trimethylbenzene	ND	7.1	ug/L	SW846 8260B	
Vinyl acetate	ND	14	ug/L	SW846 8260B	
o-Xylene	ND	7.1	ug/L	SW846 8260B	
Xylenes (total)	ND	14	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	36	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	14	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	36	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	36	ug/L	SW846 8260B	

(Continued on next page)

TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: MRC-MW14B-070108					
Sample #: 006 Date Sampled: 07/01/08 10:41 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Ethyl-t-Butyl Ether (ETBE)	ND	36	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	36	ug/L	SW846 8260B	
Benzene	ND	7.1	ug/L	SW846 8260B	
Bromoform	ND	7.1	ug/L	SW846 8260B	
Bromomethane	ND	7.1	ug/L	SW846 8260B	
Carbon tetrachloride	ND	7.1	ug/L	SW846 8260B	
Chlorobenzene	ND	7.1	ug/L	SW846 8260B	
Chloroethane	ND	7.1	ug/L	SW846 8260B	
Chloroform	**55**	**7.1**	**ug/L**	**SW846 8260B**	
Chloromethane	**86**	**7.1**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethane	**25**	**7.1**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	**2.9 J**	**7.1**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethene	**2.9 J**	**7.1**	**ug/L**	**SW846 8260B**	
1,2-Dichloropropane	ND	7.1	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	7.1	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	7.1	ug/L	SW846 8260B	
Ethylbenzene	ND	7.1	ug/L	SW846 8260B	
Methylene chloride	**68**	**7.1**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	**8.7**	**7.1**	**ug/L**	**SW846 8260B**	
Tetrachloroethene	ND	7.1	ug/L	SW846 8260B	
Toluene	ND	7.1	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**20**	**7.1**	**ug/L**	**SW846 8260B**	
Trichloroethene	**210**	**7.1**	**ug/L**	**SW846 8260B**	
Vinyl chloride	ND	7.1	ug/L	SW846 8260B	

J Estimated result. Result is less than RL.

Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	**4.2 J**	**10**	**ug/L**	**SW846 8270C**	

J Estimated result. Result is less than RL.

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TESTAMERICA LABORATORIES, INC.

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

Client Sample ID: OW6A-070108

Sample #: 007 Date Sampled: 07/01/08 14:03 Date Received: 07/02/08 Matrix: WATER

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Volatile Organics by GC/MS					Reviewed
Acetone	**250**	**20**	**ug/L**	**SW846 8260B**	
Bromobenzene	ND	4.0	ug/L	SW846 8260B	
Bromochloromethane	ND	4.0	ug/L	SW846 8260B	
1,4-Dichlorobenzene	ND	4.0	ug/L	SW846 8260B	
Dichlorodifluoromethane	ND	4.0	ug/L	SW846 8260B	
cis-1,2-Dichloroethene	ND	4.0	ug/L	SW846 8260B	
trans-1,2-Dichloroethene	ND	4.0	ug/L	SW846 8260B	
Bromodichloromethane	ND	4.0	ug/L	SW846 8260B	
2-Butanone	**7.9 J**	**20**	**ug/L**	**SW846 8260B**	
n-Butylbenzene	ND	4.0	ug/L	SW846 8260B	
sec-Butylbenzene	ND	4.0	ug/L	SW846 8260B	
tert-Butylbenzene	ND	4.0	ug/L	SW846 8260B	
Carbon disulfide	ND	4.0	ug/L	SW846 8260B	
Dibromochloromethane	ND	4.0	ug/L	SW846 8260B	
1,2-Dibromo-3-chloro-propane	ND	8.0	ug/L	SW846 8260B	
2-Chloroethyl vinyl ether	ND	20	ug/L	SW846 8260B	
2-Chlorotoluene	ND	4.0	ug/L	SW846 8260B	
4-Chlorotoluene	ND	4.0	ug/L	SW846 8260B	
1,2-Dibromoethane	ND	4.0	ug/L	SW846 8260B	
Dibromomethane	ND	4.0	ug/L	SW846 8260B	
1,2-Dichlorobenzene	ND	4.0	ug/L	SW846 8260B	
1,3-Dichlorobenzene	ND	4.0	ug/L	SW846 8260B	
1,3-Dichloropropane	ND	4.0	ug/L	SW846 8260B	
2,2-Dichloropropane	ND	4.0	ug/L	SW846 8260B	
1,1-Dichloropropene	ND	4.0	ug/L	SW846 8260B	
Trichlorofluoromethane	ND	4.0	ug/L	SW846 8260B	
Hexachlorobutadiene	ND	4.0	ug/L	SW846 8260B	
2-Hexanone	ND	20	ug/L	SW846 8260B	
Isopropylbenzene	ND	4.0	ug/L	SW846 8260B	
p-Isopropyltoluene	ND	4.0	ug/L	SW846 8260B	
tert-Butyl alcohol	**17 J**	**80**	**ug/L**	**SW846 8260B**	
4-Methyl-2-pentanone	ND	20	ug/L	SW846 8260B	
Naphthalene	ND	4.0	ug/L	SW846 8260B	
n-Propylbenzene	ND	4.0	ug/L	SW846 8260B	
Styrene	ND	4.0	ug/L	SW846 8260B	
1,1,1,2-Tetrachloroethane	ND	4.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW6A-070108					
Sample #: 007 Date Sampled: 07/01/08 14:03 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
1,2,3-Trichlorobenzene	ND	4.0	ug/L	SW846 8260B	
1,2,4-Trichloro-benzene	ND	4.0	ug/L	SW846 8260B	
1,2,3-Trichloropropane	ND	4.0	ug/L	SW846 8260B	
1,1,2-Trichloro-1,2,2-trifluoroethane	ND	4.0	ug/L	SW846 8260B	
1,2,4-Trimethylbenzene	ND	4.0	ug/L	SW846 8260B	
Vinyl acetate	ND	8.0	ug/L	SW846 8260B	
o-Xylene	ND	4.0	ug/L	SW846 8260B	
Xylenes (total)	ND	8.0	ug/L	SW846 8260B	
Methyl tert-butyl ether	ND	20	ug/L	SW846 8260B	
m-Xylene & p-Xylene	ND	8.0	ug/L	SW846 8260B	
1,2,3-Trimethylbenzene	ND	20	ug/L	SW846 8260B	
Diisopropyl Ether (DIPE)	ND	20	ug/L	SW846 8260B	
Ethyl-t-Butyl Ether (ETBE)	ND	20	ug/L	SW846 8260B	
Tert-amyl methyl ether (TAME)	ND	20	ug/L	SW846 8260B	
Benzene	ND	4.0	ug/L	SW846 8260B	
Bromoform	ND	4.0	ug/L	SW846 8260B	
Bromomethane	ND	4.0	ug/L	SW846 8260B	
Carbon tetrachloride	ND	4.0	ug/L	SW846 8260B	
Chlorobenzene	ND	4.0	ug/L	SW846 8260B	
Chloroethane	ND	4.0	ug/L	SW846 8260B	
Chloroform	**9.1**	**4.0**	**ug/L**	**SW846 8260B**	
Chloromethane	**45**	**4.0**	**ug/L**	**SW846 8260B**	
1,1-Dichloroethane	**3.3 J**	**4.0**	**ug/L**	**SW846 8260B**	
1,2-Dichloroethane	ND	4.0	ug/L	SW846 8260B	
1,1-Dichloroethene	ND	4.0	ug/L	SW846 8260B	
1,2-Dichloropropane	ND	4.0	ug/L	SW846 8260B	
cis-1,3-Dichloropropene	ND	4.0	ug/L	SW846 8260B	
trans-1,3-Dichloropropene	ND	4.0	ug/L	SW846 8260B	
Ethylbenzene	ND	4.0	ug/L	SW846 8260B	
Methylene chloride	**2.5 J**	**4.0**	**ug/L**	**SW846 8260B**	
1,1,2,2-Tetrachloroethane	ND	4.0	ug/L	SW846 8260B	
Tetrachloroethene	ND	4.0	ug/L	SW846 8260B	
Toluene	ND	4.0	ug/L	SW846 8260B	
1,1,1-Trichloroethane	**0.89 J**	**4.0**	**ug/L**	**SW846 8260B**	
Trichloroethene	ND	4.0	ug/L	SW846 8260B	

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TESTAMERICA LABORATORIES, INC.

PRELIMINARY DATA SUMMARY

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Lot #: A8G020171 BALTIMORE MD **Date Reported:** 7/17/08

PARAMETER	RESULT	REPORTING LIMIT	UNITS	ANALYTICAL METHOD	
Client Sample ID: OW6A-070108					
Sample #: 007 Date Sampled: 07/01/08 14:03 Date Received: 07/02/08 Matrix: WATER					
Volatile Organics by GC/MS					Reviewed
Vinyl chloride	ND	4.0	ug/L	SW846 8260B	
J Estimated result. Result is less than RL.					
Semivolatile Organic Compounds by GC/MS					Reviewed
1,4-Dioxane	ND	10	ug/L	SW846 8270C	

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Certificate of Analysis

Project Name:	**LOCKHEED MARTIN MIDDLE RIVER**	Workorder:	**9720000**
Purchase Order:	**1024619**	Workorder ID:	**TGG001|MSA January 2008**

Mr. Michael Martin
Tetra Tech NUS, Inc.
20251 Centruy Blvd.
Suite 200
Germantown, MD 20874

February 8, 2008

Dear Mr. Martin,

Enclosed are the analytical results for samples received by the laboratory on Monday, January 21, 2008

ALSI is a National Environmental Laboratory Accreditation Conference (NELAC) accredited laboratory and as such, certifies that all applicable test results meet the requirements of NELAC.

If you have any questions regarding this certificate of analysis, please contact Susan Baer (Project Coordinator) or Raymond J Martrano (Laboratory Manager) at (717) 944-5541.

Please visit us at www.analyticallab.com for a listing of ALSI's NELAC accreditations and Scope of Work, as well as other links to Water Quality documentation on the internet.

This laboratory report may not be reproduced, except in full, without the written approval of ALSI.

NOTE: ALSI has changed the report generation tool and while we have tried to retain the existing format, you will notice some changes in the laboratory report. Please feel free to contact ALSI in case you have any questions.

Analytical Laboratory Services, Inc.

This page is included as part of the Analytical Report and must be retained as a permanent record thereof.

Raymond J. Martrano
Laboratory Manager

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SAMPLE SUMMARY

Workorder: 9720000 TGG001|MSA January 2008 Discard Date: 02/21/2008

Lab ID	Sample ID	Matrix	Date Collected	Date Received	Collected By
9720000001	OW4S-012108	Water	1/21/08 10:31	1/21/08 19:45	Walt Pryor
9720000002	OW4I-012108	Water	1/21/08 13:12	1/21/08 19:45	Walt Pryor
9720000003	OW5S-012108	Water	1/21/08 16:19	1/21/08 19:45	Walt Pryor
9720000004	TB-012108	Water	1/21/08 19:45	1/21/08 19:45	Walt Pryor

Workorder Comments:

Notes

-- Samples collected by ALSI personnel are done so in accordance with the procedures set forth in the ALSI Field Sampling Plan (20 - Field Services Sampling Plan).
-- All Waste Water analyses comply with methodology requirements of 40 CFR Part 136.
-- All Drinking Water analyses comply with methodology requirements of 40 CFR Part 141.
-- Unless otherwise noted, all quantitative results for soils are reported on a dry weight basis.
-- The Chain of Custody document is included as part of this report.

Standard Acronyms/Flags

J, B	Indicates an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte
U	Indicates that the analyte was Not Detected (ND)
MDL	Method Detection Limit
PQL	Practical Quantitation Limit
RDL	Reporting Detection Limit
ND	Not Detected - indicates that the analyte was Not Detected at the RDL
Cntr	Analysis was performed using this container
RegLmt	Regulatory Limit
LCS	Laboratory Control Sample
MS	Matrix Spike
MSD	Matrix Spike Duplicate
DUP	Sample Duplicate
%Rec	Percent Recovery
RPD	Relative Percent Difference

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000001** Date Collected: 1/21/2008 10:31 Matrix: Water

Sample ID: **OW4S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,1,1-Trichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,1-Dichloroethane	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 03:34	JAH	A
1,1-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/1/08 03:34	JAH	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 03:34	JAH	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 03:34	JAH	A
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/1/08 03:34	JAH	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/1/08 03:34	JAH	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/1/08 03:34	JAH	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/1/08 03:34	JAH	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/1/08 03:34	JAH	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/1/08 03:34	JAH	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/1/08 03:34	JAH	A
Benzene	ND	ug/L		1.0	0.4	SW846 8260B			2/1/08 03:34	JAH	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 03:34	JAH	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
Chloroform	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 03:34	JAH	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 03:34	JAH	A
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000001** Date Collected: 1/21/2008 10:31 Matrix: Water

Sample ID: **OW4S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/1/08 03:34	JAH	A
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 03:34	JAH	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 03:34	JAH	A
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/1/08 03:34	JAH	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Tetrachloroethene	ND	ug/L		1.0	0.4	SW846 8260B			2/1/08 03:34	JAH	A
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/1/08 03:34	JAH	A
Trichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/1/08 03:34	JAH	A
Vinyl Chloride	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
cis-1,2-Dichloroethene	0.61J	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/1/08 03:34	JAH	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 03:34	JAH	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/1/08 03:34	JAH	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/1/08 03:34	JAH	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 03:34	JAH	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/1/08 03:34	JAH	A
trans-1,2-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 03:34	JAH	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	91	%		62-133		SW846 8260B			2/1/08 03:34	JAH	A
4-Bromofluorobenzene (S)	103	%		79-114		SW846 8260B			2/1/08 03:34	JAH	A
Dibromofluoromethane (S)	89	%		78-116		SW846 8260B			2/1/08 03:34	JAH	A
Toluene-d8 (S)	119	%		76-127		SW846 8260B			2/1/08 03:34	JAH	A
SEMIVOLATILES											
1,4-Dioxane	ND	ug/L		2.9	0.6	SW846 8270C	1/25/08	CAC	2/4/08 15:30	DHF	H1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	31	%	3	40-125		SW846 8270C	1/25/08	CAC	2/4/08 15:30	DHF	H1
Phenol-d5 (S)	21	%		10-49		SW846 8270C	1/25/08	CAC	2/4/08 15:30	DHF	H1
Terphenyl-d14 (S)	81	%		27-136		SW846 8270C	1/25/08	CAC	2/4/08 15:30	DHF	H1
Nitrobenzene-d5 (S)	76	%		31-110		SW846 8270C	1/25/08	CAC	2/4/08 15:30	DHF	H1
2-Fluorobiphenyl (S)	77	%		32-108		SW846 8270C	1/25/08	CAC	2/4/08 15:30	DHF	H1
2-Fluorophenol (S)	18	%	3	20-70		SW846 8270C	1/25/08	CAC	2/4/08 15:30	DHF	H1

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000001** Date Collected: 1/21/2008 10:31 Matrix: Water

Sample ID: **OW4S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
LIGHT HYDROCARBON GASES											
Ethane	ND	ug/L		3.0	0.4	RSK 175			1/22/08 16:28	ELC	F
Ethene	ND	ug/L		3.0	0.4	RSK 175			1/22/08 16:28	ELC	F
Methane	6.2	ug/L		1.0	0.5	RSK 175			1/22/08 16:28	ELC	F
WET CHEMISTRY											
Chloride	488	mg/L		10.0	1	EPA 300			1/23/08 02:41	JEP	K
Nitrate-N	0.12J	mg/L		0.20	0.02	EPA 300			1/22/08 03:58	JEP	K
Nitrite-N	ND	mg/L	1	1.00	0.1	EPA 300			1/23/08 02:41	JEP	K
Sulfate	87.4	mg/L		2.0	0.2	EPA 300			1/22/08 03:58	JEP	K
Total Organic Carbon (TOC)	4.7	mg/L		1.0	0.2	415.1/5310B			2/1/08 08:00	PAG	J
METALS											
Antimony, Total	ND	mg/L		0.0020	0.00009	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Antimony, Dissolved	0.0009J	mg/L		0.0020	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Arsenic, Total	ND	mg/L		0.0060	0.0005	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Arsenic, Dissolved	ND	mg/L	2	0.0030	0.0007	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Barium, Total	0.0584	mg/L		0.0060	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Barium, Dissolved	0.0545	mg/L		0.0050	0.0003	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Beryllium, Total	0.0002J	mg/L		0.0010	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Beryllium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Cadmium, Total	ND	mg/L		0.0010	0.0004	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Cadmium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Chromium, Total	ND	mg/L		0.0020	0.0002	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Chromium, Dissolved	0.0091	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Cobalt, Total	0.0073	mg/L		0.0060	0.0005	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Cobalt, Dissolved	0.0072	mg/L		0.0050	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Copper, Total	0.0085	mg/L		0.0060	0.0003	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Copper, Dissolved	0.0049J	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Lead, Total	ND	mg/L		0.0020	0.00004	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 08:39	CMD	E2
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 11:17	CMD	D1
Molybdenum, Total	ND	mg/L		0.0020	0.0005	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Molybdenum, Dissolved	ND	mg/L		0.0020	0.0006	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Nickel, Total	0.0066	mg/L		0.0060	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Nickel, Dissolved	0.0082	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Selenium, Total	0.006J	mg/L		0.006	0.0003	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Selenium, Dissolved	0.007	mg/L	2	0.005	0.001	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Silver, Total	ND	mg/L		0.0010	0.00004	SW846 6020	1/22/08	MNP	2/5/08 14:03	AJB	E1
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Thallium, Total	ND	mg/L		0.0010	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Thallium, Dissolved	ND	mg/L		0.0010	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2
Vanadium, Total	0.00009J	mg/L		0.0010	0.00008	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1
Vanadium, Dissolved	0.0011	mg/L		0.0010	0.00002	SW846 6020	2/4/08	AJB	2/5/08 12:29	AJB	D2
Zinc, Total	0.0042J	mg/L		0.0060	0.001	SW846 6020	1/22/08	MNP	2/4/08 18:55	AJB	E1

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000001** Date Collected: 1/21/2008 10:31 Matrix: Water

Sample ID: **OW4S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Zinc, Dissolved	0.0045J	mg/L		0.0050	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:04	AJB	D2

Sample Comments:

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000002** Date Collected: 1/21/2008 13:12 Matrix: Water

Sample ID: **OW4I-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,1,1-Trichloroethane	41.6	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,1-Dichloroethane	79.1	ug/L		1.0	0.1	SW846 8260B			2/1/08 04:17	JAH	A
1,1-Dichloroethene	657	ug/L	4	10.0	2	SW846 8260B			2/4/08 16:35	DXN	B
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/1/08 04:17	JAH	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 04:17	JAH	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 04:17	JAH	A
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/1/08 04:17	JAH	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/1/08 04:17	JAH	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/1/08 04:17	JAH	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/1/08 04:17	JAH	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/1/08 04:17	JAH	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/1/08 04:17	JAH	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/1/08 04:17	JAH	A
Benzene	0.99J	ug/L		1.0	0.4	SW846 8260B			2/1/08 04:17	JAH	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 04:17	JAH	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
Chloroform	2.3	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 04:17	JAH	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 04:17	JAH	A
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000002** Date Collected: 1/21/2008 13:12 Matrix: Water

Sample ID: **OW4I-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/1/08 04:17	JAH	A
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 04:17	JAH	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 04:17	JAH	A
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/1/08 04:17	JAH	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Tetrachloroethene	3.9	ug/L		1.0	0.4	SW846 8260B			2/1/08 04:17	JAH	A
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/1/08 04:17	JAH	A
Trichloroethene	1520	ug/L	4	10.0	2	SW846 8260B			2/4/08 16:35	DXN	B
Trichlorofluoromethane	0.46J	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/1/08 04:17	JAH	A
Vinyl Chloride	1.7	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
cis-1,2-Dichloroethene	399	ug/L	4	10.0	2	SW846 8260B			2/4/08 16:35	DXN	B
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/1/08 04:17	JAH	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 04:17	JAH	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/1/08 04:17	JAH	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/1/08 04:17	JAH	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 04:17	JAH	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/1/08 04:17	JAH	A
trans-1,2-Dichloroethene	0.75J	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 04:17	JAH	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	88	%		62-133		SW846 8260B			2/1/08 04:17	JAH	A
4-Bromofluorobenzene (S)	101	%		79-114		SW846 8260B			2/1/08 04:17	JAH	A
Dibromofluoromethane (S)	88	%		78-116		SW846 8260B			2/1/08 04:17	JAH	A
Toluene-d8 (S)	114	%		76-127		SW846 8260B			2/1/08 04:17	JAH	A
1,2-Dichloroethane-d4 (S)	90	%		62-133		SW846 8260B			2/4/08 16:35	DXN	B
4-Bromofluorobenzene (S)	97	%		79-114		SW846 8260B			2/4/08 16:35	DXN	B
Dibromofluoromethane (S)	87	%		78-116		SW846 8260B			2/4/08 16:35	DXN	B
Toluene-d8 (S)	119	%		76-127		SW846 8260B			2/4/08 16:35	DXN	B

SEMIVOLATILES

1,4-Dioxane	100	ug/L		5.8	1	SW846 8270C	1/25/08	CAC	2/4/08 16:17	DHF	H1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	85	%		40-125		SW846 8270C	1/25/08	CAC	2/4/08 16:17	DHF	H1
2-Fluorobiphenyl (S)	71	%		32-108		SW846 8270C	1/25/08	CAC	2/4/08 16:17	DHF	H1
2-Fluorophenol (S)	36	%		20-70		SW846 8270C	1/25/08	CAC	2/4/08 16:17	DHF	H1
Nitrobenzene-d5 (S)	63	%		31-110		SW846 8270C	1/25/08	CAC	2/4/08 16:17	DHF	H1

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000002** Date Collected: 1/21/2008 13:12 Matrix: Water

Sample ID: **OW4I-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Phenol-d5 (S)	20	%		10-49		SW846 8270C	1/25/08	CAC	2/4/08 16:17	DHF	H1
Terphenyl-d14 (S)	69	%		27-136		SW846 8270C	1/25/08	CAC	2/4/08 16:17	DHF	H1
LIGHT HYDROCARBON GASES											
Ethane	ND	ug/L		3.0	0.4	RSK 175			1/22/08 16:45	ELC	F
Ethene	ND	ug/L		3.0	0.4	RSK 175			1/22/08 16:45	ELC	F
Methane	6.2	ug/L		1.0	0.5	RSK 175			1/22/08 16:45	ELC	F
WET CHEMISTRY											
Chloride	89.1	mg/L		2.0	0.2	EPA 300			1/22/08 06:41	JEP	K
Nitrate-N	ND	mg/L		0.20	0.02	EPA 300			1/22/08 06:41	JEP	K
Nitrite-N	ND	mg/L		0.20	0.02	EPA 300			1/22/08 06:41	JEP	K
Sulfate	44.1	mg/L		2.0	0.2	EPA 300			1/22/08 06:41	JEP	K
Total Organic Carbon (TOC)	1.1	mg/L		1.0	0.2	415.1/5310B			1/22/08 08:00	AJG	J
METALS											
Antimony, Total	ND	mg/L		0.0020	0.00009	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Antimony, Dissolved	0.0012J	mg/L		0.0020	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Arsenic, Total	ND	mg/L		0.0060	0.0005	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Arsenic, Dissolved	ND	mg/L		0.0030	0.0007	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Barium, Total	0.0810	mg/L		0.0060	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Barium, Dissolved	0.0772	mg/L		0.0050	0.0003	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Beryllium, Total	0.0054	mg/L		0.0010	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Beryllium, Dissolved	0.0057	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Cadmium, Total	ND	mg/L		0.0010	0.0004	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Cadmium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Chromium, Total	0.0004J	mg/L		0.0020	0.0002	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Chromium, Dissolved	0.0042	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Cobalt, Total	0.0668	mg/L		0.0060	0.0005	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Cobalt, Dissolved	0.0651	mg/L		0.0050	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Copper, Total	0.0028J	mg/L		0.0060	0.0003	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Copper, Dissolved	0.0052	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Lead, Total	0.00008J	mg/L		0.0020	0.00004	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 08:57	CMD	E2
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 11:20	CMD	D1
Molybdenum, Total	ND	mg/L		0.0020	0.0005	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Molybdenum, Dissolved	ND	mg/L		0.0020	0.0006	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Nickel, Total	0.116	mg/L		0.0060	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Nickel, Dissolved	0.120	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Selenium, Total	ND	mg/L		0.006	0.0003	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Selenium, Dissolved	ND	mg/L		0.005	0.001	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Silver, Total	ND	mg/L	2	0.0010	0.00004	SW846 6020	1/22/08	MNP	2/5/08 13:50	AJB	E1
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2
Thallium, Total	ND	mg/L		0.0010	0.0001	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Thallium, Dissolved	0.0001J	mg/L		0.0010	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000002** Date Collected: 1/21/2008 13:12 Matrix: Water

Sample ID: **OW4I-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Vanadium, Total	0.0007J	mg/L		0.0010	0.00008	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Vanadium, Dissolved	ND	mg/L		0.0010	0.00002	SW846 6020	2/4/08	AJB	2/5/08 12:42	AJB	D2
Zinc, Total	0.173	mg/L		0.0060	0.001	SW846 6020	1/22/08	MNP	2/4/08 18:27	AJB	E1
Zinc, Dissolved	0.195	mg/L		0.0050	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:41	AJB	D2

Sample Comments:

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000003** Date Collected: 1/21/2008 16:19 Matrix: Water

Sample ID: **OW5S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,1,1-Trichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,1-Dichloroethane	0.88J	ug/L		1.0	0.1	SW846 8260B			2/4/08 16:04	DXN	B
1,1-Dichloroethene	0.81J	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/4/08 16:04	DXN	B
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/4/08 16:04	DXN	B
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/4/08 16:04	DXN	B
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/4/08 16:04	DXN	B
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/4/08 16:04	DXN	B
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/4/08 16:04	DXN	B
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/4/08 16:04	DXN	B
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/4/08 16:04	DXN	B
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/4/08 16:04	DXN	B
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/4/08 16:04	DXN	B
Benzene	ND	ug/L		1.0	0.4	SW846 8260B			2/4/08 16:04	DXN	B
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/4/08 16:04	DXN	B
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
Chloroform	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/4/08 16:04	DXN	B
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/4/08 16:04	DXN	B
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000003** Date Collected: 1/21/2008 16:19 Matrix: Water

Sample ID: **OW5S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/4/08 16:04	DXN	B
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/4/08 16:04	DXN	B
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/4/08 16:04	DXN	B
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/4/08 16:04	DXN	B
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Tetrachloroethene	ND	ug/L		1.0	0.4	SW846 8260B			2/4/08 16:04	DXN	B
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/4/08 16:04	DXN	B
Trichloroethene	2.9	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/4/08 16:04	DXN	B
Vinyl Chloride	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
cis-1,2-Dichloroethene	1.9	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/4/08 16:04	DXN	B
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/4/08 16:04	DXN	B
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/4/08 16:04	DXN	B
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/4/08 16:04	DXN	B
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/4/08 16:04	DXN	B
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/4/08 16:04	DXN	B
trans-1,2-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/4/08 16:04	DXN	B
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	93	%		62-133		SW846 8260B			2/4/08 16:04	DXN	B
Toluene-d8 (S)	117	%		76-127		SW846 8260B			2/4/08 16:04	DXN	B
4-Bromofluorobenzene (S)	102	%		79-114		SW846 8260B			2/4/08 16:04	DXN	B
Dibromofluoromethane (S)	84	%		78-116		SW846 8260B			2/4/08 16:04	DXN	B
SEMIVOLATILES											
1,4-Dioxane	ND	ug/L		2.9	0.6	SW846 8270C	1/25/08	CAC	2/3/08 18:02	DHF	H1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	58	%		40-125		SW846 8270C	1/25/08	CAC	2/3/08 18:02	DHF	H1
2-Fluorobiphenyl (S)	64	%		32-108		SW846 8270C	1/25/08	CAC	2/3/08 18:02	DHF	H1
Nitrobenzene-d5 (S)	65	%		31-110		SW846 8270C	1/25/08	CAC	2/3/08 18:02	DHF	H1
Terphenyl-d14 (S)	63	%		27-136		SW846 8270C	1/25/08	CAC	2/3/08 18:02	DHF	H1
Phenol-d5 (S)	21	%		10-49		SW846 8270C	1/25/08	CAC	2/3/08 18:02	DHF	H1
2-Fluorophenol (S)	29	%		20-70		SW846 8270C	1/25/08	CAC	2/3/08 18:02	DHF	H1

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000003** Date Collected: 1/21/2008 16:19 Matrix: Water

Sample ID: **OW5S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
LIGHT HYDROCARBON GASES											
Ethane	ND	ug/L		3.0	0.4	RSK 175			1/22/08 16:52	ELC	F
Ethene	ND	ug/L		3.0	0.4	RSK 175			1/22/08 16:52	ELC	F
Methane	33.9	ug/L		1.0	0.5	RSK 175			1/22/08 16:52	ELC	F
WET CHEMISTRY											
Chloride	534	mg/L		10.0	1	EPA 300			1/23/08 03:06	JEP	K
Nitrate-N	0.14J	mg/L		0.20	0.02	EPA 300			1/22/08 09:25	JEP	K
Nitrite-N	ND	mg/L	1	1.00	0.1	EPA 300			1/23/08 03:06	JEP	K
Sulfate	122	mg/L	5	2.0	0.2	EPA 300			1/22/08 09:25	JEP	K
Total Organic Carbon (TOC)	3.7	mg/L		1.0	0.2	415.1/5310B			1/22/08 08:00	AJG	J
METALS											
Antimony, Total	ND	mg/L		0.0020	0.00009	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Antimony, Dissolved	ND	mg/L		0.0020	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Arsenic, Total	ND	mg/L		0.0060	0.0005	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Arsenic, Dissolved	ND	mg/L		0.0030	0.0007	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Barium, Total	0.0524	mg/L		0.0060	0.0001	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Barium, Dissolved	0.0484	mg/L		0.0050	0.0003	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Beryllium, Total	0.0014	mg/L		0.0010	0.0001	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Beryllium, Dissolved	0.0012	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Cadmium, Total	ND	mg/L		0.0010	0.0004	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Cadmium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Chromium, Total	ND	mg/L		0.0020	0.0002	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Chromium, Dissolved	0.0058	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Cobalt, Total	0.110	mg/L		0.0060	0.0005	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Cobalt, Dissolved	0.0982	mg/L		0.0050	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Copper, Total	0.0077	mg/L		0.0060	0.0003	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Copper, Dissolved	0.0042J	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Lead, Total	ND	mg/L		0.0020	0.00004	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 09:00	CMD	E2
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 11:24	CMD	D1
Molybdenum, Total	ND	mg/L		0.0020	0.0005	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Molybdenum, Dissolved	ND	mg/L		0.0020	0.0006	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Nickel, Total	0.0246	mg/L		0.0060	0.0001	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Nickel, Dissolved	0.0233	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Selenium, Total	0.002J	mg/L		0.006	0.0003	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Selenium, Dissolved	0.001J	mg/L		0.005	0.001	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Silver, Total	ND	mg/L		0.0010	0.00004	SW846 6020	1/22/08	MNP	2/5/08 14:06	AJB	E1
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Thallium, Total	ND	mg/L		0.0010	0.0001	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Thallium, Dissolved	0.0002J	mg/L		0.0010	0.0001	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2
Vanadium, Total	ND	mg/L		0.0010	0.00008	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1
Vanadium, Dissolved	0.0009J	mg/L		0.0010	0.00002	SW846 6020	2/4/08	AJB	2/5/08 12:46	AJB	D2
Zinc, Total	0.0283	mg/L		0.0060	0.001	SW846 6020	1/22/08	MNP	2/4/08 19:19	AJB	E1

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000003** Date Collected: 1/21/2008 16:19 Matrix: Water

Sample ID: **OW5S-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Zinc, Dissolved	0.0242	mg/L		0.0050	0.0002	SW846 6020	2/4/08	AJB	2/4/08 17:56	AJB	D2

Sample Comments:

This report was modified to comment the sulfate matrix spike duplicate percent recovery. ASD 2/7/08

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000004** Date Collected: 1/21/2008 19:45 Matrix: Water

Sample ID: **TB-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,1,1-Trichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,1-Dichloroethane	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 14:18	DXN	B
1,1-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/1/08 14:18	DXN	B
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 14:18	DXN	B
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 14:18	DXN	B
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/1/08 14:18	DXN	B
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/1/08 14:18	DXN	B
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/1/08 14:18	DXN	B
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/1/08 14:18	DXN	B
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/1/08 14:18	DXN	B
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/1/08 14:18	DXN	B
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/1/08 14:18	DXN	B
Benzene	ND	ug/L		1.0	0.4	SW846 8260B			2/1/08 14:18	DXN	B
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 14:18	DXN	B
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
Chloroform	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 14:18	DXN	B
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 14:18	DXN	B
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B

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ANALYTICAL RESULTS

Workorder: 9720000 TGG001|MSA January 2008

Lab ID: **9720000004** Date Collected: 1/21/2008 19:45 Matrix: Water

Sample ID: **TB-012108** Date Received: 1/21/2008 19:45

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/1/08 14:18	DXN	B
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 14:18	DXN	B
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/1/08 14:18	DXN	B
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/1/08 14:18	DXN	B
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Tetrachloroethene	ND	ug/L		1.0	0.4	SW846 8260B			2/1/08 14:18	DXN	B
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/1/08 14:18	DXN	B
Trichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/1/08 14:18	DXN	B
Vinyl Chloride	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
cis-1,2-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/1/08 14:18	DXN	B
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/1/08 14:18	DXN	B
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/1/08 14:18	DXN	B
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/1/08 14:18	DXN	B
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/1/08 14:18	DXN	B
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/1/08 14:18	DXN	B
trans-1,2-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/1/08 14:18	DXN	B
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	96	%		62-133		SW846 8260B			2/1/08 14:18	DXN	B
4-Bromofluorobenzene (S)	101	%		79-114		SW846 8260B			2/1/08 14:18	DXN	B
Dibromofluoromethane (S)	85	%		78-116		SW846 8260B			2/1/08 14:18	DXN	B
Toluene-d8 (S)	116	%		76-127		SW846 8260B			2/1/08 14:18	DXN	B

Sample Comments:

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34 Dogwood Lane - Middletown, PA 17057 Phone: 717-944-5541 Fax: 717-944-1430

ANALYTICAL RESULTS QUALIFIERS\FLAGS

Workorder: 9720000 TGG001|MSA January 2008

PARAMETER QUALIFIERS\FLAGS

[1] Due to sample matrix interferences, this analyte was analyzed at a dilution and the detection levels adjusted accordingly.

[2] The recovery of the Matrix Spike (MS) associated to this analyte was outside of the established control limits. The sample was post-digestion spiked, and this matrix spike was within acceptable recovery limits.

[3] The surrogate recovery was outside of the established control limits.

[4] One of the method 8260 internal standards was recovered outside of the control limits in the dilution of the sample. This internal was not associated with this compound, so data is not believed to be impacted.

[5] The recovery of the Matrix Spike Duplicate (MSD) associated to this analyte was outside of the established control limits.

Report ID: 9720000

Analytical Laboratory Services, Inc.
Environmental • Industrial Hygiene • Field Services
34 Dogwood Lane • Middletown, PA 17057 • 717.944.5541 • Fax: 717.944.1430

CHAIN OF CUSTODY/ REQUEST FOR ANALYSIS

ALL SHADED AREAS MUST BE COMPLETED BY THE CLIENT / SAMPLER. INSTRUCTIONS ON THE BACK.

Courier:

Tracking #:

97200000

Co. Name: Tetra Tech NUS

Contact (Report to): Mike Martin Phone (301) 528-3528

Address: 20251 Century Blvd STE Germantown MD 20874

Bill to (if different than Report to): PO#:

Project Name/#: Middle River Center ALSI Quote #:

TAT: ☐ Normal-Standard TAT is 10-12 business days. ☐ Rush-Subject to ALSI approval and surcharges. Date Required: Approved By:

Email? ☐ -Y

Fax? ☐ -Y No.:

Sample Description/Location (as it will appear on the lab report)	COC Comments	Sample Date	Military Time	*G or C	**Matrix	***Container Type	***Container Size	*** Preservative	VOCs	Total PP metal	Diss PP metal	RSK-175	1,4 Dioxane	TOC	Chloride, nitrate, nitrite
						Clear Glass	40 ml	HCl							
						Poly	500ml	HNO3							
						Poly	500ml	HNO3							
						Glass	40ml	HCl							
						Glass	1L	Ice							
						Amber	125ml	HCl							
						Poly	250ml	Ice							
1 OW4S-012108		1-21-08	1031	G	W				3X	1X	1X	2X	3X	4X	1X
2 OW4I-012108			1312	G	W				X	X	X	X	X	X	X
3 OW5S-012108			1619	G	W				X	X	X	X	X	X	X
4 TB-012108			0000	G	W				X						
5															
6															
7															
8															

ANALYSES/METHOD REQUESTED

Enter Number of Containers Per Analysis

Receipt Information (completed by Sample Receiving)

Performed by: INITIAL HERE

Cooler Temp: 2

Therm. ID: 5102555

No. of Coolers:

Notes:

	Correct containers?	Correct sample volume?	Correct preservation?	HeadspaceVolatiles?	Circle appropriate Y or N.
	N	N	N	N	
	Y	Y	Y	Y	Y

	Custody seals Present?	(if present) Seals intact?	Received on ice?	COC/Labels complete/accurate?	Container in good condition?
	N	N	N	N	N
	Y	Y	Y	Y	Y

SAMPLED BY (Please Print): Nate Ryan

LOGGED BY (signature): DATE 1/21/08 TIME 1455

REVIEWED BY (signature): DATE 1/22/08 TIME 1335

Relinquished By / Company Name	Date	Time	Received By / Company Name	Date	Time
1 Nate Ryan TTAUS	1-21-08	1800	2	1/21/08	1800
3	1/21/08	0853	4 SAS	1-21-08	1957
5 SAS	1-21-08	1945	6	1/21/08	1945
7			8		
9			10		

Data Deliverables: ☐ Standard ☐ CLP-like ☐ NJ-Reduced ☐ NJ-Full ☐ other

EDDs Required? ☐ If yes, format type:

SDWA Forms? yes ☐ yes ☐ yes ☐ yes ☐ Other

State Samples Collected In? MD ☐ NJ ☐ NY ☐ PA ☐

DOD Criteria Required?

ALSI FIELD SERVICES: ☐ Pickup ☐ Labor ☐ Composite Sampling ☐ Rental Equipment ☐ Other:

* G=Grab; C=Composite

**Matrix: AI=Air; DW=Drinking Water; GW=Groundwater; OI=Oil; OL=Other Liquid; SL=Sludge; SO=Soil; WP=Wipe; WW=Wastewater

Copies: WHITE - ORIGINAL CANARY - CUSTOMER COPY

***Container Type: AG-Amber Glass; CG-Clear Glass, PL-Plastic. Container Size: 250ml, 500ml, 1L, 8oz., etc. Preservative: HCl, HNO3, NaOH, etc.

Rev 6/07

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Certificate of Analysis

Project Name:	**LOCKHEED MARTIN MIDDLE RIVER**	Workorder:	**9720332**
Purchase Order:	**1024619**	Workorder ID:	**TGG001|MSA January 2008**

Mr. Michael Martin
Tetra Tech NUS, Inc.
20251 Centruy Blvd.
Suite 200
Germantown, MD 20874

February 14, 2008

Dear Mr. Martin,

Enclosed are the analytical results for samples received by the laboratory on Wednesday, January 23, 2008

ALSI is a National Environmental Laboratory Accreditation Conference (NELAC) accredited laboratory and as such, certifies that all applicable test results meet the requirements of NELAC.

If you have any questions regarding this certificate of analysis, please contact Susan Baer (Project Coordinator) or Raymond J Martrano (Laboratory Manager) at (717) 944-5541.

Please visit us at www.analyticallab.com for a listing of ALSI's NELAC accreditations and Scope of Work, as well as other links to Water Quality documentation on the internet.

This laboratory report may not be reproduced, except in full, without the written approval of ALSI.

NOTE: ALSI has changed the report generation tool and while we have tried to retain the existing format, you will notice some changes in the laboratory report. Please feel free to contact ALSI in case you have any questions.

Analytical Laboratory Services, Inc.

This page is included as part of the Analytical Report and must be retained as a permanent record thereof.

Raymond J. Martrano
Laboratory Manager

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SAMPLE SUMMARY

Workorder: 9720332 TGG001|MSA January 2008 Discard Date: 02/27/2008

Lab ID	Sample ID	Matrix	Date Collected	Date Received	Collected By
9720332001	TB-012308	Water	1/23/08 19:25	1/23/08 19:25	Walt Pryor
9720332002	OW-5I-012308	Water	1/23/08 12:10	1/23/08 19:25	Walt Pryor
9720332003	OW-6I-012308	Water	1/23/08 16:21	1/23/08 19:25	Walt Pryor

Workorder Comments:

Notes

-- Samples collected by ALSI personnel are done so in accordance with the procedures set forth in the ALSI Field Sampling Plan (20 - Field Services Sampling Plan).
-- All Waste Water analyses comply with methodology requirements of 40 CFR Part 136.
-- All Drinking Water analyses comply with methodology requirements of 40 CFR Part 141.
-- Unless otherwise noted, all quantitative results for soils are reported on a dry weight basis.
-- The Chain of Custody document is included as part of this report.

Standard Acronyms/Flags

J, B	Indicates an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte
U	Indicates that the analyte was Not Detected (ND)
MDL	Method Detection Limit
PQL	Practical Quantitation Limit
RDL	Reporting Detection Limit
ND	Not Detected - indicates that the analyte was Not Detected at the RDL
Cntr	Analysis was performed using this container
RegLmt	Regulatory Limit
LCS	Laboratory Control Sample
MS	Matrix Spike
MSD	Matrix Spike Duplicate
DUP	Sample Duplicate
%Rec	Percent Recovery
RPD	Relative Percent Difference

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332001** Date Collected: 1/23/2008 19:25 Matrix: Water

Sample ID: **TB-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,1,1-Trichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,1-Dichloroethane	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 18:32	DXN	A
1,1-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/5/08 18:32	DXN	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 18:32	DXN	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 18:32	DXN	A
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/5/08 18:32	DXN	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/5/08 18:32	DXN	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/5/08 18:32	DXN	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/5/08 18:32	DXN	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/5/08 18:32	DXN	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/5/08 18:32	DXN	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/5/08 18:32	DXN	A
Benzene	ND	ug/L		1.0	0.4	SW846 8260B			2/5/08 18:32	DXN	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 18:32	DXN	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
Chloroform	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 18:32	DXN	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 18:32	DXN	A
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332001** Date Collected: 1/23/2008 19:25 Matrix: Water

Sample ID: **TB-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/5/08 18:32	DXN	A
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 18:32	DXN	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Methylene Chloride	1.0J	ug/L		1.0	0.1	SW846 8260B			2/5/08 18:32	DXN	A
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/5/08 18:32	DXN	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Tetrachloroethene	ND	ug/L		1.0	0.4	SW846 8260B			2/5/08 18:32	DXN	A
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/5/08 18:32	DXN	A
Trichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/5/08 18:32	DXN	A
Vinyl Chloride	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
cis-1,2-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
mp-Xylene	0.39J	ug/L		2.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/5/08 18:32	DXN	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 18:32	DXN	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/5/08 18:32	DXN	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/5/08 18:32	DXN	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 18:32	DXN	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/5/08 18:32	DXN	A
trans-1,2-Dichloroethene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 18:32	DXN	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	98	%		62-133		SW846 8260B			2/5/08 18:32	DXN	A
4-Bromofluorobenzene (S)	85	%		79-114		SW846 8260B			2/5/08 18:32	DXN	A
Dibromofluoromethane (S)	100	%		78-116		SW846 8260B			2/5/08 18:32	DXN	A
Toluene-d8 (S)	92	%		76-127		SW846 8260B			2/5/08 18:32	DXN	A

Sample Comments:

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332002** Date Collected: 1/23/2008 12:10 Matrix: Water

Sample ID: **OW-5I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,1,1-Trichloroethane	9.7	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,1-Dichloroethane	23.2	ug/L		1.0	0.1	SW846 8260B			2/5/08 20:46	DXN	A
1,1-Dichloroethene	136	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/5/08 20:46	DXN	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 20:46	DXN	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 20:46	DXN	A
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/5/08 20:46	DXN	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/5/08 20:46	DXN	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/5/08 20:46	DXN	A
2-Chloroethylvinyl ether	ND	ug/L	1	3.0	1	SW846 8260B			2/5/08 20:46	DXN	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/5/08 20:46	DXN	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/5/08 20:46	DXN	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/5/08 20:46	DXN	A
Benzene	2.6	ug/L		1.0	0.4	SW846 8260B			2/5/08 20:46	DXN	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Carbon Disulfide	0.49J	ug/L		1.0	0.1	SW846 8260B			2/5/08 20:46	DXN	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
Chloroform	1.1	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Dichlorofluoromethane	ND	ug/L	2	1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 20:46	DXN	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 20:46	DXN	A
Ethylbenzene	ND	ug/L	3	1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332002** Date Collected: 1/23/2008 12:10 Matrix: Water

Sample ID: **OW-5I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	1.3	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/5/08 20:46	DXN	A
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 20:46	DXN	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 20:46	DXN	A
Naphthalene	ND	ug/L	3	2.0	0.6	SW846 8260B			2/5/08 20:46	DXN	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Tetrachloroethene	0.71J	ug/L		1.0	0.4	SW846 8260B			2/5/08 20:46	DXN	A
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/5/08 20:46	DXN	A
Trichloroethene	268	ug/L		10.0	2	SW846 8260B			2/8/08 19:34	ECR	A
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/5/08 20:46	DXN	A
Vinyl Chloride	0.66J	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
cis-1,2-Dichloroethene	68.1	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/5/08 20:46	DXN	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 20:46	DXN	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/5/08 20:46	DXN	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/5/08 20:46	DXN	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 20:46	DXN	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/5/08 20:46	DXN	A
trans-1,2-Dichloroethene	0.94J	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 20:46	DXN	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	100	%		62-133		SW846 8260B			2/5/08 20:46	DXN	A
4-Bromofluorobenzene (S)	85	%		79-114		SW846 8260B			2/5/08 20:46	DXN	A
Dibromofluoromethane (S)	100	%		78-116		SW846 8260B			2/5/08 20:46	DXN	A
Toluene-d8 (S)	93	%		76-127		SW846 8260B			2/5/08 20:46	DXN	A
1,2-Dichloroethane-d4 (S)	98	%		62-133		SW846 8260B			2/8/08 19:34	ECR	A
4-Bromofluorobenzene (S)	97	%		79-114		SW846 8260B			2/8/08 19:34	ECR	A
Dibromofluoromethane (S)	99	%		78-116		SW846 8260B			2/8/08 19:34	ECR	A
Toluene-d8 (S)	101	%		76-127		SW846 8260B			2/8/08 19:34	ECR	A

SEMIVOLATILES

1,4-Dioxane	87	ug/L		2.9	0.6	SW846 8270C	1/29/08	MPP	2/3/08 23:02	DHF	J1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	82	%		40-125		SW846 8270C	1/29/08	MPP	2/3/08 23:02	DHF	J1
2-Fluorobiphenyl (S)	78	%		32-108		SW846 8270C	1/29/08	MPP	2/3/08 23:02	DHF	J1
2-Fluorophenol (S)	47	%		20-70		SW846 8270C	1/29/08	MPP	2/3/08 23:02	DHF	J1
Nitrobenzene-d5 (S)	83	%		31-110		SW846 8270C	1/29/08	MPP	2/3/08 23:02	DHF	J1

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332002** Date Collected: 1/23/2008 12:10 Matrix: Water

Sample ID: **OW-5I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Phenol-d5 (S)	31	%		10-49		SW846 8270C	1/29/08	MPP	2/3/08 23:02	DHF	J1
Terphenyl-d14 (S)	72	%		27-136		SW846 8270C	1/29/08	MPP	2/3/08 23:02	DHF	J1
LIGHT HYDROCARBON GASES											
Ethane	1J	ug/L		3.0	0.4	RSK 175			1/28/08 15:17	ELC	F
Ethene	2.3J	ug/L		3.0	0.4	RSK 175			1/28/08 15:17	ELC	F
Methane	113	ug/L		1.0	0.5	RSK 175			1/28/08 15:17	ELC	F
WET CHEMISTRY											
Chloride	55.8	mg/L		2.0	0.2	EPA 300			1/24/08 10:51	MBW	H
Nitrate-N	0.04J	mg/L		0.20	0.02	EPA 300			1/24/08 10:51	MBW	H
Nitrite-N	ND	mg/L		0.20	0.02	EPA 300			1/24/08 10:51	MBW	H
Sulfate	82.1	mg/L		2.0	0.2	EPA 300			1/24/08 10:51	MBW	H
Total Organic Carbon (TOC)	1.7	mg/L		1.0	0.2	415.1/5310B			2/1/08 08:00	PAG	I
METALS											
Antimony, Total	0.0001J	mg/L		0.0020	0.00005	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Antimony, Dissolved	0.0009J	mg/L		0.0020	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Arsenic, Total	0.0019J	mg/L		0.0060	0.0004	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Arsenic, Dissolved	0.0012J	mg/L		0.0050	0.00006	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Barium, Total	0.0541	mg/L		0.0060	0.00005	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Barium, Dissolved	0.0407	mg/L		0.0050	0.00003	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Beryllium, Total	0.0009J	mg/L		0.0010	0.00007	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Beryllium, Dissolved	ND	mg/L		0.0010	0.00006	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Cadmium, Total	ND	mg/L		0.0010	0.00001	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Cadmium, Dissolved	ND	mg/L		0.0010	0.00001	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Chromium, Total	0.0075	mg/L		0.0020		SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Chromium, Dissolved	0.0044	mg/L		0.0020	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Cobalt, Total	0.0475	mg/L		0.0060	0.00003	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Cobalt, Dissolved	0.0418	mg/L		0.0050	0.00002	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Copper, Total	0.0071	mg/L		0.0060		SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Copper, Dissolved	0.0003J	mg/L		0.0050	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Lead, Total	0.0026	mg/L		0.0020	0.00002	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 10:21	CMD	E1
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 12:26	CMD	D1
Molybdenum, Total	ND	mg/L		0.0020	0.00001	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Molybdenum, Dissolved	0.0005J	mg/L		0.0020	0.0001	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Nickel, Total	0.0448	mg/L		0.0060	0.00006	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Nickel, Dissolved	0.0356	mg/L		0.0050	0.0001	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Selenium, Total	ND	mg/L		0.006	0.001	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Selenium, Dissolved	ND	mg/L		0.005	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Silver, Total	0.0002J	mg/L		0.0010	0.00004	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/5/08	AJB	2/6/08 14:24	LAM	D2
Thallium, Total	ND	mg/L		0.0010	0.00002	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Thallium, Dissolved	ND	mg/L		0.0010	0.00001	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332002** Date Collected: 1/23/2008 12:10 Matrix: Water

Sample ID: **OW-5I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Vanadium, Total	0.0127	mg/L		0.0010	0.00003	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Vanadium, Dissolved	0.0004J	mg/L		0.0010	0.00002	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2
Zinc, Total	0.0423	mg/L		0.0060	0.002	SW846 6020	2/5/08	SRT	2/5/08 19:54	LAM	E2
Zinc, Dissolved	0.0304	mg/L		0.0050	0.0005	SW846 6020	2/5/08	AJB	2/5/08 17:47	AJB	D2

Sample Comments:

A dilution of the GCMS volatiles analysis was performed outside of the holding time because one or more of the analytes exceeded the calibration range in the initial analysis.

The dilution of the sample was run from a vial with headspace. The method requires that samples be collected without headspace in order to prevent the loss of volatile organics. Results should be considered estimated.

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332003** Date Collected: 1/23/2008 16:21 Matrix: Water

Sample ID: **OW-6I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,1,1-Trichloroethane	19.0	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,1-Dichloroethane	47.1	ug/L		1.0	0.1	SW846 8260B			2/5/08 21:20	DXN	A
1,1-Dichloroethene	269	ug/L		10.0	2	SW846 8260B			2/8/08 20:08	ECR	B
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/5/08 21:20	DXN	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 21:20	DXN	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 21:20	DXN	A
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/5/08 21:20	DXN	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/5/08 21:20	DXN	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,2-Dichloroethane	4.1	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/5/08 21:20	DXN	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/5/08 21:20	DXN	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/5/08 21:20	DXN	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/5/08 21:20	DXN	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/5/08 21:20	DXN	A
Benzene	0.91J	ug/L		1.0	0.4	SW846 8260B			2/5/08 21:20	DXN	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 21:20	DXN	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
Chloroform	2.7	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 21:20	DXN	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 21:20	DXN	A
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332003** Date Collected: 1/23/2008 16:21 Matrix: Water

Sample ID: **OW-6I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	3.0	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/5/08 21:20	DXN	A
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 21:20	DXN	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/5/08 21:20	DXN	A
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/5/08 21:20	DXN	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Tetrachloroethene	1.5	ug/L		1.0	0.4	SW846 8260B			2/5/08 21:20	DXN	A
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/5/08 21:20	DXN	A
Trichloroethene	832	ug/L		10.0	2	SW846 8260B			2/8/08 20:08	ECR	B
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/5/08 21:20	DXN	A
Vinyl Chloride	1.1	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
cis-1,2-Dichloroethene	166	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/5/08 21:20	DXN	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/5/08 21:20	DXN	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/5/08 21:20	DXN	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/5/08 21:20	DXN	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/5/08 21:20	DXN	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/5/08 21:20	DXN	A
trans-1,2-Dichloroethene	0.95J	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/5/08 21:20	DXN	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	100	%		62-133		SW846 8260B			2/5/08 21:20	DXN	A
4-Bromofluorobenzene (S)	89	%		79-114		SW846 8260B			2/5/08 21:20	DXN	A
Dibromofluoromethane (S)	97	%		78-116		SW846 8260B			2/5/08 21:20	DXN	A
Toluene-d8 (S)	91	%		76-127		SW846 8260B			2/5/08 21:20	DXN	A
1,2-Dichloroethane-d4 (S)	99	%		62-133		SW846 8260B			2/8/08 20:08	ECR	B
Dibromofluoromethane (S)	98	%		78-116		SW846 8260B			2/8/08 20:08	ECR	B
4-Bromofluorobenzene (S)	101	%		79-114		SW846 8260B			2/8/08 20:08	ECR	B
Toluene-d8 (S)	100	%		76-127		SW846 8260B			2/8/08 20:08	ECR	B

SEMIVOLATILES

1,4-Dioxane	166	ug/L		5.8	1	SW846 8270C	1/29/08	MPP	2/6/08 05:45	DHF	J1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	79	%		40-125		SW846 8270C	1/29/08	MPP	2/6/08 05:45	DHF	J1
2-Fluorobiphenyl (S)	79	%		32-108		SW846 8270C	1/29/08	MPP	2/6/08 05:45	DHF	J1
Phenol-d5 (S)	30	%		10-49		SW846 8270C	1/29/08	MPP	2/6/08 05:45	DHF	J1
Terphenyl-d14 (S)	86	%		27-136		SW846 8270C	1/29/08	MPP	2/6/08 05:45	DHF	J1

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332003** Date Collected: 1/23/2008 16:21 Matrix: Water

Sample ID: **OW-6I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Nitrobenzene-d5 (S)	81	%		31-110		SW846 8270C	1/29/08	MPP	2/6/08 05:45	DHF	J1
2-Fluorophenol (S)	46	%		20-70		SW846 8270C	1/29/08	MPP	2/6/08 05:45	DHF	J1
LIGHT HYDROCARBON GASES											
Ethane	ND	ug/L		3.0	0.4	RSK 175			1/28/08 16:16	ELC	F
Ethene	ND	ug/L		3.0	0.4	RSK 175			1/28/08 16:16	ELC	F
Methane	99.5	ug/L		1.0	0.5	RSK 175			1/28/08 16:16	ELC	F
WET CHEMISTRY											
Chloride	52.1	mg/L		2.0	0.2	EPA 300			1/24/08 14:43	MBW	H
Nitrate-N	ND	mg/L		0.20	0.02	EPA 300			1/24/08 14:43	MBW	H
Nitrite-N	ND	mg/L		0.20	0.02	EPA 300			1/24/08 14:43	MBW	H
Sulfate	12.5	mg/L		2.0	0.2	EPA 300			1/24/08 14:43	MBW	H
Total Organic Carbon (TOC)	1.0	mg/L		1.0	0.2	415.1/5310B			2/1/08 08:00	PAG	I
METALS											
Antimony, Total	ND	mg/L		0.0020	0.00005	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Antimony, Dissolved	ND	mg/L		0.0020	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Arsenic, Total	0.0008J	mg/L		0.0060	0.0004	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Arsenic, Dissolved	0.0005J	mg/L		0.0050	0.00006	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Barium, Total	0.0494	mg/L		0.0060	0.00005	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Barium, Dissolved	0.0498	mg/L		0.0050	0.00003	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Beryllium, Total	0.0002J	mg/L		0.0010	0.00007	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Beryllium, Dissolved	ND	mg/L		0.0010	0.00006	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Cadmium, Total	ND	mg/L		0.0010	0.00001	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Cadmium, Dissolved	ND	mg/L		0.0010	0.00001	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Chromium, Total	ND	mg/L		0.0020		SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Chromium, Dissolved	0.0030	mg/L		0.0020	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Cobalt, Total	0.0282	mg/L		0.0060	0.00003	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Cobalt, Dissolved	0.0283	mg/L		0.0050	0.00002	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Copper, Total	ND	mg/L		0.0060		SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Copper, Dissolved	0.0003J	mg/L		0.0050	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Lead, Total	ND	mg/L		0.0020	0.00002	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 10:24	CMD	E1
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	1/28/08	CMD	1/29/08 12:30	CMD	D1
Molybdenum, Total	ND	mg/L		0.0020	0.00001	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Molybdenum, Dissolved	0.0002J	mg/L		0.0020	0.0001	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Nickel, Total	0.0412	mg/L		0.0060	0.00006	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Nickel, Dissolved	0.0410	mg/L		0.0050	0.0001	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Selenium, Total	ND	mg/L		0.006	0.001	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Selenium, Dissolved	ND	mg/L		0.005	0.0002	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Silver, Total	ND	mg/L		0.0010	0.00004	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/5/08	AJB	2/6/08 14:27	LAM	D2
Thallium, Total	ND	mg/L		0.0010	0.00002	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Thallium, Dissolved	ND	mg/L		0.0010	0.00001	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2

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ANALYTICAL RESULTS

Workorder: 9720332 TGG001|MSA January 2008

Lab ID: **9720332003** Date Collected: 1/23/2008 16:21 Matrix: Water

Sample ID: **OW-6I-012308** Date Received: 1/23/2008 19:25

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Vanadium, Total	0.0012	mg/L		0.0010	0.00003	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Vanadium, Dissolved	ND	mg/L		0.0010	0.00002	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2
Zinc, Total	0.0658	mg/L		0.0060	0.002	SW846 6020	2/5/08	SRT	2/5/08 20:08	LAM	E2
Zinc, Dissolved	0.0670	mg/L		0.0050	0.0005	SW846 6020	2/5/08	AJB	2/5/08 17:52	AJB	D2

Sample Comments:

A dilution of the GCMS volatiles analysis was performed outside of the holding time because one or more of the analytes exceeded the calibration range in the initial analysis.

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS QUALIFIERS\FLAGS

Workorder: 9720332 TGG001|MSA January 2008

PARAMETER QUALIFIERS\FLAGS

[1] The recovery of the Matrix Spike (MS) associated to this analyte was outside of the established control limits due to the acidic matrix of the sample. This analyte was recovered in the LCS.

[2] This compound was recovered above quality control criteria in the QC associated with this sample. There were no detections found in the sample, so data is not impacted.

[3] This compound was recovered above quality control criteria in the matrix spike of this sample. The LCS had acceptable recoveries, satisfying method criteria.

Report ID: 9720332

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CHAIN OF CUSTODY/ REQUEST FOR ANALYSIS

ALL SHADED AREAS MUST BE COMPLETED BY THE CLIENT / SAMPLER. INSTRUCTIONS ON THE BACK.

Page 1 of 1
Courier:
Tracking #:

* 9 7 2 0 3 3 2 *

Co. Name: Tetra Tech NUS
Contact (Report to): Mike Manton Phone: (301) 528-3022
Address: 20251 Century Blvd STE 200
Germantown, MD 20874

Bill to (if different than Report to): PO#:

Project Name/#: MRC ALSI Quote #:

TAT: Normal-Standard TAT is 10-12 business days. Date Required:
Rush-Subject to ALSI approval and surcharges. Approved By:

Email? -Y
Fax? -Y No.:

Sample Description/Location (as it will appear on the lab report)	COC Comments	Sample Date	Military Time	*G or C	**Matrix	VOCs	Total PP metals	0,5,5 PP metals	1,4 Dioxane	RSK-175	TOC	Chloride, sulfate, nitrate, nitrite, etc.			
***Container Type						Glass	Poly	Poly	Amber	Glass	Amber	Poly			
***Container Size						40ml	500ml	500ml	1L	40ml	250ml	125ml			
*** Preservative						HCl	HNO3	HNO3	ICE	HCl	HCl	ICE			
						ANALYSES/METHOD REQUESTED									
1 TB-012308		1-23-08	0900	G	W	X2									
2 OW 5I-012308		↓	1210	G	W	X2	1X	1X	2X	2X	1X	1X			
3 OW 6I-012308		↓	1621	G	W	X2	1X	1X	2X	2X	1X	1X			
4															
5	+ sulfate added per														
6	SOW 01/25/08														
7	Confirmed with Tony														
8	Approved 01/25/08														

Enter Number of Containers Per Analysis

Receipt Information (completed by Sample Receiver)
Performed by: INITIAL HERE
Cooler Temp: 2
Therm. ID: 5102355
No. of Coolers:
Notes:

	Correct containers?	Correct sample volume?	Correct preservation?	Headspace/Volatiles?	Circle appropriate Y or N.
	N	N	N	Y	
	Y	N	N	N	N
	Y	N	N	N	N

	Custody seals Present?	(if present) Seals intact?	Received on ice?	COC/Labels complete/accurate?	Container in good condition?
	Y	Y	Y	Y	Y

SAMPLED BY (Please Print): Walt Pyon
LOGGED BY(signature): DATE 1/23/08 TIME 2121
REVIEWED BY(signature): DATE 01/25/08 TIME 1547

Relinquished By / Company Name	Date	Time	Received By / Company Name	Date	Time
1 Walt Pyon TtNUS	1-23-08	1700	2	1/23/08	2000
3	1/23/08	1828	4	1-23-8	1829
5 SNB	1-23-08	1925	6	1/23/08	1925
7			8		
9			10		

Data Deliverables: Standard; CLP-like; NJ-Reduced; NJ-Full; other
EDDs Required? If yes, format type:
SDWA Forms? yes / yes / yes / yes
State Samples Collected In? MD NJ NY PA
Other
DOD Criteria Required?

ALSI FIELD SERVICES: Pickup; Labor; Composite Sampling; Rental Equipment; Other:

* G=Grab; C=Composite
**Matrix: Al=Air; DW=Drinking Water; GW=Groundwater; Oil=Oil; OL=Other Liquid; SL=Sludge; SO=Soil; WP=Wipe; WW=Wastewater
***Container Type: AG-Amber Glass; CG-Clear Glass, PL-Plastic. Container Size: 250ml, 500ml, 1L, 8oz., etc. Preservative: HCl, HNO3, NaOH, etc.

Copies: WHITE - ORIGINAL CANARY - CUSTOMER COPY
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Certificate of Analysis

Project Name:	**LOCKHEED MARTIN MIDDLE RIVER**	Workorder:	**9720653**
Purchase Order:	**1024619**	Workorder ID:	**TGG001|MSA January 2008**

Mr. Michael Martin
Tetra Tech NUS, Inc.
20251 Centruy Blvd.
Suite 200
Germantown, MD 20874

February 18, 2008

Dear Mr. Martin,

Enclosed are the analytical results for samples received by the laboratory on Friday, January 25, 2008

ALSI is a National Environmental Laboratory Accreditation Conference (NELAC) accredited laboratory and as such, certifies that all applicable test results meet the requirements of NELAC.

If you have any questions regarding this certificate of analysis, please contact Susan Baer (Project Coordinator) or Raymond J Martrano (Laboratory Manager) at (717) 944-5541.

Please visit us at www.analyticallab.com for a listing of ALSI's NELAC accreditations and Scope of Work, as well as other links to Water Quality documentation on the internet.

This laboratory report may not be reproduced, except in full, without the written approval of ALSI.

NOTE: ALSI has changed the report generation tool and while we have tried to retain the existing format, you will notice some changes in the laboratory report. Please feel free to contact ALSI in case you have any questions.

Analytical Laboratory Services, Inc.

This page is included as part of the Analytical Report and must be retained as a permanent record thereof.

Raymond J. Martrano
Laboratory Manager

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SAMPLE SUMMARY

Workorder: 9720653 TGG001|MSA January 2008 Discard Date: 02/29/2008

Lab ID	Sample ID	Matrix	Date Collected	Date Received	Collected By
9720653001	OW6S-012508	Water	1/25/08 10:18	1/25/08 19:20	Walt Pryor
9720653002	OW1I-012508	Water	1/25/08 11:27	1/25/08 19:20	Walt Pryor
9720653003	OW1D-012508	Water	1/25/08 14:44	1/25/08 19:20	Walt Pryor
9720653004	OW-DUP-012508	Water	1/25/08 00:00	1/25/08 19:20	Walt Pryor

Workorder Comments:

Notes

-- Samples collected by ALSI personnel are done so in accordance with the procedures set forth in the ALSI Field Sampling Plan (20 - Field Services Sampling Plan).
-- All Waste Water analyses comply with methodology requirements of 40 CFR Part 136.
-- All Drinking Water analyses comply with methodology requirements of 40 CFR Part 141.
-- Unless otherwise noted, all quantitative results for soils are reported on a dry weight basis.
-- The Chain of Custody document is included as part of this report.

Standard Acronyms/Flags

J, B	Indicates an estimated value between the Method Detection Limit (MDL) and the Practical Quantitation Limit (PQL) for the analyte
U	Indicates that the analyte was Not Detected (ND)
MDL	Method Detection Limit
PQL	Practical Quantitation Limit
RDL	Reporting Detection Limit
ND	Not Detected - indicates that the analyte was Not Detected at the RDL
Cntr	Analysis was performed using this container
RegLmt	Regulatory Limit
LCS	Laboratory Control Sample
MS	Matrix Spike
MSD	Matrix Spike Duplicate
DUP	Sample Duplicate
%Rec	Percent Recovery
RPD	Relative Percent Difference

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653001** Date Collected: 1/25/2008 10:18 Matrix: Water

Sample ID: **OW6S-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,1,1-Trichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,1-Dichloroethane	0.60J	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:56	JAJ	A
1,1-Dichloroethene	0.53J	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/8/08 02:56	JAJ	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 02:56	JAJ	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 02:56	JAJ	A
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/8/08 02:56	JAJ	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/8/08 02:56	JAJ	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/8/08 02:56	JAJ	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/8/08 02:56	JAJ	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/8/08 02:56	JAJ	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/8/08 02:56	JAJ	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/8/08 02:56	JAJ	A
Benzene	ND	ug/L		1.0	0.4	SW846 8260B			2/8/08 02:56	JAJ	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:56	JAJ	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
Chloroform	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:56	JAJ	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:56	JAJ	A
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653001** Date Collected: 1/25/2008 10:18 Matrix: Water

Sample ID: **OW6S-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/8/08 02:56	JAJ	A
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:56	JAJ	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:56	JAJ	A
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/8/08 02:56	JAJ	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Tetrachloroethene	ND	ug/L		1.0	0.4	SW846 8260B			2/8/08 02:56	JAJ	A
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/8/08 02:56	JAJ	A
Trichloroethene	2.0	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/8/08 02:56	JAJ	A
Vinyl Chloride	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
cis-1,2-Dichloroethene	1.4	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/8/08 02:56	JAJ	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:56	JAJ	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/8/08 02:56	JAJ	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/8/08 02:56	JAJ	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 02:56	JAJ	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/8/08 02:56	JAJ	A
trans-1,2-Dichloroethene	0.21J	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:56	JAJ	A

Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*	*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	103	%		62-133	SW846 8260B			2/8/08 02:56	JAJ	A
4-Bromofluorobenzene (S)	105	%		79-114	SW846 8260B			2/8/08 02:56	JAJ	A
Dibromofluoromethane (S)	105	%		78-116	SW846 8260B			2/8/08 02:56	JAJ	A
Toluene-d8 (S)	113	%		76-127	SW846 8260B			2/8/08 02:56	JAJ	A

SEMIVOLATILES

1,4-Dioxane	0.8J	ug/L		2.9	0.6	SW846 8270C	1/30/08	JWY	2/4/08 06:39	DHF	F1

Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*	*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	74	%		40-125	SW846 8270C	1/30/08	JWY	2/4/08 06:39	DHF	F1
Phenol-d5 (S)	29	%		10-49	SW846 8270C	1/30/08	JWY	2/4/08 06:39	DHF	F1
Terphenyl-d14 (S)	71	%		27-136	SW846 8270C	1/30/08	JWY	2/4/08 06:39	DHF	F1
Nitrobenzene-d5 (S)	77	%		31-110	SW846 8270C	1/30/08	JWY	2/4/08 06:39	DHF	F1
2-Fluorobiphenyl (S)	69	%		32-108	SW846 8270C	1/30/08	JWY	2/4/08 06:39	DHF	F1
2-Fluorophenol (S)	46	%		20-70	SW846 8270C	1/30/08	JWY	2/4/08 06:39	DHF	F1

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653001** Date Collected: 1/25/2008 10:18 Matrix: Water

Sample ID: **OW6S-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
LIGHT HYDROCARBON GASES											
Ethane	ND	ug/L		3.0	0.4	RSK 175			2/6/08 13:52	ELC	H
Ethene	ND	ug/L		3.0	0.4	RSK 175			2/6/08 13:52	ELC	H
Methane	9.9	ug/L		1.0	0.5	RSK 175			2/6/08 13:52	ELC	H
WET CHEMISTRY											
Chloride	279	mg/L		5.0	0.5	EPA 300			1/29/08 03:12	JEP	K
Nitrate-N	0.62	mg/L		0.20	0.02	EPA 300			1/26/08 07:50	JEP	K
Nitrite-N	ND	mg/L		0.20	0.02	EPA 300			1/26/08 07:50	JEP	K
Sulfate	126	mg/L		2.0	0.2	EPA 300			1/26/08 07:50	JEP	K
Total Organic Carbon (TOC)	3.8	mg/L		1.0	0.2	415.1/5310B			2/1/08 08:00	PAG	J
METALS											
Antimony, Total	0.0001J	mg/L		0.0020	0.00005	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Antimony, Dissolved	ND	mg/L		0.0020	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Arsenic, Total	0.0006J	mg/L		0.0060	0.0004	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Arsenic, Dissolved	ND	mg/L		0.0030	0.0007	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Barium, Total	0.0451	mg/L		0.0060	0.00005	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Barium, Dissolved	0.0431	mg/L		0.0050	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Beryllium, Total	0.0012	mg/L		0.0010	0.00007	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Beryllium, Dissolved	0.0012	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Cadmium, Total	0.0002J	mg/L		0.0010	0.00001	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Cadmium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Chromium, Total	ND	mg/L		0.0020		SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Chromium, Dissolved	0.0083	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Cobalt, Total	0.0469	mg/L		0.0060	0.00003	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Cobalt, Dissolved	0.0460	mg/L		0.0050	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Copper, Total	ND	mg/L		0.0060		SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Copper, Dissolved	0.0030J	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Lead, Total	ND	mg/L		0.0020	0.00002	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 12:20	CMD	D2
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 14:28	CMD	E1
Molybdenum, Total	0.0001J	mg/L		0.0020	0.00001	SW846 6020	2/5/08	SRT	2/8/08 15:54	LAM	D1
Molybdenum, Dissolved	ND	mg/L		0.0020	0.0006	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Nickel, Total	0.0225	mg/L		0.0060	0.00006	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Nickel, Dissolved	0.0217	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Selenium, Total	0.005J	mg/L		0.006	0.001	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Selenium, Dissolved	0.004J	mg/L		0.005	0.001	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Silver, Total	0.0004J	mg/L		0.0010	0.00004	SW846 6020	2/5/08	SRT	2/8/08 15:54	LAM	D1
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Thallium, Total	0.0001J	mg/L		0.0010	0.00002	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Thallium, Dissolved	0.0001J	mg/L		0.0010	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3
Vanadium, Total	0.00005J	mg/L		0.0010	0.00003	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1
Vanadium, Dissolved	0.0021	mg/L		0.0010	0.00002	SW846 6020	2/4/08	AJB	2/5/08 13:13	AJB	D3
Zinc, Total	0.0297	mg/L		0.0060	0.002	SW846 6020	2/5/08	SRT	2/7/08 17:57	LAM	D1

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653001** Date Collected: 1/25/2008 10:18 Matrix: Water

Sample ID: **OW6S-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Zinc, Dissolved	0.0266	mg/L		0.0050	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:09	AJB	D3

Sample Comments:

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653002** Date Collected: 1/25/2008 11:27 Matrix: Water

Sample ID: **OW1I-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,1,1-Trichloroethane	0.20J	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,1-Dichloroethane	5.2	ug/L		1.0	0.1	SW846 8260B			2/8/08 03:31	JAJ	A
1,1-Dichloroethene	21.2	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/8/08 03:31	JAJ	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 03:31	JAJ	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 03:31	JAJ	A
1,2,4-Trimethylbenzene	0.63J	ug/L		1.0	0.4	SW846 8260B			2/8/08 03:31	JAJ	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/8/08 03:31	JAJ	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,2-Dichloroethane	0.37J	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/8/08 03:31	JAJ	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/8/08 03:31	JAJ	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/8/08 03:31	JAJ	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/8/08 03:31	JAJ	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/8/08 03:31	JAJ	A
Benzene	ND	ug/L		1.0	0.4	SW846 8260B			2/8/08 03:31	JAJ	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 03:31	JAJ	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
Chloroform	2.3	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 03:31	JAJ	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 03:31	JAJ	A
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A

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34 Dogwood Lane - Middletown, PA 17057 Phone: 717-944-5541 Fax: 717-944-1430

ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653002** Date Collected: 1/25/2008 11:27 Matrix: Water

Sample ID: **OW1I-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/8/08 03:31	JAJ	A
Isopropylbenzene	2.2	ug/L		1.0	0.1	SW846 8260B			2/8/08 03:31	JAJ	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Methylene Chloride	0.14J	ug/L		1.0	0.1	SW846 8260B			2/8/08 03:31	JAJ	A
Naphthalene	1.3J	ug/L		2.0	0.6	SW846 8260B			2/8/08 03:31	JAJ	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Tetrachloroethene	41.8	ug/L		1.0	0.4	SW846 8260B			2/8/08 03:31	JAJ	A
Toluene	0.48J	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Total Xylenes	1.3J	ug/L		3.0	0.4	SW846 8260B			2/8/08 03:31	JAJ	A
Trichloroethene	7390	ug/L		50.0	10	SW846 8260B			2/11/08 13:34	JAH	B
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/8/08 03:31	JAJ	A
Vinyl Chloride	178	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
cis-1,2-Dichloroethene	1730	ug/L		50.0	10	SW846 8260B			2/11/08 13:34	JAH	B
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/8/08 03:31	JAJ	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
o-Xylene	1.3	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 03:31	JAJ	A
sec-Butylbenzene	3.0	ug/L		2.0	0.8	SW846 8260B			2/8/08 03:31	JAJ	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/8/08 03:31	JAJ	A
tert-Butylbenzene	0.94J	ug/L		2.0	0.7	SW846 8260B			2/8/08 03:31	JAJ	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/8/08 03:31	JAJ	A
trans-1,2-Dichloroethene	10.2	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 03:31	JAJ	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	103	%		62-133		SW846 8260B			2/8/08 03:31	JAJ	A
Dibromofluoromethane (S)	102	%		78-116		SW846 8260B			2/8/08 03:31	JAJ	A
Toluene-d8 (S)	115	%		76-127		SW846 8260B			2/8/08 03:31	JAJ	A
4-Bromofluorobenzene (S)	104	%		79-114		SW846 8260B			2/8/08 03:31	JAJ	A
1,2-Dichloroethane-d4 (S)	104	%		62-133		SW846 8260B			2/11/08 13:34	JAH	B
Dibromofluoromethane (S)	102	%		78-116		SW846 8260B			2/11/08 13:34	JAH	B
Toluene-d8 (S)	114	%		76-127		SW846 8260B			2/11/08 13:34	JAH	B
4-Bromofluorobenzene (S)	101	%		79-114		SW846 8260B			2/11/08 13:34	JAH	B
SEMIVOLATILES											
1,4-Dioxane	4.0	ug/L		2.9	0.6	SW846 8270C	1/31/08	CAC	2/5/08 21:57	JAJ	F1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	79	%		40-125		SW846 8270C	1/31/08	CAC	2/5/08 21:57	JAJ	F1
2-Fluorobiphenyl (S)	68	%		32-108		SW846 8270C	1/31/08	CAC	2/5/08 21:57	JAJ	F1
Terphenyl-d14 (S)	62	%		27-136		SW846 8270C	1/31/08	CAC	2/5/08 21:57	JAJ	F1
Phenol-d5 (S)	30	%		10-49		SW846 8270C	1/31/08	CAC	2/5/08 21:57	JAJ	F1

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653002** Date Collected: 1/25/2008 11:27 Matrix: Water

Sample ID: **OW1I-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Nitrobenzene-d5 (S)	72	%		31-110		SW846 8270C	1/31/08	CAC	2/5/08 21:57	JAJ	F1
2-Fluorophenol (S)	46	%		20-70		SW846 8270C	1/31/08	CAC	2/5/08 21:57	JAJ	F1
LIGHT HYDROCARBON GASES											
Ethane	1J	ug/L		3.0	0.4	RSK 175			2/6/08 14:07	ELC	H
Ethene	9.5	ug/L		3.0	0.4	RSK 175			2/6/08 14:07	ELC	H
Methane	3530	ug/L		1.0	0.5	RSK 175			2/6/08 14:07	ELC	H
WET CHEMISTRY											
Chloride	60.8	mg/L		2.0	0.2	EPA 300			1/26/08 08:58	JEP	K
Nitrate-N	0.10J	mg/L		0.20	0.02	EPA 300			1/26/08 08:58	JEP	K
Nitrite-N	ND	mg/L	1	0.20	0.02	EPA 300			1/26/08 08:58	JEP	K
Sulfate	11.1	mg/L		2.0	0.2	EPA 300			1/26/08 08:58	JEP	K
Total Organic Carbon (TOC)	3.0	mg/L		1.0	0.2	415.1/5310B			2/1/08 08:00	PAG	J
METALS											
Antimony, Total	ND	mg/L		0.0020	0.00005	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Antimony, Dissolved	ND	mg/L		0.0020	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Arsenic, Total	0.0012J	mg/L		0.0060	0.0004	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Arsenic, Dissolved	ND	mg/L		0.0030	0.0007	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Barium, Total	0.0561	mg/L		0.0060	0.00005	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Barium, Dissolved	0.0512	mg/L		0.0050	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Beryllium, Total	0.0009J	mg/L		0.0010	0.00007	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Beryllium, Dissolved	0.0008J	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Cadmium, Total	0.0001J	mg/L		0.0010	0.00001	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Cadmium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Chromium, Total	ND	mg/L		0.0020		SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Chromium, Dissolved	0.0055	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Cobalt, Total	0.0875	mg/L		0.0060	0.00003	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Cobalt, Dissolved	0.0826	mg/L		0.0050	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Copper, Total	ND	mg/L		0.0060		SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Copper, Dissolved	0.0008J	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Lead, Total	0.0002J	mg/L		0.0020	0.00002	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 12:30	CMD	D2
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 14:38	CMD	E1
Molybdenum, Total	0.0001J	mg/L		0.0020	0.00001	SW846 6020	2/5/08	SRT	2/8/08 15:57	LAM	D1
Molybdenum, Dissolved	ND	mg/L		0.0020	0.0006	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Nickel, Total	0.0345	mg/L		0.0060	0.00006	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Nickel, Dissolved	0.0342	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Selenium, Total	0.004J	mg/L		0.006	0.001	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Selenium, Dissolved	ND	mg/L		0.005	0.001	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Silver, Total	0.0004J	mg/L		0.0010	0.00004	SW846 6020	2/5/08	SRT	2/8/08 15:57	LAM	D1
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3
Thallium, Total	0.00003J	mg/L		0.0010	0.00002	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Thallium, Dissolved	ND	mg/L		0.0010	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653002** Date Collected: 1/25/2008 11:27 Matrix: Water

Sample ID: **OW1I-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Vanadium, Total	0.0007J	mg/L		0.0010	0.00003	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Vanadium, Dissolved	0.0009J	mg/L		0.0010	0.00002	SW846 6020	2/4/08	AJB	2/5/08 13:16	AJB	D3
Zinc, Total	0.0384	mg/L		0.0060	0.002	SW846 6020	2/5/08	SRT	2/7/08 18:02	LAM	D1
Zinc, Dissolved	0.0357	mg/L		0.0050	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:19	AJB	D3

Sample Comments:

A dilution of the GCMS volatiles analysis was performed outside of the holding time because one or more of the analytes exceeded the calibration range in the initial analysis.

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653003** Date Collected: 1/25/2008 14:44 Matrix: Water

Sample ID: **OW1D-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,1,1-Trichloroethane	0.86J	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,1-Dichloroethane	34.4	ug/L		1.0	0.1	SW846 8260B			2/8/08 04:41	JAJ	A
1,1-Dichloroethene	253	ug/L		50.0	10	SW846 8260B			2/11/08 14:09	JAH	B
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/8/08 04:41	JAJ	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 04:41	JAJ	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 04:41	JAJ	A
1,2,4-Trimethylbenzene	2.3	ug/L		1.0	0.4	SW846 8260B			2/8/08 04:41	JAJ	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/8/08 04:41	JAJ	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,2-Dichloroethane	0.53J	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/8/08 04:41	JAJ	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/8/08 04:41	JAJ	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/8/08 04:41	JAJ	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/8/08 04:41	JAJ	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/8/08 04:41	JAJ	A
Benzene	2.8	ug/L		1.0	0.4	SW846 8260B			2/8/08 04:41	JAJ	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Carbon Disulfide	0.12J	ug/L		1.0	0.1	SW846 8260B			2/8/08 04:41	JAJ	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
Chloroform	3.6	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Dichlorofluoromethane	0.49J	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 04:41	JAJ	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 04:41	JAJ	A
Ethylbenzene	0.47J	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653003** Date Collected: 1/25/2008 14:44 Matrix: Water

Sample ID: **OW1D-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/8/08 04:41	JAJ	A
Isopropylbenzene	0.66J	ug/L		1.0	0.1	SW846 8260B			2/8/08 04:41	JAJ	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Methylene Chloride	0.81J	ug/L		1.0	0.1	SW846 8260B			2/8/08 04:41	JAJ	A
Naphthalene	3.4	ug/L		2.0	0.6	SW846 8260B			2/8/08 04:41	JAJ	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Tetrachloroethene	12.3	ug/L		1.0	0.4	SW846 8260B			2/8/08 04:41	JAJ	A
Toluene	2.5	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Total Xylenes	3.7	ug/L		3.0	0.4	SW846 8260B			2/8/08 04:41	JAJ	A
Trichloroethene	9370	ug/L		50.0	10	SW846 8260B			2/11/08 14:09	JAH	B
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/8/08 04:41	JAJ	A
Vinyl Chloride	81.1	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
cis-1,2-Dichloroethene	1740	ug/L		50.0	10	SW846 8260B			2/11/08 14:09	JAH	B
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
mp-Xylene	1.1J	ug/L		2.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/8/08 04:41	JAJ	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
o-Xylene	2.6	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 04:41	JAJ	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/8/08 04:41	JAJ	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/8/08 04:41	JAJ	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 04:41	JAJ	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/8/08 04:41	JAJ	A
trans-1,2-Dichloroethene	12.6	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 04:41	JAJ	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	103	%		62-133		SW846 8260B			2/8/08 04:41	JAJ	A
Toluene-d8 (S)	113	%		76-127		SW846 8260B			2/8/08 04:41	JAJ	A
4-Bromofluorobenzene (S)	102	%		79-114		SW846 8260B			2/8/08 04:41	JAJ	A
Dibromofluoromethane (S)	104	%		78-116		SW846 8260B			2/8/08 04:41	JAJ	A
1,2-Dichloroethane-d4 (S)	108	%		62-133		SW846 8260B			2/11/08 14:09	JAH	B
4-Bromofluorobenzene (S)	103	%		79-114		SW846 8260B			2/11/08 14:09	JAH	B
Toluene-d8 (S)	120	%		76-127		SW846 8260B			2/11/08 14:09	JAH	B
Dibromofluoromethane (S)	107	%		78-116		SW846 8260B			2/11/08 14:09	JAH	B
SEMIVOLATILES											
1,4-Dioxane	2.0J	ug/L		2.9	0.6	SW846 8270C	1/31/08	CAC	2/5/08 23:36	JAJ	F1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	148	%	2	40-125		SW846 8270C	1/31/08	CAC	2/5/08 23:36	JAJ	F1
Nitrobenzene-d5 (S)	118	%	2	31-110		SW846 8270C	1/31/08	CAC	2/5/08 23:36	JAJ	F1
Phenol-d5 (S)	48	%		10-49		SW846 8270C	1/31/08	CAC	2/5/08 23:36	JAJ	F1
Terphenyl-d14 (S)	118	%		27-136		SW846 8270C	1/31/08	CAC	2/5/08 23:36	JAJ	F1

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653003** Date Collected: 1/25/2008 14:44 Matrix: Water

Sample ID: **OW1D-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
2-Fluorobiphenyl (S)	109	%	2	32-108		SW846 8270C	1/31/08	CAC	2/5/08 23:36	JAJ	F1
2-Fluorophenol (S)	74	%	2	20-70		SW846 8270C	1/31/08	CAC	2/5/08 23:36	JAJ	F1
LIGHT HYDROCARBON GASES											
Ethane	21.1	ug/L		3.0	0.4	RSK 175			2/6/08 14:18	ELC	H
Ethene	80.4	ug/L		3.0	0.4	RSK 175			2/6/08 14:18	ELC	H
Methane	634	ug/L		1.0	0.5	RSK 175			2/6/08 14:18	ELC	H
WET CHEMISTRY											
Chloride	60.2	mg/L		2.0	0.2	EPA 300			1/26/08 11:56	JEP	K
Nitrate-N	ND	mg/L		0.20	0.02	EPA 300			1/26/08 11:56	JEP	K
Nitrite-N	ND	mg/L		0.20	0.02	EPA 300			1/26/08 11:56	JEP	K
Sulfate	43.1	mg/L		2.0	0.2	EPA 300			1/26/08 11:56	JEP	K
Total Organic Carbon (TOC)	3.1	mg/L		1.0	0.2	415.1/5310B			2/1/08 08:00	PAG	J
METALS											
Antimony, Total	0.0007J	mg/L		0.0020	0.00005	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Antimony, Dissolved	ND	mg/L		0.0020	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Arsenic, Total	0.0007J	mg/L		0.0060	0.0004	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Arsenic, Dissolved	ND	mg/L		0.0030	0.0007	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Barium, Total	0.111	mg/L		0.0060	0.00005	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Barium, Dissolved	0.123	mg/L		0.0050	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Beryllium, Total	ND	mg/L		0.0010	0.00007	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Beryllium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Cadmium, Total	0.00009J	mg/L		0.0010	0.00001	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Cadmium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Chromium, Total	ND	mg/L		0.0020		SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Chromium, Dissolved	0.0041	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Cobalt, Total	0.0298	mg/L		0.0060	0.00003	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Cobalt, Dissolved	0.0505	mg/L		0.0050	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Copper, Total	ND	mg/L		0.0060		SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Copper, Dissolved	ND	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Lead, Total	0.00006J	mg/L		0.0020	0.00002	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 12:34	CMD	D2
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 14:42	CMD	E1
Molybdenum, Total	0.0021	mg/L		0.0020	0.00001	SW846 6020	2/5/08	SRT	2/8/08 16:00	LAM	D1
Molybdenum, Dissolved	ND	mg/L		0.0020	0.0006	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Nickel, Total	0.0167	mg/L		0.0060	0.00006	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Nickel, Dissolved	0.0272	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Selenium, Total	0.002J	mg/L		0.006	0.001	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Selenium, Dissolved	ND	mg/L		0.005	0.001	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Silver, Total	0.0004J	mg/L		0.0010	0.00004	SW846 6020	2/5/08	SRT	2/8/08 16:00	LAM	D1
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3
Thallium, Total	ND	mg/L		0.0010	0.00002	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Thallium, Dissolved	ND	mg/L		0.0010	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653003** Date Collected: 1/25/2008 14:44 Matrix: Water

Sample ID: **OW1D-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Vanadium, Total	0.0004J	mg/L		0.0010	0.00003	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Vanadium, Dissolved	0.0002J	mg/L		0.0010	0.00002	SW846 6020	2/4/08	AJB	2/5/08 13:20	AJB	D3
Zinc, Total	0.0260	mg/L		0.0060	0.002	SW846 6020	2/5/08	SRT	2/7/08 18:07	LAM	D1
Zinc, Dissolved	0.0145	mg/L		0.0050	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:28	AJB	D3

Sample Comments:

In the 8270 analysis, the surrogate recovery was bias high in this sample. The sample duplicate had acceptable recovery for the same surrogates. Data was similar.

A dilution of the GCMS volatiles analysis was performed outside of the holding time because one or more of the analytes exceeded the calibration range in the initial analysis.

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653004** Date Collected: 1/25/2008 00:00 Matrix: Water

Sample ID: **OW-DUP-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
VOLATILE ORGANICS											
1,1,1,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,1,1-Trichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,1,2,2-Tetrachloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,1-Dichloroethane	0.65J	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:21	JAJ	A
1,1-Dichloroethene	0.51J	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,1-Dichloropropene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
1,2,3-Trichlorobenzene	ND	ug/L		2.0	0.6	SW846 8260B			2/8/08 02:21	JAJ	A
1,2,3-Trichloropropane	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 02:21	JAJ	A
1,2,4-Trichlorobenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 02:21	JAJ	A
1,2,4-Trimethylbenzene	ND	ug/L		1.0	0.4	SW846 8260B			2/8/08 02:21	JAJ	A
1,2-Dibromo-3-chloropropane	ND	ug/L		7.0	2	SW846 8260B			2/8/08 02:21	JAJ	A
1,2-Dibromoethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
1,2-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,2-Dichloroethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,3,5-Trimethylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,3-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,3-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
1,4-Dichlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
2,2-Dichloropropane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
2-Butanone	ND	ug/L		10.0	3	SW846 8260B			2/8/08 02:21	JAJ	A
2-Chloroethylvinyl ether	ND	ug/L		3.0	1	SW846 8260B			2/8/08 02:21	JAJ	A
2-Hexanone	ND	ug/L		5.0	0.7	SW846 8260B			2/8/08 02:21	JAJ	A
4-Methyl-2-Pentanone(MIBK)	ND	ug/L		5.0	1	SW846 8260B			2/8/08 02:21	JAJ	A
Acetone	ND	ug/L		10.0	4	SW846 8260B			2/8/08 02:21	JAJ	A
Benzene	ND	ug/L		1.0	0.4	SW846 8260B			2/8/08 02:21	JAJ	A
Bromobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Bromochloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Bromodichloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Bromoform	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Bromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Carbon Disulfide	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:21	JAJ	A
Carbon Tetrachloride	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Chlorobenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Chlorodibromomethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Chloroethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
Chloroform	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Chloromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Dibromomethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
Dichlorodifluoromethane	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Dichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
Diisopropyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:21	JAJ	A
Ethyl tert-butyl ether	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:21	JAJ	A
Ethylbenzene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653004** Date Collected: 1/25/2008 00:00 Matrix: Water

Sample ID: **OW-DUP-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Freon 113	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Hexachlorobutadiene	ND	ug/L		5.0	2	SW846 8260B			2/8/08 02:21	JAJ	A
Isopropylbenzene	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:21	JAJ	A
Methyl t-Butyl Ether	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Methylene Chloride	ND	ug/L		1.0	0.1	SW846 8260B			2/8/08 02:21	JAJ	A
Naphthalene	ND	ug/L		2.0	0.6	SW846 8260B			2/8/08 02:21	JAJ	A
Styrene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Tetrachloroethene	ND	ug/L		1.0	0.4	SW846 8260B			2/8/08 02:21	JAJ	A
Toluene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Total Xylenes	ND	ug/L		3.0	0.4	SW846 8260B			2/8/08 02:21	JAJ	A
Trichloroethene	2.0	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Trichlorofluoromethane	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
Vinyl Acetate	ND	ug/L		5.0	2	SW846 8260B			2/8/08 02:21	JAJ	A
Vinyl Chloride	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
cis-1,2-Dichloroethene	1.4	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
cis-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
mp-Xylene	ND	ug/L		2.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
n-Butylbenzene	ND	ug/L		1.0	0.5	SW846 8260B			2/8/08 02:21	JAJ	A
n-Propylbenzene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
o-Chlorotoluene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
o-Xylene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
p-Chlorotoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
p-Isopropyltoluene	ND	ug/L		1.0	0.3	SW846 8260B			2/8/08 02:21	JAJ	A
sec-Butylbenzene	ND	ug/L		2.0	0.8	SW846 8260B			2/8/08 02:21	JAJ	A
tert-Amyl methyl ether	ND	ug/L		2.0	0.8	SW846 8260B			2/8/08 02:21	JAJ	A
tert-Butylbenzene	ND	ug/L		2.0	0.7	SW846 8260B			2/8/08 02:21	JAJ	A
tert.- Butyl Alcohol	ND	ug/L		10	3	SW846 8260B			2/8/08 02:21	JAJ	A
trans-1,2-Dichloroethene	0.21J	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
trans-1,3-Dichloropropene	ND	ug/L		1.0	0.2	SW846 8260B			2/8/08 02:21	JAJ	A
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
1,2-Dichloroethane-d4 (S)	105	%		62-133		SW846 8260B			2/8/08 02:21	JAJ	A
Toluene-d8 (S)	118	%		76-127		SW846 8260B			2/8/08 02:21	JAJ	A
Dibromofluoromethane (S)	103	%		78-116		SW846 8260B			2/8/08 02:21	JAJ	A
4-Bromofluorobenzene (S)	102	%		79-114		SW846 8260B			2/8/08 02:21	JAJ	A

SEMIVOLATILES

1,4-Dioxane	1J	ug/L		2.9	0.6	SW846 8270C	1/31/08	CAC	2/5/08 21:07	JAJ	F1
Surrogate Recoveries	*Results*	*Units*	*Footnotes*	*Limits*		*Method*	*Prepared*	*By*	*Analyzed*	*By*	*Cntr*
2,4,6-Tribromophenol (S)	84	%		40-125		SW846 8270C	1/31/08	CAC	2/5/08 21:07	JAJ	F1
Phenol-d5 (S)	28	%		10-49		SW846 8270C	1/31/08	CAC	2/5/08 21:07	JAJ	F1
Terphenyl-d14 (S)	68	%		27-136		SW846 8270C	1/31/08	CAC	2/5/08 21:07	JAJ	F1
Nitrobenzene-d5 (S)	72	%		31-110		SW846 8270C	1/31/08	CAC	2/5/08 21:07	JAJ	F1
2-Fluorobiphenyl (S)	65	%		32-108		SW846 8270C	1/31/08	CAC	2/5/08 21:07	JAJ	F1
2-Fluorophenol (S)	46	%		20-70		SW846 8270C	1/31/08	CAC	2/5/08 21:07	JAJ	F1

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653004** Date Collected: 1/25/2008 00:00 Matrix: Water

Sample ID: **OW-DUP-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
LIGHT HYDROCARBON GASES											
Ethane	ND	ug/L		3.0	0.4	RSK 175			2/6/08 14:27	ELC	H
Ethene	ND	ug/L		3.0	0.4	RSK 175			2/6/08 14:27	ELC	H
Methane	9.7	ug/L		1.0	0.5	RSK 175			2/6/08 14:27	ELC	H
WET CHEMISTRY											
Chloride	282	mg/L		5.0	0.5	EPA 300			1/29/08 02:59	JEP	K
Nitrate-N	0.60	mg/L		0.20	0.02	EPA 300			1/26/08 05:47	JEP	K
Nitrite-N	ND	mg/L		0.20	0.02	EPA 300			1/26/08 05:47	JEP	K
Sulfate	126	mg/L		2.0	0.2	EPA 300			1/26/08 05:47	JEP	K
Total Organic Carbon (TOC)	3.5	mg/L		1.0	0.2	415.1/5310B			2/6/08 08:00	PAG	J
METALS											
Antimony, Total	0.00009J	mg/L		0.0020	0.00005	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Antimony, Dissolved	ND	mg/L		0.0020	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Arsenic, Total	0.0004J	mg/L		0.0060	0.0004	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Arsenic, Dissolved	ND	mg/L		0.0030	0.0007	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Barium, Total	0.0443	mg/L		0.0060	0.00005	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Barium, Dissolved	0.0435	mg/L		0.0050	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Beryllium, Total	0.0012	mg/L		0.0010	0.00007	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Beryllium, Dissolved	0.0013	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Cadmium, Total	0.0001J	mg/L		0.0010	0.00001	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Cadmium, Dissolved	ND	mg/L		0.0010	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Chromium, Total	ND	mg/L		0.0020		SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Chromium, Dissolved	0.0088	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Cobalt, Total	0.0463	mg/L		0.0060	0.00003	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Cobalt, Dissolved	0.0466	mg/L		0.0050	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Copper, Total	ND	mg/L		0.0060		SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Copper, Dissolved	0.0029J	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Lead, Total	ND	mg/L		0.0020	0.00002	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Lead, Dissolved	ND	mg/L		0.0020	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Mercury, Total	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 12:37	CMD	D2
Mercury, Dissolved	ND	mg/L		0.0005		SW846 7470A	2/5/08	CMD	2/5/08 14:45	CMD	E1
Molybdenum, Total	0.0001J	mg/L		0.0020	0.00001	SW846 6020	2/5/08	SRT	2/8/08 16:03	LAM	D1
Molybdenum, Dissolved	ND	mg/L		0.0020	0.0006	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Nickel, Total	0.0218	mg/L		0.0060	0.00006	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Nickel, Dissolved	0.0220	mg/L		0.0050	0.0004	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Selenium, Total	0.004J	mg/L		0.006	0.001	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Selenium, Dissolved	0.004J	mg/L		0.005	0.001	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Silver, Total	0.0004J	mg/L		0.0010	0.00004	SW846 6020	2/5/08	SRT	2/8/08 16:03	LAM	D1
Silver, Dissolved	ND	mg/L		0.0010	0.0003	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Thallium, Total	0.0001J	mg/L		0.0010	0.00002	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Thallium, Dissolved	ND	mg/L		0.0010	0.0001	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3
Vanadium, Total	ND	mg/L		0.0010	0.00003	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1
Vanadium, Dissolved	0.0018	mg/L		0.0010	0.00002	SW846 6020	2/4/08	AJB	2/5/08 13:23	AJB	D3
Zinc, Total	0.0282	mg/L		0.0060	0.002	SW846 6020	2/5/08	SRT	2/7/08 18:12	LAM	D1

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ANALYTICAL RESULTS

Workorder: 9720653 TGG001|MSA January 2008

Lab ID: **9720653004** Date Collected: 1/25/2008 00:00 Matrix: Water

Sample ID: **OW-DUP-012508** Date Received: 1/25/2008 19:20

Parameters	Results	Units	Footnotes	RDL	MDL	Method	Prepared	By	Analyzed	By	Cntr
Zinc, Dissolved	0.0262	mg/L		0.0050	0.0002	SW846 6020	2/4/08	AJB	2/4/08 19:37	AJB	D3

Sample Comments:

Raymond J. Martrano
Laboratory Manager

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ANALYTICAL RESULTS QUALIFIERS\FLAGS

Workorder: 9720653 TGG001|MSA January 2008

PARAMETER QUALIFIERS\FLAGS

[1] The recovery of the Matrix Spike (MS) associated to this analyte was outside of the established control limits.

[2] The surrogate recovery was outside of the established control limits.

Report ID: 9720653

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CHAIN OF CUSTODY/ REQUEST FOR ANALYSIS

ALL SHADED AREAS MUST BE COMPLETED BY THE CLIENT / SAMPLER. INSTRUCTIONS ON THE BACK.

Courier:

Tracking #:

9720653

Co. Name: Tetra Tech NUS

Contact (Report to): Mike Martin Phone: (301) 528-3022

Address: 20251 Century Blvd STE 200
Germantown, MD 20874

Bill to (If different than Report to): PO#:

Project Name/#: MRC ALSI Quote #:

TAT: Normal-Standard TAT is 10-12 business days. Date Required:
Rush-Subject to ALSI approval and surcharges. Approved By:

Email? -Y

Fax? -Y No.:

Sample Description/Location (as it will appear on the lab report)	COC Comments	Sample Date	Military Time	*G or C	**Matrix	***Container Type	***Container Size	*** Preservative	VOCs	Total PP metal	Diss PP metal	1,4 Dioxane	RSK-175	TOC	chloride, Sulfide w/ tenty, nitrate	> Arsd per SW Approved by Tony Stramaccia via email 6/8 01/28/08	Enter Number of Containers Per Analysis
1 TB 012508	Do not receive	1-25-08	0000	G	W	Glass	40 ml	HCl	X								
2 OW6S-012508			1418	G	W	Poly	500ml	HNO3	X2	X	1X	2X	2X	1X	1X		MLM 1/28/08
3 OWIII-012508	Bottles labeled 1B not 1I		1127	G	W	Poly	500ml	HNO3	X2	1X	1X	2X	2X	1X	1X		
4 OW20-012508	bottles labeled 1C not 1I		1444	G	W	Amber	1L	ICE	X2	1X	1X	2X	2X	1X	1X		
5 OW-DUP-012508	MLM 1/28/08	1b	0000	G	W	Glass	40ml	HCl	X2	1X	1X	2X	2X	1X	1X		
6						Amber	125ml	HCl									
7 *Bottles labeled "B" are the same locations as corresponding bottles labeled "I".						Poly	250ml	ICE									
8																	

Receipt Information (Logged in by Sample Receiver)
Performed by: INITIAL HERE
Cooler Temp: 2
Therm. ID: 510725
No. of Coolers:
Notes:

	Correct containers?	Correct sample volume?	Correct preservation?	Headspace/Volatiles?	Circle appropriate Y or N.
	N	N	N	Y	
	X	X	X	X	
	X	N	N	N	N
	Y	N	N	N	Y

	Custody seals Present?	(if present) Seals intact?	Received on ice?	COC/Labels complete/accurate?	Container in good condition?
	Y	Y	X	X	X

SAMPLED BY (Please Print): Matt Payon

LOGGED BY(signature): DATE 1-25-08 TIME 1430

REVIEWED BY(signature): DATE 01/28/08 TIME 1448

Relinquished By / Company Name	Date	Time	Received By / Company Name	Date	Time
1 Matt Payon TTNUS	1-25-08	1430	2	1/25/08	1630
3	1/28/08	1754	4 DNC 1-26-08		1800
5 DNC 1-25-08		1920	6	1/28/08	1920
7			8		
9			10		

Data Deliverables: Standard; CLP-like; NJ-Reduced; NJ-Full; EDDs Required? If yes, format type:

SDWA Forms? yes yes yes yes

State Samples Collected In? MD NJ NY PA

Other

DOD Criteria Required?

ALSI FIELD SERVICES: Pickup; Labor; Composite Sampling; Rental Equipment; Other:

* G=Grab; C=Composite **Matrix: AI=Air; DW=Drinking Water; GW=Groundwater; OI=Oil; OL=Other Liquid; SL=Sludge; SO=Soil; WP=Wipe; WW=Wastewater

Copies: WHITE - ORIGINAL CANARY - CUSTOMER COPY ***Container Type: AG-Amber Glass; CG-Clear Glass, PL-Plastic. Container Size: 250ml, 500ml, 1L, 8oz., etc. Preservative: HCl, HNO3, NaOH, etc.

Rev 6/07

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APPENDIX D

VIRONEX FIELD REPORT

Injection Services Report

TETRA TECH

June 24, 2008

"Bringing Chemistry and Contaminants Together"
For the Consulting Community

"Expect Performance"

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1-800-VIRONEX

INJECTION SUMMARY

Date		Injection Points Completed	Volume of Water Injected (gal)	Volume of Persulfate Injected (gal)	Volume of Peroxide Injected (gal)	Total Volume Injected (gal)
Monday	6/16/2008	Shakedown Day				
Tuesday	6/17/2008	3	459	218		677
Wednesday	6/18/2008	2		324		324
Thursday	6/19/2008	4		439	226	665
Friday	6/20/2008	2			385	385
Totals		11	459	981	611	2051



Installing the Wavefront Hornet Unit onto the DPT Rod Set



Injection Tool



Injection Using Inner Hose Method



Remediation Truck and Secondary Containment



Water Truck



Surfacing From Well OW-6 During Peroxide Injection



Surfacing From Well OW-6 During Peroxide Injection



Surfacing From Well OW-6 During Peroxide Injection



Surfacing From Well OW-6 During Peroxide Injection

NA	Klozur per point (lbs)
250.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

WATER TEST INJECTION FIELD LOG (USING HORNET)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-A	16-Jun	3:25 PM	3:33 PM	Air Diaphragm	35-34	10	2.3	9	Flow meter clogged, cleaned and re-installed
		3:33 PM	3:35 PM	Air Diaphragm	34-33	10	2.7	16	
		3:35 PM	3:39 PM	Air Diaphragm	33-32	10	2.0	27	Changed out pressure gauge on remediation rig
		3:58 PM	4:06 PM	Air Diaphragm	32-31	23	2.5	36	
	17-Jun	8:00 AM	8:01 AM	Moyno	31-30	40	4.3	45	Tool possibly plugged, switch to Moyno to open screen and formation
		8:16 AM	8:25 AM	Moyno	30-29	35	4.3	54	P = 30 psi at gauge before Hornet
		8:25 AM	8:26 AM	Moyno	29-28	35	7.2	63	
		8:26 AM	8:28 AM	Moyno	28-27	35	7.4	72	Break rods to remove Hornet
		8:47 AM	8:48 AM	Moyno	27-26	35	7.5	81	
		8:48 AM	8:49 AM	Moyno	26-25	35	7.3	90	
		8:49 AM	8:50 AM	Moyno	25-24	33	7.5	99	
		8:50 AM	8:52 AM	Moyno	24-23	33	7.5	108	Break rods
		9:08 AM	9:11 AM	Air Diaphragm	23-22	15	2.8	117	Switched back to AD pumps to better flow control
		9:11 AM	9:15 AM	Air Diaphragm	22-21	18	2.9	126	
		9:15 AM	9:18 AM	Air Diaphragm	21-20	25	2.8	135	Break rods
		9:38 AM	9:40 AM	Air Diaphragm	20-19	23	2.8	144	
		9:40 AM	9:43 AM	Air Diaphragm	19-18	22	3.1	153	
		9:43 AM	9:46 AM	Air Diaphragm	18-17	35	3.1	162	
		9:46 AM	9:49 AM	Air Diaphragm	17-16	21	3.1	171	Break rods
		10:07 AM	10:10 AM	Air Diaphragm	16-15	25	2.9	180	

NA	Klozur per point (lbs)
250.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

WATER TEST INJECTION FIELD LOG (USING HORNET)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-A	17-Jun	10:10 AM	10:14 AM	Air Diaphragm	15-14	18	2.6	189	
		10:14 AM	10:17 AM	Air Diaphragm	14-13	17	2.7	198	Water level at nearby well almost at surface (SCI = 20'-30')
		10:17 AM	10:20 AM	Air Diaphragm	13-12	17	2.8	207	Break rods
		10:30 AM	10:33 AM	Air Diaphragm	12-11	11	2.7	216	
		10:33 AM	10:36 AM	Air Diaphragm	11-10	8	2.4	225	
		10:36 AM	10:42 AM	Air Diaphragm	10-9	6	2.1	234	
		10:42 AM	10:45 AM	Air Diaphragm	9-8	8	2.1	243	Break rods
		10:53 AM	10:55 AM	Air Diaphragm	8-7	9	2.7	252	
		10:55 AM	10:58 AM	Air Diaphragm	7-6	10	3.1	261	
		10:58 AM	11:00 AM	Air Diaphragm	6-5	10	3	270	
		11:00 AM	11:02 AM	Air Diaphragm	5-4	18	2.7	276	Surfaced around annulus
					4-3				Note: Flow meters re-calibrated in field after this point
					Averages	**21**	**3.7**	**276**	**Total Mixture Injected**

NA	Klozur per point (lbs)
250.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

WATER TEST INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-B	17-Jun	11:49 AM	12:08 PM	Moyno	35-34	160	3.9	9	Pressure at 160 psi to start and open formation
		12:08 PM	12:13 PM	Moyno	34-33	42	3.3	18	
		12:13 PM	12:17 PM	Moyno	33-32	30	1.5	27	
		12:17 PM	12:20 PM	Moyno	32-31	40	2.4	36	
		12:20 PM	12:24 PM	Moyno	31-30	40	2.4	45	
		12:24 PM	12:27 PM	Moyno	30-29	41	2.6	54	
		12:27 PM	12:30 PM	Moyno	29-28	37	2.1	63	Surfacing out of MW-70B
		12:30 PM	12:34 PM	Moyno	28-27	38	2.6	72	
		12:34 PM	12:37 PM	Moyno	27-26	38	2.7	81	
		12:37 PM	12:41 PM	Moyno	26-25	37	2.4	90	
		12:41 PM	12:44 PM	Moyno	25-24	37	2.4	99	
					24-23				Pulled through zone to get above screened interval
					23-22				
					22-21				
					21-20				
					20-19				
					19-18				
		12:44 PM	12:49 PM	Moyno	18-17	36	2.2	108	
		12:49 PM	12:52 PM	Moyno	17-16	35	2.6	117	
		12:52 PM	12:56 PM	Moyno	16-15	30	2.7	126	

NA	Klozur per point (lbs)
250.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

WATER TEST INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-B	17-Jun	12:56 PM	1:00 PM	Moyno	15-14	35	2.6	135	34 psi at injection rod connection
		1:00 PM	1:03 PM	Moyno	14-13	36	2.5	144	
		1:03 PM	1:06 PM	Moyno	13-12	35	2.9	153	
		1:06 PM	1:08 PM	Moyno	12-11	34	3.1	162	
		1:08 PM	1:11 PM	Moyno	11-10	32	3.6	171	
		1:11 PM	1:14 PM	Moyno	10-9	35	2.9	180	
		1:14 PM	1:15 PM	Moyno	9-8	35	3.0	183	Surfacing at well MW-70A
					8-7				
					7-6				
					6-5				
					5-4				
					4-3				
				Averages		42	2.7	183	Total Mixture Injected

475.0	Klozur per point (lbs)
230.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-1	18-Jun	9:53 AM	9:56 AM	Moyno	35-34	21	1.8	10	Hose came off of down hole barb, re-attached fitting and re-drilled. 7 gal of water to begin point before switching to persulfate.
		9:56 AM	9:59 AM	Moyno	34-33	30	2.4	20	
		9:59 AM	10:02 AM	Moyno	33-32	30	2.5	29	
		10:02 AM	10:05 AM	Moyno	32-31	30	2.6	39	
		10:05 AM	10:08 AM	Moyno	31-30	30	2.5	49	
		10:08 AM	10:11 AM	Moyno	30-29	30	2.7	59	Backed flow rate down to < 2 gpm due to water level rise in nearby wells
		10:11 AM	10:16 AM	Moyno	29-28	20	1.7	68	
		10:16 AM	10:23 AM	Moyno	28-27	20	1.3	78	
		10:23 AM	10:26 AM	Moyno	27-26	21	1.2	88	
		10:26 AM	10:29 AM	Moyno	26-25	20	2.2	98	
		10:29 AM	10:34 AM	Moyno	25-24	21	2.1	107	
		10:34 AM	10:37 AM	Moyno	24-23	20	2.1	117	Well levels stabilized
		10:37 AM	10:41 AM	Moyno	23-22	20	2.1	127	
		10:41 AM	10:45 AM	Moyno	22-21	21	2.1	137	
		10:45 AM	10:48 AM	Moyno	21-20	21	2.1	146	
		10:48 AM	10:52 AM	Moyno	20-19	21	2.1	156	
		10:52 AM	10:56 AM	Moyno	19-18	21	2.2	166	
		10:56 AM	10:59 AM	Moyno	18-17	21	2.1	176	
		10:59 AM	11:03 AM	Moyno	17-16	21	2.1	185	
		11:03 AM	11:07 AM	Moyno	16-15	21	2.1	195	

475.0	Klozur per point (lbs)
230.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-1	18-Jun	11:07 AM	11:10 AM	Moyno	15-14	21	2.1	158	
		11:10 AM	11:14 AM	Moyno	14-13	21	1.9	215	
		11:14 AM	1:16 AM	Moyno	13-12	22	2.0	220	Lowered to 4 gal/ft to limit material surfacing
		1:16 AM	11:18 AM	Moyno	12-11	22	1.9	225	
		11:18 AM	11:20 AM	Moyno	11-10	22	1.9	230	
		11:20 AM	11:23 AM	Moyno	10-9	22	2.2	235	
		11:23 AM	11:25 AM	Moyno	9-8	20	2.1	239	Injection halted due to surfacing around annulus
					8-7				
					7-6				
					6-5				
					5-4				
					4-3				
				Averages		22.6	2.1	239	Total Mixture Injected

475.0	Klozur per point (lbs) - Calculated
230.0	Water per point (gal) - Calculated
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING HORNET)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-2	18-Jun	3:31 PM	3:37 PM	Air Diaphragm	35-34	34	2.9	8	9 gal of water to pressurize the system
		3:37 PM	3:44 PM	Air Diaphragm	34-33	38	1.7	16	Break rods, 15 gal of water to flush system (2 gpm)
		3:55 PM	3:58 PM	Air Diaphragm	33-32	37	2.0	22	Wait for pressure to subside, start back up at 1 gpm
		3:58 PM	4:02 PM	Air Diaphragm	32-31	42	1.7	30	
		4:02 PM	4:15 PM	Air Diaphragm	31-30	40	1.8	38	Break rods, 15 gal of water to flush
		4:31 PM	4:34 PM	Air Diaphragm	30-29	10	1.8	44	Wait for pressure to subside, surfacing out of well 14B
					29-28				Pulled through this zone
		4:34 PM	4:40 PM	Air Diaphragm	28-27	28	2.0	60	Break rods, 15 gal of water to flush
					27-26				Pulled through multiple zones to try to get surfacing to subside
					26-25				
					25-24				
					24-23				
		5:16 PM	5:23 PM	Air Diaphragm	23-22	20	1.2	72	Continuing to surface through 14B
		5:23 PM	5:24 PM	Air Diaphragm	22-21	10	4.3	74	
		5:24 PM	5:28 PM	Air Diaphragm	21-20	5	1.2	81	
		5:29 PM	5:31 PM	Air Diaphragm	20-19	20	1.0	83	
		5:31 PM	5:36 PM	Air Diaphragm	19-18	17	1.0	85	Surfacing continuing, point called complete
					18-17				
					17-16				
					Averages	**25.1**	**1.9**	**85**	**Total Mixture Injected**

475.0	Klozur per point (lbs)
230.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-3A	17-Jun	4:10 PM	4:12 PM	Moyno	35-34	140	2.4	8	Pressure at 140 psi to start and open formation
		4:12 PM	4:14 PM	Moyno	34-33	30	1.7	16	
		4:14 PM	4:16 PM	Moyno	33-32	40	2.4	24	
		4:16 PM	4:19 PM	Moyno	32-31	50	3.6	32	
		4:19 PM	4:21 PM	Moyno	31-30	45	3.5	40	
		4:21 PM	4:24 PM	Moyno	30-29	46	3.2	48	Starting to influence nearest well
		4:24 PM	4:26 PM	Moyno	29-28	43	3.3	54	
		4:26 PM	4:29 PM	Moyno	28-27	45	3.5	64	
		4:29 PM	4:31 PM	Moyno	27-26	50	3.3	72	
		4:31 PM	4:34 PM	Moyno	26-25	50	3.4	81	
		4:34 PM	4:36 PM	Moyno	25-24	42	3.8	89	
		4:36 PM	4:38 PM	Moyno	24-23	42	4.0	97	
		4:38 PM	4:40 PM	Moyno	23-22	42	3.9	105	
		4:40 PM	4:44 PM	Moyno	22-21	41	1.4	113	
		4:44 PM	4:46 PM	Moyno	21-20	41	4.2	121	
		4:46 PM	4:48 PM	Moyno	20-19	42	4.1	129	
		4:48 PM	4:50 PM	Moyno	19-18	44	3.4	137	Capped both intermediate and shallow wells (OW-6)
		4:50 PM	4:52 PM	Moyno	18-17	42	4.1	145	
		4:52 PM	4:54 PM	Moyno	17-16	41	3.9	153	
		4:54 PM	4:56 PM	Moyno	16-15	40	4.4	162	

475.0	Klozur per point (lbs)
230.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-3A	17-Jun	4:56 PM	4:58 PM	Moyno	15-14	41	4.0	170	
		4:58 PM	5:00 PM	Moyno	14-13	40	4.3	178	
		5:00 PM	5:02 PM	Moyno	13-12	40	4.5	186	
		5:02 PM	5:05 PM	Moyno	12-11	20	2.7	194	
		5:05 PM	5:08 PM	Moyno	11-10	22	2.7	202	
		5:08 PM	5:12 PM	Moyno	10-9	20	1.0	210	
		5:12 PM	5:15 PM	Moyno	9-8	20	1.1	218	Surfaced up well OW-6, Point Complete
					8-7				
					7-6				
					6-5				
					5-4				
					4-3				
				Averages		**42.9**	**3.3**	**218**	**Total Mixture Injected**

110.0	Peroxide per point (gal)
330.0	Water per point (gal)
440.0	Total Volume (gal)
13.75	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

PEROXIDE INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-3B	19-Jun	4:45 PM	4:49 PM	Air Diaphragm	35-34	20	2.1	16	5 gal water flush to start points
		4:49 PM	4:57 PM	Air Diaphragm	34-33	38	1.7	31	4:52 - Surfacing at OW-6I, Gas bubbles present
		4:57 PM	5:06 PM	Air Diaphragm	33-32	30	1.8	47	
		5:06 PM	5:15 PM	Air Diaphragm	32-31	30	1.8	62	
		5:15 PM	5:23 PM	Air Diaphragm	31-30	30	2.0	73	5:10 - Surfacing at OW-5 and MW-14B; 5:14 - Surfacing at OW-4, OW-6 bubbling out of well
		5:23 PM	5:31 PM	Air Diaphragm	30-29	38	1.8	93	
		5:31 PM	5:39 PM	Air Diaphragm	29-28	38	1.8	109	
		5:39 PM	5:53 PM	Air Diaphragm	28-27	24	1.7	124	5:40 - OW-5 bubbling and surfacing out of vault
		5:53 PM	6:05 PM	Air Diaphragm	27-26	37	1.1	140	
					26-25				Pulled up to get out of screened interval of intermediate wells
					25-24				
					24-23				
		6:14 PM	6:19 PM	Air Diaphragm	23-22	30	1.4	156	
		6:19 PM	6:30 PM	Air Diaphragm	22-21	20	1.4	171	
		6:30 PM	6:39 PM	Air Diaphragm	21-20	20	1.2	187	
		6:39 PM	6:52 PM	Air Diaphragm	20-19	18	1.3	202	15 gal water flush
	20-Jun	9:00 AM	9:14 AM	Air Diaphragm	19-18	5	1.7	223	5 gal water to start, pressure rose to 15 psi before dropping to 5 psi
		9:14 AM	9:19 AM	Air Diaphragm	18-17	10	1.6	226	Surfacing at OW-5, 15 gal water flush and offset 20' to South (DPT-7)
					17-16				Note, surfacing continued for 25 min after injection ceased
					16-15				

475.0	Klozur per point (lbs)
230.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-4A	19-Jun	12:31 PM	12:33 PM	Air Diaphragm	35-34	35	2.7	8	5 gal water injected to start point
		12:33 PM	12:37 PM	Air Diaphragm	34-33	20	2.0	16	
		12:37 PM	12:43 PM	Air Diaphragm	33-32	18	1.8	24	
		12:43 PM	12:48 PM	Air Diaphragm	32-31	16	1.6	32	
		12:48 PM	12:54 PM	Air Diaphragm	31-30	22	1.9	40	
		12:54 PM	1:00 PM	Air Diaphragm	30-29	22	1.7	48	
		1:00 PM	1:06 PM	Air Diaphragm	29-28	22	1.9	56	
		1:06 PM	1:12 PM	Air Diaphragm	28-27	21	1.7	64	
		1:12 PM	1:18 PM	Air Diaphragm	27-26	22	1.9	72	
		1:18 PM	4:24 PM	Air Diaphragm	26-25	23	2.0	81	Increased flow rate per Mike M.
		4:24 PM	1:28 PM	Air Diaphragm	25-24	30	2.8	89	
		1:28 PM	1:31 PM	Air Diaphragm	24-23	30	2.8	98	
		1:31 PM	1:34 PM	Air Diaphragm	23-22	30	2.7	106	
		1:34 PM	1:39 PM	Air Diaphragm	22-21	32	2.6	114	
		1:39 PM	1:44 PM	Air Diaphragm	21-20	33	3.0	123	Note: Flow meter malfunctioned at 21-20' interval, remaining interval flow and volume estimated using time and gradations on mixing tote.
		1:44 PM	1:48 PM	Air Diaphragm	20-19	31	3.0	131	
		1:48 PM	2:03 PM	Air Diaphragm	19-18	38	3.0	140	
		2:03 PM	2:05 PM	Air Diaphragm	18-17	30	4.0	149	
		2:05 PM	2:07 PM	Air Diaphragm	17-16	30	4.0	158	
		2:07 PM	2:09 PM	Air Diaphragm	16-15	30	4.0	167	

475.0	Klozur per point (lbs)
230.0	Water per point (gal)
250.0	Total Volume (gal)
7.81	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-4A	19-Jun	2:09 PM	2:11 PM	Air Diaphragm	15-14	30	4.0	176	
		2:11 PM	2:13 PM	Air Diaphragm	14-13	30	4.0	183	
		2:13 PM	2:15 PM	Air Diaphragm	13-12	30	4.0	190	
		2:15 PM	2:17 PM	Air Diaphragm	12-11	28	4.0	197	
		2:17 PM	2:19 PM	Air Diaphragm	11-10	22	4.0	204	
		2:19 PM	2:21 PM	Air Diaphragm	10-9	24	4.0	211	
		2:21 PM	2:23 PM	Air Diaphragm	9-8	28	4.0	218	
		2:23 PM	2:24 PM	Air Diaphragm	8-7	22	4.0	228	Surfacing around annulus, point complete
					7-6				
					6-5				
					5-4				
					4-3				
				Averages		26.8	3.0	228	Total Mixture Injected

55.0	Peroxide per point (gal)
155.0	Water per point (gal)
210.0	Total Volume (gal)
6.56	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

PEROXIDE INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-4B	20-Jun	1:42 PM	1:45 PM	Air Diaphragm	35-34	38	2.7	12	6 gal flush, start at 2 gpm and 40 psi, dropped to 25 psi after 8 gal
		1:45 PM	1:50 PM	Air Diaphragm	34-33	28	2.5	24	
		1:50 PM	1:54 PM	Air Diaphragm	33-32	30	2.5	36	
		1:54 PM	1:59 PM	Air Diaphragm	32-31	30	2.7	48	
		1:59 PM	2:03 PM	Air Diaphragm	31-30	30	2.6	60	
		2:03 PM	2:07 PM	Air Diaphragm	30-29	30	2.5	70	
		2:07 PM	2:11 PM	Air Diaphragm	29-28	30	2.5	80	
		2:11 PM	2:16 PM	Air Diaphragm	28-27	32	2.5	90	
		2:16 PM	2:19 PM	Air Diaphragm	27-26	38	2.3	100	
		2:19 PM	2:22 PM	Air Diaphragm	26-25	24	2.6	106	
		2:22 PM	2:25 PM	Air Diaphragm	25-24	20	2.0	112	
		2:25 PM	2:27 PM	Air Diaphragm	24-23	20	2.0	118	
		2:27 PM	2:30 PM	Air Diaphragm	23-22	25	1.9	124	
		2:30 PM	2:34 PM	Air Diaphragm	22-21	22	2.1	131	
		2:34 PM	2:37 PM	Air Diaphragm	21-20	22	1.9	136	
		2:37 PM	2:45 PM	Air Diaphragm	20-19	25	1.9	150	
		2:45 PM	2:47 PM	Air Diaphragm	19-18	25	1.8	156	
		2:47 PM	2:51 PM	Air Diaphragm	18-17	21	1.9	162	
		2:51 PM	2:54 PM	Air Diaphragm	17-16	21	1.9	168	
		2:54 PM	2:57 PM	Air Diaphragm	16-15	20	2.0	174	

55.0	Peroxide per point (gal)
155.0	Water per point (gal)
210.0	Total Volume (gal)
6.56	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

PEROXIDE INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-4B	20-Jun	2:57 PM	3:00 PM	Air Diaphragm	15-14	20	1.6	180	
		3:00 PM	3:03 PM	Air Diaphragm	14-13	18	1.7	186	
		3:03 PM	3:06 PM	Air Diaphragm	13-12	20	1.6	192	
		3:06 PM	3:10 PM	Air Diaphragm	12-11	15	1.8	198	
		3:10 PM	3:13 PM	Air Diaphragm	11-10	20	1.8	204	
		3:13 PM	3:17 PM	Air Diaphragm	10-9	10	2.0	210	20 gal flush with water
				Air Diaphragm	9-8				
				Air Diaphragm	8-7				
				Air Diaphragm	7-6				
				Air Diaphragm	6-5				
				Air Diaphragm	5-4				
				Air Diaphragm	4-3				
					Averages	**24.4**	**2.1**	**210**	**Total Mixture Injected**

354.2	Klozur per point (lbs) - Calculated
156.4	Water per point (gal) - Calculated
170.0	Total Volume (gal)
7.08	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING HORNET)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-5					35-34				DPT-5 is a continuation of DPT-2 (170 gal to inject)
					34-33				
					33-32				
					32-31				
					31-30				
					30-29				
					29-28				
					28-27				
	19-Jun	8:21 AM	8:24 AM	Air Diaphragm	27-26	28	2.0	7	Restart of DPT-2, DPT-5 located adjacent to DPT-2. 5 gal water to start point
		8:24 AM	8:27 AM	Air Diaphragm	26-25	25	2.3	15	Flushed 15 gal water through lines to dilute persulfate before breaking rods (flow rate = 2.5 gpm), waited for pressure to subside then break rods
		8:45 AM	8:49 AM	Air Diaphragm	25-24	20	1.9	24	
		8:49 AM	8:53 AM	Air Diaphragm	24-23	20	2.4	33	
		8:53 AM	8:56 AM	Air Diaphragm	23-22	20	2.6	42	
		8:56 AM	9:01 AM	Air Diaphragm	22-21	18	2.1	51	Water flush (15 gal at 2.4 gpm) then broke rods
		9:22 AM	9:25 AM	Air Diaphragm	21-20	20	2.0	60	
		9:25 AM	9:28 AM	Air Diaphragm	20-19	20	2.0	69	
		9:28 AM	9:31 AM	Air Diaphragm	19-18	20	2.0	78	
		9:31 AM	9:34 AM	Air Diaphragm	18-17	18	2.1	87	Water flush (15 gal at 2.2 gpm) then broke rods
		10:00 AM	10:03 AM	Air Diaphragm	17-16	22	2.0	96	
		10:03 AM	10:06 AM	Air Diaphragm	16-15	20	2.1	105	

354.2	Klozur per point (lbs) - Calculatec
156.4	Water per point (gal) - Calculated
170.0	Total Volume (gal)
7.08	Volume per Foot (gal) - assumes 3-35' zone

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING HORNET)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-5	19-Jun	10:06 AM	10:09 AM	Air Diaphragm	15-14	22	2.1	114	Water flush (15 gal at 2.4 gpm) then broke rods
		10:09 AM	10:12 AM	Air Diaphragm	14-13	21	2.8	123	
		10:17 AM	10:22 AM	Air Diaphragm	13-12	17	1.9	132	
		10:22 AM	10:25 AM	Air Diaphragm	12-11	21	2.1	141	
		10:25 AM	10:28 AM	Air Diaphragm	11-10	18	2.1	150	
		10:28 AM	10:31 AM	Air Diaphragm	10-9	19	2.9	155	Water flush (15 gal at 2.3 gpm) then broke rods, excessive back pressure at Hornet unit
		11:01 AM	11:03 AM	Air Diaphragm	9-8	18	2.4	160	
		11:03 AM	11:07 AM	Air Diaphragm	8-7	10	2.1	165	
		11:07 AM	11:08 AM	Air Diaphragm	7-6	NR	NR	166	Surfaced around rods, point complete
					6-5				
					5-4				
					4-3				
					Averages	**19.9**	**2.2**	**166**	**Total Mixture Injected**

104.0	Klozur per point (lbs) - Calculated
46.0	Water per point (gal) - Calculated
50.0	Total Volume (gal)
5.00	Volume per Foot (gal) - starting at 19-20' interval

Injection Rig Operator: DW

KLOZUR INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-6	19-Jun	3:31 PM	3:34 PM	Air Diaphragm	20-19	38	2.3	5	Note: this additional point was installed to inject remaining persulfate solution left after point DPT-4. Injected 5 gal water to start point
		3:34 PM	3:36 PM	Air Diaphragm	19-18	33	3.2	10	
		3:36 PM	3:38 PM	Air Diaphragm	18-17	33	3.7	15	
		3:38 PM	3:40 PM	Air Diaphragm	17-16	31	3.6	20	
		3:40 PM	3:42 PM	Air Diaphragm	16-15	32	3.5	25	
		3:42 PM	3:44 PM	Air Diaphragm	15-14	40	3.0	30	
		3:44 PM	3:46 PM	Air Diaphragm	14-13	38	3.0	35	
		3:46 PM	3:48 PM	Air Diaphragm	13-12	35	3.1	40	
		3:48 PM	3:50 PM	Air Diaphragm	12-11	30	3.9	45	Surfaced from boring annulus, point complete.
				Averages		**34.4**	**3.3**	**45**	**Total Mixture Injected**

45.0	Peroxide per point (gal) - Calculated
135.0	Water per point (gal) - Calculated
180.0	Total Volume (gal)
10.00	Volume per Foot (gal) - to start

Injection Rig Operator: DW

PEROXIDE INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-7	20-Jun	10:37 AM	10:41 AM	Air Diaphragm	35-34	40	2.2	10	Continuation of DPT-3B (20' South); 8 gal flush, initial fracture pressure was 120 psi, then dropped to 40 psi
		10:41 AM	10:45 AM	Air Diaphragm	34-33	41	2.4	20	
		10:45 AM	10:49 AM	Air Diaphragm	33-32	39	2.3	30	
		10:49 AM	10:53 AM	Air Diaphragm	32-31	32	2.4	40	
		10:53 AM	10:57 AM	Air Diaphragm	31-30	31	2.4	50	
		10:57 AM	11:01 AM	Air Diaphragm	30-29	31	2.5	60	
		11:01 AM	11:05 AM	Air Diaphragm	29-28	30	1.9	65	Volume cut back to 5 gal/ft due to surfacing concerns
		11:05 AM	11:06 AM	Air Diaphragm	28-27	30	1.9	70	
		11:06 AM	11:09 AM	Air Diaphragm	27-26	30	1.9	75	
		11:09 AM	11:11 AM	Air Diaphragm	26-25	30	1.9	80	Surfacing at wells OW-5 and OW-6
		11:11 AM	11:14 AM	Air Diaphragm	25-24	30	1.7	85	Water level at MW-14 at top of casing
		11:14 AM	11:17 AM	Air Diaphragm	24-23	30	1.8	90	
		11:17 AM	11:19 AM	Air Diaphragm	23-22	31	1.9	95	
		11:19 AM	11:23 AM	Air Diaphragm	22-21	21	1.8	100	
		11:23 AM	11:25 AM	Air Diaphragm	21-20	20	2.0	105	
		11:25 AM	11:27 AM	Air Diaphragm	20-19	18	1.5	110	
		11:27 AM	11:30 AM	Air Diaphragm	19-18	18	1.7	115	
		11:30 AM	11:32 AM	Air Diaphragm	18-17	20	1.6	120	
		11:32 AM	11:35 AM	Air Diaphragm	17-16	22	1.5	125	
		11:35 AM	11:39 AM	Air Diaphragm	16-15	19	1.6	130	

45.0	Peroxide per point (gal) - Calculated
135.0	Water per point (gal) - Calculated
180.0	Total Volume (gal)
10.00	Volume per Foot (gal) - to start

Injection Rig Operator: DW

PEROXIDE INJECTION FIELD LOG (USING INNER HOSE)

Project Name: Lockheed Martin Middle River Complex (Middle River, MD)

Original Injection Scope of work: 8 Injection Points (4 persulfate, 2 peroxide, 2 water only), 3-35 ft bgs Injection Zone, 4 Points (2 persulfate, 1 peroxide, 1 water) with Hornet Tool - balance of points to use inner hose method, 1' Injection Zone, Assumed Flow Rate = 2 gpm

Boring ID No.	Date	Start Time	End Time	Pump Type / Inj. Method	Injection Interval	Average PSI	Average Flow Rate (GPM)	Mixture Injected (GAL)	Injection Notes
DPT-7	20-Jun	11:39 AM	11:41 AM	Air Diaphragm	15-14	15	1.4	135	
		11:41 AM	11:44 AM	Air Diaphragm	14-13	60	1.4	140	Pressure spike to 60 psi, lower flow rate to 1.21 and pressure dropped
		11:44 AM	11:50 AM	Air Diaphragm	13-12	25	1.5	150	
		11:50 AM	12:15 PM	Air Diaphragm	12-11	80	1.6	175	Injected remaining material at this interval to ensure all volume was injected per Tetra Tech
					11-10				Water flush (15 gal) at 1.2 gpm
					10-9				
					9-8				
					8-7				
					7-6				
					6-5				
					5-4				
					4-3				
					Averages	**31.0**	**1.9**	**175**	**Total Mixture Injected**

APPENDIX F—
ENHANCED ANAEROBIC REDUCTIVE DECHLORINATION PILOT STUDY REPORT

Enhanced Anaerobic Reductive Dechlorination Pilot Study Report Lockheed Martin Middle River Complex 2323 Eastern Boulevard Middle River, Maryland

Prepared for:

Lockheed Martin Corporation

Prepared by:

Tetra Tech, Inc.
August 2009

_____
Michael Martin, P.G.
East Coast Regional Manager

_____
Christopher Pike, P.E.
Project Manager

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Acronyms

µg/L	micrograms per liter
ARD	anaerobic reductive dechlorination
bgs	below ground surface
CDM	CDM, Inc.
DCE	cis-1,2-dochloroethene
DHB	dehalobactor
DHC	dehalococcoides
DO	Dissolved oxygen
DSM	desulfuromonas
EBAC	eubacteria
EOS®	Emulsifed Oil Substrate
Frac Rite	Frac Rite Environmental Limited
g/d/ft	gallons per day per foot
GLM	Glenn L. Martin Company
gpm	gallons per minute
Lockheed Martin	Lockheed Martin Corporation
MDE	Maryland Department of the Environment
mg/L	Milligram per liter
MGN	methanogens
MRAS	Middle River Aircraft Systems
MRC	Middle River Complex
MS2-LS&S	Maritime Systems & Sensors – Littoral Ships & Systems
msl	mean sea level
mV	millivolts
NPDES	National Pollution Discharge Elimination System
ORP	oxidation-reduction potential
ppm	parts per million
psi	pounds per square inch

PVC	polyvinyl chloride
TCE	trichloroethene
TCER	TCE Reductase
TOC	total organic carbon
VCR	VC Reductase
VOC	volatile organic compound

Section 1
Introduction

On behalf of Lockheed Martin Corporation (Lockheed Martin), Tetra Tech has prepared the following report to document the enhanced anaerobic reductive dechlorination (ARD) pilot study conducted at the Lockheed Martin Middle River Complex (MRC) located in Middle River, Maryland. The pilot study was conducted to determine whether enhanced ARD can be applied successfully to the areas of concern and significantly and permanently reduce the chlorinated volatile organic compound (VOC) concentrations within the saturated zone of the site.

The objectives of the enhanced ARD pilot study are:

- Determine the efficacy of applying enhanced ARD in creating reducing conditions in the subsurface and reducing VOC concentrations throughout the site utilizing Emulsifed Oil Substrate (EOS®) without pH buffering or biostimulation.

- Determine the performance of hydraulic fracturing as it relates to distribution of amendments emplaced at each fracture depth.

To address the above objectives, the following activities were conducted:

- Installation of observation wells
- Baseline monitoring
- Subsurface fracturing
- Injection of EOS® in to the fractures near the observation wells in the northern portion of the eastern plume
- Performance monitoring
- Reporting

This enhanced ARD pilot test report is organized as follows:

- Section 2 – Site Background: Presents a brief description of site history, subsurface conditions, and previous investigations.

- Section 3 – Enhanced ARD Pilot Study Field Implementation: Presents a description of the field activities.

- Section 4 – Enhanced ARD Pilot Study Monitoring Results: Presents a comparison of the results of the baseline monitoring and the three rounds of pilot study performance monitoring.

- Section 5 – Conclusions: Presents the conclusions from the pilot study and how they may be applied to a full-scale site remedy.

- Section 6 – References: Cites references used to compile this report.

Section 2
Site Background

2.1 MRC BACKGROUND

The MRC, which is part of the Chesapeake Industrial Park, is located at 2323 Eastern Boulevard in Middle River, Maryland, approximately 11.5 miles northeast of downtown Baltimore. The MRC comprises approximately 161 acres including 12 main buildings, an active industrial area and yard, perimeter parking lots, an athletic field, a concrete-covered vacant lot, a trailer and parts storage lot, and numerous grass-covered green spaces along its perimeter. The MRC is bounded by Eastern Boulevard (Route 150) to the north, Dark Head Cove to the south, Cow Pen Creek to the west, and Martin State Airport to the east. A MRC layout map is presented as Figure 2-1 and site monitoring well locations are shown in Figure 2-2.

Currently, Lockheed Martin's primary activities at the MRC include facility and building management and maintenance. There are two main tenants at MRC: Middle River Aircraft Systems (MRAS), a subsidiary of General Electric, that conducts design, manufacturing, fabrication, testing, overhaul, repair, and maintenance of aeronautical structures, parts, and components for military and commercial applications; and Maritime Systems & Sensors – Littoral Ships & Systems (MS2-LS&S), a subsidiary of Lockheed Martin, that conducts fabrication, assembly, testing and support of vertical launch systems.

2.1.1 MRC History

In 1929, the Glenn L. Martin Company (GLM), a predecessor of Lockheed Martin, acquired a large parcel of land in Middle River, Maryland to conduct aircraft manufacturing for the United States government and commercial clients. Prior to the acquisition, the MRC was reportedly undeveloped land. In the early 1960s, GLM merged with American-Marietta Company, forming Martin Marietta Corporation. Around 1975, the adjacent western airport (Martin State Airport),

totaling approximately 750 acres, was transferred to the State of Maryland. In the mid-1990s, Martin Marietta Corporation merged with Lockheed, forming Lockheed Martin Corporation, with its principal subsidiary specializing in construction and testing of new ordnance for United States Government and commercial clients. Shortly following the merger, General Electric acquired the majority of Lockheed Martin's aeronautical business in Middle River, which began to function as MRAS.

2.1.2 MRC Characteristics

2.1.2.1 Current and Surrounding Land Use

The MRC is an industrial facility, and the area surrounding the property primarily consists of commercial, industrial, and residential establishments. Six facilities, comprising the remaining portion of the Chesapeake Industrial Park, are adjacent to MRC. These facilities include Tilley Chemical Company, Inc., a food and pharmaceutical chemical distributor; North American Electric, Inc., an industrial and commercial electrical contractor; Johnson and Towers, a heavy duty automotive and boat repair and maintenance company; Poly-Seal Corp., a company that produces flexible packaging; Exxon, a gasoline fill station and convenience store; and the Middle River Post Office. Residential developments are present on the opposite shores of Cow Pen Creek, Dark Head Cove, and Dark Head Creek and north of Eastern Boulevard (Route 150).

2.1.2.2 Physiography

The MRC is located within the Western Shore of the Coastal Plain Physiographic Province, which is generally characterized by low relief. The topography of the MRC is gently sloping, ranging from sea level to 32 feet above mean sea level (msl) (Cassell, July 1977). The topography slopes from Eastern Boulevard to the southwest and south towards Cow Pen Creek and Dark Head Cove.

2.1.2.3 Hydrology

The MRC is located at the junction of Cow Pen Creek and Dark Head Cove. Both surface water bodies discharge into Dark Head Creek, a tributary to Middle River, which is a tributary to Chesapeake Bay. The MRC is approximately 3.2 miles upstream of Chesapeake Bay.

No surface water bodies are present within the MRC. Excluding areas immediately adjacent to Cow Pen Creek and Dark Head Cove, surface water runoff discharges from the facility via storm drains. Lockheed Martin maintains a State of Maryland National Pollution Discharge Elimination System (NPDES) permit (State Discharge Permit No.: 00-DP-0298, NPDES No.: MD0002852), issued by Maryland Department of the Environment (MDE) Industrial Discharge Permits Division, Water Management Administration. The permit covers stormwater discharge from the entire property rather than individual tenants.

2.1.2.4 Soils

Soils underlying MRC have been mapped as Mattapex-Urban Land Complex and Sassafras-Urban Land Complex by the United States Department of Agriculture Soil Conservation Service. Mattapex-Urban Land soils consist of deep, well-drained silty soils whose original texture has been disturbed, graded over, or otherwise altered. Sassafras-Urban Land soils consist of deep, well-drained sandy soils whose original texture has been disturbed, graded over, or otherwise altered. Site characterization studies indicate that fine-grained (e.g., silt and clay) soils with low permeabilities make up the majority of soils at the MRC.

2.1.2.5 Regional Geology

Based on geologic mapping of Baltimore County, the MRC is underlain by the Potomac Group, a Cretaceous-age interbedded gravel, sand, silt, and clay unit ranging in thickness from 0 to 800 feet. The Potomac Group is composed of three units: the Raritan and Patapsco Formations, the Arundel Clay, and the Patuxent Formation. The Raritan and Patapsco Formations range up to 400 feet thick and are composed of a gray, brown, and red variegated silt and clay unit with lenses of sand and few gravels. The Arundel Clay is composed of dark gray and maroon lignitic clays

and ranges in thickness from 25 to 200 feet. The Patuxent Formation is described as a white or light gray to orange brown, moderately sorted sand unit with quartz gravels, silts, and clays and ranges up to 250 feet in thickness.

Lithologic logging of the soils beneath the MRC identified a very heterogeneous stratigraphy. The underlying soils are composed primarily of silty sands, fine-grained to medium-grained sands, silty clays, clayey silts, and plastic clay, with the primary lithology being clay to silty clay. Areas along the waterfront have historically been back-filled to their present elevation. Soils obtained from fill areas were similar in appearance and composition to soils considered to be native to the MRC.

2.1.2.6 Regional Hydrogeology

Sand and gravel zones within the unconsolidated surficial deposits, when present, may form an unconfined or water table aquifer system (Bennett and Meyer, 1952). The water table at MRC generally conforms to the shape of the land surface, with the highest water levels in the interior land areas and the lowest levels at approximately the surface water elevations along the shoreline.

The Patuxent Formation is the most important water-bearing formation in the Baltimore area. Industrial wells in the southeastern part of the area, specifically Curtis Bay and Sparrows Point, yield from 500 to 900 gallons per minute (gpm). Transmissivities and coefficients of storage in confined portions of the aquifer in these industrialized areas average about 50,000 gallons per day per foot (g/d/ft) and 0.00026, respectively. The Patapsco Formation is also an important water-bearing formation in industrialized Baltimore, where it is separated by clay into a lower and an upper aquifer. The lower aquifer yields as much as 500 to 750 gpm to industrial wells, and a transmissivity of 25,000 g/d/ft has been estimated. The upper aquifer yields quantities of water similar to industrial wells, and because it has a greater thickness than the lower aquifer, it likely has a higher overall transmissivity.

2.1.2.7 Use of Pilot Study Area

The pilot study was conducted approximately 120 feet south of Building C in an area used as a vehicle access ramp to the rear of Building C. The area has been used for that purpose since the installation of Building C; its use before that time is not known. The Power House is located west of the pilot study area and a structure known as the Drum Storage Area, including a small building and a covered, bermed area, is located southwest of the pilot study area. A berm supporting railroad tracks is located immediately east of the area. The nearest Recognized Environmental Concern (REC) is REC #41, the southern gas pump island, located west of the area.

2.2 SUMMARY OF DATA FROM THE ENHANCED ARD PILOT STUDY AREA

This section provides data from previous investigations that apply directly to the area of the enhanced ARD pilot study, primarily from the 2005 Site-Wide Groundwater Investigation, the field investigations that took place at MRC in late 2007 and early 2008, and the July-August 2008 groundwater monitoring event. More information on the 2005 activities can be found in the Site-Wide Groundwater Investigation Report (Tetra Tech, 2006), and information on the recent activities are presented in the Block I, Phase II Site Investigation Report (Tetra Tech, 2009a) and the Groundwater Monitoring Report, July – August 2008 (Tetra Tech, 2009b).

The outline of the enhanced ARD pilot test location is shown in Figure 2-3. More detail is shown in Figure 3-1.

2.2.1 Enhanced ARD Pilot Study Area Characteristics

The enhanced ARD pilot study was conducted in the northern portion of the eastern TCE plume. The eastern TCE plume is the largest contiguous area of TCE groundwater contamination at the site and extends southeastward from MW57, located at the southern end of Building C, to MW37, located near Dark Head Cove. The maximum reported concentrations of TCE from the 2008 sampling event in the monitoring wells associated with this plume are approximately 12,000 micrograms per liter (µg/L) at well MW74B in the southern portion of the plume and

approximately 10,000 µg/L at well MW81B in the northern portion of the plume. In 2008, neither benzene or 1,4-dioxane were detected within the boundaries of the eastern TCE plume. Groundwater TCE iso-concentration contours from the 2008 monitoring event are shown on Figure 2-4.

Concentrations of metals above MDE screening standards are found in the groundwater throughout the MRC. The effect of the pilot study injections on the metals concentrations is an important consideration. Beryllium, cobalt, and nickel, have been shown to be present in groundwater above applicable standards throughout the site, and the effects on the concentrations of these metals associated with changing pH and oxidation-reduction conditions in the subsurface have been studied extensively in the laboratory; therefore, the effect on these metals during this pilot study was tracked closely.

Other hydrogeologic and geochemical information was considered prior to implementation of the pilot study in this area. Depth to water in the test area ranges from 8 to 10 feet below ground surface (bgs). The pH in the area was somewhat less than optimal for completion of ARD to innocuous end products (primarily ethene), ranging from approximately 5.0 to 5.9 standard units. Dissolved oxygen (DO) and oxidation-reduction potential (ORP) readings varied widely; DO ranged from 0.0 to 4.0 milligrams per liter (mg/l) and ORP ranged from -16 to 220 millivolts (mV). Representative hydraulic conductivities determined from slug testing in the area ranged from 0.22 to 1.04 feet per day.

2.2.2 Bench-Scale Testing

In order to assist in determining the parameters for the pilot study, bench-scale studies were conducted by CDM using soil and groundwater collected from the enhanced ARD pilot study area. A brief summary of the testing is included in this section; complete data from the tests are included in the pilot test work plan (Tetra Tech, 2008).

Testing was conducted on samples from throughout the site, including samples from low and neutral pH areas of the eastern plume. The destruction of chemicals of concern was tested with several different substrates including EOS® 598, EOS® 598B42 (including vitamin B12), sodium

lactate, and whey with and without addition of a microbial culture (Shaw SDC-9™). In all tests (with the exception of the sterile and negative control tests), significant reductions of TCE and daughter products were observed. Significant formation of ethene was also observed, indicating that complete reduction was taking place, even in low pH environments, without introduction of the microbial culture. Based on the results of the bench-scale testing, it was determined that enhanced ARD would be field tested without the use of a pH buffer or the addition of a microbial culture. Due to the rapid reduction of TCE and formation of ethene using EOS® 598B42 (supplied by EOS® Remediation), this was the substrate chosen for use in the field testing. The vitamin B12 supplement is utilized to provide additional nutrients to support the growth of microbes known to support complete destruction of TCE to ethene. The bench scale study report prepared by CDM is included in Appendix A.



FIGURE 2-1

MIDDLE RIVER COMPLEX LAYOUT MAP

LEGEND

OUTFALL 004 NPDES PERMITTED OUTFALL

STORMWATER AND FLOW DIRECTION

PRE-1950 SHORELINE

EXISTING STRUCTURE

FORMER STRUCTURE

REC LOCATION (APPROXIMATE)

Lockheed Martin Middle River Complex
Middle River, Maryland

0 200 400

N

DATE MODITFIED 4/02/07

CREATED BY LR

Tetra Tech Inc.

filename: k:\gproject\middle_river\cad\newfolder\2003SiteLocationMapFigure2_16Jan07.dwg

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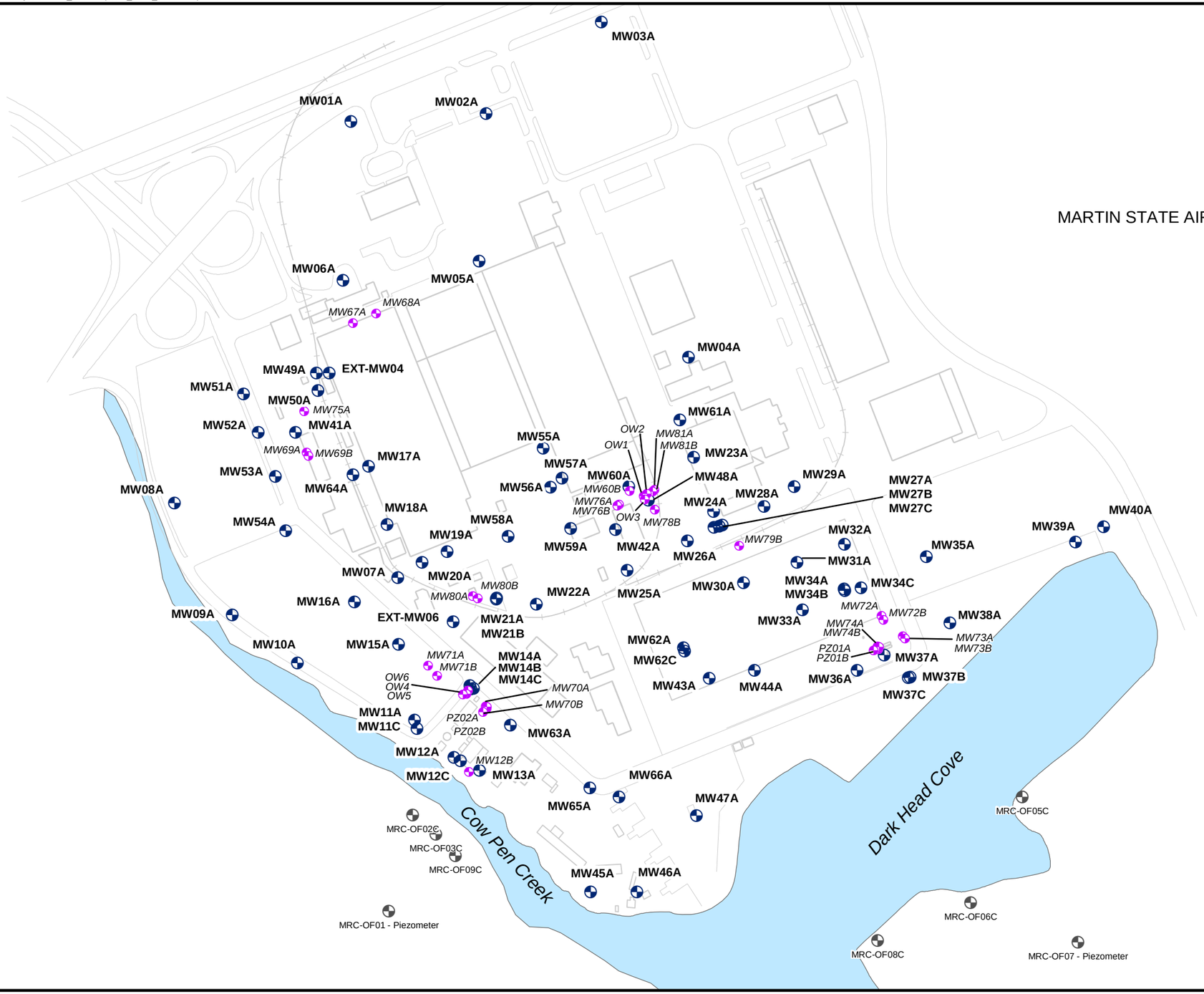


FIGURE 2-2

MONITORING WELL LOCATION MAP

LEGEND

- OFFSITE WELLS
- NEW WELLS 2007
- EXISTING WELLS

BASE MAP FEATURES

- ROADS
- BUILDINGS
- FORMER BUILDINGS
- TRACKS
- WATER

Lockheed Martin Middle River Complex
Middle River, Maryland

0 125 250 500 Feet

N

DATE MODIFIED: 7/10/08

CREATED BY: JF

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\All_wells_2008.mxd)1/29/2008

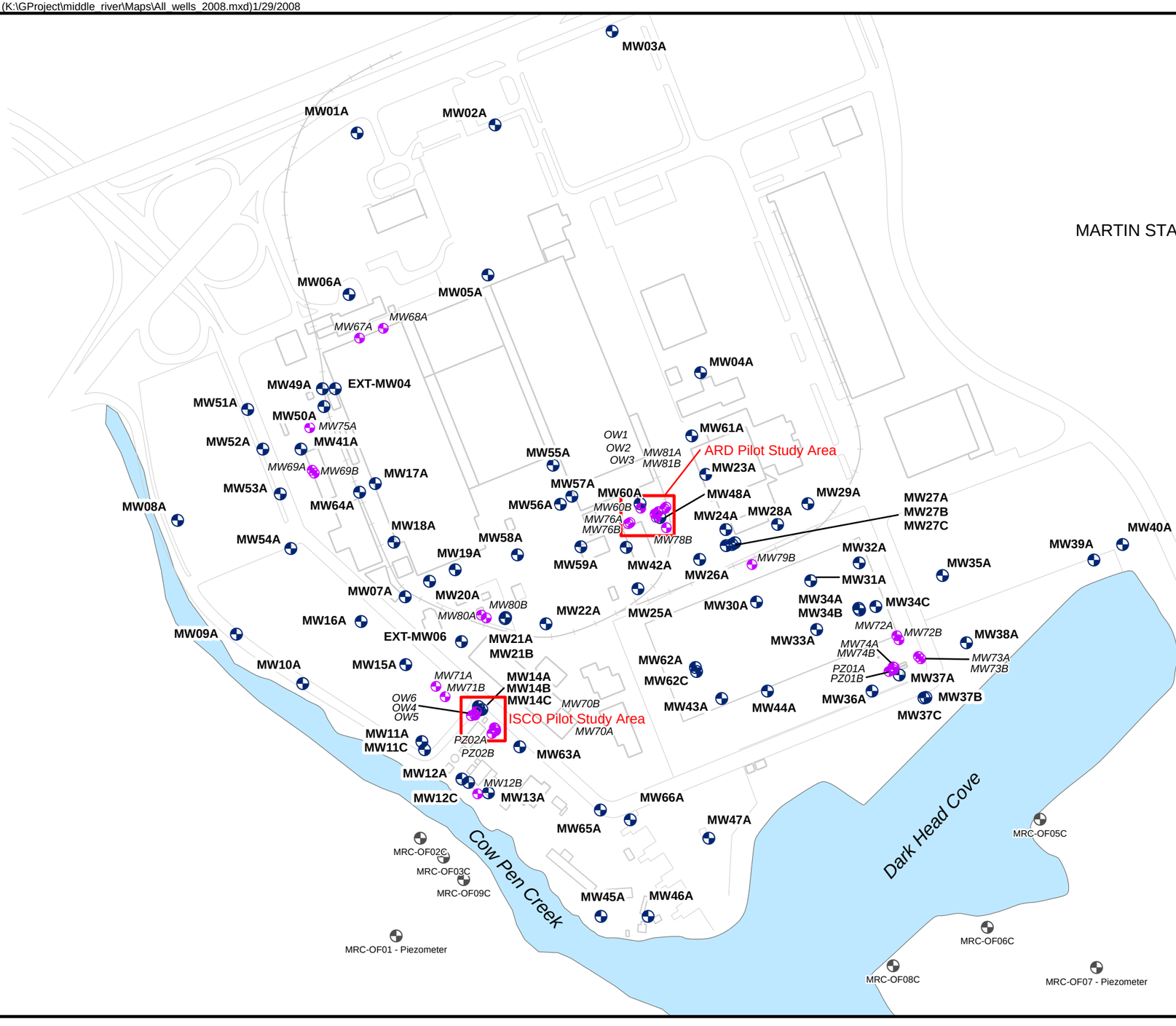


FIGURE 2-3

PILOT STUDY LOCATIONS

Legend

- New Wells 2007
- Offsite Wells
- Existing Wells

Base Map Features

- Roads
- Buildings
- Former Buildings
- Tracks
- Water

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 1/29/08

CREATED BY: LR

Tetra Tech, Inc.

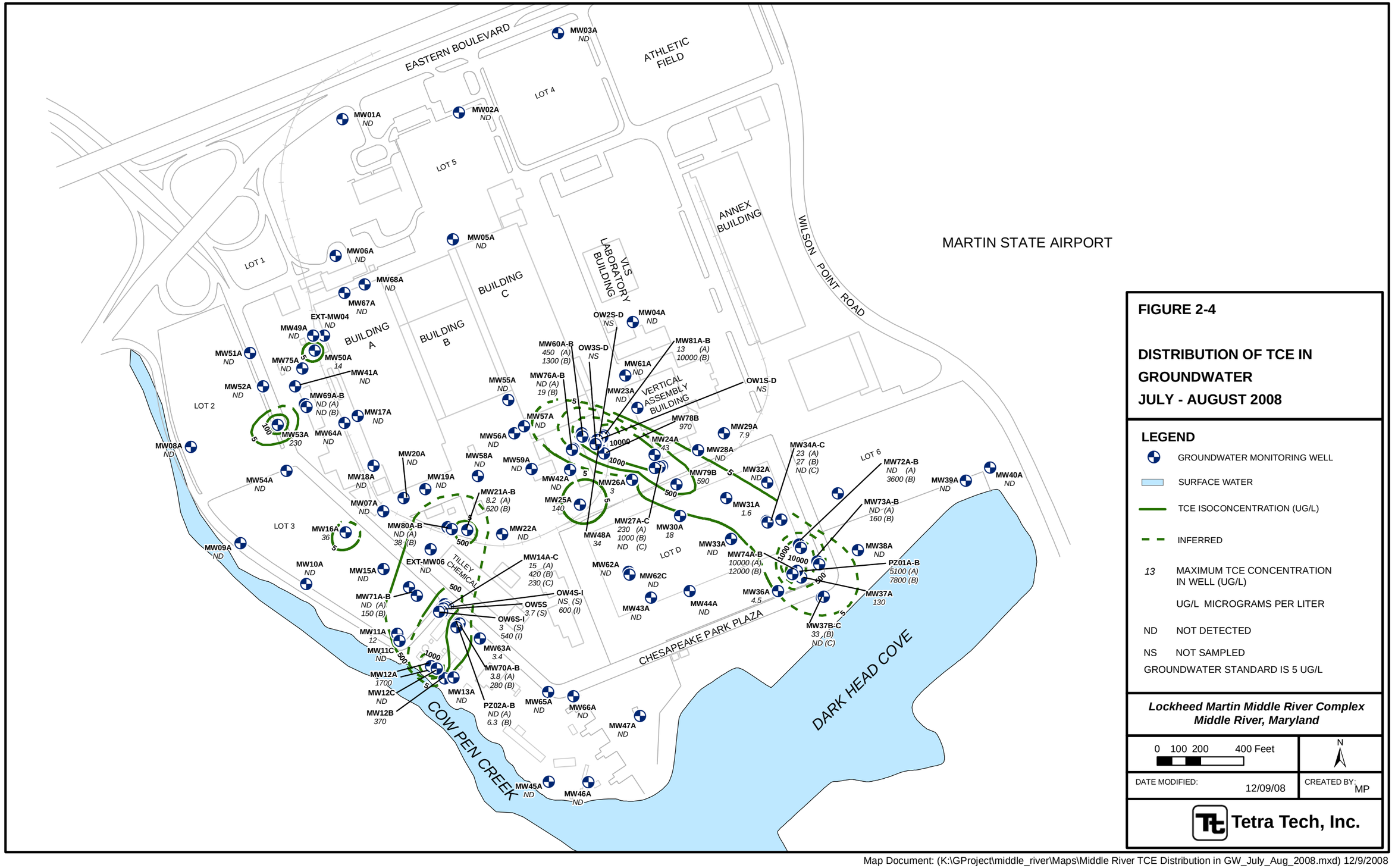


FIGURE 2-4

DISTRIBUTION OF TCE IN GROUNDWATER
JULY - AUGUST 2008

LEGEND

- GROUNDWATER MONITORING WELL
- SURFACE WATER
- TCE ISOCONCENTRATION (UG/L)
- INFERRED
- *13* MAXIMUM TCE CONCENTRATION IN WELL (UG/L)
- UG/L MICROGRAMS PER LITER
- ND NOT DETECTED
- NS NOT SAMPLED

GROUNDWATER STANDARD IS 5 UG/L

Lockheed Martin Middle River Complex
Middle River, Maryland

0 100 200 400 Feet

N

DATE MODIFIED: 12/09/08

CREATED BY: MP

Tetra Tech, Inc.

Map Document: (K:\GProject\middle_river\Maps\Middle River TCE Distribution in GW_July_Aug_2008.mxd) 12/9/2008

Section 3
Enhanced ARD Pilot Study Field Implementation

To obtain the data required for screening and development of remedial alternatives, Tetra Tech conducted an *in situ* pilot study in the eastern TCE plume. Enhanced ARD was tested using injection of EOS® via fractures emplaced in the subsurface via hydraulic fracturing. Monitoring associated with the pilot study included baseline monitoring prior to injection, and performance monitoring conducted approximately one month, three months, and six months following injection. This section provides a description of the field implementation of the study.

3.1 OBSERVATION WELL INSTALLATION

Prior to completion of the Work Plan, three sets of nested observation wells were installed in the northern portion of the study area plume in December 2007 to facilitate pilot testing (Figure 3-1). OW1S, OW2S, and OW3S were installed with a screened interval of 5 to 10 feet bgs; OW1I, OW2I, and OW3I were installed with a screened interval of 15 to 20 feet bgs; and OW1D, OW2D, and OW3D were installed with a screened interval of 25 to 30 feet bgs. In general, the "I" wells were installed in a silty clay and the "D" wells were installed in a slightly higher permeability sandy clay; boring logs and well installation diagrams for these wells are included in Appendix B.

3.2 BASELINE MONITORING

As part of the baseline monitoring associated with the pilot test, groundwater samples were collected from the six observation wells in January 2008. Samples were analyzed for VOCs, 1,4-dioxane, metals (total and dissolved), ethene, ethane, and methane, chloride, nitrate, nitrite, sulfate, and total organic carbon (TOC). Field parameters of pH, DO, and ORP were also measured and recorded. In October 2008, one week prior to injection, the field parameters were

again measured and additional samples from select wells (OW1I, OW1D, OW3I, and OW3D) were collected for microbial analysis, including dehalococcoides (DHC), desulfuromonas (DSM), dehalobactor (DHB), functional genes (TCE Reductase [TCER], BAV1 VC Reductase [BVC], and VC Reductase [VCR]), eubacteria (EBAC), methanogens (MGN), and sulfate and iron reducing bacteria (IRB/SRB).

Low-flow well purging and sample collection, documentation, sample handling and nomenclature, equipment decontamination, waste management, and the utility clearance requirements for this work followed the protocol from the On-Site Remedial Design Work Plan for MRC (Tetra Tech, 2007). Field sampling logs are included in Appendix C.

3.3 ENHANCED ARD PILOT STUDY

This enhanced ARD pilot study was designed to determine the following:

- Efficacy of applying enhanced ARD in creating reducing conditions in the subsurface and reducing VOC concentrations throughout the site utilizing EOS® without pH buffering or biostimulation.
- Performance of hydraulic fracturing as it relates to distribution of amendments emplaced at each fracture depth.

The enhanced ARD pilot study consisted of sub-surface injection of a substrate with the goal of enhancing natural reductive dechlorination of VOCs in the pilot study area. Based on the results of the ARD bench-scale testing, EOS® 598B42was utilized as the substrate. Due to the low permeability soil present in the pilot study area, injection was enhanced with installed fractures propagated in the pilot study area.

The first phase of the testing included propagation of fractures using a hydraulic fracturing technique and the second phase consisted of the substrate injection.

3.3.1 Hydraulic Fracturing and Injection Point Installation

After completion of utility clearance activities in a 50-foot radius around the proposed fracturing/injection location, on October 6, 2008, Frac Rite Environmental Limited (Frac Rite) mobilized hydraulic fracturing equipment to the enhanced ARD pilot study area at MRC. The utility clearance report is included in Appendix D. On October 8 and 9, Frac Rite, under the supervision of Tetra Tech, propagated hydraulic fractures from one location, shown on Figure 3-1. Vironex, Inc. assisted Frac Rite by pushing a direct push rod, with the fracturing tool attached, to the desired depth prior to propagation of each fracture. A total of nine fractures were propagated, beginning at 11 feet bgs and spaced every 3 vertical feet to a depth of 35 feet bgs. As the fractures were propagated, they were filled with a slurry containing sand and polymer to keep the fracture open. Tiltmeters were deployed to determine the location, thickness, size and orientation (both horizontal and vertical) of the fractures.

The report prepared by Frac Rite, providing details on the propagation procedures and results, including depictions of the tiltmeter data, is included in Appendix E; Table 3-1 provides a summary of the results of the tiltmeter analysis. Graphical depictions of each fracture are shown in Figures III-1 through III-3 in Appendix E, and are reproduced in this section as Figures 3-2 through 3-4.

Some important parameters of the fractures include the following:

- The width (or thickness) of the fractures ranged from 0.50 to 1.0 inches.
- The fractures were propagated at an average pressure of approximately 56 pounds per square inch (psi) and the average slurry flow rate was 31 gpm. The pump utilized for propagating the fractures was a 104 horsepower triplex pump rated for 100 gallons per minute (gpm) at 375 revolutions per minute.
- The two fractures closest to the surface (11 feet and 14 feet bgs) were not as large and were not propagated as far as the other fractures, to limit the potential of surfacing; 910 pounds of sand and 140 gallons of slurry were used in each of the two shallow fractures and 1,800 pounds of sand and 280 gallons of slurry were used in each of the other seven fractures. The modeled fracture volumes of the 11-foot bgs and 14-foot bgs fractures were 9.2 and 19 cubic feet, respectively. The modeled fracture volume of the other seven fractures ranged between 37 and 44 cubic feet.

- Although an attempt was made to initiate the fractures at 9 discrete depth intervals, spaced at three feet, this was not how the fractures actually propagated according to the tiltmeter data (depicted graphically in Figures III-1 through III-3 in Appendix E, and reproduced in this section as Figures 3-2 through 3-4). Two of the fractures initiated at approximately 11 feet bgs, two initiated between 15 and 16 feet bgs, four initiated between 21 and 22 feet bgs, and one initiated at approximately 24 feet bgs.

- The fractures were propagated primarily in a southwest to northeast direction, towards OW2 and travelling closer to OW3 than OW1. One fracture intersected OW2.

- The fractures were propagated at various angles to the subsurface, causing a high degree of intersection between the fractures. The second fracture, initiated at a depth of 14 feet below ground, approached within three feet of the ground surface.

- Based on the calculations prepared by Frac Rite and checked by Tetra Tech, the fractures propagated over a total of approximately 1,200 square feet of surface area, as projected to the ground surface.

Following the propagation of the fractures, temporary injection points were installed in the fracture location. The injection points were installed by using a combination of direct push technology and hollow stem auger drilling within a one-foot radius of the injection point. The points were screened at three discrete intervals in an attempt to control flow to three of the fractures at a time; therefore, the well screens were installed from 10 feet bgs to 18 feet bgs, 19 feet bgs to 27 feet bgs, and 28 feet bgs to 36 feet bgs. As noted above, however, the actual fracture propagation depths did not match the planned depths and the fractures had a high degree of interconnectivity. Therefore, regardless of the injection interval, the injected substrate was most likely distributed throughout the entire fracture matrix. The injection points were constructed of 2-inch diameter polyvinyl chloride (PVC) riser and screen.

3.3.2 Substrate Injection

Following injection well installation, substrate injection began on October 10, 2008 (prior to complete evaluation of the fracture orientation and tiltmeter) and continued through October 12, 2008. The plan called for a total of five drums (approximately 275 gallons) of EOS® 598B42 to be injected in to the fractures. Approximately 90 gallons of EOS® would be injected in to each of the three injection point screens. The Work Plan originally called for a water to EOS® dilution ratio of 5:1, resulting in a total injection volume (water and EOS®) of approximately 540 gallons in to each of the three injection point screens.

Table 3-2 provides a detailed summary of the injection time periods, volumes, flowrates, and pressures achieved on October 10, 11, and 12 2008. Data presented in the table indicates:

- At initial flowrates of 7 or more gpm, daylighting of the EOS® solution through cracks in the surface asphalt and near the injection location was observed. At a flow rate of 4 to 6 gpm, the flow was sustainable for an entire batch of EOS® solution (approximately 240 gallons). This is expected to be the maximum obtainable flowrate in a similar full-scale application.

- Based on technical discussions prior to injection, the initial water: EOS® ratio was increased to 7:1. This was increased to 11:1 for the majority of the injections and then increased to as high as 16:1 for the final injection quantities.

- A total of approximately 3,000 gallons of EOS® solution and 272 gallons of EOS® were injected for an average ratio of approximately 10 gallons water per gallon of EOS® (a 9.2 percent solution).

- The total injection time was approximately 430 minutes, leading to an average injection rate of 7 gpm.

Note that these injection quantities and flow rates are slightly different from those included in the Frac Rite report in Appendix E, and are based on the field measurements of the Tetra Tech engineer.

Prior to and following injection, a round of groundwater quality readings was collected from the observation wells (Table 3-3). This data indicated that the injections had influenced OW2I and OW3I and OW3D (each approximately 16 feet from the injection location) and not OW1I or OW1D, which supports the fracture orientation of southwest to northeast determined based on the tiltmeter data. Additionally, the tiltmeter data show that only OW3 was located within the fracture pattern; therefore, the data also show that EOS® had enterned the groundwater outside of the fracture pattern. These data show that utilizing hydraulic fracturing can provide a significant area of influence within a short time period following injection within the subsurface in the area of injection. More details on the area of influence achieved are included in Section 4.

It should be noted that the fracture point was apparently installed adjacent to abandoned storm sewer piping. This piping was not detected during utility locating activities prior to initiating field work; the piping was identified as concrete conduits during a second utility clearance following

injection. It is suspected that these conduits intersected the fracture patterns and may have provided a conduit to transport an unknown volume of EOS® solution from the injection point to the main storm water system and subsequently to Dark Head Cove, the nearby surface water body. The release was discovered in the evening of October 12; mitigation began on October 13, 2008. The primary mitigation activities included the pumping of water from the impacted storm drain on October 12, 13, and 14; a total of 22,500 gallons of water were pumped from the drain and disposed off-site. Subsequently, the lines were flushed with approximately 10,000 gallons of water; in conjunction with the flushing, approximately 7,500 gallons of water were removed from the storm drains and disposed off-site.

3.4 POST-INJECTION PERFORMANCE MONITORING

Following injection activities, the period of post-injection performance monitoring began. Three rounds of post-injection monitoring were completed.

The first round of post-injection performance monitoring was completed on November 14, 17, and 18, 2008, in conjunction with other site activities, approximately one month after injections were initiated. Samples were collected from 6 wells: OW1I, OW1D, OW2I, OW2D, OW3I, and OW3D. The groundwater samples from each well were analyzed for VOCs, 1,4-dioxane, ethene, ethane, and methane, chloride, nitrate, nitrite, sulfate, and TOC. Select wells (OW1I, OW2D, OW3I, and OW3D) were analyzed for total and dissolved metals. The field parameters pH, DO, and ORP were also measured and recorded.

The second round of post-injection performance monitoring was completed on January 13 and 15, 2009, approximately 3 months after injection. The groundwater samples from each well were analyzed for VOCs, 1,4-dioxane, ethene, ethane, methane, chloride, nitrate, nitrite, sulfate, and TOC. The field parameters pH, DO, and ORP were also measured and recorded.

A third round of post-injection performance monitoring was performed on April 21 and 22, 2009. The groundwater samples from each well were analyzed for VOCs, 1,4-dioxane, metals (total and dissolved), ethene, ethane, methane, chloride, nitrate, nitrite, sulfate, and TOC. Microbial analysis from the same wells and for the same parameters as utilized for the baseline sampling was also

completed. The field parameters pH, DO, and ORP were also measured and recorded.

Sampling Summary

Parameter	Baseline	1 Month	3 Months	6 Months
VOCs	6	6	6	6
1,4-Dioxane	6	6	6	6
Metals	6	4	0	6
NA Parameters	6	6	6	6
Microbial Analysis	4	0	0	4
Field Parameters	6	6	6	6

Low-flow well purging and sample collection, documentation, sample handling and nomenclature, equipment decontamination, waste management, and the utility clearance requirements for this work followed the protocol from the On-Site Remedial Design Work Plan for MRC (Tetra Tech, 2007).

TABLE 3-1

SUMMARY OF FRACTURE PROPOGATIONS AND TILTMETER RESULTS ANALYSIS
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Frac Hole	Date	Frac Slurry (gallons)	Sand (pounds)	Fracture Azimuth(1) (degrees)	Fracture Dip(2) (degrees)	Fracture Thickness (feet)	Fracture Length(3) (feet)	Fracture Height(4) (feet)	Fracture Depth(5) (feet)	Vector Error	RMS Error (nRad)	Modeled Frac Volume (cubic feet)	Frac Center(6) x (feet)	Frac Center(6) y (feet)
FP1-1	7-Oct	140	910	314	27	0.0840	11.0	10.0	11.0	0.142	3.43E+05	9.2	-0.9	-4.4
FP1-2	7-Oct	140	910	68	42	0.0680	10.0	28.0	11.0	0.113	3.10E+05	19.0	-3.5	-2.5
FP1-3	7-Oct	280	1820	316	30	0.0720	23.0	25.4	15.7	0.240	5.94E+05	42.1	1.6	-3.2
FP1-4	7-Oct	280	1820	239	36	0.0590	25.0	25.0	15.9	0.024	1.39E+06	36.9	5.2	-2.6
FP1-5	7-Oct	280	1820	330	14	0.0770	17.1	31.8	21.5	0.069	1.89E+06	41.9	12.4	2.4
FP1-6	7-Oct	280	1820	321	34	0.0540	22.8	33.7	21.8	0.119	2.19E+05	41.5	3.8	-0.4
FP1-7	7-Oct	280	1820	326	45	0.0580	15.3	48.8	24.2	0.161	2.75E+05	43.3	-6.5	-3.3
FP1-8	7-Oct	280	1820	140	8	0.0490	21.5	40.0	21.5	0.095	1.84E+05	42.1	4.7	-5.5
FP1-9	8-Oct	280	1820	215	47	0.0420	35.6	29.3	21.1	0.210	1.97E+05	43.8	6.8	-1.8

Notes:
1 - Orientation of fracture axis (degrees Azimuth to Magnetic North).
2 - Inclination of fracture to horizontal.
3 - Lateral fracture dimension measured along fracture plane perpendicular to fracture height.
4 - Vertical fracture dimension mesaured on fracture planes along fracture height.
5 - Depth of fracture initiation measured from ground surface.
6 - Fracture assymetry measured relative to theoretical fracture centered on borehole.
"x" - offset along east-west axis (negative is west).
"y" - offset along north-south axis (negative is south).

TABLE 3-2

SUMMARY OF SUBSTRATE INJECTIONS
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

		Time Period			Injection Volume				
Injection Location	Date	Start	End	Duration	EOS Solution	EOS	Flow (1)	Pressure (2)	Field Notes
		Time	Time	Min	Gal	Gal	gpm	Psi	
Shallow Injection Well	10/10/2008	900	930	30	228	29	7.60	7	No seepage
Shallow Injection Well	10/10/2008	1007	1019	12	228	29	19.00	8	Noticed minor seepage thru cracks of asphalt.
Intermediate Well	10/10/2008	1246	1256	12	190	24	15.83	10	Stop Injection. Noticed seepage
Intermediate Well	10/10/2008	1315	1317	2	25	3	12.50	4	Noticed seepage.
Intermediate Well	10/10/2008	1335	1337	2	25	3	12.50	7	Noticed seepage.
Intermediate Well	10/10/2008	1406	1409	3	25	2	8.33	4	All 1000 liters injected. Batch was at 8%
Deep Well	10/10/2008	1442	1456	14	100	8	7.14	5	Noticed seepage.
Deep Well	10/10/2008	1505	1508	3	50	4	16.67	7	Noticed seepage.
Deep Well	10/10/2008	1645	1648	3	115	10	38.33	7	Operator error. Flow rate too high.
Deep Well	10/10/2008	1720	1724	4	53	4	13.25	4	Begin reducing flow rate incremently to achieve "sustainable flow".
Deep Well	10/10/2008	1730	1733	3	29	2	9.67	~ 5	Noticed seepage. Use recirculation piping on frac unit to reduce flow. Start to calculate volume injected incremently according hieght on batch tank
Deep Well	10/10/2008	1746	1756	10	55	5	5.50	1	Check Flow Rate
Deep Well	10/10/2008	1821	1829	8	33	3	4.13	1	Try injecting with augering only on unit to get lowest flow rate possible. Calculated flow rate is most likely not correct as some fluid may have gravity fed overnight.
Deep Well	10/11/2008	940	955	15	2.3	0	0.15	1	Augering technique not successful.
Deep Well	10/11/2008	1004	1010	6	4	0	0.67	1	Check Flow Rate. Too low. Reduce Recirc.
Deep Well	10/11/2008	1010	1015	5	103	9	20.60	4	Noticed seepage. Increase Recirc.
Deep Well	10/11/2008	1038	1043	5	89	7	17.80	4	Noticed seepage. Increase Recirc.
Deep Well	10/11/2008	1114	1120	6	89	7	14.83	4	Noticed seepage. Increase Recirc.
Deep Well	10/11/2008	1141	1156	15	125	10	8.33	1	Noticed seepage. Increase Recirc.
Deep Well	10/11/2008	1312	1355	43	264	22	6.14	1	No seepage observed. End of batch.
Deep Well	10/11/2008	1428	1455	27	166	14	6.15	2	No seepage observed.
Intermediate Well	10/11/2008	1506	1514	8	41	3	5.13	2	Noticed seepage.
Intermediate Well	10/11/2008	1531	1539	8	58	5	7.25	1	Tank level down. Need to refill.
Intermediate Well	10/11/2008	1552	1557	5	43	4	8.60	1	Noticed seepage.
Intermediate Well	10/11/2008	1613	1653	40	222	19	5.55	1	Tank level down. Need to refill. No seepage observed.
Intermediate Well					34	3			Solution gravity fed.
Intermediate Well	10/12/2008	847	934	47	230	19	4.89	1	No seepage observed.
Intermediate Well	10/12/2008	1047	1127	40	165	11	4.13	1	No seepage observed. ~ 6.4 % solution
Intermediate Well	10/12/2008	1127	1200	33	132	11	4.00	1	No seepage observed.
Shallow Well	10/12/2008	1251	1313	22	44	3	2.00	5 to 2	No seepage observed. Only 10 liters of EOS left. ~ 6.0 % solution
			TOTAL	**431**	**2967**	**272**			

1 - Until 1720 on 10/10/08, flow was measured using the digital readout on the frac unit control panel. Once recirculation was initiated, the flow was measured based on drawdown in the tank on the frac unit.
2 - Pressure was read directly from the digital readout on the frac unit control panel.

TABLE 3-3

FIELD PARAMETER READINGS PRIOR TO AND FOLLOWING INJECTION
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

			Observation Wells					
		Date	OW-1 I	OW-1 D	OW-2 I	OW-2 D	OW-3 I	OW-3 D
Total Depth	Pre-Injection	10/2/2008	19.92	28.83	19.95	29.88	19.91	29.91
Water Level	Pre-Injection	10/2/2008	9.01	11.65	9.56	9.46	8.03	8.04
	Post-Injection	10/12/2008	8.42	11.24	8.85	7.79	6.42	6.70
pH	Pre-Injection	10/12/2008	5.61	5.64	4.85	5.87	5.46	6.21
	Post-Injection	10/12/2008	5.27	5.06	EOS (1)	5.99	EOS	Too Turbid
Conductivity	Pre-Injection	10/12/2008	0.293	0.383	0.381	0.427	0.236	0.519
	Post-Injection	10/12/2008	0.475	0.314	EOS	0.356	EOS	Too Turbid
Turbidity	Pre-Injection	10/12/2008	4.55	8.55	1	22.2	2.27	555
	Post-Injection	10/12/2008	750	180	EOS	440	EOS	Too Turbid
DO	Pre-Injection	10/12/2008	1.85	3.69	1.92	1.84	1.88	1.96
	Post-Injection	10/12/2008	2.94	5.97	EOS	2.53	EOS	Too Turbid
Temp	Pre-Injection	10/12/2008	23.15	22.42	23.24	22	23.1	21.38
	Post-Injection	10/12/2008	24	25.2	EOS	22.66	EOS	Too Turbid
ORP	Pre-Injection	10/12/2008	59	69	146	-80	117	-32
	Post-Injection	10/12/2008	20	10	EOS	-67	EOS	Too Turbid

Notes:
Data measurements were taken after approximately 30 minutes of purging for both events.
1 - EOS - EOS product observed during purging; measurements not collected.

Map Document: (K:\GProject\middle_river\Maps\All_wells_2008_fig1 B.mxd) 10/27/2008

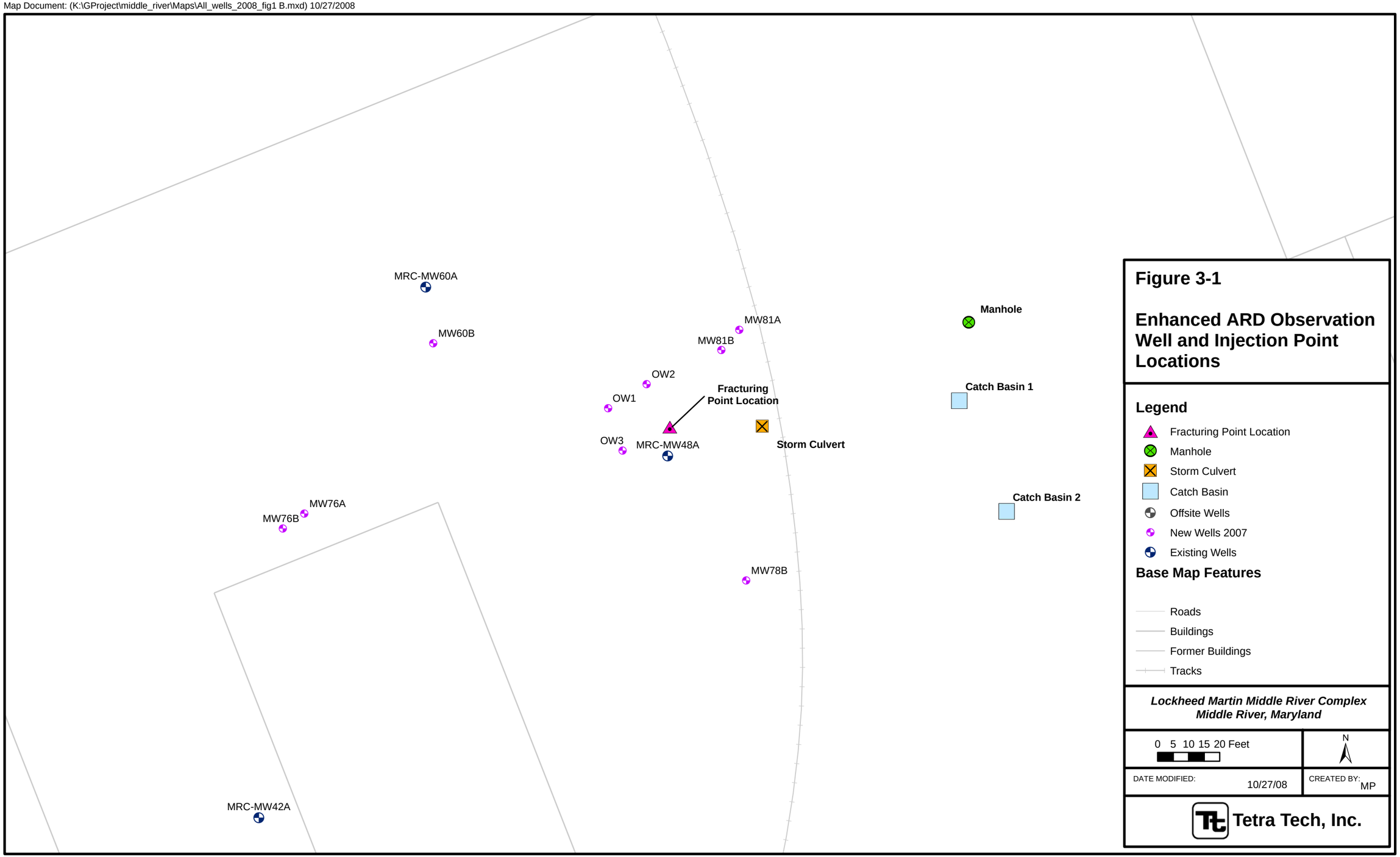


Figure 3-1

Enhanced ARD Observation Well and Injection Point Locations

Legend

- Fracturing Point Location
- Manhole
- Storm Culvert
- Catch Basin
- Offsite Wells
- New Wells 2007
- Existing Wells

Base Map Features

- Roads
- Buildings
- Former Buildings
- Tracks

Lockheed Martin Middle River Complex
Middle River, Maryland

0 5 10 15 20 Feet

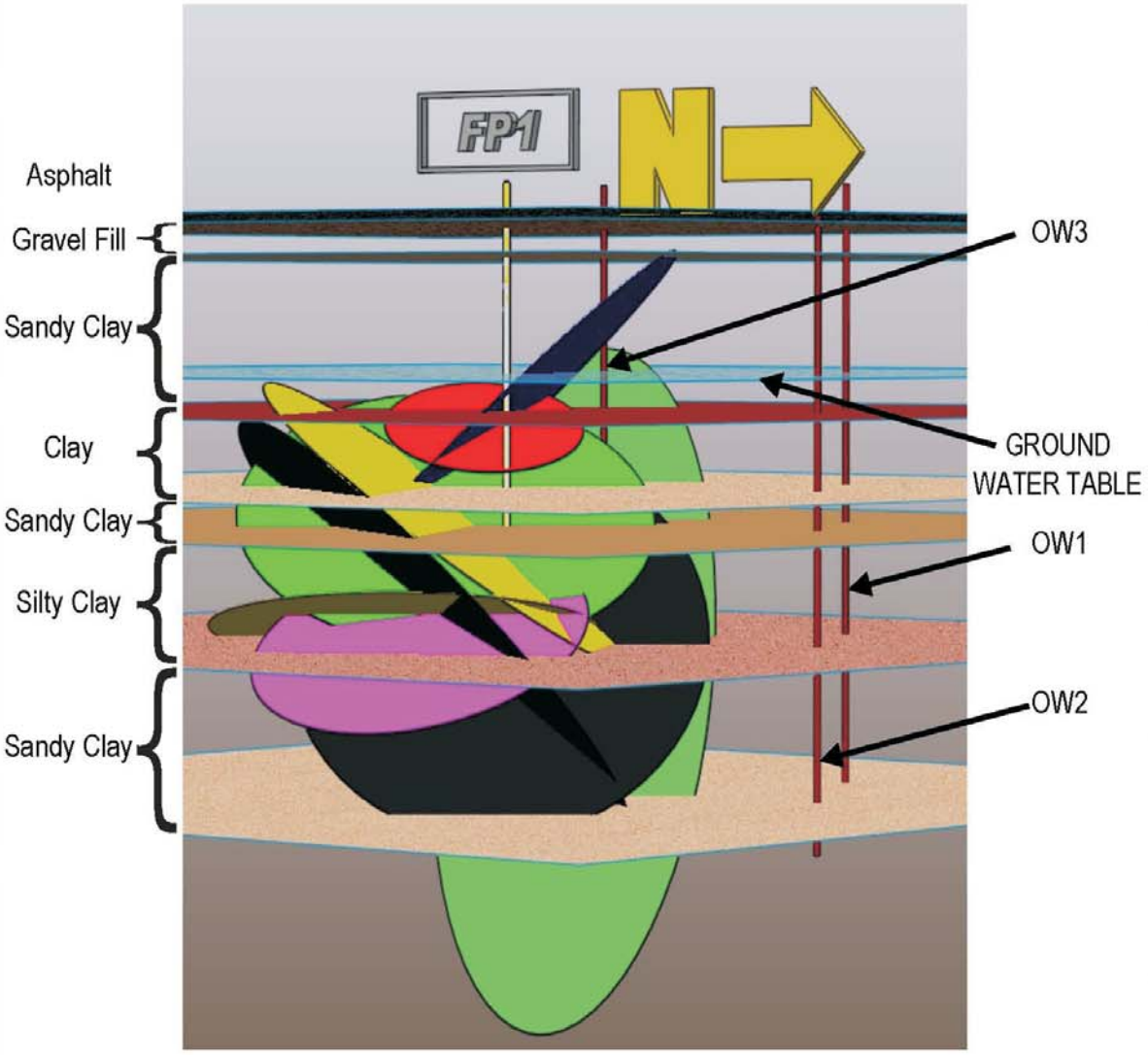
N

DATE MODIFIED: 10/27/08

CREATED BY: MP

Tetra Tech, Inc.

Fracture Point FP1



Source: Frac Rite Environmental LTD.

Figure 3-2

Three-Dimensional Representation of Sand Fractures Induced at FP1 Sheet 1
Middle River Complex

Lockheed Martin Middle River Complex
Middle River, Maryland

DATE MODIFIED:	CREATED BY:
8/14/09	MP

Tetra Tech, Inc.

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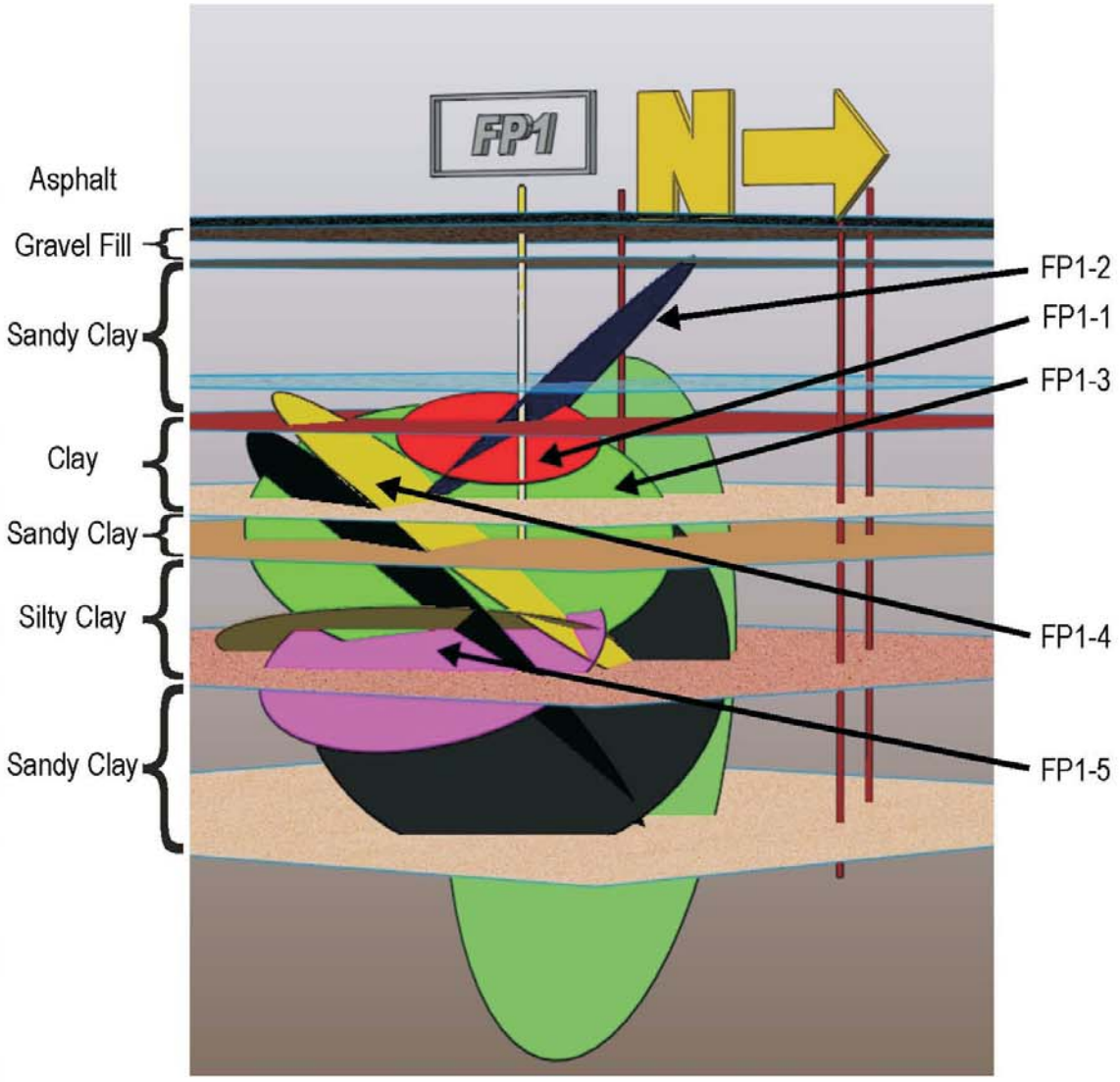
Fracture Point FP1



Source: Frac Rite Environmental LTD.

Figure 3-3

Three-Dimensional Representation of Sand Fractures Induced at FP1 Sheet 2

Middle River Complex

Lockheed Martin Middle River Complex
Middle River, Maryland

DATE MODIFIED:	CREATED BY:
8/14/09	MP

Tetra Tech, Inc.

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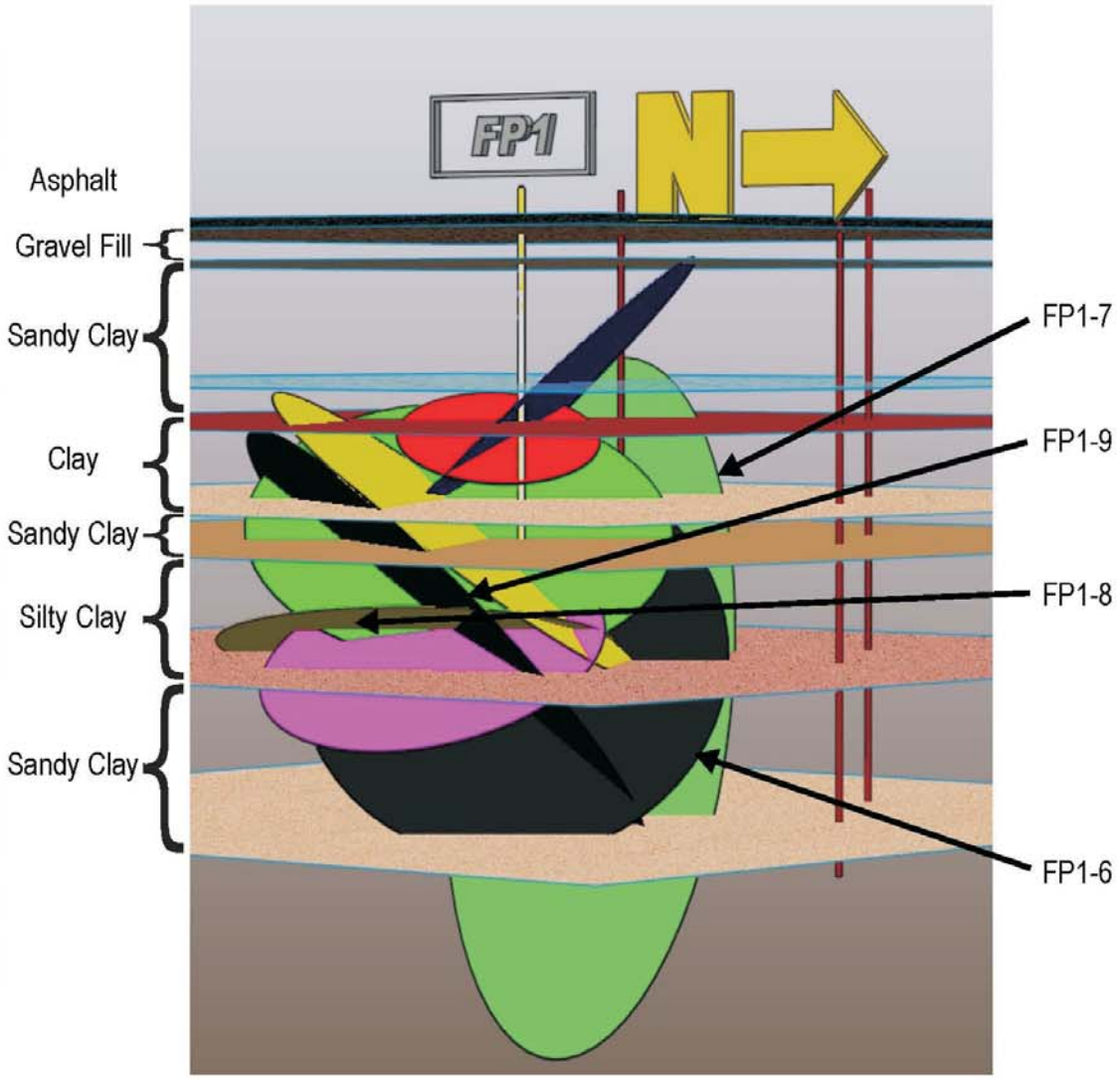
Fracture Point FP1



Source: Frac Rite Environmental LTD.

Figure 3-4

Three-Dimensional Representation of Sand Fractures Induced at FP1
Sheet 3
Middle River Complex

Lockheed Martin Middle River Complex
Middle River, Maryland

DATE MODIFIED:	CREATED BY:
8/14/09	MP

Tetra Tech, Inc.

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Section 4
Enhanced ARD Pilot Study Monitoring Results

This section provides a summary of the pilot study data generated during baseline and performance monitoring.

4.1 BASELINE MONITORING

As stated in Section 3, baseline samples were collected from the six observation wells in January and October 2008. Concentrations of several chlorinated VOCs were elevated in all six wells sampled. The "I" wells exhibited TCE concentrations ranging from 932 to 9,940 µg/L and the "D" wells had TCE concentrations ranging from 2,320 to 12,200 µg/L. The concentrations of cis-1,2-dichloroethene (DCE) (253 to 3,420 µg/L) and vinyl chloride (23 to 178 µg/L) in these wells indicate that dechlorination was occurring in this area prior to substrate addition.

Maximum concentrations of beryllium, cobalt, and nickel in the observation wells associated with this area were 5.4 µg/L, 110 µg/L, and 116 µg/L, respectively, all above the current project screening standards of 4 µg/L, 73 µg/L, and 73 µg/L, respectively.

ORP readings in the area ranged from -49 to 162 mV and DO readings ranged from 0.0 to 2.7 mg/L. The pH in the wells ranged from 4.8 to 6.7 over the two baseline monitoring events.

The microbial analysis showed that DHC concentrations in all wells were below the typical levels required for reductive dechlorination to ethene, 10^4 to 10^6 cells per liter. The highest concentration was in OW3I, 7.4 x 10^3 to cells per liter. Concentrations in the other wells were at least one order of magnitude lower.

A summary of the analytical results for TCE, cis-1,2-DCE, and vinyl chloride, metals,

geochemical parameters (TOC, methane, ethene, ethane, chloride, and sulfate) and key field parameters (pH, ORP, and DO) are included in Table 4-1. A summary of all of the analytical data is presented in Appendix F. Trends for baseline and performance data are shown for chlorinated VOCs in Figure 4-1 and ORP in Figure 4-2.

Field sampling logs are included in Appendix C and laboratory analytical reports are included in Appendix G.

4.2 FIRST ROUND OF PERFORMANCE MONITORING

As stated in Section 3, wells OW1I, 1D, 2I, 2D, 3I, and 3D were sampled in November 2008, approximately one month after substrate injections took place. A summary of the analytical results for this monitoring event are included in Table 4-1 and Appendix F. An analysis of the data is included below.

Based on the tiltmeter results and initial field readings, it appeared that the injections achieved better chemical distribution at OW2 and OW3 than at OW1. The results of the first round of post-injection performance monitoring appear to reflect this observation.

In summary, the results show that the EOS® injections modified the geochemical conditions at OW2I, OW2D, OW3I, and OW3D, yet had no measurable effect on the conditions at OW1I and OW1D. The field readings and geochemical monitoring at OW2I, OW2D, OW3I, and OW3D showed:

- In the four affected wells, the ORP was significantly reduced. The maximum post-injection ORP reading was -80 mV. The average ORP in these wells was reduced from +4 mV to - 110 mV (a range of -80 to -156 mV).

- In three of the four wells, the DO concentration was reduced to non-detect. The average in the four wells was reduced to 0.25 mg/L from 1.8 mg/L.

- Sulfate concentrations were significantly reduced in three of the four wells, indicating that sulfate-reducing conditions had been achieved.

- TOC concentrations increased in the four wells. The concentrations in these wells ranged from 24 mg/L to 310 mg/L, with an average of 130 mg/L (up significantly from a baseline

average of 3.1 mg/L). This indicates that the electron donor was distributed in these locations.

- Ethene concentrations did not show elevated concentrations over baseline conditions except at OW2D; as explained below, this well also exhibits the best evidence that reductive dechlorination was occurring one month following injection.

- The pH in the wells ranged from 5.5 to 5.6 standard units, below the optimal level for reductive dechlorination. These values are similar to the results obtained just prior to injection.

Since EOS® is primarily a slow release electron donor, it was anticipated that low DO and high TOC conditions would be maintained through the next monitoring event (three months post-injection).

Chlorinated VOC concentrations were also affected in three of the four wells. Note that explanations of the data below are based on incomplete data (only one round of post-injection monitoring). An explanation of the final monitoring results is provided in Section 4.4.

- OW2D showed TCE concentrations were reduced by 46 percent, cis-1,2-DCE concentrations increased by more than a factor of 3, and vinyl chloride concentrations increased by more than an order of magnitude. Additionally, the ethene concentration increased by more than 3 times, indicating that break down of vinyl chloride was occurring.

- OW2I had 70 percent reductions in TCE. However, cis-1,2-DCE and vinyl chloride concentrations in the wells remained basically steady.

- OW3D showed a 30 percent increase in the TCE concentration, but a 10-fold increase in the DCE concentration.

- OW3I showed increases in TCE, DCE, and vinyl chloride concentrations.

4.3 SECOND ROUND OF PERFORMANCE MONITORING

The second round of post-injection performance monitoring occurred in January 2009, approximately three months after injection and included monitoring of the same wells and parameters as the first round (with the exception of metals).

In summary, the results continue to show that the EOS® injections had a significant effect on the geochemical conditions and chlorinated VOC concentrations at OW2I, OW2D, OW3I, and OW3D, and little measurable effect on the conditions at OW1I. Well OW1D began to show some effect from the injections.

- In the four most affected wells, the ORP remained basically steady since the last monitoring round, which represents a significant reduction from the baseline conditions. The maximum second round ORP reading was -66 mV. The average ORP in these wells was reduced from a baseline of +4 mV to the current -107 mV (a range of -66 to -163 mV). These conditions are conducive to reduction dechlorination.

- In all four of the wells, the DO concentration was reduced to non-detect. The average in the four wells was 1.8 mg/L in the baseline monitoring.

- Sulfate concentrations were reduced to very low or non-detect levels in all four of the wells, indicating that sulfate-reducing conditions have been achieved and maintained.

- In general, TOC concentrations moderated between the first and second rounds of post-injection monitoring, but remain significantly higher than the baseline conditions (72 mg/L as compared to 3.1 mg/L). OW3D showed a slight increase for the previous monitoring round.

- Ethene concentrations did not provide conclusive evidence that the complete degradation pathway in all wells was occurring at this stage. A significant increase was observed at OW2I during this event, and an overall increase from baseline conditions was observed at OW2D, but the results from the OW3I and OW3D do not show an increase.

- The pH in the wells is approximately 5.5, below the optimal level for reductive dechlorination.

- Although the first round of post-injection monitoring showed no impact of the injections at OW-1D, some evidence that the effect of the EOS® has migrated to this well was observed during this monitoring event. The data show a decrease in ORP (to -36 mV), and a small, but significant increase in TOC, and moderate reductions in VOC concentrations.

These results indicate that reducing conditions were maintained three months after injection and that there is still significant carbon source in the subsurface in the pilot study area.

Chlorinated VOC concentrations were also affected in OW2I, OW2D, OW3I, and OW3D. OW3I had not shown reductions in the first round of post-injection monitoring round:

- All four wells followed the same pattern: TCE concentrations in the wells were reduced by 80 percent, 94 percent, 97 percent, and 97 percent, respectively. cis-1,2-DCE concentrations increased by 2.7 times, 3.5 times, 6.7 times, 12.1 times, respectively. Vinyl chloride concentrations increased by 3.6 times, 48 times, 2.0 times and 2.7 times, respectively. This indicates that TCE reduction was occurring, and some accumulation of DCE and VC was taking place, as can be seen on Figure 4-1.

- Molar balance calculations indicate that reductions in total moles of chlorinated VOC mass of 5 percent and 25 percent were observed in OW2I and OW2D; despite significant TCE reductions, total moles of chlorinated VOCs actually increased in OW3I and OW3D. Corresponding to those reductions, OW2I and OW2D, indicated significant ethene concentration increases.

The second-round performance monitoring data indicate clearly that the addition of the EOS® to the subsurface had caused measurable enhancement of the natural biodegradation processes in the pilot test area. The third and final post-injection event was very important to determine if the accumulation of the DCE and VC was temporary or would develop into "stall" with the DCE and VC concentrations persisting. The pH in the area (approximately 5.5) and the low natural DHC counts (between 5.5×10^{-1} and 7.4×10^{3} cells/L) were indicators that the process would continue to stall through the third monitoring period.

4.4 THIRD AND FINAL ROUND OF PERFORMANCE MONITORING

The third and final round of post-injection performance monitoring occurred in April 2009, approximately six months after injection and included monitoring of the same wells and parameters as the baseline monitoring event. The results from this round of monitoring showed that the VOC concentrations continued to decrease in many of the site wells and the populations of DHC and the important functional genes, especially BVC and VCR, increased significantly. Importantly, the results also show increased evidence of complete ARD to ethene at several

observation wells and, potentially, of reductive dechlorination at OW1D, which was originally outside the influence of the injections (as well as a limited effect at OW1I). The results are summarized in Table 4-1 and Appendix F. Figure 4-1 includes graphs showing the chlorinated VOC concentrations in each of the observation wells for each of the four monitoring events.

In general, the results show that after six months, the ORP indicates that reducing conditions are still present in the aquifer near or still at their maxima, and with a decreasing ORP trend now present at OW1D. DO readings and sulfate concentrations both increased from the second monitoring round indicating that the groundwater in the area may be returning to baseline conditions, despite the maintenance of low ORP in the wells. TOC concentrations have decreased, also indicating a return toward baseline conditions, but are still up to an order of magnitude higher than initial concentrations. Also, the data show that the metals concentrations were either lower or essentially equal to those measured prior to injection.

The effect of the injections on a well-by-well basis are summarized below:

- OW1I – This well showed the least effect from the injections. In this monitoring event, TOC did not increase and reducing conditions were not established. However, some data indicated that limited ARD may have been occurring. For example, in the second round monitoring event, chloride concentrations increased more than 2 times, and an overall reduction of 35 percent of chlorinated VOCs on a molar basis was observed. Additionally, the DHC concentrations increased by more than one order of magnitude; however, the values at this well were still below the typical values for effective ARD of TCE to ethene.

- OW1D – This well began to show an effect from the injections during the second performance event. That effect was magnified in the third event. Despite not achieving significant increases in TOC, moderate to strongly reducing conditions were established (the ORP was -103 mV). Chloride concentrations increased very significantly (4.6 times the concentration from the second monitoring round) and a sharp decrease in VOCs was observed (a 90 percent reduction of chlorinated VOCs on a molar basis). Because all of the CVOC concentrations showed decreases, physical processes may have also contributed to these decreases. DHC concentrations increased more than three orders of magnitude to 8.09×10^4 cells per liter and the BVC and VCR functional genes increased by two and three orders of magnitude, respectively.

- OW2I – Very significant reductions in chlorinated VOC concentrations, 99 percent on a molar basis, were observed at this well in conjunction with reducing conditions, TOC increase, ethene production, sulfate reductions, and an increase in chloride. This shows strong evidence that complete ARD was occurring at this well. No microbial monitoring was completed at this well.

- OW2D – Very similar conditions as observed at OW2I, with reducing conditions, TOC increase, ethene production, sulfate reductions, and an increase in chloride. Chlorinated VOC reductions at this well were 67 percent on a molar basis. No microbial monitoring was completed at this well.

- OW3I – This well also showed good response in both chlorinated VOC reduction and geochemical parameters, with an 84 percent overall reduction in VOCs on a molar basis after initial increases, showing good evidence of ARD to ethene. At this well, DHC concentrations increased by an order of magnitude, to 8.09×10^4 cells per liter. The BVC and VCR functional genes increased by more than two orders of magnitude each.

- OW3D – Results at this well were somewhat mixed indicating that ARD was taking place, but perhaps not to completion. Highly reducing conditions were created and maintained at the well, with the three post-injection ORP readings being -156, -163, and -163 mV, respectively. High TOC concentrations and the highest chloride concentrations at the site were also observed and TCE was reduced to less than 83 µg/L. Most striking was the increase in DHC concentrations from 5.5×10^1 to 3.14×10^7 cells per liter; the functional gene BVC also had a very significant increase of five orders of magnitude. However, the total chlorinated VOC concentrations actually increased by 33 percent on a molar basis and ethene production was low. It is possible that despite the significant DHC and functional gene mass at the well, the complete dechlorination pathway was not being obtained and DCE/vinyl chloride stall was being observed.

4.5 AREA OF INFLUENCE OF INJECTIONS

One of the most important goals of this test was to determine the area of the site that could be influenced via injection through emplaced fractures. An immediate effect on the groundwater conditions at OW2 and OW3 showed that a significant area could be effected. Because the tiltmeter data shows that OW3 is outside of the fracture pattern, this data also showed that the electron donor was entering the aquifer outside of the fractures, an important consideration for future injections.

The data also show that the injection affected both the "I" and "D" series wells, leading to the conclusion that good vertical distribution was obtained. The immediate change in conditions at wells OW2 and OW3 indicated that the injection influenced at least 16 feet laterally within and outside the fracture pattern. The information from the tiltmeters indicated that some of the fractures extended beyond 20 feet in these directions, so it can be concluded that the influence extended to at least that distance. The eventual change in conditions observed at OW1 indicated that over time, influence could be expected, at least in some strata of the contaminated zone, at a

distance of 20 feet from the injection location in an area perpendicular to the orientation of the fractures. A 20-foot radius of influence would be considered conservative because it provides an area nearly equal to the area of the fracture pattern and, as stated above, it is known that the influence of the injections spread beyond the area of the fractures.

Based on this information, it can be concluded that if fracturing were utilized on a full scale, a conservative radius of influence of 20 feet could be utilized.

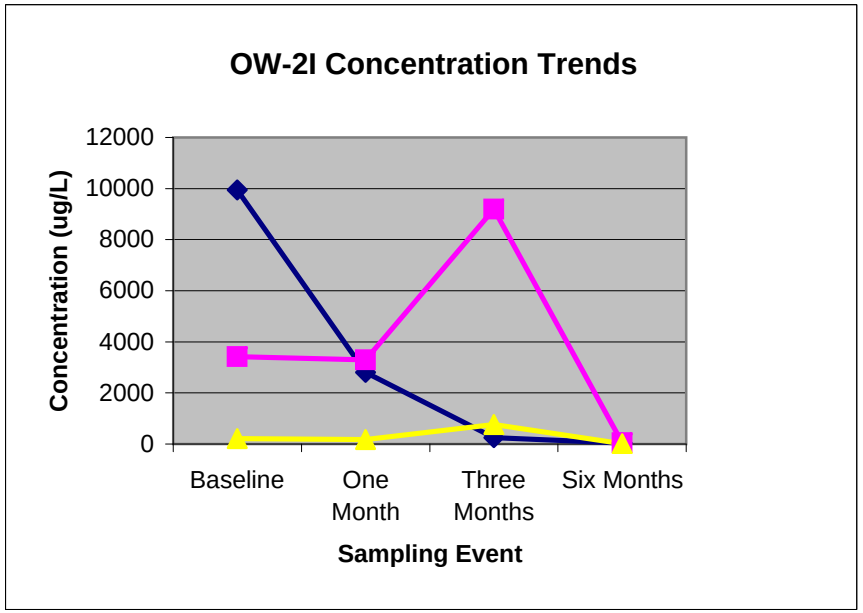
TABLE 4-1

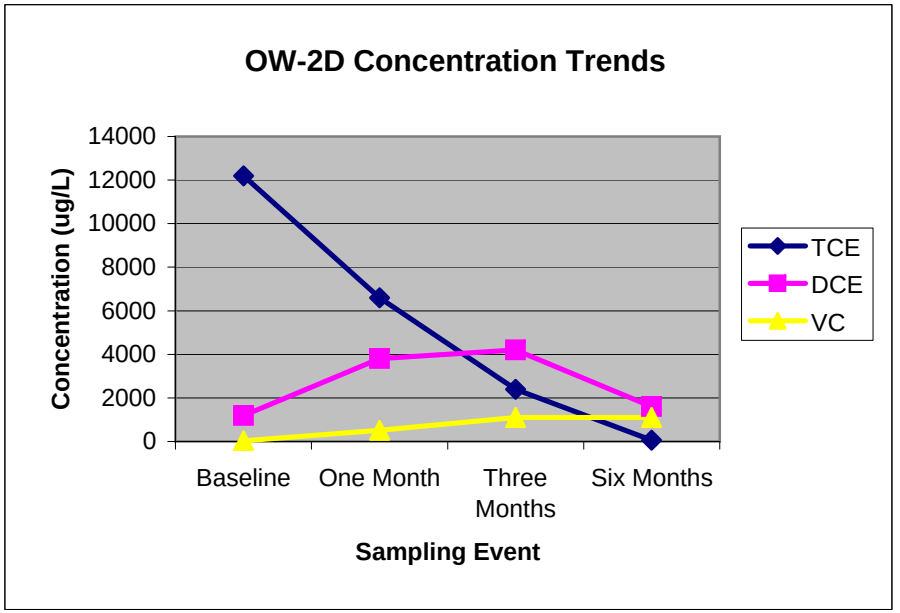
SELECTED ENHANCED ARD PILOT STUDY DATA
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

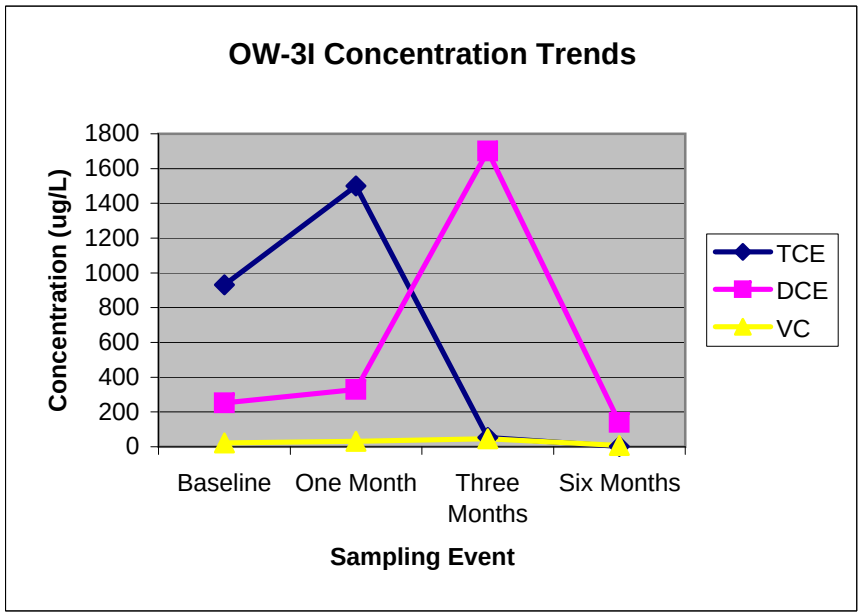
Observation Well	Sampling Round	TCE µg/L	DCE µg/L	VC µg/L	Total CVOC µ–mol/L	Beryllium µg/L	Cobalt µg/L	Nickel µg/L	Iron µg/L	TOC mg/L	Methane µg/L	Ethene µg/L	Chloride mg/L	Sulfate mg/L	pH S.U.	ORP mV	DO ppm	DHC Cells/mL
OW1I	Baseline	7390	1730	178	76.9	0.9 J	87.5	34.5	--	3.0	3530	9.5	60.8	11.1	5.88	37	2.54	--
	Baseline - 2 *	--	--	--		--	--	--	--	--	--	--	--	--	5.34	57	1.72	0.265
	Round 1	2800	740	68	30.0	0.43	21.8	11.4	--	4	1200	3.5	--	17.2	5.89	25	2.74	--
	Round 2	7700	1800	210	80.5	--	--	--	--	3	590	1.7	73.5	9.5	--	41	0.00	--
	Round 3	4100	1600	120 J	49.6	0.58 B	41.1	12.3	7080	5	1200	5.9	172	14.5	6.02	75	5.12	4.9
OW1D	Baseline	9370	1740	81	90.6	ND	29.8	16.7	--	3.1	634	80.4	60.2	43.1	6.74	-15	2.65	--
	Baseline - 2 *	--	--	--		--	--	--	--	--	--	--	--	--	5.66	-13	2.84	<0.25
	Round 1	8500	1600	170	83.9	--	--	--	--	3.0	3300	7.0	--	7.6	5.39	48	2.70	--
	Round 2	7800	880	ND	68.4	--	--	--	--	8	55	ND	32.2	2.7	--	-36	0.00	--
	Round 3	150	790	ND	9.3	0.37 B	12.2	18.8	14700	4	22	0.57	148	11.9	6.40	-103	4.81	58.9
OW2I	Baseline	9940	3420	211	114.3	5.7	235	136	--	3.1	3390	9.2	83.0	43.3	5.39	162	0.00	--
	Baseline - 2 *	--	--	--		--	--	--	--	--	--	--	--	--	4.83	153	1.92	--
	Round 1	2800	3300	170	58.1	--	--	--	--	310	3400	3.7	--	1.3	5.58	-83	0.00	--
	Round 2	250	9200	760	109.0	--	--	--	--	100	850	60	97.9	0.4	--	-111	0.00	--
	Round 3	39	53	16	1.1	0.46 B	32.4	35.1	8700	38	1200	290	169	4.6	6.60	-84	5.46	--
OW2D	Baseline	12200	1190	23	105.5	0.1 J	22.5	19.5	--	5.7	350	27.5	48.8	15.1	6.26	-30	0.58	--
	Baseline - 2 *	--	--	--		--	--	--	--	--	--	--	--	--	5.71	-49	1.58	--
	Round 1	6600	3800	510	97.6	0.37	10.2	8.8	--	24	490	89.0	--	17.2	5.62	-122	1.01	--
	Round 2	2400	4200	1100	79.2	--	--	--	--	8	193	43	48.6	ND	--	-88	0.00	--
	Round 3	60	1600	1100	34.6	0.29 B	16.8	19.4	85200	8	1400	290	462	0.20 B	6.61	-118	4.71	--
OW3I	Baseline	932	253	23	10.1	0.1 J	22.5	19.5	--	1.7	990	4.0	39.1	37.3	6.33	67	0.58	--
	Baseline - 2 *	--	--	--		--	--	--	--	--	--	--	--	--	5.46	117	1.88	7.41
	Round 1	1500	330	32	15.3	0.83	74.9	47.4	--	75	2500	5.1	--	0.5	5.51	-80	0.00	--
	Round 2	53	1700	46	18.7	--	--	--	--	41	2100	ND	50.6	0.2	--	-66	0.00	--
	Round 3	2.3 J	140	7.2	1.6	0.38 B	1.6	0.88 B	12800	13	5700	4.3 J	158	6.1	7.01	-167	4.28	80.9
OW3D	Baseline	2320	331	28	21.5	0.07 J	25.0	22.9	--	2.1	1190	15.1	41.5	75.0	6.62	-40	0.21	--
	Baseline - 2 *	--	--	--		--	--	--	--	--	--	--	--	--	5.96	-18	1.71	0.055
	Round 1	3000	2800	45	52.4	0.32	51.4	9.9	--	120	1400	11.0	--	0.3	5.54	-156	0.00	--
	Round 2	ND (140)	4000	75	42.5	--	--	--	--	140	2100	3.6	2.0	ND	--	-163	0.00	--
	Round 3	ND (83)	2700	440	34.9	0.65 B	17.6	4.4	149000	11	7100	11	862	ND	7.27	-163	4.68	31400

* This data was collected one week prior to the injections.
TCE - Trichloroethene
DCE - cis-1,2-Dichloroethene
VC - Vinyl Chloride
TOC - Total Organic Carbon
ORP - Oxidation Reduction Potential
DO - Dissolved Oxygen
mg/L - Milligrams per Liter
µg/L - Micrograms per Liter
S.U. - Standard Units
mV - millivolts
ppm - Parts per Million
DHC - Dehalococcoides

Figure 4-1
Chlorinated VOC Trends
Enhanced ARD Pilot Study
Lockheed Martin, Middle River, MD
(Page 1 of 2)







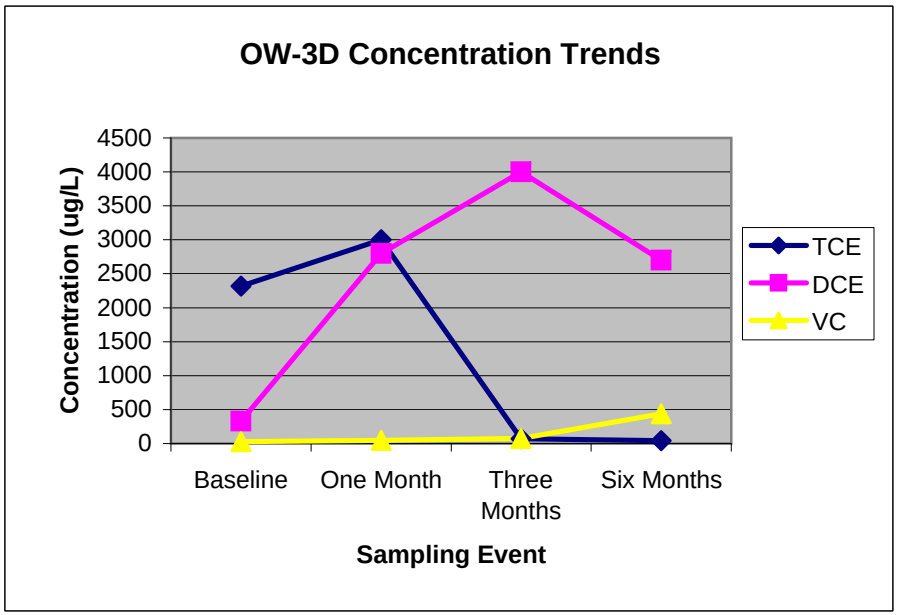
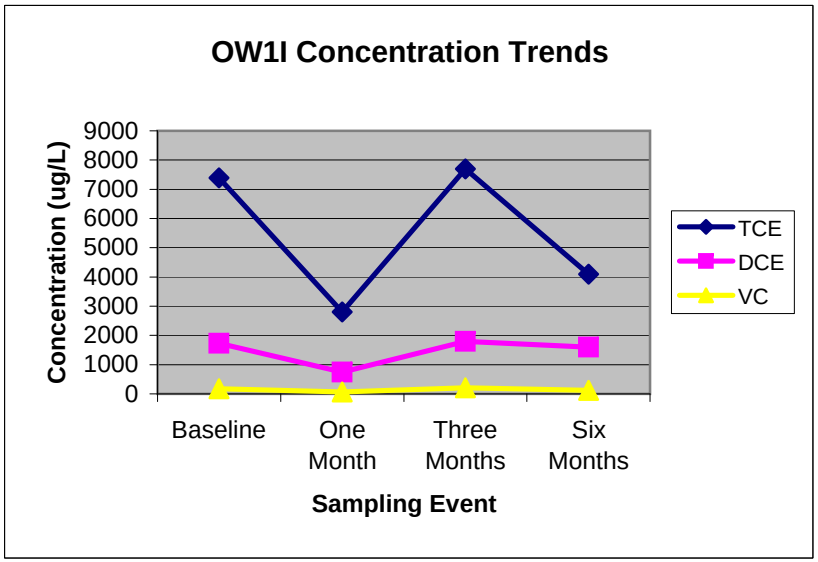


Figure 4-1
Chlorinated VOC Trend Data
Enhanced ARD Pilot Study
Lockheed Martin, Middle River, MD
(Page 2 of 2)



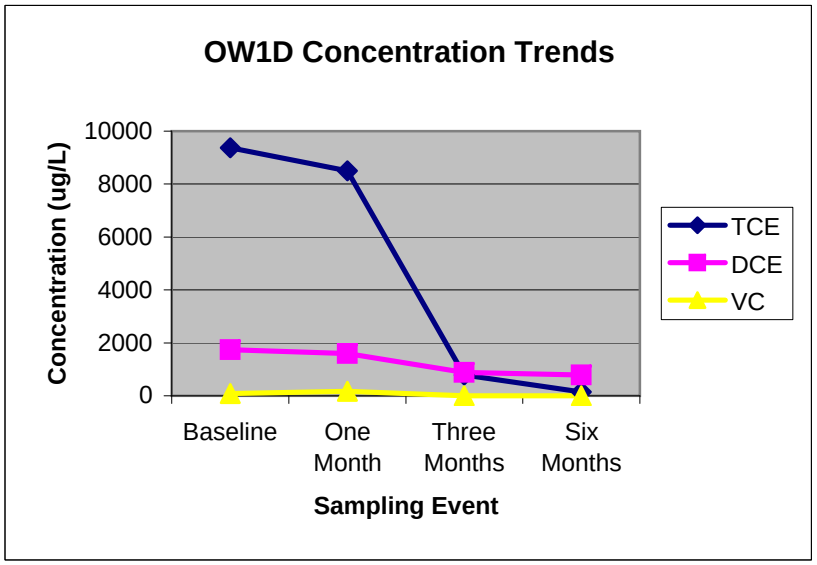
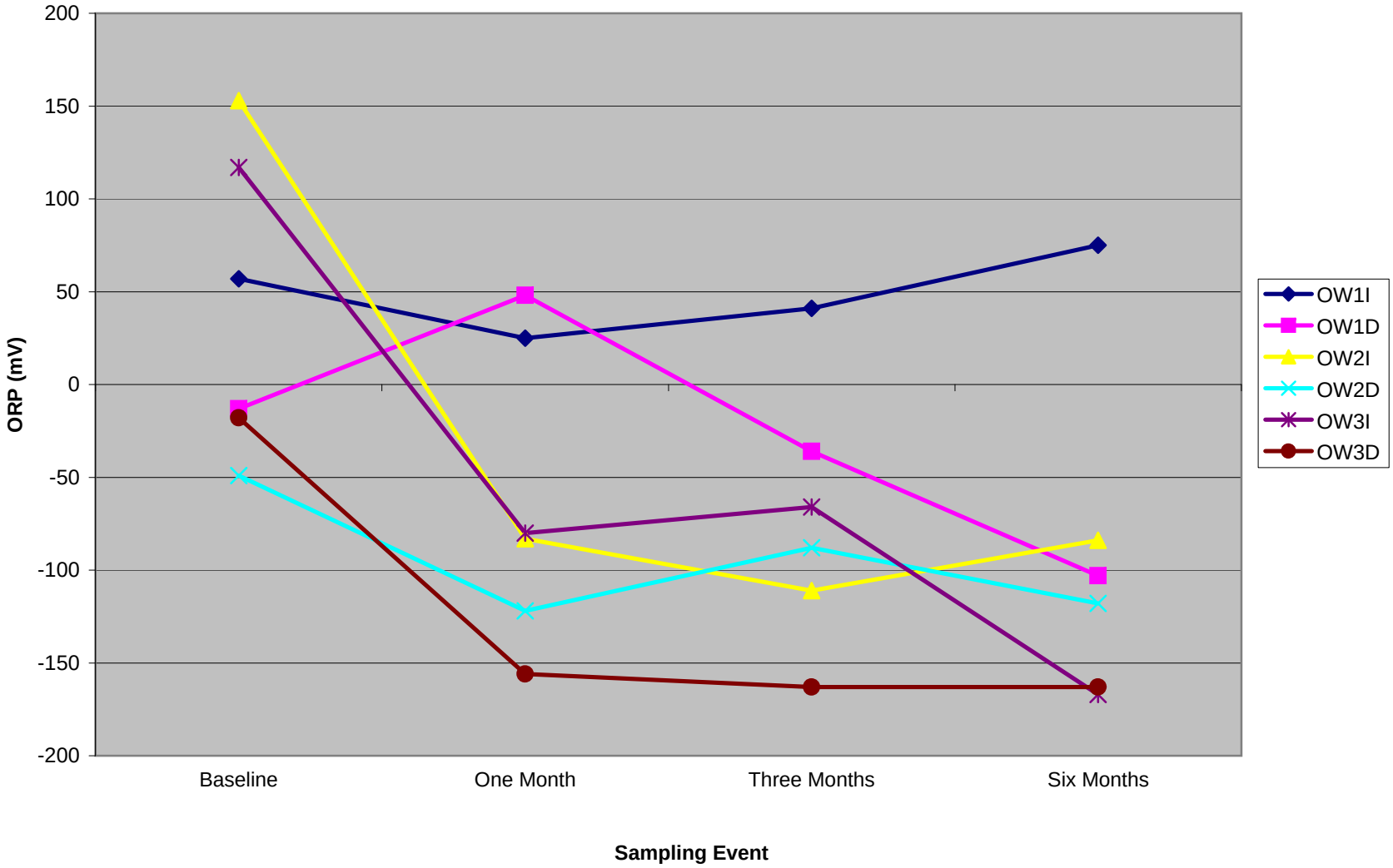


Figure 4-2
ORP Trends
Enhanced ARD Pilot Study
Lockheed Martin, Middle River, MD



Section 5
Conclusions

The following conclusions can be drawn from the enhanced ARD pilot testing activities described in this report:

- Hydraulic fracturing can be an effective means to extend the influence of a single injection point beyond what would be expected in low permeability native materials. Based on the results of the test, a conservative area of influence of approximately 1,200 square feet per fracture location (approximately equivalent to a 20-foot radius of influence) could be used for designing a full-scale remedy. However, there are risks associated with implementing this remedy in operating areas of the plant.

- If injecting in the active area of the plant, all utilities (operating and non-operating) must be identified and rates of injection must correspond with the ability of the native formation to accept the injectate. Also, other water soluble electron donors should be considered.

- The cost and efficacy of this type of injection can be compared to the costs of injection via direct push technology or permanent injection wells to determine the most cost-effective remedial strategy.

- Near-surface fractures (less than 15 feet bgs) should not be conducted since they have the potential for propagating near the ground surface and possibly daylighting.

- Control of the fracture initiation depth was not adequate; additional measures to control this parameter will be required if full-scale implementation is feasible.

- Injection of an emulsified oil substrate (without the addition of a pH buffer or a microbial consortium) in the northern portion of the eastern plume was effective in establishing reducing conditions, ARD from TCE to ethene, and growth of a significant population of DHC and other important biological parameters such as DHB, DSM, BVC, and VCR (see Section 4.3 for details). This technique would be expected to be effective if implemented on a full-scale basis in this area. Note that the lower pH present in the southern portion of the eastern plume and the presence of 1,4-dioxane in the western plume would limit the effectiveness of this remediation strategy in those areas.

- The volumes and concentration of EOS® were sufficient to enhance ARD and provide concentration reductions to near target levels in some wells. Based on the results of the test, multiple injections will be required to meet the project goals.

- Reducing conditions were maintained and ARD continued in the observation wells for a period of at least six months. This will provide guidance on the time period between injections in a full-scale application.

- No increase in the groundwater metals concentrations was observed following the EOS® injection.

Section 6
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APPENDIX A ENHANCED ARD BENCH-SCALE STUDY

Middle River Complex
Bench-Scale Study Report

October 10, 2008

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Section 1
Introduction

The primary contaminants of concern (COCs) at the Lockheed Martin Middle River Complex site include trichloroethene (TCE), 1,4-dioxane, benzene, and metals (Ni, Be, and Co). *In situ* chemical oxidization (ISCO) and enhanced anaerobic bioremediation (EAB) were proposed as potential remediation technologies. Since the optimal chemical oxidant for ISCO and the optimal bioaugmentation culture and electron donor for EAB are all site specific, a bench-scale study was performed by the CDM Environmental Treatability Laboratory (Bellevue, WA) to support remedy design.

The objectives of this bench-scale study include the following:

For ISCO tests:

- Relative effectiveness of permanganate, un-activated persulfate, and activated persulfate in removing COCs including TCE, 1,4-dioxane, and benzene in the East and West Plumes
- Soil oxidant demand (SOD) of the site soils
- Relative effectiveness of sodium persulfate as oxidant with and without activator
- The optimal activator for sodium persulfate if activation is necessary
- The optimal oxidant for COCs removal for the site
- The effect of low pH groundwater on ISCO performance

For EAB tests:

- Relative effectiveness of EOS, EOS with vitamin B12, lactate, and whey with bioaugmentation culture (Shaw SDC-9TM) in treating TCE in samples of site groundwater and soil from the East Plume.
- The effect of metals presented in the low pH area on EAB remediation results
- The optimal electron donor for use in EAB.

Section 2
Sample Receipt and Baseline Analysis

CDM Environmental Treatability Laboratory received soil and groundwater samples from both the low pH zone and the neutral pH zone from the East Plume and the West Plume. Background groundwater samples from uncontaminated areas adjacent to each of the plumes were also received. Sample information is summarized in **Table 2.1**.

Table 2.1 Sample Log

Name	*Sampled from*	*Date Received*	*Amount Received*	*ISCO Tests*	*EAB tests*
MRC Soil W-N	MW-12A	11/20/2008	six 8-oz jars	√	
MRC Soil W-L	MW-21	11/20/2008	six 8-oz jars	√	
MRC Soil E-N	MW-37	11/20/2008	twenty-six 8-oz jars	√	√
MRC Soil E-L	MW-24	11/21/2008	twenty-six 8-oz jars	√	√
MRC GW W-N	MW-12A	11/28/2008	five 1-L bottle	√	
MRC GW W-L	MW-21B	11/28/2008	five 1-L bottle	√	
MRC GW E-N	MW-37A	11/28/2008	twenty-four 1-L bottle	√	√
MRC GW E-L	MW-24A	11/28/2008	twenty-four 1-L bottle	√	√
MRC BGW-W	MW-63A	11/28/2008	five 1-L bottle	√	
MRC BGW-E	MW-57A	11/29/2008	five 1-L bottle	√	

Note:

W = West Plume
E = East Plume
N = Neutral pH Zone
L = Low pH Zone
GW = groundwater
BGW = background water (uncontaminated)

Baseline analysis of VOC concentrations in the groundwater samples was conducted upon receipt (**Table 2.2**). Samples from the West Plume contained higher concentration of TCE than samples from the East Plume. Within the same plume, samples from the neutral pH zone have higher TCE concentrations than those from low pH zone. Benzene and 1,4-dioxane were detected in samples from West Plume. Benzene was also detected at 3.4 μg/L in groundwater from the low-pH East Plume. Contaminant concentrations in the background samples were all below detection limits except TCE (4.2 μg/L) in the West Plume, which is neglectable compared with the TCE concentrations in the contaminated groundwater (120 μg/L in the low pH zone sample and 11000 μg/L in the neutral pH zone sample).

Table 2.2 Groundwater VOC Baseline Analysis

	TCE (scan) (µg/L)	*flag*	*Benzene (scan) (µg/L)*	*flag*	*Other VOCs Present in sample at >10 µg/L (Scan) (µg/L)*		*TCE (SIM) (µg/L)*	*flag*	*1-4 Dioxane (SIM) (µg/L)*	*flag*
E-GW-Low	43		3.4		1,1-DCA	16	49		<20	U
E-GW-Neutral	160		<1	U	ND	<10	170		<20	U
W-GW-Low	450		27		1,1-DCA	12	120		13	
W-GW-Neutral	1100		2.8		cis-1,2-DCE	110	1100		210	
Background-E	<1	U	<1	U	ND	<10	<1	U	<20	U
Background-W	2.8		<1	U	ND	<10	4.2		<20	U

Note:
Scan and SIM are two different GC/MS system modes. Scan mode will monitor a range of masses and SIM (Selective Ion Monitoring) mode only look for specific analytes of interest.

Soil and groundwater samples from the East Plume were also sent to OnSite Environmental analytical laboratory (Redmond, WA) for baseline metal analysis (**Table 2.3**). As expected, samples from the low pH zone contained higher concentrations of metals than those from neutral pH zone. In all samples, nickel concentrations were higher than cobalt and beryllium. Two jars of soil for each soil sample were analyzed. The results between different jars had a relative percent deviation (RPD) of 0 to 117%. After the free water in the soil samples was drained, the moisture contents of the soil samples were 19 to 20%.

Table 2.3 Baseline Metal Analysis for East Plume samples

	Beryllium		***Cobalt***		***Nickel***		***Moisture***	
	Average (µg/L)	*RPD (%)*	*Average (µg/L)*	*RPD (%)*	*Average (µg/L)*	*RPD (%)*	*Average (%)*	*RPD (%)*
GW-E-L	46	2%	200	10%	525	2%	-	-
GW-E-N	10	0%	27	44%	50	0%	-	-
Soil-E-L	1.2	51%	13	117%	16	45%	19	11%
Soil-E-N	0.75	36%	4.5	18%	12	17%	20	10%

Section 3
Setup and Deviation from Work Plan

ISCO

The treatability study was conducted in CDM's Environmental Treatability Laboratory in Bellevue, Washington according to the work plan. The bottles were setup on November 29, 2007. Duplicate bottles were constructed for 10% of the tests. Soil, groundwater, and activator (as applicable) were added to 4 ounce glass bottles. The bottles were then sealed with lids that had Teflon fluorocarbon resin/silicone septa and shaken vigorously. Oxidant was then added to each bottle by injection through the septum. The bottles were then stored in the dark and incubated at room temperature.

There were a total of two sampling event for the ISCO study at zero and seven days. Due to the vast number of bottles and required amount of analyses, for each sampling event, analyses were performed over the course of four days. Samples were filtered and refrigerated upon collection. Analyses performed for each test and the analytical methods used were consistent with the work plan.

EAB

Only samples from the East plume (both low and neutral pH zones) were used for the EAB tests. The microcosms were constructed in an anaerobic chamber with a nitrogen atmosphere between December 4th and December 7th, 2007. Ten replicate microcosms were constructed for each test. Soil, groundwater, electron donor, and, for the low pH zone microcosms, sodium hydroxide solution were added to each microcosm according to the design in the work plan. Microcosms were then sealed with thick butyl rubber stoppers and aluminum crimp tops. The microcosms were then inoculated with SDC-9 bioaugmentation culture from Shaw Environmental, Inc. through injection. The microcosms were shaken and then removed from the anaerobic chamber. Microcosms from Test 1 and Test 7 were sterilized by pressurizing at 20 pound per square inch (psi) at 260 degrees F for 20 minutes. Initial pH analyses were performed, and Tests 3, 4 and 6 showed low pH values ranging from 5.4 to 6.3. As a result, these microcosms were neutralized with the addition of sodium hydroxide (amount required for neutralization was determined through titration tests with groundwater and soil). All microcosms were re-inoculated with Shaw SDC-9 bioaugmentation culture on December 11th, 2007.

The setup, sampling and analysis were performed according to the work plan except following deviations:

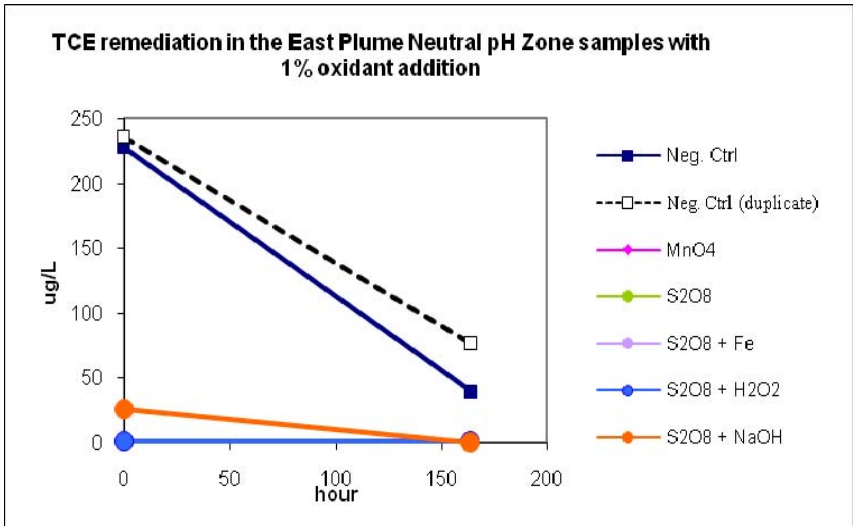
- All microcosm bottles (except killed control and negative controls) were inoculated twice, as described above.
- The EAB tests for East Plume Neutral pH Zone sample was stopped at 12 weeks of incubation (instead of 16 weeks) because all contaminants have been removed by 12 weeks.

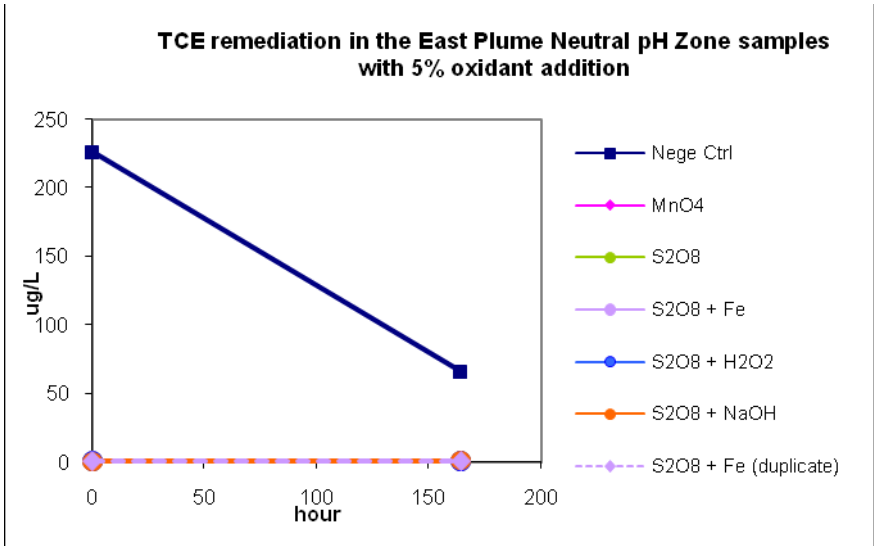
Section 4
Results from ISCO Tests

4.1 East Plume – Neutral pH Zone

The results of VOC removal in the East Plume neutral pH zone samples are presented in **Figures 4.1** to **4.3**. Time zero concentrations for many samples containing oxidant are less than the negative control. The reason is that these samples were held on the purge and trap automatic sampling apparatus awaiting analysis and during this time, oxidant was present and actively degrading the contaminants.

Figure 4.1 TCE Removal in East Plume Neutral pH Zone

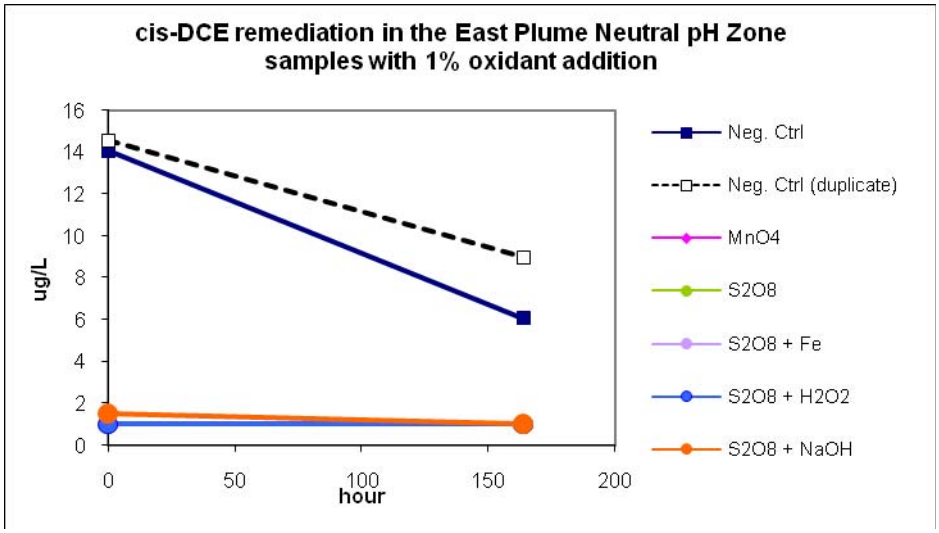




The results presented in **Figures 4.1** to **4.3** indicate that all oxidants were capable of rapidly oxidizing TCE and cis-DCE at both 1% and 5% persulfate concentrations. Unactivated persulfate was effective at oxidizing TCE and cis-DCE. Base-activated persulfate oxidized TCE and cis-DCE at the slowest rate. The concentrations of benzene were very low in this study. Therefore, definitive conclusions about benzene removal could not be made. However, benzene is readily oxidized under these conditions.

The pH results at the beginning and at the end of the test are presented in Table 4.1. Low pH was observed in the iron and hydrogen peroxide activated persulfate tests.

Figure 4.2 cis-DCE Removal in East Plume Neutral pH Zone



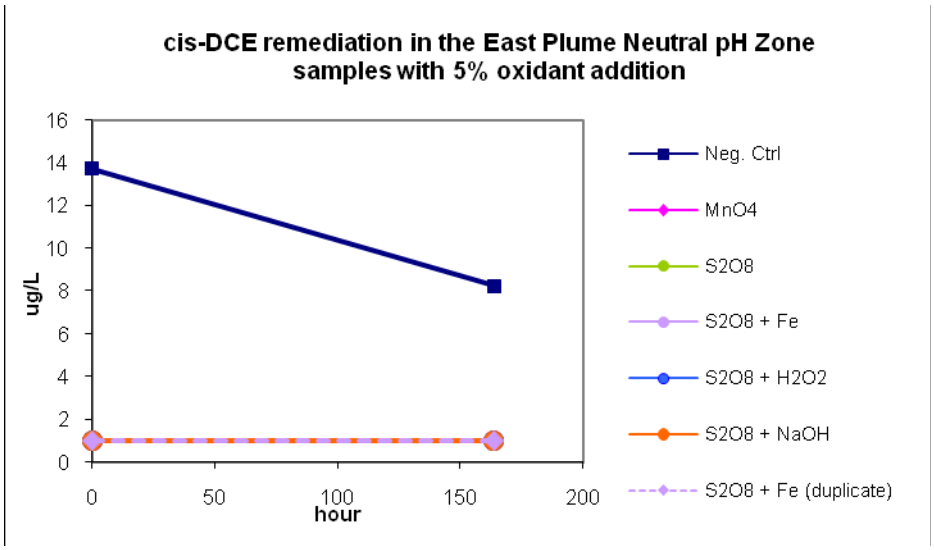
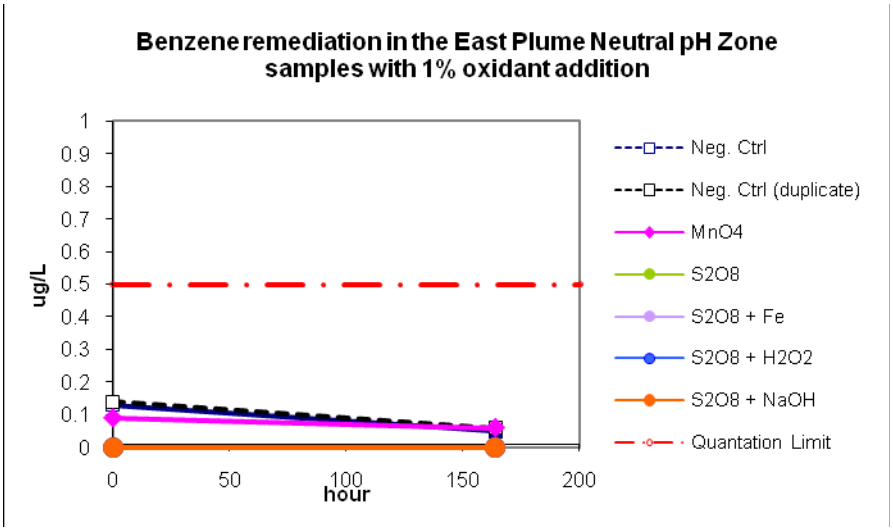


Figure 4.3 Benzene Removal in East Plume Neutral pH Zone



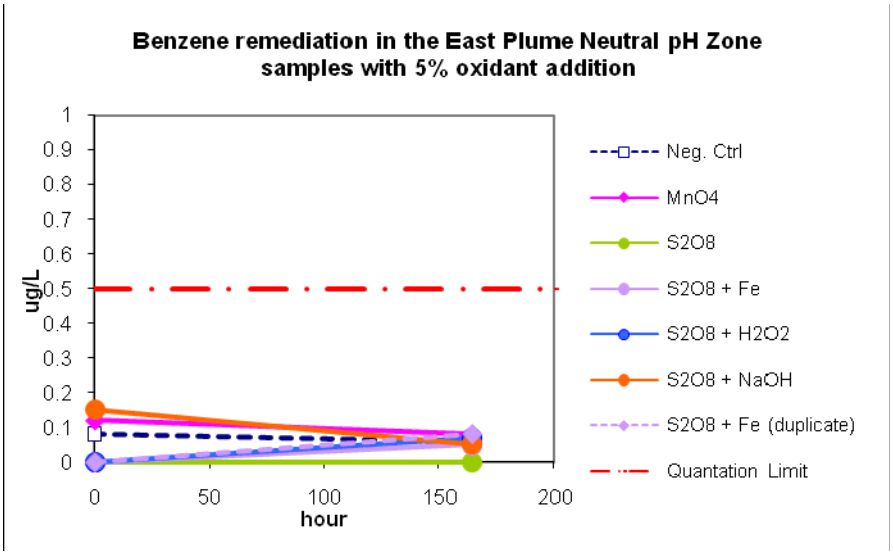


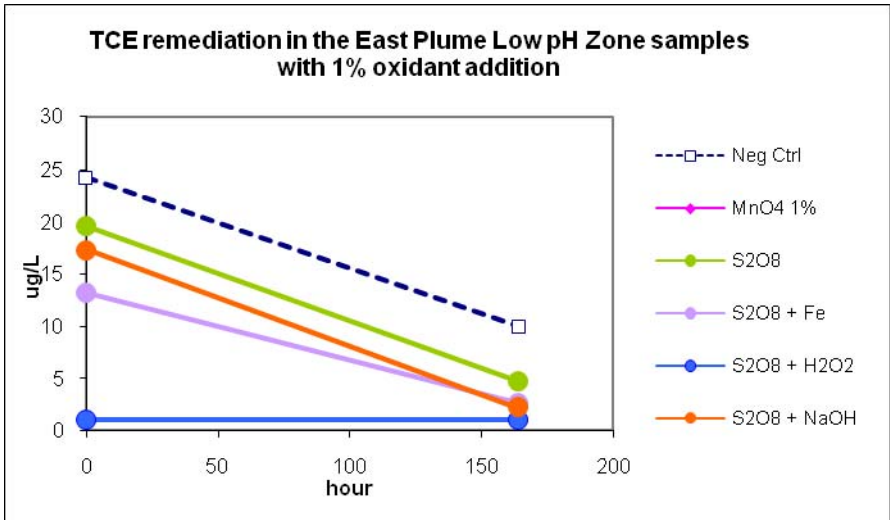
Table 4.1 Sample pH Change for Each Sample

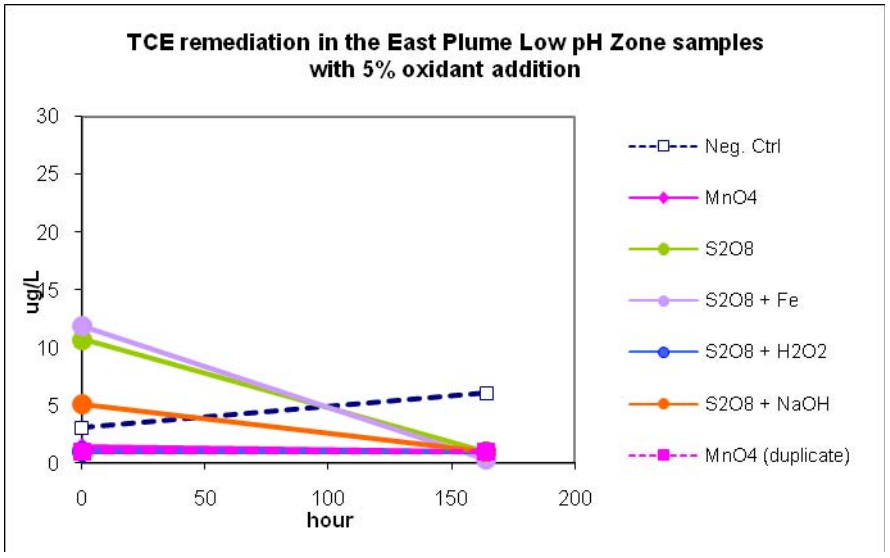
	East - Neutral		***East - Low***		***West - Neutral***		***West - Low***	
Test	t=0 days	t=7 days	t=0 days	t=7 days	t=0 days	t=7 days	t=0 days	t=7 days
Neg. Ctrl	6.3	6.6	6.9	6.6	6.1	6.0	6.6	5.5
MnO_4	6.6	8.6	6.6	8.0	5.7	6.1	7.0	6.9
S_2O_8	5.9	5.5	6.4	6.0	5.7	5.0	6.0	5.5
S_2O_8 + Fe	2.5	2.5	6.3	5.5	5.6	3.0	5.8	3.0
S_2O_8 + H_2O_2	1.6	1.5	1.8	2.0	1.8	2.0	1.6	2.0
S_2O_8 + NaOH	9.2	7.5	10.0	8.0	10.8	6.5	10.3	9.0
Neg. Ctrl	6.6	6.0	6.3	6.0	6.1	5.5	6.5	5.0
MnO_4	8.6	8.3	8.2	8.1	7.2	6.9	8.7	7.6
S_2O_8	5.6	5.0	5.8	5.5	4.9	5.0	5.8	5.0
S_2O_8 + Fe	2.4	2.0	5.9	5.0	4.2	2.5	2.2	2.5
S_2O_8 + H_2O_2	1.1	1.5	1.2	1.5	1.6	1.5	1.2	1.5
S_2O_8 + NaOH	7.9	5.5	10.0	6.9	10.5	6.5	10.7	6.6

4.2 East Plume – Low pH Zone

The results of VOC removal in the East Plume low pH zone samples are presented in **Figures 4.4** to **4.6**.

Figure 4.4 TCE Removal in East Plume Low pH Zone

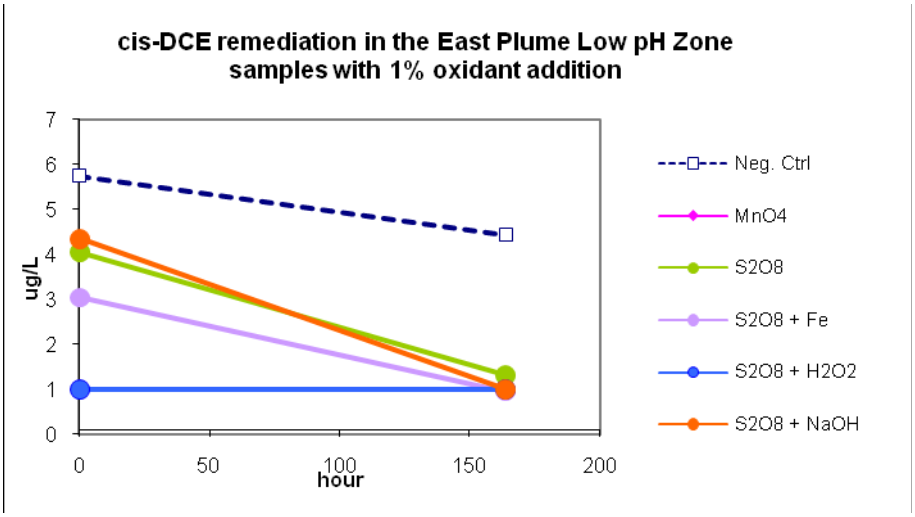




The results presented in **Figure 4.4** to **4.6** indicate that all oxidants were capable of rapidly oxidizing TCE and cis-DCE at 5% persulfate concentrations. The treatment with 1% persulfate dosage was somewhat less effective. Unactivated persulfate was capable of oxidizing TCE and cis-DCE albeit with a slower rate compared with other oxidants. Benzene was effectively treated by all persulfate tests, especially with H_2O_2 activated persulfate as oxidant. Permanganate was not effective in treating benzene in this sample.

The pH results at the beginning and at the end of the test are presented in **Table 4.1**. Low pH was observed in the hydrogen peroxide activated persulfate tests.

Figure 4.5 cis-DCE Removal in East Plume Low pH Zone



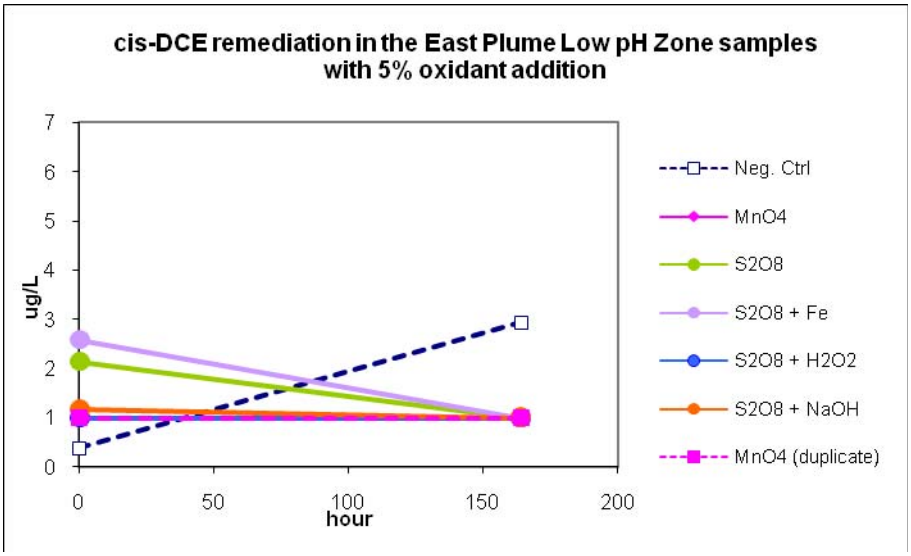
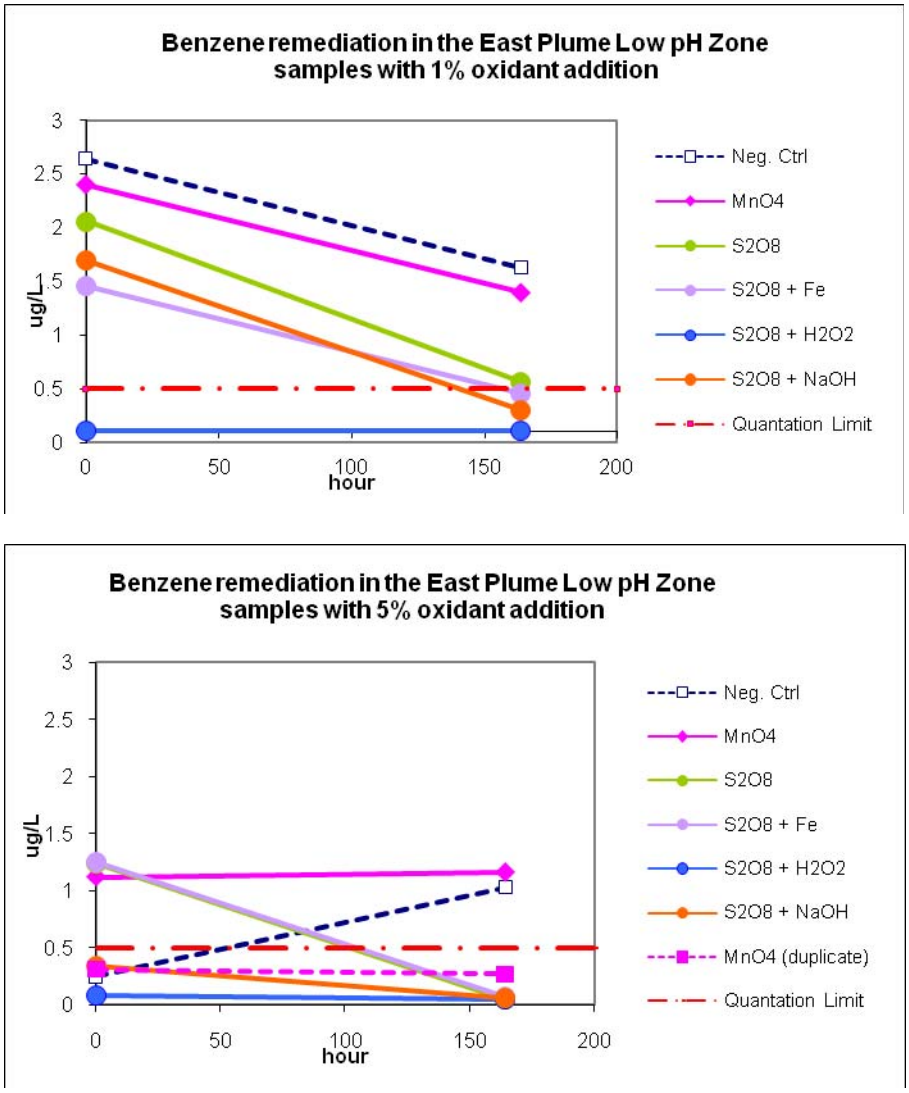


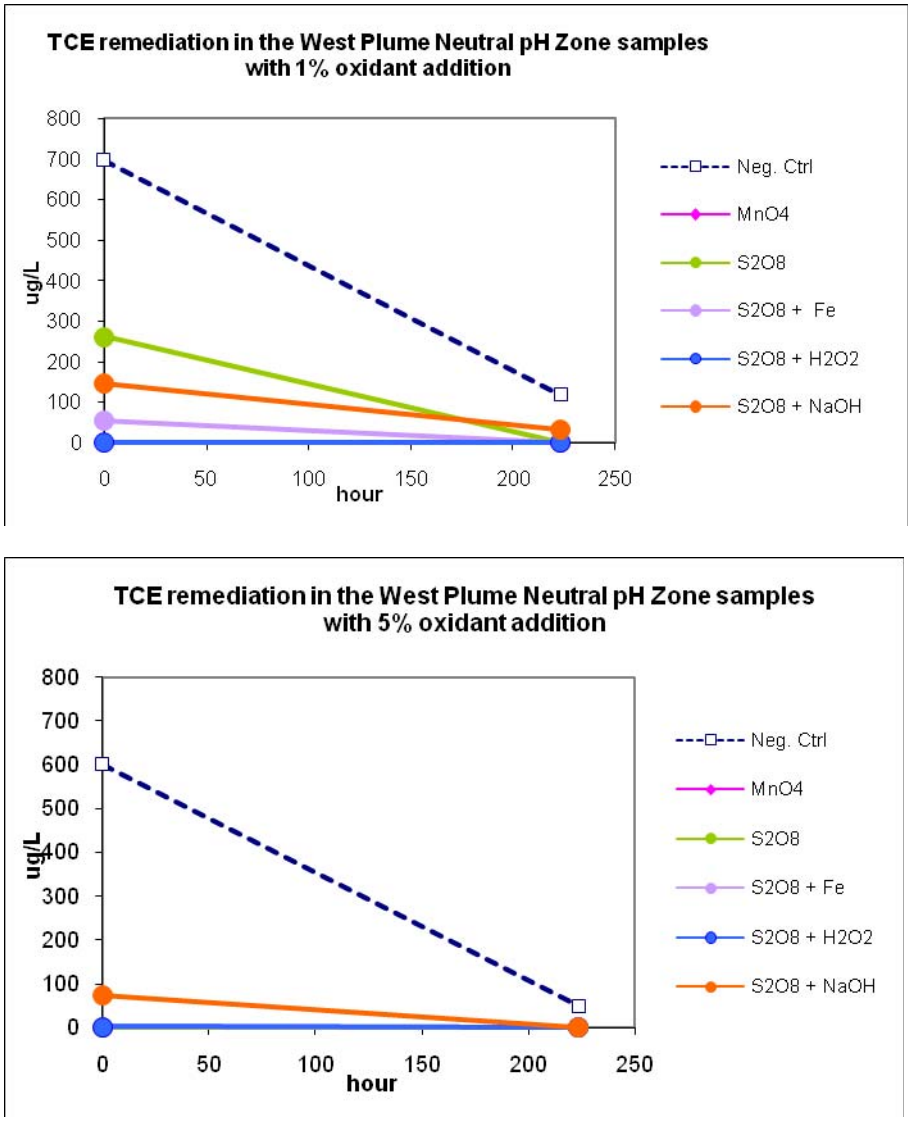
Figure 4.6 Benzene Removal in East Plume Low pH Zone



4.3 West Plume – Neutral pH Zone

The results of VOC removal in the West Plume neutral pH zone samples are presented in **Figures 4.7** and **4.8**.

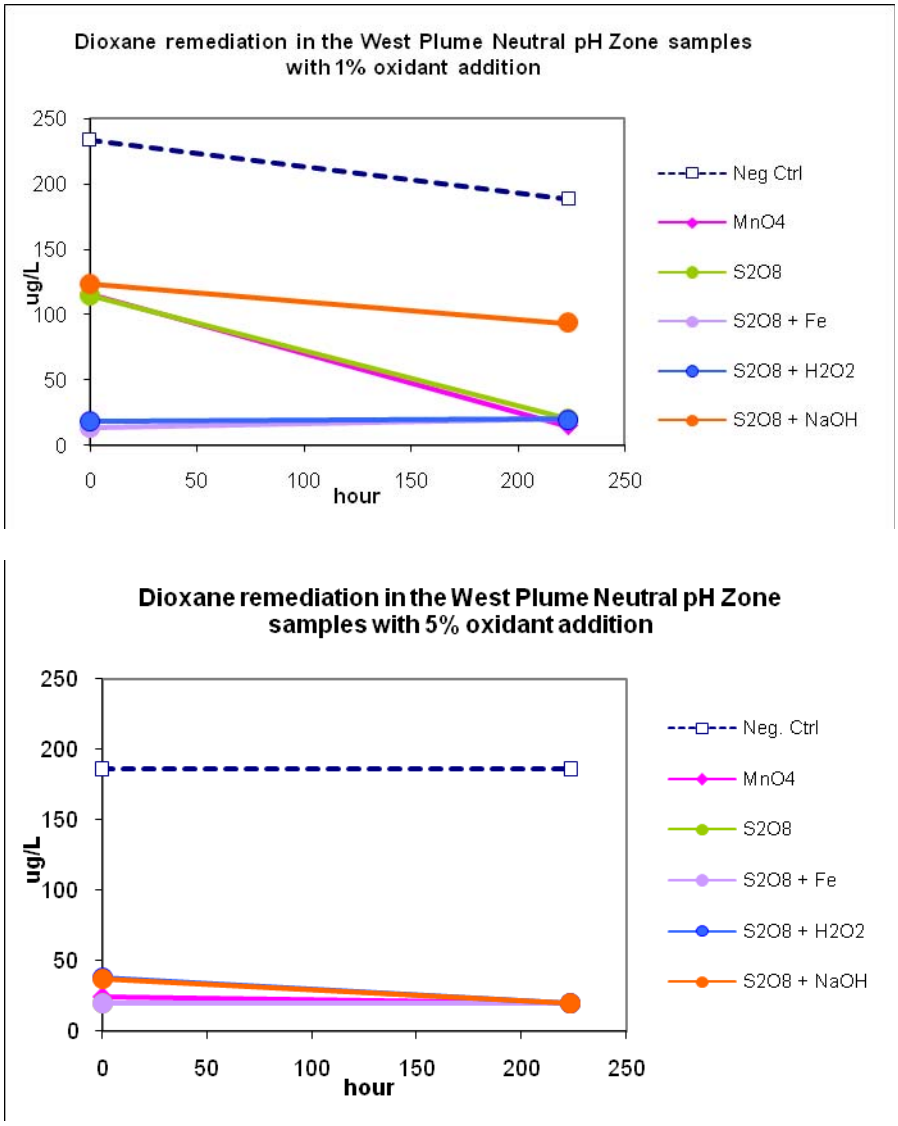
Figure 4.7 TCE Removal in West Plume Neutral pH Zone



The results presented in **Figures 4.7** and **4.8** indicate that all oxidants were capable of rapidly oxidizing TCE and dioxane at both 1% and 5% dosages with the possible exception of base-activated persulfate in dioxane removal. The ability of permanganate to rapidly oxidize dioxane is unexpected and previously unobserved (Waldemer and Tratnyek, 2006). Unactivated persulfate was effective at treating both TCE and dioxane.

The pH results at the beginning and at the end of the test are presented in **Table 4.1**. Low pH was observed in the iron and hydrogen peroxide activated persulfate tests.

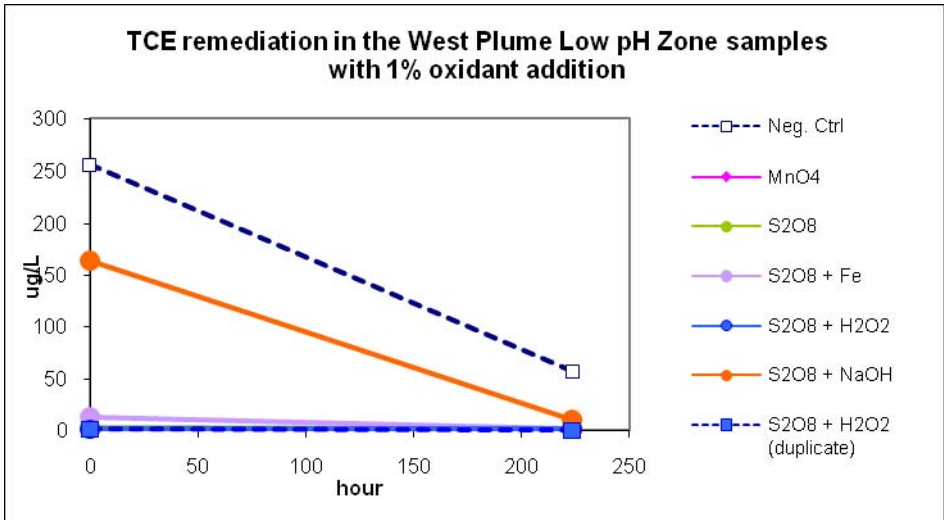
Figure 4.8 Dioxane Removal in West Plume Neutral pH Zone

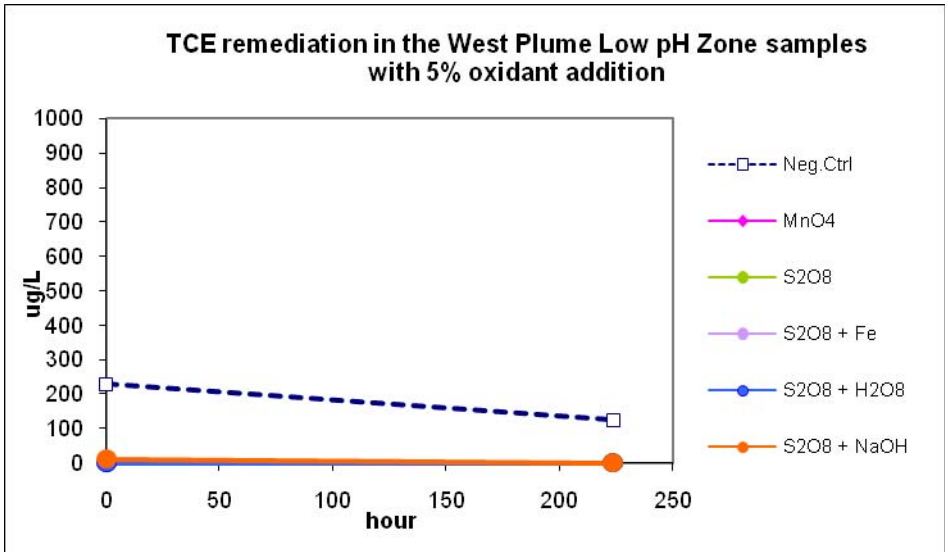


4.4 West Plume – Low pH Zone

The results of VOC removal in the West Plume low pH zone samples are presented in **Figures 4.9** and **4.10**.

Figure 4.9 TCE Removal in West Plume Low pH Zone

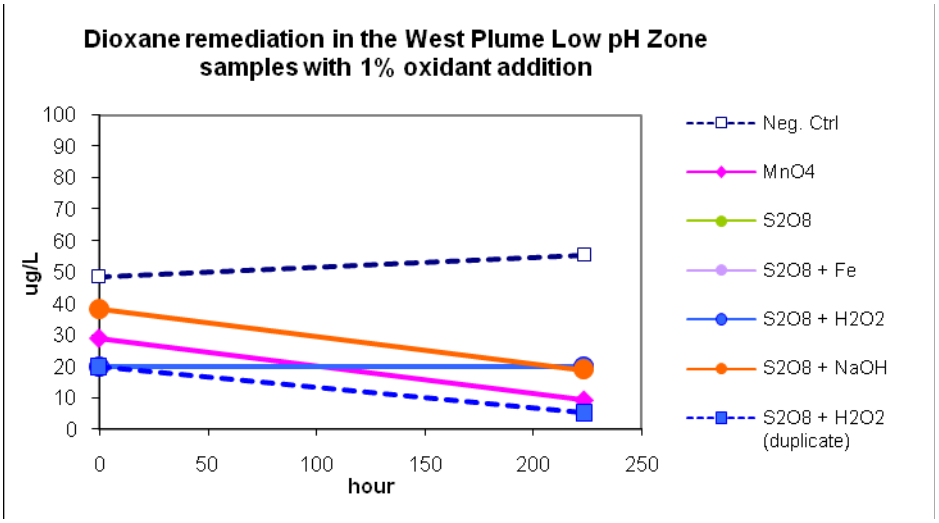


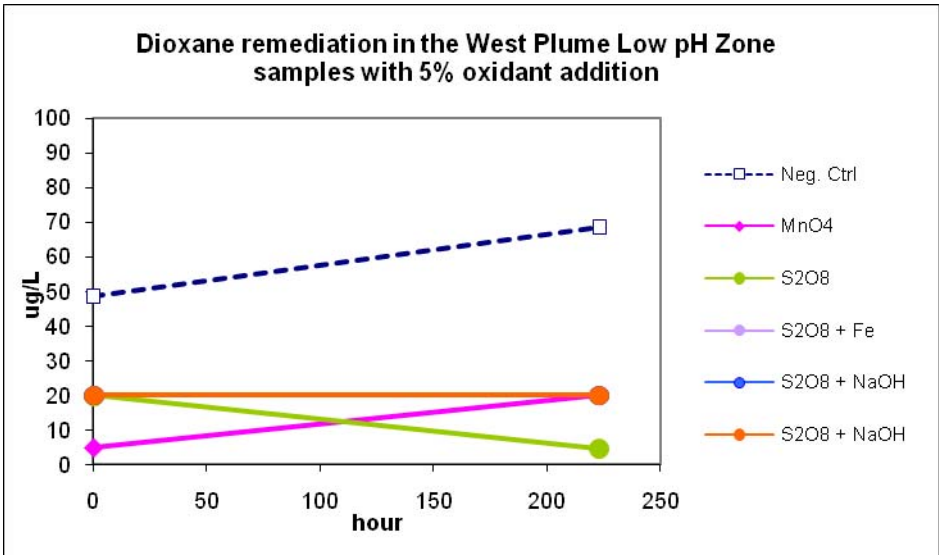


The results presented in **Figures 4.9** and **4.10** indicate that all oxidants were capable of rapidly oxidizing TCE and dioxane at both 1% and 5% concentrations with the possible exception of base-activated persulfate (in both TCE and dioxane treatment) and 1% permanganate (in dioxane treatment). The ability of 5% permanganate to rapidly oxidize dioxane is unexpected and previously unobserved in the scientific literature (Waldemer and Tratnyek, 2006). Unactivated persulfate was effective at oxidizing both TCE and dioxane.

The pH results at the beginning and at the end of the test are presented in **Table 4.1**. Low pH was observed in the iron and hydrogen peroxide activated persulfate tests.

Figure 4.10 Dioxane Removal in West Plume Low pH Zone





4.5 Soil Oxidant Demand (SOD)

A summary of SOD values for different conditions is presented in **Table 4.2**.With 1% dosage, the SOD of permanganate ranges from less than 0.2 g/kg to 12 g/kg while that of persulfate with different activators ranges from less than 2.8 g/kg to 76 g/kg, depending on the activator. The SOD of persulfate was much higher when hydrogen peroxide was used as activator as compared to the other conditions. The base-activated and naturally activated persulfate had the lowest SOD values. With 5% dose, the SOD was relatively higher than that of the 1% dose. The SOD of

permanganate ranged from 45 g/kg to 120 g/kg and the SOD of persulfate ranges from less than 14 g/kg to 280 g/kg, depending on the activators.

Table 4.2 SOD of Site Soil with Different Oxidants (g/kg)

Dose	*Oxidant*	*E-N*	*E-L*	*W-N*	*W-L*
1%	MnO_4	12	1.6	6.4	<0.2
	S_2O_8	5.6	2.8	2.8	<2.8
	S_2O_8 + Fe	2.8	2.8	<2.8	5.6
	S_2O_8 + H_2O_2	49	56	76	73
	S_2O_8 + NaOH	<2.8	<2.8	<2.8	<2.8
5%	MnO_4	120	45	100	49
	S_2O_8	<14	<14	<14	<14
	S_2O_8 + Fe	<14	14	<14	18
	S_2O_8 + H_2O_2	210	210	280	210
	S_2O_8 + NaOH	14	<14	<14	<14

Section 5
Results from EAB Tests

5.1 East Plume Neutral pH Zone

The results of contaminants treatment in the East Plume neutral pH zone are summarized in **Figure 5.1**. Within 84 days, all contaminants (benzene, TCE, and cis-DCE) were degraded. EOS, EOS with vitamin B12 supplement, whey, and sodium lactate were all effective electron donors for EAB. The TCE concentrations in bottles with electron donor and bioaugmentation dropped within 28 days of incubation. No vinyl chloride accumulated at the end of the experiment. No obvious difference between different electron donors was observed regarding to VOC treatment. No difference was observed between EOS with and without vitamin B12 supplement regarding VOC removal.

The metal concentrations at the end of the experiment are presented in **Table 5.1** (Test 1 to Test 6). The EAB process has also effectively reduced the concentration of cobalt and nickel, comparing with the killed control (no donor, no culture, and sterilized) and negative control (contains no culture and no donor). Whey was less effective in treating metals comparing with other electron donor used in this study. Beryllium was not detected.

5.2 East Plume Low pH Zone

The results of contaminants treatment in the East Plume low pH zone are presented in **Figure 5.2**. TCE has been mostly removed in all bottles except killed control and negative control within 28 days. As expected, EAB was not very effective in treating benzene in this study, regardless of the electron donor added. No obvious differences were observed among tested electron donors regarding to VOC removal.

The metal concentrations at the end of the experiment are presented in **Table 5.1** (Test 7 to Test 12). Comparing with the metal baseline results (**Table 2.3**), the metal concentration has decreased in all bottles due to the neutralization conducted to the low pH zone groundwater. The concentrations of cobalt were elevated to 160 to 190 µg/L in the microcosm bottles had EOS (with or without vitamin supplements) and whey. The nickel concentrations in bottles with sodium lactate or whey were reduced to less than 20 µg/L.

Figure 5.1 VOC Removal in East Plume Neutral pH Zone

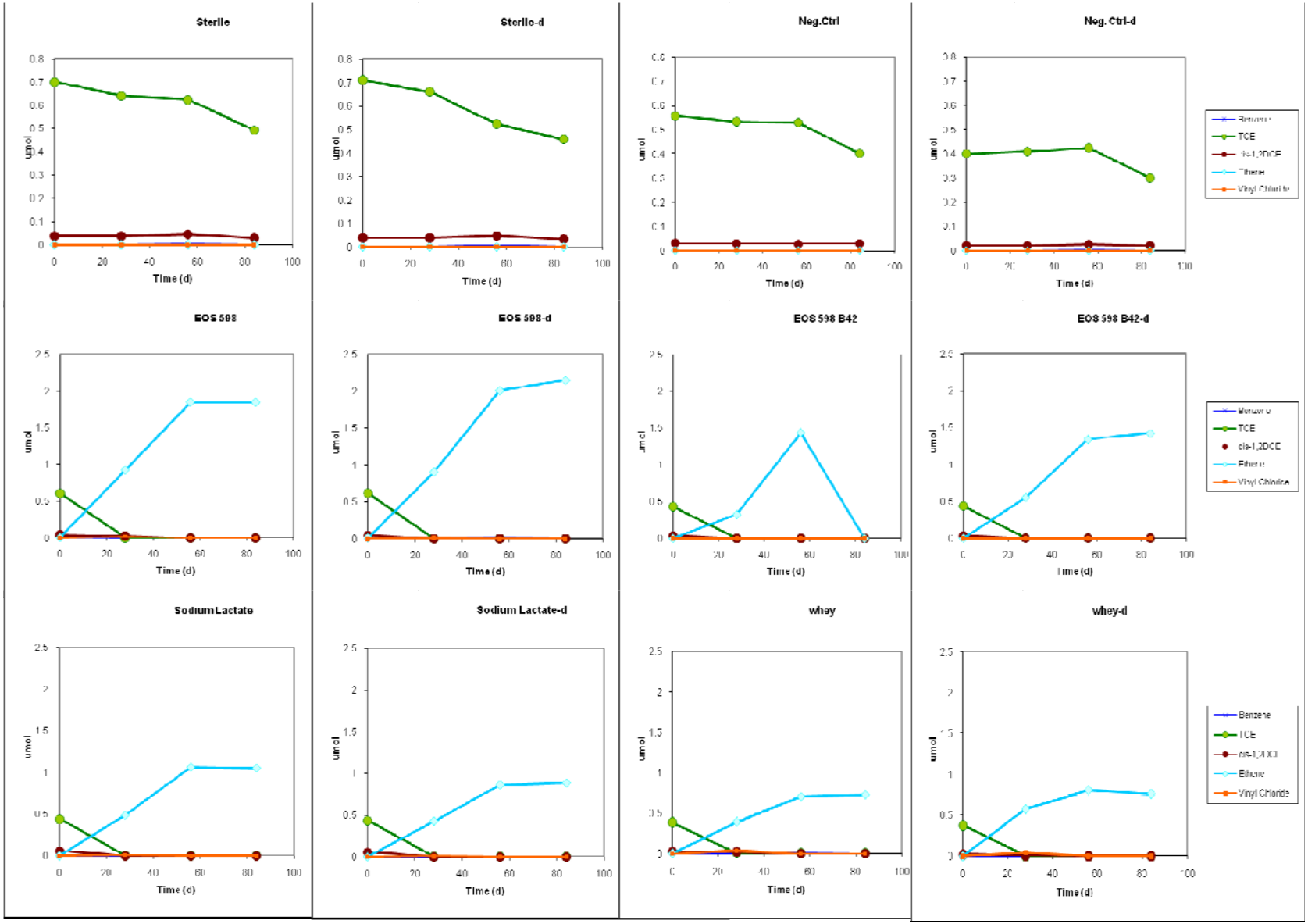


Figure 5.2 VOC Removal in East Plume Low pH Zone

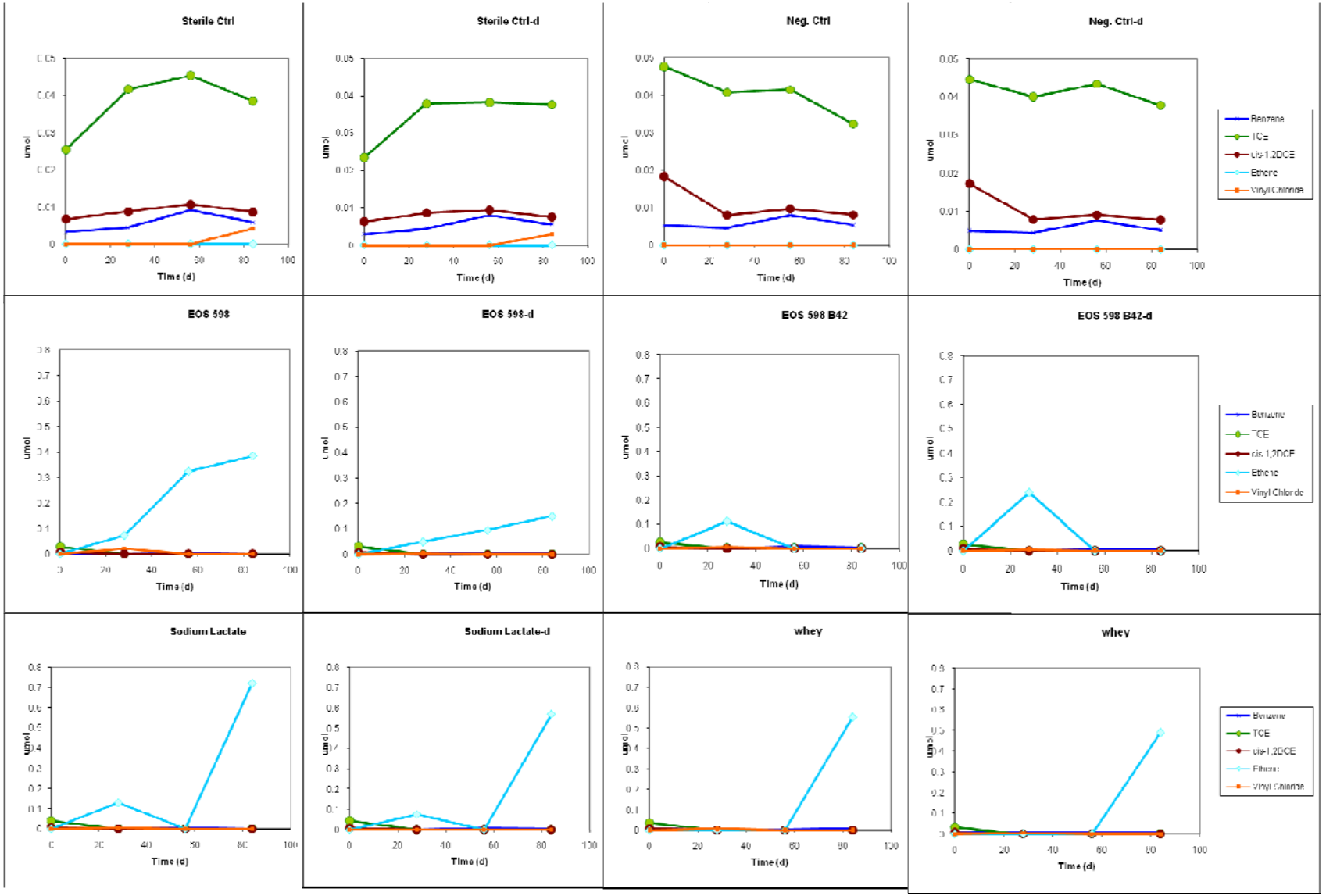


Table 5.1 Metal Concentrations at the End of the EAB Tests.

Test			Beryllium		Cobalt		Nickel	
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
			Bottle CDE	Bottle GHI	Bottle CDE	Bottle GHJ	Bottle CDE	Bottle GHJ
1	E-N	Killed Control	<10	<10	89	130	58	57
2	E-N	Neg. Ctrl	<10	<10	94	80	52	69
3	E-N	EOS 598	<10	<10	<10	<10	<20	<20
4	E-N	EOS 598B42	<10	<10	<10	<10	<20	<20
5	E-N	Sodium lactate	<10	<10	<10	<10	<20	<20
6	E-N	whey	<10	<10	16	15	<20	<20
7	E-L	Killed Control	<10	<10	28	32	27	29
8	E-L	Neg. Ctrl	<10	<10	51	42	33	27
9	E-L	EOS 598	<10	<10	170	160	29	24
10	E-L	EOS 598B42	<10	<10	180	190	46	42
11	E-L	Sodium lactate	<10	<10	57	64	<20	<20
12	E-L	whey	<10	<10	190	160	<20	<20

Section 6
Conclusions

The results from this treatability study support following conclusions:

ISCO

- Persulfate with hydrogen peroxide activation resulted in the greatest rates of contaminant oxidation but also resulted in the greatest amounts of soil oxidant demand (SOD). This greater SOD may lead to greater costs and smaller radii of influence.

- Unactivated persulfate was effective in treating TCE, cis-DCE, benzene, and dioxane and resulted in the lowest SOD. The lower SOD may lead to greater ROI.

- Permanganate was capable of TCE and cis-DCE oxidation. It was not very effective at benzene oxidation. Unexpectedly, it was capable of dioxane oxidation which should be confirmed.

- Contaminant oxidation was observed in all groundwater samples. Some variations were observed, however unactivated persulfate appears to be the best overall oxidant with respect to ability to oxidize multiple contaminants and minimize SOD. The ability of permanganate to oxidize dioxane needs to be further evaluated since it has not been observed previously. The inability of permanganate to oxidize benzene in the East Low pH Plume was also unexpected.

- Some of the low pH tests were near neutrality when conducted. Supplemental tests may need to be conducted to determine the effect of pH on oxidation.

EAB

- With bioaugmentation, all of the electron donors tested in this study, including EOS, EOS with vitamin B12 supplements, sodium lactate, and whey are effective in treating TCE.

- Vitamin B12 supplement is not necessary for this site to use EOS as an effective electron donor.

- For neutral pH zone sample, the EAB process has the potential to decrease the metal concentrations of cobalt and nickel. For the low pH zone sample, when EOS and whey served as electron donor, the concentration of cobalt may increase.

- After neutralization, using EAB technology to treat low pH zone is applicable.

Reference

Waldemer, Rachel H. and Tratnyek, Paul G. (2006) Kinetics of Contaminant Degradation by Permanganate. *Environ Sci. Technol.* 40,1055-1061

APPENDIX B OBSERVATION WELL BORING LOGS/WELL COMPLETION DIAGRAMS

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-1
DATE: 12-3-07
GEOLOGIST: Robin Henderson
DRILLER: Pete Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
	0						asphalt &		asphalt &				
							Concrete foundation		concrete				
	2	8/4		1' pellets	stiff								
0850		7/9											
S-1	4	12/12	1.0/2.0	3' Sand	very stiff	mottled	silty clay, trace sand		dry. fine sand.	1.0	0	0	0
0901		18/16		5'									
S-2	6	10/12	1.0/2.0		very stiff	mottled	silty clay, some sand		dry. fine sand.	1.2	0	0	0
0925		16/18											
S-3	8	10/8	1.2/2.0		very stiff	orange brown	sandy silty clay		dry. fine sand.	3.5	0	0	0
0929		7/8											
S-4	10	9/7	1.3/2.0	10' Sand	very stiff	green	clay, trace silt & sand		dry. fine round sand	6.0	0	0	0
0945		9/13		11' pellets									
S-5	12	12/13	2.0/2.0		very stiff	orange	clayey sand		saturated. fine to med. round sand	81.8	0	0	0
0952		13/20											
S-6	14	7/11	2.0/2.0	13' Sand	very stiff	orange	sandy clay		fine to med. satur.	84.0	0	0	0
1005		14/15		15'									
S-7	16	15/29	2.0/2.0		hard	orange	silty clay, trace sand		wet. med. sand.	101.0	0	0	0
1020		34/46											
S-8	18	4/6	1.7/2.0		medium stiff	orange	silty clay, trace sand		wet. medium sand	132.0	0	0	0
1038		6/6											
S-9	20	5/7	2.0/2.0	20' Sand	stiff	pink	clay, trace sand		fine to med. wet	168.0	0	0	0
1043		9/11											
S-10	22	4/5	1.8/2.0	22' pellets	stiff	orange	clay, some sand		fine to med. wet	261.0	0	0	0
1054		9/10											
S-11	24	10/10	2.0/2.0	23' Sand	very stiff	orange	Sandy clay		med. to coarse. wet	205.0	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 3 nested wells, flush mount. tight formation soil based on observations in well construction

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-1A, OW-1B, OW-1C

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112EC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-1
DATE: 12-3-07
GEOLOGIST: Robin Henderson
DRILLER: Pete Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	MATERIAL DESCRIPTION: Color	MATERIAL DESCRIPTION: Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
1102		10/10		Sand 25'									
S-12	26	8/13	2.0/2.0		very stiff	pink	sandy clay		med. to coarse moist	447	0	0	0
		14/15											
S-13	28	7/9	0.0/2.0		very stiff	orange	sandy clay			23	0	0	0
		11/11											
S-14	30		0.0/2.0	30'		orange	sandy clay			1.5	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 3 nested wells

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-1A, OW-1B, OW-1C

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112 IC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-2
DATE: 12-4-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
	0						asphalt & cement						
	2			1' pellets									
0905		7/7											
S-1	4	6/9	1.0/2.0	3' Sand	stiff	mottled	sandy clay		dry. Med. Sand	0.2	0	0	0
0914		10/10		5'									
S-2	6	12/22	1.1/2.0		hard	orange	sandy clay		dry. med. sand	0	0	0	0
0959		22/11											
S-3	8	11/11	0.4/2.0		very stiff	mottled	sandy gravel		fractured pebbles coarse sand	1.0	0	0	0
1003		9/7											
S-4	10	7/10	0.2/2.0	10' Sand	very stiff	mottled	sandy gravel		fractured pebbles coarse sand	0.3	0	0	0
1009		7/7											
S-5	12	8/8	1.6/2.0	11' pellets	very stiff	green	clay		wet	1.6	0	0	0
1017		7/9											
S-6	14	11/14	1.9/2.0	13' Sand	very stiff	orange	clayey Sand		med. to coarse sand, moist	49.6	0	0	0
1022		8/9											
S-7	16	10/11	2.0/2.0	15'	very stiff	orange	silty clay		wet	90.0	0	0	0
1030		7/7											
S-8	18	8/10	1.8/2.0		very stiff	orange	Silty clay		wet	170.0	0	0	0
1036		7/8											
S-9	20	15/20	2.0/2.0	20' Sand	hard	orange	sandy clay		med. to coarse wet	186.0	0	0	0
1042		5/7											
S-10	22	10/15	2.0/2.0	21' pellets	very stiff	orange	sandy clay, trace silt		wet med. to coarse.	159.0	0	0	0
1055		8/8											
S-11	24	9/10	2.0/2.0	23' sand	very stiff	orange	sandy clay			202.0	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 3 nested wells. tight formations so water level observations based on observations in well construction
flush mount

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-1A, OW-1B, OW-1C

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-2
DATE: 12-4-07
GEOLOGIST: Robin Henderson
DRILLER: Pete Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	MATERIAL DESCRIPTION: Color	MATERIAL DESCRIPTION: Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
1105		6/8		Sand									
S-12	26	13/14	2.0/2.0		very stiff	pink	Sandy clay		dry. coarse to very coarse.	5440	1	15	1
1110		8/9											
S-13	28	11/11	0.0/0.0		very stiff	orange	Sandy clay		zero recovery	0	0	0	0
1116		7/7											
S-14	30	10/11	0.0/2.0	30'	very stiff	orange	Sandy clay		zero recovery	0	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 3 Nested wells

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-2A, OW-2B, OW-2C

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112IC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-3
DATE: ~~12~~ 11-30-07
GEOLOGIST: Robin Henderson
DRILLER: Peter Hampson

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
	0								Asphalt &				
1030									concrete, No				
S-1	2	4/4	1.7/2.0	1' pellets	stiff	brown	Sandy clay		Sample, dry	0.2	0	0	0
		3/7											
	4			3' Sand	stiff	mottled	Sandy clay		dry	0	0	0	0
1045		6/8											
S-2	6	9/8	1.5/2.0	5'	very stiff	mottled	Sandy clay			4.4	0	0	0
1051		3/4											
S-3	8	3/5	1.9/2.0		stiff	green	clay		with organics/peat	3.5	0	0	0
1057		2/3											
S-4	10	3/5	1.4/2.0	10' Sand	stiff	green	Sandy clay		moist, medium rounded	6.3	0	0	0
1115		5/7											
S5	12	11/13	1.7/2.0	11' pellets	very stiff	mottled	clayey Sand		moist	4.8	0	0	0
1129		6/11											
S-6	14	13/12	1.5/2.0	13' Sand	very stiff	mottled	Sandy clay		moist, med. rnd.	11.4	0	0	0
1134		6/8											
S-7	16	12/12	2.0/2.0	15'	very stiff	orange	Sandy clay		wet, medium rounded	9.7	0	0	0
1143		6/9											
S-8	18	11/18	2.0/2.0		very stiff	orange	silty clay, trace sand		wet fine rounded sand	2.9	0	0	0
1147		6/14											
S-9	20	14/16	2.0/2.0	20' Sand	very stiff	orange	silty clay, trace sand		moist trace pebbles	7.2	0	0	0
1152		4/6											
S-10	22	4/8	2.0/2.0	21' pellets	stiff	orange	sandy silty clay		wet, fine to coarse sand	35.4/31.3	0	0	0
1158		3/6											
S11	24	8/8	2.0/2.0	23' Sand	very stiff	orange	Sandy clay, trace silt		saturated	32.3	0	0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0.0

Remarks: 3 Nested Wells. Flush MOUNT

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-3A, OW-3B, OW-3C

Tetra Tech NUS, Inc.

BORING LOG

PROJECT NAME: Lockheed Martin
PROJECT NUMBER: 112EC01219
DRILLING COMPANY: Summit
DRILLING RIG: B-57

BORING No.: OW-3
DATE: 11-30-07
GEOLOGIST: Robin Henderson
DRILLER: Pete Hampsan

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
1146		5/5		sand 25'						1230	0		
S-12	26	6/7	2/2.0		stiff	pink	Sandy clay		moist, fine to coarse	123	0	1.5	0
		5/9											
1200 S-13	28	5/11	2.0/2.0		very stiff	pink	Sandy clay		fine to med., moist	213	0	1.0	0
		4/5											
1210 S-14	30	6/7	2.0/2.0	30'	stiff	pink	clay, trace sand		fine sand, moist	45	0	1.0	0

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): 0

Remarks: 3 Nested wells

Converted to Well: Yes ✓ No _____ Well I.D. #: OW-3A, OW-3B, OW-3C

APPENDIX C FIELD SAMPLING LOGS

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC-Pilot Test-Microbial
Project No.: 18LC01599

Sample ID No.: MRC-OW1I-042109
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 113973

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 4/21/09	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Time: 1115								
Method: Low Flow	clear	6.02	0.652	17.16	19.2	5.12	0.0	75

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 4/21/09								
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material								
Type: 2" PVC								
Total Well Depth (TD): 19.50								
Static Water Level (WL): 8.90								
One Casing Volume(gal/L): 1.80								
Start Purge (hrs): 1040								
End Purge (hrs): 1233								
Total Purge Time (min): 113min								
Total Vol. Purged (gal/L): 1.75gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3-40mL vials	4/21/09@1115
Total Metals + Iron	HNO_3	1-500mL plastic bottle	
Anions (300.0), TSS, TDS	—	1-1L plastic bottle	
TOC	H_2SO_4	1-250mL plastic bottle	
Methane/Ethane/Ethene (RSK 175)	HCl	3-40mL glass vials	
Volatile Fatty Acids	—	3-40mL amber glass vials	
DHC, BVC/TCE/VC, eBAC, mcrA	—	2 microbial filters, one with 850mL and one with 150mL	
DHB, DSM, SRB/IRB			

OBSERVATIONS / NOTES:

Dissolved Oxygen: 1ppm
Iron: >10ppm
Total Iron: >10ppm
Carbon Dioxide: 50ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): Dawn L Madden

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER: 117801599
WELL ID.: MRC-OW1I-042109
DATE: 4/21/09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1040	8.90	—	—	—	—	—	—	—	—	Static WL; Begin Purge.
1045	9.09	100	6.36	0.779	156	6.37	16.91	106	0.0	
1050	9.10	100	6.18	0.745	60	5.50	16.99	80	0.0	
1055	9.11	100	6.12	0.711	41.4	5.35	16.97	77	0.0	
1100	9.11	100	6.05	0.694	26.1	5.22	17.02	75	0.0	
1105	9.11	100	6.01	0.651	20.2	5.14	17.08	74	0.0	
1110	9.11	100	6.04	0.653	18.9	5.16	17.00	75	0.0	
1115	9.11	100	6.02	0.652	19.2	5.12	17.16	75	0.0	sample.
1209	pause purging - Call Chris Pike and Tony Apanovage.									
1233	8.96	—	—	—	—	—	—	—	—	final WL; end purge.

SIGNATURE(S): Darren L Matheny

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: LMC-MRC-Pilot Test-Microbial
Project No.: 162C01599

Sample ID No.: MRC-OW1D-042109
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 113973

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 4/21/09	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 0930	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Method: Low Flow	Clear	6.40	0.488	17.41	20.9	4.81	0.0	-103

PURGE DATA:

Date: 4/21/09	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 28.74								
Static Water Level (WL): 9.04								
One Casing Volume(gal/L): 3.35								
Start Purge (hrs): 0832								
End Purge (hrs): 1008								
Total Purge Time (min): 116 mm								
Total Vol. Purged (gal/L): 3.5gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3-40mL vials	4/21/09@0930
Total Metals + Iron	HNO_3	1-500mL plastic bottle	
Anions(300.0), TSS, TDS	—	1-1L plastic bottle	
TOC	H_2SO_4	1-250ml plastic bottle	
Methane/Ethane/Ethene (RSK175)	HCl	3-40mL glass vials	
Volatile Fatty Acids	—	3-40mL amber glass vials	
DHC, BVC/TCE/VCR, eBAC, MGN, DHB, DSM, SRB/IRB	—	2 microbial filters, each filtered with 500mL	

OBSERVATIONS / NOTES:

Dissolved Oxygen: 1ppm
Iron: >1.0ppm ; >10ppm
Total Iron: >10ppm
Carbon Dioxide: 35ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): David S. MacKenzie

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Study-Microbial
PROJECT NUMBER: 112ic01599

WELL ID.: MRC-OWID-042109
DATE: 4/21/09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
			0.1	3%	10%	10%	10%	10%	10%	
0832	9.04	—	—	—	—	—	—	—	—	Static WL; Begin Purge
0835	9.60	120	6.77	0.225	32.6	9.43	16.71	78	0.0	
0840	9.61	120	7.10	0.268	37.9	3.36	16.73	19	0.0	
0845	9.68	120	7.08	0.515	67.1	9.04	16.86	-31	0.0	
0850	9.72	120	6.69	0.571	102.2	6.45	17.04	-66	0.0	
0855	9.78	120	6.64	0.543	72.6	6.12	17.13	-75	0.0	
0900	9.81	120	6.59	0.512	58.9	5.70	17.27	-80	0.0	
0905	9.87	120	6.64	0.455	37.1	5.02	17.25	-79	0.0	
0910	9.92	120	6.65	0.495	26.7	5.44	17.18	-87	0.0	
0915	9.93	120	6.48	0.494	21.0	5.16	17.30	-92	0.0	
0920	9.95	120	6.45	0.493	18.7	5.03	17.28	-95	0.0	
0925	9.95	120	6.41	0.488	19.0	4.86	17.36	-100	0.0	
0930	9.95	120	6.40	0.488	20.9	4.81	17.41	-103	0.0	sample.
1008	10.28	—	—	—	—	—	—	—	—	final WL; end purge.

SIGNATURE(S): Daniel L Mathews

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC-Pilot Study-Microbial
Project No.: 112IC01597

Sample ID No.: MRC-OW2I-042109
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 113973

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 4/21/09	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Time: 1435								ORP
Method: Low Flow	Clear	6.60	0.682	17.78	39.30	5.46	0.0	-84

PURGE DATA:

Date: 4/21/09	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 19.94								
Static Water Level (WL): 9.12								
One Casing Volume(gal/L): 1.84								
Start Purge (hrs): 1348								
End Purge (hrs): 1453								
Total Purge Time (min): 65 min								
Total Vol. Purged (gal/L): 2gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOC	HCl	3-40mL glass vials	4/21/09@1435
Methane/Ethane/Ethene (RSK175)	HCl	3-40mL glass vials	↓
TOC	H_2SO_4	1-250mL plastic bottle	↓
Total Metals + Iron	HNO_3	1-500mL plastic bottle	↓
Anions (300.0), TSS, TDS	—	1-1L plastic bottle	↓

OBSERVATIONS / NOTES:

Dissolved Oxygen: < 1ppm
Iron: > 10ppm
Total Iron: > 10ppm
Carbon Dioxid: 100ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): Dawn L Mahoney

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER: 112101597

WELL ID.: MRC-OW2I-042109
DATE: 4/21/09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1348	9.12	—	—	—	—	—	—	—	—	Static WL; Start purge
1350	9.77	120	6.57	0.505	305	7.33	18.45	-15	0.0	
1355	9.78	120	6.31	0.474	148	6.11	18.11	-31	0.0	
1400	9.79	120	6.25	0.475	164	6.56	18.14	-36	0.0	
1405	9.80	120	6.19	0.503	162	6.25	18.17	-45	0.0	
1410	9.81	120	6.24	0.571	79.6	6.32	18.16	-51	0.0	
1415	9.82	120	6.26	0.616	58.0	5.88	17.96	-58	0.0	
1420	9.83	120	6.31	0.644	49.7	5.71	17.93	-64	0.0	
1425	9.83	120	6.47	0.657	41.0	5.64	17.88	-72	0.0	
1430	9.83	120	6.54	0.673	40.3	5.54	17.84	-79	0.0	
1435	9.83	120	6.60	0.688	39.3	5.46	17.78	-84	0.0	Sample
1453	9.83	—	—	—	—	—	—	—	—	final WL; end purge.

SIGNATURE(S): Daniel L Mathews

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC-Pilot Test-Microbial
Project No.: 112RC01597

Sample ID No.: MRC-OW2D-042209
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 113974

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 4/22/09	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 0845	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Method: Low Flow	Clear	6.61	1.84	16.96	10.18	-118	0.1	-118

PURGE DATA:

Date: 4/22/09	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 29.88								
Static Water Level (WL): 9.75								
One Casing Volume(gal/L): 3.42								
Start Purge (hrs): 0818								
End Purge (hrs): 0904								
Total Purge Time (min): 46mins								
Total Vol. Purged (gal/L): 1.25gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3-40mL glass vials	4/22/09@0845
Methane/Ethane/Ethene(RSK,175)	HCl	3-40mL glass vials	↓
TOC	H_2SO_4	1-250mL plastic bottle	
Total Metals + Iron	HNO_3	1-500mL plastic bottle	
Anions(300.0), TSS, TDS	—	1-1L plastic bottle	

OBSERVATIONS / NOTES:

Dissolved Oxygen: 1 ppm
Iron: —
Total Iron: >10ppm
Carbon Dioxide: 100ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Study-Microbial
PROJECT NUMBER: 112IC01597
WELL ID.: MRC-OW2D-042209
DATE: 4/22/09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0818	9.75	—	—	—	—	—	—	—	—	Static WL; Begin Purge
0820	10.90	160	6.41	0.717	20.4	4.80	16.79	-99	0.0	
0830	12.93	200	6.58	1.80	14.7	4.45	17.36	-114	0.1	
0835	13.75	100	6.60	1.82	11.1	4.56	17.20	-116	0.1	
0840	13.34	100	6.61	1.84	11.1	4.68	16.98	-117	0.1	
0845	14.70	100	6.61	1.84	10.18	4.71	16.96	-118	0.1	sample
0904	16.55	—	—	—	—	—	—	—	—	Final WL; End Purge

SIGNATURE(S): David L MacLean

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: MRC-Pilot Test-Microbial
Project No.: 112IC01597

Sample ID No.: MRC-OW3I-042209
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: ~~113974~~ 113974
Type of Sample:
[] Low Concentration
[] High Concentration

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type: _____
[] QA Sample Type: _____

SAMPLING DATA:

Date: 4/22/09	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Time: 1200								
Method: Low Flow	Clear	7.01	0.689	15.92	14.3	4.28	0.0	-167

PURGE DATA:

Date: 4/22/09	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 18.90								
Static Water Level (WL): 7.90								
One Casing Volume(gal/L): 1.87								
Start Purge (hrs): 1041								
End Purge (hrs): 1250								
Total Purge Time (min): 129 min								
Total Vol. Purged (gal/L): 3.75gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3-40mL glass vials	4/22/09@1200
Methane/Ethane/Ethene(RSK175)	HCl	3-40ml glass vials	
Volatile Fatty Acids	—	3-40mL amber glass vials	
TOC	H_2SO_4	1-250mL plastic bottle	
Total Metals + Iron	HNO_3	1-500mL plastic bottle	
Anions (300.0), TSS, TDS		1-1L plastic bottle	
DHC, BVC/TCE/VCR, EBAC, MBAS, DHB, DSM, SRB/IRB	—	2 microbial filters one filtered with 600mL and one filtered with 400mL	

OBSERVATIONS / NOTES:

Dissolved Oxygen = 1ppm
Iron = >10ppm
Total Iron =
Carbon Dioxide = 35ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): Dawn L Madrigal

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER: 112ic01597
WELL ID.: MRC-OW3I-042209
DATE: 4/22/09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1041	7.90	—	—	—	—	—	—	—	—	Static WL; Begin Purge.
1045	8.45	140	7.21	0.436	126	5.70	15.58	-97	0.0	
1050	8.55	140	7.26	0.436	88.7	4.93	15.78	-124	0.0	
1055	8.59	140	7.25	0.453	53.4	4.73	15.75	-137	0.0	
1100	8.60	140	7.25	0.459	44.2	4.67	15.77	-139	0.0	
1105	8.61	140	7.16	0.495	34.0	4.59	15.84	-144	0.0	
1110	8.62	140	7.09	0.559	82.9	4.56	15.82	-139	0.0	
1115	8.62	140	7.08	0.534	59.5	4.50	15.97	-146	0.0	
1120	8.63	140	7.08	0.551	42.6	4.46	16.00	-153	0.0	
1125	8.62	140	7.07	0.568	33.6	4.44	16.01	-154	0.0	
1130	8.61	140	7.02	0.578	38.8	4.44	15.97	-153	0.0	
1135	8.61	140	7.02	0.616	36.5	4.41	15.97	-153	0.0	
1140	8.60	140	7.03	0.606	27.5	4.37	15.93	-157	0.0	
1145	8.60	140	7.02	0.616	21.8	4.32	15.96	-161	0.0	
1150	8.60	140	7.01	0.629	16.4	4.29	16.02	-163	0.0	
1155	8.60	140	7.01	0.643	15.2	4.30	15.88	-165	0.0	
1200	8.61	140	7.01	0.649	14.3	4.28	15.95	-167	0.0	Sample
1250	—	—	—	—	—	—	—	—	—	End Purge

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Page ___ of ___

Project Site Name: MRC-Pilot Test-Microbial
Project No.: 112IC01597

Sample ID No.: MRC-OW3D-042209
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 113974

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type: ____
[] QA Sample Type: ____

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 4/22/09	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Time: 1400								
Method: Low Flow	Clear	7.27	3.13	17.75	77.8	4.68	0.2	-163

PURGE DATA:

Date: 4/22/09	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 29.29								
Static Water Level (WL): 8.45								
One Casing Volume(gal/L): 3.54								
Start Purge (hrs): 1315								
End Purge (hrs): 1504								
Total Purge Time (min): 109 min								
Total Vol. Purged (gal/L): 2.25 gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3-40mL glass vials	4/22/09@1400
Methane/Ethane/Ethene (RSK)	HCl	3-40mL glass vials	
Volatile Fatty Acids	—	3-40mL amber glass vials.	
TOC	H_2SO_4	1-250mL plastic bottle	
Total Metals + Iron	HNO_3	1-500mL plastic bottle	
Anions (300.0), TSS, TDS	—	1-1L plastic bottle.	
DHC, BVC/TCE/VCR, eBAC, MGN, DHB, DSM, SRB/IRB	—	2 microbial filters each filtered with 500mL of H_2O.	

OBSERVATIONS / NOTES:

Dissolved Oxygen: 1 ppm
Carbon Dioxide: >100 ppm
No Iron/Total Iron Analysis.

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): Dawn L Mathews

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER: 112ic01597
WELL ID.: MRC-OW3D-042209
DATE: 4/22/09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1315	8.45	—	—	—	—	—	—	—	—	Static WL; Begin Purge
1320	9.35	120	7.10	2.13	90.5	4.76	16.55	-156	0.1	
1325	9.95	120	7.17	2.35	102	4.55	16.72	-157	0.1	
1330	10.29	120	7.21	2.57	118	4.56	16.89	-160	0.1	
1335	10.57	120	7.23	2.78	100.4	4.62	16.89	-163	0.1	
1340	10.88	120	7.26	2.91	87.4	4.54	17.52	-164	0.1	
1345	11.09	120	7.27	3.01	83.5	4.64	17.58	-165	0.1	
1350	11.19	120	7.25	3.05	76.9	4.68	17.43	-164	0.2	
1355	11.30	120	7.26	3.10	73.9	4.73	17.43	-164	0.2	
1400	11.41	120	7.27	3.13	77.8	4.68	17.75	-163	0.2	sample.
1504	—	—	—	—	—	—	—	—	—	end purge.

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Complex
Project No.: 112G01597-06

Sample ID No.: MRC-OW1F-011309
Sample Location: OW1F
Sampled By: MP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-13-09	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Time: 1007								
Method: Geo pump	Clear	8.10	0.267	16.75	8.10	0.00	0.01	41

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-13-09								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC			See Low Flow purge Data Sheet					
Total Well Depth (TD): —								
Static Water Level (WL): 7.85								
One Casing Volume(gal/L): —								
Start Purge (hrs): 0910								
End Purge (hrs): 1002								
Total Purge Time (min): 52								
Total Vol. Purged (gal/L): 2.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs (8260B)	HCl	3 - 40 ml VOA	✓
Chloride, Sulfate, Nitrate, Nitrite	ICE	1 - 250 ml Poly	✓
TOC (5310D)	H_2SO_4	1 - 200 ml Poly	✓
TSS (2540D)	ICE	1 } 1L Poly	✓
TDS (2540C)	ICE		✓
Diss Gases	HCl	3 - 40 ml VOA	✓
Fatty Acids	ICE	3 - 40 ml VOA	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:
—	

Signature(s):

Mark R

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112EC01597-06

WELL ID.: MRC-OWI-011309
DATE: 1-13-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0910	9.95	—	—	—	—	—	—	—	—	Initial, no odor
0912	10.00	150	7.19	0.285	90.1	2.71	14.73	86	0.01	Slightly cloudy with small particles
0917	9.98	150	7.49	0.276	61.3	1.00	15.85	78	0.01	
0922	9.98	150	7.75	0.278	29.4	0.31	16.78	61	0.01	
0927	9.98	150	7.88	0.276	15.8	0.15	17.21	52	0.01	
0932	9.99	150	7.95	0.281	15.4	0.00	17.48	48	0.01	
0937	9.98	150	7.99	0.282	14.0	0.00	17.65	45	0.01	
0942	10.00	150	8.01	0.281	9.94	0.00	17.71	43	0.01	Clear water
0947	10.00	150	8.04	0.282	9.31	0.00	17.69	42	0.01	
0952	10.00	150	8.10	0.290	7.98	0.00	16.57	35	0.01	
0957	10.00	150	8.11	0.288	8.00	0.00	16.90	40	0.01	
1002	10.00	150	8.10	0.287	8.10	0.00	16.75	41	0.01	
			Well parameter sampling		stabilize begins					

SIGNATURE(S): Wade R

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112IC01597-06

Sample ID No.: MRC-GW10-011309
Sample Location: GW 10
Sampled By: DP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-13-09	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Time: 1235								
Method: Geo pump	Clear	9.65	0.213	17.32	4.29	0.00	0.01	-36

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-13-09								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC			See Low Flow Purge Data Sheet					
Total Well Depth (TD):								
Static Water Level (WL): 9.80								
One Casing Volume(gal/L):								
Start Purge (hrs): 1112								
End Purge (hrs): 1230								
Total Purge Time (min): 78								
Total Vol. Purged (gal/L): 3.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
TOC	H_2SO_4	1 - 250 ml Poly	✓
Anions	ICE	1 - 250 ml Poly	✓
TSS, TDS	ICE	1 - 1L Poly	✓
Diss. Gases	HCl	3 - 40 ml VOA	✓
Fatty Acids	ICE	3 - 40 ml VOA	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s):

Walt Pa

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112SC01597-06

WELL ID.: MRC-GWID-011308
DATE: 1-13-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1112	9.90	—	—	—	—	—	—	—	—	IN, trial, no action
1115	10.20	120	8.45	0.146	6.41	10.14	14.57	37	0.1	Clear water with small particles
1120	10.12	120	8.68	0.129	2.87	8.81	15.73	25	0.00	
1125	10.18	120	8.51	0.116	5.01	7.61	16.43	41	0.00	
1130	10.18	120	8.51	0.116	9.51	5.42	16.54	33	0.00	
1135	10.18	120	8.54	0.125	7.41	4.70	16.58	25	0.00	
1140	10.18	120	8.57	0.150	4.60	2.44	16.72	-21	0.01	
1145	10.19	120	9.09	0.173	3.39	1.42	16.90	-32	0.01	
1150	10.20	120	9.14	0.178	5.98	0.84	17.05	-35	0.01	
1155	10.20	120	9.11	0.184	20.0	0.77	17.14	-33	0.01	Slightly cloudy
1200	10.20	120	9.10	0.195	17.9	0.50	17.14	-34	0.01	
1205	10.20	120	9.11	0.197	14.9	0.23	17.23	-35	0.01	
1210	10.20	120	9.10	0.204	9.63	0.10	17.23	-35	0.01	Clear water
1215	10.20	120	9.08	0.209	5.86	0.00	17.21	-34	0.01	
1220	10.20	120	9.06	0.212	4.37	0.00	17.24	-34	0.01	
1225	10.20	120	9.06	0.211	4.30	0.00	17.30	-35	0.01	
1230	10.20	120	9.05	0.213	4.29	0.00	17.32	-36	0.01	
			Well	Parameters		Stabilize				
				Sampling		Begins				

SIGNATURE(S): Nick

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112TC01597-06

Sample ID No.: MRC-OW2I-011309
Sample Location: OW2I
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Date: 1-13-09								
Time: 1524								
Method: Geo pump	Clear	9.97	0.779	18.16	2.00	0.00	0.03	-111

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-13-09								
Method: Geo Pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge Data Sheet						
Total Well Depth (TD):								
Static Water Level (WL): 10.15								
One Casing Volume(gal/L):								
Start Purge (hrs): 1427								
End Purge (hrs): 1519								
Total Purge Time (min): 52								
Total Vol. Purged (gal/L): 2.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40ml VOA	✓
TDS	H_2SO_4	1 - 250 ml Poly	✓
Diss gases	HCl	3 - 40 ml VOA	✓
Fatty Acids	—	3 - 40 ml VOA	✓
TSS, TDS	—	1 - 1L Poly	✓
Anions	—	1 - 250 ml Poly	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD —

Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112IC01597-06

WELL ID.: MRC-OW2I-011309
DATE: 1-13-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1427	10.15	—	—	—	—	—	—	—	—	Initial pre-edon
1429	10.60	170	9.62	0.803	22.5	2.60	16.13	-91	0.03	Slightly Cloudy
1434	10.60	170	9.87	0.809	10.2	0.24	17.32	-104	0.04	Clear water
1439	10.65	170	9.89	0.805	8.11	0.00	17.67	-105	0.03	
1444	10.67	170	9.89	0.789	5.25	0.00	17.79	-105	0.03	
1449	10.70	170	9.92	0.762	4.33	0.00	17.81	-107	0.03	
1454	10.70	150	9.94	0.756	3.21	0.00	17.86	-108	0.03	
1459	10.70	150	9.95	0.754	2.28	0.00	17.97	-109	0.03	
1504	10.70	150	9.96	0.768	2.08	0.00	18.10	-111	0.03	
1509	10.75	150	9.96	0.773	2.08	0.00	18.15	-111	0.03	
1514	10.75	150	9.97	0.778	2.05	0.00	18.14	-112	0.03	
1519	10.75	150	9.97	0.779	2.00	0.00	18.16	-111	0.03	
			Well Parameters Stabilize							
			Sampling Begins							

SIGNATURE(S): Wat

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.: 112COI597-06

Sample ID No.: MRC-OW20-011509
Sample Location: OW20
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-15-09	(Visual)	(S.U.)	(mS/cm)	(^{0}C)	(NTU)	(mg/l)	(%)	
Time: 1442								
Method: Geo pump	Clear	9.57	0.314	14.82	1.90	0.00	0.01	-88

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-15-09								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material								
Type: 2" PVC			See Low Flow Purge					
Total Well Depth (TD): —								
Static Water Level (WL): 10.35			Data Sheet					
One Casing Volume(gal/L): —								
Start Purge (hrs): 1335								
End Purge (hrs): 1437								
Total Purge Time (min): 62								
Total Vol. Purged (gal/L): 2.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
Diss gases	HCl	3 - 40 ml VOA	✓
Fatty Acids	ICE	3 - 40 ml VOA	✓
TOC	H$_2$SO$_4$	1 - 250 ml Poly	✓
Anions	ICE	1 - 250 ml Poly	✓
TSS, TDS	ICE	1 - 1L Poly	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD —

Duplicate ID No.: —

Signature(s):

Mark R

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112IC01597-06

WELL ID.: MRC-OW20-011509
DATE: 1-15-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1335	10.35	—	—	—	—	—	—	—	—	Initial, No odor
1337	11.15	150	9.57	0.412	93.9	1.52	13.85	-72	0.02	Slightly cloudy
1342	12.15	150	9.63	0.385	46.8	0.00	15.56	-74	0.02	↓
1347	12.80	100	9.55	0.355	10.2	0.00	15.18	-63	0.01	↓
1352	13.35	100	9.63	0.323	5.16	0.00	15.26	-69	0.01	Clear water
1357	13.85	100	9.71	0.315	3.23	0.00	15.20	-76	0.01	↓
1402	14.30	100	9.76	0.312	3.25	0.00	15.27	-79	0.01	↓
1407	14.75	100	9.79	0.307	3.32	0.00	15.06	-81	0.01	↓
1412	15.10	100	9.69	0.314	3.37	0.00	15.46	-88	0.01	↓
1417	15.45	100	9.89	0.316	2.98	0.00	14.83	-86	0.01	↓
1422	15.85	100	9.88	0.314	2.65	0.00	14.81	-87	0.01	↓
1427	~~16.97~~ 16.30	100	9.92	0.313	1.86	0.00	14.80	-88	0.01	↓
1432	16.50	100	9.97	0.315	1.88	0.00	14.81	-88	0.01	↓
1437	16.70	100	9.97	0.314	1.90	0.00	14.82	-88	0.01	↓
	←	All parameters Stabilize							→	
	←			Sampling Begins					→	

SIGNATURE(S): Wade

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middlebush Center
Project No.: 112G01557-06

Sample ID No.: MBC-GW3I-011509
Sample Location: GW3I
Sampled By: MP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-15-09	(Visual)	(S.U.)	(mS/cm)	(^{0}C)	(NTU)	(mg/l)	(%)	ORP
Time: 1201	Clear	9.80	0.430	14.69	4.90	0.00	0.02	-66
Method: Geo Pump								

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-15-09								
Method: Geo Pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC			See Low Flow Purge Data Sheet					
Total Well Depth (TD): —								
Static Water Level (WL): 9.00								
One Casing Volume(gal/L): —								
Start Purge (hrs): 1059								
End Purge (hrs): 1156								
Total Purge Time (min): 57								
Total Vol. Purged (gal/L): 2.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
Diss Gases	HCl	3 - 40 ml VOA	✓
TOC	H_2SO_4	1 - 250 ml Poly	✓
Anions	ICE	1 - 250 ml Poly	✓
TSS, TDS	ICE	1 - 1L Poly	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:
—	—

Signature(s):

Walt Pe

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112IC01597-06
WELL ID.: MRC-OW3I-011509
DATE: 1-15-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1059	9.00	—	—	—	—	—	—	—	—	Initial pre-purge
1101	9.45	130	9.20	0.435	278	0.16	13.24	-30	0.02	Cloudy water
1106	9.45	130	9.35	0.436	116	0.00	12.85	-37	0.02	↓
1111	9.45	130	9.45	0.436	47.0	0.00	13.32	-42	0.02	Slightly cloudy
1116	9.45	130	9.50	0.430	20.0	0.00	13.64	-48	0.02	↓
1121	9.45	130	9.54	0.434	12.1	0.00	14.04	-52	0.02	↓
1126	9.47	130	9.56	0.435	10.0	0.00	14.48	-55	0.02	Clear water
1131	9.47	130	9.59	0.437	7.21	0.00	14.85	-60	0.02	
1136	9.47	130	9.63	0.434	5.00	0.00	14.74	-63	0.02	
1141	9.47	130	9.71	0.430	4.83	0.00	14.17	-66	0.02	
1146	9.47	130	9.80	0.430	4.95	0.00	14.75	-67	0.02	
1151	9.47	130	9.83	0.430	4.92	0.00	14.65	-65	0.02	
1156	9.47	130	9.80	0.430	4.90	0.00	14.69	-66	0.02	
	← Well Parameters Stabilize →									
	←			Sampling Begins						→

SIGNATURE(S): [signature]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: middle River Center
Project No.: 112E01597-0C

Sample ID No.: MRC-OW30-011509
Sample Location: OW30
Sampled By: VP
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 1-15-09	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 1016	(Visual)	(S.U.)	(mS/cm)	(^{0}C)	(NTU)	(mg/l)	(%)	ORP
Method: Geo pump	Clean	10.17	0.640	13.48	1.15	0.00	0.03	-163

PURGE DATA:

Date: 1-15-09	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): —			See Low Flow purge					
Static Water Level (WL): 8.75								
One Casing Volume(gal/L): —			Data Sheet					
Start Purge (hrs): 0924								
End Purge (hrs): 1011								
Total Purge Time (min): 47								
Total Vol. Purged (gal/L): 2.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	3 - 40 ml VOA	✓
Diss Gases	HCl	3 - 40 ml VOA	✓
TOC	H_2SO_4	1 - 250 ml Poly	✓
Anions	Ice	1 - 250 ml Poly	✓
TSS, TDS	Ice	1 - 1L Poly	✓

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:
—	—

Signature(s):

Walt Pa

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER: 112IC01597-06

WELL ID.: MRC-OW30-011509
DATE: 1-15-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0924	8.75	—	—	—	—	—	—	—	—	Initial, no odor
0926	9.60	150	9.17	0.306	13.6	1.01	13.40	-66	0.01	Slightly cloudy, small black particles
0931	9.90	150	9.98	0.281	9.73	0.31	13.69	-84	0.01	
0936	10.02	150	10.50	0.386	6.35	0.00	13.24	-128	0.02	
0941	10.10	140	10.90	0.479	4.31	0.00	13.25	-150	0.02	
0946	10.15	140	11.08	0.529	2.35	0.00	13.32	-160	0.02	
0951	10.17	140	11.13	0.561	1.60	0.00	13.48	-162	0.02	
0956	10.17	140	11.17	0.636	1.41	0.00	13.42	-163	0.03	
1001	10.17	140	11.18	0.640	1.20	0.00	13.41	-163	0.03	
1006	10.17	140	11.18	0.640	1.11	0.00	13.46	-163	0.03	
1011	10.17	140	11.17	0.640	1.15	0.00	13.48	-163	0.03	
			Well Parameters Stabilize							
			Sampling Begins							

SIGNATURE(S): Walt Ahr

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: LMC-MRC
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW-3I
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 129412
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 11/14/08								
Time: 1445								
Method: Low Flow		5.51	0.494	21.1	28.9	0.00	0.0	ORP -80

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 11/14/08								
Method: Low-Flow Pump								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 19.07'								
Static Water Level (WL): 9.38								
One Casing Volume(gal/L): 1.6(gal)								
Start Purge (hrs): 1315								
End Purge (hrs): 1600								
Total Purge Time (min): 165min								
Total Vol. Purged (gal/L): ~8.0gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
TCL VOC + Oxygenates	HCl	3-40 mL vials	
1,4-Dioxane	—	2-1L amber glass bottles	
Total Metals	HNO_3	1-500 mL plastic bottle	
Dissolved Metals (Filter In Lab)	—		
TOC	H_2SO_4	4-40mL vials	
TSS, TDS, SO_4, NO_2+NO_3	—	1-1L plastic bottle	
Dissolved Gasses	HCl	3-40mL vials	

OBSERVATIONS / NOTES:

-Initial pumping contained the Vegetable oil
Iron = >10
Total Iron >10
Carbon Dioxide > 100 ppm

DO is between 0 & 1 (closer to 0)

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Plot Test Wells
PROJECT NUMBER:

WELL ID.: OW-3I
DATE: 11/14/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1315	9.38	—	—	—	—	—	—	—	—	Static WL; Begin Purge.
1317	9.21	140	4.83	0.138	905	1.60	20.8	152	0.0	
1320	9.25	140	5.10	0.140	554	0.00	21.0	78	0.0	
1325	9.28	140	5.25	0.170	391	0.00	21.1	47	0.0	
1330	9.29	140	5.33	0.168	296	0.00	21.0	17	0.0	
1335	9.31	140	5.34	0.222	226	0.00	21.0	-5	0.0	
1340	9.32	140	5.36	0.286	162	0.00	21.1	-17	0.0	
1345	9.33	140	5.38	0.318	129	0.00	21.1	-26	0.0	
1350	9.33	140	5.39	0.355	139	0.00	21.1	-34	0.0	
1355	9.35	140	5.40	0.384	91.7	0.00	21.1	-42	0.0	
1400	9.35	140	5.41	0.397	85.6	0.00	21.1	-47	0.0	
1405	9.36	140	5.43	0.412	67.2	0.00	21.1	-54	0.0	
1410	9.36	140	5.44	0.421	63.7	0.00	21.1	-58	0.0	
1415	9.36	140	5.45	0.429	60.3	0.00	21.1	-61	0.0	
1420	9.36	140	5.47	0.448	45.8	0.00	21.2	-66	0.0	
1430	9.37	140	5.48	0.468	36.0	0.00	21.2	-76	0.0	
1435	9.37	140	5.49	0.490	33.3	0.00	21.2	-74	0.0	
1440	9.37	140	5.50	0.497	29.3	0.00	21.1	-77	0.0	
1445	9.36	140	5.51	0.494	28.9	0.00	21.1	-80	0.0	Sample.
1600	9.36	—	—	—	—	—	—	—	—	Final WL; End Purge

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: LMC-MRC
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: GW-1T
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 120413
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 11/17/08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Time: 1100								
Method: Low Flow	Clear	5.60	0.226	20.4	17	1.36	0.0	77

PURGE DATA:

Date: 11/17/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 19.9'								
Static Water Level (WL): 9.85'								
One Casing Volume(gal/L): 1.7gal								
Start Purge (hrs): 1012								
End Purge (hrs): 1146								
Total Purge Time (min): 98min								
Total Vol. Purged (gal/L): 2.25gal								

60
30

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
TCL VOC + Oxygenates	HCL	3-40mL vials	
1,4-Dioxane	—	2-1L amber glass bottles	
Total Metals	HNO_3	1-500mL plastic bottle	
Dissolved Metals (Filter In Lab)	—	1-1L plastic bottle	
TOC	H_2SO_4	4-40mL vials	
TSS TDS, SO_4, NO_2+NO_3	—	1-1L plastic bottle	
Dissolved Gasses	HCl	3-40mL vials	

OBSERVATIONS / NOTES:

Ferrous Iron = Low Range = ~~0.7~~ High Range = <1.0
Total Iron = Low Range = >1.0 High Range = 1.5
Dissolved Oxygen = 1.5
Carbon Dioxide = 70 ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: LMC-MRC
PROJECT NUMBER:
WELL ID.: GW-1I
DATE: 11/17/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1012	9.85'	—	—	—	—	—	—	—	—	Static WL; Begin Purge
1015	9.95'	100	5.71	0.198	40	6.71	20.5	-36	0.0	
1020	9.95'	100	5.78	0.178	45	5.20	20.3	-8	0.0	
1025	9.95'	100	5.76	0.183	39	3.99	20.2	16	0.0	
1030	9.95'	100	5.72	0.193	34	3.38	20.3	39	0.0	
1035	9.95'	100	5.69	0.202	28	2.78	20.5	53	0.0	
1040	9.95'	100	5.67	0.207	24	2.38	20.6	60	0.0	
1045	9.95'	100	5.66	0.215	27	1.95	20.4	66	0.0	
1050	9.95'	100	5.63	0.219	19	1.73	20.3	71	0.0	
1055	9.95'	100	5.61	0.222	19	1.51	20.5	75	0.0	
1100	9.96'	100	5.60	0.226	17	1.36	20.4	77	0.0	Sample
1196	9.95'	—	—	—	—	—	—	—	—	Final WL; End Purge

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: LMC-MRC
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW-2D
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 120413
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 11/17/08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other ORP
Time: 1450								
Method: Low Flow		5.62	0.431	19.7	32	1.01	0.0	-122

PURGE DATA:

Date: 11/17/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material								
Type: 2" PVC								
Total Well Depth (TD): 29.87								
Static Water Level (WL): 10.22								
One Casing Volume(gal/L): 3.3 gal								
Start Purge (hrs): 1414								
End Purge (hrs): 1532								
Total Purge Time (min): 77 min								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
TCL VOC + Oxygenates	HCL	3-40mL vials	
1,4-Dioxane	—	2-1L amber glass bottles	
Total Metals	HNO_3	1-500mL plastic bottle	
Dissolved Metals (Filter In lab)	—	1-1L plastic bottle	
TOC	H_2SO_4	4-40mL vials	
TSS, TDS, SO_4, NO_2 + NO_3	—	1-1L plastic bottle	
Dissolved Gasses	HCl	3-40mL vials	

OBSERVATIONS / NOTES:

Ferrous Iron: Low Range = >1.0 Total Iron: Low Range = >1.0
High Range = >10.0 High Range = >10.0
Dissolved Oxygen = <1.0
Carbon Dioxide = 100ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): Dawn L Mullins

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: LMC-MRC
PROJECT NUMBER:

WELL ID.: OW-2D
DATE: 11/17/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1414	10.22	—	—	—	—	—	—	—	—	Static WL; Begin Purge
1417	11.68	100	5.42	0.436	60	0.35	19.4	-48	0.0	
1420	12.31	100	5.48	0.434	55	0.00	19.6	-83	0.0	
1425	13.19	100	5.53	0.432	45	0.42	19.8	-99	0.0	
1430	13.68	100	5.55	0.432	40	0.59	19.7	-105	0.0	
1435	14.46	100	5.58	0.432	35	0.74	19.7	-112	0.0	
1440	15.04	100	5.60	0.432	39	0.86	19.7	-116	0.0	
1445	15.81	100	5.61	0.431	36	0.94	19.8	-120	0.0	
1450	16.44	100	5.62	0.431	32	1.01	19.7	-122	0.0	sample
1532	21.79	—	—	—	—	—	—	—	—	Final WL; End Purge.

SIGNATURE(S): [signature]

PAGE 1 OF 1

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: LMC-MRC
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: GW-3D
Sample Location: MRC
Sampled By: DLM
C.O.C. No.: 129414
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 11/18/08	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 1105	(Visual)	(S.U.)	(mS/cm)	(^{0}C)	(NTU)	(mg/l)	(%)	ORP
Method: Low Flow		5.54	0.969	18.2	15	0.00	0.0	-156

PURGE DATA:

Date: 11/18/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material								
Type: 2" PVC								
Total Well Depth (TD): 29.26								
Static Water Level (WL): 8.76								
One Casing Volume(gal/L): 3.5gal								
Start Purge (hrs): 1007								
End Purge (hrs): 1149								
Total Purge Time (min): 102min								
Total Vol. Purged (gal/L): ~2.5gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
TCL VOC + Oxygenates	HCl	3-40mL vials	
1,4-Dioxane	—	2-1L amber glass bottles	
Total Metals	HNO_3	1-500mL plastic bottle	
Dissolved Metals (Filter In Lab)	—	1-1L amber glass bottle	
TOC	H_2SO_4	4-40mL vials	
TSS, TDS, SO_4, NO_3+NO_2	—	1-1L plastic bottle	
Dissolved Gasses	HCl	3-40mL vials	

OBSERVATIONS / NOTES:

Ferrous Iron: High Range: >10ppm
Low Range: >1.0ppm
Total Iron: High Range
Low Range.
Dissolved Oxygen: <1.0
CO_2 = >100ppm

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): Dawn L Mahoney

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: LMC-MRC
PROJECT NUMBER:

WELL ID.: OW-3D
DATE: 11/18/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1007	8.76'	—	—	—	—	—	—	—	—	Static WL, Begin Purge
1010	9.50'	100	4.97	0.587	450	0.49	17.0	-78	0.0	
1015	9.50	100	5.11	0.611	190	0.00	17.6	-119	0.0	
1020	9.50	100	5.15	0.657	80	0.00	17.8	-129	0.0	
1025	9.51	100	5.27	0.939	36	0.00	17.4	-140	0.0	
1030	9.53	100	5.33	0.954	27	0.00	17.5	-144	0.0	
1035	9.55	100	5.46	0.962	22	0.00	18.1	-148	0.0	
1040	9.62	100	5.52	0.983	25	0.00	18.6	-151	0.0	
1045	9.65	100	5.55	0.978	30	0.00	18.7	-154	0.0	
1050	9.68	100	5.48	0.972	20	0.00	18.5	-157	0.0	
1055	9.70	100	5.50	0.975	16	0.00	18.3	-157	0.0	
1100	9.71	100	5.57	0.973	15	0.00	18.1	-157	0.0	
1105	9.71	100	5.54	0.969	15	0.00	18.2	-156	0.0	SAMPLE
1149	10.08	—	—	—	—	—	—	—	—	Final WL; End Purge

SIGNATURE(S): Dawn L Mathews

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC - Pilot Study - Microbial
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: MRC-OW-1I-100208
Sample Location: LMC-MRC
Sampled By: DLM
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 10/2/08	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time: 0945	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Method: Low-Flow	Orange on filter.	5.34	0.305	23.23	3.05	1.72	—	57

PURGE DATA:

Date: 10/2/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low-Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 19.92'								
Static Water Level (WL): 9.01'								
One Casing Volume(gal/L): 1.85								
Start Purge (hrs): 0849								
End Purge (hrs): 1002								
Total Purge Time (min): 73mm								
Total Vol. Purged (gal/L): ~~4.75gal~~ 5.0gal								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
Dehalococcoides, BVC, TCE, VCR, eBac, MGN, DHB, DSM, SRB, IRB	? →	1 Bio-Flow Filter	10/2/08 @ 0945

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC - Pilot Study - Microbial
PROJECT NUMBER:

WELL ID.: MRC-OW-1I-100208
DATE: 10/2/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0849	9.01	—	—	—	—	—	—	—	—	Static WL; Start Purge.
0851	9.14	120	5.92	0.266	71.6	8.59	22.61	71		
0855	9.16	120	5.95	0.269	43.8	8.01	22.78	66		
0900	9.19	120	5.94	0.269	21.7	7.53	22.90	65		
0905	9.21	120	5.39	0.279	8.41	6.95	23.13	62		
0910	9.23	120	5.67	0.281	6.01	6.54	23.16	61		
0915	9.24	120	5.63	0.287	5.29	2.36	23.11	61		
0920	9.26	120	5.61	0.293	4.55	1.85	23.15	59		
0925	9.26	120	5.66	0.296	4.47	1.90	23.20	58		
0930	9.27	120	5.57	0.297	3.90	1.96	23.20	57		
0935	9.27	120	5.41	0.300	3.29	1.83	23.19	56		
0940	9.28	120	5.36	0.303	3.27	1.75	23.22	57		
0945	9.29	120	5.34	0.305	3.05	1.72	23.23	57		Sample
1002	—	—	—	—	—	—	—	—	—	End Purge

SIGNATURE(S): Daniel L. Mathieu

Total Depth = 19.92'

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC-Pilot Study-Microbial
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: MRC-OW3D-100208
Sample Location: LMC-MRC
Sampled By: DLM
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 10/2/08								
Time: 1800								
Method: Low Flow	–	–	–	–	–	–	–	–

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 10/2/08								
Method: Low-Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 28.83								
Static Water Level (WL): 11.65								
One Casing Volume(gal/L): 2.92								
Start Purge (hrs): 1030								
End Purge (hrs): 1150								
Total Purge Time (min): 80 min								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
Dehalococcoides, BVC, TCE, VCR, eBoc, MGN, DHB, DSM, SRB/IRB		1 Bio-Flow Filter	10/2/08 @ 1800

OBSERVATIONS / NOTES:

- orange particles suspended in water.
- well went dry. It was left sit sit for several hours to recharge

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): [signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Study-Microbial
PROJECT NUMBER:

WELL ID.: MRC-OW-1D-100208
DATE: 10/2/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.) 0.1	S. Cond. (mS/cm) 3%	Turb. (NTU) 10%	DO (mg/L) 10%	Temp. (Celcius) 10%	ORP mV 10%	Salinity % or ppt	Comments
1030	11.65	~~266~~	–	–	–	–	–	–	–	Static WL; Start Purge
1035	13.34	200	5.82	0.411	12.8	2.61	22.10	30		
1040	15.68	200	5.74	0.406	14.2	1.90	22.07	54		
1045	17.89	120	5.69	0.401	8.97	2.14	22.16	65		
1050	18.11	120	5.65	0.393	7.92	2.72	22.25	73		
1055	18.89	120	5.64	0.384	8.72	3.26	22.41	77		
1100	20.01	120	5.64	0.383	8.55	3.69	22.42	77		
1105	20.77	100	5.68	0.382	9.08	3.61	22.29	69		
1110	–	–	[illegible]	[illegible]	–	~~5.29~~	–	–		Flow Stopped.
1115	21.78	100	6.13	0.431	30.0	3.29	20.90	-23		
1120	22.15	100	6.17	0.447	30.1	2.13	20.85	-23		
1125	23.50	100	6.09	0.447	15.4	1.72	20.82	-13		
1130	24.31	100	6.08	0.437	17.0	1.69	20.63	-6		
1135	25.13	100	6.04	0.430	25.5	1.68	20.77	-3		
1140	25.64	100	6.04	0.423	31.4	1.75	20.99	-5		
1145	26.83	100	5.64	0.408	93.0	1.89	20.34	-12		
1150	26.96	100	5.66	0.376	86.9	2.84	20.92	-13		Well went dry.

SIGNATURE(S):

Total Depth = 19.95'
Volume Purged = ~6.0gal

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER:
WELL ID.: MRC-OW2I-100108
DATE: 10/1/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1430	9.56	—								
1435	9.56	120	4.90	0.378	9.62	8.97	23.52	133		
1440	9.56	120	4.88	0.379	3.64	2.37	23.47	140		
1445	9.56	120	4.87	0.380	1.82	1.94	23.49	143		
1450	9.57	120	4.86	0.381	1.95	1.40	23.40	145		
1455	9.58	120	4.86	0.380	1.12	1.99	23.42	145		
1500	9.59	120	4.85	0.381	1.00	1.92	23.29	146		
1505	9.60	120	4.85	0.380	0.83	1.86	23.28	146		
1510	9.35	120	4.80	0.381	0.22	1.85	23.06	159		
1515	9.34	120	4.70	0.372	0.29	1.83	23.13	172		
1520	9.36	120	4.96	0.371	1.10	1.96	23.25	138		
1525	9.34	120	5.08	0.386	7.38	2.08	23.32	127		
1530	9.33	120	5.16	0.433	10.46	2.40	23.34	121		
1535	9.36	120	5.32	0.503	11.60	4.86	23.27	113		
1540	9.35	120	5.32	0.502	12.20	4.92	23.27	113		
1545	9.34	200	5.31	0.503	11.60	5.36	23.28	114		
1550	—	—	—	—	—	—	—	—	—	
1600	9.54	200	5.03	0.440	7.44	4.26	23.42	132		
1605	9.55	200	4.89	0.434	3.52	3.75	23.30	145		
1610	9.56	200	4.87	0.428	2.76	3.48	23.30	150		
1615	9.56	200	4.85	0.404	2.59	3.17	23.31	152		
1620	9.56	200	4.84	0.402	1.60	2.36	23.29	154		
1625	9.56	200	4.83	0.397	1.49	1.92	23.25	153		End Purge

SIGNATURE(S): Daniel L. MacDonald

Total Depth = 29.88
Volume Purged = ~8.5gal

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Study-Microbial
PROJECT NUMBER:
WELL ID.: MRC-OWAD-10108
DATE: 10/1/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1150	9.46	—	—	—	—	—	—	—	—	Static WL; Start Purge
1155	11.35	200	5.74	0.417	36.9	6.09	22.28	-28		Clear water
1205	12.25	220	5.81	0.422	29.8	3.15	22.11	-62		↑ orangish when in bucket
1210	13.90	220	5.84	0.423	30.6	1.96	22.06	-71		
1215	15.41	220	5.87	0.425	24.2	1.90	22.0	-78		
1220	16.29	220	5.87	0.427	22.2	1.84	22.0	-80		
1225	17.29	220	5.86	0.427	26.8	1.68	21.82	-79		
1230	18.22	220	5.83	0.427	27.4	1.73	21.65	-76		
1235	19.17	220	5.83	0.429	51.6	2.06	21.58	-75		
1240	19.92	220	5.80	0.428	49.7	1.78	21.53	-71		
1245	20.68	220	5.81	0.425	70.7	1.77	21.73	-72		
1250	21.43	220	5.78	0.421	72.7	1.75	21.63	-65		
1255	22.1	220	5.77	0.406	41.4	1.72	21.49	-64		
1300	22.75	220	5.76	0.398	53.8	1.70	21.46	-65		
1305	23.18	220	5.78	0.395	80.6	1.71	21.26	-67		
1310	23.53	220	5.77	0.396	119.0	1.64	21.30	-65		
1315	23.75	220	5.82	0.387	92.6	1.61	21.11	-69		
1320	23.65	220	5.80	0.381	78.5	1.64	21.11	-67		
1325	23.42	220	5.81	0.383	113	1.60	21.20	-67		
1330	22.96	220	5.81	0.382	128	1.62	21.28	-63		
1335	22.55	220	5.77	0.370	116	1.64	21.12	-55		
1340	22.28	220	5.76	0.372	101.3	1.62	21.03	-56		
1345	21.86	220	5.73	0.384	119	1.60	20.96	-53		
1350	21.54	220	5.71	0.393	115	1.58	20.90	-49		Final WL; End Purge

SIGNATURE(S): Dawn L. Mathieu

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC-Pilot Test-Microbial
Project No.:

Sample ID No.: MRC-OW3I-100208
Sample Location: LMC-MRC
Sampled By: DLM
C.O.C. No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 10/2/08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Time: 1505								ORP
Method: Low Flow	Orange filter	5.46	0.236	23.10	2.27	1.88	—	117

PURGE DATA:

Date: 10/02/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low-Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 19.91'								
Static Water Level (WL): 8.03								
One Casing Volume(gal/L): 2.02								
Start Purge (hrs): 1436								
End Purge (hrs): 1519								
Total Purge Time (min): 43mm								
Total Vol. Purged (gal/L): 2.75gal								

SAMPLE COLLECTION INFORMATION:

Dehaloco Analysis	Preservative	Container Requirements	Collected
Dehalococcoides, BVC, TCE, VCR, eBac, MGN, DHB, DSM, SRB/IRB	}	2 1 Bio-Flow Filter	10/2/08 @1505

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): Dawn L. Mathews

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER:

WELL ID.: MRC-OW3I-100208
DATE: 10/2/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1436	8.03	—	—	—	—	—	—	—	—	Static WL; Start Purge
1440	8.23	120	5.37	0.250	5.60	2.53	23.79	108		
1445	8.24	120	5.45	0.246	4.11	2.07	23.63	108		
1450	8.26	120	5.46	0.243	2.65	1.95	23.34	110		
1455	8.29	120	5.45	0.242	2.22	1.86	23.28	115		
1500	8.31	120	5.43	0.237	2.24	1.82	23.24	118		
1505	8.32	120	5.46	0.236	2.27	1.88	23.10	117		sample
1519	8.25	—	—	—	—	—	—	—		Final WL; End Purge

SIGNATURE(S): Daniel J. McInerney

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: MRC-Pilot Test-Microbial
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: MRC-OW3D-100208
Sample Location: LMC-MRC
Sampled By: DLM
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date: 10/2/08	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Time: 1730								ORP
Method: Low-Flow		5.96	0.420	20.85	5.83	1.71	—	-18

PURGE DATA:

Date: 10/2/08	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method: Low-Flow								
Monitor Reading (ppm): N/A								
Well Casing Diameter & Material								
Type: 2" PVC								
Total Well Depth (TD): 29.91'								
Static Water Level (WL): 8.04								
One Casing Volume(gal/L): 3.72								
Start Purge (hrs): 1527								
End Purge (hrs): 1752								
Total Purge Time (min): 145 min								
Total Vol. Purged (gal/L): 6.75								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
Dehalococcoides, BVC, TCE, VCR, eBac, MGN, DHB, DSM, SRB/IRB		1-Bio-Flow Filter	10/2/08 @ 1730

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s): [signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER:

WELL ID.: MRC-OW3D-100208
DATE: 10/2/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1527	8.04	—	—	—	—	—	—	—	—	Static WL; Start Purge
1530	8.39	180	6.24	0.537	201	2.05	21.87	-32		
1535	8.34	140	6.26	0.540	500	2.02	22.02	-36		
1540	8.39	140	6.25	0.533	1037	2.21	21.50	-36		
1545	8.40	140	6.24	0.530	988	2.14	21.49	-36		
1550	8.41	140	6.22	0.524	727	2.05	21.38	-34		
1555	8.42	140	6.21	0.519	555	1.96	21.38	-32		
1600	8.43	140	6.20	0.513	340	1.87	21.25	-30		
1605	8.44	140	6.19	0.509	221	1.82	21.24	-29		
1610	8.45	140	6.18	0.503	167	2.69	21.08	-28		
1615	8.46	140	6.18	0.498	99.3	1.76	21.06	-28		
1620	8.46	140	6.17	0.490	59.9	1.71	21.05	-27		
1625	8.46	140	6.18	0.485	43.5	1.66	21.01	-27		
1630	8.46	140	6.14	0.479	36.7	1.70	21.02	-28		
1635	8.46	140	6.14	0.470	21.9	1.69	21.06	-27		
1640	8.46	140	6.17	0.469	18.2	1.64	20.94	-28		
1645	8.47	140	6.09	0.467	18.1	1.58	20.91	-28		
1650	8.47	140	6.17	0.461	15.7	1.42	20.92	-28		
1655	8.47	140	6.12	0.453	11.1	1.34	20.81	-27		
1700	8.47	140	6.14	0.450	9.92	1.60	20.82	-25		
1705	8.47	140	6.14	0.445	11.4	1.66	20.90	-24		
1710	8.47	140	6.00	0.438	15.5	1.34	20.88	-23		
1715	8.48	140	5.99	0.433	9.98	1.34	20.86	-22		
1720	8.48	140	5.97	0.429	7.71	1.36	20.83	-20		
1725	8.48	140	5.97	0.426	6.35	1.53	20.91	-19		
1730	8.48	140	5.96	0.420	5.83	1.71	20.85	-18		Sample
1752	8.18	—	—	—	—	—	—	—		Final WL; End Purge

SIGNATURE(S): Daniel L Mackay

Total Depth = 31.29 from TOC
Volume Purged = ~7.5gal

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: MRC-Pilot Test-Microbial
PROJECT NUMBER:
WELL ID.: MRC-MW81B-100308
DATE: 10/3/08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0930	8.85	—	—	—	—	—	—	—	—	Static WL; Start Purge
0935	10.06	120	6.09	0.350	647	2.80	21.24	-36		
0940	10.34	120	6.19	0.408	409	2.25	21.29	-59		
0945	10.60	120	6.24	0.421	332	2.31	21.23	-63		
0950	10.93	120	6.30	0.399	164	2.37	21.15	-66		
0955	11.08	120	6.24	0.398	76.6	2.33	21.14	-66		
1005	11.40	120	6.14	0.401	35.2	2.22	21.03	-51		
1015	11.54	120	6.03	0.411	21.7	2.02	20.92	-39		
1025	11.73	120	5.94	0.410	10.52	2.37	20.92	-28		
1030	11.80	120	5.85	0.408	7.79	3.10	20.90	-17		
1035	11.87	120	5.84	0.407	8.31	3.03	20.91	-15		
1040	11.90	120	5.81	0.405	7.10	2.84	20.90	-10		
1045	11.98	120	5.80	0.401	7.24	2.72	20.92	-7		
1050	11.94	120	5.76	0.395	6.81	2.63	20.94	-2		
1055	11.98	120	5.72	0.386	5.82	2.20	20.98	4		
1100	12.02	120	5.69	0.383	5.32	2.28	20.99	7		
1105	12.07	120	5.67	0.377	5.38	2.40	20.98	11		
1110	12.12	120	5.64	0.372	4.57	2.55	20.96	14		
1115	12.15	120	5.62	0.367	4.65	2.63	21.03	18		
1125	12.20	120	5.57	0.355	4.50	2.80	21.09	24		
1130	12.22	120	5.55	0.350	4.05	2.83	21.10	29		

SIGNATURE(S): _____

PAGE___OF___

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW2I-012408
Sample Location: OW2I
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-24-08								
Time: 1031								
Method: Geo pump	Clear	5.39	45.7	17.2	7.50	0.00	0.0	162

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-24-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 20.00	See Low Flow Purge							
Static Water Level (WL): 10.25								
One Casing Volume(gal/L): 1.7								
Start Purge (hrs): 0910	Data Sheet							
End Purge (hrs): 1026								
Total Purge Time (min): 76								
Total Vol. Purged (gal/L): 4.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2x2 40 ml VOA	4
Total PP metal	HNO3	2x1 500 ml poly	2
Diss PP metal	HNO3	2x1 500 ml poly	2
1,4 Dioxane	ICE	2x2 1L Ambers	4
RSK-175	HCl	2x2 40 ml VOA	4
TOC	HCl	2x1 125 ml Amber	2
Chloride, Nitrate, Nitrite	ICE	2x1 250 ml poly	2

OBSERVATIONS / NOTES:

$$\begin{array}{r} 180.00 \\ -\ 10.25 \\ \hline 9.75 \end{array} \qquad \begin{array}{r} 9.75 \\ \times\ .17 \\ \hline 6825 \\ 9750 \\ \hline 1.6575 \end{array}$$

Ferrous Iron 3.0 mg/L
Hydrogen Sulfide 0.1 mg/L

Circle if Applicable:

MS/MSD —

Duplicate ID No.: OW-DUP-012408

Signature(s): Walk

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW2I-012408
DATE: 1-24-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0906	10.25	—	—	—	—	—	—	—	—	Initial, no odor
0911	10.55	190	5.31	69.3	318	1.60	15.9	193	0.0	Cloudy water
0916	10.40	190	5.46	85.4	331	1.18	16.1	190	0.0	" " "
0921	10.40	190	5.46	54.7	139	0.80	17.0	183	0.0	" " "
0931	10.50	190	5.40	44.5	56.9	0.26	17.3	180	0.0	Slightly cloudy
0941	10.50	190	5.39	44.4	35.1	0.03	17.5	176	0.0	" " "
0951	10.50	190	5.38	44.6	26.0	0.04	17.7	173	0.0	" " "
1001	10.50	190	5.37	44.9	14.6	0.00	17.7	172	0.0	" " "
1011	10.50	190	5.36	45.2	10.7	0.00	17.6	170	0.0	Clear water
1016	10.50	190	5.40	45.7	7.34	0.00	17.3	166	0.0	" " "
1021	10.50	190	5.39	45.7	7.95	0.00	17.2	163	0.0	" " "
1026	10.50	190	5.39	45.7	7.50	0.00	17.2	162	0.0	" " "

SIGNATURE(S): Walt

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: middle River Center
Project No.:

Sample ID No.: OW20-012408
Sample Location: OW20
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-24-08	(Visual)	(S.U.)	(mS/cm)	(^{0}C)	(NTU)	(mg/l)	(%)	
Time: 1445								
Method: Geo pump	Slightly	6.26	42.1	17.4	12.0	0.58	0.0	-30

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-24-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 30.00		See Low Flow Purge Data Sheet						
Static Water Level (WL): 10.25								
One Casing Volume(gal/L): 3.4								
Start Purge (hrs): 1253								
End Purge (hrs): 1440								
Total Purge Time (min): 102								
Total Vol. Purged (gal/L): 3.5								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml vials	✓
Total PP metals	HNO3	1 - 500 ml Poly	✓
Diss PP metals	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Ambers	✓
RSK-175	HCl	2 - 40 ml vials	✓
TOC	HCl	1 - 125 ml Amber	✓
Chlorides, Nitrate, Nitrite	ICE	1 - 250 ml Poly	✓

OBSERVATIONS / NOTES:

2840 - 10.25 = 19.75

6.53 / 5.75 / .17 / 15825 / 19750 / 3.357

Ferrous Iron 3.0 mg/L 1535
Hydrogen Sulfide 0.1 mg/L 1540

Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW2D-012408
DATE: 1-24-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1253	10.25	—	—	—	—	—	—	—	—	Initial, no action
1255	11.05	200	6.58	50.7	258	1.53	18.1	-92	0.0	Cloudy water
1300	12.05	200	6.64	51.5	53.6	0.90	17.9	-99	0.0	Slightly Cloudy
1305	12.62	130	6.62	48.6	35.5	1.20	16.9	-87	0.0	" " "
1315	13.25	130	6.55	42.4	25.0	2.61	17.0	-52	0.0	" " "
1325	13.56	100	6.52	42.4	13.7	2.34	16.6	-54	0.0	" " "
1335	13.90	100	6.52	42.8	9.84	1.90	17.0	-58	0.0	Clear water
1345	14.20	100	6.48	43.7	8.27	1.43	17.0	-58	0.0	" " "
1355	14.50	100	6.42	43.2	14.2	1.02	17.2	-53	0.0	Slightly Cloudy
1405	14.74	100	6.39	43.5	22.1	0.95	17.4	-50	0.0	" " "
1415	14.95	100	6.32	43.6	13.3	0.69	17.2	-45	0.0	" " "
1425	15.09	100	6.27	43.1	11.4	0.52	17.3	-39	0.0	" " "
1430	15.16	100	6.24	42.7	11.5	0.52	17.4	-36	0.0	" " "
1435	15.25	100	6.25	42.0	12.0	0.57	17.4	-33	0.0	" " "
1440	15.26	100	6.26	42.1	12.0	0.58	17.4	-30	0.0	" " "

SIGNATURE(S): Walt

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: middle river center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 4s - 012108
Sample Location: OW 4s
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-21-08								
Time: 1031								
Method: Geo pump	clear	6.19	0.504	10.4	4.32	1.04	0.2	66

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-21-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge Data						
Total Well Depth (TD): 15.00								
Static Water Level (WL): 2.15		Sheet						
One Casing Volume(gal/L): 2.2								
Start Purge (hrs): 0920								
End Purge (hrs): 1026								
Total Purge Time (min): 66								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml VOA	✓
Total PP metals	HNO3	1 - 500 ml Poly	✓
Diss PP metals	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Ambers	✓
RSK 175 methane/Ethene/Ethane	HCl	2 - 40 ml VOA	✓
Chloride, Nitrate/Nitrite	ICE	1 - 250 ml Poly	✓
TOC	HCl	1 - 125 ml Amber	✓

OBSERVATIONS / NOTES:

15.00 − 2.15 = 12.85

12.85 × .17 = 18995 + 12850 = 2.1845

Ferrous Iron 1 mg 1108

Hydrogen Sulfide 0.0 1115

Circle if Applicable:

MS/MSD —

Duplicate ID No.:

Signature(s): Walter

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW4S - 012108
DATE: 1-21-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0920	2.15	—	—	—	—	—	—	—	—	Initial, no odor
0921	2.60	190	5.85	0.289	72.8	0.19	10.1	65	0.1	Slightly Cloudy
0926	2.60	190	5.92	0.340	71.4	0.00	10.2	60	0.2	" " "
0931	2.60	190	5.96	0.523	57.3	0.00	10.4	57	0.3	" " "
0941	2.60	190	6.03	0.715	41.4	0.47	10.4	56	0.4	" " "
0951	2.60	190	6.15	0.742	21.9	0.87	10.3	58	0.4	" " "
1001	2.60	190	6.16	0.745	12.1	0.87	10.3	61	0.4	" " "
1006	2.60	190	6.17	0.743	10.4	0.95	10.4	62	0.4	Clear water
1011	2.60	190	6.17	0.745	7.01	1.02	10.4	63	0.3	" " "
1016	2.60	190	6.17	0.505	2.95	1.03	10.4	64	0.3	" " "
1021	2.60	190	6.18	0.503	4.22	1.06	10.4	65	0.2	" " "
1026	2.60	190	6.19	0.504	4.32	1.04	10.4	66	0.2	" " "

SIGNATURE(S): [signature]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 4I-012608
Sample Location: OW 4I
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-21-08								
Time: 1312								ORP
Method: Geo pump		5.12	0.148	14.1	33.0	0.00	0.1	120

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-21-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 30.00		See Low Flow Purge						
Static Water Level (WL): 4.50								
One Casing Volume(gal/L): 4.3								
Start Purge (hrs): 1116								
End Purge (hrs): 1307		Data Sheet						
Total Purge Time (min): 110								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs			

OBSERVATIONS / NOTES:

$$\begin{array}{r} 2\cancel{3}^{9}0.00 \\ -\ 4.50 \\ \hline 25.50 \end{array} \qquad \begin{array}{r} {}^{3}25^{3}.50 \\ \times\ .17 \\ \hline 17850 \\ 25500 \\ \hline 4.3350 \end{array}$$

Ferrous Iron 2.5 mg 1358
Hydrogen Sulfide 0.0 1400

Circle if Applicable:

MS/MSD	Duplicate ID No.:
—	

Signature(s): [signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW4I-012108
DATE: 1-21-09

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1116	4.50	—	—	—	—	—	—	—	—	Init. pre purge
1117	5.40	190	5.45	79.1	224	6.66	13.3	53	0.0	Cloudy water
1122	6.30	150	5.44	93.0	248	0.00	13.4	53	0.0	" " "
1127	7.25	140	5.26	0.223	247	0.00	13.5	87	0.1	" " "
1132	8.20	180	3.87	0.145	77.8	0.00	14.4	330	0.1	" " "
1147	9.45	140	4.28	0.141	55.4	0.00	13.4	253	0.1	slightly cloudy
1157	10.05	140	4.77	0.185	73.7	0.00	13.6	183	0.1	" " "
1207	10.60	140	4.84	0.183	52.4	0.00	13.6	174	0.1	" " "
1217	11.00	140	4.90	0.172	39.6	0.00	14.0	163	0.1	" " "
1227	11.40	140	4.96	0.165	47.4	0.00	14.1	151	0.1	" " "
1237	11.80	140	4.98	0.157	45.8	0.00	14.1	147	0.1	" " "
1242	11.90	140	5.00	0.154	38.3	0.00	14.3	145	0.1	" " "
1247	12.05	140	5.01	0.150	34.3	0.00	14.2	142	0.1	" " "
1252	12.20	140	5.03	0.149	31.0	0.00	14.3	139	0.1	" " "
1257	12.21	110	5.11	0.149	33.0	0.00	14.3	123	0.1	" " "
1302	12.23	110	5.12	0.148	32.0	0.00	14.2	122	0.1	" " "
1307	12.25	110	5.12	0.148	33.0	0.00	14.1	120	0.1	" " "

SIGNATURE(S):

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 5s - 012108
Sample Location: OW 5s
Sampled By: mp
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-21-08								
Time: 1619								Orp
Method: Geo pump	Clear	5.67	0.415	9.9	4.00	0.00	0.2	131

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-21-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material								
Type: 2" PVC		See Low Flow Purge Data						
Total Well Depth (TD): 15.00								
Static Water Level (WL): 1.95								
One Casing Volume(gal/L): 2.2		Sheet						
Start Purge (hrs): 1512								
End Purge (hrs): 1614								
Total Purge Time (min): 62								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml VOA	✓
Total PP metals	HNO3	1 - 500 ml Poly	✓
Diss PP metals	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Amber	✓
RSK-175	HCl	2 - 40 ml VOA	✓
TOC	HCl	1 - 250 ml Amber	✓
Chloride, Nitrate, Nitrite	ICE	1 - 125 ml Poly	✓

OBSERVATIONS / NOTES:

15.00 (4.9)
− 1.95
13.05

13.05 (2)
× .17
19135
13050
22195

Ferrous Iron 2.5 mg 1620
Hydrogen Sulfide 0.0 1623

Circle if Applicable:

MS/MSD —

Duplicate ID No.:

Signature(s): Wat

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW5S - 012108
DATE: 1-21-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1512	1.75	—	—	—	—	—	—	—	—	Initial, no odor
1514	2.20	240	5.54	0.297	40.2	0.71	10.3	122	0.2	Slightly cloudy
1519	2.24	240	5.60	0.633	36.0	0.00	10.2	123	0.3	" " "
1524	2.20	240	5.63	0.661	36.3	0.31	10.1	122	0.4	" " "
1534	2.25	240	5.67	0.521	24.3	0.07	9.9	122	0.3	" " "
1544	2.25	240	5.66	0.523	16.6	0.00	9.9	125	0.3	" " "
1554	2.25	240	5.66	0.483	11.1	0.00	9.9	128	0.2	" " "
1559	2.25	240	5.66	0.453	9.84	0.00	9.8	129	0.2	Clear water
1604	2.25	240	5.67	0.417	7.15	0.00	10.0	129	0.2	" " "
1609	2.25	240	5.67	0.416	4.25	0.00	9.9	130	0.2	" " "
1614	2.25	240	5.67	0.415	4.00	0.00	9.9	131	0.2	" " "

SIGNATURE(S): [signature]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OWSI-012308
Sample Location: OWSI
Sampled By: VP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-23-08	(Visual)	(S.U.)	(mS/cm)	(°C)	(NTU)	(mg/l)	(%)	ORP
Time: 1210								
Method: Geo pump	Cloudy	5.83	56.6	13.1	401	0.00	0.0	22

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-23-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 18.90		See	Low	Flow	Purge			
Static Water Level (WL): 3.20								
One Casing Volume(gal/L): 2.7								
Start Purge (hrs): 0944								
End Purge (hrs): 1245		Data	Sheet					
Total Purge Time (min): 136								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml vom	✓
Total PP metals	HNO3	1 - 500 ml Poly	✓
Diss PP metals	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Amber	✓
RSK-175	HCl	2 - 40 ml vom	✓
TOC	HCl	1 - 250 ml Amber	✓
Chloride, Nitrate, Nitrite	ICE	1 - 125 ml Poly	✓

OBSERVATIONS / NOTES:

18.90
3.20
+5.70

315.70 x .17
10990
15700
2.6690

Ferrous Iron 2.5 mg 1215
Hydrogen Sulfide 0.0 1220

Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s):

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OWSI-012308
DATE: 1-23-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0944	3.20									
0945	3.90	170	5.61	55.3	>999	0.71	12.6	66	0.0	
0950	4.50	170	5.68	57.0	>999	0.04	12.5	60	0.0	
0955	5.52	170	5.68	57.3	>999	0.00	12.5	58	0.0	
1005	7.10	170	5.68	58.0	>999	0.00	12.5	57	0.0	
1015	7.10	130	5.77	65.1	>999	0.00	12.3	41	0.0	
1025	7.20	130	5.78	65.0	>999	0.00	12.6	36	0.0	
1035	7.40	130	5.78	64.1	>999	0.00	12.7	34	0.0	
1045	7.60	130	5.79	62.0	894	0.00	12.8	32	0.0	
1055	7.80	130	5.79	61.0	603	0.00	12.8	31	0.0	
1105	7.95	130	5.79	59.0	665	0.00	13.2	29	0.0	
1115	8.15	130	5.81	59.5	567	0.00	13.0	27	0.0	
1125	8.35	130	5.82	57.9	490	0.00	13.1	26	0.0	
1135	8.55	130	5.79	56.7	436	0.00	13.3	27	0.0	
1145	8.70	130	5.82	57.1	399	0.00	13.3	24	0.0	
1155	8.85	130	5.82	56.8	398	0.00	13.3	24	0.0	
1200	8.90	130	5.83	56.6	400	0.00	13.1	23	0.0	
1205	8.90	130	5.83	56.6	401	0.00	13.1	22	0.0	

SIGNATURE(S): [signature]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 6s - 012508
Sample Location: OW 6s
Sampled By: LP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-25-08								
Time: 1018								
Method: Geo pump	clear	6.22	0.157	10.4	8.33	0.00	0.1	108

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-25-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC								
Total Well Depth (TD): 15.00		See Low Flow Purge						
Static Water Level (WL): 2.20								
One Casing Volume(gal/L): 2.2								
Start Purge (hrs): 0831		Data Sheet						
End Purge (hrs): 1013								
Total Purge Time (min): 100								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2x2 40 ml VOA	4
Total PP metal	HNO3	2x1 500 ml Poly	2
Diss PP metal	HNO3	2x1 500 ml Poly	2
1,4 Dioxane	ICE	2x2 1L Ambers	4
RSK-175	HCl	2x2 40 ml VOA	4
TOC	HCl	2x1 125 ml Amber	2
Chloride, Nitrate, Nitrite	ICE	2x1 250 ml poly	2

OBSERVATIONS / NOTES:

15.00 − 2.20 = 12.80

12.80 × .17 = 18960 + 12800 = 21760

Ferrous Iron 2.5 mg/L 1105
Hydrogen Sulfide 0.0 mg/L 1110

Circle if Applicable:

MS/MSD —

Duplicate ID No.: OW-Dup-012508

Signature(s): [signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: Middle River Center
PROJECT NUMBER:

WELL ID.: OW 6S - 012509
DATE: 1-25-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
0831	2.20	—	—	—	—	—	—	—	—	Initial, no color
0833	2.33	150	6.00	0.162	446	0.79	10.4	120	0.1	Cloudy water
0838	2.30	150	6.08	0.160	275	0.59	10.2	112	0.1	" " "
0843	2.30	150	6.13	0.159	211	0.41	10.2	108	0.1	" " "
0853	2.30	150	6.17	0.157	161	0.18	10.5	103	0.1	" " "
0903	2.30	150	6.20	0.157	124	0.12	10.6	102	0.1	" " "
0913	2.33	150	6.21	0.157	94.5	0.12	10.6	102	0.1	Slightly cloudy
0923	2.33	150	6.22	0.157	57.8	0.06	10.6	103	0.1	" " "
0933	2.33	150	6.22	0.158	30.8	0.00	10.6	105	0.1	" " "
0943	2.33	150	6.22	0.157	18.7	0.00	10.6	106	0.1	" " "
0953	2.33	150	6.22	0.158	15.1	0.00	10.5	107	0.1	" " "
1003 ~~[illegible]~~	2.33	150	6.22	0.158	10.0	0.00	10.5	108	0.1	" " "
1008	2.33	150	6.22	0.157	10.0	0.00	10.4	108	0.1	" " "
1013	2.33	150	6.22	0.157	8.33	0.00	10.4	108	0.1	

SIGNATURE(S): [illegible]

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Project Site Name: Middle River Center
Project No.:

[] Domestic Well Data
[X] Monitoring Well Data
[] Other Well Type:
[] QA Sample Type:

Sample ID No.: OW 6I-012308
Sample Location: OW 6I
Sampled By: WP
C.O.C. No.:
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (^{0}C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other
Date: 1-23-08								
Time: 1621								
Method: Geo pump	Slightly	5.76	31.8	13.8	27.2	0.00	0.0	39

PURGE DATA:

	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date: 1-23-08								
Method: Geo pump								
Monitor Reading (ppm): 0.0								
Well Casing Diameter & Material Type: 2" PVC		See Low Flow Purge						
Total Well Depth (TD): 30.00								
Static Water Level (WL): 4.20								
One Casing Volume(gal/L): 4.4		Data Sheet						
Start Purge (hrs): 1440								
End Purge (hrs): 1616								
Total Purge Time (min): 96								
Total Vol. Purged (gal/L): 5.0								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected
VOCs	HCl	2 - 40 ml VOA	✓
Total PP metal	HNO3	1 - 500 ml Poly	✓
Diss PP metal	HNO3	1 - 500 ml Poly	✓
1,4 Dioxane	ICE	2 - 1L Ambers	✓
RSK-175	HCl	2 - 40 ml VOA	✓
TOC	HCl	1 - 250 ml Amber	✓
Chloride, nitrate, nitrite	ICE	1 - 125 Poly	✓

OBSERVATIONS / NOTES:

$$\begin{array}{r} 30.00 \\ -\ 4.20 \\ \hline 25.80 \end{array} \qquad \begin{array}{r} 25.80 \\ \times\ .17 \\ \hline 18060 \\ 25800 \\ \hline 4.3860 \end{array}$$

Ferrous Iron 2.5 mg

Hydrogen sulfide 0.0

Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s):

[signature]

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: middle River Center
PROJECT NUMBER:

WELL ID.: [redacted] OWGI-012308
DATE: 1-22-08

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments
1440	4.20	—	—	—	—	—	—	—	—	Initial, no odor
1441	4.65	280	5.84	23.5	543	2.08	14.5	59	0.0	Cloudy water
1446	5.40	280	5.76	23.3	789	0.00	14.2	55	0.0	" " "
1451	5.40	190	5.73	22.4	760	0.00	13.7	54	0.0	" " "
1501	5.40	190	5.73	22.7	739	0.04	13.8	49	0.0	" " "
1511	5.60	190	5.74	24.5	263	0.00	13.5	43	0.0	" " "
1521	5.65	190	5.74	25.8	156	0.00	13.9	41	0.0	" " "
1531	5.70	190	5.74	26.8	82.3	0.00	14.0	39	0.0	Slightly cloudy
1541	5.75	190	5.75	27.6	60.5	0.00	14.0	39	0.0	" " "
1551	5.75	190	5.74	28.1	36.3	0.00	14.0	39	0.0	" " "
1601	5.75	190	5.75	28.6	35.6	0.00	14.0	38	0.0	" " "
1606	5.75	190	5.76	29.8	28.6	0.00	14.0	39	0.0	" " "
1611	5.75	190	5.75	30.8	26.1	0.00	13.9	39	0.0	" " "
1616	5.75	190	5.76	31.9	27.2	0.00	13.8	39	0.0	" " "

SIGNATURE(S): Wab

APPENDIX D UTILITY CLEARANCE REPORT

September 5, 2008

Mr. Anthony Apanavage
Project Manager
Tetra Tech NUS, Inc.
20251 Century Boulevard
Suite 200
Germantown, MD 20874

Re: Geophysical Investigation - Block I
Middle River, Maryland
ARM Project 08318-2

Dear Mr. Apanavage:

ARM Geophysics (ARM) has prepared this letter report for Tetra Tech NUS, Inc. (Tetra Tech) to document the results of a geophysical survey performed during the Block I investigation on the Middle River Site, located near Middle River, Maryland. ARM geophysicists were on-site August 26 through 29 and September 2, 2008 to perform the geophysical survey. Tetra Tech contracted ARM to survey approximately 109 boring locations to locate underground utilities and other subsurface anomalies prior to drilling activities. Borings were located around Buildings A, B, and C and several borings were located on the inside of the buildings.

FIELD EFFORT

Tetra Tech supplied ARM with coordinates of the proposed drilling locations. During the first day of the investigation- ARM utilized a global positioning system (GPS) unit to locate and mark the boring locations with spray paint. Several of the boring locations needed to be moved due to surface structures, their location would interfere with traffic, or inadequate space for the boring and drilling equipment. An electronic copy of the coordinates for the revised boring locations has been included with this report. The coordinates are provided in the US State Plane, NAD83, Maryland (feet) system.

ARM conducted a multi-phase geophysical investigation at each proposed boring location in order to delineate possible utilities. The first phase of the investigation consisted of a ground penetrating radar (GPR) survey using a 400 Megahertz (MHz) antenna manufactured by Geophysical Survey Systems, Inc. (GSSI) of North Salem, NH. The GPR survey data were

collected along traverses spaced approximately 3 feet apart and oriented in two directions around each boring.

ARM conducted a high sensitivity metal detection survey using the EM61MKII manufactured by Geonics, LTD of Missauggua, Canada. EM61MKII data were collected along traverses spaced five feet apart and oriented in two directions. Several borings were not surveyed with the EM61MKII because of metallic objects and debris present in the grid. The EM61MKII was not used at the borings that are present inside of the buildings because the concrete floor contained rebar.

ARM then surveyed each grid with utility locators including a 50/60 Hertz locator to screen for buried live electric lines. The final phase of the survey included attaching the utility locator transmitter to observable utilities such as the fire hydrants and gas valves. By applying energy to the hydrants and valves, the utility locator can follow the energy and trace and mark the utility.

GEOPHYSICAL SURVEY RESULTS

Utilities detected during the survey were marked on the ground surface with spray paint. ARM followed the ANSI-designated color coding system whenever possible. Electrical lines were marked with red spray paint, gas lines were marked with yellow paint, water lines were marked with blue paint, and sanitary/storm sewers were marked with green paint. Unknown utilities were marked with white spray paint. The boring locations and their identification were marked with orange or white spray paint.

Tetra Tech personnel completed field maps of each boring location showing any utilities within a 30-foot radius of the boring location.

SURVEY LIMITATIONS

The investigation work scope included standard and/or routinely accepted practices of the geophysical industry. ARM utilized the best available methods in order to locate and delineate potential utilities and other subsurface obstructions within the survey area. Some site conditions can interfere with the effectiveness of the geophysical equipment.

However, by its nature, no subsurface survey can completely define subsurface conditions. Thus, ARM conducted this survey in accordance with industry standards and cannot accept responsibility for inherent technique limitations, survey limitations or unforeseen site-specific conditions.

CONCLUSIONS

The geophysical survey involved the location and identification of utilities within a 30-foot radius of each boring. Utilities detected during the survey were marked on the ground surface with spray paint and the locations of the utilities were mapped by the Tetra Tech on-site representative.

ARM appreciates this opportunity to provide geophysical services to Tetra Tech NUS. If you have any questions or require any further information, please feel free to contact the undersigned at your convenience.

Sincerely,

ARM Group Inc.

Alexander J. Mussio
Project Geophysicist

Beth A. Williams, P.G.
Senior Geophysicist

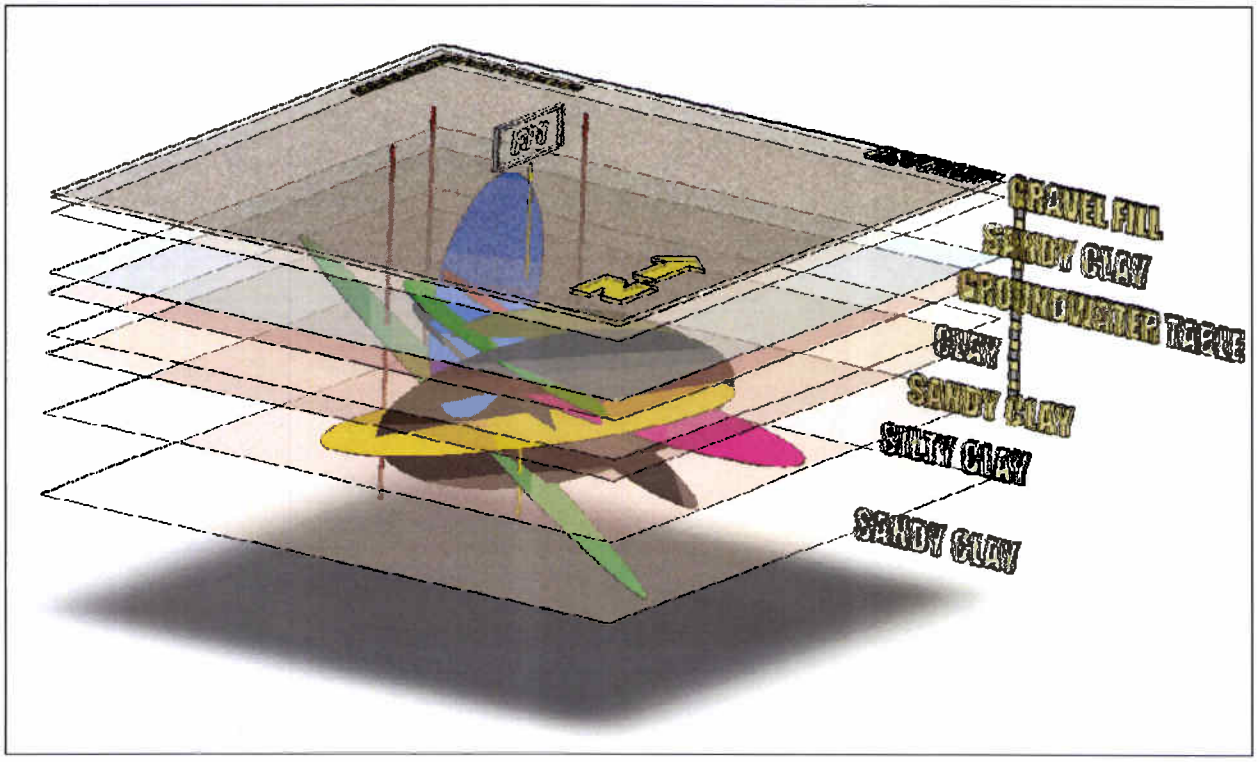
APPENDIX E FRAC RITE REPORT

APEGGA
Permit Holder

FRAC RITE
ENVIRONMENTAL LTD.

REPORT ON THE:

PILOT SOIL FRACTURING AND EOS INJECTION PROGRAM AT THE MIDDLE RIVER COMPLEX: BALTIMORE, MARYLAND, U.S.A.



Submitted to:

Tetra Tech NUS, Inc.
Pittsburg, Pennsylvania

Submitted by:

Frac Rite Environmental Ltd.
Calgary, Alberta

June, 2009

08FR10

REPORT ON THE:

PILOT SOIL FRACTURING
AND EOS INJECTION PROGRAM
AT THE MIDDLE RIVER COMPLEX:

BALTIMORE, MARYLAND, U.S.A.

Submitted to:

Tetra Tech NUS, Inc.
Pittsburg, Pennsylvania

Submitted by:

Frac Rite Environmental Ltd.
Calgary, Alberta

DISTRIBUTION:

3 Copies	**Tetra Tech NUS, Inc.** **Pittsburg, Pennsylvania**
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June, 2009 **08FR10**

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www.fracrite.ca

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EXECUTIVE SUMMARY

Frac Rite Environmental Ltd. ("Frac Rite") was retained by Tetra Tech NUS, Inc. (TtNUS) to emplace subsurface fractures containing a sand proppant into saturated, low permeability subsoils at the Middle River Complex in Baltimore, Maryland. Edible Oil Substrate (EOS) was subsequently injected into the fracture network to provide extensive distribution into the trichloroethene (TCE) solvent plume. The results of this pilot work were evaluated by TtNUS to assess the feasibility for full scale soil and groundwater remediation using fracture-enhanced EOS amendment injection at the site.

The pilot field project was conducted in the area of a former aircraft parts manufacturing site where past activities contaminated shallow underlying soils and groundwater with TCE. The TCE plume is present within fine-grained soil layers comprising clays, silty clays, and clayey sands. The objectives of the pilot study were to evaluate the effectiveness of placing a network of fractures containing a sand proppant, to assist in the injection of EOS into saturated, low permeability subsoils to (1) increase subsurface distribution of EOS and (2) destroy Contaminants of Concern (COCs) through anaerobic reductive dechlorination.

Drilling, emplacement, and geophysical mapping of the sand fractures commenced at the site on October 7, 2008. Drilling services were provided by Vironex Inc. ("Vironex"), based in Bowie, Maryland and were conducted using a truck-mounted direct-push Geoprobe drill and Frac Rite's downhole fracture tool assembly. Amendment mixing and pumping services were provided using Frac Rite's skid-mounted EF9300 fracture unit. Tiltmeter geophysical data was collected using tilt sensors and downloaded for subsequent geophysical analysis to map fracture distribution as planar features. The results were subsequently converted into three dimensional graphical representations of the fracture network.

A total of 15,150 lbs of sand was successfully emplaced as nine discrete fractures at borehole location FP1 by hydraulic fracturing. Fractures were initiated at depths of 11 to 35 ft at three foot vertical intervals in FP1. Most fractures were classified as moderately ascending towards the ground surface. The fractured borehole and two other nearby boreholes were completed as injection wells by Vironex to allow an unlimited number of post-fracture injections of EOS into the permeable sand fracture network. The distribution of EOS was extensive, with a total volume of approximately 3,076 gal distributed over an area of approximately 1,225 ft^2.

The pilot was successful in facilitating EOS injection by emplacing a sand fracture network. The vertical component of sand fractures ensured that the EOS treatment amendment injected into subsoils was distributed across multiple interbedded hydrogeologic units impacted by TCE contaminants. The results of pilot work presented herein can be used to optimize the design of a full-scale permeable sand fracture network to assist in EOS injection, which might be contemplated for the site.

1.0 INTRODUCTION

Frac Rite Environmental Ltd. ("Frac Rite") was retained by Tetra Tech NUS ("TtNUS") to emplace subsurface fractures containing a sand proppant and subsequently inject Edible Oil Substrate (EOS) into saturated, low permeability subsoils at Middle River Complex in Baltimore, Maryland. EOS is a soybean oil extract that is used as an energy source for biological organisms in bioremediation. The EOS was injected into the fracture network to provide optimal distribution into the trichloroethene (TCE) solvent plume. The results of this pilot work are being used to assess the feasibility for full scale soil and groundwater remediation at Middle River Complex using fracturing technology to facilitate injection of EOS treatment amendment.

2.0 BACKGROUND

The Middle River Complex contains a contaminated area where a former aircraft parts manufacturing facility was located, near "Building C". The pilot study was planned for this area where TCE contamination from past manufacturing activities has impacted shallow underlying soil and groundwater. The predominant subsurface lithologies, to a depth of 35 ft below ground surface (bgs), at the site are unconsolidated clayey sediments. Subsoils in the target fracture zone between 11 – 35 ft bgs comprised alternating layers of silty to sandy layers of clay and clayey sand, according to TtNUS borehole logs for observation wells OW1 to OW3, which bounded the fracture borehole. The average depth to groundwater in the proposed pilot test area of the site was reported to be 12 ft bgs.

3.0 OBJECTIVES

The objectives of the pilot study were to evaluate the effectiveness of placing a network of fractures containing a sand proppant, to subsequently assist in the injection of EOS into saturated, low permeability subsoils that will (1) increase subsurface distribution of the selected reagent and (2) destroy Contaminants of Concern (COCs) through anaerobic reductive dechlorination. Hydraulic fracturing is an implementation technology that can deliver large quantities of sand proppant to increase the permeability of fine-grained layers in the subsurface. The permeable network created allows for the injection of EOS into the fine-grained, Volatile Organic Contaminant (VOC) containing layers in the subsurface, while creating a greater area of treatment influence than without the fractures and compared to conventional delivery methods. Conventional injection methods primarily rely on natural advective flow paths within the subsurface, and the injectant may not reach the less-accessible pores containing VOC mass. Increasing soil permeability by hydraulic fracturing and injecting into these zones initiates treatment by introducing the material into the fine-grained layers and creating preferential flow paths for advection, where the amendment will diffuse both vertically and laterally away from the fracture. Both the new advection paths and diffusion from the fractures will increase the EOS zone of influence and, thereby, resident COC destruction.

4.0 FIELD PROGRAM

4.1 Method of Emplacement

The possible methods of amendment placement in subsoils are by fracturing the soils, or injection permeation, if the amendment is in solution form or is a relatively fine particulate.

The nature of emplacement of subsurface treatment amendments is a function of the average diameter of pore throats between soil grains within the soil mass relative to the particle size of the treatment amendment being emplaced. If the amendment particle size exceeds the pore throat diameter of the soils, then the treatment amendment will be emplaced by creating space for itself by physically *fracturing* the soil apart. Soil fracturing provides a secondary benefit of increasing flow and treatment in lower permeability soil units consisting of interbedded silt and clay layers at the site.

If the amendment particle size is small enough to pass through the average pore throat diameter of the soil, than emplacement of the amendment will be via permeation through the soil, also referred to as *injection.* Solution based amendments or fine powder amendments are often injected by permeating the pore space of coarser grained soils such as sands and gravels. This is a crucial distinction because the method of emplacement dictates the process and equipment required for effective subsurface distribution of the amendment.

Based on soil descriptions in borehole logs (clays and clayey sediments) and their inherent low hydraulic conductivity values, it was decided that a combination of the two emplacement methods would be used in the pilot program. Hydraulic fracturing was used in the first phase to create permeable pathways in the subsoils to facilitate the subsequent injection of a vegetable oil substrate into these pathways to effect treatment.

4.2 General Approach

The field pilot program consisted of two main steps: emplacing nine fractures in the subsoil with a sand proppant to increase soil permeability, and injecting a commercially available concentrated solution of EOS amendment (EOS® manufactured by EOS Remediation, Inc.). A sand slurry was formulated by mixing potable water, viscosifiers, and 20-40 mesh sized silica sand in preparation for fracturing. The design slurry volume for the shallowest two fractures was 130 gal carrying approximately 825 lbs of sand. Deeper fractures were emplaced with a design volume of 260 gal carrying approximately 1,800 lbs of sand. Concentrated EOS solution was subsequently diluted with water to obtain a dilution ratio between 8:1 and 12:1 and injected into the permeable sand fracture network. The program was designed for injections at three different target zones of the fracture network, i.e. intervals of 11-17 ft., 20-26ft., and 29-35 ft bgs. A design loading of approximately 3,000 gal of EOS was to be injected into the entire fracture network.

4.3 Mapping of Subsurface Fractures and EOS Distribution Pathways

One of the most problematic aspects of in situ remediation is the verification of its effectiveness, because of the inability to visually observe the effects on contamination in the subsurface. This is particularly true when treatment amendments are introduced into subsoils, because their distribution cannot be visually confirmed unless exposed by excavation or soil cores – most often a highly impractical approach.

A quick, reliable, non-intrusive, and accurate method exists for verifying the distribution of fractures in the subsoils called tiltmeter geophysical mapping. This method relies on ground surface sensors to monitor micro-displacements induced by sand emplacement in the subsoil. The resulting "tilt signals" are processed using geophysical modeling to predict the geometry of sand distribution in soils. Tiltmeter geophysics is therefore a valuable tool for demonstrating the extent of permeable sand fractures that will promote greater treatment dispersal of the injected amendment within the contaminant plume.

Tiltmeter geophysics was used to map the distribution of sand proppant emplaced by fracturing, as this method of emplacement is generally conducive to tiltmeter mapping. A total of 9 fracture-emplacements were mapped as planar fractures at Fracture Point 1 (FP1) to verify the final sand distribution in the subsurface.

4.4 Field Implementation

Drilling and emplacement of the permeable sand fractures commenced at the site on October 7, 2008. Drilling services were provided by Vironex Inc. ("Vironex"), based in Bowie, Maryland, using a Geoprobe Model 6600 truck-mounted drill. Drilling was completed exclusively at Fracture Point 1 (FP1), close in proximity to OW3, using a soil fracturing probe that was advanced with direct push rods. During drilling operations, a concentric array of eleven ES Model 700 biaxial, surface-mounted tiltmeters were placed about FP1 to monitor micro-movements in the ground surface in response to fracturing events.

The first target fracture depth was 11 ft bgs, and once reached an initial volume containing only linear gel ("pad volume") was pumped to initiate the fracture. During the drilling a sand slurry was mixed with approximately 6.6 lbs/gal of sand and was pumped following the gel until approximately 147 gal was emplaced. The rod was then advanced to the next depth and the same process was repeated for the remaining eight fractures following the specifications from Table 1. Fractures FP1-1 to FP1-8 were emplaced on October 7, 2008 and FP1-9 was emplaced on October 8, 2008.

Three separate injection wells were installed by Vironex (IWA, IWB, IWC) on October 9, 2008 to allow an unlimited number of post-fracture injections of EOS into the network of permeable sand fractures. Injection well IWB was completed in the fractured borehole at FP1, the remaining wells in close proximity.

The three wells were each screened at intervals corresponding to three zones of fracturing: IWA at 11 to 17 ft bgs, IWB at 20 to 26 ft bgs, and IWC at 29 to 35 ft bgs.

TABLE 1

FRACTURE INITIATION DEPTHS

Frac I.D.	Date	Depth (ft)	Fracture Slurry Volume (gal)	Fracture Sand Emplaced (lbs)
FP1-1	Oct 7	11.0	147	1,005
FP1-2	Oct 7	14.0	132	895
FP1-3	Oct 7	17.0	282	1,800
FP1-4	Oct 7	20.0	282	1,800
FP1-5	Oct 7	23.0	286	1,900
FP1-6	Oct 7	26.0	286	1,900
FP1-7	Oct 7	29.0	292	1,900
FP1-8	Oct 7	32.0	289	1,900
FP1-9	Oct 8	35.0	296	2,050
TOTAL			***2,292***	***15,150***

Edible Oil Substrate and vitamin B12 supplement were injected into all three injection wells (IWA, IWB, IWC) on October 10 – 12, 2008 inclusive. Vitamin B12 was included as a vitamin supplement to assist in anaerobic degradation. Wells IWA, IWB, and IWC each had one injection events on October 10, 2008 during which some minor leakage at the casing and around the well to the west of the property was observed. EOS and B12 supplement were injected into wells IWB and IWC the following day with similar leakage to the ground surface. A final injection into wells IWA and IWB was conducted on October 12, 2008, with no observed leakage to the ground surface.

During all fracturing events at FP1, pumping pressure and flow rate data were monitored and recorded to help verify the mode of sand emplacement and distribution in the subsoil. Tiltmeter data was also collected and downloaded from dataloggers for subsequent fracture mapping analysis. Tilt vectors measured at each tiltmeter station were used to model each fracture as a discrete planar feature. Pressure-time plots and slurry flow rate data were likewise considered in the interpretation of the tiltmeter data.

5.0 RESULTS

5.1 Emplacement of Sand Fractures

Analysis of the operational pressure-time curve and flow rate data indicate strong fracture profiles at all emplacement depths (Appendix I). Operational pressure-time curve and flow rate data indicated that pressures for initiating sand fractures (i.e "Break Pressure"), including friction losses due to the high viscosity of polymer slurry pumped, ranged from 49 psi (FP1-9) to 159 psi (FP1-4) in clay soils.

The average fracture propagation pressures was 56 psi and average slurry pumping rate was 31 gallons per minute (gpm). The horizontal area that the fracture network covered was 1,225 ft^2, providing a large lateral expanse for the EOS injection that followed.

5.2 Amendment Injection

The results of the pilot fracturing and injection work demonstrated that fractures containing a sand proppant can be used to facilitate EOS injection into saturated, low permeability subsoils. Two EOS injection events into IWA resulted in a total injection volume of 500 gallons; IWB had three injections totaling 1,257 gal.; and, IWC had two injection events totaling a volume of 1,319 gal. Injection well IWA received the smallest injection volume because its screened interval included the two smaller fractures at depths of 11 ft. and 14 ft (Table 1). The total volume of EOS amendment injected into the subsoils was 3,076 gal (Table 2), with average flow rates into IWA, IWB, and IWC of 10 gpm, 7.4 gpm, and 10.6 gpm.

TABLE 2

EOS SOLUTION INJECTION VOLUMES

Well ID-Injection #	Date of Injection	Screened Interval (ft bgs)	Solution Volume (gal)
IWA-I1	Oct 10, 2008	11-17	455
IWA-I2	Oct 12, 2008	11-17	45
IWB-I1	Oct 10, 2008	20-26	350
IWB-I2	Oct 11, 2008	20-26	364
IWB-I3	Oct 12, 2008	20-26	543
IWC-I1	Oct 10, 2008	29-35	436
IWC-I2	Oct 11, 2008	29-35	883
Total			**3,076**

5.3 Subsurface Mapping of Sand Fractures

The geometric configuration of the sand fractures in subsoils was interpreted after analyzing tiltmeter geophysical data collected during the pumping of the sand slurry at FP1 (Eco Scan report, Appendix II). The results of tiltmeter geophysics are summarized in Table 3.

The sand slurry emplaced into the subsoils was modeled as fractures (single planar structures), and the results were optimized on the parameters of azimuth, dip, length, height, width, depth, and deviation from borehole center. The recorded data quality was good with high signal to noise ratios. The fit of the theoretical to observed tilt to measured tilt from the single planar fracture models was generally good, although results indicated that subsurface fractures may be more complex than single planar fractures centered on the borehole.

A three-dimensional depiction of fractures emplaced at the fracture borehole location FP1 is presented in Appendix III. Fractures were classified according to their dip angles (i.e. angle of inclination from Horizontal), as summarized in Table 3. Fracture ascent ranged from near horizontal at FP1-8 to strongly ascending at FP1-9 (Table 3 and Figures III-1, III-2, and III-3). The majority of fractures (67%) were classified as moderately ascending.

TABLE 3

SUMMARY OF TILTMETER GEOPHYSICAL RESULTS

Fracture I.D.	Depth of Fracture Initiation[1] (ft)	Fracture Thickness (inches)	Fracture Height[2] (ft)	Fracture Width[3] (ft)	Fracture Azimuth[4] (degrees)	Angle of Fracture Inclination from Horizontal (degrees)	Fracture Classification[5]
FP1-1	11.0	1.01	10.0	11.0	314	27	Moderately Ascending
FP1-2	14.0 *(11)*	0.82	28.0	10.0	68	42	Moderately Ascending
FP1-3	17.0 (*15.7*)	0.86	25.4	23.0	316	30	Moderately Ascending
FP1-4	20.0 *(15.9)*	0.71	25.0	25.0	239	36	Moderately Ascending
FP1-5	23.0 *(21.5)*	0.92	31.8	17.1	330	14	Slightly Ascending
FP1-6	26.0 *(21.8)*	0.65	33.7	22.8	321	34	Moderately Ascending
FP1-7	29.0 *(24.2)*	0.70	48.8	15.3	326	45	Moderately Ascending
FP1-8	32.0 *(21.5)*	0.60	40.0	21.5	140	8	Near Horizontal
FP1-9	35.0 *(21.5)*	0.50	29.3	35.6	215	47	Strongly Ascending

Notes: 1. Depth measured from ground surface; *italicized* value is initiation depth predicted by model.
2. Vertical fracture dimension measured along fracture height
3. Lateral fracture dimension measured along horizontal, i.e., perpendicular to fracture height
4. Orientation of Fracture Axis in degrees azimuth
5. Fracture Classification: < 10° = Near Horizontal
11 to 20° = Slightly Ascending
21 to 45° = Moderately Ascending
46 to 79° = Strongly Ascending
> 80° = Near Vertical

Fractures were projected to the ground surface in plan view (Appendix III) to assess their lateral extent and orientation. Fracture orientation, as measured by the fracture azimuth, ranged from 68 degrees at FP1-2 to 330 degrees at FP1-5 (Table 3 and Appendix III). It generally favoured a northwest-southeast trend, except for FP1-4 and FP1-9 which exhibited a northeast-southwest trend, and FP1-2 which exhibited an east-west trend.

The vertical to lateral aspect ratio (i.e. fracture height/fracture width) of fractures was approximately two or less for all fractures except at FP1-2 and FP1-7 where it was 2.8 and 3.2. The maximum lateral extent of sand fractures from the fracture borehole, as measured in plan view from fracture projections to the ground surface, was 25 ft at FP1.

Fracture initiation depths were modeled at shallower depths than the actual depth of emplacement for most fractures, possibly as a result of connectivity with upper fractures. This phenomenon has been observed at other sites fractured in the past.

The thickness of the sand fractures ranged from 0.50 to 1.01 inches with a mean value of 0.71 inches (Table 3). Fracture thickness values are modeled at the time of amendment emplacement and are expected to consolidate with time due to leak-off effects and overburden pressure.

6.0 SUMMARY

A total of nine fractures were initiated from 11 – 35 ft bgs at fracture point FP1 into predominately clayey soils on October 7 and 8, 2009. A total of 3,076 gallons of EOS solution was subsequently injected into the fracture pathways through three injection wells screened at specific depth zones in the target treatment interval. The network of nine interconnected fractures emplaced by hydraulic fracturing effectively facilitated the injection of EOS into the subsoils and is anticipated to increase soil bulk permeability.

Analysis of operational pressure-time data and tiltmeter data confirmed that the mode of sand proppant emplacement into subsoils was by hydraulic fracturing. The tiltmeter modeling results were generally of good quality, although fractures may be more complex than interpreted due to effects that include leak-off into more permeable soil layers encountered, up-hole migration at certain fracture initiation depths, fluid losses through existing soil disturbances (i.e. existing boreholes and conduits), and possible excessive curvatures of fractures emplaced.

Fracture coverage was extensive and appeared consistent with slurry design volumes pumped. Nine discrete fractures comprising 15,150 lbs of sand were distributed over an area of approximately 1,225 ft^2. The results of geophysical fracture mapping indicate that the majority (i.e. 67%) of the fractures were classified as moderately ascending to the ground surface.

Fracture orientation and ascent were somewhat consistent, although variations in orientation were noted in FP1-2, FP1-4, and FP1-9, respectively. These variances may be the result of a change in localized soil stress regime and/or soil fabric across the site. The vertical component of fractures ensured that when the EOS treatment amendment was injected into subsoils it was distributed across multiple interbedded hydrogeologic units impacted by TCE contaminants. Once injected into the sand fractures, the EOS amendment is expected to continue to diffuse and migrate in the direction of groundwater flow, thus effecting treatment over a greater area than initially.

Overall, it was shown that the fracture network created had extensive coverage that successfully assisted in EOS amendment delivery. The results of the pilot work presented in this report can be used to optimize the design of any full-scale network of hydraulic fractures to facilitate EOS injection that might be contemplated for the site.

7.0 CLOSURE

This report has been prepared by Frac Rite Environmental Ltd. in a manner consistent with that level of skill and care ordinarily exercised by members of the engineering profession currently practicing under similar conditions. No other warranty, expressed or implied is made.

Tetra Tech NUS, Inc. recognizes that subsurface conditions may vary from those encountered at the location where borings, surveys, or explorations are made by Frac Rite Environmental Ltd. or others, and that the data, interpretations, and recommendations of Frac Rite Environmental Ltd. are based solely on the information made available to them. Frac Rite was retained to create a network of subsurface fractures radiating from the borehole into the surrounding soils, and Tetra Tech NUS, Inc. recognizes that fractures cannot be "steered" or manipulated to assume any particular geometry or orientation. Fractures propagate in a manner determined by the in situ stress conditions and fabric of the subsurface soils.

Frac Rite Environmental Ltd. will be responsible for its data, interpretations, and recommendations, but shall not be responsible for the interpretation by others of the information developed. Frac Rite Environmental Ltd. makes no warranty, express or implied, as to the ultimate results from remedial plans designed and/or implemented by others.

We trust that this report meets your satisfaction. Should you have any questions or concerns, then please feel welcome to contact us. Thank you for the opportunity to work with Tetra Tech NUS on this innovative remedial pilot project.

Yours truly,
FRAC RITE ENVIRONMENTAL LTD.

PROFESSIONAL ENGINEER ALBERTA G. H. BURES

Heather A. Sturm, E.I.T.
Environmental Engineer

Gordon H. Bures, M.Eng., P.Eng.
Director of Remediation Services

PERMIT TO PRACTICE
FRAC RITE ENVIRONMENTAL LTD.
Signature
Date JUNE 8, 2009
PERMIT NUMBER: P 6494
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

06/08/09/ghb/08fr10.doc

APPENDIX I

FRACTURING OPERATIONAL DATA

FRAC RITE ENVIRONMENTAL LTD

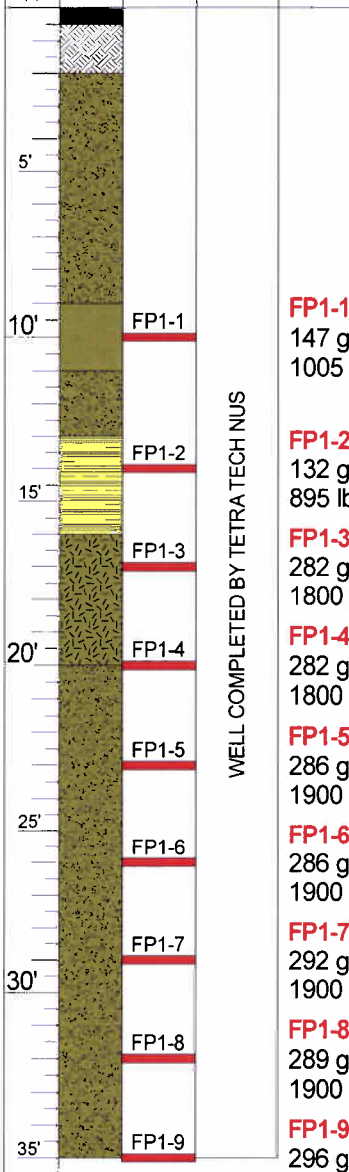
Fracture Well Number : FP-1
Date : 7, 8 October 2008
Job number : 08FR10

Client : Tetra Tech NUS
Drilling Contractor : Vironex
Pumping Contractor : Frac Rite

Frac Supervisor : GG
Drill Rig : GeoProbe DT6600
Pumping Rig : EF9300

DEPTH SCALE (ft) | SOIL TYPE | FRAC NUMBER | WELL DETAILS | REMARKS

PRESSURE (psi) vs E.T. (min)
PUMP RATE (gal/min) vs E.T. (min)



FP1-1
147 gal Frac slurry:
1005 lbs 20/40 Frac Sand

FP1-2
132 gal Frac slurry:
895 lbs 20/40 Frac Sand

FP1-3
282 gal Frac slurry:
1800 lbs 20/40 Frac Sand

FP1-4
282 gal Frac slurry:
1800 lbs 20/40 Frac Sand

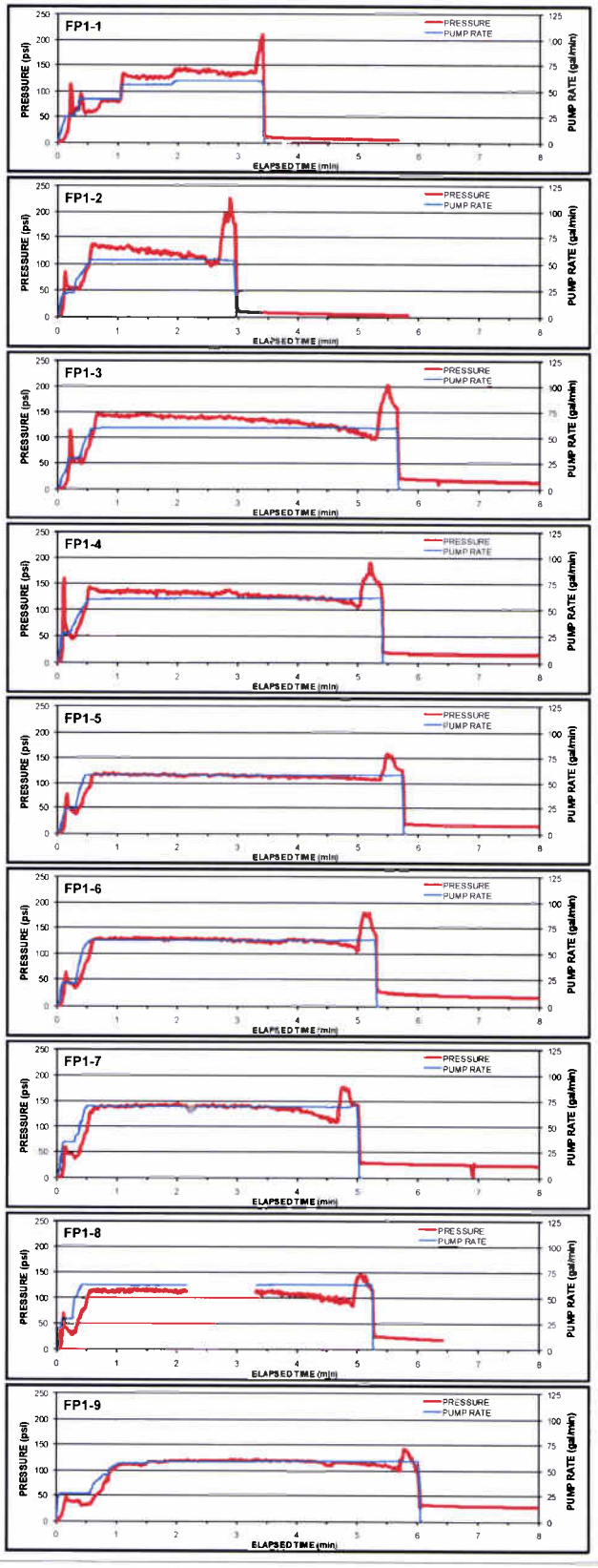
FP1-5
286 gal Frac slurry:
1900 lbs 20/40 Frac Sand

FP1-6
286 gal Frac slurry:
1900 lbs 20/40 Frac Sand

FP1-7
292 gal Frac slurry:
1900 lbs 20/40 Frac Sand

FP1-8
289 gal Frac slurry:
1900 lbs 20/40 Frac Sand

FP1-9
296 gal Frac slurry:
2050 lbs 20/40 Frac Sand



2.125" DIA. BOREHOLE FOR FRACTURING, SOIL STRATIGRAPHY INFERRED FROM BOREHOLE LOGS OF BOREHOLES IN THE VICINITY OF FP-1

SOIL TYPE
Clay | Silt | Sand | Gravel | Caliche | Asphalt
Clayey | Silty | Sandy | Till | Gravelly | Fill

FRAC INITIATION INTERVAL

WELL COMPLETION KEY
Sand | Bentonite | Cement | Solid Pipe
Grout | Backfill | Slotted Pipe

FRAC RITE ENVIRONMENTAL LTD.

FRACTURED HOLE SUMMARY SHEET

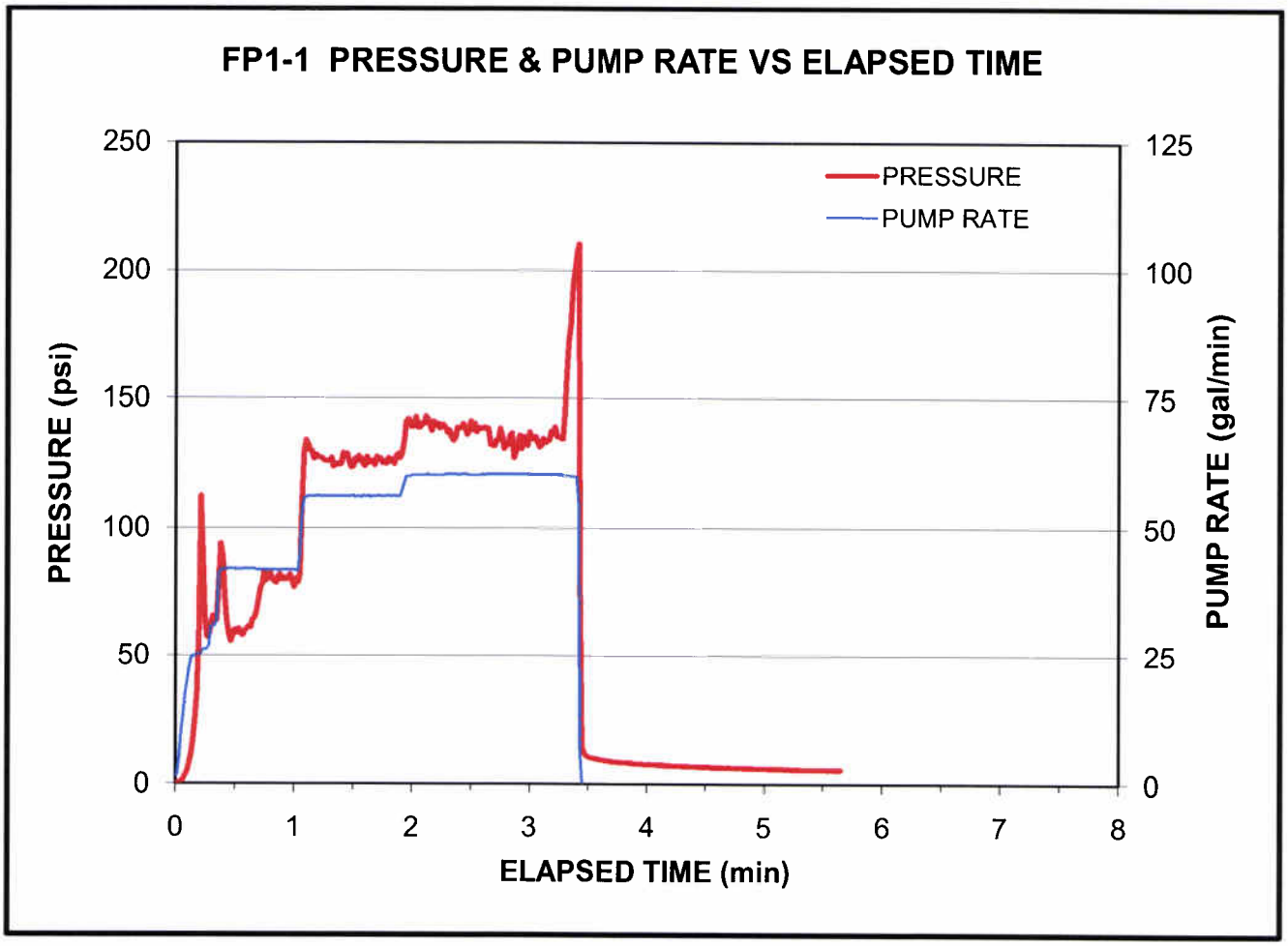
JOB NUMBER: 08FR10 DATE: 7 & 8 October 2008

FRACTURE HOLE No.: FP-1

FRACTURE No.	FP1-1	FP1-2	FP1-3	FP1-4	FP1-5	FP1-6	FP1-7	FP1-8	FP1-9
DEPTH (ft)	10	14	17	20	23	26	29	32	35
SOIL TYPE	Clay	clayey Sand	silty Clay	sandy Clay	sandy Clay	sandy Clay	sandy Clay	sandy Clay	sandy Clay
SLURRY VOL (gal)	147	132	282	282	286	286	292	289	296
GEL PAD VOL (gal)	5	2	10	5	3	3	7	8	9
GEL FLUSH VOL (gal)	24	14	26	24	29	23	30	18	24
SAND MASS (lb)	1005	895	1800	1800	1900	1900	1900	1900	2050
SAND LOADING (lb/gal)	6.8	6.8	6.4	6.4	6.6	6.6	6.5	6.6	6.9
SAND GRADATION	20/40	20/40	20/40	20/40	20/40	20/40	20/40	20/40	20/40
VENT/LOSS (gal)	0	0	0	0	0	0	0	0	0
VENT/LOSS TYPE	NA	NA	NA	NA	NA	NA	NA	NA	NA
PLACEMENT EFFICY. (%)	100	100	100	100	100	100	100	100	100
PEAK PRESSURE (psi)	210	226	204	190	160	180	178	146	142
AVG PRESSURE (psi)	113	115	126	124	110	119	128	102	105
BREAK PRESSURE (psi)	113	83	113	159	77	63	58	69	49
PEAK RATE (gal/min)	60	54	60	61	58	63	70	63	60
AVG RATE (gal/min)	52	50	57	58	56	59	66	60	55
RATE AT BREAK (gal/min)	25	22	29	27	23	21	34	28	26
REMARKS								Temporary loss of Data Acquisiton during frac	

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

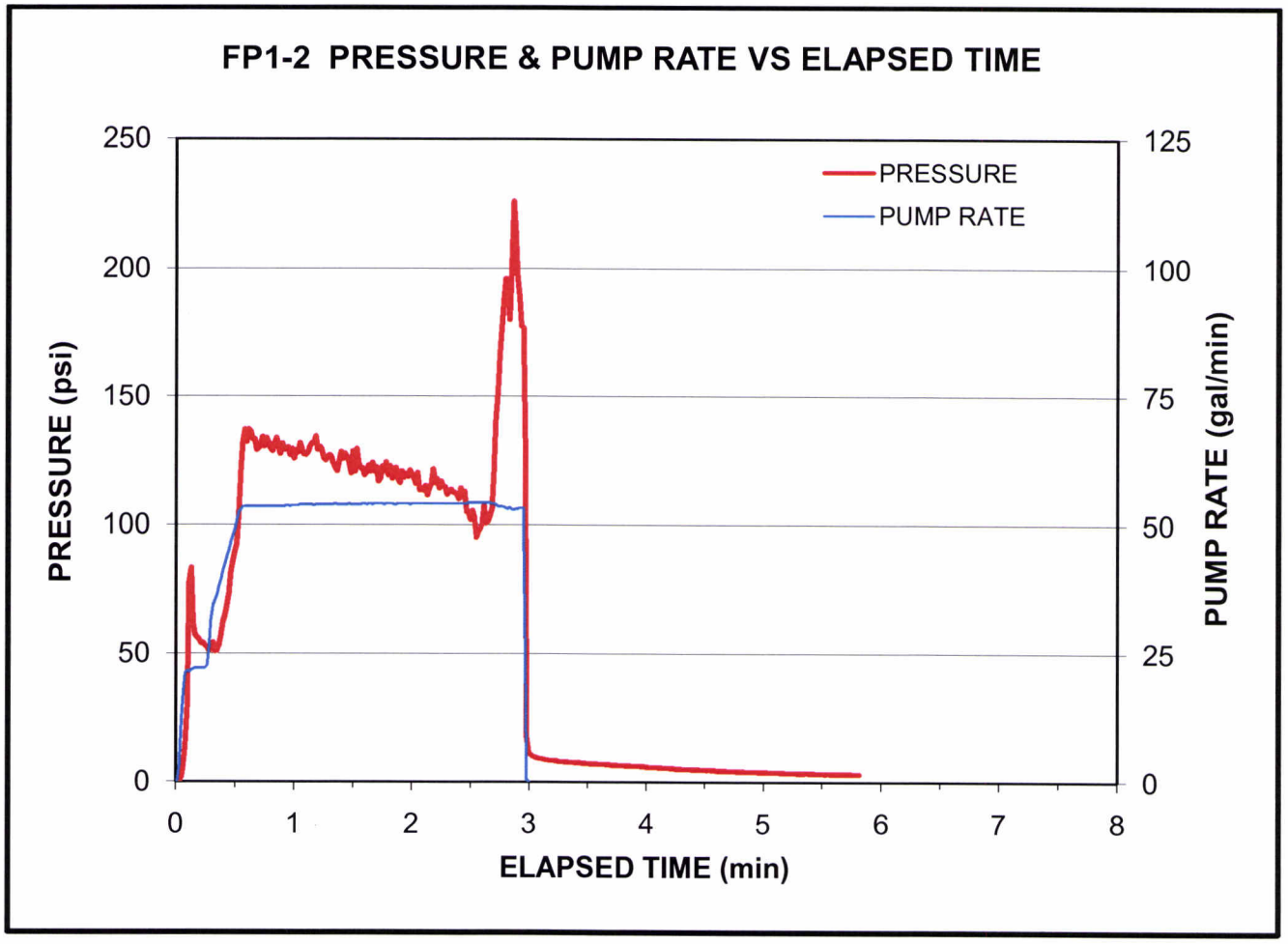


JOB NUMBER:	08FR10	DATE:	07 October 2008
FRACTURE NO.:	FP1-1	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	10 (ft)	SOIL TYPE:	Clay
VOLUME PUMPED:	147 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	1005 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	113 (psi)	AVERAGE PUMP RATE:	52 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

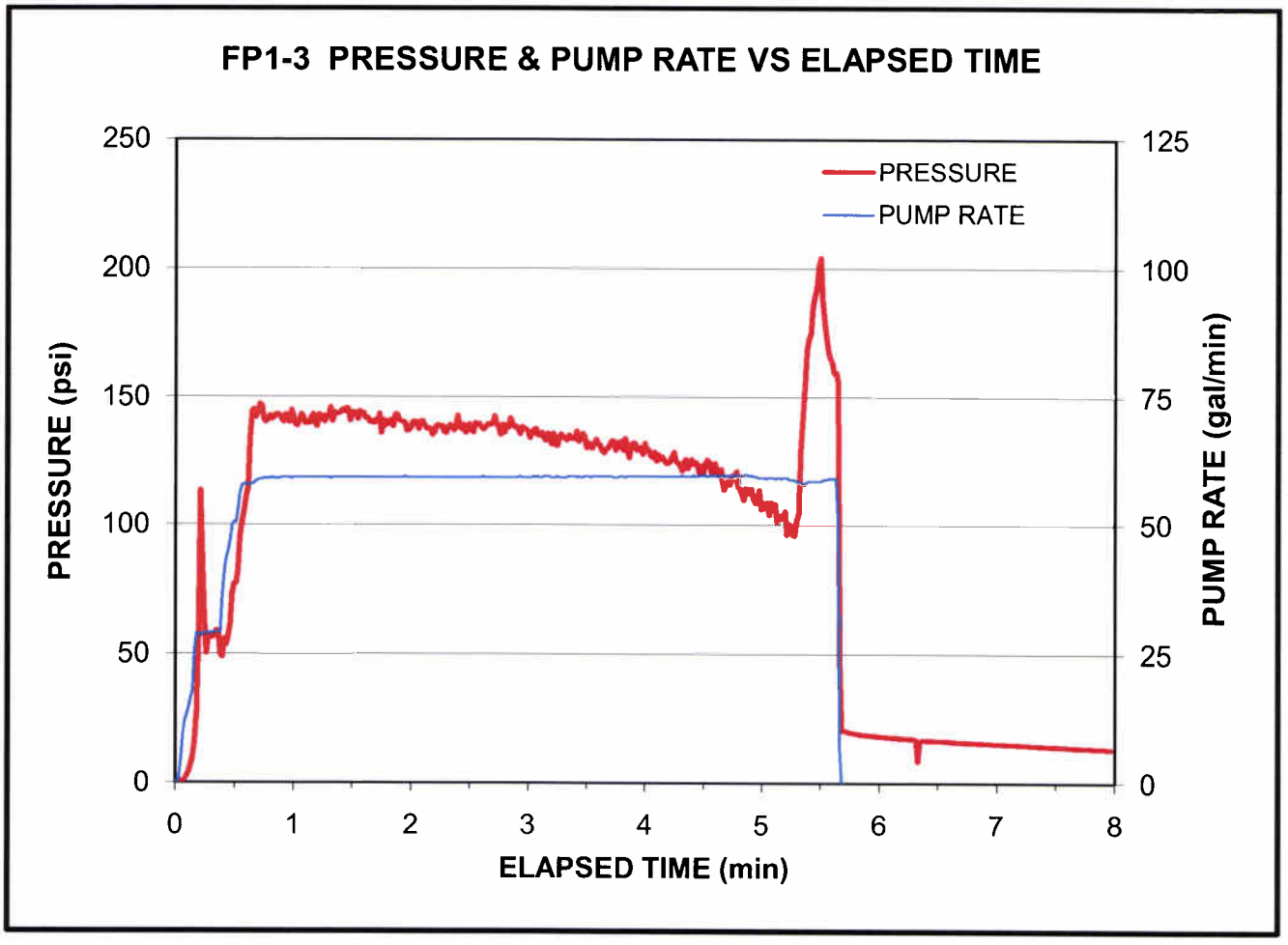


JOB NUMBER:	08FR10	DATE:	07 October 2008
FRACTURE NO.:	FP1-2	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	14 (ft)	SOIL TYPE:	clayey Sand
VOLUME PUMPED:	132 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	895 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	83 (psi)	AVERAGE PUMP RATE:	50 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

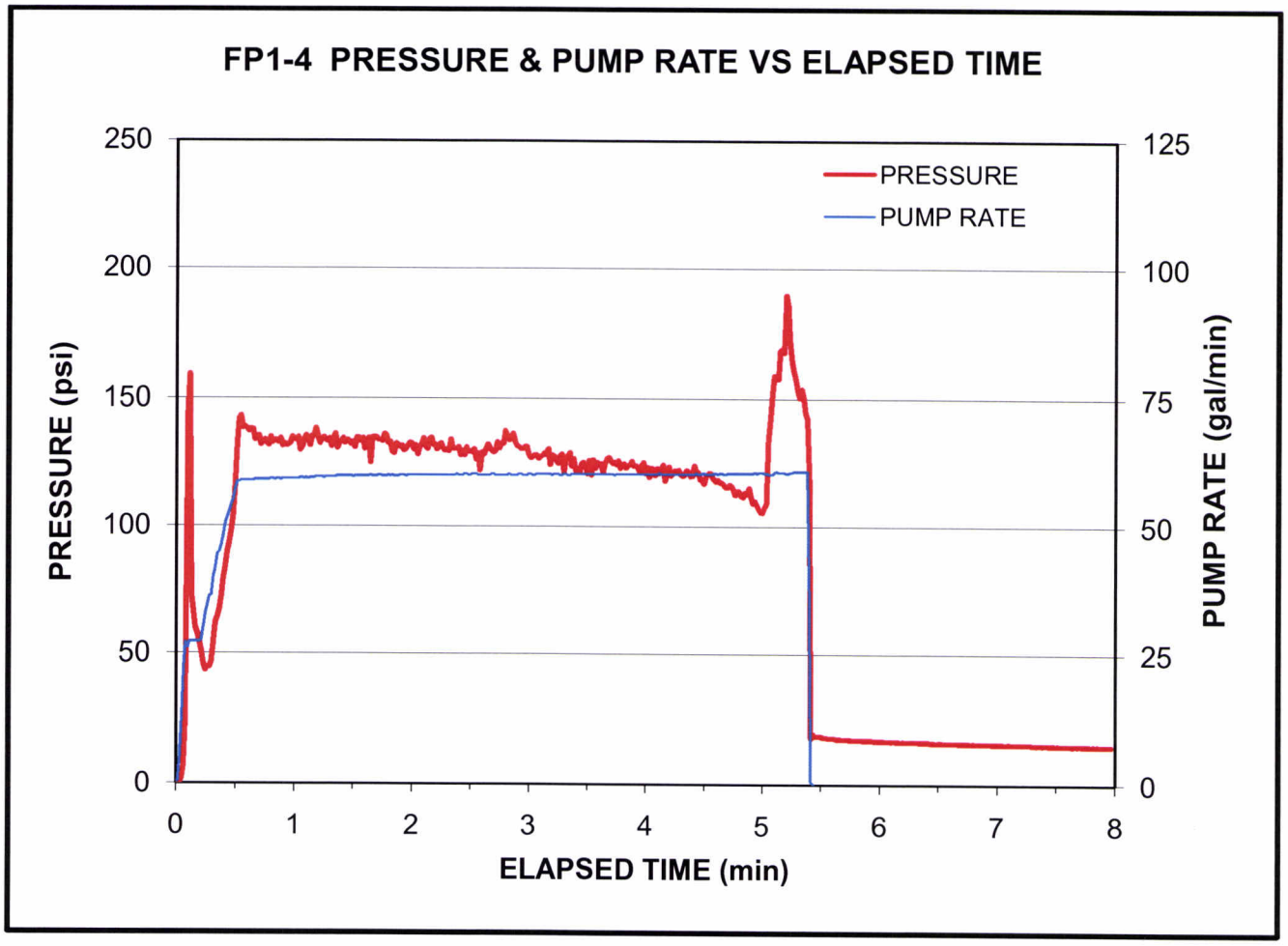


JOB NUMBER:	08FR10	DATE:	18 May 2008
FRACTURE NO.:	FP1-3	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	17 (ft)	SOIL TYPE:	silty Clay
VOLUME PUMPED:	282 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	1800 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	113 (psi)	AVERAGE PUMP RATE:	57 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

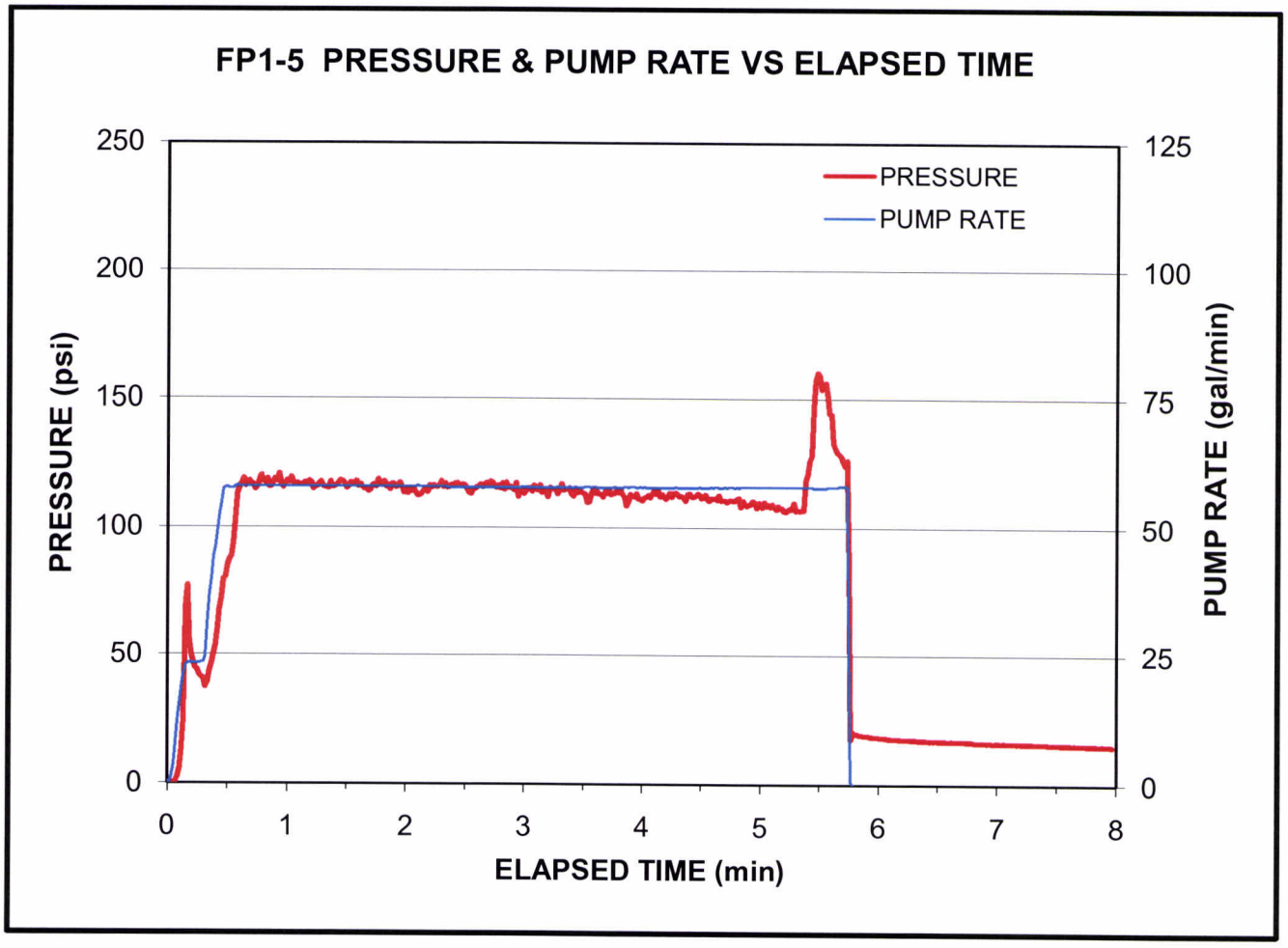


JOB NUMBER:	08FR10	DATE:	07 October 2008
FRACTURE NO.:	FP1-4	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	20 (ft)	SOIL TYPE:	sandy Clay
VOLUME PUMPED:	282 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	1800 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	159 (psi)	AVERAGE PUMP RATE:	58 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

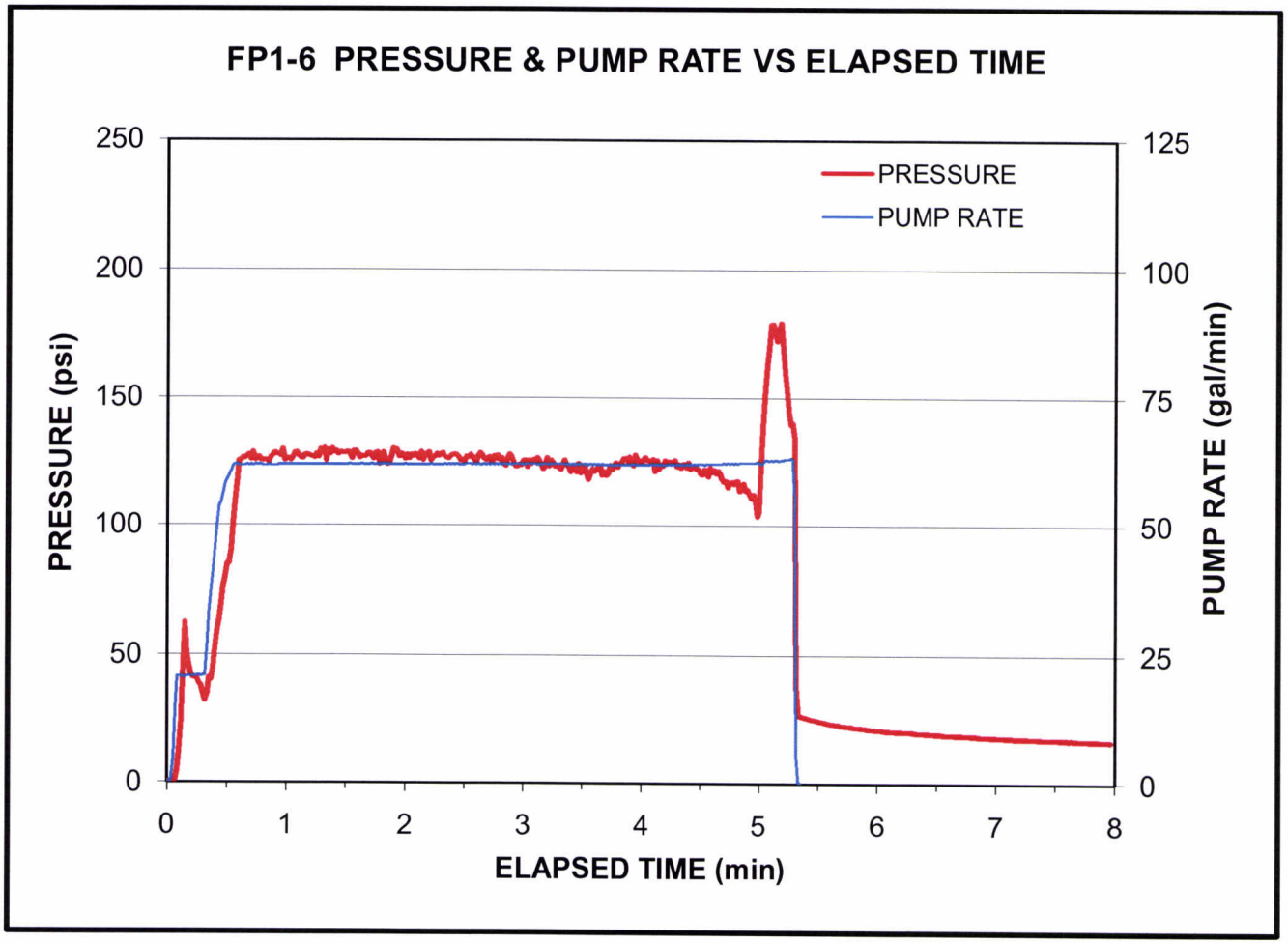


JOB NUMBER:	08FR10	DATE:	07 October 2008
FRACTURE NO.:	FP1-5	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	23.0 (ft)	SOIL TYPE:	sandy Clay
VOLUME PUMPED:	286 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	1900 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	77 (psi)	AVERAGE PUMP RATE:	56 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

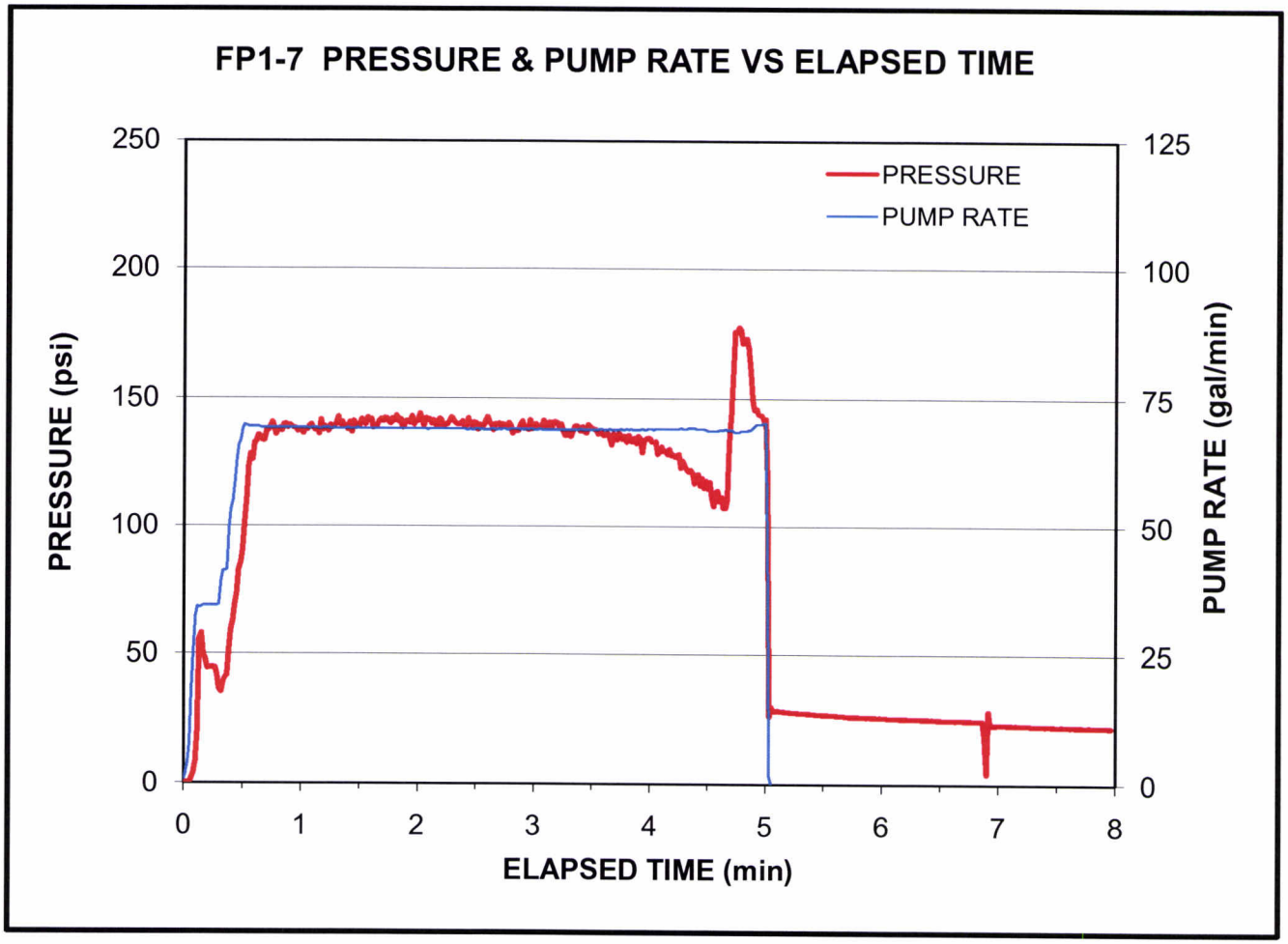


JOB NUMBER:	08FR10	DATE:	07 October 2008
FRACTURE NO.:	FP1-6	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	26.0 (ft)	SOIL TYPE:	sandy Clay
VOLUME PUMPED:	286 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	1900 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	63 (psi)	AVERAGE PUMP RATE:	59 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

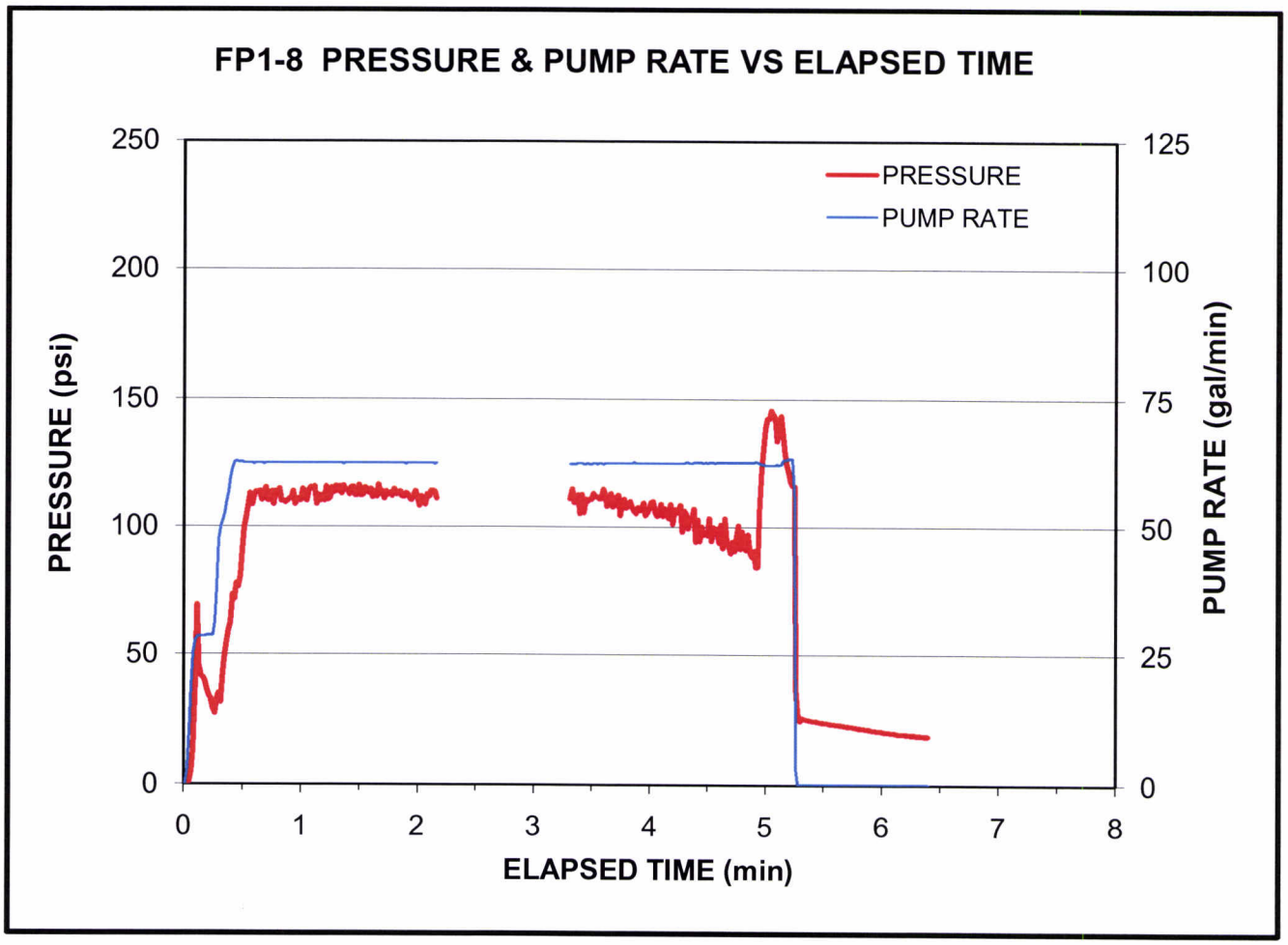


JOB NUMBER:	08FR10	DATE:	07 October 2008
FRACTURE NO.:	FP1-7	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	29.0 (ft)	SOIL TYPE:	sandy Clay
VOLUME PUMPED:	292 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	1900 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	58 (psi)	AVERAGE PUMP RATE:	66 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA

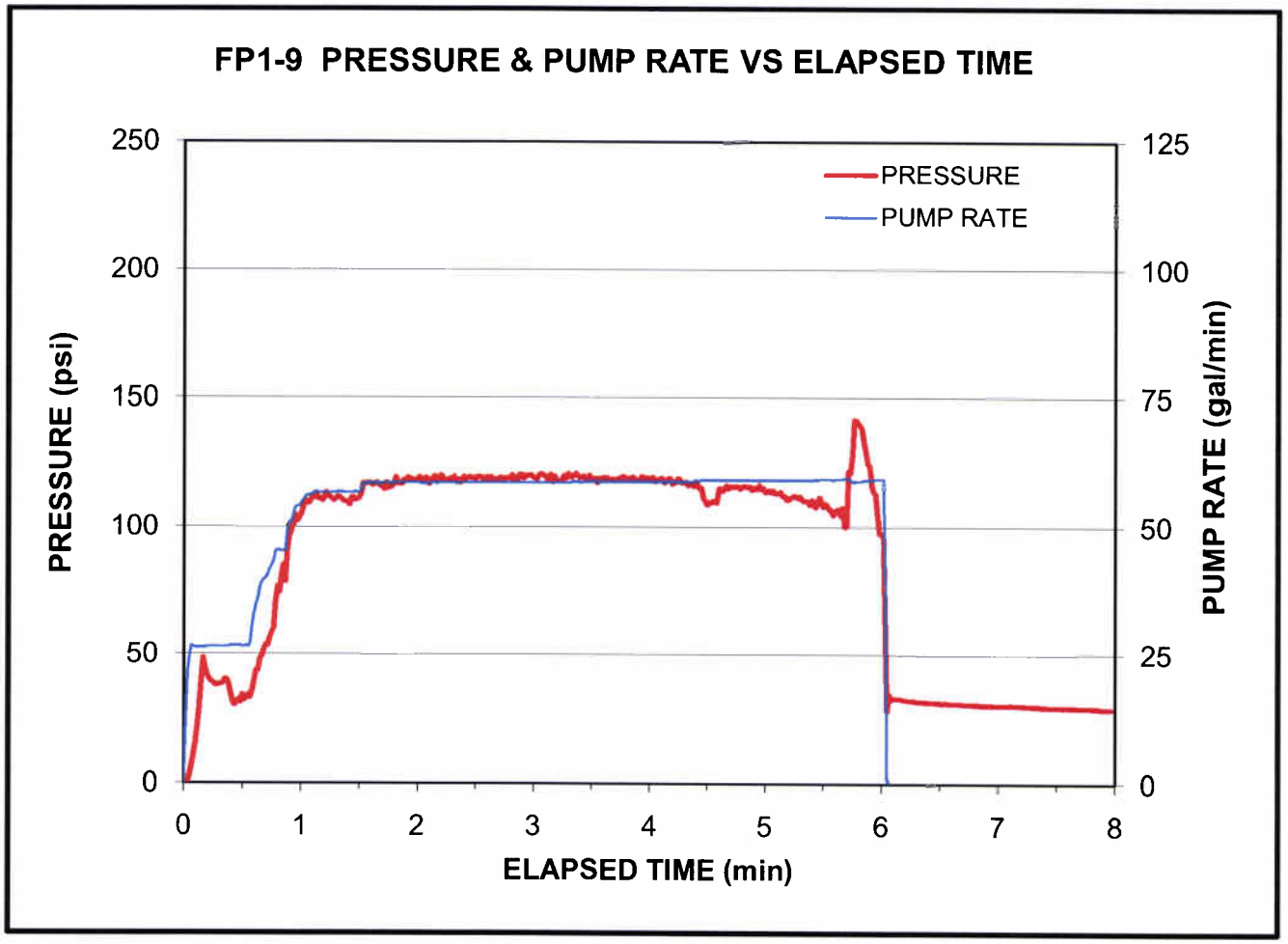


JOB NUMBER:	08FR10	DATE:	07 October 2008
FRACTURE NO.:	FP1-8	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	32.0 (ft)	SOIL TYPE:	sandy Clay
VOLUME PUMPED:	289 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	1900 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	69 (psi)	AVERAGE PUMP RATE:	60 (gal/min)

REMARKS: Temporary loss of Data Acquisiton during frac

Note: Soil type based on information received from Tetra Tech NUS

FRACTURE DATA



JOB NUMBER:	08FR10	DATE:	08 October 2008
FRACTURE NO.:	FP1-9	FRACTURE HOLE:	FP-1
FRACTURE DEPTH:	35.0 (ft)	SOIL TYPE:	sandy Clay
VOLUME PUMPED:	296 (gal)	PLACEMENT EFFICIENCY:	100 (%)
SAND PUMPED:	2050 (lb)	SAND GRADATION:	20/40
BREAK PRESSURE:	49 (psi)	AVERAGE PUMP RATE:	55 (gal/min)

REMARKS:

Note: Soil type based on information received from Tetra Tech NUS

APPENDIX II

TILTMETER GEOPHYSICAL REPORT

Tiltmeter Monitoring of

Hydraulic Fracture Injections

Lockheed-Martin EOS Fracture Pilot

Middle River, Maryland

Prepared for

Frac-Rite Environmental, Ltd.
Calgary, Alberta, Canada

Prepared by

Eco-Scan, Inc.
Denver, Colorado

November 2008

SUMMARY

On October 7 and October 8, 2008, nine hydraulic fracture injections in one boring were monitored with ECO-SCAN surface tiltmeters at a field site in Middle River, Maryland. The purpose of the injections was to propagate sand fractures into the ground followed by injection of an edible oil substrate to facilitate remediation of contaminated soils.

The injections were initiated at depths ranging from 11 feet to 35 feet below ground surface. The injections were monitored using ECO-SCAN's proprietary tiltmeter mapping system. The recorded data quality was very good with high signal to noise ratios. Tiltmeter response from the injections was generally very good with high signal to noise ratios.

Analysis of the tiltmeter data indicated that planar fractures offset from the borehole were induced in the subsurface during the injections with dips ranging between 8 degrees and 47 degrees from horizontal. Injections 2 through 9 resulted in fractures that propagated uphole from the injection depths. Very little fluid leakoff was evident in the tiltmeter results with the exception of the initial injection at the shallowest depth. Results of the tiltmeter analyses are summarized in Table 1.

ECO-SCAN's analysis of fracture parameters was base solely on the tilt and injection data with limited information of the local geologic structure and stratigraphy. Such additional information may result in better models of the data.

UNITS, DEFINITIONS, AND SIGN CONVENTION FOR FRACTURE DESCRIPTION

Except where explicitly stated otherwise, the following units are used in this report:

Length – feet
Volume – cubic feet
Pressure – PSI
Fracture angle – degrees
Tilt angle – microradians
RMS error – nanoradians
Normalized vector error – dimensionless

One microradian is the angle subtended by an arc of length 1 mm at a radius of 1 km.

RMS error is the root mean squared difference between observed and theoretical tilt vectors on completion of a non-robust chi-square optimization.

Normalized vector error is a normalized measure of the difference between the observed and theoretical tilt vectors. This error is normalized for comparison between analyses of different fracture models. A value less than 0.4 is considered a good fit of modeled to observed tilt, a value less than 0.3 is considered very good, and a value less than 0.2 is considered an excellent fit.

Each fracture is described by one or more rectangular dislocations with location and geometry specified as follows:

The location in space is defined by the (x,y,z) coordinates of the mid-point of the rectangular fracture, where x and y are the magnetic eastings and northings with respect to the injection well, and z is the depth below ground surface.

Fracture orientation is defined by azimuth and dip using the right hand rule, where azimuth is the direction of strike clockwise from magnetic north, and dip is the angle from horizontal at a right angle from the azimuth. For example, a fracture with an azimuth of 45° and a dip of 45° strikes northeast-southwest and dips to the southeast, and a fracture with a azimuth of 225° and a dip of 45° strikes southwest-northeast and dips to the northwest.

Fracture geometry is specified by length along azimuth, height along the direction of dip, and width between the fracture faces.

SUMMARY OF ECO-SCAN'S TILTMETER MAPPING SYSTEM

Many subsurface processes result in small but measurable movements at the Earth's surface. The shape of these surface deformations will depend on the processes which caused them. ECO-SCAN's tiltmeter mapping system measures these surface deformations, and a model is created of subsurface processes which caused the deformation.

Various man made processes can result in measurable deformations at the Earth's surface. Long term processes such as production of oil and gas, or production of water from an aquifer, can result in subsidence of several feet over a period of years. Shorter term processes such as injection or production tests, or hydraulic fracturing produce correspondingly smaller deformations, but with suitably sensitive instrumentation these can be measured and analyzed.

The surface of the Earth is also continuously deforming due to natural processes. These include the tidal effects of the Sun and Moon, and thermal effects as the ground heats up during the day and cools down at night. While these effects are very small, they may be on a similar scale to the effects of the processes being monitored. However, the effects of these natural processes can be predicted and removed from the data.

The process of hydraulic fracturing creates a dislocation in the subsurface with a characteristic surface deformation. A horizontal fracture (dip = 0°) causes an uplift or dome at the surface. A vertical fracture (dip = 90°) causes subsidence at the surface oriented along the azimuth of the fracture with a slight uplift outside the subsidence.

If a point on the Earth's surface is uplifted relative to another point, there will be a change in slope of the surface between the two points. ECO-SCAN's tiltmeter system continuously records changes in slope, or tilt. The change in tilt at a particular tiltmeter location is measured in two orthogonal directions, and the vector sum of these two measurements yields the magnitude and direction of the change in tilt at that location. The surface deformation due to a subsurface process may then be characterized by measuring the change in tilt at an array of tiltmeter locations around an area of interest.

Numerical models and optimization schemes are then used to determine a best fit between observed and theoretical deformations.

DATA ACQUISITION

Tiltmeter data was collected to monitor nine hydraulic fracture injections in one boring at a field site in Middle River, Maryland during the period from October 7 to October 8, 2008. An array of eleven ECO-SCAN model 700 tiltmeters was deployed at the locations shown in Appendix A. Tilt data was collected at a 10 second sample interval during the fracture injections.

DATA QUALITY

Data quality was generally very good with high signal to noise ratios for each fracture injection.

DATA ANALYSIS

Fractures generated were modeled as single planar structures, and the results were optimized on the parameters azimuth, dip, length, height, width, depth, and XY offset from the borehole. The fit of the theoretical to observed tilt from the single planar fracture models was generally very good to excellent. Dual fracture models offset from the injection points were run; however, no appreciable increase in goodness of fit of modeled tilt to measured tilt results from this additional model complexity.

Other parameters such as rock properties may be optimized, however, several of these parameters are coupled which can result in an over parameterized numerical system yielding an unreliable interpretation of the results.

There was some data loss at seven of the tiltmeter locations during the monitoring of injection 4. A fracture analysis was done on data from the remaining four tiltmeter locations with results similar to the general orientation of the fractures modeled for the other injections.

The tilt signals from injections 2 through 9 were larger than those calculated for a theoretical fracture given the volume of fluid injected at the injection depths. This indicates that the fractures propagated uphole from the injection depths. The fracture depths in these cases were determined by assuming 100% fracture efficiency and solving for fracture orientation, XY offset, and depth.

Results of the analyses of the tiltmeter data are shown in map view in Appendix A and are summarized in Table 1.

DISCUSSION

Results of the tiltmeter analyses of the hydraulic fracture injections are summarized in Table 1. Maps of modeled fractures with real and theoretical tilt vectors for the fracture treatments are shown in Appendix A. ECO-SCAN's analysis of fracture parameters was base solely on the tilt data with limited information of the local geologic structure and stratigraphy.

Analyses of the tiltmeter data indicated planar fractures dipping between 8 degrees and 47 degrees from horizontal with azimuths ranging from 68 to 330 degrees from true north. Azimuth and dip did not appear to vary systemically with depth. Very little fluid leakoff was evident in the tiltmeter analysis of the fracture injection data, with the exception of injection 1 which showed a fracture efficiency of 37% (63% fluid leakoff). Data analyses indicated that fractures 2 through 9 migrated uphole from the injection depths.

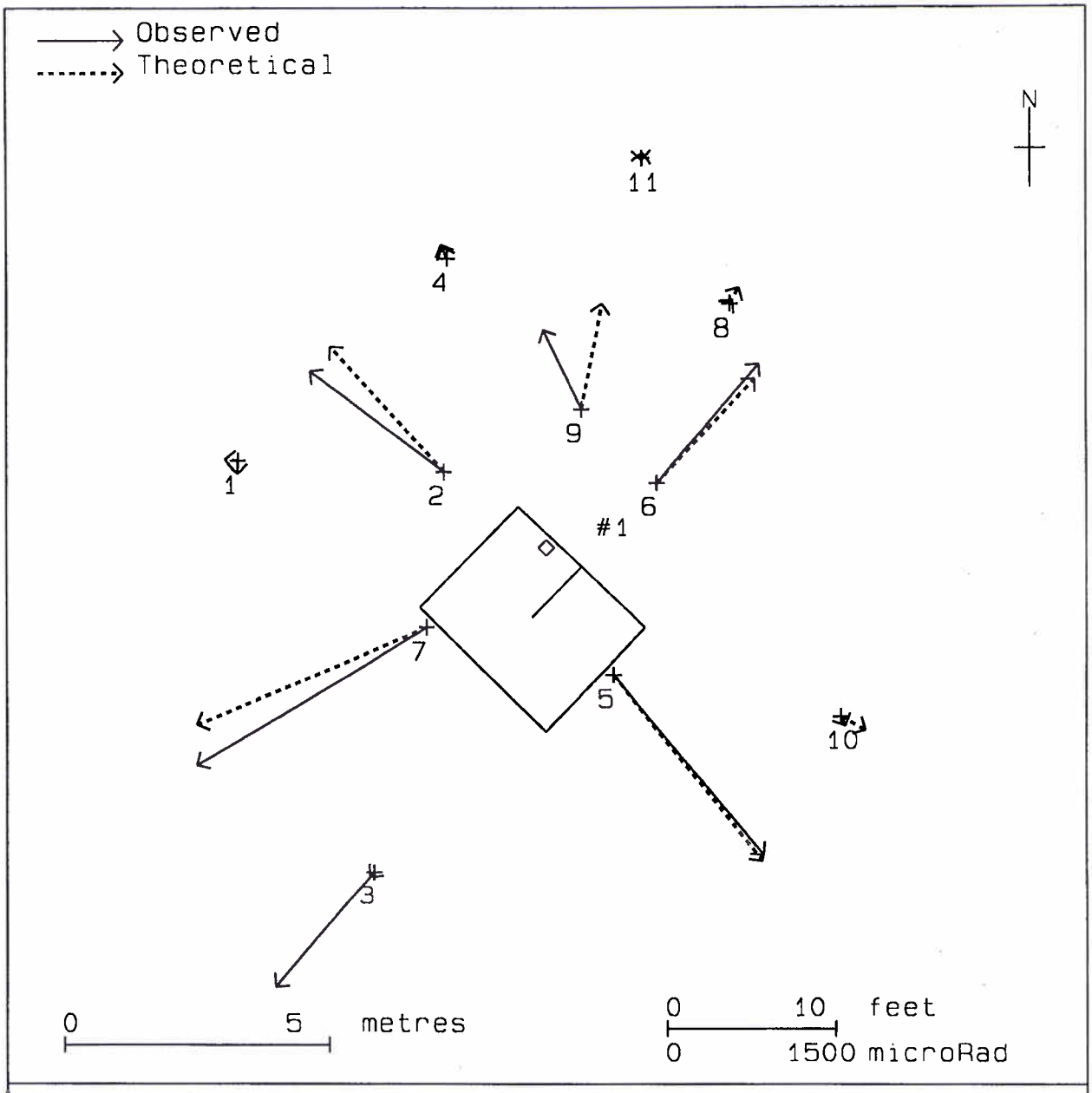
The fit of theoretical to observed tilt for injections was very good to excellent. Models were run with dual fractures offset from the borehole; however, no increase in goodness of fit between the theoretical and measured tilt was obtain with a more complex analysis.

Table 1. Summary of results of tiltmeter analyses.

Frac Hole	Date	Azimuth	Dip	Width	Length	Height	Z	Vector Error	RMS Error	Modeled Frac Volume	frac center x	frac center y
		(deg)	(deg)	(ft)	(ft)	(ft)	(ft)		(nRad)	(ft^3)	(ft)	(ft)
FB11	7-Oct	314	27	0.084	11.0	10.0	11.0	0.142	3.43E+05	9.2	-0.9	-4.4
FB12	7-Oct	68	42	0.068	10.0	28.0	11.0	0.113	3.10E+05	19.0	-3.5	-2.5
FB13	7-Oct	316	30	0.072	23.0	25.4	15.7	0.240	5.94E+05	42.1	1.6	-3.2
FB14	7-Oct	239	36	0.0590	25.0	25.0	15.9	0.024	1.39E+05	36.9	5.2	-2.6
FB15	7-Oct	330	14	0.077	17.1	31.8	21.5	0.069	1.89E+05	41.9	12.4	2.4
FB16	7-Oct	321	34	0.054	22.8	33.7	21.8	0.119	2.19E+05	41.5	3.8	-0.4
FB17	7-Oct	326	45	0.058	15.3	48.8	24.2	0.161	2.75E+05	43.3	-6.5	-3.3
FB18	7-Oct	140	8	0.049	21.5	40.0	21.5	0.095	1.84E+05	42.1	4.7	-5.5
FB19	8-Oct	215	47	0.042	35.6	29.3	21.1	0.210	1.97E+05	43.8	6.8	-1.8

NOTE: grey shading indicates modeled fracture is uphole from injection level

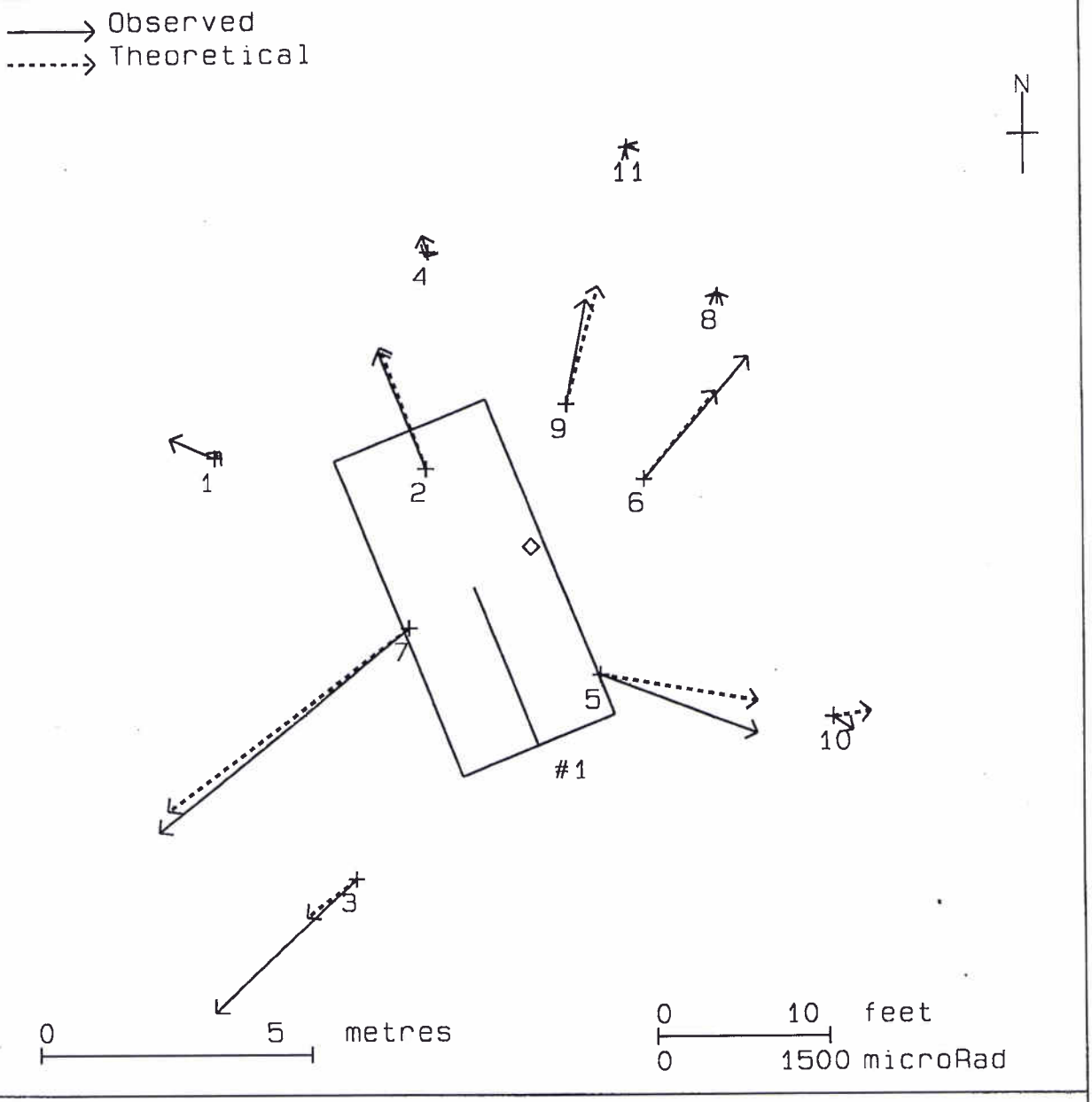
APPENDIX A



WELL: FB1 Frac 1
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	314	27	11	4.5	2	37%

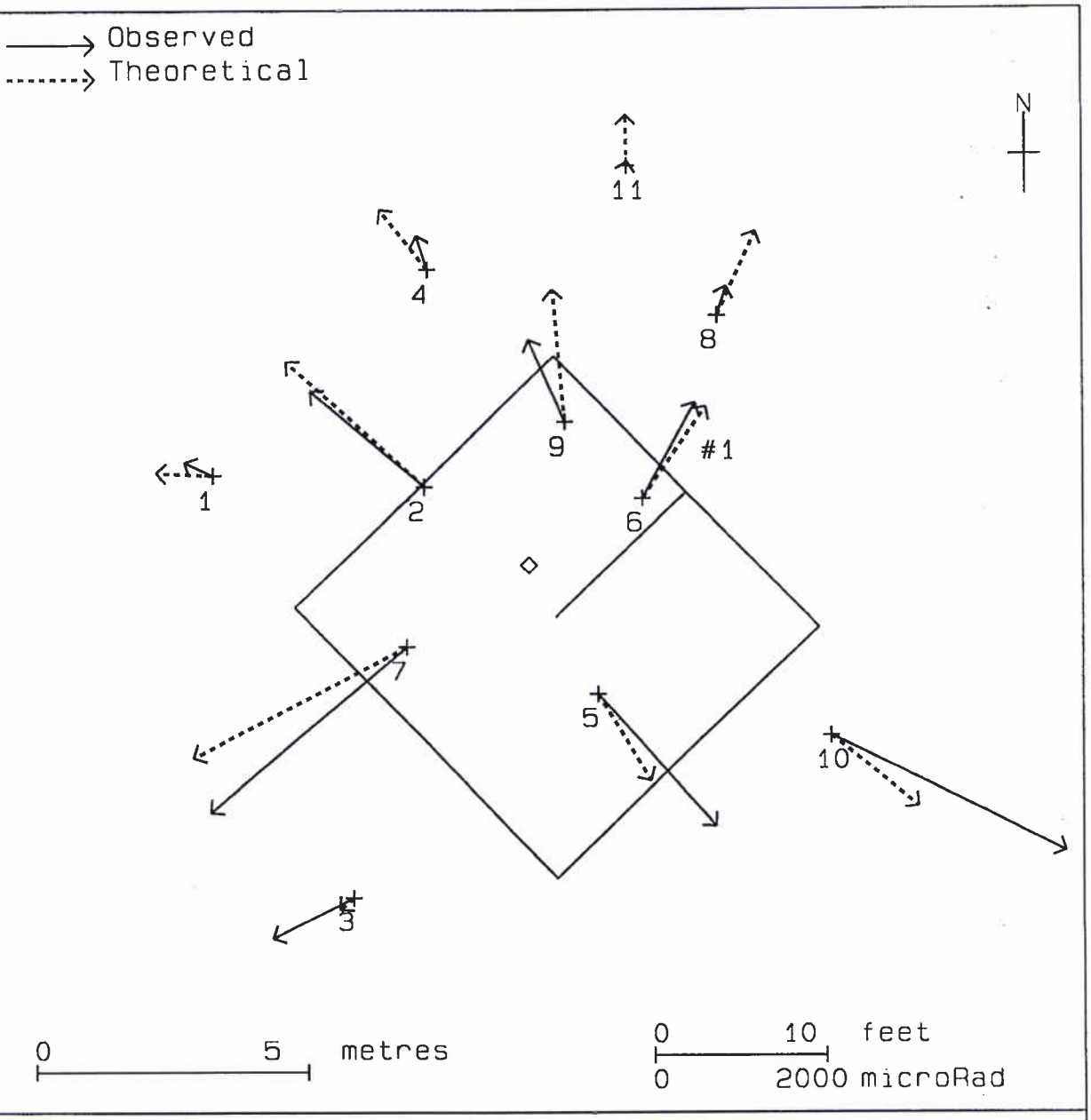
Length = 11 ft, Height = 10 ft, Width = 0.084 ft
Normalized Vector Error = 0.142
RMS Error = 3.43E5 uRad



WELL: FB1 Frac 2
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	68	42	11	3.5	3	97%

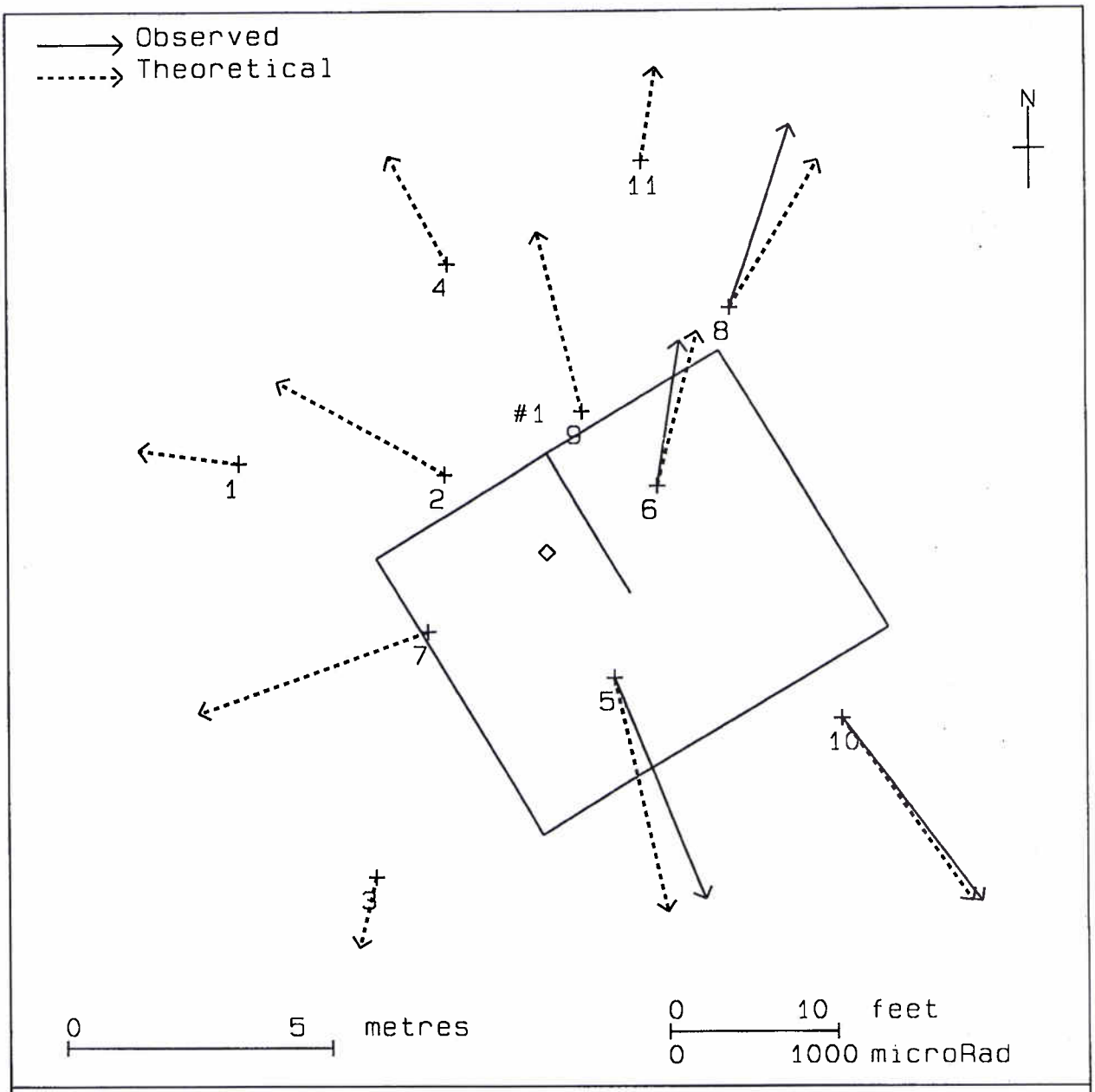
Length = 10 ft, Height = 28 ft, Width = 0.068 ft
Normalized Vector Error = 0.113
RMS Error = 3.10E5 uRad



WELL: FB1 Frac 3
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	316	30	15.7	7.6	7	99%

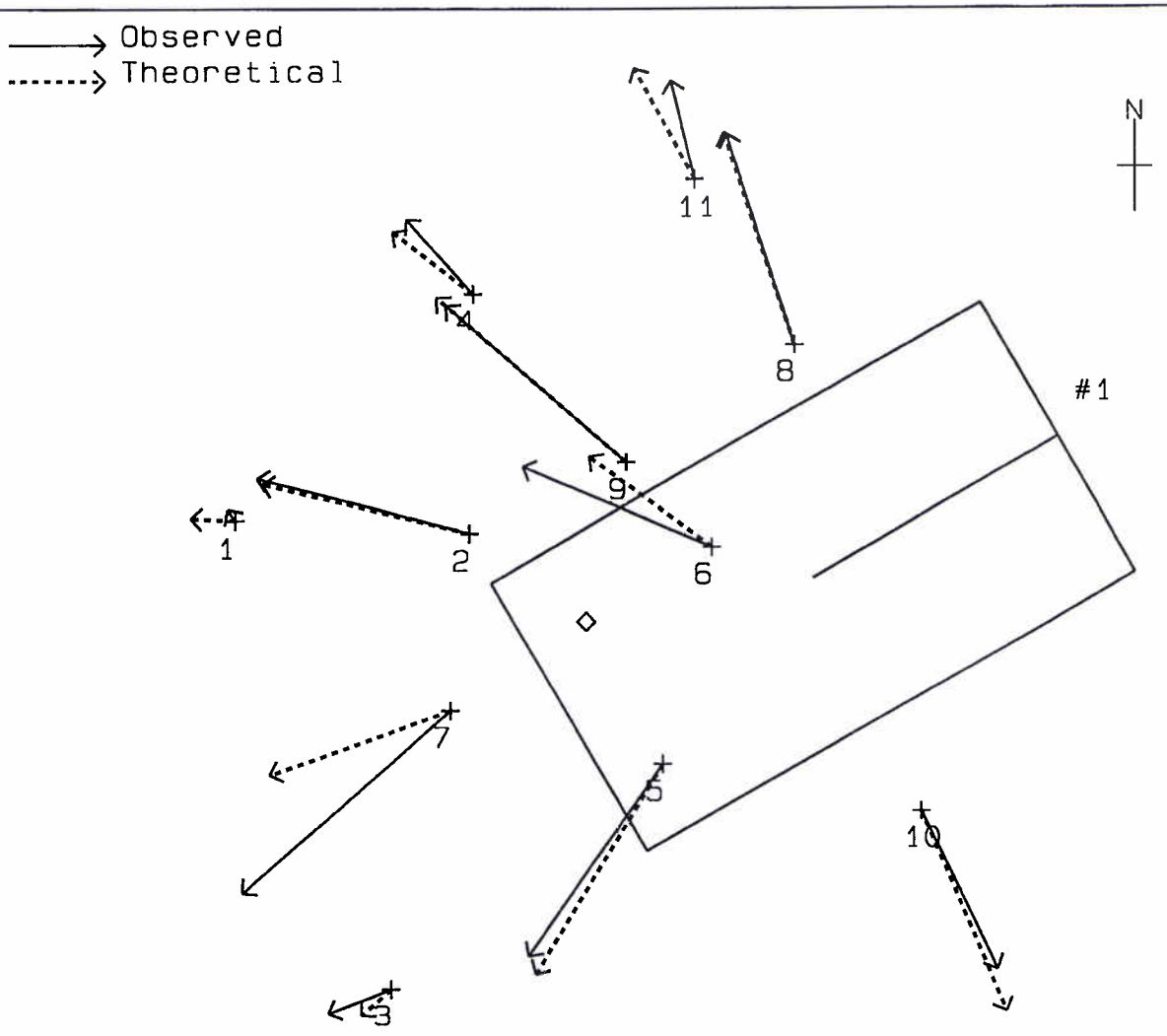
Length = 23.0 ft, Height = 25.4 ft, Width = 0.072 ft
Normalized Vector Error = 0.240
RMS Error = 5.94E5 uRad



WELL: FB1 Frac 4
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	239	36	15.9	6.6	7	100%

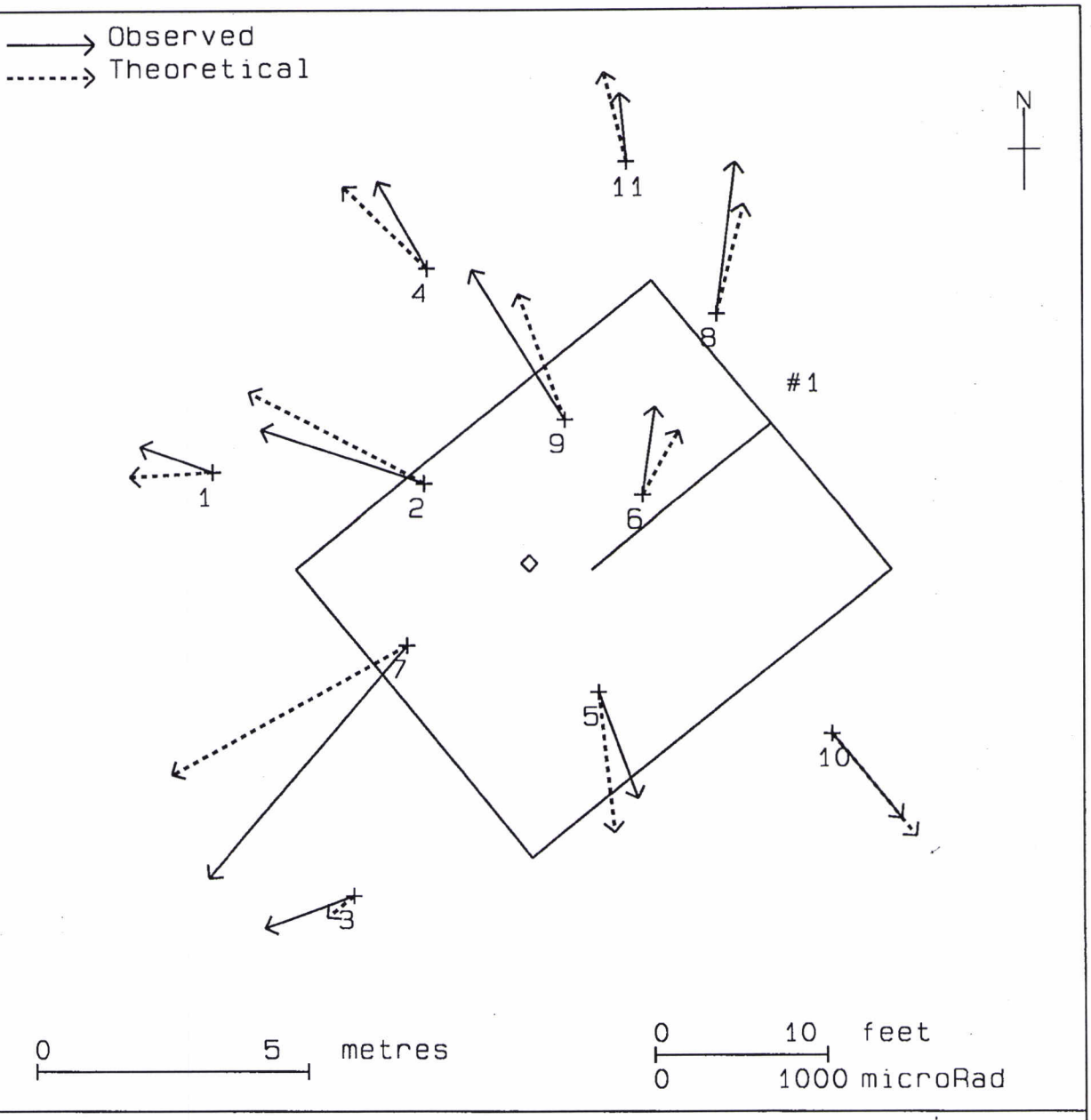
Length = 25 ft, Height = 25 ft, Width = 0.059 ft
Normalized Vector Error = 0.024
RMS Error = 1.39E5 uRad



WELL: FB1 Frac 5
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	330	14	21.5	7.5	7	99%

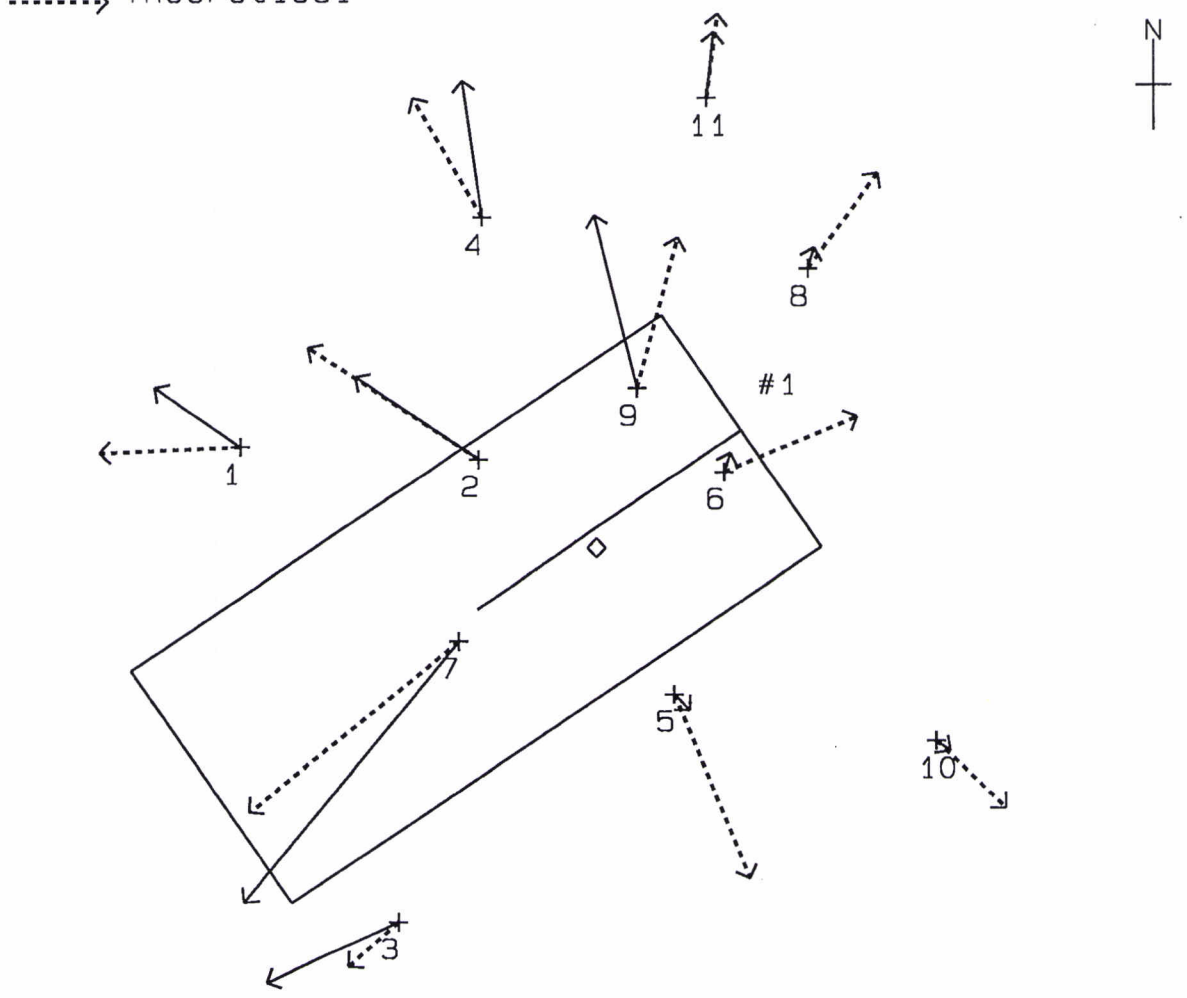
Length = 17.1 ft, Height = 31.8 ft, Width = 0.077 ft
Normalized Vector Error = 0.069
RMS Error = 1.89E5 uRad



WELL: FB1 Frac 6
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	321	34	21.8	7.5	7	99%

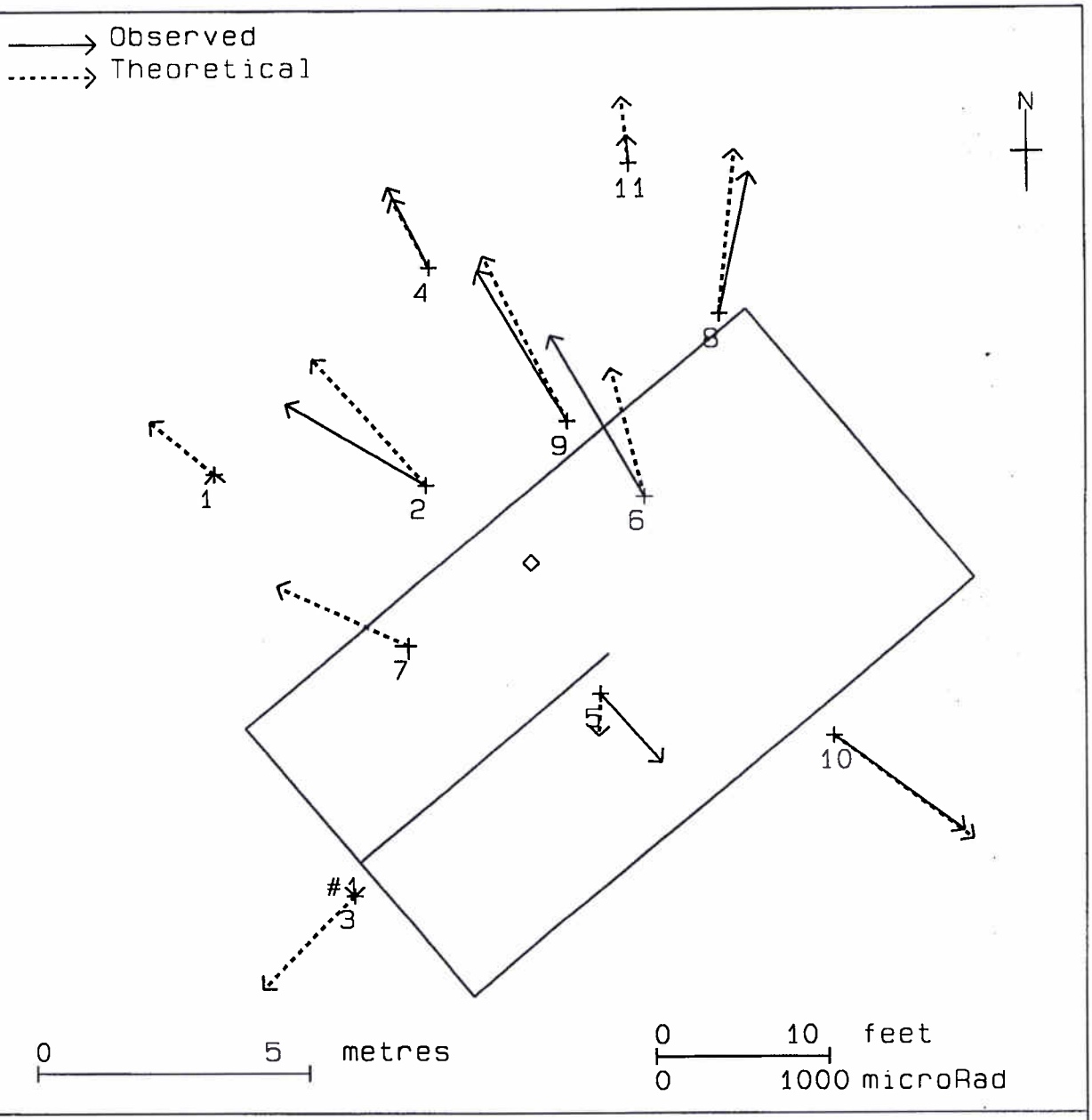
Length = 22.8 ft, Height = 33.7 ft, Width = 0.054 ft
Normalized Vector Error = 0.119
RMS Error = 2.19E5 uRad



WELL: FB1 Frac 7
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	326	45	24.2	7.7	8	100%

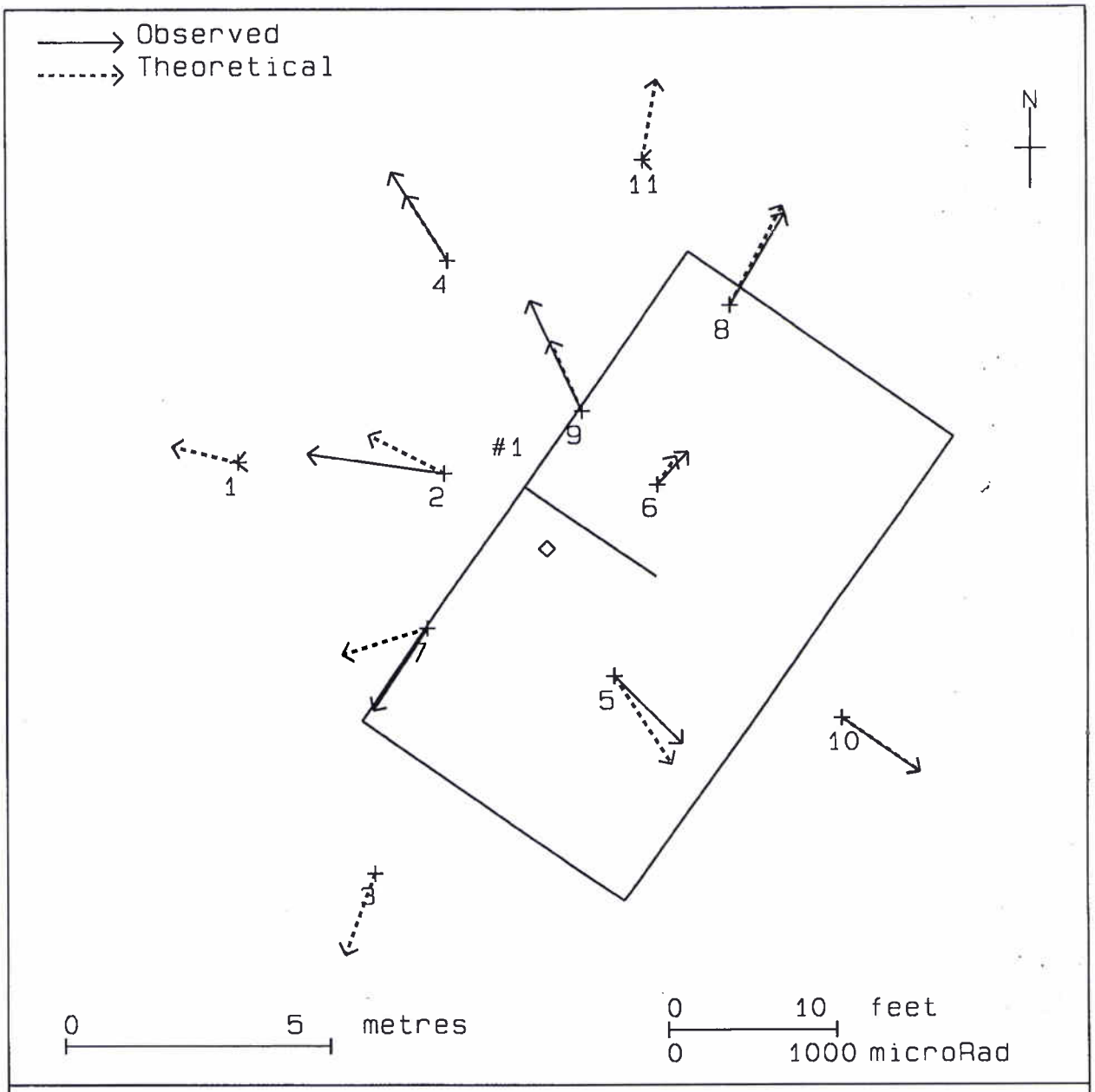
Length = 15.3 ft, Height = 48.8 ft, Width = 0.058 ft
Normalized Vector Error = 0.161
RMS Error = 2.75E5 uRad



WELL: FB1 Frac 8
DATE: 10/7/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	140	8	21.5	7.6	8	99%

Length = 21.5 ft, Height = 40.0 ft, Width = 0.049 ft
Normalized Vector Error = 0.095
RMS Error = 1.84E5 uRad



WELL: FB1 Frac 9
DATE: 10/8/08

FRAC #	AZ	DIP	DEPTH (FT)	INJECT. VOL. (bbl)	FRAC. VOL.	FRAC. EFF.
1	215	47	21.1	7.6	8	103%

Length = 35.6 ft, Height = 29.3 ft, Width = 0.042 ft
Normalized Vector Error = 0.210
RMS Error = 1.97E5 uRad

APPENDIX III

SUBSURFACE DISTRIBUTION OF SAND FRACTURES

Fracture Point FP1

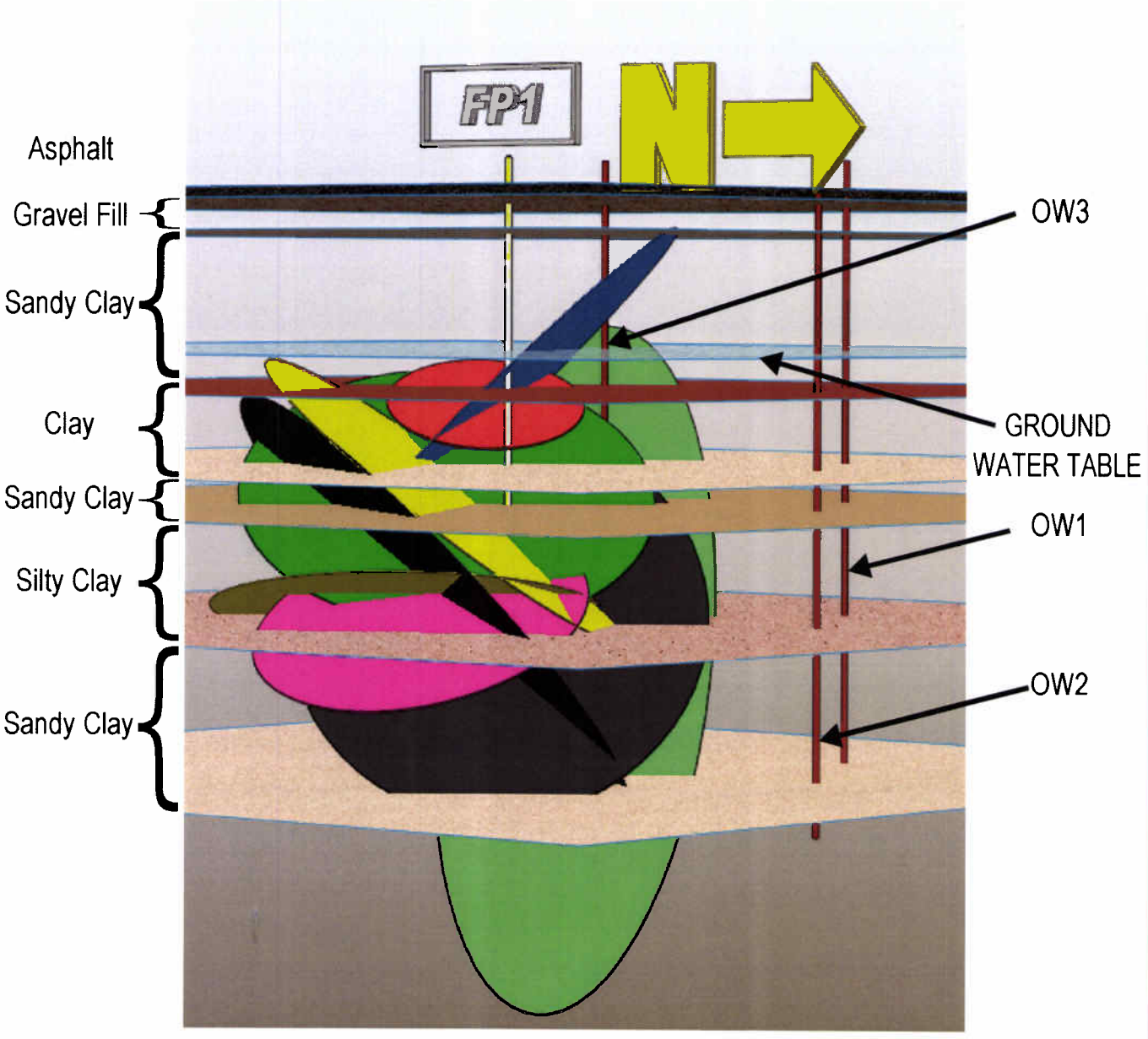


Figure III-1

Three-dimensional representation of
Sand fractures induced
at FP1

FRAC RITE
ENVIRONMENTAL LTD.

Fracture Point FP1

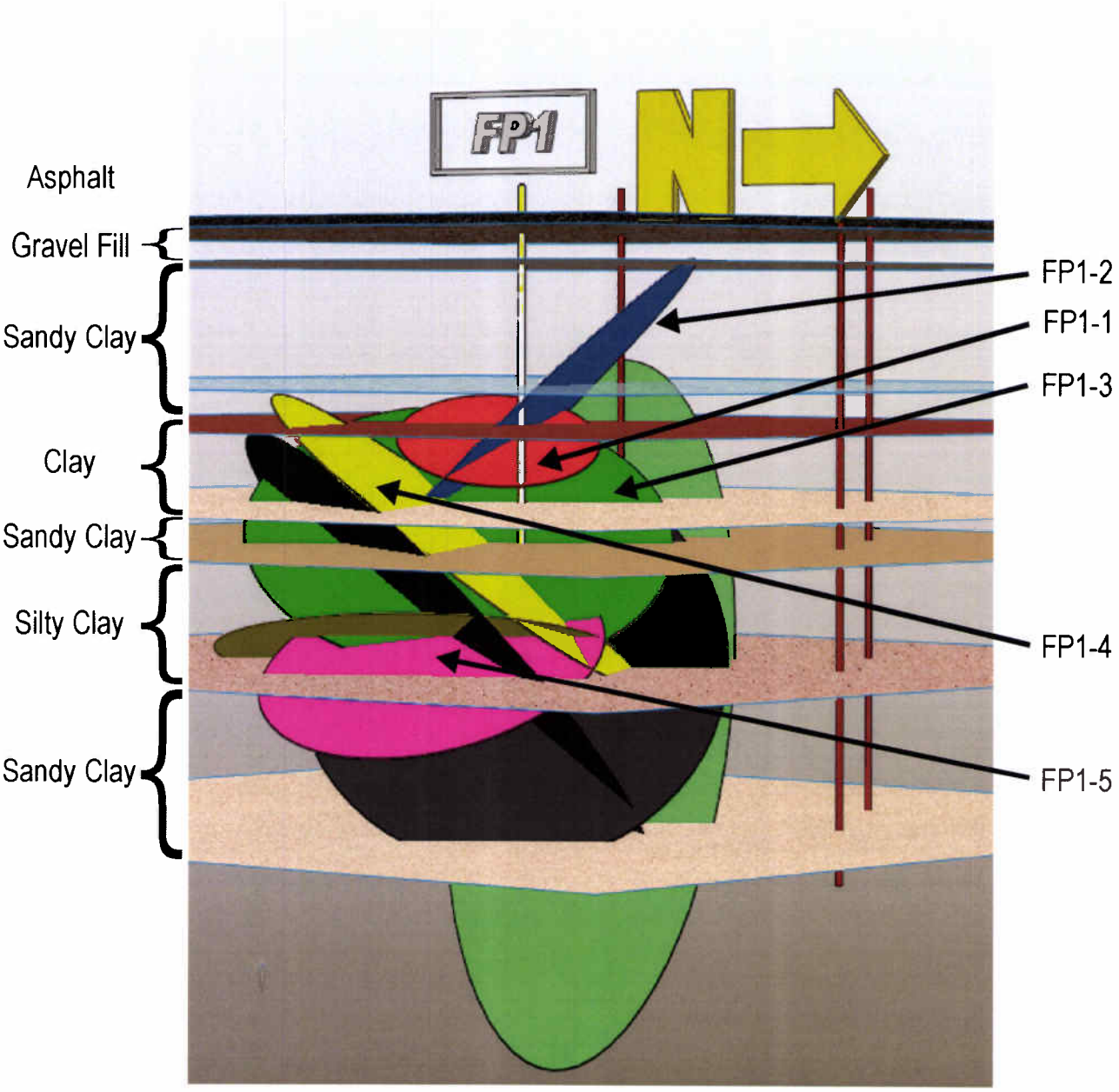


Figure III-2

Three-dimensional representation of Sand fractures induced at FP1

FRAC RITE ENVIRONMENTAL LTD.

Fracture Point FP1

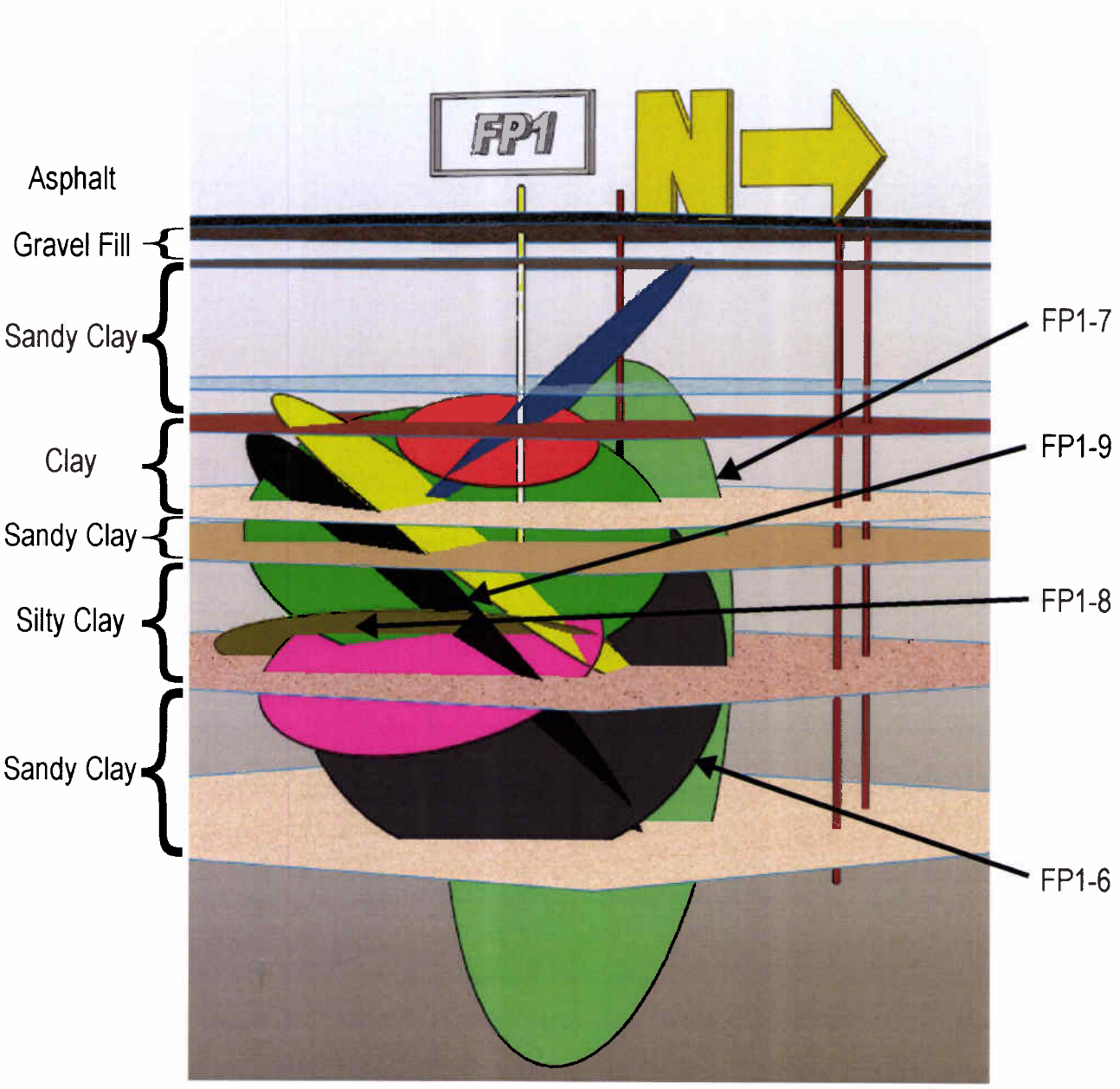


Figure III-3

Three-dimensional representation of Sand fractures induced at FP1

FRAC RITE ENVIRONMENTAL LTD.

APPENDIX F ANALYTICAL SUMMARY TABLES

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1D-012508	MRC-OW1D-100208	OW1D-111208	MRC-OW1D-011309	MRC-OW1D-011309DL	MRC-OW1D-042109	MRC-OW1D-042109DL
LABORATORY ID:	9720653003	017FJ-4	A8K130175002	640-20274-2	A9A140132003	A9D220174001	A9D220174001
SAMPLE DATE:	1/25/2008	10/2/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1D	OW1D	OW-1D	OW1D	OW1D	OW1D	OW1D
VOLATILES (ug/L)							
1,1,1,2-TETRACHLOROETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
1,1,1-TRICHLOROETHANE	0.86 J	NA	330 U	NA	200 U	NA	33 U
1,1,2,2-TETRACHLOROETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
1,1,2-TRICHLOROTRIFLUOROETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
1,1-DICHLOROETHANE	34.4	NA	330 U	NA	200 U	NA	33 U
1,1-DICHLOROETHENE	253 L	NA	330 U	NA	130 J	NA	18 J
1,1-DICHLOROPROPENE	1 U	NA	330 U	NA	200 U	NA	33 U
1,2,3-TRICHLOROBENZENE	2 U	NA	330 U	NA	200 U	NA	33 U
1,2,3-TRICHLOROPROPANE	2 U	NA	330 U	NA	200 U	NA	33 U
1,2,3-TRIMETHYLBENZENE	NA	NA	1700 U	NA	1000 U	NA	170 U
1,2,4-TRICHLOROBENZENE	2 U	NA	330 U	NA	200 U	NA	33 U
1,2,4-TRIMETHYLBENZENE	2.3	NA	330 U	NA	200 U	NA	33 U
1,2-DIBROMO-3-CHLOROPROPANE	7 U	NA	670 U	NA	400 U	NA	67 U
1,2-DIBROMOETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
1,2-DICHLOROBENZENE	1 U	NA	330 U	NA	200 U	NA	33 U
1,2-DICHLOROETHANE	0.53 J	NA	330 U	NA	200 U	NA	33 U
1,2-DICHLOROPROPANE	1 U	NA	330 U	NA	200 U	NA	33 U
1,3,5-TRIMETHYLBENZENE	1 U	NA	NA	NA	NA	NA	NA
1,3-DICHLOROBENZENE	1 U	NA	330 U	NA	200 U	NA	33 U
1,3-DICHLOROPROPANE	1 U	NA	330 U	NA	200 U	NA	33 U
1,4-DICHLOROBENZENE	1 U	NA	330 U	NA	200 U	NA	33 U
2,2-DICHLOROPROPANE	1 U	NA	330 U	NA	200 U	NA	33 U
2-BUTANONE	10 UR	NA	1700 U	NA	1000 U	NA	170 U
2-CHLOROETHYL VINYL ETHER	3 U	NA	1700 U	NA	1000 U	NA	170 U
2-CHLOROTOLUENE	1 U	NA	330 U	NA	200 U	NA	33 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1D-012508	MRC-OW1D-100208	OW1D-111208	MRC-OW1D-011309	MRC-OW1D-011309DL	MRC-OW1D-042109	MRC-OW1D-042109DL
LABORATORY ID:	9720653003	017FJ-4	A8K130175002	640-20274-2	A9A140132003	A9D220174001	A9D220174001
SAMPLE DATE:	1/25/2008	10/2/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1D	OW1D	OW-1D	OW1D	OW1D	OW1D	OW1D
2-HEXANONE	5 U	NA	1700 U	NA	1000 U	NA	170 U
4-CHLOROTOLUENE	1 U	NA	330 U	NA	200 U	NA	33 U
4-ISOPROPYLTOLUENE	1 U	NA	330 U	NA	200 U	NA	33 U
4-METHYL-2-PENTANONE	5 U	NA	1700 U	NA	1000 U	NA	170 U
ACETONE	10 UR	NA	1700 U	NA	1000 U	NA	170 U
BENZENE	2.8	NA	330 U	NA	200 U	NA	33 U
BROMOBENZENE	1 U	NA	330 U	NA	200 U	NA	33 U
BROMOCHLOROMETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
BROMODICHLOROMETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
BROMOFORM	1 U	NA	330 U	NA	200 U	NA	33 U
BROMOMETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
CARBON DISULFIDE	0.12 J	NA	330 U	NA	200 U	NA	33 U
CARBON TETRACHLORIDE	1 U	NA	330 U	NA	200 U	NA	33 U
CHLOROBENZENE	1 U	NA	330 U	NA	200 U	NA	33 U
CHLORODIBROMOMETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
CHLOROETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
CHLOROFORM	3.6	NA	330 U	NA	200 U	NA	33 U
CHLOROMETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
CIS-1,2-DICHLOROETHENE	1740 L	NA	1600	NA	880	NA	790
CIS-1,3-DICHLOROPROPENE	1 U	NA	330 U	NA	200 U	NA	33 U
DIBROMOMETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
DICHLORODIFLUOROMETHANE	1 U	NA	330 U	NA	200 U	NA	33 UJ
DIISOPROPYL ETHER	1 U	NA	1700 U	NA	1000 U	NA	170 U
ETHYL TERT-BUTYL ETHER	1 U	NA	1700 U	NA	1000 U	NA	170 U
ETHYLBENZENE	0.47 J	NA	330 U	NA	200 U	NA	33 U
FLUORODICHLOROMETHANE	0.49 K	NA	NA	NA	NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1D-012508	MRC-OW1D-100208	OW1D-111208	MRC-OW1D-011309	MRC-OW1D-011309DL	MRC-OW1D-042109	MRC-OW1D-042109DL
LABORATORY ID:	9720653003	017FJ-4	A8K130175002	640-20274-2	A9A140132003	A9D220174001	A9D220174001
SAMPLE DATE:	1/25/2008	10/2/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1D	OW1D	OW-1D	OW1D	OW1D	OW1D	OW1D
HEXACHLOROBUTADIENE	5 U	NA	330 U	NA	200 U	NA	33 U
ISOPROPYLBENZENE	0.66 J	NA	330 U	NA	200 U	NA	33 U
M+P-XYLENES	1.1 J	NA	670 U	NA	400 U	NA	67 U
METHYL TERT-BUTYL ETHER	1 U	NA	1700 U	NA	1000 U	NA	170 U
METHYLENE CHLORIDE	0.81 J	NA	330 U	NA	200 U	NA	33 U
NAPHTHALENE	3.4	NA	330 U	NA	200 U	NA	33 U
N-BUTYLBENZENE	1 U	NA	330 U	NA	200 U	NA	33 U
N-PROPYLBENZENE	1 U	NA	330 U	NA	200 U	NA	33 U
O-XYLENE	2.6	NA	330 U	NA	200 U	NA	33 U
SEC-BUTYLBENZENE	2 U	NA	330 U	NA	200 U	NA	33 U
STYRENE	1 U	NA	330 U	NA	200 U	NA	33 U
TERT-AMYL METHYL ETHER	2 U	NA	1700 U	NA	1000 U	NA	170 U
TERT-BUTYLBENZENE	2 U	NA	330 U	NA	200 U	NA	33 U
TERTIARY-BUTYL ALCOHOL	10 UR	NA	6700 UR	NA	4000 UR	NA	670 UR
TETRACHLOROETHENE	12.3 J	NA	330 U	NA	200 U	NA	33 U
TOLUENE	2.5	NA	330 U	NA	200 U	NA	33 U
TOTAL XYLENES	3.7	NA	670 U	NA	400 U	NA	67 U
TRANS-1,2-DICHLOROETHENE	12.6	NA	330 U	NA	200 U	NA	33 U
TRANS-1,3-DICHLOROPROPENE	1 U	NA	330 U	NA	200 U	NA	33 U
TRICHLOROETHENE	9370 L	NA	8500	NA	7800	NA	150
TRICHLOROFLUOROMETHANE	1 U	NA	330 U	NA	200 U	NA	33 U
VINYL ACETATE	5 U	NA	670 U	NA	400 U	NA	67 U
VINYL CHLORIDE	81.1	NA	170 J	NA	200 U	NA	33 U
DISSOLVED GASES (ug/l)							
ETHANE	21.1	NA	0.5 U	NA	5 U	0.43 J	NA
ETHENE	80.4	NA	7	NA	5 U	0.57	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1D-012508	MRC-OW1D-100208	OW1D-111208	MRC-OW1D-011309	MRC-OW1D-011309DL	MRC-OW1D-042109	MRC-OW1D-042109DL
LABORATORY ID:	9720653003	017FJ-4	A8K130175002	640-20274-2	A9A140132003	A9D220174001	A9D220174001
SAMPLE DATE:	1/25/2008	10/2/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1D	OW1D	OW-1D	OW1D	OW1D	OW1D	OW1D
METHANE	634	NA	3300	NA	55	22	NA
MISCELLANEOUS (mg/L)							
CHLORIDE	60.2	NA	NA	32.2	NA	148	NA
LACTIC ACID		NA	NA	NA	NA	2.7 U	NA
NITRATE-N	0.2 U	NA	0.1 U	0.1 U	NA	0.1	NA
NITRITE-N	0.2 U	NA	0.1 U	0.1 U	NA	0.1 U	NA
PYRUVIC ACID	NA	NA	NA	NA	NA	0.63 U	NA
SULFATE	43.1	NA	7.6	2.7	NA	11.9	NA
TOTAL DISSOLVED SOLIDS	NA	NA	160	160	NA	270	NA
TOTAL ORGANIC CARBON	3.1	NA	3	8	NA	4	NA
TOTAL SUSPENDED SOLIDS	NA	NA	4 U	4 U	NA	26	NA
SEMIVOLATILES (ug/L)							
1,4-DIOXANE	2 J	NA	NA	NA	NA	NA	NA
INORGANICS (ug/L)							
ANTIMONY	0.7 B	NA	NA	NA	NA	0.2 B	NA
ARSENIC	0.7	NA	NA	NA	NA	0.092 UL	NA
BARIUM	111	NA	NA	NA	NA	87	NA
BERYLLIUM	1 U	NA	NA	NA	NA	0.37 B	NA
CADMIUM	0.09	NA	NA	NA	NA	0.16 B	NA
CHROMIUM	2 U	NA	NA	NA	NA	0.58 B	NA
COBALT	29.8	NA	NA	NA	NA	12.2	NA
COPPER	6 U	NA	NA	NA	NA	1.4	NA
IRON	NA	NA	NA	NA	NA	14700	NA
LEAD	0.06	NA	NA	NA	NA	0.87	NA
MANGANESE	NA	NA	NA	NA	NA	1180	NA
MERCURY	0.5 U	NA	NA	NA	NA	0.1 U	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1D-012508	MRC-OW1D-100208	OW1D-111208	MRC-OW1D-011309	MRC-OW1D-011309DL	MRC-OW1D-042109	MRC-OW1D-042109DL
LABORATORY ID:	9720653003	017FJ-4	A8K130175002	640-20274-2	A9A140132003	A9D220174001	A9D220174001
SAMPLE DATE:	1/25/2008	10/2/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1D	OW1D	OW-1D	OW1D	OW1D	OW1D	OW1D
MOLYBDENUM	2.1	NA	NA	NA	NA	1.5	NA
NICKEL	16.7	NA	NA	NA	NA	18.8	NA
SELENIUM	2	NA	NA	NA	NA	0.25 B	NA
SILVER	0.4 B	NA	NA	NA	NA	0.006 U	NA
THALLIUM	1 U	NA	NA	NA	NA	0.33 B	NA
VANADIUM	0.4	NA	NA	NA	NA	2.1 B	NA
ZINC	26	NA	NA	NA	NA	56.3	NA
INORGANICS FILTERED (ug/L)							
ANTIMONY	2 U	NA	NA	NA	NA	NA	NA
ARSENIC	3 U	NA	NA	NA	NA	NA	NA
BARIUM	123	NA	NA	NA	NA	NA	NA
BERYLLIUM	1 U	NA	NA	NA	NA	NA	NA
CADMIUM	1 U	NA	NA	NA	NA	NA	NA
CHROMIUM	4.1	NA	NA	NA	NA	NA	NA
COBALT	50.5	NA	NA	NA	NA	NA	NA
COPPER	5 U	NA	NA	NA	NA	NA	NA
IRON	NA	NA	NA	NA	NA	NA	NA
LEAD	2 U	NA	NA	NA	NA	NA	NA
MANGANESE	NA	NA	NA	NA	NA	NA	NA
MERCURY	NA	NA	NA	NA	NA	NA	NA
MOLYBDENUM	2 U	NA	NA	NA	NA	NA	NA
NICKEL	27.2	NA	NA	NA	NA	NA	NA
SELENIUM	5 U	NA	NA	NA	NA	NA	NA
SILVER	1 U	NA	NA	NA	NA	NA	NA
THALLIUM	1 U	NA	NA	NA	NA	NA	NA
VANADIUM	0.2	NA	NA	NA	NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	**OW1D-012508**	**MRC-OW1D-100208**	**OW1D-111208**	**MRC-OW1D-011309**	**MRC-OW1D-011309DL**	**MRC-OW1D-042109**	**MRC-OW1D-042109DL**
LABORATORY ID:	**9720653003**	**017FJ-4**	**A8K130175002**	**640-20274-2**	**A9A140132003**	**A9D220174001**	**A9D220174001**
SAMPLE DATE:	**1/25/2008**	**10/2/2008**	**11/12/2008**	**1/13/2009**	**1/13/2009**	**4/21/2009**	**4/21/2009**
LOCATION:	**OW1D**	**OW1D**	**OW-1D**	**OW1D**	**OW1D**	**OW1D**	**OW1D**
ZINC	14.5	NA	NA	NA	NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1I-012508	MRC-OW1I-100208	OW-1I	MRC-OW1I-011309	MRC-OW1I-011309DL	MRC-OW1I-042109	MRC-OW1I-042109DL
LABORATORY ID:	9720653002	017FJ-1	A8K180174001	640-20274-1	A9A140132002	A9D220174002	A9D220174002
SAMPLE DATE:	1/25/2008	10/2/2008	11/17/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I
VOLATILES (ug/L)							
1,1,1,2-TETRACHLOROETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
1,1,1-TRICHLOROETHANE	0.2 J	NA	77 U	NA	200 U	NA	250 U
1,1,2,2-TETRACHLOROETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
1,1,2-TRICHLOROTRIFLUOROETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
1,1-DICHLOROETHANE	5.2	NA	77 U	NA	200 U	NA	250 U
1,1-DICHLOROETHENE	21.2	NA	77 U	NA	200 U	NA	250 U
1,1-DICHLOROPROPENE	1 U	NA	77 U	NA	200 U	NA	250 U
1,2,3-TRICHLOROBENZENE	2 U	NA	77 U	NA	200 U	NA	250 U
1,2,3-TRICHLOROPROPANE	2 U	NA	77 U	NA	200 U	NA	250 U
1,2,3-TRIMETHYLBENZENE	NA	NA	380 U	NA	1000 U	NA	1200 U
1,2,4-TRICHLOROBENZENE	2 U	NA	77 U	NA	200 U	NA	250 U
1,2,4-TRIMETHYLBENZENE	0.63 J	NA	77 U	NA	200 U	NA	250 U
1,2-DIBROMO-3-CHLOROPROPANE	7 U	NA	150 U	NA	400 U	NA	500 U
1,2-DIBROMOETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
1,2-DICHLOROBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
1,2-DICHLOROETHANE	0.37 J	NA	77 U	NA	200 U	NA	250 U
1,2-DICHLOROPROPANE	1 U	NA	77 U	NA	200 U	NA	250 U
1,3,5-TRIMETHYLBENZENE	1 U	NA	NA	NA	NA	NA	NA
1,3-DICHLOROBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
1,3-DICHLOROPROPANE	1 U	NA	77 U	NA	200 U	NA	250 U
1,4-DICHLOROBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
2,2-DICHLOROPROPANE	1 U	NA	77 U	NA	200 U	NA	250 U
2-BUTANONE	10 UR	NA	380 U	NA	1000 U	NA	1200 U
2-CHLOROETHYL VINYL ETHER	3 U	NA	380 U	NA	1000 U	NA	1200 U
2-CHLOROTOLUENE	1 U	NA	77 U	NA	200 U	NA	250 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1I-012508	MRC-OW1I-100208	OW-1I	MRC-OW1I-011309	MRC-OW1I-011309DL	MRC-OW1I-042109	MRC-OW1I-042109DL
LABORATORY ID:	9720653002	017FJ-1	A8K180174001	640-20274-1	A9A140132002	A9D220174002	A9D220174002
SAMPLE DATE:	1/25/2008	10/2/2008	11/17/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I
2-HEXANONE	5 U	NA	380 U	NA	1000 U	NA	1200 U
4-CHLOROTOLUENE	1 U	NA	77 U	NA	200 U	NA	250 U
4-ISOPROPYLTOLUENE	1 U	NA	77 U	NA	200 U	NA	250 U
4-METHYL-2-PENTANONE	5 U	NA	380 U	NA	1000 U	NA	1200 U
ACETONE	10 UR	NA	380 U	NA	1000 U	NA	1200 U
BENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
BROMOBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
BROMOCHLOROMETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
BROMODICHLOROMETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
BROMOFORM	1 U	NA	77 U	NA	200 U	NA	250 U
BROMOMETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
CARBON DISULFIDE	1 U	NA	77 U	NA	200 U	NA	250 U
CARBON TETRACHLORIDE	1 U	NA	77 U	NA	200 U	NA	250 U
CHLOROBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
CHLORODIBROMOMETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
CHLOROETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
CHLOROFORM	2.3	NA	77 U	NA	200 U	NA	250 U
CHLOROMETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
CIS-1,2-DICHLOROETHENE	1730 L	NA	740	NA	1800	NA	1600
CIS-1,3-DICHLOROPROPENE	1 U	NA	77 U	NA	200 U	NA	250 U
DIBROMOMETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
DICHLORODIFLUOROMETHANE	1 U	NA	77 U	NA	200 U	NA	250 UJ
DIISOPROPYL ETHER	1 U	NA	380 U	NA	1000 U	NA	1200 U
ETHYL TERT-BUTYL ETHER	1 U	NA	380 U	NA	1000 U	NA	1200 U
ETHYLBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
FLUORODICHLOROMETHANE	1 U	NA	NA	NA	NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1I-012508	MRC-OW1I-100208	OW-1I	MRC-OW1I-011309	MRC-OW1I-011309DL	MRC-OW1I-042109	MRC-OW1I-042109DL
LABORATORY ID:	9720653002	017FJ-1	A8K180174001	640-20274-1	A9A140132002	A9D220174002	A9D220174002
SAMPLE DATE:	1/25/2008	10/2/2008	11/17/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I
HEXACHLOROBUTADIENE	5 U	NA	77 U	NA	200 U	NA	250 U
ISOPROPYLBENZENE	2.2	NA	77 U	NA	200 U	NA	250 U
M+P-XYLENES	2 U	NA	150 U	NA	400 U	NA	500 U
METHYL TERT-BUTYL ETHER	1 U	NA	380 U	NA	1000 U	NA	1200 U
METHYLENE CHLORIDE	0.14 J	NA	77 U	NA	200 U	NA	250 U
NAPHTHALENE	1.3 J	NA	77 U	NA	200 U	NA	250 U
N-BUTYLBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
N-PROPYLBENZENE	1 U	NA	77 U	NA	200 U	NA	250 U
O-XYLENE	1.3	NA	77 U	NA	200 U	NA	250 U
SEC-BUTYLBENZENE	3	NA	77 U	NA	200 U	NA	250 U
STYRENE	1 U	NA	77 U	NA	200 U	NA	250 U
TERT-AMYL METHYL ETHER	2 U	NA	380 U	NA	1000 U	NA	1200 U
TERT-BUTYLBENZENE	0.94 J	NA	77 U	NA	200 U	NA	250 U
TERTIARY-BUTYL ALCOHOL	10 UR	NA	1500 UR	NA	4000 UR	NA	5000 UR
TETRACHLOROETHENE	41.8 J	NA	29 J	NA	200 U	NA	250 U
TOLUENE	0.48 J	NA	77 U	NA	200 U	NA	250 U
TOTAL XYLENES	1.3 J	NA	150 U	NA	400 U	NA	500 U
TRANS-1,2-DICHLOROETHENE	10.2	NA	77 U	NA	200 U	NA	250 U
TRANS-1,3-DICHLOROPROPENE	1 U	NA	77 U	NA	200 U	NA	250 U
TRICHLOROETHENE	7390 L	NA	2800	NA	7700	NA	4100
TRICHLOROFLUOROMETHANE	1 U	NA	77 U	NA	200 U	NA	250 U
VINYL ACETATE	5 U	NA	150 U	NA	400 U	NA	500 U
VINYL CHLORIDE	178	NA	68 J	NA	210	NA	120 J
DISSOLVED GASES (ug/l)							
ETHANE	1 J	NA	0.5 U	NA	2.5 U	1.5	NA
ETHENE	9.5	NA	3.5	NA	1.7 J	5.9	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1I-012508	MRC-OW1I-100208	OW-1I	MRC-OW1I-011309	MRC-OW1I-011309DL	MRC-OW1I-042109	MRC-OW1I-042109DL
LABORATORY ID:	9720653002	017FJ-1	A8K180174001	640-20274-1	A9A140132002	A9D220174002	A9D220174002
SAMPLE DATE:	1/25/2008	10/2/2008	11/17/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I
METHANE	3530	NA	1200	NA	590	1200	NA
MISCELLANEOUS (mg/L)							
CHLORIDE	60.8	NA	NA	73.5	NA	172	NA
LACTIC ACID	NA	NA	NA	NA	NA	2.7 U	NA
NITRATE-N	0.1	NA	0.1	0.1 U	NA	0.1 U	NA
NITRITE-N	0.2 U	NA	0.1 U	0.1 U	NA	0.1 U	NA
PYRUVIC ACID	NA	NA	NA	NA	NA	0.63 U	NA
SULFATE	11.1	NA	14.6	9.5	NA	14.5	NA
TOTAL DISSOLVED SOLIDS	NA	NA	130	180	NA	340	NA
TOTAL ORGANIC CARBON	3	NA	4	3	NA	5	NA
TOTAL SUSPENDED SOLIDS	NA	NA	7	12	NA	14	NA
SEMIVOLATILES (ug/L)							
1,4-DIOXANE	4 J	NA	1 U	NA	NA	NA	NA
INORGANICS (ug/L)							
ANTIMONY	2 U	NA	0.23 B	NA	NA	0.23 B	NA
ARSENIC	1.2	NA	0.082 U	NA	NA	0.092 UL	NA
BARIUM	56.1	NA	19.7	NA	NA	32.5	NA
BERYLLIUM	0.9	NA	0.43	NA	NA	0.58	NA
CADMIUM	0.1	NA	0.16 B	NA	NA	0.51 K	NA
CHROMIUM	2 U	NA	0.74 B	NA	NA	0.6 B	NA
COBALT	87.5	NA	21.8	NA	NA	41.1	NA
COPPER	6 U	NA	1.6 K	NA	NA	2.1	NA
IRON	NA	NA	1340	NA	NA	7080	NA
LEAD	0.2	NA	0.23	NA	NA	0.77	NA
MANGANESE	NA	NA	1360	NA	NA	2550	NA
MERCURY	0.5 U	NA	0.1 U	NA	NA	0.1 U	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1I-012508	MRC-OW1I-100208	OW-1I	MRC-OW1I-011309	MRC-OW1I-011309DL	MRC-OW1I-042109	MRC-OW1I-042109DL
LABORATORY ID:	9720653002	017FJ-1	A8K180174001	640-20274-1	A9A140132002	A9D220174002	A9D220174002
SAMPLE DATE:	1/25/2008	10/2/2008	11/17/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I
MOLYBDENUM	0.1	NA	0.41 B	NA	NA	0.8 B	NA
NICKEL	34.5	NA	11.4	NA	NA	12.3	NA
SELENIUM	4	NA	0.2 B	NA	NA	0.46 B	NA
SILVER	0.4 B	NA	0.009 B	NA	NA	0.02 B	NA
THALLIUM	0.03	NA	0.23 B	NA	NA	0.41 B	NA
VANADIUM	0.7	NA	1.1 B	NA	NA	1.6 B	NA
ZINC	38.4	NA	81.8	NA	NA	81.1	NA
INORGANICS FILTERED (ug/L)							
ANTIMONY	2 U	NA	0.24 B	NA	NA	NA	NA
ARSENIC	3 U	NA	0.082 U	NA	NA	NA	NA
BARIUM	51.2	NA	18.1	NA	NA	NA	NA
BERYLLIUM	0.8	NA	0.34	NA	NA	NA	NA
CADMIUM	1 U	NA	0.22 B	NA	NA	NA	NA
CHROMIUM	5.5	NA	0.15 B	NA	NA	NA	NA
COBALT	82.6	NA	25.5	NA	NA	NA	NA
COPPER	0.8	NA	0.92 K	NA	NA	NA	NA
IRON	NA	NA	782	NA	NA	NA	NA
LEAD	2 U	NA	0.17 U	NA	NA	NA	NA
MANGANESE	NA	NA	1600	NA	NA	NA	NA
MERCURY	NA	NA	0.1 U	NA	NA	NA	NA
MOLYBDENUM	2 U	NA	0.5 B	NA	NA	NA	NA
NICKEL	34.2	NA	13	NA	NA	NA	NA
SELENIUM	5 U	NA	0.26 B	NA	NA	NA	NA
SILVER	1 U	NA	0.019 B	NA	NA	NA	NA
THALLIUM	1 U	NA	0.58 B	NA	NA	NA	NA
VANADIUM	0.9	NA	0.32 B	NA	NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW1I-012508	MRC-OW1I-100208	OW-1I	MRC-OW1I-011309	MRC-OW1I-011309DL	MRC-OW1I-042109	MRC-OW1I-042109DL
LABORATORY ID:	9720653002	017FJ-1	A8K180174001	640-20274-1	A9A140132002	A9D220174002	A9D220174002
SAMPLE DATE:	1/25/2008	10/2/2008	11/17/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009
LOCATION:	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I	OW1I
ZINC	35.7	NA	77.4	NA	NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2D-012408	OW-2D	MRC-OW2D-011509	MRC-OW2D-011509DL	MRC-OW2D-042209	MRC-OW2D-042209DL	OW2I-012408
LABORATORY ID:	9720529004	A8K180174002	640-20361-1	A9A160250004	A9D230208001	A9D230208001	9720529002
SAMPLE DATE:	1/24/2008	11/17/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW2D	OW-2D	OW2D	OW2D	OW2D	OW2D	OW2I
VOLATILES (ug/L)							
1,1,1,2-TETRACHLOROETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,1,1-TRICHLOROETHANE	5 U	200 U	NA	250 U	NA	50 U	3.7
1,1,2,2-TETRACHLOROETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,1,2-TRICHLOROTRIFLUOROETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,1-DICHLOROETHANE	14.1	200 U	NA	250 U	NA	50 U	38.1
1,1-DICHLOROETHENE	95.3	71 J	NA	250 U	NA	50 U	137
1,1-DICHLOROPROPENE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,2,3-TRICHLOROBENZENE	10 U	200 U	NA	250 U	NA	50 U	2 U
1,2,3-TRICHLOROPROPANE	10 U	200 U	NA	250 U	NA	50 U	2 U
1,2,3-TRIMETHYLBENZENE	NA	1000 U	NA	1200 U	NA	250 U	NA
1,2,4-TRICHLOROBENZENE	10 U	200 U	NA	250 U	NA	50 U	2 U
1,2,4-TRIMETHYLBENZENE	3.9 J	200 U	NA	250 U	NA	50 U	0.45 J
1,2-DIBROMO-3-CHLOROPROPANE	35 U	400 U	NA	500 U	NA	100 U	7 U
1,2-DIBROMOETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,2-DICHLOROBENZENE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,2-DICHLOROETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,2-DICHLOROPROPANE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,3,5-TRIMETHYLBENZENE	5 U	NA	NA	NA	NA	NA	1 U
1,3-DICHLOROBENZENE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,3-DICHLOROPROPANE	5 U	200 U	NA	250 U	NA	50 U	1 U
1,4-DICHLOROBENZENE	5 U	200 U	NA	250 U	NA	50 U	0.25 J
2,2-DICHLOROPROPANE	5 U	200 U	NA	250 U	NA	50 U	1 U
2-BUTANONE	50 UR	1000 U	NA	1200 U	NA	250 U	10 UR
2-CHLOROETHYL VINYL ETHER	15 U	1000 U	NA	1200 U	NA	250 U	3 U
2-CHLOROTOLUENE	5 U	200 U	NA	250 U	NA	50 U	1 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2D-012408	OW-2D	MRC-OW2D-011509	MRC-OW2D-011509DL	MRC-OW2D-042209	MRC-OW2D-042209DL	OW2I-012408
LABORATORY ID:	9720529004	A8K180174002	640-20361-1	A9A160250004	A9D230208001	A9D230208001	9720529002
SAMPLE DATE:	1/24/2008	11/17/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW2D	OW-2D	OW2D	OW2D	OW2D	OW2D	OW2I
2-HEXANONE	25 U	1000 U	NA	1200 U	NA	250 U	5 U
4-CHLOROTOLUENE	5 U	200 U	NA	250 U	NA	50 U	1 U
4-ISOPROPYLTOLUENE	5 U	200 U	NA	250 U	NA	50 U	1 U
4-METHYL-2-PENTANONE	25 U	1000 U	NA	1200 U	NA	250 U	5 U
ACETONE	50 UR	1000 U	NA	1200 U	NA	250 U	10 UR
BENZENE	4.3 J	200 U	NA	250 U	NA	50 U	1.5
BROMOBENZENE	5 U	200 U	NA	250 U	NA	50 U	1 U
BROMOCHLOROMETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
BROMODICHLOROMETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
BROMOFORM	5 U	200 U	NA	250 U	NA	50 U	1 U
BROMOMETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
CARBON DISULFIDE	5 U	200 U	NA	250 U	NA	50 U	1 U
CARBON TETRACHLORIDE	5 U	200 U	NA	250 U	NA	50 U	8.4
CHLOROBENZENE	5 U	200 U	NA	250 U	NA	50 U	1 U
CHLORODIBROMOMETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
CHLOROETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
CHLOROFORM	5 U	200 U	NA	250 U	NA	50 U	18.7
CHLOROMETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
CIS-1,2-DICHLOROETHENE	1190 L	3800	NA	4200	NA	1600	3420 L
CIS-1,3-DICHLOROPROPENE	5 U	200 U	NA	250 U	NA	50 U	1 U
DIBROMOMETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
DICHLORODIFLUOROMETHANE	5 U	200 U	NA	250 U	NA	50 UJ	1 U
DIISOPROPYL ETHER	5 U	1000 U	NA	1200 U	NA	250 U	1 U
ETHYL TERT-BUTYL ETHER	5 U	1000 U	NA	1200 U	NA	250 U	1 U
ETHYLBENZENE	5 U	200 U	NA	250 U	NA	50 U	1 U
FLUORODICHLOROMETHANE	5 U	NA	NA	NA	NA	NA	1 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2D-012408	OW-2D	MRC-OW2D-011509	MRC-OW2D-011509DL	MRC-OW2D-042209	MRC-OW2D-042209DL	OW2I-012408
LABORATORY ID:	9720529004	A8K180174002	640-20361-1	A9A160250004	A9D230208001	A9D230208001	9720529002
SAMPLE DATE:	1/24/2008	11/17/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW2D	OW-2D	OW2D	OW2D	OW2D	OW2D	OW2I
HEXACHLOROBUTADIENE	25 U	200 U	NA	250 U	NA	50 U	5 U
ISOPROPYLBENZENE	5 U	200 U	NA	250 U	NA	50 U	1.6
M+P-XYLENES	3.2 J	400 U	NA	500 U	NA	100 U	0.51 B
METHYL TERT-BUTYL ETHER	5 U	1000 U	NA	1200 U	NA	250 U	1 U
METHYLENE CHLORIDE	2 J	200 U	NA	290 B	NA	50 U	1
NAPHTHALENE	6 J	200 U	NA	250 U	NA	50 U	4.1
N-BUTYLBENZENE	5 U	200 U	NA	250 U	NA	50 U	1 U
N-PROPYLBENZENE	5 U	200 U	NA	250 U	NA	50 U	1 U
O-XYLENE	2.5 J	200 U	NA	250 U	NA	50 U	4.5
SEC-BUTYLBENZENE	10 U	200 U	NA	250 U	NA	50 U	1.1 J
STYRENE	5 U	200 U	NA	250 U	NA	50 U	1 U
TERT-AMYL METHYL ETHER	10 U	1000 U	NA	1200 U	NA	250 U	2 U
TERT-BUTYLBENZENE	10 U	200 U	NA	250 U	NA	50 U	2 U
TERTIARY-BUTYL ALCOHOL	50 UR	4000 UR	NA	5000 UR	NA	1000 UR	10 UR
TETRACHLOROETHENE	14.2 J	200 U	NA	250 U	NA	50 U	55.5 J
TOLUENE	2.4 J	200 U	NA	250 U	NA	50 U	0.53 J
TOTAL XYLENES	5.7 J	400 U	NA	500 U	NA	100 U	5
TRANS-1,2-DICHLOROETHENE	8.9	200 U	NA	250 U	NA	18 J	56
TRANS-1,3-DICHLOROPROPENE	5 U	200 U	NA	250 U	NA	50 U	1 U
TRICHLOROETHENE	12200 L	6600	NA	2400	NA	60	9940 L
TRICHLOROFLUOROMETHANE	5 U	200 U	NA	250 U	NA	50 U	1 U
VINYL ACETATE	25 UR	400 U	NA	500 U	NA	100 U	5 UR
VINYL CHLORIDE	23.3	510	NA	1100	NA	1100	211 L
DISSOLVED GASES (ug/l)							
ETHANE	5	2.4	0.5 U	NA	NA	55	3.2
ETHENE	27.5	89	43	NA	NA	290	9.2

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2D-012408	OW-2D	MRC-OW2D-011509	MRC-OW2D-011509DL	MRC-OW2D-042209	MRC-OW2D-042209DL	OW2I-012408
LABORATORY ID:	9720529004	A8K180174002	640-20361-1	A9A160250004	A9D230208001	A9D230208001	9720529002
SAMPLE DATE:	1/24/2008	11/17/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW2D	OW-2D	OW2D	OW2D	OW2D	OW2D	OW2I
METHANE	350	490	190	NA	NA	1400	3390
MISCELLANEOUS (mg/L)							
CHLORIDE	48.8	NA	48.6	NA	462	NA	83
LACTIC ACID	NA	NA	NA	NA	NA	NA	NA
NITRATE-N	0.2 U	0.1 U	0.1 U	NA	0.1 U	NA	0.06
NITRITE-N	0.2 U	0.1 U	0.1 U	NA	0.1 U	NA	0.2 U
PYRUVIC ACID	NA	NA	NA	NA	NA	NA	NA
SULFATE	15.1	17.2	1 U	NA	0.2	NA	43.3
TOTAL DISSOLVED SOLIDS		270	230	NA	880	NA	NA
TOTAL ORGANIC CARBON	5.7	24	NA	8	8	NA	3.1
TOTAL SUSPENDED SOLIDS	NA	20	9	NA	60	NA	NA
SEMIVOLATILES (ug/L)							
1,4-DIOXANE	1.9 J	0.86 J	NA	NA	NA	NA	2.1 J
INORGANICS (ug/L)							
ANTIMONY	0.1 B	0.14 B	NA	NA	0.13 B	NA	0.2 B
ARSENIC	0.9	0.19 B	NA	NA	0.3 B	NA	1.3
BARIUM	110	49.3	NA	NA	249	NA	208
BERYLLIUM	0.1	0.37	NA	NA	0.29 B	NA	5.7
CADMIUM	0.3	0.033 B	NA	NA	0.21 B	NA	0.4
CHROMIUM	2 U	0.87 B	NA	NA	0.45	NA	2 U
COBALT	30.8	10.2	NA	NA	16.8	NA	235
COPPER	6 U	0.57 K	NA	NA	0.97 B	NA	6 U
IRON	NA	38900	NA	NA	85200	NA	NA
LEAD	2 U	0.17 U	NA	NA	0.28 B	NA	2 U
MANGANESE	NA	3210	NA	NA	5580	NA	NA
MERCURY	0.5 U	0.1 U	NA	NA	0.1 UL	NA	0.5 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2D-012408	OW-2D	MRC-OW2D-011509	MRC-OW2D-011509DL	MRC-OW2D-042209	MRC-OW2D-042209DL	OW2I-012408
LABORATORY ID:	9720529004	A8K180174002	640-20361-1	A9A160250004	A9D230208001	A9D230208001	9720529002
SAMPLE DATE:	1/24/2008	11/17/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW2D	OW-2D	OW2D	OW2D	OW2D	OW2D	OW2I
MOLYBDENUM	0.8	0.43 B	NA	NA	0.26 B	NA	0.2
NICKEL	20.6	8.8	NA	NA	19.4	NA	136
SELENIUM	2	0.09 U	NA	NA	0.12 B	NA	5
SILVER	0.4 B	0.009 B	NA	NA	0.006 U	NA	0.4 B
THALLIUM	0.02	0.3 B	NA	NA	0.09 U	NA	0.06
VANADIUM	0.3	0.98 B	NA	NA	0.86 B	NA	1 U
ZINC	19.8	14.6 B	NA	NA	21.8 B	NA	137
INORGANICS FILTERED (ug/L)							
ANTIMONY	2 U	0.072 B	NA	NA	NA	NA	2 U
ARSENIC	3 U	0.2 B	NA	NA	NA	NA	3 U
BARIUM	108	39.4	NA	NA	NA	NA	205
BERYLLIUM	1 U	0.31 B	NA	NA	NA	NA	5.9
CADMIUM	1 U	0.02 B	NA	NA	NA	NA	1 U
CHROMIUM	5.4	2.1 B	NA	NA	NA	NA	6.7
COBALT	30.2	7.2	NA	NA	NA	NA	230
COPPER	5 U	0.05 U	NA	NA	NA	NA	1.4
IRON	NA	36400	NA	NA	NA	NA	NA
LEAD	2 U	0.17 U	NA	NA	NA	NA	2 U
MANGANESE	NA	3120	NA	NA	NA	NA	NA
MERCURY	NA	0.1 U	NA	NA	NA	NA	NA
MOLYBDENUM	2 U	0.26 B	NA	NA	NA	NA	2 U
NICKEL	24.1	6.7	NA	NA	NA	NA	137
SELENIUM	5 U	0.09 U	NA	NA	NA	NA	2 K
SILVER	1 U	0.0032 U	NA	NA	NA	NA	1 U
THALLIUM	1 U	0.24 B	NA	NA	NA	NA	1 U
VANADIUM	1 U	0.36 B	NA	NA	NA	NA	1.1

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

	SAMPLE ID:	OW2D-012408	OW-2D	MRC-OW2D-011509	MRC-OW2D-011509DL	MRC-OW2D-042209	MRC-OW2D-042209DL	OW2I-012408
	LABORATORY ID:	9720529004	A8K180174002	640-20361-1	A9A160250004	A9D230208001	A9D230208001	9720529002
	SAMPLE DATE:	1/24/2008	11/17/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
	LOCATION:	OW2D	OW-2D	OW2D	OW2D	OW2D	OW2D	OW2I
ZINC		22.5	4.5 B	NA	NA	NA	NA	129

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2I-012408-D	OW2I-111208	MRC-OW2I-011309	MRC-OW2I-011309DL	MRC-OW2I-042109	MRC-OW2I-042109DL	OW3D-012408
LABORATORY ID:	9720529006	A8K130175003	640-20274-3	A9A140132004	A9D220174003	A9D220174003	9720529005
SAMPLE DATE:	1/24/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009	1/24/2008
LOCATION:	OW2I	OW-2I	OW2I	OW2I	OW2I	OW2I	OW3D
VOLATILES (ug/L)							
1,1,1,2-TETRACHLOROETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,1,1-TRICHLOROETHANE	4	110 U	NA	330 U	NA	2 U	1 U
1,1,2,2-TETRACHLOROETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,1,2-TRICHLOROTRIFLUOROETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,1-DICHLOROETHANE	37.1	110 U	NA	330 U	NA	7.6	3.2
1,1-DICHLOROETHENE	134	80 J	NA	91 J	NA	0.72 J	8.6
1,1-DICHLOROPROPENE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,2,3-TRICHLOROBENZENE	2 U	110 U	NA	330 U	NA	2 U	2 U
1,2,3-TRICHLOROPROPANE	2 U	110 U	NA	330 U	NA	2 U	2 U
1,2,3-TRIMETHYLBENZENE	NA	560 U	NA	1700 U	NA	1.3 J	NA
1,2,4-TRICHLOROBENZENE	2 U	110 U	NA	330 U	NA	2 U	2 U
1,2,4-TRIMETHYLBENZENE	0.44 J	110 U	NA	330 U	NA	2 U	1 J
1,2-DIBROMO-3-CHLOROPROPANE	7 U	220 U	NA	670 U	NA	4 U	7 U
1,2-DIBROMOETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,2-DICHLOROBENZENE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,2-DICHLOROETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,2-DICHLOROPROPANE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,3,5-TRIMETHYLBENZENE	1 U	NA	NA	NA	NA	NA	1 U
1,3-DICHLOROBENZENE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,3-DICHLOROPROPANE	1 U	110 U	NA	330 U	NA	2 U	1 U
1,4-DICHLOROBENZENE	0.25 J	110 U	NA	330 U	NA	2 U	1 U
2,2-DICHLOROPROPANE	1 U	110 U	NA	330 U	NA	2 U	1 U
2-BUTANONE	10 UR	560 U	NA	1700 U	NA	19	10 UR
2-CHLOROETHYL VINYL ETHER	3 U	560 U	NA	1700 U	NA	10 U	3 U
2-CHLOROTOLUENE	1 U	110 U	NA	330 U	NA	2 U	1 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2I-012408-D	OW2I-111208	MRC-OW2I-011309	MRC-OW2I-011309DL	MRC-OW2I-042109	MRC-OW2I-042109DL	OW3D-012408
LABORATORY ID:	9720529006	A8K130175003	640-20274-3	A9A140132004	A9D220174003	A9D220174003	9720529005
SAMPLE DATE:	1/24/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009	1/24/2008
LOCATION:	OW2I	OW-2I	OW2I	OW2I	OW2I	OW2I	OW3D
2-HEXANONE	5 U	560 U	NA	1700 U	NA	10 U	5 U
4-CHLOROTOLUENE	1 U	110 U	NA	330 U	NA	2 U	1 U
4-ISOPROPYLTOLUENE	1 U	110 U	NA	330 U	NA	2 U	1 U
4-METHYL-2-PENTANONE	5 U	560 U	NA	1700 U	NA	10 U	5 U
ACETONE	10 UR	560 U	NA	1700 U	NA	5.4 J	10 UR
BENZENE	1.4	110 U	NA	330 U	NA	2 U	0.57 J
BROMOBENZENE	1 U	110 U	NA	330 U	NA	2 U	1 U
BROMOCHLOROMETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
BROMODICHLOROMETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
BROMOFORM	1 U	110 U	NA	330 U	NA	2 U	1 U
BROMOMETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
CARBON DISULFIDE	1 U	110 U	NA	330 U	NA	2 U	1 U
CARBON TETRACHLORIDE	8.3	110 U	NA	330 U	NA	2 U	1 U
CHLOROBENZENE	1 U	110 U	NA	330 U	NA	2 U	1 U
CHLORODIBROMOMETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
CHLOROETHANE	0.81 J	110 U	NA	330 U	NA	2 U	1 U
CHLOROFORM	18.5	110 U	NA	330 U	NA	2 U	1 U
CHLOROMETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
CIS-1,2-DICHLOROETHENE	3470 L	3300	NA	9200	NA	53	331 L
CIS-1,3-DICHLOROPROPENE	1 U	110 U	NA	330 U	NA	2 U	1 U
DIBROMOMETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
DICHLORODIFLUOROMETHANE	1 U	110 U	NA	330 U	NA	2 UJ	1 U
DIISOPROPYL ETHER	1 U	560 U	NA	1700 U	NA	10 U	1 U
ETHYL TERT-BUTYL ETHER	1 U	560 U	NA	1700 U	NA	10 U	1 U
ETHYLBENZENE	1 U	110 U	NA	330 U	NA	2 U	1 U
FLUORODICHLOROMETHANE	1 U	NA	NA	NA	NA	NA	1 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2I-012408-D	OW2I-111208	MRC-OW2I-011309	MRC-OW2I-011309DL	MRC-OW2I-042109	MRC-OW2I-042109DL	OW3D-012408
LABORATORY ID:	9720529006	A8K130175003	640-20274-3	A9A140132004	A9D220174003	A9D220174003	9720529005
SAMPLE DATE:	1/24/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009	1/24/2008
LOCATION:	OW2I	OW-2I	OW2I	OW2I	OW2I	OW2I	OW3D
HEXACHLOROBUTADIENE	5 U	110 U	NA	330 U	NA	2 U	5 U
ISOPROPYLBENZENE	1.7	110 U	NA	330 U	NA	0.44 J	0.73 J
M+P-XYLENES	0.49 B	220 U	NA	670 U	NA	4 U	0.55 B
METHYL TERT-BUTYL ETHER	1 U	560 U	NA	1700 U	NA	10 U	1 U
METHYLENE CHLORIDE	0.94 J	110 U	NA	330 U	NA	2 U	1 U
NAPHTHALENE	4	110 U	NA	330 U	NA	1 J	1.4 J
N-BUTYLBENZENE	1 U	110 U	NA	330 U	NA	2 U	1 U
N-PROPYLBENZENE	1 U	110 U	NA	330 U	NA	2 U	1 U
O-XYLENE	4.1	110 U	NA	330 U	NA	0.75 J	0.45 J
SEC-BUTYLBENZENE	1.1 J	110 U	NA	330 U	NA	2 U	2 U
STYRENE	1 U	110 U	NA	330 U	NA	2 U	1 U
TERT-AMYL METHYL ETHER	2 U	560 U	NA	1700 U	NA	10 U	2 U
TERT-BUTYLBENZENE	2 U	110 U	NA	330 U	NA	2 U	2 U
TERTIARY-BUTYL ALCOHOL	10 UR	2200 UR	NA	6700 UR	NA	40 UR	10 UR
TETRACHLOROETHENE	53.5 J	110 U	NA	330 U	NA	2 U	19.4 J
TOLUENE	0.53 J	110 U	NA	330 U	NA	2 U	0.37 J
TOTAL XYLENES	4.6	220 U	NA	670 U	NA	4 U	1 B
TRANS-1,2-DICHLOROETHENE	55.9	32 J	NA	330 U	NA	12	2.4
TRANS-1,3-DICHLOROPROPENE	1 U	110 U	NA	330 U	NA	2 U	1 U
TRICHLOROETHENE	9910 L	2800	NA	250 J	NA	39	2320 L
TRICHLOROFLUOROMETHANE	1 U	110 U	NA	330 U	NA	2 U	1 U
VINYL ACETATE	5 UR	220 U	NA	670 U	NA	4 U	5 UR
VINYL CHLORIDE	211 L	170	NA	760	NA	16	27.9
DISSOLVED GASES (ug/l)							
ETHANE	3.2	0.5 U	NA	2.5 U	NA	6.2	2.7 J
ETHENE	9.1	3.7	NA	60	NA	290	15.1

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2I-012408-D	OW2I-111208	MRC-OW2I-011309	MRC-OW2I-011309DL	MRC-OW2I-042109	MRC-OW2I-042109DL	OW3D-012408
LABORATORY ID:	9720529006	A8K130175003	640-20274-3	A9A140132004	A9D220174003	A9D220174003	9720529005
SAMPLE DATE:	1/24/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009	1/24/2008
LOCATION:	OW2I	OW-2I	OW2I	OW2I	OW2I	OW2I	OW3D
METHANE	3530	3400	NA	850	NA	1200	1190
MISCELLANEOUS (mg/L)							
CHLORIDE	82.6	NA	97.9	NA	169	NA	41.5
LACTIC ACID	NA	NA	NA	NA	NA	NA	NA
NITRATE-N	0.2 U	0.1 UL	0.1 U	NA	0.1 U	NA	0.04
NITRITE-N	0.2 U	0.1 UL	0.1 U	NA	0.1 U	NA	0.2 U
PYRUVIC ACID	NA	NA	NA	NA	NA	NA	NA
SULFATE	42.2	1.3	0.4	NA	4.6	NA	75
TOTAL DISSOLVED SOLIDS	NA	760	590	NA	400	NA	NA
TOTAL ORGANIC CARBON	3.3	310	NA	100	38	NA	2.1
TOTAL SUSPENDED SOLIDS	NA	30	59	NA	43	NA	NA
SEMIVOLATILES (ug/L)							
1,4-DIOXANE	2.5 J	NA	NA	NA	NA	NA	2.1 J
INORGANICS (ug/L)							
ANTIMONY	2 U	NA	NA	NA	0.12 B	NA	0.07 B
ARSENIC	1.1	NA	NA	NA	0.29 B	NA	0.6
BARIUM	197	NA	NA	NA	287	NA	86.6
BERYLLIUM	5.7	NA	NA	NA	0.46	NA	0.07
CADMIUM	0.3	NA	NA	NA	0.18 B	NA	0.1
CHROMIUM	2 U	NA	NA	NA	0.97 B	NA	2 U
COBALT	225	NA	NA	NA	32.4	NA	25
COPPER	6 U	NA	NA	NA	1.3	NA	6 U
IRON	NA	NA	NA	NA	55100	NA	NA
LEAD	2 U	NA	NA	NA	0.76	NA	2 U
MANGANESE	NA	NA	NA	NA	8700	NA	NA
MERCURY	0.5 U	NA	NA	NA	0.1 U	NA	0.5 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	OW2I-012408-D	OW2I-111208	MRC-OW2I-011309	MRC-OW2I-011309DL	MRC-OW2I-042109	MRC-OW2I-042109DL	OW3D-012408
LABORATORY ID:	9720529006	A8K130175003	640-20274-3	A9A140132004	A9D220174003	A9D220174003	9720529005
SAMPLE DATE:	1/24/2008	11/12/2008	1/13/2009	1/13/2009	4/21/2009	4/21/2009	1/24/2008
LOCATION:	OW2I	OW-2I	OW2I	OW2I	OW2I	OW2I	OW3D
MOLYBDENUM	0.1	NA	NA	NA	0.49 B	NA	0.3
NICKEL	133	NA	NA	NA	35.1	NA	22.9
SELENIUM	4	NA	NA	NA	0.36 B	NA	2
SILVER	0.4 B	NA	NA	NA	0.038 B	NA	0.4 B
THALLIUM	0.04	NA	NA	NA	0.19 B	NA	0.03
VANADIUM	1 U	NA	NA	NA	2 B	NA	0.05
ZINC	131	NA	NA	NA	54.2	NA	12.8
INORGANICS FILTERED (ug/L)							
ANTIMONY	2 U	NA	NA	NA	NA	NA	2 U
ARSENIC	3 U	NA	NA	NA	NA	NA	3 U
BARIUM	202	NA	NA	NA	NA	NA	82
BERYLLIUM	5.9	NA	NA	NA	NA	NA	1 U
CADMIUM	1 U	NA	NA	NA	NA	NA	1 U
CHROMIUM	6.2	NA	NA	NA	NA	NA	3.2
COBALT	218	NA	NA	NA	NA	NA	23.5
COPPER	0.5	NA	NA	NA	NA	NA	0.9
IRON	NA	NA	NA	NA	NA	NA	NA
LEAD	2 U	NA	NA	NA	NA	NA	2 U
MANGANESE	NA	NA	NA	NA	NA	NA	NA
MERCURY	NA	NA	NA	NA	NA	NA	NA
MOLYBDENUM	2 U	NA	NA	NA	NA	NA	2 U
NICKEL	127	NA	NA	NA	NA	NA	22.4
SELENIUM	2 K	NA	NA	NA	NA	NA	5 U
SILVER	1 U	NA	NA	NA	NA	NA	1 U
THALLIUM	1 U	NA	NA	NA	NA	NA	1 U
VANADIUM	1.1	NA	NA	NA	NA	NA	0.6

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	**OW2I-012408-D**	**OW2I-111208**	**MRC-OW2I-011309**	**MRC-OW2I-011309DL**	**MRC-OW2I-042109**	**MRC-OW2I-042109DL**	**OW3D-012408**
LABORATORY ID:	**9720529006**	**A8K130175003**	**640-20274-3**	**A9A140132004**	**A9D220174003**	**A9D220174003**	**9720529005**
SAMPLE DATE:	**1/24/2008**	**11/12/2008**	**1/13/2009**	**1/13/2009**	**4/21/2009**	**4/21/2009**	**1/24/2008**
LOCATION:	**OW2I**	**OW-2I**	**OW2I**	**OW2I**	**OW2I**	**OW2I**	**OW3D**
ZINC	128	NA	NA	NA	NA	NA	11.8

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3D-100208	OW-3D	MRC-OW3D-011509	MRC-OW3D-011509DL	MRC-OW3D-042209	MRC-OW3D-042209DL	OW3I-012408
LABORATORY ID:	017FJ-3	A8K190154001	A9A160250002	A9A160250002	A9D230208003	A9D230208003	9720529003
SAMPLE DATE:	10/2/2008	11/18/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW3D	OW-3D	OW3D	OW3D	OW3D	OW3D	OW3I
VOLATILES (ug/L)							
1,1,1,2-TETRACHLOROETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,1,1-TRICHLOROETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,1,2,2-TETRACHLOROETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,1,2-TRICHLOROTRIFLUOROETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,1-DICHLOROETHANE	NA	100 U	NA	140 U	NA	83 U	2.2
1,1-DICHLOROETHENE	NA	34 J	NA	140 U	NA	83 U	2.5
1,1-DICHLOROPROPENE	NA	100 U	NA	140 U	NA	83 U	1 U
1,2,3-TRICHLOROBENZENE	NA	100 U	NA	140 U	NA	83 U	2 U
1,2,3-TRICHLOROPROPANE	NA	100 U	NA	140 U	NA	83 U	2 U
1,2,3-TRIMETHYLBENZENE	NA	500 U	NA	720 U	NA	420 U	NA
1,2,4-TRICHLOROBENZENE	NA	100 U	NA	140 U	NA	83 U	2 U
1,2,4-TRIMETHYLBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
1,2-DIBROMO-3-CHLOROPROPANE	NA	200 U	NA	290 U	NA	170 U	7 U
1,2-DIBROMOETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,2-DICHLOROBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
1,2-DICHLOROETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,2-DICHLOROPROPANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,3,5-TRIMETHYLBENZENE	NA	NA	NA	NA	NA	NA	1 U
1,3-DICHLOROBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
1,3-DICHLOROPROPANE	NA	100 U	NA	140 U	NA	83 U	1 U
1,4-DICHLOROBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
2,2-DICHLOROPROPANE	NA	100 U	NA	140 U	NA	83 U	1 U
2-BUTANONE	NA	500 U	NA	720 U	NA	420 U	10 UR
2-CHLOROETHYL VINYL ETHER	NA	500 U	NA	720 U	NA	420 U	3 U
2-CHLOROTOLUENE	NA	100 U	NA	140 U	NA	83 U	1 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3D-100208	OW-3D	MRC-OW3D-011509	MRC-OW3D-011509DL	MRC-OW3D-042209	MRC-OW3D-042209DL	OW3I-012408
LABORATORY ID:	017FJ-3	A8K190154001	A9A160250002	A9A160250002	A9D230208003	A9D230208003	9720529003
SAMPLE DATE:	10/2/2008	11/18/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW3D	OW-3D	OW3D	OW3D	OW3D	OW3D	OW3I
2-HEXANONE	NA	500 U	NA	720 U	NA	420 U	5 U
4-CHLOROTOLUENE	NA	100 U	NA	140 U	NA	83 U	1 U
4-ISOPROPYLTOLUENE	NA	100 U	NA	140 U	NA	83 U	1 U
4-METHYL-2-PENTANONE	NA	500 U	NA	720 U	NA	420 U	5 U
ACETONE	NA	500 U	NA	720 U	NA	420 U	10 UR
BENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
BROMOBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
BROMOCHLOROMETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
BROMODICHLOROMETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
BROMOFORM	NA	100 U	NA	140 U	NA	83 U	1 U
BROMOMETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
CARBON DISULFIDE	NA	100 U	NA	140 U	NA	83 U	1 U
CARBON TETRACHLORIDE	NA	100 U	NA	140 U	NA	83 U	1 U
CHLOROBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
CHLORODIBROMOMETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
CHLOROETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
CHLOROFORM	NA	100 U	NA	140 U	NA	83 U	1 U
CHLOROMETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
CIS-1,2-DICHLOROETHENE	NA	2800	NA	4000	NA	2700	253 L
CIS-1,3-DICHLOROPROPENE	NA	100 U	NA	140 U	NA	83 U	1 U
DIBROMOMETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
DICHLORODIFLUOROMETHANE	NA	100 U	NA	140 U	NA	83 UJ	1 U
DIISOPROPYL ETHER	NA	500 U	NA	720 U	NA	420 U	1 U
ETHYL TERT-BUTYL ETHER	NA	500 U	NA	720 U	NA	420 U	1 U
ETHYLBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
FLUORODICHLOROMETHANE	NA	NA	NA	NA	NA	NA	1 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3D-100208	OW-3D	MRC-OW3D-011509	MRC-OW3D-011509DL	MRC-OW3D-042209	MRC-OW3D-042209DL	OW3I-012408
LABORATORY ID:	017FJ-3	A8K190154001	A9A160250002	A9A160250002	A9D230208003	A9D230208003	9720529003
SAMPLE DATE:	10/2/2008	11/18/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW3D	OW-3D	OW3D	OW3D	OW3D	OW3D	OW3I
HEXACHLOROBUTADIENE	NA	100 U	NA	140 U	NA	83 U	5 U
ISOPROPYLBENZENE	NA	100 U	NA	140 U	NA	83 U	0.58 J
M+P-XYLENES	NA	200 U	NA	290 U	NA	170 U	2 U
METHYL TERT-BUTYL ETHER	NA	500 U	NA	720 U	NA	420 U	1 U
METHYLENE CHLORIDE	NA	100 U	NA	230 B	NA	83 U	1 U
NAPHTHALENE	NA	100 U	NA	140 U	NA	83 U	2 U
N-BUTYLBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
N-PROPYLBENZENE	NA	100 U	NA	140 U	NA	83 U	1 U
O-XYLENE	NA	100 U	NA	140 U	NA	83 U	1 U
SEC-BUTYLBENZENE	NA	100 U	NA	140 U	NA	83 U	2 U
STYRENE	NA	100 U	NA	140 U	NA	83 U	1 U
TERT-AMYL METHYL ETHER	NA	500 U	NA	720 U	NA	420 U	2 U
TERT-BUTYLBENZENE	NA	100 U	NA	140 U	NA	83 U	2 U
TERTIARY-BUTYL ALCOHOL	NA	2000 UR	NA	2900 UR	NA	1700 UR	10 UR
TETRACHLOROETHENE	NA	100 U	NA	140 U	NA	83 U	17 J
TOLUENE	NA	100 U	NA	140 U	NA	83 U	1 U
TOTAL XYLENES	NA	200 U	NA	290 U	NA	170 U	3 U
TRANS-1,2-DICHLOROETHENE	NA	100 U	NA	140 U	NA	83 U	1.7
TRANS-1,3-DICHLOROPROPENE	NA	100 U	NA	140 U	NA	83 U	1 U
TRICHLOROETHENE	NA	3000	NA	140 U	NA	83 U	932 L
TRICHLOROFLUOROMETHANE	NA	100 U	NA	140 U	NA	83 U	1 U
VINYL ACETATE	NA	200 U	NA	290 U	NA	170 U	5 UR
VINYL CHLORIDE	NA	45 J	NA	75 J	NA	440	23
DISSOLVED GASES (ug/l)							
ETHANE	NA	0.5 U	NA	5 U	NA	10 U	3 U
ETHENE	NA	11	NA	3.6 J	NA	11	4

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3D-100208	OW-3D	MRC-OW3D-011509	MRC-OW3D-011509DL	MRC-OW3D-042209	MRC-OW3D-042209DL	OW3I-012408
LABORATORY ID:	017FJ-3	A8K190154001	A9A160250002	A9A160250002	A9D230208003	A9D230208003	9720529003
SAMPLE DATE:	10/2/2008	11/18/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW3D	OW-3D	OW3D	OW3D	OW3D	OW3D	OW3I
METHANE	NA	1400	NA	2100	NA	7100	990
MISCELLANEOUS (mg/L)							
CHLORIDE	NA	NA	2	NA	862	NA	39.1
LACTIC ACID	NA	NA	NA	NA	2.7 U	NA	NA
NITRATE-N	NA	0.1 U	0.1 U	NA	0.1 U	NA	0.08
NITRITE-N	NA	0.1 U	0.1 U	NA	0.5 U	NA	0.2 U
PYRUVIC ACID	NA	NA	NA	NA	0.63 U	NA	NA
SULFATE	NA	0.3	1 U	NA	1 U	NA	37.3
TOTAL DISSOLVED SOLIDS	NA	540	550	NA	1500	NA	NA
TOTAL ORGANIC CARBON	NA	120	NA	140	11	NA	1.7
TOTAL SUSPENDED SOLIDS	NA	90	58	NA	300	NA	NA
SEMIVOLATILES (ug/L)							
1,4-DIOXANE	NA	1 U	NA	NA	NA	NA	1.8 J
INORGANICS (ug/L)							
ANTIMONY	NA	0.018 U	NA	NA	0.024 U	NA	0.2 B
ARSENIC	NA	0.53	NA	NA	0.83 J	NA	0.5
BARIUM	NA	193	NA	NA	418	NA	85.7
BERYLLIUM	NA	0.32	NA	NA	0.65	NA	0.1
CADMIUM	NA	0.0042 UL	NA	NA	0.007 UL	NA	0.04
CHROMIUM	NA	0.42 K	NA	NA	2.1 K	NA	2 U
COBALT	NA	51.4	NA	NA	17.6	NA	22.5
COPPER	NA	0.78	NA	NA	3.2 K	NA	6 U
IRON	NA	93900	NA	NA	149000	NA	NA
LEAD	NA	0.17 U	NA	NA	1.2 K	NA	0.04
MANGANESE	NA	7050	NA	NA	3890	NA	NA
MERCURY	NA	0.1 U	NA	NA	0.1 UL	NA	0.5 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3D-100208	OW-3D	MRC-OW3D-011509	MRC-OW3D-011509DL	MRC-OW3D-042209	MRC-OW3D-042209DL	OW3I-012408
LABORATORY ID:	017FJ-3	A8K190154001	A9A160250002	A9A160250002	A9D230208003	A9D230208003	9720529003
SAMPLE DATE:	10/2/2008	11/18/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009	1/24/2008
LOCATION:	OW3D	OW-3D	OW3D	OW3D	OW3D	OW3D	OW3I
MOLYBDENUM	NA	0.27 B	NA	NA	0.37 B	NA	0.6
NICKEL	NA	9.9	NA	NA	4.4	NA	19.5
SELENIUM	NA	0.09 U	NA	NA	1.1 B	NA	2
SILVER	NA	0.0032 U	NA	NA	0.006 U	NA	0.4 B
THALLIUM	NA	0.094 U	NA	NA	0.09 U	NA	0.03
VANADIUM	NA	0.46 B	NA	NA	3.5	NA	0.4
ZINC	NA	3.5 B	NA	NA	26.5 B	NA	47.5
INORGANICS FILTERED (ug/L)							
ANTIMONY	NA	0.018 U	NA	NA	NA	NA	2 U
ARSENIC	NA	0.22 B	NA	NA	NA	NA	3 U
BARIUM	NA	155	NA	NA	NA	NA	89.7
BERYLLIUM	NA	0.014 U	NA	NA	NA	NA	1 U
CADMIUM	NA	0.0042 UL	NA	NA	NA	NA	1 U
CHROMIUM	NA	0.17 K	NA	NA	NA	NA	3.9
COBALT	NA	49.7	NA	NA	NA	NA	22.4
COPPER	NA	0.12 B	NA	NA	NA	NA	0.7
IRON	NA	71600	NA	NA	NA	NA	NA
LEAD	NA	0.17 U	NA	NA	NA	NA	2 U
MANGANESE	NA	7160	NA	NA	NA	NA	NA
MERCURY	NA	0.1 U	NA	NA	NA	NA	NA
MOLYBDENUM	NA	0.32 B	NA	NA	NA	NA	2 U
NICKEL	NA	8.7	NA	NA	NA	NA	16.4
SELENIUM	NA	0.09 U	NA	NA	NA	NA	5 U
SILVER	NA	0.0032 U	NA	NA	NA	NA	1 U
THALLIUM	NA	0.32 B	NA	NA	NA	NA	1 U
VANADIUM	NA	0.19 U	NA	NA	NA	NA	0.8

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	**MRC-OW3D-100208**	**OW-3D**	**MRC-OW3D-011509**	**MRC-OW3D-011509DL**	**MRC-OW3D-042209**	**MRC-OW3D-042209DL**	**OW3I-012408**
LABORATORY ID:	**017FJ-3**	**A8K190154001**	**A9A160250002**	**A9A160250002**	**A9D230208003**	**A9D230208003**	**9720529003**
SAMPLE DATE:	**10/2/2008**	**11/18/2008**	**1/15/2009**	**1/15/2009**	**4/22/2009**	**4/22/2009**	**1/24/2008**
LOCATION:	**OW3D**	**OW-3D**	**OW3D**	**OW3D**	**OW3D**	**OW3D**	**OW3I**
ZINC	NA	2.9 B	NA	NA	NA	NA	45.9

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3I-100208	OW-3I	MRC-OW3I-011509	MRC-OW3I-011509DL	MRC-OW3I-042209	MRC-OW3I-042209DL
LABORATORY ID:	017FJ-2	A8K150126001	A9A160250003	A9A160250003	A9D230208002	A9D230208002
SAMPLE DATE:	10/2/2008	11/14/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009
LOCATION:	OW3I	OW-3I	OW3I	OW3I	OW3I	OW3I
VOLATILES (ug/L)						
1,1,1,2-TETRACHLOROETHANE	NA	40 U	NA	56 U	NA	5 U
1,1,1-TRICHLOROETHANE	NA	40 U	NA	56 U	NA	5 U
1,1,2,2-TETRACHLOROETHANE	NA	40 U	NA	56 U	NA	5 U
1,1,2-TRICHLOROTRIFLUOROETHANE	NA	40 U	NA	56 U	NA	5 U
1,1-DICHLOROETHANE	NA	40 U	NA	56 U	NA	5 U
1,1-DICHLOROETHENE	NA	9.4 J	NA	56 U	NA	5 U
1,1-DICHLOROPROPENE	NA	40 U	NA	56 U	NA	5 U
1,2,3-TRICHLOROBENZENE	NA	40 U	NA	56 U	NA	5 U
1,2,3-TRICHLOROPROPANE	NA	40 U	NA	56 U	NA	5 U
1,2,3-TRIMETHYLBENZENE	NA	200 U	NA	280 U	NA	25 U
1,2,4-TRICHLOROBENZENE	NA	40 U	NA	56 U	NA	5 U
1,2,4-TRIMETHYLBENZENE	NA	40 U	NA	56 U	NA	5 U
1,2-DIBROMO-3-CHLOROPROPANE	NA	80 U	NA	110 U	NA	10 U
1,2-DIBROMOETHANE	NA	40 U	NA	56 U	NA	5 U
1,2-DICHLOROBENZENE	NA	40 U	NA	56 U	NA	5 U
1,2-DICHLOROETHANE	NA	40 U	NA	56 U	NA	5 U
1,2-DICHLOROPROPANE	NA	40 U	NA	56 U	NA	5 U
1,3,5-TRIMETHYLBENZENE	NA	NA	NA	NA	NA	NA
1,3-DICHLOROBENZENE	NA	40 U	NA	56 U	NA	5 U
1,3-DICHLOROPROPANE	NA	40 U	NA	56 U	NA	5 U
1,4-DICHLOROBENZENE	NA	40 U	NA	56 U	NA	5 U
2,2-DICHLOROPROPANE	NA	40 U	NA	56 U	NA	5 U
2-BUTANONE	NA	200 U	NA	280 U	NA	25 U
2-CHLOROETHYL VINYL ETHER	NA	200 U	NA	280 U	NA	25 U
2-CHLOROTOLUENE	NA	40 U	NA	56 U	NA	5 U

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3I-100208	OW-3I	MRC-OW3I-011509	MRC-OW3I-011509DL	MRC-OW3I-042209	MRC-OW3I-042209DL
LABORATORY ID:	017FJ-2	A8K150126001	A9A160250003	A9A160250003	A9D230208002	A9D230208002
SAMPLE DATE:	10/2/2008	11/14/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009
LOCATION:	OW3I	OW-3I	OW3I	OW3I	OW3I	OW3I
2-HEXANONE	NA	200 U	NA	280 U	NA	25 U
4-CHLOROTOLUENE	NA	40 U	NA	56 U	NA	5 U
4-ISOPROPYLTOLUENE	NA	40 U	NA	56 U	NA	5 U
4-METHYL-2-PENTANONE	NA	200 U	NA	280 U	NA	25 U
ACETONE	NA	200 U	NA	280 U	NA	11 J
BENZENE	NA	40 U	NA	56 U	NA	5 U
BROMOBENZENE	NA	40 U	NA	56 U	NA	5 U
BROMOCHLOROMETHANE	NA	40 U	NA	56 U	NA	5 U
BROMODICHLOROMETHANE	NA	40 U	NA	56 U	NA	5 U
BROMOFORM	NA	40 U	NA	56 U	NA	5 U
BROMOMETHANE	NA	40 U	NA	56 U	NA	5 U
CARBON DISULFIDE	NA	40 U	NA	56 U	NA	5 U
CARBON TETRACHLORIDE	NA	40 U	NA	56 U	NA	5 U
CHLOROBENZENE	NA	40 U	NA	56 U	NA	5 U
CHLORODIBROMOMETHANE	NA	40 U	NA	56 U	NA	5 U
CHLOROETHANE	NA	40 U	NA	56 U	NA	5 U
CHLOROFORM	NA	40 U	NA	56 U	NA	5 U
CHLOROMETHANE	NA	40 U	NA	56 U	NA	5 U
CIS-1,2-DICHLOROETHENE	NA	330	NA	1700	NA	140
CIS-1,3-DICHLOROPROPENE	NA	40 U	NA	56 U	NA	5 U
DIBROMOMETHANE	NA	40 U	NA	56 U	NA	5 U
DICHLORODIFLUOROMETHANE	NA	40 U	NA	56 U	NA	5 UJ
DIISOPROPYL ETHER	NA	200 U	NA	280 U	NA	25 U
ETHYL TERT-BUTYL ETHER	NA	200 U	NA	280 U	NA	25 U
ETHYLBENZENE	NA	40 U	NA	56 U	NA	5 U
FLUORODICHLOROMETHANE	NA	NA	NA	NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3I-100208	OW-3I	MRC-OW3I-011509	MRC-OW3I-011509DL	MRC-OW3I-042209	MRC-OW3I-042209DL
LABORATORY ID:	017FJ-2	A8K150126001	A9A160250003	A9A160250003	A9D230208002	A9D230208002
SAMPLE DATE:	10/2/2008	11/14/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009
LOCATION:	OW3I	OW-3I	OW3I	OW3I	OW3I	OW3I
HEXACHLOROBUTADIENE	NA	40 U	NA	56 U	NA	5 U
ISOPROPYLBENZENE	NA	40 U	NA	56 U	NA	5 U
M+P-XYLENES	NA	80 U	NA	110 U	NA	10 U
METHYL TERT-BUTYL ETHER	NA	200 U	NA	280 U	NA	25 U
METHYLENE CHLORIDE	NA	40 U	NA	66 B	NA	5 U
NAPHTHALENE	NA	40 U	NA	56 U	NA	5 U
N-BUTYLBENZENE	NA	40 U	NA	56 U	NA	5 U
N-PROPYLBENZENE	NA	40 U	NA	56 U	NA	5 U
O-XYLENE	NA	40 U	NA	56 U	NA	5 U
SEC-BUTYLBENZENE	NA	40 U	NA	56 U	NA	5 U
STYRENE	NA	40 U	NA	56 U	NA	5 U
TERT-AMYL METHYL ETHER	NA	200 U	NA	280 U	NA	25 U
TERT-BUTYLBENZENE	NA	40 U	NA	56 U	NA	5 U
TERTIARY-BUTYL ALCOHOL	NA	800 UR	NA	1100 UR	NA	100 UR
TETRACHLOROETHENE	NA	40 U	NA	56 U	NA	5 U
TOLUENE	NA	40 U	NA	56 U	NA	5 U
TOTAL XYLENES	NA	80 U	NA	110 U	NA	10 U
TRANS-1,2-DICHLOROETHENE	NA	40 U	NA	56 U	NA	5 U
TRANS-1,3-DICHLOROPROPENE	NA	40 U	NA	56 U	NA	5 U
TRICHLOROETHENE	NA	1500	NA	53 J	NA	2.3 J
TRICHLOROFLUOROMETHANE	NA	40 U	NA	56 U	NA	5 U
VINYL ACETATE	NA	80 U	NA	110 U	NA	10 U
VINYL CHLORIDE	NA	32 J	NA	46 J	NA	7.2
DISSOLVED GASES (ug/l)						
ETHANE	NA	0.5 U	NA	10 U	NA	5 U
ETHENE	NA	5.1	NA	10 U	NA	4.3 J

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3I-100208	OW-3I	MRC-OW3I-011509	MRC-OW3I-011509DL	MRC-OW3I-042209	MRC-OW3I-042209DL
LABORATORY ID:	017FJ-2	A8K150126001	A9A160250003	A9A160250003	A9D230208002	A9D230208002
SAMPLE DATE:	10/2/2008	11/14/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009
LOCATION:	OW3I	OW-3I	OW3I	OW3I	OW3I	OW3I
METHANE	NA	2500	NA	2100	NA	5700
MISCELLANEOUS (mg/L)						
CHLORIDE	NA	NA	50.6	NA	158	NA
LACTIC ACID	NA	NA	NA	NA	2.7 U	NA
NITRATE-N	NA	0.1 U	0.1 U	NA	0.1 U	NA
NITRITE-N	NA	0.1 U	0.1 U	NA	0.1 U	NA
PYRUVIC ACID	NA	NA	NA	NA	0.63 U	NA
SULFATE	NA	0.5 K	0.2	NA	6.1	NA
TOTAL DISSOLVED SOLIDS	NA	300	300	NA	400	NA
TOTAL ORGANIC CARBON	NA	75	NA	41	13	NA
TOTAL SUSPENDED SOLIDS	NA	35	18	NA	37	NA
SEMIVOLATILES (ug/L)						
1,4-DIOXANE	NA	10 U	NA	NA	NA	NA
INORGANICS (ug/L)						
ANTIMONY	NA	0.035 B	NA	NA	0.26 B	NA
ARSENIC	NA	0.56	NA	NA	0.092 UL	NA
BARIUM	NA	53.8	NA	NA	36.4	NA
BERYLLIUM	NA	0.83	NA	NA	0.38 B	NA
CADMIUM	NA	0.022 B	NA	NA	0.058 B	NA
CHROMIUM	NA	0.64 K	NA	NA	0.88	NA
COBALT	NA	74.9	NA	NA	1.6	NA
COPPER	NA	0.96 B	NA	NA	1.1 B	NA
IRON	NA	57200	NA	NA	12800	NA
LEAD	NA	0.19	NA	NA	0.64 B	NA
MANGANESE	NA	12100	NA	NA	1380	NA
MERCURY	NA	0.1 UL	NA	NA	0.1 UL	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

SAMPLE ID:	MRC-OW3I-100208	OW-3I	MRC-OW3I-011509	MRC-OW3I-011509DL	MRC-OW3I-042209	MRC-OW3I-042209DL
LABORATORY ID:	017FJ-2	A8K150126001	A9A160250003	A9A160250003	A9D230208002	A9D230208002
SAMPLE DATE:	10/2/2008	11/14/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009
LOCATION:	OW3I	OW-3I	OW3I	OW3I	OW3I	OW3I
MOLYBDENUM	NA	0.23 B	NA	NA	0.53 B	NA
NICKEL	NA	47.4	NA	NA	0.88	NA
SELENIUM	NA	0.35 B	NA	NA	0.41 B	NA
SILVER	NA	0.021 B	NA	NA	0.006 U	NA
THALLIUM	NA	0.094 U	NA	NA	0.18 B	NA
VANADIUM	NA	0.44 B	NA	NA	2.3	NA
ZINC	NA	13.4 B	NA	NA	99.5	NA
INORGANICS FILTERED (ug/L)						
ANTIMONY	NA	0.063 B		NA	NA	NA
ARSENIC	NA	0.19 B		NA	NA	NA
BARIUM	NA	48.4		NA	NA	NA
BERYLLIUM	NA	0.49		NA	NA	NA
CADMIUM	NA	0.0042 UL		NA	NA	NA
CHROMIUM	NA	0.3 K		NA	NA	NA
COBALT	NA	78.2		NA	NA	NA
COPPER	NA	0.23 B		NA	NA	NA
IRON	NA	49800		NA	NA	NA
LEAD	NA	0.17 U		NA	NA	NA
MANGANESE	NA	12100		NA	NA	NA
MERCURY	NA	0.1 UL		NA	NA	NA
MOLYBDENUM	NA	0.087 U		NA	NA	NA
NICKEL	NA	50.5		NA	NA	NA
SELENIUM	NA	0.18 B		NA	NA	NA
SILVER	NA	0.0032 U		NA	NA	NA
THALLIUM	NA	0.17 B		NA	NA	NA
VANADIUM	NA	0.19 U		NA	NA	NA

TABLE E-1
ANALYTICAL RESULTS FOR GROUNDWATER
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

	SAMPLE ID:	MRC-OW3I-100208	OW-3I	MRC-OW3I-011509	MRC-OW3I-011509DL	MRC-OW3I-042209	MRC-OW3I-042209DL
	LABORATORY ID:	017FJ-2	A8K150126001	A9A160250003	A9A160250003	A9D230208002	A9D230208002
	SAMPLE DATE:	10/2/2008	11/14/2008	1/15/2009	1/15/2009	4/22/2009	4/22/2009
	LOCATION:	OW3I	OW-3I	OW3I	OW3I	OW3I	OW3I
ZINC		NA	11.2 B		NA	NA	NA

B - Analyte was detected but is considered to be a laboratory contaminant.
J - Positive value is considered estimated as a result of technical noncompliance.
K - Positive value is considered biased high as a result of techical noncompliance.
L - Positive value is considered biased low as a result of technical noncompliance.
U - Not detected
R - Rejected
mg/l - milligrams per liter
ug/l - micrograms per liter
NA - Not Analyzed

TABLE E-2

SUMMARY OF LABORATORY MICROBIAL DATA
LOCKHEED MARTIN MIDDLE RIVER COMPLEX, MIDDLE RIVER, MARYLAND

Observation Well	Sampling Round	Date	DHC cells/mL	DSM µg/L	DHB µg/L	TCER µg/L	BVC µg/L	VCR µg/L	EBAC µg/L	IRB/SRB µg/L	MGN mg/L
OW1I	Baseline	10/2/2008	2.65E-01	<5E-01	<5E-01	<2.5E-01	<2.5E-01	<2.5E-01	3.34E+02	<3.75E-01	<5E-01
	Round 3	4/21/2009	4.90E+00	3.11E+03	2.54E+03	<5.00E-01	<5.00E-01	<5.00E-01	2.12E+06	8.95E+02	2.23E+05
OW1D	Baseline	10/2/2008	5.5E-02(J)	<5E-01	<5E-01	<2.5E-01	<2.5E-01	<2.5E-01	1.54E+04	<3.75E-01	<5E-01
	Round 3	4/21/2009	5.89E+01	3.03E+03	1.24E+03	<5.00E-01	4.37E+01	6.56E+02	8.32E+06	1.01E+05	5.90E+04
OW3I	Baseline	10/2/2008	7.41E+00	1.00E+01	2.95E+02	<2.5E-01	1.28E-01(J)	9.42E-02(J)	9.33E+05	2.18E+01	1.01E+03
	Round 3	4/22/2009	8.09E+01	4.89E+02	4.81E+02	<5.00E-01	5.82E+01	2.20E+00	7.61E+06	2.08E+06	9.60E+05
OW3D	Baseline	10/2/2008	5.5E-02(J)	<5E-01	1.73E+01	<2.5E-01	<2.5E-01	<2.5E-01	1.15E+04	7.99E+00	7.99E+00
	Round 3	4/22/2009	3.14E+04	2.10E+00	2.55E+03	<5.00E-01	2.13E+04	5.50E+00	6.47E+06	1.08E+06	1.17E+06

DHC - Dehalococcoides spp.
DSM - Desulfuromonas spp.
DHB - Dehalobactor spp.
TCER - tceA Reductase
BVC - bvcA Reductase
VCR - Vinyl Chloride Reductase
EBAC - Total Eubacteria
IRB/SRB - Iron and sulfate reducing
MGN - Methanogen

APPENDIX G LABORATORY ANALYTICAL RESULTS

APPENDIX G—GROUNDWATER MODELING REPORT

DEVELOPMENT AND CALIBRATION OF A GROUNDWATER FLOW AND SOLUTE TRANSPORT MODEL FOR THE MIDDLE RIVER COMPLEX SITE

MIDDLE RIVER, MD

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1. INTRODUCTION

This report summarizes the development, calibration, and predictive use of a groundwater flow and transport model of the Lockheed Martin Middle River Complex (MRC) site, which is located in Middle River, Maryland (**Figure 1**).

1.1 GOALS AND OBJECTIVES

The groundwater modeling has been performed in support of a remediation conceptual design for addressing volatile organic compounds (VOCs) and 1,4-dioxane groundwater plumes. The engineering team will utilize the modeling output in an iterative manner to develop groundwater remediation alternatives. The remediation approaches being considered include options for controlling, capturing, and/or treating the plumes in-situ.

The fate and transport modeling focused on trichloroethene (TCE) and 1,4-dioxane as the primary contaminants driving the remedial action plan (RAP) approach. The primary areas of concern are two significant VOC groundwater contamination plumes (**Figure 2**). The west VOC plume, and 1,4-dioxane plume (**Figure 3**), is thought to emanate from Block I, extend southwest under the Tilley Chemical site, and ultimately discharges into Cow Pen Creek. The east VOC groundwater plume appears to emanate from Block I, extend southeast within the Tax Block E area and ultimately discharges into Dark Head Cove. A second source of contamination in the east plume is potentially present near the down-gradient end of the measured plume, as will be discussed later in this report.

2. CONCEPTUAL MODEL

The conceptual model of a hydrogeologic system is a working description of the characteristics and dynamics of the system. Its purpose is to consolidate site and regional hydrologic data into a set of assumptions and concepts that can be evaluated quantitatively (ASTM, 1996). The conceptual model is subsequently translated into a numerical representation in the groundwater model.

2.1 GEOLOGY

The MRC is underlain by the Potomac group, a lower Cretaceous-age inter-bedded gravel, sand, silt, and clay unit ranging in thickness from zero to 800 feet. The Potomac group at the site consists of three units (from the top down): the Patapsco formation, the Arundel clay, and the Patuxent formation. The sediments of the Potomac Group were deposited in a river-delta environment (Hansen, 1969). The deposits of the Patapsco formation constitute fine to medium sand and silt beds characteristic of back swamps and flood-plain deposits (Clark and others, 1918). The Patapsco formation, which is the primary formation of interest in this investigation, is composed primarily of silty sands, fine-grained to medium-grained sands, silty clays, clayey silts, and plastic clay. The Arundel clay is composed of dark gray and maroon lignitic clays and ranges between 25 and 200 feet thick beneath the site (TT NUS, 2008). Based on deep borings at the adjacent Martin State Airport site, the top of the Arundel clay is found at between -65 and -75 ft MSL.

Investigations at the site by TT NUS (2008) indicate that the subsurface is characterized by a complex arrangement of predominantly clay, silty clay, silt, and clayey silt, with smaller, more permeable zones of silty sand and sand. Thick sequences of low-permeability clay, silty clay, clayey silt and silt are present in the northern two-thirds of the MRC site. Interbedded sands, silty sands, sandy silts, and silts are encountered south of Buildings A, B, and C.

2.2 HYDROLOGY

The hydrogeologic system beneath the site consists of multiple, laterally- and vertically-discontinuous relatively permeable units that provide the primary pathways for groundwater flow

and contamination. Water enters these units via natural infiltration of precipitation (recharge) and collected and redirected storm-water and snowmelt and discharges to the surface waters that bound the site to the southwest (Cow Pen Creek) and the southeast (Dark Head Cove). These relatively shallow permeable zones, part of the Patapsco formation, are underlain at depths of 70 to 100 feet by the Arundel formation, a regionally extensive, thick, dense clay confining unit. The top of the Arundel formation forms the base of the groundwater flow system that was modeled in this program.

The more permeable units beneath the site are laterally and vertically discontinuous, making it difficult/impossible to delineate distinct aquifer layers and confining units. Some documents refer to an upper surficial and a lower surficial aquifer (TT NUS, 2008). However, wells have been completed at the site according to general depth intervals: A – shallow (typically <25 feet), B – intermediate (typically <35 feet), and C – deep (55 to 75 feet deep).

2.3 AQUIFER CHARACTERISTICS

Based on slug tests conducted by NUS at 28 wells on site (**Table 1**), the hydraulic conductivity of the more permeable deposits increases with depth at the site (TT NUS, 2008). The average hydraulic conductivity of the shallow wells is 0.22 ft/d (geometric mean, GM = 0.07 f/d); average of the intermediate wells was 0.48 ft/d (GM=0.22 f/d); and average of deep wells was 3.82 (GM=0.89 f/d). In general, the deeper the well completion interval, the more sand (SM) is present in the interval and the higher the hydraulic conductivity. With respect to the "A" zone, wells completed near the center of the site (potentiometric high) monitor a substantially lower permeability layer than do those elsewhere at the site.

Aquifer hydraulic response testing was conducted at two well pairs at the site: MW-70/70B and MW-74A/74B. Each test consisted of an initial step test, followed by a three-day constant rate pumping test. To date, these tests have not been formally documented.

2.4 INFLUENCE OF SURFACE WATERS

Water levels in the shallow and intermediate zones form a potentiometric high near the center of the site, with groundwater flowing away to the southwest and southeast to discharge to Cow Pen Creek and Dark Head Cove, respectively (**Figure 4**). Although water level data from

the deep "C" zone are limited, water levels and associated groundwater flow in the deep zone appear to not be influenced by Cow Pen Creek and flow appears to be principally toward the southeast and Dark Head Cove.

2.5 WATER BUDGET

2.5.1 EVAPOTRANSPIRATION

Much of the site is paved or covered by buildings; the remainder of the site is primarily covered by grass. As such, evapotranspiration is expected to be a very minimal factor on site and was not explicitly represented in the groundwater model.

2.5.2 RUNOFF

The topography of the site, which is gently sloping from Eastern Boulevard to the southwest and south, towards Cow Pen Creek and Dark Head Cove, and the nature of the ground surface (much is paved or covered by buildings) create a significant potential for runoff from precipitation. At the same time, runoff from the buildings and some or all of the paved areas is captured and conveyed through a storm sewer system.

2.5.3 RECHARGE

Areal variations in recharge rates are influenced by topography and surficial geology, including the presence or absence of paved surfaces. Precipitation in the area is approximately 44 inches per year (Tenbus and Fleck, 2001). Recharge is expected to occur primarily in the late winter and early spring months when precipitation is relatively high and evapotranspiration minimal. Tenbus and Fleck (2001) estimated recharge rates of between 0 and 9 inches per year at the nearby Graces Quarters site, which is located in the Edgewood Area of Aberdeen Proving Ground. Rates applied in the associated groundwater model were varied based on topography, the presence of fine-grained sediment within or above the surficial aquifer, the presence of wetlands, and field observations of overland flow.

Recharge to the groundwater system in locations where the ground surface is not covered by buildings or pavement at the MRC site is expected to be at the low end of the 0 to 9 inch per year range referred to by Tenbus and Fleck (2001) due to the low permeability of the surface

soil. However, a site field inspection of the potential for artificial recharge via runoff water was conducted in May 2009 by TT NUS personnel. Based upon this review a number of locations where the potential for enhanced recharge was great were identified. Many of these locations are located in the same area in which a potentiometric high/groundwater mound is present (**Figure 4**).

3. NUMERICAL FLOW MODEL

Development of a numerical groundwater flow model is the process of transforming the conceptual model into a mathematical form. Fundamental components of the groundwater flow model include dimensionality, discretization, boundary and initial conditions, and hydraulic properties (ASTM, 1996).

3.1 CODE SELECTION

The groundwater flow model was developed using MODFLOW-2000, a well-documented, widely-used and accepted code developed by the U.S. Geological Survey (USGS) (McDonald and Harbaugh, 1988; Harbaugh et al., 2000A; Harbaugh et al., 2000B).

3.2 MODEL GRID AND LAYERING

A total of nine (9) model layers were used to represent the shallow groundwater system beneath the site. The base of the model corresponds to approximately the top of the Arundel clay, which is treated as a no-flow boundary in the model. **Table 2** summarizes information on the model layering.

The model grid, which is shown in **Figure 5**, is oriented approximately 30 degrees off of vertical. The grid is aligned so that it is approximately consistent with the alignment of the model for the adjacent Martin State Airport site. That model encompasses the entire Middle River site but with a grid that is too coarse to be used for the evaluation described herein.

3.3 BOUNDARY CONDITIONS

The lateral model boundary conditions are also shown in **Figure 5**. In model layer one, Dark Head Cove and Cow Pen Creek are represented using the MODFLOW river package. The water level in both was set to 0 feet above sea level. These surface waters form natural hydraulic discharge boundaries for groundwater in the shallow zone. No flow boundaries are specified in all model layers at cells along the far shore of these surface waters. As previously noted the base

of model layer nine is generally coincident with the top of the Arundel clay and is assumed to be impermeable.

3.4 HYDRAULIC PROPERTIES

At the start of the modeling program, GeoTrans utilized geologic interpretations provided by TT NUS to define the lateral and vertical distribution of the various geologic materials. TT NUS had characterized the stratigraphy at each monitor well according to whether it is (a) sand; (b) silty sand or sandy silt; (3) silt or clayey silt; (4) clay or silty clay; (5) gravel; or (6) concrete/asphalt. Kriging was used to assign the appropriate material to each cell in the model domain.

Hydraulic conductivity values of unconsolidated deposits through which monitor wells are screened range from 0.0005 to 9.2 ft/d, based on slug tests conducted at these wells (see **Table 1**). The lowest values are from wells completed primarily in clay, silty clay, and clayey silt; the highest values are from "C" interval wells completed in fine sand. Based on the results of these tests, an initial value of hydraulic conductivity was assigned to each of the geologic materials present. These initial values are presented in **Table 3**. They were modified as appropriate during the model calibration program, which is described in the following section.

4. FLOW MODEL CALIBRATION

4.1 INTRODUCTION

Calibration of the groundwater flow model is the process of adjusting hydraulic parameters, boundary conditions, and initial conditions within reasonable ranges to obtain a match between measured and simulated potentials, flow rates, or other calibration targets (ASTM, 1996). The groundwater flow model was calibrated to a synoptic set of water level measurements taken at the site monitor wells on October 30, 2008. Groundwater levels were assumed to be under approximate steady-state conditions. The quality of the calibration was assessed and quantified through statistical analysis of residuals. Both first- and second-order statistics were utilized.

Calibration of a groundwater flow model to a single set of field measurements, with the presumption of steady state conditions, does not produce a unique solution. In order to avoid non-uniqueness, a model must be tested against a different set of boundary conditions or stresses. This is the process of model verification (ASTM, 1996). The groundwater flow model was verified by simulating two of the 72-hour pumping tests that have been conducted at the site in the recent past. Such simulations have the added advantage of facilitating an evaluation of the model's ability to simulate both transient (i.e., not steady-state) hydraulic conditions and pumping stresses, plus the measurement of flow rates reduces uncertainty and non-uniqueness significantly within the zone affected by the pumping.

4.2 STEADY-STATE FLOW

Groundwater levels measured at the site on October 30, 2008 were used for the steady-state calibration targets. In the process of calibrating the model, the hydraulic conductivities of the different materials were modified within reasonable ranges. The final distribution of hydraulic conductivity by model layer is presented in **Figure 6a** through **Figure 6i**. In addition, groundwater recharge was varied as part of the calibration process. Ultimately recharge was primarily only applied to a limited area of the site where field investigation suggested that enhanced recharge (equivalent to 10 in/yr) from surface drainage is occurring (**Figure 7**).

Table 4 presents a statistical summary of the match between measured and simulated groundwater levels for the calibrated model. Ideally the average error should be equal to zero, indicating that positive and negative residuals balance out and that there is no trend in the error (Anderson and Woessner, 1992). In addition, the absolute error should be equal to or less than ten percent of the measured range in water levels across the spatial extent of the monitoring points providing the target water levels.

Review of **Table 4** reveals that both of these criteria are met on a model-wide basis. The average error is effectively zero (0.03 ft) and the absolute average error (2.05 ft) is well below ten percent of the measured range (2.94 ft). It is noted that more than half of the wells (69 of 101, or 68%) are completed in model layer 1. Simulated water levels in model layer 1 are, on average, slightly lower than the measured water levels. The comparison between measured and simulated water levels in the other three model layers in which more than one well is completed (layers 2, 3, and 7) is not quite as good as that of model layer one. Measured and simulated water levels are plotted relative to one another in **Figure 8**. The simulated potentiometric surfaces in model layers one, two, three, and seven, along with model residuals, are presented in **Figures 9A, 9B, 9C,** and **9D**, respectively.

4.3 SIMULATION OF 72-HOUR PUMPING TESTS

Tetra Tech NUS conducted 72-hour pumping tests at each well of two well pairs at the site in November 2007: MW74A/MW74B, located in the east plume; and MW70A/MW70B, located in the west plume (**Figure 10**). To verify the calibrated, steady-state groundwater flow model, two of the tests – those conducted at MW74B and MW70B – were simulated. These were transient simulations. Additional refinements to the hydraulic conductivity in some zones in the area of the tests were made during this verification process. The steady-state simulation results presented in the previous section and in **Table 4** were achieved with this further refined model.

A comparison of measured and simulated drawdowns at wells monitored during each test is presented in **Table 5A** and **Table 5B**, respectively.

The test at well MW74B, a well located in model layer 3 at the down-gradient end of the east plume (**Figure 10**), was conducted at a rate of 0.30 gallon per minute (gpm). According to

TT NUS, an associated water-level decline was only observed in one of the wells being monitored, PZ-01B (0.46 ft), located approximately 20 feet away. The calibrated model predicted drawdowns of between 0.00 and 0.29 feet at the wells that did not appear to respond to the pumping of MW74B. The best results were achieved at the four wells completed in model layer one, all of which showed no response to the pumping at MW74B. The model over-predicted the drawdown at PZ-01B (1.7 ft versus 0.46 ft), located 19 feet from the pumping well; at the same time, the model under-predicted the drawdown at the pumped well (2.0 ft versus 10.4 ft).

These results indicate that the model predicts a deeper, more laterally-extensive cone of drawdown in model layer three for the MW74B test than was measured. However, relatively small responses were simulated. In addition, the relatively great drawdown measured at the pumped well may be more a reflection of an inefficient well (i.e. includes significant well loss) than an indication of relatively low hydraulic conductivity in the area of the well.

The test at well MW70B, a well located in model layer three at the down-gradient end of the west plume (**Figure 10**), was conducted at a rate of 0.75 gallons per minute (gpm). A much greater water level response was noted by TT NUS at the associated monitor wells than was noted in the MW74B test, because of the higher sustained pumping rate. Simulated results at this well are significantly better than those achieved in simulating the MW74B test (see **Table 5B**).

5. HYDRAULIC CONTAINMENT

5.1 INTRODUCTION

The calibrated groundwater flow model was used to identify potential groundwater extraction programs that would successfully contain and capture contaminated groundwater. A variety of alternative programs were tested at each location. For the east plume, the extent of TCE contamination in excess of 5 ug/L was the target capture zone. For the west plume, the target capture zone included that necessary to capture both TCE in excess of 5 ug/L and 1,4-dioxane in excess of 3 ug/L. At both locations, extraction trenches were included near the down-gradient end of the plumes, adjacent to Dark Head Cove (east plume) and Cow Pen Creek (west plume), respectively. The use of extraction trenches in such a configuration is believed to be the most effective means of preventing and eliminating plume discharge to the surface water in this hydrogeologic environment.

Potential extraction-wells were represented using the *MODFLOW* drain package. Water levels at the extraction wells were modeled as fixed at 2.0 ft above the base of the model layer 1. Wells were assumed to have an effective diameter of one foot and an efficiency of 50 percent. The extraction trenches were also represented using the *MODFLOW* drain package. Uniform fixed water levels were established in each individual trench. Conductance and well efficiency were estimated as follows.

Conductance Term— the conductance term (C) of each drain cell representing a fixed-head well was calculated using the following equation (based on Prickett [1967] and Anderson and Woessner [1992]):

$$C = 2K_e \pi b/\ln (\text{delta } x/4.81r_w) \qquad (1)$$

where K_e is the effective hydraulic-conductivity at the cell (ft/d), b is the saturated thickness of the cell (ft), *delta x* is the representative grid spacing (ft), and r_w is the well radius (ft).

Efficiency— because the wells were represented as drains in the model, the extraction rate (Q) achieved is effectively calculated by the model and controlled by the aquifer properties, as described in the equation:

$$Q = C (h - d) * \text{efficiency} \qquad (2)$$

where *h* is the water level in the grid cell (ft) and *d* is the elevation of the water level in the drain. An efficiency value of 50 percent was applied to both the wells and the trenches as a conservative measure to reflect potential well loss.

5.2 EAST PLUME

There is evidence that the east VOC plume (**Figure 2**) has two residual sources of contamination; one located at the up-gradient end of the plume near well MW81B, the second located near the down-gradient end of the plume near well MW74B. In both these wells the measured concentration of TCE in 2008 (10,000 ug/L and 12,000 ug/L) is close to or greater than 10% of the solubility of TCE (11,000 ug/L). For purposes of containment, all well and extraction trench configurations that were considered and simulated included wells designed to contain and isolate contamination emanating from the up-gradient residual source near MW81B, together with an extraction trench adjacent to Dark Head Cove that is intended to capture contaminated groundwater before it can discharge to the Cove.

The final groundwater containment system developed for the east plume in this analysis consists of thirteen (13) extraction wells and an extraction trench. The three most up-gradient wells are designed to isolate the up-gradient source area from the rest of the plume. The predicted plume capture associated with this system under steady-state conditions is presented in **Figure 11**. A total extraction rate of 3.9 gpm (1.1 gpm from the trench, 2.8 gpm from wells) is associated with this configuration.

5.3 WEST PLUME

The west plume actually consists of two plumes: (1) a VOC plume, and (2) a 1,4-dioxane plume (see **Figures 2** and **3**). In contrast to the east plume, concentrations of TCE measured in 2008 in the west plume are not indicative of a continuing (residual) source of contamination. Both plumes are believed to have originated from an [old underground storage tank, REC #9] located near well MW21B. For purposes of containment, all well and extraction trench configurations evaluated included wells focused on the VOC/TCE plume and an extraction

trench adjacent to Cow Pen Creek that is intended to extend a sufficient distance to keep both the VOC and 1,4-dioxane plumes from discharging to the creek.

The final groundwater containment system developed for the west plume in this analysis consists of seven (7) extraction wells and an extraction trench. The predicted plume capture associated with this system under steady-state conditions is presented in **Figure 12**. A total extraction rate of 1.9 gpm (1.2 gpm from the trench, 0.7 gpm from wells) is associated with this configuration.

6. TRANSPORT MODEL DEVELOPMENT

6.1 CODE SELECTION

Contaminant mass fate and transport modeling was conducted using the finite difference code, MT3D v. 5.2 (Zheng, 1998; Zheng, 2006). MT3D utilizes MODFLOW-2000 to simulate the advective transport of dissolved constituents. MT3D accounts directly for other fate and transport mechanisms including hydrodynamic dispersion, diffusion, sorption and sequential biodegradation.

6.2 CONTAMINANTS OF CONCERN

The fate and transport modeling considered TCE and 1,4-dioxane as the only contaminants driving the RAP approach. Both compounds are components of the west plume while 1,4-dioxane is only detected at very low concentrations (less than or just marginally above the 3 ug/L clean-up criterion for this compound) at three disparate locations in the east plume. The distribution of each of these compounds, as measured in the Summer of 2008, is shown in **Figure 2** (TCE) and **Figure 3** (1,4-dioxane).

6.3 RELEVANT PHYSICAL AND CHEMICAL TRANSPORT PROCESSES

The important physical and chemical processes affecting the fate and transport of dissolved constituents in groundwater at the study area are advection, hydrodynamic dispersion, sorption, and degradation. These processes cause changes in both the mass and distribution of dissolved constituents in groundwater. A discussion of these processes and their relative importance in the study area is provided below.

For dissolved transport, advection is defined as the movement of contaminants as a result of the dissolved contaminants being carried by moving groundwater. The observed spreading of dissolved contaminants in the study area is also the result of hydrodynamic-dispersion processes. Hydrodynamic dispersion is a physical process whereby dissolved constituents spread at the macroscopic level both horizontally and vertically away from the plume center of mass.

Adsorption is a chemical process whereby dissolved chemicals react with the surfaces of solids. Several laboratory studies have shown that the mass of organic constituents adsorbed to soils is proportional to the amount of organic carbon in the soils (e.g. Karickhoff et al., 1985). Field studies indicate that adsorption is the primary cause for organic-compound plumes that migrate at a slower rate than groundwater (e.g. Roberts et al., 1980). A retardation factor is used to quantify this reduced migration rate.

Degradation processes are biological and chemical processes that decrease the mass of dissolved constituents. These processes include the effects of biodegradation, photolysis, oxidation-reduction, and hydrolysis, and are generally grouped into either biologic or abiotic (chemical) degradation processes. TCE is potentially subject to degradation.
Using results of laboratory, field, and modeling studies at other sites, Aronson and Howard (1997) and Wiedemeier et al. (1999) report a wide range of first-order biodegradation rates for TCE under aerobic and anaerobic conditions. For anaerobic conditions, reported biodegradation-rate-constant ranges for TCE were 0.053–0.90 yr-1 (13.1 to 0.77 years) (Aronson and Howard, 1997; Wiedemeier, et.al., 1999). For the simulations presented in this report, TCE was assigned a half-life of 10 years; 1,4-dioxane was assumed not to degrade. It should be noted that the TCE half-life only applies to the dissolved phase of the TCE. TCE is assumed not to degrade in the sorbed phase. Consequently, its "effective half-life" is equal to its half-life in the dissolved phase (10 years) times the retardation coefficient. Thus, the simulated effective half-life of TCE is approximately 17 years.

In addition to compound half life, input parameters for the transport simulations include fraction of organic carbon (foc), partitioning coefficient (Koc), distribution coefficient (Kd), effective porosity, bulk density, retardation coefficient, and dispersivity. The values of these parameters used in the contaminant-mass fate and transport modeling are presented in **Table 6**.

Retardation (R) was calculated using the equation:

$$R = 1 + (\text{bulk density}/\text{effective porosity}) \times foc \times Koc \qquad (1)$$

Dispersivity values (lateral, transverse, and vertical) were estimated based on model analysis and best scientific judgment. A longitudinal dispersivity value of 1.0 foot was assigned

to all model layers. By convention, the transverse and vertical dispersivities were set to 0.1 and 0.01 times the longitudinal dispersivity value, respectively.

6.4 INITIALIZING MASS IN PLACE

All transport simulations were conducted by predicting the change in contaminant distribution over time, beginning with "current" conditions. Current conditions were equated to concentrations measured at the site in the July/August of 2008 (NUS, 2008). For the east plume, TCE has been detected in wells completed in model layers 1, 2, 3, and 4. Consequently, these are the layers in which TCE mass was initialized for the transport model simulations of the east plume. For the west plume, both TCE and 1,4-dioxane have been detected in wells completed in model layers 1, 2, and 3. Consequently, these are the layers in which TCE and 1,4-dioxane mass was initialized for the transport model simulations of the west plume[1].

6.5 TRANSPORT MODEL CALIBRATION

6.5.1 INTRODUCTION

A strict calibration of the transport model was not carried out as part of this modeling program. Knowledge regarding the sources of contamination, timing of source releases, and water quality data from site monitor wells are insufficient to make that possible. Rather, the model was calibrated in a more general manner. This process consisted of **first** evaluating the flow model's ability to predict a plume distribution that is consistent with the observed TCE plumes. To do this, particle tracking with the calibrated groundwater flow model was used to predict the long-term horizontal and vertical pathways that contamination originating at the hypothesized source areas of the east and west plumes would follow. In the **second** step of the process, a constant source of unit concentration was specified at the location of each of the hypothesized source areas and the transport model was used to predict the distribution of contamination at the end of approximately 50 years of plume development. The simulated general distribution of contamination in the groundwater system was then compared to the

[1] TCE was detected at 230 ug/L in well MW14C, which is completed in model layer 7. However, subsequent sampling indicated that this sampling result was erroneous and that no TCE is present at this relatively deep well.

measured distribution to determine whether the model predicted a plume distribution that is generally consistent with the measured distribution.

6.5.2 PARTICLE TRACKING

Particle tracking analysis with the calibrated flow model produced horizontal plume trajectories that were consistent with the TCE distribution in the east plume measured in 2008. The predicted results for the vertical pathway were less successful, with the model predicting a deeper plume pathway (into model layer 7) than is suggested by the available water quality data (into model layer 4). Various attempts to adjust the model to prevent particles from traveling along this deeper pathway were unsuccessful.

Particle tracking analysis with the calibrated flow model produced horizontal and vertical plume trajectories that were consistent with the TCE distribution in the west plume measured in 2008. However, because of the observed and simulated mound in the potentiometric surface in the up-gradient end of the plume, the model predicts that particles originating along the up-gradient eastern side of the delineated plume (see **Figure 2**) move in a south-southeasterly direction, beyond the delineated plume. It is noted, however, that there are no monitor wells in this area (between wells MW22A and MW63A), to confirm the possibility of the flow path.

6.5.3 TRANSPORT SIMULATIONS

The transport simulations involved specifying a constant source of unit concentration at the location of each of the hypothesized up-gradient source areas and using the transport model to predict the distribution of contamination at the end of a 50- year period under steady-state flow conditions. For the east plume, the up-gradient source that was specified in these simulations is believed to be a continuing (residual) source. For the west plume, a constant up-gradient source was specified in these simulations although no such continuing source is believed to be present in the plume.

These simulations generally confirmed the viability of the transport models. However a number of observations warrant mentioning.

1. A plume the length of the east VOC plume originating *solely* from a source located in the area of well MW81B and reaching its extent in a period of 50 to 60 years is implausible. A second source located much closer to the river is suggested by the available water quality data and supported by these transport simulations.

2. Consistent with the particle tracking results, these transport simulations predicted the movement of contamination into portions of the groundwater system that are deeper than has been indicated by observed data. There are a limited number of monitor wells completed in this deeper zone.

3. A significant southerly component of plume movement from the *hypothesized* continuing source area in the west plume was present in these simulations. As previously noted, there are no monitor wells between wells MW22A and MW63A, the area though which a plume originating in the vicinity of well MW21B is predicted to travel.

7. FATE AND TRANSPORT MODEL SIMULATIONS

7.1 INTRODUCTION

The groundwater flow and solute transport models were used to make predictions about the length of time it might take to achieve various cleanup goals under a number of different remediation programs and to confirm that adequate plume capture would be achieved. The majority of simulations involved the well configurations described in Section 6 of this report. Within these primary designs a number of alternative assumptions were made regarding the potential reduction in initial contaminant (TCE and 1,4-dioxane) concentrations in the groundwater that might be achieved using alternative remediation programs such as electrical resistive heating (ERH).

In all of the predictive simulations, only the contaminant concentrations in model layers one through four within the field-identified bounds of the plumes were quantified with respect to mass in place and cleanup time. No contaminant mass was predicted to extend below model layer 4 in the west plume and the simulated movement of TCE into layers 5 and below in the east plume is not considered realistic. In all instances, predicted cleanup times in the shallower layers were the longest.

7.2 EAST TCE PLUME

A summary of the simulations and results for the east TCE plume is presented in **Table 7**. Predicted times to achieve cleanup are characterized with respect to goals of 100 ug/L and 5 ug/L. The extraction wells included in the eastern plume simulations are shown in **Figure 13**. The full set of 13 wells was used in most simulations. However, the first simulation used only seven of the wells (#1, #2, #3, #5, #9, #10, #11) and simulations were conducted assuming (1) use of only passive reactive barriers (PRB), and (2) assuming no action. Several simulations included assumptions about how much initial (current) concentrations of TCE could be reduced in the down-gradient area where concentrations exceed 1000 ug/L prior to start of plume extraction. These reductions ranged from 80% to 99%.

Plume-wide, predicted cleanup times for the eastern TCE plume were insensitive to assumptions about initial reductions in concentrations in the down-gradient end of the plume.

Reducing concentrations in the down-gradient target area by 90%, time to achieve 100 ug/L was predicted to be reduced from 25 years to 20 years; no change in time to achieve 5 ug/L was predicted. With this assumed 90% reduction, initial TCE mass in place was reduced from approximately 100 pounds to approximately 62 pounds. Greater reductions of 95% and 99% of initial concentration yielded effectively the same predicted cleanup times as were achieved with the 90% reduction. The predicted change in dissolved TCE concentration in model layer 3 at various times under the 13-well pumping program (no initial reduction in concentration) is shown in **Figure 14**.

In one simulation it was assumed that, rather than wells and an extraction trench, two passive reactive barriers would be utilized: one constructed perpendicular to the plume and approximately aligned with the railroad tracks, and a second one located in the same place as the extraction trench. To simulate this scenario, remediation of groundwater contamination up-gradient of the first PRB was evaluated (that is, time to cleanup of that lobe of the plume was determined) separately from the plume-lobe down-gradient of the PRB. It was further assumed that no contaminated groundwater (that is, no groundwater with TCE in excess of 5 ug/L) would pass through the PRB (i.e. the PRB was assumed to be 100% effective). No explicit accounting for the second, down-gradient PRB was necessary as this PRB is 100% effective. Review of the results presented in **Table 7** reveals that this remediation approach results in substantially longer cleanup times than does the program that uses extraction wells.

7.3 WEST TCE PLUME

A summary of the simulations and results for the west TCE plume is presented in **Table 8A**. The extraction wells included in the western plume simulations are shown in **Figure 15**. The full set of seven (7) wells was used in most simulations. However, the first simulation used only three of the wells (#1, #2, and #3) and a simulation was conducted assuming use of only passive reactive barriers. As with the eastern plume, several simulations included assumptions about how much the initial (current) concentrations of TCE could be reduced in the down-gradient area where concentrations exceed 1000 ug/L prior to start of plume extraction. These reductions ranged from 80% to 99%.

Plume-wide, predicted cleanup times for the western TCE plume were very insensitive to assumptions about initial reductions in concentrations in the down-gradient portion of the plume. By reducing concentrations in the down-gradient target area by 90%, time to achieve 100 ug/L was predicted to be reduced from 38 years to 33 years; no change in time to achieve 5 ug/L was predicted. With this assumed 90% reduction, initial TCE mass in place was reduced from approximately 29 pounds to approximately 16 pounds. The predicted change in dissolved TCE concentration in model layer 2 at various times under the 13-well pumping program (no initial reduction in concentration) is shown in **Figure 16**.

In one simulation it was assumed that, rather than wells and an extraction trench, two passive reactive barriers were utilized: one approximately aligned with the road along the south side of the Tilley Chemical building, and a second one located in the same place as the extraction trench. This scenario was simulated in the same manner as for the PRB scenario for the east plume. Review of the results presented in **Table 8** reveals that this remediation approach results in predicted cleanup times that are similar to those achieved with seven extraction wells.

7.4 WEST 1,4-DIOXANE PLUME

A summary of the simulations and results for the 1,4-dioxane plume is presented in **Table 8B**. In all simulations, extremely long times to achieve a cleanup criterion of 3 ug/L were predicted, many in excess of 200 years. This occurred even though the initial mass of 1,4-dioxane in place was estimated to be only about 2.5 pounds and, in all simulations that include the use of extraction wells, only 2% to 4% of the initial mass is still in place after 100 years.

The longest predicted cleanup time is for model layer 2. In developing the initial concentration of 1,4-dioxane for these simulations, relatively high concentrations were specified in a zone of very low hydraulic conductivity (0.02 ft/d) in layer 2 as a result of the presence of two wells (MW14B and MW7B) completed partially in this layer and partially in model layer 3. It is in this zone that 1,4-dioxane in excess of 3 ug/L remains the longest of any location in the model. Because the low permeability of this zone might preclude the true presence of significant concentration of 1,4-dioxane (concentrations may be only representative of model layer 2 at the two wells cited above) a sensitivity analysis was conducted in which the 1,4-dioxane was not initially included in this low permeability zone. This change reduced the predicted cleanup time

from >200 years to 175 years, with the longest cleanup time still predicted for model layer 2. Review of the predicted distribution of 1,4-dioxane after 100 years indicates that there was movement of 1,4-dioxane back in to parts of the low-permeability zone during the course of the simulated remediation program.

8. SUMMARY AND CONCLUSIONS

This report summarizes the development, calibration, and predictive use of groundwater flow and contaminant fate and transport modeling of a designated area within the Lockheed Martin Middle River site, located in Middle River, Maryland. The groundwater modeling was performed in support of a remediation conceptual design for addressing volatile organic compounds (VOCs) and 1,4-dioxane groundwater plumes. The engineering team will utilize the modeling output to develop remediation alternatives. These remediation alternatives include options for controlling, capturing, and/or treating the plumes in-situ.

The predictive fate and transport modeling described in this report focused on trichloroethene (TCE) and 1,4-dioxane as the primary contaminants driving the remedial action plan (RAP) approach. The primary areas of concern are two significant VOC groundwater contamination plumes. The west VOC plume and 1,4-dioxane plume are thought to emanate from Block I, extend southwest under the Tilley Chemical site, and ultimately discharges into Cow Pen Creek. The east VOC groundwater plume appears to emanate from Block I, extend southeast within the Tax Block E area and ultimately discharges into Dark Head Cove. A second source of contamination is potentially present near the down-gradient end of the measured plume

Viable groundwater extraction systems were identified for both the east and west TCE plumes and the west 1,4-dioxane plume. The east plume system includes thirteen (13) extraction wells completed through model layers 1 through 4 and an extraction trench oriented perpendicular to the plume and immediately adjacent to Dark Head Cove. A total extraction rate of 3.9 gpm was simulated with this extraction system. The predicted times to achieve a cleanup criterion of 5ug/L for TCE in the east plume with this system is just short of 80 years. The west plume system includes seven (7) extraction wells completed through model layers 1 through 3 and an extraction trench oriented perpendicular to the plume and immediately adjacent to Cow Pen Creek. A total extraction rate of 1.9 gpm was simulated with this extraction system. The predicted time to achieve a cleanup criterion of 5ug/L for TCE in the west plume with this system is approximately 75 years. The west 1,4-dioxane plume is predicted to require in excess of 150 years to achieve a 3 ug/L criterion.

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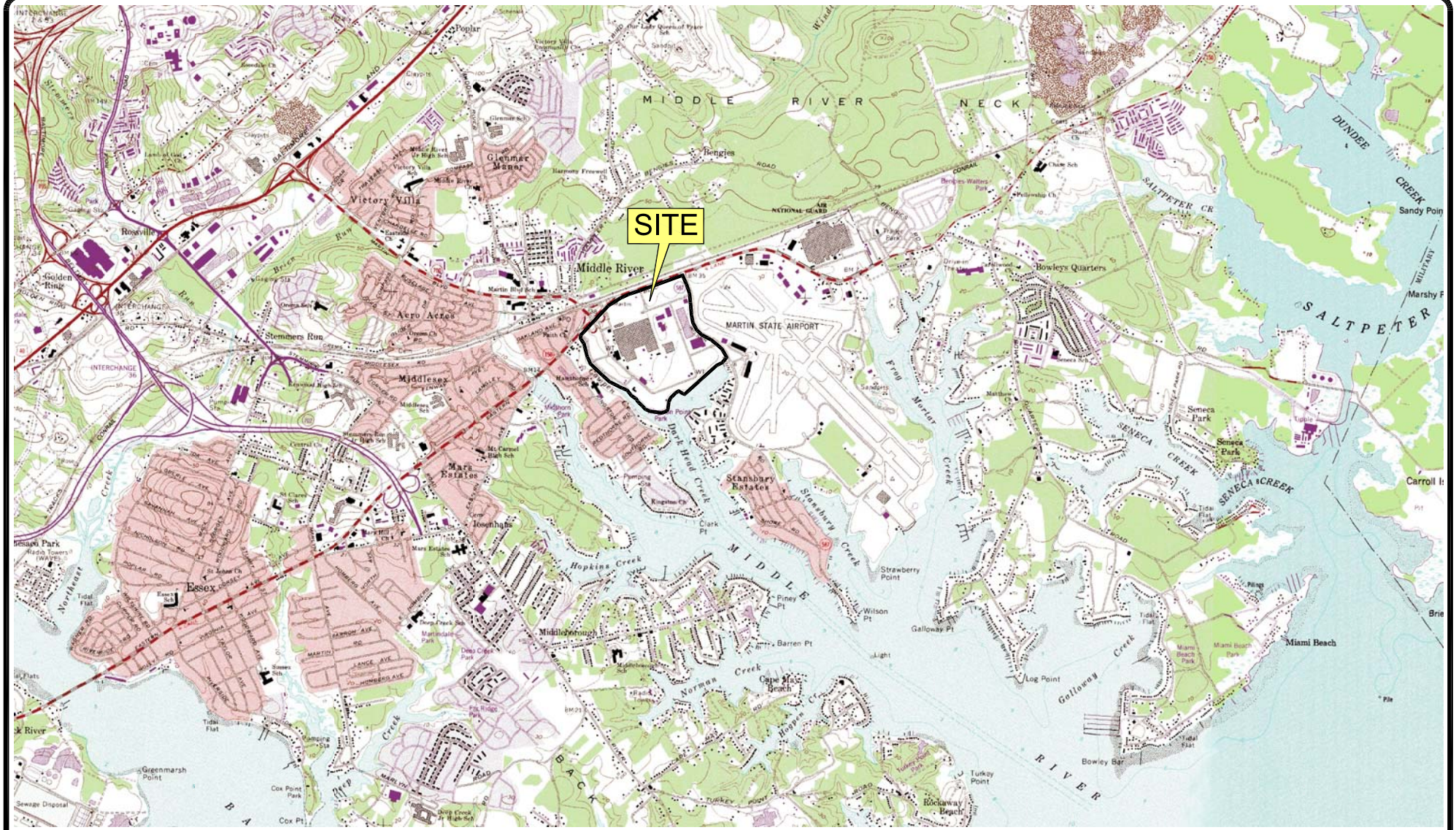
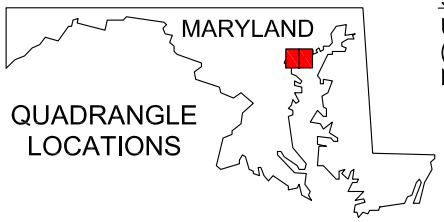
FIGURES

P:\ACAD\0512-031-MRVR\0512031023A.DWG





SOURCE:

U.S.G.S. QUADRANGLES MIDDLE RIVER, MD (1969) PHOTOREVISED 1985 AND GUNPOWDER NECK, MD (1949) PHOTREVISED 1986.

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SCALE IN FEET

N

TITLE:

SITE LOCATION MAP

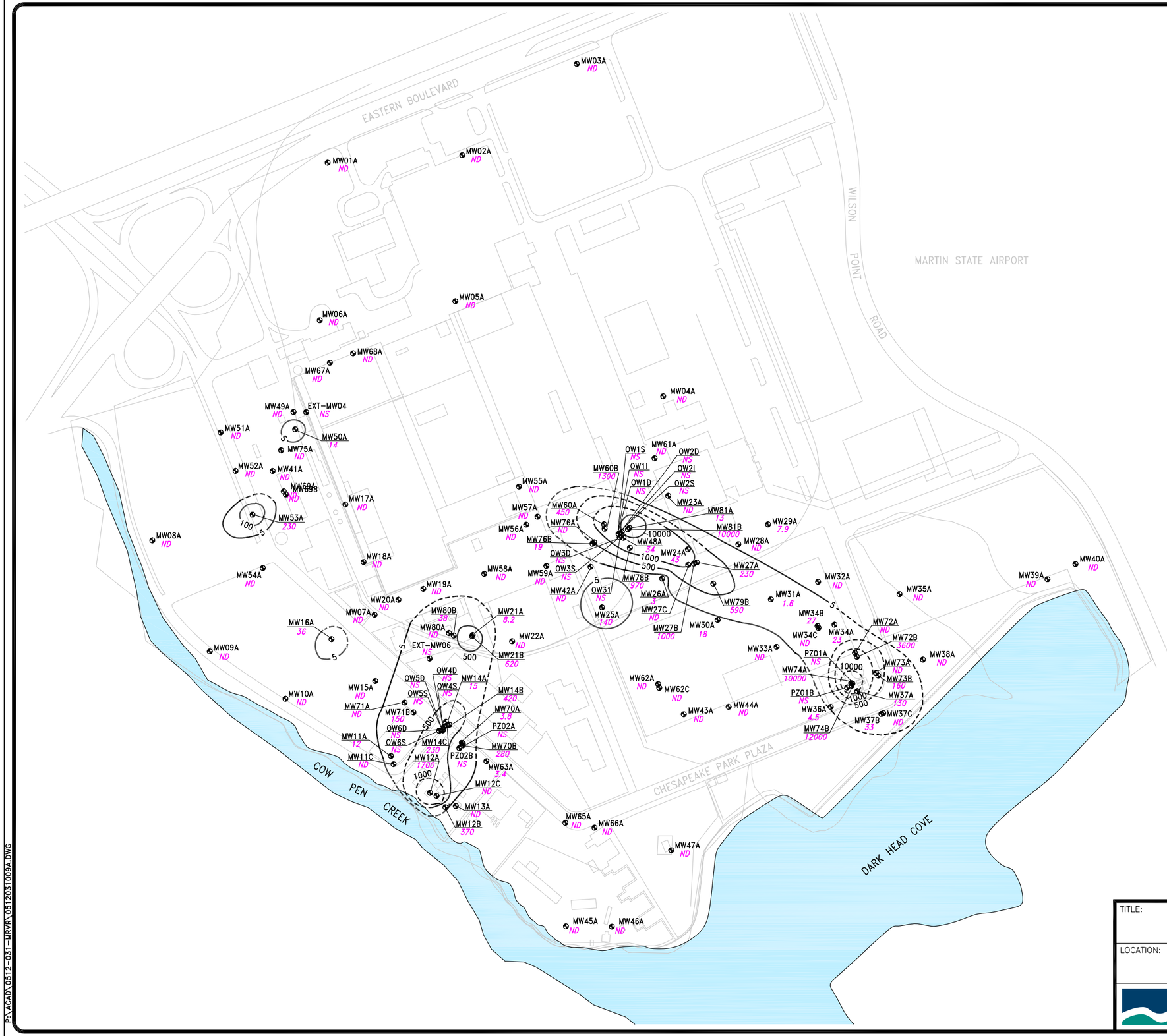
LOCATION:

Middle River Complex, Middle River, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512042.01
DATE	7-30-09

FIGURE 1



LERGEND

MW29A	GROUNDWATER MONITORING WELL
	SURFACE WATER
	TCE ISOCONCENTRATION (ug/L)
	INFERRED
7.9	MAXIMUM TCE CONCENTRATION IN WELL (ug/L)
ug/L	MICROGRAMS PER LITER
ND	NOT DETECTED
NS	NOT SAMPLED

0 400 800

SCALE IN FEET

TITLE: **DISTRIBUTION OF TCE IN GROUNDWATER JULY - AUGUST 2008**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
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PROJECT#	117–0512031.02
DATE	12–14–09

FIGURE 2

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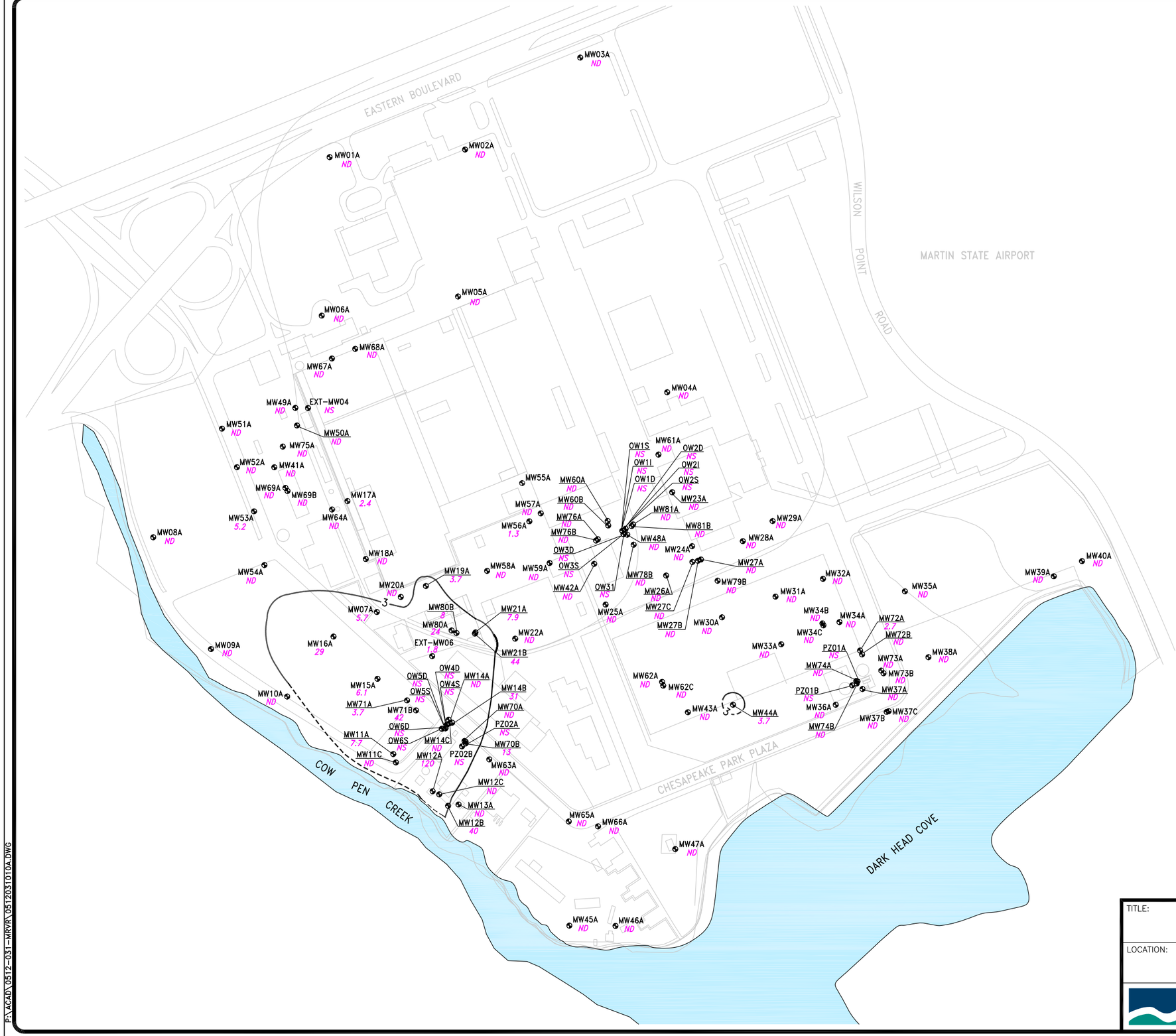

N

LERGEND

MW29A	GROUNDWATER MONITORING WELL
	SURFACE WATER
	TCE ISOCONCENTRATION (ug/L)
	INFERRED
2.7	MAXIMUM TCE CONCENTRATION IN WELL (ug/L)
ug/L	MICROGRAMS PER LITER
ND	NOT DETECTED
NS	NOT SAMPLED

0 400 800

SCALE IN FEET

TITLE: **DISTRIBUTION OF 1,4-DIOXANE IN GROUNDWATER JULY - AUGUST 2008**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	12-14-09

FIGURE 3

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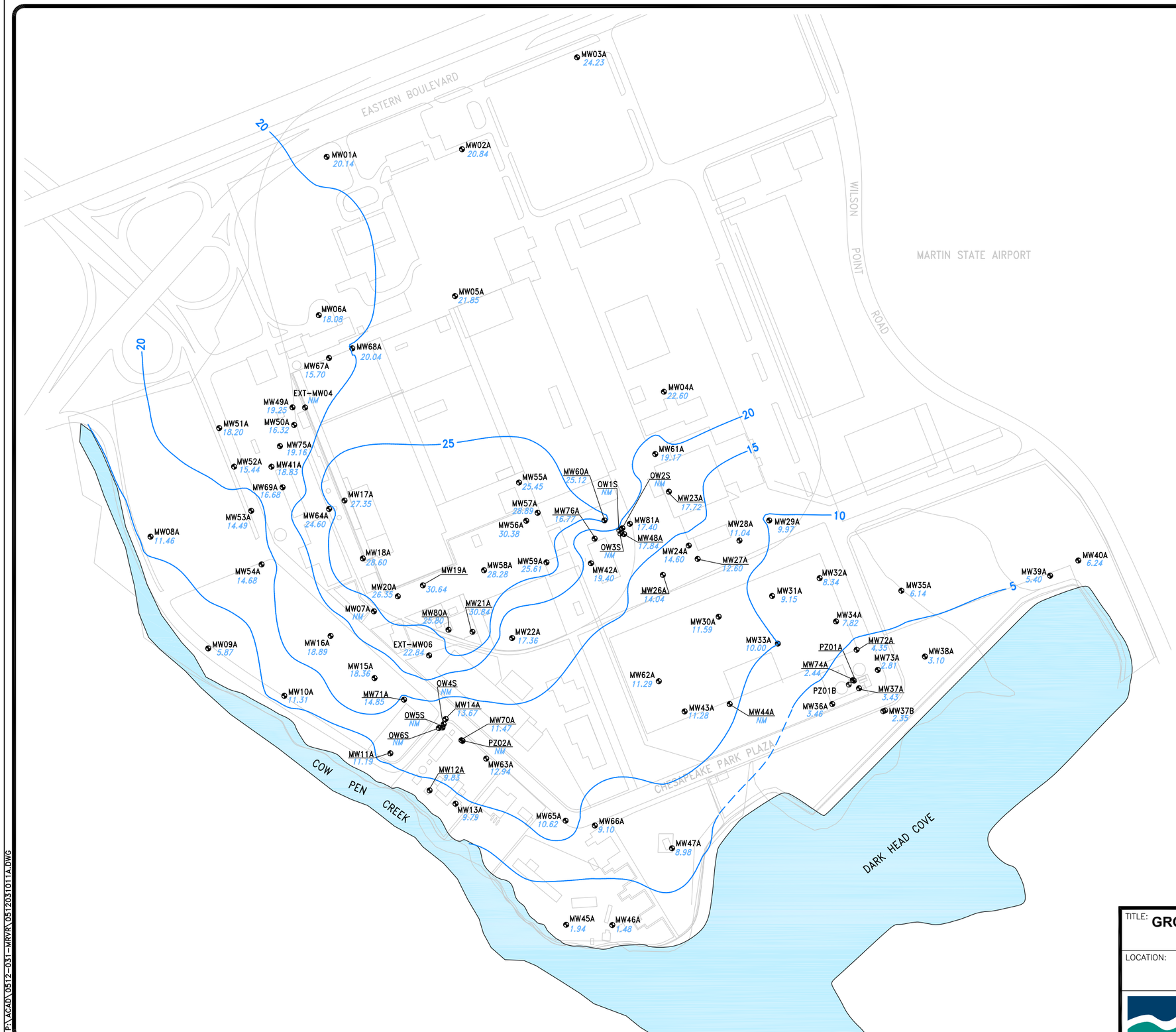

LERGEND

MW29A	GROUNDWATER MONITORING WELL
	SURFACE WATER
	GROUNDWATER CONTOUR CONTOUR INTERVAL = 5 FT
	INFERRED
2.7	WATER LEVEL (FEET MSL)
NM	NOT MEASURED

TITLE: **GROUNDWATER LEVELS IN THE UPPER SURFICIAL AQUIFER OCTOBER 2008**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
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PROJECT#	117-0512031.02
DATE	12-14-09

FIGURE 4

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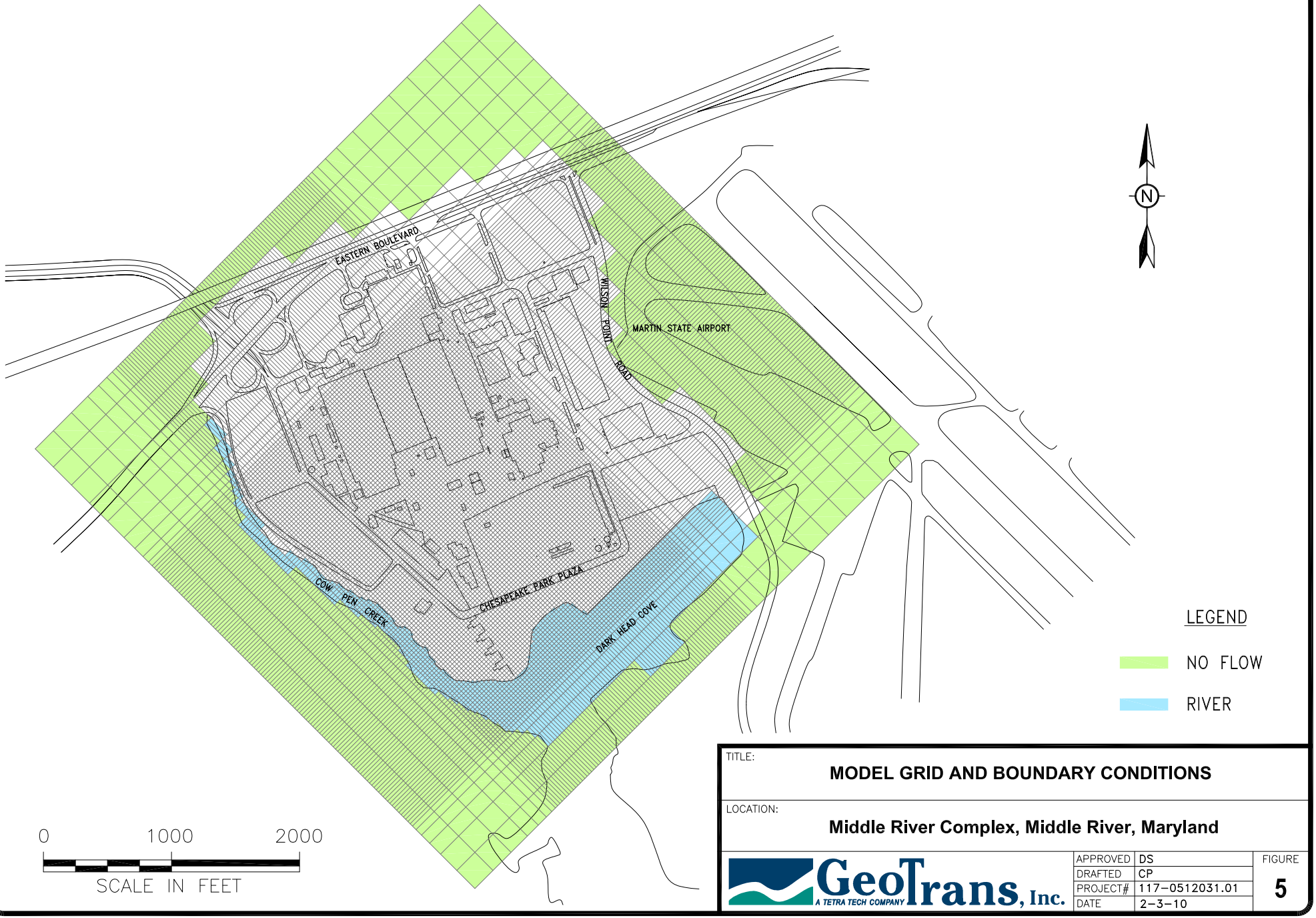

TITLE:

MODEL GRID AND BOUNDARY CONDITIONS

LOCATION:

Middle River Complex, Middle River, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

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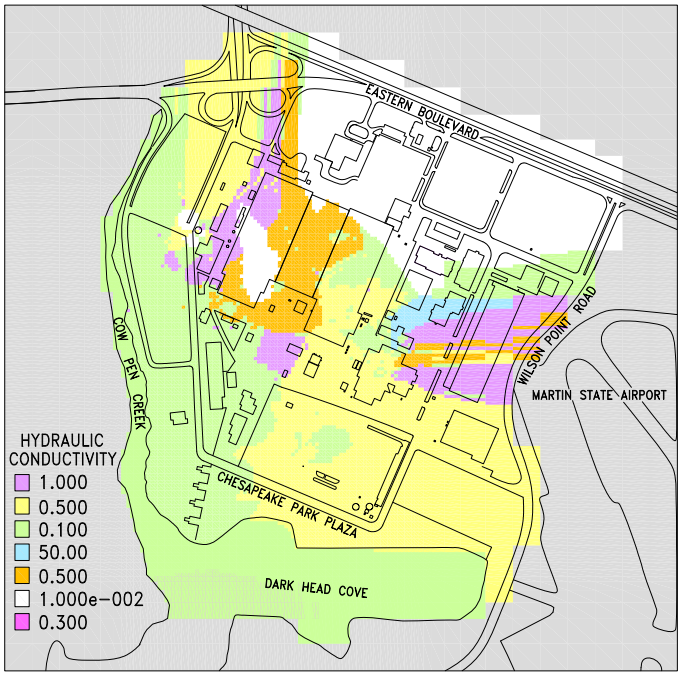
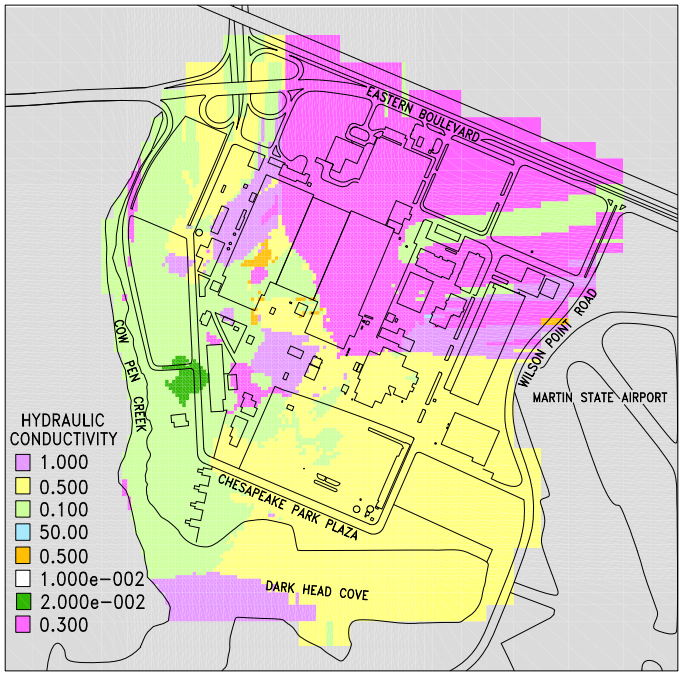
PROJECT#	117-0512031.01
DATE	2-3-10

FIGURE 5



LAYER 1



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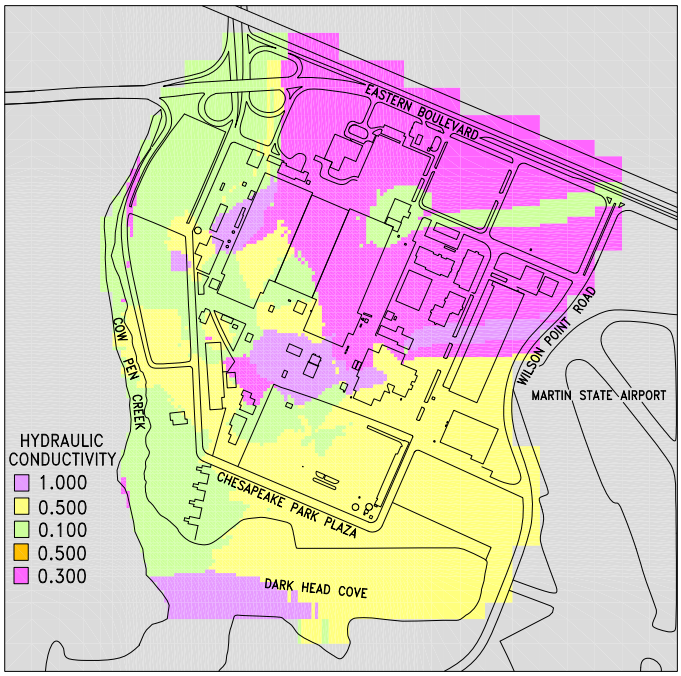
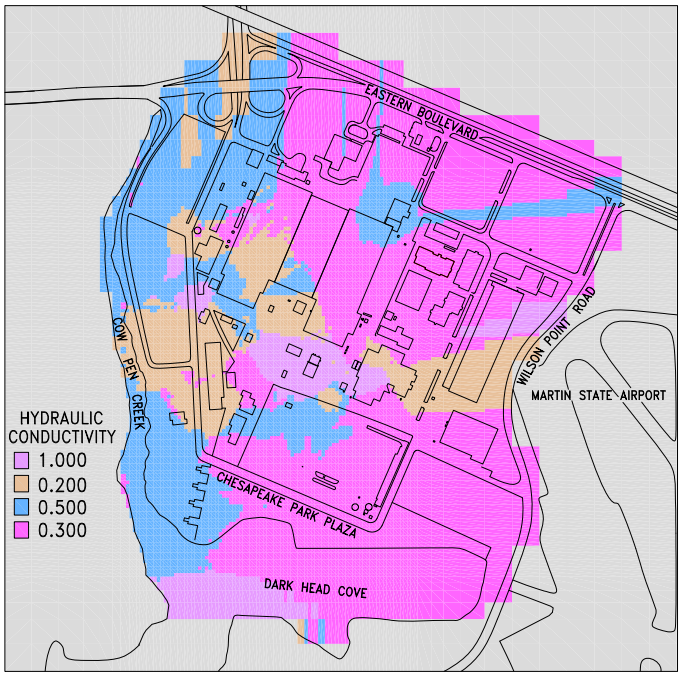
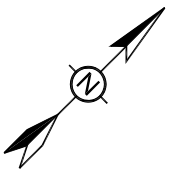


LAYER 3



LAYER 4





TITLE: **HYDRAULIC CONDUCTIVITY (ft/d) DISTRIBUTION IN THE CALIBRATED MODEL, LAYERS 1 THROUGH 4**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

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PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE **6A**

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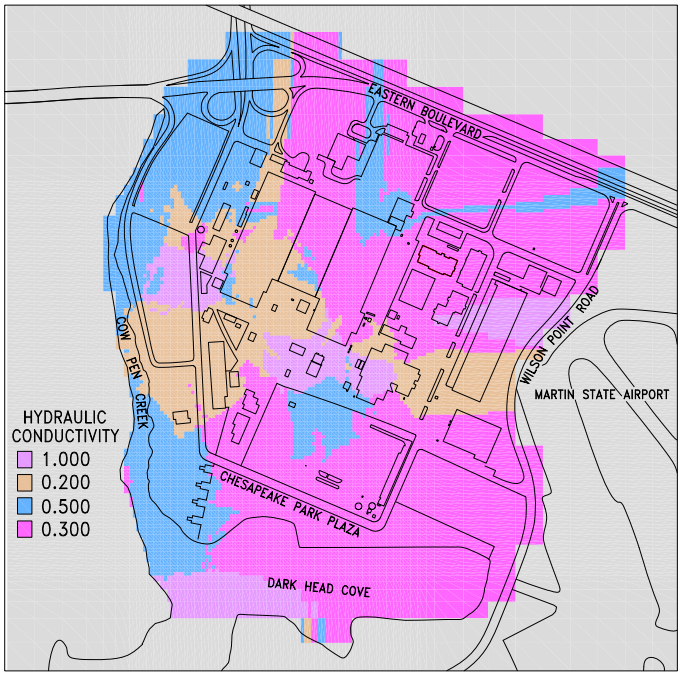
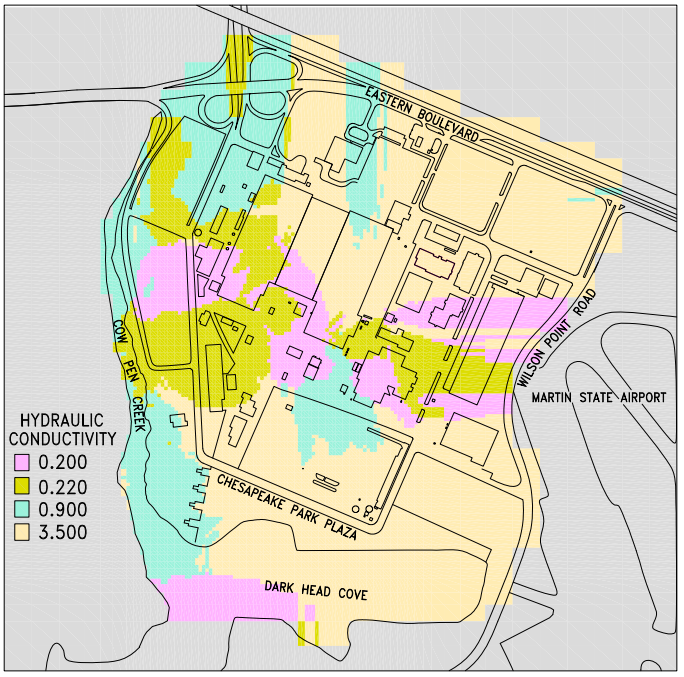
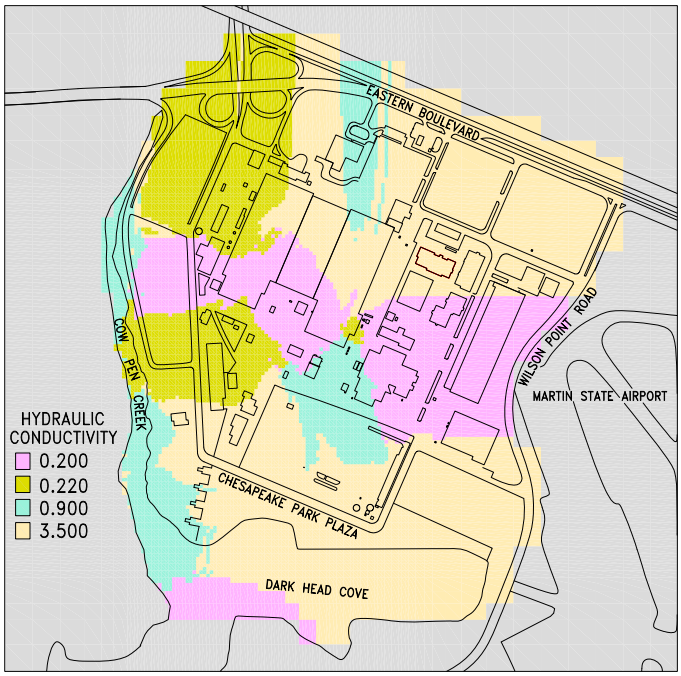


LAYER 5



LAYER 6



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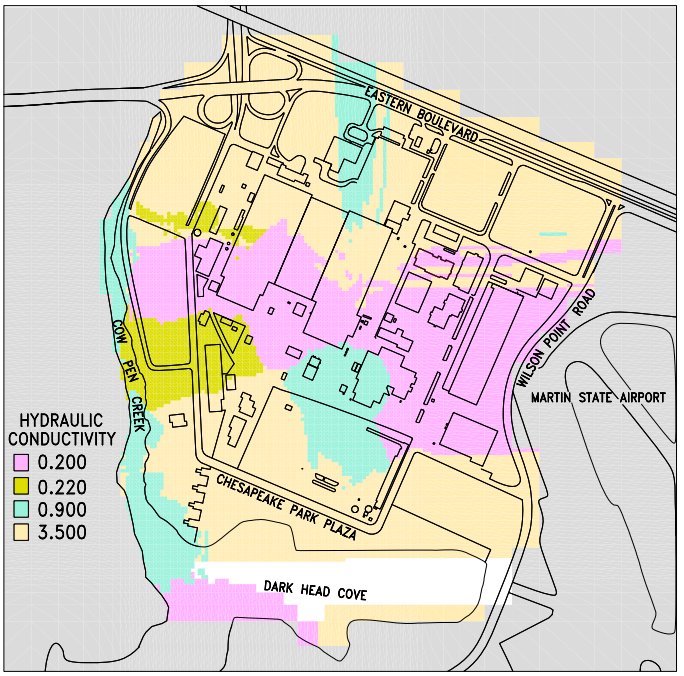
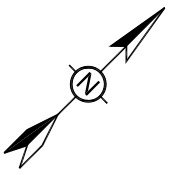


LAYER 8



0 1400 2800

SCALE IN FEET

TITLE: **HYDRAULIC CONDUCTIVITY (ft/d) DISTRIBUTION IN THE CALIBRATED MODEL, LAYERS 5 THROUGH 8**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE **6B**

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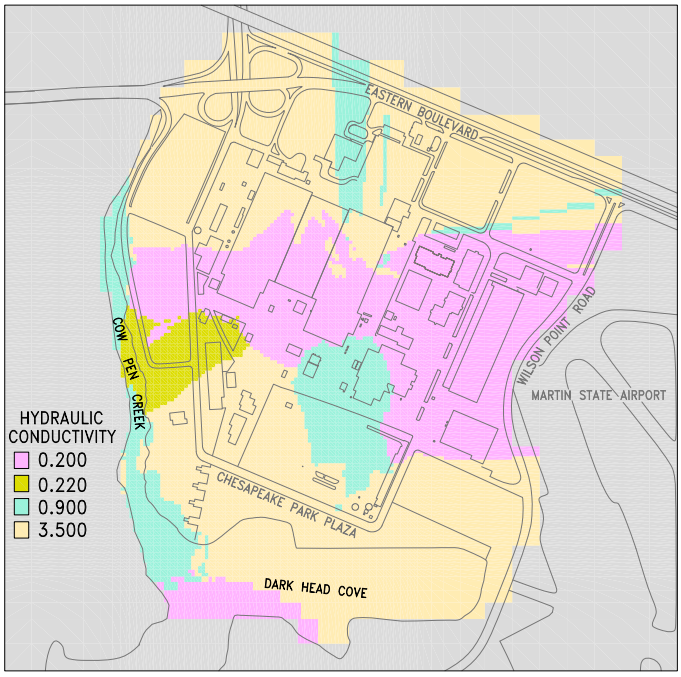
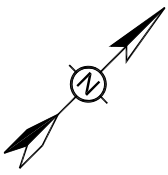


LAYER 9



0 1400 2800

SCALE IN FEET

TITLE: **HYDRAULIC CONDUCTIVITY (ft/d) DISTRIBUTION IN THE CALIBRATED MODEL, LAYER 9**

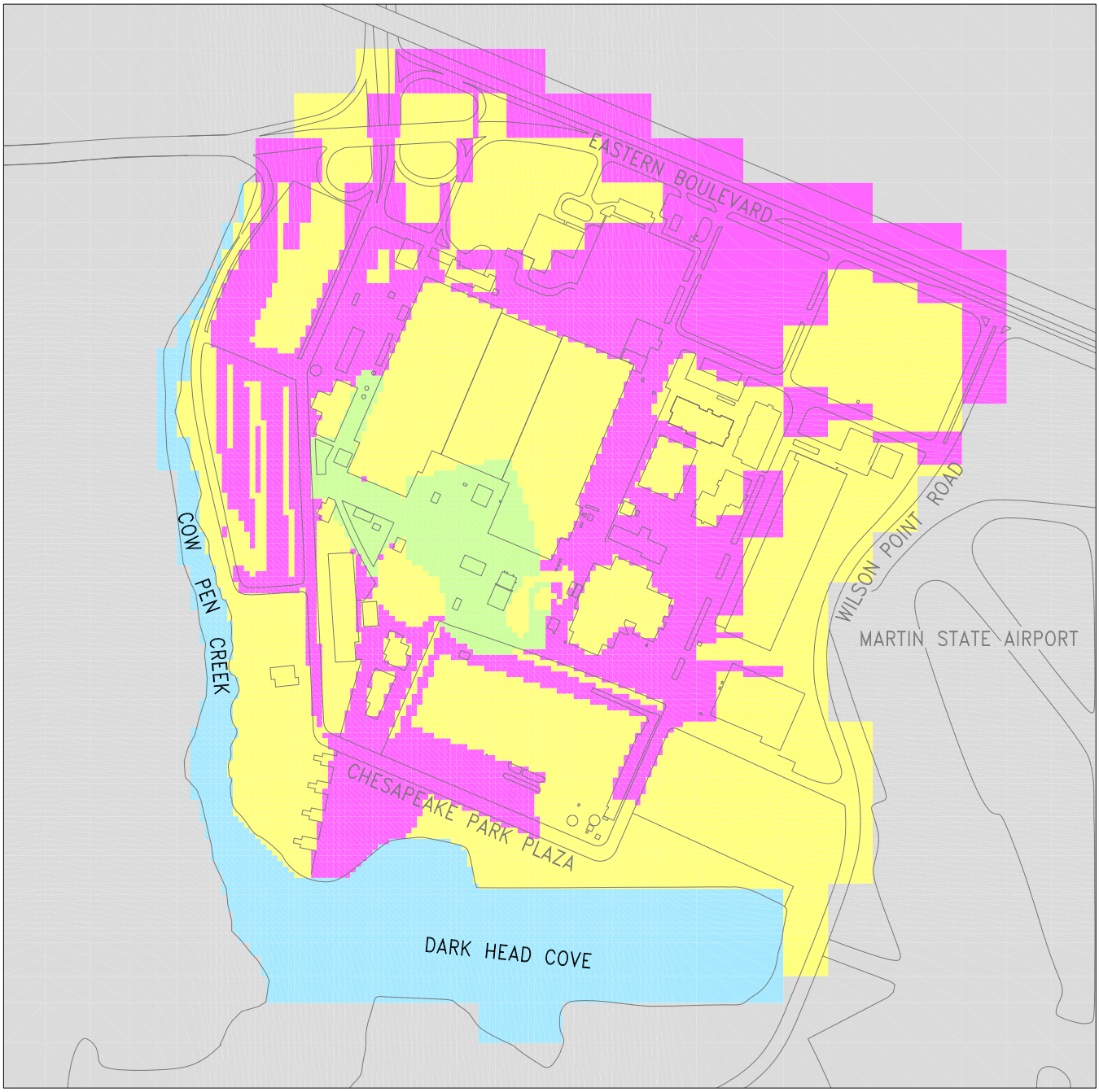
LOCATION: **Middle River Complex, Middle River, Maryland**

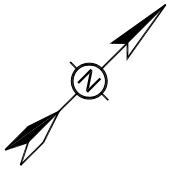
GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 6C

P:\ACAD\0512-031-MRVR\0512031015A.DWG





0 700 1400

SCALE IN FEET

RECHARGE (in/yr)

- 0
- 0.7
- 10

TITLE: **PREDICTED DISTRIBUTION OF GROUNDWATER RECHARGE IN THE CALIBRATED MODEL**

LOCATION: **Middle River Complex, Middle River, Maryland**

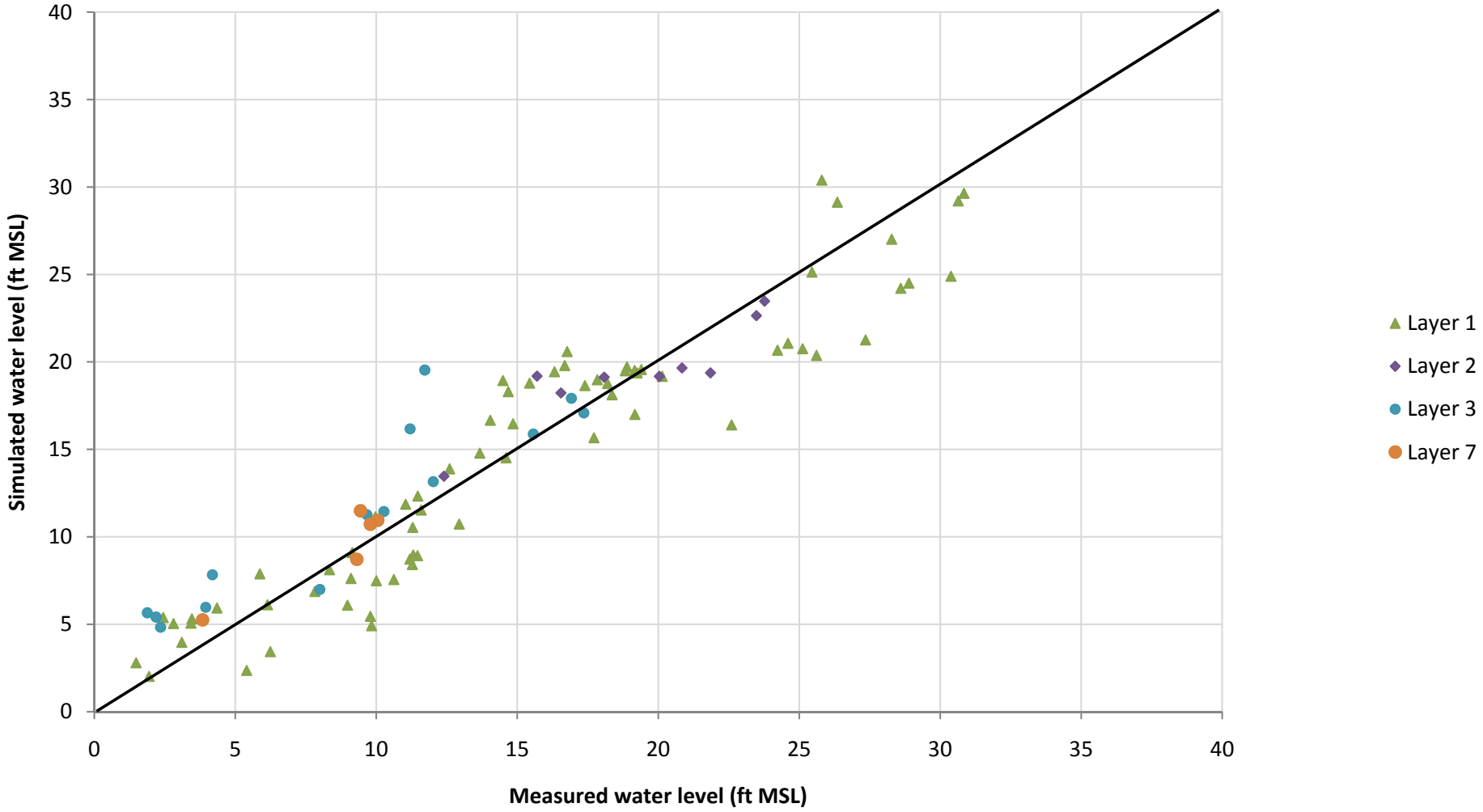
GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 7

P:\ACAD\0512-031-MRVR\0512031016A.DWG

P:\ACAD\0512-031-MRVR\0512031021A.DWG



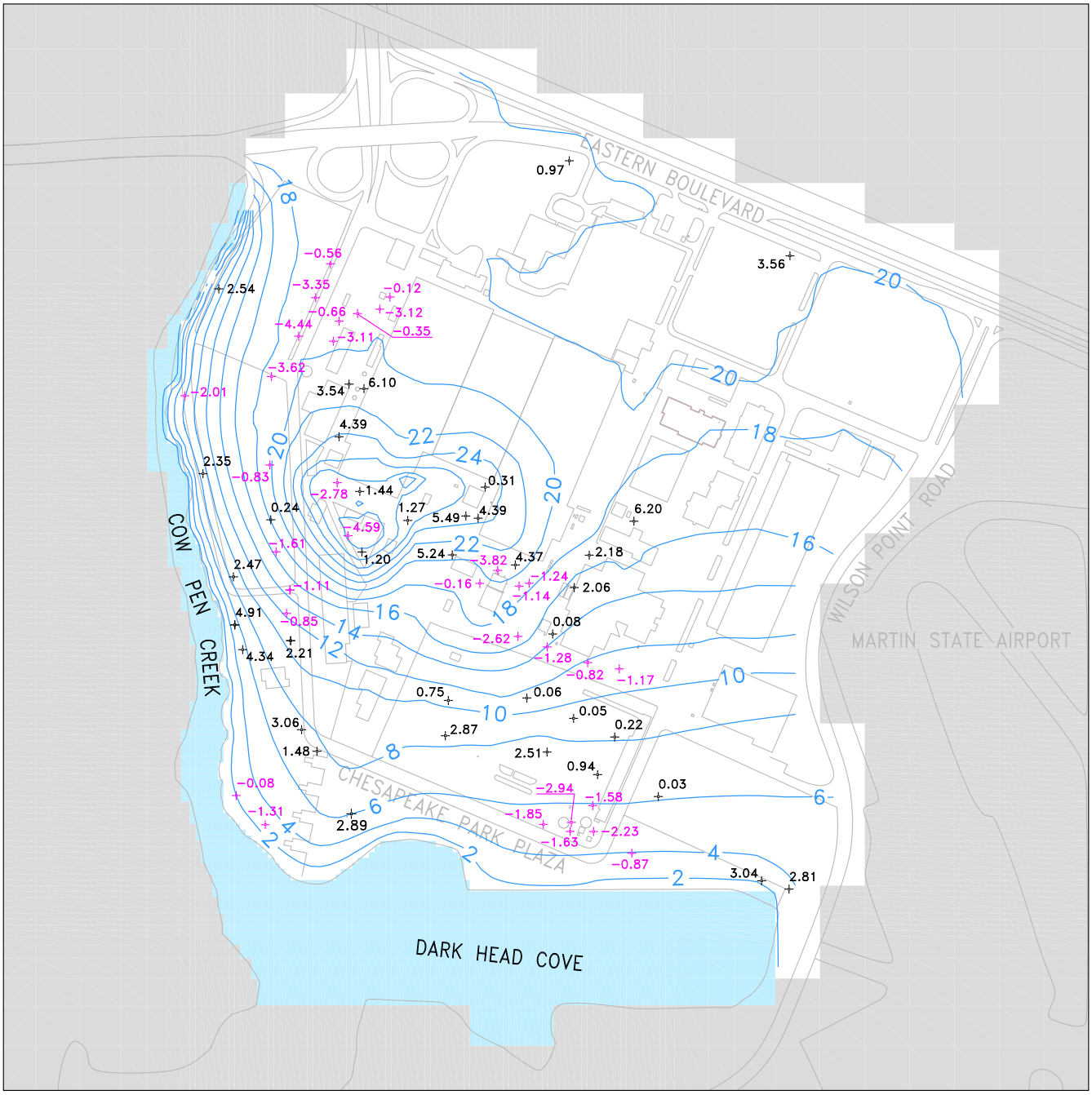
TITLE: **MEASURED AND SIMULATED GROUNDWATER LEVELS OCTOBER 2008**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.03
DATE	12-15-09

FIGURE 8



LEGEND

— 4 — POTENTIOMETRIC CONTOUR (Ft MSL)

0.75 SIMULATED < OBSERVED RESIDUAL (ft)

-1.17 SIMULATED > OBSERVED RESIDUAL (ft)

0 700 1400

SCALE IN FEET

TITLE: **SIMULATED POTENTIOMETRIC SURFACE AND RESIDUALS IN MODEL LAYER 1**

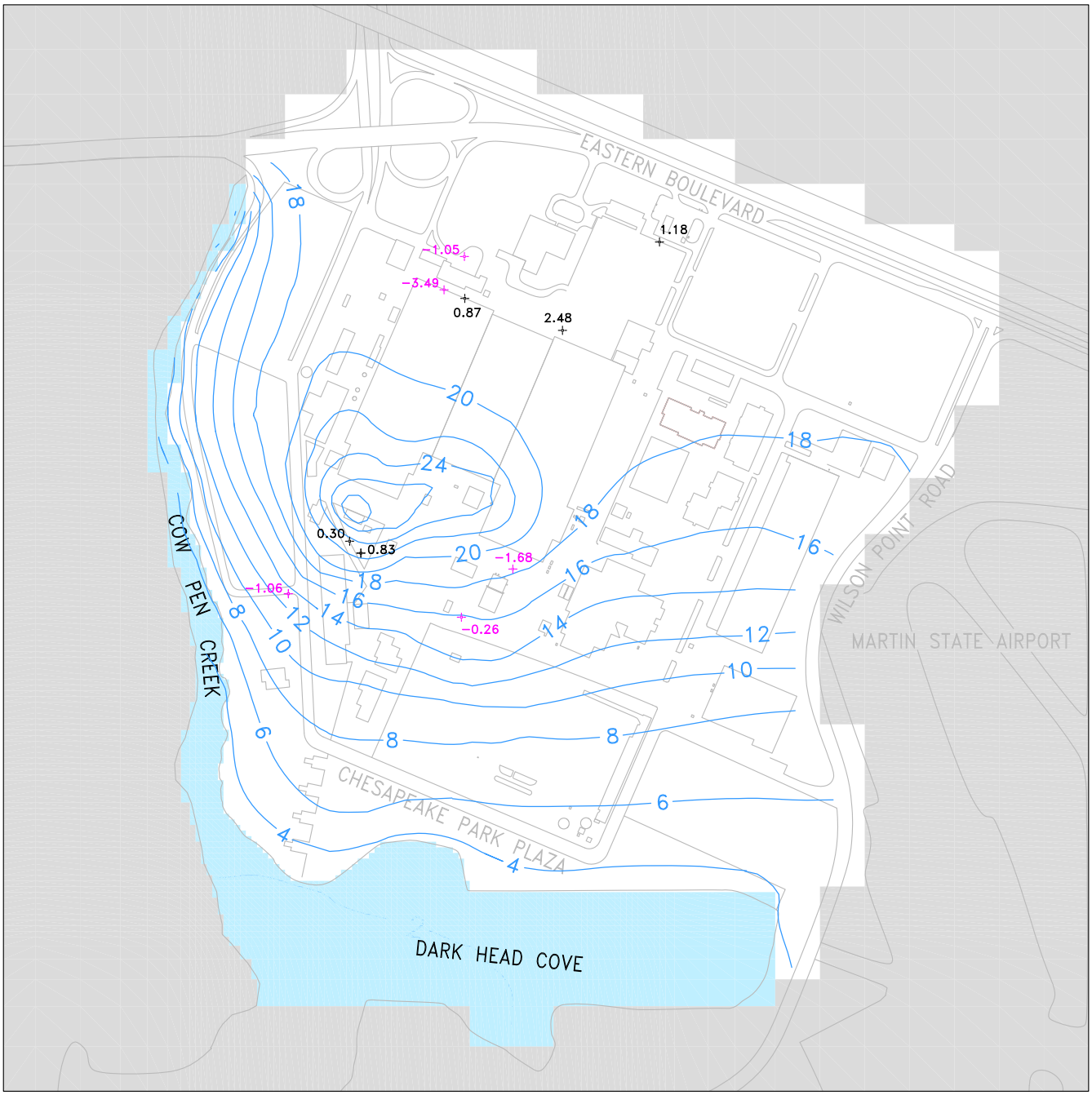
LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	12-14-09

FIGURE **9A**

P:\ACAD\0512-031-MRVR\0512031017A.DWG



LEGEND

— 4 — POTENTIOMETRIC CONTOUR (Ft MSL)

0.75 SIMULATED < OBSERVED RESIDUAL (ft)

-1.17 SIMULATED > OBSERVED RESIDUAL (ft)

0 700 1400

SCALE IN FEET

TITLE: **SIMULATED POTENTIOMETRIC SURFACE AND RESIDUALS IN MODEL LAYER 2**

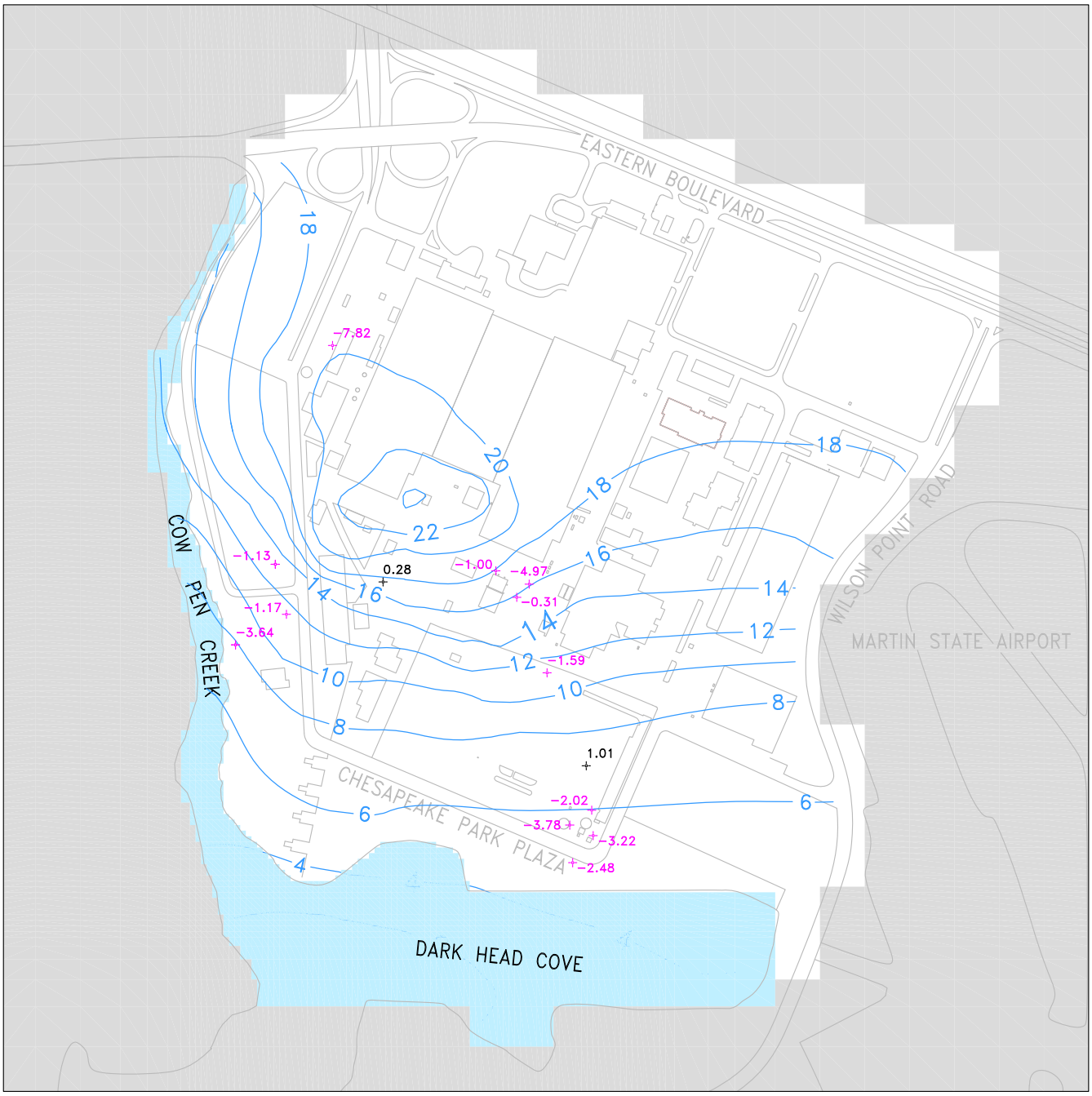
LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	12-14-09

FIGURE **9B**

P:\ACAD\0512-031-MRVR\0512031018A.DWG



LEGEND

— 4 — POTENTIOMETRIC CONTOUR (Ft MSL)

0.75 SIMULATED < OBSERVED RESIDUAL (ft)

-1.17 SIMULATED > OBSERVED RESIDUAL (ft)

0 700 1400

SCALE IN FEET

TITLE: **SIMULATED POTENTIOMETRIC SURFACE AND RESIDUALS IN MODEL LAYER 3**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	12-14-09

FIGURE **9C**

P:\ACAD\0512-031-MRVR\0512031019A.DWG



LEGEND

— 4 — POTENTIOMETRIC CONTOUR (Ft MSL)

0.75 SIMULATED < OBSERVED RESIDUAL (ft)

-1.17 SIMULATED > OBSERVED RESIDUAL (ft)

0 700 1400

SCALE IN FEET

TITLE: **SIMULATED POTENTIOMETRIC SURFACE AND RESIDUALS IN MODEL LAYER 7**

LOCATION: **Middle River Complex, Middle River, Maryland**

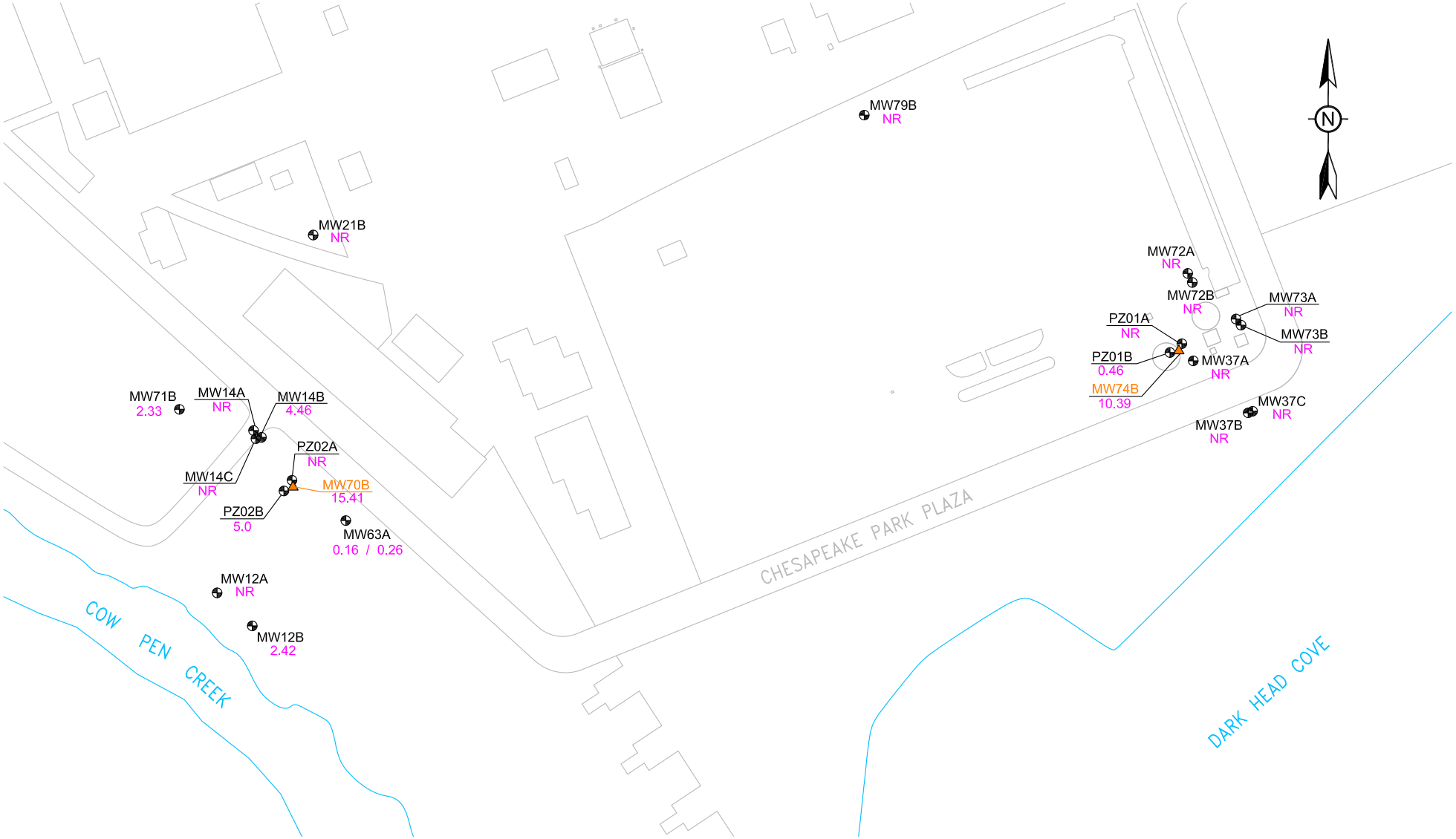
GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	12-14-09

FIGURE **9D**

P:\ACAD\0512-031-MRVR\0512031020A.DWG

P:\ACAD\0512-031-MRVR\0512031022A.DWG



LEGEND

MW71B — MONITORING WELL

MW70B — PUMPING WELL

0.46 — OBSERVED DRAWDOWN

0 250 500

SCALE IN FEET

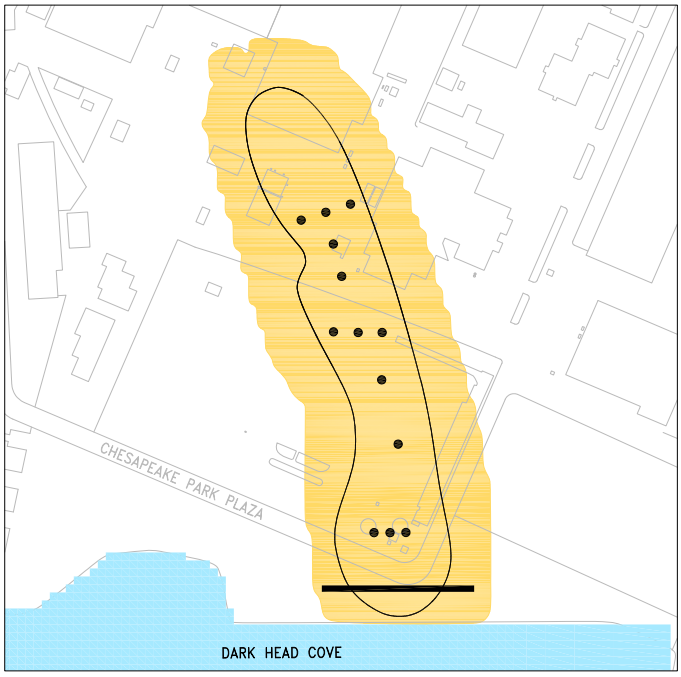
TITLE: **LOCATION OF WELLS MONITORED DURING THE 72-HOUR TEST AT WELL MW74B AND MW-70B**

LOCATION: **Middle River Complex, Middle River, Maryland**

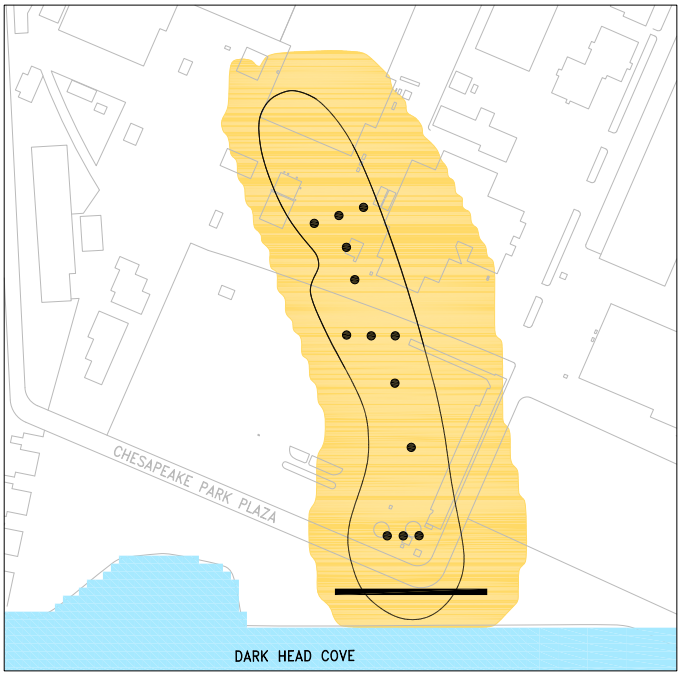
GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.01
DATE	12-15-09

FIGURE 10



LAYER 1



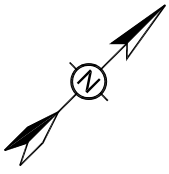
LAYER 2



LAYER 3



LAYER 4



0 600 1200

SCALE IN FEET

LEGEND

CAPTURE ZONE

EXTRACTION WELL

TCE > 5 ug/L

TITLE: **PREDICTED CAPTURE IN THE EAST PLUME WITH 13 WELLS AND EXTRACTION TRENCH (Q=3.9 gpm)**

LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 11

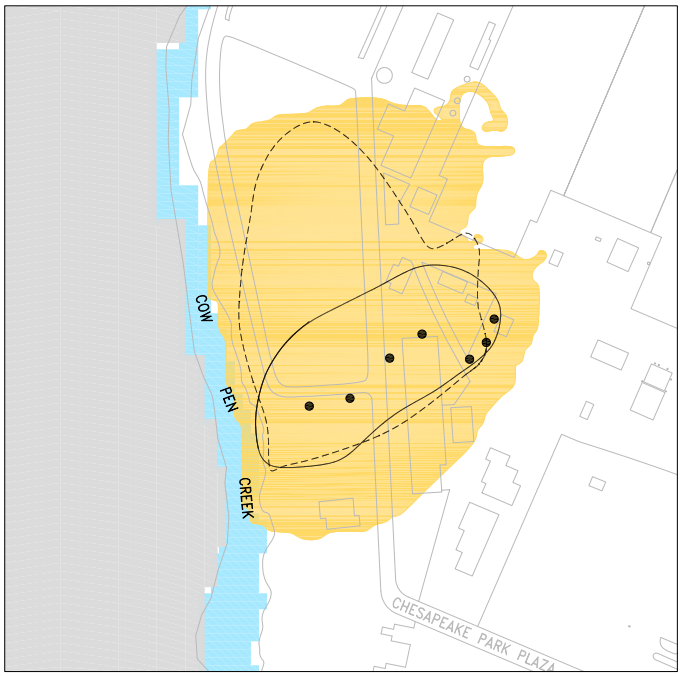
P:\ACAD\0512-031-MRVR\0512031024A.DWG



LAYER 1



LAYER 2



LAYER 3



LAYER 4

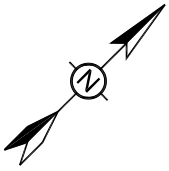
LEGEND

CAPTURE ZONE

EXTRACTION WELL

TCE > 5 ug/L

1,4-DIOXANE > 3 ug/L



0 600 1200

SCALE IN FEET

TITLE: **PREDICTED CAPTURE IN THE WEST PLUME WITH 7 WELLS AND EXTRACTION TRENCH (Q=1.9 gpm)**

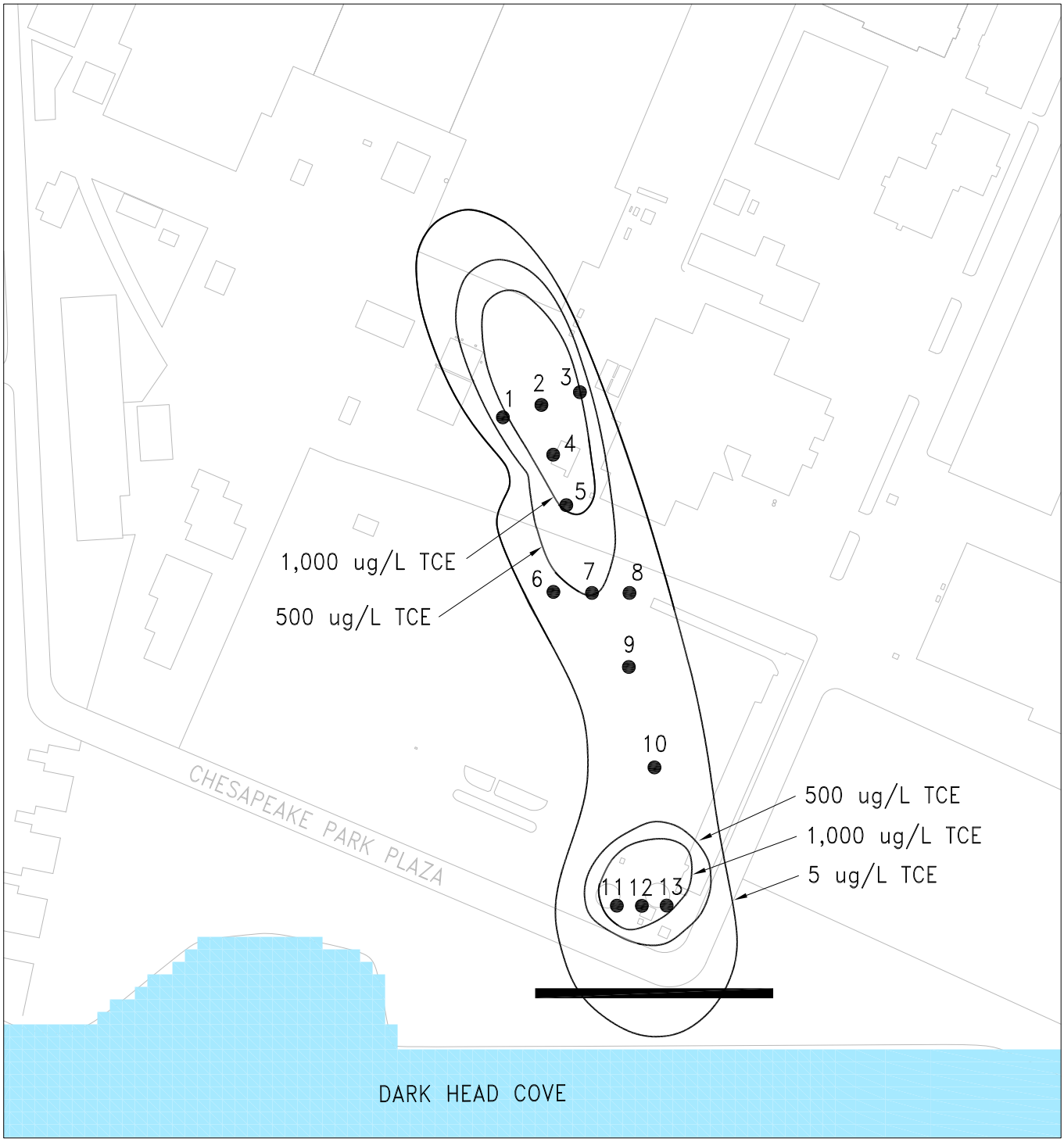
LOCATION: **Middle River Complex, Middle River, Maryland**

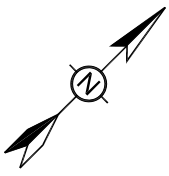
GeoTrans, Inc. A TETRA TECH COMPANY

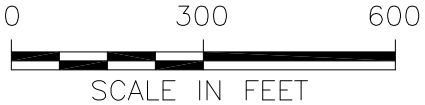
APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 12

P:\ACAD\0512-031-MRVR\0512031025A.DWG







LEGEND

- EXTRACTION WELL
- EXTRACTION TRENCH

TITLE:

LOCATIONS OF EXTRACTION WELLS AND TRENCH, EAST PLUME

LOCATION:

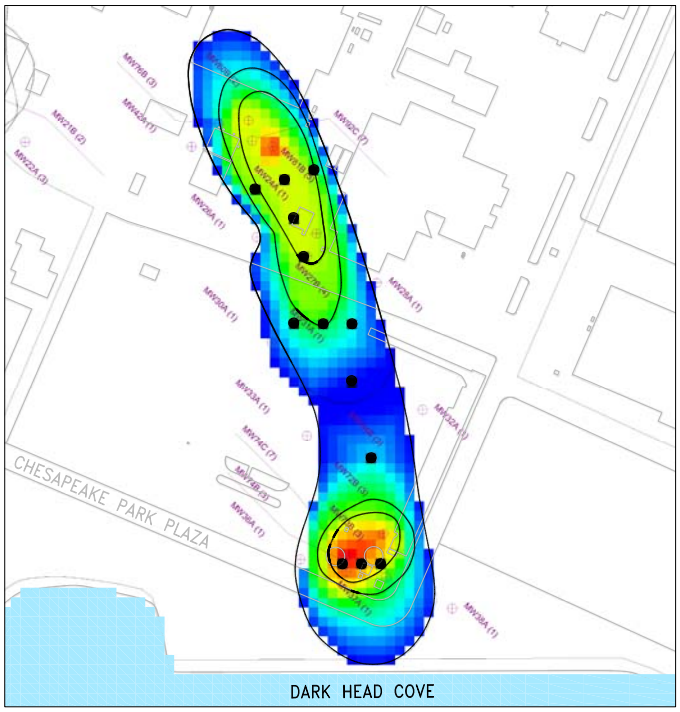
Middle River Complex, Middle River, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

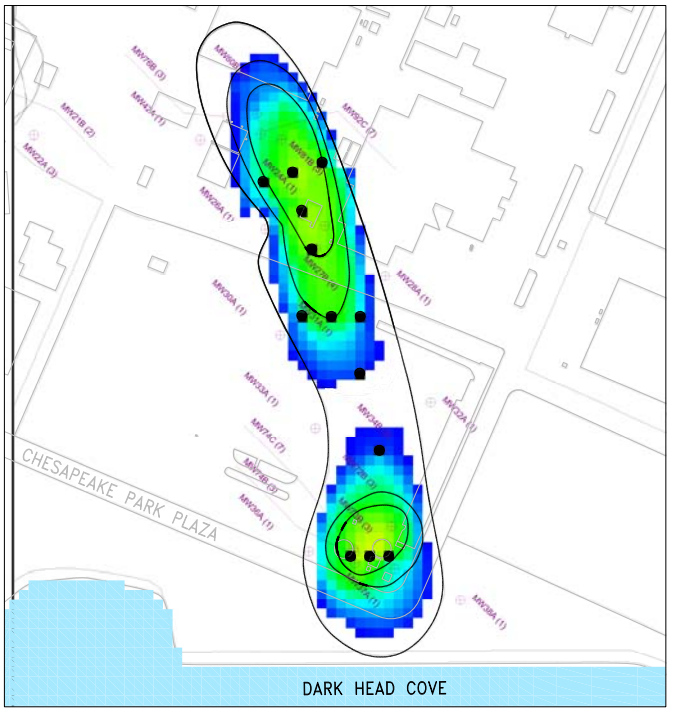
APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 13

P:\ACAD\0512-031-MRVR\0512031026A.DWG



INITIAL



10 YEARS

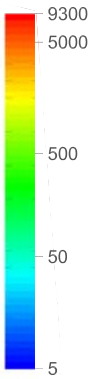


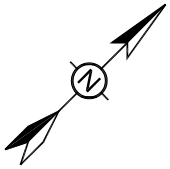
40 YEARS

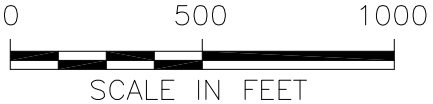


70 YEARS

CONCENTRATION







TITLE: **PREDICTED TCE CONCENTRATION IN MODEL LAYER 3 AT TIME 0, 10, 40, AND 70 YEARS, EAST PLUME (Q=3.9 gpm)**

LOCATION: **Middle River Complex, Middle River, Maryland**

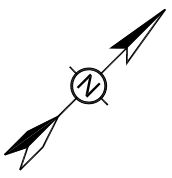
GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 14

P:\ACAD\0512-031-MRVR\0512031028A.DWG





0 300 600

SCALE IN FEET

LEGEND

- EXTRACTION WELL
- EXTRACTION TRENCH

TITLE:

LOCATIONS OF EXTRACTION WELL AND TRENCH, WEST PLUME

LOCATION:

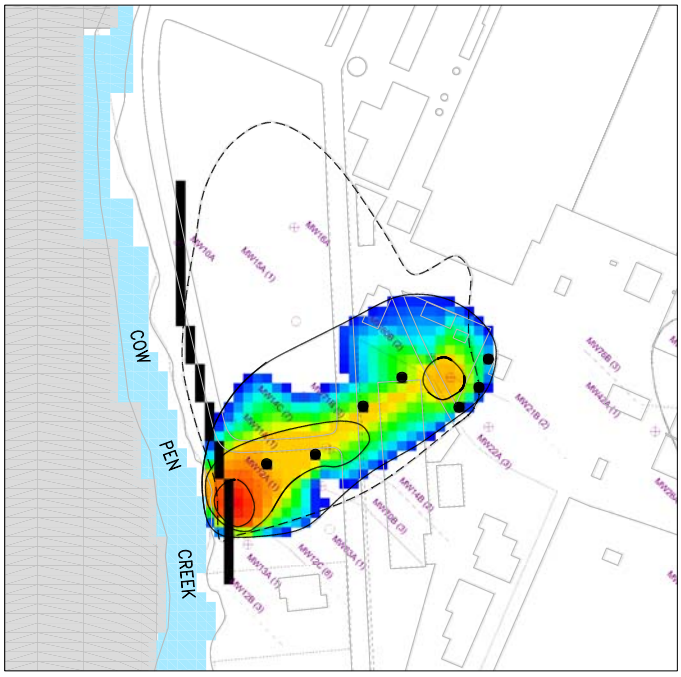
Middle River Complex, Middle River, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

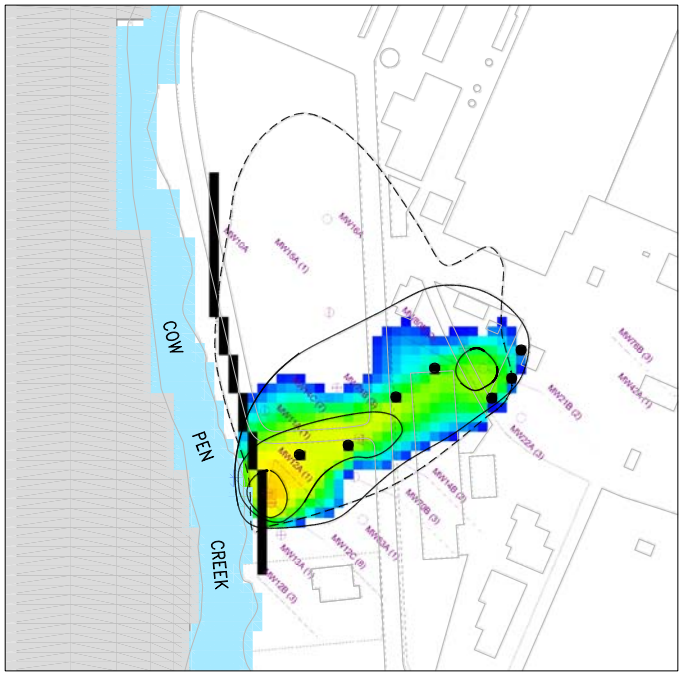
APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 15

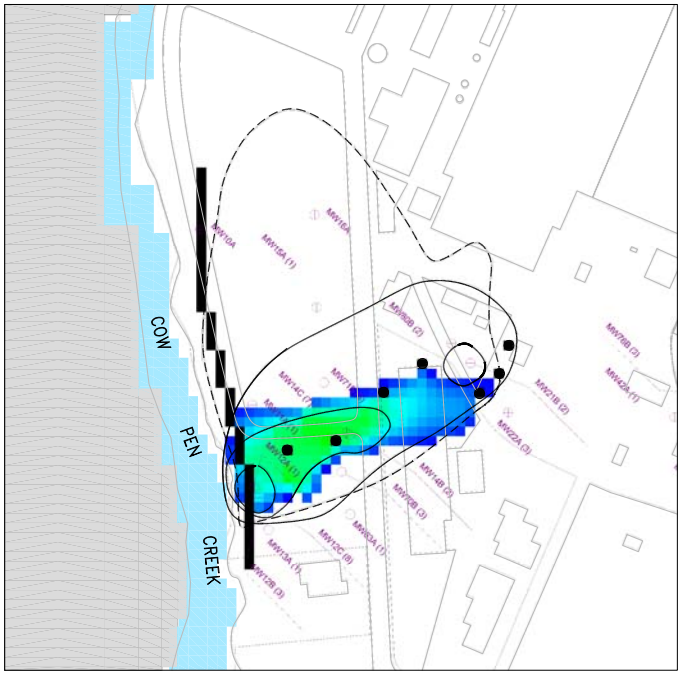
P:\ACAD\0512-031-MRVR\0512031027A.DWG



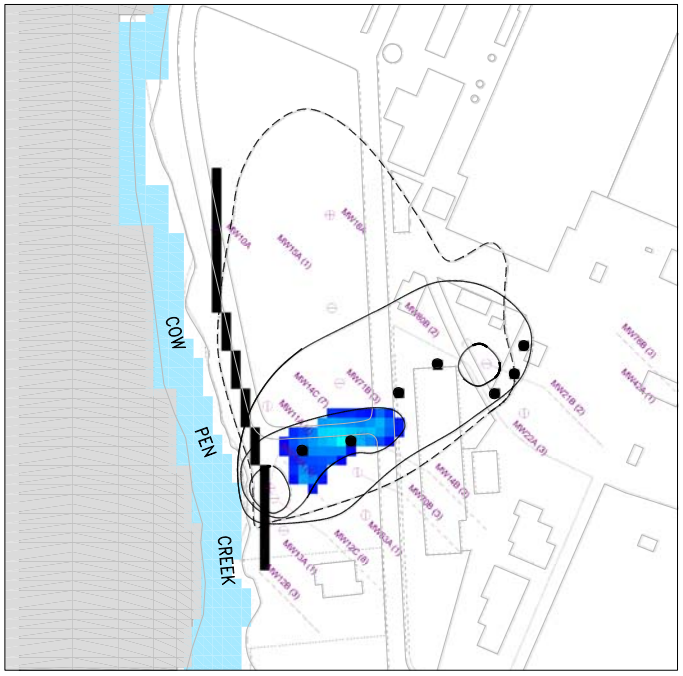
INITIAL



10 YEARS

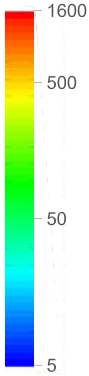


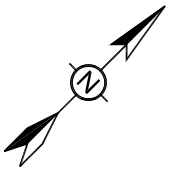
40 YEARS

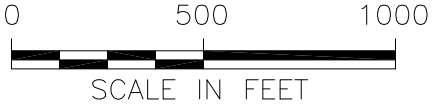


70 YEARS

CONCENTRATION







TITLE: **PREDICTED TCE CONCENTRATIONS IN MODEL LAYER 2 AT TIME 0, 10, 40, AND 70 YEARS, WEST PLUME (Q=1.9 gpm)**

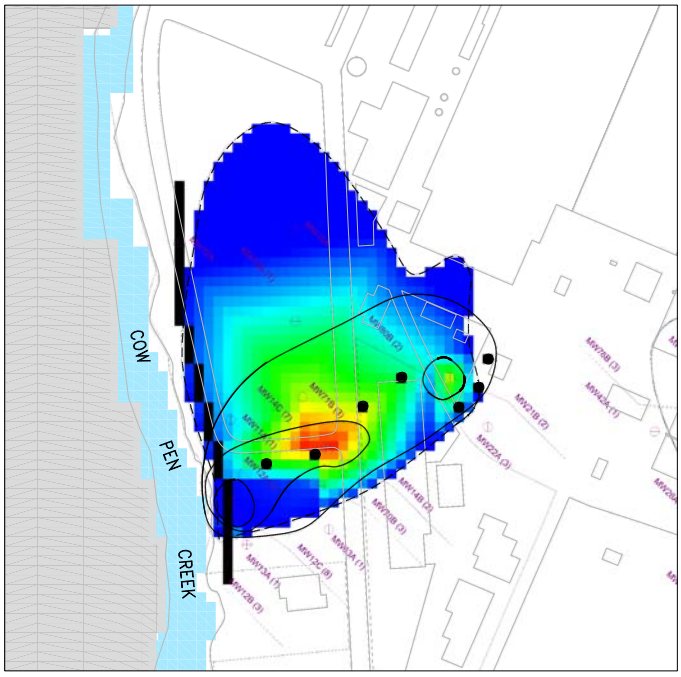
LOCATION: **Middle River Complex, Middle River, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

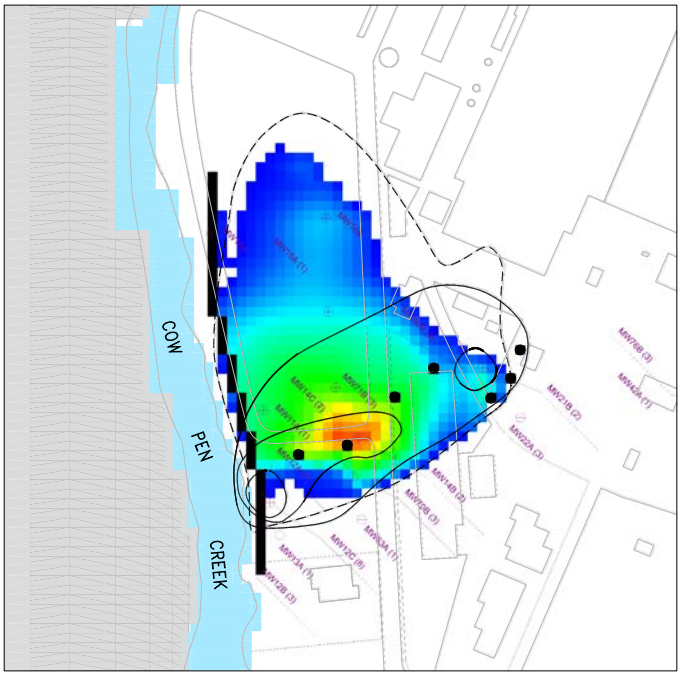
APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 16

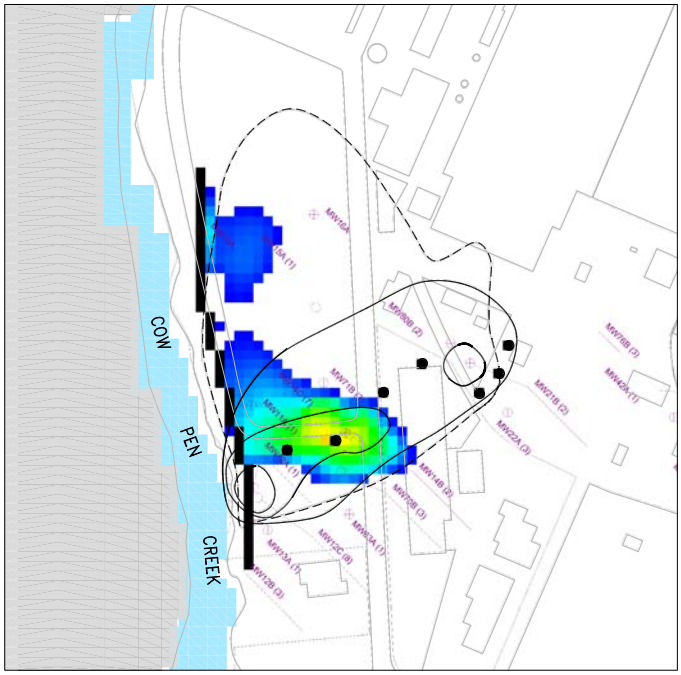
P:\ACAD\0512-031-MRVR\0512031029A.DWG



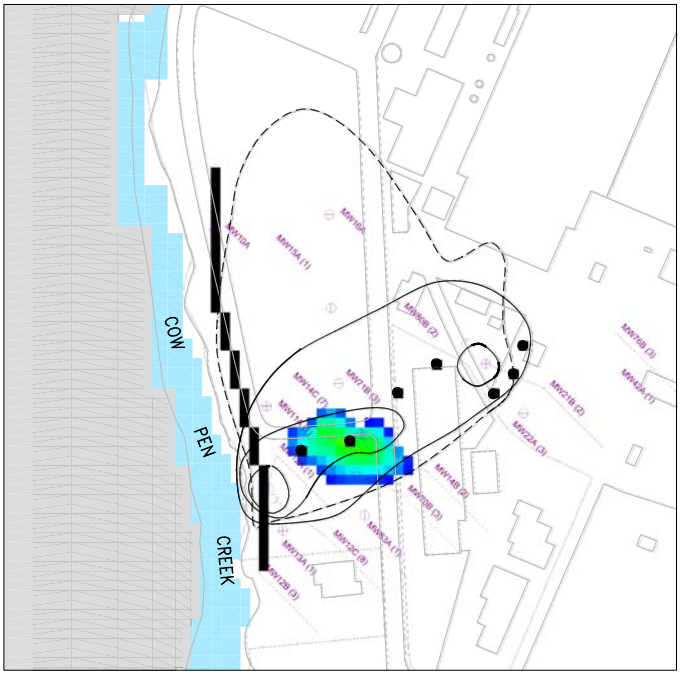
INITIAL



10 YEARS

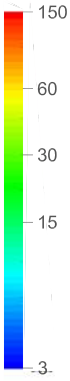


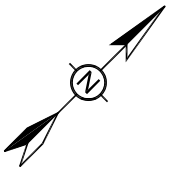
50 YEARS

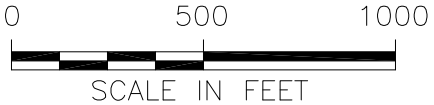


100 YEARS

CONCENTRATION







TITLE:
PREDICTED 1,4-DIOXANE CONCENTRATIONS IN MODEL LAYER 2 AT TIME 0, 10, 50, AND 100 YEARS, WEST PLUME (Q=1.9 gpm)

LOCATION:
Middle River Complex, Middle River, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DS
DRAFTED	CP
PROJECT#	117-0512031.02
DATE	2-3-10

FIGURE 17

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TABLES

Table 1. Results of slug tests at selected wells (TT NUS, 2008).

Name	Hydraulic conductivity (ft/d)	Completion Depth	Description	Name	Hydraulic conductivity (ft/d)	Completion Depth	Description	Name	Hydraulic conductivity (ft/d)	Completion Depth	Description
MW66A	1.25	19	SM	MW34B	0.92	30	SM, SC, CL	MW12C	9.16	75	SM
MW65A	0.99	18	SM	MW14B	0.71	30	SM, ML	MW27C	6.3	78	SM
MW50A	0.30	26	ML,SM,ML	MW37B	0.56	34	SM, ML, SM	MW11C	5.14	73	SM
MW60A	0.22	22	CL, ML	MW21B	0.23	34	SM, ML	MW62C	3.57	65	SP
MW54A	0.17	13	SC	MW27B	0.006	50	SM	MW34C	2.22	55	SM
MW52A	0.10	13	ML, SC, CL					MW14C	0.35	75	SM, ML
MW53A	0.10	13	CL, SC, CL					MW37C	0.00053	70	SM, ML
MW56A	0.10	13	SM, CL								
MW62A	0.06	13	CL, SM								
MW63A	0.06	14	SP, ML								
MW61A	0.049	14	SM, CL								
MW59A	0.046	12	ML, CL								
MW64A	0.03	16	SM, CL, SP, ML								
MW58A	0.006	18	SM, CL, SP								
MW55A2	0.0049	22	CL								
MW57A	0.0027	12	ML, SM								

SP	*fine sand*
SM	*sand; silty sand*
SC	*sand with clay*
ML	*silt; sandy silt; clayey silt*
CL	*clay; silty clay*

Table 2. Summary of model layers

Layer	Elevation of Top [1]		Elevation of Bottom [1]		Average thickness (ft)
	Min	Max	Min	Max	
1	0.0	36.8	-15.0	14.4	19.1
2	-15.0	14.4	-21.0	5.5	7.6
3	-21.0	5.5	-28.5	-5.7	9.5
4	-28.5	-5.7	-36.0	-16.9	9.5
5	-36.0	-16.9	-43.5	-28.0	9.5
6	-43.5	-28.0	-51.0	-39.2	9.5
7	-51.0	-39.2	-58.5	-50.4	9.5
8	-58.5	-50.4	-66.0	-61.6	9.6
9	-66.0	-61.6	-75.0	-75.0	11.4

[1] ft MSL

Table 3. Initial values of hydraulic conductivity assigned to geologic materials

Material	Horizontal hydraulic conductivity
Sand	1.0
Silty sand	0.5
silt; clayey silt	0.1
clay; silty clay	0.05
gravel	50
	ft/d

Table 4. Summary statistics, measured versus simulated groundwater levels.

Layer	# Observations	Range	Average Error	Absolute Average Error	10% Range
All	101	29.4	0.03	2.05	2.94
		(ft)	(ft)	(ft)	(ft)

Table 5a. Comparison of measured and simulated drawdown (ft) at end of 72-hour test, well MW74B, east plume.

Well	37A	37B	37C	72A	72B	73A	73B	74B	79B	PZ-01B	PZ-01A
Layer:	1	3	7	1	3	1	3	3	3	3	1
Simulated:	0.03	0.19	0.08	NR	0.24	NR	0.29	2.0	0.02	1.7	0.02
Observed:	NR	NR	NR	NR	NR	NR	NR	10.4	NR	0.46	NR

Table 5a. Comparison of measured and simulated drawdown (ft) at end of 72-hour test, well MW70B, west plume.

Well	12A	12B	14A	14B	21B	71B	PZ-02A	PZ-02B	70B	63A
Layer:	1	3	1	2	2	3	1	3	3	1
Simulated:	NR	1.4	NR	3.2	0.4	2.4	NR	6.7	14.3	NR
Observed:	NR	2.4	NR	4.5	NR	2.3	NR	5.0	15.4	0.26

NR - no response

Table 6. Input parameter values for the transport model

	Units	Sand	Silty sand	Silty clayey sand	Clayey silty sand	Gravel	Source
f_{oc}	%	0.07%	0.07%	0.07%	0.07%	0.07%	MRC field values
TCE: K_{oc}		104	104	104	104	104	literature value
1,4-dioxane: K_{oc}	L/Kg	3.47	3.47	3.47	3.47	3.47	literature value
bulk density	g/cm^3	2.5	2.5	2.5	2.5	2.5	MRC field values
porosity	--	0.40	0.40	0.48	0.45	0.32	best estimate
effective porosity	--	0.20	0.20	0.24	0.23	0.16	best estimate
Trichloroethene (TCE)							
distribution coeff, Kd	L/Kg	7.5E-02	7.5E-02	7.5E-02	7.5E-02	7.5E-02	f_{oc} x K_{oc}
retardation, R	--	1.93	1.93	1.78	1.83	2.16	calculated
1,4-Dioxane							
distribution coeff, Kd	L/Kg	2.5E-03	2.5E-03	2.5E-03	2.5E-03	2.5E-03	f_{oc} x K_{oc}
retardation, R	--	1.03	1.03	1.03	1.03	1.04	calculated

Table 7. Summary of east plume transport simulations.

GeoTrans ID	Description	Trench Elev	# Wells	Half Life	Source Reduction*		Flux (gpm)			Time to Cleanup (yrs; L1-L4)			
										Up-Gradient		Dwn-Gradient	
					>1,000	>100/<1,000	Trench	Wells	Total	100 ug/L	5 ug/L	100 ug/L	5 ug/L
36-1	7 wells, no source reduction	-2	7	10	NA	NA	1.29	2.06	**3.35**	42	97	39	78
37-1	13 wells, no source reduction	-2	13	10	NA	NA	1.11	2.84	**3.95**	42	78	25	52
37-2	13 wells, 90% source reduction	-2	13	10	90%	NA				42	78	20	52
37-3	13 wells, 95% source reduction	-2	13	10	95%	NA				42	78	20	52
37-4	13 wells, 99% source reduction	-2	13	10	99%	NA				42	78	20	52
37-5	13 wells, 80% source reduction	-2	13	10	80%	NA				42	78	21	52
38-1	passive reactive barriers only	NA	0	10	90%	50%	0	0	**0**	43 [1]	85 [1]	38 [1]	91 [1]
39-1	no action	NA	0	10	90%	NA	0	0	**0**	44	93	43	94
		(ft MSL)	--	(yrs)									

*Source reduction in the east plume is limited to the down-gradient end/source in the plume. No change at up-gradient source.

[1] for this run, up-gradient and down-gradient is relative to the first hypothetical passive reactive barrier, located near MW79B and RR tracks.

Table 8. Summary of west TCE plume transport simulations.

										Time to Cleanup (yrs; L1-L4)			
					Source Reduction*		Flux (gpm)			Up-Gradient		Dwn-Gradient	
GeoTrans ID	Description	Trench Elev	# Wells	TCE HL	>500	>100/<500	Trench	Wells	Total	100 ug/L	5 ug/L	100 ug/L	5 ug/L
24-1	3 wells, no source reduction	-2	3	10	NA	NA	1.37	0.32	**1.69**	71	>100	>100	>100
23-1	7 wells, no source reduction	-2	7	10	NA	NA	1.22	0.70	**1.92**	30	74	38	>100
23-2	7 wells, 90% source reduction	-2	7	10	90%	NA				30	74	33	93
23-3	7 wells, 80% source reduction	-2	7	10	80%	NA				30	74	33	93
23-9	9 wells, 80% source reduction	-2	9	10	80%	NA	1.16	0.87	**2.03**	30	73	33	94
PRB	passive reactive barriers only	NA	0	10	90%	50%	0	0	**0**	28 [1]	77 [1]	NA	NA
		(ft MSL)	--	(yrs)									

*Source reduction in the west plume is limited to the down-gradient end. No change at the up-gradient end of plume.

[1] for this run, up-gradient of the hypothetical passive reactive barrier, located adjacent to the river. No down-gradient (between PRB & river) calculated.

Table 8b. Summary of west 1,4-dioxane plume transport simulations.

GeoTrans ID	Description	Trench Elev	# Wells	Source Reduction*	Flux (gpm)			Time to Cleanup (yrs; L1-L4)	
				Area in which TCE ≥500 ug/L	Trench	Wells	Total	3 ug/L	15 ug/L
24-2		-2	3	NA	1.37	0.32	**1.69**	>100	NC
23-4	7 wells, no source reduction	-2	7	NA	1.22	0.70	**1.92**	>200	NC
23-5	7 wells, 70% source reduction	-2	7	70%				>200	141
23-7	7 wells, 70% source reduction; remove mass from layer 2	-2	7	70%	1.22	0.70	**1.92**	175	89
23-8	9 wells, 70% source reduction	-2	9		1.16	0.87	**2.03**	>100	92
PRB	passive reactive barriers only	NA	0	70%	0	0	**0**	>200	NC
25-1	trench only	NA	0	70%	1.41	0	**1.41**	>200	NC
		(ft MSL)	--						

*Source reduction in the west plume is limited to the down-gradient end. Reduction is to 1,4-dioxane in specified TCE area.

NC - not calculated

Supplemental Groundwater Modeling for *In Situ* Bioremediation

Following completion of the groundwater modeling presented in the Development and Calibration of a Groundwater Flow and Transport Model for the Middle River Complex Site (Groundwater Modeling Report), Lockheed Martin Corporation determined that additional modeling was necessary to determine the flow and transport characteristics associated with injection of a substrate into the subsurface at this site.

The additional modeling was completed primarily to provide the following:

- An estimate of the effect that groundwater extraction would have on distribution of injected substrate.
- Preliminary design injection rates that would lead to acceptable groundwater mounding and pressure head values.
- The distribution of substrate that could be obtained with injection using various well layout and injection scenarios (i.e., no extraction).

For the purpose of obtaining the information required for completion of the Groundwater Response Action Plan (RAP), the project team decided to focus the additional simulations on one injection area. It was determined that the southeastern plume would be simulated; this area exhibits the highest groundwater trichloroethene (TCE) concentrations and has subsurface conditions that adequately represent the other two injection areas. Prior to finalizing the designs for injections in the other two injection areas, a similar modeling exercise will be conducted for these areas.

The previously prepared model used a 25-foot by 25-foot horizontal grid with 9 vertical layers to represent the shallow groundwater system beneath the site. This was adequate for the simulations completed in the Groundwater Modeling Report. However, the 25-foot by 25-foot horizontal grid was too coarse to adequately simulate the injection of substrate which would occur in a relatively small area surrounding each injection well. Therefore, for the purposes of these additional simulations, a 2-foot by 2-foot grid was established for the southeastern injection area over an area approximately 170 feet-by-210 feet (35,700 square feet). No other characteristics of the original model were altered. The finer grid is represented over the entire model domain in Exhibit 1 and for the southeastern injection area in Exhibit 2.

To do the initial simulations, a network of 25 injection wells was simulated in the southeastern area. The model simulations were designed to match the preliminary design in the Groundwater RAP; i.e., injection would be simulated at a depth of 15 to 30 feet below ground surface (bgs) at each of the well locations, corresponding to Layers 2 and 3 of the model.

Two initial simulations (Runs 3 and 4) were performed to compare the distribution of substrate with and without groundwater extraction. Details of these runs are as follows:

Run 3 – Injection Only

- Liquid injection over a 10-day interval was simulated.
- The simulated injection rate at each well was 0.2 gallons per minute (gpm) with a total injection of approximately 3,000 gallons of liquid at each of the 24 wells during the 10-day period.
- The concentration of the injected liquid was set at one and the distribution of the injected liquid was simulated over a 270-day period. The distribution of the injected liquid at the end of the 10-day injection period and 270 days after the initiation of the injection are shown in Exhibits 3 and 4, respectively. These exhibits show the simulated concentrations in model Layer 2; results for the other layer in which fluid is injected (Layer 3) are very similar.

Run 4 – Injection and Extraction

- The injection scenario was identical to that above.
- In addition, three extraction wells were simulated in the southern portion of the modeled area. Operation of these wells was simulated over the entire 270-day simulation period; drawdown in each of the wells was set at 2 feet below the static water table. The total extraction rate was less than 1 gpm.
- The liquid distribution at the end of the 10-day injection period and 270 days after the initiation of the injection are shown in Exhibits 5 and 6, respectively. These exhibits show the simulated concentrations in model Layer 2; as in Run 3, results for Layer 3 are very similar.

The results of these two runs were compared closely to determine the impact of the groundwater extraction on the liquid distribution. To eliminate the effects of numerical dispersion represented by the low concentration areas shown in blue and green on the exhibits, only the areas with simulated concentrations greater than 1×10^{-3} (represented by red and yellow on the exhibits) were considered in the comparison.

A visual comparison of the simulated distribution shows that, as expected, the distribution is aided by the groundwater extraction, especially in the southern injection wells in the 270-day simulation. Based on the estimated areas of the concentrations above 1 x 10^{-3} in Runs 3 and 4, the groundwater extraction led to an approximately 15% greater distribution area at 270 days in the southern injection wells and 10% increase in injection area in the northern injection wells. This data was used in the determination of the selected remedy.

The groundwater mounding and pressure head development associated with the injection simulated in Run 3 were also analyzed. These are represented in Exhibits 7, 8, and 9. Exhibit 7 shows the groundwater table elevation increase as shown in Layer 1 of the model. A maximum mounding of approximately 0.6 feet was simulated. This mounding was less than 1 foot and therefore was considered acceptable. Exhibits 8 and 9 show the pressure head development in Layers 2 and 3 of the model at the end of the injection period. A maximum pressure of approximately 11 feet of water was indicated; this was slightly higher than the desired limit (10 feet of water). A slightly reduced injection rate of 0.15 gpm was simulated and provided acceptable mounding and pressure heads; therefore, this injection rate was used for future simulations.

Having determined the effect of groundwater extraction on the distribution of substrate in the subsurface, additional simulations were conducted to determine the preliminary design of an injection-only *in situ* bioremediation system. Based on the initial simulations, an injection rate of 0.15 gpm and an injection volume of 3,000 gallons were used as the preliminary design basis. The goals of this portion of the modeling simulation were:

- Using the preliminary design basis, determine the well layout required to meet the project goal of a 100 milligram per liter (mg/L) concentration of substrate over 50% of the injection area following the initial injection event.
- Confirm the preliminary injection flow rate will provide acceptable mounding and pressure heads with the revised well layout.

Several simulations were run to determine the injection well layout. The results of the analysis led to the injection well layout represented in Exhibit 10 and simulated in Run 8. This includes a total of 52 injection wells. The wells are laid out in seven rows that are approximately 40 feet apart; within each row, the wells are spaced 20 feet apart. Exhibit 10 shows the distribution of

injected liquid (0.15 gpm and 3,000 gallons per well; 14-day injection period) following injection; Exhibit 11 shows the distribution of the liquid after 270 days. Similar to what was described for Runs 3 and 4, a representation of model Layer 2 is shown in these exhibits. Exhibits 10 and 11 show a good distribution of the liquid throughout the injection area in Layer 2, predicting the success of this injection scenario. Note that due to the increase in model horizontal grid size at the boundaries of the injection area, the liquid distribution is artificially expanded in these areas; this portion of the model was not considered in the analysis of the injection system design.

Another important consideration in the design of the injection system was to limit the amount of substrate present at the groundwater table (model Layer 1) where TCE concentrations are generally much lower. As can be seen in Exhibit 12, which represents the liquid concentrations in Layer 1 following the 14-day injection period, the concentrations and distribution of the injected liquid are much lower in Layer 1. This was confirmed in cross-sectional views from the model. Therefore, the injection system as proposed is expected to be effective in limiting the mass of substrate migrating vertically into area of lower contamination.

Next, the groundwater mounding and pressure head development in Run 8 were analyzed. The mounding in Layer 1 and the pressure head development in Layers 2 and 3 are shown in Exhibits 13, 14, and 15, respectively. A groundwater mounding of 1.1 feet in Layer 1 and pressure head development of approximately 16 feet of water in Layers 2 and 3 were simulated. These are greater than the project goals. Therefore, an alternate injection scenario was developed. In this scenario, liquid is injected into only 50 percent of the wells at any one time. Based on the results of the 0.15 gpm injection scenario in Run 3 (24 injection wells), this alternate injection scenario is expected to limit the mounding and pressure head development to allowable levels. All design parameters will be tested in the field prior to full-scale injection activities.

The final step in the supplemental groundwater modeling was to predict the area over which an acceptable concentration of the substrate will be distributed using the proposed injection scenario. To accomplish this, the injection was simulated in a slightly different way. The initial injection concentration was set at 10,000 mg/L, equivalent to the 1% substrate solution proposed in the groundwater RAP.

The goal for the injection system, as simulated, was to distribute substrate at a concentration of 100 mg/L or greater over at least 50% of the treatment area after one injection event. Using the initial injection concentration of 10,000 mg/L, the substrate concentration throughout the treatment area was simulated throughout the same 270-day period used in the other simulations. To be conservative, and account for the breakdown of the substrate over the 270-day period, the distribution of the substrate after the 14-day injection period was used for the evaluation (this is considered conservative because the natural groundwater flow would be expected to cause migration of the substrate over a greater area during the remainder of the 270-day period).

Exhibit 16 shows the projected substrate concentrations throughout the treatment area following the injection period. From this distribution, the area containing 100 mg/L or greater of substrate is expected to be 22,100 square feet, or approximately 67% of the injection area. This exceeds the 50% goal for substrate distribution.

In summary, the supplemental groundwater modeling predicted the following:

- The effect of adding groundwater extraction during and after the injection of liquid to the subsurface causes a minor increase in the liquid distribution, ranging from approximately 10 to 15%.
- Using a network of 52 injection wells, an injection rate of 0.15 gpm per well, and an injection volume of 3,000 gallons per well is predicted to provide adequate substrate distribution.
- The injection scenario in which 0.15 gpm is injected into half of the wells at any one time will result in acceptable groundwater mounding and pressure head development.
- Substrate injection at a depth interval of 15 to 30 feet bgs will provide focused injection at that depth interval with limited vertical distribution of substrate to less contaminated areas.

EXHIBIT 1
REVISED MODEL GRID - ENTIRE MODEL DOMAIN

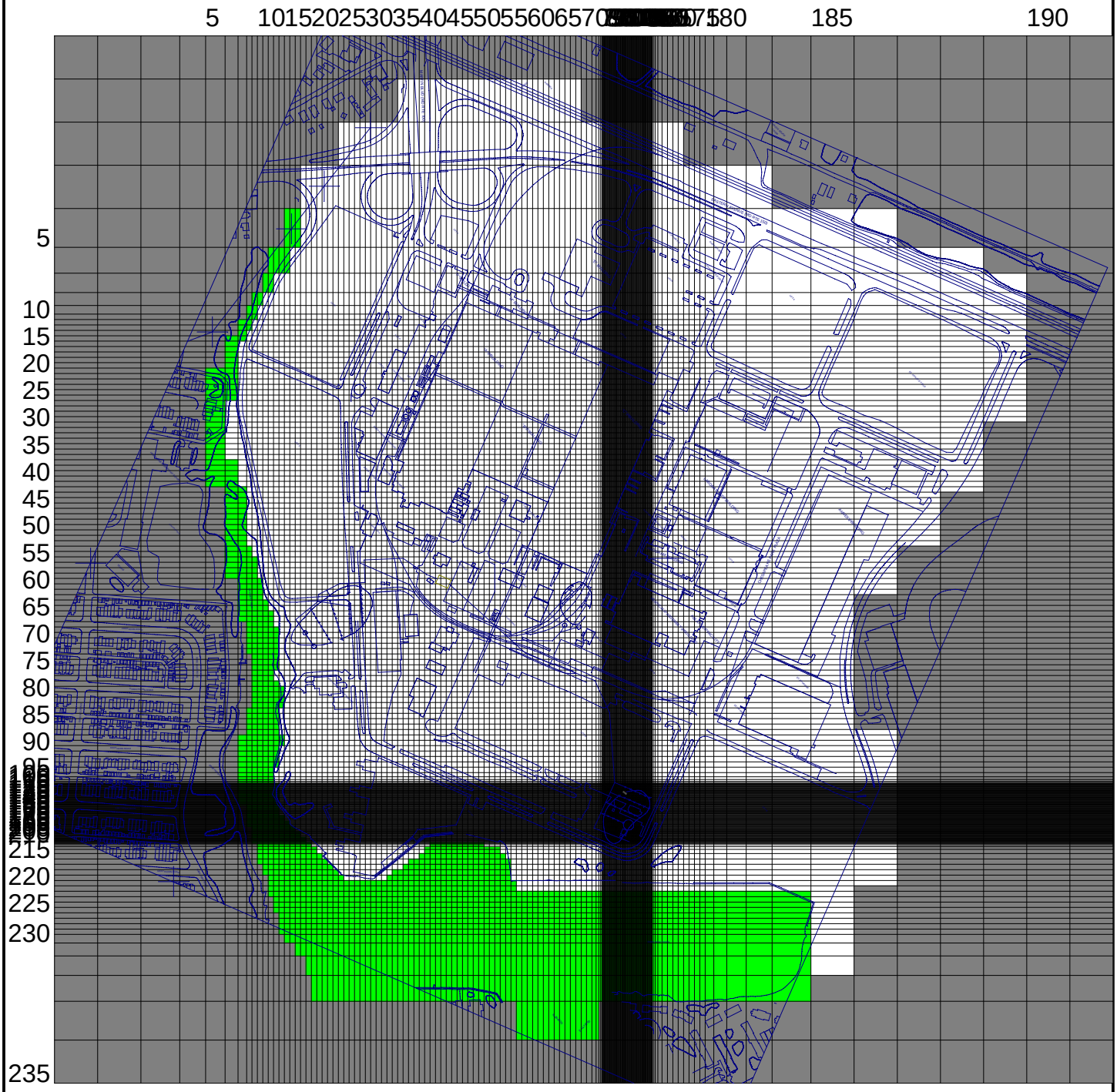


EXHIBIT 2
REVISED MODEL GRID -
SOUTHEASTERN TREATMENT AREA

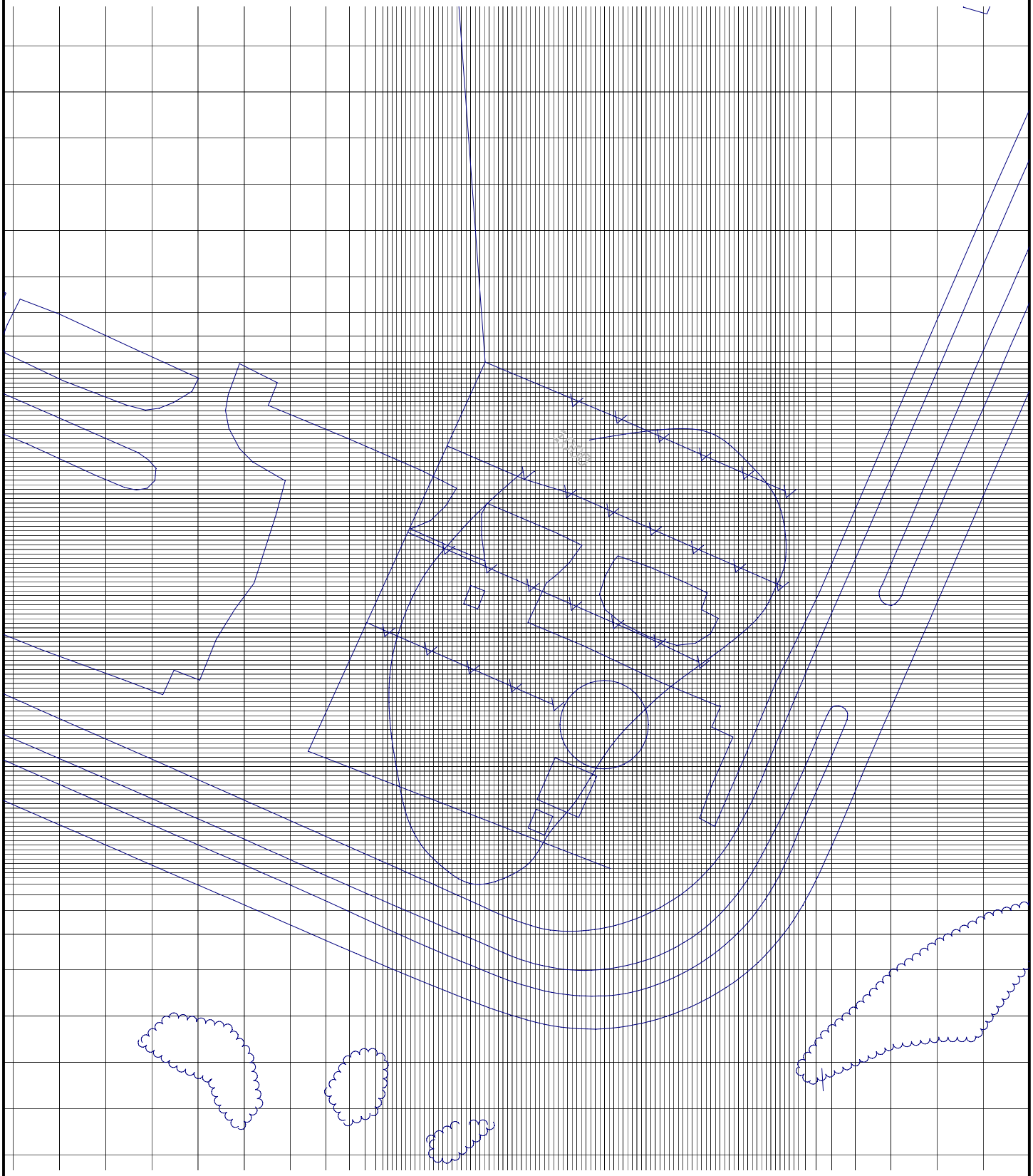


EXHIBIT 3
DISTRIBUTION AT DAY 10 - RUN 3
LAYER 2
INJECTION ONLY

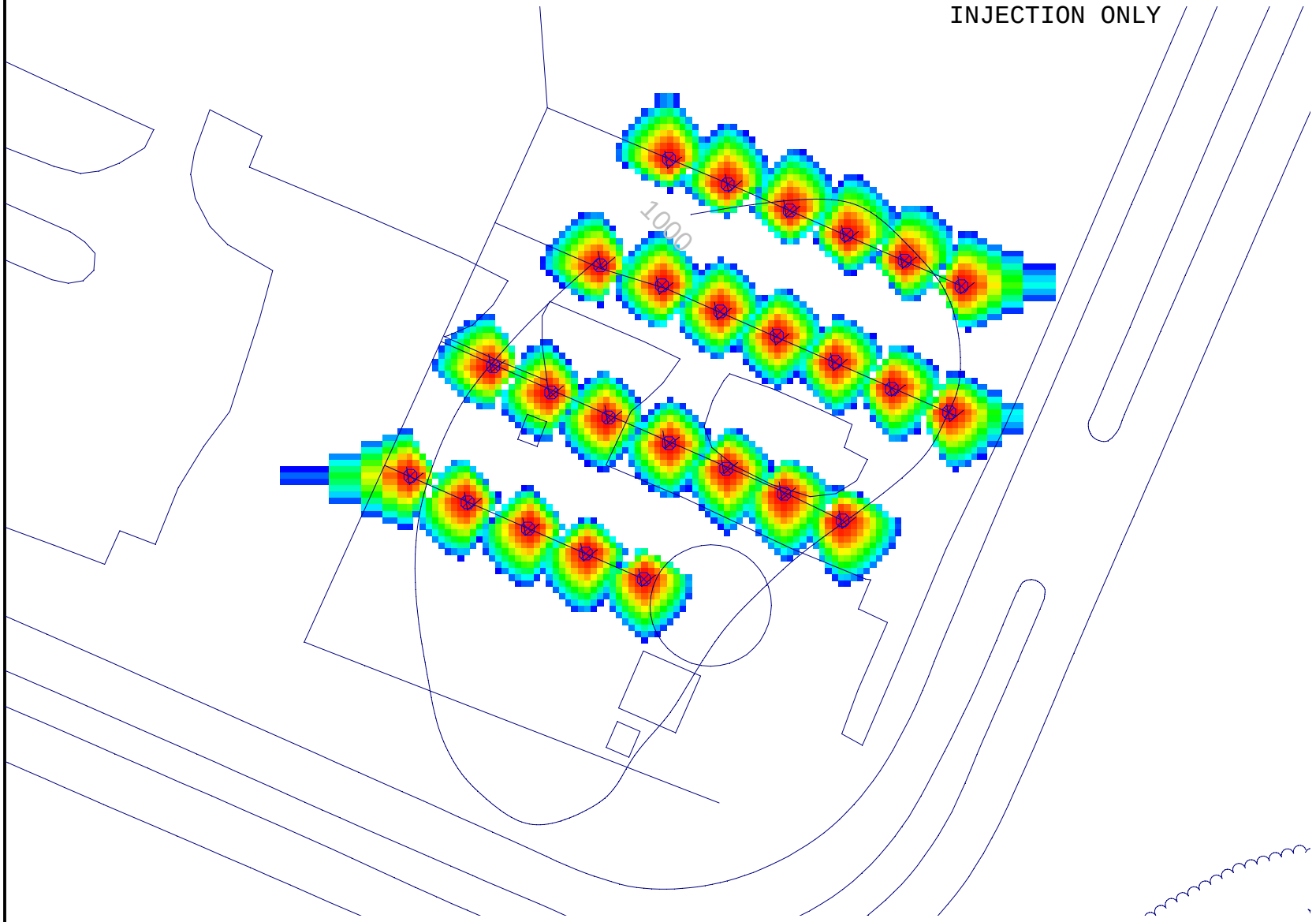


EXHIBIT 4
DISTRIBUTION AT DAY 270 - RUN 3
LAYER 2
INJECTION ONLY



EXHIBIT 5
DISTRIBUTION AT DAY 10 - RUN 3
LAYER 2
INJECTION WITH EXTRACTION



EXHIBIT 6
DISTRIBUTION AT DAY 270 - RUN 4
LAYER 2
INJECTION WITH EXTRACTION

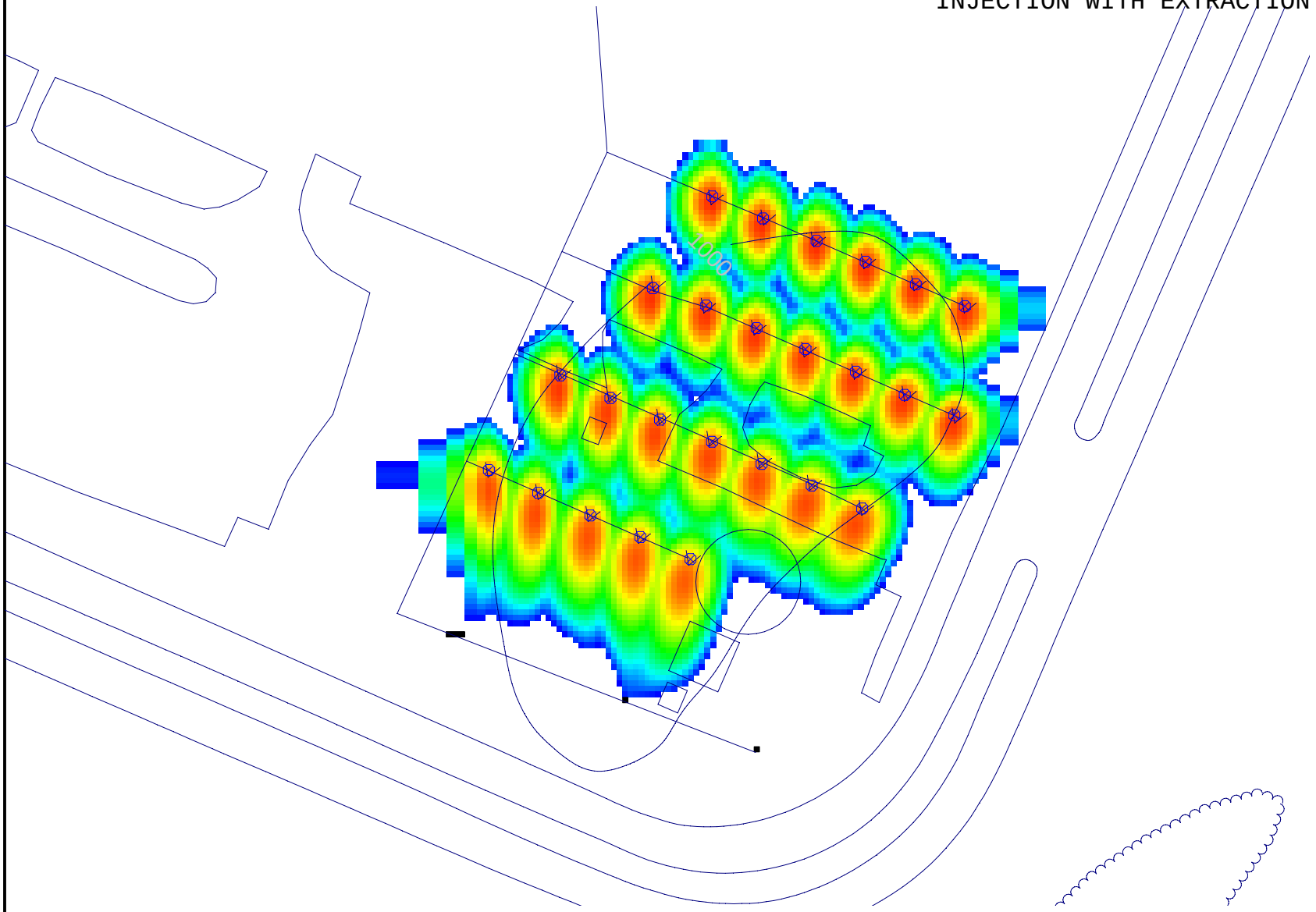


EXHIBIT 7
LAYER 1 GROUNDWATER MOUNDING (FEET)
RUN 3 - INJECTION ONLY

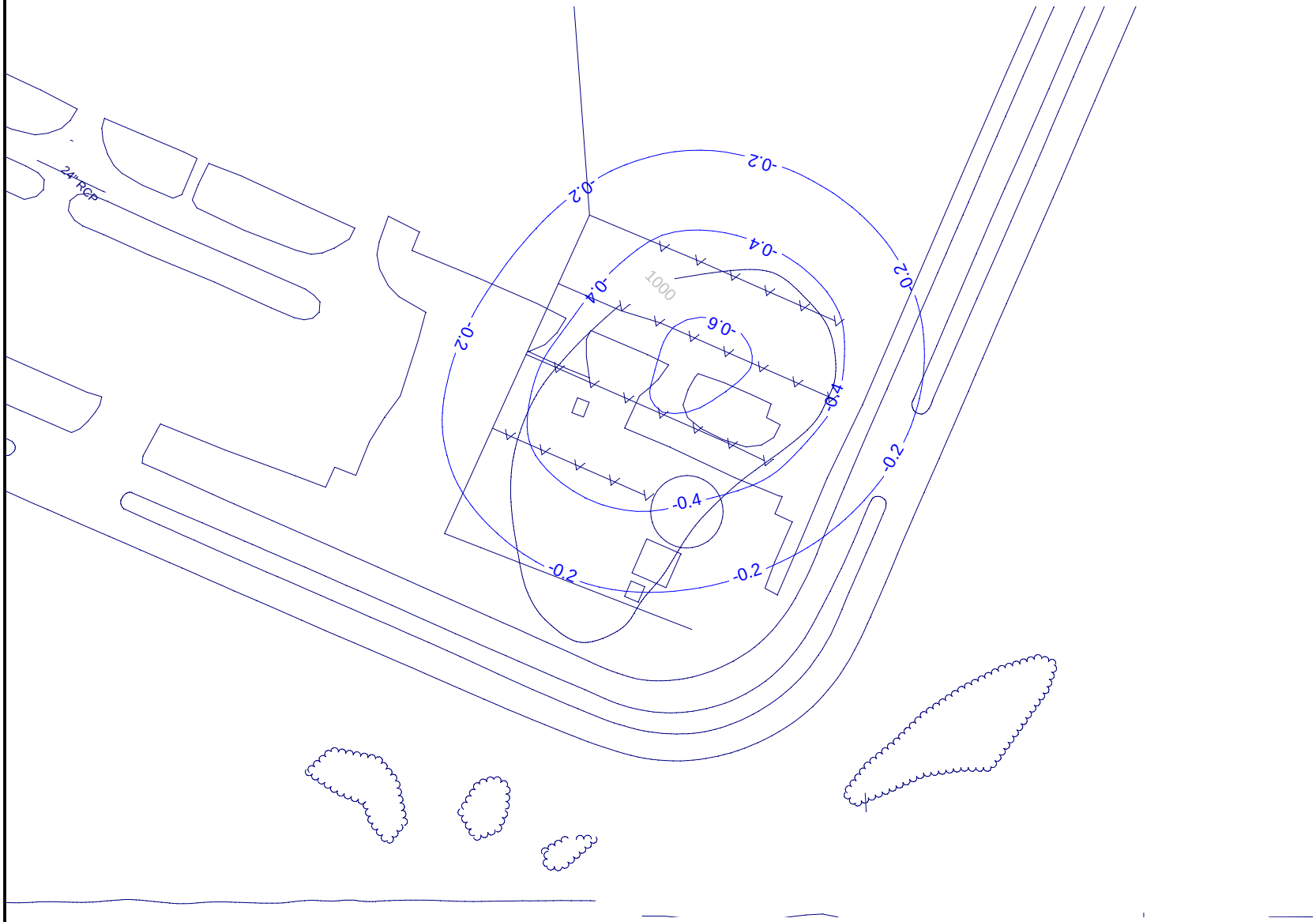


EXHIBIT 8
LAYER 2 PRESSURE HEADS (FEET OF WATER)
RUN 3 - INJECTION ONLY

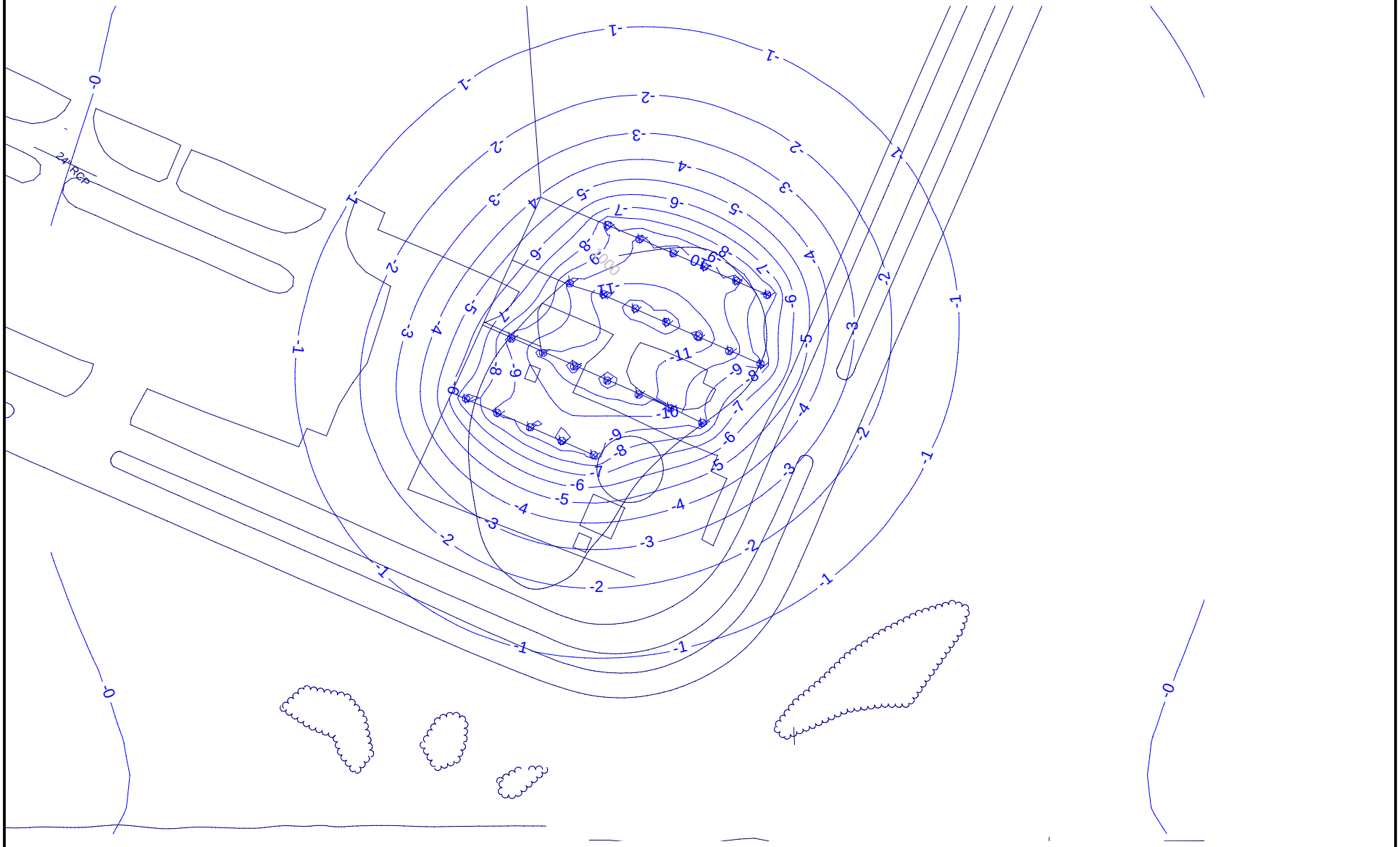
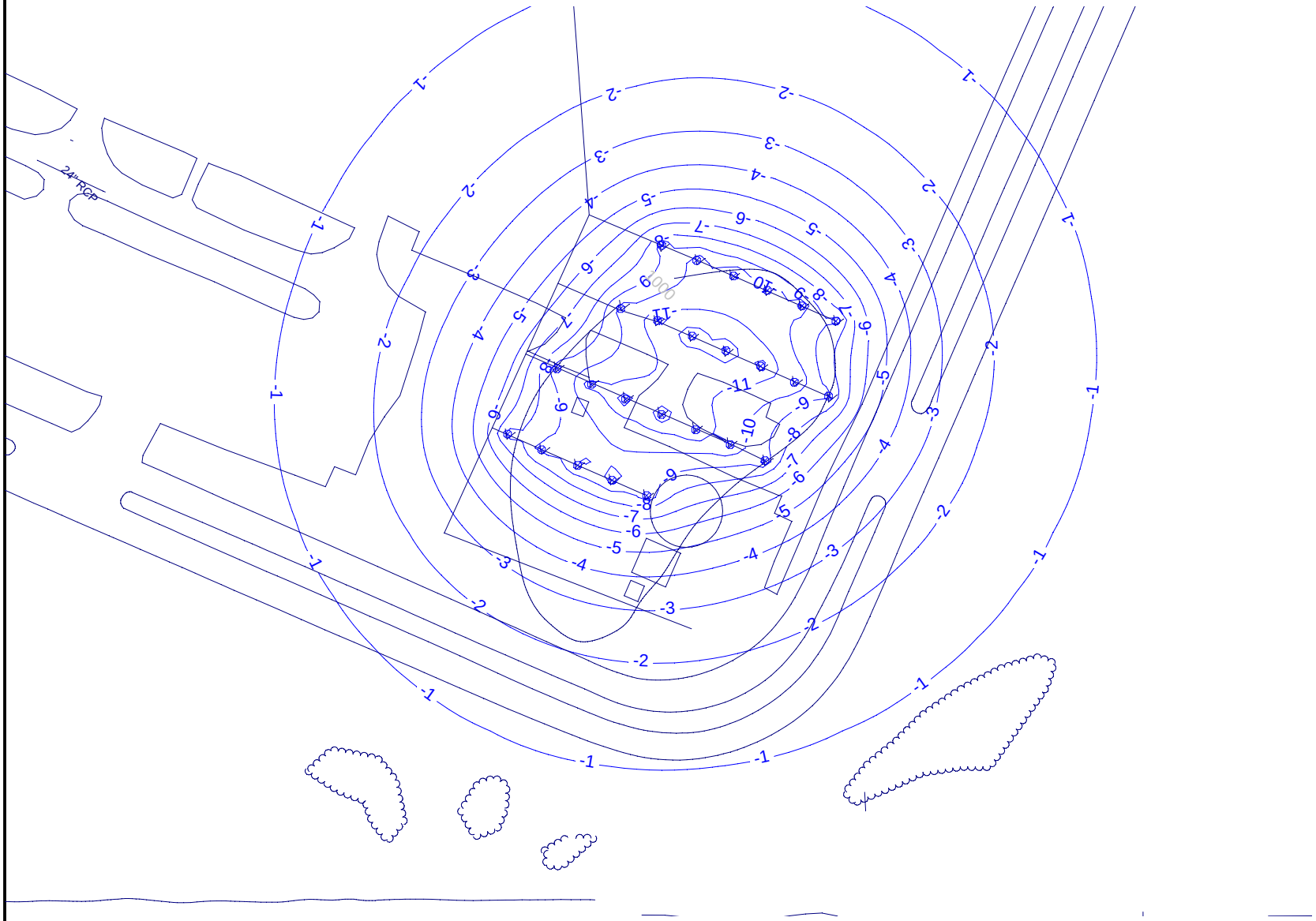


EXHIBIT 9
LAYER 3 PRESSURE HEADS (FEET OF WATER)
RUN 3 - INJECTION ONLY



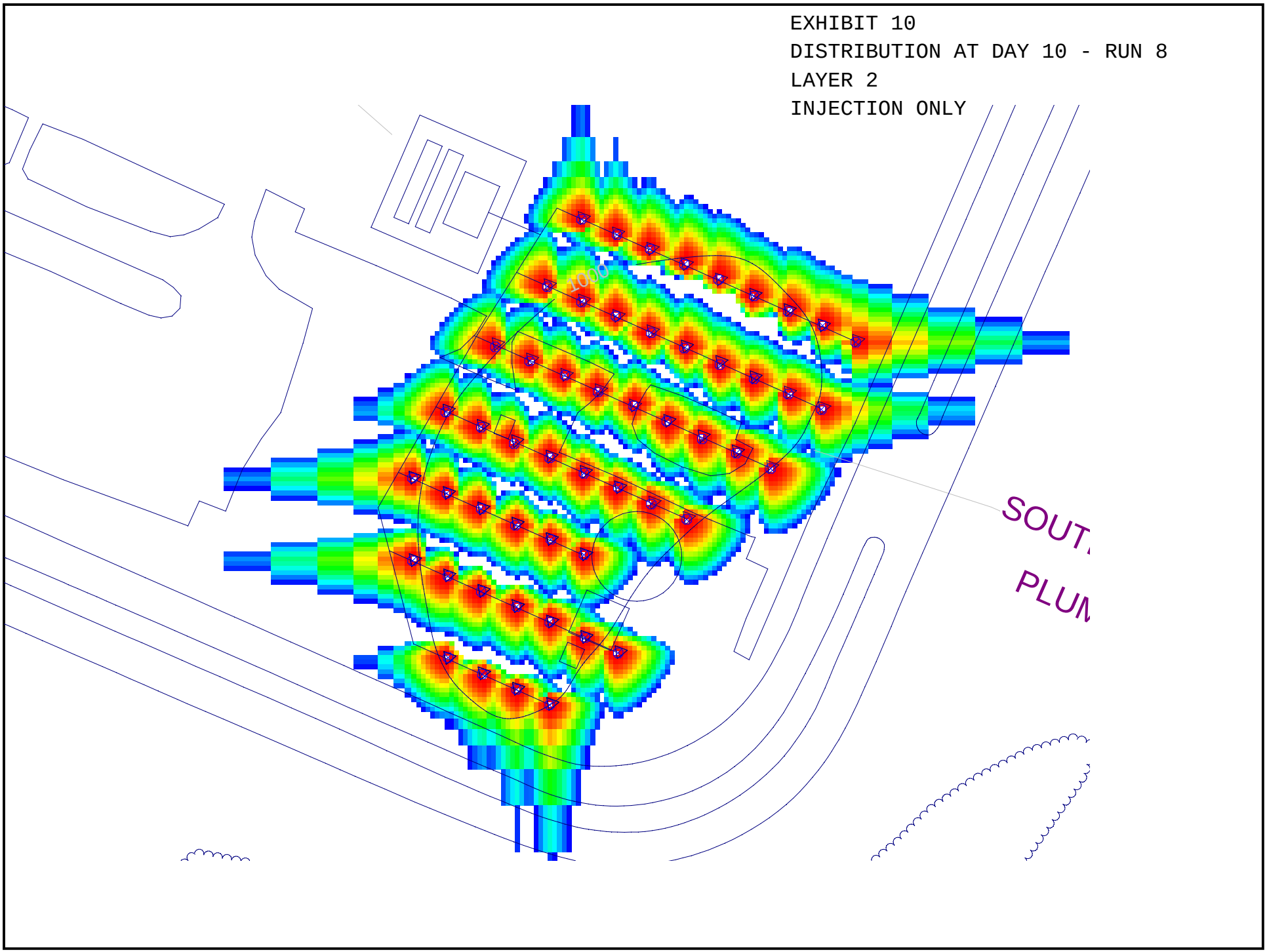


EXHIBIT 10
DISTRIBUTION AT DAY 10 - RUN 8
LAYER 2
INJECTION ONLY
1000
SOUT
PLUM

EXHIBIT 11
DISTRIBUTION AT DAY 270 - RUN 8
LAYER 2
INJECTION ONLY

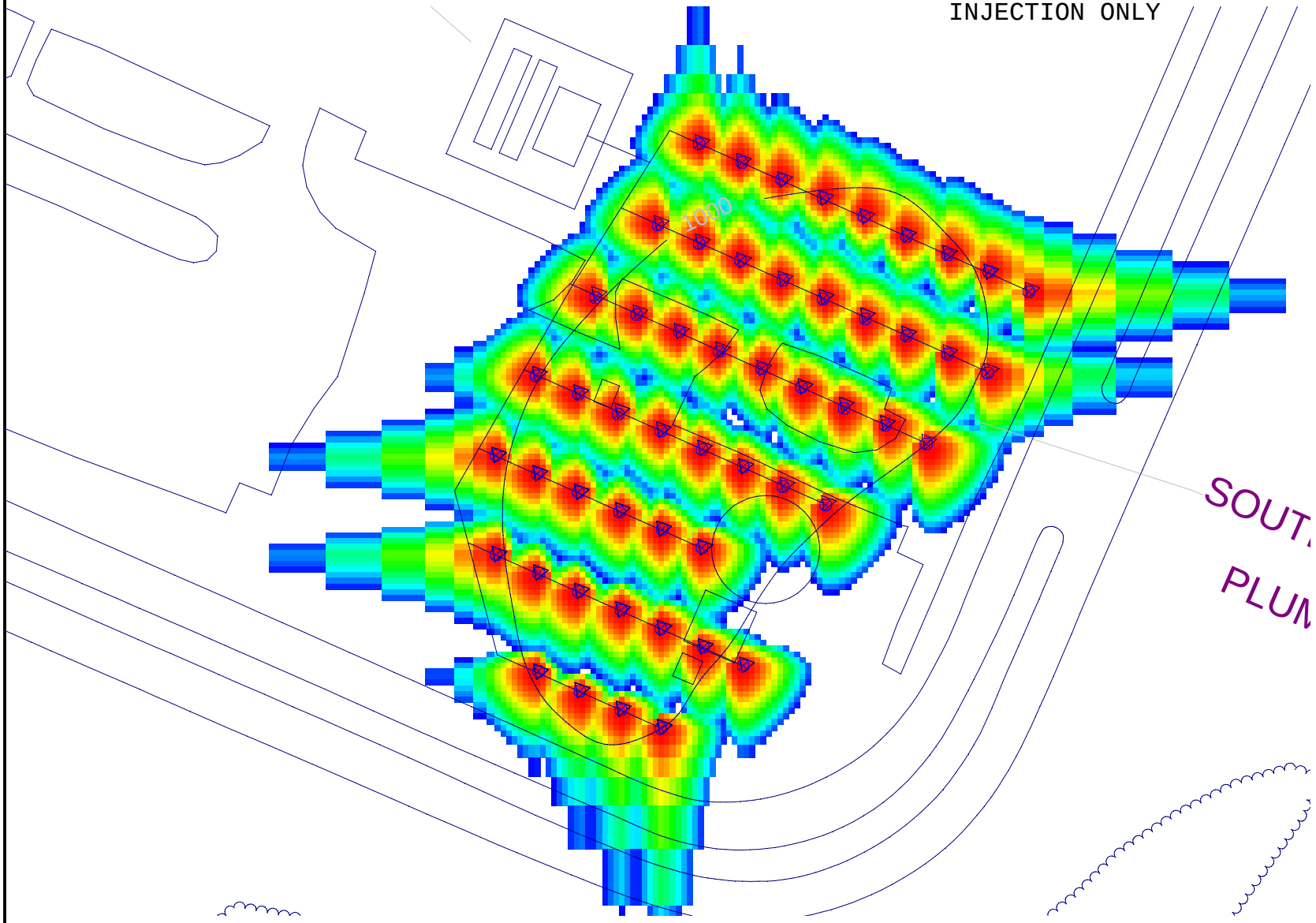


EXHIBIT 12
DISTRIBUTION AT DAY 10 - RUN 8
LAYER 1
INJECTION ONLY



EXHIBIT 13
LAYER 1 GROUNDWATER MOUNDING (FEET)
RUN 8

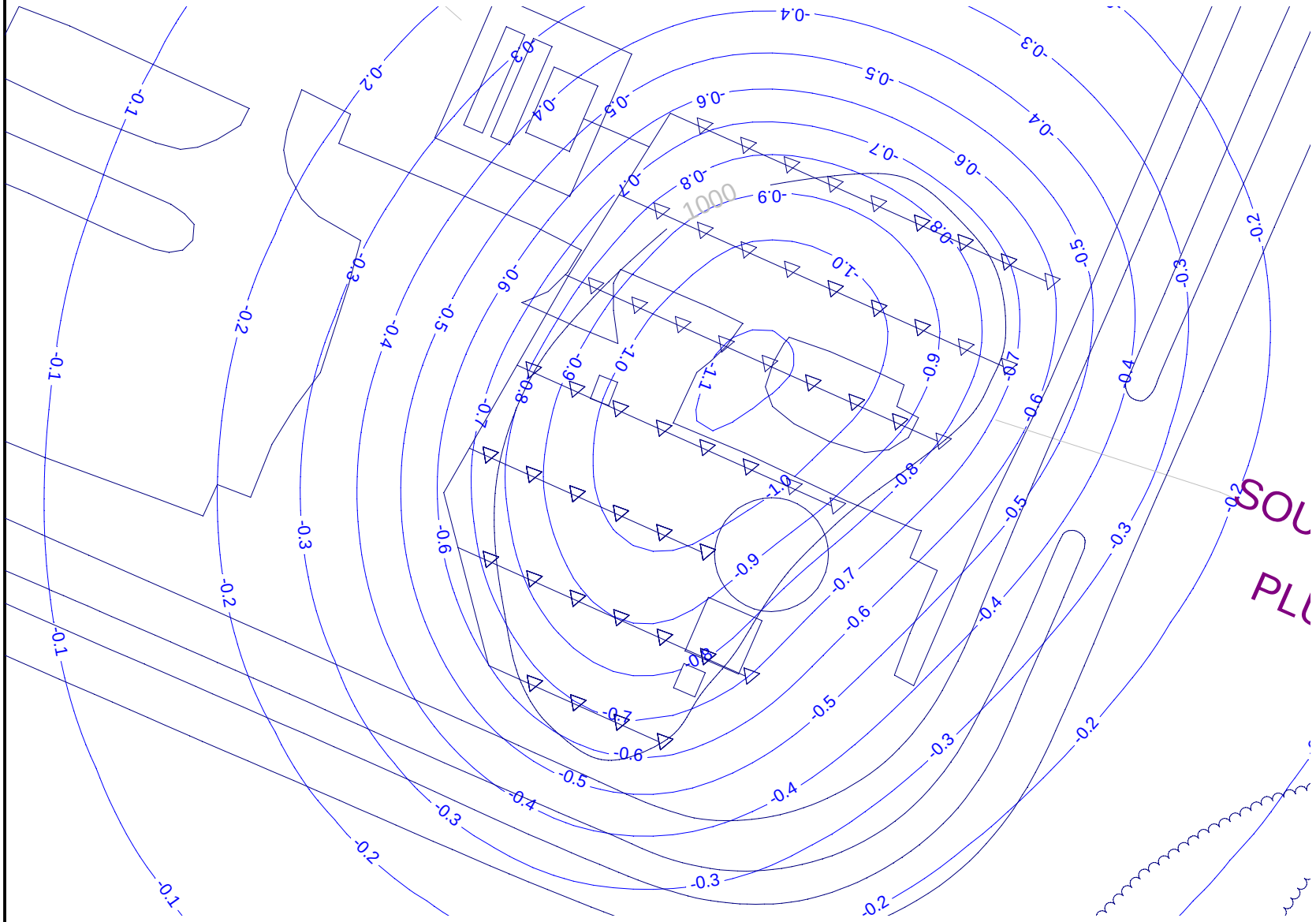


EXHIBIT 14
LAYER 2 PRESSURE HEADS (FEET OF WATER)
RUN 8 - INJECTION ONLY

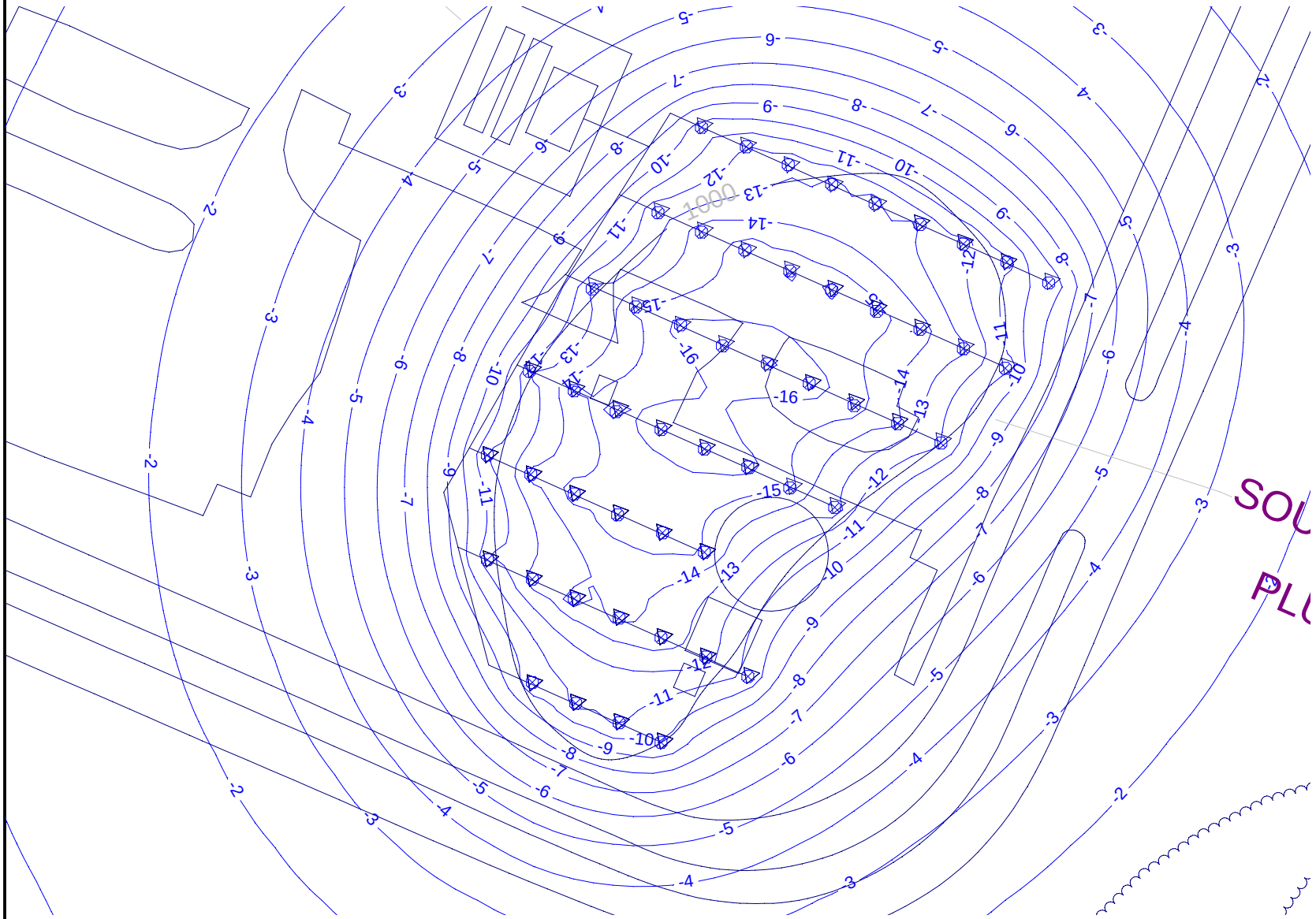


EXHIBIT 15
LAYER 3 PRESSURE HEADS (FEET OF WATER)
RUN 8 - INJECTION ONLY

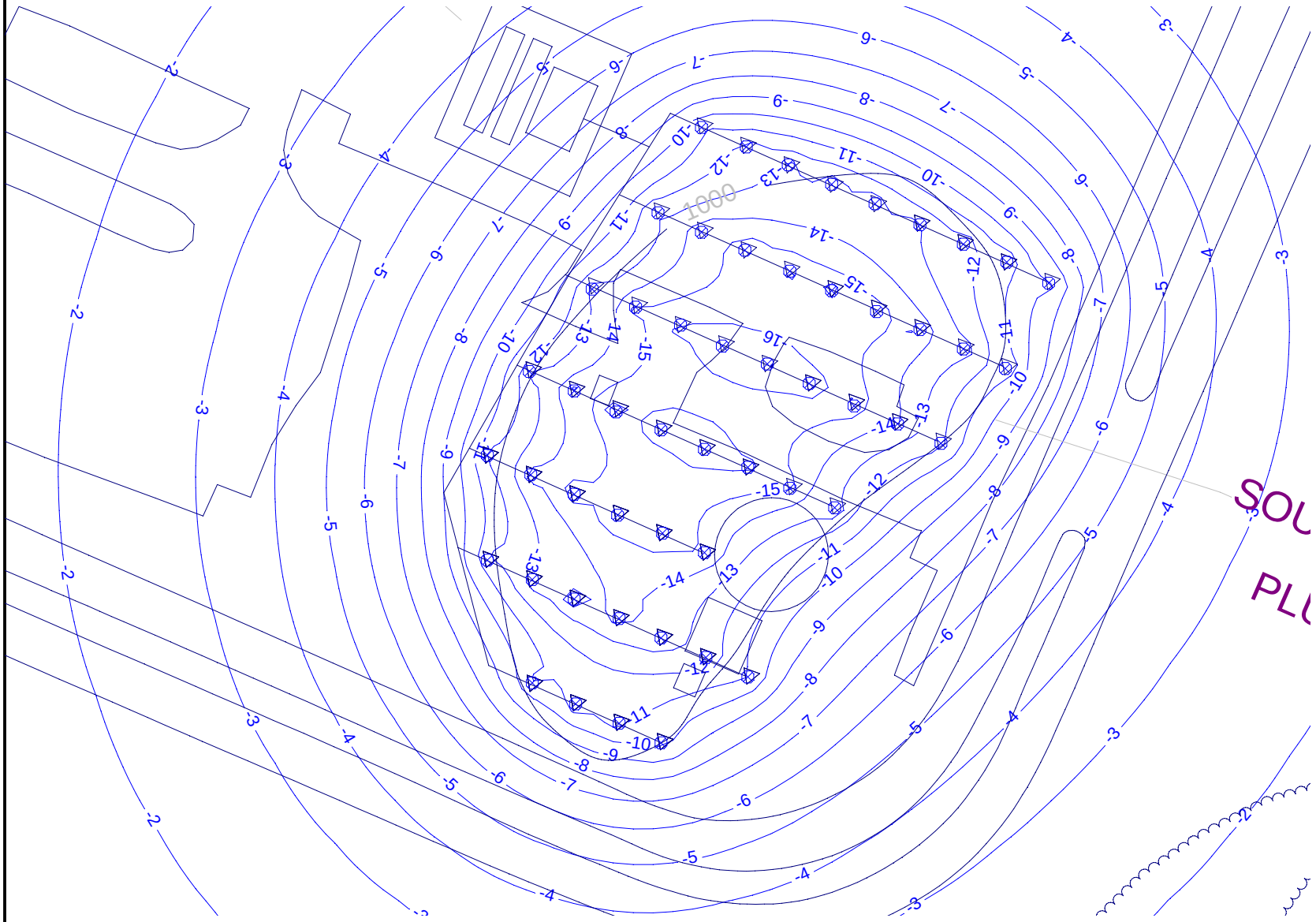
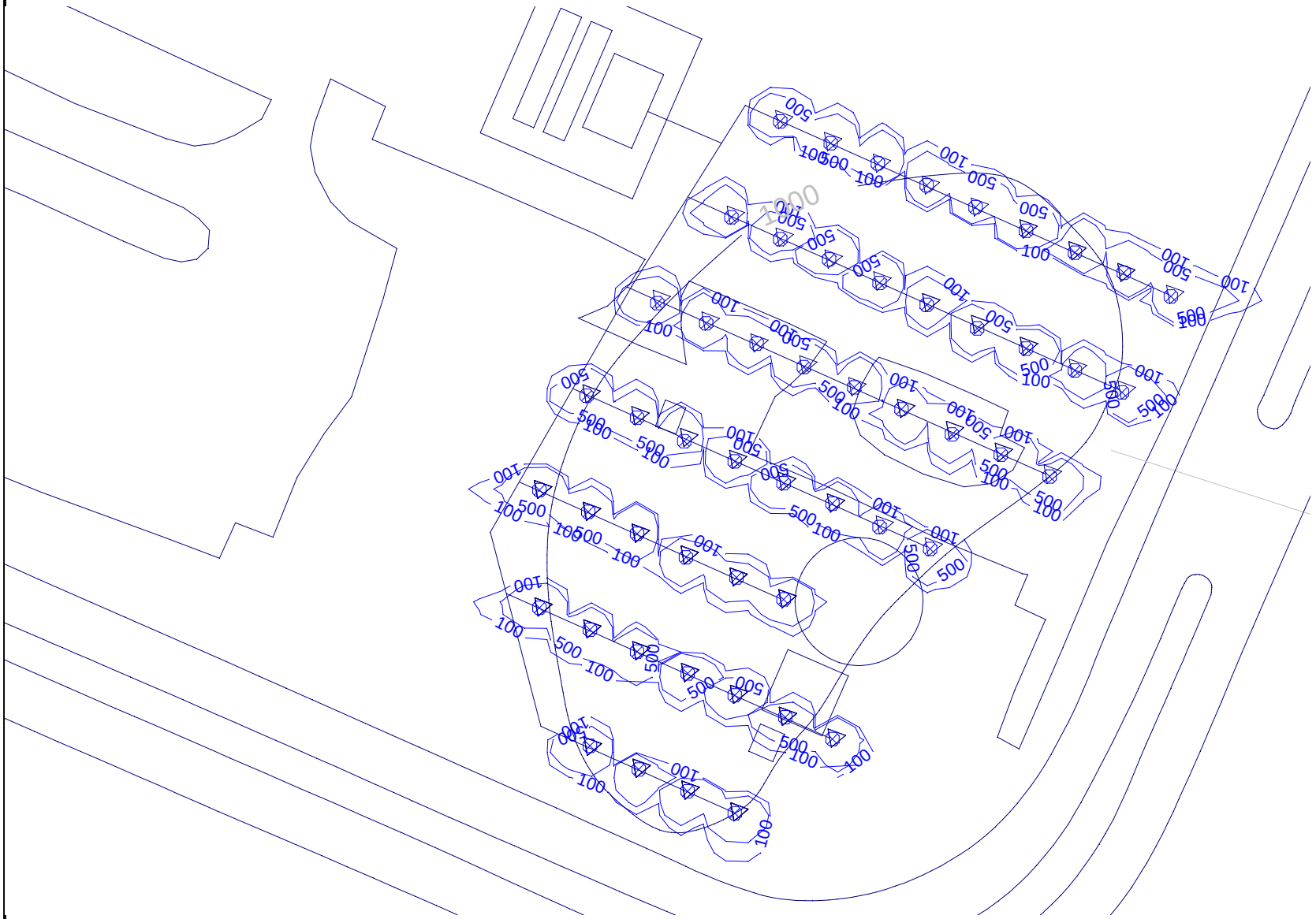


EXHIBIT 16
SUBSTRATE CONCENTRATION CONTOURS (mg/L)
RUN 8 - LAYER 2



APPENDIX H—VAPOR INTRUSION CALCULATIONS AND SURFACE-WATER CONCENTRATION MODELING

Vapor Intrusion Model (ViM) and Johnson and Ettinger Vapor Intrusion Modeling

Industrial Scenario

Summary of Indoor Air Modeling and Calculation of Risk-based Groundwater Goals Protective of Indoor Workers
Middle River Complex, Maryland

Risk-based goals (RBGs) for groundwater were derived to be protective of onsite workers inhaling indoor air in Buildings A, B, and C of Block I of the Middle River Complex. The RBGs were calculated using modeling of vapor intrusion into the buildings using two modeling approaches: the Johnson and Ettinger Model (USEPA 2004a) and ViM (Mills et al. 2007). Detailed descriptions of each model can be found in their respective references. A summary comparison is shown in the table below. The Johnson and Ettinger model is the simpler of the two models and assumes a steady-state source term. ViM accommodates a time-variable source term. Another difference in the two models is that ViM has the option of using a Monte Carlo analysis. This feature can be used to create a confidence interval about the predicted results, assuming a range of input data can be reasonably specified.

ViM and Johnson & Ettinger Comparison

Capability	ViM	Johnson & Ettinger
Basements, slab-on-grade	✓	✓
Crawl space	✓	
Multiple compartments	✓	
Outdoor air intrusion	✓	
Non-steady conditions	✓	
Lifetime exposure	✓	✓
Monte Carlo: Uncertainty Analysis	✓	
Chemical Processes: biodecay, adsorption	✓	
Sensitivity Analysis	✓	✓

The Johnson and Ettinger model was used to calculate preliminary RBGs for four COPCs: trichloroethene (TCE), tetrachloroethene (PCE), vinyl chloride, and benzene. Modeling was conducted using a unitary groundwater source term (i.e., a concentration of 1), therefore, the following linear relationship was used to calculate RBGs based on the modeling results:

$$\frac{\text{Risk - based Goal}_{gw}}{\text{Risk-Based Concentration}_{(\text{indoor air})}} = \frac{\text{Unitary Source Term}_{(gw)}}{\text{Predicted Concentration}_{(\text{indoor air})}}$$

This equation can be re-arranged to calculate RBGs for each chemical of potential concern (COPC) as follows:

$$\text{Risk - based Goal}_{(gw)} = \frac{\text{Risk-Based Concentration}_{(\text{indoor air})}}{\text{Predicted Concentration}_{(\text{indoor air})}} \times \text{Unitary Source Term}_{(gw)}$$

ViM was used to refine the RBGs by addressing uncertainties in the input data.

Johnson and Ettinger Modeling

The Johnson and Ettinger indoor air model (USEPA 2004a) GW-ADV version calculates the intrusion and subsequent accumulation of contaminant vapors in buildings from subsurface groundwater. Input data

to the Johnson and Ettinger model (Table 1) were primarily obtained from the soil gas to indoor air modeling performed for Block I described in the Site Characterization Report (Tetra Tech 2006). This includes both soil and building properties. The depth to groundwater was assumed to be the average depth for wells near the buildings as measured in October 2009 (Table 2). An indoor air exchange rate of 1 exchange per hour was used instead of the EPA (2004b) default of 0.25 exchanges per hour. The EPA default of 0.25 is based on residential buildings. For industrial buildings, a value of 1 exchange per hour is more appropriate, as it is based on minimum building code ventilation requirements (DTSC 2005). Also, building-specific data were not available for Building B, so the size and depth below grade were assumed to be the same for Building B as for Building A.

Because of the configuration of this site, some adjustments had to be made to the site conceptual model to fit the Johnson and Ettinger conceptual model. The Johnson and Ettinger GW-ADV model defines a capillary zone immediately above the water table that is separate from the soil layer. The characteristics of the capillary zone are calculated from a user-selected soil type. Adjustments to the site conceptual model were made as follows:

1. The model requires buildings to be above the capillary zone. For buildings A and C, the depth to the water table had to be increased by 1.4 ft and 4 ft, respectively, which are the minimum depths to put the buildings above the capillary zone.
2. The soil type of the capillary zone was specified to be clay loam. While the Site Characterization report (Tetra Tech 2006) indicates predominant soil types of clay and silty clay, use of these soil types in the model resulted in an error that the calculated water content (0.412 for clay and 0.424 for silty clay) exceeded the porosity of the soil (0.405). Use of the clay and silty clay soil types would also increase the thickness of the capillary zone by 35 cm and 145 cm, respectively.

The Johnson and Ettinger (2004b) default chemical properties were used in the modeling (Table 3).

Modeling was conducted using a unitary groundwater source term (i.e., a concentration of 1). The predicted indoor air concentrations for buildings A, B, and C for TCE, PCE, vinyl chloride, and benzene are shown in Table 4. These concentrations are used with the indoor air risk-based concentrations (RBCs) in the calculation of the groundwater RBGs, as shown previously.

Indoor Air Risk-based Concentrations

Indoor air RBCs were assumed to be the EPA Region 3 (2009) ambient air regional screening levels (RSLs) for workers. RBCs used in the evaluations were based on both the carcinogenic and non-carcinogenic effects of the four COPCs. These health effects were, in turn, based on a potential cancer risk of 1×10^{-6} (i.e., one chance in a million) and a target hazard index (HI) of 1. The indoor air RBCs are shown in Table 5. These indoor air RBCs are divided by the indoor air concentrations predicted using the Johnson and Ettinger Model with a unitary source term in groundwater to calculate the groundwater RBGs.

Groundwater RBGs

The carcinogenic and non-carcinogenic groundwater RBGs protective of indoor workers for each building are presented in Table 6. For each chemical, an overall groundwater RBG representing the lowest calculated RBG was selected to be protective of the entire site. The RBGs were lowest for the carcinogenic route for Building A; therefore, these were selected to be the overall RBGs.

Uncertainty Analysis

A number of uncertainties are associated with the use of the Johnson and Ettinger model in calculating groundwater concentration goals. A number of assumptions were made regarding the conceptual model that may influence the results.

At this site, the groundwater is at or above the bottom of the basement of the buildings in some places. The Johnson and Ettinger model requires that the water table be below the basement depth plus a model-calculated capillary zone depth. Initial depth to groundwater concentrations calculated from nearby wells put the water table above the bottom of the basement for Buildings A and C and therefore resulted in a model error. In both cases, the water table was adjusted to be deeper to avoid this error.

The soil type at this site is clay and silty clay. However, because the water table is situated so close to the bottom of the building basements, use of this soil type in the Johnson and Ettinger model may not be appropriate. It is likely that an engineered fill was placed beneath the buildings during construction which may not have the same soil properties as the surrounding soils.

The indoor air exchange rate of 1.0 exchanges per hour is based on minimum ventilation requirements for buildings (DTSC 2005). However, actual exchange rates vary by building depending on a number of factors, such as the type of ventilation system and its maintenance and operation.

ViM Modeling

The ViM model was used to address uncertainties in the input data used in modeling of this site. Since the overall groundwater RBGs represent Building A, ViM modeling was performed for Building A only.

For those input data required by both the Johnson and Ettinger model and the ViM model, they were specified to have the same values. ViM has embedded within it a version of the Johnson and Ettinger model (called JEM) that accepts input data from the same file as does ViM. This ensures that both models are using the same data, and that any differences between the two models are not due to data differences. Attachment A shows the input data used by ViM.

Figure 1 shows simulated results for both ViM and the JEM model for trichloroethene for Building A. The figure shows time-variable results because the ViM model is time-variable; however for this site we did not start with a time-variable source term and are therefore only concerned with the steady-state concentrations, once they are attained. Thus the uncertainty associated with when chemicals in groundwater first appeared at the site is not relevant for this analysis. As shown on the plot, the steady-

state values of the JEM and ViM model are the same, confirming agreement of the input data between the two models.

ViM was run in Monte Carlo mode with a 10 percent variation in both directions for each parameter's value. Two hundred Monte Carlo runs were executed to produce the results shown in Figure 2. This figure shows the results of the Monte Carlo analysis that have been processed to show the 5 percentile, 50 percentile and 95 percentile. The groundwater source term was set so that the 95 percentile concentration equaled the RBC. This process was repeated for the 1-50-99 percentiles, and the 0.1-50-99.9 percentiles. The RBGs are shown in Table 7. This process was repeated for PCE, benzene, and vinyl chloride, whose RBGs for those percentiles are also shown in Table 7. As shown in the table, the RBGs calculated using ViM are 50 to 75 percent lower than those predicted using the Johnson and Ettinger model.

Comparisons to Measured Concentrations

The groundwater RBGs were compared to the COPC concentrations measured in the Summer 2009 sampling event (Tetra Tech 2009) for TCE (Figure 3), PCE (Figure 4), vinyl chloride (Figure 5) and benzene (Figure 6). Both the RBGs calculated using the Johnson and Ettinger model and ViM (99.9^{th} percentile) are shown. As demonstrated in the figures, the concentrations measured in groundwater are much lower than the groundwater RBGs for all four COPCs.

Indoor Air Data Analysis

The measured indoor air concentrations were plotted against the carcinogenic indoor air RBCs for the four COPCs and are shown in Figures 7, 8, and 9 for TCE, PCE, and benzene, respectively. Vinyl chloride was not detected in indoor air. Average background concentrations in outdoor air are also shown on the figures. The measured indoor air concentrations indicate that for TCE, indoor air concentrations are mostly below the indoor air RBC particularly for the most recent rounds of samplings. PCE and benzene shows more exceedences of the indoor air RBCs in previous sampling rounds, but do not exceed their indoor air RBCs in the most recent sampling round.

Comparison of co-located sub-slab vapor sampling points with indoor air sampling points may provide insight into a site-specific attenuation factor. In the most recent sampling round (July 2009), sub-slab sampling locations were co-located with indoor air sampling locations. Table 8 shows the sub-slab and indoor air concentrations and calculated attenuation factors. As shown in the figures and table, the attenuation factors vary widely. Most are lower than 1 and the range is 0.00006 to 2.3. Note that some of these samples may occur in the area of the sub slab vapor mitigation system that is operating in the Building A Plating Shop and the south end of the Building C Basement. Because of the relatively few co-located data points, these data were not used quantitatively in the analysis.

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Table 1
Input Data for the Johnson and Ettinger Model

		Building A		Building B		Building C	
Parameter Name	**Units**	**Value**	**Source**	**Value**	**Source**	**Value**	**Source**
Average groundwater temperature	deg C	15	1	15	1	15	1
Depth below grade to bottom of closed space floor	cm	335	1	335	6	483	1
Depth below grade to water table	cm	384	2,3	399	2	530	2,3
SCS Soil type directly above water table	-	clay loam	4	clay loam	4	clay loam	4
SCS soil type used to estimate vapor permability	-	clay loam	4	clay loam	4	clay loam	4
Dry bulk density	g/cm3	1.58	1	1.58	1	1.58	1
Soil total porosity	-	0.405	1	0.405	1	0.405	1
Water-filled porosity	cm3/cm3	0.242	1	0.242	1	0.242	1
Enclosed space floor thickness	cm	15	1	15	1	25	1
Soil-building pressure differential	g/cm-s2	40	1	40	1	40	1
Floor length	cm	3658	1	3658	6	7132	1
Floor width	cm	884	1	884	6	9114	1
Height	cm	320	1	320	6	457	1
Floor wall seam crack width	cm	0.1	1	0.1	1	0.1	1
Indoor air exchange rate	1/hr	1	5	1	5	1	5
Average vapor flow rate into bldg	L/min	0.0744	7	0.0744	7	0.256	7
Crack to total area ratio	-	0.000145	7	0.000145	7	0.000043	7

Sources:

1. Site Characterization Report (Tetra Tech 2006)
2. Average depth to groundwater of nearby wells, summer 2009 (see Table 2)
3. Adjusted to move building outside capillary fringe.
4. Modified from clay or silty clay to prevent model error of water content > porosity.
5. Default for industrial buildings (DTSC 2005).
6. Assumed same as building A.
7. Calculated by the model.

Table 2
Depth to Groundwater for Nearby Wells

Building A		Building B		Building C	
Well	Depth to groundwater (ft)	Well	Depth to groundwater (ft)	Well	Depth to groundwater (ft)
MRC-MW17A	7.04	MRC-MW05A	14.22	MRC-MW05A	14.22
MRC-MW18A	4.95	MRC-MW55A	12.59	MRC-MW55A	12.59
MRC-MW19A	6.7	MRC-MW68A	12.37		
MRC-MW20A	10.91				
MRC-MW49A	12				
MRC-MW50A	14.72				
MRC-MW67A	20.69				
MRC-MW68A	12.37				
Average	*11.2*	*Average*	*13.1*	*Average*	*13.4*

Source: Tetra Tech 2009

Table 3
Chemical Properties Used in Johnson and Ettinger Model

Chemical	Diffusivity in air cm2/s	Diffusivity in water cm2/s	Henry's constant at 25°C atm-m3/mol	Organic carbon partition coefficient cm3/g
Trichloroethene	7.90E-02	9.10E-06	1.03E-02	166
Tetrachloroethene	7.20E-02	8.20E-06	1.84E-02	155
Vinyl Chloride	1.06E-01	1.23E-05	2.69E-02	18.6
Benzene	8.80E-02	9.80E-06	5.54E-03	58.9

Source: Johnson & Ettinger Model (EPA 2004b)

Table 4
Predicted Indoor Air Concentrations Using the Johnson and Ettinger Model

Chemical	Predicted Indoor Air Concentration Using a Unitary Source Term (ug/m3)		
	Building A	Building B	Building C
Trichloroethene	6.4E-04	6.4E-04	1.1E-04
Tetrachloroethene	8.9E-04	8.9E-04	1.8E-04
Vinyl Chloride	1.8E-03	1.8E-03	3.4E-04
Benzene	4.3E-04	4.3E-04	6.7E-05

Table 5
Indoor Air RBCs

Chemical	Carcinogenic indoor air goal ug/m3	Noncarcinogenic indoor air goal ug/m3
Trichloroethene	6.13	-
Tetrachloroethene	2.08	1190
Vinyl Chloride	2.79	438
Benzene	1.57	131

Source: Mid-Atlantic Risk Assessment User's Guide (USEPA Region 3, 2009)
(www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm)

Table 6
Predicted Groundwater Concentration Goals Using Johnson and Ettinger Model

Chemical	Groundwater RBGs (ug/L)						
	Building A		Building B		Building C		Overall
	Non-carcinogenic	Carcinogenic	Non-carcinogenic	Carcinogenic	Non-carcinogenic	Carcinogenic	
Trichloroethene	-	9,505	-	9,519	-	54,128	9,505
Tetrachloroethene	1,339,941	2,342	1,341,698	2,345	6,784,938	11,859	2,342
Vinyl chloride	244,644	1,558	244,873	1,560	1,274,750	8,120	1,558
Benzene	303,598	3,639	304,079	3,644	1,950,880	23,381	3,639

Table 7
RBGs for Groundwater Calculated Using ViM

Percentile	Groundwater RBG (ug/L)			
	Trichloroethene	Tetrachloroethene	Vinyl chloride	Benzene
95th	4,800	920	650	3,200
99th	4,200	800	550	1,900
99.9th	4,000	750	500	1,800
Johnson & Ettinger	9,505	2,342	1,558	3,639

Table 8
Analysis of Site-Specific Attenuation Factors

	Trichloroethene			Tetrachloroethene			Benzene		
	Sub-Slab Concentration (ug/m3)	Indoor Air Concentration (ug/m3)	Attenuation Factor	Sub-Slab Concentration (ug/m3)	Indoor Air Concentration (ug/m3)	Attenuation Factor	Sub-Slab Concentration (ug/m3)	Indoor Air Concentration (ug/m3)	Attenuation Factor
Building A									
SV-A-1-6	18	ND	-	1.8	ND	-	1.2	0.86	0.72
SV-A-4-6	19	0.95	0.05	ND	1.9	-	ND	0.61	-
SV-A-7-6	26	0.24	0.00923	20	ND	-	0.51	-	-
SV-A-8-6	ND	0.87	-	ND	ND	-	ND	0.31	-
SV-15-A-6	16	ND	-	0.26	0.22	0.85	-	-	-
SV-17-A-6	170	0.15	0.00088	1.2	0.17	0.14	0.59	-	-
SV-18-A-6	43000	2.6	6.05E-05	0	0.25	-	ND	1.2	-
Minimum	*16*	*0.15*	*6.05E-05*	*0*	*0.17*	*0.14*	*0.51*	*0.31*	*0.72*
Maximum	*43000*	*2.6*	*0.05*	*20*	*1.9*	*0.85*	*1.2*	*1.2*	*0.72*
Average	*7208*	*0.962*	*0.015*	*4.652*	*0.635*	*0.49*	*0.77*	*0.745*	*0.72*
Building B									
SV-B-2-6	1.5	0.2	0.13	4.1	0.37	0.09	1.3	0.89	0.68
SV-B-3-6	1.8	1.8	1	1.8	1.8	1	3.4	0.87	0.26
SV-B-4-6	0.41	0.15	0.37	4.6	0.22	0.048	1.2	0.55	0.46
SV-B-5-6	0.64	0.94	1.47	1.5	0.56	0.373	1.7	0.86	0.51
SV-B-6-6	2	ND	-	1.3	0.19	0.146	1.1	0.49	0.45
ISG-04-B-6	23	0.31	0.013	1.4	ND	-	-	-	-
ISG-05-B-6	1.4	0.48	0.34	ND	0.6	-	0.95	0.84	0.88
ISG-06-B-6	3.7	1.3	0.35	4.1	0.37	0.090	1.4	0.69	0.49
ISG-07-B-6	5.9	0.46	0.078	8.9	0.42	0.047	0.64	0.8	1.25
ISG-09-B-6	2.8	ND	-	13	0.17	0.013	0.74	0.6	0.81
ISG-10-B-6	72	0.25	0.0035	3.6	0.35	0.097	0.49	0.73	1.49
Minimum	*0.41*	*0.15*	*0.0035*	*1.3*	*0.17*	*0.013*	*0.49*	*0.49*	*0.26*
Maximum	*72*	*1.8*	*1.46875*	*13*	*1.8*	*1*	*3.4*	*0.89*	*1.49*
Average	*10.47*	*0.65*	*0.42*	*4.43*	*0.51*	*0.21*	*1.29*	*0.73*	*0.73*
Building C									
SV-C-1-6	0.33	0.34	1.03	1.2	0.58	0.48	2.1	0.9	0.43
SV-C-2-6	1.1	0.38	0.35	0.92	0.4	0.43	1.7	0.72	0.42
SV-C-3-6	180	1.1	0.0061	3.4	0.68	0.2	2.2	0.94	0.43
SV-C-4-6	260	0.22	0.00085	0.95	0.36	0.38	2.8	0.7	0.25
SV-C-5-6	0.41	0.2	0.49	0.73	0.35	0.48	1.1	0.52	0.47
SV-C-7-6	0.12	0.14	1.17	0.53	0.49	0.92	1	0.75	0.75
ISG-03-C-6	280	0.22	0.00079	8.3	1.7	0.20	ND	1.3	-
ISG-11-C-6	4	0.27	0.068	150	0.45	0.0030	1.1	0.77	0.7
ISG-12-C-6	7.1	0.29	0.041	11	0.58	0.053	0.42	0.95	2.3
ISG-13-C-6	ND	0.23	-	ND	0.57	-	2.8	0.98	0.35
ISG-14-C-6	86	0.46	0.005	ND	0.53	-	21	0.76	0.036
SV-1-C-6	270	12	0.044	3.3	0.72	0.22	-	0.95	-
SV-5-C-6	1.5	0.15	0.10	94	ND	-	0.86	0.49	0.57
SV-7-C-6	ND	0.4	-	3.4	0.75	0.22	-	0.98	-
SV-9-C-6	1.8	0.22	0.12	7.8	0.53	0.068	-	0.82	-
Minimum	*0.12*	*0.14*	*0.0008*	*0.53*	*0.3500*	*0.003*	*0.42*	*0.49*	*0.036*
Maximum	*280*	*12*	*1.17*	*150*	*1.70*	*0.92*	*21*	*1.30*	*2.26*
Average	*84.03*	*1.11*	*0.26*	*21.96*	*0.62*	*0.31*	*3.37*	*0.84*	*0.61*

Notes:

- = Sample was B qualified or value could not be calculated.

Figure 1. Comparison of the Johnson and Ettinger Model results with the ViM model for indoor air predictions. The models' source terms were chosen to predict the RBC for TCE (6.13 ug/m3)

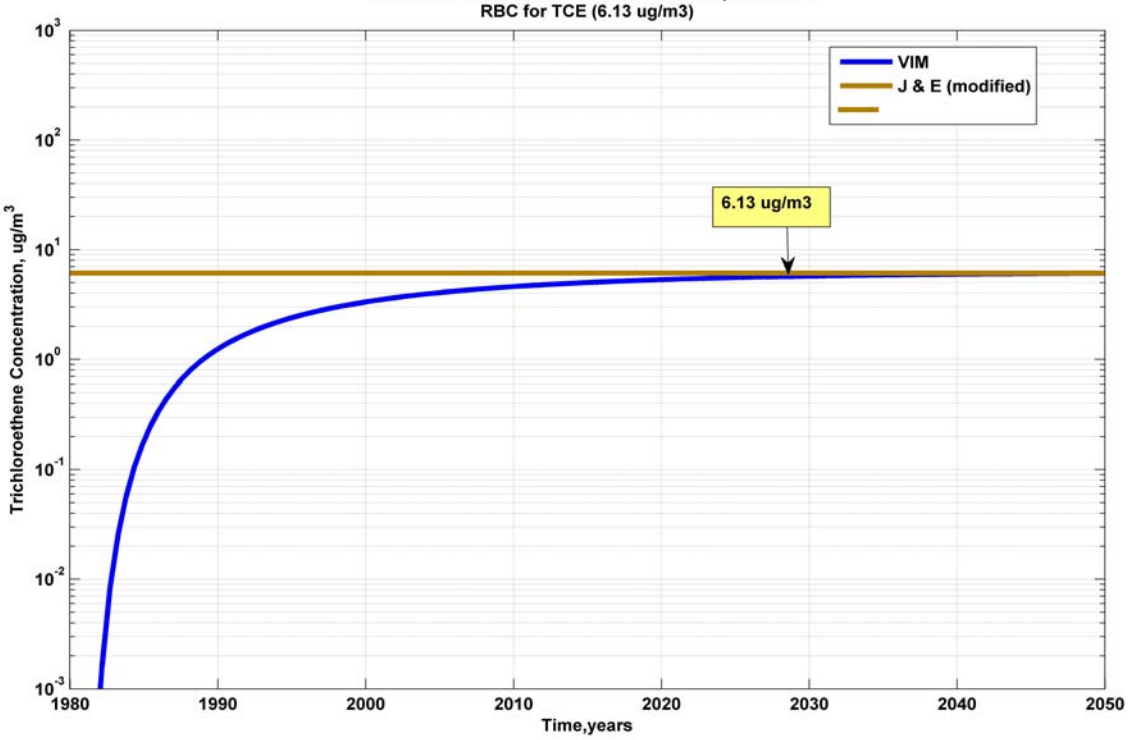
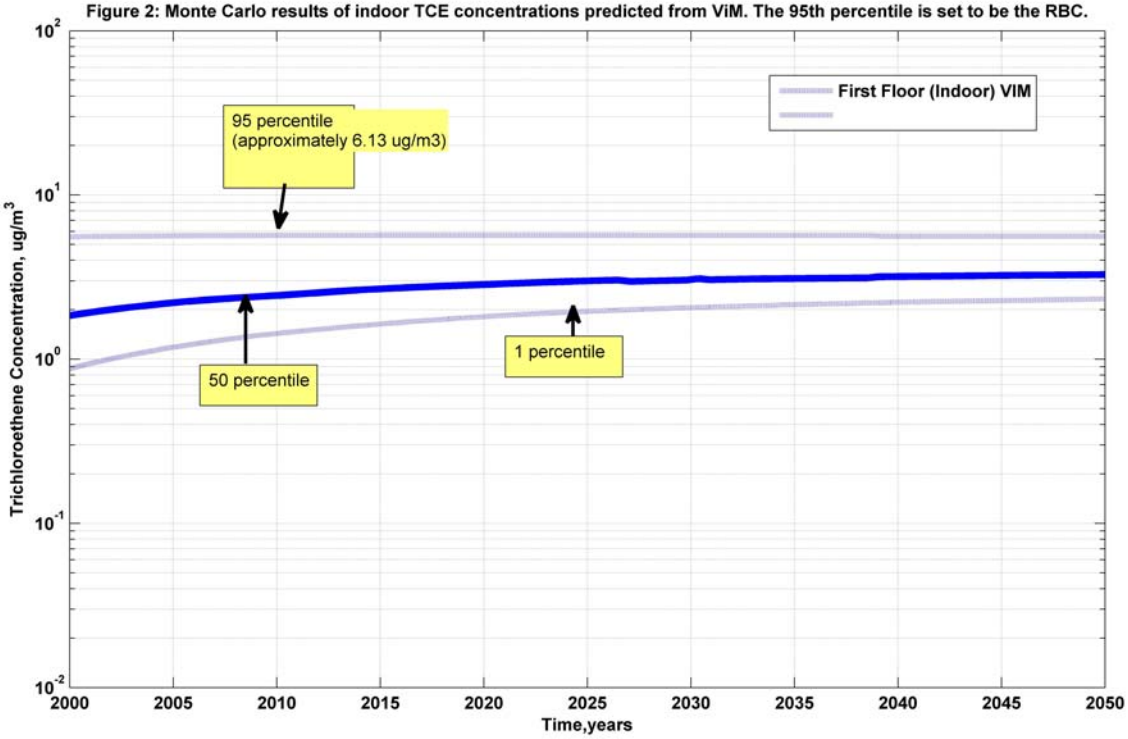


Figure 2: Monte Carlo results of indoor TCE concentrations predicted from ViM. The 95th percentile is set to be the RBC.



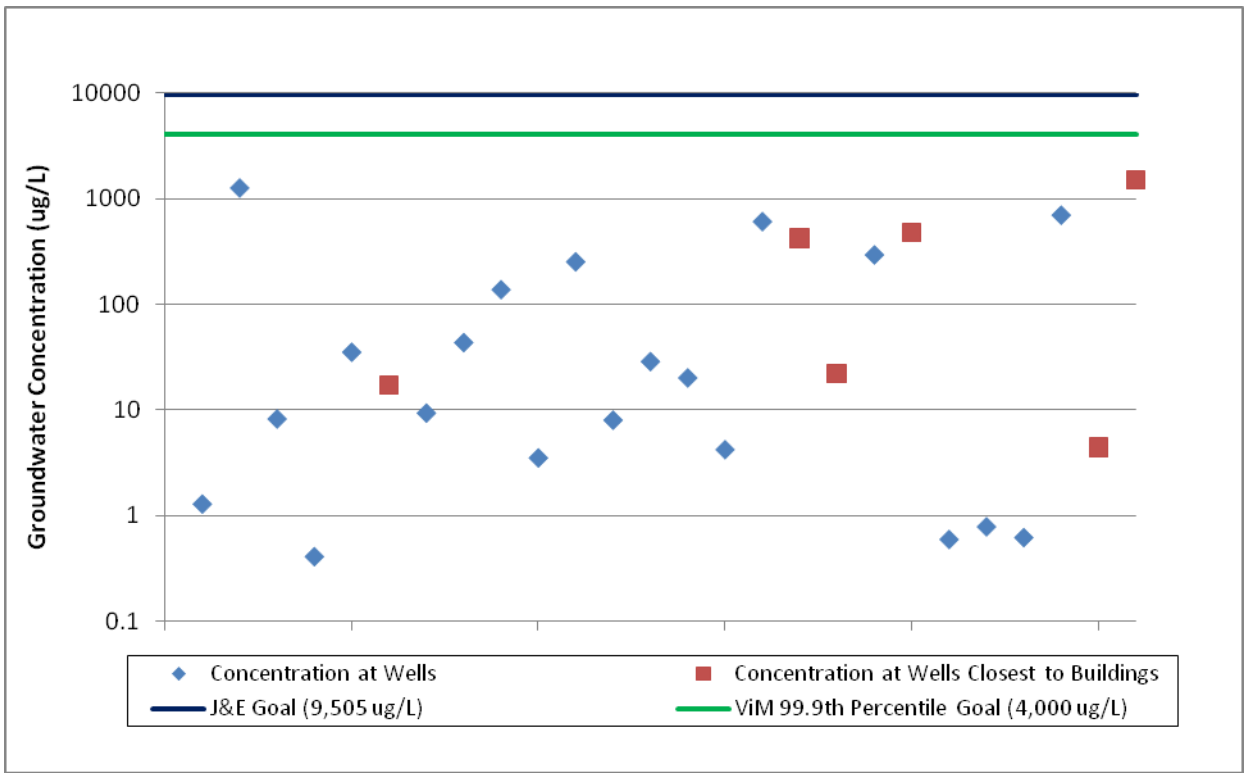


Figure 3. Groundwater RBGs versus summer 2009 groundwater concentrations for trichloroethene.

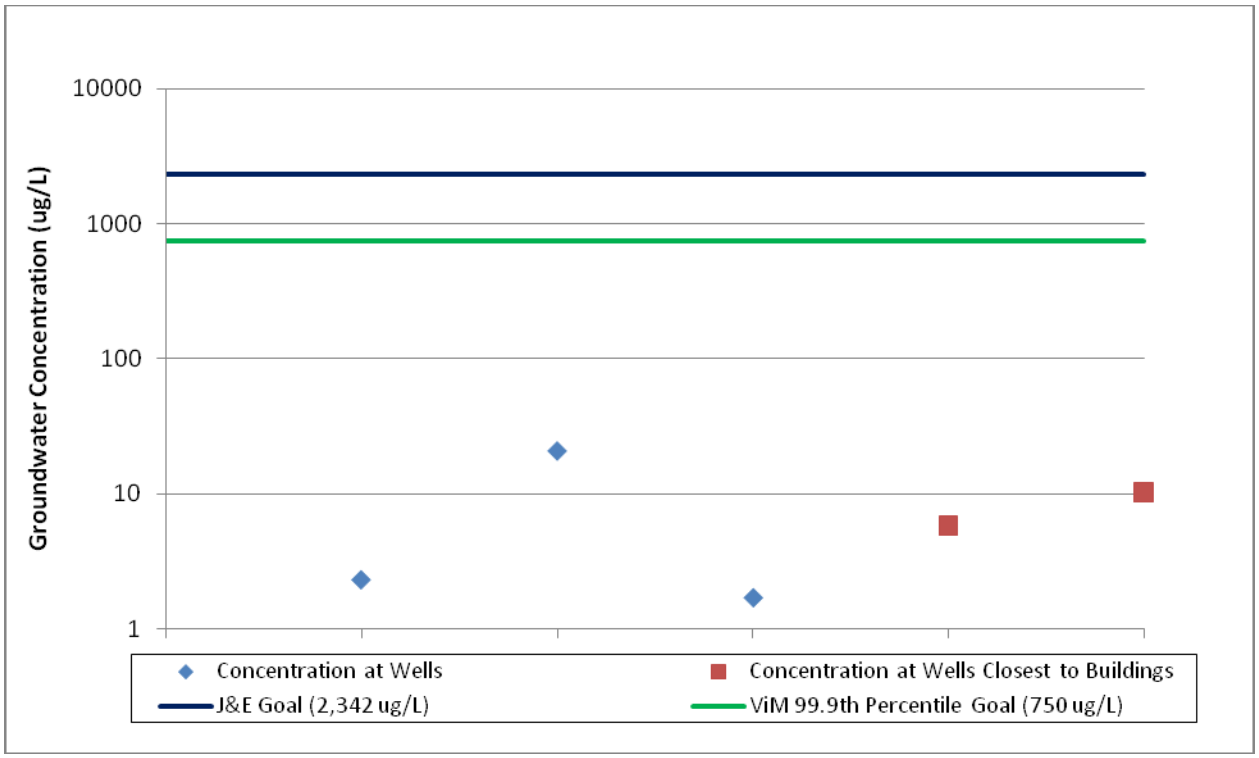


Figure 4. Groundwater RBGs versus summer 2009 groundwater concentrations for tetrachloroethene.

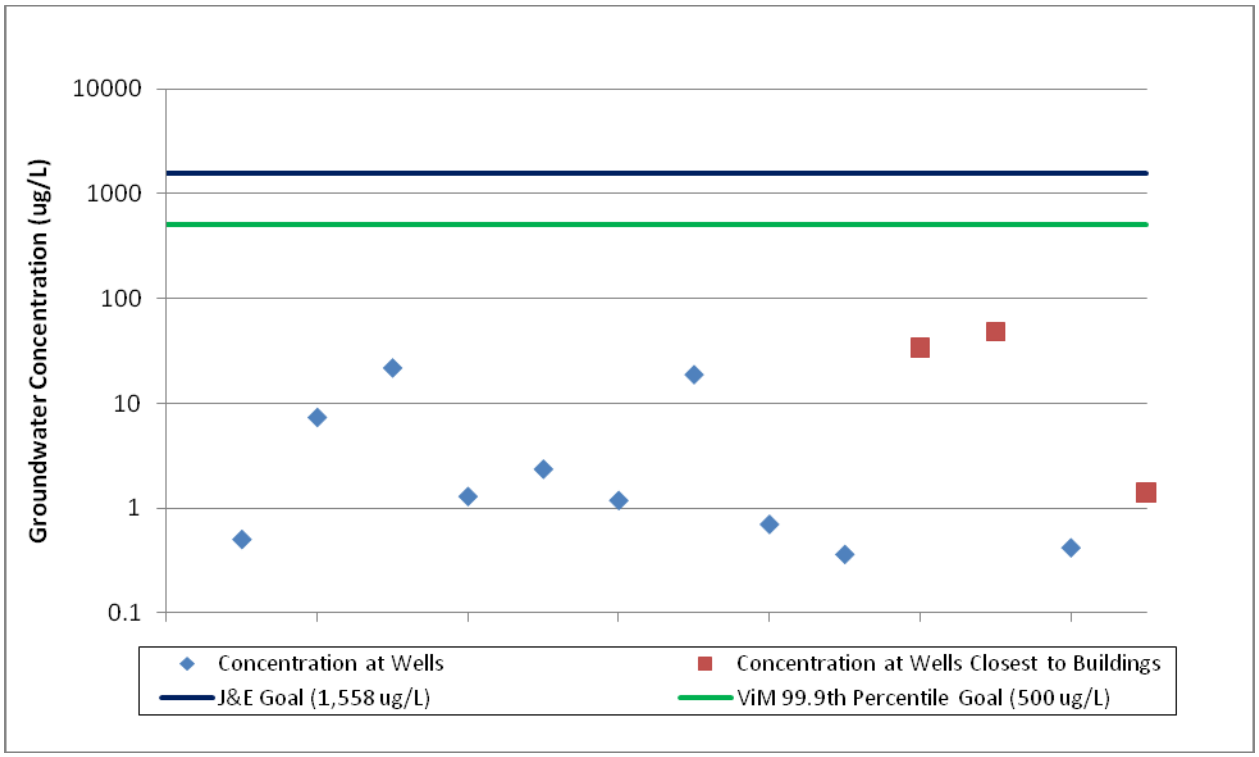


Figure 5. Groundwater RBGs versus summer 2009 groundwater concentrations for vinyl chloride.

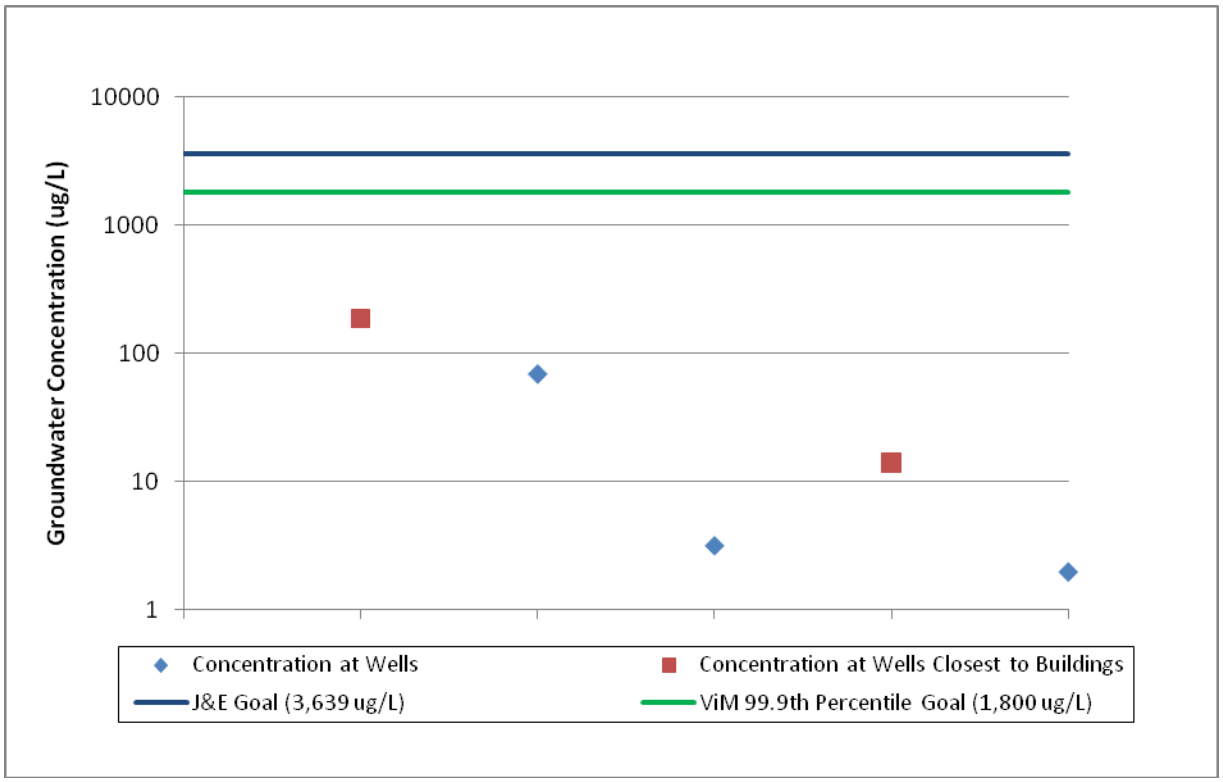


Figure 6. Groundwater RBGs versus summer 2009 groundwater concentrations for benzene.

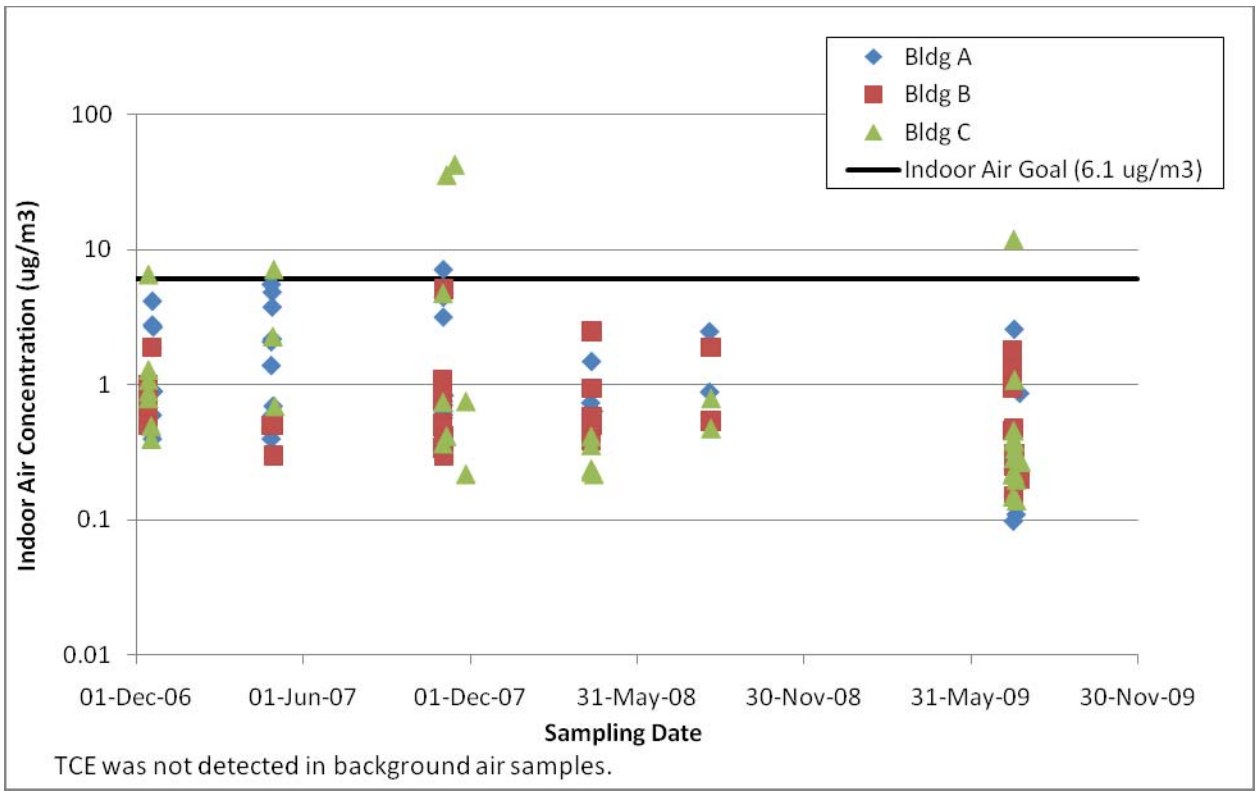


Figure 7. Indoor air concentrations versus the indoor air goal for trichloroethene.

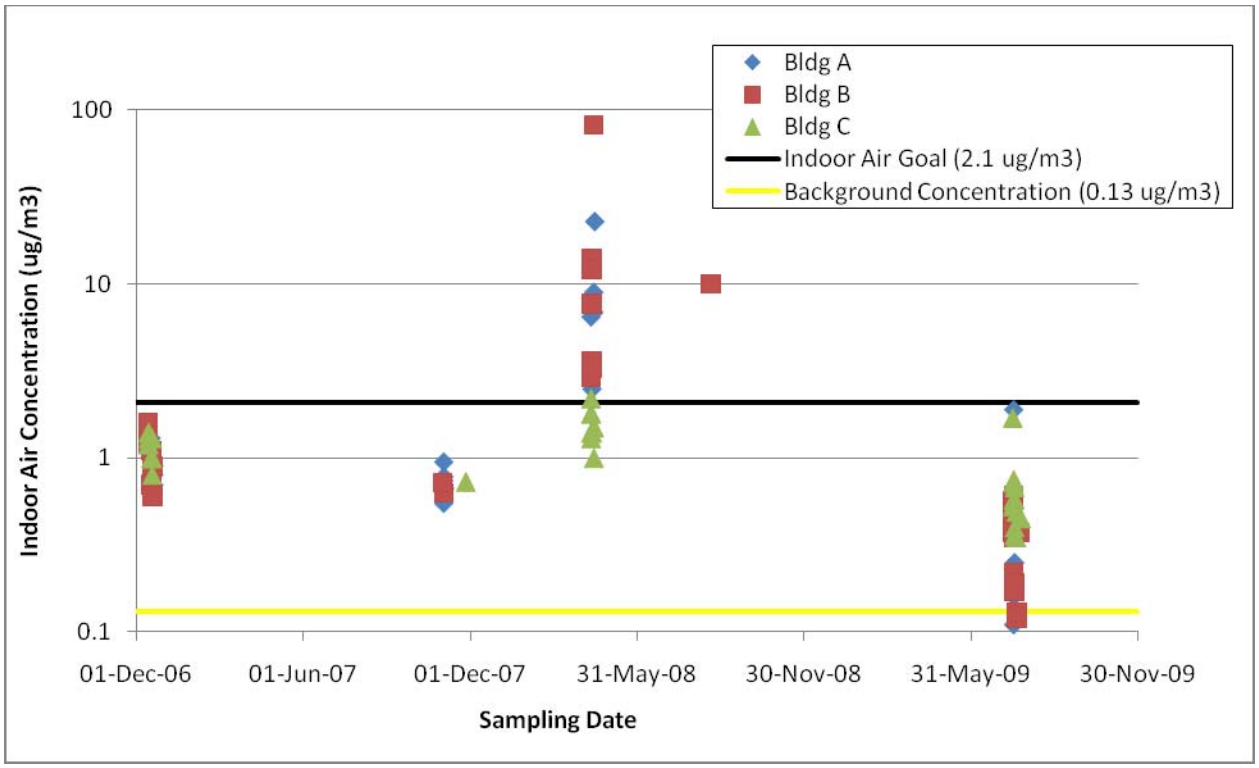


Figure 8. Indoor air concentrations versus the indoor air goal for tetrachloroethene.

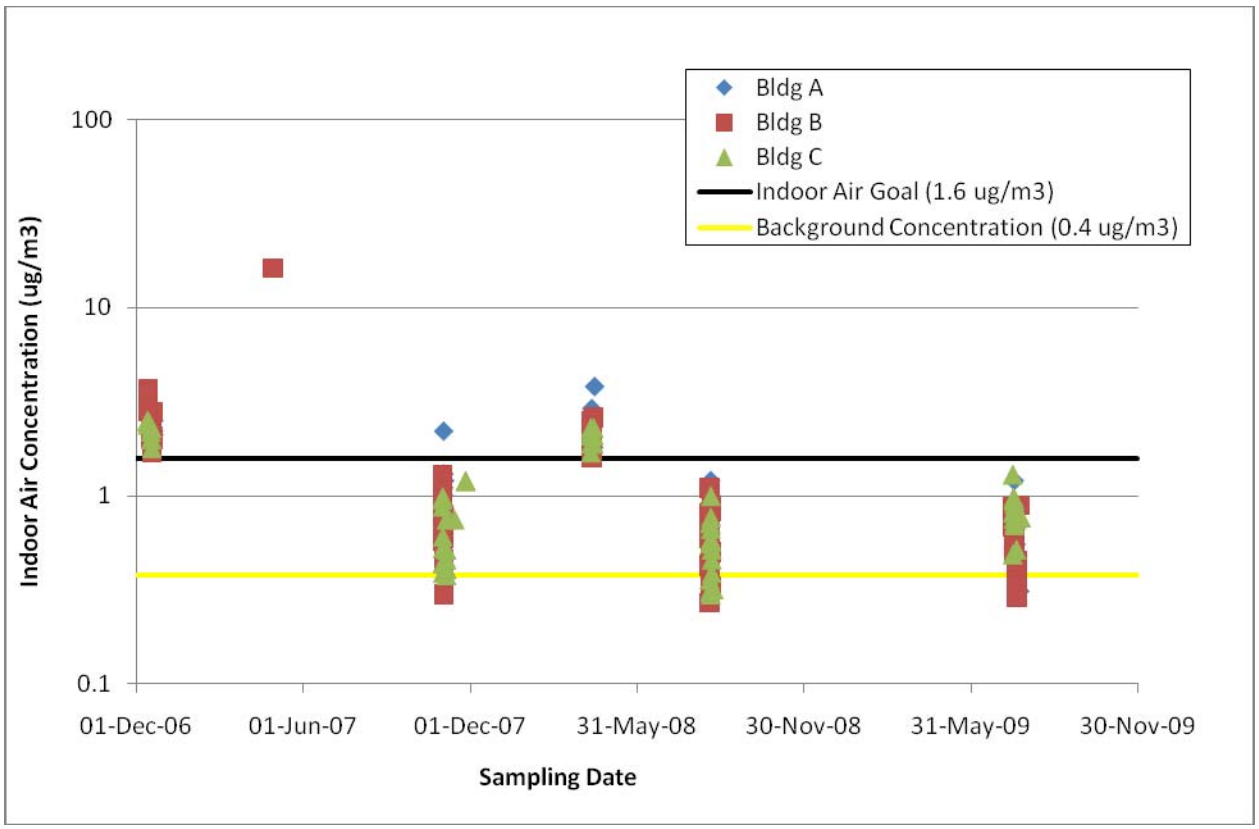
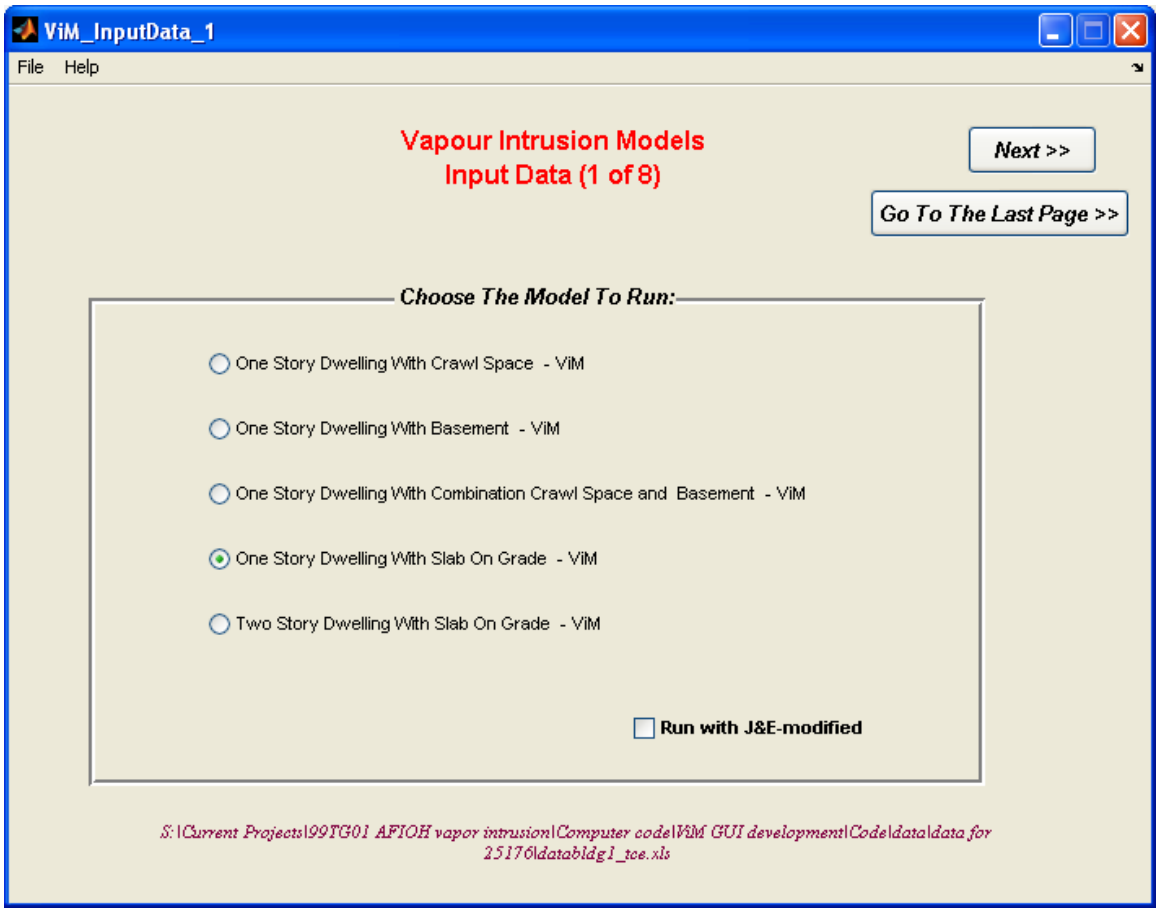
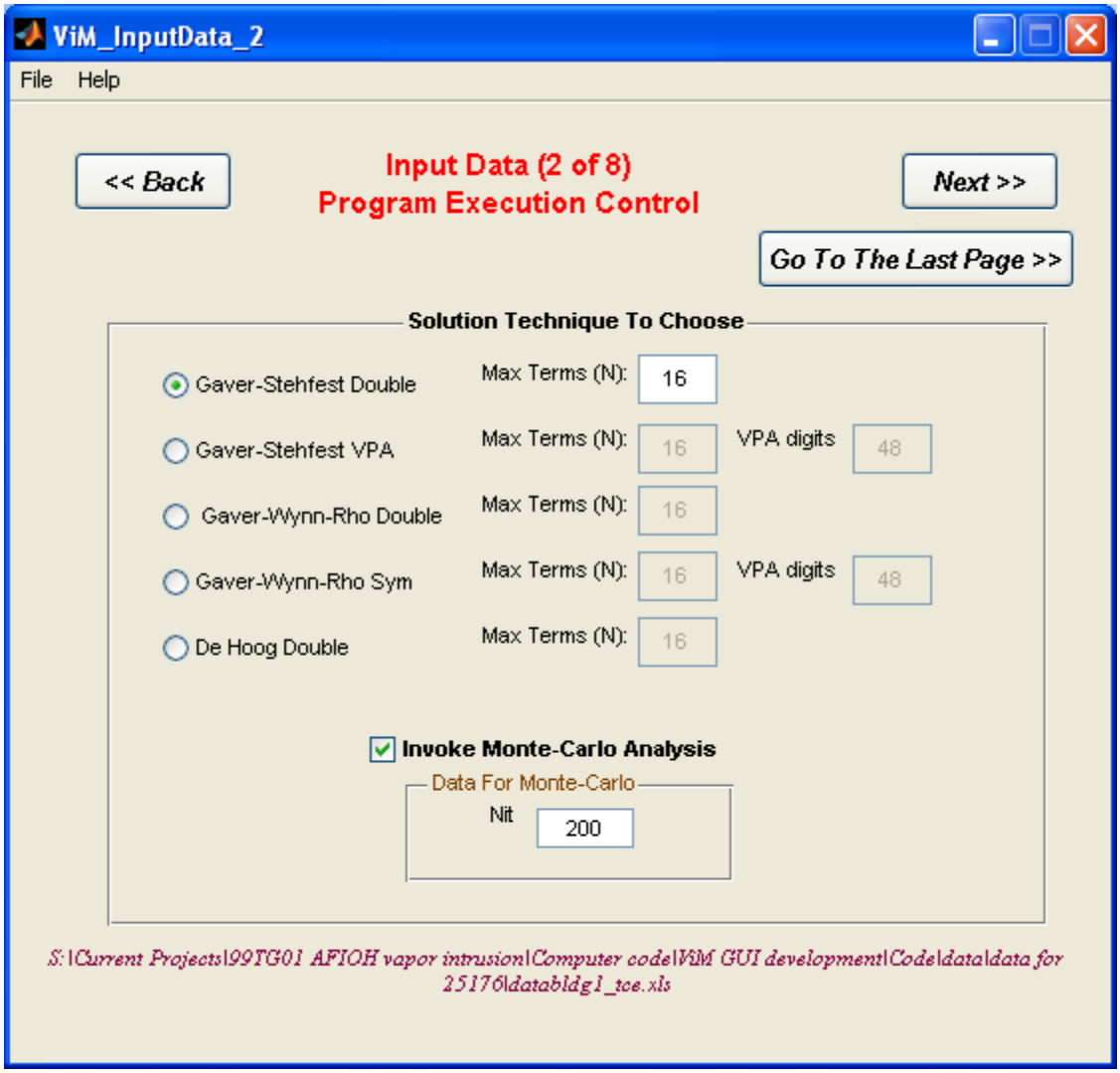


Figure 9. Indoor air concentrations versus the indoor air goal for benzene.

Attachment A: Input data screens for ViM




ViM_InputData_2
File
Help
<< Back
Input Data (2 of 8)
Program Execution Control
Next >>
Go To The Last Page >>
Solution Technique To Choose
Gaver-Stehfest Double
Max Terms (N):
16
Gaver-Stehfest VPA
Max Terms (N):
16
VPA digits
48
Gaver-Wynn-Rho Double
Max Terms (N):
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Gaver-Wynn-Rho Sym
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Invoke Monte-Carlo Analysis
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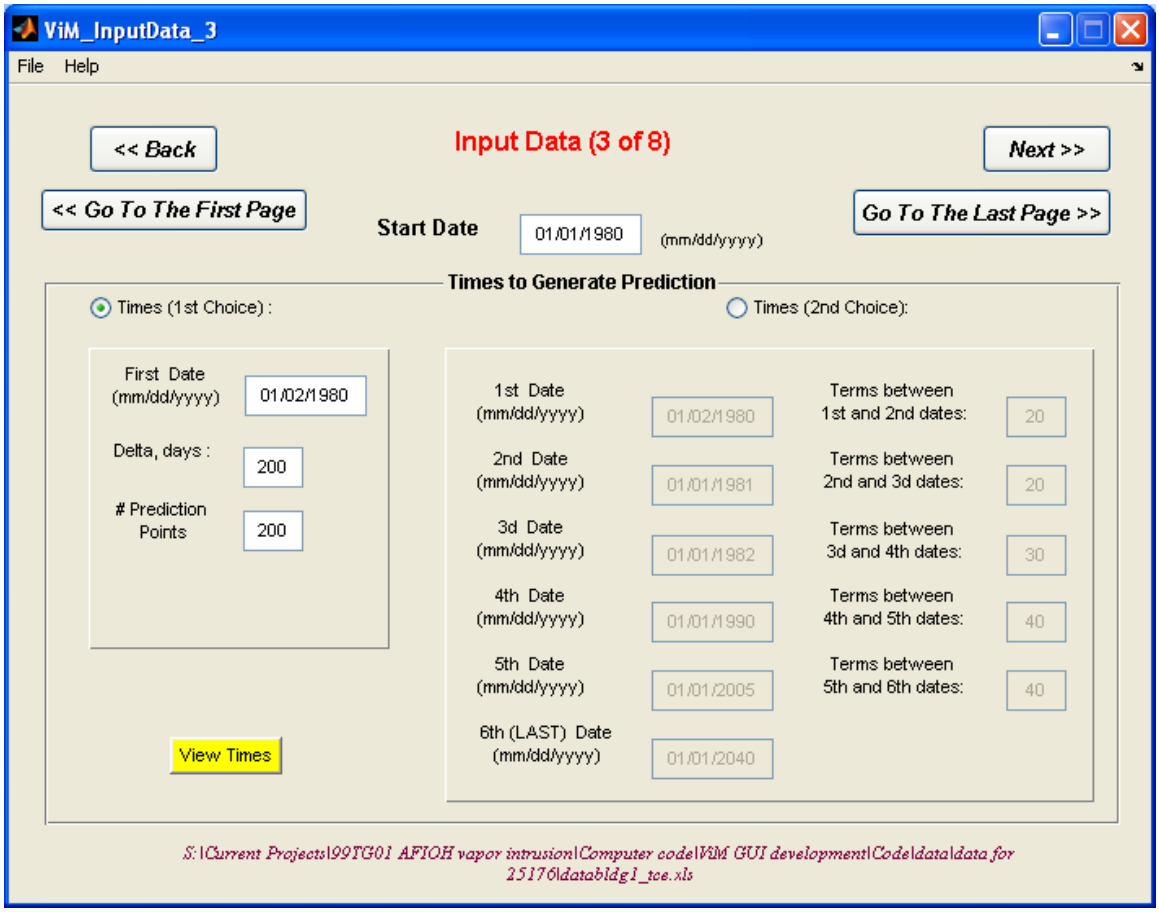
ViM_InputData_3
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Help
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Input Data (3 of 8)
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Start Date
01/01/1980
(mm/dd/yyyy)
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Times to Generate Prediction
Times (1st Choice) :
Times (2nd Choice):
First Date (mm/dd/yyyy)
01/02/1980
Delta, days :
200
Prediction Points
200
View Times
1st Date (mm/dd/yyyy)
01/02/1980
2nd Date (mm/dd/yyyy)
01/01/1981
3d Date (mm/dd/yyyy)
01/01/1982
4th Date (mm/dd/yyyy)
01/01/1990
5th Date (mm/dd/yyyy)
01/01/2005
6th (LAST) Date (mm/dd/yyyy)
01/01/2040
Terms between 1st and 2nd dates:
20
Terms between 2nd and 3d dates:
20
Terms between 3d and 4th dates:
30
Terms between 4th and 5th dates:
40
Terms between 5th and 6th dates:
40
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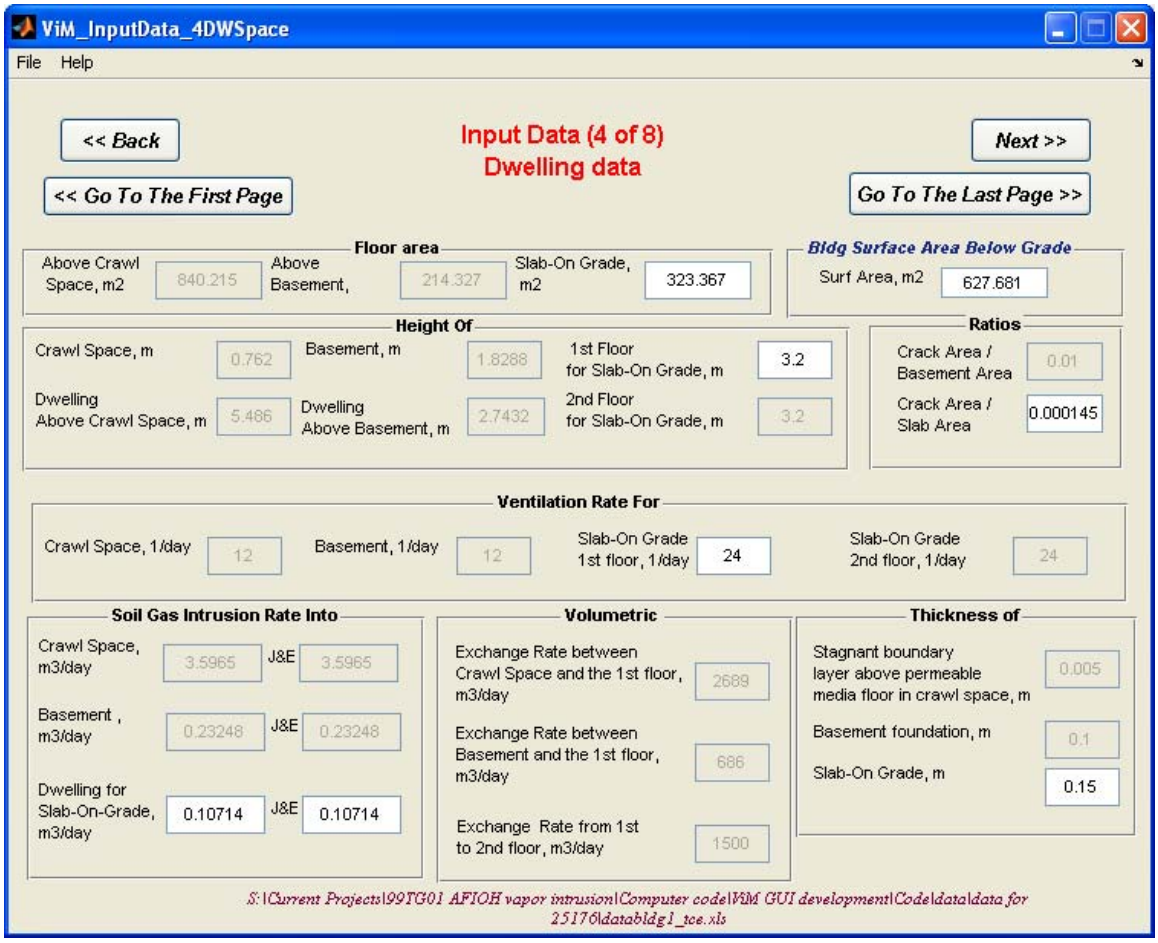
ViM_InputData_4DWSpace
File Help
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Input Data (4 of 8)
Dwelling data
Next >>
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Floor area
Above Crawl Space, m2
840.215
Above Basement,
214.327
Slab-On Grade, m2
323.367
Bldg Surface Area Below Grade
Surf Area, m2
627.681
Height Of
Crawl Space, m
0.762
Basement, m
1.8288
1st Floor for Slab-On Grade, m
3.2
Dwelling Above Crawl Space, m
5.486
Dwelling Above Basement, m
2.7432
2nd Floor for Slab-On Grade, m
3.2
Ratios
Crack Area / Basement Area
0.01
Crack Area / Slab Area
0.000145
Ventilation Rate For
Crawl Space, 1/day
12
Basement, 1/day
12
Slab-On Grade 1st floor, 1/day
24
Slab-On Grade 2nd floor, 1/day
24
Soil Gas Intrusion Rate Into
Crawl Space, m3/day
3.5965
J&E
3.5965
Basement , m3/day
0.23248
J&E
0.23248
Dwelling for Slab-On-Grade, m3/day
0.10714
J&E
0.10714
Volumetric
Exchange Rate between Crawl Space and the 1st floor, m3/day
2689
Exchange Rate between Basement and the 1st floor, m3/day
686
Exchange Rate from 1st to 2nd floor, m3/day
1500
Thickness of
Stagnant boundary layer above permeable media floor in crawl space, m
0.005
Basement foundation, m
0.1
Slab-On Grade, m
0.15
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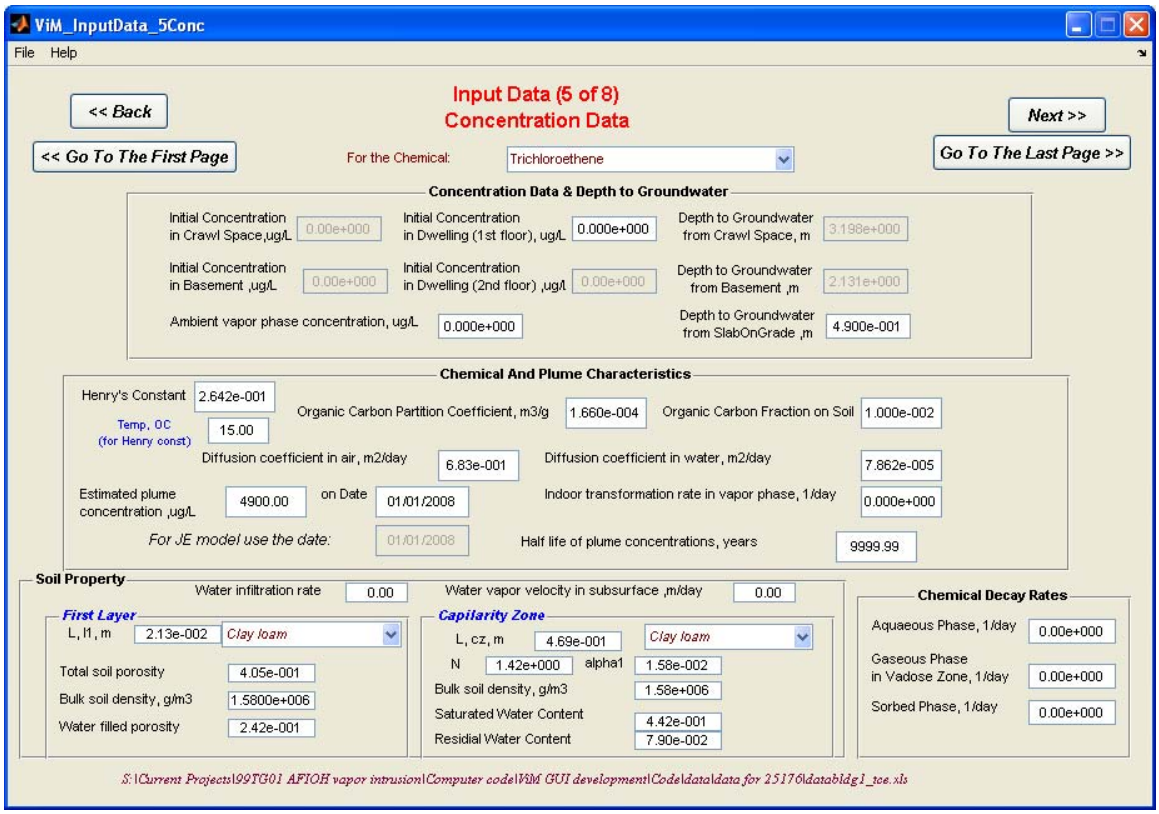
ViM_InputData_5Conc
File Help
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Input Data (5 of 8)
Concentration Data
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For the Chemical: Trichloroethene
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Concentration Data & Depth to Groundwater
Initial Concentration in Crawl Space,ug/L 0.00e+000
Initial Concentration in Dwelling (1st floor), ug/L 0.000e+000
Depth to Groundwater from Crawl Space, m 3.198e+000
Initial Concentration in Basement ,ug/L 0.00e+000
Initial Concentration in Dwelling (2nd floor) ,ug/L 0.00e+000
Depth to Groundwater from Basement ,m 2.131e+000
Ambient vapor phase concentration, ug/L 0.000e+000
Depth to Groundwater from SlabOnGrade ,m 4.900e-001
Chemical And Plume Characteristics
Henry's Constant 2.642e-001
Temp, OC (for Henry const) 15.00
Organic Carbon Partition Coefficient, m3/g 1.660e-004
Organic Carbon Fraction on Soil 1.000e-002
Diffusion coefficient in air, m2/day 6.83e-001
Diffusion coefficient in water, m2/day 7.862e-005
Estimated plume concentration ,ug/L 4900.00
on Date 01/01/2008
Indoor transformation rate in vapor phase, 1/day 0.000e+000
For JE model use the date: 01/01/2008
Half life of plume concentrations, years 9999.99
Soil Property
Water infiltration rate 0.00
Water vapor velocity in subsurface ,m/day 0.00
First Layer
L, l1, m 2.13e-002 Clay loam
Total soil porosity 4.05e-001
Bulk soil density, g/m3 1.5800e+006
Water filled porosity 2.42e-001
Capilarity Zone
L, cz, m 4.69e-001 Clay loam
N 1.42e+000 alpha1 1.58e-002
Bulk soil density, g/m3 1.58e+006
Saturated Water Content 4.42e-001
Residial Water Content 7.90e-002
Chemical Decay Rates
Aquaeous Phase, 1/day 0.00e+000
Gaseous Phase in Vadose Zone, 1/day 0.00e+000
Sorbed Phase, 1/day 0.00e+000
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VIM_InputData_7_SOG
File Help
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Input Data (7 of 8)
Randomizing Options For The SOG
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MIN MAX a What To Use For Randomize (min/max or a)
Af_surf 6.28e+002 5.65e+002 9.24e+002 0.10 Use Min/Max
Af 3.23e+002 2.91e+002 9.24e+002 0.10 Use Min/Max
H(1) 3.20e+000 2.88e+000 6.04e+000 0.10 Use Min/Max
H(2) 3.20e+000 2.47e+000 3.52e+000 0.10 Use Min/Max
eta 1.45e-004 1.31e-004 1.10e-002 0.10 Use Min/Max
dair 1.50e-001 9.00e-002 1.65e-001 0.10 Use Min/Max
Xd1 2.40e+001 3.60e+000 2.64e+001 0.10 Use Min/Max
Xd2 2.40e+001 3.60e+000 2.64e+001 0.10 Use Min/Max
Q12 1.50e+003 1.35e+003 1.65e+003 0.10 Use Min/Max
Qs 1.07e-001 9.64e-002 3.96e+000 0.10 Use Min/Max
Qsje 1.07e-001 9.64e-002 3.96e+000 0.10 Use Min/Max
Cd1 0.00e+000 0.00e+000 0.00e+000 0.10 Use Min/Max
Cd2 0.00e+000 0.00e+000 0.00e+000 0.10 Use Min/Max
Cgw0 4.90e+003 9.00e+001 1.05e+004 0.00 Use Min/Max
L 4.90e-001 4.58e-001 4.22e+000 0.10 Use Min/Max
Tau 1.00e+004 9.00e+003 1.10e+004 0.10 Use Min/Max
N 1.42e+000 1.27e+000 1.56e+000 0.10 Use Min/Max
theta_r 7.90e-002 7.11e-002 8.69e-002 0.10 Use Min/Max
theta_s 4.42e-001 3.98e-001 4.86e-001 0.10 Use Min/Max
D air 6.83e-001 7.11e-002 7.51e-001 0.10 Use Min/Max
D water 7.86e-005 8.19e-006 8.65e-005 0.10 Use Min/Max
Ca 0.00e+000 0.00e+000 8.80e-005 0.10 Use Min/Max
kw 0.00e+000 0.00e+000 1.10e-001 0.10 Use Min/Max
kg 0.00e+000 0.00e+000 0.00e+000 0.10 Use Min/Max
kads 0.00e+000 0.00e+000 0.00e+000 0.10 Use Min/Max
Kh 2.64e-001 1.99e-001 4.62e-001 0.20 Use Min/Max
thetal 2.42e-001 1.98e-001 2.42e-001 0.10 Use Min/Max
rhob 1.58e+006 1.31e+006 1.60e+006 0.10 Use Min/Max
foc 1.00e-002 9.00e-003 1.10e-002 0.10 Use Min/Max
phi 4.05e-001 4.05e-001 4.95e-001 0.10 Use Min/Max
Vbl 0.00e+000 0.00e+000 0.00e+000 0.10 Use Min/Max
Vbg 0.00e+000 0.00e+000 0.00e+000 0.10 Use Min/Max
Koc 1.66e-004 1.49e-004 1.83e-004 0.10 Use Min/Max
rhob_cz 1.58e+006 1.31e+006 1.60e+006 0.10 Use Min/Max
Lcz 4.69e-001 4.41e-001 5.39e-001 0.10 Use Min/Max
L_l1 2.13e-002 1.89e-002 2.31e-002 0.10 Use Min/Max
alpha1 1.58e-002 1.42e-002 1.74e-002 0.10 Use Min/Max
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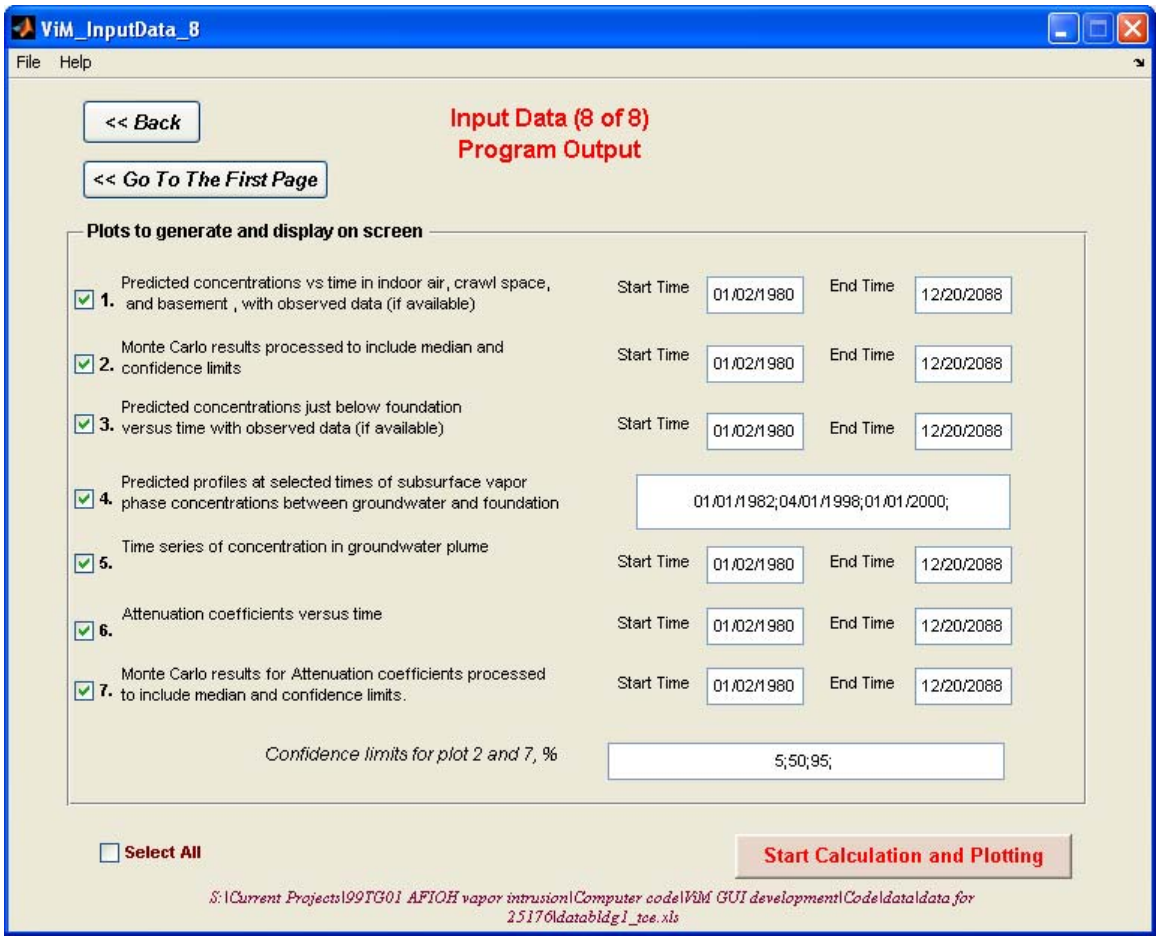
ViM_InputData_8
File Help
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Input Data (8 of 8)
Program Output
Plots to generate and display on screen
1. Predicted concentrations vs time in indoor air, crawl space, and basement , with observed data (if available)
Start Time 01/02/1980 End Time 12/20/2088
2. Monte Carlo results processed to include median and confidence limits
Start Time 01/02/1980 End Time 12/20/2088
3. Predicted concentrations just below foundation versus time with observed data (if available)
Start Time 01/02/1980 End Time 12/20/2088
4. Predicted profiles at selected times of subsurface vapor phase concentrations between groundwater and foundation
01/01/1982;04/01/1998;01/01/2000;
5. Time series of concentration in groundwater plume
Start Time 01/02/1980 End Time 12/20/2088
6. Attenuation coefficients versus time
Start Time 01/02/1980 End Time 12/20/2088
7. Monte Carlo results for Attenuation coefficients processed to include median and confidence limits.
Start Time 01/02/1980 End Time 12/20/2088
Confidence limits for plot 2 and 7, %
5;50;95;
Select All
Start Calculation and Plotting
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Johnson and Ettinger Vapor Intrusion Modeling

Residential Scenario

The USEPA's Johnson and Ettinger volatilization model (USEPA, 2004) was utilized to estimate groundwater concentrations that would be protective of residential expose to contaminants that have volatilized from groundwater and migrated through building foundations into indoor air. Input parameters to the model were obtained from the *Summary of Indoor Air Modeling and Calculation of Risk-based Groundwater Goals Protective of Indoor Workers, Middle River Complex, Maryland* (CDM, 2010). A value of 15º C was used for the average groundwater temperature. The depth below grade to soil was assumed to be 150 cm. The Soil Conservation Services (SCS) soil type was determined to be clay loam (CL). Site-specific values were also used for the dry bulk density (1.58 g/cm^3), total porosity (0.405), and water filled porosity (0.242 cm^3/cm^3). Model default parameters were used for the remaining model input parameters. All the model input parameters are summarized in Table 1. The estimate groundwater concentrations are presented in Table 2.

References

USEPA, February 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. Office of Emergency and Remedial Response, Washington, DC.

Table 1
Input Data for the Johnson and Ettinger Model

Parameter Name	Units	Value	Source
Average groundwater temperature	deg C	15	1
Depth below grade to bottom of closed space floor	cm	15	2
Depth below grade to water table	cm	150	3
SCS Soil type directly above water table	-	clay loam	4
SCS soil type used to estimate vapor permability	-	clay loam	4
Dry bulk density	g/cm3	1.58	1
Soil total porosity	-	0.405	1
Water-filled porosity	cm3/cm3	0.242	1
Enclosed space floor thickness	cm	10	2
Soil-building pressure differential	g/cm-s2	40	2
Floor length	cm	1000	2
Floor width	cm	1000	2
Height	cm	244	2
Floor wall seam crack width	cm	0.1	2
Indoor air exchange rate	1/hr	0.25	2
Average vapor flow rate into bldg	L/min	5	2
Crack to total area ratio	-	0.000377	5

Sources:

1. Site Characterization Report (Tetra Tech 2006).

2 - J&E Model default value.

3. Average depth to groundwater in area likely to be developed for residential use.

4. Modified from clay or silty clay to prevent model error of water content > porosity.

5. Calculated by the model.

Table 2
Predicted Groundwater Concentration Goals For Residential Exposures Using Johnson and Ettinger Model

Chemical	Residential Air RSL (ug/m^3)(1)		Predicted Indoor Air Concentration using a Unitary Source Term	Groundwater RBCs (ug/L)	
	Carcinogenic	Noncarcinogenic		Carcinogenic	Noncarcinogenic
Benzene	0.31	31	3.79E-03	82	8,184
Tetrachloroethene	0.41	280	4.65E-03	88	60,153
Trichloroethene	1.2	NA	4.15E-03	289	NA
Vinyl Chloride	0.16	100	9.85E-03	16	10,148

1 - USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites, May 2010.
[Cancer benchmark value = 1E-06, Hazard index (HI) = 1.0].

Surface Water Modeling

Middle River Groundwater to Surface Water Modeling

Calculations were done with the Environmental Fluid Dynamics Code (EFDC) model (EPA, 2007).

The Model Grid, as shown below, was established with 1740 horizontal grid cells at an approximate 15 meter (m) resolution as shown in Figure 1. Figure 2 presents the surface water depths in the model area.

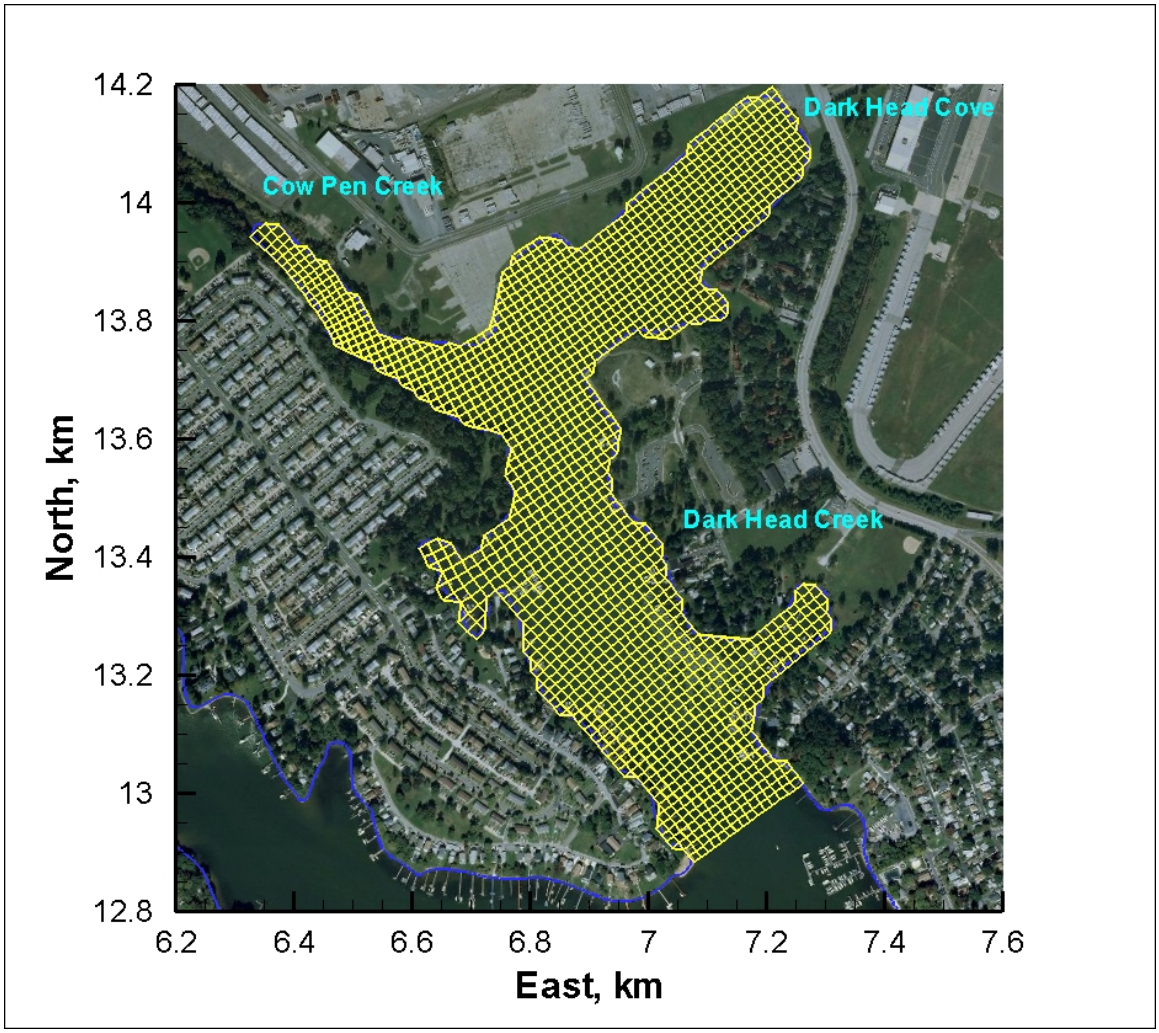

Figure 1. Model grid

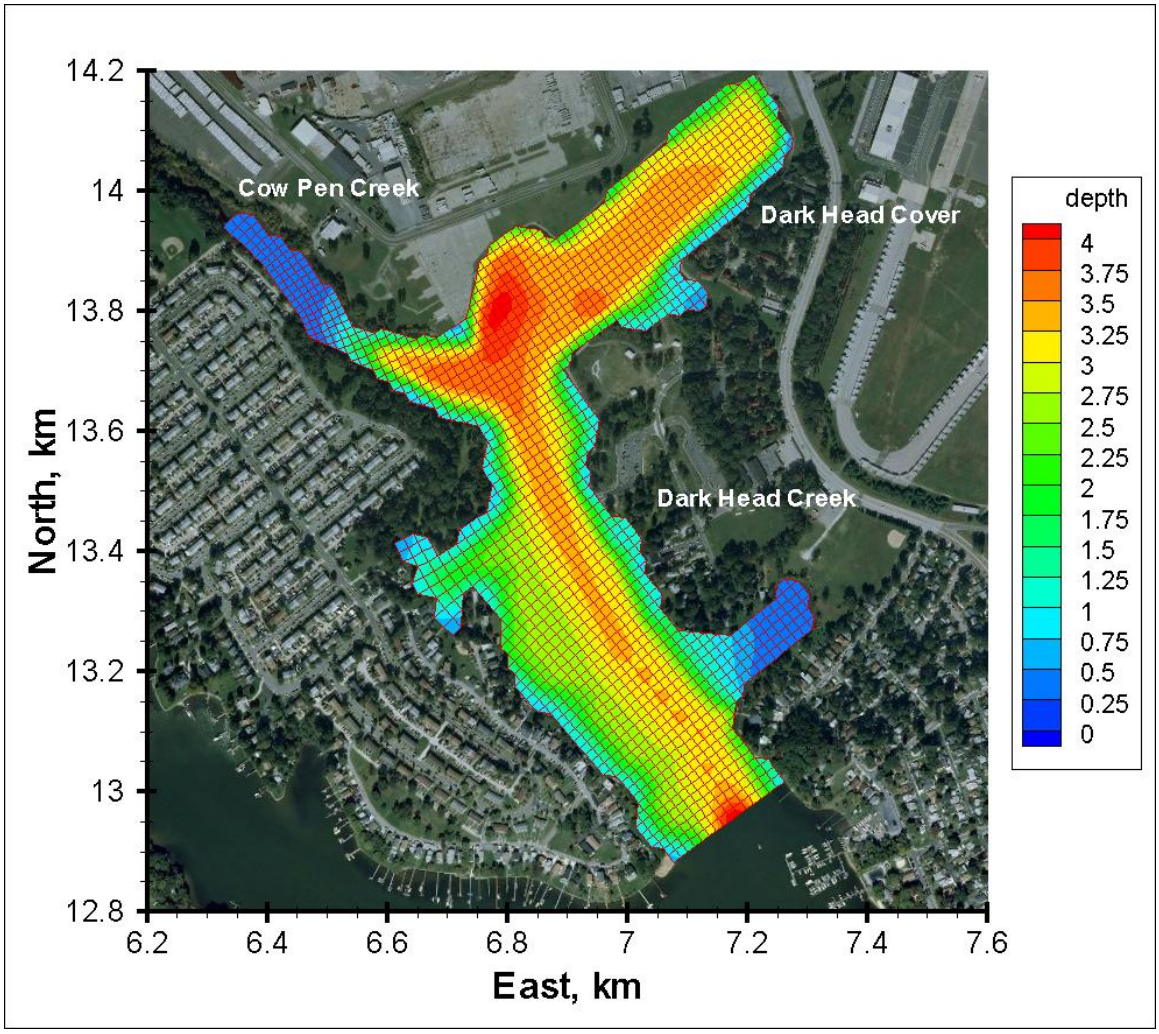

Figure 2. Model grid showing water depth

At the open boundary, the model is forced by a tide range of 0.48 meters (m) based on the closest National Oceanic and Atmospheric Administration (NOAA) prediction. A salinity of 5 practical salinity units (psu) was applied at the open boundary

Annual runoff was estimated to the equivalent to an inflow rate of 0.037 cubic meters per second (cms). To account for evaporation, which was not simulated by the model, the inflow rate was reduced to 0.022 cms.

Total ground water flow specified as 3-4 gallons per minute (gpm) with 3.5 gpm used (0.00022 cms). This is considerable smaller than estimated net freshwater inflow of 0.022 cms

Based on the groundwater model, a flow rate of 0.4 gpm (0.000025 cms) was used as the inflow for the contaminated groundwater plume.

The total annual contaminate load was assumed to be 1 pound per year (lb/year) (0.00007 grams per second). Using the 0.000025 cms flow, that leads to a site groundwater concentration of 2.8 milligrams per liter (mg/l) or 2800 micrograms per liter (ug/l), consistent with the stated maximum concentration of 17000 ug/L in the ground water plume

The dilution of the ground water plume was simulated using EFDC. The simulation ran for 120 days with a dynamic steady state (tidal averaged steady state) being reached after approximately 60 days. The maximum concentration is approximately 10 ug/L and occurs in Cow Pen Creek. The average concentration over the whole region was approximately 1 ug/l, while concentrations in Cow Pen Creek were above 5 ug/l. Figure 3 shows the modeled TCE maximum concentrations in the surface water.

These results can be compared with a simple dilution factor based on the ratio of the plume flow, 2.5E-5 cms to the fresh water inflow 2.2E-2 cms of 0.0011. Multiplying times the average concentration of 2800 ug/l gives 3.2 ug/l, which is on the order of the predicted concentrations.

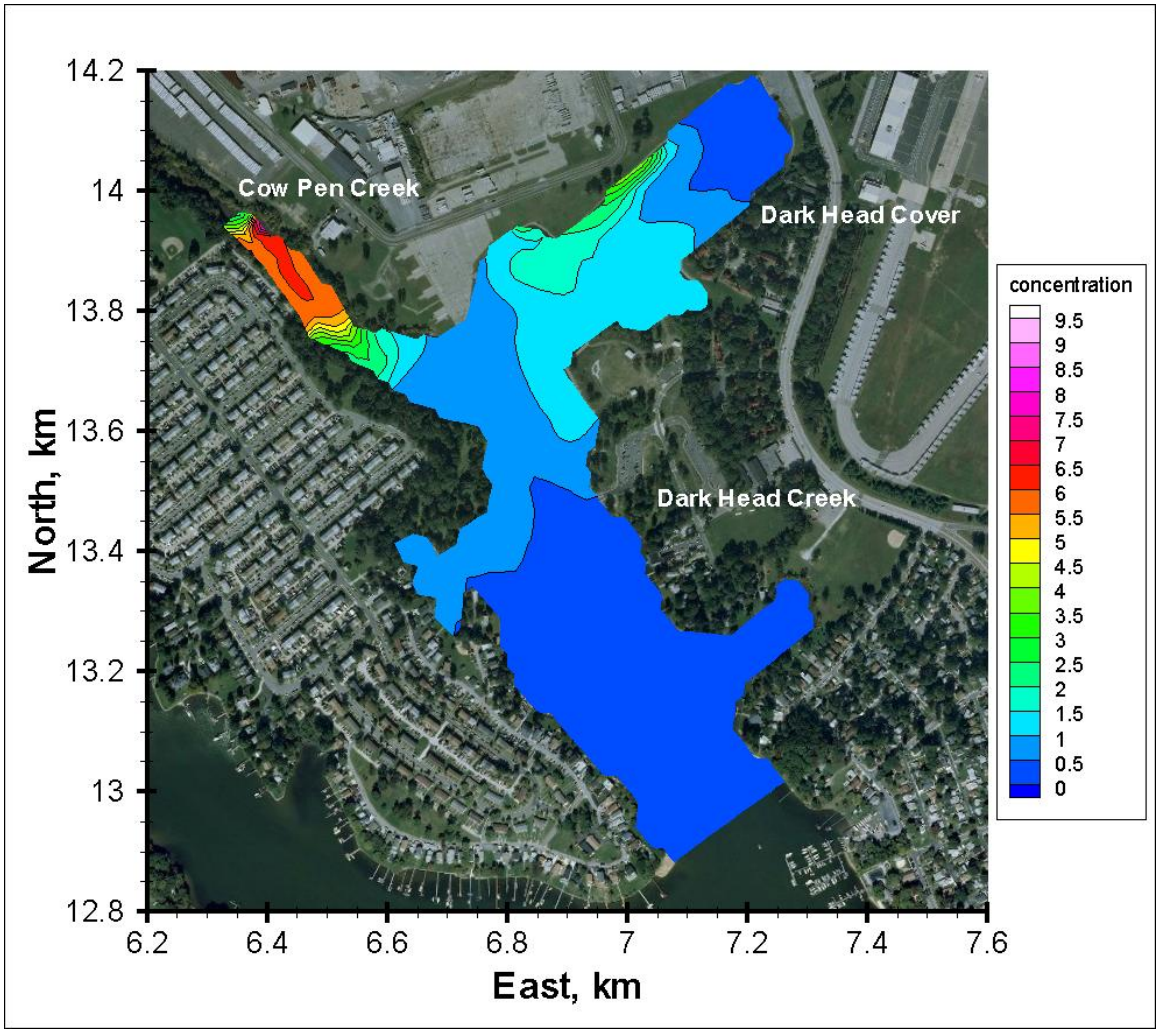

Figure 3. Distribution of maximum concentration

Tetra Tech, Inc.
10306 Eaton Place, Suite 340
Fairfax, VA 20176
703.385.6000

Memorandum

Date: November 18, 2010

From: John Hamrick, Tetra Tech

To: Eric Samuels, Tetra Tech NUS

Subject: Lockheed Martin Middle River Site Sediment Stability Analysis

This document includes a Summary section with references and associated figures suitable for inclusion in a main report and a more detailed section referred to as Appendix X with associated figures.

Summary - Sediment Stability Analysis

A modeling analysis was conducted to estimate the stability of bed sediment in Cow Pen Creek and Dark Head Cove forks of Dark Head Creek, a tributary of the Middle River in Baltimore County Maryland. The analysis considered two of extreme events, a high rainfall event in the Cow Pen Creek and Dark Head Creek watersheds and a historical storm surge and accompanying period high wind. The Environmental Fluid Dynamic Code (Hamrick, 1992; Tetra Tech, 2007; US EPA, 2007) was used for the modeling analysis which involved determination of bed stresses during simulated events. The model grid and bathymetry are shown in Figure 1. Model forcing functions included runoff into Cow Pen Creek and Dark Head Cove, tidal water surface elevation at the mouth of Dark Head Creek, and wind forcing over the entire model domain. The high rainfall-runoff event was based on a 100 year annual recurrence interval 24 hour rainfall of 8.7 inches (24.7 cm) resulting in a 49 cfs (1.39 cms) flow into Cow Pen Creek and a 66 cfs (1.88 cms) flow into Dark Head Cover. A spring tide range of 0.48 meters was assumed to occur during the rainfall event. Maximum sediment bed stresses for this event are shown in Figure 2. Bed stresses are less than 0.1 N/m^2 over most of the study area with the exception of the upstream area of Cow Pen Creek where the maximum

stresses reach 4 N/m^2. Field investigations of critical bed stresses for the erosion of cohesive sediments in the Chesapeake Bay region (Maa, et al., 1998, 2002, 2008) indicate 0.1 N/m^2 to be a lower boundary for the critical erosion stress. Sand and noncohesive behaving silt beds are also stable at stresses below 0.1 N/m^2 (Garcia, 2008).

The second event was based on the historical storm surge and wind event associated with Hurricane Isabella during September 2003. Figure 3 shows the water surface elevation at the NOAA station in Baltimore Harbor which was used for the tidal boundary condition. The wind forcing was based on observed wind speed, Figure 4, and direction at BWI Airport. The distribution of maximum bed stresses during the one month simulation is shown in Figure 5. Stresses are less than 0.1 N/m^2 over much of the area, with high stresses again occurring in the upstream area of Cow Pen Creek. Bands of high stress occur along the southwest shoreline of Dark Head Cove and in Dark Head Creek. To determine the relative importance of the wind forcing, the surge simulation was repeated without wind with the stress distribution shown in Figure 6. Stresses associated with only the surge are below 0.03 N/m^2 over the entire area indicating that the high wind speed in excess of 16 m/s (36 mph) are primarily responsible for the higher stresses. Since local sheltering effects are not accounted for, the wind induced stresses can be viewed as conservative. The general conclusion of the analysis is that the sediment bed is stable in the area of interest, with the exception of the upstream area of Cow Pen Creek.

References – for Summary Version

Garcia, M. (editor), 2008. Sedimentation Engineering: Processes, Measurements, Modeling, and Practice. ASCE Manuals and Reports on Engineering Practice No. 110, American Society of Civil Engineers. 1132 pp.

Hamrick, J. M., 1992: A three-dimensional environmental fluid dynamics computer code: Theoretical and computational aspects. The College of William and Mary, Virginia Institute of Marine Science, Special Report 317, 63 pp.

Maa, J. P.-Y., 2008. Sediment erosion characteristics in the Anacostia River. *Journal of Hydraulic Engineering*, 134(8), 1102-1109.

Maa, J. P.-Y., L. Sanford, and J. P. Halka. 1998. Sediment resuspension characteristics in the Baltimore Harbor. *Marine Geology*, 146:147-145.

Maa, J. P.-Y. and S.-C. Kim, 2002. A constant erosion rate model for fine sediment in the York River, Virginia. *Environmental Fluid Mechanics*, 1, 343-360.

Tetra Tech, Inc. 2007: The Environmental Fluid Dynamic Code: theory and computation, Volume 2: Sediment and contaminant transport and Fate. Fairfax, VA., 96 pp.

U. S. Environmental Protection Agency, Office of Research and Development, Center for Exposure Assessment Modeling, 2007: Link to Environmental Fluid Dynamics Code web page. http://www.epa.gov/ceampubl/swater/efdc

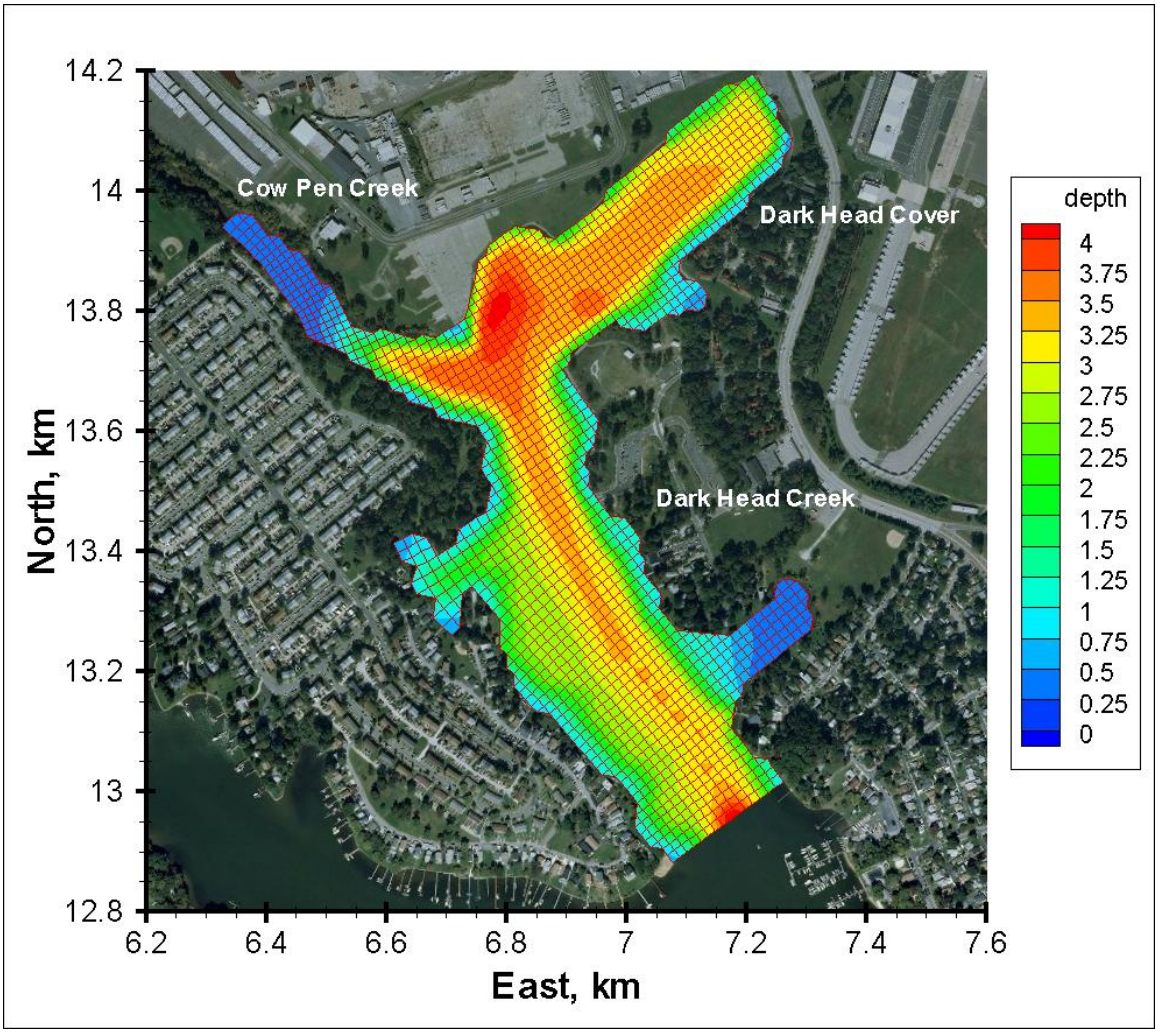

Figure1. Model grid of Dark Head creek in the vicinity of the Middle River Complex site showing water depth in meters below mean sea level

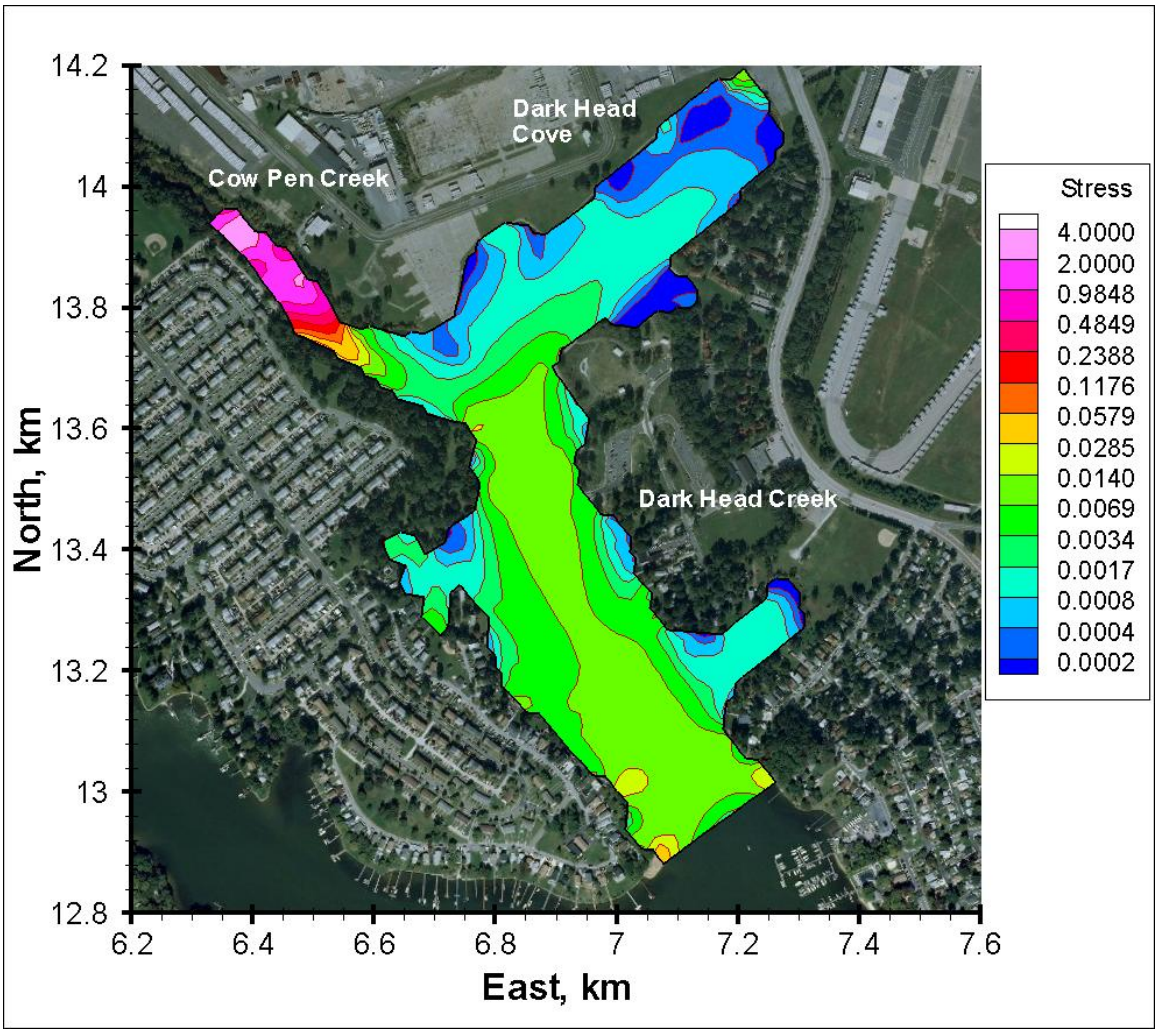

Figure 2. Distribution of maximum bed stress (N/m^2) during a 100 year annual recurrence interval, 24 hour rainfall of 8.7 inches (24.7 cm), daily rainfall event coincident with spring tide conditions.

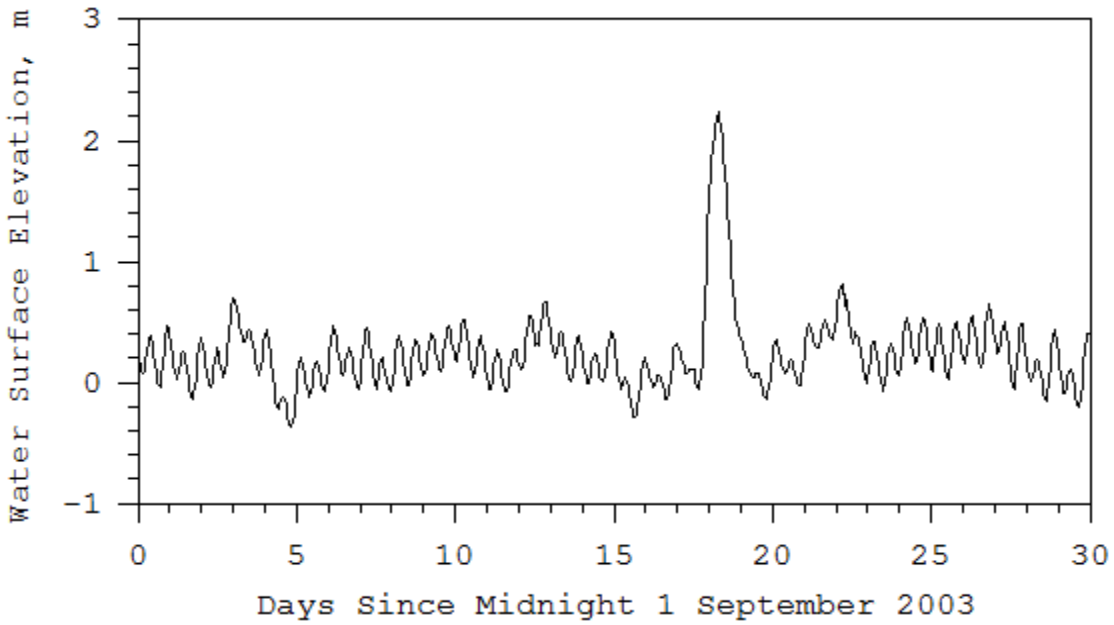

Figure 3. Water surface elevation at NOAA gage in Baltimore Harbor during September 2003 showing the Hurricane Isabella storm surge.

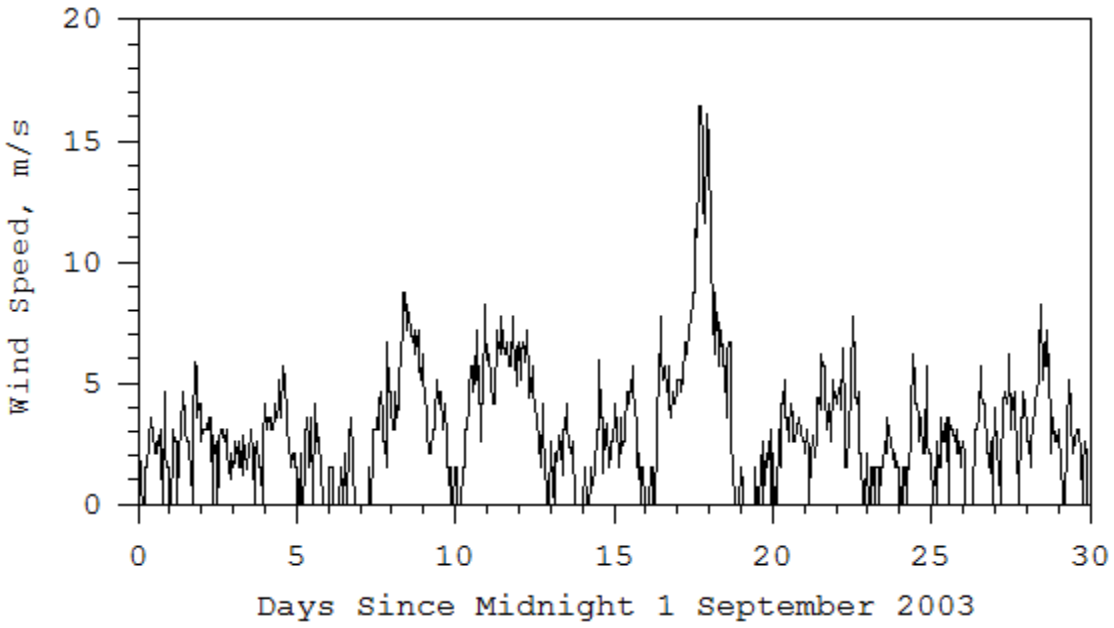

Figure 4. Wind speed at BWI Airport during September 2003

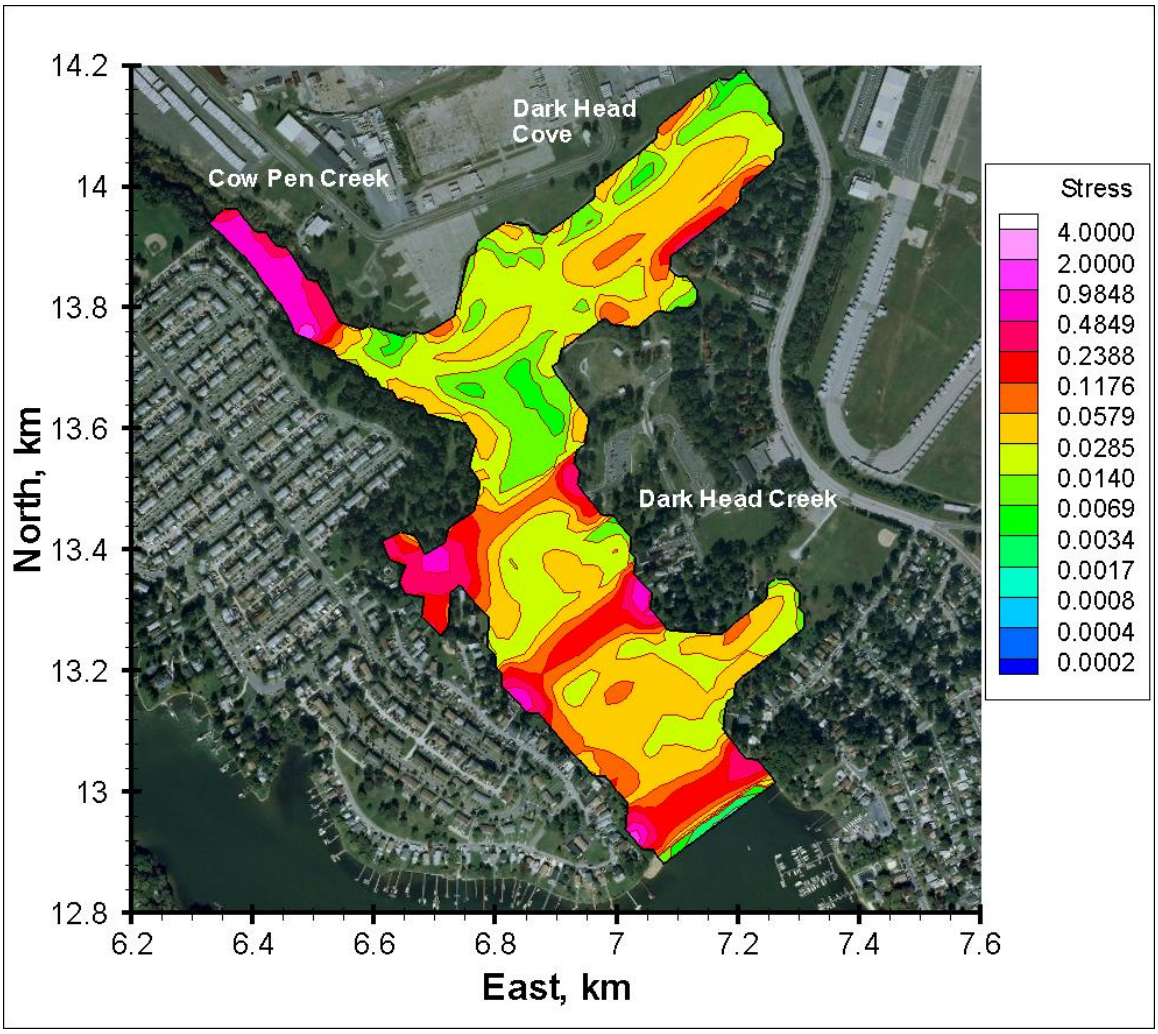

Figure 5. Distribution of maximum bed stress (N/m^2) during Hurricane Isabella storm surge and wind event in September 2003.

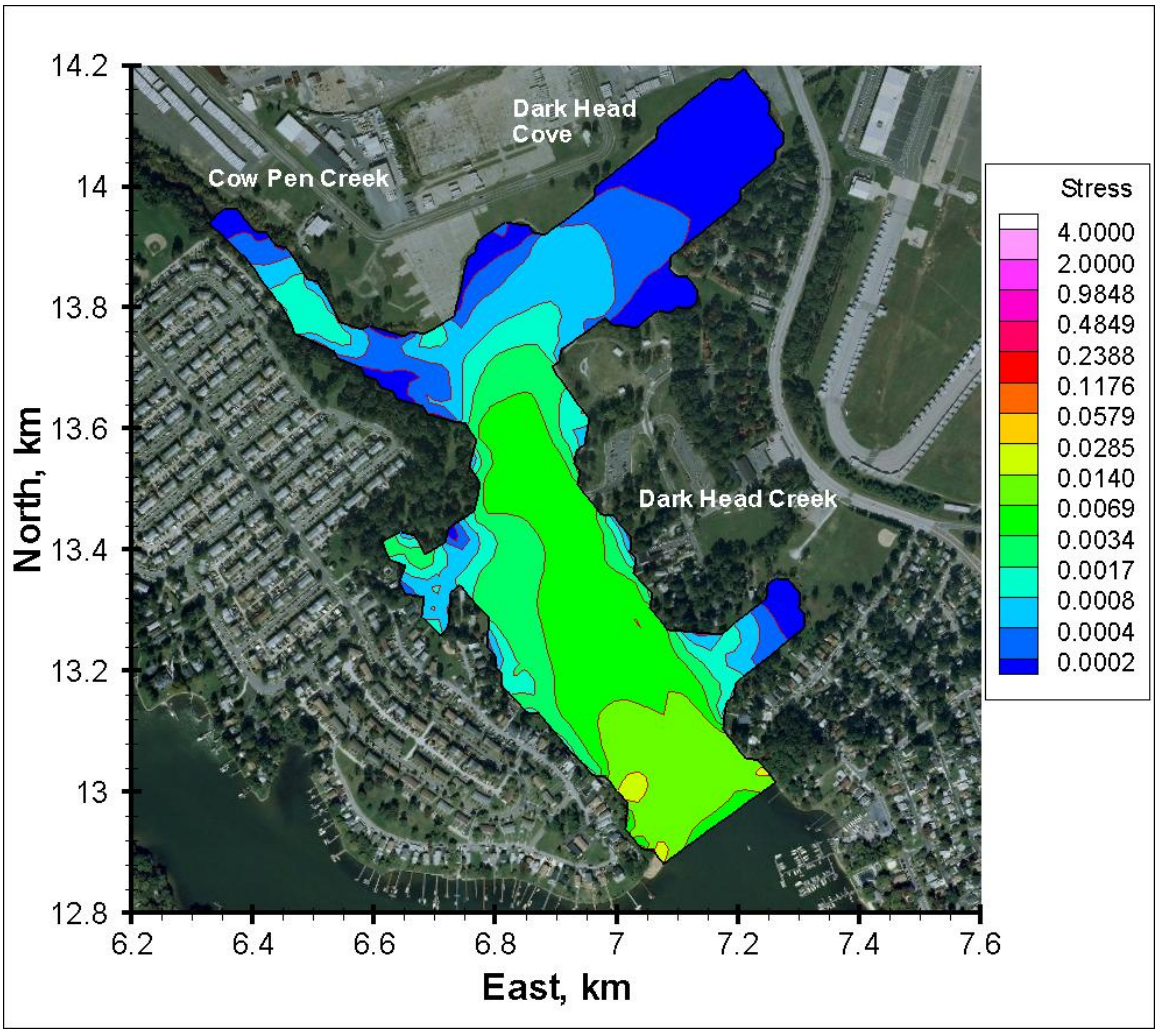

Figure 6. Distribution of maximum bed stress (N/m^2) during Hurricane Isabella storm surge and wind event in September 2003. Simulation.

Appendix X - Sediment Stability Analysis

Introduction

A modeling analysis was conducted to estimate the stability of bed sediment in Cow Pen Creek and Dark Head Cove forks of Dark Head Creek, a tributary of the Middle River in Baltimore County Maryland. The analysis considered two of extreme events, a high rainfall event in the Cow Pen Creek and Dark Head Creek watersheds and a historical storm surge and accompanying period high wind. The Environmental Fluid Dynamic Code (Hamrick, 1992; Tetra Tech, 2007; US EPA, 2007) was used for the modeling analysis which involved determination of bed stresses during simulated events. This Appendix documents the modeling analysis including configuration of the model, selection of the events, and presentation and discussion of the model predictions of sediment stability.

Model Configuration

The EFDC model was configured to simulation flow in the study region which includes Cow Pen Creek, Dark Head Cove and Dark Head Creek. The model grid is shown in Figure X1 and has approximately 50 feet (15 m) square grid cells . Bathymetric and topographic data for configuration of the model included a recent bathymetric survey conducted by Tetra Tech EC during summer 2010 and NOAA Coastal Relief bathymetry and topography. Figure X2 shows the extent of the bathymetric survey, while Figure X3 shows the filled bathymetry over the entire grid. The presences of vegetation precluded collection of bathymetry in the upstream area of Cow Pen Creek and a minimum water depth of one foot (30 cm) was used in this area and blended with measured bathymetry. For the downstream area of Dark Head Creek, an open boundary bathymetric profile is assumed at the mouth and blended with the measured bathymetry.

The model was further configured to simulate two extreme events. The first event is a high rainfall-runoff event based on a 100 year annual recurrence interval 24 hour rainfall of 8.7 inches (24.7 cm). The runoff volumes from the Cow Pen Creek and Dark Head Cove watersheds, were estimated using the Simple Method for runoff from urban areas (SMRC, 2010). Data requirements for the approach include the subwatershed drainage area, impervious cover, and precipitation. The subwatersheds of the study area were delineated using available data sources. Elevation contours derived from U.S. Geological survey 10-meter digital elevation models (USGS, 2009) of the study area were the primary source. The watershed delineation also incorporated site utility information for Chesapeake Park, owned by LMC Properties, Inc. The subwatershed delineations of Cow Pen Creek and Dark Head Cove are shown in Figure X4. General land use/land cover data sets for the subwatersheds were extracted from the National Land Cover Dataset (NLCD) database (MRLC, 2001). NLCD data were derived from satellite imagery taken circa 2001 and provide detailed categorization of urban and natural areas. Land use categories were divided into separate pervious and impervious land units based on the impervious percentages description provided in the NLCD metadata. Table X1 presents the land use distributions of the Cow Pen Creek and Dark Head Cove

subwatersheds. Rainfall totals were taken from rainfall frequency data released by The National Weather Service that are available through the National Oceanic and Atmospheric Administration's (NOAA) Precipitation Frequency Data Server. Rainfall frequency data for the study area are presented in Table X2 and may be accessed at http://hdsc.nws.noaa.gov/. Using the datasets described above, peak runoff volumes were estimated for the two watersheds for a 24-hr 100-year storm. These runoff volumes result in a 49 cfs (1.39 cms) flow into Cow Pen Creek and a 66 cfs (1.88 cms) flow into Dark Head Cover. A spring tide with range of 1.58 feet (0.48 m) was applied at the open boundary at the mouth of Dark Head Creek for this event.

The second event was based on the historical storm surge and wind event associated with Hurricane Isabella during September 2003. Figure X5 shows the water surface elevation at the NOAA station in Baltimore Harbor which was used for the tidal boundary condition. In addition to the surge, the September period includes a spring tide. The wind forcing was based on observed wind speed, Figure X6, and direction at BWI Airport.

Event Simulation Results

The high rainfall-runoff event was simulated as a continuous inflow of 49 cfs (1.39 cms) into Cow Pen Creek and 66 cfs (1.88 cms) into Dark Head Cove accompanied by a 1.58 foot (0.48 m) range spring tide at the mouth of Dark Head Creek. The resulting distribution of maximum sediment bed stresses are shown in Figure X7. Bed stresses are less than 0.1 N/m^2 over most of the study area with the exception of the upstream area of Cow Pen Creek where the maximum stresses reach 4 N/m^2. Field investigations of critical bed stresses for the erosion of cohesive sediments in the Chesapeake Bay region (Maa, et al., 1998, 2002, 2008) indicate 0.1 N/m^2 to be a lower boundary for the critical erosion stress. Sand and noncohesive behaving silt beds are also stable at stresses below 0.1 N/m^2 as shown in Figure X8 (Garcia, 2008).

The storm surge and wind event simulation was executed for the entire month of September 2003 and maximum bed stresses in each model grid cell were determined form the model output. The distribution of maximum bed stresses is shown in Figure X9. Stresses are less than 0.1 N/m^2 over much of the area, with high stresses again occurring in the upstream area of Cow Pen Creek. Bands of high stress occur along the southwest shoreline of Dark Head Cove and in Dark Head Creek. To determine the relative importance of the wind forcing, the surge simulation was repeated without wind with the stress distribution shown in Figure X10. Stresses associated with only the surge are below 0.03 N/m^2 over the entire area indicating that the high wind speed in excess of 16 m/s (36 mph) is primarily responsible for the higher stresses. This also confirms that normal tidal conditions, including monthly spring tides do not pose the potential for erosion. Since local sheltering effects are not accounted for, the wind induced stresses can be viewed as conservative.

The general conclusion of the analysis is that the sediment bed is stable in the area of interest, with the exception of the upstream area of Cow Pen Creek. It is likely that this area has been eroded and renewed by new deposits relatively frequently, since shorter

duration rainfall events with lower annual recurrence interval can produce similar peak discharges at the 100 year 24 hour event. The 100 year 24 hour event was selected in this case since its duration could transport erode material outside of study area..

Table X1. Land use areas for the Cow Pen Creek and Dark Head Cove subwatersheds

Land Use Description	% Impervious	Area (acres)	
		Cow Pen Creek	Dark Head Cove
Open Water	100.0%	8.2	25.8
Developed, Open Space	10.0%	56.0	66.5
Developed, Low Intensity	34.5%	87.0	61.4
Developed, Med. Intensity	64.5%	94.7	111.6
Developed, High Intensity	90.0%	35.6	70.5
Barren	50.0%	0.9	5.3
Deciduous Forest	0.0%	49.1	208.8
Evergreen Forest	0.0%	2.2	4.4
Pasture/Hay	0.0%	16.7	50.3
Cultivated Crops	0.0%	8.9	23.1
Woody Wetlands	0.0%	9.6	26.9
Herbaceous Wetlands	0.0%	2.0	5.3
Total (excluding open water)		362.7	634.3

Table X2. Rainfall frequency totals for the study area

Annual Recurrence Interval (years)	Rainfall Frequency total (in)									
	5-min	10-min	15-min	30-min	60-min	120-min	3-hr	6-hr	12-hr	24-hr
1	0.35	0.55	0.69	0.95	1.18	1.41	1.52	1.9	2.3	2.69
2	0.41	0.66	0.83	1.15	1.45	1.72	1.85	2.3	2.78	3.26
5	0.49	0.79	1	1.42	1.82	2.17	2.34	2.91	3.54	4.21
10	0.55	0.88	1.11	1.61	2.1	2.53	2.73	3.4	4.19	5.04
25	0.62	0.99	1.25	1.86	2.48	3.02	3.29	4.14	5.17	6.3
50	0.67	1.07	1.36	2.04	2.77	3.43	3.74	4.76	6.04	7.43
100	0.72	1.15	1.46	2.23	3.07	3.85	4.23	5.44	7	8.7
200	0.77	1.23	1.55	2.41	3.38	4.3	4.74	6.18	8.08	10.13
500	0.83	1.32	1.66	2.64	3.79	4.92	5.47	7.26	9.72	12.33
1,000	0.88	1.39	1.74	2.82	4.12	5.43	6.07	8.18	11.15	14.27

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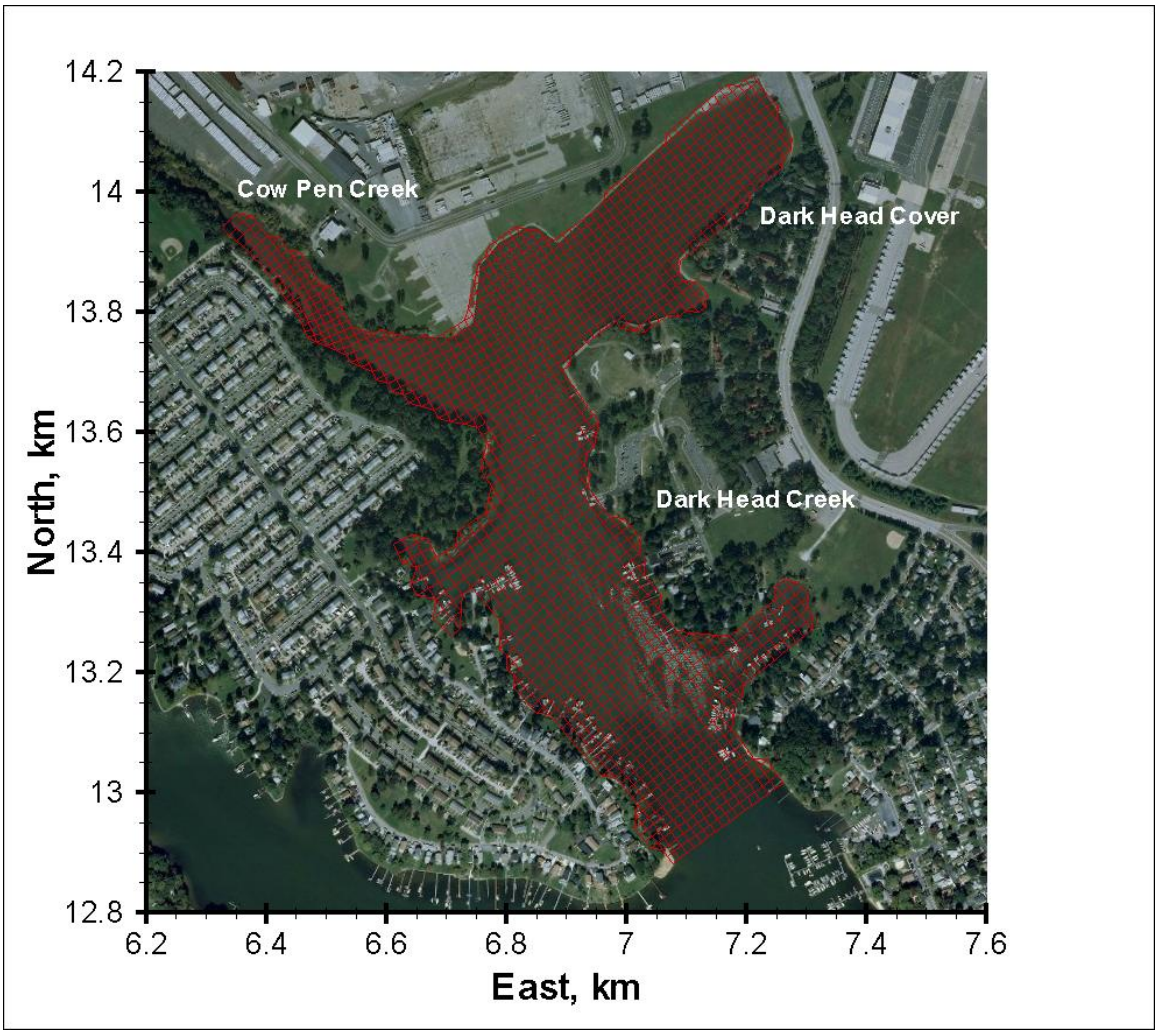


Figure X1. EFDC model grid of Dark Head Creek.

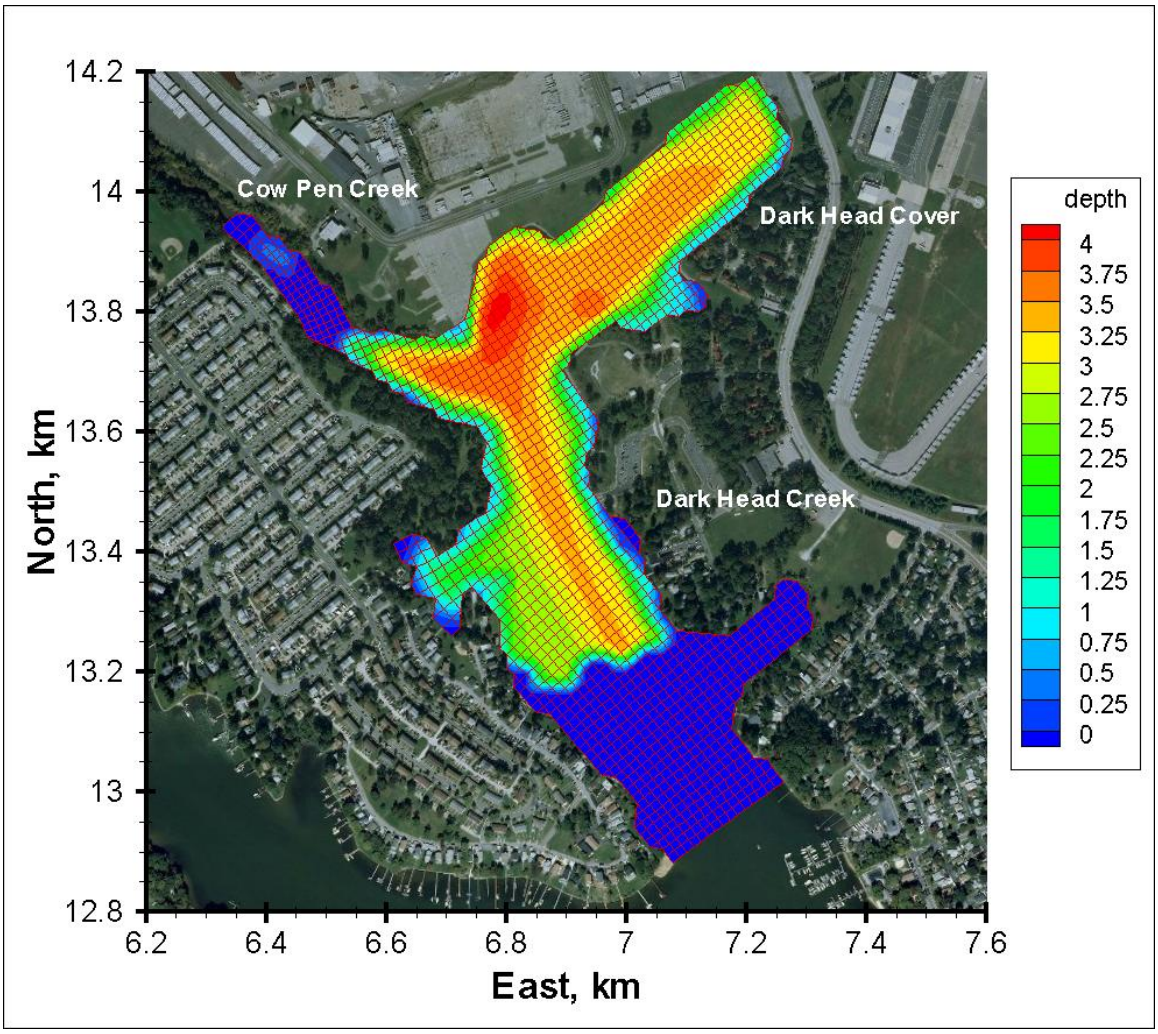


Figure X2. Extent of bathymetric survey shown on model grid. Depths are in meters below mean sea level. Darkest blue represents areas not surveyed.

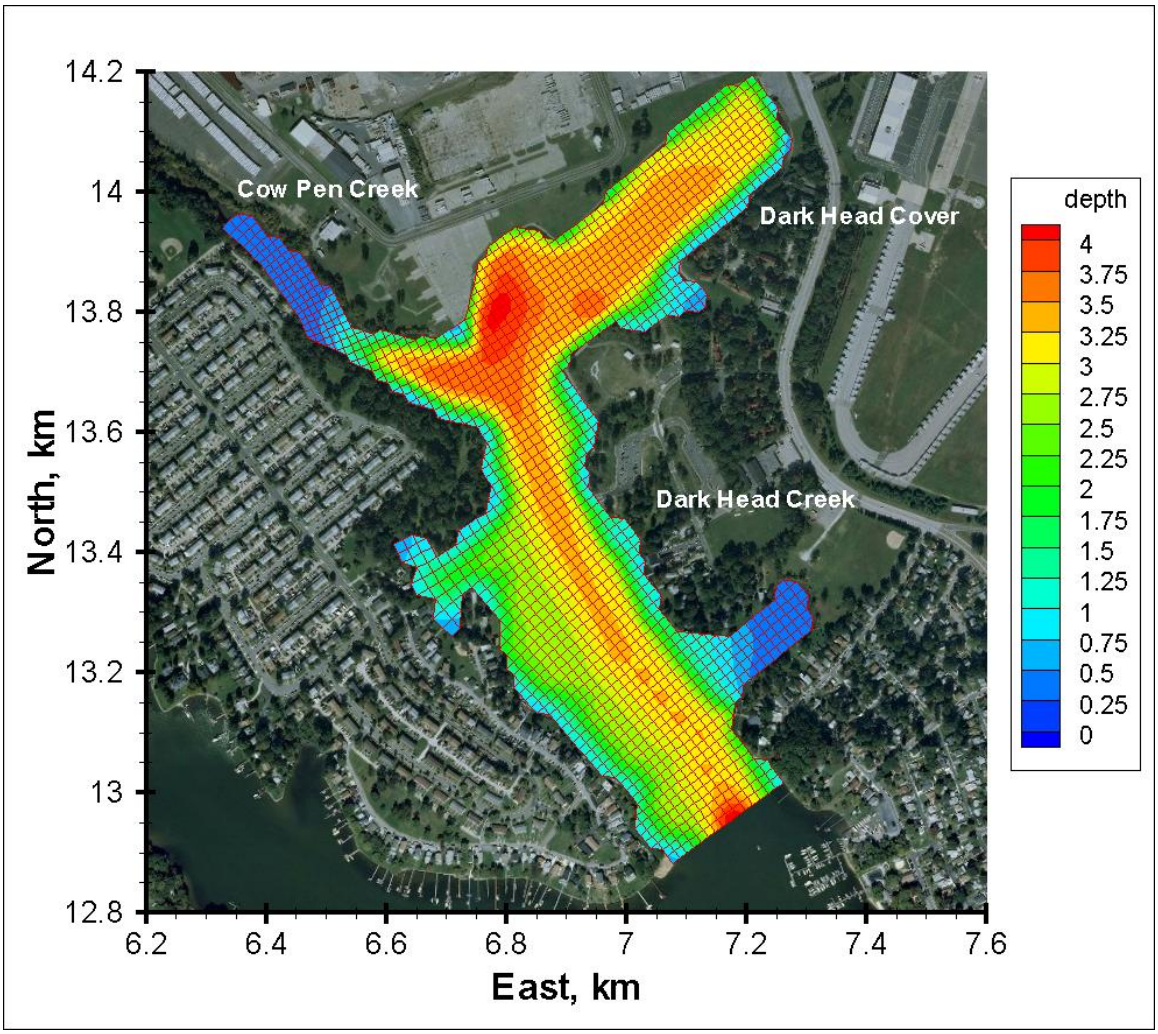


Figure X3. Model grid of Dark Head creek in the vicinity of the Middle River Complex site showing water depth in meters below mean sea level.

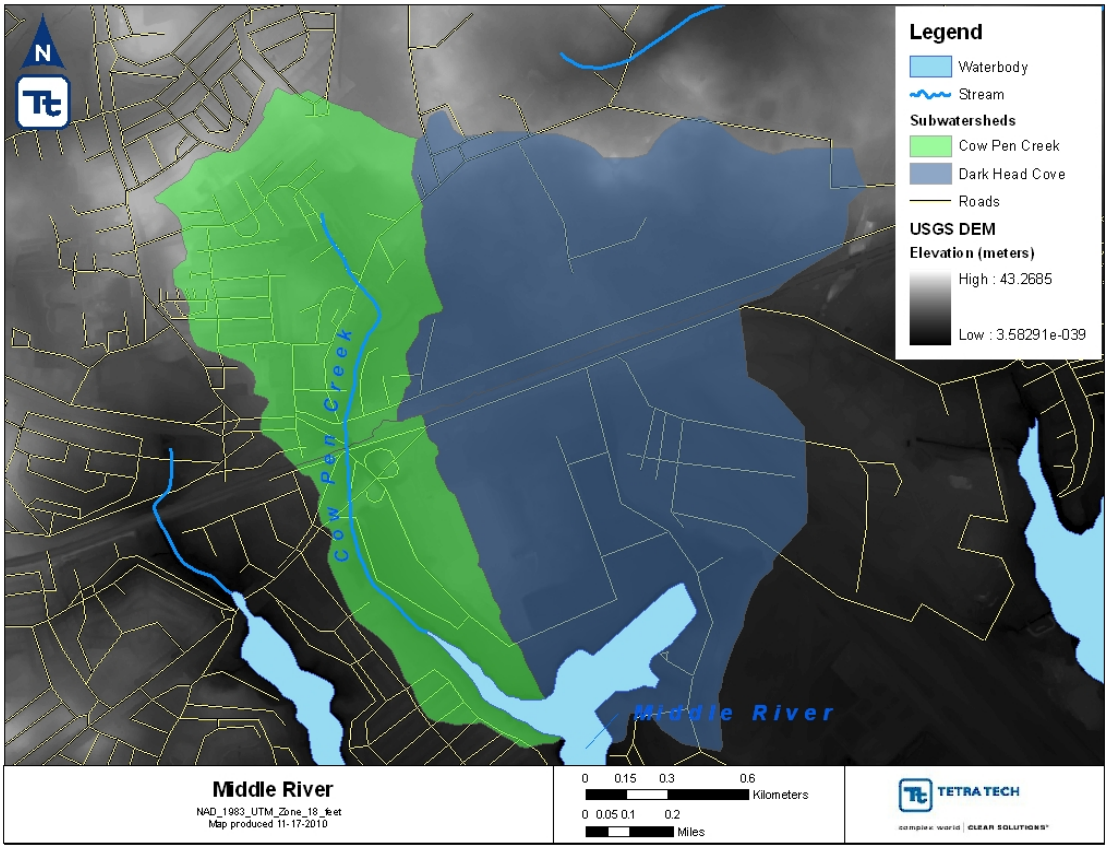


Figure X4. Cow Pen Creek and Dark Head Cove sub-watersheds

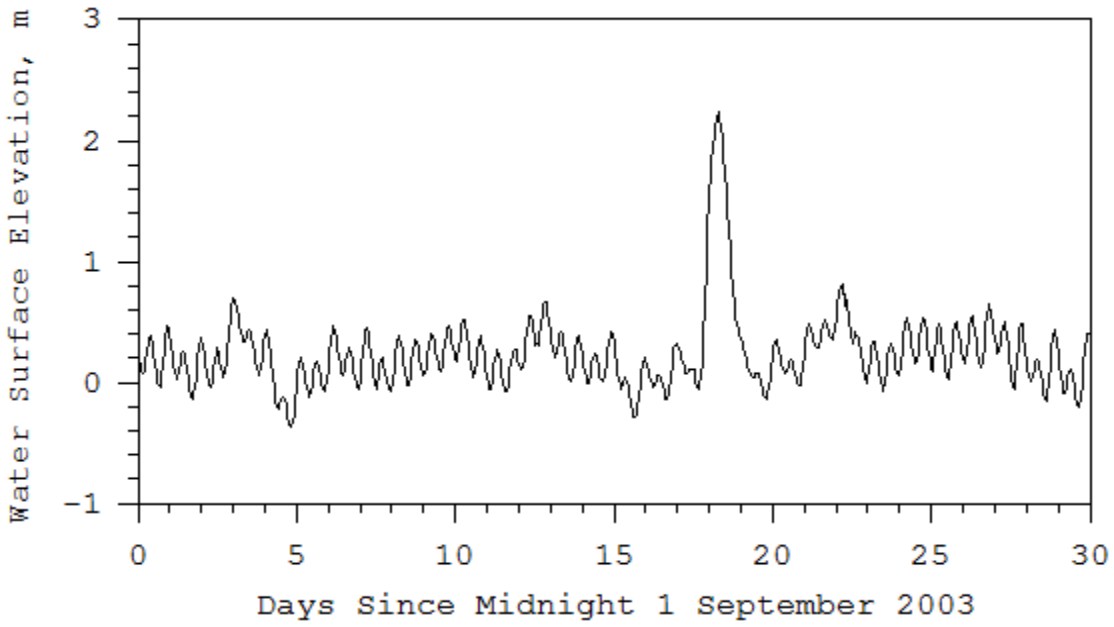


Figure X5. Water surface elevation at NOAA gage in Baltimore Harbor during September 2003 showing the Hurricane Isabella storm surge.

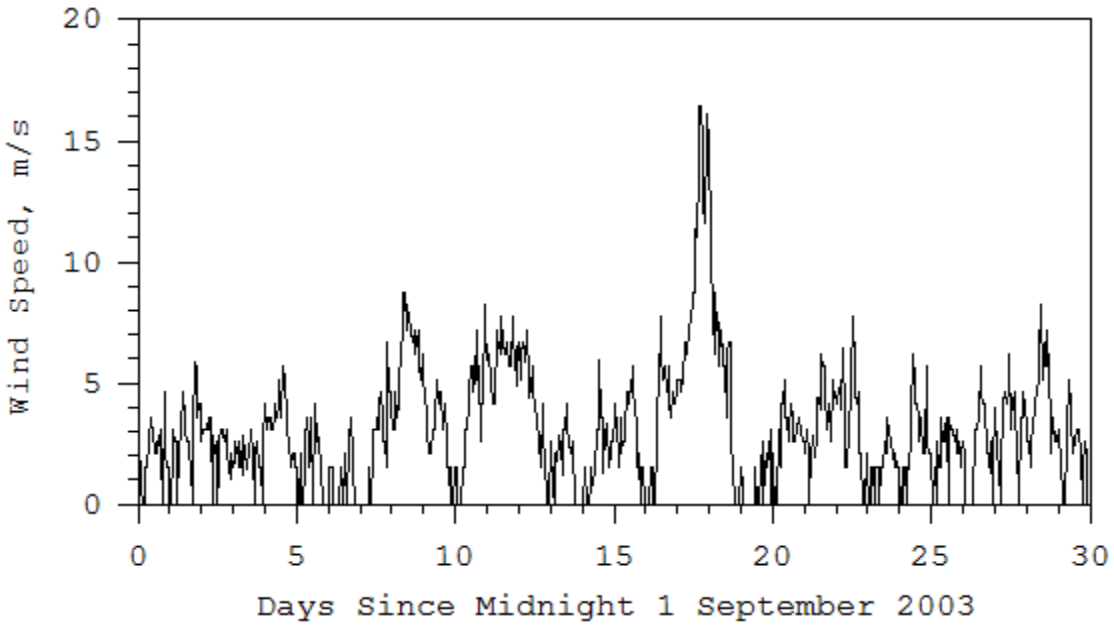


Figure X6. Wind speed at BWI Airport during September 2003

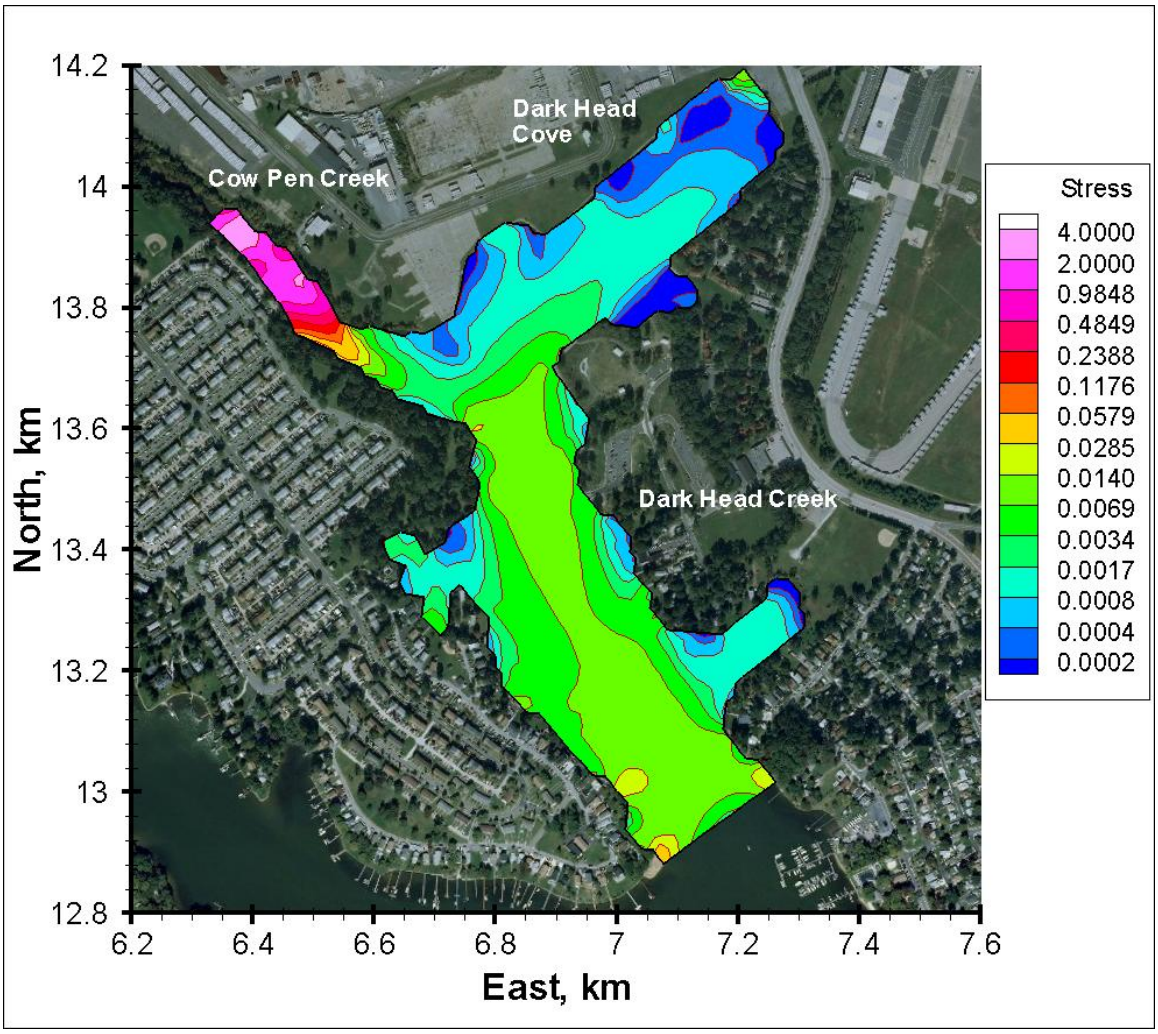


Figure X7. Distribution of maximum bed stress (N/m^2) during a 100 year annual recurrence interval, 24 hour rainfall of 8.7 inches (24.7 cm). daily rainfall event coincident with spring tide conditions.

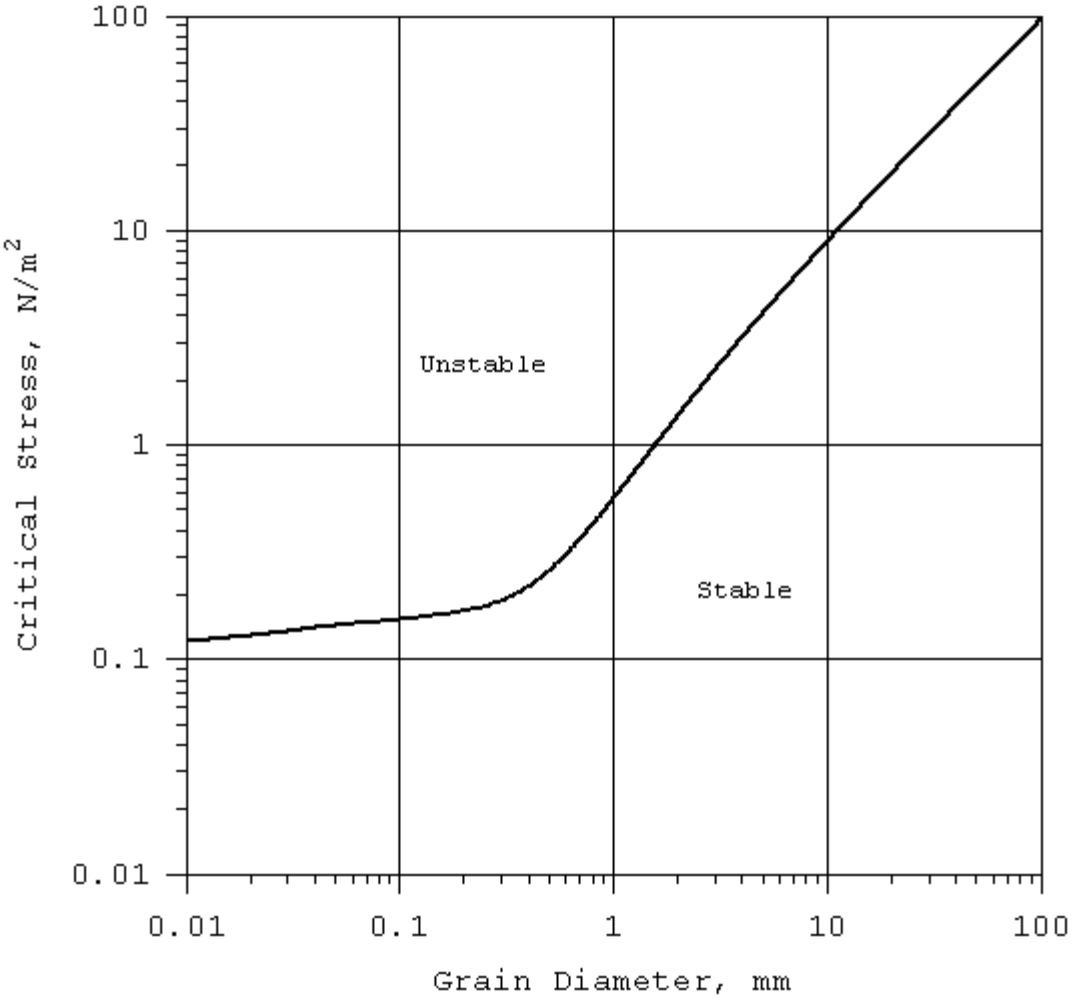


Figure X8. Modified Shield's diagram showing critical stress for erosion of noncohesive sediment as a function of grain diameter.

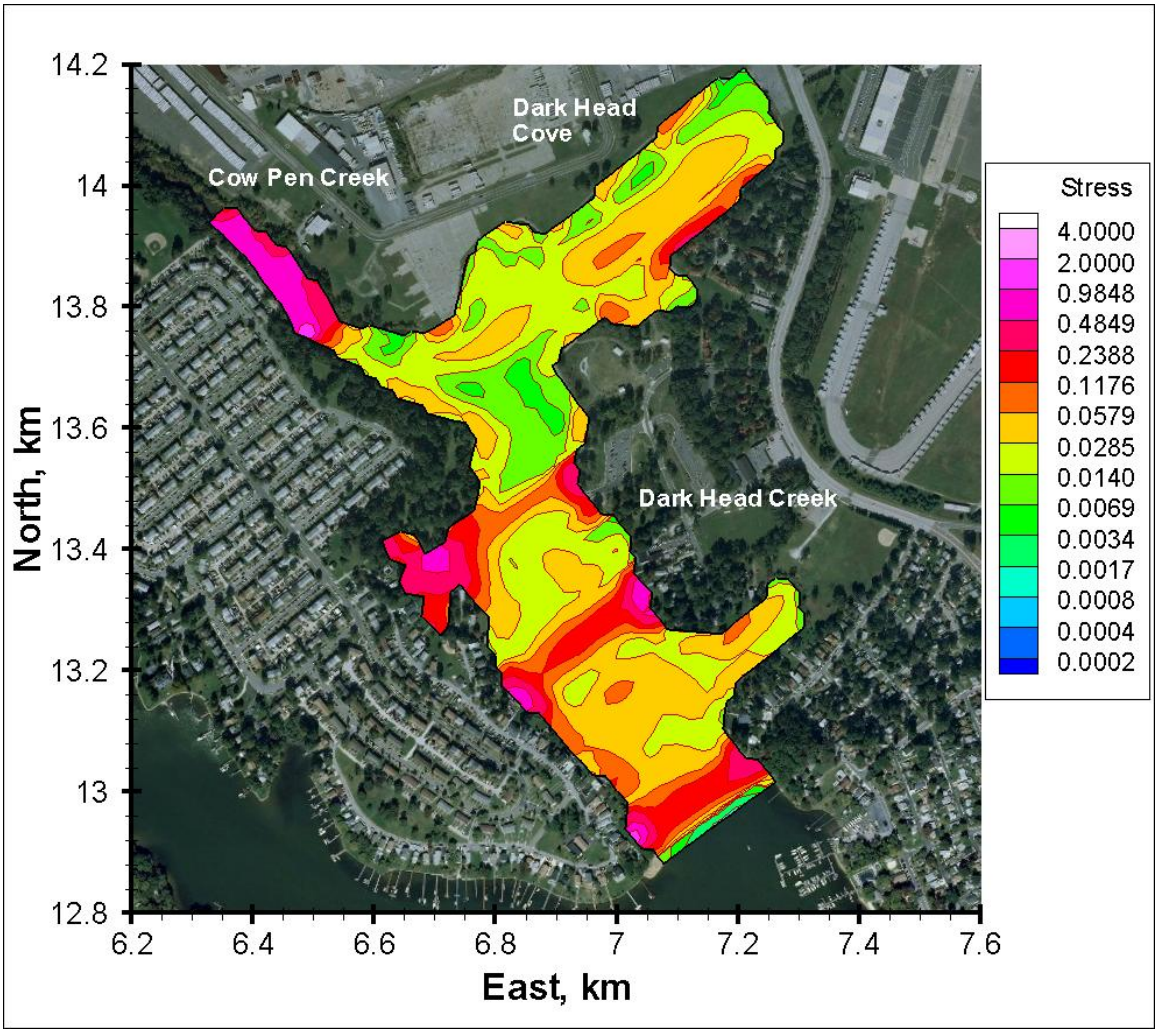


Figure x9. Distribution of maximum bed stress (N/m^2) during Hurricane Isabella storm surge and wind event in September 2003.

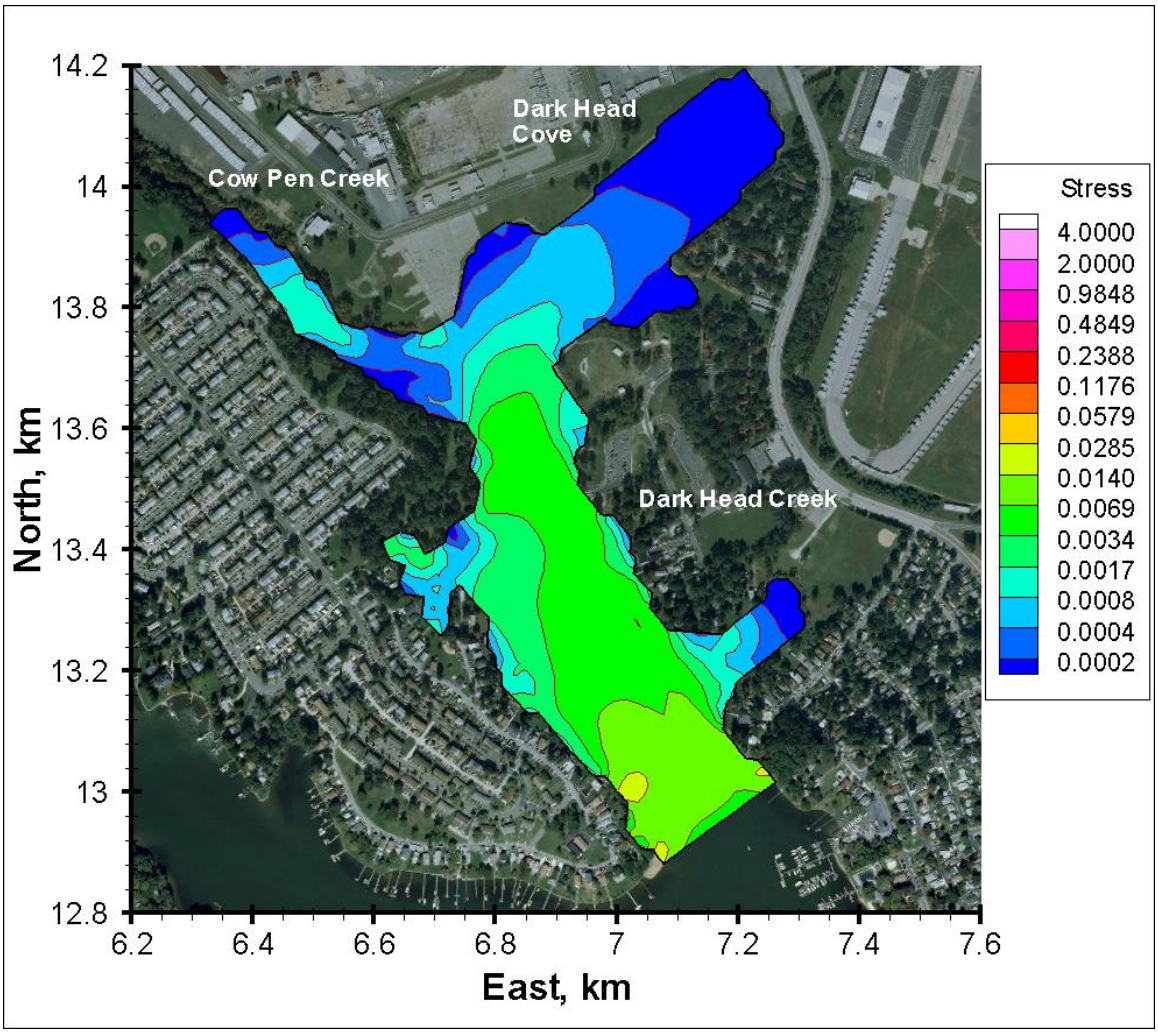
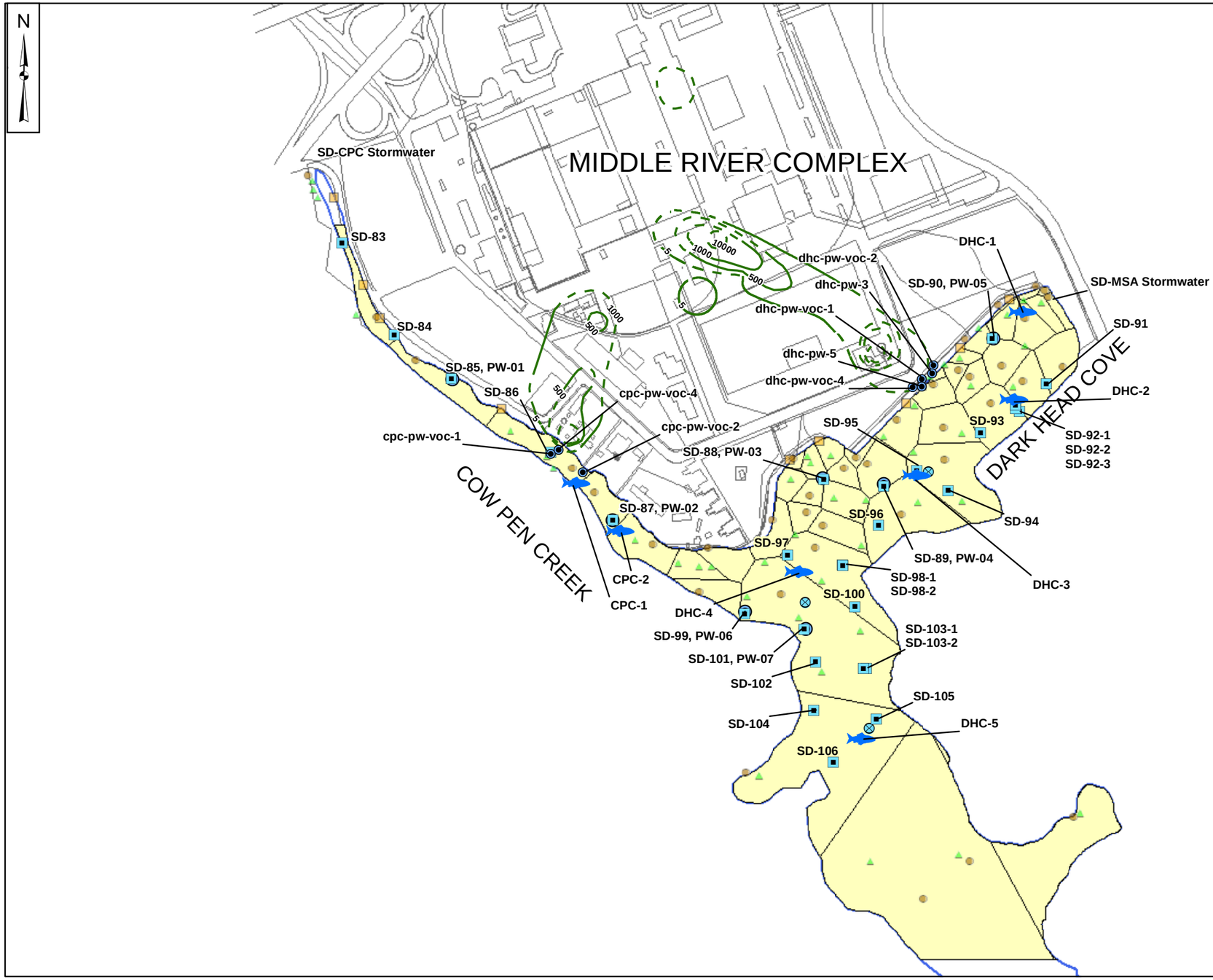


Figure X10. Distribution of maximum bed stress (N/m^2) during Hurricane Isabella storm surge and wind event in September 2003. Simulation.

APPENDIX I—2010 SEDIMENT AND PORE-WATER SAMPLING RESULTS



TETRA TECH

Figure 3-1
Sample Locations
August 2010
Lockheed Martin Middle River Complex
Middle River, Maryland

Legend

- Sample Locations- 2005
- Sample Locations- Nov 2008
- Stormwater Outfall Locations
- Delineation Sample
- Age Dating Sample
- Porewater Sample (VOCs)
- Fish and Benthic Sample Location
- Tce Isoconcentration (UG/L)
- Inferred
- Middle River Complex
- Water

500 250 0 500
Feet

Drawn By: MP 12/15/10
Checked By:
Approved By:

Contract Number: 112IC01633

Map Document: (K:\GProject\middle_river\Maps\Figure 3-1_sediment_sample_locations 121510.mxd)
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Table 4-7
Occurrence and Distribution of Chemicals - Subsurface Sediment, >18-30"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV[1]	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil[1]
Volatile Organics (ug/kg)												
2-BUTANONE	3/5	13 J	40 J	SD-16	43	74	24.7	26.5	25710 [6]	0	28000000 N	0
ACETONE	4/10	110	240	SD-16, SD-40	21	140	178	92.6	60030 [6]	0	61000000 N	0
CARBON DISULFIDE	4/10	5 J	11 J	SD-16	7	12	7.8	5.9	0.851	4	820000 N	0
CHLOROBENZENE	1/10	7 J	7 J	SD-27	7	16	7	6.0	8.42	0	290000 N	0
CIS-1,2-DICHLOROETHENE	1/10	2 J	2 J	SD-19	7	16	2	5.5	1050 [7]	0	780000 N	0
ISOPROPYLBENZENE	2/10	3 J	38 K	SD-13	7	16	20.5	8.8	86	0	2100000 N	0
METHYL TERT-BUTYL ETHER	2/10	2 J	3 J	SD-31	14	27	2.5	8.7	NA	0	430000 C	0
SEC-BUTYLBENZENE	2/10	7 J	180 K	SD-13	7	16	93.5	23.4	880 [6]	0	NA	0
TOLUENE	4/10	1 J	10	SD-19	10	16	5.8	6.2	2880 [6]	0	5000000 N	0
Semivolatile Organics (ug/kg)												
1-METHYLNAPHTHALENE	3/46	88 J	950	SD-58	340	1100	393	345	20.2 [8]	3	220000 C	0
2-METHYLNAPHTHALENE	4/46	310 J	1100 J	SD-58	340	1100	568	359	20.2	4	310000 N	0
ACENAPHTHENE	18/68	20 J	11000 J	SD-58	0.39	1100	919	440	6.7	18	3400000 N	0
ACENAPHTHYLENE	16/68	8.1 J	460	SD-90	0.46	1100	141	257	5.9	16	3400000 N[9]	0
ANTHRACENE	29/68	0.77 J	19000	SD-58	0.4	1100	1067	613	57.2	25	17000000 N	0
BAP EQUIVALENT-1/2 NON-DETECTS	32/68	58.5	38692	SD-58	0.4	1100	3359	1711	NA	0	150 C	30
BAP EQUIVALENT-POSITIVE RESULTS	32/68	17.2	38387	SD-58	0.4	1100	3069	1574	NA	0	150 C	23
BENZO(A)ANTHRACENE	23/68	18	38000	SD-58	0.51	1100	3299	1300	108	21	1500 C	10
BENZO(A)PYRENE	24/68	14	30000	SD-58	0.4	1100	2864	1190	150	22	150 C	22
BENZO(B)FLUORANTHENE	32/68	46	31000	SD-58	0.64	1100	2890	1490	NA	0	1500 C	10
BENZO(G,H,I)PERYLENE	24/68	37	11000 J	SD-58	0.4	1100	1582	735	170	22	1700000 N[10]	0
BENZO(K)FLUORANTHENE	17/68	8 J	25000	SD-58	0.82	1100	2398	742	240	11	15000 C	1
BIS(2-ETHYLHEXYL)PHTHALATE	5/9	140 J	1700	SD-40	460	740	704	527	180	4	350000 C	0
CARBAZOLE	2/9	400 J	410 J	SD-16	460	1000	405	358	NA	0	NA	0
CHRYSENE	32/68	20	37000	SD-58	0.48	1100	2727	1414	166	30	150000 C	0
DIBENZO(A,H)ANTHRACENE	17/68	4.7 J	1400	SD-86	0.45	1100	487	331	33	16	150 C	12
DIBENZOFURAN	2/9	240 J	330 J	SD-13	460	1000	285	331	415	0	78000 N	0
FLUORANTHENE	36/68	3.6 J	78000	SD-58	0.43	1100	4494	2496	423	24	2300000 N	0
FLUORENE	22/68	1 J	10000 J	SD-58	0.53	1100	700	416	77.4	14	2300000 N	0
INDENO(1,2,3-CD)PYRENE	28/68	70 J	12000 J	SD-58	0.42	1100	1382	719	17	28	1500 C	7
NAPHTHALENE	18/68	23 J	2200 J	SD-58	0.35	1100	338	289	176	10	36000 C	0
PHENANTHRENE	36/68	1.2 J	76000	SD-58	5.8	1100	3267	1862	204	25	1700000 N[10]	0
PYRENE	35/68	2.2 J	76000	SD-58	0.41	1100	5016	2703	195	31	1700000 N	0
TOTAL PAHS	39/68	1.2	457300	SD-58	0	0	25090	14390	1610	29	NA	0
PCBs (ug/kg)												
AROCLOR-1248	1/68	430 J	430 J	SD-86	0.96	6100	430	83.1	59.8 [11]	1	2200 C	0
AROCLOR-1260	26/68	28 J	1300	SD-89	1.4	56	372	151	59.8 [11]	24	2200 C	0
TOTAL AROCLOR	26/68	28	1300	SD-89	0	0	389	149	59.8	24	2200 C[12]	0
Metals (mg/kg)												
ANTIMONY	33/69	0.048 J	132 L	SD-58	0.05	0.97	5.5	2.7	2	12	31 N	1
ARSENIC	68/69	1.4	12.3	SD-50	0.77	0.77	6.3	6.2	9.8	7	3.9 C	55
BARIUM	47/47	8	238	SD-58	--	--	52.4	52.4	130 [15]	1	15000 N	0
BERYLLIUM	69/69	0.22 J	2.9	SD-69	--	--	1.8	1.8	NA	0	160 N	0
CADMIUM	63/69	0.016	296	SD-86	0.0074	0.13	21.7	19.8	0.99	42	70 N	2
CHROMIUM	69/69	9.4	2060 J	SD-86	--	--	309	309	43.4	42	120000 N[13]	0
COBALT	47/47	1.1	37.9	SD-69	--	--	14.0	14.0	50	0	23 N	2
COPPER	69/69	7.4 J	147 J	SD-86	--	--	47.5	47.5	31.6	35	3100 N	0
LEAD	69/69	4.1	316	SD-40	--	--	89.4	89.4	35.8	37	400	0
MERCURY	60/69	0.0079	6.1 L	SD-16	0.0066	0.054	0.94	0.82	0.18	38	23 N[14]	0
MOLYBDENUM	43/47	0.059	4.7	SD-75	0.07	0.45	1.4	1.3	NA	0	390 N	0
NICKEL	69/69	0.67	66.2	SD-50	--	--	30.5	30.5	22.7	42	1500 N	0
SELENIUM	52/69	0.33 J	2.8	SD-54	0.33	1.04	1.4	1.2	2	11	390 N	0
SILVER	54/69	0.0088 J	55.8	SD-76	0.074	0.46	10.0	7.8	1	39	390 N	0
THALLIUM	25/69	0.059 J	2.3	SD-58	0.2	1.78	0.37	0.29	21.3 [16]	0	NA	0
VANADIUM	47/47	15.8	110 K	SD-76	--	--	45.2	45.2	57 [15]	9	390 N	0
ZINC	69/69	2	2980	SD-58	--	--	288	288	121	35	23000 N	0
Metals (ug/kg)												

Table 4-7
Occurrence and Distribution of Chemicals - Subsurface Sediment, >18-30"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV[1]	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil[1]
DIBUTYLTIN	2/3	5.5	8.5	SD-40	2.8	2.8	7.0	5.1	NA	0	NA	0

Table 4-7
Occurrence and Distribution of Chemicals - Subsurface Sediment, >18-30"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV[1]	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil[1]
Miscellaneous Parameters (%)												
PERCENT SOLIDS	37/37	30	83	SD-55	--	--	51.5	51.5	NA	0	NA	0
Miscellaneous Parameters (mg/kg)												
TOTAL ORGANIC CARBON	21/21	3100	54000 K	SD-31	--	--	25064	25064	NA	0	NA	0
AVS/SEM (umoles/g)												
ACID VOLATILE SULFIDE	5/7	0.74 J	18.7	SD-90	0.29	0.41	6.6	4.8	NA	0	NA	0
CADMIUM	7/7	0.0007 J	1.4	SD-87	--	--	0.33	0.33	NA	1	NA	0
CHROMIUM	7/7	0.0089 J	15.4	SD-87	--	--	5.1	5.1	NA	0	NA	0
COPPER	6/7	0.023 J	0.48	SD-89	0.0021	0.0021	0.26	0.23	NA	0	NA	0
LEAD	7/7	0.011 J	1	SD-87	--	--	0.45	0.45	NA	0	NA	0
NICKEL	7/7	0.039 J	0.29	SD-87	--	--	0.16	0.16	NA	0	NA	0
SILVER	5/7	0.0007 J	0.014	SD-89	0.00025	0.00036	0.0067	0.0048	NA	0	NA	0
ZINC	7/7	0.35 J	9.3	SD-87	--	--	4.2	4.2	NA	0	NA	0

Notes:

1 - Sample and duplicate are considered as two separate samples when determining the minimum and maximum detected concentrations and as one sample when determining the frequency of detection and exceedances.

2 - Average of positive analytical results only.

3 - Average of all analytical results are calculated using half of the detection limit for nondetects.

4 - USEPA Region 3 Biological Technical Assistance Group (BTAG) screening levels for freshwater sediment (USEPA, August 2006).

5 - Screening criteria for sediment are based on USEPA Regional Screening Levels (RSLs) for residential soil (November, 2010). To account for the anticipated reduced exposure to sediment, the screening criteria presented in the table for sediment are 10 times those typically used for soil (which are also based on RSLs). Therefore, the screening criteria for carcinogens in the sediment are set at 10 times the RSL for residential soil. The screening criteria for non-carcinogens in the sediment are set equal to the RSL for residential soil

6 - TCEQ Ecological Benchmarks for Sediment, January 2006.

7 - Value for trans-1,2-dichloroethene used as a surrogate for cis-1,2-dichloroethene.

8 - Value for 2-methylnaphthalene used as a surrogate for 1-methylnaphthalene

9 - The value for acenapthene is used as a surrogate for acenaphthylene.

10 - The value for pyrene is used as a surrogate for benzo(g,h,i)perylene and phenanthrene

11 - Value for Total PCBs used as a surrogate for Aroclor-1248 and Aroclor-1260.

12 - The value is for high risk PCBs.

13 - The value is for trivalent chromium.

14 - The value is for mercuric chloride.

15 - NOAA Quick Reference Tables (Buchman, 2008); value is for marine sediment.

16 - Value is for marine sediment.

Definitions:

C = Carcinogenic
J = Estimated
K = Biased high
L = Biased low
N = Non-carcinogenic
NA = Not applicable or not available

Associated Samples:

SD-95-02	SD-14-02	SD-48-02	SD-75-02
SD-96-02	SD-16-02	SD-49-02	SD-75-02-D
SD-97-02	SD-19-02	SD-50-02	SD-76-02
SD-98-02	SD-27-02	SD-51-02	SD-77-02
SD-99-02	SD-28-02	SD-51-02-D	SD-80-02
SD-100-02	SD-29-02	SD-53-02	SD-81-02
SD-100-02-D	SD-31-02	SD-54-02	SD-82-02
SD-101-02	SD-40-02	SD-55-02	SD-83-02
SD-102-02	SD-42-02	SD-56-02	SD-84-02
SD-103-02	SD-43-02	SD-57-02	SD-85-02
SD-104-02	SD-44-02	SD-58-02	SD-86-02
SD-105-02	SD-45-02	SD-59-02	SD-87-02
SD-106-02	SD-46-02	SD-59-02-D	SD-88-02
SD-13-02	SD-47-02	SD-60-02	

Table 4-5
Occurrence and Distribution of Chemicals - Subsurface Sediment, >6-18"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV[1]	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil[1]
Volatile Organics (ug/kg)												
2-BUTANONE	3/5	18 J	37 J	SD-19	52	64	27	28	25710 [6]	0	28000000 N	0
ACETONE	3/10	36 J	220	SD-19	50	270	152	87.7	60030 [6]	0	61000000 N	0
CARBON DISULFIDE	6/10	5 J	19 J	SD-14	13	15	8.0	7.6	0.851	6	820000 N	0
ISOPROPYLBENZENE	2/10	3 J	10 J	SD-19	9	54	6.5	8.4	86	0	2100000 N	0
METHYL TERT-BUTYL ETHER	2/10	3 J	4 J	SD-16	21	110	3.5	15.5	NA	0	430000 C	0
SEC-BUTYLBENZENE	2/10	20 L	33	SD-19	9	54	26.5	12.4	880 [6]	0	NA	0
TERT-BUTYLBENZENE	1/10	2 J	2 J	SD-19	9	54	2.0	8.1	1210 [6]	0	NA	0
TOLUENE	1/10	2 J	2 J	SD-31	9	54	2.0	8.3	2880 [6]	0	5000000 N	0
Semivolatile Organics (ug/kg)												
1,2-DICHLOROBENZENE	1/9	260 J	260 J	SD-13	710	1000	260	418	16.5	1	1900000 N	0
1,4-DICHLOROBENZENE	2/9	100 J	180 J	SD-13	100	1000	140	331	599	0	24000 C	0
1-METHYLNAPHTHALENE	1/47	150 J	150 J	SD-58	320	3900	150	429	20.2 [7]	1	220000 C	0
2-METHYLNAPHTHALENE	2/47	220 J	340 J	SD-13	320	3900	280	427	20.2	2	310000 N	0
ACENAPHTHENE	22/71	1.2 J	2400 J	SD-58	0.95	3900	277	329	6.7	21	3400000 N	0
ACENAPHTHYLENE	14/71	18 J	280	SD-90	1.1	3900	116	312	5.9	14	3400000 N[8]	0
ANTHRACENE	29/71	35	4400 J	SD-58	0.97	1400	477	381	57.2	26	17000000 N	0
BAP EQUIVALENT-1/2 NON-DETECTS	44/71	238	12075	SD-58	0.99	1100	1907	1280	NA	0	150 C	44
BAP EQUIVALENT-POSITIVE RESULTS	44/71	0.093	12075	SD-58	0.99	1100	1436	988	NA	0	150 C	29
BENZO(A)ANTHRACENE	26/71	150	12000	SD-58	1.2	3900	1715	850	108	26	1500 C	8
BENZO(A)PYRENE	28/71	150	9000	SD-58	0.99	3900	1504	807	150	27	150 C	27
BENZO(B)FLUORANTHENE	43/71	120 J	10000 J	SD-13	1.6	1100	1510	1016	NA	0	1500 C	10
BENZO(G,H,I)PERYLENE	33/71	59 J	4800 J	SD-13	0.99	1400	972	617	170	30	1700000 N[9]	0
BENZO(K)FLUORANTHENE	27/71	100 J	7300	SD-58	2	1100	1074	517	240	23	15000 C	0
BIS(2-ETHYLHEXYL)PHTHALATE	6/9	340 J	3400 J	SD-13	710	850	1080	848	180	6	350000 C	0
BUTYL BENZYL PHTHALATE	1/9	830 J	830 J	SD-13	710	1000	830	481	10900	0	2600000 C	0
CARBAZOLE	4/9	310 J	1000 J	SD-13	710	940	595	495	NA	0	NA	0
CHRYSENE	44/71	93 J	12000	SD-58	1.2	1100	1339	928	166	39	150000 C	0
DIBENZO(A,H)ANTHRACENE	19/71	75	790 J	SD-13	1.1	3900	340	350	33	19	150 C	14
DIBENZOFURAN	2/9	270 J	400 J	SD-13	710	1000	335	416	415	0	78000 N	0
FLUORANTHENE	51/71	1.8 J	20000 J	SD-58	1.1	1100	1791	1362	423	34	2300000 N	0
FLUORENE	23/71	13 J	2000 J	SD-58	1.3	3900	226	316	77.4	12	2300000 N	0
INDENO(1,2,3-CD)PYRENE	39/71	63 J	5600 J	SD-13	1	1100	855	592	17	39	1500 C	6
NAPHTHALENE	21/71	10 J	550 J	SD-13	0.85	3900	151	293	176	7	36000 C	0
PHENANTHRENE	46/71	2.4 J	15000 J	SD-58	3.5	1200	1160	860	204	33	1700000 N[9]	0
PYRENE	50/71	1.5 J	24000 J	SD-13	1	1100	2391	1760	195	46	1700000 N	0
TOTAL PAHS	52/71	2.4	118470	SD-58	0	0	11657	8537	1610	40	NA	0
PCBs (ug/kg)												
AROCLOR-1248	2/71	550	2300	SD-86	1	3000	1425	74.8	59.8 [10]	2	2200 C	1
AROCLOR-1260	42/71	17	14000	SD-58	1.6	57	968	578	59.8 [10]	39	2200 C	3
TOTAL AROCLOR	42/71	17	14000	SD-58	0	0	1036	613	59.8	39	2200 C[11]	3
Metals (mg/kg)												
ANTIMONY	38/72	0.076 J	55.1 J	SD-75	0.057	1.64	2.7	1.5	2	7	31 N	1
ARSENIC	71/72	1.4	12.6	SD-31	1.46	1.46	7.1	7.0	9.8	16	3.9 C	58
BARIUM	48/48	8.1	236	SD-58	--	--	53.8	53.8	130 [15]	1	15000 N	0
BERYLLIUM	72/72	0.34	6.9	SD-69	--	--	1.8	1.8	NA	0	160 N	0
CADMIUM	66/72	0.026	306	SD-46	0.0069	0.037	22.0	20.2	0.99	48	70 N	4
CHROMIUM	72/72	8.9	2460	SD-46	--	--	293	293	43.4	48	120000 N[12]	0
COBALT	48/48	1.6 J	33	SD-69	--	--	15.9	15.9	50	0	23 N	3
COPPER	72/72	5.1	178 J	SD-65	--	--	70.1	70.1	31.6	47	3100 N	0
HEXAVALENT CHROMIUM	1/10	1.6	1.6	SD-42	1	1.6	1.6	0.77	43.4	0	2.9 C[13]	0
LEAD	72/72	2.9	1370	SD-75	--	--	131	131	35.8	50	400	2
MERCURY	62/72	0.015	3.5 L	SD-16	0.0072	0.1	0.60	0.52	0.18	47	23 N[14]	0
MOLYBDENUM	38/48	0.18	3.3	SD-75	0.21	1.7	1.4	1.2	NA	0	390 N	0
NICKEL	72/72	4.1 J	70.4	SD-46	--	--	34.2	34.2	22.7	50	1500 N	0
SELENIUM	56/72	0.51	2.6	SD-66	0.38	1.44	1.5	1.2	2	10	390 N	0
SILVER	61/72	0.02 J	37.2	SD-75	0.074	0.42	5.7	4.8	1	45	390 N	0
THALLIUM	26/72	0.063 J	2.1	SD-16	0.2	2.45	0.28	0.30	21.3 [16]	0	NA	0
VANADIUM	48/48	11	110	SD-16	--	--	54.3	54.3	57 [15]	20	390 N	0
ZINC	72/72	10.8	1300	SD-58	--	--	293	293	121	50	23000 N	0
Metals (ug/kg)												
DIBUTYLTIN	1/3	5	5	SD-40	3	3.5	5	2.8	NA	0	NA	0

Table 4-5
Occurrence and Distribution of Chemicals - Subsurface Sediment, >6-18"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV[1]	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil[1]
Miscellaneous Parameters (%)												
PERCENT SOLIDS	37/37	24	85	SD-44	--	--	45.6	45.6	NA	0	NA	0
Miscellaneous Parameters (mg/kg)												
TOTAL ORGANIC CARBON	18/18	2200	46000	SD-40	--	--	25606	25606	NA	0	NA	0
AVS/SEM (umoles/g)												
ACID VOLATILE SULFIDE	5/7	2.4	19	SD-90	0.23	0.38	9.1	6.5	NA	0	NA	0
CADMIUM	7/7	0.0003 J	0.48	SD-87	--	--	0.13	0.13	NA	0	NA	0
CHROMIUM	7/7	0.016 J	4.6	SD-87	--	--	1.8	1.8	NA	0	NA	0
COPPER	7/7	0.037	0.52	SD-88	--	--	0.24	0.24	NA	0	NA	0
LEAD	7/7	0.015 J	0.75	SD-88	--	--	0.47	0.47	NA	0	NA	0
NICKEL	7/7	0.035 J	0.2	SD-88	--	--	0.14	0.14	NA	0	NA	0
SILVER	5/7	0.001 J	0.0083	SD-88	0.0002	0.00033	0.0041	0.0030	NA	0	NA	0
ZINC	7/7	0.11 J	6.9	SD-87	--	--	3.3	3.3	NA	0	NA	0

Notes:

1 - Sample and duplicate are considered as two separate samples when determining the minimum and maximum detected concentrations and as one sample when determining the frequency of detection and exceedances.

2 - Average of positive analytical results only.

3 - Average of all analytical results are calculated using half of the detection limit for nondetects.

4 - USEPA Region 3 Biological Technical Assistance Group (BTAG) screening levels for freshwater sediment (USEPA, August 2006).

5 - Screening criteria for sediment are based on USEPA Regional Screening Levels (RSLs) for residential soil (November, 2010). To account for the anticipated reduced exposure to sediment, the screening criteria presented in the table for sediment are 10 times those typically used for soil (which are also based on RSLs). Therefore, the screening criteria for carcinogens in the sediment are set at 10 times the RSL for residential soil. The screening criteria for non-carcinogens in the sediment are set equal to the RSL for residential soil.

6 - TCEQ Ecological Benchmarks for Sediment, January 2006.

7 - Value for 2-methylnaphthalene used as a surrogate for 1-methylnaphthalene.

8 - The value for acenapthene is used as a surrogate for acenaphthylene.

9 - The value for pyrene is used as a surrogate for benzo(g,h,i)perylene and phenanthrene.

10 - Value for Total PCBs used as a surrogate for Aroclor-1248 and Aroclor-1260.

11 - The value is for high risk PCBs.

12 - The value is for trivalent chromium.

13 - The value is for hexavalent chromium.

14 - The value is for mercuric chloride.

15 - NOAA Quick Reference Tables (Buchman, 2008); value is for marine sediment.

16 - Value is for marine sediment.

Definitions:

C = Carcinogenic
J = Estimated
L = Biased low
N = Non-carcinogenic
NA = Not applicable or not available

Associated Samples:

SD-94-01	SD-27-01	SD-55-01	SD-73-01	SD-93-01
SD-95-01	SD-28-01	SD-56-01	SD-74-01	
SD-95-01-D	SD-29-01	SD-57-01	SD-75-01	
SD-96-01	SD-31-01	SD-58-01	SD-76-01	
SD-96-01-D	SD-40-01	SD-59-01	SD-77-01	
SD-97-01	SD-42-01	SD-60-01	SD-79-01	
SD-98-01	SD-43-01	SD-61-01	SD-80-01	
SD-99-01	SD-44-01	SD-62-01	SD-81-01	
SD-100-01	SD-45-01	SD-63-01	SD-82-01	
SD-101-01	SD-46-01	SD-64-01	SD-83-01	
SD-102-01	SD-46-01-D	SD-65-01	SD-84-01	
SD-103-01	SD-47-01	SD-66-01	SD-85-01	
SD-104-01	SD-48-01	SD-67-01	SD-86-01	
SD-105-01	SD-49-01	SD-68-01	SD-87-01	
SD-106-01	SD-50-01	SD-68-01-D	SD-88-01	
SD-13-01	SD-50-01-D	SD-69-01	SD-89-01	
SD-14-01	SD-51-01	SD-70-01	SD-90-01	
SD-16-01	SD-53-01	SD-71-01	SD-91-01	
SD-19-01	SD-54-01	SD-72-01	SD-92-01	

Table 4-3
Occurrence and Distribution of Chemicals - Surface Sediment, 0-6"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV[1]	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil[1]
Volatile Organics (ug/kg)												
1,3-DICHLOROBENZENE	1/41	2 J	2 J	SD-22	5.9	24	2.0	7.8	4430	0	NA	0
1,4-DICHLOROBENZENE	4/41	1 J	3 J	SD-22	5.9	24	1.8	7.1	599	0	24000 C	0
2-BUTANONE	3/18	17 J	23 J	SD-13, SD-19	12	120	21	20	25710 [6]	0	28000000 N	0
ACETONE	6/38	7.1 J	150 J	SD-40	13	240	82	50	60030 [6]	0	61000000 N	0
CARBON DISULFIDE	2/40	9.1 J	12 J	SD-29	5.9	24	11	8.2	0.851	2	820000 N	0
CHLOROBENZENE	1/41	3 J	3 J	SD-22	5.9	24	3.0	7.8	8.42	0	290000 N	0
CHLOROMETHANE	1/41	13 J	13 J	SD-35	12	49	13	16	17800 [6]	0	120000 N	0
METHYL TERT-BUTYL ETHER	24/41	3 J	9 J	SD-23, SD-18, SD-16, SD-32	5.9	36	6.0	6.9	NA	0	430000 C	0
NAPHTHALENE	1/30	7 J	7 J	SD-13	6	24	7.0	8.8	176	0	36000 C	0
TOLUENE	3/41	3 J	10 J	SD-27	5.9	24	5.7	7.9	2880 [6]	0	5000000 N	0
Semivolatile Organics (ug/kg)												
1,3-DICHLOROBENZENE	1/39	420 J	420 J	SD-27	390	1600	420	531	4430	0	NA	0
1,4-DICHLOROBENZENE	8/39	76 J	850 J	SD-27	74	1600	280	386	599	1	24000 C	0
1-METHYLNAPHTHALENE	1/66	39 J	39 J	SD-44	350	6400	39	596	20.2 [7]	1	220000 C	0
2-METHYLNAPHTHALENE	1/77	34 J	34 J	SD-4	350	6400	34	564	20.2	1	310000 N	0
ACENAPHTHENE	21/101	3.9 J	790 J	SD-28	1.2	6400	129	406	6.7	20	3400000 N	0
ACENAPHTHYLENE	19/101	8.7 J	790	SD-84	1.4	6400	114	448	5.9	19	3400000 N[8]	0
ANTHRACENE	44/101	2.6 J	2300	SD-84	2.3	6400	254	443	57.2	34	17000000 N	0
BAP EQUIVALENT-1/2 NON-DETECTS	82/101	3.4	6472	SD-28	8.7	6400	1340	1200	NA	0	150 C	76
BAP EQUIVALENT-POSITIVE RESULTS	82/101	0.17	6472	SD-28	8.7	6400	772	732	NA	0	150 C	61
BENZO(A)ANTHRACENE	59/101	5.6 J	5200 J	SD-28	11	6400	700	665	108	51	1500 C	4
BENZO(A)PYRENE	63/101	9.4 J	4400 J	SD-28, SD-84	2.4	6400	694	652	150	55	150 C	55
BENZO(B)FLUORANTHENE	78/101	14	5800 J	SD-28	3.7	6400	940	843	NA	0	1500 C	12
BENZO(G,H,I)PERYLENE	48/101	29	3100 J	SD-28	2.4	6400	650	601	170	40	1700000 N[9]	0
BENZO(K)FLUORANTHENE	47/101	9.7 J	2700 J	SD-28	2.5	6400	549	446	240	36	15000 C	0
BIS(2-ETHYLHEXYL)PHTHALATE	37/39	78 J	2900 J	SD-32	860	1500	781	771	180	35	350000 C	0
BUTYL BENZYL PHTHALATE	3/39	120 J	190 J	SD-34	390	1600	157	514	10900	0	2600000 C	0
CARBAZOLE	5/39	130 J	990 J	SD-28	390	1600	348	524	NA	0	NA	0
CHRYSENE	77/101	9.1 J	5400	SD-84, SD-28	2.8	6400	805	746	166	67	150000 C	0
DIBENZO(A,H)ANTHRACENE	16/101	41 J	720	SD-84	1.4	6400	294	468	33	16	150 C	10
DIBENZOFURAN	1/39	340 J	340 J	SD-28	390	1600	340	527	415	0	78000 N	0
FLUORANTHENE	84/101	8 J	10000	SD-84	9.3	1400	1190	1060	423	57	2300000 N	0
FLUORENE	26/101	2.2 J	1400	SD-84	3.1	6400	149	438	77.4	12	2300000 N	0
INDENO(1,2,3-CD)PYRENE	54/101	33	3400 J	SD-28	2.4	6400	566	576	17	54	1500 C	4
NAPHTHALENE	20/101	2.8 J	290 J	SD-28	2	6400	87	437	176	3	36000 C	0
PHENANTHRENE	62/101	7.2 J	12000	SD-84	3.8	6400	842	748	204	48	1700000 N[9]	0
PYRENE	82/101	6.2 J	13000 J	SD-28	8.8	6400	1500	1330	195	73	1700000 N	0
TOTAL PAHS	84/101	19.8	63660	SD-28	0	0	7260	6040	1610	63	NA	0
PCBs (ug/kg)												
AROCLOR-1254	1/101	400 J	400 J	SD-43	1.5	11000	400	144	59.8 [10]	1	1100 N[11]	0
AROCLOR-1260	78/101	14 J	54000	SD-9	1.7	79	1790	1380	59.8 [10]	69	2200 C	9
TOTAL AROCLOR	79/101	14	54000	SD-9	0	0	1770	1380	59.8	70	2200 C[12]	9
Metals (mg/kg)												
ANTIMONY	48/103	0.11 J	2320 L	SD-84	0.099	2.1	49.4	23.2	2	4	31 N	1
ARSENIC	103/103	1.5	37.2 J	SD-105	--	--	8.2	8.2	9.8	33	3.9 C	92
BARIUM	68/68	6.2	112	SD-77	--	--	50.2	50.2	130 [16]	0	15000 N	0
BERYLLIUM	103/103	0.19	6.9	SD-69	--	--	1.7	1.7	NA	0	160 N	0
CADMIUM	100/103	0.03695	296	SD-43	0.0078	0.069	11.2	10.9	0.99	86	70 N	1
CHROMIUM	103/103	10.9	699 J	SD-43	--	--	147	147	43.4	85	120000 N[13]	0
COBALT	68/68	3 J	28.5	SD-69	--	--	16.4	16.4	50	0	23 N	3
COPPER	103/103	6.3	183 J	SD-105	--	--	90.8	90.8	31.6	78	3100 N	0
HEXAVALENT CHROMIUM	5/41	0.53 J	13 J	SD-37	0.44	2.5	4.7	1.3	43.4	0	2.9 C[14]	2
LEAD	103/103	3.9	31500	SD-84	--	--	407	407	35.8	85	400	1
MERCURY	97/103	0.00925	3.5 J	SD-30	0.0078	0.038	0.38	0.36	0.18	75	23 N[15]	0
MOLYBDENUM	56/68	0.55	2.3 J	SD-15, SD-40	0.05	1.6	1.4	1.2	NA	0	390 N	0
NICKEL	103/103	4.8	62.8 J	SD-28	--	--	31.8	31.8	22.7	76	1500 N	0
SELENIUM	66/103	0.345 JL	3.1 J	SD-66	0.37	1.9	1.5	1.2	2	16	390 N	0
SILVER	81/103	0.029 J	28.6 J	SD-28	0.081	3.4	2.7	2.2	1	62	390 N	0
THALLIUM	26/103	0.049 J	2.1 J	SD-16	0.22	4	0.27	0.43	21.3 [17]	0	NA	0
VANADIUM	68/68	6.5	120 J	SD-28	--	--	48.4	48.4	57 [16]	24	390 N	0
ZINC	103/103	22.4	636 J	SD-28	--	--	290	290	121	82	23000 N	0
Metals (ug/kg)												
DIBUTYLTIN	3/6	5.5 J	11 J	SD-40	3.3	5.6	8.8	5.5	NA	0	NA	0

Table 4-3
Occurrence and Distribution of Chemicals - Surface Sediment, 0-6"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV[1]	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil[1]
Miscellaneous Parameters (%)												
PERCENT SOLIDS	69/69	20	85	SD-3	--	--	39.1	39.1	NA	0	NA	0
Miscellaneous Parameters (mg/kg)												
TOTAL ORGANIC CARBON	24/24	1600	58100	SD-87	--	--	31900	31900	NA	0	NA	0
AVS/SEM (umoles/g)												
ACID VOLATILE SULFIDE	6/7	1.5	44.6 J	SD-101	0.41	0.41	17.1	14.6	NA	0	NA	0
CADMIUM	7/7	0.0035	0.25	SD-87	--	--	0.092	0.092	NA	0	NA	0
CHROMIUM	7/7	0.064	2.5	SD-88	--	--	1.2	1.2	NA	0	NA	0
COPPER	6/7	0.086 J	0.68	SD-89	0.011	0.011	0.34	0.29	NA	0	NA	0
LEAD	7/7	0.037	0.63	SD-88	--	--	0.38	0.38	NA	0	NA	0
NICKEL	7/7	0.077	0.2 J	SD-101	--	--	0.15	0.15	NA	0	NA	0
SILVER	4/7	0.00072	0.011	SD-88	0.00035	0.0005	0.0055	0.0032	NA	0	NA	0
ZINC	7/7	0.43	6.8	SD-87	--	--	3.4	3.4	NA	0	NA	0

Notes:

1 - Sample and duplicate are considered as two separate samples when determining the minimum and maximum detected concentrations and as one sample when determining the frequency of detection and exceedances.

2 - Average of positive analytical results only.

3 - Average of all analytical results are calculated using half of the detection limit for nondetects.

4 - USEPA Region 3 Biological Technical Assistance Group (BTAG) screening levels for freshwater sediment (USEPA, August 2006).

5 - Screening criteria for sediment are based on USEPA Regional Screening Levels (RSLs) for residential soil (November, 2010). To account for the anticipated reduced exposure to sediment, the screening criteria presented in the table for sediment are 10 times those typically used for soil (which are also based on RSLs). Therefore, the screening criteria for carcinogens in the sediment are set at 10 times the RSL for residential soil. The screening criteria for non-carcinogens in the sediment are set equal to the RSL for residential soil.

6 - TCEQ Ecological Benchmarks for Sediment, January 2006.

7 - Value for 2-methylnaphthalene used as a surrogate for 1-methylnaphthalene.

8 - The value for acenapthene is used as a surrogate for acenaphthylene.

9 - The value for pyrene is used as a surrogate for benzo(g,h,i)perylene and phenanthrene.

10 - Value for Total PCBs used as a surrogate for Aroclor-1254 and Aroclor-1260.

11 - One tenth the noncarcinogenic value is less than the carcinogenic value; the noncarcinogenic value is presented.

12 - The value is for high risk PCBs.

13 - The value is for trivalent chromium.

14 - The value is for hexavalent chromium.

15 - The value is for mercuric chloride.

16 - NOAA Quick Reference Tables (Buchman, 2008); value is for marine sediment.

17 - Value is for marine sediment.

Definitions:

C = Carcinogenic
J = Estimated
L = Biased low
N = Non-carcinogenic
NA = Not applicable or not available

Associated Samples:

SD-10-031805	SD-24-SS	SD-45-SS	SD-65-SS	SD-86-SS
SD-100-SS	SD-25-SS	SD-46-SS	SD-66-SS	SD-87-SS
SD-101-SS	SD-26-SS	SD-47-SS	SD-67-SS	SD-88-SS
SD-102-SS	SD-27-SS	SD-48-SS	SD-68-SS	SD-89-SS
SD-103-SS	SD-28-SS	SD-48-SS-D	SD-69-SS	SD-9-031805
SD-104-SS	SD-29-SS	SD-49-SS	SD-69-SS-D	SD-90-SS
SD-104-SS-D	SD-3-031705	SD-5-031805	SD-7-031805	SD-91-SS
SD-105-SS	SD-30-SS	SD-50-SS	SD-70-SS	SD-92-SS
SD-106-SS	SD-31-SS	SD-51-SS	SD-71-SS	SD-93-SS
SD-11-031805	SD-32-SS	SD-53-SS	SD-72-SS	SD-94-SS
SD-12-031805	SD-33-SS	SD-53-SS-D	SD-73-SS	SD-95-SS
SD-13-SS	SD-34-SS	SD-54-SS	SD-74-SS	SD-96-SS
SD-14-SS	SD-35-SS	SD-55-SS	SD-75-SS	SD-97-SS
SD-15-SS	SD-36-SS	SD-56-SS	SD-76-SS	SD-98-SS
SD-16-SS	SD-37-SS	SD-57-SS	SD-77-SS	SD-99-SS
SD-17-SS	SD-38-SS	SD-58-SS	SD-79-SS	
SD-18-SS	SD-39-SS	SD-59-SS	SD-8-031805	
SD-19-SS	SD-4-031705	SD-6-031805	SD-80-SS	
SD-2-031805	SD-40-SS	SD-60-SS	SD-81-SS	
SD-20-SS	SD-41-SS	SD-61-SS	SD-82-SS	
SD-21-SS	SD-42-SS	SD-62-SS	SD-83-SS	
SD-22-SS	SD-43-SS	SD-63-SS	SD-84-SS	
SD-23-SS	SD-44-SS	SD-64-SS	SD-85-SS	

Table 4-9
Occurrence and Distribution of Chemicals - Subsurface Sediment, >30-52"
Lockheed Martin, Middle River Complex
Middle River, Maryland

Parameter	Frequency of Detection[1]	Minimum Concentration[1]	Maximum Concentration[1]	Location of Maximum Concentration	Minimum Non-detect	Maximum Non-detect	Average of Positive Results[2]	Overall Average[3]	Ecological Screening Value (ESV)[4]	# Detects Greater Than ESV	Adjusted Regional Screening Level (RSL) For Residential Soil[5]	# Detects Greater Than Adjusted RSL For Residential Soil
Semivolatile Organics (ug/kg)												
ACENAPHTHENE	10/51	2.2 J	130 J	SD-76	0.47	870	27.7	160	6.7	9	3400000 N	0
ACENAPHTHYLENE	11/51	2.4 J	58	SD-98	0.56	870	22.1	164	5.9	9	3400000 N[6]	0
ANTHRACENE	14/51	0.9 J	110 K	SD-76	1.5	870	33.9	164	57.2	3	17000000 N	0
BAP EQUIVALENT-1/2 NON-DETECTS	15/51	9.8	810	SD-50	0.49	870	255	217	NA	0	150 C	8
BAP EQUIVALENT-POSITIVE RESULTS	15/51	0.090	319	SD-98	0.49	870	117	176	NA	0	150 C	5
BENZO(A)ANTHRACENE	12/51	7.2 J	190	SD-98	0.61	870	83.4	179	108	3	1500 C	0
BENZO(A)PYRENE	12/51	5 J	170	SD-98	0.49	870	78.6	178	150	3	150 C	3
BENZO(B)FLUORANTHENE	13/51	8.5 J	310	SD-98	0.76	870	135	187	NA	0	1500 C	0
BENZO(G,H,I)PERYLENE	11/51	22	170	SD-98, SD-105	0.48	870	97.6	180	170	0	1700000 N[7]	0
BENZO(K)FLUORANTHENE	3/51	10.25 J	200 J	SD-50	0.98	870	86.4	158	240	0	15000 C	0
CHRYSENE	15/51	7.3 J	220 J	SD-50	0.58	870	102	172	166	3	150000 C	0
DIBENZO(A,H)ANTHRACENE	7/51	32	83	SD-98	0.54	870	59.0	168	33	6	150 C	0
FLUORANTHENE	18/51	3.1 J	430	SD-98	1.6	870	157	191	423	1	2300000 N	0
FLUORENE	13/51	1.2 J	180 J	SD-76	2	870	31.4	163	77.4	1	2300000 N	0
INDENO(1,2,3-CD)PYRENE	12/51	26	160	SD-98	0.5	870	101	183	17	12	1500 C	0
NAPHTHALENE	11/51	4.7 J	83	SD-105	0.42	870	28.0	165	176	0	36000 C	0
PHENANTHRENE	19/51	2.4 J	700	SD-76	4.4	870	110	183	204	1	1700000 N[7]	0
PYRENE	16/51	3.5 J	480 J	SD-50	1.5	870	191	202	195	6	1700000 N	0
TOTAL PAHS	20/51	2.4	2544	SD-98	0	0	894	351	1610	4	NA	0
PCBs (ug/kg)												
AROCLOR-1260	6/51	11 J	120	SD-105	1.7	44	44.3	13.8	59.8 [8]	2	2200 C	0
TOTAL AROCLOR	6/51	11	120	SD-105	0	0	44.3	5.2	59.8	2	2200 C[9]	0
Metals (mg/kg)												
ANTIMONY	16/51	0.16 J	23.9 L	SD-76	0.027	0.27	1.8	0.63	2	1	31 N	0
ARSENIC	50/51	0.55	35.9	SD-88	0.75	0.75	5.3	5.2	9.8	2	3.9 C	28
BARIUM	31/31	4.4	54.1	SD-76	--	--	22.2	22.2	130 [12]	0	15000 N	0
BERYLLIUM	51/51	0.17	5.6	SD-67	--	--	1.7	1.7	NA	0	160 N	0
CADMIUM	35/51	0.017 J	33.6	SD-105	0.0069	0.14	3.5	2.4	0.99	17	70 N	0
CHROMIUM	51/51	6 J	597 K	SD-105	--	--	59.7	59.7	43.4	16	120000 N[10]	0
COBALT	31/31	0.76	70.8 J	SD-68	--	--	12.2	12.2	50	1	23 N	2
COPPER	51/51	1.6	84.1	SD-105	--	--	18.9	18.9	31.6	7	3100 N	0
LEAD	51/51	1.5	163	SD-105	--	--	18.9	18.9	35.8	7	400	0
MERCURY	35/51	0.0079	1.5	SD-105	0.0068	0.057	0.13	0.10	0.18	7	23 N[11]	0
MOLYBDENUM	22/31	0.052	2.4 J	SD-64	0.051	1	1.0	0.73	NA	0	390 N	0
NICKEL	51/51	2.7	103 L	SD-88	--	--	21.7	21.7	22.7	18	1500 N	0
SELENIUM	40/51	0.42 L	2.1	SD-105	0.37	0.86	1.0	0.80	2	1	390 N	0
SILVER	30/51	0.021 J	9.1	SD-76	0.072	0.17	1.5	0.91	1	12	390 N	0
THALLIUM	20/51	0.064 J	20.3	SD-88	0.2	0.46	1.2	0.54	21.3 [13]	0	NA	0
VANADIUM	31/31	6.4 J	48.1	SD-58	--	--	30.0	30.0	57 [12]	0	390 N	0
ZINC	51/51	3.8	4370	SD-88	--	--	159	159	121	9	23000 N	0
Miscellaneous Parameters (%)												
PERCENT SOLIDS	23/23	38	84	SD-48, SD-75	--	--	64.9	64.9	NA	0	NA	0
Miscellaneous Parameters (mg/kg)												
TOTAL ORGANIC CARBON	8/8	1400	30000	SD-44	--	--	11393	11393	NA	0	NA	0
AVS/SEM (umoles/g)												
ACID VOLATILE SULFIDE	2/7	0.33 J	5.7	SD-99	0.26	0.38	3.0	0.97	NA	0	NA	0
CADMIUM	7/7	0.0006 J	0.035	SD-87	--	--	0.013	0.013	NA	0	NA	0
CHROMIUM	7/7	0.0057 J	0.52	SD-87	--	--	0.24	0.24	NA	0	NA	0
COPPER	7/7	0.013 J	0.26	SD-87	--	--	0.093	0.093	NA	0	NA	0
LEAD	7/7	0.0071 J	0.2	SD-87	--	--	0.067	0.067	NA	0	NA	0
NICKEL	7/7	0.024 J	0.13	SD-87	--	--	0.052	0.052	NA	0	NA	0
SILVER	5/7	0.001 J	0.0055	SD-90	0.00022	0.00032	0.0029	0.0021	NA	0	NA	0
ZINC	7/7	0.24 J	1.2	SD-87	--	--	0.57	0.57	NA	0	NA	0

Notes:

1 - Sample and duplicate are considered as two separate samples when determining the minimum and maximum detected concentrations and as one sample when determining the frequency of detection.

2 - Average of positive analytical results only.

3 - Average of all analytical results are calculated using half of the detection limit for nondetects.

4 - USEPA Region 3 Biological Technical Assistance Group (BTAG) screening levels for freshwater sediment (USEPA, August 2006).

5 - Screening criteria for sediment are based on USEPA Regional Screening Levels (RSLs) for residential soil (November, 2010). To account for the anticipated reduced exposure to sediment, the screening criteria presented in the table for sediment are 10 times those typically used for soil (which are also based on RSLs). Therefore, the screening criteria for carcinogens in the sediment are set at 10 times the RSL for residential soil. The screening criteria for non-carcinogens in the sediment are set equal to the RSL for residential soil.

6 - The value for acenapthene is used as a surrogate for acenaphthylene.

7 - The value for pyrene is used as a surrogate for benzo(g,h,i)perylene and phenanthrene.
8 - Value for Total PCBs used as a surrogate for Aroclor-1260.
9 - The value is for high risk PCBs.
10 - The value is for trivalent chromium.
11 - The value is for mercuric chloride.
12 - NOAA Quick Reference Tables (Buchman, 2008); value is for marine sediment.
13 - Value is for marine sediment.

Definitions:
C = Carcinogenic
J = Estimated
K = Biased high
L = Biased low
N = Non-carcinogenic
NA = Not applicable or not available

Associated Samples:

SD-100-04	SD-49-04	SD-64-04	SD-85-04
SD-101-04	SD-50-04	SD-65-04	SD-86-04
SD-102-04	SD-51-04	SD-66-04	SD-87-04
SD-102-04-D	SD-53-04	SD-67-04	SD-88-04
SD-104-04	SD-54-04	SD-68-04	SD-89-04
SD-105-04	SD-56-04	SD-70-04	SD-90-04
SD-106-04	SD-56-04-D	SD-71-04	SD-93-04
SD-43-04	SD-57-04	SD-73-04	SD-94-04
SD-44-04	SD-58-04	SD-75-04	SD-95-04
SD-45-04	SD-59-04	SD-76-04	SD-96-04
SD-46-04	SD-60-04	SD-77-04	SD-97-04
SD-47-04	SD-61-04	SD-77-04-D	SD-98-04
SD-47-04-D	SD-62-04	SD-79-02	SD-99-04
SD-48-04	SD-63-04	SD-83-04	

APPENDIX J—DETAILED EVALUATION OF GROUNDWATER TREATMENT TECHNOLOGIES AND PROCESS OPTIONS

Appendix J

Detailed Evaluation of Groundwater Treatment Technologies and Process Options

This section identifies and develops the representative process options that will be used in the formulation of response action alternatives to accomplish the response action objectives (RAOs) and meet the cleanup goals identified for groundwater in Section 5.

J.1 Limited Action

The technologies considered under this general response actions (GRA) are land use controls and monitoring.

Land Use Controls

During response action design, implementation, and a period of post-response action sampling, groundwater concentrations at the site would be greater than site cleanup goals. During this period, administrative land use controls would be used to prevent exposure to site groundwater and address vapor intrusion risks. These land use controls will be established by the Maryland Department of the Environment (MDE) in their Block-specific Certificates of Completion which are anticipated to be issued following submittal and execution of soil RAPs for each tax block.

These land use controls established by the MDE would likely prohibit groundwater use and the installation of wells for any purpose other than groundwater monitoring and extraction for purposes of remediation. They would also limit, or specify engineering controls for, existing buildings with a vapor intrusion risk and the construction of buildings in areas where vapor intrusion may present an unacceptable risk. These land use controls would be removed from individual areas of the MRC (by agreement of the MDE and the site owner) as cleanup progressed and concentrations are reduced to below target concentrations.

Effectiveness

Land use controls would be an effective method to prevent exposure to groundwater and vapor if implemented correctly with regular inspection and enforcement.

Implementability

Land use controls would be easily implemented, but would require significant and long term monitoring to ensure compliance.

Cost

Cost of implementing the groundwater land use controls would be low because it would be an administrative and compliance activity only.

Costs associated with the implementation of the vapor mitigation program land use controls required in existing and newly-erected buildings are moderate to high. Costs depend on the concentrations of VOCs in the groundwater and soil vapor over time, the time period required for active remediation, and whether the engineering controls are retrofitted to an existing building or incorporated into the design and construction of an existing site building.

Conclusion

Land use controls are retained in combination with other process options for the development of response action alternatives.

Monitoring/Monitored Natural Attenuation

During response action implementation, it would be necessary to establish a monitoring program to determine the effectiveness of the response action in addressing the extent of contamination and for use in the optimization of any active groundwater treatment used in the response.

Monitoring data would be used to design contingent response action activities, if necessary, and to determine when active remediation is complete. Following active remediation, and in areas where active remediation is not recommended, monitoring would be necessary to track geochemical conditions and attenuation of the COCs; i.e., monitored natural attenuation (MNA).

Effectiveness

A long-term monitoring program would be effective in tracking response action efforts, in determining where active remediation is required, in determining when active remediation could

be discontinued, and in determining when land use controls can be removed from various areas of the site.

Implementability

A monitoring program would be easily implemented.

Cost

Cost of implementing the monitoring program would be low to moderate. Cost would include sampling of a large number of wells for multiple parameters (VOCs, 1,4-dioxane, metals, and geochemical parameters) over a period extending several decades.

Conclusion

Monitoring and MNA are retained in combination with other process options for the development of response action alternatives.

J.2 TCE Area Containment

Groundwater Extraction

The technology considered under this GRA is containment via a groundwater hydraulic barrier using groundwater extraction trenches or recovery wells.

Groundwater extraction trenches or wells would be installed in the affected depth interval of the aquifer to access the contaminated groundwater, and then pumping used to extract the water to the surface. The process of extraction creates a hydraulic gradient that induces further flow of groundwater into the extraction network. Extraction trenches or wells placed in the path of migration of a contaminant plume can thus be used to intercept and contain the plume. The selection of the appropriate extraction system depends on the depth of contamination, the hydrogeological and geological characteristics of the aquifer, and the locations and depths of potentially interfering utilities.

Effectiveness

Groundwater containment calculations and modeling (see Appendix F) indicate that this response action could effectively prevent COC migration but would not effectively cleanup or remove mass in a timely manner. The modeling predicted cleanup times of over 100 years to reach drinking water standards.

Modeling and direct sampling of surface water, sediments, and off-site wells indicate that containment with the objective of preventing plume discharge to surface water is not necessary for protection of human health and the environment. Containment technology could, however, be used in conjunction with other remediation technologies to enhance contaminant removal and optimize groundwater flow for distribution of amendments injected into the subsurface.

Implementability

Groundwater extraction is a well-established, well-proven, and implementable containment technology. Implementation would consist of installing groundwater extraction trenches or wells, pumps and infrastructure (service and discharge lines). *Ex situ* treatment (i.e., treatment of groundwater after it has been extracted from the ground) and discharge/disposal of extracted groundwater would be required as detailed in Sections 6.2.2.4 and 6.2.2.6, respectively.

Cost

The cost for installation and operation of a hydraulic containment barrier would be low to moderate. The trenches, wells, and piping are relatively simple to install; however, long-term operation of the system would have a significant cost.

Conclusion

Hydraulic containment is retained in combination with other process options for the development of response action alternatives.

J.3 Collection

Groundwater and Vapor Extraction via Wells or Trenches

The technology considered under this GRA is groundwater and vapor recovery from a network of extraction wells installed to collect groundwater from the contaminant source areas and high concentration areas. This technology could also be used in conjunction with an *in situ* remedy to control migration from high concentration area treatment zones and assist in the distribution of the injected substrate. If this technology is selected, pump tests and groundwater modeling would provide the basis for the design and assist in the determination of the pumping rates and well spacing required to provide adequate capture of contaminated groundwater. Treatment of groundwater and vapor would be required prior to discharge.

Extraction wells would be supplemented with a vapor recovery system to enhance contaminant recovery rates in and near high concentration areas. Vapor would be recovered from the wells, which would be placed under partial vacuum, via a vacuum blower installed in the treatment system area, or, if necessary, closer to the wells.

Effectiveness

Groundwater extraction would be effective in reducing the contaminant mass and groundwater COC concentrations and would be effective in controlling migration from injection zones and assisting in the distribution of substrate when used in conjunction with an *in situ* remedy.

Vapor recovery would be effective in enhancing the groundwater flow rates obtainable from each well, providing additional mass removal of VOCs sorbed to the soil in the vadose and saturated zones, and in controlling vapors that may migrate under and into buildings located near areas of high VOC concentrations.

Implementability

Groundwater pumping and vapor recovery are established technologies that have been implemented at a wide variety of sites. Therefore, it is assumed that they could be implemented with relative ease at the MRC. Complications include installing wells and underground piping in the presence of existing utilities and interference with future site uses.

Ex situ treatment (i.e., treatment of groundwater after it has been extracted from the ground) and discharge/disposal of extracted groundwater would be required as detailed in Sections 6.2.2.4 and 6.2.2.6, respectively.

Cost

The cost for installation and operation of groundwater pumping and vapor recovery would be moderate. The number of wells is moderate but the piping lengths are relatively high. The duration of the system operation would be limited thus the O&M costs would be moderate.

Conclusion

Extraction of high concentration groundwater and vapors is retained in combination with other

J.4 *Ex Situ* Treatment

The technologies considered under this GRA are physical and chemical treatment.

Physical Treatment

Ex situ physical treatment would be used in conjunction with any technology involving groundwater and/or vapor extraction. Filtration, air stripping, granular activated carbon (GAC) adsorption, and sedimentation are evaluated below within this response action technology.

Filtration

Filtration uses a porous medium to remove solid particles from a liquid or gas. This technology is generally used as a groundwater pre-treatment to remove suspended material before other treatment processes and/or for the final cleaning or polishing of treated effluent.

Liquid filtration may be accomplished by numerous methods including screens, fibrous fabrics (paper or cloth), or beds of granular material such as sand. Flow through a filter can be encouraged by pressure on the inlet side or by drawing a vacuum on the filter outlet.

Most types of liquid filters, except those using disposable filter elements (such as cartridge filters), require periodic cleaning to remove suspended solids accumulated in the filter medium and to restore filtration efficiency. This cleaning is typically performed with a countercurrent of water, or backwash, which carries away the solids retained on the filter medium.

Effectiveness

Filtration alone would not be effective for the removal of COCs from groundwater. However, filtration is a proven technology for the removal of suspended solids from groundwater that might otherwise reduce the efficiency of downstream treatment technologies such as liquid-phase GAC adsorption.

Implementability

Filtration would be readily implementable. Filtration systems are commercially available from a wide variety of manufacturers and can be readily ordered to almost any specification. Liquid or solid residues resulting from periodic cleaning or replacement of the filter medium would have to be properly disposed.

Cost

The capital and O&M costs for filtration would be moderate and would depend on the frequency of maintenance/replacement of the filter media.

Conclusion

Filtration is retained for the development of groundwater remedial alternatives in combination with other process options for the development of groundwater remedial alternatives.

Air Stripping

Air stripping is an aeration process that promotes the transfer of VOCs from the aqueous phase to the gas phase. Air stripping is typically most effective for the removal of VOCs with a Henry's Law constant greater than or equal to 3.0 atmosphere-liters per mole, such as TCE. Removal efficiencies of VOCs typically exceed 99 percent depending on the operating parameters and the physical properties of the organic contaminants.

A countercurrent low-profile tray tower is the most commonly used air stripping configuration. Water is distributed over the top of the unit while air is forced upward through the bottom. VOCs dissolved in the water are transferred into the air stream. Key factors that influence process performance include air-to-water ratio, number of trays, operating temperature, surface hydraulic loading, air-water ratio, and contact time.

Effectiveness

Air stripping is a proven and reliable technology that would be effective for removing TCE and other VOCs from groundwater. Removal efficiencies greater than 99 percent could theoretically be achieved for the chlorinated VOCs.

However, air stripping is not effective in removing 1,4-dioxane present in groundwater. Also, high concentrations of metals in the air stripper influent stream may also be oxidized and precipitate, potentially fouling the stripper and decreasing its effectiveness; therefore, metals removal prior to air stripping is required.

Since air stripping transfers the contaminants from the water into the air stream, and the air stripper exhaust gas may require further treatment to meet air discharge regulations prior to release to the atmosphere.

Implementability

Air stripping would be readily implementable. There are a significant number of vendors that provide air stripping equipment.

A maintenance problem commonly associated with air stripping is the channeling of flow resulting from clogging in the stripper trays. Typical causes of clogging include suspended solids, metals precipitation, bacteria growth and scaling from slightly soluble salts such as calcium carbonate. Additional maintenance would be required if air stripper fouling/clogging is prevalent. Handling, storage, and disposal of potentially hazardous cleaning agents could be required for preventative maintenance of the air stripping trays/media.

Cost

Capital cost for air stripping would be low. O&M costs would be low to moderate depending on influent contaminant concentrations, the degree of contaminant removal required, and the effectiveness of the pretreatment systems for solids and metals removal.

Conclusion

Air stripping is retained in combination with other process options for the development of groundwater remedial alternatives.

Granular Activated Carbon Adsorption

Granular activated carbon is a commonly applied technology for the removal of organic contaminants from aqueous and vapor stream. GAC adsorption involves the physical attraction of organic solute molecules to exchange sites on the internal pore surface areas of specially treated (activated) carbon grains. As the contaminants pass through one or more vessels containing GAC, contaminants are captured on the active sites of the carbon grains and eventually occupy all of these sites. The exhausted GAC must then either be regenerated or disposed.

Typical GAC adsorption treatment systems include pressurized vessels operating in series and/or parallel configuration. Factors such as pH and temperature of the influent, bed contact time, surface area to volume ratio of the activated carbon, and solubility of the organic compound can affect the carbon adsorption process.

Vapor-phase GAC vessels (VGAC) utilize different carbon formulations designed to improve the effectiveness of contaminant removal in vapor phase. VGAC vessels are typically designed for lower working pressures compared to LGAC vessels.

Effectiveness

The effectiveness of GAC for the adsorption of chlorinated VOCs from groundwater and from vapor stream is well documented.

However, GAC adsorption would not be an effective stand-alone treatment alternative, as GAC does not effectively remove 1 metals from the extracted groundwater stream. A treatment process for metals prior to GAC adsorption would also be required.

Vapor phase GAC adsorption would also be effective in treating vapors recovered via vacuum extraction.

Implementability

Granular activated carbon adsorption would be readily implementable. Treatment systems components are commercially available As previously mentioned, it is anticipated that pretreatment with metals removal and filtration would be required for LGAC. Granular activated carbon would have to be periodically replaced as the media becomes saturated with COCs, and the spent GAC would require off-site disposal and/or regeneration. Treatability testing might be required to determine the anticipated frequency of GAC replacement.

Cost

The capital cost for liquid- and vapor-phase GAC adsorption would be low. Operations and maintenance costs would be low to moderate based on expected GAC consumption.

Conclusion

Liquid- and vapor-phase GAC adsorption is retained for the development of groundwater remedial alternatives.

Sedimentation

Sedimentation is a process that removes the suspended solids from a liquid by producing quiescent (non-turbulent) hydraulic conditions. This allows gravity to settle out the unstable solids from suspension. Sedimentation may be used in conjunction with coagulation/flocculation as discussed later in this section. Two slightly different sedimentation options are used: clarification (to produce a sludge with 2 to 8 percent solids); and, thickening (to further concentrate clarified sludges to solids concentration of 8 to 15 percent).*Effectiveness*Sedimentation would not by itself be effective for the removal of COCs from groundwater. However, this technology would be effective for the removal of excessive concentrations of suspended solids and precipitated metals that would otherwise reduce the efficiency of other treatment technologies or result in discharge limit exceedences.

For removal of dissolved metals, sedimentation must be used in combination with chemical precipitation and sedimentation/flocculation.

Implementability

Sedimentation would be readily implementable. Numerous qualified equipment vendors and contractors offer this type of equipment and services. The primary complication with implementing this technology is handling the sludge that is formed during the process.

Cost

Capital and O&M costs for sedimentation would be moderate due to the handling, management, and disposal of solids.

Conclusion

Sedimentation is retained because high concentrations of solids, including dissolved and total metals, are anticipated in the extracted groundwater.

Chemical Treatment

Ex situ chemical treatment would be used in conjunction with groundwater extraction. Chemical precipitation, coagulation/flocculation, and advanced oxidation are evaluated below within this response action technology.

Chemical Precipitation

Chemical precipitation is a process which consists of adding chemical reagents to the water stream resulting in the formation of solids as the dissolved metals precipitate from the groundwater stream. This allows the metals to be removed in other downstream processes.

Effectiveness

Chemical precipitation through oxidation is a proven process for removing dissolved metals from the groundwater stream. Through the addition of, for example, ozone the dissolved metals such as iron, manganese, nickel, and others are oxidized and precipitated. It is often required to increase pH to achieve faster metals precipitation. Sodium hydroxide is commonly used to raise pH.

Implementability

Chemical precipitation would be readily implementable. Several qualified equipment vendors and contractors offer this type of equipment and service. The primary complications with implementing the technology are proper dosing to ensure adequate reductions in dissolved metals concentrations.

Cost

Capital and O&M costs for chemical precipitation would be moderate to low. The equipment is relatively low cost; the primary O&M cost would be for the chemicals and sludge disposal.

Conclusion

Chemical precipitation is retained because high concentrations of dissolved metals (primarily iron and manganese) are anticipated in the extracted groundwater.

Coagulation/Flocculation

Coagulation/flocculation is a process which consists of adding chemical reagents which result in the agglomeration of small suspended solids particles into larger ones, thus increasing significantly the effectiveness of sedimentation or filtration.

Effectiveness

Coagulation/flocculation alone would not be effective for the removal of COCs from groundwater. However, coagulation/flocculation would be effective for the removal of excessive concentrations of suspended solids and precipitated metals that would otherwise reduce the efficiency of other treatment technologies.

Implementability

Coagulation/flocculation would be readily implementable. Numerous qualified equipment vendors and contractors offer this type of equipment and services. The primary complications with implementing the technology are long-term operation, sludge handling and the handling, storage, and use of coagulants/flocculants.

Cost

Capital and O&M costs for coagulation/flocculation and sedimentation would be moderate.

Conclusion

Coagulation/Flocculation is retained because high concentrations of suspended solids, particularly metals, are anticipated in the water stream following chemical precipitation.

J.5 *In Situ* Treatment

The technologies considered under this GRA are chemical, biological, and thermal treatment.

Chemical Treatment - In Situ Chemical Oxidation (ISCO)

In situ chemical oxidation (ISCO) chemical treatment involves the injection of an oxidant into the aquifer to destroy site contaminants via chemical oxidation, and produce by-products of carbon dioxide and water. Chemical oxidation agents include oxidants such as iron-catalyzed hydrogen peroxide (known as Fenton's Reagent), sodium persulfate, or potassium permanganate. Milder oxidants such as catalytically complexed sodium percarbonate (marketed as RegenOx™) have also been successfully used.

In situ chemical oxidation reagents are generally introduced into impacted groundwater using either multiple direct push technology (DPT) injection well points or one or more focused groundwater recirculation systems. Focused recirculation provides better control of the subsurface distribution of reagents but also requires a more complex system, especially for large plumes. Direct push technology injection is simpler to implement and can be used over large or small areas, but the technical difficulty and cost of installing DPT injection points increases if subsurface materials are very tight, depths exceed approximately 75 feet bgs, or a very large area of treatment is required.

Bench-scale testing of groundwater from the western plume was conducted, followed by pilot-scale testing within the western TCE area. Bench-scale testing was conducted using various oxidants including potassium permanganate, activated sodium persulfate (using hydrogen peroxide, sodium hydroxide, and iron as activators), and unactivated sodium persulfate.

Based on the results of the bench-scale testing, a field-scale pilot study was performed using sodium persulfate (with and without the use of hydrogen peroxide as an activator) to determine the effectiveness of ISCO destruction of COCs and the feasibility of injecting the liquid via DPT.

Although rebound of COCs was observed during field-scale pilot test sampling events, and there were issues associated with daylighting of reagents at the ground surface and in adjacent monitoring points during injection, ISCO using the above-mentioned reagents was deemed a viable technology to reduce COCs in groundwater.

Due to the occurrence of rebounding COC concentrations following the ISCO injections, it is expected that multiple injection events throughout the TCE areas would be required to obtain the cleanup goals.

Effectiveness

In situ chemical oxidation has been shown to be effective in reducing contaminant concentrations at a wide variety of sites. Pilot testing indicates that ISCO would have some degree of success at the MRC.

Of the site COCs, benzene is the most responsive when this technology is used. Pilot-scale testing confirmed that the technology is also effective in treating TCE and 1,4-dioxane.

Implementability

The primary complications with implementing the technology are handling, storage, and use of oxidants. An additional complication is the control of the distribution of reagents to the target locations. ISCO also may alter the geochemical properties of the aquifer. The pilot study results indicated a temporary increase in metals concentrations due to localized metal solubilization from site soils, caused by the significant decrease in pH in those areas. The low permeability soils limit the certainty of significant mass reductions using this technology, due to difficulty in ensuring contact of the injected reagents with the contaminant mass.

Distribution of the injected reagents can be difficult to predict. The reagents can follow preferential pathways naturally present in the site soils or bedding for foundations and utilities. Monitoring of the nearby utilities, particularly storm drains and outfall piping, is necessary

during and following reagent injection. An action plan to contain reagent migration must be a part of the full-scale program.

Cost

Costs of *in situ* chemical oxidation would be moderate for source zone treatment and high for treatment of the entire area contaminated with TCE. If alternative forms of injection are required, the cost could increase significantly. Since rebound of COC concentrations was observed following ISCO pilot testing, multiple injections would likely be required to reach the groundwater cleanup goals.

Conclusion

Despite the potential difficulties in achieving subsurface distribution of the injected fluids, *in situ* chemical oxidation is retained in combination with other process options for the development of response action alternatives.

Biological Treatment - Enhanced Anaerobic Reductive Dechlorination (ARD)

Biological treatment would include injection of a substrate (and dechlorinating cultures if required) into the subsurface to enhance natural biodegradation of the COCs. Specifically, enhanced ARD would be used to treat the portions of the site contaminated with TCE and other chlorinated compounds noted in Section 5. ARD is the primary biological degradation process by which chlorinated VOCs are transformed into innocuous compounds such as carbon dioxide, ethene, ethane, and chloride. In the presence of a suitable electron donor (e.g., hydrogen), the appropriate microbial consortia, and favorable geochemical conditions, a hydrogen atom can replace a chlorine atom on a chlorinated ethene molecule. Hydrogen is typically generated when organic carbon is fermented. In this case, the organic carbon would come from an injected carbon substrate, such as lactate or vegetable oil.

Lactate is a soluble substrate that dissolves in water and is typically used quickly by microorganisms. An advantage of soluble substrates is that delivery and distribution is more easily achieved in a heterogeneous environment, and the injection from a given point can cover a larger area than with non-soluble slow-release substrates.

Vegetable oil is a slow-release substrate that slowly releases fatty acids into groundwater, which in turn are metabolized and utilized by microbes for ARD. Many of these substrates persist for months or years before being exhausted.

In the detailed analysis of alternatives using this technology (Sections 6.3.3.2 and 6.3.3.3), the use of a substrate including both vegetable oil and lactate is recommended.

Appropriate microbial consortia are required to facilitate ARD. Baseline and performance ARD pilot test sampling of groundwater confirmed that appropriate microbes (such as dehalococcoides) are present in sufficient quantities to provide complete ARD of chlorinated VOCs to harmless compounds such as ethane and ethene. The results from the enhanced ARD pilot study also indicated a pH buffering amendment such as sodium bicarbonate was not required to facilitate ARD processes, provided that the groundwater pH remains between the optimal range of 6 to 8 standard units (S.U.). However, if ARD is to be implemented, monitoring of aquifer biological and geochemical parameters should be performed to confirm that the biological populations are flourishing and the geochemical conditions are not limiting ARD processes.

Effectiveness

ARD has been shown to be effective in reducing TCE concentrations at a wide variety of sites and was effective in the pilot testing at MRC. However, ARD has not been demonstrated to be effective in addressing benzene or 1,4-dioxane. Additionally, the lower pH values in the southern portion of the eastern TCE area may limit the effectiveness of ARD in these areas; in this area, the shallow groundwater would also limit the use of hydraulic fracturing for amendment distribution.

These factors limit the certainty of obtaining significant mass reduction at the site using *in situ* biological treatment.

Implementability

Hydraulic fracturing is not recommended prior to the direct injection of the substrate. Implementation of hydraulic fracturing on a large scale would be difficult and costly. Near-

surface fracturing should not be conducted since fractures have the potential for propagating near the ground surface and possibly daylighting.

The use of DPT to inject biological amendments is also not recommended because prohibitively long time would be required for injections due to low achievable injection rates and high volume of injection fluids.

The preferred method to introduce the biological amendments would be the use of semi-permanent injection wells connected by the underground conveyance piping to a central location where biological amendments and pumping equipment will be located. This method allows to inject the required volume of liquid without disrupting the MRC facility operation. With the use of injection wells, the implementation of ARD would be relatively simple, as contractors are readily available to install the injection wells and conveyance piping. To reduce the cost, the conveyance piping to a central location can be co-located with the piping for the groundwater extraction system.

As with ISCO, distribution of the injected substrate can be difficult to predict. The substrate can follow preferential pathways naturally present in the site soils or bedding for foundations and utilities. Monitoring of the nearby utilities, particularly storm drains and outfall piping, is necessary during and following reagent injection. An action plan to contain substrate migration must be a part of the full-scale program.

Cost

Cost of *in situ* biological treatment of the targeted source areas would be moderate. If hydraulic fracturing is required for injection in some areas of the site, costs would increase significantly.

Conclusion

Despite the potential difficulties in achieving subsurface distribution of injected fluids, *in situ* biological treatment via enhanced ARD is retained in combination with other process options for the development of response action alternatives.

Thermal Treatment - Electric Resistance Heating (ERH)

In situ thermal treatment via ERH involves passing three- or six-phase current between electrodes in the ground, which heats the material through which the current passes. With six-phase heating, six electrodes are placed in a circular array, with each electrode connected to a single-phase transformer. Six-phase heating generally provides more uniform heat distribution than three-phase heating. The electrodes typically consist of steel sheet piling or steel wells with conductive iron filings and graphite in the annular space. The aquifer is heated until the boiling point of water is reached, driving volatile contaminants and water vapor into the upper portion of the vadose zone, where the vapors are extracted using the electrodes as vapor extraction points. Vapors and condensate are recovered via slotted vapor recovery points installed in the treatment area and treated with GAC adsorption or other appropriate technologies prior to discharging to the atmosphere. Additional treatment of condensate in the *ex situ* groundwater treatment system is usually necessary during operation.

Effectiveness

Site characteristics are generally favorable for the implementation of ERH. Geological conditions and depth of groundwater contamination are within the design parameters of this technology.

ERH has been shown to be effective in low permeability, heterogeneous aquifers such as those present at MRC because the low permeability soils have electrical resistance values similar to the higher permeability soils.

ERH would also likely result in rapid source area chlorinated VOC concentration reductions; active operation is expected to last less than 6 months. Additionally, the low groundwater flow velocities present at the site will limit the influx of colder groundwater to the treatment area and reduce overall energy use. A period of up to one year, however, would be required for the subsurface soil to return to its normal temperature. Intrusive activities in the treatment area would be limited during that time. Limited reductions of 1,4-dixane concentrations would be expected in treatment via ERH.

ERH is a very aggressive and costly technology best suited for application at well-defined localized source areas with very high contaminant mass where source mass removal is categorically required. This is the case in a few small areas at the MRC (such as the source areas in the northern and southern portions of the eastern TCE area). However, in general, ERH may not be the most cost-effective technology to treat areas of lower concentrations such as those present in the western TCE area and the areas of the eastern TCE area outside of the small source areas. Technically, ERH can be applied at the MRC site but the cost of treatment and the energy spent per unit mass of contaminants removed would be high.

Implementability

ERH is an established and proven technology that is available from a number of qualified contractors. It has been shown to be effective in significantly reducing VOC concentrations at locations with low permeability soil such as the MRC, but there may be limited success with treatment of 1,4-dioxane.

Additionally, care would have to be taken with implementation of this technology at an operating facility. Underground utilities inside the treatment area that may melt would have to be removed and replaced prior to operation. Great care would be taken to ensure that current would not be transferred through metallic utilities to locations outside of the treatment area. The vapor recovery system would have to be designed to capture vapors created to avoid issues with vapor intrusion into existing buildings.

Cost

Treatment costs of the source areas alone would be moderately high. The cost of *in situ* thermal treatment of the entire COC areas (including locations with lower TCE concentrations) via ERH would be extremely high due to the large treatment volume of groundwater requiring treatment and the high energy consumption requirements.

Conclusion

Although expensive, ERH would result in contaminant removal in a short time frame and provides a high certainty of success for removal of most COCs, based on applications in other

low permeability environments. *In situ* thermal treatment via ERH is retained for the development of response action alternatives to present a scenario for aggressive treatment of the source areas.

J.6 Discharge/Disposal

The technologies considered under this GRA are discharge of treated groundwater via subsurface reinjection, to a publicly owned treatment works (POTW), or to a surface water body. The water being discharged would be treated effluent from the groundwater extraction and treatment ystems described above.

Disposal of sludge generated by on-site treatment systems is also included in each of the options below.

Discharge to Publicly Owned Treatment Works (POTW)/Surface Water

Treated water would be discharged to the Baltimore County POTW or to a nearby surface water body. Permits would be required for both discharge options. If both discharge options are accepted by the authorities, the appropriate option would be selected based on costs of permitting (including POTW tap-in fees), discharge requirements, treatment costs to meet those requirements, and per gallon discharge fees.

Sludge generated during the metals treatment process would be thickened and sent to a local landfill or disposal facility. It is expected that the material would be considered non-hazardous, although that would be confirmed by testing.

Effectiveness

Either option would be equally effective in disposing of treated water. Disposal of sludge at a landfill or disposal facility would also be effective.

Implementability

It is expected that both discharge to the surface water and discharge to the POTW would be relatively easy to permit and implement. Sludge disposal would be easily implemented.

Cost

The cost of permitting and disposing of water under an National Pollution Discharge Elimination System (NPDES) or POTW permit would be relatively low. The cost of sludge disposal over the course of system operation may be significant.

Conclusion

Discharge to surface water and disposal of sludge at a landfill or disposal facility are retained in combination with other process options for the development of response action alternatives.

APPENDIX K—LIFE-CYCLE ASSESSMENT INFORMATION

Life Cycle Assessment

SimaPro v. 7.2 Evaluation

Lockheed Martin Middle River Complex

Groundwater Remedial Alternatives Sustainability Evaluation: SimaPro v.7.2

LCA Final Draft Results

January 7, 2011





Contents

- Groundwater Remedial Alternatives Description
  - Flowcharts
- Life Cycle Assessment
  - Introduction to LCA
    - Life Cycle Assessment Defined
    - Life Cycle Assessment Process
    - Review of LCIA Methodologies
      - TRACI
      - ReCiPe 2008
  - LCA Results
    - Scope & Boundary
    - Life Cycle Inventory
    - Life Cycle Impact Assessment
      - Characterization & Normalization per alternative & alternatives comparison
    - Interpretation

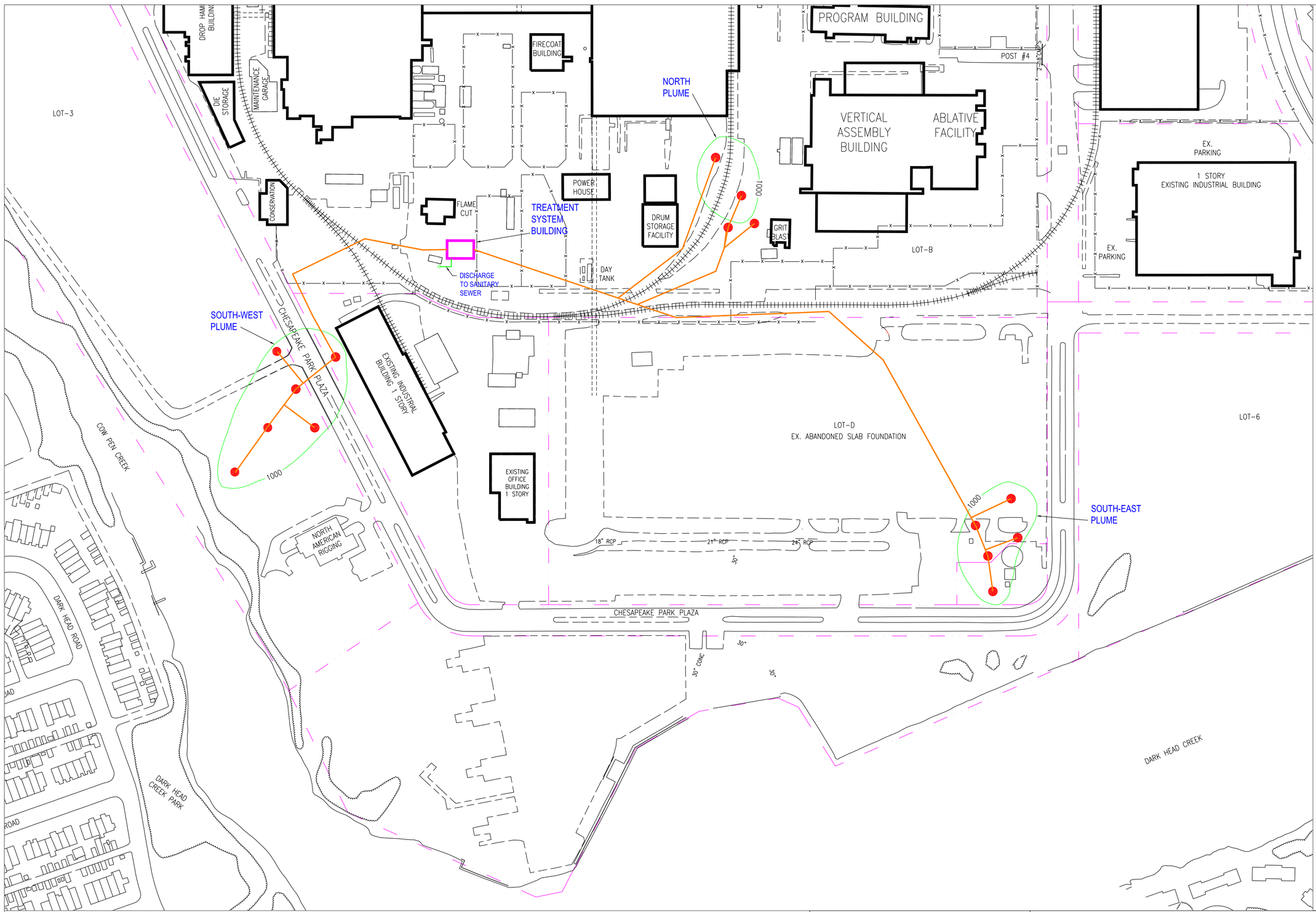
GROUNDWATER REMEDIAL ALTERNATIVES DESCRIPTION

The Three Remedial Alternatives

Final draft results based on 10% design of the 3 RAP short-listed alternatives.

1. Vacuum enhanced groundwater extraction, with extracted water treatment (15 yr); followed by monitored natural attenuation (MNA) (15 yr).
2. *In situ* enhanced anaerobic bioremediation (EAB) (7 yr), with downgradient migration control by vacuum enhanced extraction in wells and extracted water treatment (8 yr-simultaneous); followed by MNA (22 yr).
3. EAB (7 yr); followed by MNA (23 yr).

**Total time for each alternative is 30 years*



LEGEND

- PROPERTY LINE
- PROPOSED PIPING ROUTE
- PROPOSED EXTRACTION WELL

BASE MAP: BASED ON DRAWING PREPARED BY TAI CONSULTING ENGINEERS, INC.

TOPOGRAPHY: TOPOGRAPHY WITHIN AREA OF DISTURBANCE FROM FIELD RUN SURVEY CONDUCTED BY DMW, INC. IN JUNE 1999 FLOATED TO STATE GRID.

HORIZONTAL INFORMATION OUTSIDE OF LIMIT OF DISTURBANCE FROM BALTIMORE COUINTY OFFICE OF INFORMATION TECHNOLOGY GIS SERVICES UNIT. DATE OF CAPTURE: MARCH 1995

EXISTING UTILITIES: FIELD INFORMATION OBTAINED FROM DMW FIELD RUN SURVEY AND LOCKHEED MARTIN ENTITLED "EXHIBIT #6 EXISTING UTILITIES PLAN."

BOUNDARY LINES: BOUNDARY INFORMATION TAKEN FROM RECORDED PLAT E.H.K., JR. 51 FOLIO 43 "1ST AMENDED CHESAPEAKE PARK RE-SUBDIVISION" PREPARED BY MARYLAND SURVEYING AND ENGINEERING CO., INC. 4/24/84. BOUNDARY HAS BEEN ORIENTED TO THE BALTIMORE COUNTY METROPOLITAN DISTRICT GRID, BUT SHOULD NOT BE CONSIDERED A BOUNDARY SURVEY.

SCALE

0' 125' 250' 500'

TETRA TECH

GROUNDWATER AND VAPOR EXTRACTION IN HIGH CONCENTRATION AREAS, MNA, ICs ALTERNATIVE 1

LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

DATE:	11-05-10
PROJECT NO.:	
DESIGNED BY:	BD
DRAWN BY:	BD
CHECKED BY:	CP

FIGURE 6-1

LIMITS OF TREATMENT SYSTEM BUILDING

OIL-SEALED VACCUM BLOWER PACKAGE

SEAL OIL TANK

VACUUM BLOWER

MOISTURE SEPARATOR

VAPORS MAX 500 SCFM

HEATER

VAPOR PHASE GAC TREATMENT

TREATED DISCHARGE

VAPORS MAX 500 SCFM

VGAC CANISTER

LINES FROM EXTRACTION WELLS 25 GPM MAX

COAGULANT

pH ADJUSTMENT (DECREASE)

CARTRIDGE FILTERS

pH ADJUSTMENT (INCREASE)

INFLUENT CONTACT TANK

GRAVITY

COAGULANT MIXING TANK

GRAVITY

INCLINED PLATE CLARIFIER

TRANSFER PUMP

SHALLOW-TRAY AIR STRIPPER

TRANSFER PUMP

FAN

TIMER

ADDITIONAL OXIDIZER (OPTIONAL)

AIR

COMPRESSOR <1 SCFM

SLUDGE TANK

PUMP

CIRCULATION PUMP

OFF-SITE DISPOSAL

pH ADJUSTMENT (INCREASE)

LIQUID PHASE GAC POLISH

TREATED DISCHARGE

VACUUM HEADER FROM EXTRACTION WELLS

EW-1

EW-2

TOTAL OF 15 EXTRACTION WELLS

ELECTRICAL SUBMERSIBLE PUMP

EW-15

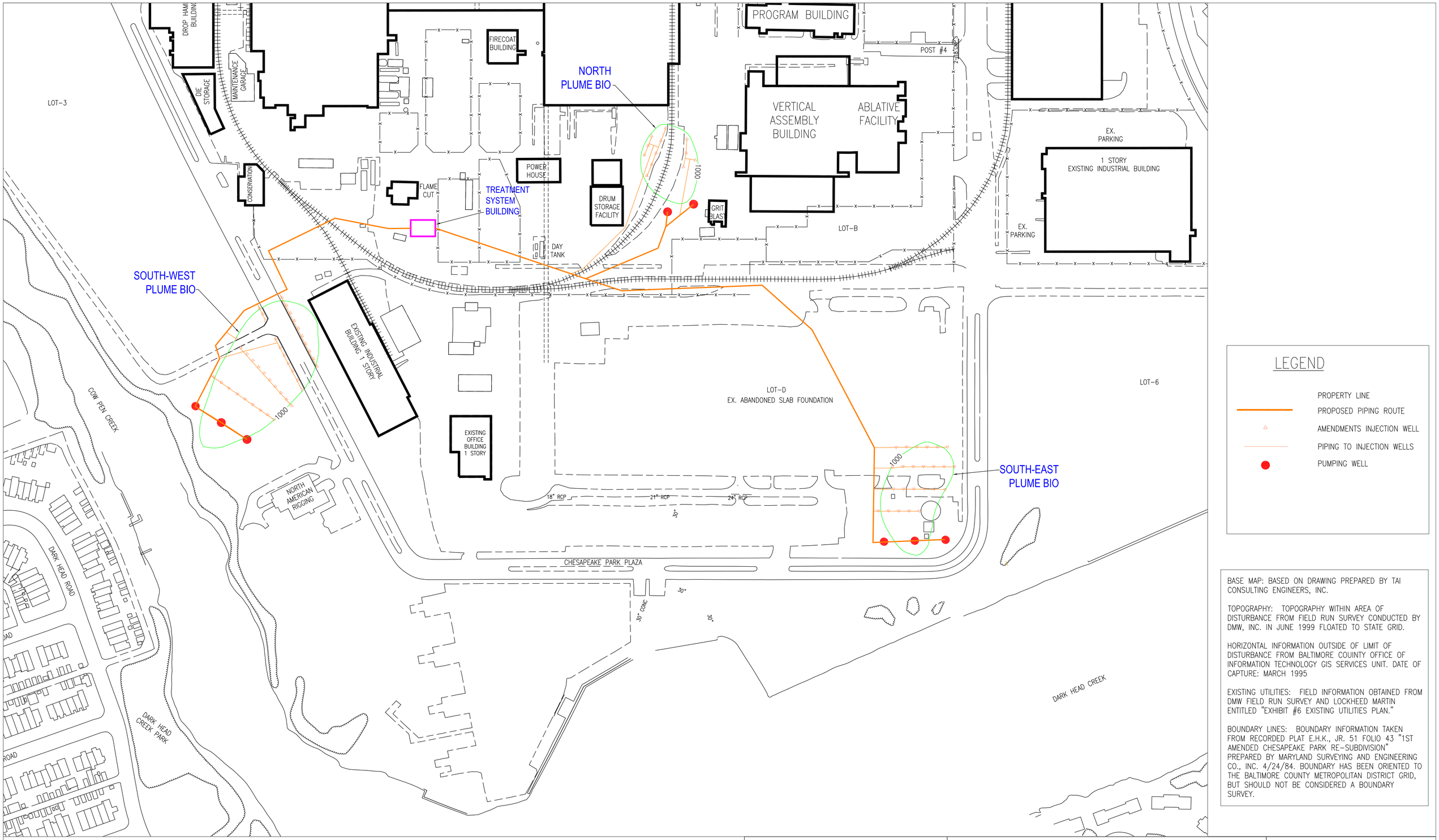
TETRA TECH

GROUNDWATER REMEDIATION SYSTEM
PROCESS FLOW DIAGRAM
ALTERNATIVE 1

LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

DATE:	11-06-2010
PROJECT NO.:	
DESIGNED BY:	BD
DRAWN BY:	BD
CHECKED BY:	CP
SCALE:	N.T.S.

FIGURE 6-3



LEGEND

- PROPERTY LINE
- PROPOSED PIPING ROUTE
- AMENDMENTS INJECTION WELL
- PIPING TO INJECTION WELLS
- PUMPING WELL

BASE MAP: BASED ON DRAWING PREPARED BY TAI CONSULTING ENGINEERS, INC.

TOPOGRAPHY: TOPOGRAPHY WITHIN AREA OF DISTURBANCE FROM FIELD RUN SURVEY CONDUCTED BY DMW, INC. IN JUNE 1999 FLOATED TO STATE GRID.

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EXISTING UTILITIES: FIELD INFORMATION OBTAINED FROM DMW FIELD RUN SURVEY AND LOCKHEED MARTIN ENTITLED "EXHIBIT #6 EXISTING UTILITIES PLAN."

BOUNDARY LINES: BOUNDARY INFORMATION TAKEN FROM RECORDED PLAT E.H.K., JR. 51 FOLIO 43 "1ST AMENDED CHESAPEAKE PARK RE-SUBDIVISION" PREPARED BY MARYLAND SURVEYING AND ENGINEERING CO., INC. 4/24/84. BOUNDARY HAS BEEN ORIENTED TO THE BALTIMORE COUNTY METROPOLITAN DISTRICT GRID, BUT SHOULD NOT BE CONSIDERED A BOUNDARY SURVEY.

SCALE

0' 125' 250' 500'

TETRA TECH

IN-SITU BIOREMEDIATION IN HIGH CONCENTRATION AREAS WITH GROUNDWATER EXTRACTION VIA WELLS, MNA/ICs
ALTERNATIVE 2

LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

DATE:	01-03-11
PROJECT NO.:	
DESIGNED BY:	BD
DRAWN BY:	BD
CHECKED BY:	CP

FIGURE 6-5

NOTE: DISSOLVED OXYGEN IS REMOVED BY ADDING SUBSTRATE AND ALLOWING AEROBIC BACTERIA TO CONSUME OXYGEN

INJECTION WATER
(OXYGEN AND CHLORINE REMOVED)

21,000-GAL FRAC TANK

INJECTION WATER PREPARATION

21,000-GAL FRAC TANK

LIMITS OF TREATMENT SYSTEM BUILDING

INJECTION PUMP

DHC CULTURES

SUBSTRATE

CHLORINE REMOVAL GACs IF POTABLE WATER USED

CIRCULATION PUMP

TO INJECTION WELLS

OIL-SEALED VACCUM BLOWER PACKAGE

SEAL OIL TANK

VACUUM BLOWER

MOISTURE SEPARATOR

VAPORS
MAX 500 SCFM

HEATER

VAPOR PHASE GAC TREATMENT

TREATED DISCHARGE

VAPORS
MAX 500 SCFM

VACUUM HEADER FROM EXTRACTION WELLS

LINES FROM EXTRACTION WELLS
25 GPM TOTAL MAX

VGAC CANISTER

COAGULANT

pH ADJUSTMENT (DECREASE)

CARTRIDGE FILTERS

pH ADJUSTMENT (INCREASE)

ADDITIONAL OXIDIZER (OPTIONAL)

INFLUENT CONTACT TANK

AIR

COMPRESSOR
<1 SCFM

GRAVITY

COAGULANT MIXING TANK

GRAVITY

INCLINED PLATE CLARIFIER

TIMER

SLUDGE TANK

PUMP

OFF-SITE DISPOSAL

TRANSFER PUMP

FAN

SHALLOW-TRAY AIR STRIPPER

TRANSFER PUMP

CIRCULATION PUMP

pH ADJUSTMENT (INCREASE)

LIQUID PHASE GAC POLISH

TREATED DISCHARGE

TOTAL OF 8 EXTRACTION WELLS

EW-1

EW-2

ELECTRICAL SUBMERSIBLE PUMP

EW-8

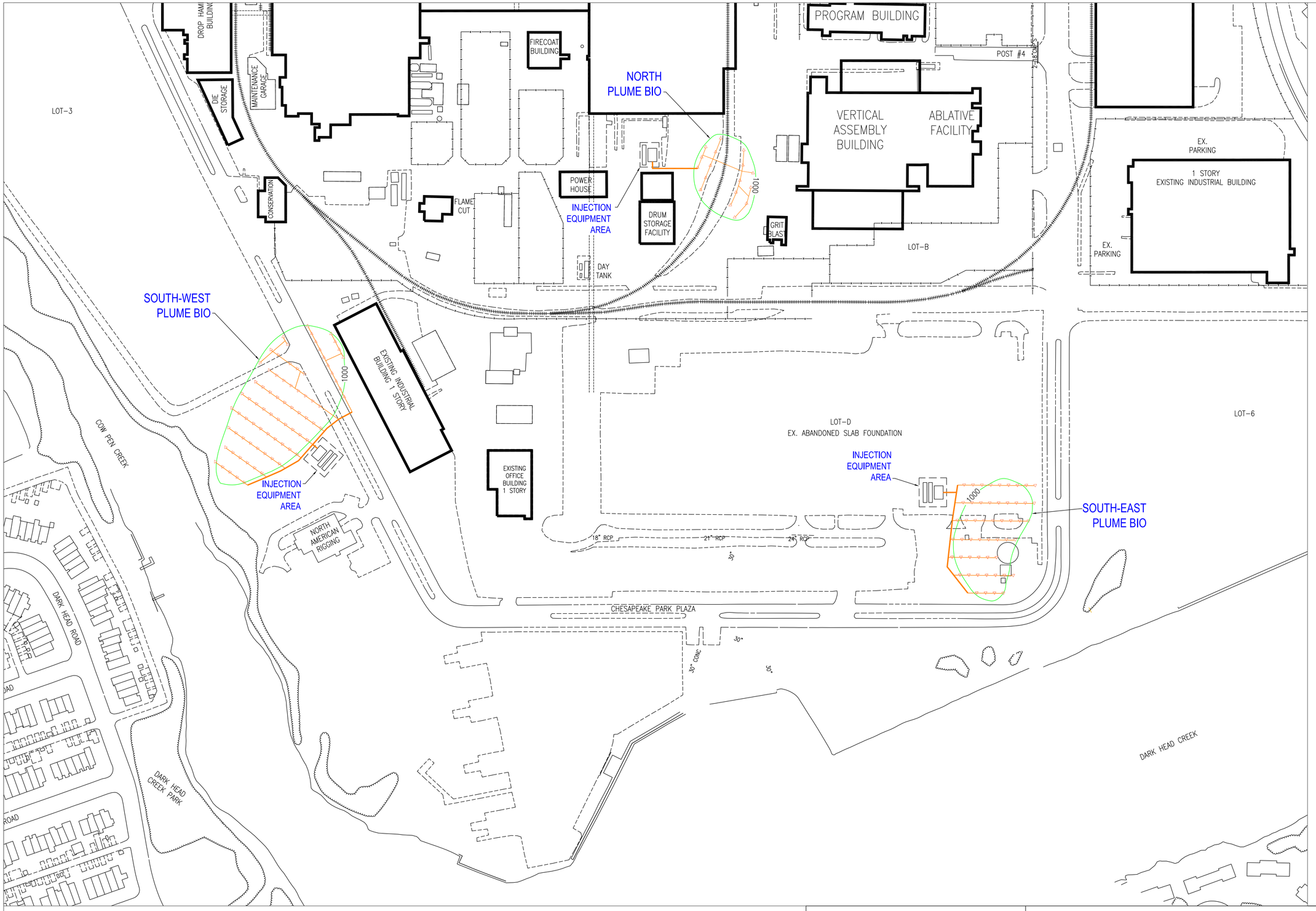
TETRA TECH

GROUNDWATER REMEDIATION SYSTEM PROCESS FLOW DIAGRAM ALTERNATIVE 2

LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

DATE:	01-04-2011
PROJECT NO.:	
DESIGNED BY:	BD
DRAWN BY:	BD
CHECKED BY:	CP
SCALE:	N.T.S.

FIGURE 6-8



LEGEND

- PROPERTY LINE
- PROPOSED PIPING ROUTE
- AMENDMENTS INJECTION WELL
- PIPING TO INJECTION WELLS

BASE MAP: BASED ON DRAWING PREPARED BY TAI CONSULTING ENGINEERS, INC.

TOPOGRAPHY: TOPOGRAPHY WITHIN AREA OF DISTURBANCE FROM FIELD RUN SURVEY CONDUCTED BY DMW, INC. IN JUNE 1999 FLOATED TO STATE GRID.

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SCALE

0' 125' 250' 500'

TETRA TECH

IN-SITU BIOREMEDIATION IN HIGH CONCENTRATION AREAS AND MNA/ICs
ALTERNATIVE 3

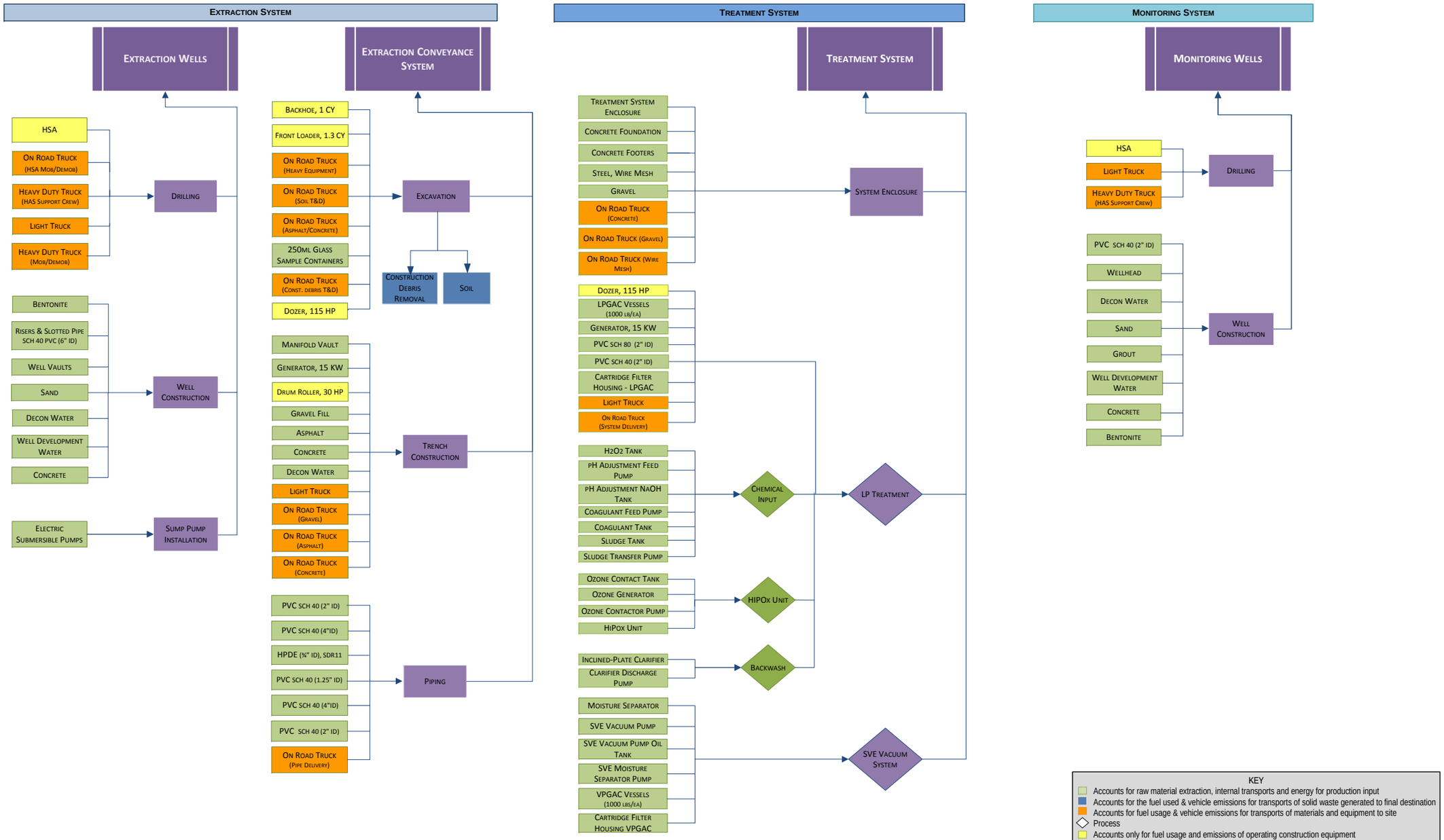
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

DATE:	12-15-10
PROJECT NO.:	
DESIGNED BY:	BD
DRAWN BY:	BD
CHECKED BY:	CP

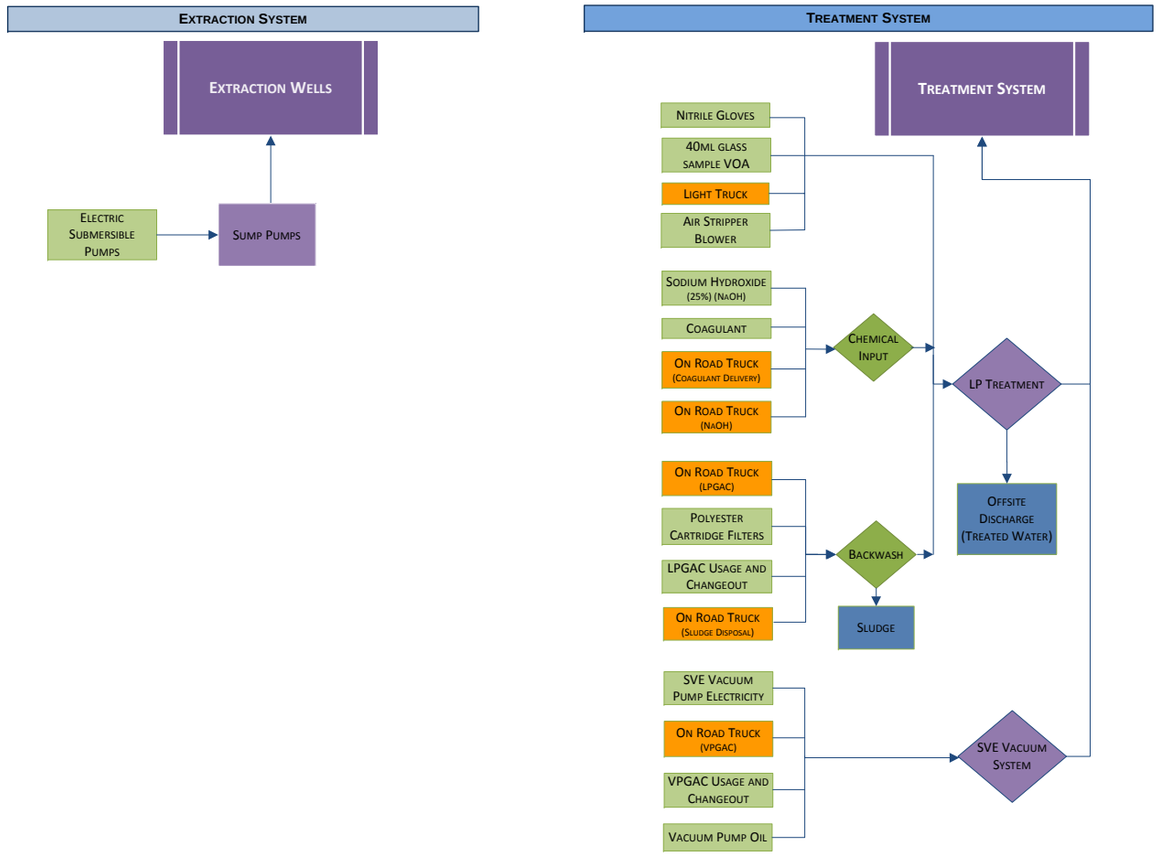
FIGURE 6-13

Alternative 1: Pump and Treat

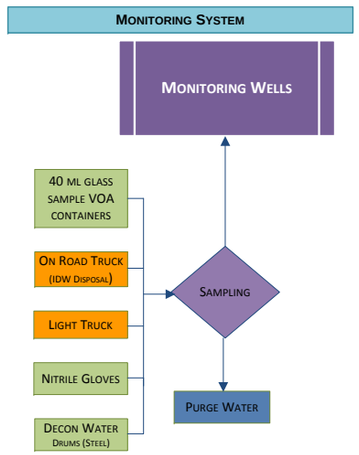
Installation Phase



ALTERNATIVE 1: PUMP AND TREAT
SYSTEM OPERATION PHASE



ALTERNATIVE 1: PUMP AND TREAT
MONITORED NATURAL ATTENUATION

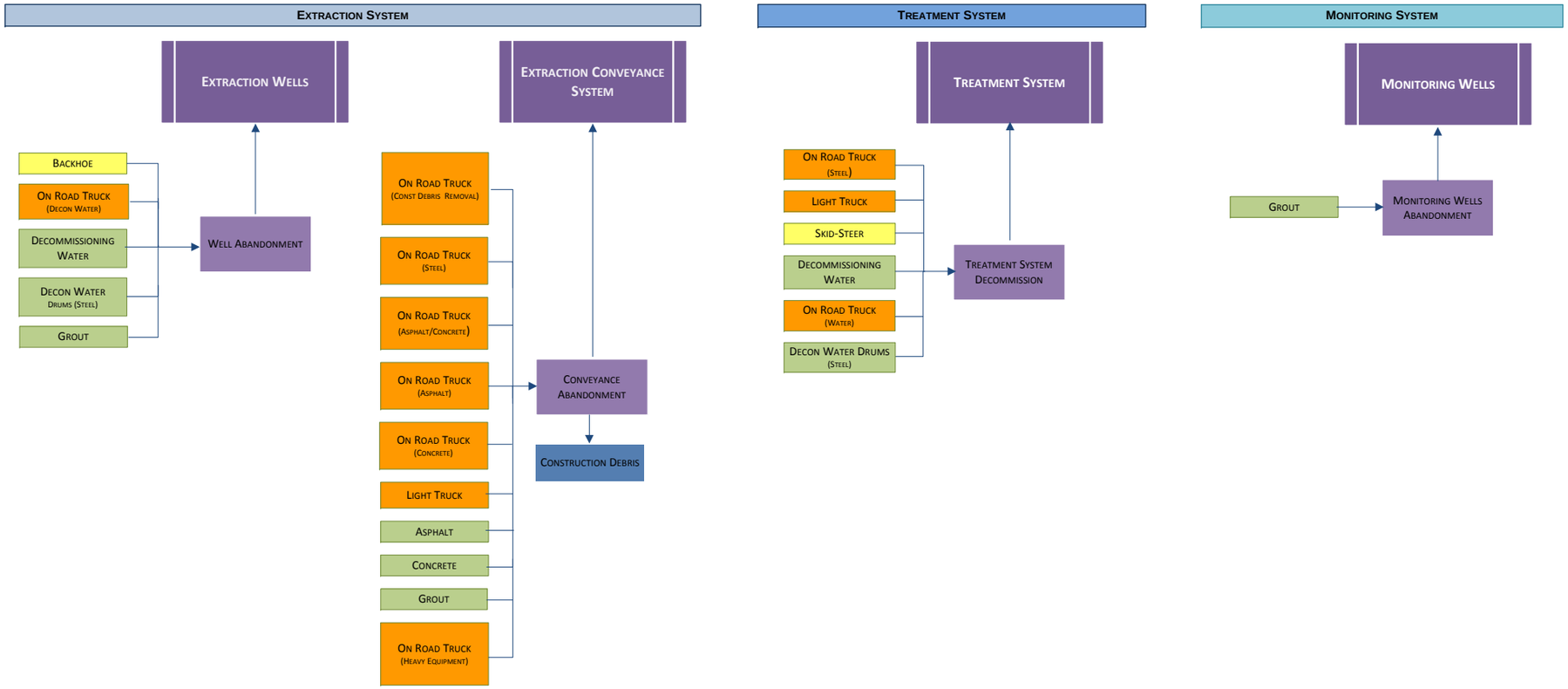


KEY
- Accounts for raw material extraction, internal transports and energy for production input
- Accounts for the fuel used & vehicle emissions for transports of solid waste generated to final destination
- Accounts for fuel usage & vehicle emissions for transports of materials and equipment to site
- Process
- Accounts only for fuel usage and emissions of operating construction equipment

HSA Hollow Stem Auger

ALTERNATIVE 1: PUMP AND TREAT

DECOMMISSION PHASE



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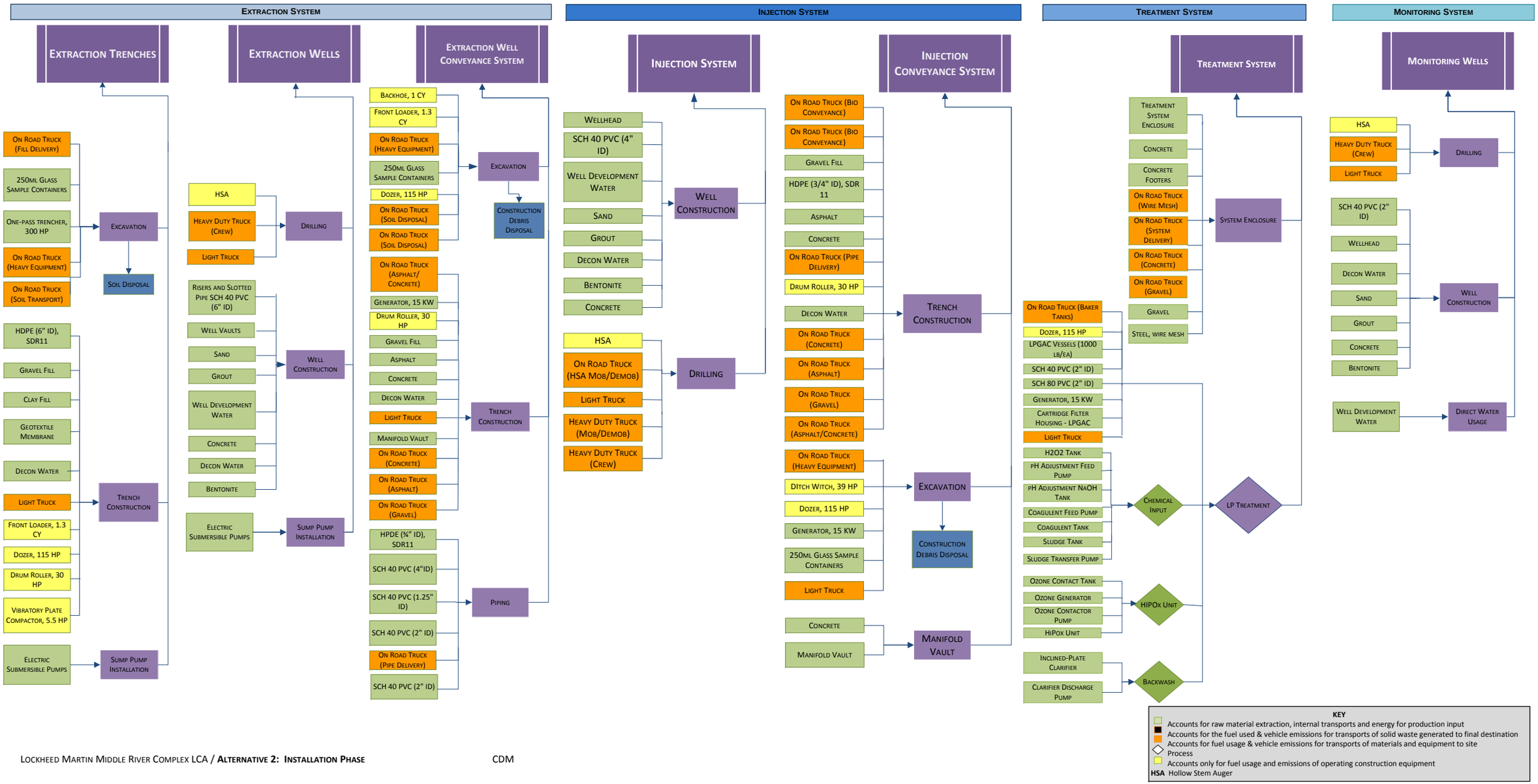
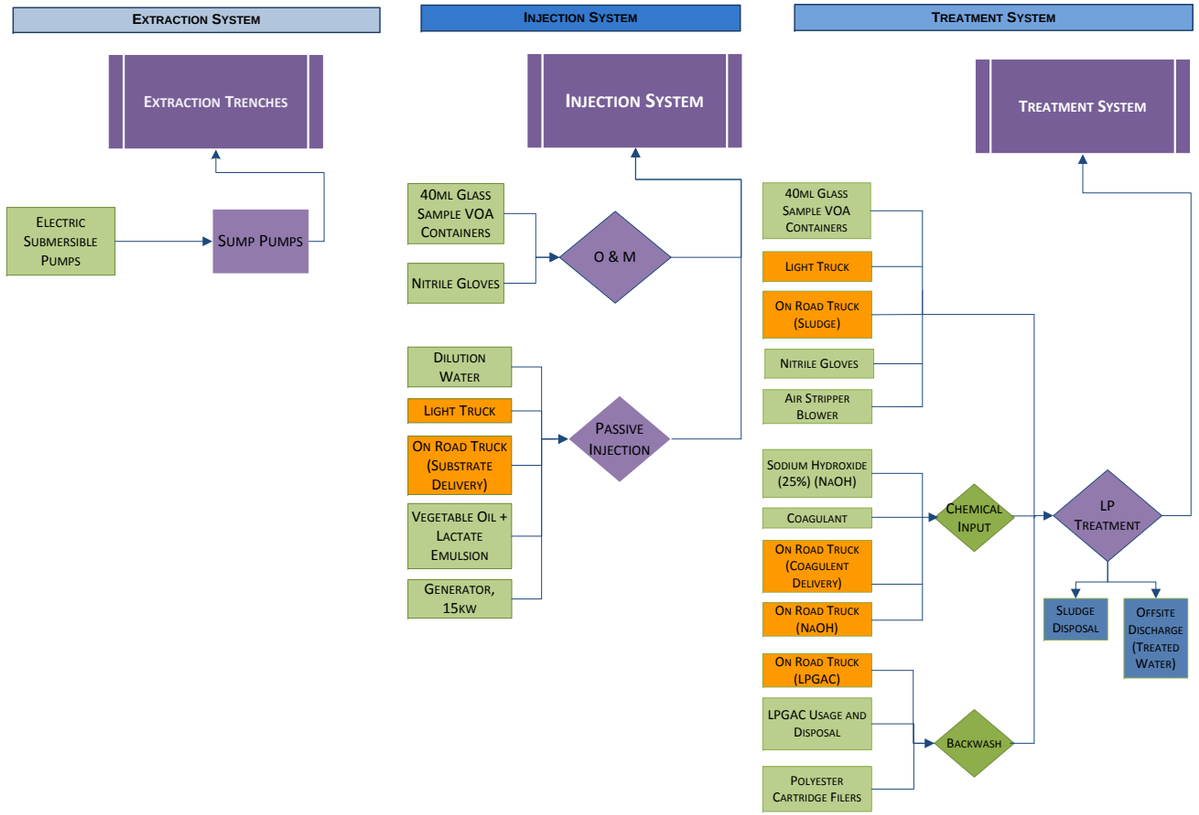
Alternative 2: Extraction/Injection

Installation Phase



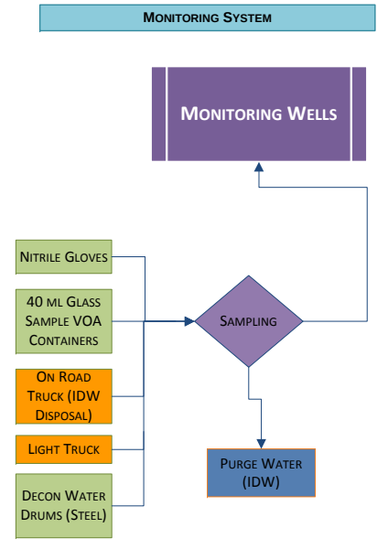
ALTERNATIVE 2: EXTRACTION/INJECTION

SYSTEM OPERATION PHASE



ALTERNATIVE 2: EXTRACTION/INJECTION

MONITORED NATURAL ATTENUATION



KEY

- ACCOUNTS FOR RAW MATERIAL EXTRACTION, INTERNAL TRANSPORTS AND ENERGY FOR PRODUCTION INPUT
- ACCOUNTS FOR THE FUEL USED & VEHICLE EMISSIONS FOR TRANSPORTS OF SOLID WASTE GENERATED TO FINAL DESTINATION
- ACCOUNTS FOR FUEL USAGE & VEHICLE EMISSIONS FOR TRANSPORTS OF MATERIALS AND EQUIPMENT TO SITE
- PROCESS
- ACCOUNTS ONLY FOR FUEL USAGE AND EMISSIONS OF OPERATING CONSTRUCTION EQUIPMENT

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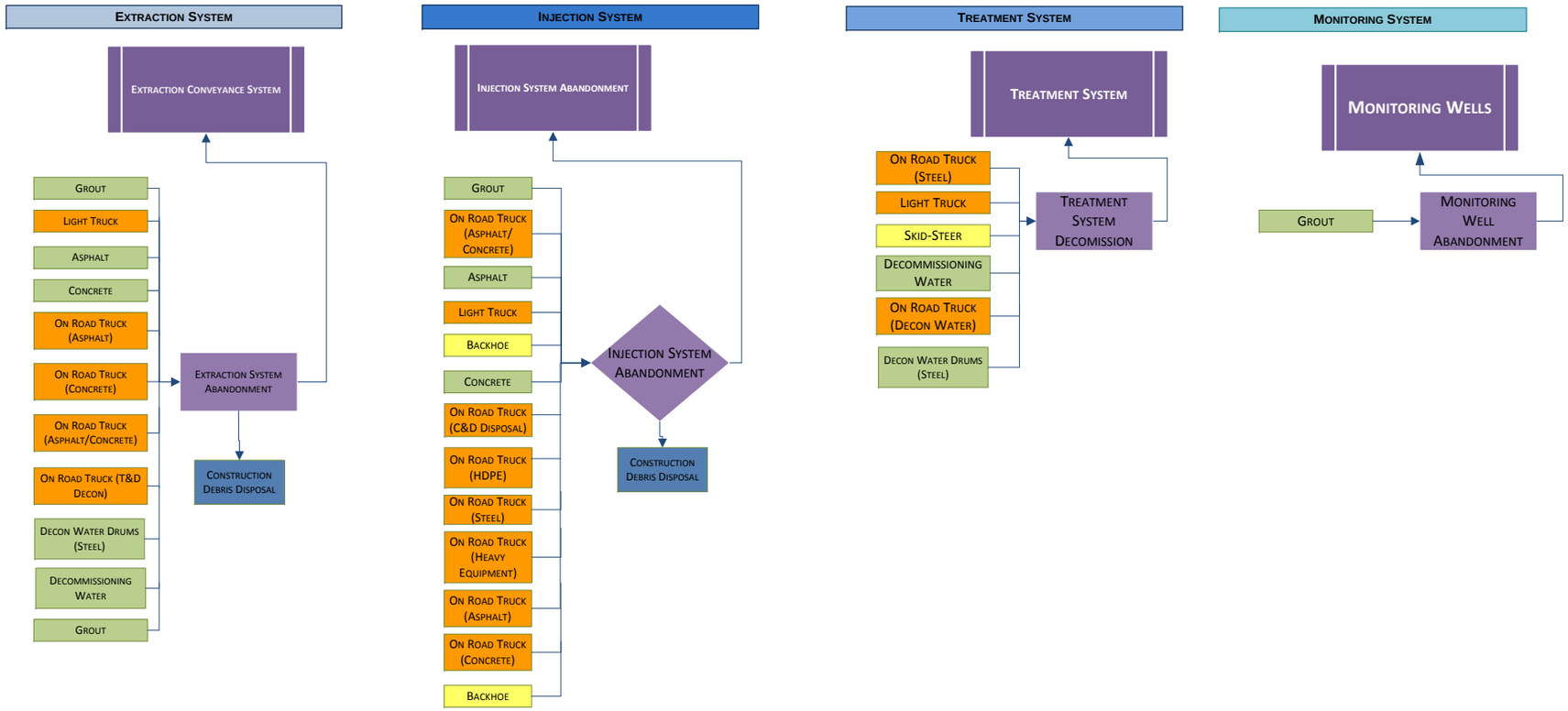
Alternative 2: Extraction/Injection

Decommission Phase



KEY

- Accounts for raw material extraction, internal transports and energy for production input
- Accounts for the fuel used & vehicle emissions for transports of solid waste generated to final destination
- Accounts for fuel usage & vehicle emissions for transports of materials and equipment to site
- Process
- Accounts only for fuel usage and emissions of operating construction equipment

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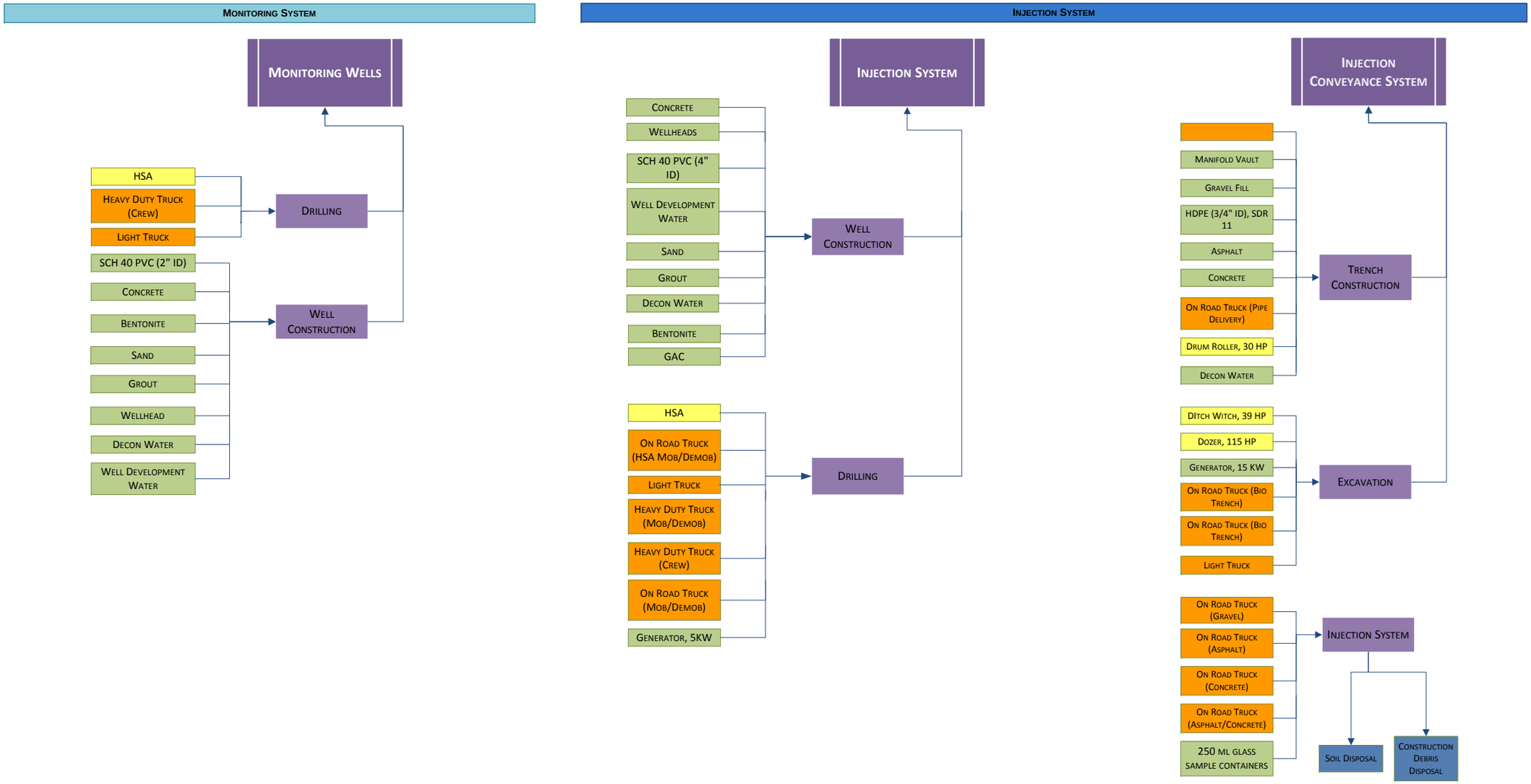
ALTERNATIVE 3: BIO-INJECTION

INSTALLATION PHASE



KEY

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- PROCESS
- ACCOUNTS ONLY FOR FUEL USAGE AND EMISSIONS OF OPERATING CONSTRUCTION EQUIPMENT

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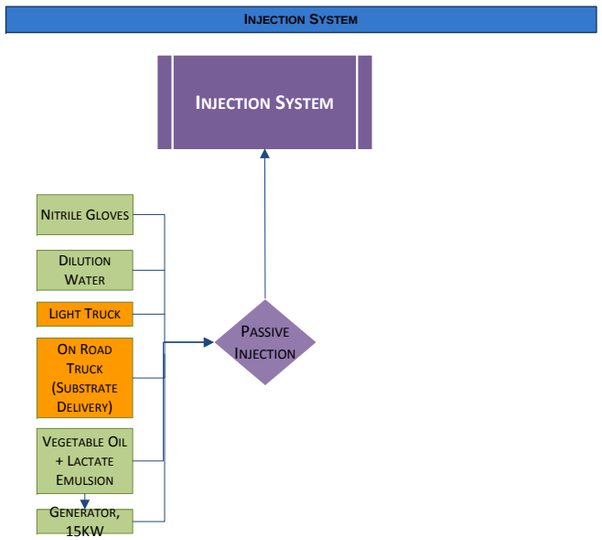
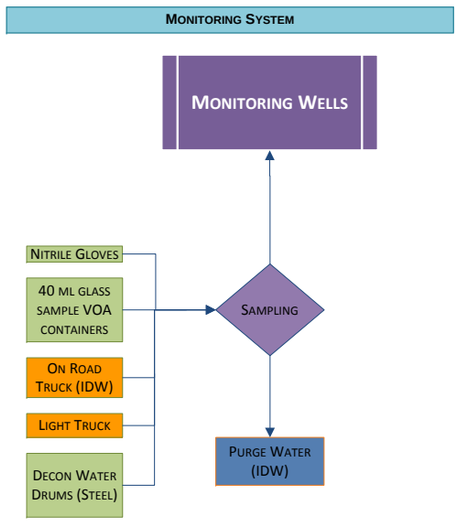
ALTERNATIVE 3: BIO-INJECTION
OPERATION PHASE



ALTERNATIVE 3: BIO-INJECTION
MONITORED NATURAL ATTENUATION



KEY
- ACCOUNTS FOR RAW MATERIAL EXTRACTION, INTERNAL TRANSPORTS AND ENERGY FOR PRODUCTION INPUT
- ACCOUNTS FOR THE FUEL USED & VEHICLE EMISSIONS FOR TRANSPORTS OF SOLID WASTE GENERATED TO FINAL DESTINATION
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- PROCESS
- ACCOUNTS ONLY FOR FUEL USAGE AND EMISSIONS OF OPERATING CONSTRUCTION EQUIPMENT

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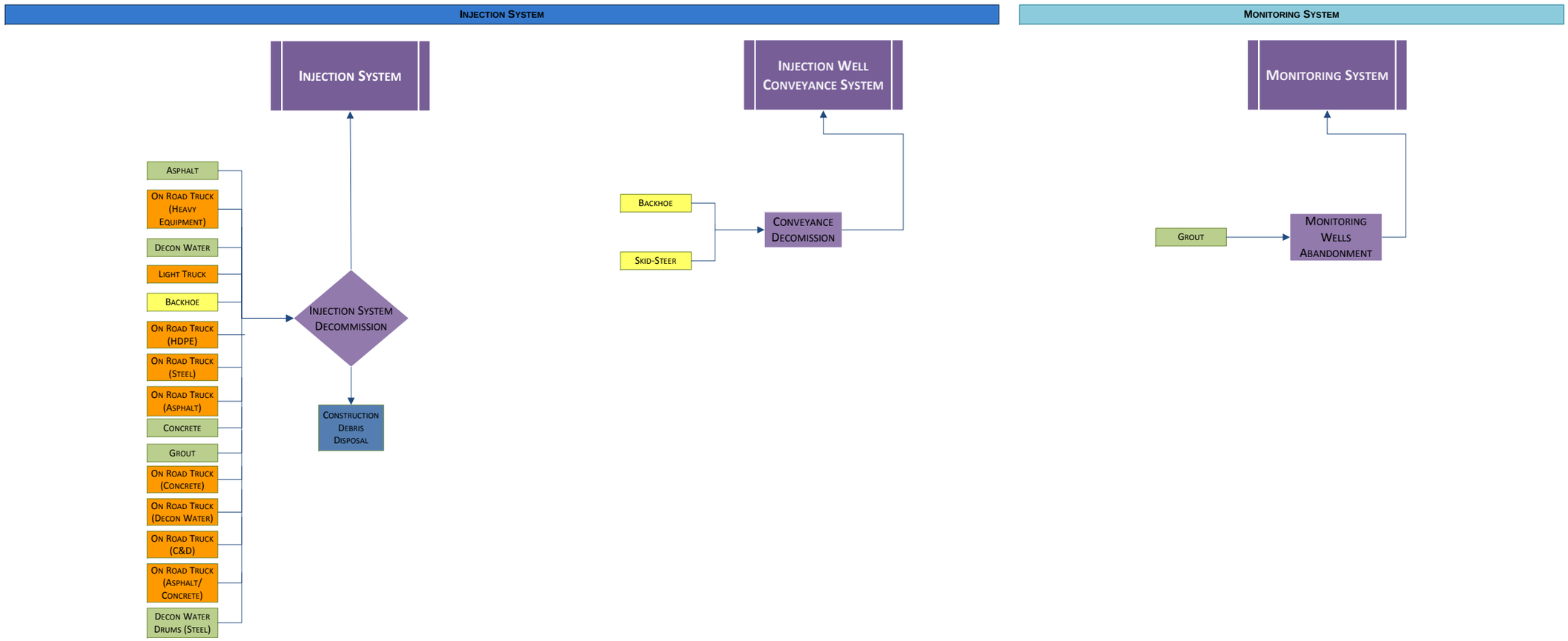
ALTERNATIVE 3: BIO-INJECTION

DECOMMISSION PHASE



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- ACCOUNTS ONLY FOR FUEL USAGE AND EMISSIONS OF OPERATING CONSTRUCTION EQUIPMENT

HSA HOLLOW STEM AUGER

INTRODUCTION TO LIFE CYCLE ASSESSMENT

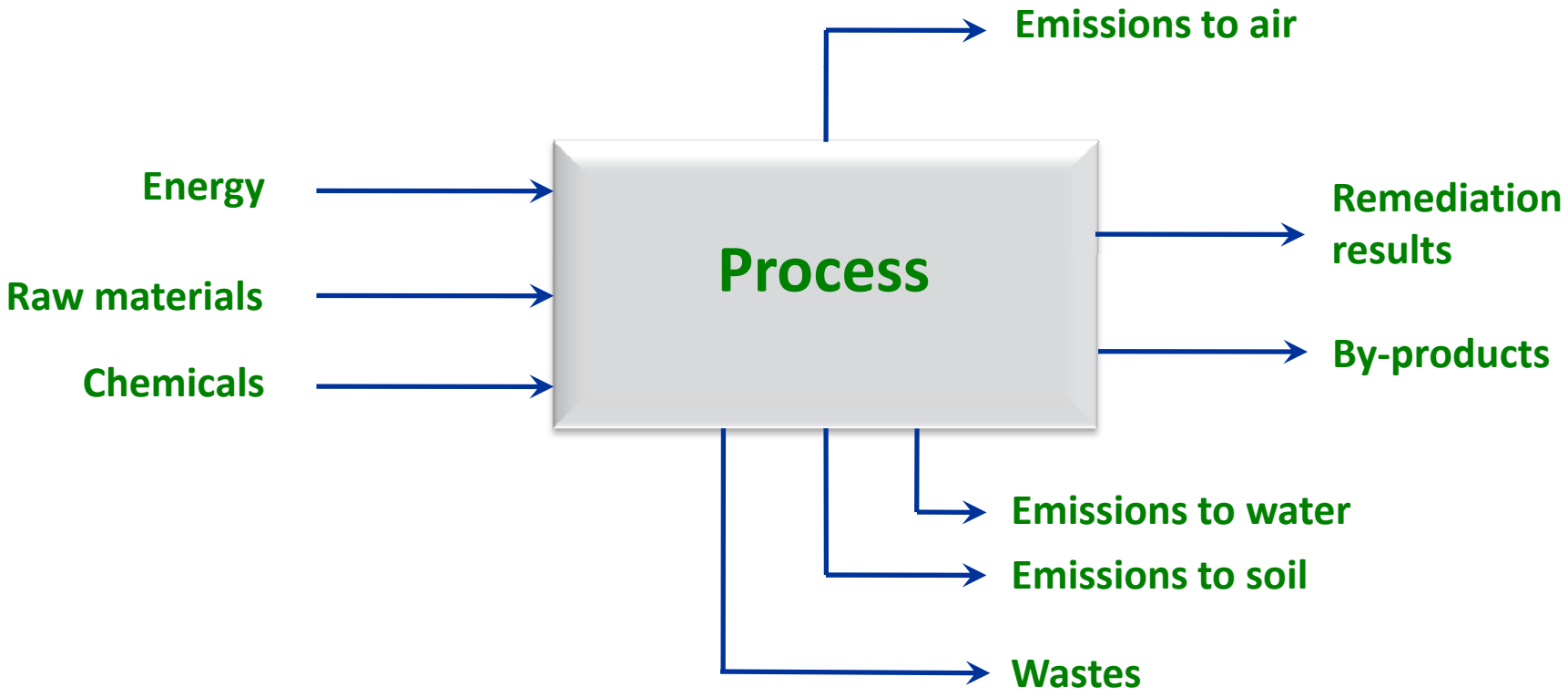
Life Cycle Assessment Defined

- A life cycle assessment captures the resource and energy use and emissions throughout the production and supply chain of a product or throughout the course of a process

- LCA refers to an evaluation of all stages of a product or process, recognizing the interconnections/interdependence of each step to the next

Life Cycle Assessment Defined

- Inputs and Outputs
- Environmental Impacts



Life Cycle Assessment Process

Goal and Scope

- Specify objective of the analysis
- Define assumptions
- Establish clear boundaries

Life Cycle Inventory (LCI)

- Quantify inputs
- Understand relationships between inputs and processes

Life Cycle Impact Assessment (LCIA)

- Analyze results of the LCA modeling process
- Review environmental impacts

Interpretation

- Review and interpret results
- Understand uncertainties and assumptions
- Use results for planning

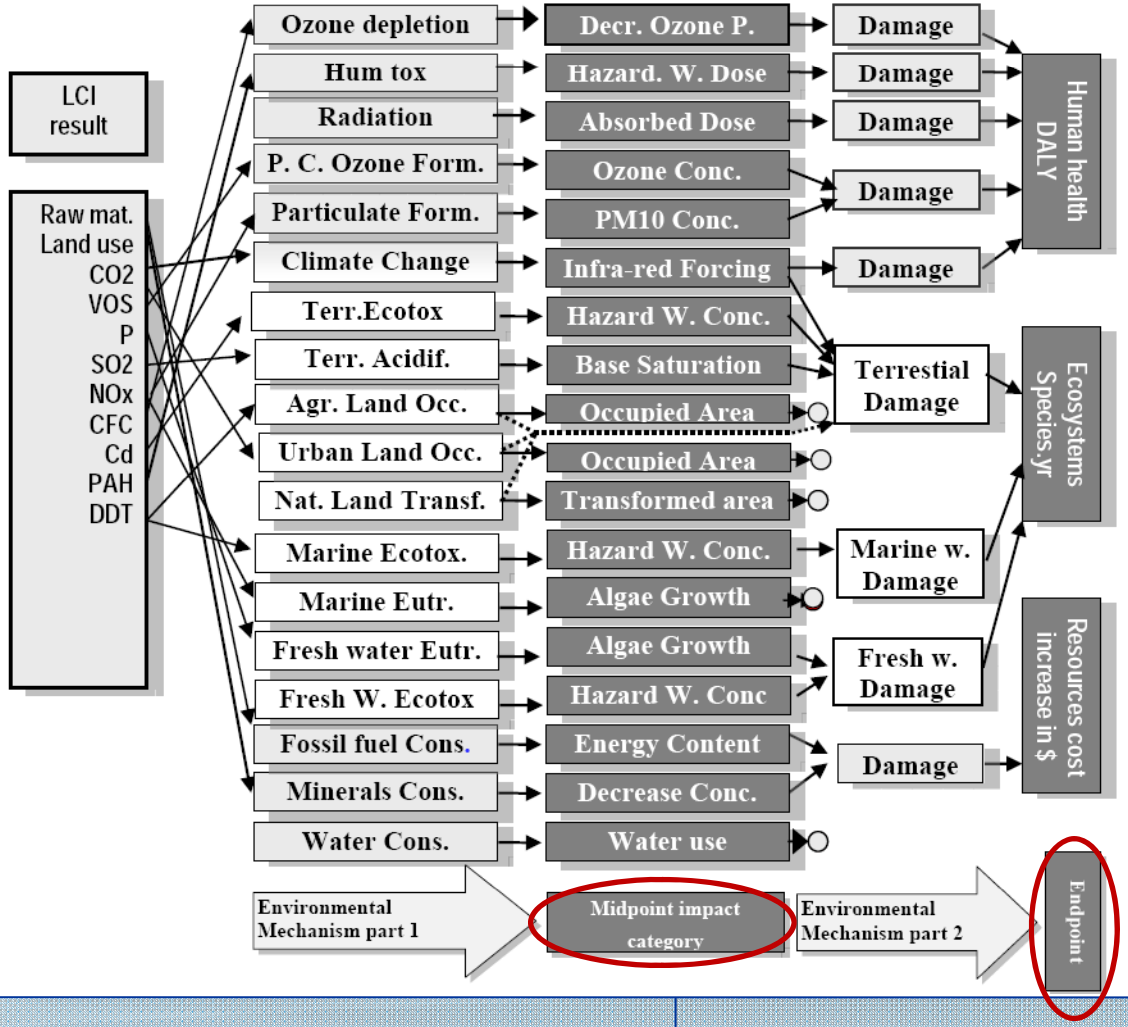
Review of LCIA Methodologies

Characterization

- Characterization is a step within the LCA process where all relevant emissions causing an effect on each specific impact category are quantified and unified (characterization factor) per impact category
- Characterized results are plotted as percentages, with the highest score per impact category set to 100%
- Difficult to interpret
  - All impact categories are expressed in different units
  - What are the relevant categories?
  - Is the result high or not?
- Midpoint and Endpoint Levels
  - Midpoint: different emissions and substances are classified and categorized by impact based on the environmental mechanism (impact categories)
  - Endpoint: impact categories aggregated into different “areas of protection”:
    - Human health, ecosystem quality, resource availability

Review of LCIA Methodologies

Characterization: Understanding midpoint and endpoint categories



Source: Goedkoop et al. (2009). ReCiPe 2008 Characterization Report.

Review of LCIA Methodologies

Normalization only in ReCiPe 2008

- Normalization offers a reference situation of the pressure on the environment for each impact category
- The impact category is divided by the reference for comparison among categories
  - Dimensionless score—each impact category indicator is divided by a parameter with the same unit
  - Understand if the 100% characterization score is high or not
- Normalization is based on global values (for this project specifically)
- Endpoint "weighting" of normalized values enables creation of single score

Review of LCIA Methodologies

TRACI

- TRACI stands for:
  - Tool for the Reduction and Assessment of Chemical and other environmental Impacts
- Tool developed by US EPA to support:
  - Life Cycle Impact Inventory Assessment (LCIA)
  - Pollution Prevention
  - Sustainability Metrics
  - Process Design
- Developed to be consistent with US location
- Only midpoint characterization results

Review of LCIA Methodologies

TRACI Midpoint Impact Categories

Impact Category	Midpoint Level	Level of Specificity	Unit
Ozone depletion	Potential to destroy ozone based on the chemical's reactivity and lifetime	Global	CFC-11 eq
Global warming	Potential global warming based on chemical's radiative force and lifetime	Global	CO_2 eq
Acidification	Potential to cause wet or dry acid deposition	US	H+ eq
Eutrophication	Potential to cause eutrophication	US	N
Photochemical oxidation (smog)	Potential to cause smog	US	NO_x eq
Ecotoxicity	Potential of a chemical released into an evaluative environment to cause harm	US	2,4-D eq
Human health: criteria air pollutants	Exposure to criteria air pollutants	US	PM 2.5 eq
Human health: carcinogenics	Potential of a chemical released into an evaluative environment to cause human cancer effects	US	Benzene eq
Human health: non-cancinogenics	Potential of a chemical released into an evaluative environment to cause human noncancer effects	US	Toluene eq

Sources: Hirschier et al, (2009), Implementation of Life Cycle Impact Assessment Methods, Ecoinvent report No. 3 and Bare et al. (2003), TRACI, Journal of Industrial Ecology V.6, N.3-4

Review of LCIA Methodologies

ReCiPe 2008

- Presents “latest state of affairs” in LCIA
- Builds on
  - Centrum Milieukunde Leiden (CML) – approach proposed to be baseline for characterization method for the midpoint approach
  - Ecoindicator-99 – endpoint approach
- Normalization data available for Europe and World
- Weighting has been determined by a panel using cultural values
- Uncertainty is dealt with in three different perspectives
    - Individualist (I), Hierarchist (H), Egalitarian (E)

Review of LCIA Methodologies

ReCiPe 2008: Description of perspectives for uncertainty and assumptions

- Perspective I:
  - Based on the short-term interest, impact types that are undisputed, technological optimism
- Perspective H: (chosen for this project)
  - Based on the most common policy principles with regards to time-frame and other issues
- Perspective E:
  - Is the most precautionary perspective, taking into account the longest time-frame, impact types that are not yet fully established but for which some indication is available, etc.
  - Involves the highest level of uncertainty

Review of LCIA Methodologies

ReCiPe 2008 Midpoint Impact Categories

Midpoint Impact Category	Midpoint Level	Unit
Climate Change	global warming potential	kg (CO2 to air)
Ozone Depletion	ozone depletion potential	kg (CFC-11 to air)
Terrestrial Acidification	terrestrial acidification potential	kg (SO2 to air)
Freshwater Eutrophication	freshwater eutrophication potential	kg (P to freshwater)
Marine Eutrophication	marine eutrophication potential	kg (N to freshwater)
Human Toxicity	human toxicity potential	kg (1,4DCB to urban air)
Photochemical Oxidant Formation	photochemical oxidant formation potential	kg (NMVOC to air)
Particulate Matter Formation	particulate matter formation potential	kg (PM10 to air)
Terrestrial Ecotoxicity	terrestrial ecotoxicity potential	kg (1,4DCB to industrial soil)
Freshwater Ecotoxicity	freshwater ecotoxicity potential	kg (1,4DCB to freshwater)
Marine Ecotoxicity	marine ecotoxicity potential	kg (1,4-DCB to marine water)
Ionising Radiation	ionising radiation potential	kg (U235 to air)
Agricultural Land Occupation	agricultural land occupation potential	m2×yr (agricultural land)
Urban Land Occupation	urban land occupation potential	m2×yr (urban land)
Natural Land Transformation	natural land transformation potential	m2 (natural land)
Water Depletion	water depletion potential	m3 (water)
Mineral Resource Depletion	mineral depletion potential	kg (Fe)
Fossil Resource Depletion	fossil depletion potential	kg (oil)

Source: Goedkoop et al. (2009), ReCiPe 2008 Characterization Report.

Review of LCIA Methodologies

ReCiPe 2008 Endpoint Impact Categories

Endpoint Impact category Name	abbr.	Indicator Name	unit
Damage to human health	HH	Disability-adjusted loss of life years	yr
Damage to ecosystem diversity	ED	Loss of species during a year	yr
Damage to resource availability	RA	Increased cost	$

Source: Goedkoop et al. (2009), ReCiPe 2008 Characterization Report.

Review of LCIA Methodologies

Recipe 2008 From Midpoint to Endpoint

Impact Category	Human Health	Ecosystem Diversity	Resource Availability
Climate Change	+	+	
Ozone Depletion	+	-	
Terrestrial Acidification		+	
Freshwater Eutrophication		+	
Marine Eutrophication		-	
Human Toxicity	+		
Photochemical Oxidant Formation	+	-	
Particulate Matter Formation	+		
Terrestrial Ecotoxicity		+	
Freshwater Ecotoxicity		+	
Marine Ecotoxicity		+	
Ionising Radiation	+		
Agricultural Land Occupation		+	-
Urban Land Occupation		+	-
Natural Land Transformation		+	-
Water Depletion			-
Mineral Resource Depletion			+
Fossil Resource Depletion			+

Legend: + means that a quantitative connection has been established for this link in ReCiPe 2008;
– means that although this is an important link, no quantitative connection could be established.

Source: Goedkoop et al. (2009), ReCiPe 2008 Characterization Report.

Recipe 2008 Methodology

From Weighting and Single Score

- ReCiPe 2008 uses the weighting set designed for Eco-indicator 99
- Swiss LCA interest groups were asked to rank and weigh three damage categories:
  - Human Health
  - Ecosystem Quality
  - Resources
- Weighting factors as applied in SimaPro v.7.2 for perspective H:
  - Human Health — 300
  - Resources — 300
  - Ecosystems quality — 400
- Single score combines endpoint normalized LCA results to a single score by application of the weighting factors

LCA FINAL DRAFT RESULTS

Final Draft Results

- LCIA - Characterization and Normalization results using TRACI and ReCiPe 2008 for:
  - Each alternative
  - Comparison of the three
  - Comparison of the three by year (only normalization)
  - Absolute results have been converted to US units
- Normalization results are presented both at the midpoint and endpoint levels, including single score.
- Relevant process contributions:
  - Based on a 1% cut-off
  - Presenting contributions that account for 50% or more of the impacts
  - Upstream impacts related to one activity and impact category have been aggregated
  - For ReCiPe 2008, process contributions are shown only for relevant impact categories, based on normalization results

Limitations & Main Assumptions

- Results are based on an inventory developed from a 10% design of the three RAP alternatives
- Primary or foreground processes are not part of the study, only secondary or background processes have been included*
- ReCiPe 2008 method has a limited validity for all regions that cannot be defined as well-developed temperate regions—especially in the following impact categories: acidification, eutrophication, photochemical ozone formation, toxicity, land use and water-use
- TRACI method, which is specific to the US is used to bridge this gap in the available impact categories, only at the midpoint characterization level
- ReCiPe 2008 uses global data for normalization; US data is not available for most impact categories in Recipe 2008

*Primary or foreground processes refer to the contaminants and the efficiency of the system, while secondary processes refer to the activities and materials needed to install, operate, monitor and decommission the site.

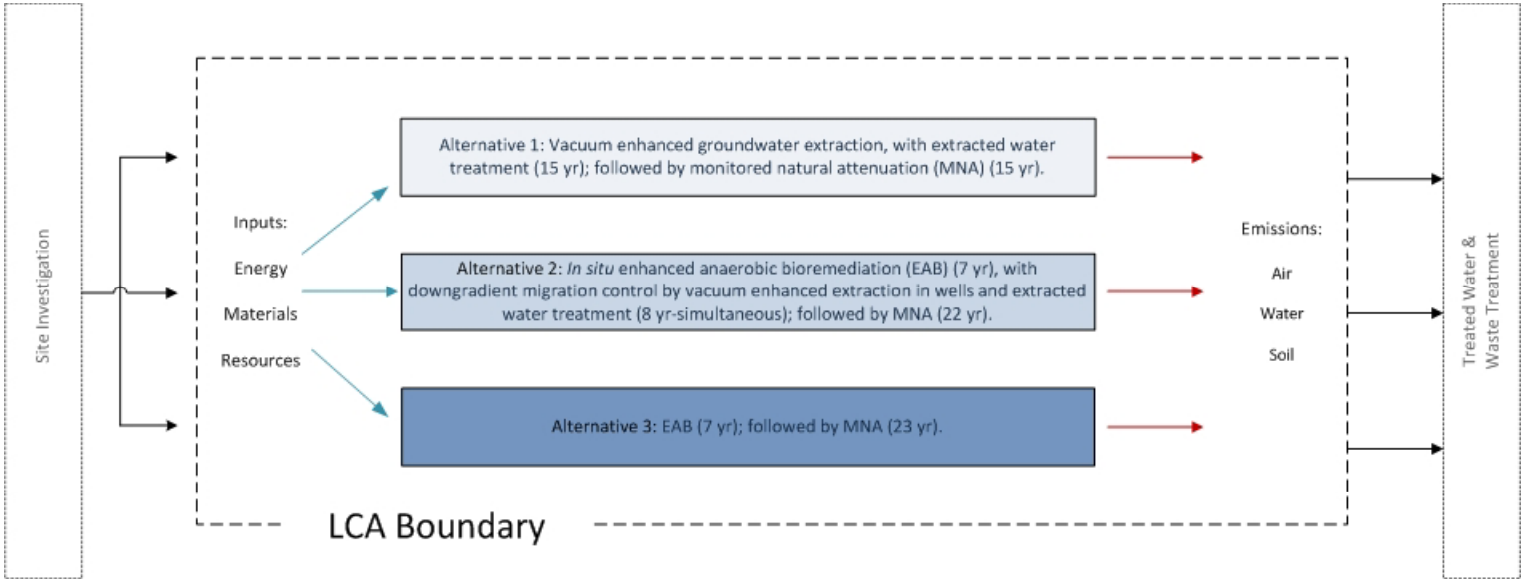
Goal of the Study

- Evaluate and compare the three shortlisted RAP alternatives to identify and understand their impacts on the environment
- Results will be part of a broader set of criteria to select the final alternative
- Understand the relevance of performing a full life cycle assessment vs. a streamlined footprint analysis (SiteWise™) on the selection of remediation alternatives*
- Understand the differences and limitations of the two tools used*

* These aspects of the study will be presented in a separate report

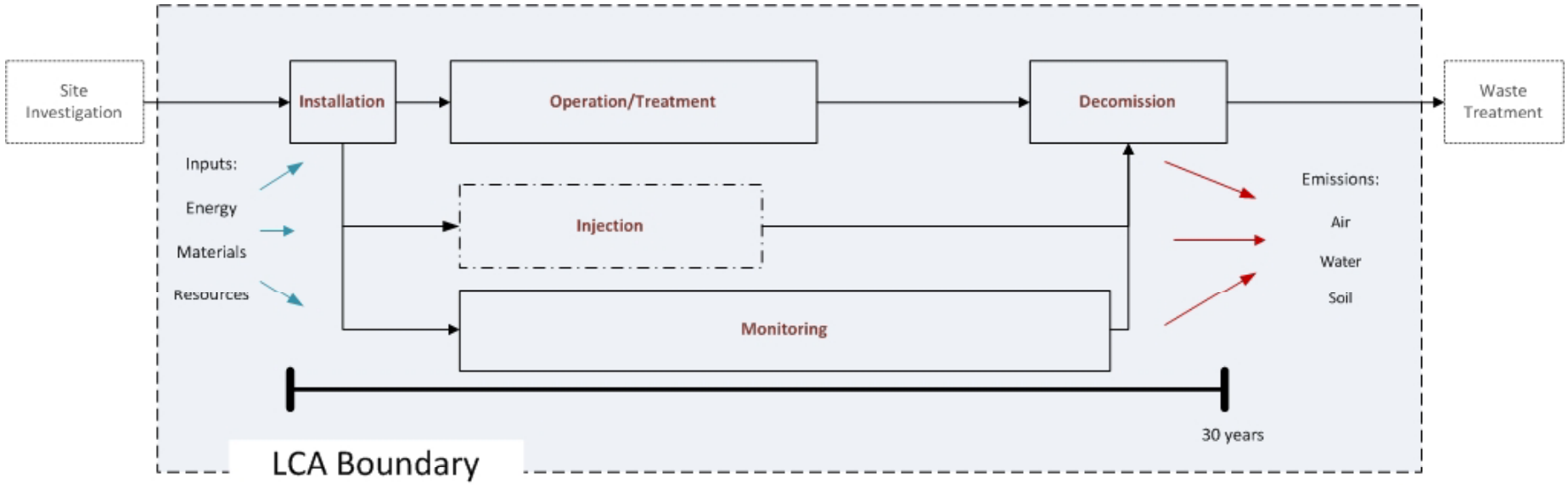
Scope & Boundary

- The system will account for the life cycle of all inputs that are fully consumed on-site
- Will account for fuel usage and emissions for construction equipment and transportation of materials
- Infrastructure of inputs are not part of the study
- Contaminants and system efficiency are not part of the study



Scope & Boundary

The **functional unit**: cleaned site = 70% reduction within 1,000 microgram/liter of TCE concentration contour.



Life Cycle Inventory

- Inventory site specific data provided by TetraTech for each alternative
- Data format and additional calculations performed to account for full life cycles of materials and equipment fully used on site
- SimaPro v.7.2 software used for LCA
- Databases used to create inventory:
  - Ecoinvent data v.2.2
  - National Renewable Energy Laboratory U.S. Life Cycle inventory (USLCI)
- Electricity inputs modeled using US average grid mix
- Recent Changes to the alternatives have been modeled as follows:
  - HiPox Unit: retired from alternatives 1 & 2
  - Air Stripper: inputs for the installation of the air stripper and associated vapor phase treatment have not been included, the model only accounts for the electricity consumption during the operation phase for alternatives 1 & 2

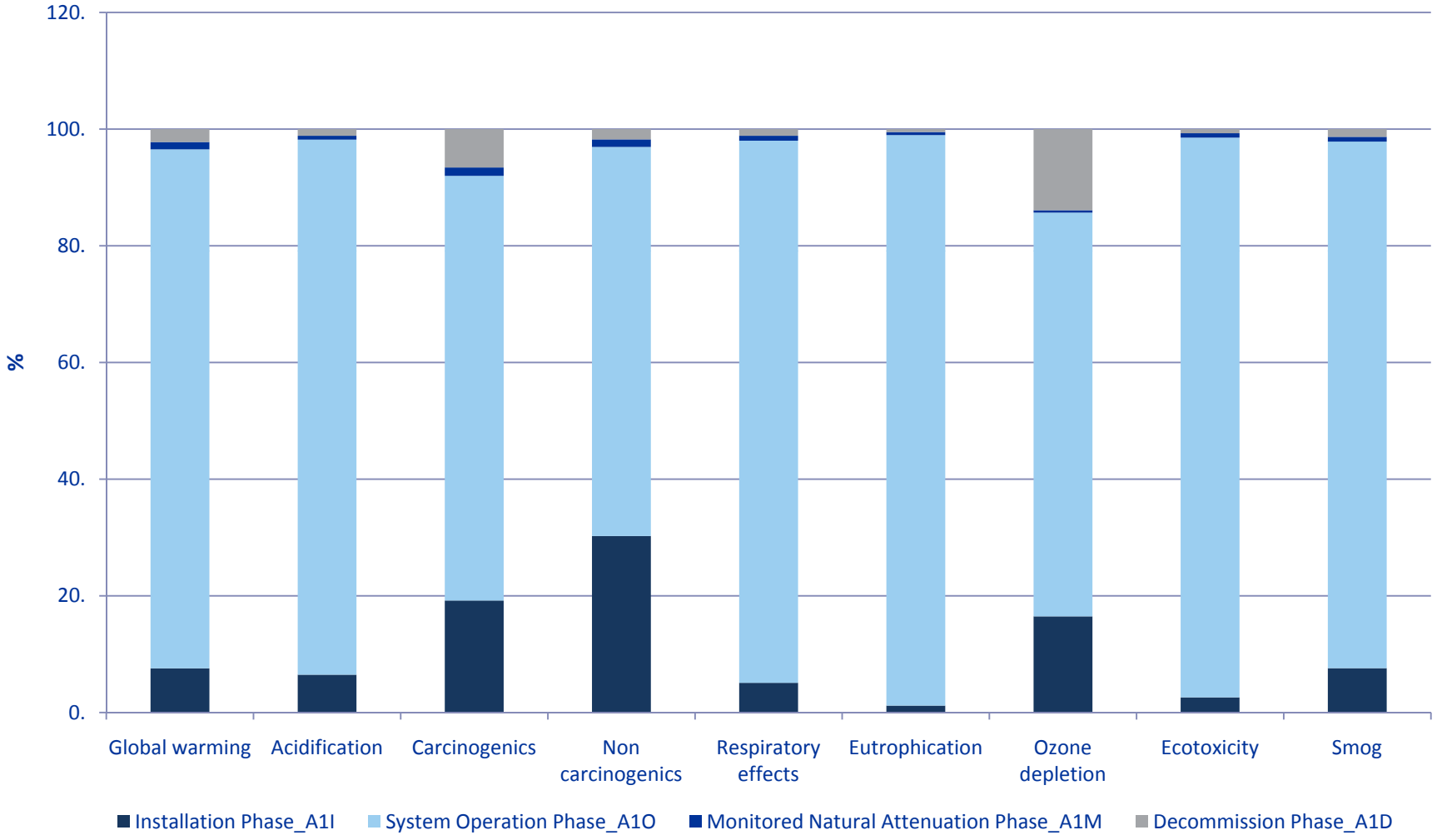
Life Cycle Inventory (cont…)

- Data gaps were filled with aggregated emissions for:
  - GAC production – source SiteWise™ emission factors
  - The use of the GAC vessels has been prorated based on a use-life of 20 years
  - Construction equipment: emissions have been calculated based on vehicle average efficiency, using US EPA Non-Road model
  - Transportation: emissions have been calculated based on vehicle average efficiency and load using GSRx emissions factors, functional unit is not ton/mile but mile
  - LactOil data based on research from different manufacturers. Used proxy data (polylactide acid) to model lactic acid as one of the inputs
  - Coagulant data based on research from manufacturer
  - It is assumed that drums for purge water are not reused

Life Cycle Impact Assessment (LCIA)

- TRACI characterization results per alternative
  - Phase contribution per impact category
  - Relevant process contribution:
    - Based on a 1% cut-off
    - Presenting contributions that aggregated or individually account for more of the impacts
    - Similar upstream impacts related to one activity and impact category have been aggregated
- ReCiPe 2008 characterization & normalization results per alternative (midpoint)
  - Phase contribution per impact category
  - Relevant Process contribution:
    - Based on a 1% cut-off
    - Presenting contributions that account for 50% or more of the impacts
    - Similar upstream impacts related to one activity and impact category have been aggregated
    - Process contributions are shown only for relevant impact categories, based on normalization results
- Although ReCiPe 2008 and TRACI share some impact categories, their unit of measure is different. The only two impact categories that can be compared on a 1:1 basis are:
  - Climate Change / Global Warming
  - Ozone Depletion

Alternative 1 – TRACI
Characterization



Alternative 1
TRACI Impact Contribution by Phase
Life Cycle Percentage Values of 30 Years

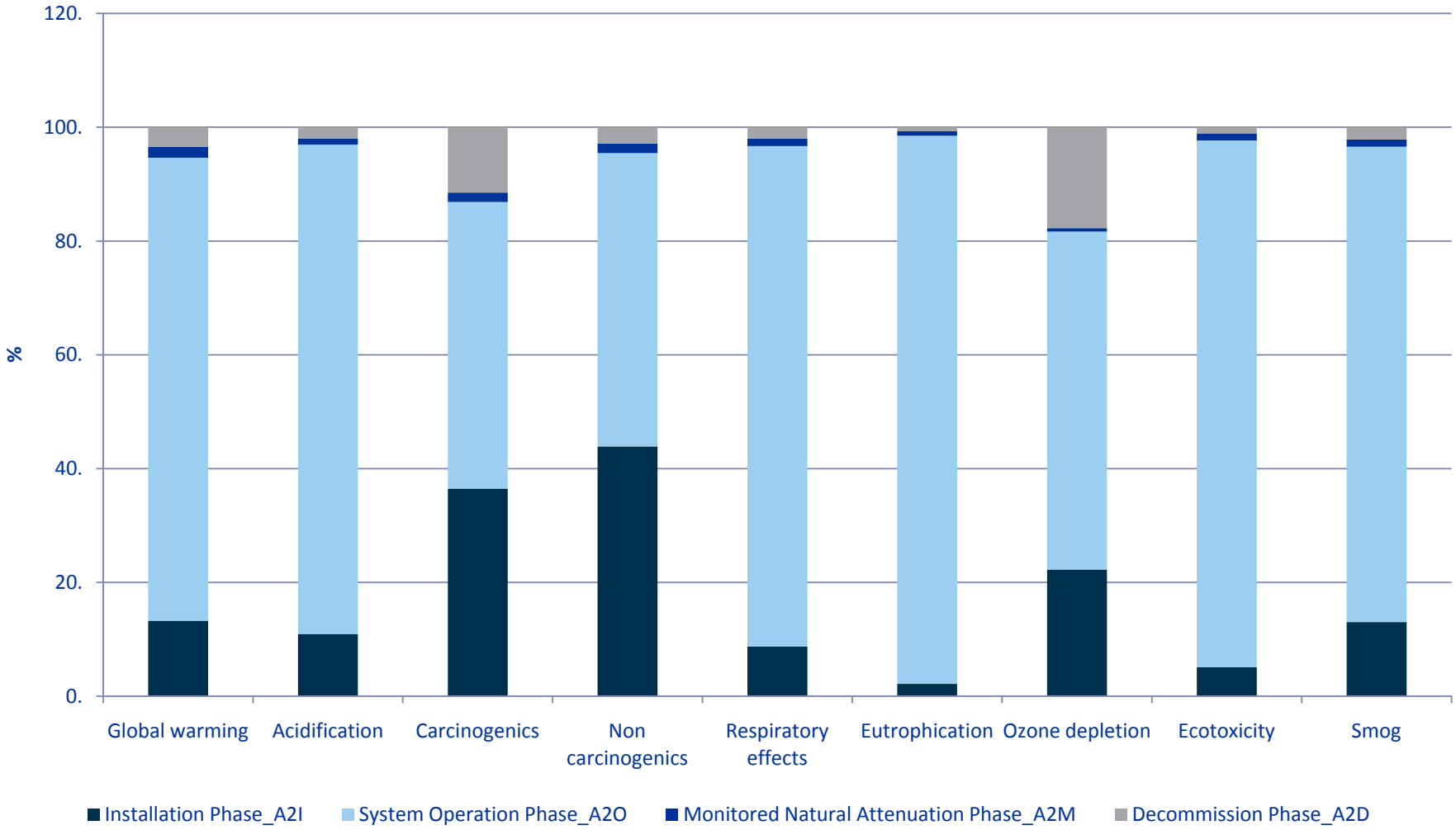
Impact Category	Installation Phase	Operation Phase	MNA* Phase	Decommission Phase
Global warming	7.6%	88.9%	1.3%	2.2%
Acidification	6.5%	91.7%	0.7%	1.2%
Carcinogenics	19.2%	72.8%	1.5%	6.6%
Non carcinogenics	30.2%	66.7%	1.3%	1.8%
Respiratory effects	5.1%	92.9%	0.8%	1.2%
Eutrophication	1.2%	97.8%	0.5%	0.5%
Ozone depletion	16.5%	69.2%	0.4%	13.9%
Ecotoxicity	2.6%	96.0%	0.7%	0.7%
Smog	7.6%	90.2%	0.8%	1.3%

*MNA = Monitored Natural Attenuation
= Phase driving environmental impacts based

Alternative 1
TRACI Relevant Process Contribution
Life Cycle Percentage Values of 30 Years

Impact Category	Relevant Process Contributions	% Contribution
Global Warming	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	54
	GAC Production - GAC Vessels	23
Acidification	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	48
	GAC Production - GAC Vessels	33
Carcinogenics	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	64
	Cement - Grout	13
	Galvanized Steel Sheet - System Enclosure and Well Vaults	5
Noncarcinogenics	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	58
	Galvanized Steel Sheet - System Enclosure and Well Vaults	27
Respiratory Effects	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	73
	GAC Production - GAC Vessels	12
Eutrophication	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	80
	Coagulant - LP Treatment	12
Ozone Depletion	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	65
	Coagulant - LP Treatment	20
	Crude Oil - Asphalt	10
Ecotoxicity	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	92
Smog	GAC Production - GAC Vessels	63
	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	20

Alternative 2 – TRACI
Characterization



Alternative 2
TRACI Impact Contribution by Phase
Life Cycle Percentage Values of 30 Years

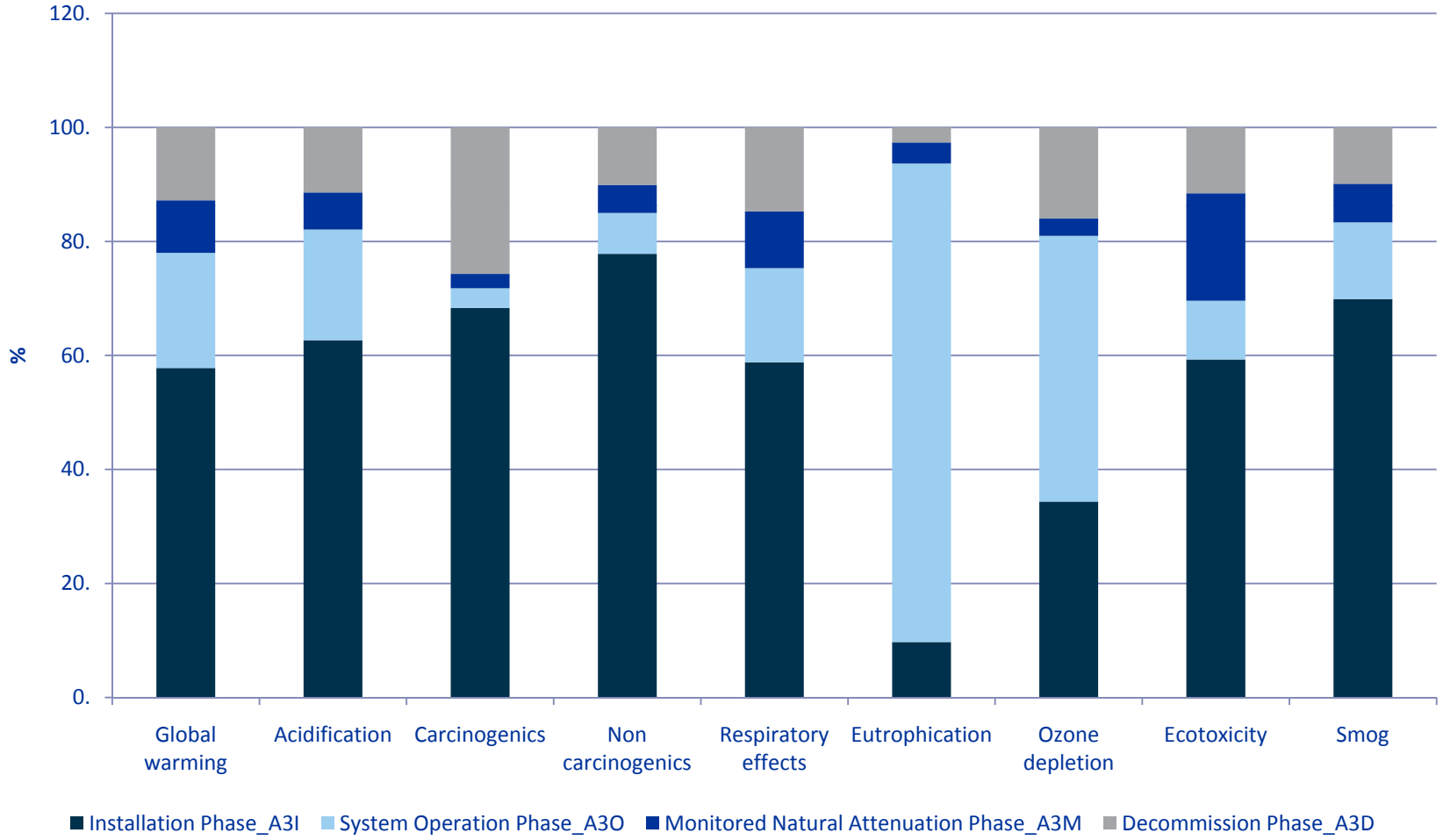
Impact Category	Installation Phase	Operation Phase	MNA* Phase	Decommission Phase
Global warming	13.3%	81.4%	1.9%	3.4%
Acidification	10.9%	86.0%	1.1%	2.0%
Carcinogenics	36.5%	50.4%	1.7%	11.5%
Non carcinogenics	43.9%	51.6%	1.7%	2.9%
Respiratory effects	8.7%	88.0%	1.3%	2.0%
Eutrophication	2.2%	96.3%	0.8%	0.7%
Ozone depletion	22.3%	59.4%	0.6%	17.7%
Ecotoxicity	5.1%	92.6%	1.2%	1.1%
Smog	13.0%	83.6%	1.3%	2.1%

*MNA = Monitored Natural Attenuation
= Phase driving environmental impacts based

Alternative 2
TRACI Relevant Process Contribution
Life Cycle Percentage Values of 30 Years

Impact Category	Relevant Process Contributions	% Contribution
Global Warming	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	46
	GAC Production - GAC Vessels	22
Acidification	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	43
	GAC Production - GAC Vessels	33
Carcinogenics	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	41
	Cement - Grout	32
	Galvanized Steel Sheet - System Enclosure and Well Vaults	6
Noncarcinogenics	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	39
	Galvanized Steel Sheet - System Enclosure and Well Vaults	30
	Disposal of Material - Manufacture of Well Vaults	6
	Cement - Grout	6
	Crude Oil - On-Road Truck and Light Truck	5
Respiratory Effects	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	64
	GAC Production - GAC Vessels	12
Eutrophication	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	71
	LactOil	14
Ozone Depletion	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	47
	Crude Oil - Asphalt	34
	Coagulant - LP Treatment	8

Alternative 3 – TRACI
Characterization



Alternative 3
TRACI Impact Contribution by Phase
Life Cycle Percentage Values of 30 Years

Impact Category	Installation Phase	Operation Phase	MNA*Phase	Decommission Phase
Global warming	57.8%	20.2%	9.2%	12.8%
Acidification	62.7%	19.4%	6.5%	11.4%
Carcinogenics	68.3%	3.5%	2.5%	25.7%
Non carcinogenics	77.8%	7.2%	4.9%	10.1%
Respiratory effects	58.8%	16.5%	10.0%	14.7%
Eutrophication	9.7%	83.9%	3.7%	2.6%
Ozone depletion	34.4%	46.6%	3.0%	16.0%
Ecotoxicity	59.3%	10.3%	18.8%	11.6%
Smog	69.9%	13.4%	6.8%	9.9%

*MNA = Monitored Natural Attenuation
= Phase driving environmental impacts based

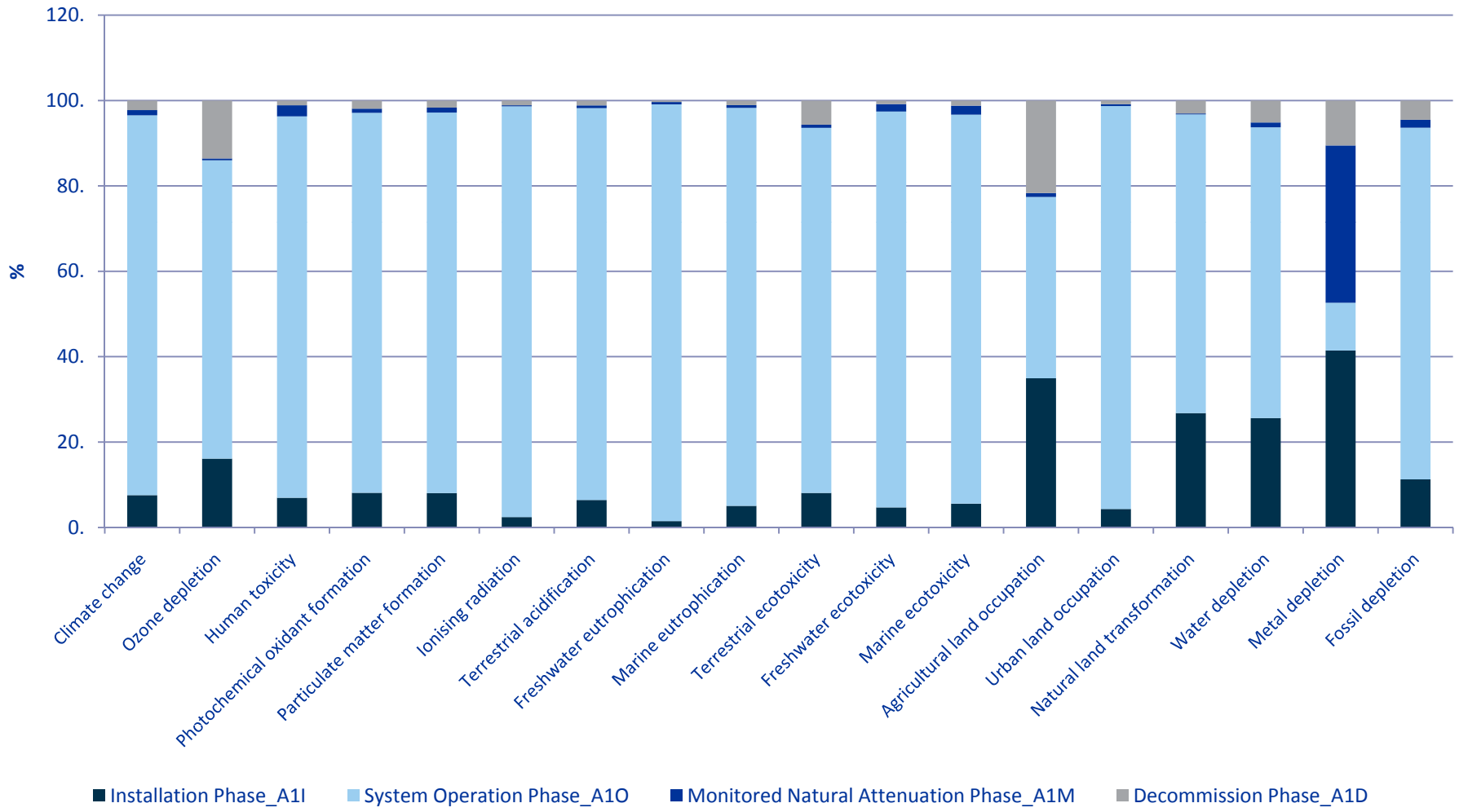
Alternative 3
TRACI Relevant Process Contribution
Life Cycle Percentage Values of 30 Years

Impact Category	Relevant Process Contributions	% Contribution
Global Warming	Cement and Bituminous Coal - Grout	27
	HSA Drill Rig	10
	Light Truck (Gasoline)	7
	Concrete (Clinker) - Well Construction and Trench Construction	6
	GAC Production - GAC Vessels	5
Acidification	Cement manufacturing - Grout	25
	HSA Drill Rig	16
	GAC Production - GAC Vessels	9
	LactOil	7
	Natural Gas - Production of PVC for Well Construction and LPGAC Vessels	6
Carcinogenics	Cement - Grout	78
	Steel and galvanized steel production for Wellheads and Manifold vaults	7
Noncarcinogenics	Galvanized Steel Sheet - Wellheads and manifold vaults	33
	Cement for Grout	24
	Disposal of Material - Upstream galvanized sheets for well heads and manifold	15
	Crude Oil - HSA Drill Rig	9
Respiratory Effects	Cement for Grout various upstream processes	29
	Natural Gas - General Production Processes	10
	HSA Drill Rig	6
	Steel - Wellheads and Decon Water Drums	6
	Iron Ore - Production of Decon Water Drums	5
Eutrophication	LactOil	84
	Disposal from LactOil and Decon Water Drum Production	6

Alternative 3
TRACI Relevant Process Contribution
Life Cycle Percentage Values of 30 Years

Impact Category	Relevant Process Contributions	% Contribution
Ozone Depletion	Crude Oil - Diesel, Asphalt, and electricity generation for different production processes	53
	LactOil (Natural Gas, Uranium, and Trichloromethane)	39
Ecotoxicity	LactOil - Electricity and Maize Starch	70
	Crude Oil - Diesel for HSA Drill Rig and Gasoline for Light Truck	15
Smog	HSA Drill Rig operation	28
	Cement and Bituminous Coal - Grout	17
	GAC Production - GAC Vessels	14

Alternative 1 – ReCiPe 2008
Characterization

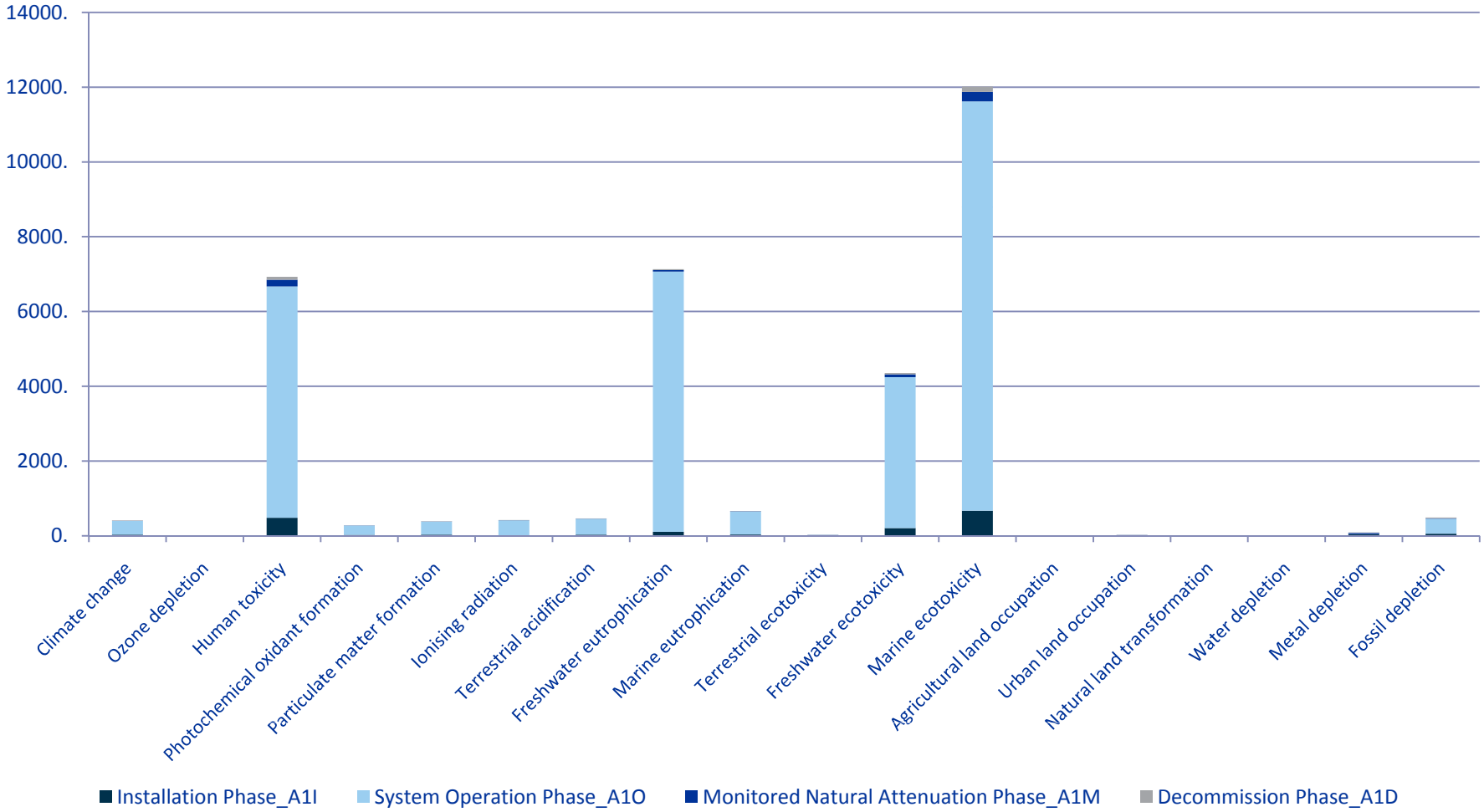


Alternative 1
ReCiPe 2008 Impact Contribution by Phase
Life Cycle Percentage Values of 30 Years

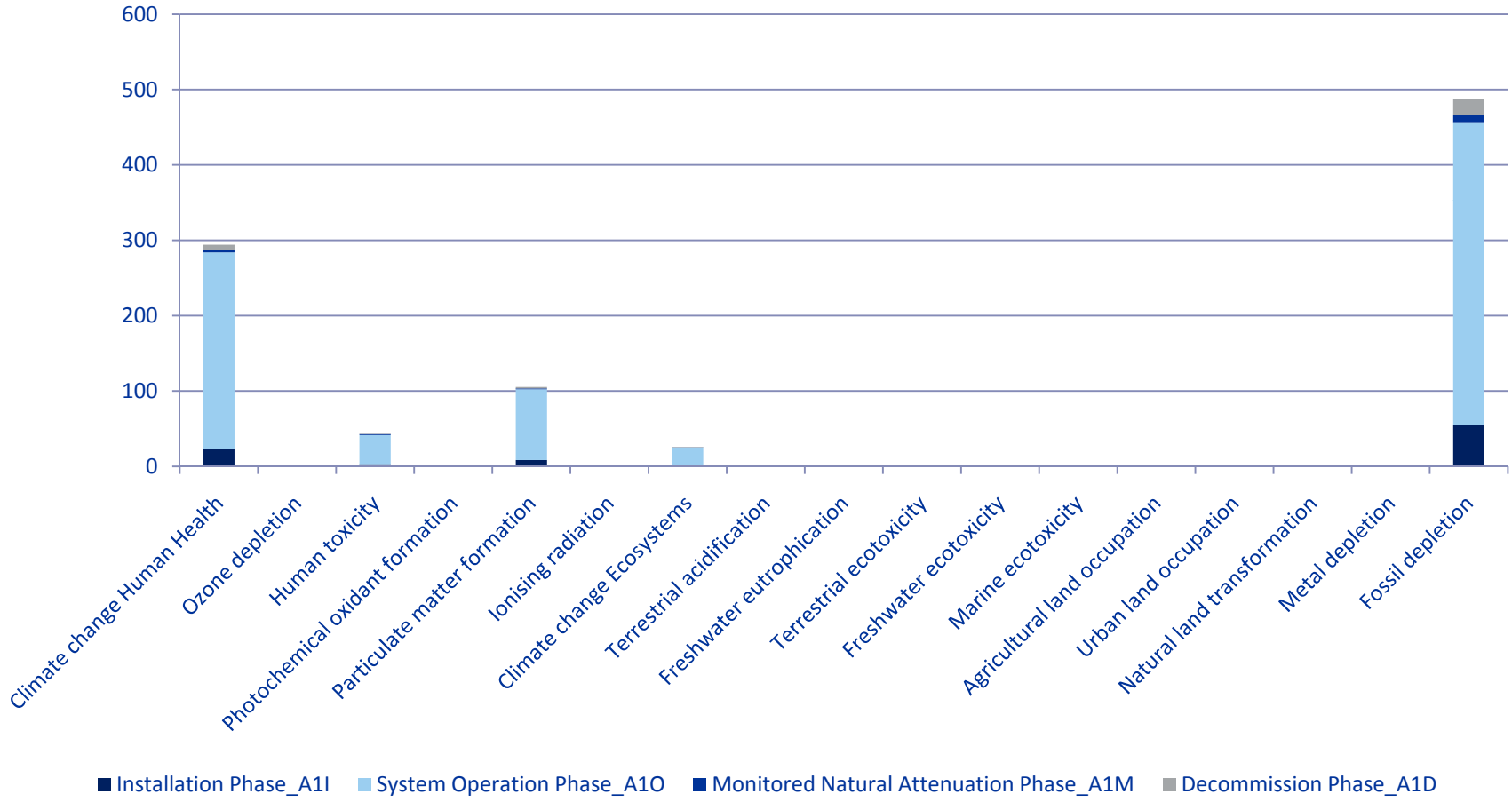
Impact Category	Installation Phase	Operation Phase	MNA* Phase	Decommission Phase
Climate change	7.6%	89.0%	1.2%	2.2%
Ozone depletion	16.1%	69.9%	0.4%	13.6%
Human toxicity	6.9%	89.4%	2.6%	1.1%
Photochemical oxidant formation	8.1%	89.0%	1.0%	1.9%
Particulate matter formation	8.1%	89.1%	1.2%	1.7%
Ionizing radiation	2.4%	96.2%	0.2%	1.1%
Terrestrial acidification	6.4%	91.8%	0.7%	1.1%
Freshwater eutrophication	1.5%	97.6%	0.6%	0.4%
Marine eutrophication	5.1%	93.2%	0.7%	1.1%
Terrestrial ecotoxicity	8.1%	85.5%	0.8%	5.7%
Freshwater ecotoxicity	4.7%	92.7%	1.8%	0.8%
Marine ecotoxicity	5.6%	91.1%	2.1%	1.2%
Agricultural land occupation	34.9%	42.5%	0.9%	21.7%
Urban land occupation	4.3%	94.4%	0.4%	0.9%
Natural land transformation	26.8%	70.0%	0.2%	3.0%
Water depletion	25.6%	68.1%	1.1%	5.1%
Metal depletion	41.4%	11.2%	36.8%	10.5%
Fossil depletion	11.3%	82.4%	1.9%	4.5%

*MNA = Monitored Natural Attenuation
= Phase driving environmental impacts based

Alternative 1 – ReCiPe 2008
Normalization Midpoint



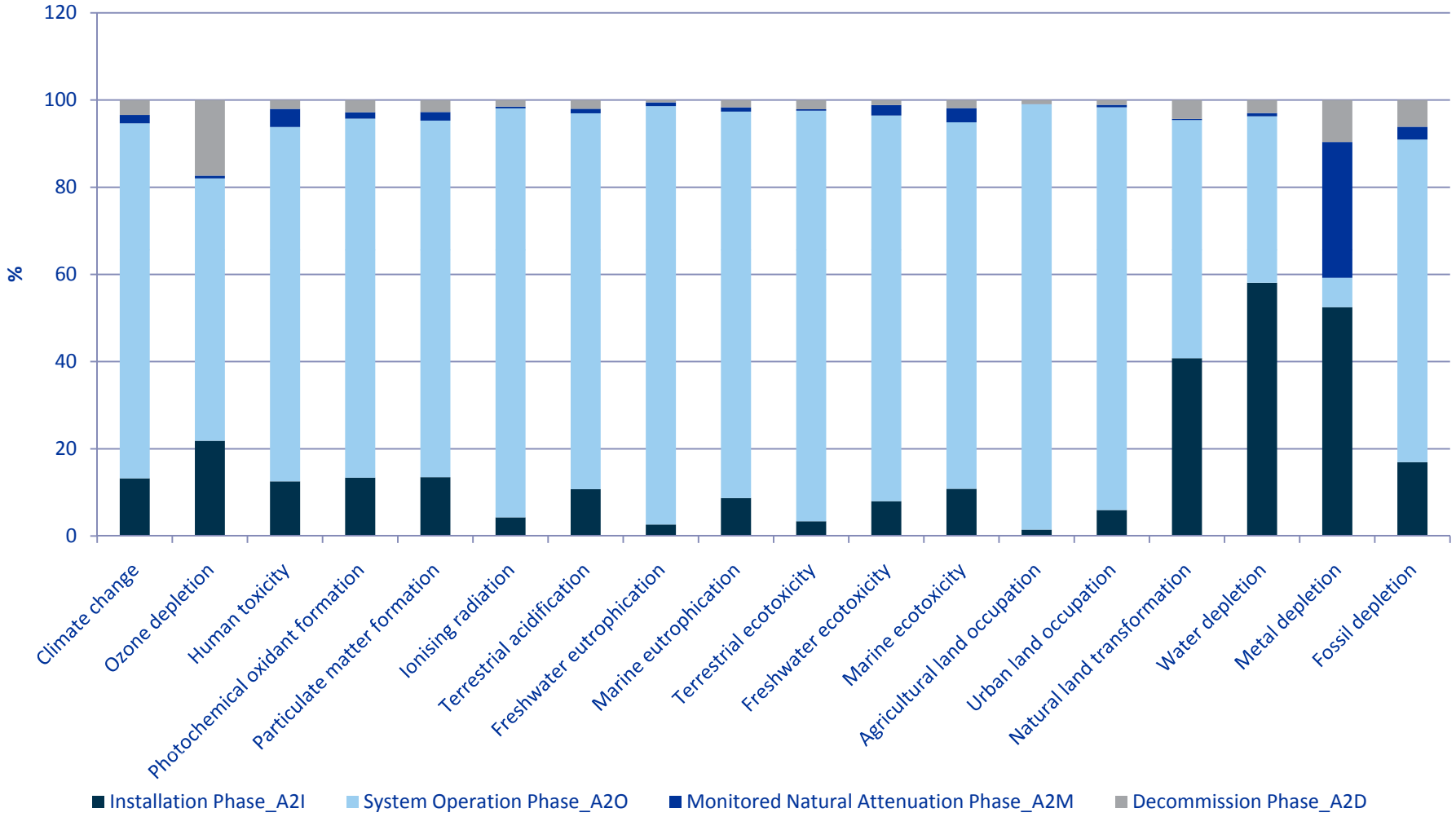
Alternative 1 – ReCiPe 2008
Normalization Endpoint



Alternative 1
ReCiPe 2008 Relevant Process Contribution
Life Cycle Percentage Values of 30 Years for relevant impact categories

Impact Category	Relevant Process Contributions	% Contribution
Climate Change	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	54
	GAC Production - Input to GAC Vessels	23
Human Toxicity	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	75
	Crude Oil - Diesel and Gasoline Production for On-Road Truck and Light Truck	15
Freshwater Eutrophication	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	99
Marine Eutrophication	GAC Production - GAC Vessels	52
	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	17
	Coagulant - LP Treatment	16
Freshwater Ecotoxicity	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	91
Marine Ecotoxicity	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	89
	Crude Oil - Diesel and Gasoline Production for On-Road Truck and Light Truck	5
Fossil Depletion	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	69
	Crude Oil - Diesel and Gasoline Production for On-Road Truck and Light Truck and Asphalt	24
Particulate Matter Formation	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	41
	GAC Production - GAC Vessels	34
	On-Road Truck (Diesel)	7

Alternative 2 – ReCiPe 2008
Characterization

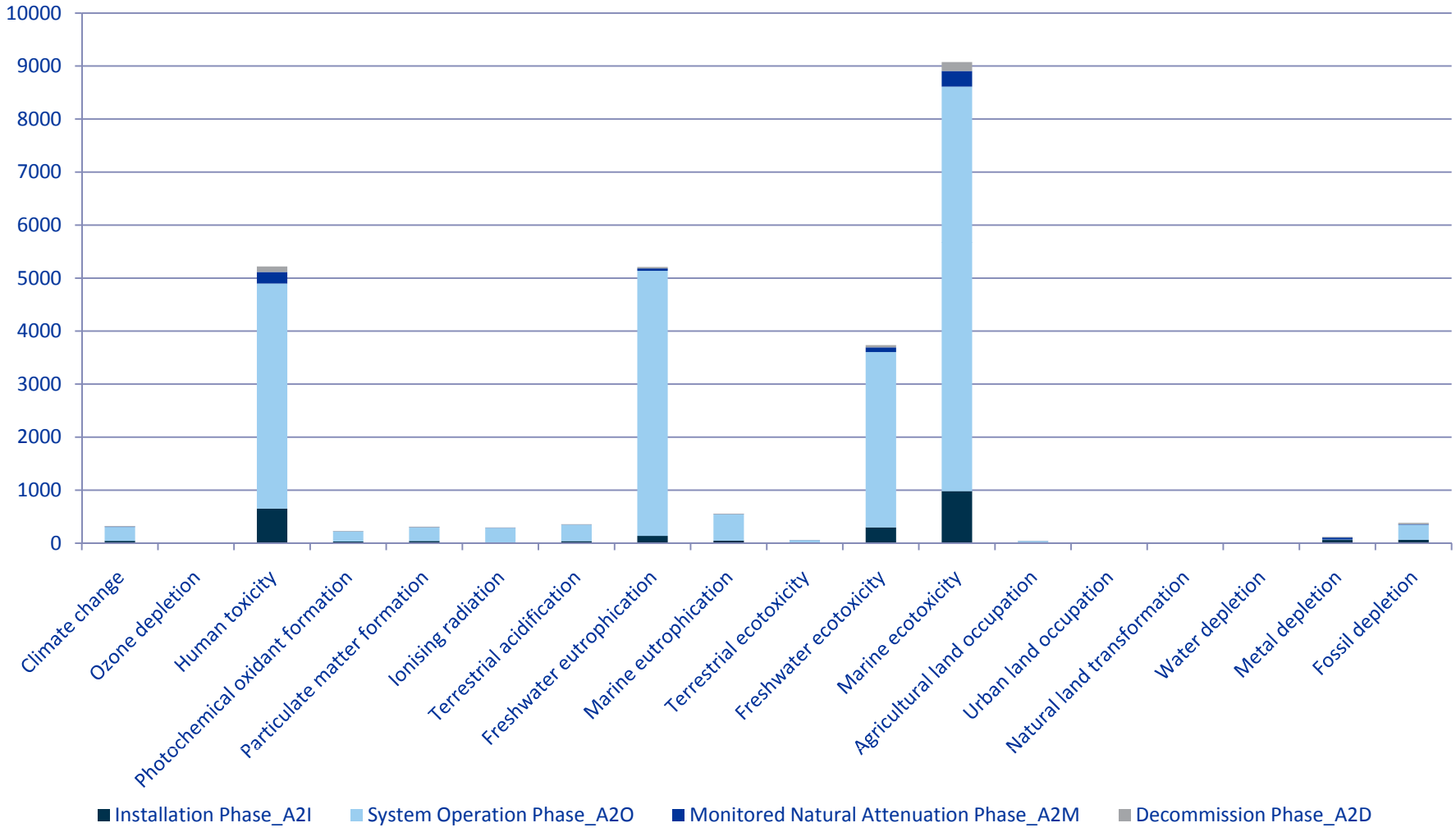


Alternative 2
ReCiPe 2008 Impact Contribution by Phase
Life Cycle Percentage Values of 30 Years

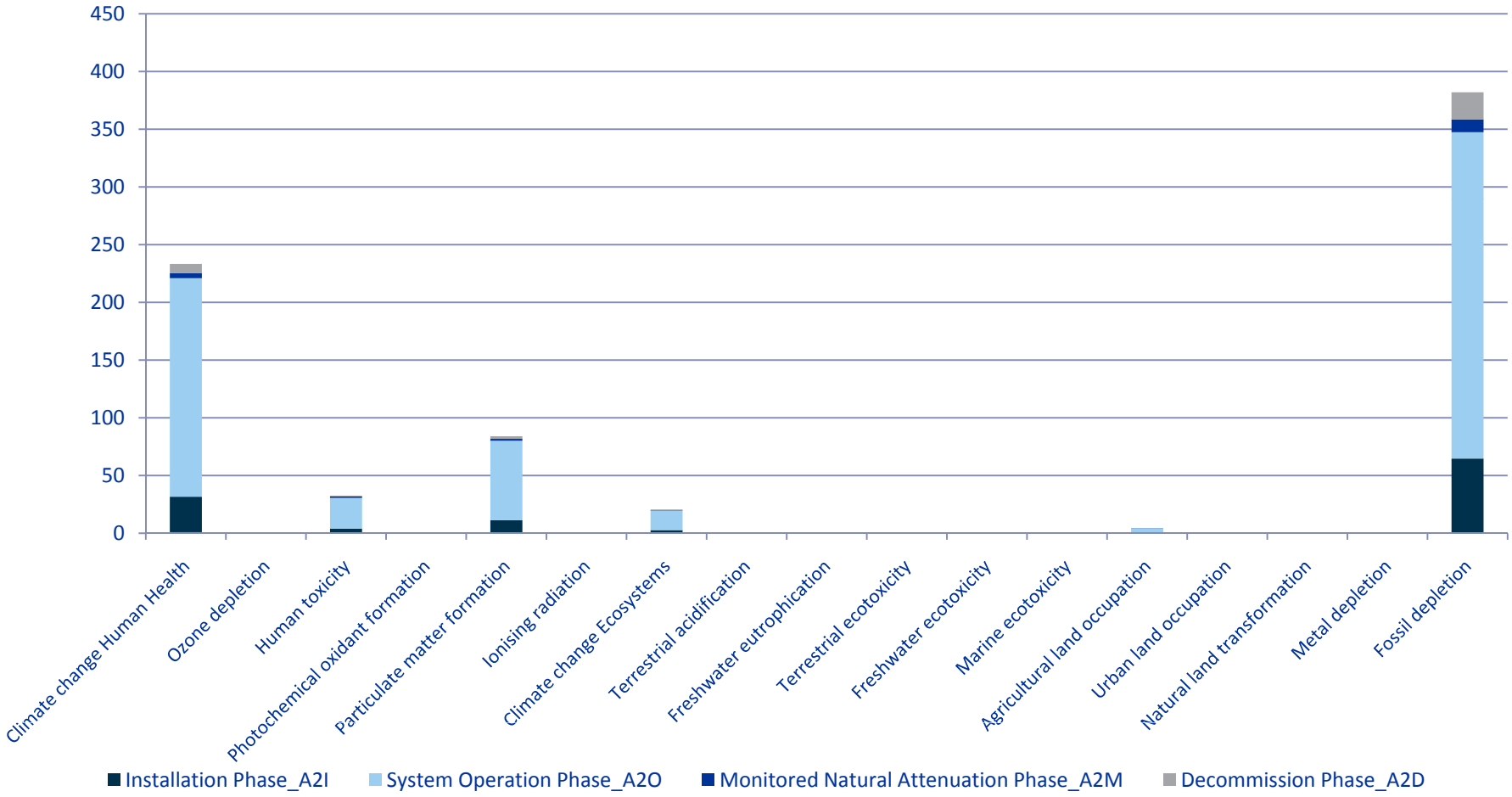
Impact Category	Installation Phase	Operation Phase	MNA* Phase	Decommission Phase
Climate change	13.2%	81.4%	1.9%	3.4%
Ozone depletion	21.8%	60.2%	0.6%	17.3%
Human toxicity	12.5%	81.3%	4.2%	2.0%
Photochemical oxidant formation	13.4%	82.3%	1.5%	2.8%
Particulate matter formation	13.5%	81.8%	2.0%	2.8%
Ionizing radiation	4.3%	93.8%	0.4%	1.5%
Terrestrial acidification	10.7%	86.2%	1.1%	2.0%
Freshwater eutrophication	2.6%	96.0%	0.9%	0.5%
Marine eutrophication	8.7%	88.6%	1.0%	1.7%
Terrestrial ecotoxicity	3.4%	94.2%	0.3%	2.1%
Freshwater ecotoxicity	8.0%	88.5%	2.4%	1.1%
Marine ecotoxicity	10.8%	84.1%	3.3%	1.8%
Agricultural land occupation	1.5%	97.6%	0.0%	0.9%
Urban land occupation	6.0%	92.4%	0.6%	1.1%
Natural land transformation	40.8%	54.6%	0.3%	4.3%
Water depletion	58.1%	38.2%	0.7%	3.0%
Metal depletion	52.5%	6.8%	31.1%	9.6%
Fossil depletion	17.0%	74.0%	2.9%	6.1%

*MNA = Monitored Natural Attenuation
= Phase driving environmental impacts based

Alternative 2 – ReCiPe 2008
Normalization Midpoint



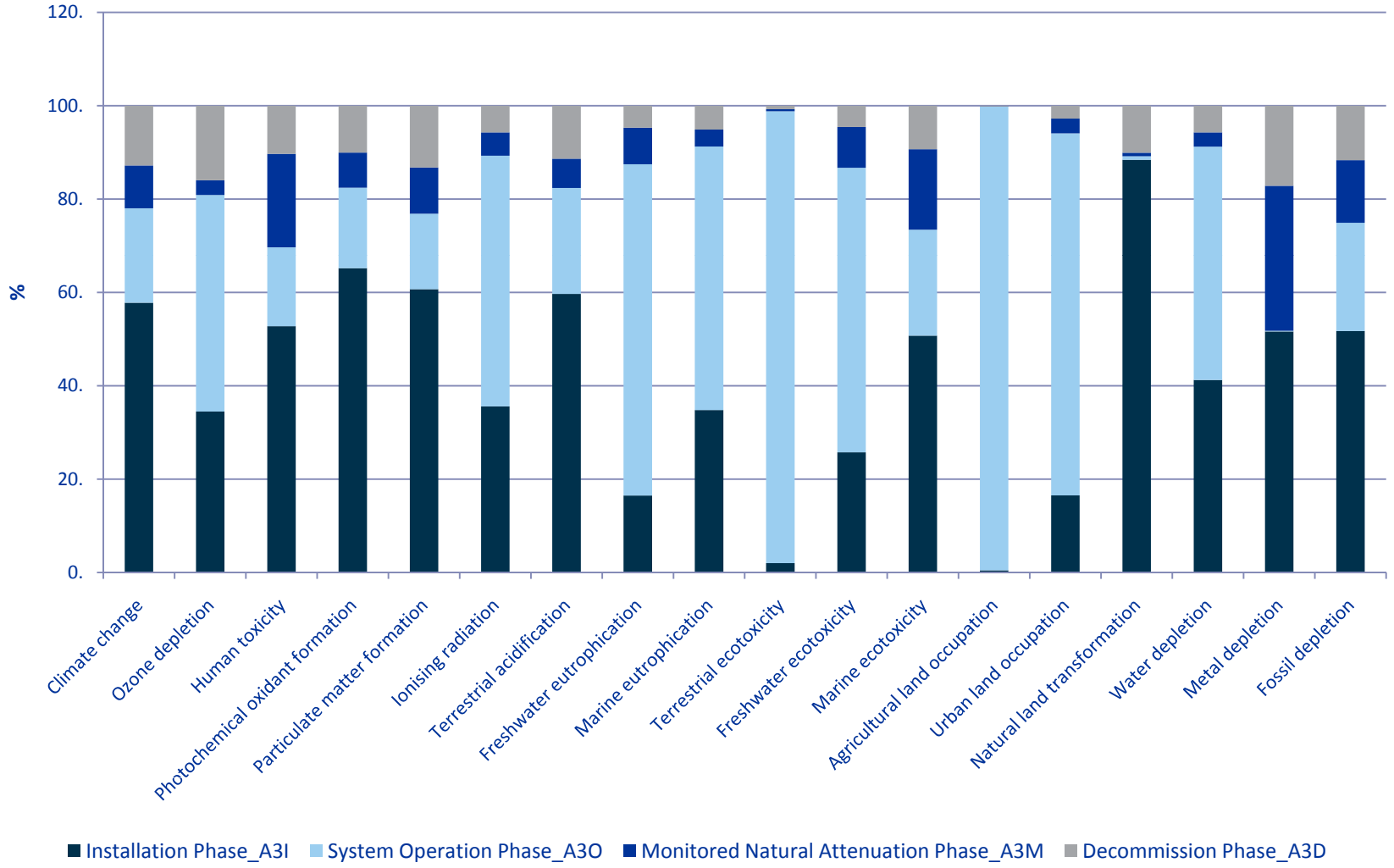
Alternative 2 – ReCiPe 2008
Normalization Endpoint



Alternative 2
ReCiPe 2008 Relevant Process Contribution
Life Cycle Percentage Values of 30 Years

Impact Category	Relevant Process Contributions	% Contribution
Climate Change	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	47
	GAC Production - GAC Vessels	22
Human Toxicity	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	69
	Crude Oil - Diesel and Gasoline Production for On-Road Truck and Light Truck	21
Freshwater Eutrophication	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	94
Marine Eutrophication	GAC Production - GAC Vessels	48
	LactOil	13
	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	15
	Coagulant - LP Treatment	5
Freshwater Ecotoxicity	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	71
	LactOil	14
	Crude Oil - Diesel and Gasoline Production for On-Road Truck and Light Truck	5
	Disposal of Steel for Wellhead	5
Marine Ecotoxicity	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	79
	Crude Oil - Diesel and Gasoline Production for On-Road Truck and Light Truck	7
	Disposal of Steel for Wellhead	6
Particulate Matter Formation	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	34
	GAC Production - GAC Vessels	33
	On-Road Truck (Diesel)	7
Fossil Depletion	Electricity - SVE Vacuum System, Sump Pumps and Air Stripper	57
	Crude Oil - Diesel and Gasoline Production for On-Road Truck and Light Truck	15
	Crude Oil for Asphalt	15

Alternative 3 – ReCiPe 2008
Characterization



Alternative 3 – ReCiPe Impact Contribution Percentages By Phase

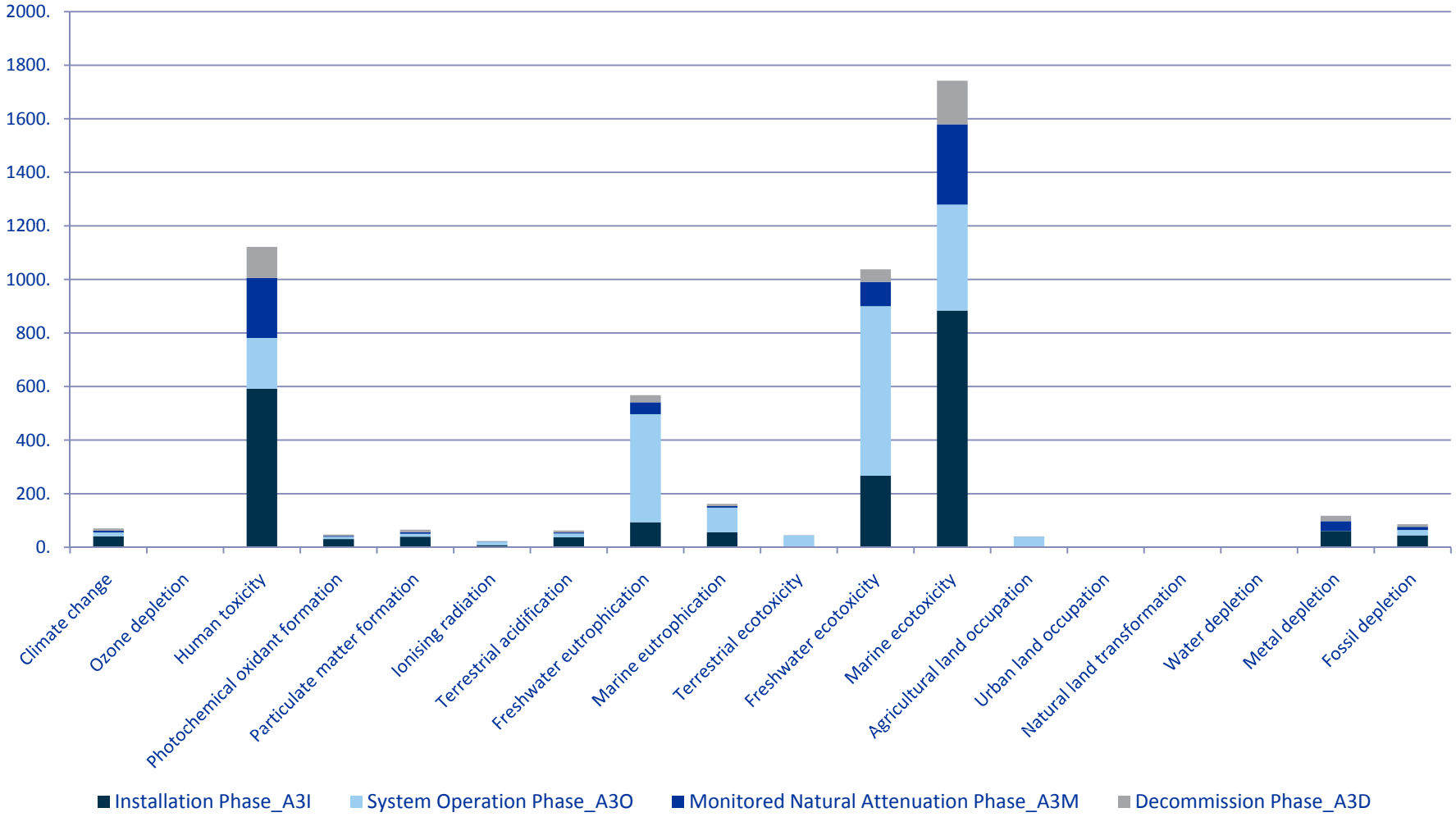
Life Cycle Percentage Values of 30 Years

Impact Category	Installation Phase	Operation Phase	MNA* Phase	Decommission Phase
Climate change	57.8%	20.3%	9.2%	12.8%
Ozone depletion	34.5%	46.4%	3.2%	16.0%
Human toxicity	52.8%	16.9%	20.0%	10.3%
Photochemical oxidant formation	65.2%	17.2%	7.5%	10.0%
Particulate matter formation	60.7%	16.2%	9.9%	13.2%
Ionizing radiation	35.6%	53.7%	5.0%	5.7%
Terrestrial acidification	59.7%	22.7%	6.3%	11.3%
Freshwater eutrophication	16.5%	71.0%	7.9%	4.7%
Marine eutrophication	34.8%	56.5%	3.6%	5.1%
Terrestrial ecotoxicity	2.0%	96.8%	0.4%	0.8%
Freshwater ecotoxicity	25.7%	61.0%	8.7%	4.6%
Marine ecotoxicity	50.7%	22.7%	17.2%	9.3%
Agricultural land occupation	0.5%	99.3%	0.0%	0.2%
Urban land occupation	16.5%	77.6%	3.2%	2.8%
Natural land transformation	88.4%	0.8%	0.8%	10.1%
Water depletion	41.2%	50.0%	3.0%	5.7%
Metal depletion	51.6%	0.1%	31.1%	17.2%
Fossil depletion	51.7%	23.2%	13.4%	11.7%

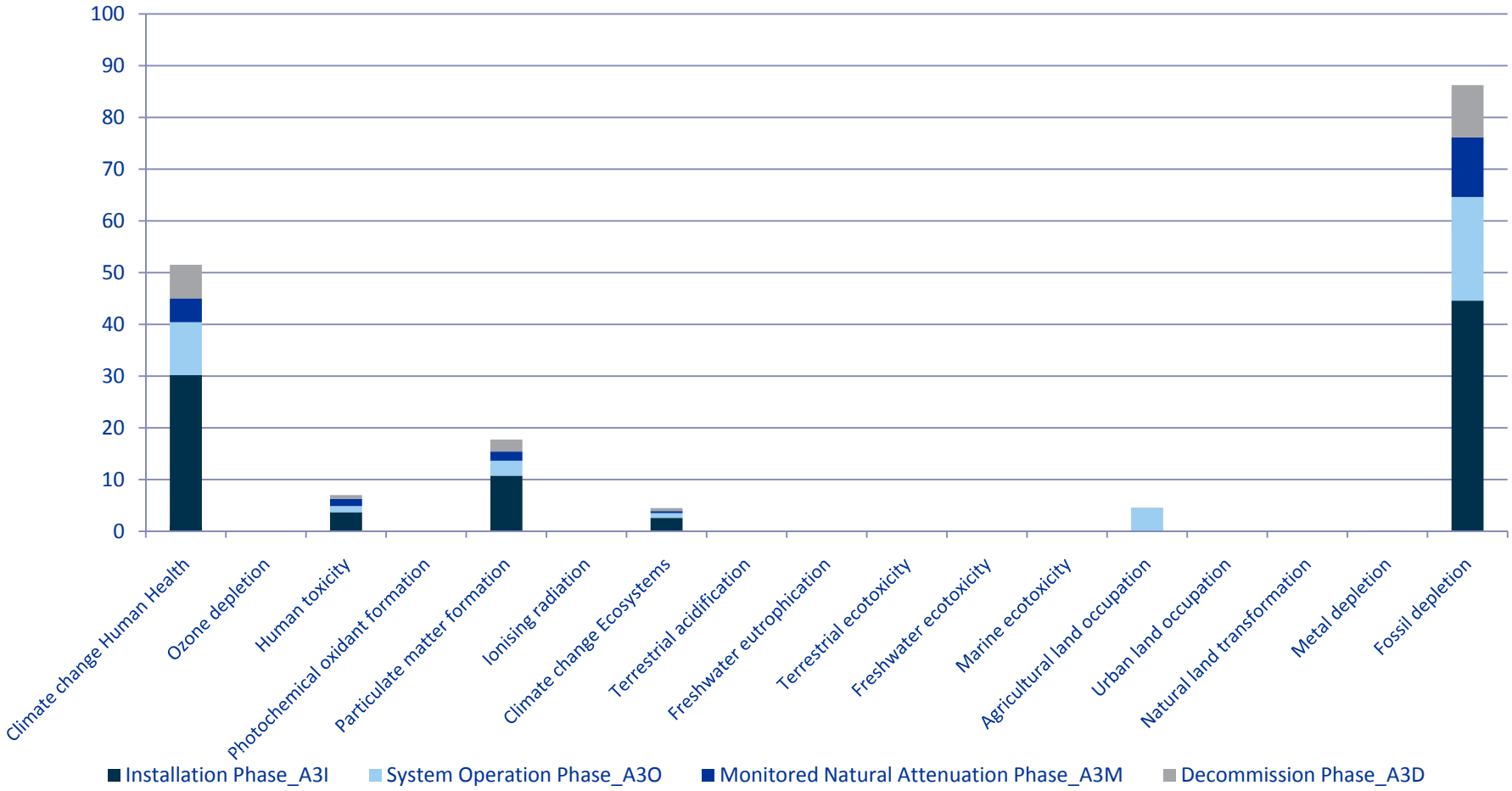
*MNA = Monitored Natural Attenuation

= Phase driving environmental impacts based

Alternative 3 – ReCiPe 2008
Normalization Midpoint



Alternative 3 – ReCiPe 2008
Normalization Endpoint



Alternative 3
ReCiPe 2008 Relevant Process Contribution
Life Cycle Percentage Values of 30 Years

Impact Category	Relevant Process Contributions	% Contribution
Climate Change	Cement - Grout	18
	HSA Drill Rig	10
	Bituminous Coal - Cement	9
	Light Truck (Gasoline)	7
	Concrete - Well Construction	6
	Electricity - LactOil Production	6
	GAC Production - GAC Vessels	5
Human Toxicity	Crude Oil - Diesel and Gasoline Production for HSA Drill Rig, Generator, Backhoe, On-Road Truck, and Light Truck	66
	Electricity - LactOil Production	13
	VOAS Manufacture	5
	Steel - Wellheads and Decon Water Drums	5
Freshwater Eutrophication	LactOil	44
	Electricity - LactOil Production	34
	VOAS Manufacture	16
Marine Eutrophication	LactOil	49
	HSA Drill Rig	14
	GAC Production - GAC Vessels	8
	Cement - Grout	6
Freshwater Ecotoxicity	LactOil	52
	Steel - Wellheads and Decon Water Drums	19
	Crude Oil - HSA Drill Rig, Generator, Backhoe and On-Road Truck	13
	Electricity - LactOil Production	7

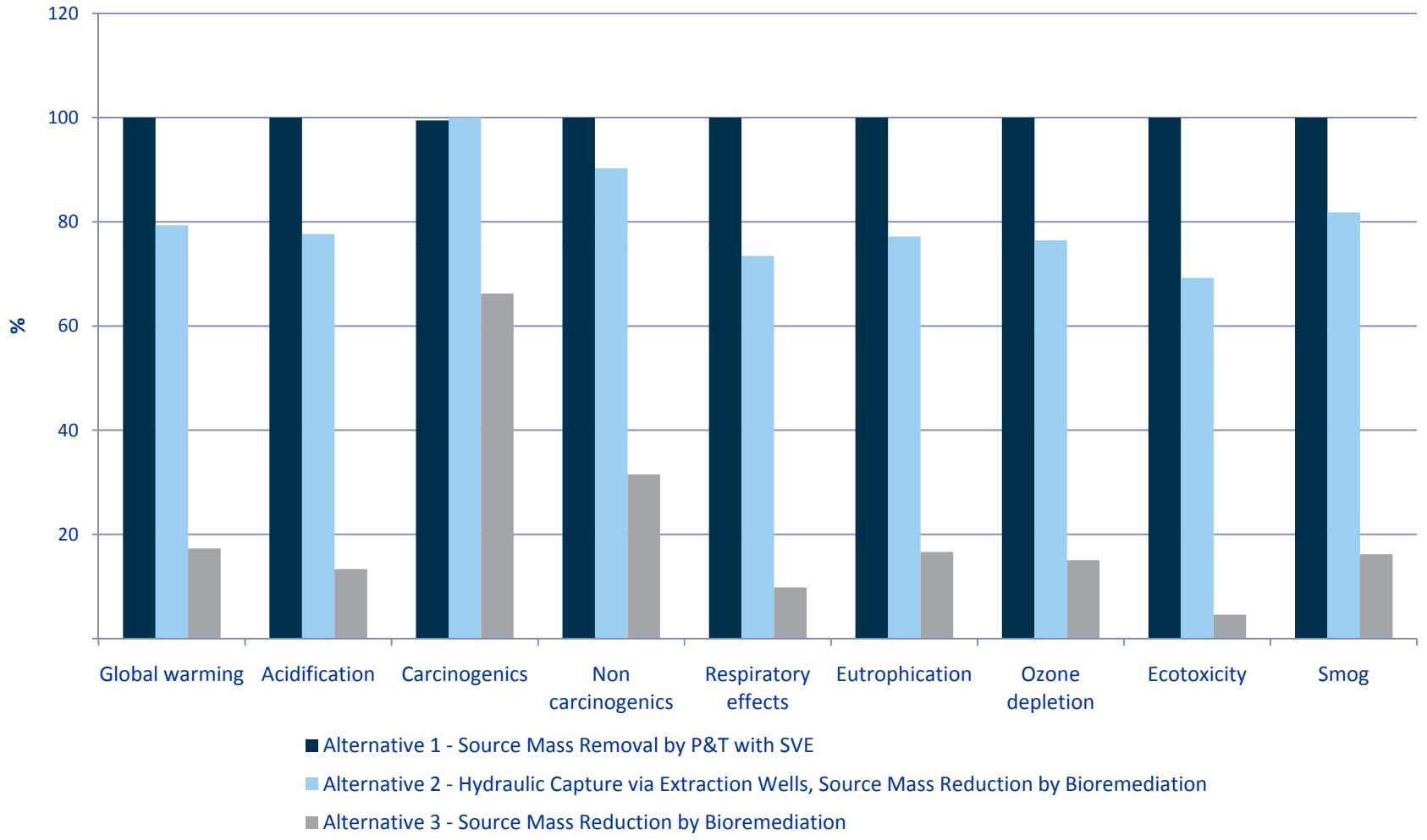
Alternative 3
ReCiPe 2008 Relevant Process Contribution
Life Cycle Percentage Values of 30 Years

Impact Category	Relevant Process Contributions	% Contribution
Marine Ecotoxicity	Steel - Wellheads and Decon Water Drums	38
	Crude Oil - HSA Drill Rig, Heavy Duty Truck, Generator, On-Road Truck and Light Truck	26
	Electricity - LactOil Production	14
	LactOil	7
	VOAS Manufacture	6
Particulate Matter Formation	HSA Drill Rig	16
	Cement - Grout	12
	Bituminous Coal - Cement	10
	On-Road Truck (Diesel)	8
	GAC Production - GAC Vessels	7
	Steel - Wellheads and Decon Water Drums	6
	Diesel Production	5
Fossil Depletion	Crude Oil - Diesel and Gasoline Production for HSA Drill Rig, Generator, Backhoe, On-Road Truck, Light Truck and Asphalt	58

Alternatives Comparison

- Bar heights in the comparison of each alternative represent the relative contribution of each alternative to each impact category, based on the alternative with the highest impact
- Alternative 1 most consistently reports the greatest impacts, therefore, Alternatives 2 and 3 are expressed relative to Alternative 1

LCIA: Comparison of Three Alternatives Using TRACI

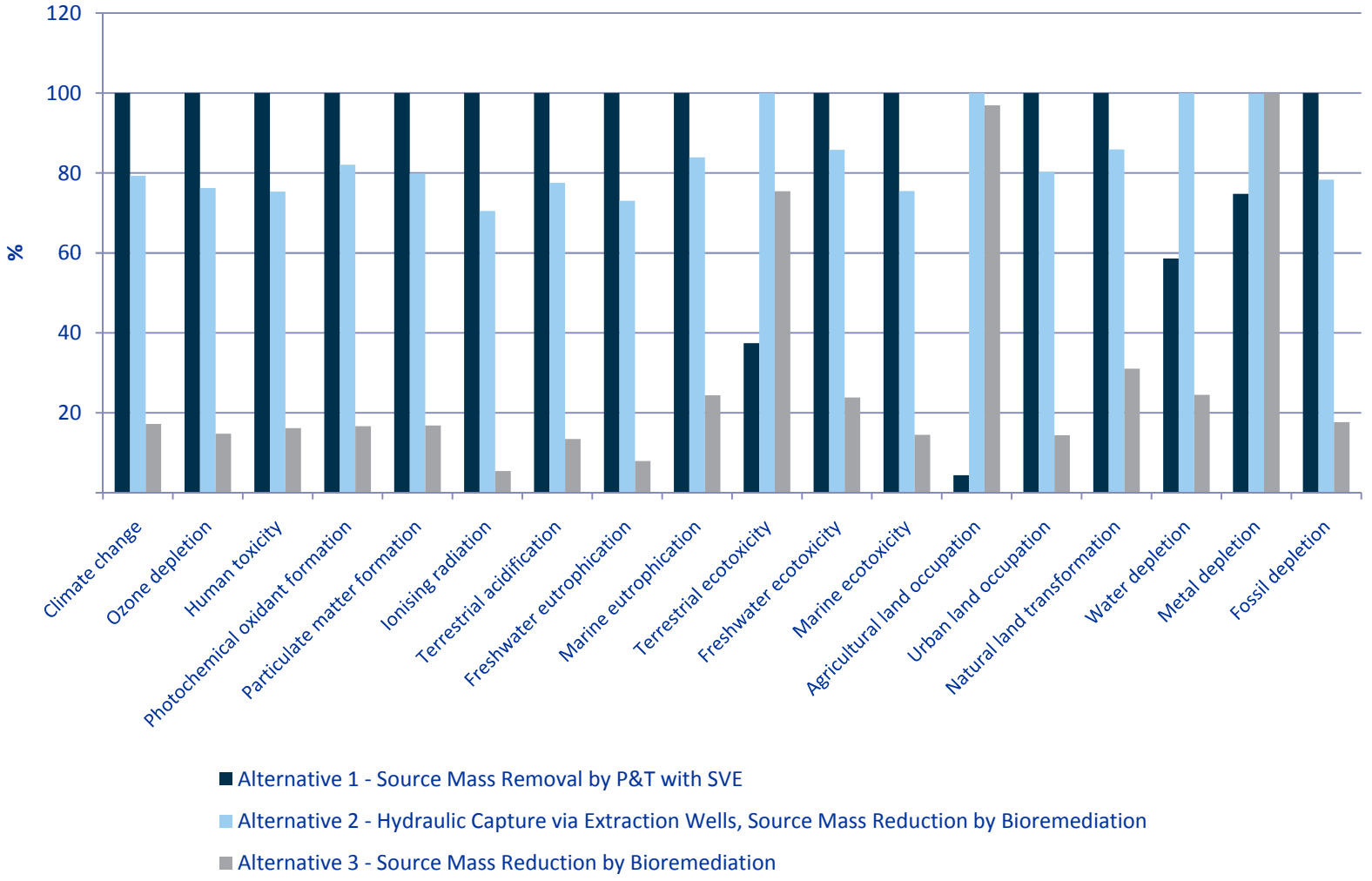


TRACI Methodology

Life Cycle Values Over 30 Years

Impact Category	Unit	Alternative 1	Alternative 2	Alternative 3
Global warming	metric tons CO_2 eq	2,801.12	2,222.88	484.64
Acidification	H+ moles eq	1,051.18	816.44	140.03
Carcinogenics	metric tons benzene eq	5.62	5.65	3.74
Non carcinogenics	metric tons toluene eq	43,129.79	38,931.07	13,588.20
Respiratory effects	metric tons PM2.5 eq	3.99	2.93	0.39
Eutrophication	metric tons N eq	8.24	6.36	1.37
Ozone depletion	metric tons CFC-11 eq	0.00010	0.00007	0.00001
Ecotoxicity	metric tons 2,4-D eq	4,845.33	3,354.35	222.80
Smog	metric tons NOx eq	0.012	0.010	0.002

LCIA: Comparison of Three Alternatives Using ReCiPe



ReCiPe 2008 Midpoint Characterization Results

Life Cycle Values Over 30 Years

Impact Category	Unit	Alternative 1	Alternative 2	Alternative 3
Climate change	metric tons CO2 eq	2,805.89	2,225.49	483.61
Ozone depletion	metric tons CFC-11 eq	0.00010	0.00007	0.00001
Human toxicity	metric tons 1,4-DCB eq	829.53	625.13	134.31
Photochemical oxidant formation	metric tons NMVOC	14.00	11.48	2.33
Particulate matter formation	metric tons PM10 eq	5.43	4.34	0.91
Ionizing radiation	metric tons U235 eq	547.52	385.99	29.77
Terrestrial acidification	metric tons SO2 eq	17.55	13.61	2.36
Freshwater eutrophication	metric tons P eq	0.90	0.66	0.07
Marine eutrophication	metric tons N eq	5.92	4.97	1.45
Terrestrial ecotoxicity	metric tons 1,4-DCB eq	0.14	0.38	0.28
Freshwater ecotoxicity	metric tons 1,4-DCB eq	18.53	15.90	4.42
Marine ecotoxicity	metric tons 1,4-DCB eq	15.90	12.00	2.30
Agricultural land occupation	ha a	0.95	21.55	20.89
Urban land occupation	ha a	1.14	0.91	0.16
Natural land transformation	acres	0.013	0.011	0.004
Water depletion	cu ft	272,110.09	464,165.13	113,725.76
Metal depletion	metric tons Fe eq	38.87	51.88	51.98
Fossil depletion	metric tons oil eq	665.47	521.45	117.70

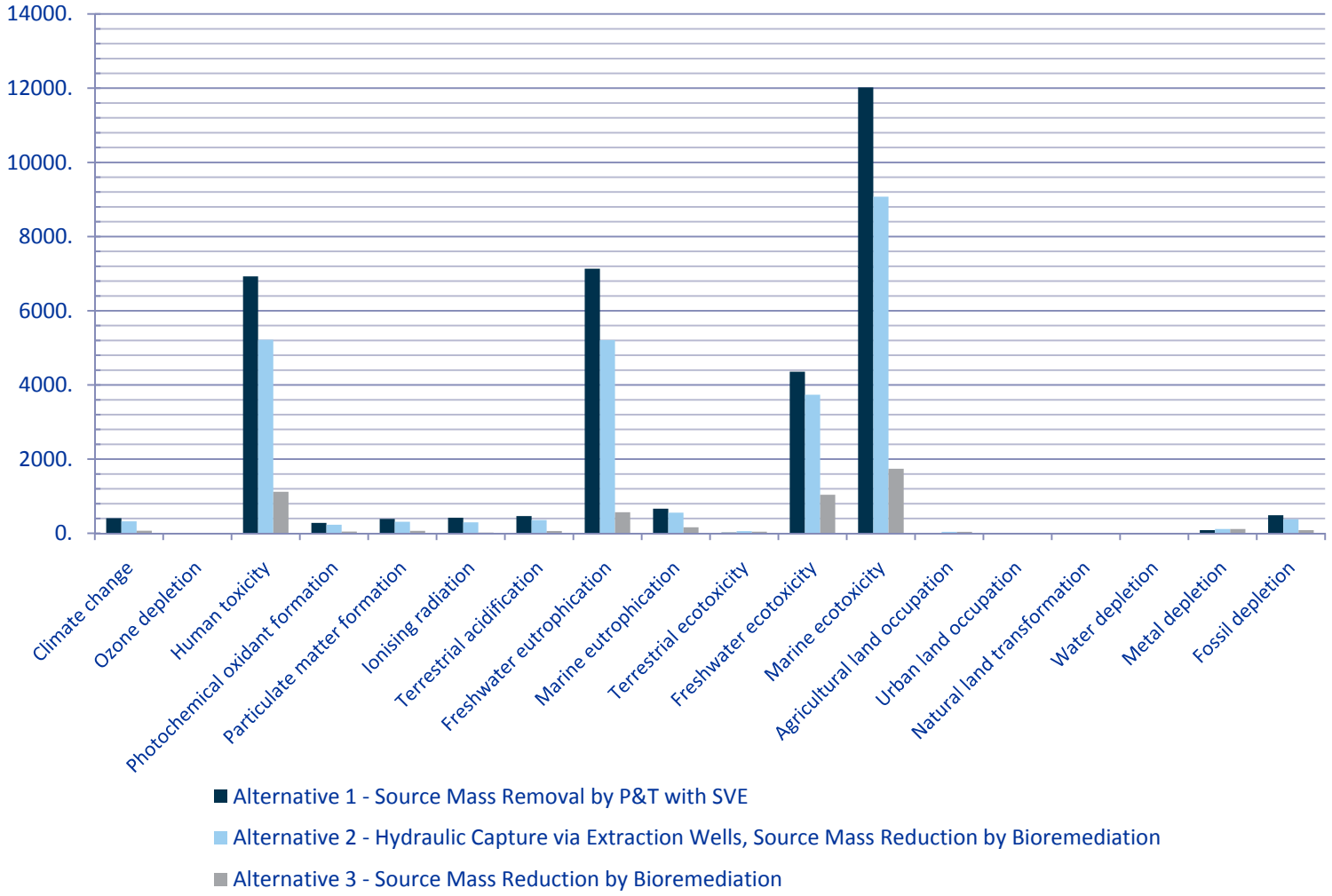
Midpoint and Endpoint Normalization Comparison

Differences between midpoint and endpoint normalization:

- Midpoint focuses on the environmental mechanism causing the impact
- Endpoint aggregates impacts to determine overall damage to human health, ecosystem diversity and resource availability
- Following graphs display the normalized results using midpoint and endpoint indicators

Alternatives Comparison ReCiPe 2008:

Midpoint Normalization

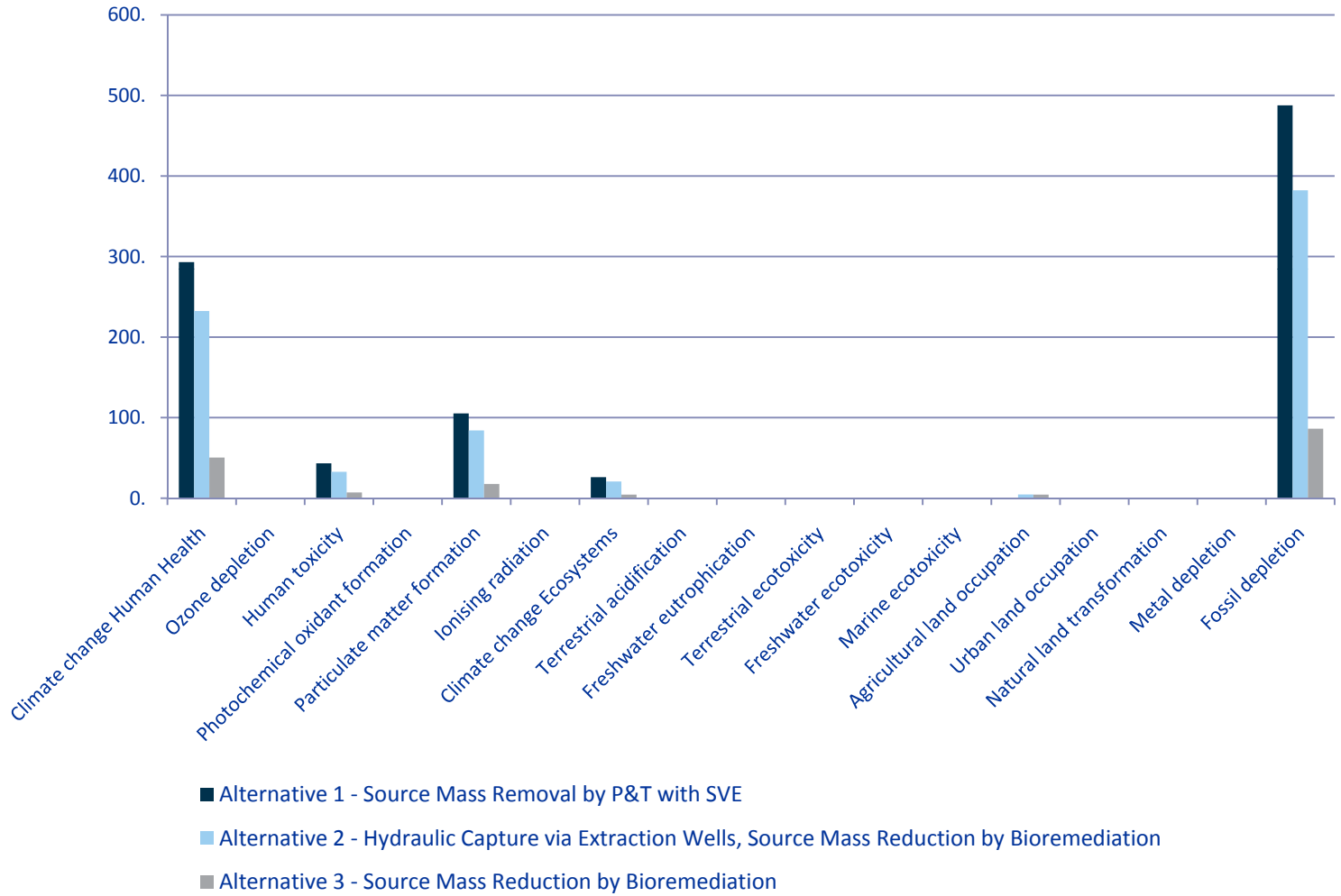


Alternatives Comparison ReCiPe 2008:
Midpoint Normalization

- Most relevant impacts at the midpoint level:
  - ***Marine Ecotoxicity***: driven primarily by upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2; and by steel production for wellheads and decon water drums as well as crude oil (diesel) production for heavy equipment (drill rig) and vehicles for Alternative 3
  - ***Human Toxicity***: driven primarily by upstream impacts of electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2; and by crude oil production for heavy equipment (drill rig) and vehicles for Alternative 3
  - ***Freshwater Eutrophication***: driven primarily by upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2; driven primarily by LactOil production for Alternative 3
  - ***Freshwater Ecotoxicity***: driven primarily by upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2; driven primarily by LactOil production for Alternative 3
  - ***Climate Change***: driven primarily by upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2 along with the production of virgin GAC; and by the production of grout and use of the HSA drill rig for Alternative 3
  - ***Fossil Depletion***: driven primarily by upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2 ; driven primarily by crude oil production for heavy equipment, vehicles and asphalt for Alternative 3

Alternatives Comparison ReCiPe 2008

Endpoint Normalization by Impact Category



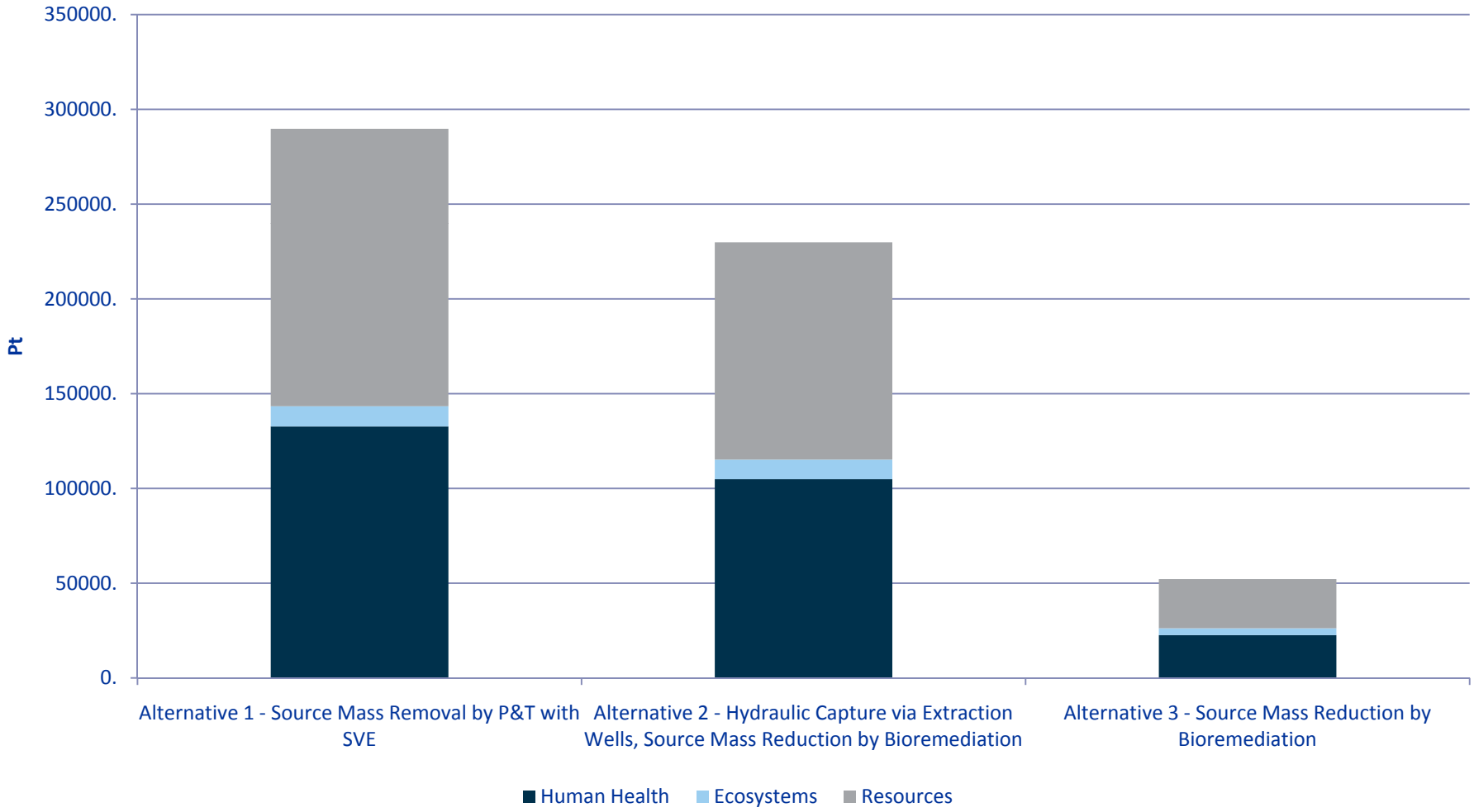
Alternatives Comparison ReCiPe 2008:
Endpoint Normalization

- Most relevant impacts at the endpoint level:
  - ***Climate Change Human Health***: driven primarily by upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2 as well as the production of virgin GAC; driven primarily by the production of grout and use of the HSA drill rig for Alternative 3
  - ***Human Toxicity***: driven primarily by upstream impacts of electricity generation associated with the SVE vacuum system, sump pumps and air stripper as well as crude oil production for gasoline and diesel used in the light trucks and on-road trucks for Alternatives 1 and 2; driven primarily by crude oil production for gasoline /diesel used in the light/on-road trucks for Alternative 3
  - ***Particulate Matter Formation***: driven primarily by production of virgin GAC upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2; driven primarily by the use of the HSA drill rig and production of grout for Alternative 3
  - ***Climate Change Ecosystems***: driven primarily by production of virgin GAC upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper for Alternatives 1 and 2; driven primarily by the production of grout and use of the HSA drill rig for Alternative 3
  - ***Fossil Fuel Depletion***: driven primarily by upstream activities related to electricity generation associated with the SVE vacuum system, sump pumps and air stripper as well as crude oil production for gasoline /diesel used in the light/on-road trucks for Alternatives 1 and 2; driven primarily by crude oil production for gasoline /diesel used in the light/on-road trucks for Alternative 3
  - ***Agricultural Land Occupation***: driven primarily by the production of LactOil for Alternatives 2 and 3

ReCiPe 2008 Results

Endpoint: Single Score

The use of the single score was developed so designers and engineers would have environmental information in a single format, it is intended for internal use only, especially for product or process development. Since it is based on value-choices (weighting) and not scientific data it is considered to add uncertainty to the results.

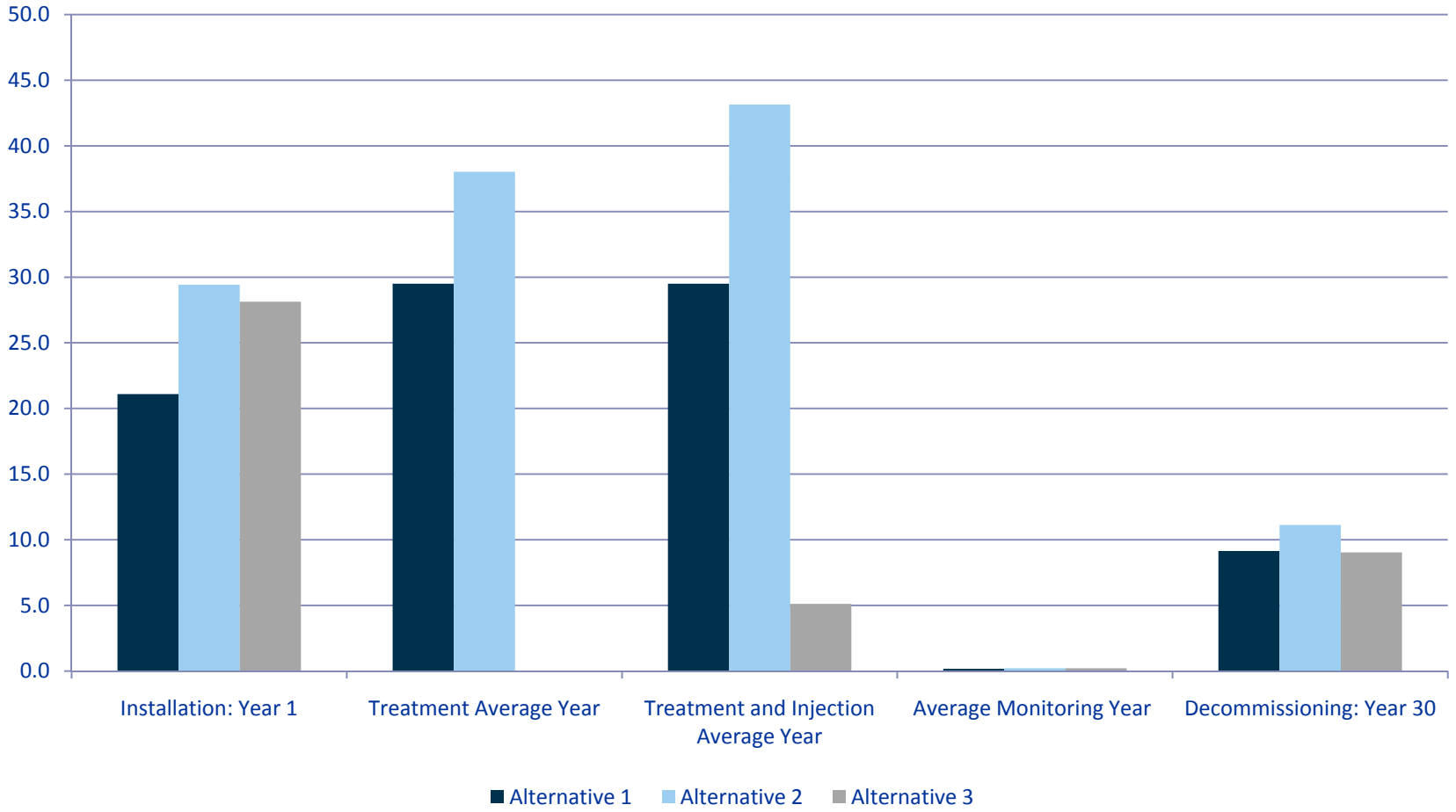


Interpretation

- Characterization values for the project full life cycle of 30 years
- Normalization issues:
  - Project life cycle 30 years
  - Normalization values based on reference values on a yearly basis
  - The normalization is overestimating impacts per category
- Disaggregated model to present relevant impacts for an average year
  - Average first year
  - Average operation year
  - Average injection + operation year
  - Average monitoring year
  - Average decommissioning year
- Generated a timeline for relevant impact indicators comparing normalized results:
  - Per year
  - Cumulative

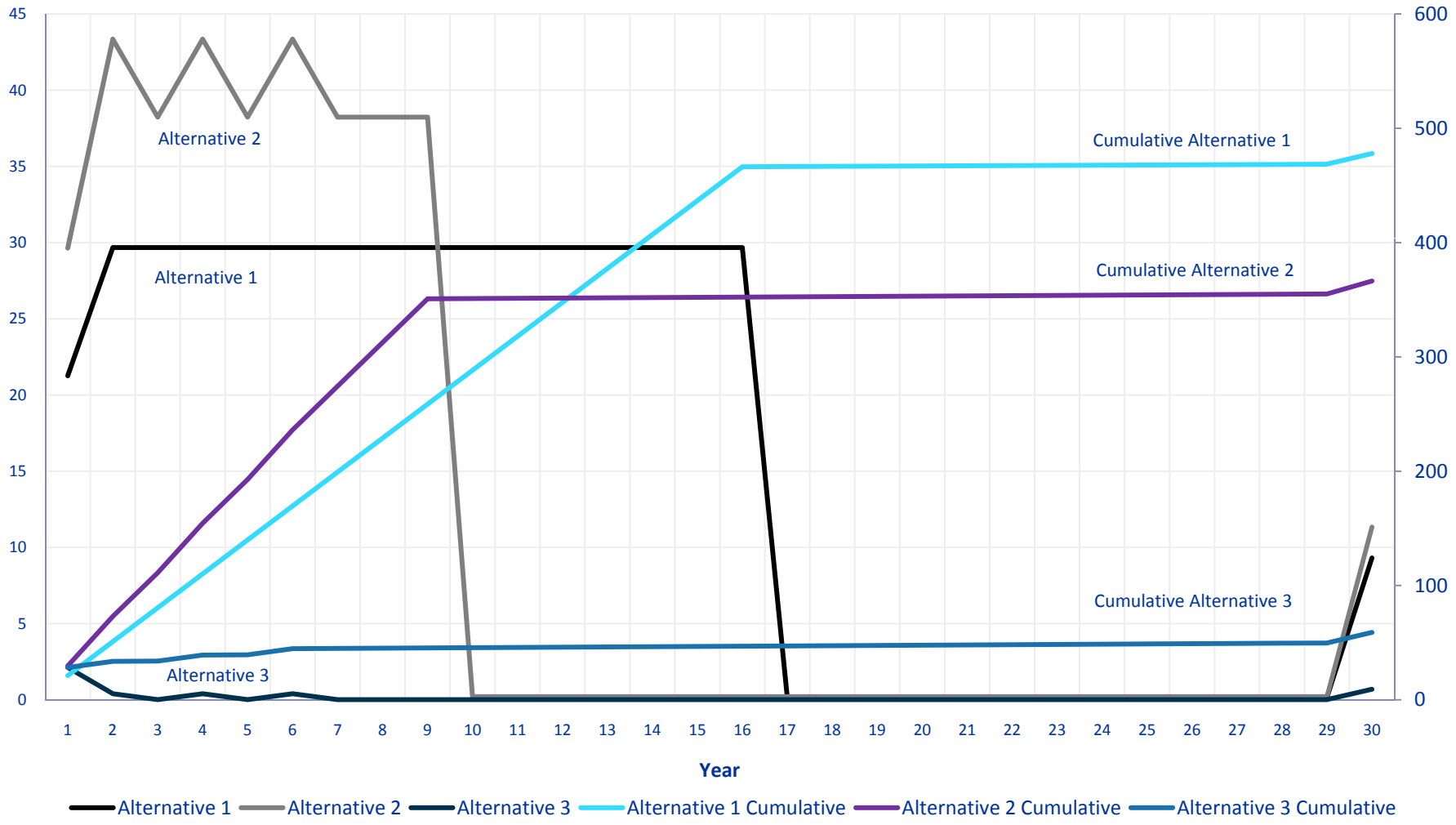
ReCiPe 2008 Climate Change

Midpoint normalization results by average year for each phase



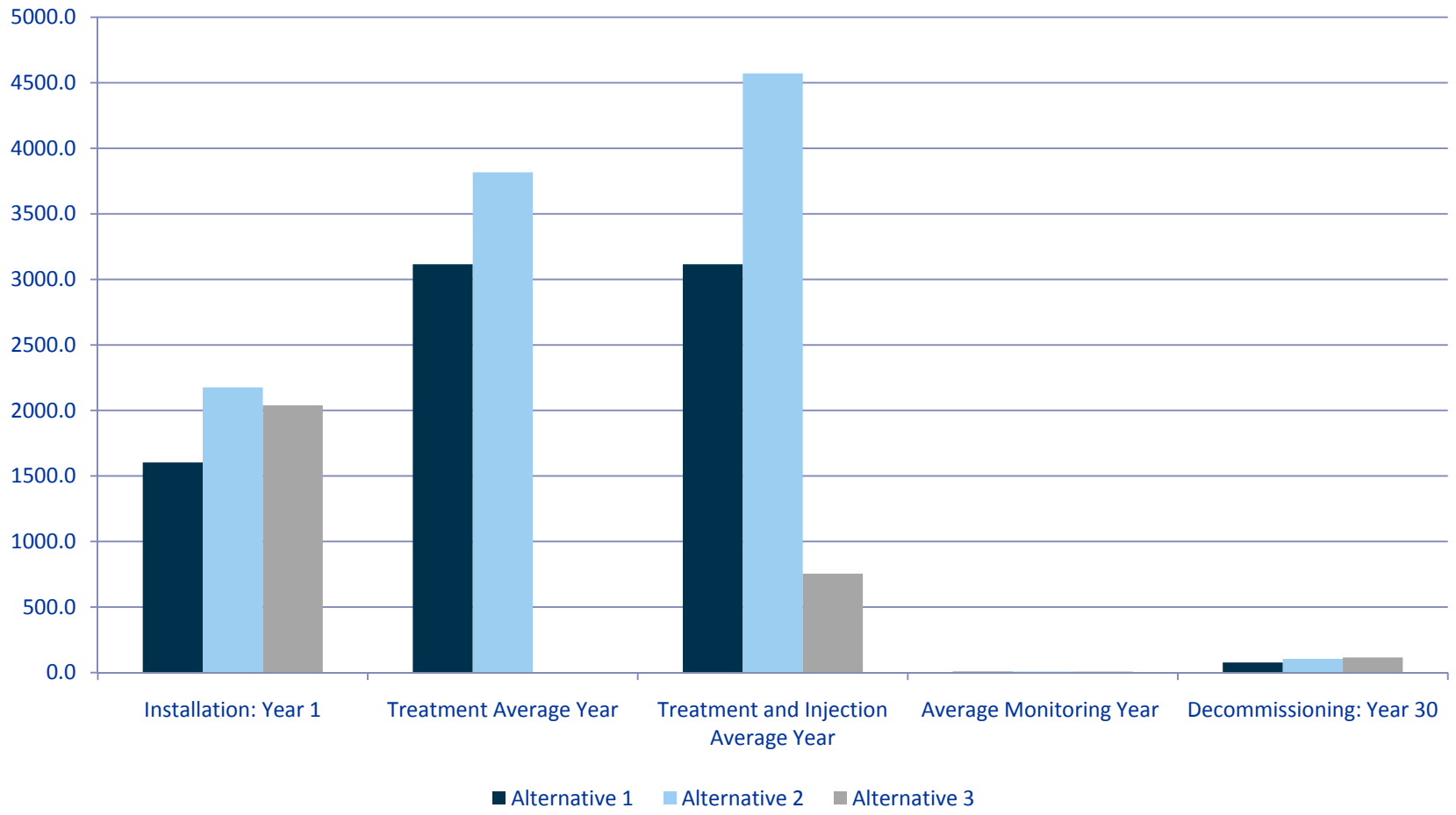
ReCiPe 2008 Climate Change

Midpoint normalization by year and cumulative



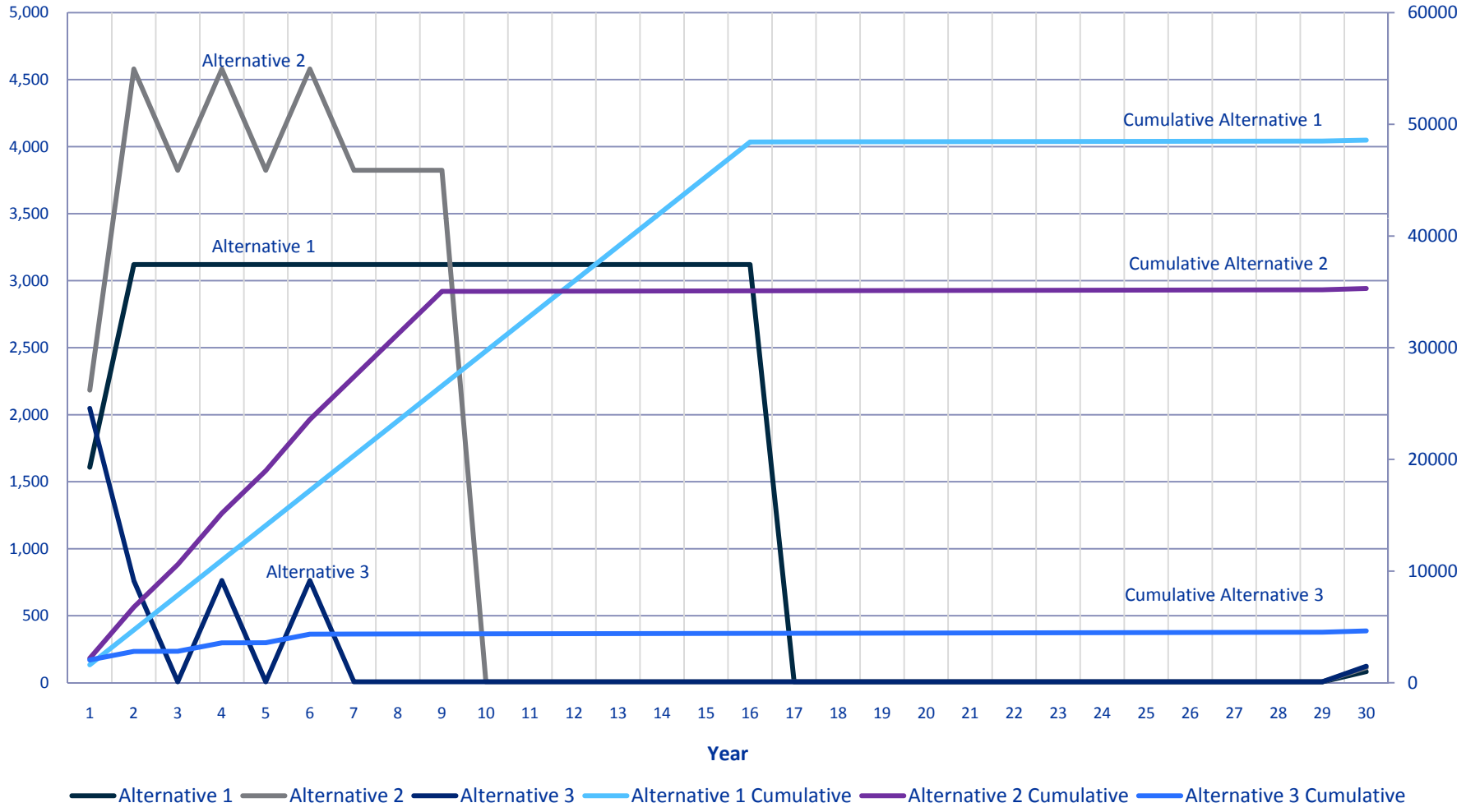
ReCiPe 2008 Human Toxicity

Midpoint normalization results by average year for each phase



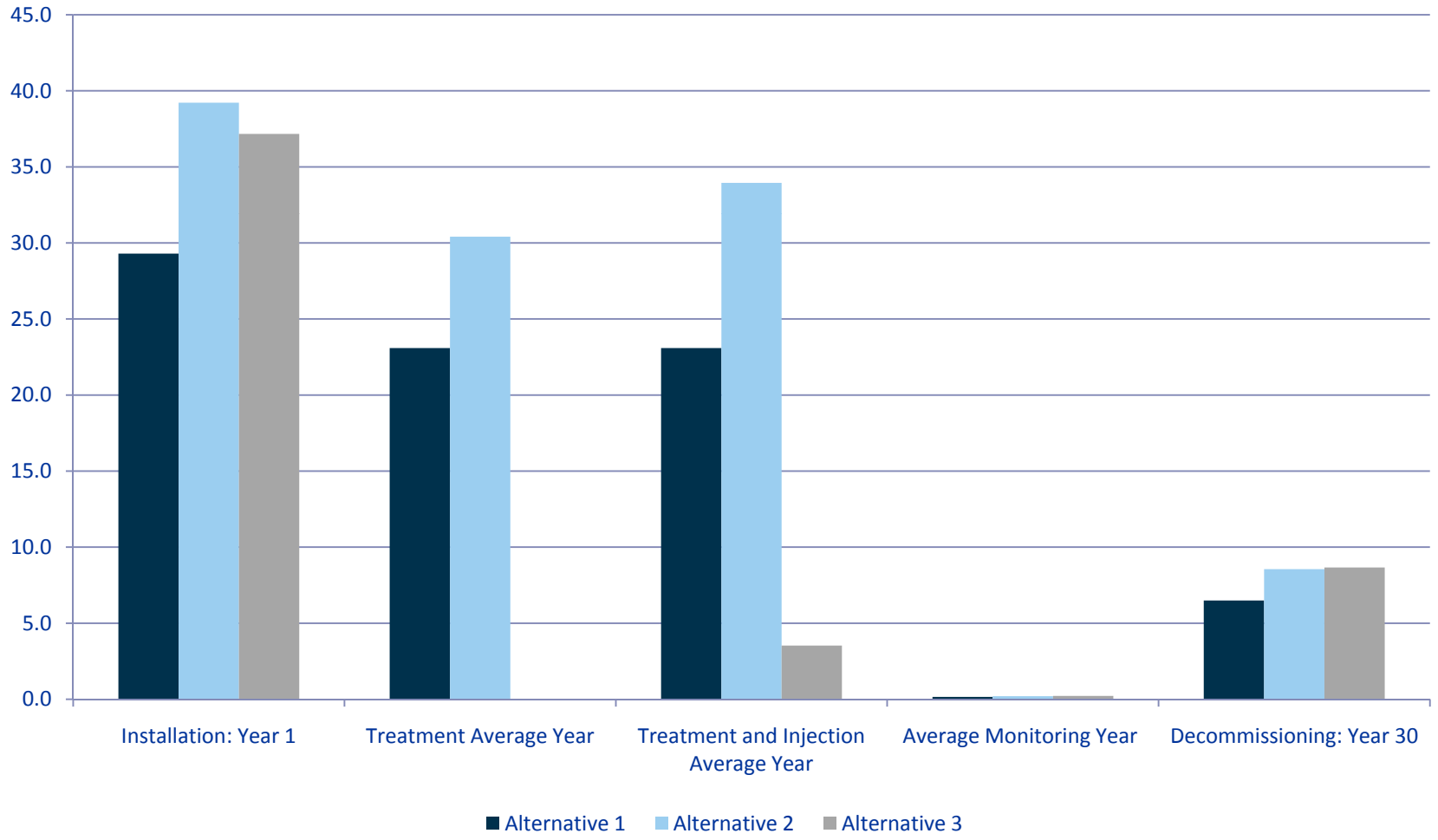
ReCiPe 2008 Human Toxicity

Midpoint normalization by year and cumulative



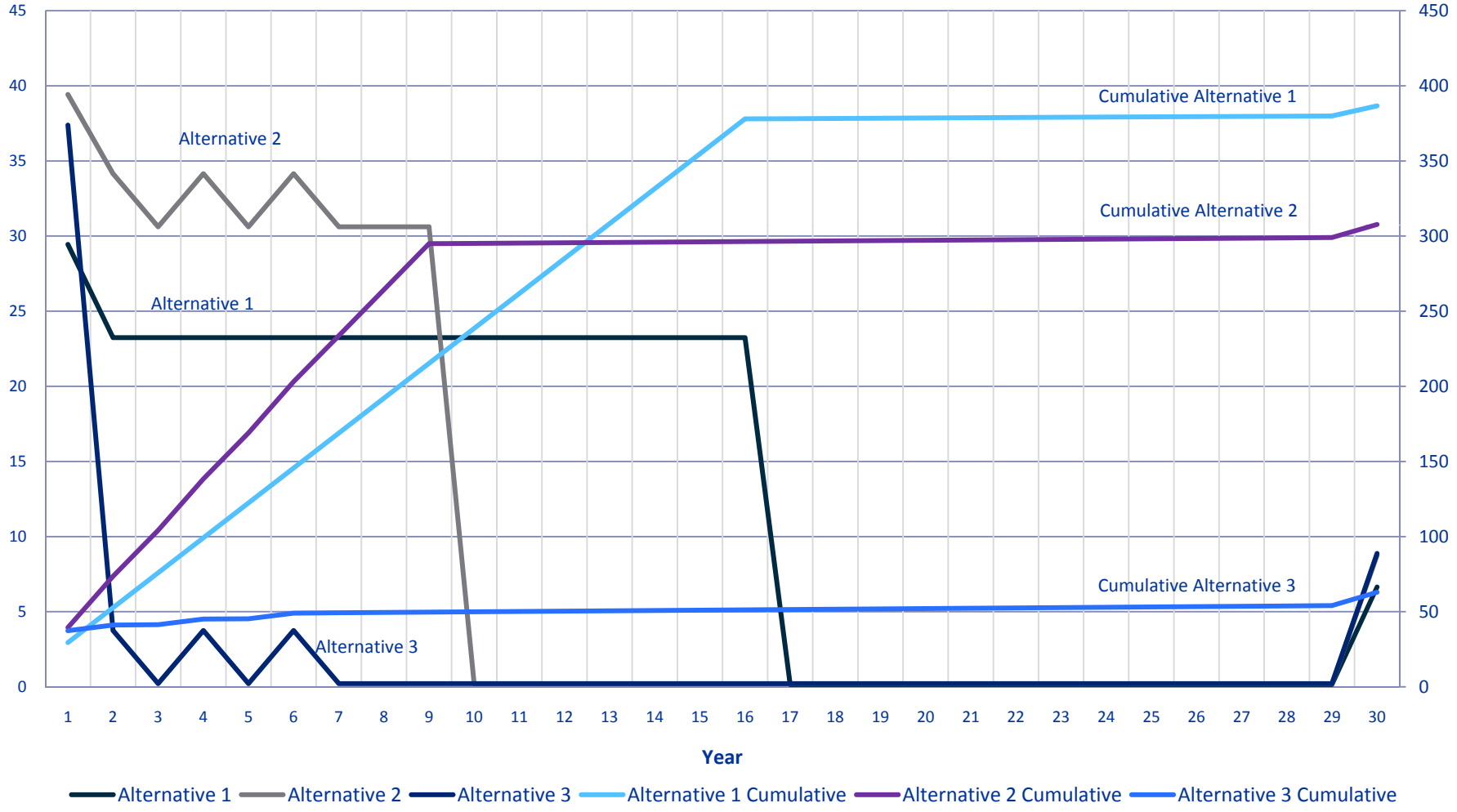
ReCiPe 2008 Particulate Matter Formation

Midpoint normalization results by average year for each phase



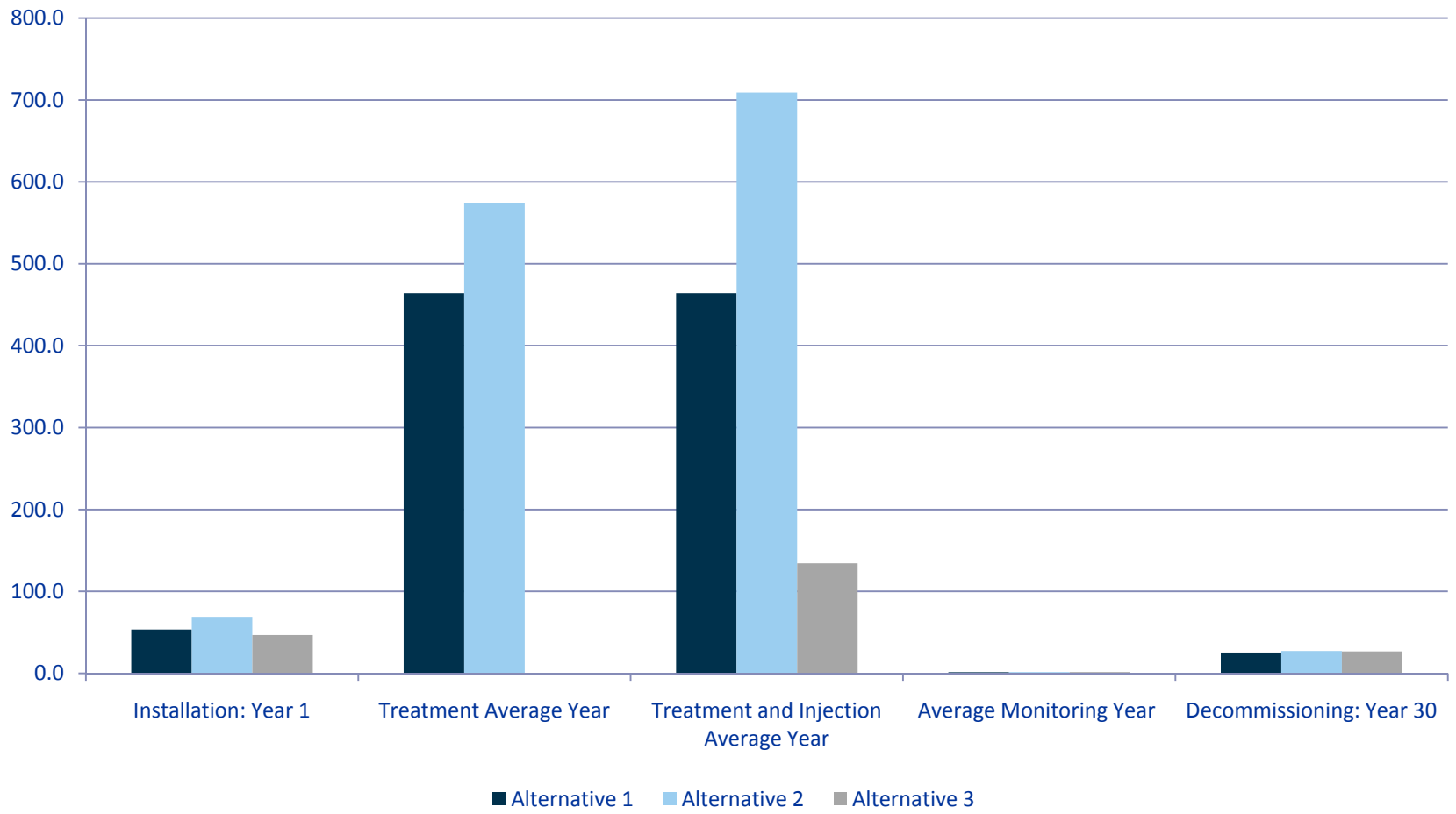
ReCiPe 2008 Particulate Matter Formation

Midpoint normalization by year and cumulative



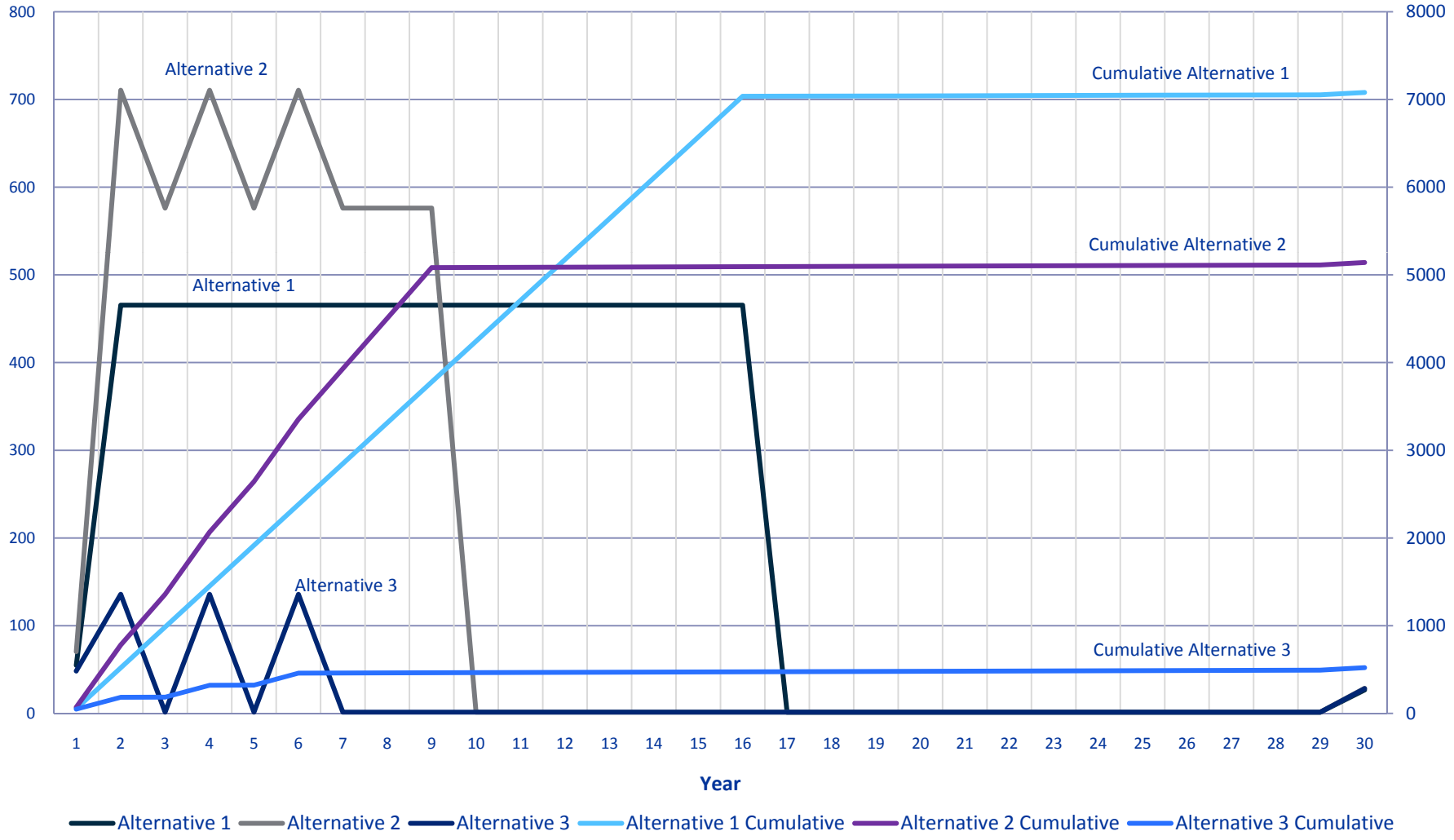
ReCiPe 2008 Freshwater Eutrophication

Midpoint normalization results by average year for each phase



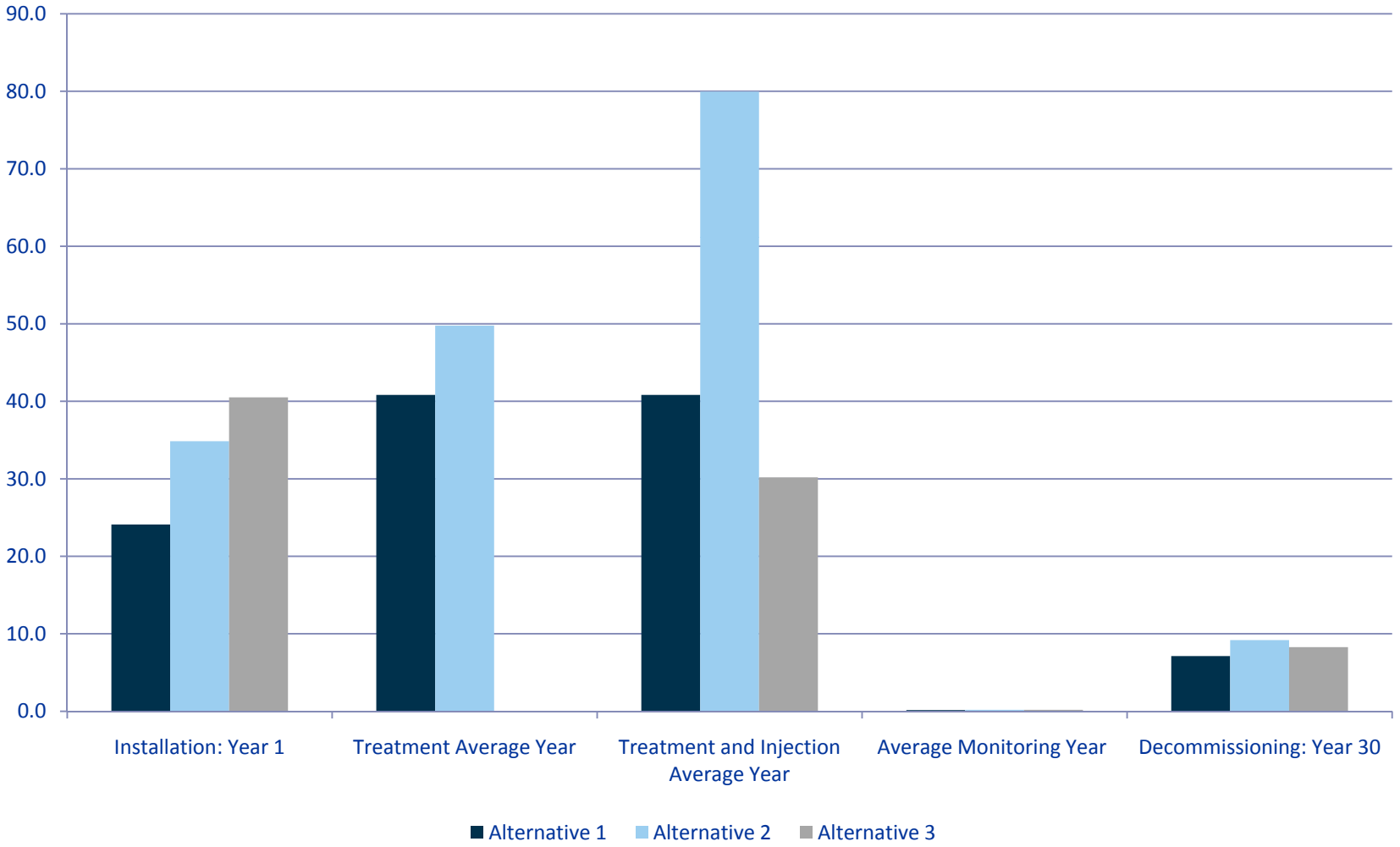
ReCiPe 2008 Freshwater Eutrophication

Midpoint normalization by year and cumulative



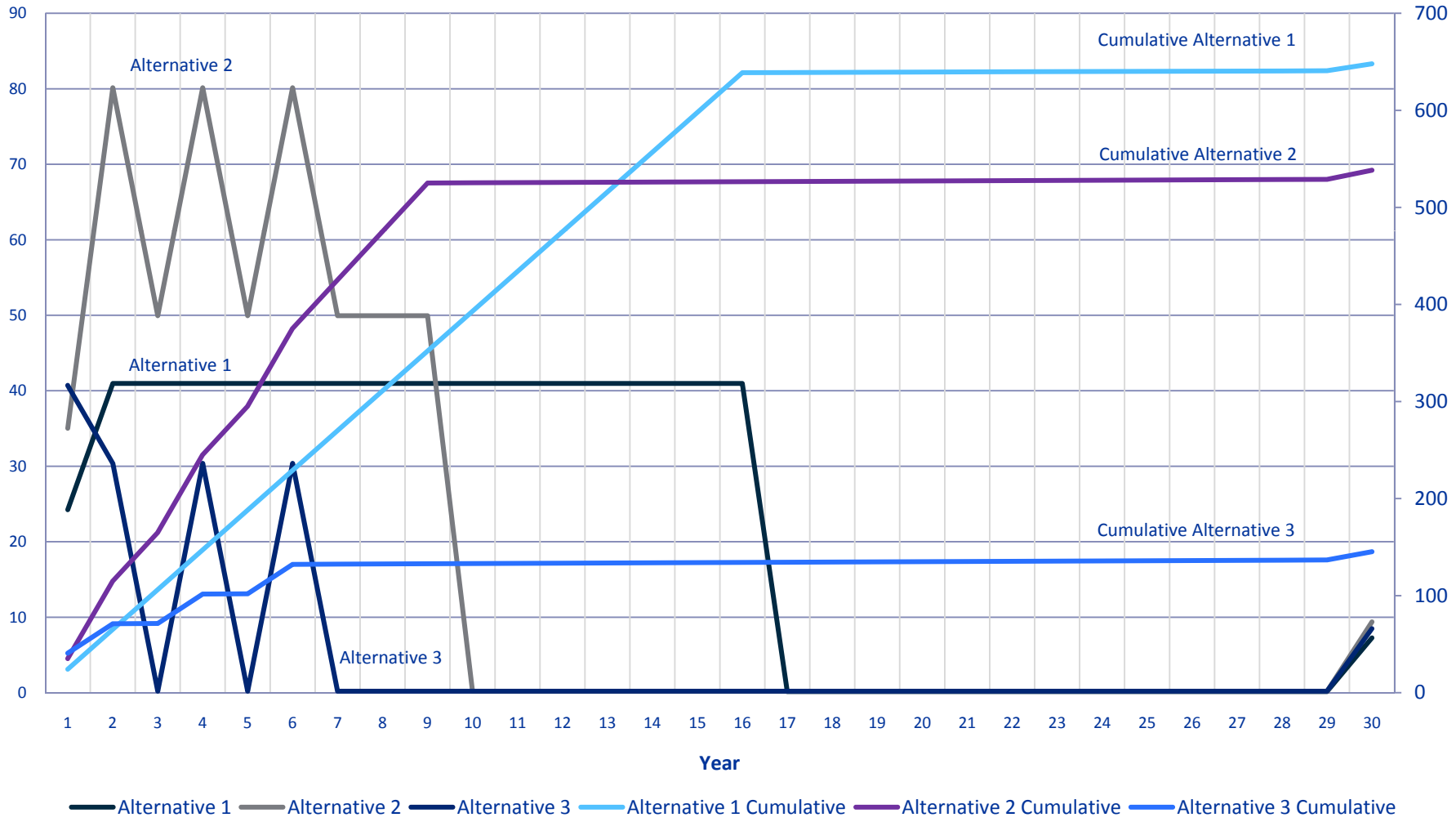
ReCiPe 2008 Marine Eutrophication

Midpoint normalization results by average year for each phase



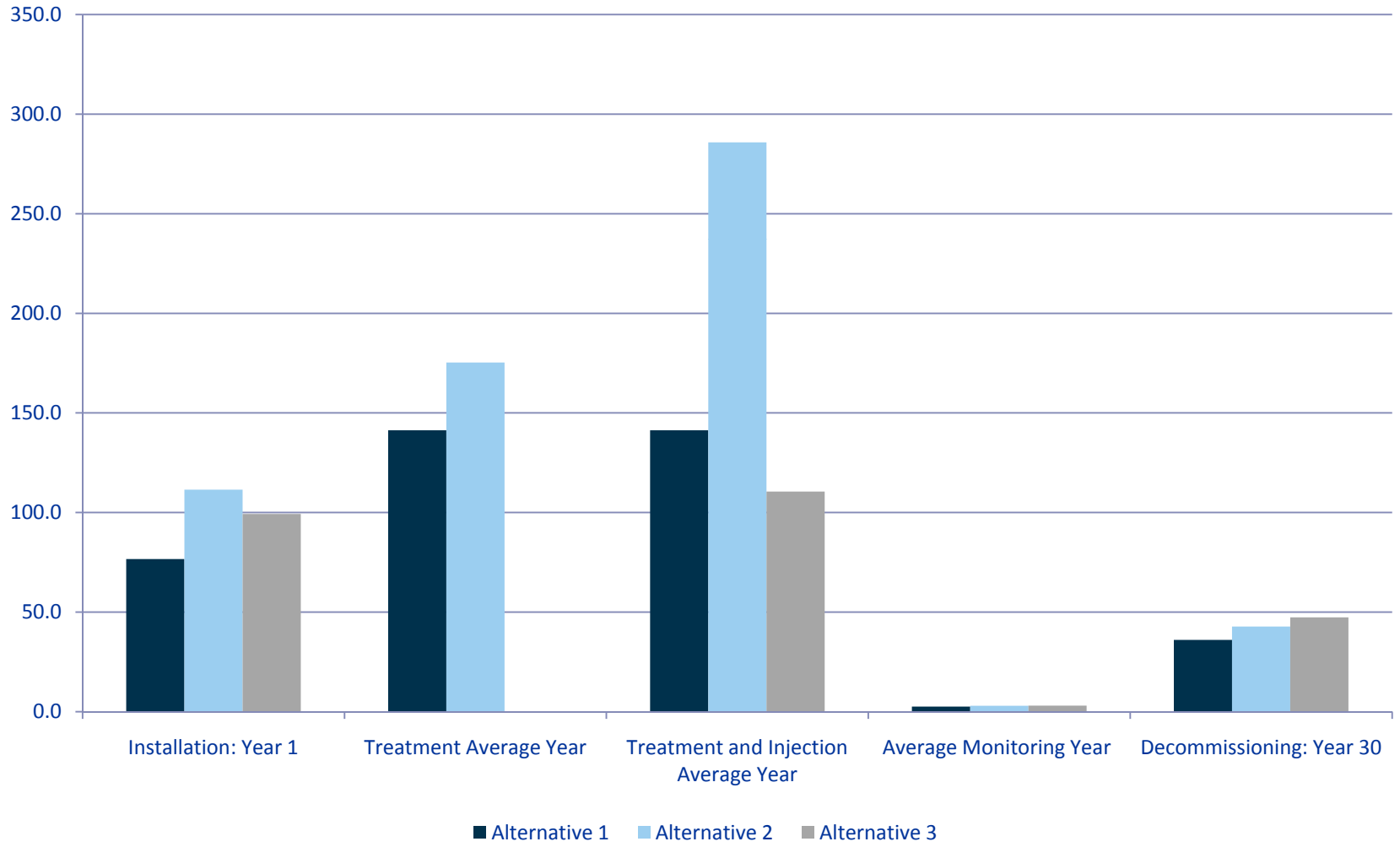
ReCiPe 2008 Marine Eutrophication

Midpoint normalization by year and cumulative



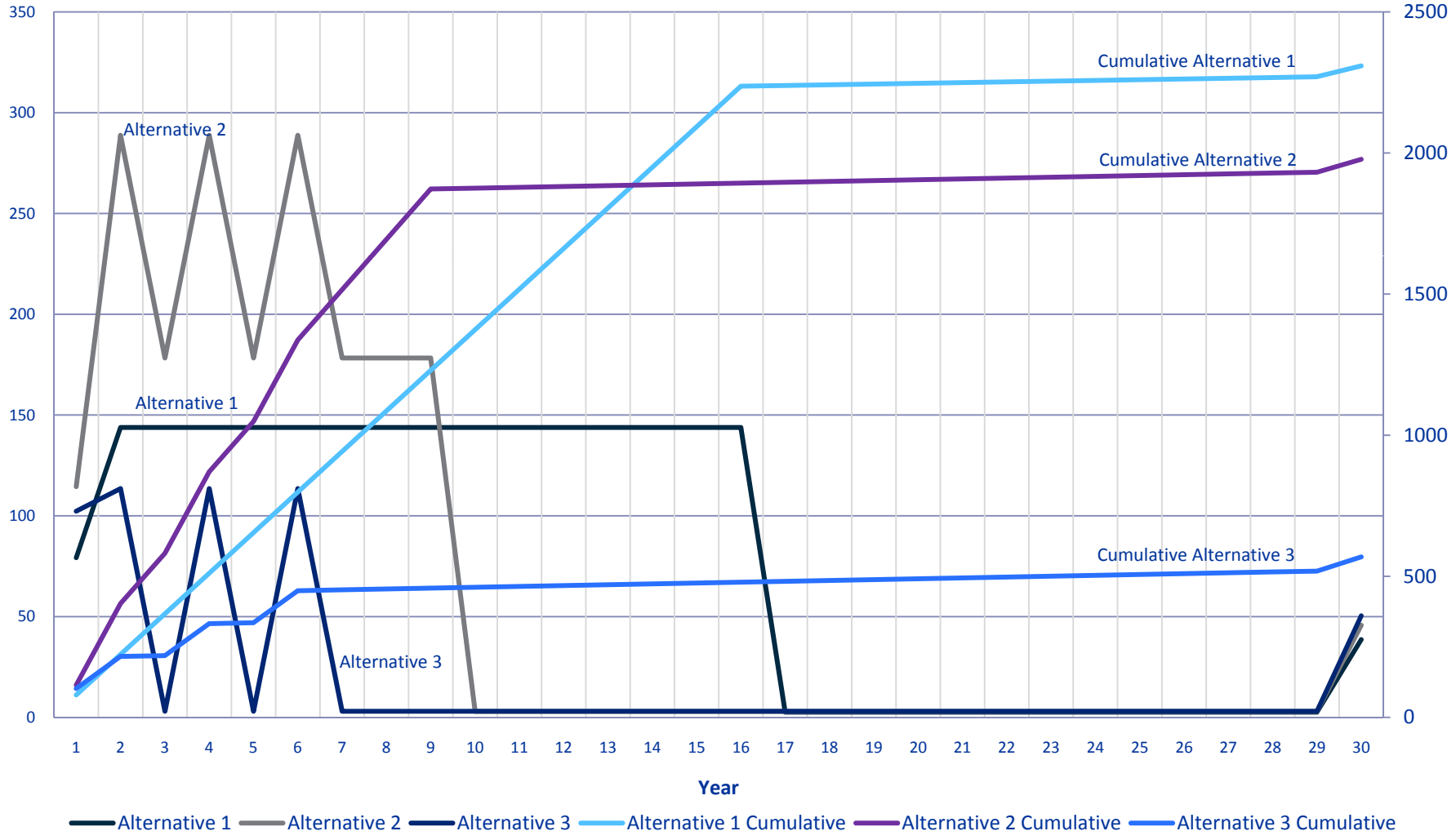
ReCiPe 2008 Freshwater Ecotoxicity

Midpoint normalization results by average year for each phase



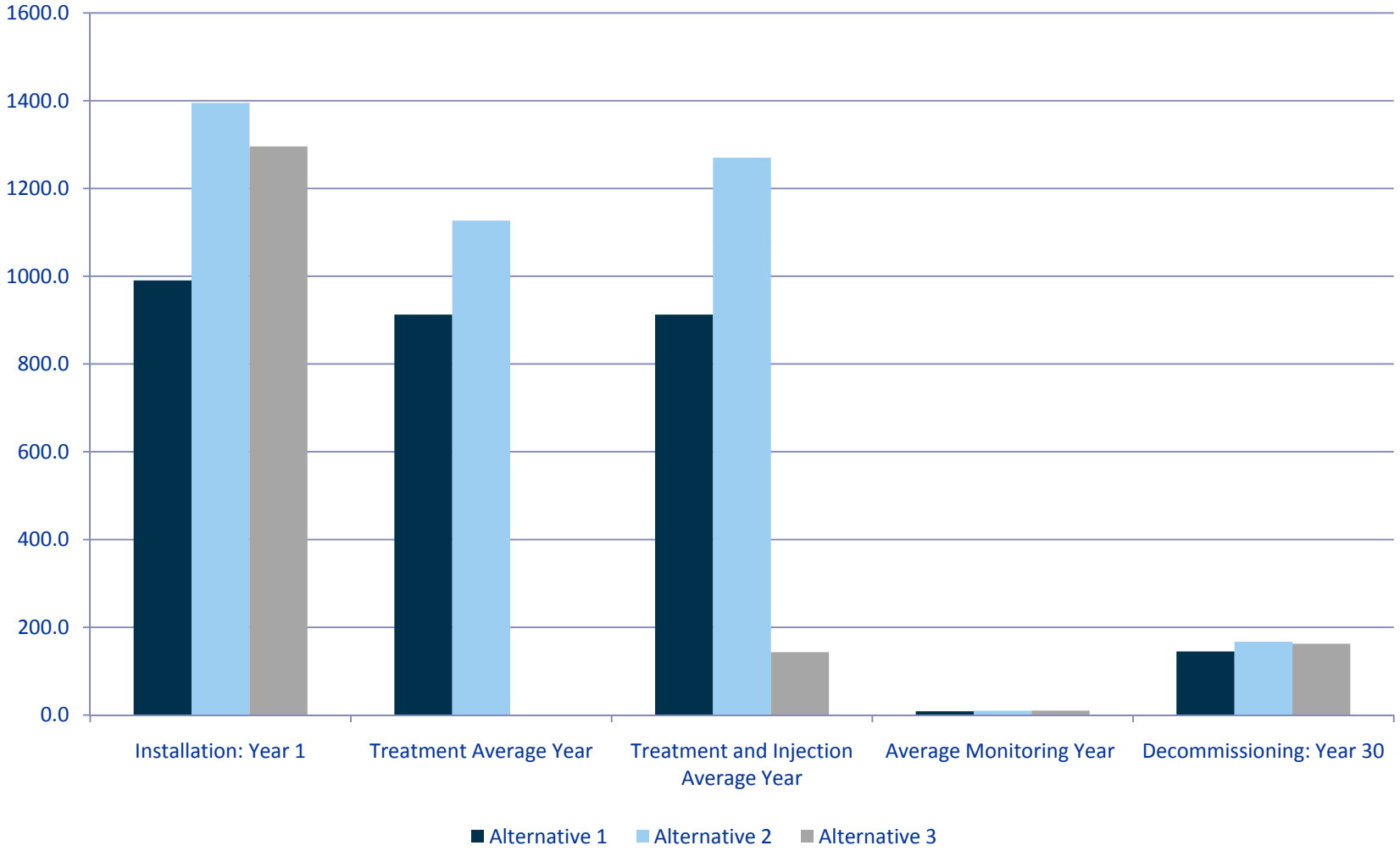
ReCiPe 2008 Freshwater Ecotoxicity

Midpoint normalization by year and cumulative



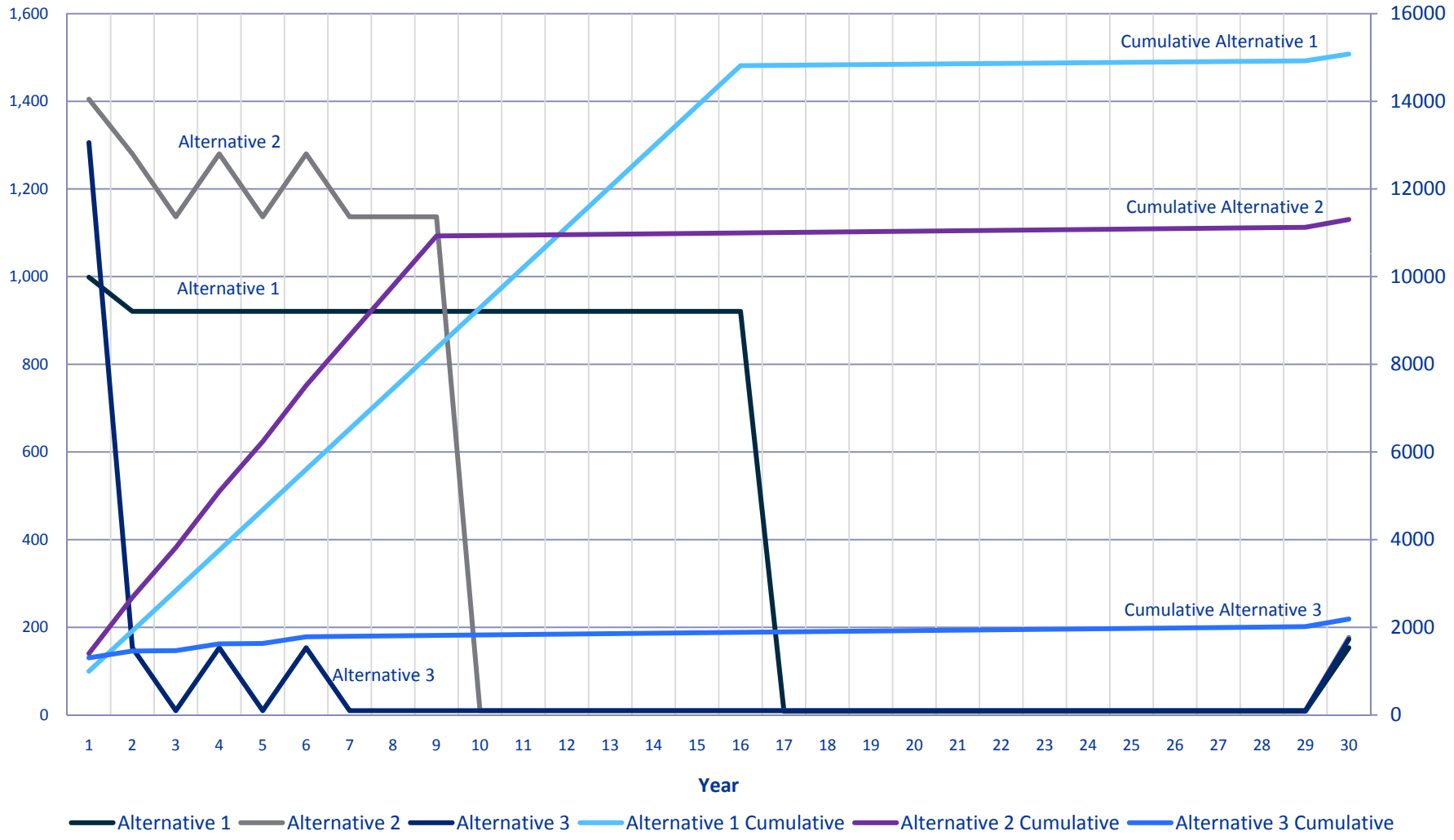
ReCiPe 2008 Marine Ecotoxicity

Midpoint normalization results by average year for each phase



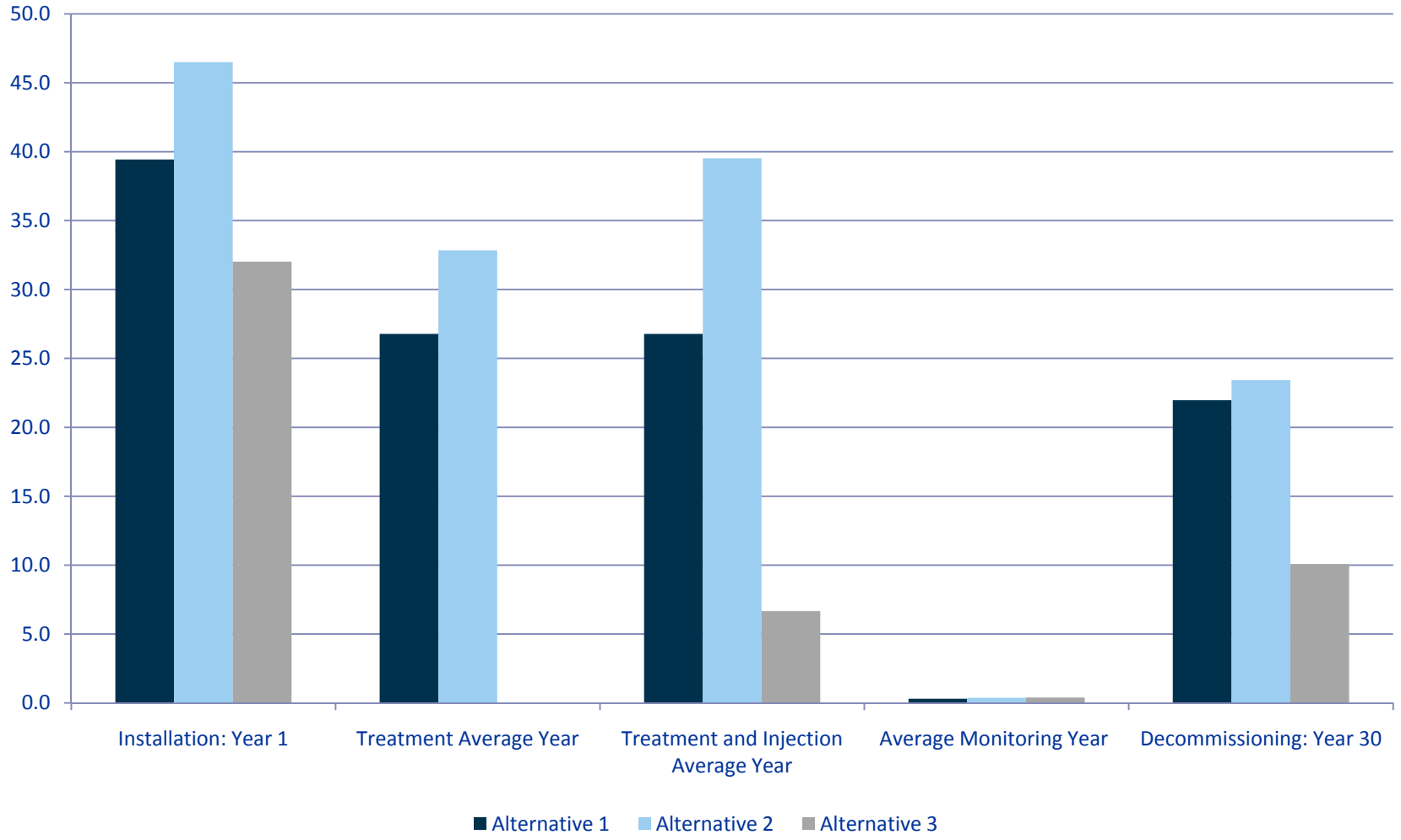
ReCiPe 2008 Marine Ecotoxicity

Midpoint normalization by year and cumulative



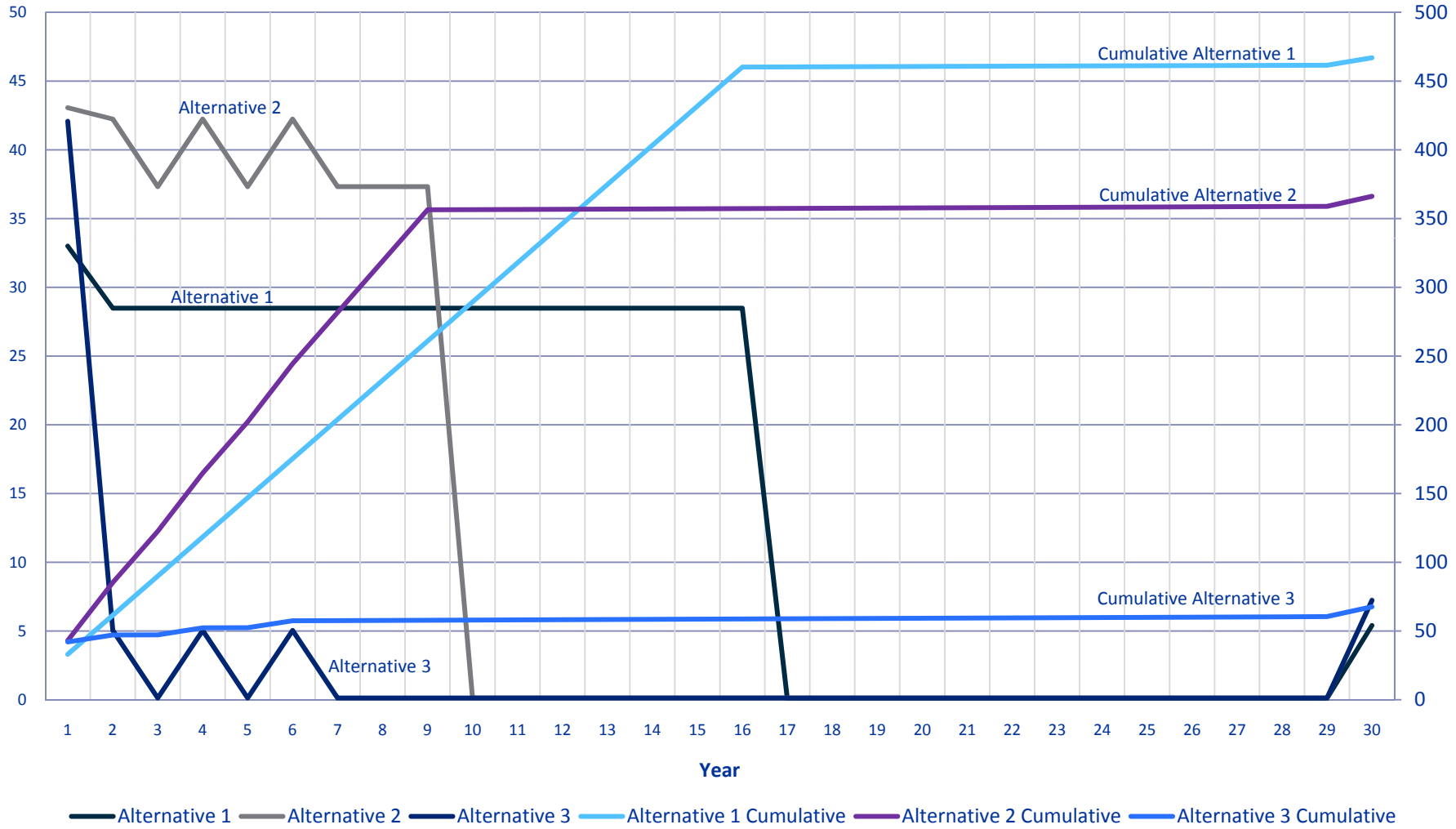
ReCiPe 2008 Fossil Depletion

Midpoint normalization results by average year for each phase



ReCiPe 2008 Fossil Depletion

Midpoint normalization by year and cumulative



Conclusions & Recommendations

- Alternative 1 had the highest environmental impact, followed closely by alternative two. Alternative Three revealed significantly lower environmental impacts in 24 of the 27 impact categories assessed.
- Major environmental impact of remedial alternatives under consideration is associated with electrical power consumption.
  - Alternative 1 involves 15 years of water treatment, a very energy-intensive process, opposed to the 8 years in Alternative 2.
  - Alternative 3 does not include any water treatment, therefore without this electrical use, it yields comparatively low environmental impacts.
- The number of injection wells are also major drivers for installation and decommissioning – sensitivity analysis is important to understand inflection points
- Not clear level of uncertainty from a 10% to a 100% design of the chosen alternative

Conclusions & Recommendations

- Electricity is a primary driver of the study results:
  - US average grid from database is very similar to US current grid, with 48% of total electricity coming from coal (EIA, 2008)
  - Almost 50% of the electricity generation in Virginia comes from coal (US EPA)
  - It is important to do sensitivity analysis on some of the upstream impacts to understand the level of uncertainty of the results
- The results of the production of virgin GAC are relevant to the study, however it would be important to further refine this inventory item because the current model is based on aggregated data
- LactOil uses proxy data for some of its inputs; sensitivity and uncertainty analysis would be important here as well, to identify if refinement of the inventory is needed.

Life Cycle Assessment

SiteWise Evaluation

Middle River Complex

SiteWise Evaluation of Groundwater Alternatives January 2011

LOCKHEED MARTIN

Lockheed Martin Proprietary Information

SiteWise Evaluation Overview

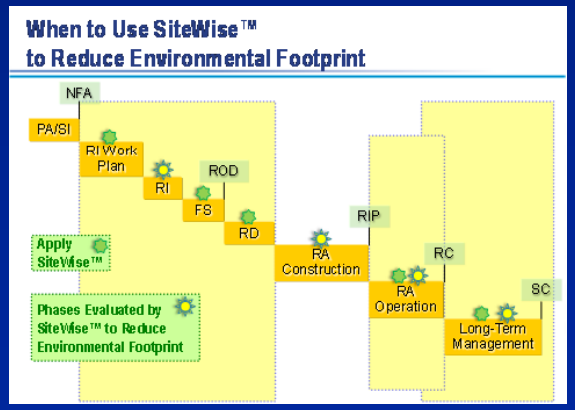
- *Introduction to SiteWise*
- *Inventory/SiteWise Inputs*
- *Alternative G-1 Results*
- *Alternative G-2 Results*
- *Alternative G-3 Results*
- *Comparison of Results*
- *Conclusions*

SiteWise Overview

- *Environmental footprint evaluation tool developed by U.S. Army Corps, U.S. Navy, and Battelle*
- *Built as an MS Excel based tool intended to augment remedial decision-making processes throughout any phase of remediation*
- *Compares up to 6 remedial alternatives*
- *Alternatives evaluated in remedial phases*
  - *Remedial Investigation*
  - *Remedial Action Construction*
  - *Remedial Action Operation*
  - *Long Term Monitoring*

SiteWise Evaluation Metrics

- ***For the SiteWise GSR evaluation, quantitative SiteWise metrics were evaluated, including:***
  - ***Greenhouse gases (CO_2, N_20, CH_4)***
  - ***Criteria pollutants (NO_x, SO_x, PM_{10})***
  - ***Water Usage***
  - ***Energy Demand***
  - ***Collateral risk (worker injury and fatality risk)***
- ***SiteWise evaluates four remedial phases (remedial investigation, remedial construction, remedial action operations, and long term monitoring)***



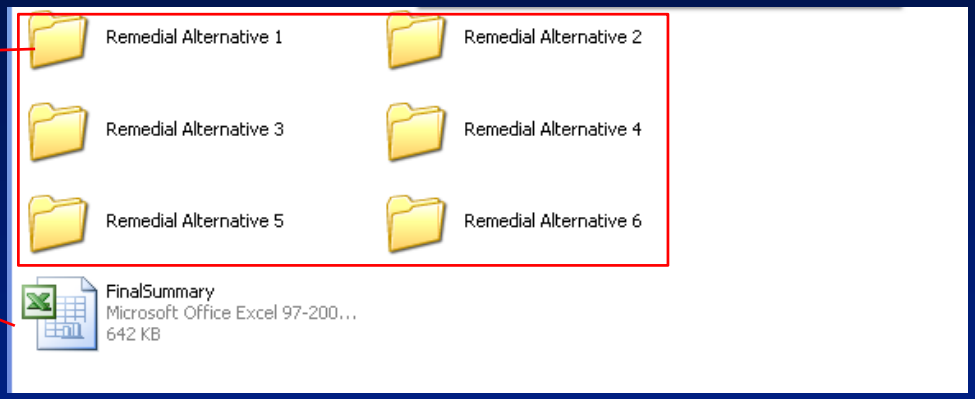
Lockheed Martin Proprietary Information

SiteWise Structure

- ***Main SiteWise Folder Level***

Remedy specific inputs, calculations, and summary

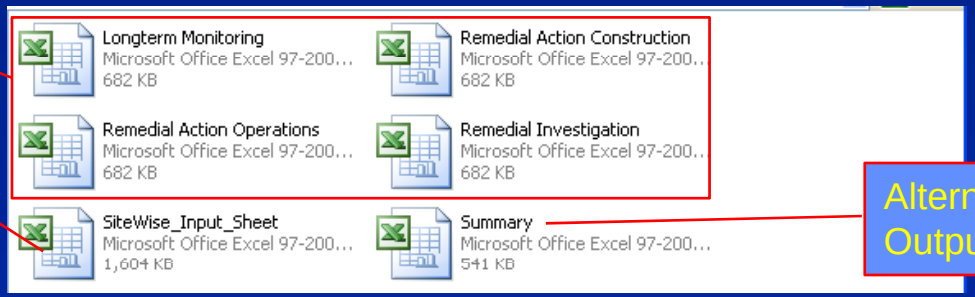
Output Comparison of Alternative Metrics



- ***Remedial Alternative Folder Level (1 of 6)***

Phase-Specific Calculation Sheets

Input Entry



Alternative-Specific Output Summary

SiteWise Metric Database

- ***Correlates site-specific input units to metric factors (i.e., emission factors, etc)***
- ***Sources***
- ***Footprint Calculation Databases:***
  - ***U.S. EPA Climate Leaders Program (U.S. EPA, 2009)***
  - ***Argonne National Laboratory's GREET model***
  - ***U.S. EPA's AP-42, Mobile 6 model, and Non-road model.***
  - ***Emission factors for consumables are life cycle based obtained from sources that provide life cycle inventories (e.g.) National Renewable Energy Laboratory***
- ***Energy Usage Calculation Methodology:***
  - ***Fuel usage for transportation and equipment***
  - ***Electricity usage based on actual equipment specified***
- ***Water Usage:***
  - ***Material manufacture lifecycle values (NREL)***
  - ***Direct water consumption***
- ***Accident Risk Calculation Methodology:***
  - ***Automobile Transport Statistics (Department of Transportation)***
  - ***Airplane Transport Statistics (Department of Transportation)***
  - ***Railroad Transport Statistics (Department of Transportation)***
  - ***Labor Statistics (Bureau of Labor Statistics)***

Sample Metric Calculations

Equipment Use – Table of Outputs: Energy, Pollutants, Risks

Metric	Formula	Earthmoving	Well Drilling	Electric Pumps	Fuel Pumps	General Electrical	Electric Generators	Agricultural	Stabilization	Mixing
BTU	Gallons * BTU/gallon = BTU	X	X		X		X	X	X	X
	MWh * conversion = BTU			X		X				
CO_2	Hours * grams/hour * conversion = metric tons	X			X		X	X	X	X
	MWH * pounds/MWh * conversion = metric tons			X		X				
	Gallons * kilograms/gallon * conversion = metric tons		X							
N_2O	Gallons * grams/gallon * GWP * conversion = metric tons	X	X		X		X	X	X	X
	MWH * pounds/MWh * GWP * conversion = metric tons			X		X				
CH_4	Gallons * grams/gallon * GWP * conversion = metric tons	X	X		X		X	X	X	X
	MWH * pounds/MWh * GWP * conversion = metric tons			X		X				
NO_x	Hours * grams/hour * conversion = metric tons	X	X		X		X	X	X	X
	MWH * pounds/MWh * conversion = metric tons			X		X				
SO_x	Hours * grams/hour * conversion = metric tons	X	X		X		X	X	X	X
	MWH * pounds/MWh * conversion = metric tons			X		X				
PM_{10}	Hours * grams/hour * conversion = metric tons	X	X		X		X	X	X	X
Risk	Hours * risk/hour = risk	X	X		X		X	X	X	X

Using SiteWise

Input

This worksheet allows the user to define material production, transportation, equipment use, and residual handling variables for the remedial alternative
Yellow cells require the user to choose an input from a drop down menu
White cells require the user to type in a value

MATERIAL PRODUCTION

Reset All Values

WELL MATERIALS	Well Type 1	Well Type 2	Well Type 3	Well Type 4	Well Type 5	Well Type 6
Input number of wells	15					
Input depth of wells (ft)	30					
Choose well diameter (in) from drop down menu	6	1/2	1/2	1/2	1/2	1/2
Choose material type from drop down menu	PVC	PVC	PVC	PVC	PVC	PVC
Choose specific material schedule from drop down menu	Schedule 40 PVC	Schedule 40 PVC	Schedule 40 PVC	Schedule 40 PVC	Schedule 40 PVC	Schedule 40 PVC

TREATMENT CHEMICALS & MATERIALS	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
Input number of injection points						
Choose material type from drop down menu	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide
Input amount of material injected at each point (pounds dry mass)						
Input number of injections per injection point						

GAC	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
Input weight of GAC used (lbs)						
Choose material type from drop down menu	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC

	Extr. Trench	Extr. Trench	Convey. Trench	Convey. Trench	Asphalt	System Pad
CONSTRUCTION MATERIALS	Material 1	Material 2	Material 3	Material 4	Material 5	Material 6
Choose material type from drop down menu	HDPE Liner	Gravel	Gravel	General Concrete	General Concrete	General Concrete
Input area of material (ft^2)	3,000	3,000	11,100	1,350	4,890	2,000
Input depth of material (ft)	0.01	15	1	0.67	0.5	0.5

WELL DECOMMISSIONING	Well Type 1	Well Type 2	Well Type 3	Well Type 4	Well Type 5	Well Type 6
Input number of wells						
Input depth of wells (ft)						
Input well diameter (in)	1	1	1	1	1	1
Choose material from drop down menu	Soil	Soil	Soil	Soil	Soil	Soil

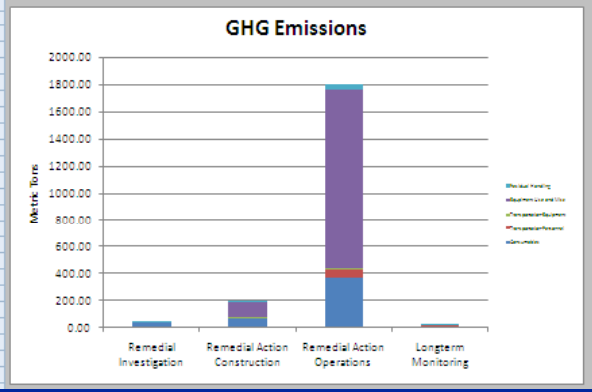
TRANSPORTATION

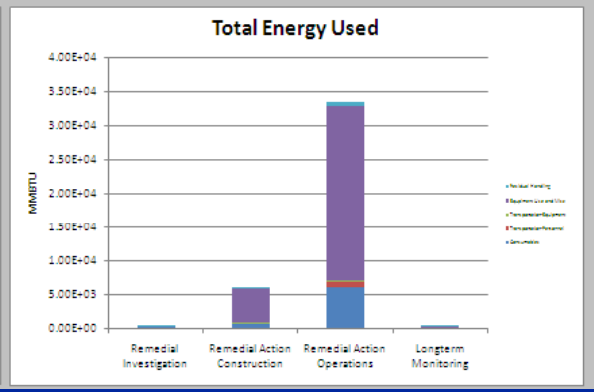
	Extraction Trench	Extraction Wells	Conveyance Trench	System Installation	Drill Rig Support Truck	
PERSONNEL TRANSPORTATION - ROAD	Trip 1	Trip 2	Trip 3	Trip 4	Trip 5	Trip 6
Will DIESEL-run vehicles be retrofitted with a particulate reduction technology?	No	No	No	No	No	No
Choose vehicle type from drop down menu*	Light truck	Light truck	Light truck	Light truck	Heavy Duty	Cars
Choose fuel used from drop down menu	Gasoline	Gasoline	Gasoline	Gasoline	Diesel	Gasoline
Input distance traveled per trip (miles)	50	50	50	50	50	
Input number of trips taken	5	15	25	30	15	

Using SiteWise

Alternative-Specific Output

Phase	Activities	GHG Emissions (metric ton)	Total energy Use (MMBTU)	Water Consumption (gallons)	NOx emissions (metric ton)	SOx Emissions (metric ton)	PM10 Emissions (metric ton)	Accident Risk Fatality	Accident Risk Injury
Remedial Investigation	Consumables	33.95	2.3E+02	NA	NA	NA	NA	NA	NA
	Transportation-Personne	0.57	6.2E+00	NA	6.1E-04	1.5E-04	9.2E-05	1.9E-05	1.4E-03
	Transportation-Equipmen	1.14	1.7E+01	NA	1.3E-03	2.5E-04	1.7E-04	1.6E-06	3.3E-04
	Equipment Use and Misc	1.43	2.3E+01	4.0E+03	1.3E-02	9.6E-04	2.5E-03	0.0E+00	0.0E+00
	Residual Handling	2.14	4.5E+01	NA	2.4E-03	4.7E-04	3.2E-04	6.8E-06	1.4E-03
	Sub-Total	39.22	3.18E+02	4.00E+03	1.75E-02	1.82E-03	3.11E-03	2.75E-05	3.11E-03
Remedial Action Construction	Consumables	64.42	6.1E+02	NA	NA	NA	NA	NA	NA
	Transportation-Personne	4.75	5.8E+01	NA	5.2E-03	1.2E-03	7.5E-04	9.3E-05	6.6E-03
	Transportation-Equipmen	11.90	1.7E+02	NA	1.4E-02	2.6E-03	1.8E-03	1.7E-05	3.5E-03
	Equipment Use and Misc	109.97	5.1E+03	9.8E+04	1.5E-01	1.5E-01	3.2E-02	1.2E-05	5.2E-03
	Residual Handling	3.56	7.8E+01	NA	4.1E-03	7.8E-04	5.4E-04	1.1E-05	2.4E-03
	Sub-Total	194.60	6.04E+03	9.80E+04	1.76E-01	1.59E-01	3.51E-02	1.33E-04	1.77E-02
Remedial Action Operations	Consumables	365.65	6.1E+03	NA	NA	NA	NA	NA	NA
	Transportation-Personne	58.95	6.4E+02	NA	6.3E-02	1.5E-02	9.5E-03	6.6E-04	4.8E-02
	Transportation-Equipmen	15.83	2.3E+02	NA	1.8E-02	3.4E-03	2.4E-03	3.2E-05	6.6E-03
	Equipment Use and Misc	1,320.46	2.6E+04	8.0E+07	2.1E+00	6.6E+00	1.0E-03	0.0E+00	0.0E+00
	Residual Handling	40.62	6.0E+02	NA	4.6E-02	8.8E-03	6.2E-03	1.3E-04	2.7E-02
	Sub-Total	1,801.51	3.35E+04	8.01E+07	2.24E+00	6.59E+00	1.91E-02	8.24E-04	8.10E-02
Longterm Monitoring	Consumables	0.00	0.0E+00	NA	NA	NA	NA	NA	NA
	Transportation-Personne	14.74	1.6E+02	NA	1.6E-02	3.8E-03	2.4E-03	3.3E-04	2.4E-02
	Transportation-Equipmen	0.00	0.0E+00	NA	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
	Equipment Use and Misc	0.67	5.9E+01	1.3E+04	0.0E+00	1.6E-03	4.7E-04	0.0E+00	0.0E+00
	Residual Handling	1.78	2.6E+01	NA	2.0E-03	3.9E-04	2.7E-04	5.7E-06	1.2E-03
	Sub-Total	17.19	2.46E+02	1.34E+04	1.79E-02	5.78E-03	3.12E-03	3.37E-04	2.50E-02
Total		**2052.52**	**4.01E+04**	**8.02E+07**	**2.45**	**6.76**	**6.04E-02**	**1.32E-03**	**0.13**



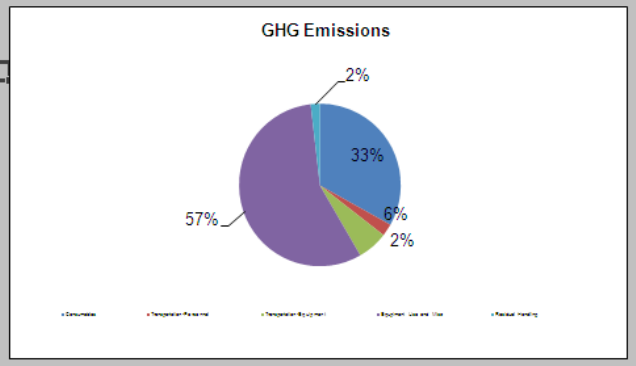


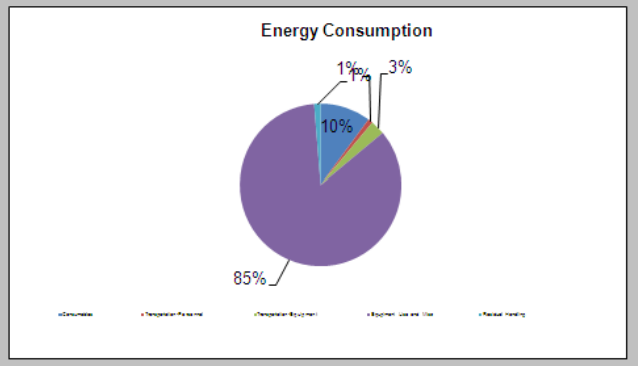
Using SiteWise

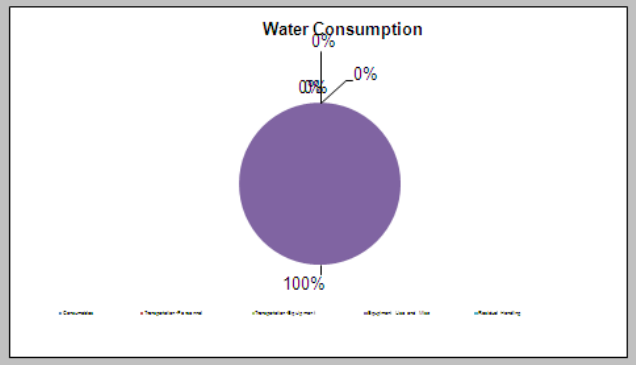
Phase-Specific Output

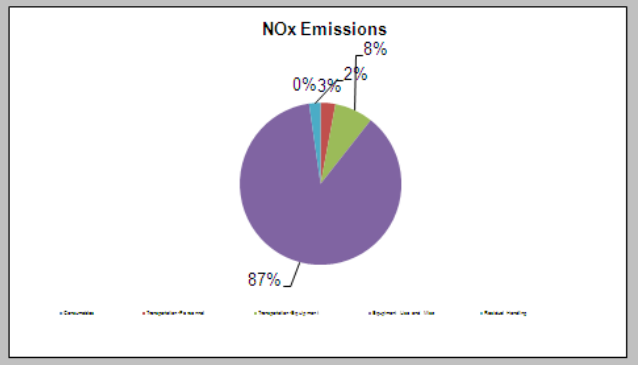
Sustainable Remediation Summary - Remedial Action Construction

Activities	GHG Emissions	Percent Total	Total energy Used	Percent Total	Water Consumption	Percent Total	NOx emissions	Percent Total	SOx Emissions	Percent Total	PM10 Emissions	Percent Total	Accident Risk Fatality	Percent Total	Accident Risk Injury	Percent Total
	metric ton	%	MMBTU	%	gallons	%	metric ton	%	metric ton	%	metric ton	%		%		%
Consumables	64.42	33.1	6.1E+02	10.1	NA	NA	NA	-	NA	-	NA	-	NA	NA	NA	NA
Transportation-Personnel	4.75	2.4	5.8E+01	1.0	NA	NA	5.2E-03	3.0	1.2E-03	0.7	7.5E-04	2.1	9.3E-05	69.8	6.6E-03	37.6
Transportation-Equipment	11.90	6.1	1.7E+02	2.9	NA	NA	1.4E-02	7.7	2.6E-03	1.6	1.8E-03	5.1	1.7E-05	12.6	3.5E-03	19.7
Equipment Use and Misc	109.97	56.5	5.1E+03	84.8	9.8E+04	100.0	1.5E-01	87.1	1.5E-01	97.2	3.2E-02	91.2	1.2E-05	9.1	5.2E-03	29.4
Residual Handling	3.56	1.8	7.8E+01	1.3	NA	NA	4.1E-03	2.3	7.8E-04	0.5	5.4E-04	1.5	1.1E-05	8.5	2.4E-03	13.3
Total	194.60	100.0	6.04E+03	100.0	9.80E+04	100.0	1.76E-01	100.0	1.59E-01	100.0	3.51E-02	100.0	1.33E-04	100.0	1.77E-02	100.0





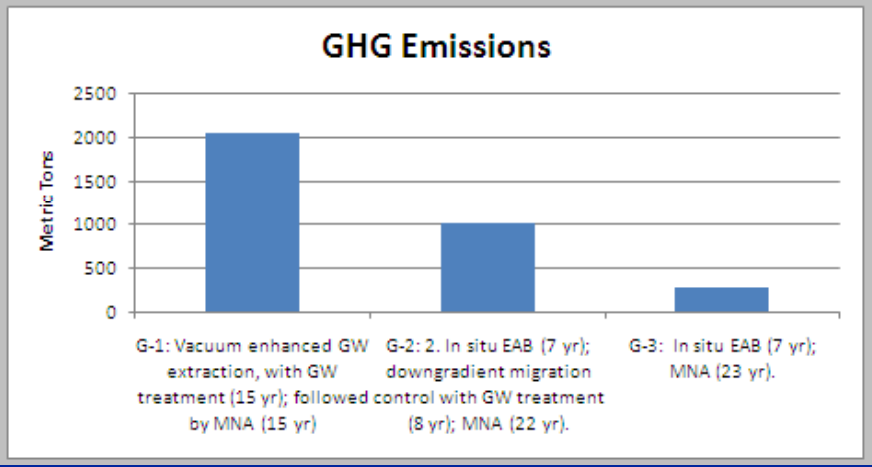


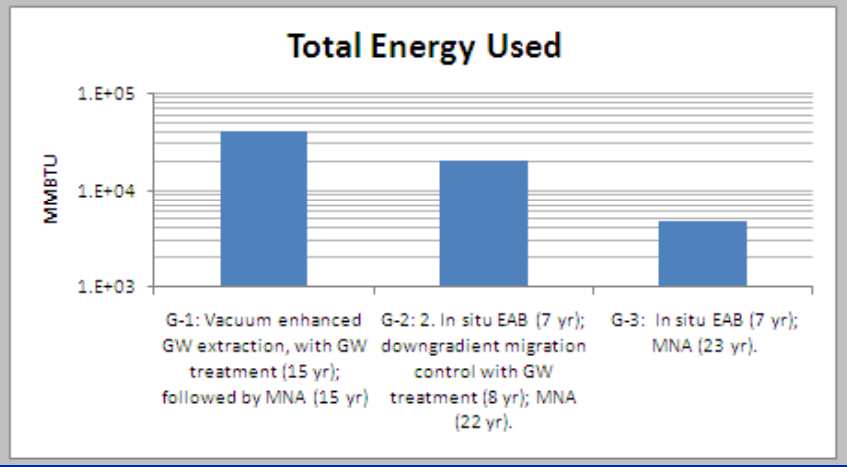


Using SiteWise

Alternative Comparison Output

Remedial Alternatives	GHG Emissions	Total energy Used	Water Consumption	NO_x emissions	SO_x Emissions	PM_{10} Emissions	Accident Risk Fatality	Accident Risk Injury
	metric ton	MMBTU	gallons	metric ton	metric ton	metric ton		
G-1: Vacuum enhanced GW extraction, with GW treatment (15 yr); followed by MNA (15 yr)	2052.52	40056.57	8.02E+07	2.45E+00	6.76E+00	6.04E-02	1.32E-03	1.27E-01
downgradient migration control with GW treatment (8 yr); MNA (22 yr).	1014.59	20254.45	2.20E+07	1.40E+00	4.21E+00	7.16E-02	1.13E-03	1.07E-01
G-3: In situ EAB (7 yr); MNA (23 yr).	282.77	4724.33	4.49E+05	5.54E-01	1.12E-01	5.26E-02	7.12E-04	7.42E-02





Groundwater Remedial Alternatives

- ***Alternative G-1: Vacuum enhanced groundwater extraction, with extracted water treatment (15 yr); followed by monitored natural attenuation (15 yr).***

- ***Alternative G-2: In situ enhanced anaerobic bioremediation (EAB) (7 yr), with downgradient migration control by vacuum enhanced extraction in wells and extracted water treatment (8 yr-simultaneous); followed by monitored natural attenuation (22 yr).***

- ***Alternative G-3: EAB (7 yr); followed by monitored natural attenuation (23 yr).***

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Evaluation Method

- ***A hybrid SiteWise GSR evaluation was utilized, using SiteWise for available and applicable inputs.***
- ***Data gaps input and calculated into Tt's GSR tool, GSR_x.***
- ***Results from GSR_x were entered into each remedial phase in SiteWise as "Other Known Site Activities"***



Sample GSR$_x$ Screen (Alt G-3)

Technology Module	Module Components	Comments / Assumptions	Quantity	(Units)	Greenhouse Gas Emissions $CO_{2\ equiv}$	CO_2	N_2O	CH_4	Criteria Pollutant Emission NO_x	SO_x	PM_{10}	Energy Consumption	Water Consumption
Materials							Tonnes					MWhr	gal x 1000
1.3 Injection Wells	PVC	4" SCH 40 PVC Extraction wells (86x 30' deep,2.01 lbs/lft)	2,580	lft	11.69	5.88	0.01	0.07	0.00	0.02	0.0033	44.10	4
	Steel	Injection wells 86x (1' diam x 1.5' deep H20 rated, steel), 50 lbs/ea	4,300	lbs	5.48	5.27	0.00	0.00	0.00	0.00	0.0000	18.66	4
	Soil	Bentonite, 12.46 CY, 1,800 lbs/CY	22,428	lbs	0.23	0.23	0.00	0.00	0.00	0.00	0.0000	1.27	0.00
	Soil	Sand, 13.29 CY, 2,000 lbs/CY	26,580	lbs	0.28	0.28	0.00	0.00	0.00	0.00	0.0000	1.51	0.00
	General Concrete	Grout, 1.66 CY, 2,500 lbs/CY	4,150	lbs	0.24	0.24	0.00	0.00	0.00	0.00	0.0000	0.50	0.00
1.4 Monitoring Wells	PVC	Monitoring wells (8x 35' deep and 7x 20' deep, 0.68 lbs/lft)	420	lft	3.34	1.68	0.00	0.02	0.00	0.01	0.0009	12.61	1
	Steel	Monitoring wells, 15x (1' diam x 1.5' deep H20 rated, steel), assume 30 lbs/each	450	lbs	0.57	0.55	0.00	0.00	0.00	0.00	0.0000	1.95	0
	Soil	Bentonite,1.60 CY, 1,800 lbs/CY	2,880	lbs	0.03	0.03							0.00
	Soil	Sand, 0.97 CY, 2,000 lbs/CY	1,940	lbs	0.02	0.02							0.00
	General Concrete	Grout, 0.19 CY, 2,500 lbs/CY	475	lbs	0.03	0.03							0.00
1.5 Conveyance Trench	Steel	Injection manifold vault 4x (4' x 4' x 1.5' H20 rated, steel), 250 lbs/ea	1,000	lbs	1.27	1.22							1
	HDPE	Bio conveyance piping 0.75" HDPE, SDR11 (0.1022 lbs/lft)	2,500	lft	0.57	0.30							0.90
2.1 Operating Consumables	Glass	525 VOA bottles, assume 0.1 lbs/ea	53	lbs	0.04	0.02							0
	PVC	Assume 2497 pairs total, 0.04 lbs/ pair	100	lbs	0.23	0.11							0
3.1 Monitoring Consumables	Glass	Site Monitoring [3 jars per sample, 100 samples per event, 30 events), assume 0.1 lbs/ea	900	lbs	0.74	0.35							0
	PVC	Assume one pair per sample collected, assume 0.04 lbs/pair	360	lbs	0.81	0.41							1
4.1 Decomissioning	Soil	Bentonite, 2.1 CY, 1,800 lbs/CY	3,780	lbs	0.04	0.04	0.00	0.00	0.00	0.00	0.0000	0.21	0.00
				Subtotal	**25.62**	**16.66**	**0.02**	**0.10**	**0.00**	**0.04**	**0.0050**	**94.52**	**12.13**
Transportation							Tonnes					MWhr	gal x 1000
Input Into SiteWise													
				Subtotal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Construction Equipment							Tonnes					MWhr	gal x 1000
1.5 Conveyance Trench	Trencher, 40 HP (diesel)	Bio Convey. trench installation	50	hrs	0.60	0.60	0.00	0.00	0.00	0.00	0.0005	3.06	
	Dozer, 105 HP (D5) w/A Blade (diesel)	Bio Convey. trench installation	25	hrs	1.50	1.50	0.00	0.00	0.01	0.00	0.0010	8.05	
	Roller, 25 HP (diesel)	Bio Convey. trench installation	25	hrs	0.21	0.21	0.00	0.00	0.00	0.00	0.0002		
4.1 Decomissioning	Loader, 100 HP, 2 CY (diesel)	Excavation of well vaults and pipe abandonment (5 days)	40	hrs	0.66	0.66	0.00	0.00	0.01	0.00	0.0010	2.93	
	Loader, 100 HP, 2 CY (diesel)	Removal of Bio conveyance HDPE piping for recycling (assume 500 ft/d, 2600 ft)	40	hrs	0.66	0.66	0.00	0.00	0.01	0.00	0.0010	2.93	
	Skid Steer (diesel)	Site restoration (5d)	40	hrs	0.52	0.49	0.00	0.00	0.00	0.00	0.0009	2.44	
				Subtotal	**4.14**	**4.12**	**0.00**	**0.00**	**0.03**	**0.01**	**0.0047**	**19.41**	**0.00**
							Tonnes					MWhr	gal x 1000
	No direct electrical consumption		0	MWhr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Subtotal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
				Total	**29.76**	**20.78**	**0.02**	**0.10**	**0.03**	**0.04**	**0.01**	**113.94**	**12.13**

Items evaluated in GSRx and input into SiteWise as "Other"



Alternative 3

Values Input into SiteWise as "Other"

Module	Greenhouse Gas Emissions $CO_{2\ equiv}$	CO_2	N_2O (CO2e)	CH_4 (CO2e)	Criteria Pollutant Emission NO_x	SO_x	PM_{10}	Energy Consumption	Water Consumption
			Tonnes					MMBTU	gal
RI	3.99E+00	2.31E+00	1.27E+00	4.13E-01	1.22E-06	6.99E-03	9.41E-04	1.49E+01	1.13E+00
RAC	2.23E+01	1.59E+01	4.93E+00	3.51E-03	1.47E-02	3.30E-02	5.22E-03	8.58E+01	1.03E+01
RAO	2.14E+00	1.98E+00	1.07E-01	5.42E-02	1.57E-02	3.08E-03	3.12E-03	9.47E+00	1.78E-01
LTM	1.55E+00	7.55E-01	6.96E-01	9.94E-02	0.00E+00	2.28E-03	5.14E-04	4.76E+00	7.27E-01

Note: 1 MWhr = 3412141.4799 BTU, 1MMTBU = 10^6 BTU

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Input Inventory

- ***Inputs (i.e., materials, transportation, etc) for each remedial alternative were compiled into a spreadsheet input list (typical of each Alternative).***

Operation Phase

Materials (O&M consumables)

Process/System	Item	Quantity	Units	Comments
Treatment System	Sodium Hydroxide (25%)	13,688	gal	2.5 gpd, 15 yrs
Treatment System	Coagulant	2,738	gal	0.5 gpd, 15 yrs, Tramfloc 724
Treatment System	Polyester Cartridge filters	1,560	ea	Assume 1 complete bi-monthly changeout of 4x filters, 15 years
Treatment System	LPGAC Usage and Disposal	33,000	lb	2200 lb/yr GAC, 15 yrs
Treatment System	VPGAC Usage and Disposal	90,000	lb	6000 lb/yr GAC, 15 yrs
Treatment System	Sludge Disposal	79,500	gal	5300 gal/yr sludge generated, 15 yrs
Treatment System	40 ml glass sample VOA containers	1620	ea	System Process Sampling [3 jars per sample, 3 samples per month (infl, midfl, effl), 15 years]
Treatment System	Nitrile Gloves	2100	pairs	Assume 2 pairs per O&M visit (52 visits/yr, 15 yrs) and one pair per sample collected
Treatment System	Vacuum Pump Oil	263	gal	Assume oil changeout every 3000 hours of operation, 6 gal reservoir capacity

Transportation

Process/System	Item	Quantity	Units	Comments
Treatment System	On Road Truck	3,000	mi	Sludge Disposal (2 trips/yr, 100 mi/trip, 15 yrs)
Treatment System	On Road Truck	10,950	mi	NaOH Delivery (13,688 gal usage, 250 gal tote/trip, 200 mi/trip)
Treatment System	On Road Truck	2,190	mi	Coagulant Delivery (2,738 gal usage, 250 gal tote/trip, 200 mi/trip)
Treatment System	On Road Truck	9,300	mi	LPGAC Changeout/Disposal (31x changeouts, 1,000 lb/changeout, 300 mi/trip)
Treatment System	On Road Truck	26,400	mi	VPGAC Changeout/Disposal (88x changeouts, 1,000 lb/changeout, 300 mi/trip)
Treatment System	Light Truck	78,000	mi	System O&M (1 man crew, 52 trip/yr, 100 mi/trip, 15 yrs)

Lockheed Martin Proprietary Information

Alternative Summary: G-1

- ***Alternative G-1: Vacuum enhanced groundwater extraction, with extracted water treatment (15 yr); followed by monitored natural attenuation (15 yr).***
  - ***Source mass removal: 15 extraction wells (groundwater and soil vapor extraction)***
  - ***Infrastructure***
  - ***Treatment system: Vacuum pump, air stripper, transfer pumps, pH control, coagulant dosing, clarifier, sediment filtration, liquid- and vapor-phase GAC, and surface water discharge***
  - ***Long term monitoring (30 year monitoring)***

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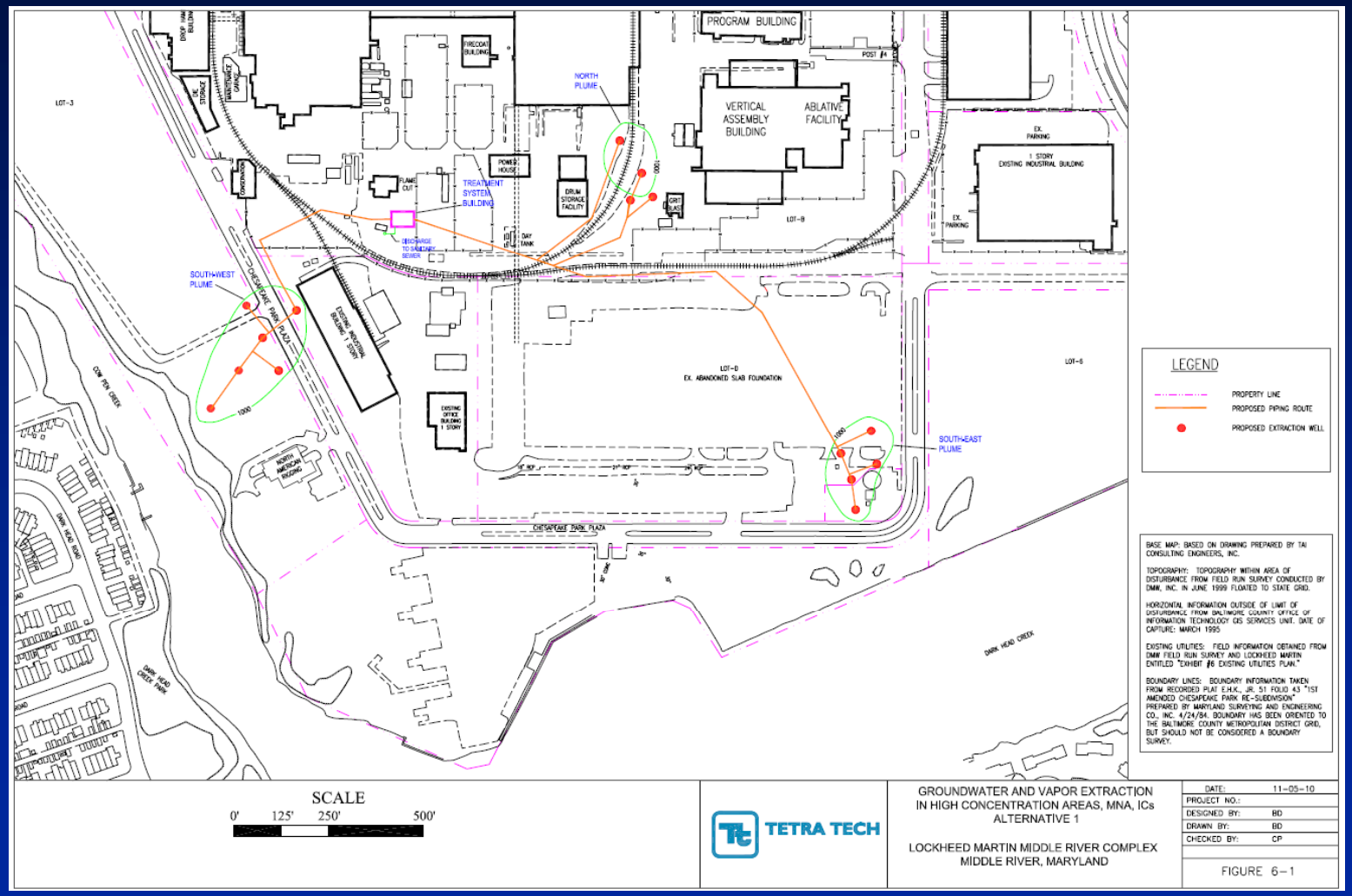
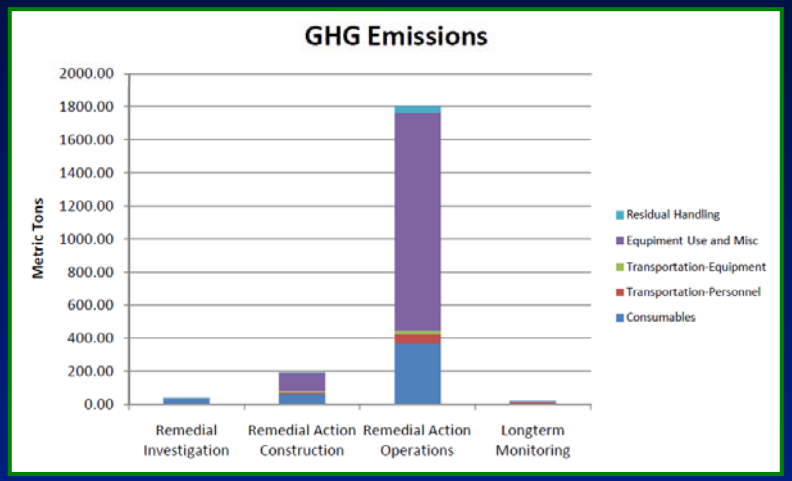
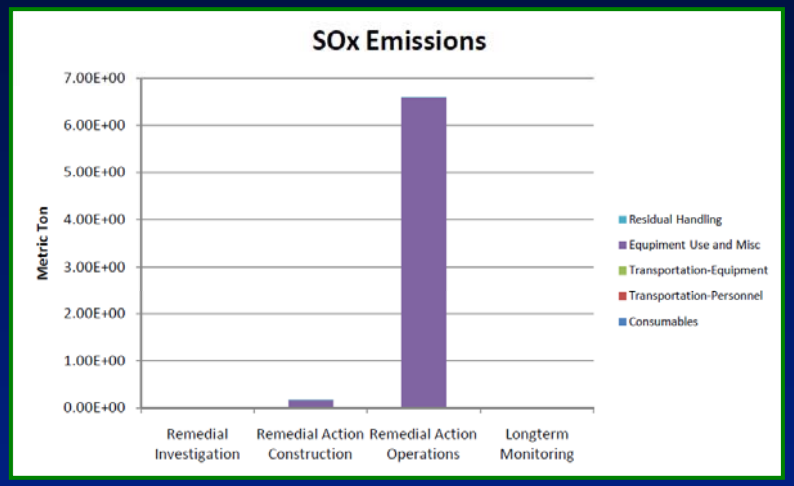
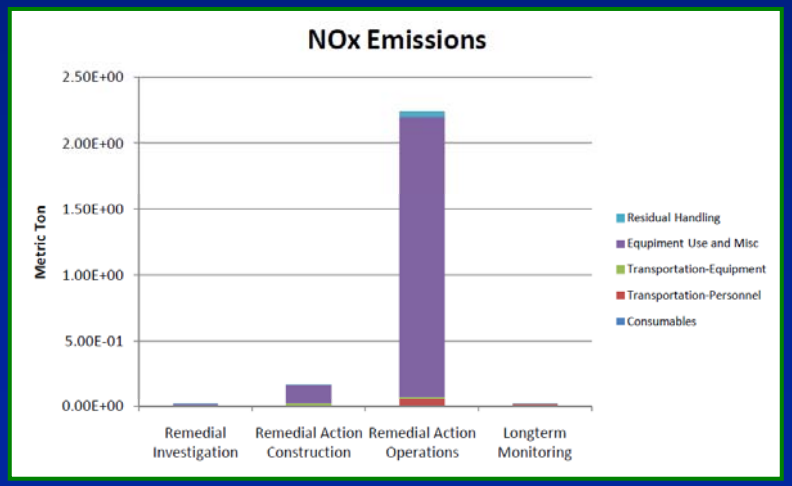
Alternative G-1 Layout

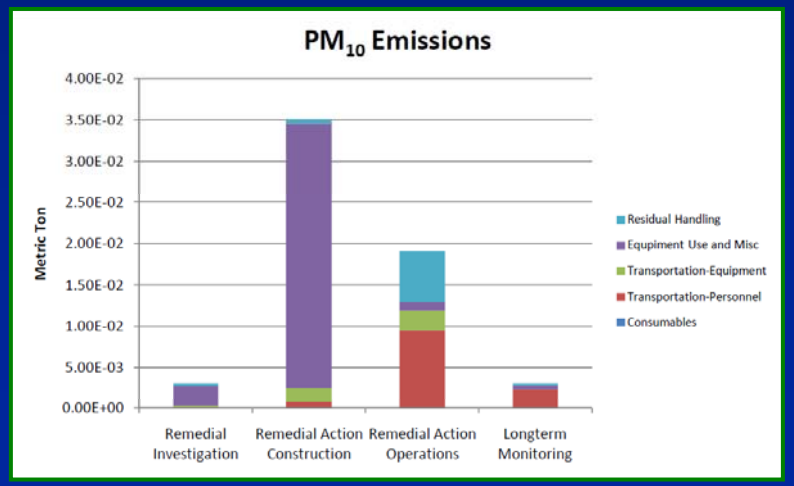


GSR Evaluation Results: G-1









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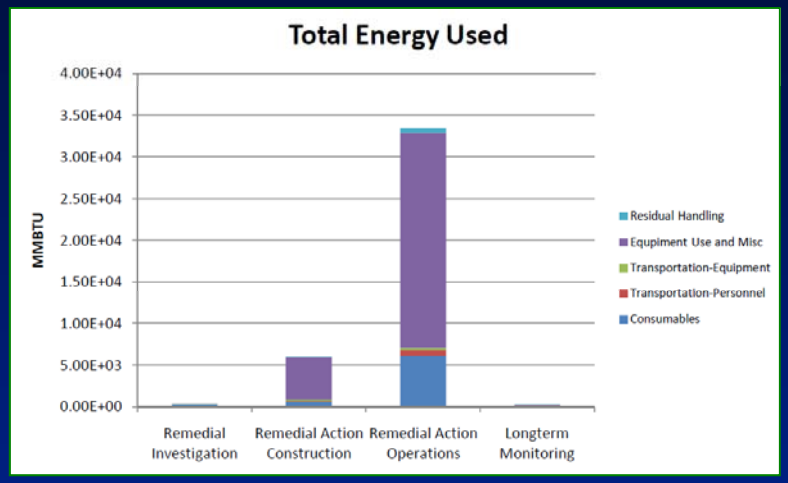
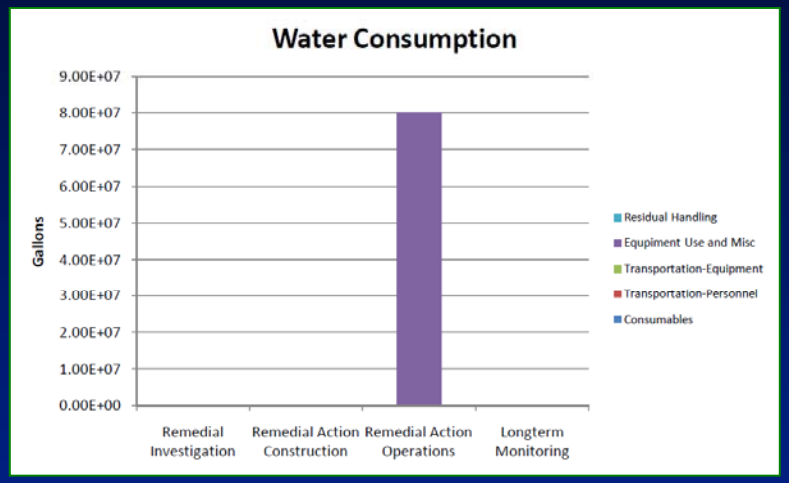
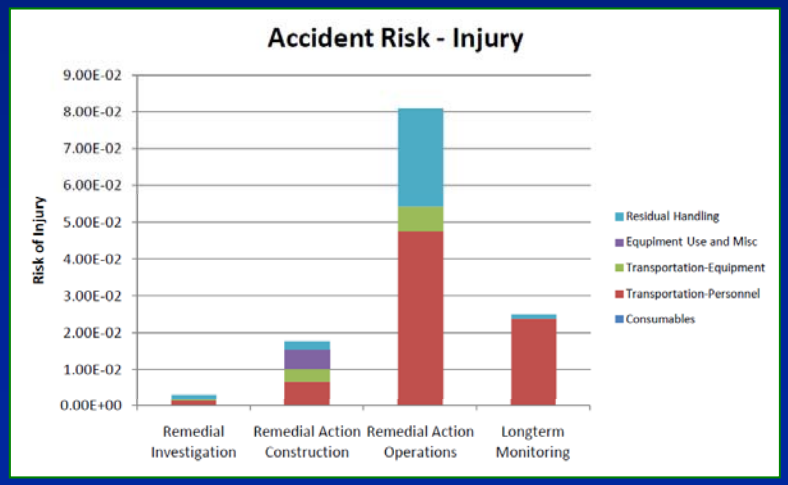
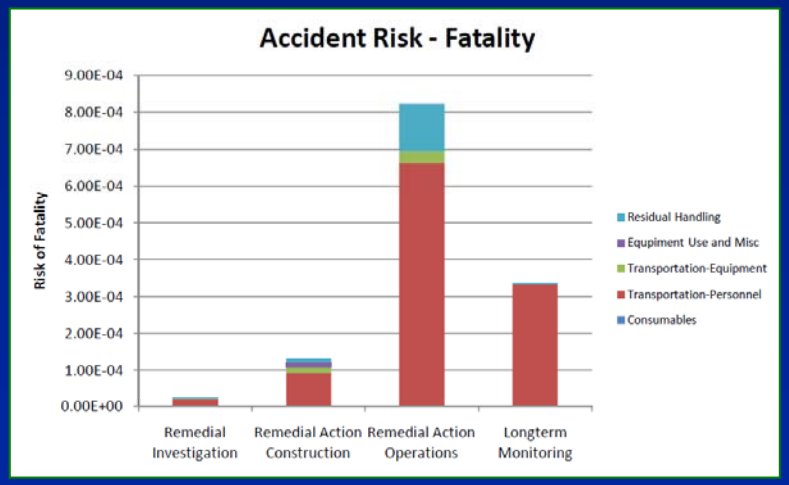
GSR Evaluation Results: G-1









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GSR Evaluation Result Summary: G-1

- ***GHG emissions drivers*: Electricity production for system operation (1,320 tonnes), material usage for system operation (320 tonnes GAC, 50 tonnes chemical consumables), and HDPE, PVC, and steel installation materials (89 tonnes)**
- ***NO_x emissions drivers*: Electricity production for system operation (86%)**
- ***SO_x emissions drivers*: Electricity production for system operation (98%)**
- ***PM_{10} emissions drivers*: Installation equipment operation (53%), personnel transportation (21%), residual handling (11%), and equipment transportation (7%).**
- ***Energy demand drivers*: System operation electricity demand (65%), GAC (14%), installation materials (12%)**
- ***Water usage drivers*: Water extraction and discharge (>99%)**
- ***Collateral risk drivers*: Personnel transportation, equipment transportation, and residual handling**

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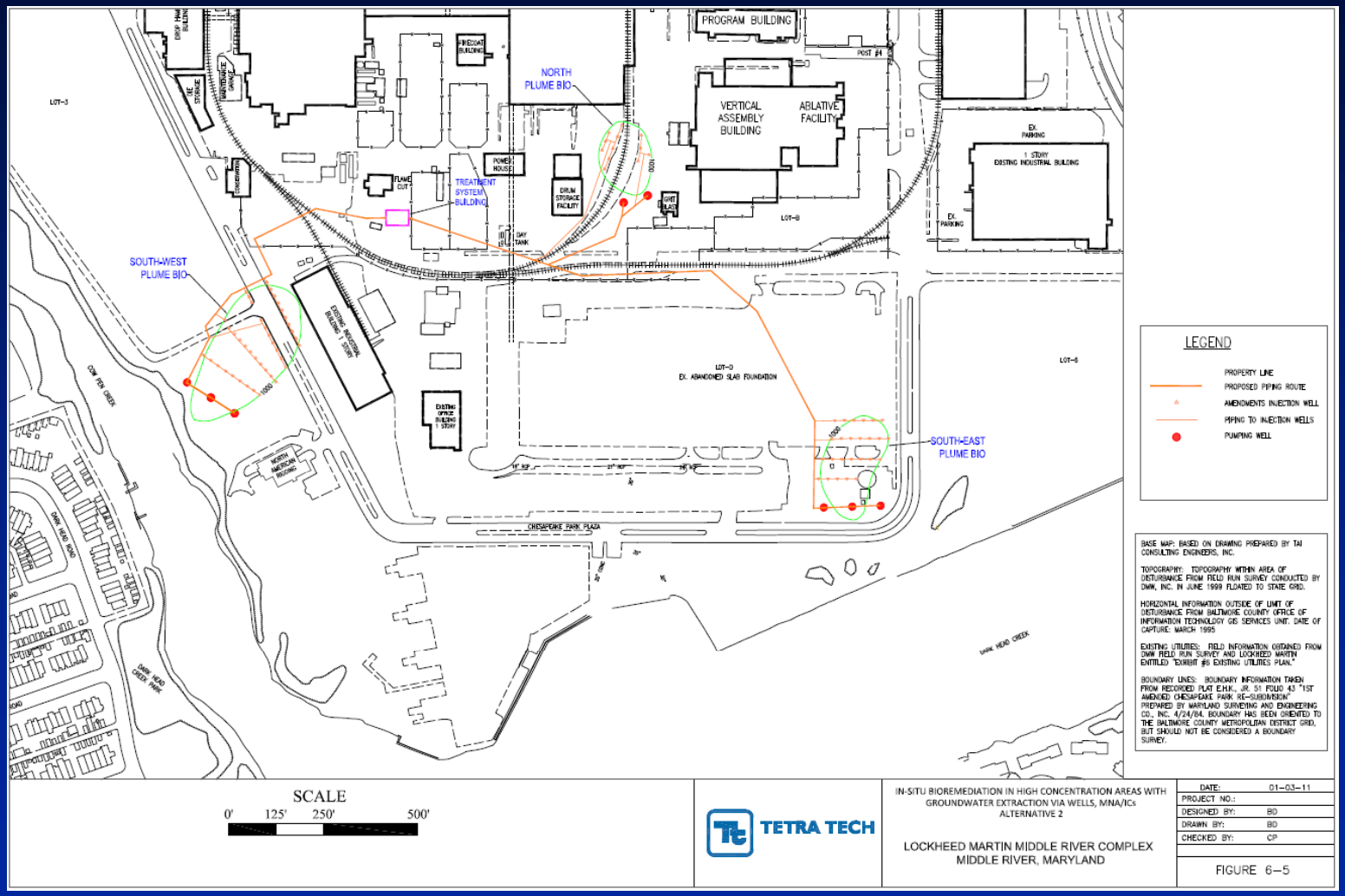
Alternative Summary: G-2

- ***Alternative G-2: In situ enhanced anaerobic bioremediation (EAB) (7 yr), with downgradient migration control by vacuum enhanced extraction in wells and extracted water treatment (8 yr-simultaneous); followed by monitored natural attenuation (22 yr).***
  - ***Source mass removal :***
    - ***9 extraction wells (groundwater and soil vapor extraction)***
    - ***Bioremediation substrate injection at 78 permanent injection points via mobile injection (7 year treatment period, 3 injection events)***
  - ***Infrastructure (injection points manifolded by region)***
  - ***Treatment System: Vacuum pump, air stripper, transfer pumps, pH control, coagulant dosing, clarifier, sediment filtration, liquid- and vapor-phase GAC, and surface water discharge***
  - ***Long term monitoring (30 year monitoring)***

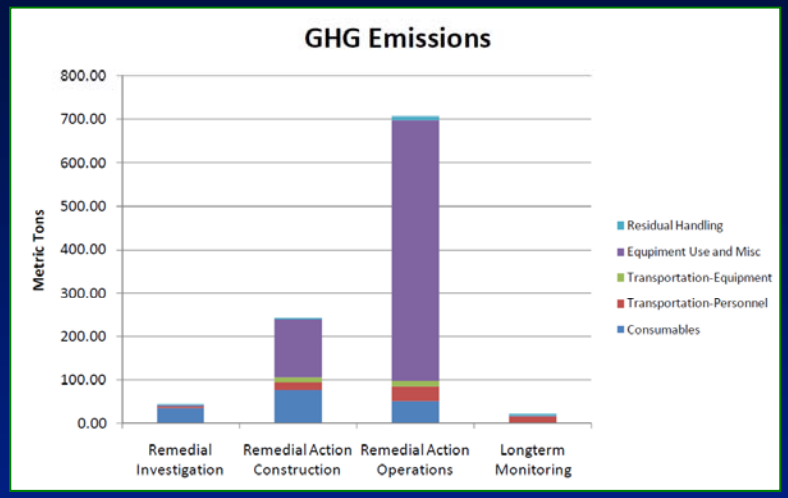
Lockheed Martin Proprietary Information

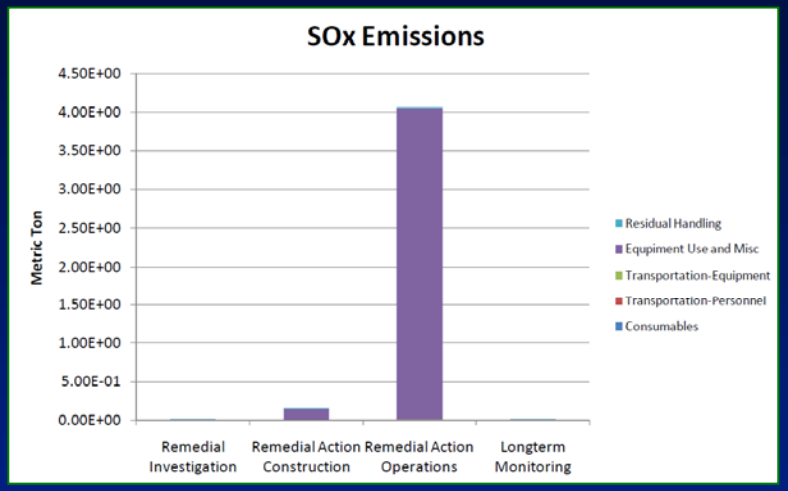
Alternative Summary: G-2

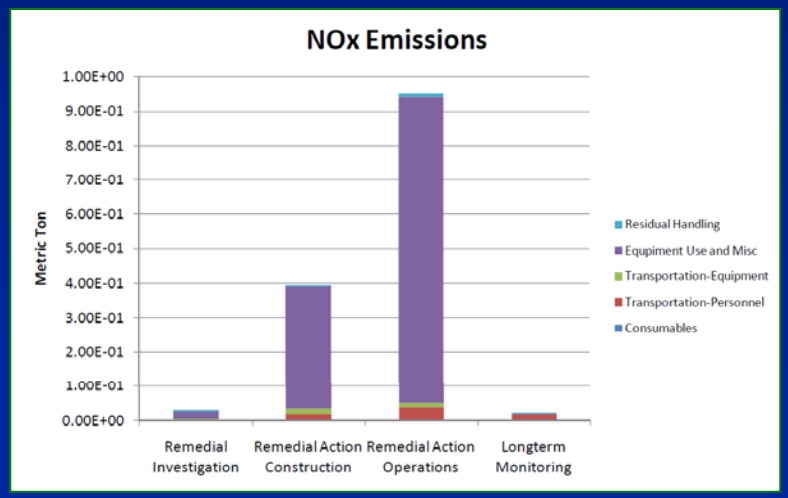


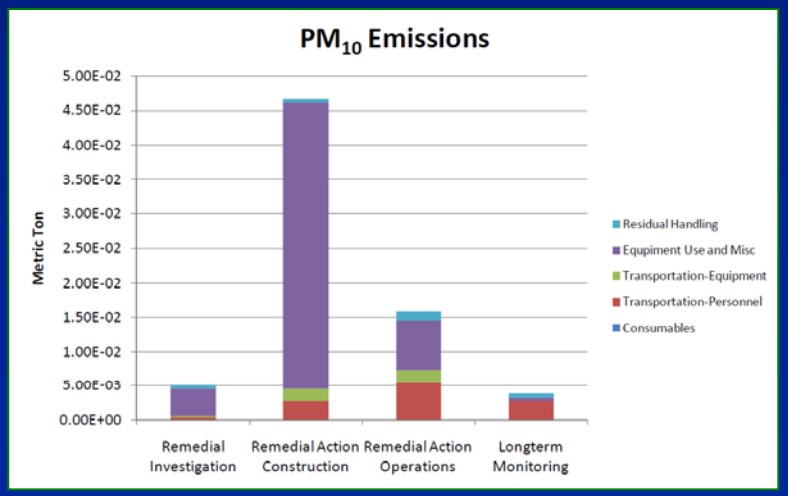
Lockheed Martin Proprietary Information

GSR Evaluation Results: G-2









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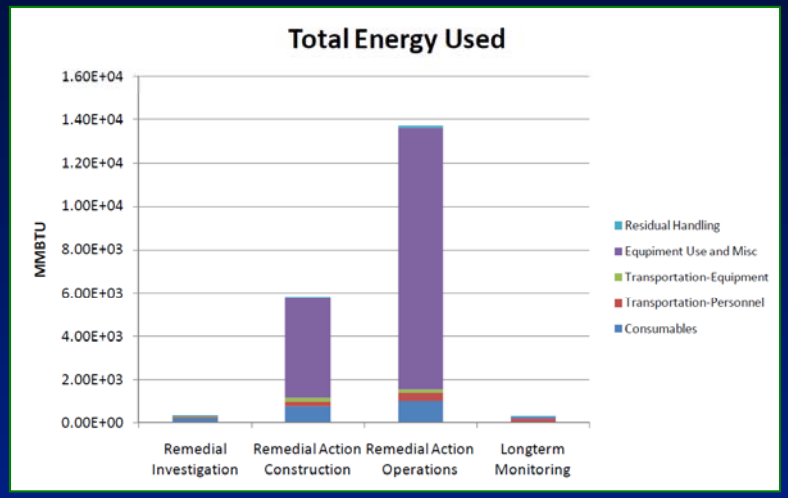
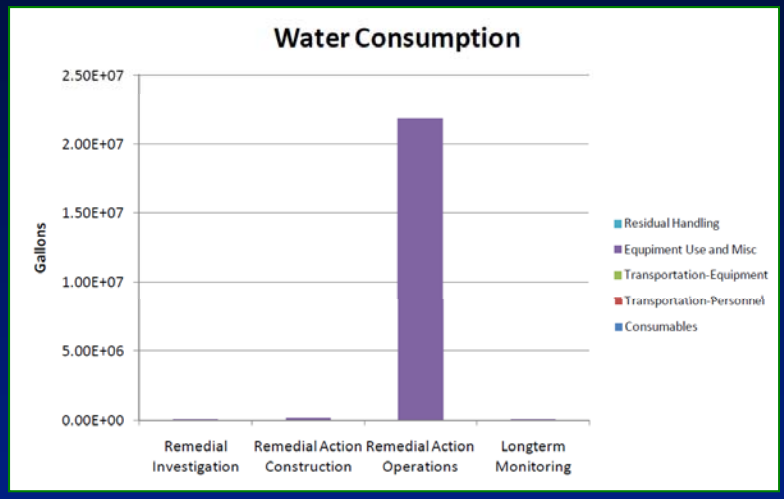
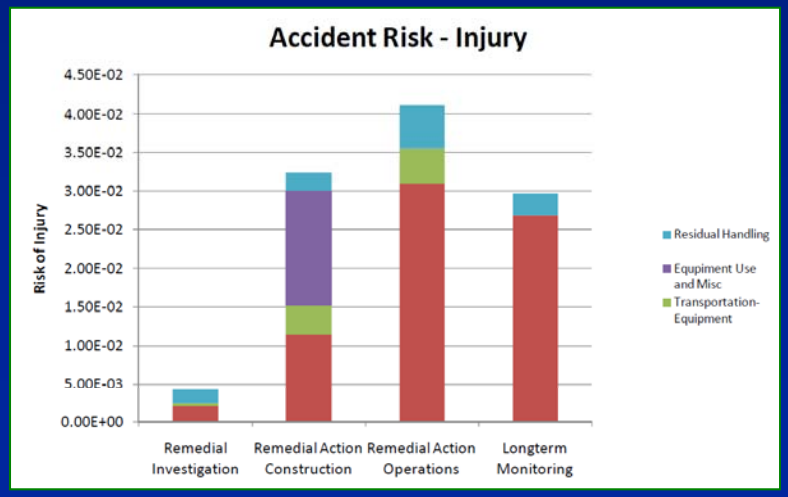
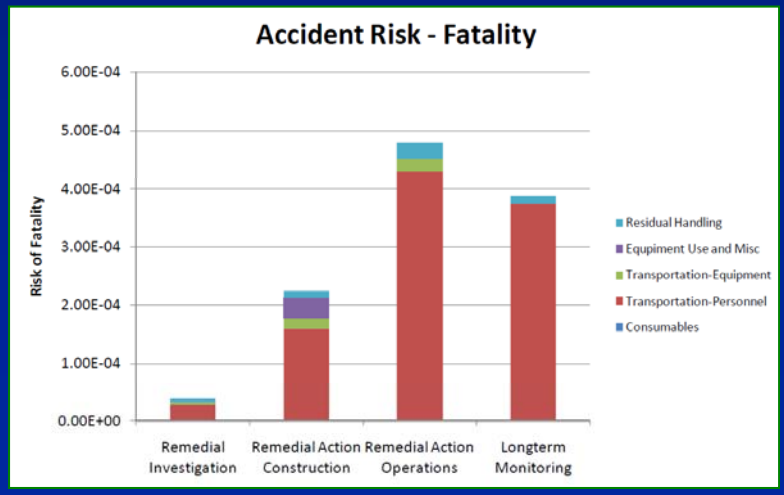
GSR Evaluation Results: G-2









Lockheed Martin Proprietary Information

GSR Evaluation Result Summary: G-2

- ***GHG emissions drivers*: Electricity production for system operation (600 tonnes), HDPE, PVC, and steel installation materials (169 tonnes), and GAC, NaOH, and bioremediation substrate material usage for system operation (51 tonnes)**
- ***NO_x emissions drivers*: Electricity production for system operation (64%) and installation heavy equipment operation (23%)**
- ***SO_x emissions drivers*: Electricity production for system operation (95%)**
- ***PM_{10} emissions drivers*: Heavy equipment usage (61%) and transportation of personnel and equipment (20%)**
- ***Energy demand drivers*: System operation electricity demand (56%), installation equipment (26%),**
- ***Water usage drivers*: Groundwater extraction and discharge (99%)**
- ***Collateral risk drivers*: Personnel transportation, equipment transportation, and residual handling**

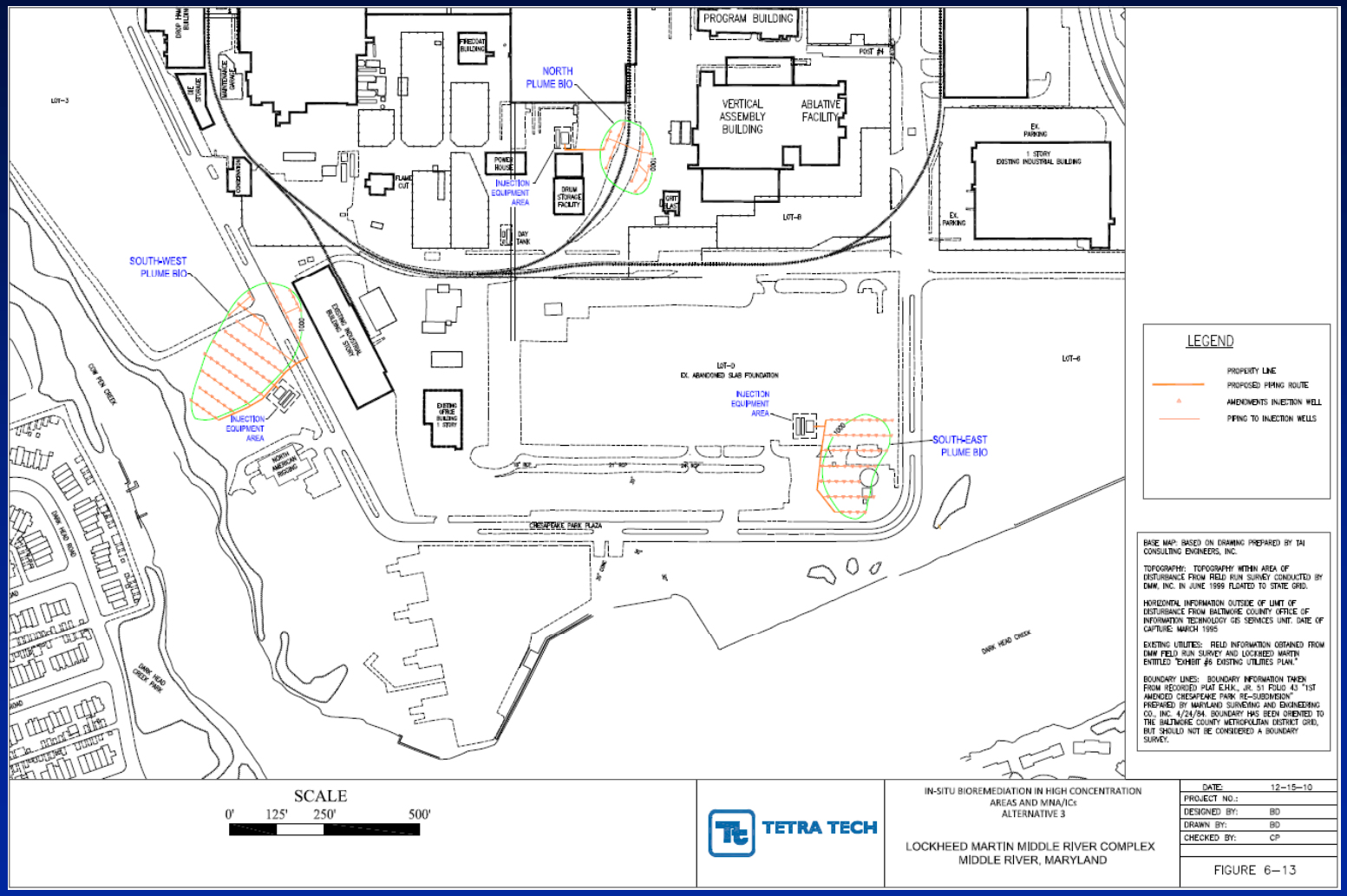
Lockheed Martin Proprietary Information

Alternative Summary: G-3

- ***EAB (7 yr); followed by monitored natural attenuation (23 yr). Major Components:***
  - ***Source mass removal : Bioremediation substrate injection at 148 permanent injection points via mobile injection (7 year treatment period, 3 injection events)***
  - ***Infrastructure (injection points manifolded by region)***
  - ***Long term monitoring (30 year monitoring)***

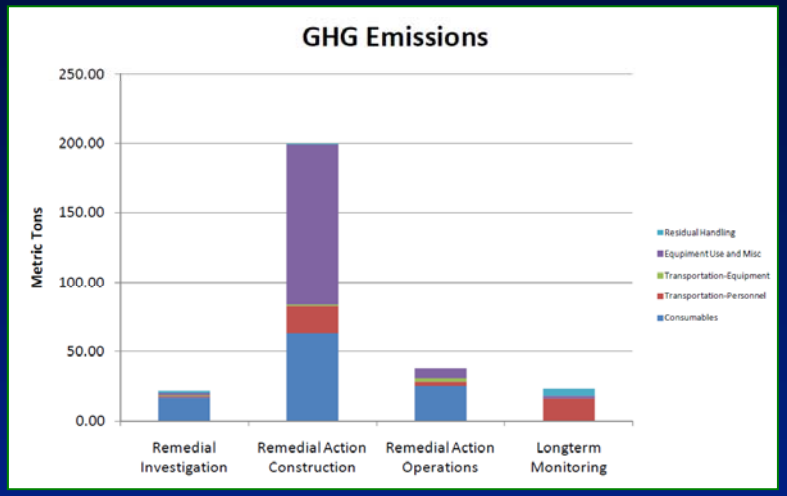
Lockheed Martin Proprietary Information

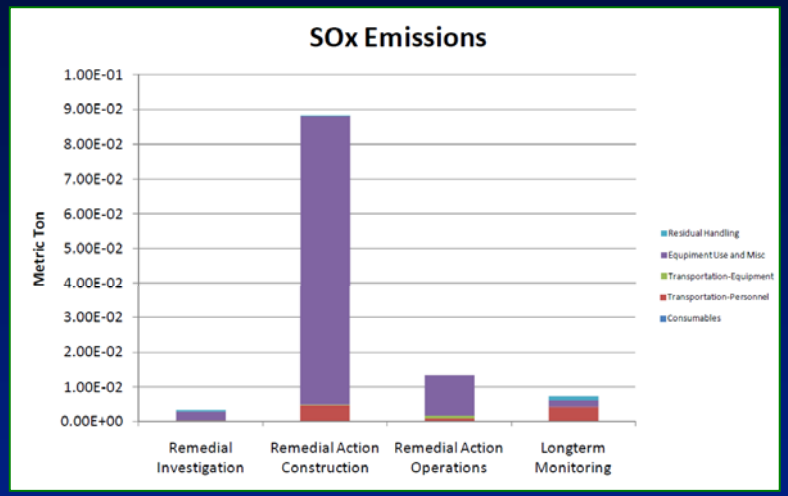
Alternative Summary: G-3

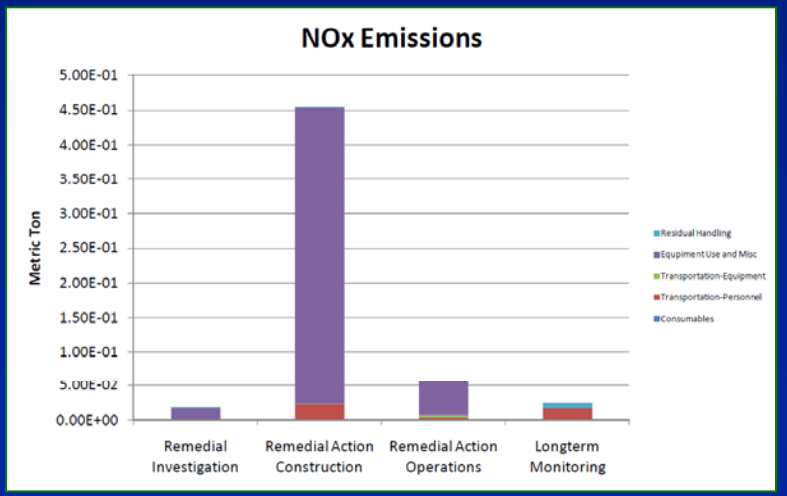


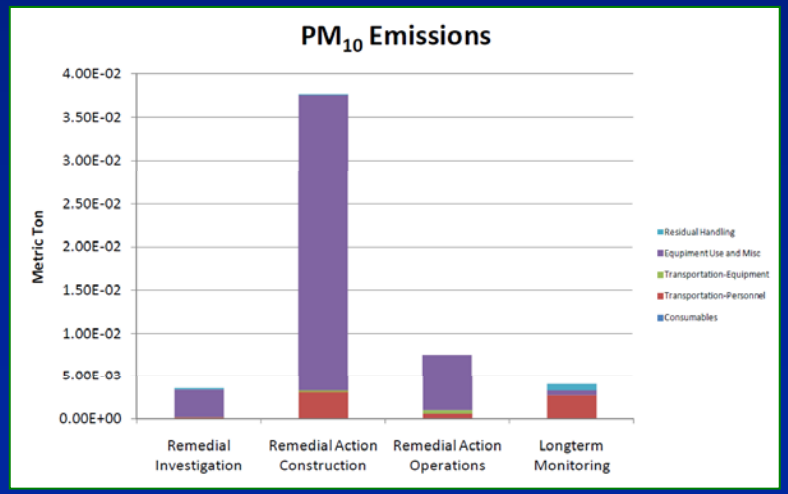
Lockheed Martin Proprietary Information

GSR Evaluation Results: G-3









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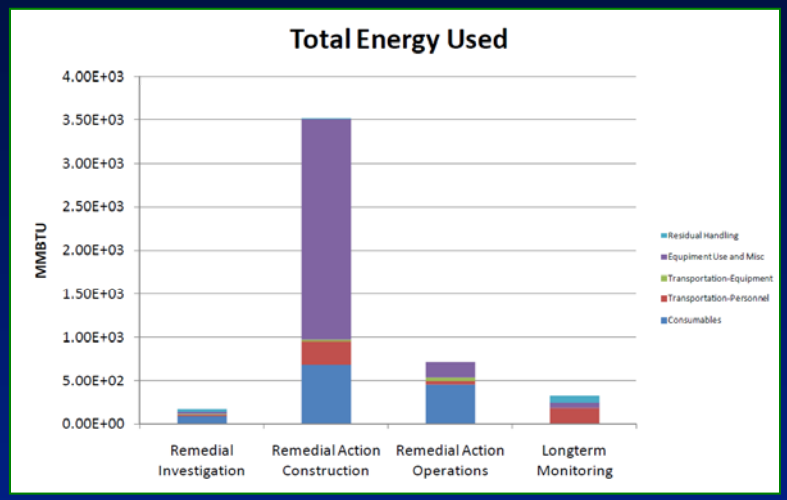
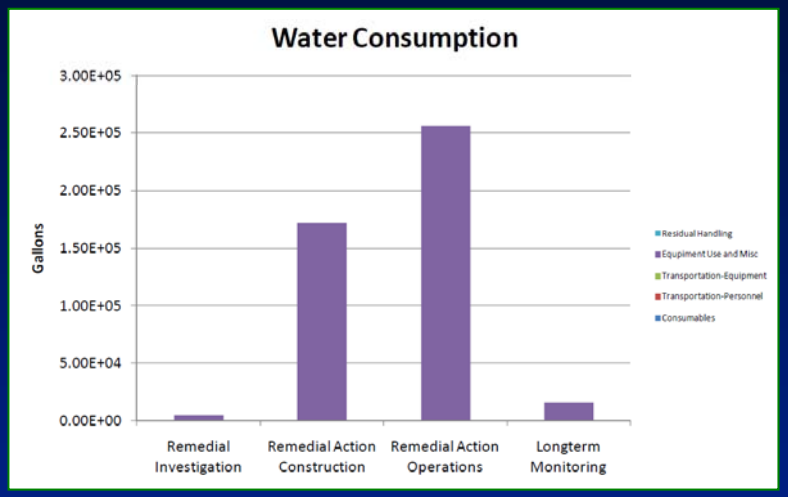
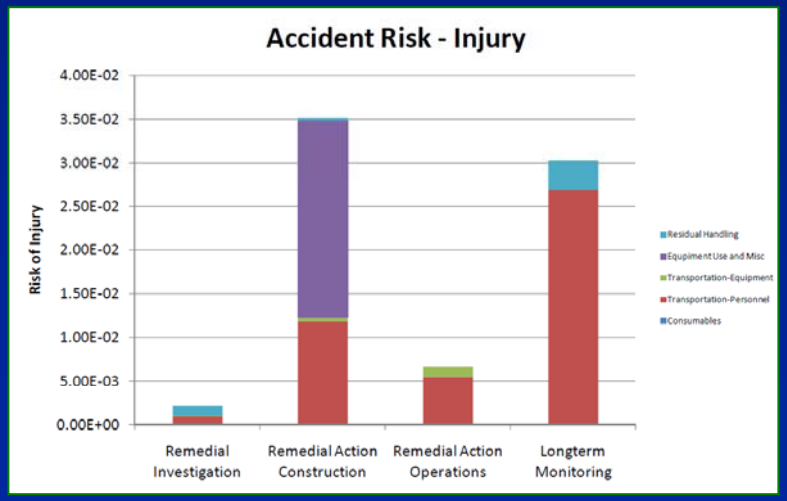
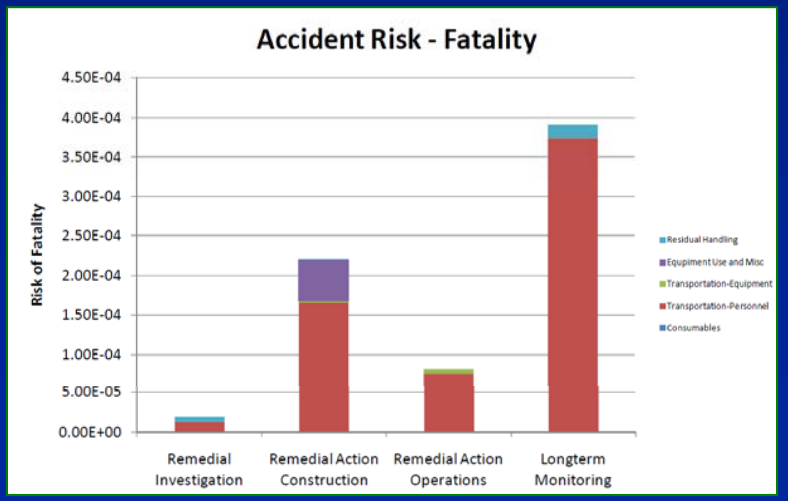
GSR Evaluation Results: G-3









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GSR Evaluation Result Summary: G-3

- ***GHG emissions drivers*: Well installation equipment (67 tonnes drilling), HDPE, PVC, and steel installation materials (63 tonnes), bioremediation substrate material manufacture (25 tonnes), and LTM personnel transportation (16 tonnes)**
- ***NO_x emissions drivers*: Well Installation equipment (73%)**
- ***SO_x emissions drivers*: Well Installation equipment (71%), substrate injection (10%)**
- ***PM_{10} emissions drivers*: Injection point installation (65%)**
- ***Energy demand drivers*: Installation equipment usage (54%), installation material manufacture (15%), bioremediation substrate manufacture (10%)**
- ***Water usage drivers*: Bioremediation substrate dilution (57%), well development (38%)**
- ***Collateral risk drivers*: Personnel transportation**

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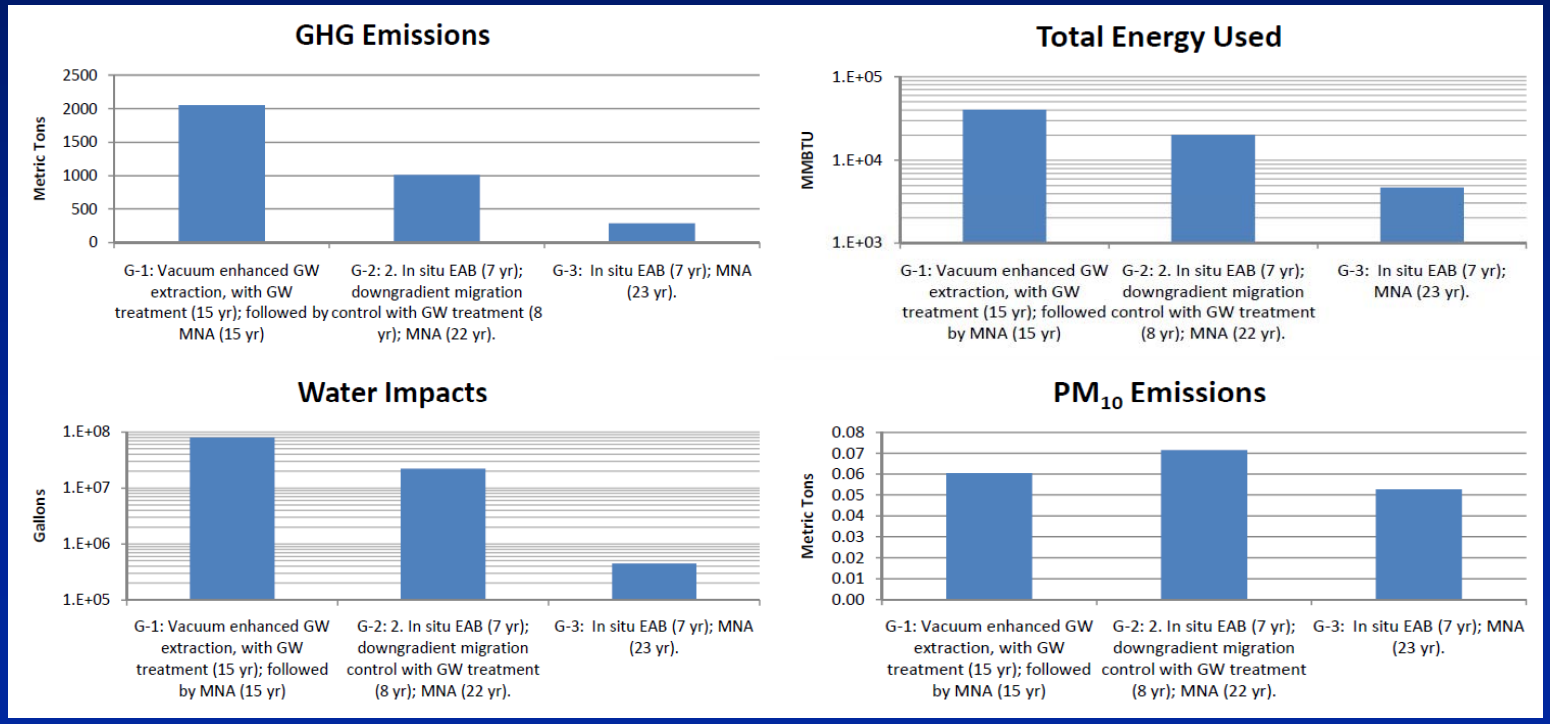
GSR Evaluation Results - Overall

Remedial Alternative	GHG Emissions metric ton	NOx emissions metric ton	SOx Emissions metric ton	PM10 Emissions metric ton	Total energy Used MMBTU	Water Consumption gallons	Accident Risk Fatality	Accident Risk Injury
G-1: Vacuum enhanced GW extraction, with GW treatment (15 yr); followed by MNA (15 yr)	2052.5	2.45	6.76	0.060	40056.6	80221371	0.13%	12.7%
G-2: 2. In situ EAB (7 yr); downgradient migration control with GW treatment (8 yr); MNA (22 yr)	1014.6	1.40	4.21	0.072	20254.5	22036773	0.11%	10.7%
G-3: In situ EAB (7 yr); MNA (23 yr)	282.8	0.55	0.11	0.053	4724.3	448973	0.07%	7.4%



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Conclusions

- ***SiteWise should not be viewed as a "black box" and additional support may be required while performing quantitative GSR evaluations with the tool.***
- ***GSRx was an effective supplement to SiteWise to address data gaps.***
- ***Alternative G-1 has considerably higher resulting values for the metrics evaluated in comparison to Alternatives G-2 and G-3.***
- ***Replacing the source mass removal element of groundwater extraction (Alternative G-1) with bioremediation (G-2) resulted in a dramatically decreased environmental footprint between the two alternatives (49% decrease, 1,040 tonne reduction in GHG).***
- ***Similarly, removal of hydraulic containment elements to form Alternative G-3 resulted in the lowest environmental footprint of all the alternatives.***

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Conclusions

- ***During selection and design of the remedy, a sensitivity analysis considering elements of the remedy that have the greatest impact on remedy effectiveness, life-cycle cost, and sustainability metrics may provide additional insight into appropriate optimization. For example,***
  - ***Optimization of equipment sizing and operation (e.g. VFDs, pulsing, etc)***
  - ***Purchase of electricity from a renewable energy source***
  - ***Optimization of chemical selection, application methods, and injection locations***
  - ***Emission control devices and alternate fuels in installation equipment and transportation vehicles to reduce on-site emissions (specifically criteria pollutants)***

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Questions

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412-921-8790

Note: Input and results from the GSR evaluation are available in pdf, upon request.

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APPENDIX L—TOTAL COST ANALYSIS INFORMATION

Middle River Total Cost Assessment - Quantitative and Qualitative Elements

I. Direct Costs	Included in quantitative cost estimate	Included in Qualitative Assessment in Evaluation Criteria
Engineering (Design)	Included in NPV Calculation	
Construction	Included in NPV Calculation	
OM&M	Included in NPV Calculation	
Permitting and Agency Interaction	Included in Engineering (Design)	
Legal Costs	Legal Costs to support the program are in Category II	
II. Hidden and Overhead		
EESH	Included in NPV Calculation	
Corporate Legal	Included in NPV Calculation	
Corporate Accounting	Included in NPV Calculation	
III Future & Contingent Liability		
Natural Resource Damages		Long Term Effectiveness, State and Community Acceptance
Fines and Penalties		Long Term Effectiveness
Property Damage		Short Term Effectiveness, Implementability (Technical Feasibility and Interference with Plant Operations_
Personal Injury		Implementability (and Health and Safety Program)
Remedy Re-Dos		Long Term Effectiveness - There is uncertainty with all final alternatives. The RAP will include a discussion of monitoring and contingency planning
Currently unknown issues:		
New, Unrecognized, Plumes		The Operating Facilities (Block I) occupy half the area of the MRC. There is a monitoring program in place under and around the buildings. Effects on remediation, if any, will be identified as remedial operations and monitoring proceed in the future.
Changing Regulatory Standards affecting the significance nature and extent of contamination, transport and impacts of known contaminants		Cannot identify these issues with certainty. LMC's emerging contaminant initiative and Federal initiative to improve water quality in Chesapeake Bay are part of the ongoing remediation planning.
Unknown nature and extent of contamination under Block I buildings		See discussion under "New, Unrecognized, Plumes"
Future spills or releases of contaminants to groundwater		Cannot quantify this issue. Plant and remediation project team have procedures in place to deal with spills.
Effect of demolition of all or part of Block I buildings on groundwater flow patterns with need to reconfigure remediation systems		Will be studied if there is a plan to demolish the buildings. Adjustments to the remediation program will be made if active remediation is still occurring. If necessary, remediation will be initiated in the Block I building footprints after demolition.
Emerging Contaminants and effects on source treatment and extracted groundwater treatment.		Known emerging contaminants are considered in the present groundwater remediation proposals
Disposal facility failures		
Waste generated during construction		This is a risk that is not addressed in the RAP. Presumption is that the LMC qualification process is the best means to minimize this risk
Waste generated during operation		This is a risk that is not addressed in the RAP. Presumption is that the LMC qualification process is the best means to minimize this risk
Issues Related to Development under Land Use Controls		
Encounter unexpected contamination		Land Use Controls are part of the plan and will require monitoring of future ntrusive work
IV Internal Intangible		
Community Relations		Community Accepance Evaluation Criterion. LMC actively engages community in the remediation planning process.
Regulatory Relations		State Accepance Evaluation Criterion. LMC actively engages regulators in the remediation planning process.
Consumer Acceptance		Not addressed in RAP. Not expected to be an issue related to remediation planning and execution.
Customer Loyalty		Not addressed in RAP. Not expected to be an issue related to remediation planning and execution.
Corporate Image		Not addressed in RAP. Not expected to be an issue related to remediation planning and execution.
Worker Morale		Short Term and Long Term Effectiveness. Potentially impacted plant workers and managers are actively engaged in the process. Remediation workers will be operating in an environment that places a high priority on safety, worker awareness of contaminants and measures taken to protect them from unsafe exposures
Worker Wellness		Short Term and Long Term Effectiveness. Potential impacts on plant workers are continually assessed and mitigated through the subslab and indoor air monitoring programs. Remediation workers will be working under OSHA and HAZWOPER protocols which have the objectives of protecting worker health and safety. Active remediation workplace and perimeter monitoring with adjustments to remediation procedures, if necessary, have the objectives of protecting remediation workers, plant workers and the community from unsafe contaminant exposure
V External		
Environmental Deterioration		Long Term Effectiveness Criterion
Resource Depletion		Addressed in Life Cycle Assessment
Protection of Future Residents and Workers		
LMC cost associated with future development of the properties(vapor mitigation and additional contaminant remova;l)		Cannot be quantified at this time. Remedial Action Objectives for groundwater recognize the need for Land Use Controls. Remediation objectives for soil,to be addressed in the Soil RAPs, is the other part of this conside
Cost associated with expanded and continuing Soil Vapor Intrusion monitoring		This is a separate, soil remediation-related program

Annual and Net Present Value Costs
For Remediation Alternatives 1, 2 and 3

Year	Alternative 1	Alternative 2	Alternative 3
2011	$515,000	$515,000	$364,000
2012	$2,041,000	$3,409,000	$2,142,000
2013	$304,000	$532,000	$449,000
2014	$304,000	$541,000	$430,000
2015	$304,000	$326,000	$179,000
2016	$278,000	$479,000	$370,000
2017	$250,000	$233,000	$88,000
2018	$228,000	$226,000	$88,000
2019	$228,000	$226,000	$88,000
2020	$202,000	$200,000	$63,000
2021	$203,000	$47,000	$39,000
2022	$202,000	$39,000	$39,000
2023	$202,000	$39,000	$39,000
2024	$203,000	$39,000	$39,000
2025	$202,000	$39,000	$39,000
2026	$202,000	$39,000	$39,000
2027	$202,000	$39,000	$39,000
2028	$32,000	$32,000	$32,000
2029	$32,000	$26,000	$26,000
2030	$32,000	$32,000	$32,000
2031	$32,000	$26,000	$26,000
2032	$32,000	$32,000	$32,000
2033	$26,000	$26,000	$26,000
2034	$32,000	$32,000	$32,000
2035	$26,000	$26,000	$26,000
2036	$32,000	$32,000	$32,000
2037	$26,000	$26,000	$26,000
2038	$32,000	$32,000	$32,000
2039	$26,000	$26,000	$26,000
2040	$32,000	$32,000	$32,000
2041	$26,000	$26,000	$26,000
2042	$32,000	$32,000	$32,000
2043	$26,000	$26,000	$26,000
2044	$558,000	$445,000	$588,000

Net Present Values at 7% Discount Rate:

Alternative 1	Alternative 2	Alternative 3
$4,666,000	$5,991,000	$3,979,000

Alternative 1 - Groundwater Recovery with Vacuum Enhancement

	Annual Costs					
Year	Design	Construction	Decommissioning	OMM	LMC Internal	Total
2011	$409,282				$105,539	$514,821
2012		$1,935,886			$105,539	$2,041,425
2013				$198,569	$105,539	$304,107
2014				$198,569	$105,539	$304,107
2015				$198,856	$105,539	$304,395
2016				$198,569	$79,164	$277,732
2017				$198,569	$51,536	$250,105
2018				$176,661	$51,536	$228,197
2019				$176,374	$51,536	$227,910
2020				$176,374	$26,034	$202,407
2021				$176,661	$26,034	$202,695
2022				$176,374	$26,034	$202,407
2023				$176,374	$26,034	$202,407
2024				$176,661	$26,034	$202,695
2025				$176,374	$25,502	$201,876
2026				$176,374	$25,502	$201,876
2027				$176,374	$25,502	$201,876
2028				$6,659	$25,502	$32,161
2029				$6,659	$25,502	$32,161
2030				$6,659	$25,502	$32,161
2031				$6,659	$25,502	$32,161
2032				$6,659	$25,502	$32,161
2033				$0	$25,502	$25,502
2034				$6,659	$25,502	$32,161
2035				$0	$25,502	$25,502
2036				$6,659	$25,502	$32,161
2037				$0	$25,502	$25,502
2038				$6,659	$25,502	$32,161
2039				$0	$25,502	$25,502
2040				$6,659	$25,502	$32,161
2041				$0	$25,502	$25,502
2042				$6,659	$25,502	$32,161
2043				$0	$25,502	$25,502
2044			$526,183	$6,659	$25,502	$558,344

Net Present Value at 7% Discount Rate $4,666,127

Alternative 2 - In Situ Bioremediation with Localized Groundwater Management

			Annual Costs				
Year	Design	Construction	Bioremediation Injection	Decommissioning	OMM	LMC Internal	Total
2011	$409,282					$105,539	$514,821
2012		$3,303,002				$105,539	$3,408,540
2013			$189,057		$237,698	$105,539	$532,293
2014			$189,057		$246,565	$105,539	$541,160
2015					$220,107	$105,539	$325,646
2016			$189,057		$210,999	$79,164	$479,219
2017					$181,677	$51,536	$233,213
2018					$174,431	$51,536	$225,967
2019					$174,144	$51,536	$225,680
2020					$174,144	$26,034	$200,177
2021					$20,850	$26,034	$46,884
2022					$13,317	$26,034	$39,351
2023					$13,317	$26,034	$39,351
2024					$13,317	$26,034	$39,351
2025					$13,317	$25,502	$38,819
2026					$13,317	$25,502	$38,819
2027					$13,317	$25,502	$38,819
2028					$6,659	$25,502	$32,161
2029					$0	$25,502	$25,502
2030					$6,659	$25,502	$32,161
2031					$0	$25,502	$25,502
2032					$6,659	$25,502	$32,161
2033					$0	$25,502	$25,502
2034					$6,659	$25,502	$32,161
2035					$0	$25,502	$25,502
2036					$6,659	$25,502	$32,161
2037					$0	$25,502	$25,502
2038					$6,659	$25,502	$32,161
2039					$0	$25,502	$25,502
2040					$6,659	$25,502	$32,161
2041					$0	$25,502	$25,502
2042					$6,659	$25,502	$32,161
2043					$0	$25,502	$25,502
2044				$413,141	$6,659	$25,502	$445,302

Net Present Value at 7% Discount Rate = $5,991,070

Alternative 3 - In Situ Bioremediation

			Annual Costs				
Year	Design	Construction	Bioremediation Injection	Decommissioning	OMM	LMC Internal	Total
2011	$258,424					$105,539	$363,962
2012		$2,036,379				$105,539	$2,141,917
2013			$217,415		$126,154	$105,539	$449,108
2014			$217,415		$107,418	$105,539	$430,372
2015					$73,709	$105,539	$179,248
2016			$217,415		$73,709	$79,164	$370,289
2017					$36,855	$51,536	$88,391
2018					$36,855	$51,536	$88,391
2019					$36,855	$51,536	$88,391
2020					$36,855	$26,034	$62,888
2021					$13,317	$26,034	$39,351
2022					$13,317	$26,034	$39,351
2023					$13,317	$26,034	$39,351
2024					$13,317	$26,034	$39,351
2025					$13,317	$25,502	$38,819
2026					$13,317	$25,502	$38,819
2027					$13,317	$25,502	$38,819
2028					$6,659	$25,502	$32,161
2029					$0	$25,502	$25,502
2030					$6,659	$25,502	$32,161
2031					$0	$25,502	$25,502
2032					$6,659	$25,502	$32,161
2033					$0	$25,502	$25,502
2034					$6,659	$25,502	$32,161
2035					$0	$25,502	$25,502
2036					$6,659	$25,502	$32,161
2037					$0	$25,502	$25,502
2038					$6,659	$25,502	$32,161
2039					$0	$25,502	$25,502
2040					$6,659	$25,502	$32,161
2041					$0	$25,502	$25,502
2042					$6,659	$25,502	$32,161
2043					$0	$25,502	$25,502
2044				$556,201	$6,659	$25,502	$588,362

Net Present Value at 7% Discount Rate = $3,979,176

APPENDIX M—*CRITERIUM DECISION PLUS* RESULTS

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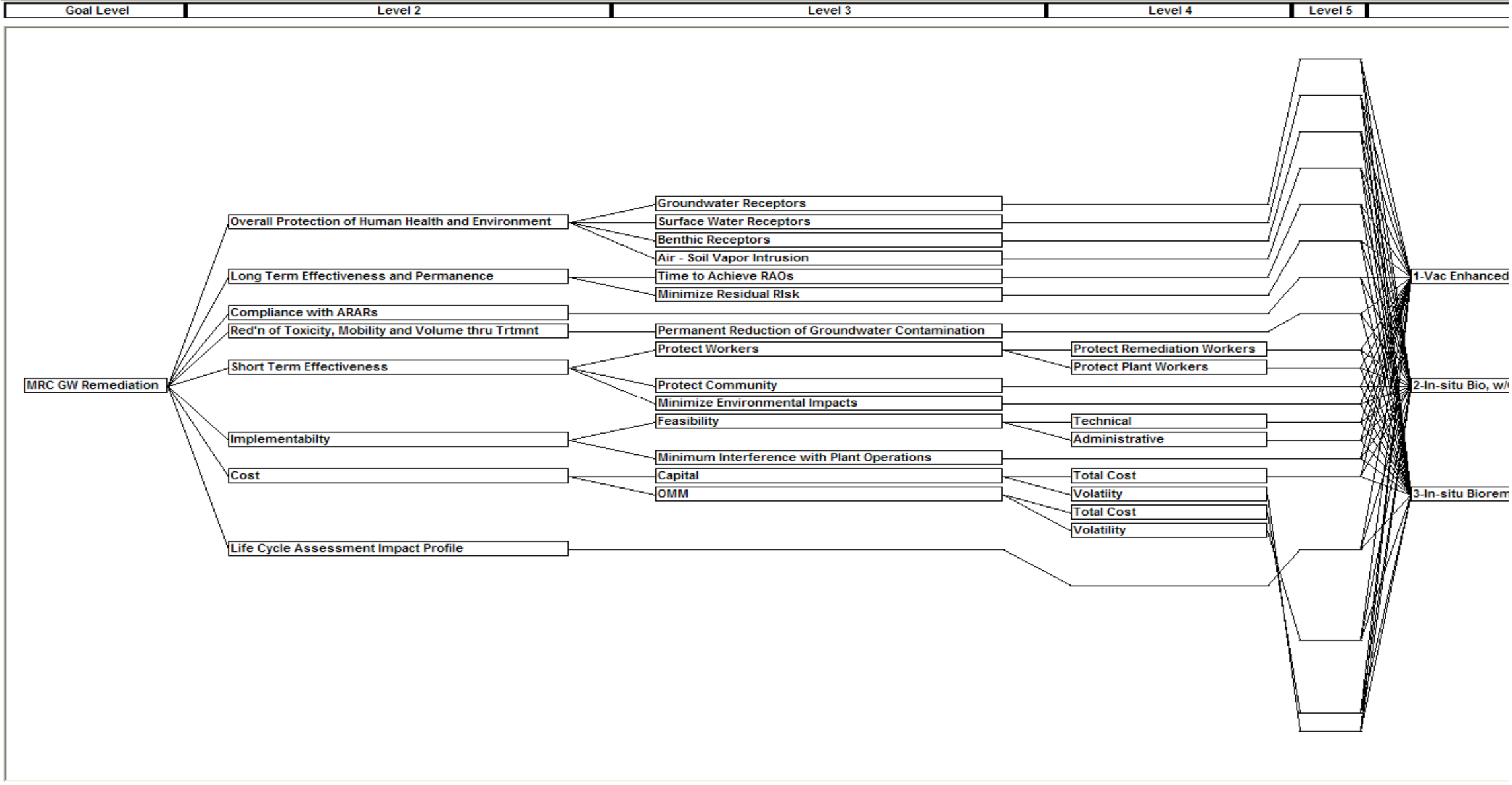


Alternatives	Value	Decision Scores
1-Vac Enhanced GW Recov, Water&Vap Tmt, Discharge	0.478	
2-In-situ Bio, w/GW Mgt by Wells	0.526	
3-In-situ Bioremediation	0.644	

APPENDIX N—SOIL MANAGEMENT PLAN

APPENDIX N—
SOIL MANAGEMENT PLAN FOR MRC GROUNDWATER REMEDIAL ACTION

1.0 BACKGROUND

This soil management plan (SMP) describes how soils disturbed during implementation of the groundwater remedial action (RA) at the Lockheed Martin Middle River Complex (MRC) in Middle River, Maryland will be managed. This document is the revised Appendix N to the *Groundwater Response Action Plan—Lockheed Martin Middle River Complex* prepared by Tetra Tech, Inc. (Tetra Tech) for Lockheed Martin Corporation (Lockheed Martin) in accordance with the requirements of the Maryland Department of the Environment's Voluntary Cleanup Program (Section 7-508 of the "Environment Article," *Annotated Code of Maryland*). As stated in the groundwater response action plan (RAP), the proposed remedy involves *in situ* bioremediation in high contaminant-concentration areas and institutional controls that will prohibit groundwater use in other areas.

Implementation of *in situ* bioremediation will require the installation of a number of injection wells and associated infrastructure, including injection lines and bioremediation equipment. The injection lines will be installed in trenches leading up to each injection well. The bioremediation--amendment preparation equipment (including tanks, mixers, pumps and other appurtenances) will be housed in a container in each block.

Three separate *in situ* bioremediation injection systems will be installed to address three elevated-concentration areas associated with groundwater plumes (one each in Blocks G, E, and I) that have been identified on the Middle River Complex site. MRC soils in these areas are known to be impacted either by chemical constituents inherent in historical fill materials used at various times to construct or reshape the land around the MRC, or by release(s) associated with past site activities. In addition, soils outside of known impacted areas may also be impacted due to the heterogeneity of the fill material, the long history of industrial activity at the site, and the extent of subsurface investigation data.

The groundwater system is expected to remain in place for many years, and its placement would significantly complicate future industrial-reuse-based cleanup of soils under and around the infrastructure. Therefore, to avoid future complications and as part of site preparation, soils impacted by chemical concentrations above industrial preliminary remedial goals will be removed. Pre-construction soil remediation will be undertaken in the areas of Blocks E and G, near the groundwater remediation system infrastructure. Soil will be generally removed to a maximum depth of two to three feet below grade in Block E and three feet below grade in Block G before installation of any groundwater remediation infrastructure.

Soil remediation in Block I (which is generally comprised of the currently operating facility) is expected to proceed following the completion of additional soil characterization at Block I planned after completion of the groundwater RA; therefore, no pre-construction soil remediation will be done in Block I. Block I soils that are disturbed will be characterized and either reused as backfill in the same area or taken off-site for disposal. All soil outside the disturbance area in Block I will remain in place at this time.

The infrastructure footprints in Blocks E and G are encompassed by the injection wells, the piping infrastructure, and the process containers. This soil remediation will be performed under the contract for final design, construction, and initial operation of the *in situ* bioremediation system. Sampling to delineate impacted soils in Blocks E and G within the groundwater RA footprint is scheduled to occur in 2013, in accordance with the *Soil Sampling and Analysis Plan, Groundwater Remediation System Installation, Blocks E, G and I, Middle River Complex, Middle River, Maryland* (Tetra Tech, 2013), hereinafter referred to as the "SAP."

2.0 PURPOSE

This SMP is for managing Blocks E and G soils that will be disturbed during implementation of the groundwater RA. The soil RAPs and SMPs associated with full-scale remediation of impacted soils in each tax block will be submitted later as separate documents. This SMP outlines only the remedial approach selected for soils that will be disturbed during implementation of the groundwater RA, or as part of site preparations for RA implementation.

3.0 OUTLINE OF SOIL MANAGEMENT ACTIVITIES DURING GROUNDWATER REMEDIAL ACTION

Following is an outline of soil management activities that will be performed during the groundwater RA. Additional detail is in Section 5 of this appendix.

1. Pre-construction soil remediation will not be done in Block I. In Block I, excavations are anticipated only to install piping and foundations, as applicable. For these specific installation activities, environmental controls will be used and pre-excavation soil sampling will characterize the soil to determine whether it will be disposed of or re-used as backfill.

2. In Blocks E and G, locations where soils will be disturbed during implementation of the groundwater RA will be identified, surveyed, and staked. This includes: (a) areas that will require trenching to install injection lines and underground utilities, (b) areas to be significantly disturbed during system installation activities, and (c) soils beneath permanent structures or the semi-permanent locations of containers used to house equipment.

    a. Areas with impacted soils (within the groundwater RA footprint) will be identified by comparing the soil sampling analytical results from delineation samples collected during 2013 and in previous investigations to risk-based industrial-cleanup values, as identified in the human health risk assessment (HHRA) and summarized in Section 4 of this appendix. In addition, areas with PCB concentrations above 1 mg/kg will also be identified for potential removal. Soil volumes to be excavated and transported off-site will be quantified for disposal purposes.

    b. Impacted soils at Block E will be excavated to a depth of three feet (deeper if necessary for foundations or utilities) within the planned trench excavation areas, and up to two feet for additional impacted soils contiguous with the trench excavations. These are soils that, based on prior sampling analytical results, are known to have contaminant concentrations exceeding the industrial-risk-based cleanup value or to have PCB concentrations greater than 1 mg/kg.

    c. Impacted soils at Block G will be excavated to a depth of three feet for soils within the planned trench areas and for impacted soils contiguous with the trench excavations (deeper if necessary for foundations or utilities).

    d. Cleanup-verification samples will be collected from the base and sidewalls of the excavations. Because this is an interim action (i.e., its purpose is only to remove impacted soil near the groundwater-remediation infrastructure), these results will not be used to define additional excavations at this time. These results will only be used to develop soil RAPs for Blocks E and G.

e. Verification sampling results will be appended to a construction completion report for the groundwater RA for all the blocks, and evaluated in the soil remedial design for Blocks E and G to be prepared and submitted separately outside of the groundwater RA contract-framework.

3. Pre-excavation waste-characterization sampling and analysis, as specified in the SAP (Tetra Tech 2013), will be performed for the parameters required by the selected disposal facility for all blocks.

4. Imported fill used in the remediation areas will be clean fill, in accordance with Maryland Department of the Environment's (MDE's) *Facts About Voluntary Cleanup Program [VCP] Clean Imported Fill Material,* which can be found at the Web address below:
   http://www.mde.state.md.us/programs/Land/MarylandBrownfieldVCP/MDVCPInformation/Documents/www.mde.state.md.us/assets/document/Clean%20Imported%20Fill%20Material(1).pdf.

4.0 SOIL SAMPLING AND HHRA RESULTS

Tetra Tech prepared an HHRA using the detected concentrations of chemicals in soil at a number of tax blocks, including Blocks E and G (Tetra Tech, 2012). The HHRA update does not include Block I, since the investigation of Block I is ongoing and site soils are unlikely to be remediated before decommissioning of the entire facility (which is not currently planned). The HHRA indicates that the following preliminary remedial goals are applicable for a future industrial land use scenario, and they will be used for Blocks E and G:

Chemical	Preliminary remedial goal[(1)] (mg/kg)
Benzo(a)pyrene equivalents	2.9[(2)]
PCBs, total (Block E only)	10[(3)]
Arsenic (Block G only)	27.3[(4)]
1,2,4-Trichlorobenzene (Block E only)	175[(5)]

Preliminary remedial goal units given as mg/kg concentration in soils.

(1) From the *Human Health Risk Assessment for Blocks D, E, F, G, and H Soils, Middle River Complex, Middle River, Maryland*, prepared by Tetra Tech, Inc. for Lockheed Martin Corporation, September 2012.

(2) Based on a 1×10^{-5} cumulative carcinogenic risk to human health for the industrial worker.

(3) Based on the Toxic Substance Control Act and a 1×10^{-5} cumulative carcinogenic risk to human health for the industrial worker. A conservative cleanup level of 1 mg/kg was established for this pre-construction excavation.

(4) Based on a 1×10^{-5} cumulative carcinogenic risk to human health for the industrial worker.

(5) Based on a hazard index of 0.5 (adjusted by 50% from a hazard index of 1.0, to account for cumulative effects of VOCs in target organs).

A preliminary residual-risk analysis (RRA) identified those locations that must be remediated so that remaining "representative" soil concentrations do not exceed the preliminary remedial goals established for the contaminants of concern in the tax block soils. Some of the areas that will be proposed in future RAPs for soil remediation and which are based on the RRA overlap with the planned groundwater system installation excavations in Blocks E and G. To simplify future soil remedial actions, soil areas contiguous with the groundwater system installation will be excavated and removed at the time of groundwater remedial construction, as described below.

5.0 PROPOSED RA PROCEDURE

RA procedures are as set forth in the associated drawings, specifications, and contract documents; figures excerpted from the design are attached. The remedial design documents specify the following:

1. Identification of the areas to be excavated and the approximate volume of soil that will be excavated (see attached Figures 2-1 and 2-2 and Drawings C-3 and C-4). In Blocks E and G, before construction begins, the remediation contractor will evaluate the results of the pre-construction delineation-sampling program performed in 2013 (see attached Figures 2-1 and 2-2). The contractor will re-define the areas to be excavated based on the target analytes listed in the cleanup goals section of this SMP (Section 4), and delineate by survey the impacted areas to be excavated and the volume of soil to be disposed of.

2. In Blocks E and G, based on the results of the pre-construction delineation-sampling performed in 2013 and the surveyed, re-defined excavation boundaries, the contractor will excavate and manage removed soil in this manner:

    a. All soil will be removed from an area 7.5-feet wide, centered at the piping trenches required for the groundwater remediation system; these areas will be excavated to a depth of three feet, or to the depth of groundwater, whichever comes first.

    b. Impacted soils are planned to be excavated to a depth of two feet in areas outside the 7.5-feet-wide areas at Block E; this depth may decrease based on the results of the 2013 pre-construction delineation-sampling. In areas outside the 7.5 feet wide areas at Block G, the planned excavation depth is three feet.

    c. Cleanup-verification samples will be collected within the trenches (from the sidewalls and base) as grab samples, at a frequency of one sample every 30–50 feet (approximately), as shown in the attached figures. Overall, verification samples will be collected linearly as the excavation proceeds and will alternate between base and sidewall samples. Each sidewall sample will be collected from alternating sides (e.g., first sidewall sample from the east side, and the next sidewall sample from the west side) of the trench. Between alternating sidewall samples (east and west), a verification base-sample will be collected from the bottom of the trench. The distance

between each sidewall or base sample will be 30 to 50 feet. Further details on verification sampling are in the SAP. Excavation will not be conducted beyond the limits established in the remedial design drawings C-3 and C-4.

d. No vertical "chasing" of soils will be done below the three-foot depth specified for the RA footprints or the two- to three-foot depths specified for the contiguous areas at Blocks E and G, respectively. If necessary, excavation will be extended laterally to the limits of the groundwater RA footprints (as defined in the design documents for the groundwater RA), plus 10 feet.

3. In all tax blocks:

   a. Samples will be collected before excavation for analytical characterization for disposal purposes. These pre-construction characterization samples are described in the SAP (Tetra Tech 2013) and shown in Figures 3-3, 3-5, and 3-6 (attached).

   b. Soils will be excavated by methods that permit observation of exposed subsurface soils to identify obviously contaminated materials. Observably contaminated materials can be identified by characteristics including, but not limited to, staining, oil or chemical odor, and the presence of non-aqueous liquid.

   c. Imported fill required to bring the ground surface back to grade will be clean fill in accordance with MDE's "Facts About VCP Clean Imported Fill Material," found at the Web address below:
      http://www.mde.state.md.us/programs/Land/MarylandBrownfieldVCP/MDVCPInformation/Documents/www.mde.state.md.us/assets/document/Clean%20Imported%20Fill%20Material(1).pdf

   d. The excavation work area will be monitored by a calibrated photoionization detector to identify any significant (above background concentration) organic vapor released.

   e. Dust in the area of excavation will be monitored and controlled to maintain excavation work areas sufficiently free from dust, and to avoid causing a hazard or nuisance, as determined by the Lockheed Martin representative. The National Ambient Air Quality Standard (NAAQS) 24-hour limit for particulate matter larger than 10 microns or (PM_{10}) is 150 micrograms per cubic meter ($\mu g/m^3$).

4. Impacted soils generated by the work will be managed to ensure protection of health, safety, public welfare, and the environment. Soils will be handled, stored, transported, and disposed of in compliance with Maryland regulations and all other applicable federal and local laws and regulations, including the federal Resource Conservation and Recovery Act (RCRA) and federal Toxic Substances and Control Act (TSCA).

5. All groundwater and surface water collected as part of the planned soil excavation will be managed in compliance with the applicable provisions of the *Waste Management Plan* for the MRC and the project-specific pre-design work plans (see the "Construction Means and Methods Plan" (in Appendix E) for requirements concerning the dewatering of excavations).

6. The RA specifications require the following items to be supplied and/or implemented by the RA implementation contractor:

    a. Work plans that conform to the construction documents (drawings and specifications) and this SMP. Work plans will include, but will not be limited to, erosion and sedimentation control, construction quality control, and air quality monitoring plans.

    b. The SAP, which outlines sampling requirements for pre-construction delineation sampling (Blocks E and G) and the verification and waste characterization/disposal-facility sampling requirements (all blocks). Sampling locations, analytical methods, sampling frequency, and lab turnaround times are in the SAP.

    c. A written list of proposed disposal facilities, generated from the Lockheed Martin-approved list of facilities. This list will include the disposal facility name, address, contact name and phone number, title of contact person, regulatory agency or similar permit number for the facility, and the facility acceptance criteria for contaminated soils.

    d. A plan showing truck ingress and egress routes and possible locations for proposed storage area(s) and proposed stockpile locations (see "Construction Means and Methods Plan" in Appendix E; see also the "Erosion and Sedimentation Control Plan").

    e. A contractor's health and safety plan (HASP) prepared by a qualified health professional.

    f. Waste hauler information, including name and address of hauler(s) licensed to transport RCRA-classified hazardous waste material, TSCA waste, and nonhazardous materials.

    g. Laboratory reports showing analytical results, quality assurance/quality control (QA/QC) statement, and chain-of-custody log for *in situ* pre-characterization sampling analyses.

7. Upon conclusion of the remedial action excavation and disposal tasks, excavation and disposal documentation will be submitted, including all pre-characterization data, disposal-facility sampling analytical data, copies of waste manifests and weight tickets, photographic documentation, and other pertinent information.

6.0 ADMINISTRATIVE REQUIREMENTS

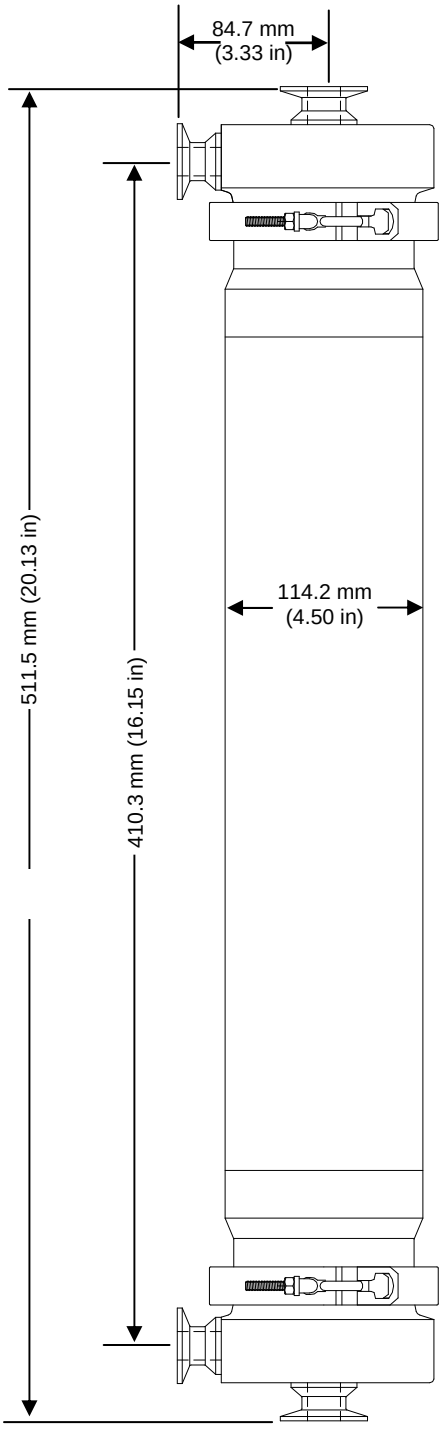
All administrative requirements stipulated by Maryland Department of the Environment Voluntary Cleanup Program, including a written agreement, zoning certification, and health and safety plan requirements, will be met during the groundwater remedial action.

APPENDIX O—RESPONSE ACTION EQUIPMENT INFORMATION

DISSOLVED OXYGEN REMOVAL EQUIPMENT

Membrane Contactor Data Sheet

4 x 13 EXTRA-FLOW PRODUCT DATA SHEET



Membrane Characteristics

Cartridge Configuration	Extra-Flow with Center Baffle	
Liquid Flow Guidelines	0.7 – 3.41 m^3/hr (3 –15 gpm)	
Membrane Type	**X50**	**X40**
	Recommended for CO2 removal from water	Recommended for all other gas transfer applications
Membrane/Potting Material	Polypropylene / Polyethylene	
Typical Membrane Surface Area	8.1 m^2 (87 ft^2)	
Priming Volume (approximate)		
Shellside	1.26 liters (0.33 gal.)	
Lumenside	0.61 liters (0.16 gal.)	

Pressure Guidelines*

	PP X50 or X40	**316L SS X50**	**316L SS X40**
Maximum Shellside LIQUID Working Temperature/ Pressure	5-30° C, 7.2 bar (41-86° F, 105 psig) 40° C, 5.2 bar (104° F, 75 psig)	5-50° C, 7.2 bar (41-122° F, 105 psig) 70° C, 2.1 bar (158° F, 30 psig)	5-50° C, 9.3 bar (41-122° F, 135 psig) 70° C, 2.1 bar (158° F, 30 psig)
If no vacuum is used, 1.05 bar (15 psig) can be added to pressures above.			
Maximum Applied Gas Pressure	6.2 bar (90 psig)		
Max applied gas pressure is for integrity testing at ambient temperatures. Normal operating pressures are typically lower.			
*Pressures are based on non-dangerous liquids and gasses per the European Union Pressure Equipment Directive /97/23/EC. See Operating Guide for pressure limits in the European Union with dangerous liquids and gasses. Also, see Operating Guide for complete temp/pressure limits for housings and membrane. Note: Liquid pressure should always exceed gas pressure.			

Housing Options & Characteristics

Material	**Polypropylene**	**316L SS**
Flange Connections		
Shellside (Liquid Inlet/Outlet)	• 1 inch Sanitary • ¾ inch NPT Female • 1 inch GF • Rc ¾ per JIS B0203	• 1 inch Sanitary (316L SS) • ¾ inch NPT Female (304 SS)
Lumenside (Gas/Vacuum)	• 1 inch 90° Sanitary • ¾ inch 90° NPT Female • Rc ¾ per JIS B0203	• 1 inch 90° Sanitary (316L SS) • ¾ inch 90° NPT Female (304 SS)

Seal Options

Material	**Applications**
Viton	General Purpose
K-UPW	Ultra Pure Water
K-EXT	Chemical Extraction
Buna-N	Beverage

Weight	**PP**	**316L SS**
Dry weight	2.6 kg. (5.8 lbs.)	4.9 kg (10.7 lbs.)
Liquid full (shellside)	3.7 kg. (8.2 lbs.)	7.4 kg (16.4 lbs.)
Shipping Weight	3.3 kg. (7.3 lbs.)	6.4 kg (14.0 lbs.)

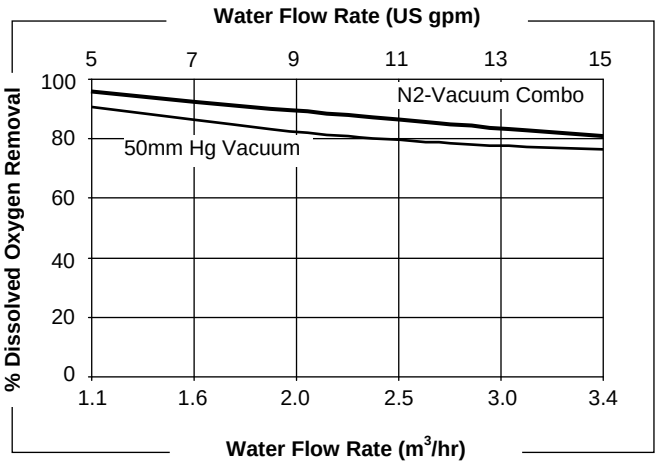
Regulatory

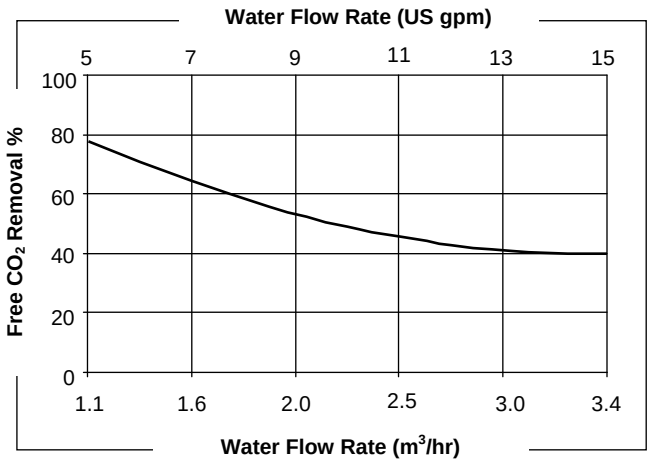
Meets RoHS threshold limits. Complies with the PED 97/23/EC. CFR Title 21 compliant.

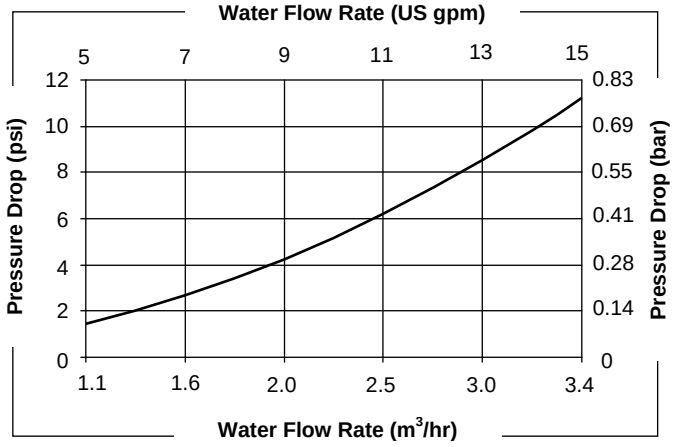
Note: *All dimensions are nominal values.*
This represents PP housing. All housing options are located on www.Liqui-Cel.com.

Liqui-Cel®
MEMBRANE CONTACTORS

4 x 13 EXTRA-FLOW PRODUCT DATA SHEET







Cartridge Specifications		
Characteristics	**Test Conditions**	**Specifications**
Performance 0_2 Removal	Shellside water flow: 12 gpm 20°C (68°F) Lumenside N_2 Flow: 1 ft^3/min, 1.0 atm at 20°C	77% minimum
Pressure Drop	Shellside water flow: 12 gpm, 20°C (68°F)	8.5 psi maximum

Curves represent nominal values, generated using water at 20°C. Characteristics may change under different operating conditions.

Test condition O_2 Removal with X40 membrane: N_2-vacuum combo mode, vacuum: 50 mm Hg N2 sweep: 0.05 scfm at 20°C. Vacuum mode, vacuum: 50 mm Hg at 20°C.

Test condition CO_2 Removal with X50 membrane: N_2-vacuum combo mode, vacuum: 150 mm Hg, N_2 sweep 0.1 scfm at 20°C.

All components of the Liqui-Cel® Extra-Flow Membrane Contactor, when used in accordance with recommendations given in our product literature for treatment or processing of water, alcoholic and non-alcoholic beverages, and aqueous, acid and non-acid food products at and below ambient temperatures, are in compliance with all relevant FDA regulations as specified in Title 21 of the Code of Federal Regulations.

This product is to be used only by persons familiar with its use. It must be maintained within the stated limitations. All sales are subject to Seller's terms and conditions. Purchaser assumes all responsibility for the suitability and fitness for use as well as for the protection of the environment and for health and safety involving this product. Seller reserves the right to modify this document without prior notice. Check with your representative to verify the latest update. To the best of our knowledge the information contained herein is accurate. However, neither Seller nor any of its affiliates assumes any liability whatsoever for the accuracy or completeness of the information contained herein. Final determination of the suitability of any material and whether there is any infringement of patents, trademarks, or copyrights is the sole responsibility of the user. Users of any substance should satisfy themselves by independent investigation that the material can be used safely. We may have described certain hazards, but we cannot guarantee that these are the only hazards that exist.

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Certified System
ISO 9001
ISO 14001

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Our MiniModules, 2.5 x 8, 4 x 13, 4 x 28 and 6 x 28 and 10 x 28 Industrial Contactors are manufactured with Sound Engineering Practice. Our 10 x 28 high purity and our 14 x 28 products have a product classification – Category 1 per PED 97/23/EC.

I. Technology Description

Liqui-Cel® Membrane Contactors make it possible to transfer gas to or from an aqueous stream without dispersion. The membrane contactors contain thousands of Celgard® microporous polypropylene hollow fibers knitted into an array that is wound around a distribution tube. The hollow fibers are arranged in a uniform open packing, allowing greater flow capacity and utilization of the total membrane surface area. Because the hollow fiber membrane is hydrophobic, the aqueous stream will not penetrate the pores. The gas/liquid interface is immobilized at the pore by applying a higher pressure to the aqueous stream relative to the gas stream. Unlike dispersed-phase contactors such as packed columns, Liqui-Cel Membrane Contactors provide a constant interfacial area for transfer over the entire operating range of flow rates.

Although Liqui-Cel Membrane Contactors utilize a microporous membrane, the separation principle differs substantially from other membrane separations such as filtration and gas separation. With Liqui-Cel Membrane Contactors, there is no convective flow through the pores as occurs in other membrane separations. Instead, the membrane acts as an inert support that brings the liquid and gas phases in direct contact without dispersion. The mass transfer between the two phases is governed entirely by the pressure of the gas phase. Because of the Celgard hollow fibers and the contactor geometry, the surface area per unit volume is an order of magnitude higher than traditional technologies such as packed columns, forced draft deaerators and vacuum towers. This high level of surface area to volume leads to a dramatic reduction in contactor/system size for a given level of performance.

Contactor Design

It is important to note that there are now three design variants for Liqui-Cel Membrane Contactors. Our traditional **Extra-Flow design** uses a radial liquid flowpath around a central baffle. Liquid flows on the outside (shellside) of the hollow fibers. Our 2 and 4-inch SuperPhobic® Contactors are also Extra-Flow devices. They will use the same operating instructions and parts as the Extra-Flow contactor.

Our **NB, No Baffle design,** does not utilize a central baffle, but it is still a radial flow device. The liquid outlet port on the no baffle design is located in the middle of the device rather than at the contactor ends as in the Extra-Flow design. One end of the NB contactor is capped and allows liquid to flow outward or radially across the fibers from a central distribution tube. This variant is only available in a 6-inch size and it is best suited for vacuum operation.

Our **Liqui-Cel MiniModule® design** allows for liquid flow inside of the hollow fiber (lumenside). These devices are not radial flow devices. The same operating principles can be applied to both Extra-Flow and MiniModule® contactor designs. The difference will always be that the liquid flows on the shellside in Extra-Flow designs. The liquid flows on the lumenside for MiniModule® designs. MiniModules are suited for small flow applications.

Membrane Selection

Liqui-Cel Membrane Contactors utilize two primary fiber types for absorption/stripping techniques for water. X-40 membrane has a thicker wall with a smaller inside diameter and is recommended for oxygen removal. X-50 membrane has a slightly thinner wall with a larger inside diameter. This feature allows for greater carbon dioxide removal as compared to the X-40 membrane. **Table 1** compares X-40 and X-50 fibers.

Table 1: X-40 and X-50 Hollow Fiber Comparison

		Fiber Type	
Characteristic	**Unit**	**X-40**	**X-50**
Fiber OD (nominal)	Microns	300	300
Fiber ID (nominal)	Microns	200	220
Bubble Point	psi	240	240
Load at Break	grams	430	430
Porosity	%	25	40
Pore Size	Microns	0.03	0.04

A third fiber variant, a proprietary microporous polyolefin, was introduced in our smaller contactors for gas transfer of low surface tension fluids. It is available in our SuperPhobic® product variants and the fluid always flows on the shellside in these devices. Additionally, XIND fiber was introduced in our 10 x 28 Industrial Contactors. It is geared to non-FDA degassing applications.

Gas Absorption

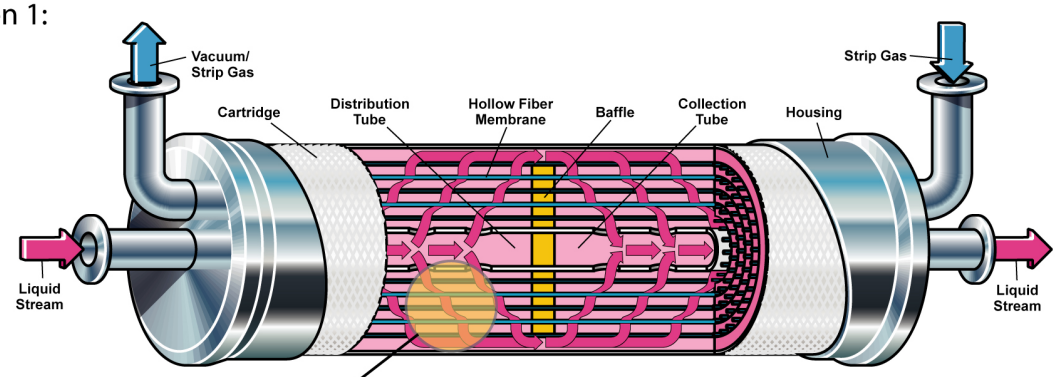
When using Liqui-Cel Extra-Flow or No-Baffle Membrane Contactors in gas absorption applications such as aeration or carbonation, etc., a gas is introduced into the inside (lumenside) of the hollow fiber membrane and the liquid phase is introduced to the outside (shellside) of the hollow fiber. The partial pressure of the gas and the water temperature controls the amount of gas dissolved in the liquid phase. When using Liqui-Cel MiniModules® in this application, the liquid is introduced to the lumenside while the gas is introduced to the shellside. MiniModules are not Radial Flow devices.

Gas Stripping

When using Liqui-Cel Extra-Flow or No Baffle Membrane Contactors in gas stripping applications such as decarbonation or deoxygenation, a vacuum or stripping gas or combination of those is applied to the lumenside of the hollow fiber. The liquid stream is introduced to the outside of the fiber. The partial pressure of the gas is decreased to remove dissolved gases from the liquid phase. When using Liqui-Cel MiniModules in this application, the liquid is introduced to the lumenside while the gas/vacuum is applied to the shellside.

You can view an animated product tour, which demonstrates the liquid and gas flow paths in detail in our product tour available at www.liqui-cel.com.

Illustration 1:
Liqui-Cel®
Extra-Flow
Membrane
Contactor



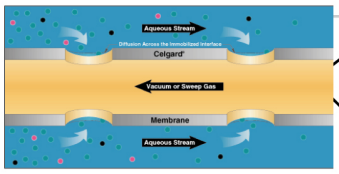


Illustration 2:
NB® Membrane
Contactor

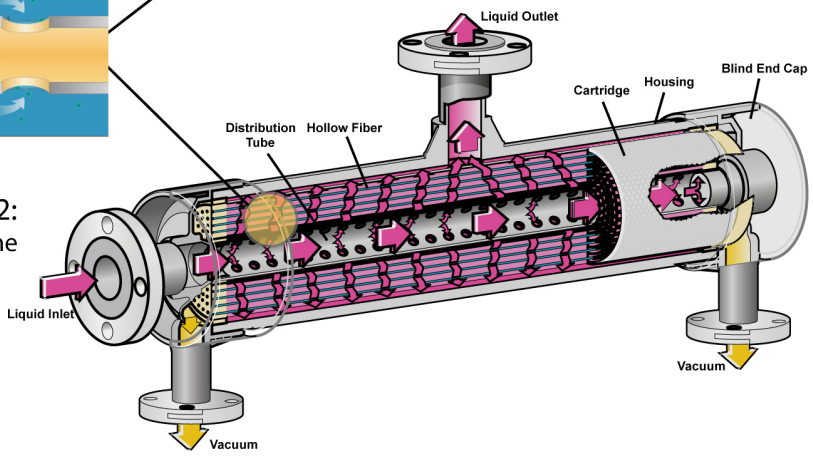
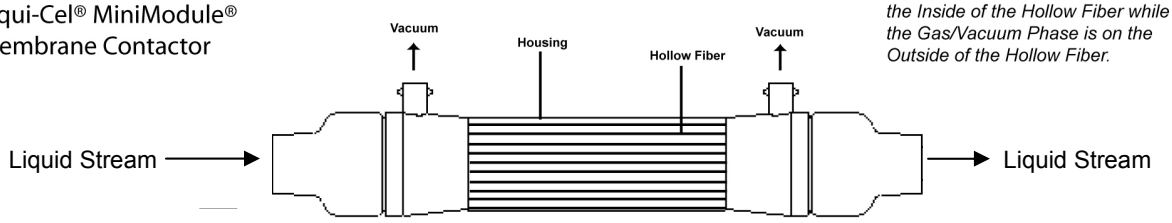


Illustration 3:
Liqui-Cel® MiniModule®
Membrane Contactor



For MiniModule the Liquid Flows on the Inside of the Hollow Fiber while the Gas/Vacuum Phase is on the Outside of the Hollow Fiber.

II. Gas Stripping Techniques

A dissolved gas can be removed from an aqueous stream by three methods.

- Sweep Gas
- Vacuum
- Sweep-Assisted Vacuum (Combo Mode)

A. Sweep Gas Mode

Operation Note:
Sweep gas is the most economical technique for removing carbon dioxide from the liquid stream.

Sweep-gas mode is a process by which a gas in the lumenside of the Extra-Flow contactor flows counter-current to the water flow. By choosing a gas different from the target gas you wish to remove, a partial pressure gradient is created between the liquid phase (shellside) and the gas phase (lumenside). This forces the target gas to transfer to the lumenside and be swept away. The sweep gas purity will impact the outlet dissolved gas level achieved. When using this technique, the liquid stream becomes saturated with the sweep gas. The same principle applies to MiniModules®. The gas phase, however, is on the shellside of the contactor while the liquid phase is on the lumenside.

Gas-Side Configuration and Operation

The following is a list of the minimum instrumentation required to design a sweep-gas line to the Liqui-Cel Membrane Contactor when using compressed gases (see **Figures 1 & 2**).

- Pressure regulator valve (PCV-201)
- Needle valve (V-212)
- Pressure indicator (PI-201)
- Flowmeter (FI-201)

Compressed gases or oil-free compressed air (for Carbon Dioxide removal) can be used as a sweep gas. To operate the system, follow these steps:

1. Set the pressure at < 0.7 kg/cm^2 (< 10 psig, 0.69 bar), by adjusting the PCV-201 valve.
2. Set the recommended total sweep flow rate by adjusting the V-212 valve and the reading on the FI-201 Flowmeter.
3. Introduce fresh sweep gas into each contactor.
4. Vent the outlet gases to an open area to avoid possible oxygen depletion within the operating area.
5. If using compressed air, make sure that it is oil-free. A 0.2-micron filter located prior to the PCV-201 valve is highly recommended for high purity applications. A 1.0-micron filter rating is sufficient for industrial applications.

If compressed gases or oil-free compressed air (for Carbon Dioxide Removal) are not available and your application is for CO_2 removal, you may use a blower to create an air sweep. The sizing program (available from your Membrana representative) will calculate the pressure drop on the gas side expressed in inches of water. Use this information to choose the blower size. When using a blower, follow steps 2 to 3 listed above.

It is also important that the blower does not increase the temperature to >30° C (86°F). Air warmer than this can have a negative impact on fiber life.

Table 2 below lists the range of air sweep gas that will be required for each size contactor.

Table 2: Estimated Air-Sweep Requirements for CO_2 Removal

	Typical Air Sweep per Contactor	
Contactor	**m^3/hr**	**scfm**
1 x 5.5	0.06 – 0.3	0.04 – 0.2
1.7 x 5.5	0.2 – 0.9	0.1 – 0.5
2.5 x 8	0.2 – 1.8	0.1 – 1.1
4 x 13	0.8 – 4.8	0.5 – 3
4 x 28	1.6 – 9.6	1 – 6
6 x 28	1.6 – 32	1 – 20
10 x 28	6.4 – 40.2	4 – 25
14 x 28	10 – 64	6 – 40

For water side configuration and operation, check General System Design Guidelines in Section III on page 19.

Important Operating Notes:

PROTECTING THE MEMBRANE:
When using <u>air</u> in the sweep gas mode, note the following information:

- **Water temperature should not exceed 30°C (86°F).**
- **Air temperature should not exceed 30° C (86° F).**
- **Remove free chlorine, ozone and any other oxidizing elements prior to the Liqui-Cel Membrane Contactor**

When using an <u>inert gas</u> in the sweep gas mode, note the following information:

- **Remove free chlorine, ozone and any other oxidizing elements prior to the Liqui-Cel Membrane Contactor. See the following exception for free chlorine.**
- **The use of city water containing ≤ 1 ppm free chlorine at ambient temperatures (≤ 40°C, 104°F) is allowable. However, to reduce the effects of membrane oxidation, always maintain a constant sweep gas especially during any on-and-off operation of the feedwater stream. The sweep gas must remain an inert gas. <u>Do</u> <u>not</u> use air sweep >30° C (86° F) when free chlorine is present.**

Avoid contact with surfactants, alcohols and oxidizing agents (ozone, etc.)

Operating outside of these guidelines can negatively impact the membrane life and/or void the performance warranty. If you have questions about your system design, contact your Membrana representative.

PROTECTING OTHER EQUIPMENT IN YOUR SYSTEM:

If membrane failure was to occur for any reason, water would flow to the gas side of the membrane. This would occur because the liquid must always maintain a greater pressure than the gas phase. In normal operating mode, gases exit the membrane system at atmospheric pressure, and in case of membrane failure, water will be drained out at the drain system exit. In the extreme case of a major water bypass to the drain, water will stop flowing in its regular path. To prevent any equipment damage downstream of the membrane system, a low pressure alarm switch or a flow switch is recommended.

MAINTAINING PERFORMANCE:

Since water vapor and other volatile gases will pass through the membrane, the sweep gas will become saturated with the water vapor. Depending upon the ambient temperature, condensation could occur in the outlet gas piping. Therefore, the outlet piping should be sloped away from the contactors. The piping must be designed to drain this water from the contactors and out of the piping. If water vapor is not removed, it can collect over time and reduce the performance of the contactors. The condensation rate will depend on the liquid temperature. The warmer the liquid stream, the higher the water-vapor transport rate. This condensation phenomenon is normal.

B. Vacuum Mode

Operation note:
The vacuum method is recommended for total gas control and bulk gas removal.

Vacuum mode is a process in which a vacuum is applied to the lumenside of the fiber in an Extra-Flow or NB device. A vacuum should be drawn from both lumen ports. When the vacuum is applied, it creates a partial pressure gradient between the liquid phase (shell) and the gas phase (lumen). This vacuum causes transfer of dissolved gases from the shellside to the lumenside. These gases are discharged through the vacuum pump. Vacuum levels affect the removal efficiency. The deeper the vacuum, the lower the outlet concentrations will be. **Table 3** illustrates gas removal at different vacuum levels. The same principle applies to MiniModules®. The gas/vacuum phase, however, is on the shellside of the contactor while the liquid phase is on the lumenside.

Table 3: Outlet Dissolved Oxygen Concentration, Using the Vacuum Mode

The following table provides and illustration of how vacuum level affects performance. All other operating parameters were the same except the vacuum level.

Vacuum Level (absolute gas pressure, assuming 760 mm Hg atmospheric pressure)	25 in. Hg (125 mm Hg)	27 in. Hg (74 mm Hg)	28 in. Hg (50 mm Hg)	28.5 in. Hg (36 mm Hg)
Outlet Concentration, ppb	1400	850	580	425

Conditions: Two 4x28, X-40 contactors in series
Flow rate 20 gpm (4.5 m^3/hr)
Temperature 77°F (25°C)
Calculations are based on inlet saturation conditions for nitrogen, oxygen and carbon dioxide.

Vacuum-Side Configuration and Operation

The following is a list of the minimum instrumentation that is required to operate in the vacuum mode. (See **Figures 3, 4, 5 & 6**).

- Pressure switch (PS-301)
- Pressure indicator (PI-301) for vacuum application.
- Check valve (V-302)
- Vacuum Liquid Trap

To operate the system, follow these steps:

Follow the vacuum pump manufacturers instructions for startup.

1. Open the V-301 valve.
2. Turn on the vacuum pump.
3. Slowly open the water inlet valve, V-101.

Successful operation of the Liqui-Cel or SuperPhobic® Membrane Contactor degasification system depends on a well-designed vacuum system (piping and vacuum pump). It is important to follow these recommendations when designing a vacuum system:

1. Piping

- Design the vacuum lines for vacuum service. Threads, pipe dope, and pipe tape should not be used. Any air leak will affect the degassing efficiency.
- Avoid long runs of piping and loops. Minimize the use of elbows and other sources of pressure loss.
- Design the vacuum manifold to handle the vapor load of the entire system.

Since water vapor and other volatile gases will pass through the membrane, the lumenside gas will become saturated with the water vapor. Depending upon the ambient temperature, condensation could occur in the outlet gas piping. Therefore, **the outlet piping should be sloped away from the contactors to allow this water to drain from the contactors and out of the piping.** If water vapor is not removed, it can collect over time and possibly reduce the performance of the vacuum pump, which will then affect the performance of the contactors. The condensation rate will depend on the liquid temperature. The warmer the liquid stream, the higher the water vapor transport rate. This condensation phenomenon is normal.

2. Vacuum Pump Type and Sizing

- Utilize the sizing program or contact your Membrana representative to estimate the vapor load to the vacuum pump expressed in Actual Cubic Feet per Minute (ACFM) or standard cubic meters per hour. The vapor load value and the vacuum level will determine the size of the vacuum pump.
- A liquid ring pump is recommended. There are many brands of liquid ring pumps; choose the one that satisfies your needs and ask your supplier for a complete vacuum system, which includes: a vacuum pump, separator, check valve, air bleed valve, gauges and a complete make up water line. Membrana now offers vacuum systems in addition to membrane contactors, so you may now call us for your vacuum pump needs. (See **Figures 3 and 4**).

For waterside configuration and operation, check the General System Design Guidelines in Section III.

Important Operating Notes:

PROTECTING THE MEMBRANE:

When using vacuum mode, note the following information:

- **Remove free chlorine, ozone and any other oxidizing elements prior to the Liqui-Cel Membrane Contactor. See the following exception for free chlorine.**
- **Use of city water containing ≤ 1 ppm free chlorine at ambient temperatures ≤ 40°C (≤ 104° F) is allowable. However, to reduce the effects of membrane oxidation, leave the vacuum source operating at all times, especially during any on-and-off operation of the feed water stream.**

Avoid contact with surfactants, alcohols and oxidizing agents (ozone, etc.)
Operating outside of these guidelines can negatively impact the membrane life and/or void the performance warranty. If you have questions about your system design, contact your Membrana representative.

PROTECTING OTHER EQUIPMENT IN YOUR SYSTEM:

If membrane failure was to occur for any reason, water would flow to the gas side of membrane. This would occur because the liquid must always maintain a greater pressure than the gas phase. To protect the overall system in case of membrane failure, a liquid vacuum trap and a high vacuum pressure switch are recommended when operating in vacuum or combo mode.

A low pressure alarm switch or a flow switch located at the water membrane system exit is recommended. This will prevent the pump or other major equipment from running dry. Use the following as a guideline for establishing this precaution in your system.

Vacuum trap set up (locate vacuum trap at the lowest point in the system):

1. **Solenoid valves are normally closed.**
2. **During vacuum pump start up, V-201 should open, while V204 and V-202 should remain closed during normal operation.**
3. **When liquid reaches the upper set up level, V-201 should close. Then with a time delay of no more than couple of seconds, V-202 and V-204 should open.**
4. **When liquid reaches the lower set up level, V-204, V-202 should close. Then with a couple seconds time delay V-201 should open.**

Note: In the rare instance of major membrane failure, water would quickly fill the vacuum trap. In this case a significant increase in vacuum level will be detected by the high vacuum pressure switch PS-301. Under this condition, V-201, V-202 and V-204 should open and the vacuum pump should be shut down.
During start up the high vacuum pressure switch should have a time delay allowing the vacuum level to come down.

Figure 4. Generic P & ID for Vertical Mounting vacuum mode operation for an Extra-Flow Contactor.

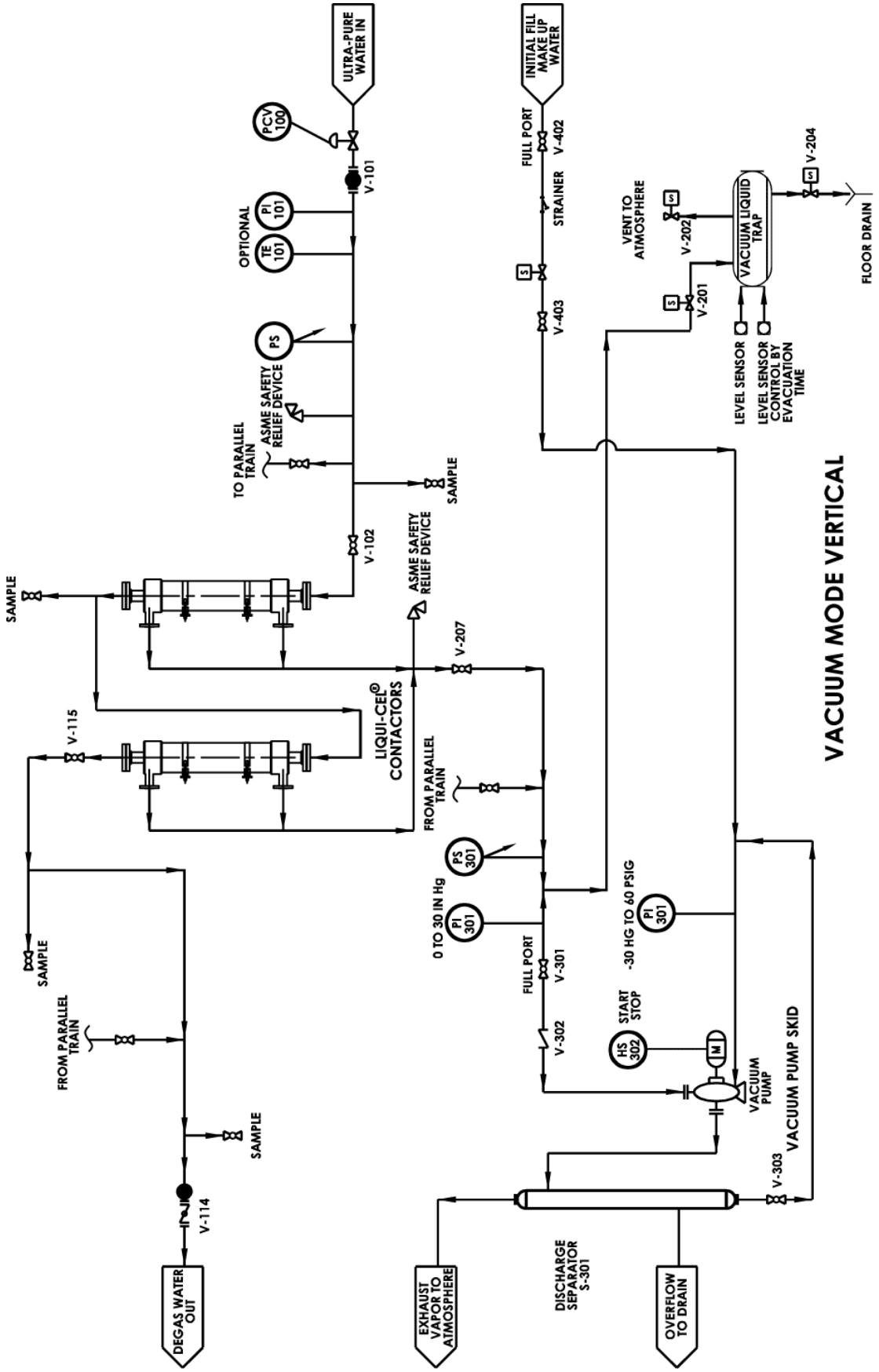
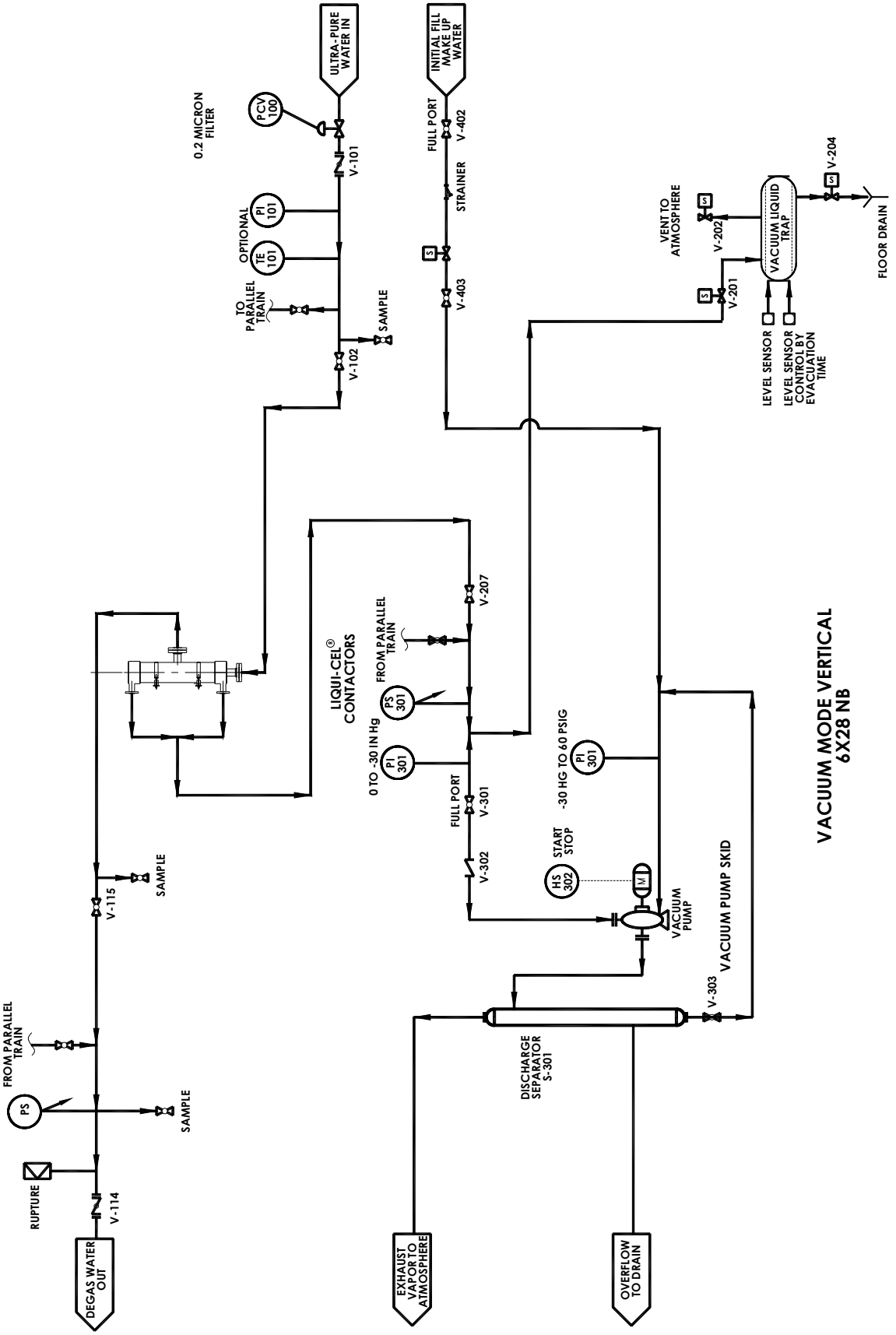


Figure 5. Generic P& ID for Vertical Mounting vacuum only operation with 6-inch NB Contactor.



C. Sweep-Assisted Vacuum (COMBO)

Operation note:
Sweep-assisted vacuum is the most efficient way to achieve low levels of dissolved oxygen or Carbon Dioxide.

Sweep-Assisted Vacuum (Combo Mode) is a method in which a sweep gas is applied to one lumenside port of the contactor, while the other is connected to a vacuum source. The sweep gas helps move and dilute the gas that is in the vacuum stream. The recommended vacuum level is 28 in. Hg (50 mm Hg absolute).

Sweep and Vacuum-Side Configuration and Operation

Gas Side:

The following is a list of the minimum instrumentation that is required to integrate a sweep line to the Liqui-Cel Membrane Contactor operating in a Combo mode (see **Figures 7, 8 & 9**):

- Pressure regulator valve (PCV-201)
- Needle valve (V-212)
- Compound Gauge (PI 201)
- Flowmeter (FI-201)

Compressed gas or oil-free compressed air (for carbon dioxide removal) can be used as the sweep gas. To operate to the system in combo mode, follow these steps:

1. Start up as described in vacuum mode operation.
2. Set pressure at < 0.07 kg/cm^2 (< 1 psig, 0.069 bar), by adjusting PCV-201.
3. Set the recommended total sweep flow rate by adjusting the V-212 valve and the reading on the FI-201 flowmeter.
4. Introduce fresh sweep gas into each contactor.
5. If using compressed air, make sure that it is oil-free. A 0.2-micron filter is highly recommended for high purity applications. A 1.0-micron filter rating is sufficient for industrial applications.

The needle valve (V-212) is installed on the sweep gas inlet line between the contactor and the gas flowmeter. This allows the flowmeter to operate under a positive pressure thus eliminating possible air leaks into the gas line through the flowmeter.

Note: For CO_2 removal, room air can be used. If room air is used, PCV-201 is not needed.

Vacuum Side:

The following is a list of the minimum instrumentation that is required to operate in Combo mode. (See **Figures 7, 8 & 9**).

- Pressure switch (PS-301)
- Pressure indicator (PI-301) for vacuum application
- Check valve (V-302)
- Vacuum Liquid Trap

Successful operation of the Liqui-Cel or SuperPhobic® Membrane Contactor degasification system depends on a well designed gas line and vacuum system (piping and vacuum pump). It is important to follow these recommendations when designing a vacuum system:

1. Piping

- Design the vacuum lines for vacuum service. Threads, pipe dope, and pipe tape should not be used. Any air leak will affect the degassing efficiency.
- Avoid long runs of piping and loops. Minimize the use of elbows and other sources of pressure loss.
- Design the vacuum manifold to handle the vapor load of the entire system.

Since water vapor and other volatile gases will pass through the membrane, the lumenside gas will become saturated with the water vapor. Depending on the temperature, condensation could occur in the outlet gas piping. Therefore, **the outlet piping should be sloped away from the contactors to allow this water to drain from the contactors and out of the piping.** If water vapor is not removed, it can collect over time and possibly reduce the performance of the vacuum pump, which will affect the performance of the contactors. The condensation rate depends on the liquid temperature. The warmer the liquid stream, the higher the water-vapor transport rate. This condensation phenomenon is normal. Purging the lumens with sweep gas for 5 minutes at 40-60 psi will facilitate clearing water vapor out of the lumens.

Additionally, when operating in sweep or combo mode with low flow rates in smaller contactors (<6-inch), we recommend vertically mounting the contactors. The downward sweep used in vertically mounted contactors also facilitates keeping the lumens purged of condensation.

2. Vacuum Pump Type and Sizing

- Utilize the sizing program or contact your local Membrana representative to estimate the vapor load to the vacuum pump expressed in Actual Cubic Feet per Minute (ACFM) or standard cubic meters per hour. The vapor load value and the vacuum level will determine the size of the vacuum pump.
- A liquid ring pump is recommended. There are many brands of liquid ring pumps; choose the one that satisfies your needs and ask your supplier for a complete vacuum system, which includes: a vacuum pump, separator, check valve, air bleed valve, gauges and a complete make up water line. Membrana now offers vacuum systems in addition to Membrane Contactors so you may now single source your contactors and your vacuum pump from us if desired. (See **Figures 5 & 6**).

Table 4: Nitrogen Sweep Range for Combo Mode

	Typical Nitrogen Sweep per Contactor	
Contactor	**m^3/hr**	**Scfm**
1 x 5.5	0.006 – 0.03	0.004 – 0.02
1.7 x 5.5	0.02 – 0.09	0.01 – 0.05
2.5 x 8	0.03 – 0.2	0.02 – 0.1
4 x 13	0.04 – 0.4	0.03 – 0.3
4 x 28	0.08 – 0.8	0.05 – 0.5
6 x 28	0.2 – 11	0.1 – 7
10 x 28	0.3 – 5.6	0.15 – 3.5
14 x 28	0.34 – 17	0.2 – 10

Important Operating Notes

PROTECTING THE MEMBRANE:

When using air-sweep in the Combo mode, note the following information:

- **Water temperature should not exceed 30° C (86° F).**
- **Air temperature should not exceed 30° C (86° F).**
- **Remove free chlorine, ozone and any other oxidizing elements prior to the Liqui-Cel Membrane contactor**

When using an inert gas in the Combo mode, note the following information:

- **Remove free chlorine, ozone and any other oxidizing elements prior to the Liqui-Cel Membrane contactor. See the following exception for free chlorine.**
- **Use of city water containing ≤ 1 ppm free chlorine at ambient temperatures, (≤ 40°C, ≤ 104°F) is allowable. However, to reduce the effects of membrane oxidation, always maintain a constant sweep gas especially during any on-and-off operation of the feed water stream. The sweep gas must remain an inert gas. Do not use air sweep to >30° C (86°F) when free chlorine is present.**

Avoid contact with surfactants, alcohols and oxidizing agents (ozone, etc.)

Operating outside of these guidelines can negatively impact the membrane life and/or void the performance warranty. If you have questions about your system design, contact your Membrana representative.

PROTECTING OTHER EQUIPMENT IN YOUR SYSTEM:

If membrane failure was to occur for any reason, water would flow to the gas side of the membrane. This would occur because the liquid must always maintain a greater pressure than the gas phase. To protect the overall system in case this was to happen, a liquid vacuum trap and a high vacuum pressure switch are recommended when operating in vacuum or combo mode.

A low pressure alarm switch or a flow switch located at the water membrane system exit is recommended. This will prevent the pump or other major equipment from running dry. Use the following as a guideline for establishing this precaution in your system.

Vacuum trap set up (locate vacuum trap at the lowest point in the system):

1. **Solenoid valves are normally closed.**
2. **During vacuum pump start up, V-201 should open, while V204 and V-202 should remain closed during normal operation.**
3. **When liquid reaches the upper set up level, V-201 should close. Then with a time delay of no more than couple of seconds, V-202 and V-204 should open.**
4. **When liquid reaches the lower set up level, V-204, V-202 should close. Then with a couple seconds time delay V-201 should open.**

Note: In the rare instance of major membrane failure, water would quickly fill the vacuum trap. In this case a significant increase in vacuum level will be detected by the high vacuum pressure switch PS-301. Under this condition, V-201, V-202 and V-204 should open and the vacuum pump should be shut down.

During start up the high vacuum pressure switch should have a time delay allowing the vacuum level to come down.

III. General System Design Guidelines

The following guidelines apply to all three gas removal techniques.

Important Notes:

- Both gas/vacuum ports should not be closed during operation. These ports provide a safety vent in the contactors so that pressure does not build up.
- All plastic port extensions should be supported to prevent bending of extensions under excessive piping loads.

A. Flow Pattern Configurations

1. Determination of Series and Parallel Configuration

Each type of Liqui-Cel® Membrane Contactor has a maximum design flow rate. For system flow rates that exceed the individual contactor flow rate, it is necessary to split the flow into parallel trains. To determine the number of parallel trains, divide the total system flow rate by the maximum flow rate as given in **Table 5**.

Table 5: Minimum and Maximum Contactor Flow Rates

Contactor	Minimum Flow Rate	Maximum Flow Rate
0.75 x 5 MiniModule®	5 ml/min (0.001 gpm)	500 ml/min (0.13 gpm)
1.7 x 5.5 MiniModule	500 ml/min (0.13 gpm)	2500 ml/min (0.66 gpm)
2.5 x 8 Extra-Flow or SuperPhobic®	0.023 m^3/hr (0.1 gpm)	0.68 m^3/hr (3 gpm)
4 x 13 Extra-Flow or SuperPhobic	0.5 m^3/hr (2.2 gpm)	3.41 m^3/hr (15 gpm)
4 x 28 Extra-Flow or SuperPhobic	1.0 m^3/hr (4.4 gpm)	6.8 m^3/hr (30 gpm)
6 x 28 Extra-Flow or NB	1.14 m^3/hr (5 gpm)	11.4 m^3/hr (50 gpm)
10 x 28 Extra-Flow	10 m^3/hr (44 gpm)	56.8 m^3/hr (250 gpm) X40 Fiber
10 x 28 Extra-Flow	10 m^3/hr (44 gpm)	47.7 m^3/hr (210 gpm) X50 and XIND Fiber
14 x 28 Extra-Flow	16 m^3/hr (70 gpm)	90.8 m^3/hr (400 gpm)

After calculating the minimum number of parallel trains, additional contactors can be added in series to obtain the desired dissolved gas concentration. The number of contactors in series will be a function of the required gas outlet and the maximum allowable system pressure drop. Typically 5 in series is the maximum. Performance is also improved with lower flow rates. If you reach the maximum desired pressure drop, you can also add additional parallel trains to achieve lower gas outlets.

2. Liquid-Stream Flow Configuration

The following are guidelines for designing the water process lines for a Liqui-Cel, Extra-Flow, NB or SuperPhobic Membrane Contactor system. These guidelines take into consideration the contactor orientation. While Fluids typically flow on the shellside of the contactor, some applications utilize lumenside liquid flow. It should be noted, however, that fluids should <u>always</u> flow on the shellside of the SuperPhobic Contactors.

B. Vertical or Horizontal Mounting

- If the water pressure coming to the Liqui-Cel Membrane Contactor system is greater than or could be greater than the maximum operating pressure (refer to appropriate data sheet or Section C. Maximum Temperature and Pressure Guideline Recommendations on page 24-25 of this guide), a pressure regulator will be required.

- If a pump is located downstream of the contactor system, an automatic on/off valve connected to the pump's motor is required. The valve should operate with a time delay with a slow open/close ramp. The valve should be located between the pump and the contactor system. This will reduce the risk of water hammer.

- To avoid damage from water hammer, a rupture disc should be placed on the downstream side of the contactor system.

- Low-point drains, high-point vents, pressure indicators and temperature indicators should be included in the design.

- Gas must flow countercurrent to liquid for all contactors. Lower efficiencies will result if co-current flow is used.

- The contactors should not be exposed to freezing temperatures during periods of system shutdown.

Note: Horizontal Mounting is typically used to achieve a smaller footprint on large systems. If you are designing a smaller system with less than 8 – 10 contactors (as a guideline) we typically recommend vertically mounting. We also recommend vertically mounting smaller contactors. This facilitates keeping lumens free of liquids if small gas flow rates are being used.

Vertical Mounting:

- The liquid flowing into the contactor must enter from the bottom and exit from the top or side. If Extra-Flow contactors are connected in series, the liquid leaving the preceding contactor must flow into the bottom of the next contactor. When operating 2 NB contactors in series, you may use the H configuration (see illustration 7).
- The bottom gas port should be located higher than the inlet port of the liquid ring pump. This will allow free drainage of condensed water to the vacuum pump. **(Illustration 4 and 5).**

Illustration 4

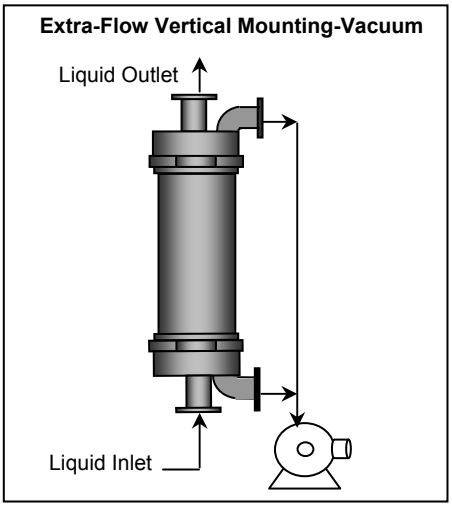


Illustration 5

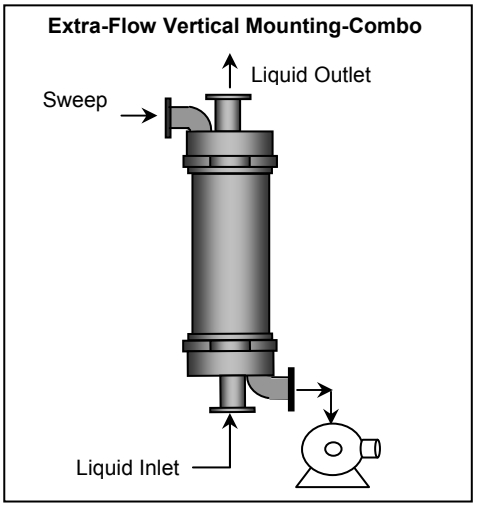


Illustration 6

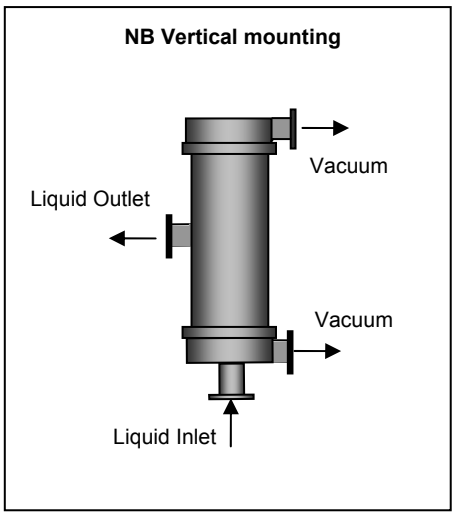
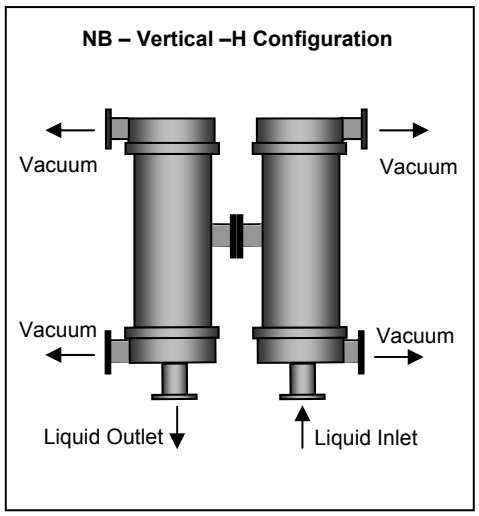


Illustration 7



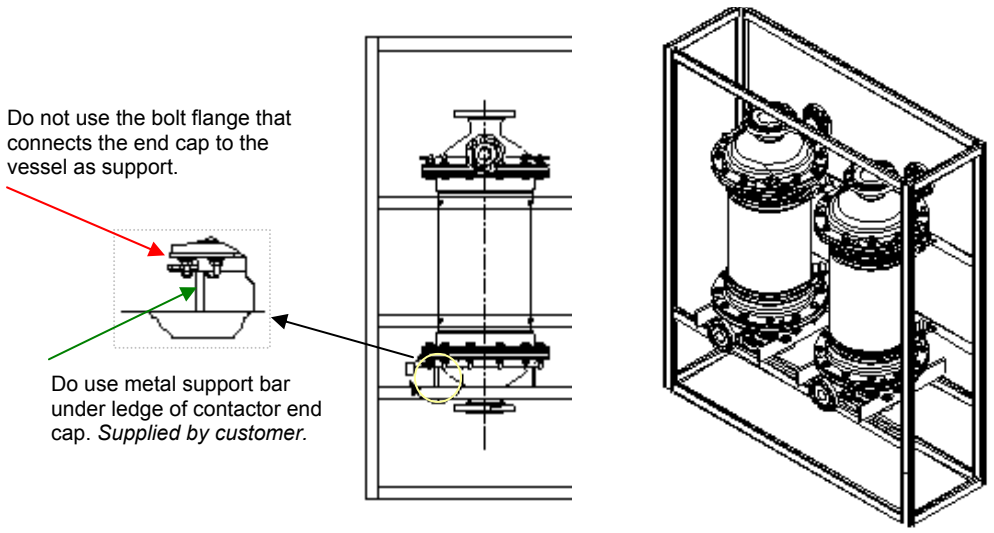
*Note: The vacuum pump should always be located below the outlet gas/vacuum port of the contactor to facilitate draining.

Additional Information for Vertically Mounting 14 x 28 Contactors

We recommend using our mounting kits and an additional steel bar support under the contactors to adequately support the full weight of the 14-inch contactors. Do not place the contactor load on the bolt flange that is used to secure the end caps onto the housing. You also do not want to place the contactor load on the piping materials. Please refer to the vertical 14-inch system layout drawing on our website entitled '14inch vertical skid draw12-6450. This will provide you will more detailed information. A basic view of the metal support that is located under the bottom end caps is depicted below.

Illustration 8:

Supporting 14-inch Contactors when Mounted Vertically



Horizontal Mounting:

- For vacuum only operation, the gas ports should be oriented downward, with the gas ports located higher than the inlet port of the vacuum pump. **(See Illustration 9)**
- For combo or sweep mode operation with Extra-Flow contactors, the gas ports should be oriented 180° in relation to each other, and the vacuum side or gas exit should be in the downward position. The gas port exit should be higher than inlet port of vacuum pump to facilitate water drainage into the vacuum pump. **(See Illustration 10)**

Illustration 9

NB Horizontal Mounting - Vacuum

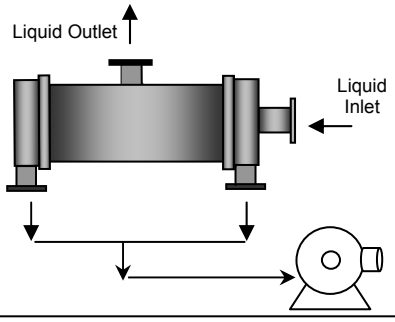
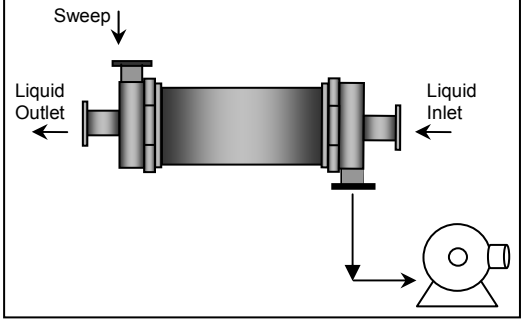


Illustration 10

Extra-Flow Horizontal Mounting-Combo

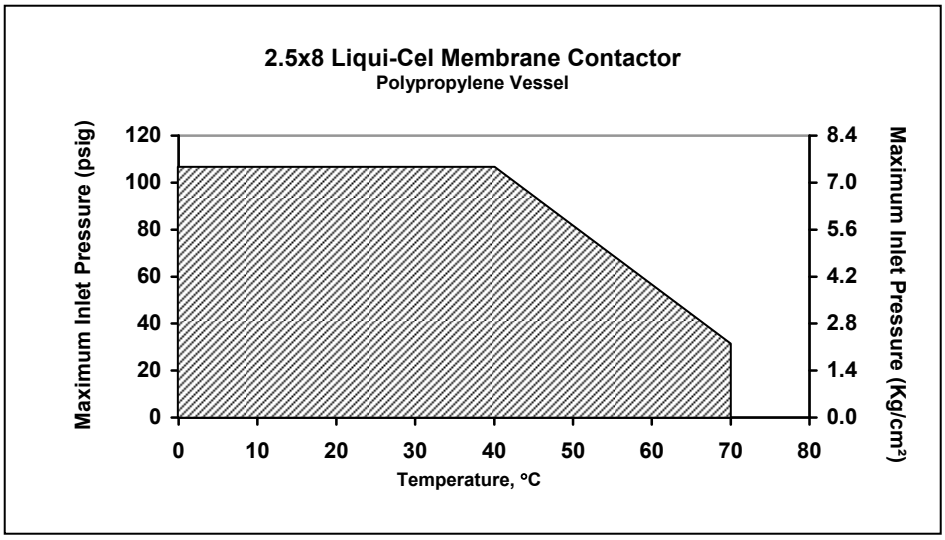


C. Maximum Operating Temperature and Pressure Guidelines

There are two pressure ratings on the contactors. There is a transmembrane pressure rating and a housing pressure rating. In some cases these ratings are the same but be certain to review both prior to operation.

Transmembrane pressure is the difference from the inside to the outside of the fiber. For example, you could run a liquid pressure of 150 psi with a 316 LSS vessel so long as you maintain 30 psi of pressure on the lumenside or gas side of the membrane. This would keep the transmembrane pressure at 120 psi.

Illustration 11



Note: Fiber used in SuperPhobic® Contactors is limited to 70 psi (4.9 kg/cm², 4.8 bar) at 25° C

Illustration 12

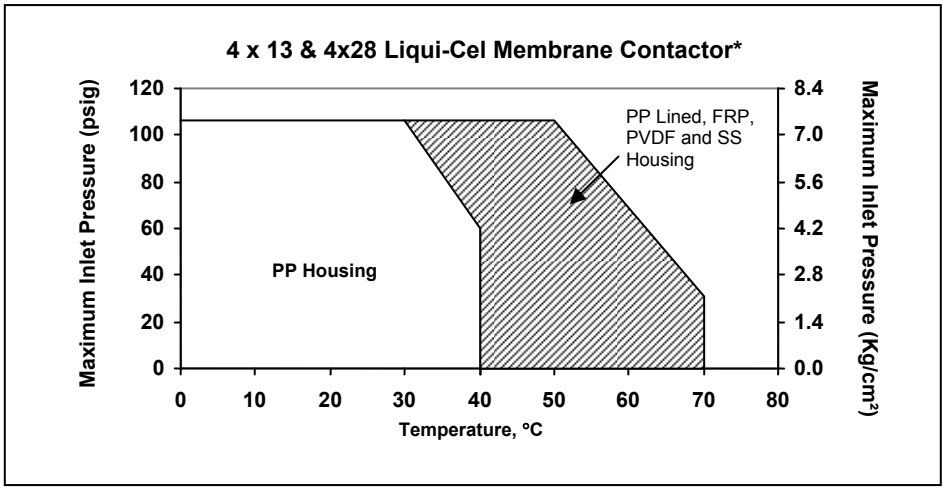
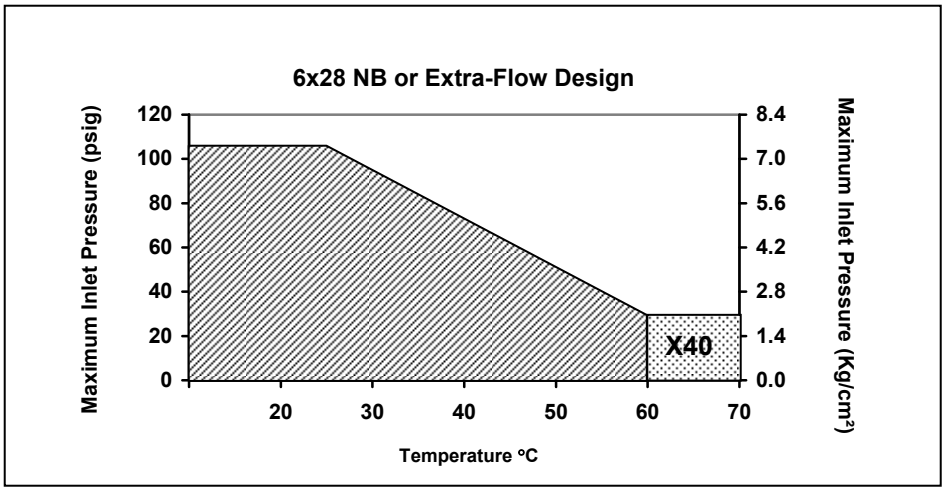


Illustration 13



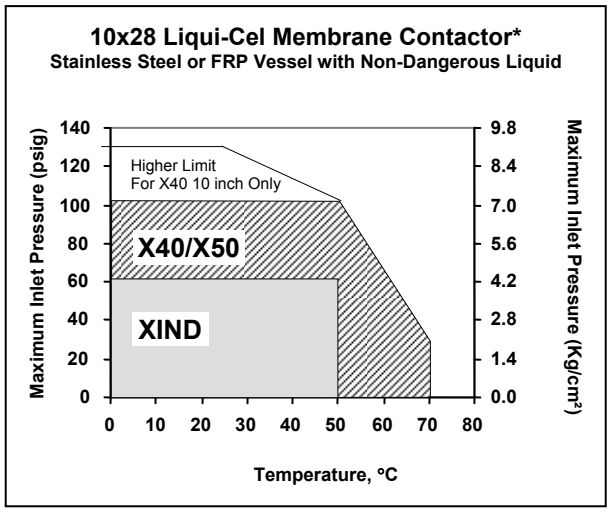
*Add 15 psig (1.05 kg/cm^2) for X50 or X40 fiber when vacuum is not used on 4 (FRP Reinforced, PVDF & SS), 6-inch and 10-inch contactors

10 x 28 Operating Temperature And Pressure Guidelines

The 10 x 28 pressure ratings are summarized below. There are two sets of pressure limits specified for the 10 x 28 Contactor. The Pressure Equipment Directive (PED) 97/23/EC put forth by the European Union has specific guidelines that place devices in various hazardous classifications. We chose to limit some pressure ratings in our 10 inch device for sales into the European Union (EU) because the lower pressures do not affect our primary applications and uses. These limits keep them in a lower hazard classification and eliminate additional testing and fabrication costs associated with higher ratings. Pressure limits only apply to the use of dangerous liquids or gases in 10-inch products sold into European Union Member States. All other countries are free to operate to the higher pressures summarized in the table below.

MiniModules®, 2-inch, 4-inch and 6-inch products do not require CE Marking per the PED 97/23/EC.

Illustration 14



NOTE: Liquid flows on the shellside (outside) of the membrane and gasses are used on the lumenside (inside) of the membrane. If conducting a pressurized gas test on the shellside to check for system integrity, do not exceed pressure limits given for the gas side, as the gasses will permeate through the membrane when liquid is not present.

Table 6: 10 x 28 Pressure Rating Summary

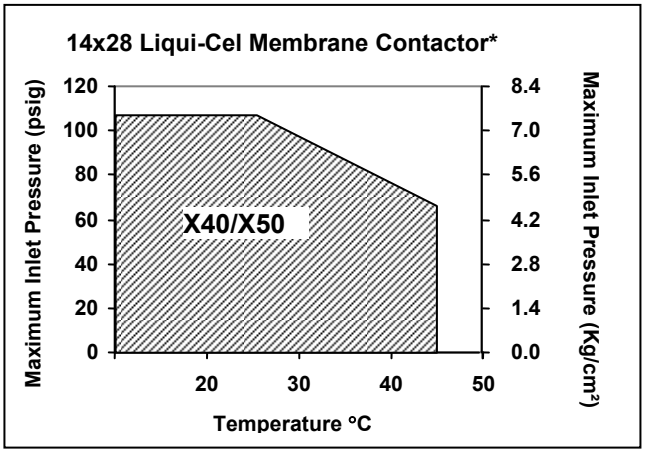
Product	Rest of World – All Applications			
	Membrane PP		Housing/ Liquid Side	Housing/ Gas Side
	X50	X40		
10 x 28 with 316L SS Housing	8.3 8.4 120	10.3 bar 10.5 Kg/cm² 150 psi	10.3 bar 10.5 Kg/cm² 150 psi	9.0 bar 9.1 Kg/cm² 130 psi
10 x 28 with FRP Housing	8.3 8.4 120	10.3 bar 10.5 Kg/cm² 150 psi	10.3 bar 10.5 Kg/cm² 150 psi	6.2 bar 6.3 Kg/cm² 90 psi

Product	*European Union Member States*			
	Dangerous Liquid M/H*	Non-Dangerous Liquid M/H*	Dangerous Gas M/G*	Non-Dangerous Gas M/G*
10 x 28 X50 with 316L SS Housing†	8.3/10 bar 120/145 psi	8.3/10.3 bar 120/150 psi	8.3/4.7 bar 120/68 psi	8.3/9.0 bar 120/130 psi
10 x 28 X50 with FRP Housing†	8.3/10 bar 120/145 psi	8.3/10.3 bar 120/150 psi	8.3/4.7 bar 120/68 psi	8.3/6.2 bar 120/90 psi

* M = Membrane, H = Housing Liquid Pressure, G = Gas Side Pressure
Pressures to be 15 psi lower when using vacuum mode
† X40 Membrane can be operated to 150 psi pressure. Housing pressure limits must also be taken into consideration.

14-inch Operating Temperature And Pressure Guidelines

Illustration 15



*Add 15 psig (1.05 kg/cm²) for X50 or X40 fiber when vacuum is not used.

Table 7: 14 x 28 Pressure Rating Summary

Product	EU and Rest of World – All Applications		
	Membrane PP **X50/X40**	Housing/ Liquid Side	Housing/ Gas Side
14 x 28	8.3 bar 8.4 Kg/cm² 120 psi	8.3 bar 8.4 Kg/cm² 120 psi	4.1 bar 4.2 Kg/cm² 60 psi

Pressures to be 15 psi lower when using vacuum mode

Note: The maximum shell to lumen pressure differential is not to exceed 120 psi.

D. Contactor Weights for System Fabrication:

The System Frame work should be designed to support the maximum Liquid-full weights of the contactors. The weights listed below are for one contactor so the total number of contactors will need to be taken into consideration when designing the skid support structure. Also note that these are maximum weights. Some housing options may weigh less. See product data sheet for more details.

Table 8:Contactor Weights

Product	Kg.	Lbs.
1 x 5/1.7 x 5.5	0.05/0.19	0.11/0.43
2.5 x 8	0.9	2
4 x 13	3.7	8.2
4 x 28	11.3	25
6 x 28	17.1	37.7
10 x 28	137.0	302
14 x 28	112.2	248

E. Filtration Requirements

The inlet liquid and gas streams should be prefiltered. **Table 9** provides recommended guidelines. Depending on the liquid stream composition, it may be necessary to adjust the filtration requirements. Fluids containing adsorbing or agglomerating particles may require a more stringent filtration.

Table 9: General Filtration Guidelines

Liquid stream (shellside)	10 microns 4.5 microns when installed downstream of a carbon bed
Gas stream (lumenside)*	0.2 micron for high-purity applications 1.0 micron is sufficient for industrial applications

**oil- and aerosol-free*

F. Membrane Fouling

When a Liqui-Cel Membrane Contactor system is placed between a clarification unit and an RO unit to remove CO2 from a water stream, be aware of water pH changes. Precipitation of solids can occur when water is treated with flocculation chemicals followed by a change in pH. One typical example is the use of Alum (aluminum sulfate), which is used to remove suspended matter from water. The removal takes place by coagulation, flocculation and precipitation in the water clarifier tank. The precipitation occurs in the form of polymeric aluminum hydroxide at certain pH ranges. If CO_2 is present in large quantities and is removed continuously as the feed water flows through the membrane contactors, the pH will rise. This change in pH may be enough to precipitate excess aluminum hydroxide or other ionic compounds on the membrane's surface. The thin coating layer will prevent normal gas transfer through the membrane and the system's removal capacity will drop. Fortunately this process is reversible by using a 3% w/w ortho-phosphoric acid solution (refer to the Liqui-Cel Membrane Contactor Cleaning Guidelines). The phosphoric acid solution will restore the degassing performance to original manufacture's specifications.

When the contactors are installed down stream from the carbon beds, a 4.5 micron absolute filter should be installed and the carbon beds should be flushed to drain after the carbon change-out until all carbons fines are flush out. Care should also be taken when back flushing carbon beds that are downstream of Membrane Contactors. Filtration should be added to keep the contactors free from carbon particles, which can be difficult to clean.

When Liqui-Cel Membrane Contactors are installed upstream of RO membranes, a cleaning cycle is highly recommended in order to prevent fouling of the Liqui-Cel Membrane Contactor. Please refer to the Liqui-Cel Membrane Contactor Cleaning Guidelines available on-line at www.liqui-cel.com or from your Membrana representative.

G. Minimum System Instrumentation Required

- **Pressure gauges** (bourdon type; Weksler, Ashcroft, US Gage)
  - Process inlet near contactor inlet, glycerin filled, diaphragm seal, isolation valve optional
  - Process outlet near contactor outlet, glycerin filled, diaphragm seal, isolation valve optional
  - Nitrogen inlet, isolation valve optional
  - Nitrogen flow meter pressure, isolation valve optional
  - Vacuum line pressure, compound, isolation valve optional
  - Vacuum service water near pump connection, compound, isolation valve optional

- **Flow meters**
  - Nitrogen sweep, rotometer type, Fisher & Porter
  - Process inlet turbine, vortex, or magmeter type, Fisher & Porter, Hoffer (optional)

- **Pressure control**
  - Nitrogen pressure regulator, which brings the line pressure down to atmospheric

- **Valves**
  - Process stream
    - Isolation valves, butterfly or ball
    - Inlet manual flow control valve, butterfly
    - Pressure relief valve
  - Vacuum pump
    - Suction check valve
  - Vacuum pressure relief / vacuum breaker
    - (to prevent pump cavitation)
  - Vacuum service water
    - Check valve
    - Needle valve
    - Solenoid
    - Inlet shut-off
  - Nitrogen
    - Shut-off
    - Manual flow control valve
    - Pressure relief valve if required

- **Pressure switches**
  - Process inlet high pressure switch to shutdown or warn operator
  - Vacuum line high pressure switch to warn operator

- **Temperature measurement** (bimetal dial-type thermometer with thermowell)
  - Process fluid
  - Nitrogen at flowmeter, optional
  - Vacuum service water feed, optional

H. Warnings of Misuse

Avoid the following: Water hammer, over pressurization, dropping, and over torquing the end cap clamp bolts. Nuts should NOT be quick driven onto bolts. Nuts should be driven slowly by hand to prevent galling. Using power driven tools can produce excessive friction and increase the risk of galling. Also note that if membrane failure occurs, liquid pressure could enter the gas side. Though this would be extremely rare, a pressure-limiting device downstream of the gas outlets would protect downstream technologies. Also note that the membrane will allow gases to pass from the gas side to the liquid side if water is not present on one side of the membrane. Therefore, any system pressure tests with compressed gas should be used only to the maximum listed gas side pressure of 90 psi for 10-inch FRP end caps, 130 psi for 10-inch SS end caps, and 60 psi for 14 x 28 Nylon end caps. It is also important to follow recommendations when supporting 14-inch contactors in a system. The bolt flange that attaches the end caps to the vessel should not be used to support the weight of the contactor.

IV. System Design Requirements for Obtaining Low Levels of Dissolved Oxygen

To ensure optimum performance, it is important to follow the instructions below to minimize the chances of oxygen contamination or leakage from the atmosphere into the system. As specified by the standard product performance warranty, customer compliance with the following conditions is required.

- Do not use threaded connections in the sweep gas or vacuum piping. All-welded systems are recommended. When service connections are required, flanged connections or specially designed vacuum fittings are recommended.
- The system must be designed and installed such that there are no air leaks.
- Performance results are dependent upon sweep gas purity. For units targeting < 5 ppb residual D.O. concentration, the minimum purity nitrogen required is 99.99%. For units targeting < 1 ppb residual D.O. concentration, the minimum purity nitrogen required is 99.995%. Both purity levels are based on molar compositions.
- The sample lines used to measure D.O. concentrations must be constructed of materials that are impermeable to gases (e.g. PEEK or stainless steel) to prevent contamination from atmospheric oxygen. Do not use perfluoroalkoxy (PFA) or polyethylene tubing.
- Residual dissolved oxygen concentrations of < 5 ppb must be measured using an accurately calibrated Orbisphere model MOCA 3600 dissolved-oxygen analyzer that is equipped with a flow-cell type sensor having model 2956A membranes. The instrument calibration, operation and measurement conditions must be according to Orbisphere specifications and standards.
- Residual dissolved oxygen measurements must be made as close as practically possible to the outlet of the final contactor(s).
- Adequate vacuum pump capacity is critical for systems designed with vacuum. For vacuum pump sizing purposes, a design safety factor of 20 to 25% is recommended. Ideally, the vacuum pump capacity should be large enough to achieve > 28 in. Hg (< 50 mm Hg. absolute) pressure under the maximum gas loading condition. Lowering the absolute vacuum pressure enhances degassing performance.
- A very simple, but very important part of a degassing system design/operation includes the sample lines and the oxygen instrumentation and calibration. All Liqui-Cel Membrane Contactors are subject to a QC performance test before they are shipped to a customer site. Oxygen removal performance, pressure drop, and fiber leakage are all included in the QC testing. The possibility of a contactor being shipped that has lower performance than indicated in the sizing program due to a membrane or manufacturing defect is rare. Poor system performance during start-up is generally caused by an air leak in the system or a poorly operated or calibrated oxygen analyzer. Check equipment and sample lines for leaks.
- Avoid fittings not rated for vacuum service when building a degasification unit that operates under vacuum-only or sweep-assisted vacuum mode. These fittings can be a source of air leaks in the degassing system.

V. Startup and Shutdown Procedures

A. General start-up instructions for the liquid phase

Note: Both gas/vacuum ports should not be closed during operation. These ports provide a safety vent in the contactors so that pressure does not build up.

1. Slowly introduce water to the system, making sure that water inlet pressure and water flow rate through the contactor never exceed the maximum operating limits (see page 22-23).
2. Adjust water flow rate and inlet pressure to the desired levels by adjusting the appropriate valves on the system.

B. Start-Up Instructions for strip gas and vacuum phase

Note: Vacuum when used in combo, should always be pulled from the lowest gas port to facilitate draining and ensure performance.

Sweep Gas Mode

Set the pressure entering the contactor at ≤ 10 psig (0.7 bar, 0.7 kg/cm^2) by adjusting the appropriate valve in the gas delivery system.

1. Set the recommended total sweep flow rate by adjusting the appropriate valves. See the sweep guidelines for typical sweep gas flow rate ranges in table 2 on page 4.
2. Introduce fresh sweep gas into each contactor.

NOTE: If condensation is in the lumens from a shut down cycle, we recommend purging the lumens with sweep gas or air at 40-60 psi for about 5 minutes. This will clear the water condensation on the lumen side and will allow normal system performance.

Sweep Gas with Vacuum (Combo) Mode

1. Set the gas pressure entering the contactor at ≤ 1 psig (0.07 bar, 0.07 kg/cm^2) by adjusting the appropriate valve on the gas delivery system.
2. Set the recommended total sweep flow rate by adjusting the appropriate valve. See sweep guidelines for typical sweep gas flow rate ranges in table 4 on page 14.
3. Introduce fresh sweep gas into each contactor.
4. Apply vacuum as described in the vacuum section below.

NOTE: If condensation is in the lumens from a shut down cycle, we recommend purging the lumens with sweep gas or air at 40-60 psi for about 5 minutes. This will clear the water condensation on the lumen side and will allow normal system performance.

Vacuum Only Mode

1. Start vacuum pump following vacuum pump manufacturer's instructions.
2. Apply vacuum to the contactor by opening appropriate valve.
3. Adjust absolute gas pressure on the vacuum side to the desired level at the vacuum port on the contactor.

C. Shutdown Procedure

1. Slowly close the water inlet and outlet valves. If possible drain all liquids from the contactor.
2. Mode:
   a. Sweep-gas mode using nitrogen or other inert gas:
      - Allow the nitrogen (or CO_2 or other inert gas) to purge the system for 1 hour.
      - Close the nitrogen outlet valves only. This will allow the water to become saturated with nitrogen thereby inhibiting bacterial growth. Maintain a low pressure, 0.07 - 0.14 kg/cm^2 (1 – 2 psig) nitrogen pressure during shutdown period.

   b. Sweep-gas mode using air sweep or Combo with air or vacuum only mode:
      - Shut off the vacuum pump and close the gas outlet valves (if applicable).
      - Close the air inlet valve(s) (if applicable).
      - To prevent biological growth, either follow step 2a. or fill the liquid side with a biocide, such as 2000 ppm of sodium metabisulfite (SMS), for the duration of the shutdown period. Monitor the biocide level to maintain its effectiveness.

3. If your shutdown period will be less than 24 hours, we recommend leaving sweep or vacuum on. This will keep the lumens purged of liquid

D. Startup after Shutdown Procedure

During the shutdown period, the water that condenses inside of the hollow fibers must be removed.

- Open the vacuum inlet valve (if applicable) and start the vacuum pump.
- Open the gas outlet valves.
- Open the air sweep inlet valves (if applicable).
- For a pressurized gas system (N_2 sweep, N_2 combo, air combo) raise the inlet gas pressure to 2.1 kg/cm^2 (40-60 psig, 2.068427 bar) for 10 minutes.

VI. Maintenance

Limited maintenance is required for Liqui-Cel Membrane Contactors. We suggest a weekly or bi-weekly check of the system to insure the performance is acceptable. For warranty purposes a log recording the information in the example below should be maintained.

Date	Operator	Flow Rate	Pressure Into Contactors	Temperature	Inlet Gas Concentration	Outlet Gas Concentration

This log will show the user a pattern of consistent performance or a decline in performance over time. If the contactors are still performing to the stated performance, no maintenance is required. If a decline in performance is noted, it may be time to clean the membrane. Cleaning is typically the only maintenance required. See the Membrana Cleaning Guide available on-line at www.liqui-cel.com.

VII. Expected Service Life

- 2.5 x 8, 4 x 13, 4 x 28, and 6 x 28 Membrane Contactor: The expected service life of polypropylene and ABS vessels is 5 years when used with water temperatures of < 70^0 C (158^0 F).
- 4 x 28 and 10 x 28 Membrane Contactors: The expected service life of the FRP vessel is > 10 years when used with water temperatures of < 70^0 C (158^0 F).
- 14 x 28 Membrane Contactors: The expected service life of the PVC vessel and nylon end caps is > 5 years when used with water temperatures of < 45^0 C (113^0 F).
- Refer to the appropriate data sheet and page 24-25 for maximum operating temperature for the membrane cartridge installed in the vessel. Membrane life will vary based on inlet conditions.

VIII. Plastic and FRP Vessel Operating Precautions

- To maintain the service life of the vessel, temperature cycling with FRP vessels should be minimized. Heat-up and cool-down rates should not exceed 1°C/minute (1.8°F/minute).
- To prevent premature failure of the PVDF, ABS and Nylon fittings, accurate alignment and proper support of those connections is critical. Pipe that is not properly supported will put additional stress on the plastic fittings, which can lead to a fitting failure. Use proper plastic pipe support guidelines when installing plastic vessels.

IX. Contactor Storage

Refer to the Liqui-Cel Membrane Contactor Storage and Handling guidelines located on the back of the Start Up Procedures and in the product shipping box or crate.

X. Contactor Sanitizing, Cleaning and Clean-in-Place

Refer to the Liqui-Cel Membrane Contactor Cleaning Guidelines document available at www.liqui-cel.com in the Technical Support Section or from your Membrana representative.

XI. Chemical Compatibility

For general guidelines, refer to the Liqui-Cel Membrane Contactor Chemical Resistance Guide available at www.liqui-cel.com in the Technical Support Section or from your Membrana representative.

XII. Cartridge Installation

For a detailed description, refer to the Liqui-Cel Membrane Contactor Assembly and Disassembly Instructions available at www.liqui-cel.com in the Technical Support Section or from your Membrana representative.

XIII. Troubleshooting

Problem Description	Probable Cause	Corrective Action
Outlet dissolved gas concentration above specification or low performance after use.	▪ Membrane Contamination/fouling.	▪ Clean contactor. Refer to Cleaning Guidelines.
	▪ Dust covers used in shipping may not have been removed.	▪ Verify shipping dust plugs are removed from gas ports.
	▪ Sweep Gas Contaminated.	▪ Verify sweep gas purity level.
	▪ Air leaks in the gas purge lines.	▪ Tighten gas side flange connections. ▪ Pressurize gas line and monitor for leaks. – Soap test – look for bubbles. – Pressure test – Pressurize then isolate and monitor for pressure decay. – Electronic leak detection systems. ▪ Operate system and collect data points. – Stop gas flow and operate in Vacuum only mode. Record conditions and outputs in sweep only mode. – Stop vacuum pump, open vacuum manifold and start gas flow. Record conditions and outputs in sweep only mode. ▪ Contact Membrana Representative**.**
	▪ Low Vacuum Level.	▪ Ensure that the vacuum system is sized correctly for system and that the vacuum manifold is sized to handle vapor load for the system.
	▪ Air leaks in the vacuum system.	▪ Check system for air leaks. If the outlet dissolved gas concentration is within the sizing estimate limits, the leak is probably in the vacuum line after the contactor. Draw a vacuum on the contactor when it is filled with water and verify that it holds vacuum. Look for water accumulation in the vacuum piping. – Does the vacuum line slope down from contactor to vacuum? If no, re pipe per page 11. – Disconnect the vacuum line from the contactor. If the water leak is > 20ml per minute (without sweep gas). Contact a Membrana Representative. – Condensation is a normal occurrence, insulate vacuum manifold. ▪ Install larger capacity vacuum pump. Contact a Membrana Representative First.

XIII. Troubleshooting (Continued)

Problem Description	Probable Cause	Corrective Action
Outlet dissolved gas concentration above specification or low performance after use.	▪ Condensation in contactor or vacuum lines.	▪ If contactor has been sitting wet while not in operation, there may be water condensation in the lumen. – Remove condensate inside of the fibers with a gas purge. – Pressurize the gas side to 2.1 kg/cm^2 (30 psi, 2.1 bar) and release pressure by opening the exit valve. – Continue to sweep gas at high rate until no water drips from the gas exit port. – If the water drip continues for several minutes, contact a Membrana Representative. ▪ Look for water accumulation in vacuum pipe. – Does vacuum line slope down from contactor to vacuum? If no, re-pipe per page 11. – Condensation is a normal occurrence, insulate vacuum manifold. ▪ Disconnect vacuum line from contactor. If water leak > 20 ml per minute, (without sweep gas), contact a Membrana Representative.
	▪ Liquid temperature below design specification.	▪ Raise temperature.
	▪ Liquid flow rate higher than design specification.	▪ Reduce flow rate.
	▪ Low sweep gas flow rate.	▪ Increase sweep gas flow rate.
	▪ Unequal liquid flow through contactor trains.	▪ Verify train flow rate. ▪ Adjust valves accordingly to equalize flow rates.
High liquid-side pressure drop.	▪ Dust covers used in shipping may not have been removed.	▪ Verify dust covers /end cap plugs have been removed.
	▪ Particulate accumulation on shellside.	▪ Check filter system. ▪ Clean contactors. Refer to Cleaning Guidelines. ▪ Dissolve particles if soluble in acid or base. ▪ Replace contactors. ▪ Check flow rate: (do not exceed max.) – 1 x 5.5 = <500 ml/min – 1.7 x 5.5 = <2500 ml/min – 2.5 x 8 = 0.68 m^3/hr max.(3 gpm) – 4 x 28 = 6.8m^3/hr max. (30 gpm) – 6 x 28 = 11.4 m^3/hr max. (50 gpm) – 10 x 28(X50) = 47.7 m^3/hr max.(210 gpm) – 10 x 28(X40) = 57 m^3/hr max.(250 gpm) – 14 x 28 = 90.8 m^3/hr max.(400 gpm)

XIII. Troubleshooting (Continued)

Problem Description	Probable Cause	Corrective Action
Significant liquid passage into lumenside stream.	▪ Verify the liquid inlet is connected to the shellside port. ▪ Center seal nut may be loose. ▪ Contactor shellside o-ring may not be sealing. ▪ Verify contactor integrity. ▪ Membrane break through (wet-out). If surfactants, oils, and/or alcohols have been introduced to the membrane, wet-out may have occurred.	▪ Change piping connections. ▪ See contactor Assembly and Disassembly Instructions for details on how to tighten center seal nut. ▪ Remove and install new o-ring. See contactor Assembly and Disassembly Instructions for details. ▪ Pressurize shellside to 4.2 kg/cm^2 (60 psi, 4.1 bar). ▪ Monitor lumenside for leakage. ▪ Rinse and clean the contactor. ▪ Remove fluid and dry the membrane fibers by passing air through the pores. See Cleaning Guidelines for drying procedures.
Nuts are seizing when I tighten them	▪ The nuts should not be quick driven onto the bolts. ▪ Using power driven tools can produce excessive friction and increase the risk of galling.	▪ Nuts should be driven slowly by hand to prevent galling.

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OP151-Rev.14 Operating Procedures (1/07)

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Underlining Performance

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LIQUID PHASE GAC ADSORBERS

PG Series Polyglass Adsorbers

PG180, PG500, PG750, PG1100, PG1400, PG2200, PG5000

Applications

Siemens Water Technologies offers a full line of polyglass liquid phase adsorbers engineered to remove contaminants from high pressure liquid streams while providing maximum corrosion resistance. These adsorbers are manufactured with fiberglass reinforced resin and an inner polyethylene liner. The PG series adsorbers can be utilized by industrial, municipal, or commercial users in a variety of applications.

- Decolorization
- Product Purification
- Process Water Filtration
- Groundwater Remediation
- Wastewater Treatment
- Drinking Water Treatment

Installation, Startup and Operation

Siemens Water Technologies can provide a total service package that includes utilizing OSHA trained personnel providing on-site carbon changeouts, packaging and transportation of spent carbon for recycling at our reactivation facilities.

At the time of purchase or rental of the adsorbers, arrangements should be made for the reactivation of the spent carbon. Siemens Water Technologies will provide instructions and assistance on how to obtain acceptance of the spent carbon at our reactivation facilities. Spent carbon cannot be accepted for reactivation until the acceptance process is completed.

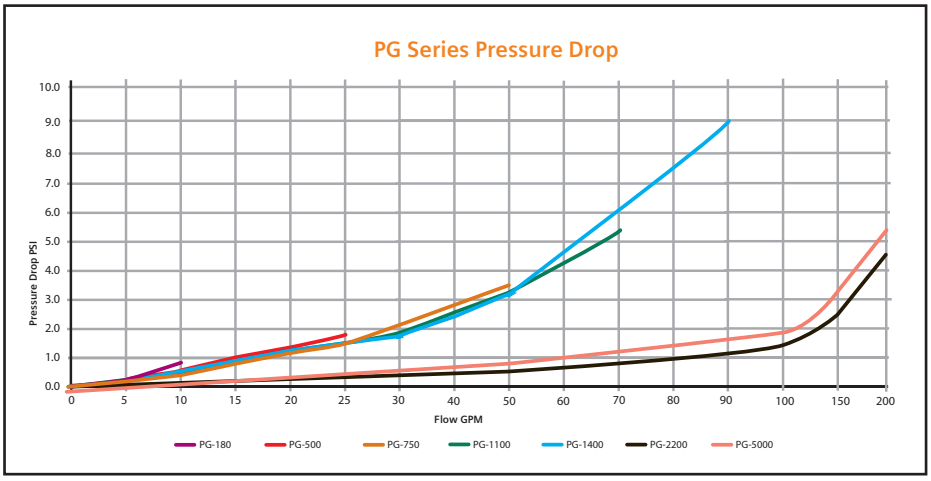
Benefits & Design Features

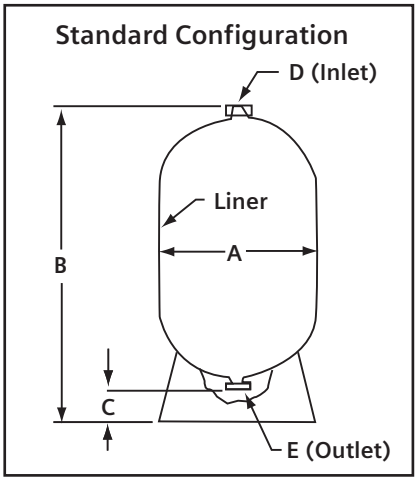
- Durable, Fiberglass Reinforced Resin construction – provides strength for high pressure applications and protection from corrosive environments
- Polyethylene liner and Polypropylene Internal Fittings – provides excellent internal protection against corrosive liquids
- Optional Transport Frame provided for easy transport and installation
- Optional Carbon Fill and Discharge piping (Schedule 80 PVC) provided for slurry carbon transfer
- Available for Purchase or Rental
- Approved for the transport of hazardous spent carbon (when supplied with optional Transport Frame)
- Maximum working pressure of 100 psig (689 kPa) for model PG5000, and maximum working pressure of 150 psig (1034 kPa) for all other models
- Temperature Limit of 140°F (60 C)



Dimensions and Capacities									
Adsorber	A inches	B inches	C inches	D inches	E inches	Max. Flow (GPM)	Approximate Carbon Fill (lbs.)	Empty Shipping Weight (lbs.)(See NOTE)	Est. Operating Weight (lbs.)
PG180	24	60	12	3	3	10	180	100	460
PG500	30	89	10	3	3	35	500	211	1211
PG750	36	91	11	3	3	50	750	285	1785
PG1100	42	89	11	3	3	65	1100	400	2600
PG1400	48	93	11	3	3	90	1400	494	3294
PG2200	63	109	27	3	3	175	2200	950	5350
PG5000	63	169	27	3	3	200	5000	1398	11398

Note: *PG adsorbers without Transport Frame must ship empty of carbon. If Transport Frame is included, units may ship filled with carbon. Approximate weight of units with Transport Frame are 350 lbs. higher than empty shipping weights shown above.*
Note: *Standard vessels are furnished with FNPT inlet and outlet fittings. Other optional fittings can be provided as required.*





Pressure drop in psi through vessel filled with 8x30 carbon

Safety Note: Wet activated carbon readily adsorbs atmospheric oxygen. Dangerously low oxygen levels may exist in closed vessels or poorly ventilated storage areas. Workers should follow all applicable state and federal safety guidelines for entering oxygen depleted areas.

Siemens makes no warranties as to completeness of information. Users are responsible for evaluating individual product suitability for specific applications. Siemens assumes no liability whatsoever for any special, indirect or consequential damages arising from the sale, resale or misuse of its products. All information presented herein is believed reliable and in accordance with accepted engineering practice.

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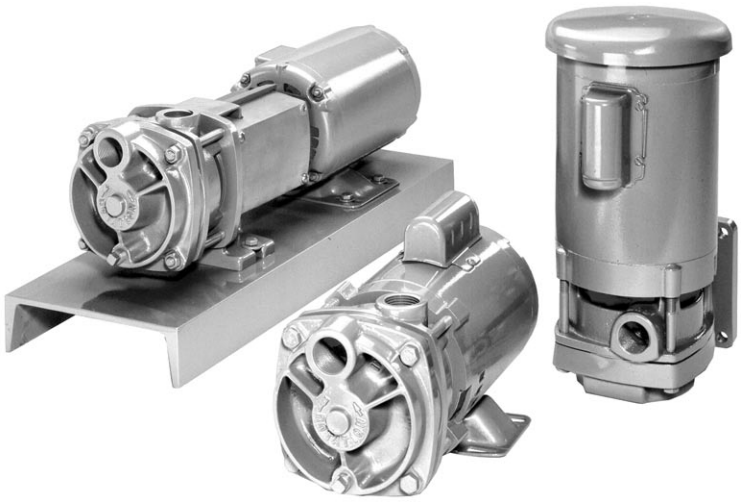
BOOSTER PUMPS

MTH PUMPS

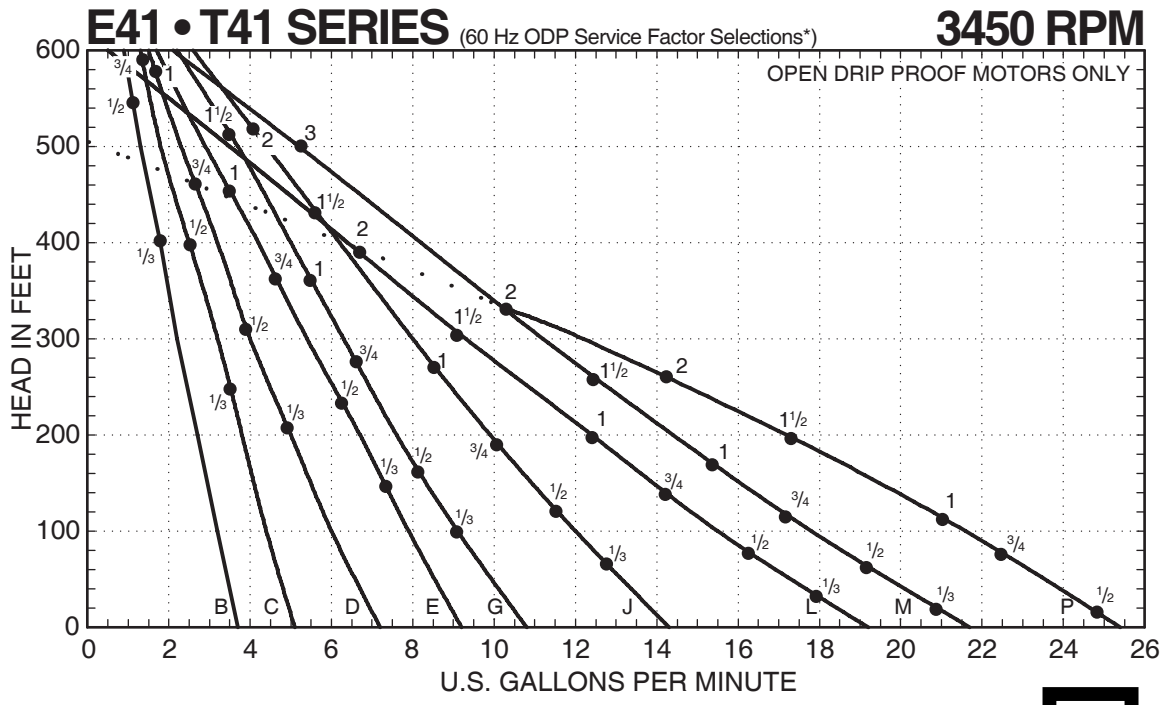
E41 • T41 Series



- **Capacities to 24 GPM**
- **Heads to 600 Feet**
- **Low NPSH Requirements**
- **Horizontal Close Coupled**
- **Vertical Flange Mounted**
- **Flex Coupled**

E41 • T41 SERIES

Composite Curves



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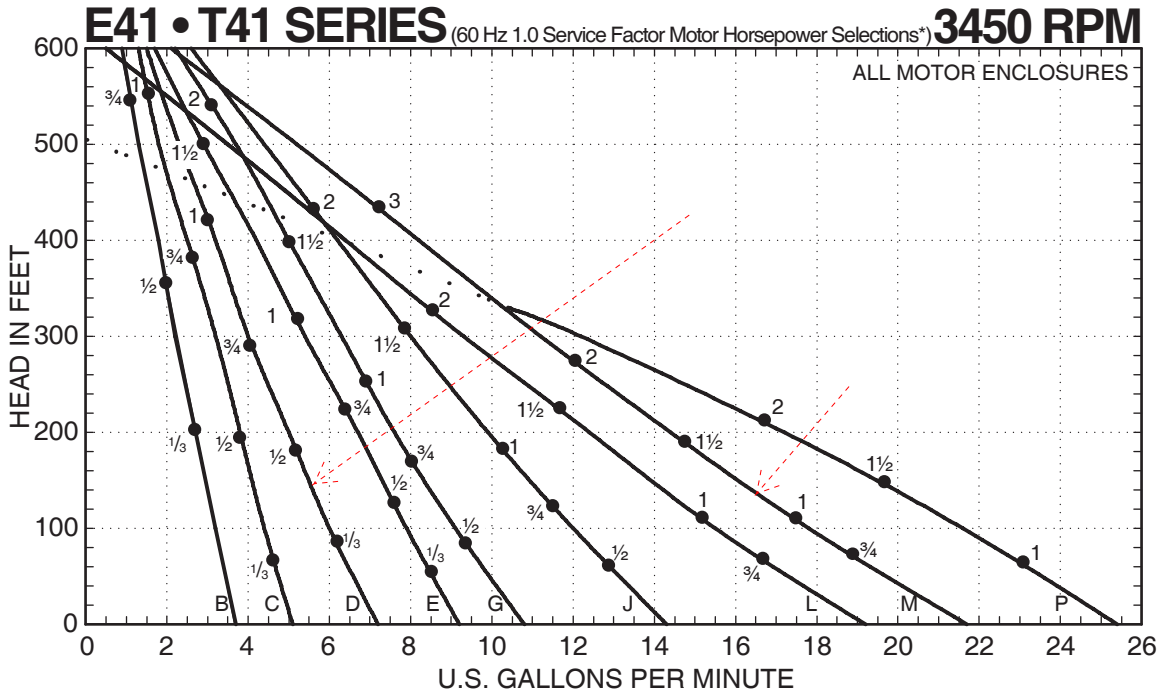
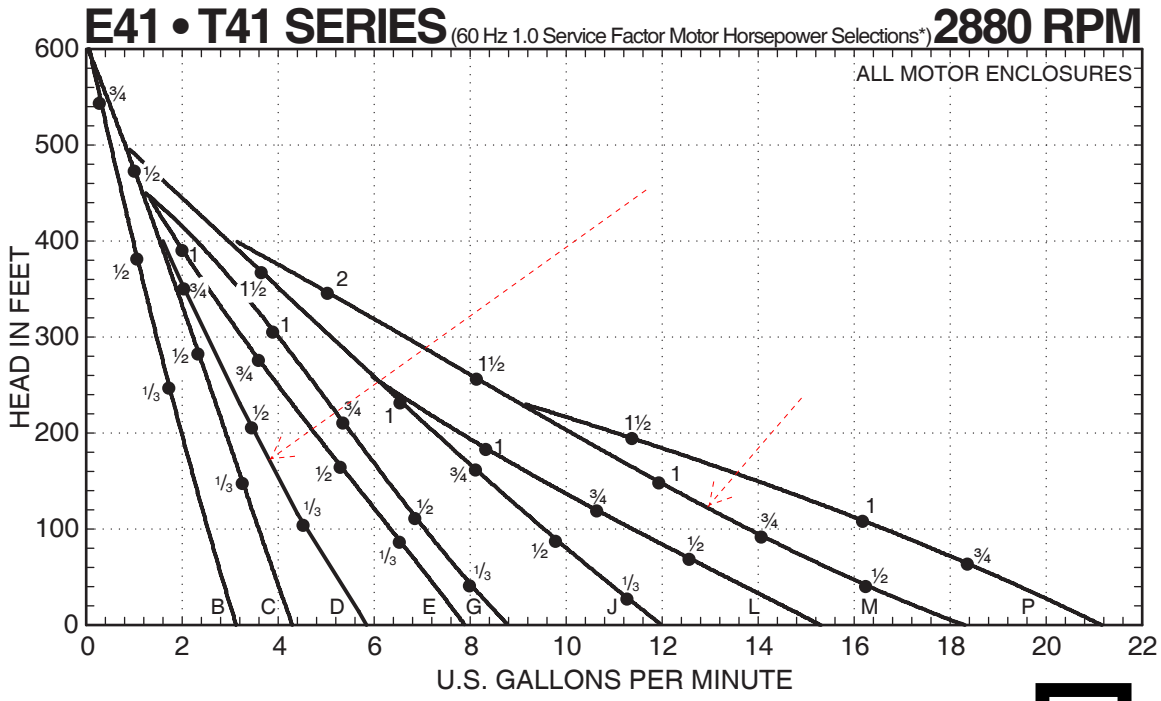
E41 • T41 SERIES

Composite Curves





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* Horsepower data is valid for 1.0 specific gravity fluids only

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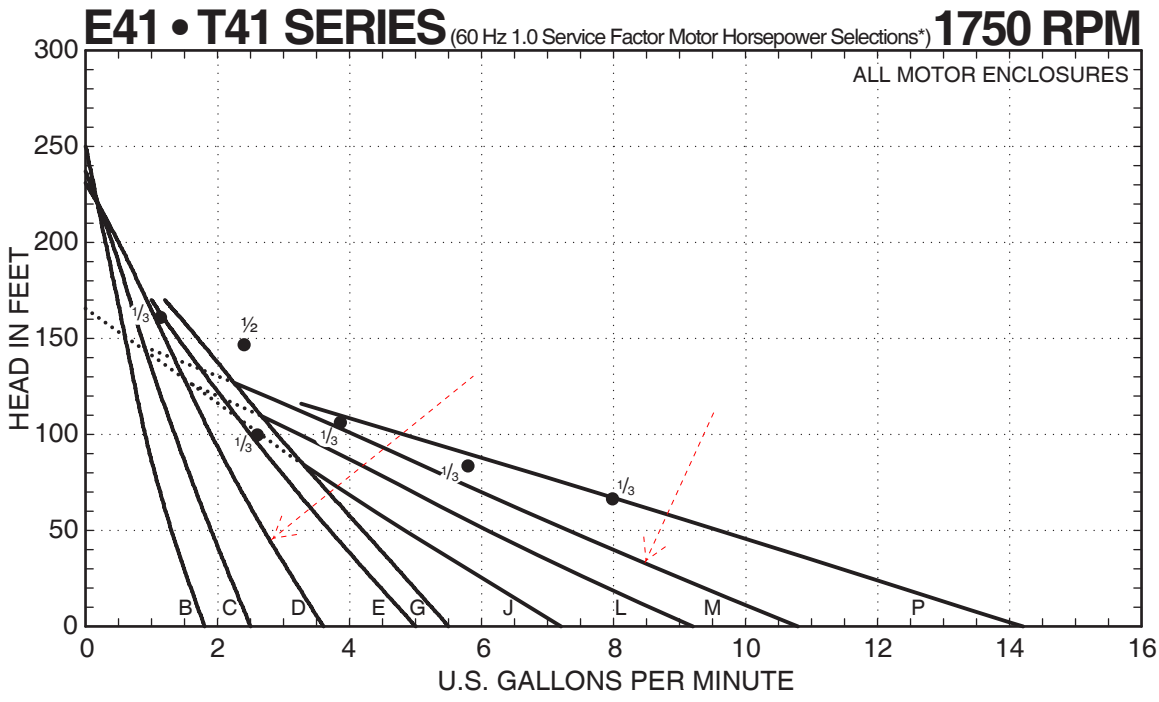
E41 • T41 SERIES

Composite Curves



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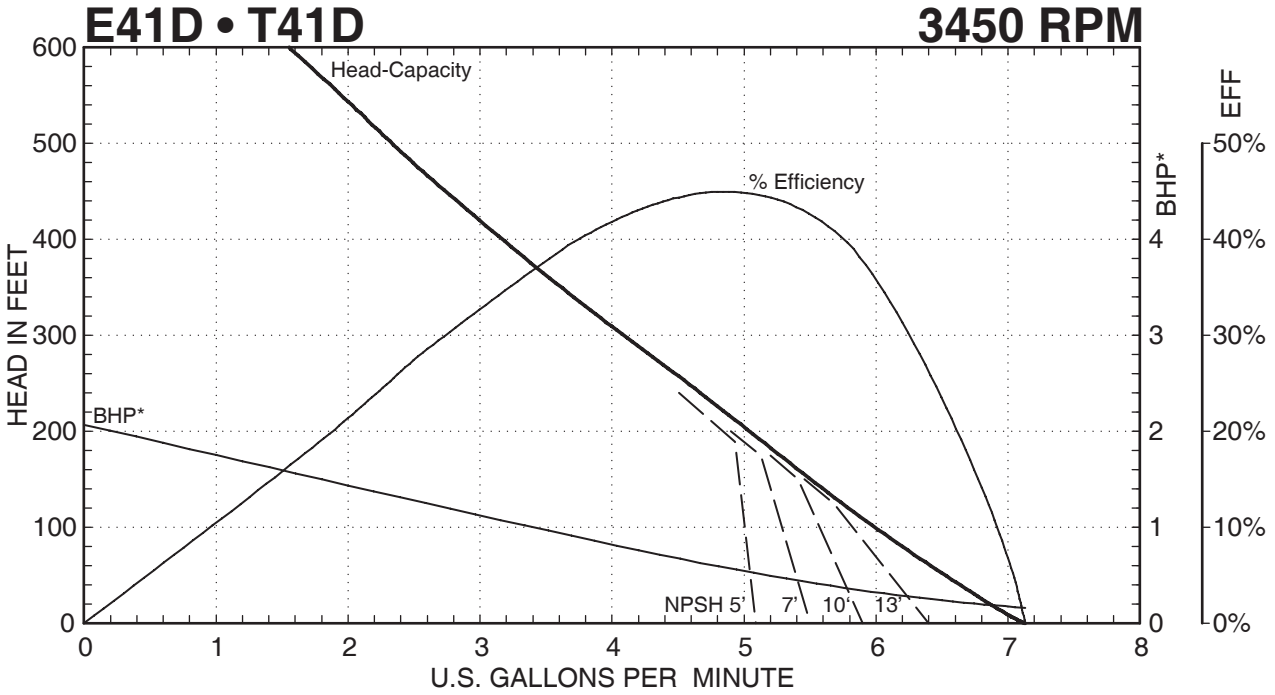
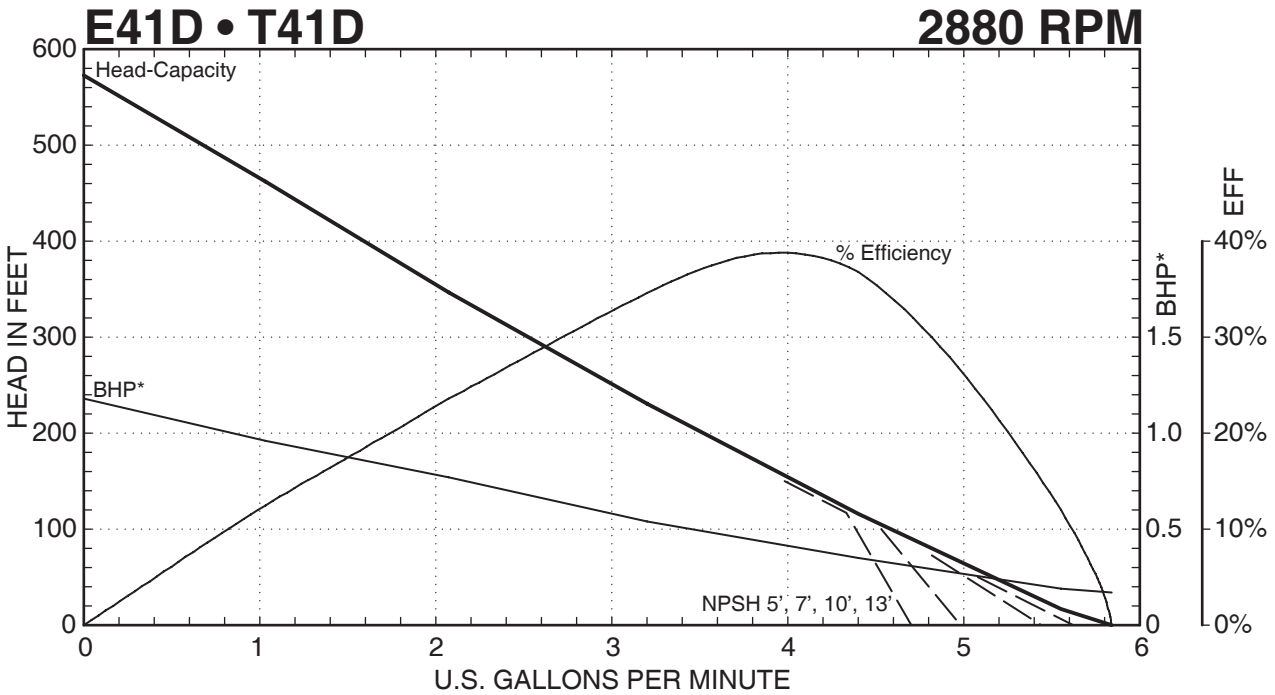
Performance Curves





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— — —Indicates altered performance at NPSH Available
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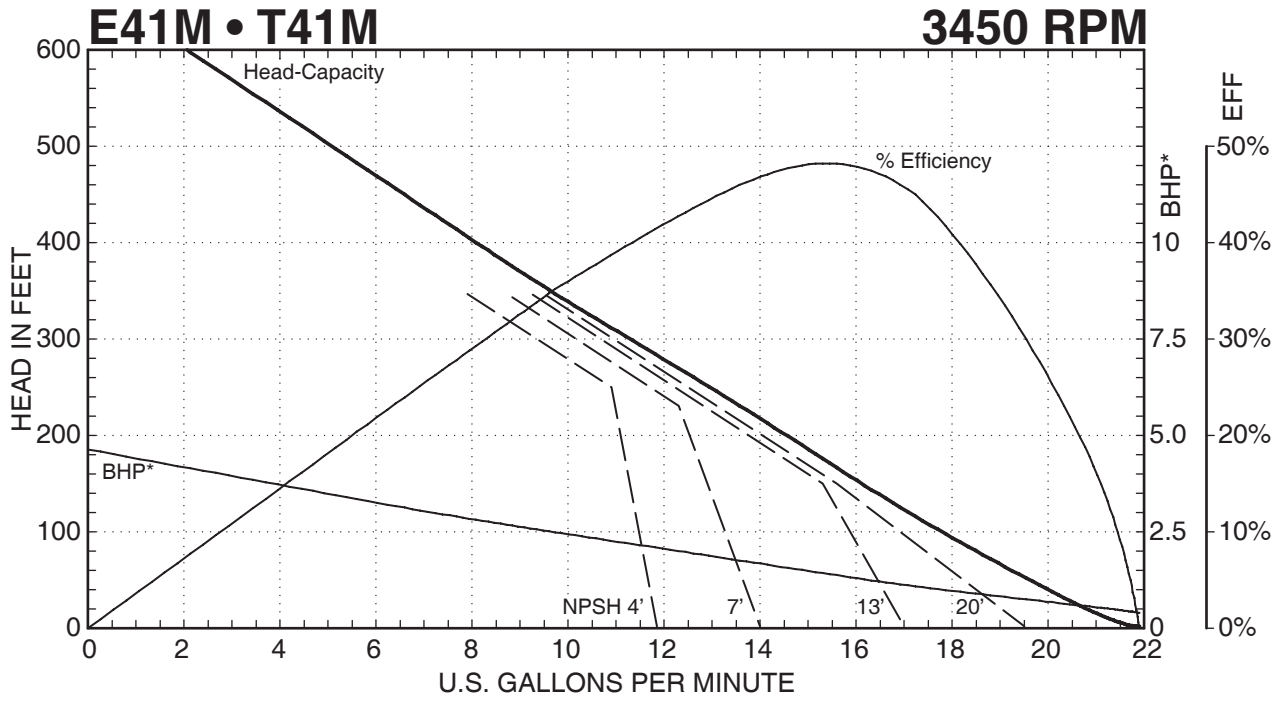
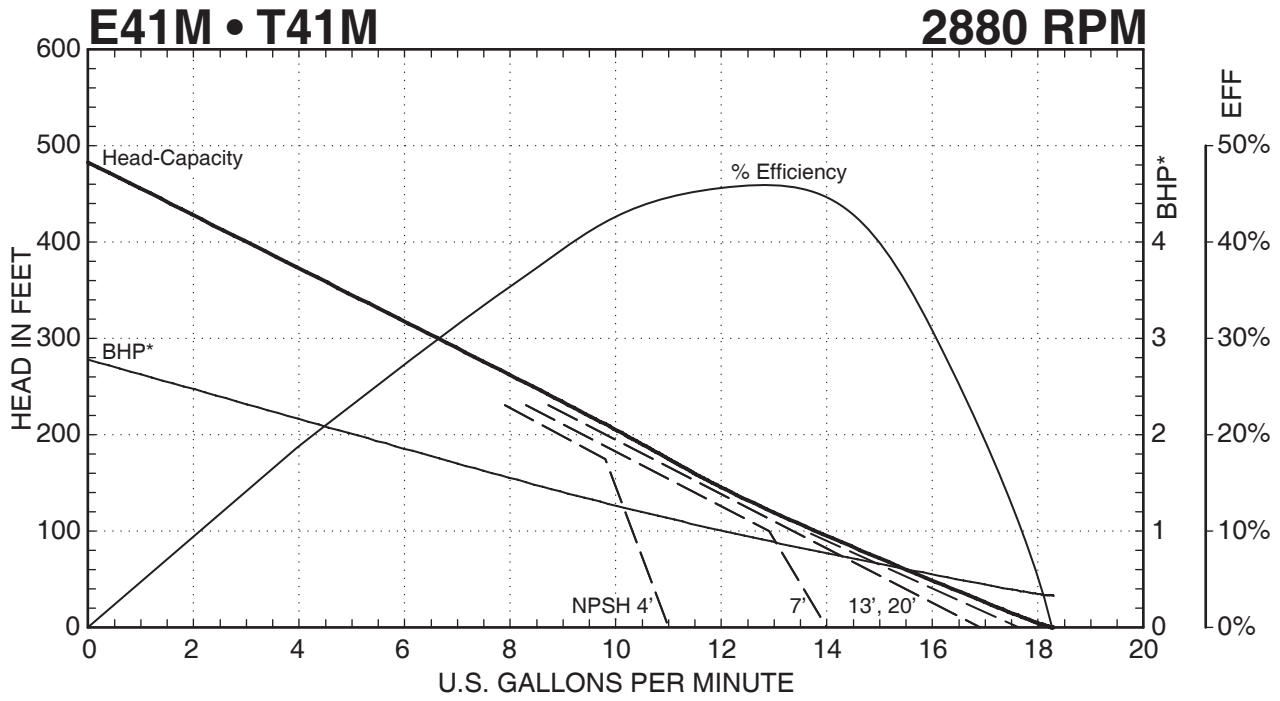
Performance Curves





—— —— –Indicates altered performance at NPSH Available
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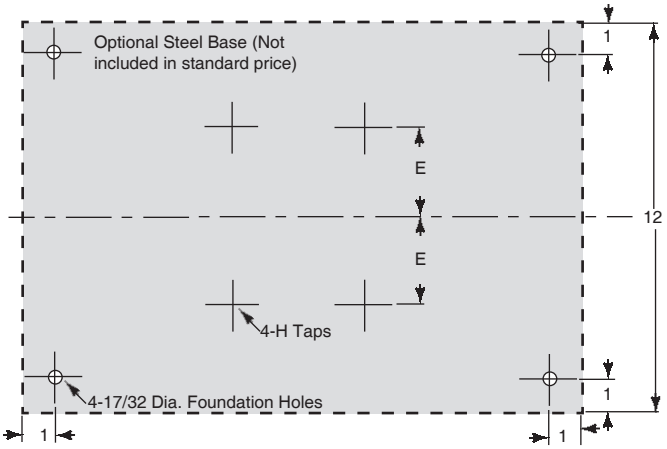
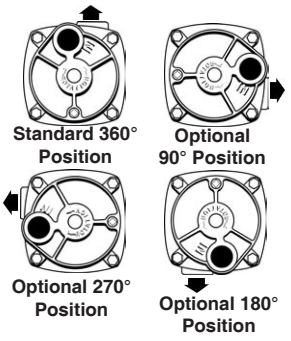
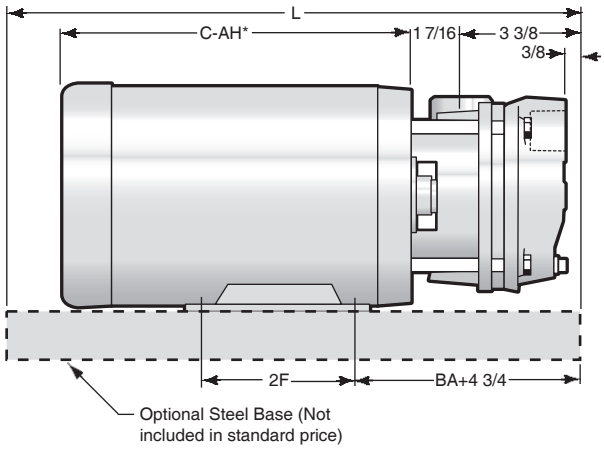
E41 • T41 SERIES

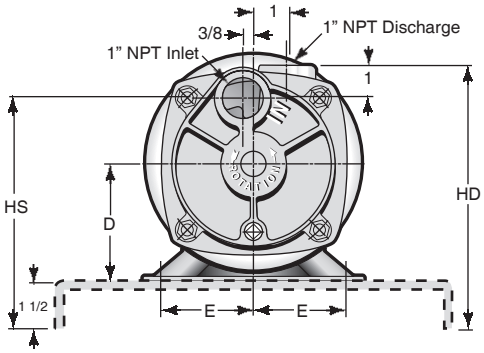
Dimensions

T41 Horizontal Close Coupled









56C Thru 215TC Motor Frames

FRAME	D	BA+4 3/4	2F	E	H	HS	HD	L
56 C	3 1/2	7 3/8	3	2 7/16	5/16 - 18	7	8	18
143 TC	3 1/2	7 5/8	4	2 3/4	5/16 - 18	7	8	18
145 TC	3 1/2	7 5/8	5	2 3/4	5/16 - 18	7	8	18
182 TC	4 1/2	8 3/8	4 1/2	3 3/4	3/8 - 16	8	9	20
184 TC	4 1/2	8 3/8	5 1/2	3 3/4	3/8 - 16	8	9	20
213 TC	5 1/4	9 1/8	5 1/2	4 1/4	3/8 - 16	8 3/4	9 3/4	22
215 TC	5 1/4	9 1/8	7	4 1/4	3/8 - 16	8 3/4	9 3/4	22

NOTES
All dimensions in inches. May vary ± ¼ inches.
Not for construction purposes unless certified.
*See motor dimensions for "C-AH" dimension (Varies depending on motor enclosure).

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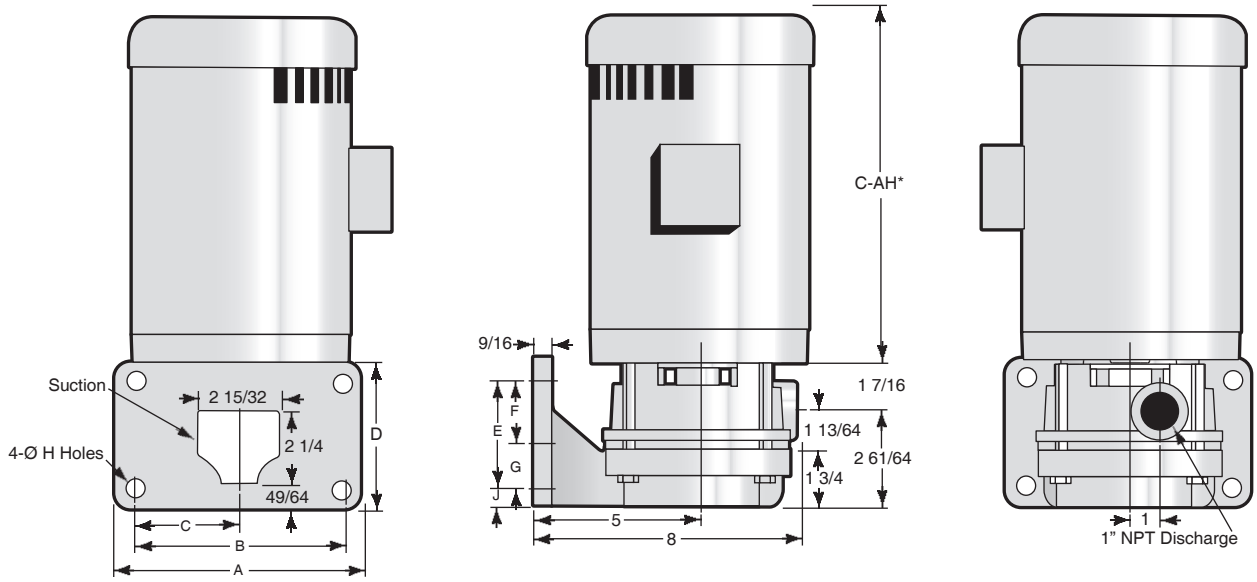
Dimensions

T41 Flange Mounted Close Coupled



56C Thru 215TC Motor Frames

FLANGE STYLE	A	B	C	D	E	F	G	H	J
AU (7 1/2 x 4 1/2)	7 1/2	6 1/4	3 1/8	4 1/2	3 1/4	2 1/8	1 1/8	9/16	5/8
DB (4 1/2 x 4 1/2)	4 1/2	3.270	1.635	4 1/2	3.270	2.135	1.135	1/2	.615
FE (7 3/4 x 4 3/4)	7 1/2	6 1/4	3 1/8	4 1/2	3 1/2	2 1/4	1 1/4	9/16	1/2
PA (6 1/2 x 3 3/4)	6 1/2	5 1/2	2 3/4	3 3/4	2 5/8	1 1/2	1 1/8	9/16	5/8
SH & BU (6 1/4 x 4)	6 1/4	5	2 1/2	4	2 3/4	1 5/8	1 1/8	9/16	5/8
SK (6 1/8 x 4 1/8)	6.13	4.94	2.47	4.13	2.69	1.66	1.03	9/16	.72
ST (5 x 5)	5	3 3/4	1 7/8	5	3 3/4	2 5/8	1 1/8	1/2	5/8
WI (5 x 5)	5	4 1/8	2 1/16	5	4 1/8	2 13/16	1 5/16	7/16	7/16

NOTES
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*See motor dimensions for "C-AH" dimension
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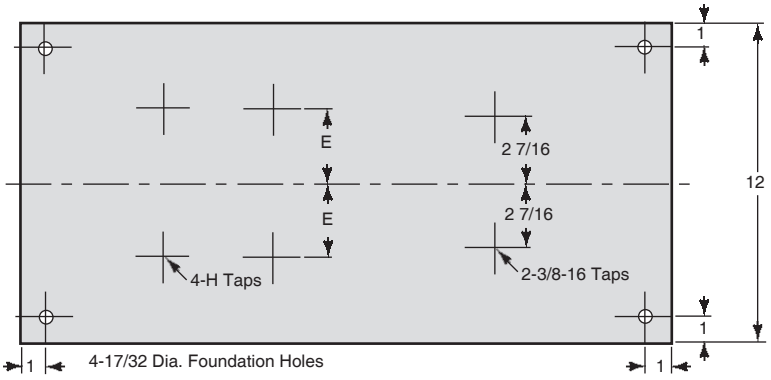
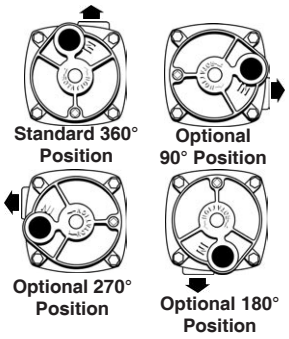
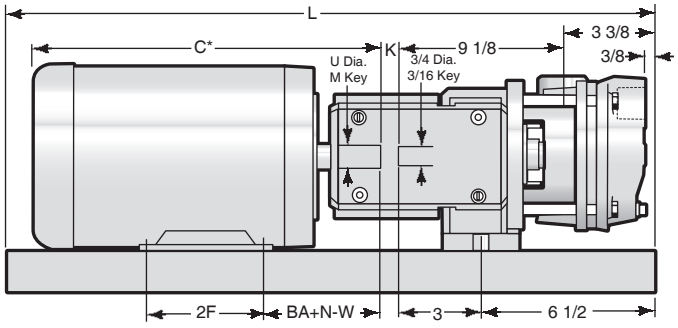
E41 • T41 SERIES

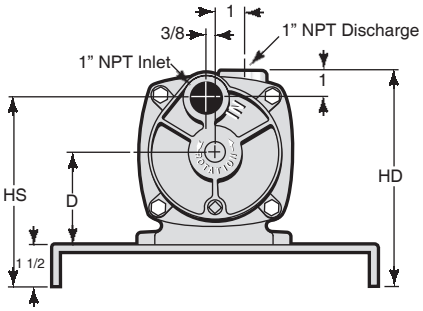
Dimensions

P3 Bearing Pedestal









56T Thru 184T Motor Frames

FRAME	D	U	BA+N-W	2F	E	H	K	HS	HD	L	M
56 T	3 1/2	5/8	4 5/8	3	2 7/16	5/16 - 18	5/8	7	8	24	3/16
143 T	3 1/2	7/8	4 1/2	4	2 3/4	5/16 - 18	5/8	7	8	24	3/16
145 T	3 1/2	7/8	4 1/2	5	2 3/4	5/16 - 18	5/8	7	8	24	3/16
182 T	4 1/2	1 1/8	5 1/2	4 1/2	3 3/4	3/8 - 16	3/4	8	9	26	1/4
184 T	4 1/2	1 1/8	5 1/2	5 1/2	3 3/4	3/8 - 16	3/4	8	9	26	1/4

NOTES
All dimensions in inches. May vary ± ¼ inches.
Not for construction purposes unless certified.
*See motor dimensions for "C-AH" dimension (Varies depending on motor enclosure).

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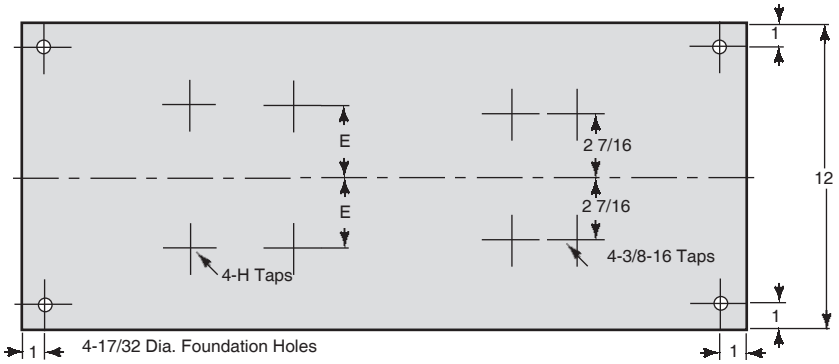
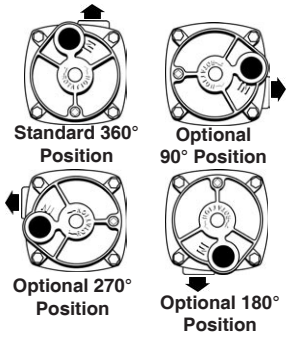
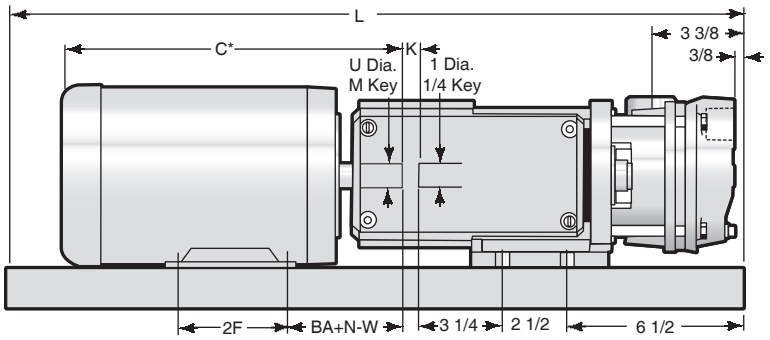
E41 • T41 SERIES

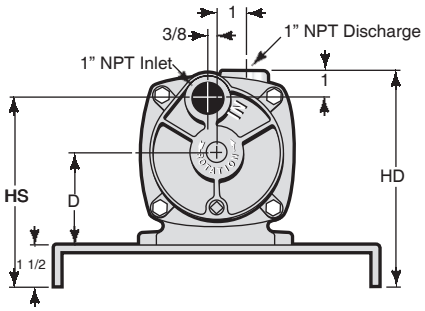
Dimensions

P15 Bearing Pedestal









143T Thru 215T Motor Frames

FRAME	D	U	BA+N-W	2F	E	H	K	HS	HD	L	M
143 T	3 1/2	7/8	4 1/2	4	2 3/4	5/16 - 18	5/8	7	8	28	3/16
145 T	3 1/2	7/8	4 1/2	5	2 3/4	5/16 - 18	5/8	7	8	28	3/16
182 T	4 1/2	1 1/8	5 1/2	4 1/2	3 3/4	3/8 - 16	3/4	8	9	30	1/4
184 T	4 1/2	1 1/8	5 1/2	5 1/2	3 3/4	3/8 - 16	3/4	8	9	30	1/4
213 T	5 1/4	1 3/8	6 7/8	5 1/2	4 1/4	3/8 - 16	7/8	8 3/4	9 3/4	33	5/16
215 T	5 1/4	1 3/8	6 7/8	7	4 1/4	3/8 - 16	7/8	8 3/4	9 3/4	33	5/16

NOTES
All dimensions in inches. May vary ± ¼ inches.
Not for construction purposes unless certified.
*See motor dimensions for "C-AH" dimension (Varies depending on motor enclosure).

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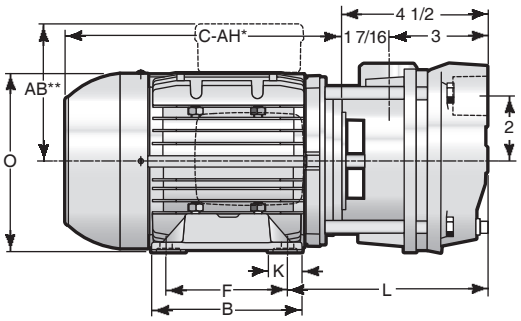
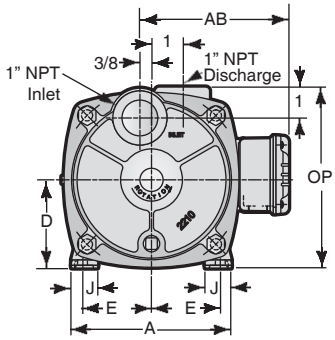
Dated **January 2008**

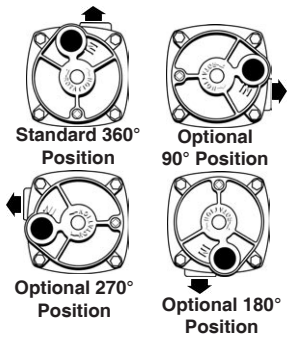
E41 • T41 SERIES

Dimensions

E41 Horizontal Close Coupled





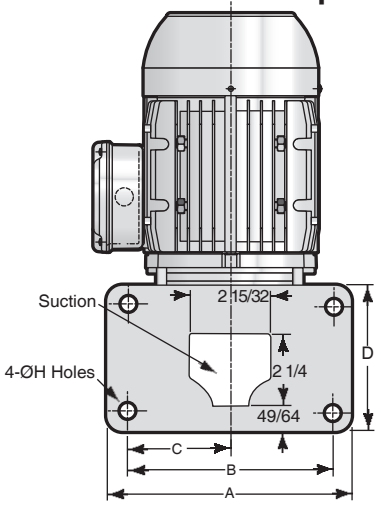


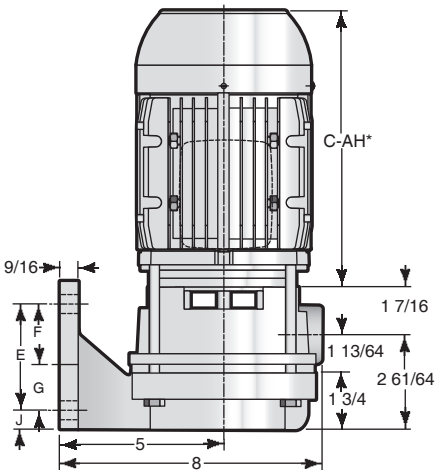
48 Thru 90 Motor Frames

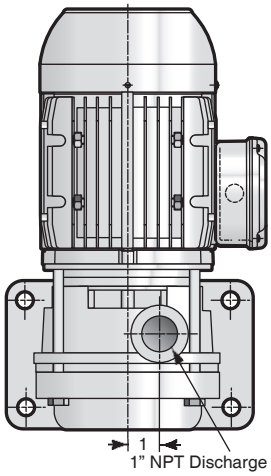
FRAME	Phase	A	AB	B	D	E	F	J	K	L	O	OP
48	1	6.14	---	3.54	3.00	2.12	2.72	---	---	7.08	5.64	6.00
56	1	6.53	---	6.50	3.50	2.44	3.00	---	---	7.73	6.54	6.50
71	3	5.28	5.00	4.25	2.80	2.20	3.54	1.10	1.19	6.53	5.47	5.80
80	3	6.10	5.12	4.88	3.15	2.46	3.94	1.26	1.10	6.7	6.18	6.15
90	3	6.69	5.91**	5.75	3.54	2.76	4.92	1.38	---	7.0	6.97	6.54

**Denotes conduit box mounted on top(90 frame only)

E41 Vertical Close Coupled







48 Thru 90 Motor Frames

FLANGE STYLE	A	B	C	D	E	F	G	H	J
AU (7 1/2 x 4 1/2)	7 1/2	6 1/4	3 1/8	4 1/2	3 1/4	2 1/8	1 1/8	9/16	5/8
DB (4 1/2 x 4 1/2)	4 1/2	3.270	1.635	4 1/2	3.270	2.135	1.135	1/2	.615
FE (7 3/4 x 4 3/4)	7 1/2	6 1/4	3 1/8	4 1/2	3 1/2	2 1/4	1 1/4	9/16	1/2
PA (6 1/2 x 3 3/4)	6 1/2	5 1/2	2 3/4	3 3/4	2 5/8	1 1/2	1 1/8	9/16	5/8
SH & BU (6 1/4 x 4)	6 1/4	5	2 1/2	4	2 3/4	1 5/8	1 1/8	9/16	5/8
SK (6 1/8 x 4 1/8)	6.13	4.94	2.47	4.13	2.69	1.66	1.03	9/16	.72
ST (5 x 5)	5	3 3/4	1 7/8	5	3 3/4	2 5/8	1 1/8	1/2	5/8
WI (5 x 5)	5	4 1/8	2 1/16	5	4 1/8	2 13/16	1 5/16	7/16	7/16

NOTES
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Not for construction purposes unless certified.
*See motor dimensions for "C-AH" dimension
(Varies depending on motor enclosure).

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NEEDLE FLOW METERING VALVES

Metering Valves

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1300 Series	2
1600 Series	5
2300 Series	8







metering valves

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2300 Series

Bar Stock Metering Valves





Typical Applications

- Metering liquids and gases on analytical equipment
- Laboratory sampling
- Gas chromatography, analyzers
- Flow meters and gauges

Technical Data

BODY*	316 stainless steel, brass
MAXIMUM OPERATING PRESSURE	*Brass* • 3000 psig up to 200° F (207 bar @ 93° C) *316 stainless steel* • 3000 psig 100° F (207 bar @ 38° C) • 1000 psig 250° F (68.9 bar @ 121° C)
OPERATING TEMPERATURE RANGE	*Buna N O-ring Packing* • -40° to 200° F (-40° to 93° C) *Teflon® Packing* • -60° to 250° F (-51° to 121° C)
ORIFICE	.062", .125" (1.59 mm, 3.17 mm)
CV FACTOR**	1° stem, 0.062" orifice: 0.012 8° stem, 0.062" orifice: 0.086 8° stem, 0.125" orifice: 0.30

** Consult factory for other materials*

*** Cv factors shown are based on flow through entire metering range, approximately 20 handle turns*

Features & Benefits

- Micrometer vernier handle provides visual control and precise establishment of flow settings. To order, specify 2300K1 following the valve number.
- 20 turn stem displacement for fine metering
- 2 orifice sizes 0.062" (1.59mm) and 0.125" (3.17mm) are available with standard 8° stem
- Spring loaded stem in all 316 stainless steel valves prevents galling and enlargement of the orifice.
- For ultra fine metering, a 1° spring loaded stem design is available for all valves with 0.062" (1.59mm) orifice. See flow curves for details.
- Panel mounting is standard on all valves
- Bonnet lock prevents accidental disengagement of bonnet.
- Special High Tolerance NPT Thread

metering valves

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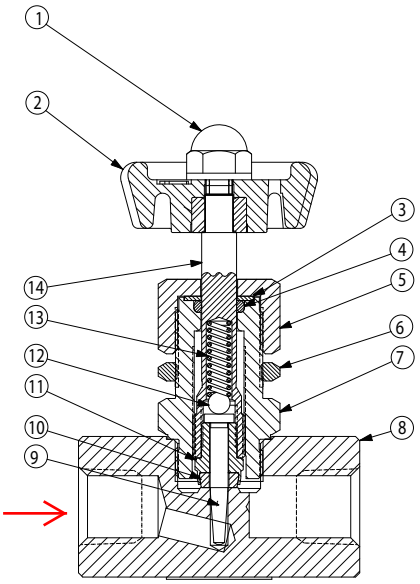
2300 Series

Materials of Construction

316 Stainless Steel Valves (Teflon® Packing)

	DESCRIPTION	MATERIAL
1	CAP NUT (10-24)	Zinc Alloy
2	HAND WHEEL*	Nylon
3	WASHER	Teflon®
4	PACKING	Teflon®
5	PACKING NUT	316 stainless
6	MOUNTING NUT	316 stainless
7	HOUSING	316 stainless
8	BODY	316 stainless
9	SPINDLE POINT	316 stainless
10	SEAT	PCTFE
11	SEAT HOLDER	316 stainless
12	BALL	316 stainless
13	COMPRESSION SPRING	316 stainless
14	STEM	316 stainless

* Optional micrometer handle - Aluminum

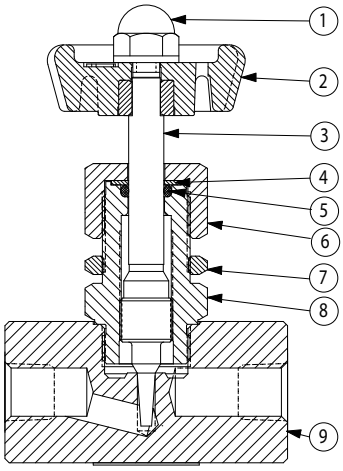


2335F[ ]Y / 2315F[ ]Y
stainless steel

Brass Valves (Buna-N Packing)

	DESCRIPTION	MATERIAL
1	CAP NUT (10-24)	Zinc Alloy
2	HAND WHEEL*	Nylon
3	STEM	316 stainless
4	WASHER	Nylon
5	O-RING	Nylon
6	PACKING NUT	Brass
7	MOUNTING NUT	FCB
8	HOUSING	Brass
9	BODY	Brass

* Optional micrometer handle - Aluminum

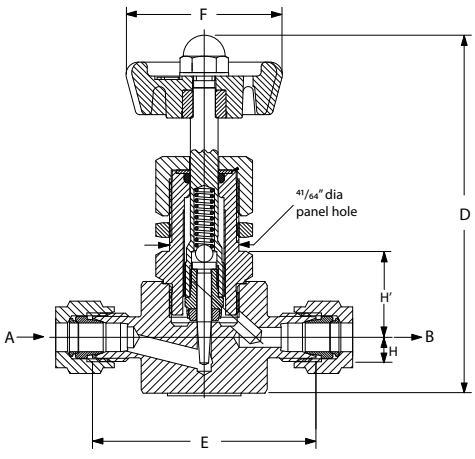


2331F[ ]B
Brass

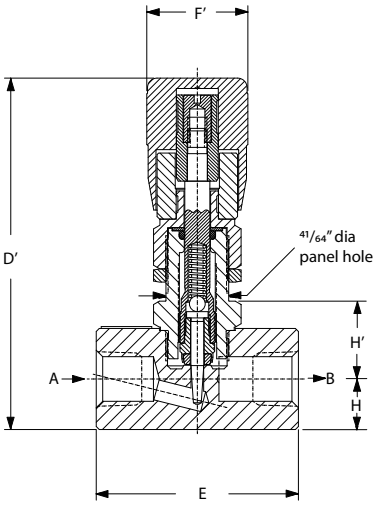
Dimensions

FLOW PATTERN	A & B CONNECTIONS		D	D′	E	F	F′	H	PANEL MOUNTING DIMENSIONS H′	PANEL THICKNESS	HOLE SIZE
GLOBE	¼″ NPT FEMALE	inch	3.59	3.88	2	1.41	1	0.5	0.75	0.13	0.64
		mm	91	98	51	36	25	12.7	19	3	16
	⅛″ NPT FEMALE	inch	3.59	3.88	2	1.41	1	0.5	0.75	0.13	0.64
		mm	91	98	51	36	25	12.7	19	3	16
	¼″ GYROLOK®	inch	3.59	3.88	2.63	1.41	1	0.5	0.75	0.13	0.64
		mm	91	98	67	36	25	12.7	19	3	16
ANGLE	¼″ NPT FEMALE	inch	3.75	4.06	1.44	1.41	1	0.56	0.81	0.13	0.64
		mm	95	103	37	36	25	14	21	3	16
	⅛″ NPT FEMALE	inch	3.75	4.06	1.44	1.41	1	0.56	0.81	0.13	0.64
		mm	95	103	37	36	25	14	21	3	16

Dimensions for reference only, subject to change.



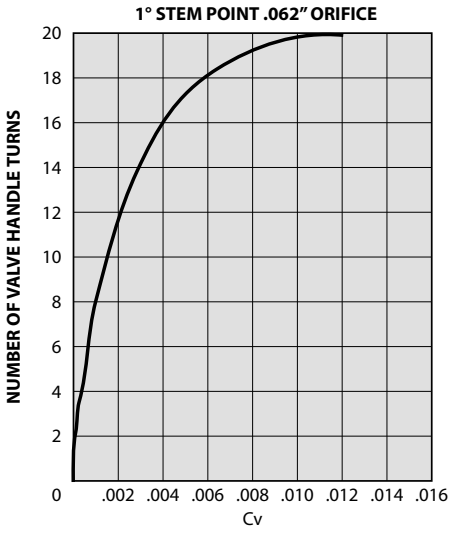
2335G[ ]Y / 2315G[ ]Y
316 stainless steel

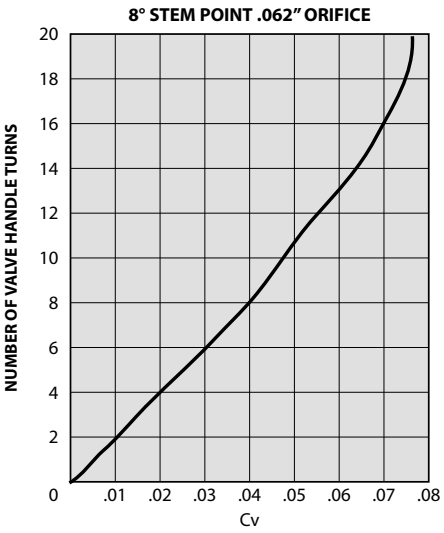


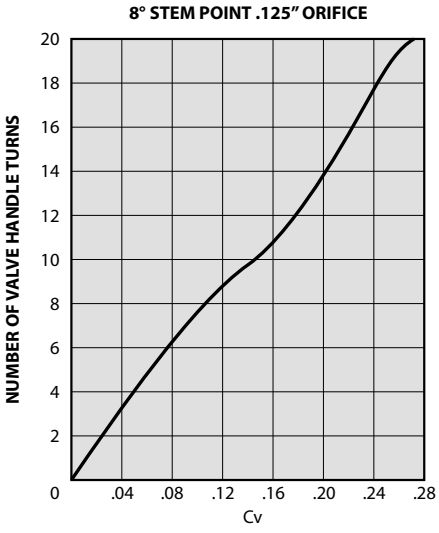
2335F4Y / 2315F4Y
316 stainless steel
(with optional micrometer handle)

2300 Series

Curves







How to Order

FLOW PATTERN	CONNECTIONS	316 STAINLESS STEEL VALVES			BRASS VALVES	
		TEFLON® PACKING			BUNA-N O-RING PACKING	
		1° STEM SPRING LOADED	8° STEM SPRING LOADED	8° STEM SPRING LOADED	SOLID 8° STEM	SOLID 8° STEM
		.062 " ORIFICE	.062" ORIFICE	.125" ORIFICE	.062" ORIFICE	.125" ORIFICE
GLOBE	⅛" NPT FEMALE	2355F2Y	2315F2Y	2335F2Y	2311F2B	2331F2B
	¼" NPT FEMALE	2355F4Y	2315F4Y	2335F4Y	2311F4B	2331F4B
	¼" GYROLOK®	2355G4Y	2315G4Y	2335G4Y	—	2331G4B
ANGLE	⅛" NPT FEMALE	—	—	—	2321F2B	2341F2B
	¼" NPT FEMALE	—	—	—	2321F4B	2341F4B

FOR YOUR SAFETY

IT IS SOLELY THE RESPONSIBILITY OF THE SYSTEM DESIGNER AND USER TO SELECT PRODUCTS SUITABLE FOR THEIR SPECIFIC APPLICATION REQUIREMENTS AND TO ENSURE PROPER INSTALLATION, OPERATION AND MAINTENANCE OF THESE PRODUCTS. MATERIAL COMPATIBILITY, PRODUCT RATINGS AND APPLICATION DETAILS SHOULD BE CONSIDERED IN THE SELECTION. IMPROPER SELECTION OR USE OF PRODUCTS DESCRIBED HEREIN CAN CAUSE PERSONAL INJURY OR PROPERTY DAMAGE.

Ordering Options

Spare Parts

Spare parts and repair kits are available for all needle valves. Please contact your distributor for specific information.

Cleaning and Testing

When ordering, please specify if oxygen cleaning or helium leak testing is required.

Additional Sizes

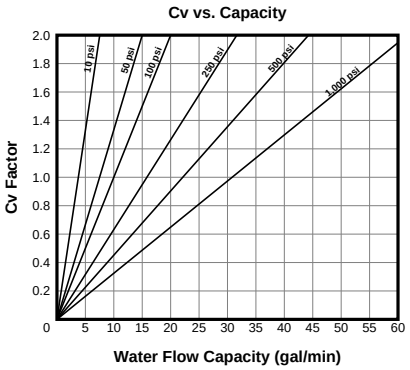
Additional sizes and options are available on special request. Please consult your local HOKE distributor.

Liquid Flow capacity of Hoke Metering Valves

To determine the Cv or flow of a **liquid** @ 60° F (16° C):

$$\mathbf{Cv} = \frac{GPM}{\sqrt{\frac{\Delta p}{S.G.}}} \quad \text{or} \quad \mathbf{GPM} = Cv\sqrt{\frac{\Delta p}{S.G.}}$$

where: $\Delta p = p_1 - p_2$
p_1 = inlet pressure in psia
p_2 = outlet pressure in psia
GPM = flow in gallons per minute
S.G. = specific gravity of liquid where water = 1.0 @ 60° F (16° C)

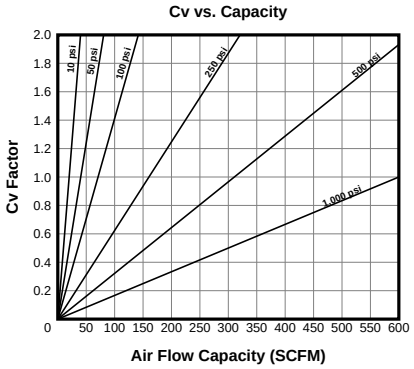


Gas Flow capacity of Hoke Metering Valves

To determine the Cv or flow of a **gas** @ 70° F (21° C):

$$\mathbf{Cv} = \frac{SCFH}{1360\sqrt{\frac{(\Delta p)(p_1)}{(460+T)(S.G.)}}} \quad \text{or} \quad \mathbf{SCFH} = 1360\,Cv\sqrt{\frac{(\Delta p)(p_1)}{(460+T)(S.G.)}}$$

where: $\Delta p = p_1 - p_2$
p_1 = inlet pressure in psia
p_2 = outlet pressure in psia
SCFH = flow in standard cubic feet per hour
S.G. = specific gravity of gas where air = 1.0 @ 70° F (21° C) and 14.7 psia
T = temperature in ° F



Specifying metering valves for critical analytical instrumentation and applications which demand precise stem positioning requires a complete knowledge of your process conditions.

Before you start, it is important that your flow requirements be defined in terms of Cv or flow coefficient.

Cv is the valve flow coefficient expressing the rate of flow in gallons per minute of 60° F water with a pressure drop of 1 PSI across the valve. By correctly using the formula for liquids or gases, you will obtain an accurate Cv, necessary for your valve selection.

Cv should be calculated for expected variations in pressure and required flow range. The Cv range for Hoke metering valves is approximately 10 to 1. This is illustrated in the Cv vs handle turns flow curves shown with each valve series. Note that the more handle turns required to achieve a specified change in flow, the greater the valve's accuracy.

The Cv range providing best control should fall within the straight portion of the curve with the nominal value centered. Using the straight portion of the curve gives approximately the same incremental flow for each turn of the valve handle.

Once Cv requirements are determined, the following steps must be evaluated before making your final valve selection.

1. Define Pressure/Temperature Requirements

Hoke metering valves are available from moderate vacuum to 5000 psig. Operating temperatures range from -65° to 450° F. There are no restrictions on pressure drop or downstream pressure for Hoke valves.

2. Know Your Material Requirements

Corrosion resistance should be your prime consideration when selecting materials, particularly the wetted or pressure boundary parts. There are times when the environment must also be considered in addition to the fluid media.

The pressure/temperature demands of materials are normally covered by the material manufacturer's product specifications.

Hoke products are designed using materials of similar corrosion properties whenever possible. If material selection is critical, please contact your nearby Hoke distributor. He can recommend options to help solve your problem.

3. Options

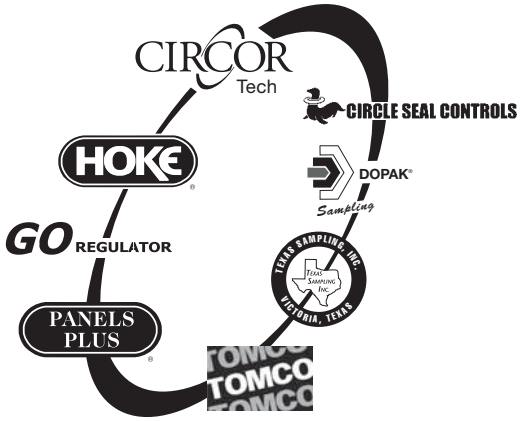
Dial Indicator and micrometer handles are available for reproducing stem positioning. The Hoke Milli-Mite 1300 series is provided with a micrometer handle as standard equipment. Other handle options are available or can be made to order.

4. Final Performance

Engineering design and manufacturing standards are critical elements of the metering valve you select and will affect its actual performance.

Total control of these quality elements at Hoke assures you of valves with excellent stem positioning repeatability, low hysteresis, and extended metering range.

CIRCOR
Instrumentation Technologies



Hoke • GO Regulator • Tomco • CIRCOR Tech

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CIRCOR Instrumentation Technologies

CIRCOR Instrumentation Technologies (CIT) is a product group of CIRCOR International (NYSE: CIR), specializing in fluid process control solutions with orifice sizes typically up to 1″. Our main product lines include ball, needle, packless, diaphragm, solenoid, and metering valves, pressure regulators, quick couplers, Gyrolok® compression tube fittings, and fully integrated sampling systems.

CIT markets primarily to the petrochemical, refining, power generation, food and beverage, semiconductor, and pharmaceutical industries, and to OEM's. CIT separates itself from the competition by offering highly engineered components manufactured to exacting standards and a variety of custom options.

79013 • 12/09 • APS2007

FLOW REGULATING VALVES

NEW

Flo-Miser

The Economical Flow Regulator...
Something Simple from the Experts in Flow Control



W. A. Kates® company

Just Set it and Forget it!



Flo-Miser

Specifications

Materials of Construction:	316 Stainless Steel
Body Seals:	Teflon®
Maximum Working Pressure:	1440 psi
Maximum Working Temperature:	400 F
Process Connections:	FNPT
Accuracy:	± 5%
Repeatability:	±1%
Rangeability:	10:1 turndown
Response Time:	1-2 seconds

Teflon® is a registered trademark of DuPont Corporation

Line Size	Part #	Flow Range
3/8"	FM38	0.3 to 3 gpm (11 lpm)
1/2"	FM50	1 to 10 gpm (38 lpm)
3/4"	FM75	3 to 20 gpm (75 lpm)

W.A. Kates Company Limited Product Warranty

The W.A. KATES COMPANY guarantees every piece of equipment manufactured by it to be inspected and tested, and free from defects in workmanship or material when shipped from its factory. No warranty of corrosion resistance of any parts or assembly is expressed or implied.

This guarantee is valid for one year from date of shipment from its plant. Within that time the W.A. KATES COMPANY will replace, free of charge, any equipment returned, with shipping charges prepaid, found to have been defective at time of shipment.

This warranty does not apply to: (a) damage resulting from misuse or inadequate handling; (b) damage resulting from continued use after defect is apparent; (c) any other damage, loss or liability; or (d) any piece of equipment that is changed modified or altered in any way after it leaves the factory.

The liability of the W.A. KATES COMPANY shall be limited to the replacement, f.o.b. our factory, of any equipment found to have been defective at time of shipment, with duplicate or similar equipment of equal performance rating, but such liability shall in no event exceed the contract price for said equipment.

w.a. kates® company

W.A. Kates Company · 1363 Anderson · Clawson, MI 48017
Phone (248) 435-8225 · Fax (248) 435-8255
E-mail: info@wakates.com
Internet: www.wakates.com

Recommended Protection for Kates Flow Controllers

For long lasting maintenance free operation, we recommend that a strainer or filter be installed immediately upstream of the Kates Flow Rate Controller.

Strainer/ Controller Size	Filter/ Mesh	Micron
3/8"	10 Micron Sintered	10
1/2"	10 Micron Sintered	10
3/4"	200	75

The recommendation of screen size is a matter of judgement comprised of:

a. Operability. Removal of all particles will insure continuous operation at all times.

b. The tolerable interval between cleaning. Removal of all particles may require a screen so fine that required cleaning may be too costly.

c. Allowable pressure drop.

The screen sizes listed are recommendations resulting from service experience. We cannot make operating guarantees because of the variety of fluid characteristics and the infinite number of combinations of particle size and nature encountered in practice. To obtain satisfactory results with a Kates Flow Rate Controller, the particles must be nonabrasive, non-fibrous, and must not adhere or coat on the controller internal parts, nor have a tendency to settle out of solution.

Check out our Web Site Today at:

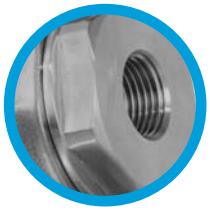
www.wakates.com

Distributed by:

Flo-Miser



Economical
Flow Regulator


Inline
Connections


Simple
Adjustment


3/8", 1/2", 3/4"
Line Sizes


Accurate Flow
Rate Controller



w. a. Kates company

For more than 50 years, the W.A. Kates Company has been producing high quality, low maintenance, purely mechanical flow rate controllers. These products have been applied successfully throughout industry for a wide variety of liquid and gas applications. Our motto is **"To serve our customers as we desire our suppliers to serve us"**. This motto exemplifies our commitment to quality and service.

The New **Flo-Miser** is an economical, lighter duty version of our standard flow rate controllers. It offers many of the same flow characteristics of our high performance Kates Flow Rate Controllers at a substantially lower cost.

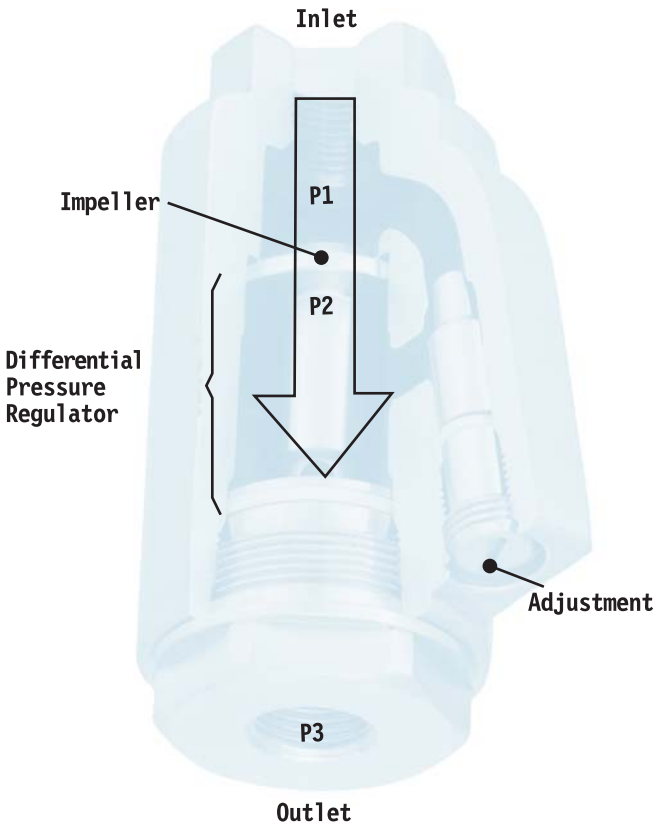
Easily adjust your flow set point by turning the micrometer-like needle valve adjustment. Once set, the **Flo-Miser** will control your flow accurately, regardless of changes in your process.

The **Flo-Miser** combines a characteristic needle valve with an internal differential pressure regulating valve. By controlling the pressure drop across the adjustable orifice, flow rate will always remain constant. Since the control portion is immersed in fluid, response time due to pressure variations is immediate. Hunting and oscillation is eliminated.

The Kates **Flo-Miser**...for high quality, low cost flow rate control...

"Just set it and forget it"!

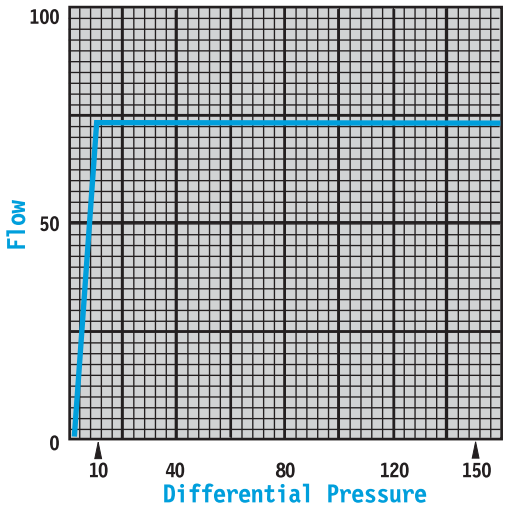
How the Flo-Miser Works

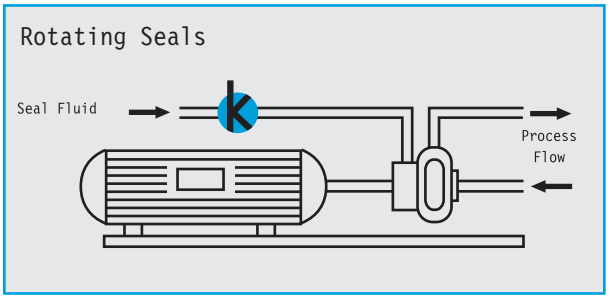


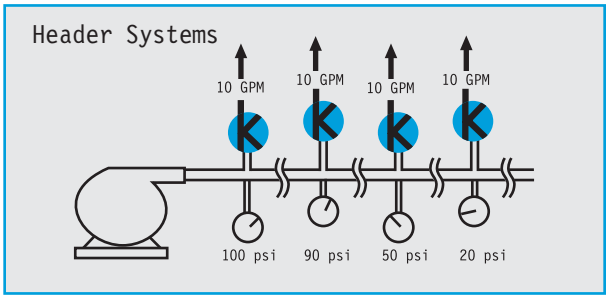
P1 = P2 + Spring Force

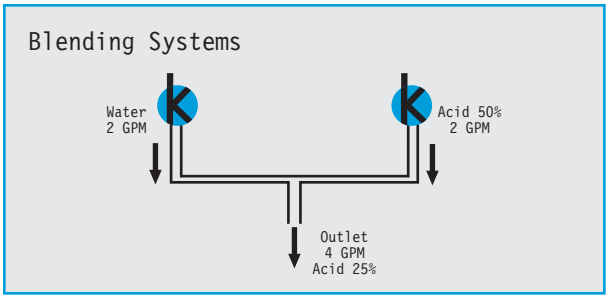
If supply pressure (P1) increases, the resulting momentary pressure imbalance immediately moves the impeller downward. This action restricts the valve ports thus increasing orifice backpressure (P2), restoring differential pressure and the flow rate to the original setting. The Flo-Miser will respond equally well to an upset in outlet pressure (P3).

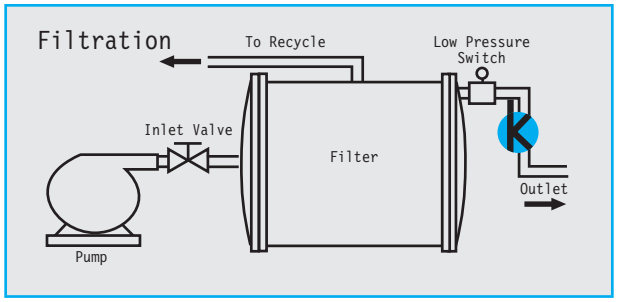
Flow Characteristics











Typical Applications

Deionized Water • Rotating Seals • Additives/Blending • Nitrogen Blanketing • Liquid Ring Vacuum Pumps • Oil Well Water Flooding • Natural Gas • Bleaching Systems • Reverse Osmosis Dynamometers • Ratio Blending • Humidity Control • Heat Exchangers • Cooling Water • Dust Suppression Aircraft Deicing • Test Cells • Caustics • Acids • Analytical Fast Loops...and hundreds more!

METERING PUMPS

Data Sheet

Series C
Electronic Metering Pumps

Configuration Data

Model C92 1 - 363SI

Control & Output Code

Manual Control

Speed (stroking frequency) and stroke length manually adjustable.

C10 --- 1.3 GPH (4.9 l/h) ... 300 psi (20.7 Bar)
C11 --- 2.5 GPH (9.5 l/h) ... 150 psi (10.3 Bar)
C12 --- 4.0 GPH (15.1 l/h) ... 100 psi (6.9 Bar)
C13 --- 8.0 GPH (30 l/h) ..... 60 psi (4.1 Bar)
C14 ---- 20 GPH (76 l/h) ..... 25 psi (1.7 Bar)

Instrument Responsive/Manual Control

Manual adjustment features of C1 Series plus switch conversion to external control for automatic systems.

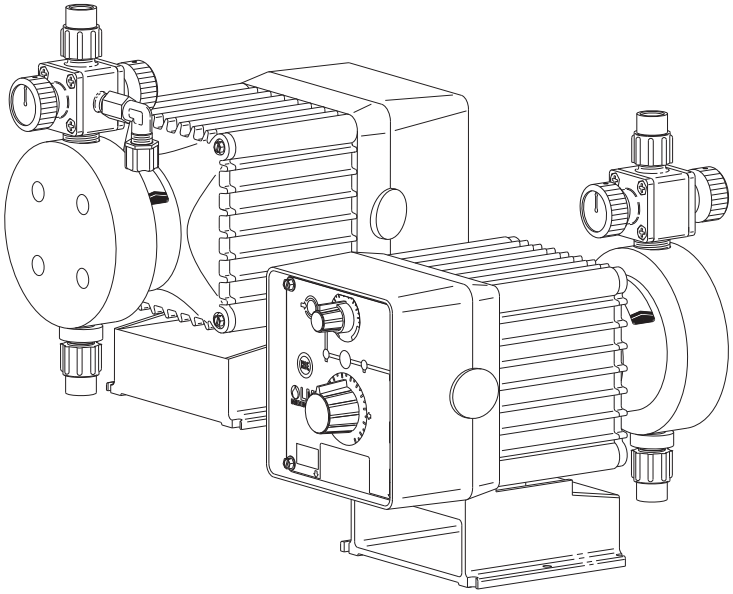
C70 --- 1.3 GPH (4.9 l/h) ... 300 psi (20.7 Bar)
C71 --- 2.5 GPH (9.5 l/h) ... 150 psi (10.3 Bar)
C72 --- 4.0 GPH (15.1 l/h) ... 100 psi (6.9 Bar)
C73 --- 8.0 GPH (30 l/h) ..... 60 psi (4.1 Bar)
C74 ---- 20 GPH (76 l/h) ..... 25 psi (1.7 Bar)
C76* -- 4.0 GPH (15.1 l/h) ... 175 psi (12.1 Bar)
C77* --- 10 GPH (38 l/h) ..... 80 psi (5.5 Bar)
C78* --- 25 GPH (95 l/h) ..... 30 psi (2.07 Bar)
C90 --- 1.3 GPH (4.9 l/h) ... 300 psi (20.7 Bar)
C91 --- 2.5 GPH (9.5 l/h) ... 150 psi (10.3 Bar)
C92 --- 4.0 GPH (15.1 l/h) ... 100 psi (6.9 Bar)
C93 --- 8.0 GPH (30 l/h) ..... 60 psi (4.1 Bar)
C94 ---- 20 GPH (76 l/h) ..... 25 psi (1.7 Bar)

Voltage Code

1 -------- 120 VAC US Plug
2 -------- 240 VAC US Plug
3 -------- 220-240 VAC DIN Plug
5 -------- 240-250 VAC, UK Plug
6 -------- 240-250 VAC, AUST/NZ Plug
7 -------- 220-240 VAC, SWISS Plug

Liquid End

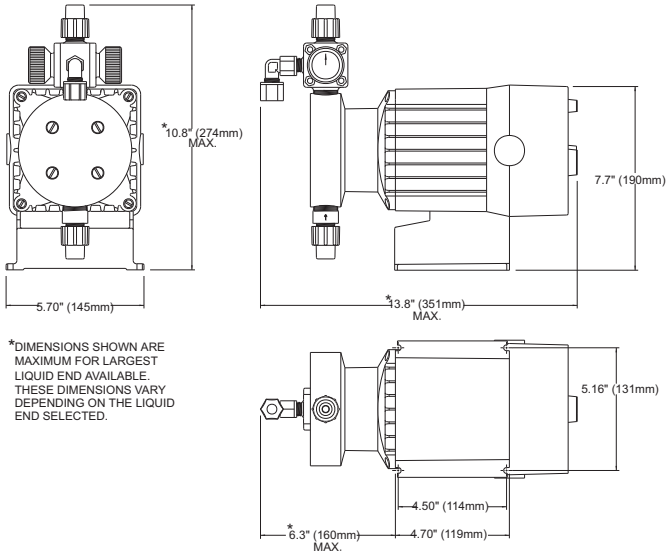
See next page for complete liquid end specifications and selection.



Specifications

Series	Strokes Per Minute (Adjustable) Min	Max	Stroke Length (Adjustable) Recommended Minimum	Average Input Power @Max Speed	Shipping Weight
C10, C70, C90 C11, C71, C91 C12, C72, C92 C13, C73, C93 C14, C74, C94	1	100	10%	44 watts	20 lbs (9.1 kg)
C76 C77 C78	1	100	10%	87 watts	28 lbs (12.7 kg)

Dimensions



*DIMENSIONS SHOWN ARE MAXIMUM FOR LARGEST LIQUID END AVAILABLE. THESE DIMENSIONS VARY DEPENDING ON THE LIQUID END SELECTED.

LMI MILTON ROY

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Ivyland, PA 18974 USA
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TEL: (215) 293-0401
FAX: (215) 293-0445
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Replaces same of Rev.H 09/07
1712.I 06/09

Standard Liquid End Configuration Data & Materials of Construction

Drive Assembly	Liquid End No.	Size Code	Materials of Construction				Accessory	Tubing & Connections	
			Head & Fittings	Balls	Liquifram™	Check Valve		Discharge	Suction
C90, C70 ■ -	498SP	0.9	PVC	Ceramic	Fluorofilm™	PVDF / PTFE	4FV	Pipe 1/2" NPT M	
C10 ■ -	297	0.9	316 S.S.	316 S.S.	Fluorofilm™	316 S.S.		Pipe 1/4" NPT M	
	468SI	1.8	PVC / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .375" O.D.	
	460SI	1.8	Acrylic / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .375" O.D.	
C92 ■ -	469SI	1.8	Acrylic / PVDF	PTFE	Fluorofilm™	PVDF / Polyprel®	4FV	PE .375" O.D.	
C91 ■ -	368SI†	1.8	PVC / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .375" O.D.	
C72 ■ -	362SI†	1.8	PVDF / PVDF	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .375" O.D.	
C71 ■ -	363SI†	1.8	PVDF / PVDF	Ceramic	Fluorofilm™	PVDF / PTFE	4FV	PE .375" O.D.	
C12 ■ -	465SI	1.8	Polypropylene	Ceramic	Fluorofilm™	PVDF / PTFE	4FV	PE .375" O.D.	
C11 ■ -	75HV	1.8	Polypropylene	316 S.S.	Fluorofilm™	PTFE		PE .5" O.D.	Vinyl .938" O.D.
	76HV	1.8	Acrylic/PP	316 S.S.	Fluorofilm™	Hypalon®		PE .5" O.D.	Vinyl .938" O.D.
	277	1.8	316 S.S.	316 S.S.	Fluorofilm™	316 S.S.		Pipe 1/4" NPT M	
	312SI#	3.0	PVDF / PVDF	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .5" O.D.	
	313SI#	3.0	PVDF / PVDF	Ceramic	Fluorofilm™	PVDF / PTFE	4FV	PE .5" O.D.	
	318SI#	3.0	PVC / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .5" O.D.	
	410SI#	3.0	Acrylic / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .5" O.D.	
	415SI#	3.0	Polypropylene	Ceramic	Fluorofilm™	PVDF / PTFE	4FV	PE .5" O.D.	
C93 ■ -	418SI#	3.0	PVC / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .5" O.D.	
C73 ■ -	419SI#	3.0	Acrylic / PVDF	PTFE	Fluorofilm™	PVDF / Polyprel®	4FV	PE .5" O.D.	
C13 ■ -	20	3.0	Acrylic / PVC	Ceramic	Fluorofilm™	Hypalon®		PE .5" O.D.	
	20HV	3.0	Acrylic/PP	316 S.S.	Fluorofilm™	Hypalon®		PE .5" O.D.	Vinyl .938" O.D.
	20S	3.0	Acrylic/PVC	Ceramic	Fluorofilm™	Hypalon®	4FV	PE .5" O.D.	Vinyl .5" O.D.
	24	3.0	PVC	Ceramic	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
	25HV	3.0	Polypropylene	316 S.S.	Fluorofilm™	PTFE		PE .5" O.D.	Vinyl .938" O.D.
	26	3.0	PVC	Ceramic	Fluorofilm™	Viton®		PE .5" O.D.	
	26S	3.0	PVC	Ceramic	Fluorofilm™	Viton®	4FV	PE .5" O.D.	
	27	3.0	316 S.S.	316 S.S.	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
	29	3.0	UHMW PE	Ceramic	Fluorofilm™	Hypalon®		PE .5" O.D.	
	30	6.0	Acrylic/PVC	Ceramic	Fluorofilm™	PTFE		PE .5" O.D	Vinyl .5" O.D.
C94 ■ -	34	6.0	PVC	Ceramic	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
C78 ■ -	35P	6.0	Polypropylene	Ceramic	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
C74 ■ -	35T	6.0	Polypropylene	Ceramic	Fluorofilm™	PTFE		PE .5" O.D.	
C14 ■ -	36	6.0	PVC	Ceramic	Fluorofilm™	PTFE		PE .5" O.D.	
	37	6.0	316 S.S.	316 S.S.	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
	468SP	1.8	PVC/PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	Pipe 1/2" NPT M	
C76 ■ -	74S	1.8	PVC	Ceramic	Fluorofilm™	PTFE	4FV	Pipe 1/4" NPT M	
	277	1.8	316 S.S.	316 S.S.	Fluorofilm™	316 S.S.		Pipe 1/4" NPT M	
	20HV	3.0	Acrylic/PP	316 S.S.	Fluorofilm™	Hypalon®		PE .5" O.D.	Vinyl .938" O.D.
	20S**	3.0	Acrylic/PVC	Ceramic	Fluorofilm™	Hypalon®	4FV	PE .5" O.D.	Vinyl .5" O.D.
C77 ■ -	24	3.0	PVC	Ceramic	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
	25HV	3.0	Polypropylene	316 S.S.	Fluorofilm™	PTFE		PE .5" O.D.	Vinyl .938" O.D.
	25P	3.0	Polypropylene	Ceramic	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
	25T	3.0	Polypropylene	Ceramic	Fluorofilm™	PTFE		PE .5" O.D.	
	26S**	3.0	PVC	Ceramic	Fluorofilm™	Viton®	4FV	PE .5" O.D.	
	27	3.0	316 S.S.	316 S.S.	Fluorofilm™	PTFE		Pipe 1/2" NPT M	
	29	3.0	UHMW PE	Ceramic	Fluorofilm™	Hypalon®		PE .5" O.D.	

Output Information

Series	Gallons per Hour Min	Gallons per Hour Max	Liters per Hour Min	Liters per Hour Max	mL/cc per Minute Min	mL/cc per Minute Max	mL/cc per Stroke Min	mL/cc per Stroke Max	Maximum Injection Pressure
C10, C70*, C90*	0.001	1.3	0.005	4.9	0.08	82	0.08	0.82	300 psi (20.7 Bar)
C11, C71*, C91*	0.003	2.5	0.010	9.5	0.16	158	0.16	1.58	150 psi (10.3 Bar)
C12, C72*, C92*	0.004	4.0	0.015	15.1	0.25	252	0.25	2.52	100 psi (6.9 Bar)
C13, C73*, C93*	0.008	8.0	0.030	30.0	0.51	505	0.51	5.05	60 psi (4.1 Bar)
C14, C74*, C94*	0.020	20.0	0.076	76.0	1.26	1262	1.26	12.62	25 psi (1.7 Bar)
C76*	0.004	4.0	0.015	15.1	0.25	252	0.25	2.52	175 psi (12.1 Bar)
C77*	0.010	10.0	0.038	38.0	0.63	631	0.63	6.31	80 psi (5.5 Bar)
C78*	0.025	25.0	0.095	95.0	1.58	1577	1.58	15.77	30 psi (2.07 Bar)

* Minimum output is based on 1 stroke per minute and 10% stroke setting, minimum output can be reduced further in external mode. Series C9 pumps may be programmed for strokes per hour for lower outputs.

AutoPrime Liquid End Configuration Data & Materials of Construction

Drive Assembly	Liquid End No.	Size Code	Head & Fittings	Balls	Liquifram™	Check Valve	Accessory	Tubing & Connections
C11 C71 C91	D60HI	1.8	Acrylic / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .375" O.D.
C12 C72 C92	D68HI	1.8	PVC / PVC	Ceramic	Fluorofilm™	PVDF / Polyprel®	4FV	PE .375" O.D.

Output Information - Autoprime Liquid Ends (Liquid end models beginning with "D")

Series	Maximum Output GPH	Maximum Output Liters/hr	Maximum Output mL/cc per minute	Maximum Output mL/cc per stroke	Maximum Pressure PSI	Maximum Pressure Bar
C11, C71, C91	2	7.5	125.0	1.25	150 psi	10.3
C12, C72, C92	2.5	9.5	158.3	1.58	100 psi	6.9

Auto prime liquid ends have 3 check valves: Suction on the bottom; Discharge on the front; Autoprime bleed on the top. By design, a repeatable portion of the process fluid continuously bleeds through the top check valve to be returned to the chemical supply. The result is the assurance that any gas in the head is automatically relieved thus eliminating air-binding. The maximum output per the tables above is reduced to account for the continuous bleed.

■ See front page for voltage code specifications.
Plastic heads with tubing connection include 1/2" NPT and 1/2" BSP.
**These Liquid Ends are available without a 4FV, simply drop the 'S' at the end of the Liquid End number to order the model without a 4FV.
#These liquid ends use 3/8" diameter balls. Pump output may be reduced in some applications.
†To specify ¼" NPT male, change 'I' to 'P'.
To specify black, UV resistant tubing, change "I"to "U".
To specify 3FV, change "S" to "T".
3FV indicates that the pump is equipped with an LMI Three Function Valve (pressure relief, priming aid, line drain).
4FV indicates that the pump is equipped with an LMI Four Function Valve. This diaphragm type, anti-syphon/pressure relief valve is installed on the pump head. It provides anti-syphon protection and aids priming, even under pressure.

Fluorofilm™ is a copolymer of PTFE and PFA. Polyprel® is an elastomeric PTFE copolymer.
Polyprel is a registered trademark of the Milton Roy Company.
Fluorofilm and Liquifram are trademarks of the Milton Roy Company.
Hypalon is a registered trademark of E. I. du Pont de Nemours & Co., Inc.

DIGITAL FLOMETER-TOTALIZER

BRASS – SPECIFICATIONS

Fitting Type:		NPT or ISO (Female)	
Housing Material:		Brass	
Meter Sizes Available:		1/2" 3/4" 1" 1-1/2" 2"	
Flow Range:	**1/2" (B05)**	1 - 10 GPM	(3.8 - 37.9 LPM)
	3/4" (B07)	2 - 20 GPM	(7.6 - 75.7 LPM)
	1" (B10)	5 - 50 GPM	(18.9 - 190 LPM)
	1-1/2" (B15)	10 - 100 GPM	(38.0 - 380 LPM)
	2" (B20)	20 - 200 GPM	(76 - 760 LPM)
Accuracy (% of Reading):		**Turbine Only**	**Turbine w/Computer**
	1/2" (B05)	± 2.0%	± 1.5%
	3/4" (B07)	± 1.5%	± 1.0%
	1" (B10)	± 1.5%	± 1.0%
	1-1/2" (B15)	± 1.0%	± 0.75%
	2" (B20)	± 1.0%	± 0.75%
Repeatability:		± 0.1%	
Pressure Rating:		300 PSI / 21 BAR	
Operating Temperature Range:		-40° F to +250° F (-40° C to +121° C)	
with Computer:		0° F to +140° F (-18° C to +60° C)	
Typical K-Factor:	**1/2" (B05)**	2,500	
	3/4" (B07)	1,100	
	1" (B10)	565	
	1-1/2" (B15)	215	
	2" (B20)	100	
Wetted Materials:	**Housing:**	Brass	
	Bearings:	Ceramic	
	Shaft:	Tungsten Carbide	
	Rotor:	PVDF	
	Rings:	316 Stainless Steel	
Frequency Range:	**1/2" (B05)**	42 - 420 Hz @ 1 - 10 GPM	
	3/4" (B07)	37 - 370 Hz @ 2 - 20 GPM	
	1" (B10)	47 - 470 Hz @ 5 - 50 GPM	
	1-1/2" (B15)	36 - 360 Hz @ 10 - 100 GPM	
	2" (B20)	33 - 330 Hz @ 20 - 200 GPM	
Recommended Strainer Size:			
	1/2" (B05)	55 mesh	
	3/4" (B07)	55 mesh	
	1" (B10)	55 mesh	
	1-1/2" (B15)	28 mesh	
	2" (B20)	28 mesh	
Maximum Flow:	**1/2" (B05)**	15 GPM (56.8 LPM)	
	3/4" (B07)	30 GPM (113.6 LPM)	
	1" (B10)	75 GPM (284 LPM)	
	1-1/2" (B15)	150 GPM (568 LPM)	
	2" (B20)	300 GPM (1,136 LPM)	
Wrench Flat Size:	**1/2" (B05)**	1-1/16 inch (27 mm)	
	3/4" (B07)	1-5/16 inch (33 mm)	
	1" (B10)	1-5/8 inch (41 mm)	
	1-1/2" (B15)	2-3/8 inch (60 mm)	
	2" (B20)	3 inch (75 mm)	
Shipping Weight:	**1/2" (B05)**	2.4 lbs./1.0 kg - Turbine Only: 2.2 lbs./1.0 kg	
	3/4" (B07)	2.6 lbs./1.1 kg - Turbine Only: 2.4 lbs./1.0 kg	
	1" (B10)	3.1 lbs./1.4 kg - Turbine Only: 2.9 lbs./1.3 kg	
	1-1/2" (B15)	3.1 lbs./1.4 kg - Turbine Only: 2.9 lbs./1.3 kg	
	2" (B20)	10.0 lbs./4.5 kg - Turbine Only: 9.8 lbs./4.4 kg	

ELECTRONIC CHOICES

Local Display, Remote Display & Remote Transmitter Options:	See Electronics Section.

APPROVALS

FM APPROVED · c UL us · CE · Ex · NEMA 4 · ATEX · **IP44**



"Look for the blue label!"

The G2 Industrial Brass Meter allows another choice for fluid compatibility. The GPI Brass Meter works well with most water applications. Use with glucose, lacquer thinners and vegetable juices for example.

For complete part number, see "Number Reference" chart on page 15.

Select Your Meter Size:

1/2 inch 3/4 inch 1 inch 1-1/2 inch 2 inch

Features and Benefits:

- ✓ High pressure and durable turbine flowmeters.
- ✓ Modular design allows for use with Output Modules, Sensors and Remote Transmitters.
- ✓ 2 Totals (Batch = Resettable, Cumulative = Non-Resettable); Rate of Flow. Factory calibrated in gallons and litres. Field calibratable. Allows user calibration. Includes non-volatile totals.
- ✓ Internal parts are simple to replace for easy maintenance.
- ✓ Lithium battery life: 5 years.

APPENDIX P—PERMIT LIST

Pre-Permit Application Meetings

Meeting Name	Regulators Represented	Purpose	Materials Required	Timing of Meeting	Contact
Joint Agency Review Meeting	Baltimore County – Dept. of Environmental Protection and Resource Management Local Critical Area Commission MD Department of Environment MD Department of Natural Resources US Army Corps of Engineers	First look at project by regulatory stakeholders, input from regulatory stakeholders into specific permits required and other pre-application and/or post-application requirements..	Brief writeup/description of intended project accompanied by a map/diagram. Note : this is a fairly preliminary project review meeting, so brief information is requested. Separate agencies will require more detailed information as part of the permit application process.	Held every third Thursday on an as-needed basis. Need to schedule intent for meeting at least 30 days prior to the next potential meeting date.	Tom Vidmar – Baltimore County 410-887-3980 tvidmar@baltimorecountymd.gov

Groundwater Selected Remedy

Applicable Permit	Parameters/Applicability	Permitting Process/Permit Components	Link to Permit Forms	Cost	Approval Time	Permit Duration	Regulator Contact
Federal/State - WATERWAY AND 100-YEAR FLOODPLAIN (NONTIDAL WETLANDS AND WATERWAYS PERMIT) ***Note: Part of "Joint Federal/State Application for the Alteration of any Floodplain, Waterway, Tidal or Nontidal Wetland in Maryland" application.***	Authorization is required for construction or repair of the following projects in a waterway or a 100-year floodplain: • Excavation, filling or construction	1) Complete a "Joint Federal/State Application for the Alteration of any Floodplain, Waterway, Tidal or Nontidal Wetland in Maryland" application. 2) Mail the original plus four copies of the application, plans, vicinity maps and any supporting documentation to: Regulatory Services Coordination (RSC)Office MDE, Water Management Administration 1800 Washington Boulevard, Suite 430 Baltimore, Maryland 21230-1708 3) Upon receipt of the application package, the RSC will determine what type of permit is necessary and will forward the application to the appropriate governmental agencies. The RSC receives applications for the Nontidal Wetlands and Waterways Division, Tidal Wetlands Division, and Dam Safety Division of the Maryland Department of the Environment, as well as the U.S. Army Corps of Engineers. The Department conducts the review in cooperation with local, state, and federal agencies. Although the Department often coordinates with local governments on specific applications, it is the applicant's responsibility to obtain all local approvals for the project. 4) Depending on the nature of the project, it may be advertised for comment and an opportunity for a public informational hearing. The applicant may be required to notify adjacent property owners. 5) The Department may perform a site evaluation. 6) At the conclusion of the review process, the Department will make a decision on the application. Upon receipt of final construction plans, a permit or license is issued by the Department. In some instances, a license may be issued by the Maryland Board of Public Works (BPW) based on a recommendation from the Department.	http://www.mde.state.md.us/assets/document/wetlandswaterways/alter.pdf	No fee	Minor projects - 10 months Major projects - 12 months Minor Projects: Projects that involve: minor repair or maintenance; temporary construction; clearing and grading activities in the 100-year floodplain that involve less than 100 cubic yards of disturbance; or, minor changes or modifications to existing permits. Minor projects are not placed on public notice. Major Projects: Projects that propose permanent impacts to: construct, reconstruct a reservoir, dam or other waterway obstruction; construct a waterway; or, dredge, fill, bulkhead or change the shoreline. **Major projects are placed on public notice**.	Maximum of five years and may be extended for an additional five years. Construction must be initiated within three years.	Amanda Sigillito Nontidal Wetlands and Waterways Division asigillito@mde.state.md.us (410) 537-3766
Federal/State - Tidal Wetland Licenses and Permits – MDE ***Note: Part of "Joint Federal/State Application for the Alteration of any Floodplain, Waterway, Tidal or Nontidal Wetland in Maryland" application.***	The following activities are regulated by the Department: • Filling of open water and vegetated wetlands • Construction of piers, bulkheads, revetments • Dredging • Marsh establishment			A fee of up to $1000 may be assessed by the BPW, depending on the purpose of the project.	Minor projects - 5 months Major projects - 10 months Major projects are those that require public notice or coordination with other State and federal regulatory and environmental review agencies. Minor projects are those authorized by Category I of the Maryland State Programmatic General Permit (MDSPGP).	Maximum of three years	Richard J. Ayella Tidal Wetlands Division rayella@mde.state.md.us (410) 537-3837

Applicable Permit	Parameters/Applicability	Permitting Process/Permit Components	Link to Permit Forms	Cost	Approval Time	Permit Duration	Regulator Contact
Baltimore County – **Erosion/Sediment Control Plan** Approvals	Erosion/Sediment Control Plan approval is required for any construction activity that disturbs 5,000 square feet or more of soil or results in the excavation of 100 cubic yards or more of soil. An Erosion and Sediment Control Plan, along with grading plans, will be submitted to Baltimore County for review by the **Baltimore County Soil Conservation District**. The plan will be prepared in accordance with the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control (MDE, 1994) or revised standards and specifications to be published in early 2010. The Baltimore County will coordinate review of the plans with the Critical Areas Commission.	A combined Grading Plan and Erosion and Sediment Control Plan will be submitted for review and approval by the Baltimore County Soil Conservation District (BC SCD) for the MRC site. The plan will be prepared in accordance with the 1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control and adhere to the Policy and Guidelines for Erosion and Sediment Control, Stormwater management, Sediment Basin, and Small Pond Review published by BC SCD in January 1999. Necessary Erosion and Sediment Control Plan content for the initial review of the plan includes sediment control prints, a completed sediment control information sheet, sediment control drainage area maps, computations (if applicable), and the permit fee.	http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/erosionsedimentcontrol/standards.asp	Flat rate of $0.004 per square foot of disturbed area with a maximum fee of $1,800. There is no charge for the first plan revision unless there is a one acre or more increase in the disturbed area. The fee for all subsequent revisions is one-half of the initial fee, plus the fee for any additional disturbed area.	An estimate of the average review time is approximately 4 weeks	2 years from date of issuance	Jim Tracy Sediment, Stormwater, and Dam Safety Program jtracy@mde.state.md.us (410) 537-3563
Baltimore County - Stormwater Management Plan	The purpose of the Stormwater Management Plan is to maintain after development, as nearly as possible, the predevelopment runoff characteristics of a site, and to reduce stream channel erosion, pollution, siltation and sedimentation, and local flooding by implementing environmental site design to the maximum extent practicable and using appropriate structural Best Management Practices (BMP) only when necessary {COMAR 26.17.02.01}.	A Stormwater Management Plan is required to be submitted to the Baltimore County Department of Environmental Protection and Resources Management (BC DEPRM) for review and approval before a grading permit can be issued and soil response action activities can commence unless an exemption, waiver, or variance has been granted. The Stormwater Management Plan will be designed in accordance with the "2000 Maryland Stormwater Design Manual, Volumes I and II," revised in 2009.	http://www.mde.state.md.us/programs/waterprograms/sedimentandstormwater/stormwater_design/index.asp	flat rate of $50.00 per acre of disturbed area with a minimum fee of $50.00 and a maximum fee of $450	An estimate of the average review time is approximately 2 to 6 weeks.	2 years from date of issuance	Al Wirth Baltimore County Stormwater Management 410-887-3768
Baltimore County Grading Permit (Baltimore County Code 33-4 and 33-5; COMAR 26.17.01 and 26.17.02)	If the proposed grading disturbs over 5,000 square feet of surface area or over 100 cubic yards of fill material is utilized, a permit is required. As a condition of grading permit issuance, a Stormwater Management Plan (see above) will be submitted to Baltimore County for review and approval. The Stormwater Management Plan will be prepared in accordance with the 2000 Maryland Stormwater Design Manual, Volumes I and ," revised in 2009.	To acquire the grading permit for the MRC site, a combined Grading Plan and Erosion and Sediment Control Plan will be submitted for review and approval by the Baltimore County Soil Conservation District (BC SCD). Per BCC 33-5-202(b)(1) and COMAR 26.17.01.05F, the grading permit application must include the approved Grading Plan and the approved Erosion and Sediment Control Plan. Additionally, a grading permit may not be issued for any site unless a performance security has been posted, an environmental agreement has been executed, and a Stormwater Management Plan has either been approved or an exemption, waiver, or variance for the Stormwater Management Plan has been granted (BCC 33-4-108). Necessary grading plan content includes the site plan and vicinity maps, limits of disturbance, existing and proposed contours reflecting changes made to topography and surface finishes, and changes in the site impervious area. Separate proposed contours maps will not be necessary for the MRC site because post-construction site grades will match pre-construction grades and post-construction surface finishes will be the same as pre-construction site finishes.		$0.002 per square foot of land on which grading activities occur. The minimum fee is $40 and the maximum fee is $5,000. In addition, a performance security equal to $0.05 per square foot of land area to be disturbed, not to exceed $30,000, is also required.	An estimate of the average review time is approximately 3-6 months.	Two years from the date of issuance with an option to request an extension of up to one additional year upon written request	Al Wirth Baltimore County Stormwater Management 410-887-3768

Applicable Permit	Parameters/Applicability	Permitting Process/Permit Components	Link to Permit Forms	Cost	Approval Time	Permit Duration	Regulator Contact
MDE - Permit for Stormwater Associated with Construction Activity (COMAR 26.08.04)	Required for all construction activity in Maryland with a planned total disturbance of 1 acre or more. Conditions of the permit include compliance with approved erosion/sediment control and stormwater management plans, compliance with water quality standards and TMDLs, self-monitoring and record keeping.	1) Obtain an application form for an individual permit at the website below or by calling the Department at (410)537-3510. Complete the form and mail with payment to: MDE, Water Management Administration P.O. Box 2057 Baltimore, MD 21203-2057 The individual permit can be submitted any time prior to the start of construction activity, but note that the permit issuance process takes 60 to 90 days, and may take longer in some instances. Applicants are encouraged to submit one permit application regardless of how many stages or phases of construction will occur over time. 2) The Department reviews the application to insure completion. 3) The Department follows the multi-step process of individual permit issuance as required by State regulations. These steps are outlined in the website below. http://www.mde.state.md.us/Permits/WaterManagementPermits/water_applications/gp_construction.asp 4) The Department then sends the applicant a package which includes a letter verifying coverage and issuing the project a unique permit number, a copy of the individual permit, and a receipt card which must be posted at the site. In addition to the general permit for construction activity, you may also need an erosion/sediment control plan approval (3.21).	http://www.mde.state.md.us/Permits/WaterManagementPermits/water_applications/gp_construction.asp	1 to less than 10 acres - $100 10 to less than 15 acres - $500 15 to less than 20 acres - $1,500 20 acres or more - $2,500	At least 60 to 90 days.	Expires five years from the date the permit is issued to the project or until a Notice of Termination has been completed	Karen Smith Compliance Program ksmith@mde.state.md.us (410) 537-3510
Baltimore County - Critical Area Project Notification Application	Chesapeake Bay Critical Area consists of all land within 1,000 feet of mean high tidal waters or the edge of tidal wetlands. The State Chesapeake Bay Critical Area Commission was created to formulate the protective criteria for the use and development of land within the Critical Area. Critical Area land is broken up into three categories of land development: Intense Development Area (IDA), Limited Development Area (LDA), and Resource Conservation Area (RCA). Land use must follow criteria specific to that category of land. Furthermore, land within 100 feet of mean high tidal waters or the edge of tidal wetlands is considered to be the Buffer, an existing, naturally vegetated area, or an area established in vegetation and managed to protect aquatic, wetlands, shoreline, and terrestrial environments from man-made disturbances {COMAR 27.01.09.01}.	Prior to submission of a project to the Critical Area Commission, the following requirements must be completed: • Public notice of the project was published for one business day in a newspaper of general circulation in the geographic area in which the proposed development would occur; • At least 14 days were provided for public comment in the local jurisdiction in which the proposed development would occur; and • The affected land was posted in accordance with the posting requirements in COMAR 27.03.01.03 D. Critical Area Project Notification Applications are submitted for review and approval by the BC DEPRM. A Critical Area Project Notification Application must be submitted for sites wholly or partially within IDAs in which the land disturbance is at least 15,000 square feet. Necessary Critical Area Project Notification Application content includes the application, site plans with Buffer areas and other Habitat Protection Features shown (as applicable) on each plan, site maps with Critical Area and 100-year floodplain boundaries indicated, acreage of IDA, LDA, RCA areas, acreage of disturbed area, pre- and post-work impervious surface area, and pre- and post-work woodland/trees area.	http://www.dnr.state.md.us/criticalarea/forms/projectnotificationform.pdf	No fee	A Critical Area Project Notification Application will be sent for BC DEPRM review at the same time that the Erosion and Sediment Control Plan and Stormwater Management Plan are submitted for review. The time of review by the BC DEPRM is expected to be similar to the review periods for the Erosion and Sediment Control Plan and Stormwater Management Plans.	Two years plus any applicable extension	Pat Farr Critical Area Commission 410-887-3980
Utility Clearance	Miss Utility for Maryland will be notified (1-800-257-7777, www.missutility.net) at least 48 hours, but not more than 10 working days, before any excavation or well drilling activities are conducted.			No fee		10 working days	Miss Utility of Maryland 800-257-7777

Applicable Permit	Parameters/Applicability	Permitting Process/Permit Components	Link to Permit Forms	Cost	Approval Time	Permit Duration	Regulator Contact
MDE/Baltimore County – Well Construction Permit	A well construction permit is required before installing any well that will explore for water, obtain or monitor ground water, or inject water into any underground formation from which ground water may be produced. The well construction permit is obtained by the well driller from the local health department.	Permits are obtained through a well driller licensed in the State of Maryland.		Environment Article Section 9-1307 allows up to $160 per permit. Each county establishes the fee, but may not exceed $160 per permit. **Baltimore County indicates cost of $80 per permit.**	30 days (This may vary depending on the local health department.)		MDE - Barry Glotfelty Delegated Program Section bglotfelty@mde.state.md.us (410) 537-3784
Baltimore County – Building Permits	Any time a **building greater than 100 square feet** in size is erected, altered, added to, or demolished, a permit is required. Building permits also are required for piers, bulkheads, retaining walls, swimming pools over 250 square feet, fences over 42 inches high, and accessory buildings.	Develop and submit a site plan (two to ten copies, depending on the type of work) drawn to scale and showing what is to be built and how it is to be situated on the property. Construction plans (two sets) are required for buildings over 1,000 square feet and additions over 600 square feet. Commercial permit applications require a Plan Review Data Sheet (three copies). Major work and commercial work requires these plans be sealed by an architect or engineer. The tax account number of the property will also be required	http://www.baltimorecountymd.gov/Agencies/permits/pdm_permitsprocess/pdmfper.html	http://resources.baltimorecountymd.gov/Documents/Permits/Permits%20Fee%20Schedules/building_permit_fee_schedule.pdf	up to 30 days		Building Permit Processing Bureau 410-887-3900
For Bioremediation Injection Wells MDE Groundwater Permits Division	Information on the proposed nature and type of injection well operation(s) will be submitted to the MDE Groundwater Permits Division. MDE will then determine whether the injection wells would be authorized by rule, whether an individual permit would be required, and/or whether additional information and/or operational requirements are needed to comply with State regulations.						Ching-Tzone Tien Groundwater Permits Division ctien@mde.state.md.us 410-537-3662
No specific permitting requirements							

APPENDIX Q—ADMINISTRATIVE REQUIREMENTS

Written Agreement
Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

WRITTEN AGREEMENT

If the Response Action Plan is approved by the Maryland Department of the Environment, Lockheed Martin Corporation agrees, subject to the withdrawal provisions of Section 7-512 of the Environment Article, to comply with the provisions of the Response Action Plan. Lockheed Martin Corporation understands that if Lockheed Martin Corporation fails to implement and complete the requirements of the approved plan and schedule, the Maryland Department of the Environment may reach an agreement with Lockheed Martin Corporation to revise the schedule of completion in the approved Response Action Plan or, if an agreement cannot be reached, the Department may withdraw approval of the plan.

Brad W. Owens
Printed Name

Director, Environmental Remediation
Title

Brad W.
Signature

April 25, 2012
Date

Zoning Certification
Response Action Plan
Lockheed Martin Middle River Complex, Middle River, Maryland

CERTIFIED STATEMENT FOR COUNTY AND MUNICIPAL ZONING REQUIREMENTS

Lockheed Martin Corporation hereby certifies that the property meets all applicable county and municipal zoning requirements.

Lockheed Martin Corporation acknowledges that there are significant penalties for falsifying any information required by the Maryland Department of the Environment under Title 7, Subtitle 5 of the Environment Article, Annotated Code of Maryland, and that this certification is required to be included in a response action plan for the Voluntary Cleanup Program pursuant to Title 7, Subtitle 5 of the Environment Article, Annotated Code of Maryland.

Brad W. Owens
Printed Name

Director, Environmental Remediation
Title

Signature

April 25, 2012
Date