Interim Remedial Action - Feasibility Study for the Groundwater Operable Unit at the Dump Road Area Site at Martin State Airport Middle River, Maryland

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ACRONYMS

AOP	advanced oxidation process
ARAR	applicable or relevant and appropriate requirement
atm-L/mole	atmosphere-liter per mole
bgs	below ground surface
BMP	best management practice
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfm	cubic feet per minute
CFR	*Code of Federal Regulations*
COC	chemical of concern
COMAR	*Code of Maryland Regulations*
COPC	chemical of potential concern
CSF	cancer slope factor
CWA	Clean Water Act
cVOC	chlorinated volatile organic compound
DCE	dichloroethene
DHC	dehalococcoides
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DOJ	United States of Department of Justice
DPT	direct push technology
DRA	Dump Road Area
DRO	diesel range organics
EBCT	empty bed contact time
ED	electron donor
EM	electromagnetic
EOS	emulsified oil substrate
EPA	United States Environmental Protection Agency
ERA	ecological risk assessment

FS	feasibility study
ft^3	cubic foot (feet)
GAC	granular activated carbon
gpd	gallons per day
gpm	gallons per minute
GRA	general response action
GRO	gasoline range organics
HCA	high concentration area
HHRA	human health risk assessment
HI	hazard index
hp	horsepower
IE	ion exchange
ILCR	incremental lifetime cancer risk
kW-hr	kilowatt-hour
lb	pound(s)
lb/day	pounds per day
Lockheed Martin	Lockheed Martin Corporation
LUC	land use control
MAA	Maryland Aviation Administration
MDANG	Maryland Air National Guard
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDE	Maryland Department of the Environment
µg/L	micrograms per liter
MNA	monitored natural attenuation
MSA	Martin State Airport
msl	mean sea level
NCP	*National Oil and Hazardous Substances Pollution Contingency Plan*
NPDES	National Pollutant Discharge Elimination System
NPW	net present worth
O&M	operation and maintenance
ORC®	oxygen release compound
ORP	oxidation reduction potential

OSHA	Occupational Safety and Health Administration
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PFD	process flow diagram
POTW	publicly owned treatment works
PPE	personal protective equipment
PPZ	potassium permanganate impregnated zeolite
PRB	permeable reactive barrier
PRG	preliminary remediation goal
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RfD	reference dose
RI	remedial investigation
SVOC	semivolatile organic compound
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSDF	treatment, storage, and disposal facility
Tetra Tech	Tetra Tech, Inc.
USGS	United States Geological Survey
UV	ultraviolet
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
VSA	vacuum swing adsorption
WQC	water quality criteria
ZVI	zero-valent iron

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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.

Anaerobic reductive dechlorination — 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 upon completion of remedial actions subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Aquifer — An underground layer of rock, sand, silt, or clay that contains water in sufficient amounts to serve as sources of groundwater for wells and springs.

Bioaugmentation — A treatment technology in which specialized bacteria that consume organic compounds are added to the subsurface. Chemicals and/or nutrients are often added to promote biological activity.

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 of concern (COC) — Chemicals that are identified by a regulatory agency (such as EPA or a state environmental agency) that are found at concentrations higher than those considered to be safe, and must be cleaned up and/or monitored.

Chemical of potential concern (COPC) — Chemicals identified during a remedial investigation (RI) that are at concentrations that have the potential to harm human health and/or the environment.

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 enacted in 1980 and amended in 1986 by the Superfund Amendments and Reauthorization Act to address remediation of abandoned hazardous waste sites.

Consent Order — A legally enforceable agreement between an environmental regulator and a responsible party.

Containment — A technology 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.

Dense non-aqueous phase liquids (DNAPLs) — An accumulation of liquid chemicals, like solvents, in the ground that are denser than water, and tend to sink. Dense non-aqueous phase liquids 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, and that effectively allow fluids to flow through the rock or sediment. Because some of the pores are dead end, and some of the groundwater will cling on to the sediment or rock surfaces and not drain, the "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.

Feasibility study (FS) — A report presenting the development, analysis, comparison, and selection of cleanup alternatives.

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

Human health risk assessment (HHRA) — A study that evaluates the harmful effects and risks from eating, breathing or touching a chemical (current and future).

Hydraulic conductivity — The rate at which water can move through a permeable medium, like 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.

***In situ* enhanced 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 breakdown the compounds.

Maximum contaminant level (MCL) — The highest level (concentration) of a chemical allowed in drinking water, set by the EPA.

Model domain — The modeling area of interest (with boundaries defined by the model's boundary conditions).

***National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) —** The federal government's plan for responding to oil spills and hazardous substance releases.

Net present worth (NPW) — A present worth analysis evaluates costs over a specific period of time by discounting all future costs to a common base year. It represents the amount of money that, if invested in the base year and dispersed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life. Net present worth considers both capital (construction) and annual (such as maintenance and labor) costs.

Permeable reactive barrier (PRB) — 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, and the nature and type of contaminant.

Potentiometric surface — The imaginary surface for 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 while the potentiometric surface of a confined aquifer (one that is capped by a less permeable layer) may rise above the actual top of the aquifer.

Preliminary remediation goal (**PRG) —**Contaminant concentration goals for soil, sediment, water, and air, listed by land use option, that are considered to be protective to human health and the environment. Customarily used at Superfund, Federal Facilities, Brownfield and RCRA sites, and complies with all ARARs. Preliminary remediation goals serve as a target during the initial development, analysis and selection of cleanup alternatives.

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

Remedial action — The actual construction or implementation phase of the selected remedial alternative.

Remedial action objectives (RAOs) — Objectives that specify contaminants to be cleaned up, the level of cleanup, the area and media of cleanup, and the time required to achieve cleanup to protect human health and the environment.

Remedial investigation — An in-depth study of a site that gathers data needed to determine the nature and extent of contamination, assess risk to human health and the environment, establish cleanup criteria, identify preliminary remedial action alternatives, and provide a technical and cost analysis of the alternatives.

Remediation — The process of correcting and/or cleaning up environmental contamination. Remediation involves taking action to reduce, isolate, or remove contamination from environmental media (e.g., soil, air, groundwater, surface water), with the goal protecting human health and the environment.

Residual — A modeling term that represents the difference between the model-computed and field measured values (like 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 of contaminants to soil and natural organic material that effectively holds contaminants back, and limits its ability to move at the same speed as the groundwater.

Slug test — A test that is conducted 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” (in liters per kilogram [L/kg]).

Sorb, sorption — A chemical process where 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 that 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 that flows 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.

Supernatant — Water that remains after solids settle out from a mixture of solids and water.

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. Because some of the pores are dead ends, and some of the groundwater will cling on to the sediment or rock surfaces and not drain, the "total porosity" is greater than the "effective porosity."

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

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

Vapor intrusion — The movement (migration) of chemical vapors from under the ground into overlying buildings.

Volatile organic compounds (VOCs) — A group of chemicals (organic compounds) that will vaporize or evaporate at room temperature into the atmosphere. 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 (ZVI) — A type of pure iron, typically in the form of small particles, used in the construction of subsurface reactive walls to treat and reduce the levels of contamination in groundwater.

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Executive Summary

Tetra Tech, Inc. has prepared this *Interim Remedial Action - Feasibility Study for the Groundwater Operable Unit at the Dump Road Area Site at Martin State Airport, Middle River, Maryland* for Lockheed Martin Corporation. Martin State Airport is located at 701 Wilson Point Road in Middle River, Maryland, and is bounded by Frog Mortar Creek to the east and Stansbury Creek to the west. Both creeks join Chesapeake Bay at the southern side of the airport. The Dump Road Area Site is located in the southeast portion of the airport and is bounded by Frog Mortar Creek to the east and the main airport runway to the west (Figure ES-1).

The purpose of the Feasibility Study is to evaluate technologies for the interim remediation of groundwater at the site, with the primary goal of minimizing off-site migration of contaminants. The extensive treatment of areas of the site with high concentrations of contaminants in groundwater is not a primary goal of this remedial action and will be further addressed in future documents. Additional investigations for several areas of the site with high concentrations of contaminants are planned for 2012.

As part of this evaluation, an interim remedial action is recommended. Following approval of the Feasibility Study and subsequent Proposed Plan, Lockheed Martin Corporation will implement the recommended interim remedial action.

Groundwater remedial actions in addition to those presented in this Feasibility Study may be considered along with final remedies for the contaminated soil and waste material in the final Feasibility Study for the Dump Road Area Site; these will be based on existing site data and the additional data to be collected in 2012.

Environmental issues with the Dump Road Area Site were originally discovered in July 1991. As part of the investigations of these environmental issues, more than 540 groundwater samples have been collected from 85 permanent monitoring wells and 125 temporary monitoring wells and more than 320 soil samples have been collected from approximately 180 borings and 65

test pits or trenches. These sample collection activities, and associated geophysical investigations, identified waste material (and associated soil and groundwater contamination) at the Dump Road Area Site over an area of approximately 25 acres. These investigations are detailed in the Remedial Investigation Report for this site (Tetra Tech, 2010b).

Soil contamination at the site includes volatile organic compounds, semivolatile organic compounds, polychlorinated biphenyls, and metals. The soil contamination and associated waste material will be addressed in a separate Feasibility Study.

This Feasibility Study is based on groundwater sampling results from 2007 through 2009. Over 200 groundwater samples were collected during this time period. The results of these samples show significant contamination at various depth intervals throughout the Dump Road Area Site. The contaminated aquifer is divided into upper (from the ground surface to an elevation 15 feet below mean sea level), intermediate (from 15 feet below to 45 feet below mean sea level), and deep (from 45 feet below to 73 feet below mean sea level) zones. The deep zone is underlain by a very competent clay layer (see report Section 1.2.3.2).

The following is a summary of the nature and extent of the contamination in groundwater (for selected contaminants) at the Dump Road Area Site:

- Concentrations of chlorinated volatile organic compounds (such as trichloroethene, cis-1,2-dichloroethene, and vinyl chloride) exceeded federal and Maryland groundwater standards throughout a large portion of the investigation area and at multiple depths. Figure ES-2 shows the groundwater trichloroethene concentrations at various depth intervals; the other chlorinated volatile organic compounds listed above follow similar patterns.

- The compound 1,4-dioxane was primarily detected in groundwater samples from the upper and intermediate surficial aquifer zones. It is generally present in areas containing the highest concentrations of chlorinated volatile organic compounds. Figure ES-3 shows the groundwater 1,4-dioxane concentrations at various depth intervals.

- Concentrations of cadmium exceeded the Maryland groundwater standards in 20 percent of samples, and the greatest concentrations of cadmium are associated with high levels of volatile organic compounds in the intermediate surficial aquifer.

- Petroleum-related compounds such as benzene were detected less frequently and at lower concentrations with respect to groundwater standards than the chlorinated volatile organic compounds.

For more information on site groundwater contaminants, see report Section 1.2.5.

Chemicals of concern in groundwater, which include the chemicals listed above, were selected based primarily on the human health risk assessment prepared as part of the Remedial Investigation Report (see report Section 1.2.7.1). A preliminary remediation goal was then developed for each of these contaminants. Preliminary remediation goals that are protective of human health were selected from among Maryland Groundwater Cleanup Criteria, United States Environmental Protection Agency drinking water standards, or risk-based criteria. The groundwater contaminants of concern are presented in Section 2.1, and their respective preliminary remediation goals are presented in Section 2.4 and Table 2-4 of this Feasibility Study.

In order to determine the basis for selecting the appropriate interim remedial action for groundwater, objectives for the interim remedial action were developed. These Remedial Action Objectives for the interim remedial action for groundwater are listed below:

Remedial Action Objective	Description
1	Prevent lateral migration of contaminated groundwater toward Frog Mortar Creek at concentrations that would cause exceedance of ambient water quality criteria or risk-based criteria.
2	Prevent human exposure (including via showering, drinking, and irrigation) to groundwater containing chemical of concern concentrations greater than preliminary remediation goals.
3	Prevent exposure of industrial workers and construction workers to volatile organic compounds resulting from vapor intrusion into buildings that cause unacceptable risk.

After identifying the Remedial Action Objectives, the evaluation of interim remedial alternatives for groundwater was conducted (see Section 3.1 of the Feasibility Study). Initially, a total of 22 process options, separated into 7 general response actions categories, were considered. The general response action categories included no action, limited action, containment, removal, *in situ* treatment, *ex situ* treatment, and disposal (see Table 3-1 of the Feasibility Study for more information).

A detailed screening of the process options was conducted and the remaining options were combined into the following six remedial alternatives to be further evaluated:

- ***Alternative G-1 —*** No action.
- ***Alternative G-2 —*** Hydraulic control by extraction, *ex situ* treatment of groundwater, discharge to publicly owned treatment works/surface water, monitoring, and land use controls.
- ***Alternative G-3 —*** Hydraulic control by extraction, *ex situ* treatment of groundwater, reinjection of groundwater, discharge to publicly owned treatment works/surface water, monitoring, and land use controls.
- ***Alternative G-4 —*** Hydraulic control by extraction, extraction in high concentration areas, *ex situ* treatment of groundwater, reinjection of groundwater, discharge to publicly owned treatment works/surface water monitoring, and land use controls.
- ***Alternative G-5 —*** Hydraulic control by extraction, *ex situ* treatment of groundwater, *in situ* bioremediation of high concentration areas, discharge to publicly owned treatment works/surface water, monitoring, and land use controls.
- ***Alternative G-6 —*** Zero-valent iron permeable reactive barrier, monitoring, and land use controls.

Alternative G-1 was developed and analyzed as a baseline against which the other alternatives could be compared.

Alternative G-2 was developed as a base case with hydraulic control of the plume only (to minimize off-site migration of contaminants). Extracted groundwater is then treated to remove contaminants prior to discharge. Groundwater contaminants upgradient of the extraction wells will eventually flow to the extraction wells, but the design does not incorporate acceleration of the overall groundwater cleanup.

Alternative G-3 is an enhanced version of Alternative G-2, in that some of the treated groundwater will be amended with an electron-donor compound and then reinjected upgradient of the high concentration areas to promote biological remediation. The treatment system in this alternative is sized for a larger flow rate to address the potential for flexibility in future operations, including the final site groundwater remedy.

Alternative G-4 is a more aggressive extraction and treatment approach that includes extraction and treatment of highly contaminated groundwater from the high concentration areas, and

reinjection of treated groundwater (with amendments to promote biological activity). Treating additional groundwater may reduce the time required to restore groundwater quality.

Alternative G-5 is similar to Alternative G-4 in that highly contaminated groundwater in the high concentration areas is treated. However, in Alternative G-5, highly contaminated groundwater in the high concentration areas is treated *in situ* by enhanced bioremediation to reduce the time to restore groundwater quality, and extracted groundwater is not reinjected. The treatment system in this alternative is also sized for a larger flow rate to permit flexibility in future operations.

Alternative G-6 uses a permeable reactive barrier for passive treatment of groundwater contaminants instead of a groundwater extraction and treatment system. A description and detailed analysis of these alternatives are presented in Sections 4.2.1 through 4.2.6 of the Feasibility Study. The key features of each alternative are summarized in Table 4-1 of the document.

A detailed evaluation of each alternative was conducted with respect to the following evaluation criteria: 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; Sustainability; and Cost (see report Sections 4.2.1 through 4.2.6). A comparison of the alternatives based on these criteria was then completed (see Table 5-1 of the Feasibility Study).

Based on this evaluation, Alternative G-3 (hydraulic control by extraction, *ex situ* treatment of groundwater, reinjection of groundwater in high concentration areas, discharge to publicly owned treatment works/surface water, monitoring, and land use controls) was selected as the interim remedial action for groundwater at the Dump Road Area Site. This alternative meets the interim remedial action requirement in that it provides containment to minimize off-site migration of trichloroethene, 1,4-dioxane, and cadmium. It also provides additional groundwater treatment capacity so that the groundwater extraction system can be expanded in the future, particularly after the soil and landfill waste have been remediated.

Future expansion of this alternative could include groundwater recirculation and *in situ* bioremediation in the high concentration areas to provide some destruction of chlorinated

volatile organic compounds, and such expansion could be designed for implementation in conjunction with the soil/landfill waste remedy. This alternative is economical and provides both effective treatment of all chemicals of concern and operational flexibility. The general site layout for Alternative G-3 is shown in Figure ES-4. More details on the criteria for selection are included in Section 5.3 of the report.

As part of Lockheed Martin Corporation's "Go Green" program, sustainability was a factor in selecting the recommended remedial alternative, and sustainability practices will be included in the design, installation, and operation of the interim remedial action for groundwater. Sustainability practices in general are those that consider economic and natural resources, ecology, human health and safety, quality of life, and reduction of the overall environmental "footprint". Details on these practices as they relate to this Feasibility Study are included in Section 5.4 of the report.

The interim remedial action-groundwater feasibility study was presented and submitted to the on site stakeholders for their review: the Maryland Aviation Administration and the Maryland Air National Guard. Comments from these stakeholders were incorporated in this revised report.

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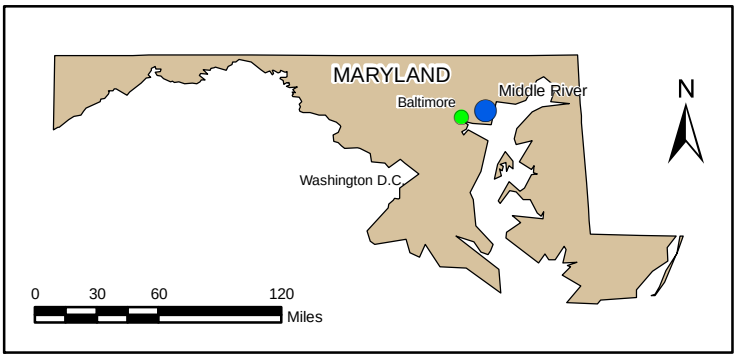

Figure ES-1

Dump Road Area Site Location Map

Lockheed Martin, Martin State Airport
Middle River, Maryland

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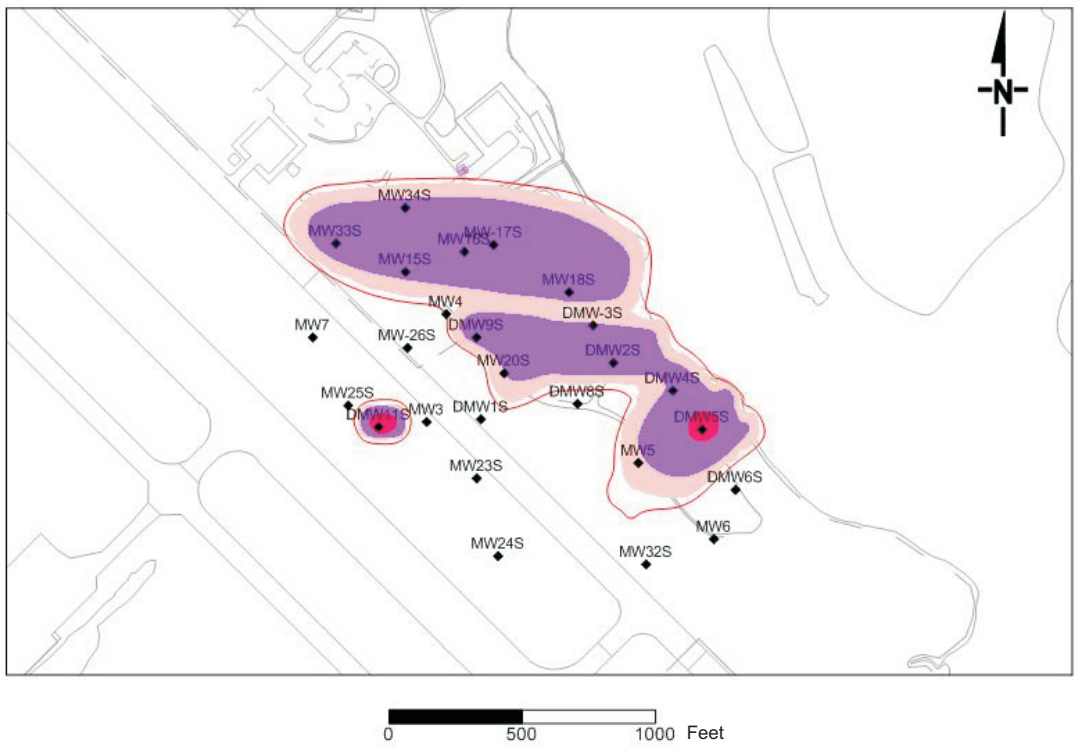
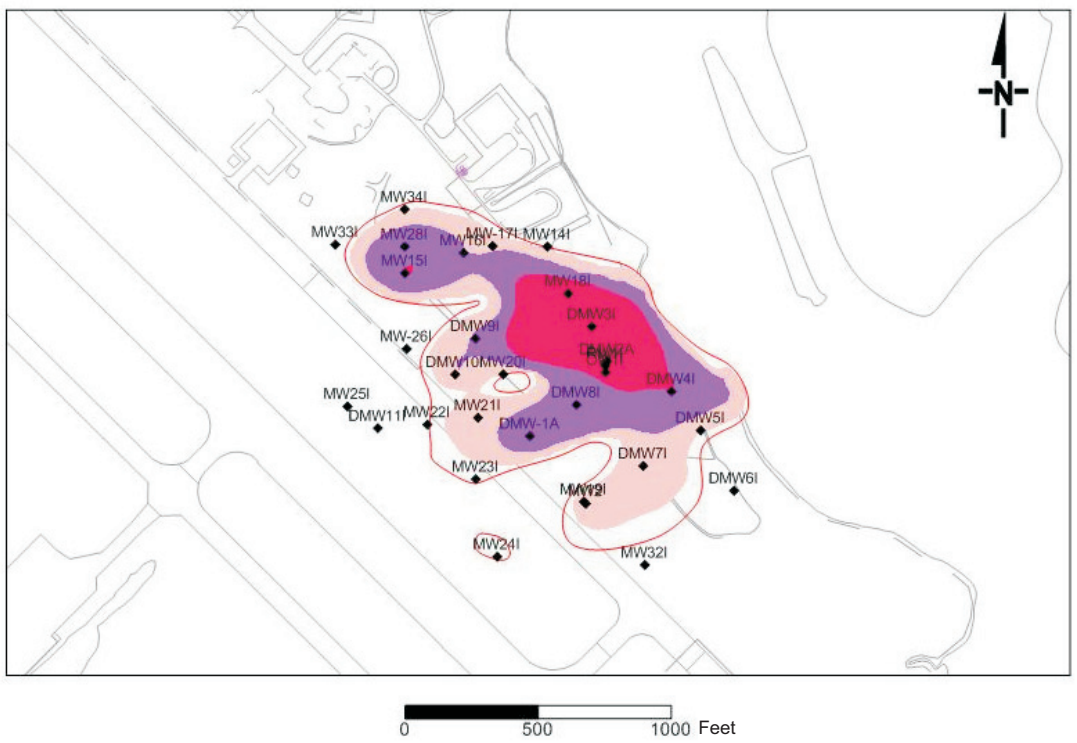
8/03/10	MP

Tetra Tech, Inc.

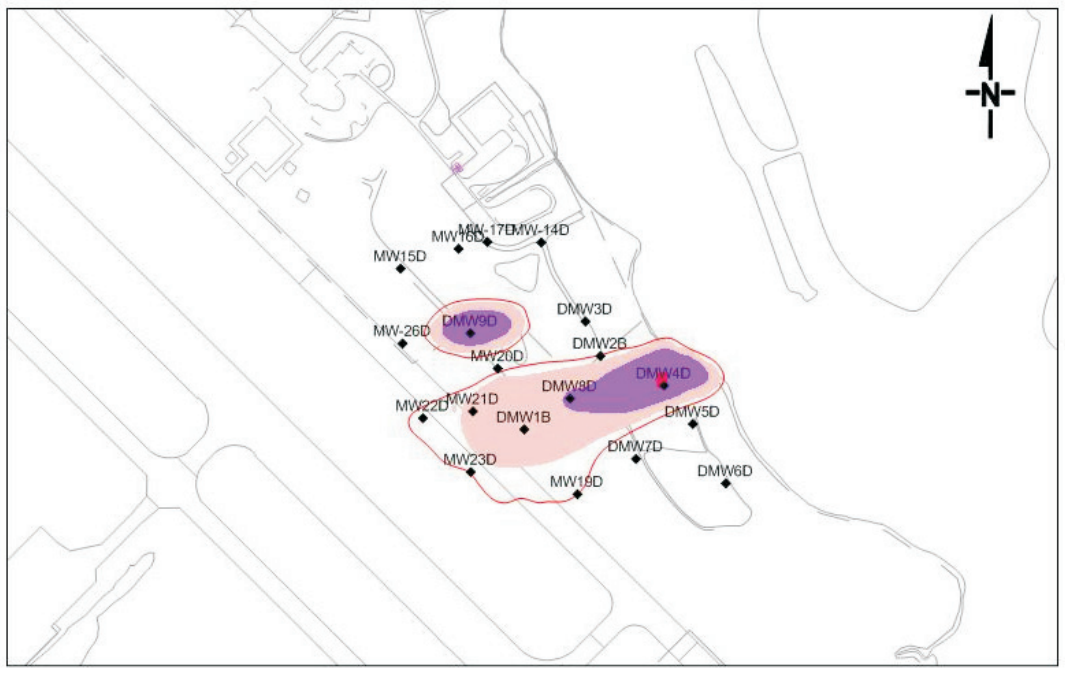
Upper Surficial Aquifer



Intermediate Surficial Aquifer



Lower Surficial Aquifer



Concentration ug/L

5000

500

50

5

5 ug/L

Note: Contours generated by groundwater model

Tetra Tech NUS, Inc

Groundwater Plume - Trichloroethene
Dump Road Area Site
Lockheed Martin, Martin State Airport
Middle River, Maryland

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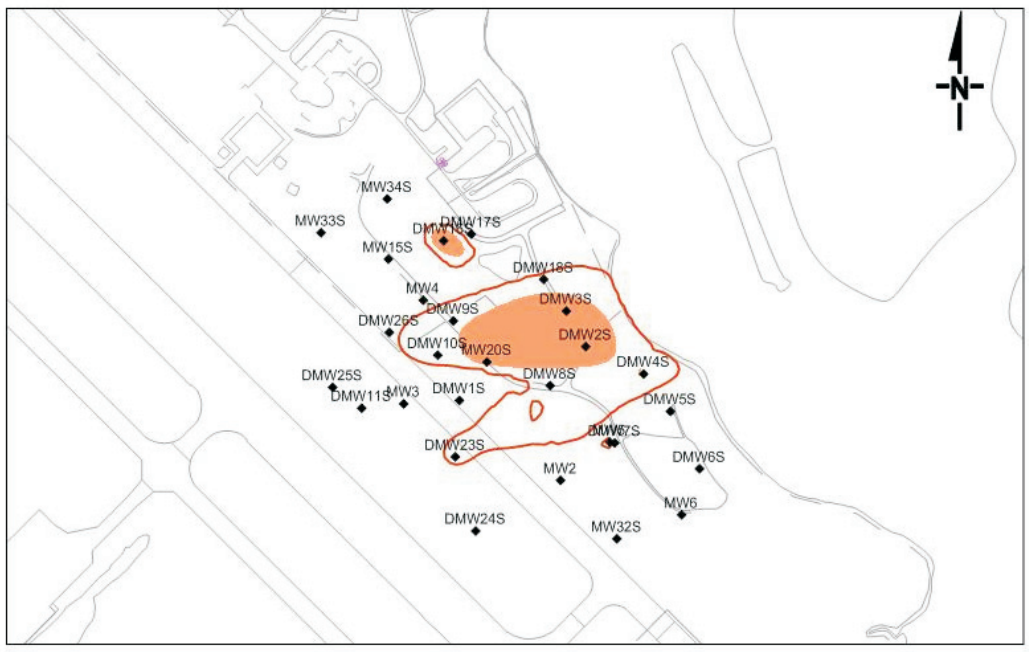
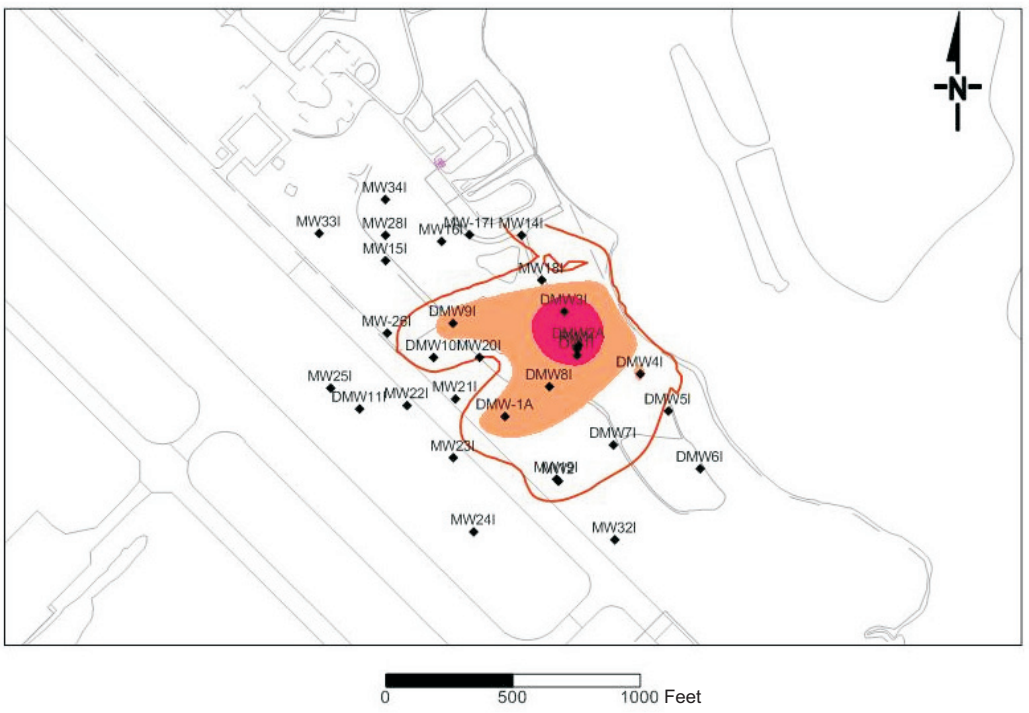
Upper Surficial Aquifer



Intermediate Surficial Aquifer



Lower Surficial Aquifer



Concentration ug/L



6 ug/L

Note: Contours generated by groundwater model

Tetra Tech NUS, Inc

Groundwater Plume - 1,4- Dioxane
Dump Road Area Site
Lockheed Martin, Martin State Airport
Middle River, Maryland

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FIGURE NUMBER	ES-3

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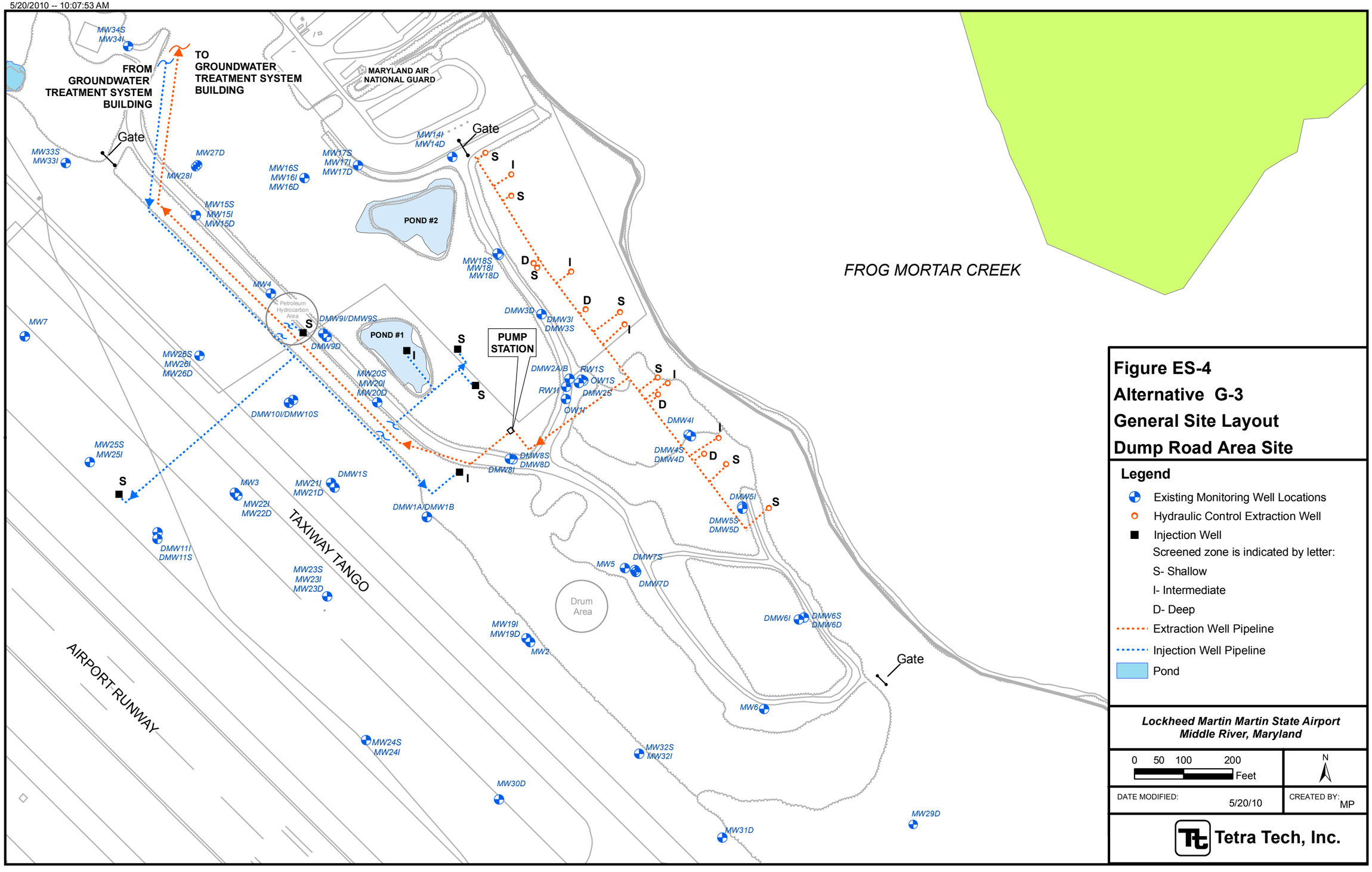

Figure ES-4
Alternative G-3
General Site Layout
Dump Road Area Site

Legend

- Existing Monitoring Well Locations
- Hydraulic Control Extraction Well
- Injection Well
  Screened zone is indicated by letter:
  S- Shallow
  I- Intermediate
  D- Deep
- Extraction Well Pipeline
- Injection Well Pipeline
- Pond

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

DATE MODIFIED: 5/20/10

CREATED BY: MP

Tetra Tech, Inc.

Section 1
Introduction

1.1 REPORT PURPOSE AND ORGANIZATION

1.1.1 Purpose

Tetra Tech, Inc. (Tetra Tech) has prepared this *Interim Remedial Action - Feasibility Study (FS) for the Groundwater Operable Unit at the Dump Road Area (DRA) Site at Martin State Airport (MSA), Middle River, Maryland* (Groundwater FS herein) for Lockheed Martin Corporation (Lockheed Martin) to evaluate alternatives for an interim remedial action, primarily considering containment of contaminated groundwater at the DRA Site. Containment alternatives that include limited source area treatment are also evaluated. This FS is not a comprehensive evaluation of groundwater remediation across the entire DRA Site, as intensive source treatment is not a primary consideration.

A comprehensive evaluation of groundwater remedies will be included in a separate FS, along with remedies for contaminated soil and landfill waste associated with this site. The FS for the contaminated soil and landfill waste, as well as the comprehensive evaluation of the site groundwater, will be completed in consultation with the current property owner [Maryland Aviation Authority (MAA)] and tenant [Maryland Air National Guard (MDANG)]. Additional investigations in several areas of the site containing high concentrations of contaminants are planned for 2012, and will be used in the preparation of the separate FS.

This document was prepared following the requirements for a feasibility study as outlined in the United States Environmental Protection Agency's (EPA) *National Oil and Hazardous Pollution Contingency Plan* (NCP). Although the site does not fall under the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the NCP process was nevertheless followed in this feasibility study to provide information in a recognized format and to fully evaluate options to properly contain groundwater contamination caused by waste disposed at the DRA Site. The FS process is aimed at gathering and evaluating

information sufficient to select an appropriate interim remedial action for DRA Site groundwater. This Groundwater FS establishes remedial action objectives (RAOs) and cleanup goals and screens remedial action technologies that may be suitable for addressing areas of groundwater at the DRA Site with contaminant concentrations greater than cleanup goals. It assembles, evaluates, and compares several remedial action alternatives for such groundwater, and then recommends one of these as the best interim remedial action for the DRA Site.

This Groundwater FS was prepared for review and approval by the Maryland Department of the Environment (MDE) and is subject to the regulatory requirements of Maryland's Hazardous Substance Response Plan (Code of Maryland Regulations Title 26, Subtitle 14). Maryland's Hazardous Substance Response Plan grants MDE the authority to choose how a cleanup will be performed.

This Groundwater FS is based on data collected during a series of investigations conducted from 1992 to 2010 and on the results and conclusions of the remedial investigation (RI) report, including the human health and ecological risk assessments (Tetra Tech, 2010b). In this Groundwater FS report, the results of previous investigations and risk assessments are used to develop and evaluate potential remedial action alternatives that will permanently and significantly reduce risks to human health and the environment that have been identified at the site. The proposed alternatives provide cost-effective and sustainable methods to mitigate the risks identified in the human health and ecological risk assessments.

The interim remedial action selected will be designed and implemented so that it does not interfere with future parallel soil and landfill waste remediation projects at this site. The design of the groundwater containment system includes flexibility to treat additional groundwater if site conditions should change in the future. Lockheed Martin will implement the preferred interim remedial action subsequent to MDE concurrence with this Groundwater FS.

1.1.2 Report Organization

This Groundwater FS is organized to meet the general format requirements specified in EPA's remedial investigation/feasibility study guidance document (EPA, 1988). This FS report is organized as follows:

Section 1.0: Introduction - Describes the purpose of the Groundwater FS, the site background, and summarizes the findings of previous site investigations and risk assessments.

Section 2.0: Remedial Action Objectives and General Response Actions - Provides remedial action objectives, chemicals of concern (COCs), environmental media of concern, applicable or relevant and appropriate requirements (ARARs) and other guidance criteria, groundwater cleanup goals and associated general response actions (GRAs), and estimates of the volumes of contaminated groundwater and mass of contaminants.

Section 3.0: Technology Screening and Process Options - Describes a two-tiered process for screening potentially applicable groundwater remediation technologies and assembling them into remedial action alternatives.

Section 4.0: Assembly and Detailed Analysis of Remedial Action Alternatives - Describes evaluation criteria and detailed analyses of the groundwater interim remedial action alternatives, in accordance with the CERCLA process. This section also makes optimization recommendations to enhance the sustainability of the selected interim remedial action.

Section 5.0: Comparative Analysis of Remedial Action Alternatives - Compares groundwater remedial action alternatives on a criterion-by-criterion basis and selects the recommended alternative.

Section 6.0: Future Actions - Summarizes future activities to address environmental issues at the DRA Site.

Section 7.0: References - Lists documents used to prepare this Groundwater FS.

Appendix A presents selected figures and tables from the MSA RI report (Tetra Tech, 2010b). Appendix B is the groundwater modeling report. Appendix C contains volume computations of groundwater contaminants identified at the site at concentrations greater than cleanup goals. Appendix D describes the screening of remediation technologies and process options. Appendix E presents preliminary design calculations and detailed process descriptions for interim remedial action alternatives. Appendix F presents cost estimates for the remedial action alternatives.

1.2 SITE BACKGROUND

The following subsections provide background information about the DRA Site. Figure 1-1 is a general location map; Figure 1-2 is a site map showing general site features. Figure 1-3 shows the main site features (such as areas of concern where previous investigations were conducted), and Figure 1-4 shows site monitoring well locations.

1.2.1 Site Description

Martin State Airport is located at 701 Wilson Point Road in Middle River, Maryland, and is bounded by Frog Mortar Creek to the east and Stansbury Creek to the west (Figure 1-2). Both creeks join Chesapeake Bay at the southern side of the airport. The DRA Site is on the southeast portion of MSA and is bounded by Frog Mortar Creek to the east and Taxiway Tango and the main airport runway to the west.

Martin State Airport was owned and operated by the Glenn L. Martin Company (a predecessor firm of Martin Marietta Corporation) from approximately 1929–1975. Runways and hangars were built in 1939–1940. The Glenn L. Martin Company consolidated with American Marietta Corporation in September 1961 to form Martin Marietta Corporation. Lockheed Corporation and Martin Marietta merged in 1996 to form Lockheed Martin Corporation. In July 1955, the MDANG began leasing the property from the Glenn L. Martin Company. In September 1975, the MAA purchased the land now used as the airfield.

Environmental issues associated with the DRA Site were initially identified in July 1991, when MAA encountered four drums adjacent to Taxiway Tango during trenching to install an electrical cable. These drums were subsequently disposed of off-site. Discovery of these buried drums led to investigation of the surrounding area for possible soil and groundwater contamination. These investigations also showed that the DRA Site had been used as a landfill for wastes associated with aircraft manufacturing.

1.2.2 Previous Investigations

The Maryland Aviation Administration (1991–1997) and Lockheed Martin (1998–2009) performed 20 site investigations and/or sampling events to outline the extent of environmental contamination at the DRA Site. The early investigations identified four areas of concern (see Figure 1-3):

- Taxiway Tango Median Anomaly
- Drum Area
- Two ponds
- Petroleum Hydrocarbon Area

They were identified as areas of concern based on earlier analyses of soil samples and observations of debris and waste material found at these locations. Site investigations included

monitoring well installation, soil and groundwater sampling, test pit excavations, and geophysical surveys. These investigations also identified the extent of historical landfilling and waste disposal. More than 540 groundwater samples were collected from approximately 85 permanent monitoring wells, 125 temporary monitoring wells, and temporary groundwater sampling points. More than 324 soil samples were collected from approximately 180 borings and 65 test pits or trenches. The results of these investigations are summarized in reports listed in Section 7, References, below.

An RI was conducted to refine the lateral and vertical extent of landfill material to support the remedial design for the landfill area and to quantify subsurface contaminant mass for groundwater remediation. Fieldwork for the RI was performed in late 2009, and the RI report was completed in May 2010 (Tetra Tech, 2010b). A secondary objective of the RI was to identify the northern extent of groundwater contamination. The RI provides an evaluation of the nature and extent of environmental contamination at the DRA Site and includes a human health risk assessment (HHRA) and an ecological risk assessment (ERA). The results of the RI are used in this Groundwater FS to establish current environmental conditions and to help choose an appropriate remedial action. Select figures and tables from the RI are included in Appendix A to supplement this Groundwater FS.

1.2.3 Geology and Hydrogeology

1.2.3.1 Regional Geology and Hydrogeology

Martin State Airport is on the Western Shore of Chesapeake Bay and situated within 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 to 800 feet thick. The Potomac Group at the site consists of three 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 formation of primary interest in this investigation, 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 to 200 feet thick beneath the site. The Arundel Clay probably acts as an impermeable barrier to the downward movement of any constituents found in the overlying groundwater. Below the Arundel Formation is the Patuxent Formation. It is a multi-aquifer unit, due to various inter-bedded sand and silt/clay layers and the rapid changes of deposited material types over short distances (Glaser, 1969).

1.2.3.2 Dump Road Area Site Geology and Hydrogeology

Previous and recent investigations at the DRA Site indicate that the subsurface is characterized by inter-bedded zones of heterogeneous sand, silt, and clay deposits from the Patapsco Formation. Figure 1-5 depicts a generalized cross-section of the surficial aquifer at the DRA Site. Boring logs and cross-sections across the site indicate the presence of relatively continuous layers of sand and gravel that are locally separated by silts and clays. These shallow permeable zones form the surficial aquifer. Both regional information (Andreasen, 2007; Fleck and Vroblesky, 1996; Chapelle, 1985) and recent deep borings at the DRA Site indicate the presence of a thick clay unit approximately 120 feet below the site, which may be the top of the Arundel Formation.

The hydrogeologic system beneath MSA consists of relatively continuous zones of sand and gravel that provide the primary pathways for groundwater flow and contaminant transport. These zones are interlayered with zones of lower permeability sediments, resulting in a relatively complex stratigraphic sequence. Water enters these units [primarily via natural infiltration of precipitation (i.e., recharge)] through the shallow fill materials, and then reaches the water table. From there, the groundwater migrates along various pathways depending on location, with some of the groundwater flowing vertically downward to recharge units below the water table. Eventually, almost all of the groundwater flows laterally through permeable zones, and discharges to estuaries surrounding the peninsula on which MSA is located. In the Dump Road Area, the estuary of relevance is Frog Mortar Creek. Site data indicate that the surficial aquifer is divided into three hydraulically connected monitoring zones: upper (shallow), intermediate, and lower (deep).

The surficial aquifer is underlain at approximately 75 to 85 feet below mean sea level (msl) by a relatively thick clay unit that acts as a basal confining unit. Cross-sections of the surficial

aquifer are presented along various transects in Appendix A. Deep borings at the site indicate the presence of deeper sand zones, which are confined above and below by clay units. These are most likely from the Arundel Formation, which is a regionally extensive, thick, dense, clay confining unit.

Frog Mortar Creek is influenced by tidal fluctuations with average amplitudes of approximately 1.2 feet, and thus a tidal range of about 2.4 feet. In the upper zone, water level recordings indicate that tidal fluctuation amplitudes decrease to less than 0.1 foot within a few hundred feet from Frog Mortar Creek. This damping effect is most likely due to the relatively high storage coefficient of the water table aquifer, in which primary storage space just above the water table can readily fill and drain. In the intermediate and lower zones, tidal fluctuations diminish less rapidly with distance from Frog Mortar Creek because of the semi-confined or confined conditions in these zones. Much less damping of tidal variation occurs under these conditions because the aquifer units are fully saturated and under artesian pressure.

Groundwater flow in the upper zone is generally to the east toward Frog Mortar Creek. A similar flow direction is seen in the intermediate and lower zones. At monitoring well clusters, the concurrently measured water levels for a given cluster indicate that groundwater vertical head differences in the surficial aquifer are generally downward in the upland areas and upward near Frog Mortar Creek.

Slug tests at the site yielded hydraulic conductivity estimates ranging from 5 to 20 feet/day in sand zones to 0.01 to 0.2 feet/day in clay zones (Tetra Tech, 2004). Pumping tests were performed in both the upper and intermediate zones of the surficial aquifer. Intermediate zone pumping tests indicate an average horizontal hydraulic conductivity ranging from 42 to 140 feet/day, with a mean of 68 feet/day (Tetra Tech, 2010a). No pumping tests have been performed in the lower zone. Figures 4-4 through 4-14 in the RI report (see Appendix A) show geologic cross-sections that illustrate the lithologic characteristics of the subsurface.

1.2.3.3 Surface Water Hydrology

The eastern, southern, and western boundaries of MSA are bordered by Frog Mortar Creek and Stansbury Creek, which are wide, brackish, tidal tributaries of the middle Chesapeake Bay. Surface water runoff from MSA enters these creeks via localized gullies in the eastern and

western undeveloped portions of the site, or via storm sewers that drain the airport runway, taxiways, and developed portions of the facility. In the DRA, six drainage areas direct flow from the runway, taxiways, and wooded areas and discharge to Frog Mortar Creek on the east side of MSA.

Two small ponds and adjacent pond margin wetlands are in the DRA, and a storm water management pond is near the Fire Pump House in the western portion of MSA. These ponds and wetlands are contained in each drainage area and do not discharge to Frog Mortar Creek. Comparisons of the pond water surface elevations to the groundwater table elevation suggest that the ponds are not well connected to the surficial aquifer. Additional investigations are being undertaken in 2012 to determine the level of hydaulic connection between the surface water and groundwater, and to evaluate the potential effect groundwater withdrawal may have on the water level in the ponds.

A site-wide wetlands identification and mapping study has been prepared by the MAA.

1.2.4 Nature and Extent of Contamination — Soil

Chemical analyses of numerous soil samples and several pond sediment samples indicate the presence of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), and several metals in soil and pond bottom sediment at concentrations exceeding EPA human health and ecological risk-based screening levels and MDE soil cleanup standards. The primary VOCs detected in soil and pond sediment samples are trichloroethene (TCE), TCE degradation products such as cis-1,2-dichloroethene (DCE) and vinyl chloride, and benzene, toluene, ethylbenzene, and xylenes (BTEX). Semivolatile organic compounds detected in soil and sediment include polynuclear aromatic hydrocarbons (PAHs), which are a group of compounds derived from the combustion of materials. Metals detected in soil and pond sediment at the site include antimony, arsenic, cadmium, copper, chromium, lead, mercury, nickel, and zinc.

A detailed description of the nature and extent of soil contamination at the site is provided in the RI report (Tetra Tech, 2010b). Remedial action for soil at the DRA Site will be addressed later in a separate report, which will evaluate appropriate remedial technologies such as soil excavation, capping, and consolidation.

1.2.5 Nature and Extent of Contamination — Groundwater

Groundwater sampling results evaluated in this section consist of data from three sampling events in 2007, 2008, and 2009. Analyses of these samples focus on contaminants that had been frequently detected during previous sampling events, specifically VOCs, 1,4-dioxane, and total and dissolved metals. Analyses for perchlorate and hexavalent chromium were also performed on a subset of the samples.

As with site soils, contaminants detected in groundwater are common to aircraft manufacturing. The 2007 and 2008 sampling events included all installed wells. In 2009, six newly installed wells and a subset of existing wells were sampled. Upper surficial aquifer well samples were analyzed in 2009 for total petroleum hydrocarbons (TPH), diesel range organics (DRO), and gasoline range organics (GRO). The maximum contaminant concentrations detected in each aquifer zone are shown in Table 1-1. Selected wells were also analyzed for natural attenuation parameters such as:

- alkalinity
- chemical oxygen demand
- dissolved gasses (methane, ethane, ethene, hydrogen, oxygen, and carbon dioxide)
- anions
- total organic carbon

Up to 200 groundwater samples were collected between 2007 to 2009 for the upper, intermediate, and lower surficial aquifers and deep confined aquifer. The nature and extent of groundwater contamination is described in the RI report (Tetra Tech, 2010b). Tables and figures summarizing analytical results from the RI are included in Appendix A. The extent of TCE, cis-1,2-DCE, vinyl chloride, and 1,4-dioxane in each surficial aquifer zone is shown in Figures 1-6, 1-7, 1-8, and 1-9, respectively. As presented in the RI report, the nature and extent of COCs are summarized below:

- Concentrations of chlorinated volatile organic compounds (cVOCs) (such as TCE and cis-1,2-DCE) exceeded federal and Maryland groundwater standards throughout an area of approximately 30 acres and at multiple depths. Multiple cVOC sources at the site have resulted in cVOC-contaminated groundwater extending to areas north of Pond 2 and south to wells DMW6I and DMW7I (see RI Figures 5-14 through 5-17 in Appendix A).

- Concentrations of cVOCs in groundwater have generally decreased as compared to the 2004 analytical results. Reductions of TCE concentrations and high concentrations of the chemical daughter products cis-1,2-DCE, vinyl chloride, and ethene indicate that TCE degradation has occurred at the site and may continue.

- The compound 1,4-dioxane was detected primarily in groundwater samples from the upper and intermediate surficial aquifer zones. It is generally collocated in areas with the highest concentrations of cVOCs, primarily near and east of Pond 1 (see RI Figures 5-23 and 5-24 in Appendix A).

- Concentrations of cadmium exceeded the maximum contaminant level (MCL) in 20 percent of samples, and the greatest concentrations of cadmium are associated with high levels of VOCs in the intermediate surficial aquifer at wells DMW1A, DMW2A, DMW8I, and DMW3I, south and east of Pond 1. Concentrations of metals such as chromium, hexavalent chromium, lead, mercury, and zinc exceeded MCLs in less than 10 percent of samples, ranging from one exceedance each for mercury and zinc to five exceedances for lead. Dissolved lead and mercury concentrations did not exceed MCLs.

- The BTEX compounds associated with petroleum constituents were detected less frequently and at lower concentrations with respect to federal and state groundwater standards than cVOCs. Well DMW9S (near the Petroleum Hydrocarbon Area) had the greatest concentrations of BTEX (see RI Figure 5-18 in Appendix A).

- In 2009, groundwater samples from the upper surficial aquifer were analyzed for TPH DRO (which was detected in more than half of the samples), with the greatest concentration reported for well DMW20S in the upper surficial aquifer, south of the Petroleum Hydrocarbon Area (Figure 1-3). Nearly all of the samples had detectable levels of TPH-GRO, with the greatest concentration reported for well DMW9S in the upper surficial aquifer, south of the Petroleum Hydrocarbon Area. Substantially lower concentrations of TPH-DRO and TPH-GRO were reported for wells near the Drum Area and Taxiway Tango.

- Concentrations of TCE were detected at levels greater than 1 percent of its solubility, which suggests the presence of dense non aqueous phase liquid (DNAPL) in the subsurface. However, no DNAPL was observed.

The primary objective of the interim remedial action alternatives addressed in this Groundwater FS is containment. However, active remediation of groundwater with the highest contaminant concentrations would decrease containment duration. Therefore, limited remediation of the high concentration areas (HCAs) is also considered in developing some of the remedial alternatives in this Groundwater FS. High concentration areas are areas where concentrations of TCE, cis-1,2-DCE, or vinyl chloride are greater than 5,000 micrograms per liter (µg/L), or, in the case of 1,4-dioxane, greater than 100 µg/L. High concentration areas for TCE, cis-1,2-DCE,

and vinyl chloride are shown in red in Figures 1-6 through 1-8 (at the end of Section 1), and HCAs for 1,4-dioxane are shown in orange areas in Figure 1-9.

Additional investigations are being conducted in several of the HCAs. The purpose of these investigations is to better characterize and delineate the areas of the site with the highest contaminant concentrations in order to focus potential future remedial actions. The results of these investigations will be submitted in future documents and will be used to plan potential remedial actions conducted subsequent to this IRA. The HCAs being investigated further include the vicinity of DMW-11S, the area in and around Pond 1, the Drum Area, and the vicinity of boring TA-1.

1.2.6 Contaminant Fate and Transport

Historical waste disposal has contaminated groundwater at the DRA Site. Very little information about past waste disposal practices is available. At one time, the two ponds on-site were used to dispose of acid wastes. At the other three areas of concern, evidence of waste disposal (such as drums and discolored soil) has been observed at the surface. Geophysical surveys and test pits also suggest that waste disposal occurred here.

Contaminants from these wastes eventually migrated through the soil to groundwater, since the topography is generally flat. Precipitation passing through the soil would have likewise carried contaminants to the groundwater. From there, contaminants migrated vertically downward and topographically downgradient toward Frog Mortar Creek. Natural biological activity has since degraded some VOCs and cVOCs.

Groundwater modeling was performed in support of the Groundwater FS and the groundwater modeling report is provided in Appendix B. Groundwater flow numerical models were developed based on field observations, tests, and laboratory analyses. Groundwater modeling supports the development of alternatives for an interim remedial action to address VOC and 1,4-dioxane contamination in groundwater at the DRA Site, focusing on containment (that is, on preventing contaminated groundwater from migrating off-site toward Frog Mortar Creek). Additional model simulations examined the effect of placing injection and extraction wells in the HCAs. Modeling results indicated that the site's contaminated groundwater could be effectively controlled via groundwater extraction.

1.2.7 Baseline Risk Assessments

1.2.7.1 Human Health Risk Assessment

An HHRA was conducted in 2010 and included in the RI report. It used the RI results to evaluate risk to potential human receptors under current and likely future land uses, and in accordance with EPA and MDE guidelines. The HHRA primarily considers receptor exposure under non-residential (e.g., industrial, recreational) land use scenarios. Although the site is not expected to be used for residential purposes in the foreseeable future, residential land uses also were evaluated. The HHRA also developed preliminary cleanup goals for site soil and groundwater contaminants that significantly contribute to the estimated cancer risk and/or hazard index.

The predominant chemicals evaluated for human health risk, based on direct contact exposure, are cVOCs (via direct contact with soils, groundwater, and sediments), BTEX (via soils and groundwater), substituted benzene compounds (via soils and groundwater), PAHs (via soils and sediments), perchlorate (via groundwater), and several heavy metals (i.e., cadmium, lead, copper, chromium, nickel) (via soils and groundwater). Ingestion of groundwater at the DRA Site is expected to be limited to exposures that might occur under a future residential scenario. Incidental ingestion of groundwater by construction workers might occur during construction/excavation activities. Future workers could be exposed to unacceptable concentrations of VOCs via vapor intrusion into buildings built over the contaminant plume. Trespassers/visitors could incidentally ingest surface water while on-site. However, only one surface water chemical was detected, and no COCs were identified for surface water. Trespassers could also be exposed to contaminants in pond sediments through incidental ingection and dermal contact.

Groundwater is not currently used as a source of potable or industrial water at the site, nor is such use likely in the future. The groundwater user survey also indicates the possibility of wells near MSA, but these wells, if they exist, would be upgradient of MSA and would not be affected by any on-site contaminant sources. Groundwater remediation at this site is appropriate due to the risks identified in the HHRA and the presence of groundwater contaminants at concentrations greater than EPA and MDE standards.

1.2.7.2 Ecological Risk Assessment

An ERA was also conducted in 2010 as part of RI activities, in accordance with EPA guidelines to evaluate risk to potential ecological receptors in surface soil, sediment, and groundwater (evaluated as surface water). The central area of the site northwest of Pond No. 1 appears to be the area of greatest ecological risk, based on current sampling data. Surface soil ecological chemicals of potential concern (COPCs) for invertebrates and plants include:

- TCE
- cis-1,2-DCE
- antimony
- chromium
- copper
- manganese
- molybdenum
- zinc

PAHs are COPCs only for soil invertebrates, whereas cadmium, lead, nickel, and selenium were retained as COPCs only for plants. Further evaluation of surface soil identified several metals (mercury, cadmium, lead, and molybdenum) as risks to wildlife (e.g., quail, shrews, robins). Volatile organic compounds, PAHs, PCBs, and several metals were retained as COPCs for Pond No. 1 sediment. For groundwater evaluated as surface water, several VOCs and metals exceeded surface water criteria. Even with dilution factors as high as 50-fold applied to chemical concentrations, numerous chemicals in groundwater still exceeded surface water criteria. Therefore, risks to aquatic biota are possible from detected concentrations of VOCs and metals in groundwater, assuming up to a 50-fold dilution of groundwater discharging into a water body at the groundwater/surface water interface.

Table 1-1

Maximum Detection Results of Contaminants - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Location	Upper Surficial Aquifer	Intermediate Surficial Aquifer	Lower Surficial Aquifer	Deep Confined Aquifer	Maximum Contaminant Level (1)
Parameter	**Maximum Result**	**Maximum Result**	**Maximum Result**	**Maximum Result**	
Volatile Organics (ug/l)					
1,1,2,2-TETRACHLOROETHANE	20	ND	ND	ND	0.066*
1,1-DICHLOROETHANE	83.3	21.7	4.4	ND	2.4*
1,1-DICHLOROETHENE	222	83	18.8	ND	7
1,2,3-TRICHLOROBENZENE	3	115	3.5	ND	5.2*
1,2,4-TRICHLOROBENZENE	29	730	22.4	ND	70
1,2,4-TRIMETHYLBENZENE	375	30	0.8	0.4	15*
1,2-DICHLOROETHANE	113	160	32.6	ND	5
1,3,5-TRIMETHYLBENZENE	190	11	2.2	ND	87*
BENZENE	570	41	15.2	ND	5
CARBON TETRACHLORIDE	96.9	430	3.2	ND	5
CHLOROBENZENE	720	270	4.8	ND	100
CHLOROFORM	1,870	100	310	20	0.19*
CIS-1,2-DICHLOROETHENE	41,000	17,000	6,310	ND	70
ETHYLBENZENE	2,610	18	ND	0.2	700
METHYLENE CHLORIDE	34.1	140	135	ND	5
TETRACHLOROETHENE	32.7	41	16	ND	5
TOLUENE	6,500	220	154	1.2	1,000
TOTAL XYLENES	28,500	113	16	0.98	10,000
TRANS-1,2-DICHLOROETHENE	376	57	40	ND	100
TRICHLOROETHENE	41,100	20,000	6,590	ND	5
VINYL CHLORIDE	56,000	4,300	4,000	ND	2
Semivolatile Organics (ug/l)					
1,4-DIOXANE	1,800	1,500	870	ND	6.1**
NAPHTHALENE	63.3	14.2	0.32	ND	0.14*

Table 1-1

Maximum Detection Results of Contaminants - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Location	Upper Surficial Aquifer	Intermediate Surficial Aquifer	Lower Surficial Aquifer	Deep Confined Aquifer	Maximum Contaminant Level (1)
Parameter	**Maximum Result**	**Maximum Result**	**Maximum Result**	**Maximum Result**	
Inorganics (ug/l)					
ANTIMONY	2.9	1.7	0.9	0.67	6
ARSENIC	79.6	49.9	82.2	19.6	10
BARIUM	1,610	138	156	278	2000
BERYLLIUM	9.9	9.5	5.1	3.8	4
CADMIUM	242	1,130	997	1.4	5
CHROMIUM	158	349	889	42.8	100
COBALT	724	606	437	13.9	4.7*
COPPER	172	534	161	37.2	1,300
IRON	275,000	73,500	52,900	24,400	11,000*
MANGANESE	13,400	9,940	6,300	1,270	320*
MERCURY	0.11	2.6	13.2	0.83	2
NICKEL	991	228	149	21.3	300*
SELENIUM	149	41.7	36.2	2.7	50
THALLIUM	0.5	0.5	0.4	0.18	2
VANADIUM	116	66.9	139	52.6	78*
ZINC	3,150	1,780	646	882	4,700*

Table 1-1

Maximum Detection Results of Contaminants - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Location	Upper Surficial Aquifer	Intermediate Surficial Aquifer	Lower Surficial Aquifer	Deep Confined Aquifer	Maximum Contaminant Level (1)
Parameter	**Maximum Result**	**Maximum Result**	**Maximum Result**	**Maximum Result**	
Filtered Inorganics (ug/l)					
ANTIMONY	1.3	1.3	0.9	0.61	6
ARSENIC	77.3	39.2	20.8	7.9	10
BARIUM	1,720	137	148	72.9	2,000
BERYLLIUM	9	10.4	4.7	0.44	4
CADMIUM	238	1,070	956	ND	5
CHROMIUM	24.9	260	229	4.5	100
COBALT	692	589	415	14.3	4.7*
COPPER	157	136	67.8	6.5	1,300
IRON	284,000	70,900	34,300	6,300	11,000*
MANGANESE	12,600	10,700	6,960	1,370	320*
MERCURY	0.19	0.14	0.34	ND	2
NICKEL	942	211	143	21.8	300*
SELENIUM	139	44	37.4	0.8	50
THALLIUM	0.4	0.22	0.3	ND	2
VANADIUM	141	27.4	4.8	2.9	78*
ZINC	2,860	533	461	22.4	4,700*
Miscellaneous Parameters (ug/l)					
NITRATE	15,000	3,600	2,800	ND	10,000
NITRITE	2,100	1,700	ND	ND	1,000
PERCHLORATE	4	8	5.8	0.09	15

1 - If no Maximum Contaminant Level is available, an alternative criterion is provided as noted.
* - United States Environmental Protection Agency Regional Screening Level.
** - United States Environmental Protection Agency Guidance.
COC - Chemical of concern.
ND - Not detected.
µg/l - Micrograms per liter.

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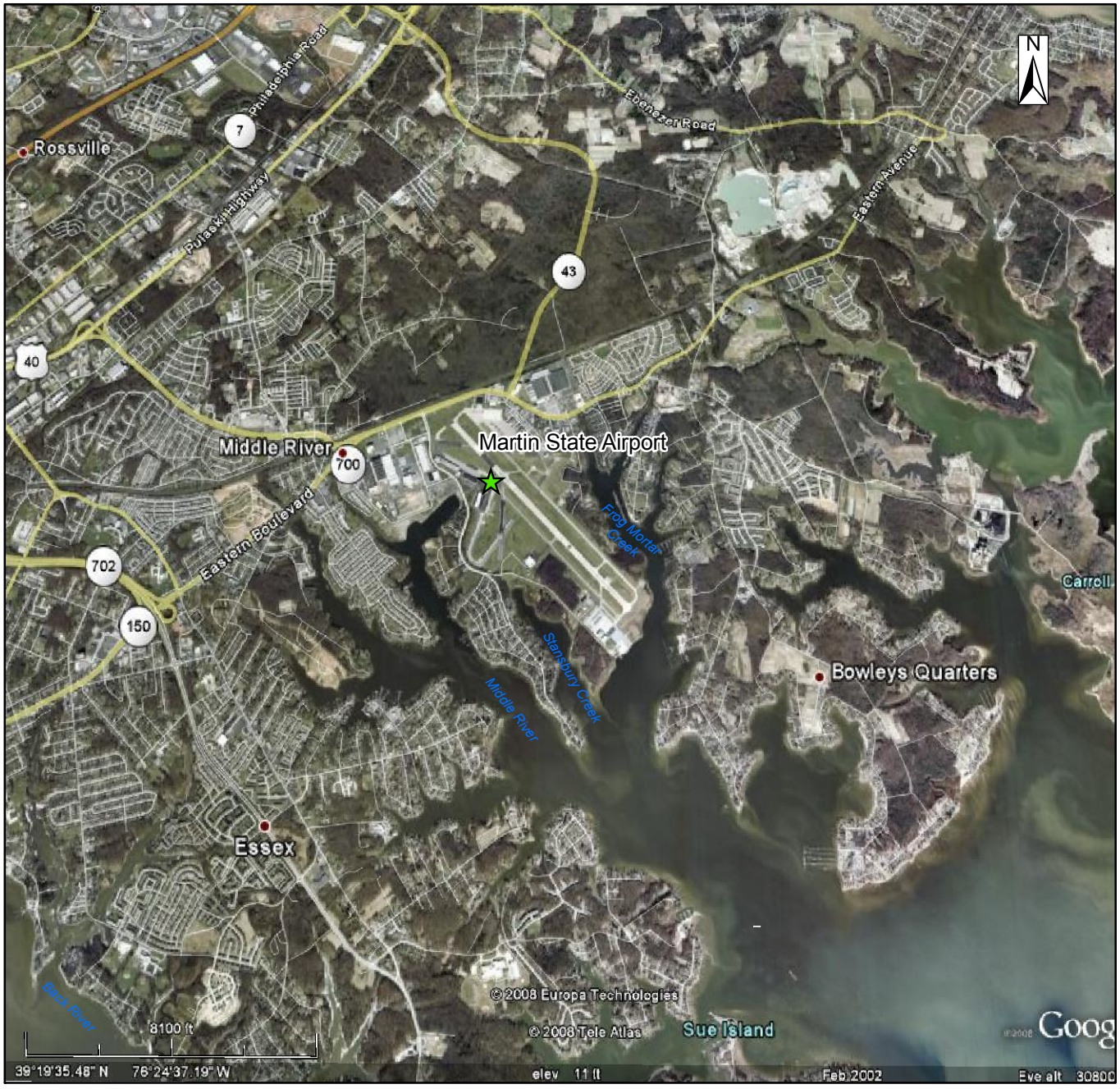

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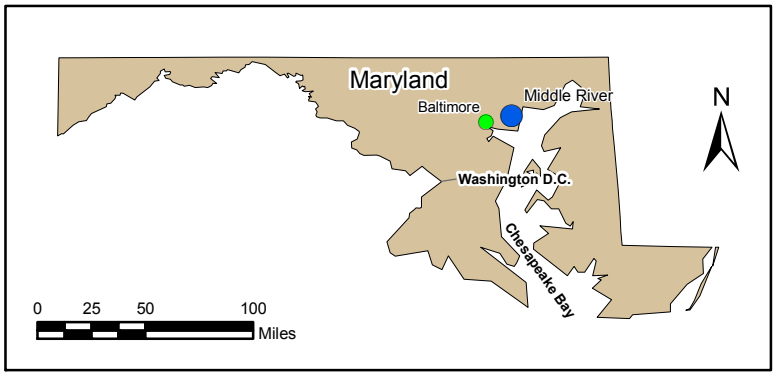

Figure 1-1

Martin State Airport Location Map

Lockheed Martin, Martin State Airport
Middle River, Maryland

DATE MODIFIED:	8/03/10	CREATED BY:	MP

Tetra Tech, Inc.

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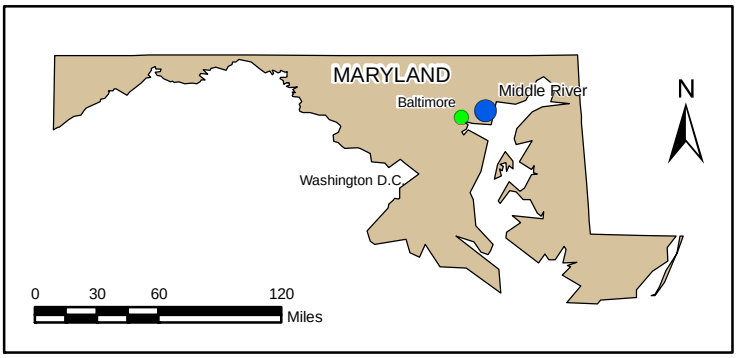

Figure 1-2

Dump Road Area Site Location Map

Lockheed Martin, Martin State Airport
Middle River, Maryland

DATE MODIFIED:	CREATED BY:
8/03/10	MP

Tetra Tech, Inc.

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Figure 1-3

Site Features and Early Areas of Concern Dump Road Area Site

Legend

Pond

Lockheed Martin, Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

DATE MODIFIED: 8/03/10

CREATED BY: MP

Tetra Tech, Inc.

Map Document: (K:\GProject\MartinStateAirport-LMC\MapDocs\MXD\Maps\Groundwater monitoring well locs_figure 1-4.mxd)
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MW34S
MW34I
MARYLAND AIR NATIONAL GUARD
Gate
MW33S
MW33I
MW27D
MW28I
MW16S
MW16I
MW16D
MW17S
MW17I
MW17D
MW14I
MW14D
Gate
MW15S
MW15I
MW15D
POND #2
MW18S
MW18I
MW18D
FROG MORTAR CREEK
MW4
Petroleum Hydrocarbon Area
DMW9I/DMW9S
DMW9D
DMW3I
DMW3S
DMW3D
MW7
MW26S
MW26I
MW26D
POND #1
DMW2A/B
RW1S
OW1S
RW1I
DMW2S
OW1I
DMW10I/DMW10S
MW20S
MW20I
MW20D
DMW4I
DMW4S
DMW4D
MW25S
MW25I
DMW8I
DMW8S
DMW8D
MW3
MW21I
MW21D
DMW1S
MW22I
MW22D
DMW1A/DMW1B
DMW5I
DMW5S
DMW5D
TAXIWAY TANGO
DMW11I
DMW11S
TT-11
MW23S
MW23I
MW23D
MW5
DMW7S
DMW7D
Drum Area
DMW6I
DMW6S
DMW6D
MW19I
MW19D
MW2
AIRPORT RUNWAY
TT-12
TT-14
MW1
Gate
MW6
TT-13
MW24S
MW24I
MW32S
MW32I
MW30D
MW29D
MW31D

Figure 1-4

Groundwater Monitoring Well Locations Dump Road Area Site

Legend

- Monitoring Well
- Ponds

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

DATE MODIFIED: 8/03/10

CREATED BY: MP

Tetra Tech, Inc.

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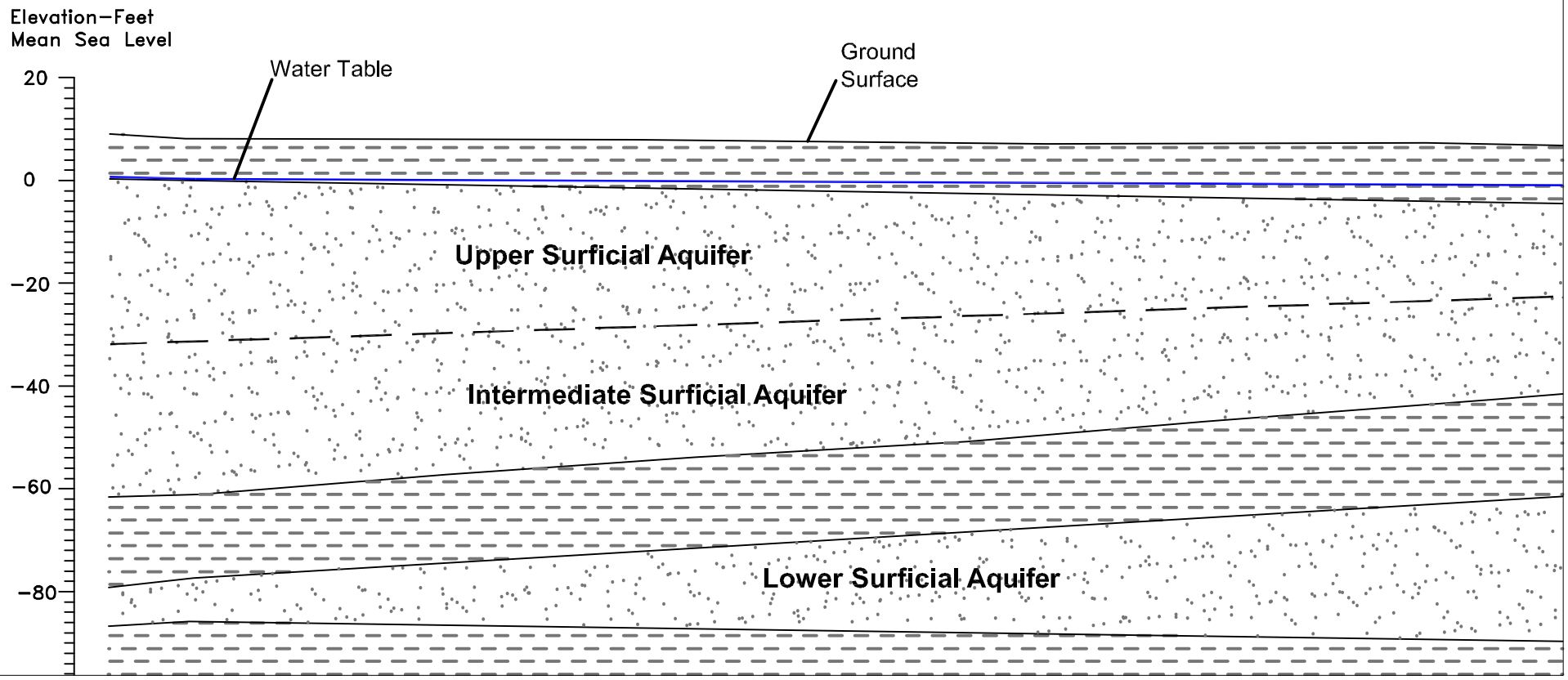

LEGEND

SAND AND-SAND SILT MIXTURES

CLAY AND CLAY MIXTURES

Figure 1-5
Generalized Cross-Section of Surficial Aquifer Dump Road Area Site

Lockheed Martin, Martin State Airport, Middle River, Maryland

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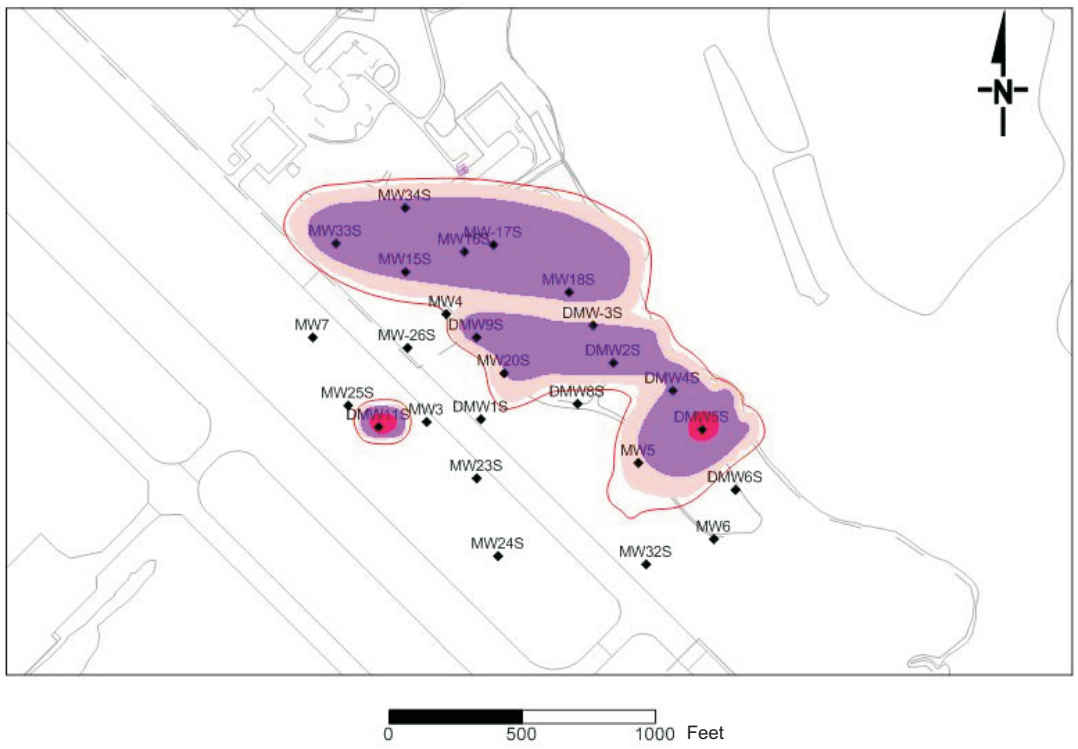
8/10/10

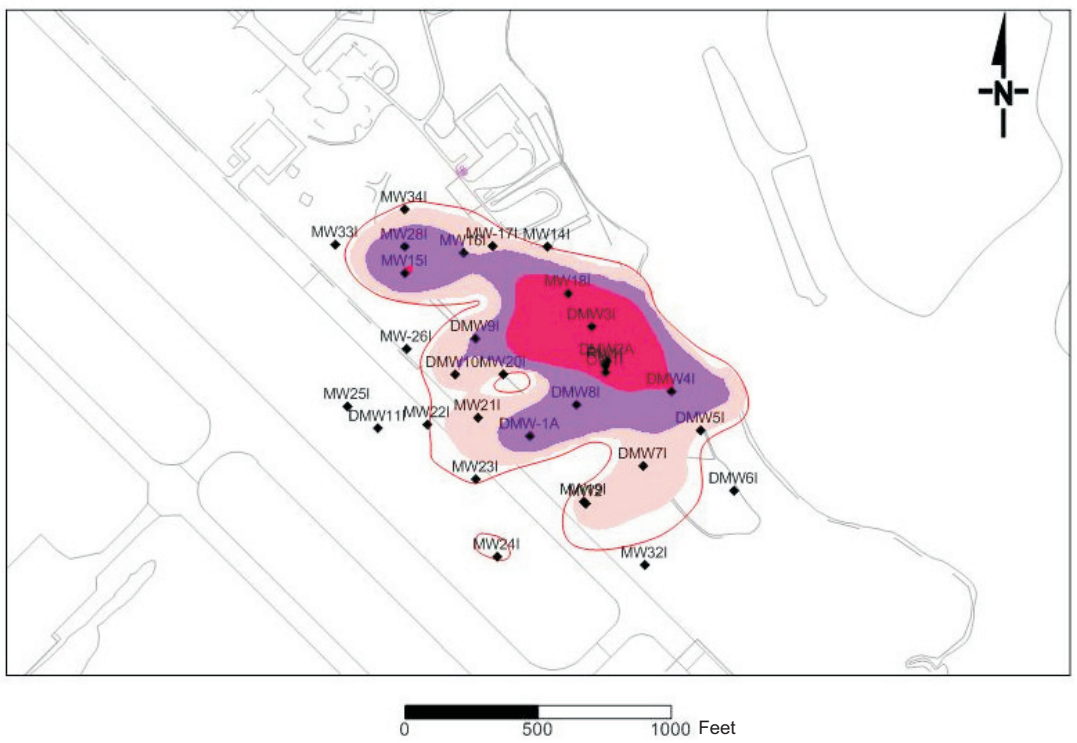
CREATED BY
MP

Tetra Tech, Inc.

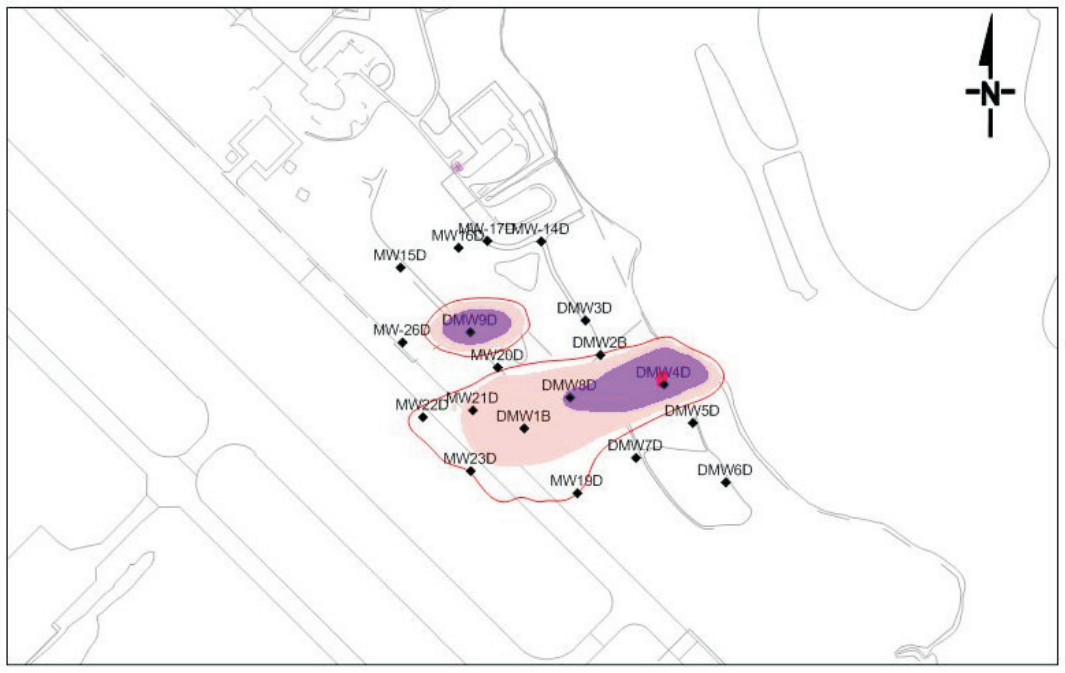
Upper Surficial Aquifer



Intermediate Surficial Aquifer



Lower Surficial Aquifer



Concentration ug/L

5000

500

50

5

5 ug/L

Note: Contours generated by groundwater model

Tetra Tech NUS, Inc

Groundwater Plume - Trichloroethene
Dump Road Area Site
Lockheed Martin, Martin State Airport
Middle River, Maryland

SCALE	AS NOTED
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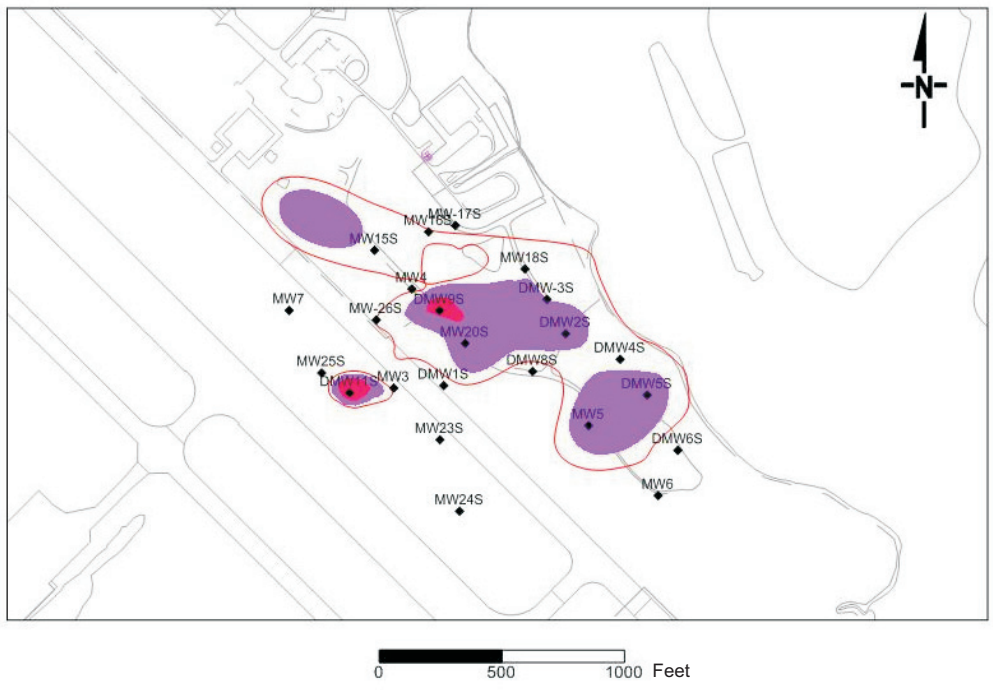
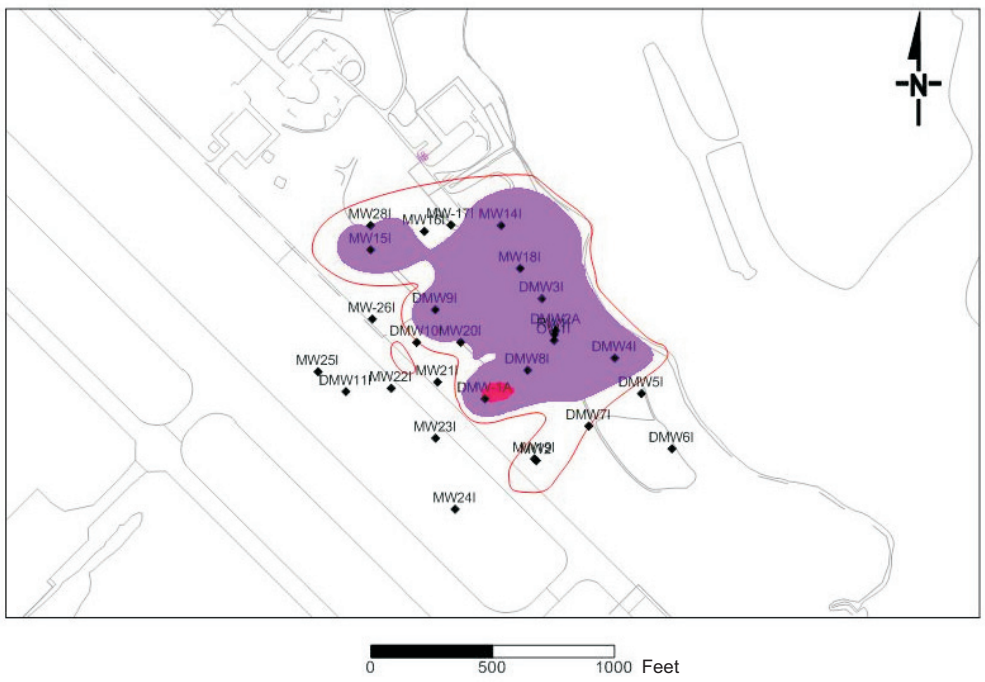
FIGURE NUMBER	1-6

Upper Surficial Aquifer



Intermediate Surficial Aquifer



Concentration ug/L

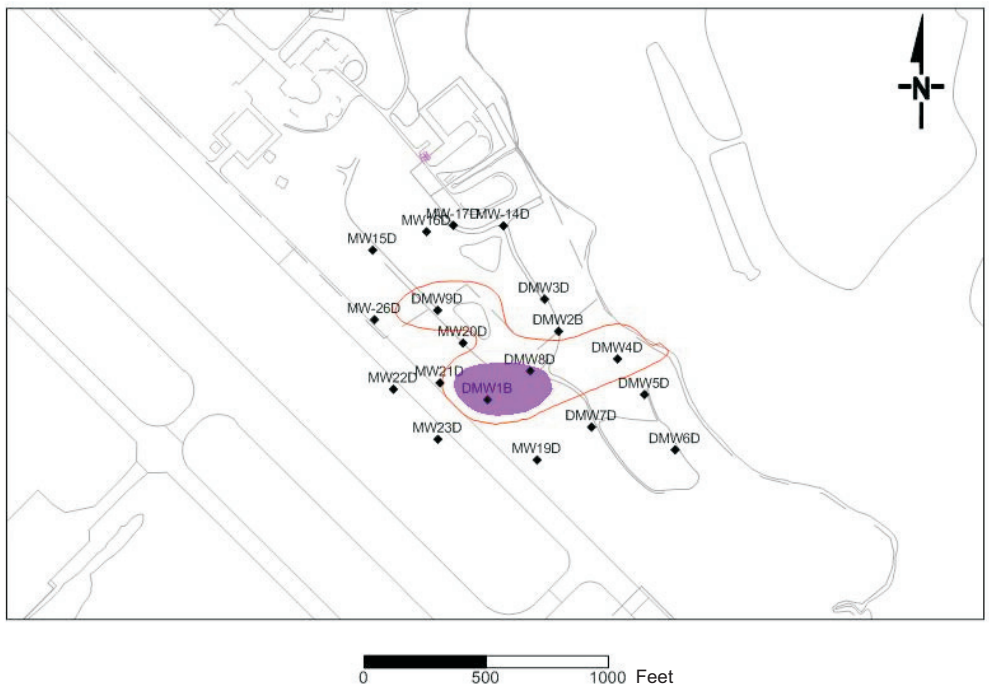
5000

500

70

70 ug/L

Lower Surficial Aquifer



Note: Contours generated by groundwater model

Tetra Tech NUS, Inc

Groundwater Plume - cis- 1,2- Dichloroethene
Dump Road Area Site
Lockheed Martin, Martin State Airport
Middle River, Maryland

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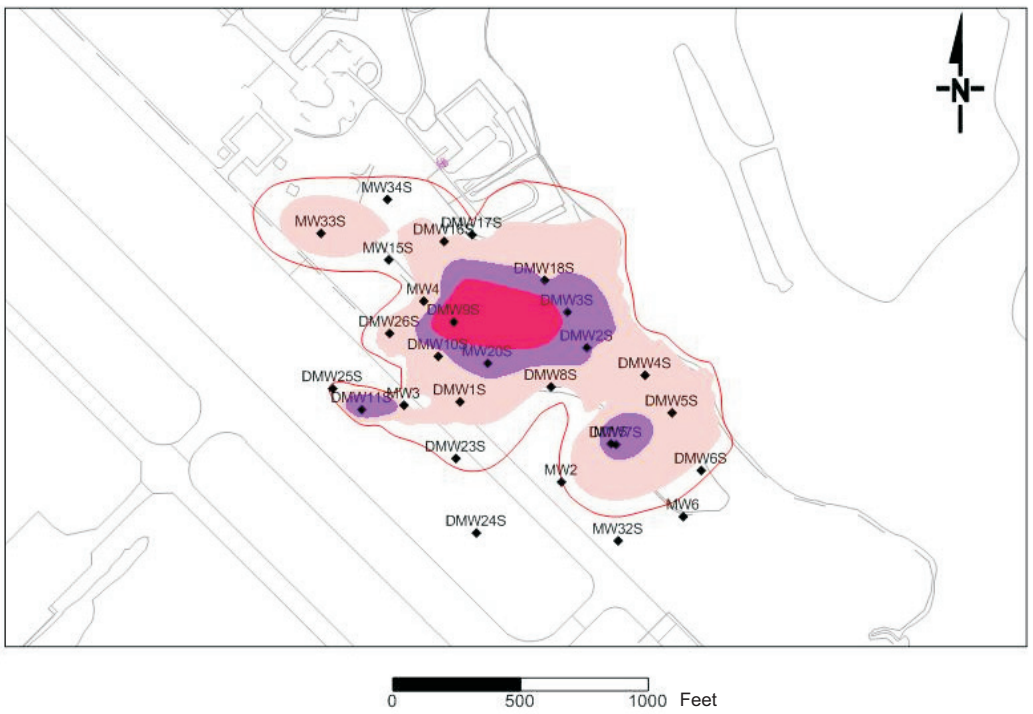
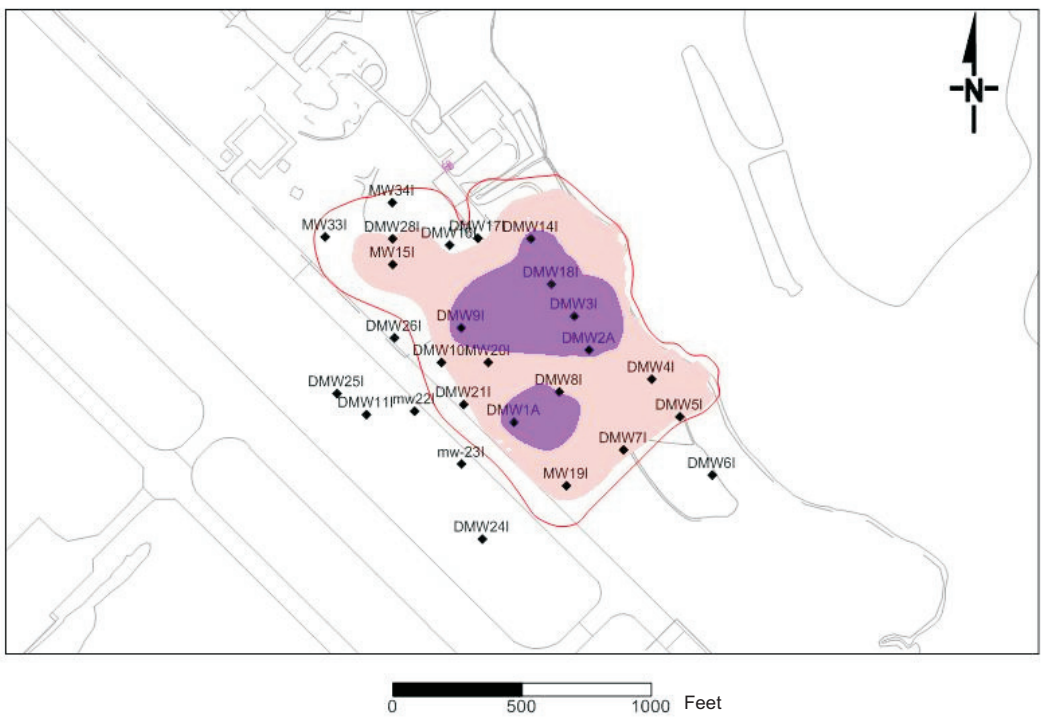
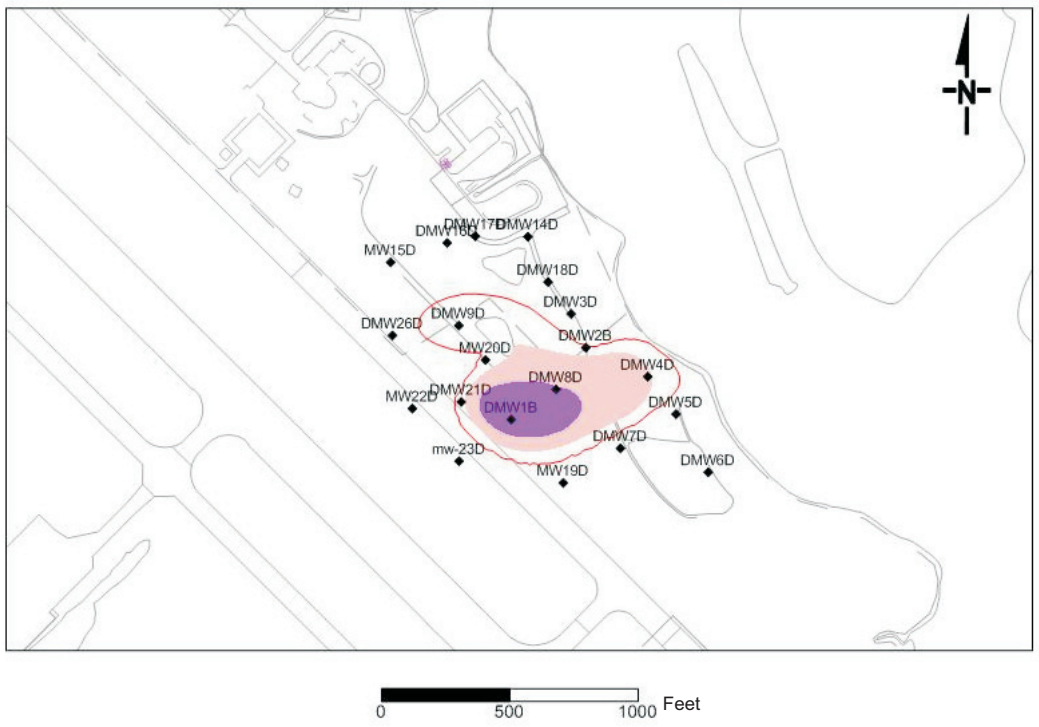
Upper Surficial Aquifer



Intermediate Surficial Aquifer



Lower Surficial Aquifer



Concentration ug/L

5000

500

50

2

2 ug/L

Note: Contours generated by groundwater model

Tetra Tech NUS, Inc

Groundwater Plume - Vinyl Chloride
Dump Road Area Site
Lockheed Martin, Martin State Airport
Middle River, Maryland

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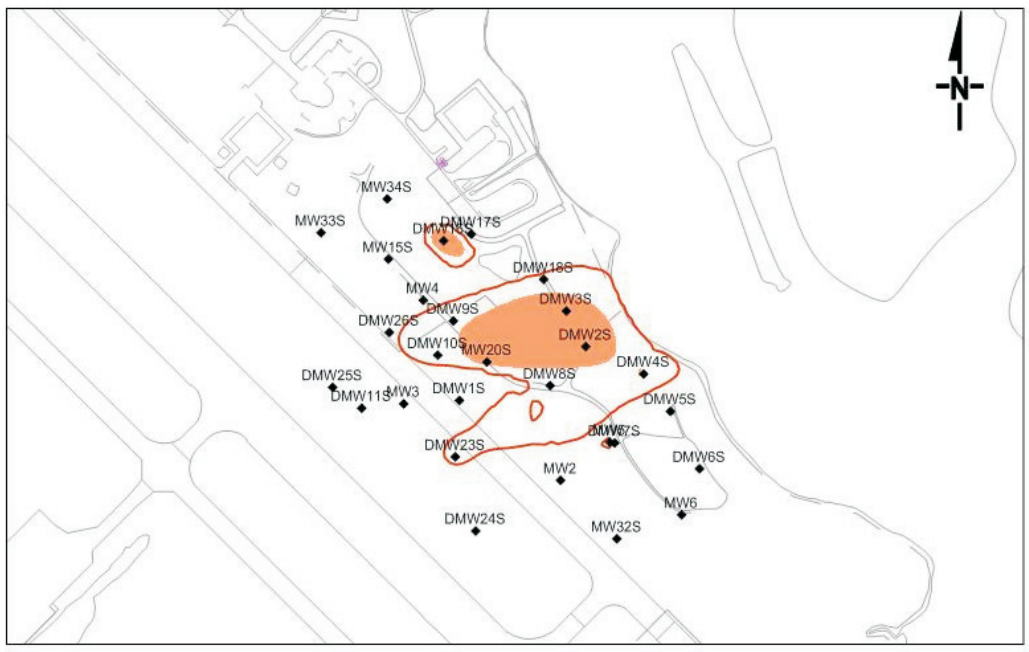
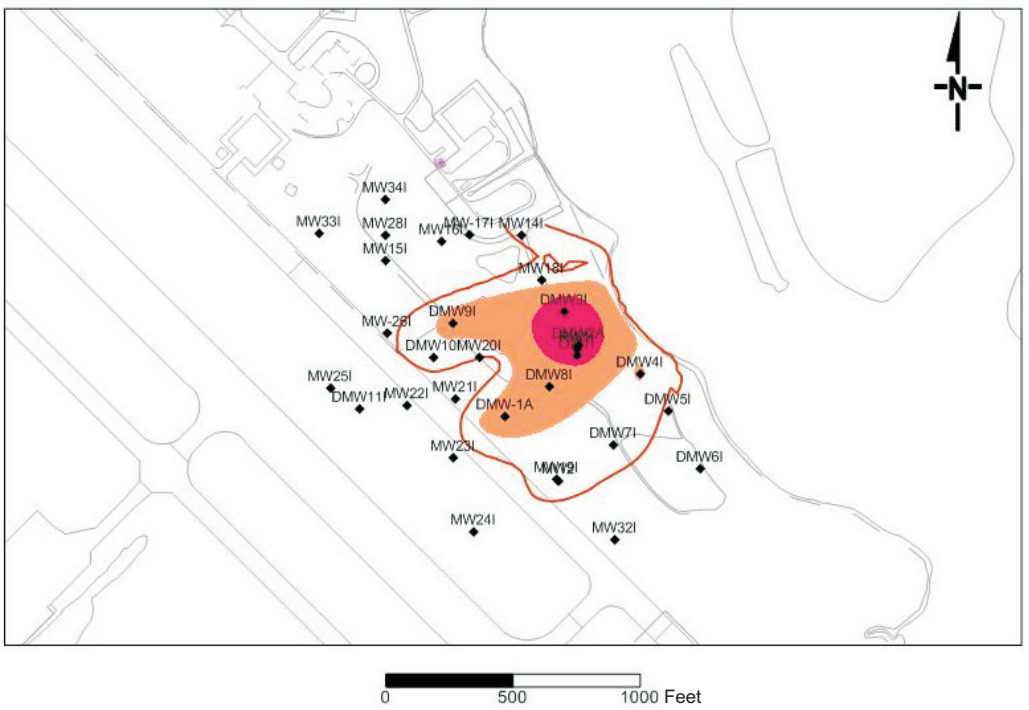
FIGURE NUMBER	1-8

Upper Surficial Aquifer



Intermediate Surficial Aquifer



Lower Surficial Aquifer



Note: Contours generated by groundwater model

Concentration ug/L



6 ug/L

Tetra Tech NUS, Inc

Groundwater Plume - 1,4- Dioxane
Dump Road Area Site
Lockheed Martin, Martin State Airport
Middle River, Maryland

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Section 2
Remedial Action Objectives and General Response Actions

The development of remedial action objectives (RAOs) and cleanup goals for contaminated groundwater is presented in this section. Regulatory requirements and guidance [e.g., applicable or relevant and appropriate requirements (ARARs)] that may potentially govern remedial activities are also presented in this section. In addition, chemicals of concern (COCs), the conceptual pathways through which these COCs may affect human health and the environment, and general response actions (GRAs) that may be suitable to achieve the cleanup goals are presented. Finally, estimates of the volumes of contaminated groundwater present at the site are provided.

2.1 ENVIRONMENTAL MEDIA OF CONCERN

This document addresses contaminated groundwater at the Dump Road Area (DRA) Site, based on the discussions in Section 1. Chemicals of concern migrating as vapor from groundwater to indoor air could potentially expose occupants of a future residence or industrial building above the groundwater plume. Although no buildings exist above the plume now, the site could be developed in the future.

2.2 CHEMICALS OF CONCERN FOR REMEDIATION

The DRA Site is currently undeveloped and consists of open space adjacent to the airport taxiway. Consistent with airport operations, current site use would be considered commercial/industrial. Anticipated future land use is not expected to change and so would remain classified as commercial/industrial. However, the Maryland Aviation Administration (MAA) may consider the site for future development or expansion of the Maryland Air National Guard (MDANG) leasehold.

Chemicals of concern in groundwater were identified based on the human health risk assessment (HHRA) prepared during the remedial investigation (RI) (Table 2-1). Perchlorate was also evaluated in the HHRA, but no unacceptable risk was identified. Several COCs were also detected at concentrations that would lead to unacceptable risk based on the vapor intrusion pathway. The exposure pathway (direct exposure and/or vapor intrusion) for each COC is/are noted in Table 2-1.

2.3 REMEDIAL ACTION OBJECTIVES

The RAOs are medium-specific goals that define the objective of conducting remedial actions to protect human health and the environment. They specify the COCs, potential exposure routes and receptors, and acceptable concentrations (i.e., cleanup goals) for the site. Developing cleanup goals requires consideration of chemical-specific ARARs and guidance documents when promulgated criteria are unavailable. Section 2.3.2 identifies ARARs and other relevant guidance for groundwater remediation.

2.3.1 Statement of Remedial Action Objectives

The following RAOs were developed for groundwater for the interim remedial action at the DRA Site:

- ***Groundwater RAO No. 1 —*** Prevent the lateral migration of contaminated groundwater toward Frog Mortar Creek at concentrations that would cause exceedance of ambient water quality criteria or risk-based exposure criteria.

- ***Groundwater RAO No. 2 —*** Prevent human exposure (including via showering, drinking, and irrigation) to groundwater containing COC concentrations greater than preliminary remediation goals (PRGs).

- ***Groundwater RAO No. 3 —*** Prevent exposure of industrial workers and construction workers to VOCs resulting from vapor intrusion into buildings that cause unacceptable risk (total incremental lifetime cancer risk (ILCR) greater than 1×10^{-5} or hazard index (HI) greater than 1).

2.3.2 Applicable or Relevant and Appropriate Requirements and Guidance Criteria

For a site regulated under (or, in the present case, being addressed according to) the federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), remediation requirements generally consist of existing cleanup or control standards or

environmental protection requirements, criteria, or limitations promulgated under other federal or state environmental laws and regulations. Requirements may be directly applicable to the actions or conditions at a particular site, or they may be interpreted as relevant and appropriate because the situation is sufficiently similar to the intended application of the requirements. In addition to laws and regulations, other advisories, criteria, or guidance developed by EPA, other federal agencies, or states must be considered in developing CERCLA remedies. These applicable or relevant and appropriate requirements are referred to as ARARs.

Note that the DRA site is not a CERCLA site, so the only regulatory requirements that must be considered are those that are "applicable." Maryland Department of the Environment (MDE) regulations, such as Maryland's Hazardous Substance Response Plan, are considered applicable. Interpretations of regulations that might be "relevant and appropriate" are not required.

ARARs fall into three categories: chemical-specific ARARs are health- or risk-based numerical values or methodologies that establish concentration or discharge limits for particular contaminants. Location-specific ARARs restrict actions or contaminant concentrations in certain environmentally sensitive areas, such as floodplains or wetlands. Action-specific ARARs are technology- or activity-based requirements, limitations on actions, or conditions for specific activities, such as closure requirements for hazardous waste treatment, storage, or disposal facilities.

Federal and Maryland chemical-specific ARARs and groundwater guidance are presented in Table 2-2. Federal and Maryland location-specific ARARs and groundwater guidance are presented in Table 2-3. Action-specific ARARs and guidance are discussed along with GRAs in Section 2.5.2.

2.4 PRELIMINARY REMEDIATION GOALS

Preliminary remediation goals (PRGs) were developed to establish target cleanup goals for remedial actions to reduce COC concentrations in DRA Site groundwater and to mitigate unacceptable risks to human health and the environment associated with this groundwater. Preliminary remediation goals must protect current and anticipated future receptors identified at the site, and should be reasonable and practical to implement. These goals can be developed

based on chemical-specific ARARs (when available) or risk-based factors. The presence of COCs at concentrations greater than background is also considered in developing PRGs. However, a site-specific background data set for groundwater has not been developed for the DRA Site, and no generic state-wide background values are available. Thus, background concentrations will not be used to develop PRGs. The methods used to develop candidate PRGs are discussed below.

2.4.1 Applicable or Relevant and Appropriate Requirements and Guidance-Based Preliminary Remediation Goals

Federal maximum contaminant levels (MCLs) and non-zero MCL goals (MCLGs) have been identified as potential chemical-specific ARARs for groundwater at the DRA Site. These values are included in Table 2-4. Maximum contaminant levels are promulgated, legally enforceable standards for drinking water. Available MCLs and non-zero MCLGs were considered in selecting PRGs for groundwater because the site is underlain by a potential drinking water source area.

Maryland Department of the Environment cleanup standards were also identified as potential chemical-specific ARARs for groundwater at the site. These values are included in Table 2-4. Maryland Department of the Environment cleanup standards may be used at the discretion of the site owner. Property-specific cleanup standards may be developed using approved risk assessment techniques. Maryland Department of the Environment groundwater cleanup standards were considered for COCs lacking MCLs or MCLGs.

2.4.2 Human Health Risk-Based Preliminary Remediation Goals

Chemicals with unacceptable human health risks were identified as COCs for human receptors in Section 2.2. Human health risk-based PRGs were developed for the COCs. Human health risk assessment risk calculations are provided in the RI report (Tetra Tech, 2010b). The methodology used to derive PRGs is described below.

To develop a range of options for reducing human health risks at the site, potential groundwater PRGs representing human cancer risk levels of 1×10^{-4}, 1×10^{-5}, and 1×10^{-6}, and non-cancer hazard indices of 0.1 and 1, were calculated for each COC, based on the RI report. Risk-based PRGs were calculated using exposure assumptions developed for residential and construction

worker exposure to site groundwater. The residential scenario is considered because of uncertainty about future site use.

The RI report contained risks calculated for the vapor intrusion pathway for residential and industrial scenarios. Preliminary remediation goals for vapor intrusion for residential and industrial scenarios were developed for a 1×10^{-6} cancer risk level and an HI of 1. However, only the industrial scenario for vapor intrusion was considered in overall PRG selection, due to current and expected land use. If residential uses are ever proposed for the site, additional remedial actions to address vapor intrusion will need to be evaluated at that time.

The range of potential cancer and non-cancer risk-based groundwater PRGs for human health COCs is presented in Table 2-4. Consistent with MDE methodology for developing cleanup standards, the lower of the values representing the 10^{-6} cancer risk level and an HI of 0.1 for each COC was selected as the human health risk-based PRG. These conservative values were selected so that the overall site risks would be less than a 10^{-5} cancer risk level and an HI of 1.

2.4.3 Selection of Preliminary Remediation Goals

The selected PRGs are the COC concentrations that would provide the greatest level of protection of human health and the environment, while still being reasonably achievable by current remediation techniques. The rationale for PRG selection is described below. Potential and selected PRGs for each COC and their basis for selection are presented in Table 2-4.

PRGs were selected from ARARs (either MCLs or non-zero MCLGs), if available. If an MCL or non-zero MCLG was not available, then the residential risk-based PRG and MDE cleanup standard were considered. Residential risk-based PRGs were considered consistent with MCLs, which are also based on residential use. The larger of the two values was selected because both represent comparable exposure scenarios (since the residential risk-based PRGs are comparable to the MDE cleanup standards). However, the following exceptions (for iron and manganese) were made to this approach. For iron and manganese, USEPA Regional Sreening Levels were used because the secondary drinking water criteria (used to develop MDE cleanup standards) are based on aesthetic considerations. The less conservative values were selected because the groundwater would not be used as a potable water source.

For cobalt, the risk-based PRG (based on an HI of 0.1) is very low. Cobalt is not a priority pollutant, and has no MCL. Therefore, a more reasonable and slightly less conservative PRG based on an HI of 1 was used.

The selected PRGs for groundwater are summarized in Table 2-4. A comparison of site data with the proposed PRGs for groundwater is provided in Table 2-5, which shows the maximum concentrations and the number of times each COC was detected at a concentration greater than the PRG. The number of exceedances of the PRGs provides an indication of the extent of contamination.

2.5 GENERAL RESPONSE ACTIONS AND ACTION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

General response actions are broadly defined remedial approaches that may be used (either by themselves or in combination with one or more of the others) to attain RAOs. Action-specific ARARs and guidance are those regulations, criteria, and guidance that must be complied with or considered during remedial activities at a site.

2.5.1 General Response Actions

The following GRAs will be considered for the interim remedial action for groundwater at the DRA Site:

- No action
- Limited action (such as natural attenuation, land use controls (LUCs), and monitoring)
- Containment
- Removal
- *In situ* (in place) treatment
- *Ex situ* (on-site) treatment
- Disposal

2.5.2 Action-Specific Applicable or Relevant and Appropriate Requirements

Table 2-6 includes federal and state action-specific ARARs and guidance for groundwater.

2.6 ESTIMATED VOLUME OF CONTAMINATED GROUNDWATER AND MASS OF CONTAMINANTS

2.6.1 Volume of Contaminated Groundwater

Trichloroethene (TCE), cis-1,2-dichloroethene (DCE), vinyl chloride, and 1,4-dioxane are referred to as primary COCs because they are detected frequently throughout the site at concentrations significantly greater than their PRGs. The extent of contaminated groundwater in each zone of the surficial aquifer for the primary COCs is shown in Figures 1-6 through 1-9. These figures also show selected intermediate concentration contours. The plume extends from the water table to a depth of approximately 90 to 100 feet below ground surface (bgs). The porosity value, based on site investigation data, is 0.28.

The volume of groundwater in the plume is approximately 210 million gallons, as calculated in the groundwater model (see Appendix B) based on TCE, cis-1,2-DCE, vinyl chloride, and 1,4-dioxane concentrations greater than 5 micrograms per liter (µg/L). This volume also includes additional COCs and other contaminants, such as cadmium, petroleum hydrocarbons, diesel range organics (DRO), and gasoline range organics (GRO).

2.6.2 Masses of Contaminants— Dissolved and Adsorbed Phases

The masses of contaminants in groundwater and adsorbed to saturated soil were estimated using investigation data and the groundwater model. Partition coefficients were obtained from the scientific literature, and the value for organic carbon in the soil was estimated from site data. The mass of each primary COC in groundwater (TCE, cis-1,2-DCE, vinyl chloride, and 1,4-dioxane) is summarized at right. These calculations are included in Appendix C. Although other contaminants are present (see Table 2-1), their masses were not quantified because their concentrations and/or frequencies of detections are low compared to the primary COCs (see Table 2-5).

Contaminant	Mass (lb)
TCE	6,400
cis-1,2-DCE	3,300
Vinyl chloride	5,800
1,4-Dioxane	280

Table 2-1

Contaminants of Concern in Groundwater - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Contaminant	Direct Exposure	Vapor Intrusion
Organic Compounds		
1,1- Dichloroethene	X	
1,1- Dichloroethane	X	
1,1,2,2 -Tetrachloroethane	X	
1,2- Dichloroethane	X	X
1,2,3 - Trichlorobenzene	X	
1,2,4 - Trichlorobenzene	X	
1,2,4 - Trimethylbenzene	X	
1,3,5 - Trimethylbenzene	X	
1,4-Dioxane	X	
Benzene	X	X
Carbon tetrachloride	X	X
Chlorobenzene	X	
Chloroform	X	X
cis-1,2-Dichloroethene	X	
Ethylbenzene	X	X
Methylene chloride	X	
Naphthalene	X	
Tetrachloroethene	X	
Toluene	X	
trans-1,2- Dichloroethene	X	X
Trichloroethene	X	X
Vinyl chloride	X	X
Xylenes	X	X
Inorganics		
Antimony	X	
Arsenic	X	
Barium	X	
Beryllium	X	
Cobalt	X	
Copper	X	
Cadmium	X	
Chromium	X	
Iron	X	
Manganese	X	
Mercury	X	
Nickel	X	
Nitrate	X	
Nitrite	X	
Perchlorate	X	
Selenium	X	
Thallium	X	
Vanadium	X	
Zinc	X	

Notes:
An “X” indicates the exposure pathway.

Table 2-2

Chemical-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
Safe Drinking Water Act (SDWA) Regulations, Maximum Contaminant Levels (MCLs)	40 Code of Federal Regulations (CFR) Part 141 subparts B and G	Applicable	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 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				
Regulation of Water Supply, Sewage Disposal, and Solid Waste Drinking Water Quality	Code of Maryland Regulations (COMAR) 26.04.01	Applicable	Establishes drinking water standards for public water systems.	Would be used as protective levels for groundwater that are current or potential drinking water sources.

Table 2-2

Chemical-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Ground Water Quality Standards	COMAR 26.08.02.09	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 2-3

Location-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal				
Endangered Species Act Regulations	50 CFR Parts 81, 225, and 402	Applicable	This act requires federal agencies to take action to avoid jeopardizing the continued existence of federally listed endangered or threatened species.	If remediation could potentially affect an endangered species or its habitat, these regulations would apply (no endangered species or associated habitats have been identified at MSA, although bald eagles are known to nest in the general vicinity).
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	Applicable	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.
Threatened and Endangered Species	Code of Maryland Regulations (COMAR) 03.08	Applicable	Provides for conservation of threatened and endangered species of animal and plants.	If remediation could potentially affect an endangered species or its habitat, these regulations would apply (no endangered species or associated habitats have been identified at MSA, although bald eagles are known to nest in the general vicinity).

Table 2-3

Location-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State (continued)				
Critical Area Act	Annotated Code of Maryland 8-1808(d); COMAR 27	Applicable	The Act regulates and restricts land development to: minimize adverse impacts on water quality; conserve fish, wildlife, and plant habitat; and establish land-use policies for development that accommodate growth. Commission reviews developments in critical areas of the Chesapeake and Atlantic Coastal Bay. Administered on the county level.	According to the county classification mapping, the site classification is an intensely developed area which is the least restrictive classification.

Table 2-4

Selection of Human Health Risk-Based Groundwater PRGs - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Chemical	USEPA RSL[(1)] (ug/L)	Con Workers		Child Res		Adolescent Res		Adult Res		Lifelong Res	
		Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)
1,1-Dichloroethane	2.4	NA	NA	30	290	24	390	18	680	7.6	NA
1,1-Dichloroethene	260	NA	NA	NA	69	NA	95	NA	NA	NA	NA
1,2-Dichloroethane	0.15	NA	NA	1.9	8.9	1.5	12	1.2	21	0.5	NA
1,1,2,2-Tetrachloroethane	0.066	NA	NA	0.81	28	0.67	38	0.61	65	0.23	NA
1,2,3-Trichlorobenzene	5.2	NA	NA	NA	0.5	NA	0.82	NA	1.2	NA	NA
1,2,4-Trichlorobenzene	3.9	460	880	2.8	6.9	2.6	11	2.7	3.4	0.89	NA
1,2,4-Trimethylbenzene	15	NA	NA	NA	NA	NA	NA	NA	11	NA	NA
1,3,5-Trimethylbenzene	87	NA	NA	NA	8.8	NA	13	NA	20	NA	NA
Benzene	0.39	NA	NA	2.9	5.4	2.4	7.5	2.1	9.5	0.81	NA
Carbon Tetrachloride	0.39	550	400	2.1	5	1.7	70	1.8	11	0.62	NA
Chlorobenzene	72	NA	NA	NA	23	NA	33	NA	32	NA	NA
Chloroform	0.19	1,070	6000	5.4	14	4.4	20	2.1	28	1.1	NA
cis-1,2-Dichloroethene	28	NA	1600	NA	2.8	NA	3.8	NA	6.5	NA	NA
trans-1,2-Dichloroethene	86	NA	NA	NA	28	NA	38	NA	37	NA	NA
Ethylbenzene	1.3	NA	NA	10	99	9.2	140	7.6	200	3.0	NA
Methylene Chloride	84	NA	NA	16	9	24	12	87	21	8.8	NA
Naphthalene	0.14	NA	NA	NA	19	NA	28	3.5	6.1	3.5	NA
Tetrachloroethene	35	NA	NA	55	6	48	8.7	47	12	0.19	NA
Toluene	860	NA	NA	NA	93	NA	130	NA	210	NA	NA
Trichloroethene	2.6	1,300	36	1.8	0.67	0.062	0.93	3.0	1.1	4.0	NA
Total Xylenes	190	NA	NA	NA	200	NA	300	NA	110	NA	NA
Vinyl Chloride	0.015	97	0.0046	0.051	4.5	0.22	6	0.26	9.5	0.049	NA
1,4-Dioxane	0.67	970	4200	1.8	47	1.5	62	1.8	110	0.6	NA
Antimony	6	NA	NA	NA	0.6	NA	0.81	NA	1.4	NA	NA
Arsenic	0.045	62	40	0.12	0.47	0.097	0.62	0.12	1.1	0.037	NA
Barium	2900	NA	NA	NA	286	NA	396	NA	679	NA	NA
Beryllium	16	NA	NA	NA	1.6	NA	2.7	NA	4.2	NA	NA
Cadmium	6.9	NA	30.6	NA	0.69	NA	0.97	NA	1.7	NA	NA
Chromium	0.031	32	450	0.045	3.1	0.075	4.8	0.26	7.7	0.025	NA

Table 2-4

Selection of Human Health Risk-Based Groundwater PRGs - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Chemical	USEPA RSL[(1)] (ug/L)	Con Workers		Child Res		Adolescent Res		Adult Res		Lifelong Res	
		Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)	Cancer Risk Level 10^{-6} (ug/L)	Hazard Index = 0.1 (ug/L)
Cobalt	4.7	NA	40	NA	0.47	NA	0.62	NA	1.1	NA	NA
Copper	620	NA	NA	NA	62	NA	83	NA	145	NA	NA
Iron	11000	NA	NA	NA	1090	NA	1450	NA	2540	NA	NA
Lead	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	320	NA	NA	NA	32	NA	46	NA	78	NA	NA
Mercury	4	NA	NA	NA	0.43	NA	0.59	NA	NA	NA	NA
Nickel	300	NA	NA	NA	30	NA	41	NA	71	NA	NA
Selenium	78	NA	NA	NA	7.8	NA	10	NA	18	NA	NA
Thallium	0.16	NA	NA	NA	0.0055	NA	0.01	NA	0.015	NA	NA
Vanadium	78	NA	NA	NA	7.8	NA	10	NA	18	NA	NA
Zinc	4700	NA	NA	NA	467	NA	624	NA	1090	NA	NA
Nitrate	25000	NA	NA	NA	2500	NA	3340	NA	5840	NA	NA
Nitrite	1600	NA	NA	NA	156	NA	208	NA	365	NA	NA
Perchlorate	11	NA	NA	NA	1.1	NA	1.5	NA	2.5	NA	NA
TPH - GRO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TPH - DRO	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 2-4

Selection of Human Health Risk-Based Groundwater PRGs - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Chemical	USEPA RSL[1] (ug/L)	Minimum Con Risk (ug/L)	Minimum Res Risk (ug/L)	Basis for Min Res Risk	USEPA MCL[2] (ug/L)	MDE Cleanup Standard (ug/L)	VI - Ind (ug/L)	Selected PRG (ug/L)	PRG Selection Basis
1,1-Dichloroethane	2.4	NA	7.6	LL-C	NA	90(3)	NA	90	MDE
1,1-Dichloroethene	260	NA	69	CR-NC	7	7	NA	7	MCL
1,2-Dichloroethane	0.15	NA	0.5	LL-C	5	5	NA	5	MCL
1,1,2,2-Tetrachloroethane	0.066	NA	0.23	LL-C	NA	0.053(3)	NA	0.23	Res risk
1,2,3-Trichlorobenzene	5.2	NA	0.5	CR-NC	NA	NA	NA	0.5	Res risk
1,2,4-Trichlorobenzene	3.9	460	0.89	LL-C	70	70(3)	NA	70	MCL
1,2,4-Trimethylbenzene	15	NA	11	AR-NC	NA	NA	NA	11	Res risk
1,3,5-Trimethylbenzene	87	NA	8.8	CR-NC	NA	NA	NA	8.8	Res risk
Benzene	0.39	NA	0.81	LL-C	5	5	120	5	MCL - VI
Carbon Tetrachloride	0.39	400	0.62	LL-C	5	5	32	5	MCL - VI
Chlorobenzene	72	NA	23	CR-NC	100	100	NA	100	MCL
Chloroform	0.19	1070	1.1	LL-C	NA	80(3)	48	80	MDE - VI
cis-1,2-Dichloroethene	28	1600	2.8	CR-NC	70	70	NA	70	MCL
trans-1,2-Dichloroethene	86	NA	28	CR-NC	100	100	NA	100	MCL
Ethylbenzene	1.3	NA	3	LL-C	700	700	350	700	MCL - VI
Methylene Chloride	84	NA	8.8	LL-C	5	5	NA	5	MCL
Naphthalene	0.14	NA	3.5	LL-C	NA	0.65(3)	NA	3.5	Res risk
Tetrachloroethene	35	NA	0.19	LL-C	5	5	NA	5	MCL
Toluene	860	NA	93	CR-NC	1000	1000	NA	1000	MCL
Trichloroethene	2.6	36	0.062	AdR-C	5	5	290	5	MCL - VI
Total Xylenes	190	NA	110	AR-NC	10000	10000	NA	10000	MCL
Vinyl Chloride	0.015	0.0046	0.049	LL-C	2	2	15	2	MCL - VI
1,4-Dioxane	0.67	970	0.6	LL-C	6.1**	NA	NA	6.1	EPA guidance
Antimony	6	NA	0.6	CR-NC	6	6	NA	6	MCL
Arsenic	0.045	40	0.037	LL-C	10	10	NA	10	MCL
Barium	2900	NA	286	CR-NC	2000	2000	NA	2000	MCL
Beryllium	16	NA	1.6	CR-NC	4	4	NA	4	MCL
Cadmium	6.9	31	0.69	CR-NC	5	5	NA	5	MCL
Chromium	0.031	32	0.025	LL-C	100	100	NA	100	MCL

Table 2-4

Selection of Human Health Risk-Based Groundwater PRGs - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Chemical	USEPA RSL[1] (ug/L)	Minimum Con Risk (ug/L)	Minimum Res Risk (ug/L)	Basis for Min Res Risk	USEPA MCL[2] (ug/L)	MDE Cleanup Standard (ug/L)	VI - Ind (ug/L)	Selected PRG (ug/L)	PRG Selection Basis
Cobalt	4.7	40	0.47	CR-NC	NA	NA	NA	4.7	RSL (HI = 1)
Copper	620	NA	62	CR-NC	1300	1300	NA	1300	MCL
Iron	11000	NA	1090	CR-NC	NA	300(3)	NA	11000	RSL (HI = 1)
Lead	NA	NA	NA	NA	15	15	NA	15	MCL
Manganese	320	NA	32	CR-NC	NA	50(3)	NA	320	RSL (HI = 1)
Mercury	4	NA	0.43	CR-NC	2	2	NA	2	MCL
Nickel	300	NA	30	CR-NC	NA	73(3)	NA	73	MDE
Selenium	78	NA	7.8	CR-NC	50	50	NA	50	MCL
Thallium	0.16	NA	0.0055	CR-NC	2	2	NA	2	MCL
Vanadium	78	NA	7.8	CR-NC	NA	3.7(3)	NA	7.8	Res risk
Zinc	4700	NA	467	CR-NC	NA	5000(3)	NA	5000	MDE
Nitrate	25000	NA	2500	CR-NC	10000	10000	NA	10000	MCL
Nitrite	1600	NA	156	CR-NC	1000	1000	NA	1000	MCL
Perchlorate	11	NA	1.1	CR-NC	15	2.6(3)	NA	15	MCL
TPH - GRO	NA	NA	NA	NA	NA	47(3)	NA	47	MDE
TPH - DRO	NA	NA	NA	NA	NA	47(3)	NA	47	MDE

Notes:
NA - Not applicable.
LL - Lifelong resident
AdR - Adolescent resident
AR - Adult resident
CR - Child resident
C - Cancer risk
NC - Non-cancer risk
VI - Vapor instrusion
Ind - Industrial
Res - Residential
Con - Construction

1 - USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites, November 2011. [Cancer benchmark value = 1E-06, Hazard index (HI) = 1.0.

2 - 2009 Edition of the Drinking Water Standards and Health Advisories (USEPA, October 2009).

3 - MDE Cleanup Standards for Soil and Groundwater, 2008. Guidance only.

** - There is no MCL for 1,4-dioxane. This value is EPA guidance.

Table 2-5

Comparison of Groundwater Data with Proposed PRGs - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

COC	PRG	Max Detect	Exceedances/ Sample Count
Volatile Organics (ug/l)			
1,1-DICHLOROETHANE	90	83.3	0/200
1,1-DICHLOROETHENE	7	222	22/200
1,1,2,2-TETRACHLOROETHANE	0.23	20	1/200
1,2-DICHLOROETHANE	5	160	28/200
1,2,3-TRICHLOROBENZENE	0.5	115	5/200
1,2,4-TRICHLOROBENZENE	70	730	8/200
1,2,4-TRIMETHYLBENZENE	11	375	6/200
1,3,5-TRIMETHYLBENZENE	8.8	190	4/62
BENZENE	5	570	24/200
CARBON TETRACHLORIDE	5	430	7/200
CHLOROBENZENE	100	720	7/200
CHLOROFORM	80	1,870	11/200
CIS-1,2-DICHLOROETHENE	70	41,000	88/200
ETHYLBENZENE	700	2,610	3/200
METHYLENE CHLORIDE	5	140	18/200
TETRACHLOROETHENE	5	40.9	10/200
TOLUENE	1000	6,500	6/200
TOTAL XYLENES	10000	28,500	3/200
TRANS-1,2-DICHLOROETHENE	100	376	7/200
TRICHLOROETHENE	5	41,100	101/200
VINYL CHLORIDE	2	56,000	108/200
Semivolatile Organics (ug/l)			
1,4-DIOXANE	6.1	1,800	79/199
NAPHTHALENE	3.5	63.3	5/208

Table 2-5

Comparison of Groundwater Data with Proposed PRGs - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

COC	PRG	Max Detect	Exceedances/ Sample Count
Inorganics (mg/l)			
ANTIMONY	0.006	0.0029	0/200
ARSENIC	0.01	0.0822	43/200
BARIUM	2	1.61	0/200
BERYLLIUM	0.004	0.0099	22/200
CADMIUM	0.005	1.13	41/200
CHROMIUM	0.1	0.889	8/200
COBALT	0.0047	0.724	143/200
COPPER	1.3	0.534	0/200
IRON	11	275	87/138
MANGANESE	0.32	13.4	102/138
MERCURY	0.002	0.0132	4/200
NICKEL	0.073	0.991	39/200
SELENIUM	0.05	0.149	2/200
THALLIUM	0.002	0.0005	0/200
VANADIUM	0.0078	0.139	45/200
ZINC	5	3.15	0/200
Filtered Inorganics (mg/l)			
ANTIMONY	0.006	0.0013	0/199
ARSENIC	0.01	0.0773	34/199
BARIUM	2	1.72	0/199
BERYLLIUM	0.004	0.0104	23/199
CADMIUM	0.005	1.07	34/199
CHROMIUM	0.1	0.26	3/199
COBALT	0.0047	0.692	139/199
COPPER	1.3	0.157	0/199
IRON	11	284	87/149
MANGANESE	0.32	12.6	99/137
MERCURY	0.002	0.00034	0/199
NICKEL	0.073	0.942	38/199
SELENIUM	0.05	0.139	1/199
THALLIUM	0.002	0.0004	0/199
VANADIUM	0.0078	0.141	16/199
ZINC	5	2.86	0/199

Table 2-5

Comparison of Groundwater Data with Proposed PRGs - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

COC	PRG	Max Detect	Exceedances/ Sample Count
Miscellaneous (mg/l)			
NITRATE	10	15	1/12
NITRITE	1	2.1	5/12
PERCHLORATE	0.015	8	19/90
Petroleum Hydrocarbons (mg/l)			
DIESEL RANGE ORGANICS	0.047	1.3	13/23
Petroleum Hydrocarbons (ug/l)			
GASOLINE RANGE ORGANICS	47	70,000	15/23

Max Detect - Maximum concentration detected.
PRG - Preliminary remediation goal.
Exceedances /Sample Count - Number of sample detections with concentrations greater than the PRG.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
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	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 groundwater and treatment residuals are hazardous, either by being listed or by exhibiting a hazardous characteristic.
RCRA Regulations, Standards Applicable to Generators	40 CFR 262, Subparts A, B, C, and D	Applicable	Establishes manifesting, pre-transport, and recordkeeping requirements for hazardous waste.	These regulations would apply to investigative-derived waste (IDW) and side streams [such as spent granular activated carbon (GAC)].
RCRA Regulations, Standards Applicable to Transporters of Hazardous Waste	40 CFR 263	Applicable	Establishes manifesting and recordkeeping requirements for transport of hazardous waste.	These regulations would apply to the transportation for off-site disposal of hazardous waste, such as spent GAC.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal (continued)				
RCRA Regulations, Permitting Exemptions	40 CFR 264.1(g)(6) and 270.1(c)(2)(v)	Applicable	Exempts treatment systems that meet the RCRA definition of wastewater treatment unit from RCRA permitting and TSDF requirements of 40 CFR 264.	Because the groundwater is a hazardous waste, the treatment system must be designed to meet the exemption provisions.
RCRA Regulations, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDFs).	40 CFR Part 264	Applicable	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 (such as spent GAC) at an off-site TSDF.
RCRA Regulations, Use and Management of Containers	40 CFR Part 264, Subpart I	Applicable	Sets standards for the storage of containers of hazardous waste.	This requirement would apply to storage of a hazardous waste (for example, contaminated soil or groundwater from monitoring well installation) in containers prior to disposal.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Federal (continued)				
RCRA Regulations, Corrective Action Management Units (CAMUs)	40 CFR Part 264.552	Applicable	CAMUs are special units created to facilitate treatment, storage, and disposal of hazardous wastes managed for implementing cleanup.	If hazardous waste must be managed on the ground at the site (such as excavations for groundwater barriers), then CAMUs may be used without other RCRA permits. MDE has not adopted this rule.
Migratory Bird Treaty Act	16 USC 703-711	Applicable	Protects migratory birds and their nests.	Proposed response action shall not kill migratory birds or destroy their nests and eggs. Bald eagles have been observed nesting in the vicinity of the airport.
Clean Water Act National Pollutant Discharge Elimination System	40 CFR Part 122 through 125, and 131	Applicable	NPDES permits are required for any discharges to navigable waters.	Any alternative that includes discharges into any navigable water would require compliance with these regulations.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State				
Maryland Hazardous Substance Response Plan	Code of Maryland Regulations (COMAR) 26.14.01 and 26.14.02	Applicable	The Hazardous Substances Response Plan establishes the framework for conducting assessment and cleanup activities. The required work is broken into three phases: Assessment; Cleanup; and Operation and Monitoring. MDE evaluates the remedial alternatives and then selects the remedy that is determined to be the most appropriate solution.	These regulations would apply to the evaluation and selection of the remedial alternative.
Maryland Hazardous Waste Management System – Identification	COMAR 26.13.02	Applicable	Identifies definitions and methods of identification of hazardous waste.	These regulations would apply when determining whether or not groundwater and treatment residuals are hazardous, either by being listed or by exhibiting a hazardous characteristic.
Maryland Hazardous Waste Management System – Generators	COMAR 26.13.03	Applicable	Establishes manifesting, pre-transport, and recordkeeping requirements for hazardous waste.	These regulations would apply to IDW and side streams (such as spent GAC).

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State (continued)				
Maryland Hazardous Waste Management System – Transport	COMAR 26.13.04	Applicable	Establishes manifesting and recordkeeping requirements for transport of hazardous waste.	These regulations would apply to the transportation for off-site disposal of hazardous waste, such as spent GAC.
Maryland Hazardous Waste Management System - TSDF	COMAR 26.13.05	Applicable	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.	If response actions involve management of RCRA wastes (such as spent GAC) at an off-site TSDF.
Maryland General Permit for Construction Activity	COMAR 26.17	Applicable	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 during wastewater treatment plant construction.
Water Pollution Surface Water Quality Criteria	COMAR 26.08.02.03	Applicable	Establish minimum standards for surface water quality for each designated use. Standards are available for the protection of human health and the protection of aquatic life.	Considered for determining extent of surface water contamination and discharge criteria for alternatives that involve discharges to surface water.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State (continued)				
Maryland Water Management Erosion and Sediment Control	COMAR 26.17.01	Applicable	Contains requirements for erosion and sediment control during construction.	Remedial actions involving excavation would require submittal of an erosion and sediment control plan and a stormwater management plan during wastewater treatment plant construction.
Maryland Water Management Stormwater Management	COMAR 26.17.02	Applicable	Establishes requirements for stormwater discharges to protect the surface waters of the state.	Remedial actions would consider the impact of the stormwater discharges during wastewater treatment plant construction.
Air Pollution Control; General Administrative Provisions, and Permits, Approvals, and Registration	COMAR 26.11.01 and 26.11.02	Applicable	Establishes permitting requirements for all sources of air pollution.	These regulations would be applied to an air stripper. Permits to construct and operate would be required. (Note that Title V requirements are unlikely to apply because emission rate would be expected to be much less than the permitting thresholds.
Air Quality Toxic Air Pollutants	COMAR 26.11.15 and 26.11.16	Applicable	Establishes standards for industries that emit toxic air pollutants, including sources regulated by NESHAPs.	Hazardous air pollutants may be discharged during groundwater treatment activities, such as air stripping.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State (continued)				
Regulation of Water Supply, Sewage Disposal, and Solid Wastes Well Construction	COMAR 26.04.04	Applicable	Contains design standards and procedures for construction of wells.	The requirements would apply to new monitoring wells, injection wells, and extraction wells.
Maryland Water Pollution Permits	COMAR 26.08.04	Applicable	Contains requirements for discharges to surface water	Any alternative that includes a discharge to surface water would comply with these requirements.
Underground Injection Control	COMAR 26.08.01	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 or reinjection of treated groundwater.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
State (continued)				
Maryland Pollutant Discharge Elimination System: Water Quality, Discharge Limitations, Discharge Permit Limits, and Pretreatment Requirements to POTWs	COMAR 26.08.02, 26.08.03, 26.08.04.02, and 26.08.08	Applicable	These standards govern discharge of water into surface waters and POTWs.	Extracted groundwater would be treated as required prior to discharge to either surface water or POTW.

Table 2-6

Action-Specific Applicable or Relevant and Appropriate Requirements and Other Guidance – Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Requirement	Citation	Status	Synopsis	Evaluation/Action to be Taken
Local				
Baltimore County Department of Public Works and Development Management – Permit to Discharge to Sanitary Sewer	NA	Applicable	Establishes limitations on contaminant concentrations, flow rates, and monitoring requirements.	This permit will be required if treated groundwater is discharged to the POTW.
Baltimore County Grading Permit	NA	Applicable	A grading permit is required for grading or land disturbance greater than 5,000 square feet.	The permit may be needed for the construction of the groundwater treatment plant.

Section 3
Technology Screening and Process Options

Information that describes the identification, screening, and evaluation of potential technologies and process options that may apply to the selection of remedial alternatives for contaminated groundwater at the Dump Road Area (DRA) Site are provided in this section. The primary objective of this phase of the Groundwater Feasibility Study (FS) is to develop an appropriate range of remedial technologies and process options to be used in developing remedial alternatives. This includes completing the following analytical steps:

- Identification and screening of remedial technologies and process options
- Evaluation and selection of representative process options

Various technologies and process options are identified under each general response action (GRA) and are then screened (assessed). The screening is first conducted at a preliminary level to focus on relevant technologies and process options, and then the screening is conducted at a more detailed level based on certain evaluation criteria. Finally, process options are selected to represent technologies that have passed the detailed evaluation and screening.

The evaluation criteria for detailed screening of technologies and process options that have been retained after the preliminary level screening are effectiveness, implementability, and cost:

- ***Effectiveness***
    - Protection of human health and the environment; reduction in toxicity, mobility, or volume of contaminants; and permanence of the solution
    - Ability of the technology to address the estimated areas or volumes of contaminated media

- Ability of the technology to attain the preliminary remediation goals (PRGs) required to achieve the remedial action objectives (RAOs)
- Technical reliability (innovative versus well-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 (O&M) costs

3.1 PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

The results of the identification and screening of remediation technologies and process options for groundwater at a preliminary stage based on implementation with respect to site-specific conditions and chemicals of concern (COCs) are provided in this section. The results of this preliminary screening process are summarized in Table 3-1. It presents the GRAs, identifies the technologies and process options, and provides a brief description of each process option followed by comments about the results of the screening process. The following groundwater technologies and process options remain for detailed screening and are included in Appendix D:

General response action	Technology	Process options
No action	None	Not applicable
Limited action	Land use controls (LUCs)	Groundwater use restrictions, construction restrictions
	Monitoring	Sampling and analysis
	Monitored natural attenuation	Sampling and analysis
Containment	Vertical barrier (physical)	Cut-off walls, grout curtain, sheet piling
	Vertical barrier (hydraulic)	Extraction wells
Removal	Groundwater extraction	Extraction wells
In situ treatment	Biological	Enhanced bioremediation with an electron-donor compound
	Chemical	Permeable reactive barrier (PRB) with zero-valent iron (ZVI)
Ex situ treatment	Physical	Filtration
		Air stripping
		Liquid-phase granular activated carbon (GAC) adsorption
		Vapor-phase GAC adsorption
		Vapor-phase potassium permanganate impregnated zeolite (PPZ) adsorption
		Sedimentation
	Chemical	Coagulation/flocculation
		Neutralization/pH adjustment
		Ion exchange
		Advanced oxidation
Disposal	Surface discharge	Direct surface water discharge
		Indirect discharge to publicly owned treatment works (POTW)
	Subsurface discharge	Reinjection

3.2 SELECTION OF REPRESENTATIVE TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER

The following technologies and process options, under the GRAs as noted, were retained for further development of groundwater containment remedial alternatives, based on the analysis in Appendix D:

- *No action*
- *Containment*: hydraulic barrier
- In situ *treatment*:
  enhanced bioremediation,
  ZVI PRB
- Ex situ *treatment*: filtration,
  air stripping,
  liquid-phase GAC adsorption,
  vapor-phase GAC adsorption,
  vapor-phase PPZ adsorption,
  neutralization/pH adjustment,
  coagulation/flocculation,
  sedimentation,
  ion exchange,
  advanced oxidation
- *Limited action*: LUCs, monitoring
- *Removal*: extraction
- *Disposal*: indirect discharge to POTW,
  reinjection,
  direct discharge

The purpose of this FS is to evaluate containment of and eliminating exposure to contaminated groundwater, which must consider the overall depth of the contaminated groundwater (approximately 90 to 100 feet below ground surface [bgs]) and the wide variety of contaminants (for example, cVOCs, metals, and 1,4-dioxane). Therefore, the number of processes and technologies that can be applied is limited. The primary objective of containment also limits the selection of processes, and contaminant removal technologies that might be applied throughout the plume were not considered. All remediation technologies and processes will be revisited when the FS for the site-wide soil and groundwater remedy is prepared.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
No Action	None	Not Applicable	No activities conducted at site to remedy or monitor contamination. Site is released for unrestricted development.	Retain. No action is retained as a baseline for comparison with other technologies.
Limited Action	Monitoring	Sampling and Analysis	Periodic sampling and analysis of groundwater to track changes in the extent of contamination.	Retain. This technology could assess migration of contaminants and evaluate progress of active remediation.
	Land Use Controls	Active Controls: Physical Barriers/ Security Guards	Fencing, markers, and warning signs to restrict site access.	Retain. Restrictions would be used to prevent damage to cover and wells. Exposure to groundwater would also be restricted.
		Passive Controls: Deed and Land Use Restrictions	Administrative action using LUCs to restrict future site use and to prohibit use of groundwater as a source of drinking water.	Retain. Groundwater is currently not used as a drinking water source, and this technology will limit all future uses of groundwater.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
Limited Action (continued)	Natural Attenuation	Naturally Occurring Biodegradation. Sorption, Dispersion, Volatilization, and Dilution	Monitoring groundwater to assess the reduction in concentrations of COCs through natural processes.	Retain. This technology may decrease concentrations of TCE and other VOCs that may have already migrated beyond the containment. Natural attenuation will occur within the contained area, but only to a limited extent.
Containment	Vertical Barriers	Slurry Wall	Low-permeability wall formed in a perimeter trench to restrict horizontal migration of groundwater.	Retain. Depth to confining layer is approximately 90 feet limiting installation to specialty equipment. Some groundwater treatment required.
		Sheet Piling	Metal or HDPE sheet piling driven/vibrated into the ground to restrict horizontal migration of groundwater.	Retain. This method is effective in the sand, silts, and clays at the site. Shallow surface excavation will be needed to remove debris. Some groundwater treatment required.
		Grout Curtain	Pressure injection of grout to form a low-permeability perimeter wall to restrict horizontal migration of groundwater.	Retain. This method is effective in the sand, silts, and clays at the site. Shallow surface excavation will be needed to remove debris. Some groundwater treatment required.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
Containment (continued)	Vertical Barriers (continued)	Hydraulic Barrier	Use of extraction wells and/or collection trenches to restrict horizontal migration of groundwater.	Retain. Common method applicable to sandy soil. Heterogeneity would affect capture of groundwater and well design. Requires groundwater treatment.
	Horizontal Barriers	Physical Barrier	Injection of bottom-sealing grout beneath source to minimize vertical migration of groundwater.	Eliminate. Confining unit prevents further downward migration of contaminants.
Removal	Groundwater Extraction	Extraction Wells	Series of vertical pumping wells or horizontal wells used to remove contaminated groundwater.	Retain. Would be needed to remove water from infiltration and flow from upgradient area. May be effective in reducing contaminant concentrations in combination with ex-situ treatment. Because of levels of contaminant concentrations, MCLs are unlikely to ever be reached.
		Collection Trench	A permeable trench used to intercept and collect groundwater.	Eliminate. A deep trench would be needed to capture the full depth of the plume. Heterogeneity and aquicludes would limit effectiveness. Depth of trench would be 50 to 80 feet.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
In-Situ Treatment	Biological	Anaerobic/ Aerobic	Enhancement of biodegradation of organics in an anaerobic (oxygen-deficient) or aerobic (oxygen-rich) environment by injection of electron-donor compounds or oxygen source. Microorganism cultures may need to be added.	Retain. Anaerobic reductive dechlorination is effective at removing TCE and other chlorinated VOCs. Would not directly affect inorganics. Sulfides formed during anaerobic activity may precipitate metals. Effectiveness of bioremediation on 1,4-dioxane is uncertain.
	Physical/ Biological	Air Sparging (AS) or AS/ Soil Vapor Extraction (SVE)	Volatilization and enhancement of biodegradation of organic compounds by supply of air with or without capture and treatment of volatilized compounds.	Eliminate. Well and piping installation would need to be coordinated with cover system. Metals are not affected by process. Heterogeneity of subsurface would interfere with air sparging distribution.
		Dynamic Underground Stripping	Steam injection at the periphery of the contaminated area resulting in the vaporization of volatile compounds bound to soil and the movement of contaminants to a centrally located extraction well.	Eliminate. The heterogeneous subsurface would make effective implementation of this method difficult. Metals are not affected by process.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
In-Situ Treatment (continued)	Chemical	Chemical Oxidation	Chemical destruction of organic COCs through oxidation with hydrogen peroxide and ferrous iron (Fenton's Reagent), catalyzed percarbonate (RegenOx™), or potassium permanganate.	Eliminate. Extensive area and subsurface heterogeneity would affect distribution. Metals are not affected by process.
		Permeable Reactive Barrier (PRB)	Use of a PRB with zero-valent iron, which allows the passage of groundwater and reacts with the VOCs.	Retain. Size and depth of contaminant plume would make construction of PRB difficult. Would not be effective for metals and 1,4-dioxane.
	Thermal	Electrical Resistance Heating	Volatilization of organic COCs through groundwater and soil heating with electrodes in combination with vacuum extraction of volatilized material.	Eliminate. Large volume would be costly to treat with this process.
Ex-Situ Treatment	Biological	Aerobic/ Anaerobic	Natural degradation of organic COCs via microorganisms in an aerobic (oxygen-rich) or anaerobic (oxygen-deficient) environment.	Eliminate. VOCs are more readily treated by air stripping and/or GAC. Would not be effective for metals. Effectiveness on 1,4-dioxane is uncertain.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
Ex-Situ Treatment (Continued)	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. Would not be effective on metals and 1,4-dioxane.
		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. Effective for 1,4-dioxane in uncertain.
		Potassium Permanganate Impregnated Zeolite	Removal of vinyl chloride from vapor streams by sorption and subsequent reaction onto zeolite.	Retain. This process is needed because vinyl chloride is poorly removed by vapor-phase GAC.
		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.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
Ex-Situ Treatment (Continued)	Physical (Continued)	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.
		Neutralization/ pH Adjustment	Use of acid or base to counteract high or low pH conditions.	Retain. May be needed for final pH adjustment prior to discharge. May be needed for metals removal. May be needed for incidental removal of iron and manganese.
		Chemical Precipitation	Use of reagents to convert soluble compounds into insoluble compounds.	Eliminate. Metals in groundwater are commonly removed by pH adjustment.
		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.	Retain. May be needed as final polishing step prior to discharge.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

General Response Action	Technology	Process Options	Description	Screening Comment
Ex-Situ Treatment (Continued)	Chemical (Continued)	Advanced Oxidation	Use of oxidizers such as ozone, hydrogen peroxide, or potassium permanganate to break down certain organic compounds.	Retain. This technology is demonstrated for removal of 1,4-dioxane and other VOCs. Metals would not be affected.
Discharge/ Disposal	Surface Discharge	Direct Discharge	Discharge of treated water to surface water.	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 POTWs.	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.	Retain. Water reinjected upgradient of source can be amended to promote bioremediation.

Table 3-1

Preliminary Screening of Remedial Technologies and Process Options for Groundwater
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

AS - Air sparge.
COC - Chemical of concern.
GAC - Granular activated carbon.
HDPE - High-density polyethylene.
POTW - Publicly owned treatment works.
LUC - Land use control.
PRB - Permeable reactive barrier.
STP - Sewage treatment plant.
SVE - Soil vapor extraction.
TCE - Trichloroethene.
VOC - Volatile organic compound.

Section 4
Assembly and Detailed Analysis of Remedial Alternatives

4.1 INTRODUCTION

Each remedial alternative for the interim remedial action was evaluated with respect to the following evaluation criteria set forth in EPA's *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) [40 *Code of Federal Regulations* (CFR), Part 300]. These criteria and their relative importance are described in the following subsections:

- Overall protection of human health and the environment
- Compliance with applicable or relevant and appropriate requirement (ARARs)
- Long-term effectiveness and permanence
- Reduction of contaminant toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- Regulatory agency acceptance
- Community acceptance

An additional non-Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criterion, sustainability, will also be evaluated. Sustainability is an important consideration for Lockheed Martin Corporation and is evaluated here to minimize the environmental footprint of the remedial action, while still protecting human health and the environment. These criteria were applied to the alternatives being evaluated with the view that this will be an interim remedial action, focusing primarily on containment. Maintaining flexibility to expand the system as part of a future final remedy is also an important factor.

4.1.1 Overall Protection of Human Health and the Environment

Remedial alternatives must be assessed for adequate protection of human health and the environment, in both the short and long term, from unacceptable risks posed by hazardous substances or contaminants at the site. This is accomplished by eliminating, reducing, or controlling exposure to contaminant levels exceeding preliminary remediation goals (PRGs). Overall protection draws on the assessments pursuant toother evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

4.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

For sites in the CERCLA program, alternatives must be assessed to determine whether they attain ARARs under federal environmental laws and state environmental or facility siting laws (see Section 2.3.2). However, because remediation of the Dump Road Area (DRA) Site is not being conducted under CERCLA authority, only applicable regulations need to be considered. The relevant and appropriate evaluation process does not apply to this site. In addition, all federal, state, and local permits must be obtained, whereas sites under CERCLA authority do not need to obtain permits.

4.1.3 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 would prove successful. Factors to be considered, as appropriate, include:

- ***Magnitude of residual risk —*** Risk posed by untreated waste or treatment residuals at the conclusion of remedial activities
- ***Adequacy and Reliability of Controls —*** Controls such as containment systems and land use controls (LUCs) that are necessary to manage treatment residuals and untreated waste must be shown to be reliable

4.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The degree to which an alternative uses recycling or treatment to reduce the toxicity, mobility, or volume of contaminants must be assessed, including how treatment addresses principal threats posed by the site. Factors to be considered, as appropriate, include:

- Treatment or recycling processes the alternative uses, and the materials these processes will treat

- The amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled

- The degree of expected reduction in toxicity, mobility, or volume of waste due to treatment or recycling and the specification of which reduction(s) is/are occurring

- The degree to which the treatment is irreversible

- Type and quantity of residuals that will remain following treatment, considering the persistence, toxicity, mobility, and tendency to bioaccumulate of such hazardous substances and their constituents

- The degree to which treatment reduces the inherent hazards posed by principal threats at the site

4.1.5 Short-Term Effectiveness

The short-term effects of the alternative are to be assessed considering the following:

- Short-term risks that might be posed to the community during implementation

- Potential effects on workers during remedial action and the effectiveness and reliability of protective measures

- Potential environmental effects of the remedial action and the effectiveness and reliability of mitigation measures during implementation

- Time until protection of human health and the environment is achieved

4.1.6 Implementability

The ease or difficulty of implementing the alternatives is assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, its reliability, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy

- Administrative feasibility, including activities necessary to coordinate with regulatory agencies and other offices, and the ability and time required to obtain any necessary approvals and permits from relevant agencies (for off-site actions)

- Availability of services and materials, including the availability of adequate off-site treatment, storage, and disposal capacity and services, availability of necessary

equipment and specialists and provisions to ensure necessary additional resources, availability of services and materials, and the availability of prospective technologies

The selected containment alternative must be designed and implemented so that it does not interfere with the soil and landfill waste remediation projects planned for the site. The design of the containment system must include the flexibility to treat additional groundwater if conditions at the site should change, or the final groundwater FS incorporates additional treatment needs.

4.1.7 Sustainability

The sustainability of each alternative will be evaluated. Factors to be considered, as appropriate, include:

- *Environmental factors*, such as energy use and greenhouse gas emissions
- *Resource consumption*
- *Waste generation* as compared to recycling and reuse of materials. The percentage of contaminants destroyed rather than removed is also considered under this category. This component is evaluated as part of the CERCLA criteria, under the "Reduction of Toxicity, Mobility, or Volume through Treatment" criterion
- *Economic factors*, such as life cycle costs, and the development potential of the site after remediation. Costs are considered as part of the CERCLA criteria, under the "Cost" criterion
- *Social factors*, such as traffic and noise. These factors are also considered as part of the CERCLA criteria, under the "Short-Term Effectiveness" criterion

Evaluation of sustainability is consistent with Lockheed Martin's corporate "Go Green" program. Under this program, Lockheed Martin seeks to reduce adverse environmental effects through activities such as improved energy efficiency and reduced waste generation and water usage.

4.1.8 Cost

Capital costs, including both direct and indirect costs, and annual operation and maintenance (O&M) costs will be evaluated for each alternative. A net present worth (NPW) value of the capital and O&M costs, based on a 30-year operating period, is provided for an economic comparison of the alternatives. A current value equal to the sum of the capital costs and annual O&M costs adjusted by an annual inflation rate of 2 percent is also provided. Typically, the cost estimate accuracy range for a feasibility study (FS) is +50 percent to -30 percent.

4.1.9 Regulatory Agency Acceptance

This Groundwater FS was prepared for review and approval by the MDE and is subject to the regulatory requirements of Maryland's Hazardous Substance Response Plan. Maryland's Hazardous Substance Response Plan grants MDE the authority to choose how the cleanup will be performed.. In addition, the property owner, Maryland Aviation Administration (MAA), and property leaser, the Maryland Air National Guard (MDANG), will also be given the opportunity to comment on the Groundwater FS. Regulators' concerns that must be assessed include:

- The position and key concerns of the MDE relative to the preferred and other alternatives
- MDE's comments on ARARs or the proposed use of waivers

These concerns cannot be completely evaluated until the agencies have reviewed and commented on this Groundwater FS and the Proposed Plan to be prepared subsequent to this document.

4.1.10 Community Acceptance

The Groundwater FS, which includes a recommendation for one of the alternatives, and the subsequent Proposed Plan will be made available to the public for review and comment. This criterion consists of community responses to the selected remedy. Comments from the public on the selected remedy will be assessed once they have been received at the conclusion of the public comment period.

4.1.11 Relative Importance of Criteria

The following are considered threshold criteria:

- Overall protection of human health and the environment
- Compliance with ARARs (excluding those that may be waived)

The threshold criteria must be satisfied for an alternative to be eligible for selection. Among the remaining criteria, the following six are the primary balancing criteria:

- Long-term effectiveness and permanence
- Implementability

- Reduction of contaminant toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Sustainability
- Cost

The balancing criteria are used to weigh the relative merits of the alternatives being evaluated. The remaining two criteria, "Regulatory Agency Acceptance" and "Community Acceptance," are modifying criteria that must be considered during remedy selection. These last two criteria will be evaluated after this Groundwater FS has been reviewed by EPA and MDE, and after an alternative has been selected. This document therefore addresses only 8 of the 10 criteria.

4.1.12 Remedy Selection

Remedy selection is expected to follow a two-step process. The first step identifies a preferred alternative (see Section 5.3) which must meet the following criteria:

- Protection of human health and the environment
- Compliance with ARARs

The second step reviews public comments and determines whether the preferred alternative remains the most appropriate remedial action for the site, with EPA and MDE concurrence.

4.2 ASSEMBLY AND DETAILED ANALYSIS OF GROUNDWATER ALTERNATIVES

Based on the detailed screening of technologies and process options presented in Section 3.2, alternatives were developed for the interim remedial action at the DRA Site. These alternatives primarily consider containment of contaminated groundwater at the DRA Site, although some alternatives include limited source area treatment. The design of the containment system must include flexibility for treatment of additional groundwater if conditions at the site change or the final groundwater FS incorporates additional treatment. The following six interim remedial action alternatives were developed:

- ***Alternative G-1 —*** No action

- ***Alternative G-2 —*** Hydraulic control by extraction, *ex situ* treatment of groundwater, discharge to publicly owned treatment works (POTW)/surface water, monitoring, and LUCs

- ***Alternative G-3 —*** Hydraulic control by extraction, *ex situ* treatment of groundwater, reinjection of groundwater, discharge to POTW/surface water, monitoring, and LUCs

- ***Alternative G-4 —*** Hydraulic control by extraction, extraction in high concentration areas (HCAs), *ex situ* treatment of groundwater, reinjection of groundwater, discharge to POTW/surface water, monitoring, and LUCs

- ***Alternative G-5 —*** Hydraulic control by extraction, *ex situ* treatment of groundwater, *in situ* bioremediation of HCAs, discharge to POTW/surface water, monitoring, and LUCs

- ***Alternative G-6 —*** Zero-valent iron (ZVI) permeable reactive barrier (PRB), monitoring, and LUCs

Alternative G-1 was developed and analyzed as a baseline against which the other alternatives can be compared, as required by the NCP. Alternative G-2 was developed as a base case with hydraulic control of the plume only. Groundwater contaminants upgradient of the extraction wells will eventually flow to the extraction wells, but the design does not incorporate acceleration of groundwater cleanup.

Alternative G-3 is an enhanced version of Alternative G-2, in that some of the treated groundwater will be amended with an electron-donor compound and then reinjected upgradient of the HCAs to promote biological remediation. The treatment system in this alternative is sized for a larger flow rate to address the potential for flexibility in future operations, including the final site groundwater remedy. Alternative G-4 is a more aggressive extraction and treatment approach that includes extraction, treatment of highly contaminated groundwater from the HCAs, and reinjection of treated groundwater (with amendments to promote biological activity). Treating additional groundwater may reduce the time required to restore groundwater quality.

Alternative G-5 is similar to Alternative G-4 in that highly contaminated groundwater in the HCAs is treated. In Alternative G-5, highly contaminated groundwater in the HCAs is treated *in situ* by enhanced bioremediation to reduce the time to restore groundwater quality, but extracted groundwater is not reinjected. The treatment system in this alternative is also sized for a larger flow rate to permit flexibility in future operations. Alternative G-6 uses a PRB for passive treatment instead of a groundwater extraction and treatment system. A description and detailed

analysis of these alternatives are presented in the following sections. The key features of each alternative are summarized in Table 4-1.

Groundwater modeling was performed to determine recovery well locations and pumping rates in order to obtain hydraulic control of the plumes (Alternative G-2). An additional modeling simulation (Alternative G-4) was performed to examine the effect of mass removal from extraction wells located in high concentration areas of the plume and reinjection of treated groundwater amended with an electron-donor to promote biological degradation into points upgradient of the high concentration areas. Although the effects of the electron-donor were not simulated in this scenario, additional model simulations may be performed to examine these effects in the enhanced remedial alternatives once the reaction rates are better understood during pilot testing. The extraction rates and extraction well locations that were determined from the hydraulic containment for Alternative G-2 were assumed to be sufficient for Alternatives G-3 and G-5. Similarly, the effects of reinjection modeled for Alternative G-4 were assumed to be sufficient for Alternative G-3. Therefore, specific modeling scenarios for Alternatives G-2 and G-4 were prepared. No modeling was performed for Alternative G-6 because that scenario does not have any groundwater extraction.

4.2.1 Alternative G-1: No Action

4.2.1.1 Description

The no action alternative maintains the site as is. This alternative does not address groundwater contamination and is retained as a baseline for comparison to other alternatives. It would achieve no reduction in toxicity, mobility, or volume of the contaminants other than what would result from natural dispersion, dilution, biodegradation, and other attenuating factors.

4.2.1.2 Detailed Analysis

Overall protection of human health and the environment — Alternative G-1 would provide no protection of human health and the environment. Under the current industrial land use, the potential for human and ecological exposure to contaminated groundwater would remain. In addition, under a future residential land use scenario, unacceptable risks to human and ecological receptors from exposure to contaminated groundwater would not be reduced. Potential off-site migration of chemicals of concern (COCs) would not be detected because no

groundwater monitoring would be conducted. The potential for vapor intrusion into future buildings would not be considered under this alternative. Thus, potential migration of COCs would not be detected.

Compliance with ARARs and other guidance — Alternative G-1 would not comply with chemical-specific ARARs or other guidance because no action would be taken to reduce contaminant concentrations. Chemical-specific ARARs may eventually be met by natural attenuation, but no monitoring would be conducted to verify the changes. Compliance with location-specific ARARs or other guidance would be purely incidental. Action-specific ARARs or other guidance are not applicable.

Long-term effectiveness and permanence — Alternative G-1 would have little long-term effectiveness and permanence because contaminated groundwater would remain on-site. In the absence of LUCs to restrict building construction methods, unacceptable risks could potentially be posed to human receptors via vapor intrusion. Potential off-site migration of COCs would not be detected because groundwater monitoring would not be conducted under this alternative. Although COC concentrations might eventually decrease to cleanup goals through natural attenuation, no monitoring would verify this.

Reduction of toxicity, mobility, or volume through treatment — Alternative G-1 would not reduce the toxicity, mobility, or volume of contaminants through treatment because no treatment would occur. Some reduction of the toxicity and volume of COCs might occur through natural dispersion, dilution, or other attenuation processes, but no monitoring would be performed to verify this.

Short-term effectiveness — Implementation of Alternative G-1 would produce no short-term adverse effects to the local community or the environment due to cleanup activities, because no action would be undertaken. Alternative G-1 would never achieve the remedial action objectives (RAOs) and, though the cleanup goals might eventually be achieved through natural attenuation, this would not be verified through monitoring.

Implementability — Alternative G-1 would be readily implementable because no action would occur. The technical feasibility criteria, including constructability, operability, and reliability,

are not applicable. Implementability of additional administrative measures is not applicable because no such measures would be taken.

Sustainability — Alternative G-1 is highly sustainable, since no action would occur. No energy or resources would be consumed, no greenhouse gases would be generated, and no waste would be generated. No costs or increases in negative social factors, such as traffic and noise, are associated with this alternative. An economic factor to consider is that site development would be limited because of the potential for exposure to contaminated groundwater or to contaminants volatilizing from the groundwater and into buildings, but with no controls in place under this alternative.

Cost — The No Action alternative would incur no costs beyond the existing monitoring program.

4.2.2 Alternative G-2: Hydraulic Control by Extraction, *ex situ* Treatment of Groundwater, Discharge to Publicly Owned Treatment Works/Surface Water, Monitoring, and Land Use Controls

4.2.2.1 Description

Alternative G-2 would consist of five major components: (1) hydraulic control of the plume by extraction, (2) *ex situ* treatment of groundwater, (3) discharge of treated groundwater to the POTW or surface water, (4) monitoring, and (5) LUCs. Components 1 through 3 are summarized below. See Appendix E for detailed descriptions of these components.

Component 1 (Alternative G-2): Hydraulic control — This component would consist of installing an array of groundwater extraction wells and operating them until the groundwater contamination is remediated. Pumping rates and well locations were selected using the groundwater model to optimize the extraction required for hydraulic containment of the plume. Modeling results for this component are provided in Appendix B. Design calculations for this component are provided in Appendix E.

The results of groundwater modeling suggest that 16 extraction wells at various depths would be sufficient to intercept contaminated groundwater before it reaches Frog Mortar Creek. One result of the groundwater modeling analysis is that most of the extracted groundwater would be from the site and very little water would be drawn in from Frog Mortar Creek. Contaminant

concentrations from locations upgradient of the containment wells would also be reduced as groundwater flows toward the extraction wells.

Under Alternative G-2, seven wells would be screened in the upper zone (at approximately 35 feet deep), five wells would be screened in the intermediate zone (at approximately 65 feet deep), and four would be screened in the lower zone (at approximately 90 feet deep). Each well screen would be at least 10 feet long. The total groundwater extraction rate is estimated to be 40 gallons per minute (gpm). Extraction well locations are shown in Figure 4-1.

A submersible centrifugal pump would be installed in each groundwater extraction well. Each of these pumps would be connected to a piping network that would convey the extracted groundwater to an on-site pumping station (see Figure 4-1). From there, groundwater would be pumped to an off-site treatment system near Eastern Boulevard. Extracted groundwater will be conveyed through double-walled pipes because the contaminated groundwater will pass through areas of uncontaminated groundwater.

Surface water levels in the two ponds and adjacent wetlands will be monitored during extraction. The ponds do not appear to be hydraulically connected to the groundwater. The existence of a hydraulic connection with wetlands is unknown at this time.

Component 2 (Alternative G-2): **Ex situ** ***treatment of groundwater*** **—** Recent groundwater modeling estimates that the total groundwater extraction rate would be approximately 40 gpm. The treatment system conceptual design is sized for a maximum instantaneous flow of 50 gpm. This component would include the installation of a treatment system and operation of it as long as groundwater is being extracted.

As shown in the process flow diagram (PFD) (see Figure 4-2), the extracted groundwater would enter the system at a feed tank, flow through a metals removal system, filter unit, air stripper, advanced oxidation system, the liquid-phase granular activated carbon (GAC) unit, an ion exchange unit, and then exit the system via the GAC unit. Sludge generated by the metals removal step would be thickened, dewatered, and disposed of off-site. The treatment system is described further below.

A conceptual layout of the treatment building is shown in Figure 4-3. Design calculations for this component and a more detailed process description are provided in Appendix E. The following description is typical; the description of the final system will depend on the vendor-specific equipment selected.

The feed tank controls water flow through the treatment system. The tank would also blend groundwater from the various extraction wells to buffer variations in the quality of the treatment system influent. Side streams from the wastewater treatment system will also be sent to the feed tank.

The feed pump would move groundwater through the treatment system to the metals removal system. Groundwater would enter a primary pH adjustment tank, where pH would be adjusted to 10 with caustic soda, followed by addition of hydrogen peroxide to oxidize and precipitate iron and manganese. The groundwater would then enter a secondary pH adjustment tank where pH would be adjusted to 11 with caustic soda to precipitate other metals (such as cadmium) out of the groundwater being treated.

Following pH adjustment, groundwater would flow into the flocculation tank where it would be mixed with a polymer to coagulate and flocculate the suspended solids. The groundwater then would flow into the clarifier, where solids settle out. Clarified effluent would then flow into a final pH adjustment tank where hydrochloric acid would be added to return pH to the range of 6–9 for discharge after final treatment.

Chemicals would be stored in drums or tote tanks, depending on chemical usage rates. Alternative, less aggressive chemicals may be considered. For example, lime or magnesium hydroxide may be used instead of caustic soda. Citric acid or carbon dioxide may be used in place of hydrochloric acid. Mechanical aeration with a blower may be considered for oxidizing iron and manganese instead of using hydrogen peroxide.

Neutralized groundwater would flow by gravity into the clarified water feed tank and pumped through a sand filter. The sand filter will remove the balance of suspended solids (including precipitated iron and manganese). By removing suspended solids, the sand filter will also remove metals so that discharge limitations are met. Three sand filter tanks would be arrayed in parallel: two on-line and one off-line. As solids accumulate, the pressure drop across the sand

filter will increase. When a pre-set pressure drop is reached, the off-line sand filter will automatically be brought on-line while the original sand filter is taken off-line. The off-line sand filter would then be backwashed, as described below.

Following filtration, groundwater flows to the top of an air stripper where the groundwater would then cascade down through multiple trays of a low-profile air stripper where a countercurrent of air would volatilize the volatile organic compounds (VOCs). Treated groundwater would then be collected in a sump at the bottom of the air stripper unit. Treated water would then be pumped to the advanced oxidation process (AOP) and GAC units.

For the purposes of this Groundwater FS, the treatment process described here includes use of HiPOx®, a commercially available system, although other processes can be used. Water from the air stripper would enter the HiPOx® unit, where ozone and hydrogen peroxide would be added to the groundwater undergoing treatment to oxidize organic compounds, particularly 1,4-dioxane. Treated groundwater would then flow through the GAC system.

A GAC system is included to polish the groundwater, that is, to remove remaining diesel range organics (DRO) and gasoline range organics (GRO) and to provide contingency treatment in the event the AOP unit malfunctions. Two GAC tanks would be arrayed in series in a lead-lag configuration. When the GAC in the lead tank reaches capacity (based on analytical testing of the influent and effluent), the flow will be switched to the lag tank while the first tank is taken off-line, so that the GAC can be replaced with fresh GAC. After the GAC is replaced, the GAC tank is put back on-line in the lag position. Following GAC treatment, the treated water flows via the discharge piping to an existing sewer connected to the sanitary sewer system.

Gas exhausted from the top of the air stripper unit would pass through an off-gas treatment unit to remove volatilized contaminants before venting to the atmosphere. The off-gas treatment unit would consist of an electric heater, followed by two vapor-phase GAC adsorption units, followed by two potassium permanganate impregnated zeolite (PPZ) adsorption units. The exhaust gas heater would reduce the relative humidity of the air stripper unit off-gas from nearly 100 percent to approximately 50 percent, to allow efficient operation of the vapor-phase GAC adsorption units.

VOCs in the extracted vapors would be removed by the vapor-phase GAC adsorption units. Upon exhaustion of the carbon in the lead vapor-phase GAC unit, it would be taken out for disposal or regeneration. The lag vapor-phase GAC adsorption unit would then be placed in the lead position and a fresh unit would be placed in the lag position. Potassium permanganate impregnated zeolite is used because vinyl chloride is poorly sorbed by GAC. Vinyl chloride is oxidized by potassium permanganate. Upon exhaustion of the PPZ unit, it would be taken out for disposal.

For discharge to surface water, the contaminant concentrations must also conform to EPA and MDE water quality criteria. For cadmium, the preliminary remediation goal (PRG) is 5 µg/L, and conventional treatment by pH adjustment, clarification, and filtration cannot meet this level. To meet the cadmium requirement, an ion exchange (IE) unit would be provided following the GAC unit. Cartridge filters would be required upstream of the IE system to prevent clogging of the IE resin and to further remove metals sorbed onto fine suspended solids passing through the sand filters. Two tanks would be used: one on-line and the second on standby. The effluent would be routinely monitored for cadmium, and as the concentration approached the PRG, the tank would be taken off-line and the standby tank would be brought into service. The resin would be regenerated off-site by a resin regeneration service.

Part of the treated water will be diverted to a backwash supply tank. The backwash supply tank is sized to provide sufficient water for one backwash cycle each for a sand filter and GAC tank. When a sand filter requires backwashing, the backwash pump is activated and water flows up through the sand filter, suspending the sand and carrying the solids out of the sand filter to the waste backwash tank.

After backwashing, the backwash pump is stopped and the sand filter is ready to be used when the next on-line sand filter reaches capacity. Similarly, when the GAC in a GAC tank is replaced, fines are generated during transfer of the GAC and then removed by backwashing. Water in the waste backwash tank is then slowly metered back to the feed tank.

Settled sludge in the clarifier would be periodically transferred to the sludge thickener tank. In the sludge thickener, the solids content of the sludge is increased by gravity sedimentation from approximately 0.5 percent (by weight) to approximately 4 percent (by weight). Thickened

sludge would be periodically pumped from the bottom of the thickener to a recessed plate filter press. In the filter press, the solids content of the thickened sludge is increased to 25–35 percent (by weight) to form a solid cake that is stored in a roll-off container and later hauled away for appropriate disposal. Supernatant water from the thickener and filtrate water from the filter press is then pumped to the feed tank.

The DRA Site is bordered by taxiways and runways, the MDANG property, and Frog Mortar Creek, making access for routine maintenance difficult, so the location of the treatment building is planned to be off of the Martin State Airport (MSA) property. The property for the treatment building would need to be purchased or leased. Figure 4-4 shows the pipeline routing across the MSA property between the DRA Site and the general area of the treatment building. The planned building has an estimated size of 130 feet by 60 feet. An area of approximately 180 feet by 120 feet would be needed to accommodate construction, parking, and deliveries.

The Groundwater Treatment Plant Building will be designed to contain spills within the building. Spills will flow or be directed into the building sump and transferred to the feed tank. Controls in the sump would activate an alarm and would shut down the extraction wells in the event of a spill. A spare sump pump would be provided. Influent, effluent, and intermediate locations in this process will be sampled routinely to monitor treatment effectiveness and progress. These results will also be used to determine if the GAC needs to be replaced.

Component 3 (Alternative G-2): Discharge to POTW and surface water — 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. The design discharge rate of 50 gpm is greater than the 25,000 gallons per day (gpd) threshold for a significant industrial user, so reporting would be required twice per year and annual user fees, in addition to sewage service charges, are also required.

After the extraction and treatment system has operated for two to three years, extraction flow rates, groundwater concentrations, and treated water concentrations will be well established.

Plant operation data will be used to apply for a National Pollutant Discharge Elimination System (NPDES) permit to discharge to surface water (either Frog Mortar Creek or Stansbury Creek). The application will include developing an MDE-approved estuary model to calculate effluent limitations and to field calibrate the model, to obtain effluent limitations from MDE. Treated water would then be discharged to surface water through a submerged multiple diffuser outfall. Discharge would be metered and routinely sampled to comply with the NPDES permit.

Component 4 (Alternative G-2): Monitoring — Monitoring would consist of regularly measuring groundwater levels and collecting and analyzing groundwater samples to evaluate changes in contaminant concentrations (in the plume downgradient of the extraction wells) due to extraction. Tracking water levels will measure the capture zone to confirm hydraulic capture of the plume. Samples would be collected from existing as well as new monitoring wells installed specifically to evaluate system performance. Wells in the monitoring program would include the extraction wells, five three-well clusters in the plume (between the Taxiway Tango and Frog Mortar Creek), two three-well clusters between the runway and Taxiway Tango, and a newly installed pair of two-well clusters (extending into the intermediate and lower zones), with each pair installed downgradient of the extraction wells. Final selection of monitoring wells will be made in the design phase of the project, with the concurrence of relevant regulatory agencies.

Samples will be analyzed for VOCs, 1,4-dioxane, DRO, GRO, and metals. The extraction wells would be sampled semiannually for the first three years because concentrations in these wells are expected to change quickly, then sampled annually thereafter. All other wells would be sampled annually. Groundwater sampling and analysis reports would be submitted annually to the relevant regulatory agencies. The groundwater monitoring program would be reviewed at least every five years to determine if changes are needed in sampling frequency, analyses, or the wells that are sampled. Pumping rates of the extraction wells would also be evaluated for optimization.

Component 5 (Alternative G-2): LUCs — Land use controls for groundwater would include limiting land use to industrial purposes, prohibiting residential use, and prohibiting surficial aquifer use for drinking and industrial purposes. Deed restrictions would be required to implement the LUCs. Land use controls would be maintained as long as groundwater

contaminant concentrations are greater than PRGs. An additional LUC would also be required to restrict construction methods for new buildings on the site.

Vapor intrusion is a potential problem because TCE and other VOCs are present in shallow groundwater. Thus, an additional LUC would be applied to areas overlying shallow groundwater where VOC concentrations are greater than the vapor intrusion PRGs (see Table 2-4). For example, for TCE, the vapor intrusion PRG is 290 µg/L, and for vinyl chloride it is 15 µg/L. The additional LUC would require special construction methods, such as installation of vapor barriers and foundation venting, to prevent unacceptable exposure to VOCs via vapor intrusion.

4.2.2.2 Detailed Analysis

Overall protection of human health and the environment — Alternative G-2 would protect human health and the environment. The extraction wells would prevent contaminated groundwater from entering Frog Mortar Creek. Extraction of groundwater from the leading edge of the plume would also gradually remediate groundwater contamination as the plume flows toward the extraction wells. This would eventually reduce risk from exposure to contaminated groundwater and protect future human receptors that may be exposed during intrusive activities.

Monitoring would protect human health and the environment by evaluating extraction effectiveness and remediation progress and detecting potential migration of contaminants through groundwater. Land use controls would likewise protect human health and the environment during the remediation period until PRGs are achieved. Restricting groundwater use would also protect human health and the environment by avoiding unacceptable risks of exposure to contaminated groundwater. Exposure to VOCs via vapor intrusion would be controlled by requirements placed on building construction methods.

Compliance with ARARs and other guidance — Alternative G-2 would eventually comply with chemical-specific ARARs and other guidance through a combination of extraction, treatment, and plume migration toward the extraction system. Alternative G-2 would also comply with location- and action-specific ARARs and guidance. The chemical-, location-, and action-specific ARARs and other guidance are described in Section 2.

Long-term effectiveness and permanence — Alternative G-2 would provide long-term effectiveness and permanence. Extraction would effectively and permanently remove contaminants from groundwater. Extraction is a well-established method of groundwater treatment. Many extraction systems reach a long-term steady-state groundwater concentration that is greater than the target treatment goal, which is usually a maximum contaminant level (MCL).

Monitoring treatment progress would effectively evaluate remediation progress and verify that COCs are not migrating. Groundwater use restrictions would effectively prevent groundwater use until PRGs are met. Requirements for specific construction methods would effectively prevent exposure to VOCs via vapor intrusion. The controls proposed in this alternative are considered reliable. This alternative contains little flexibility for expansion or use in the final remedial action at the DRA Site.

Reduction of toxicity, mobility, or volume through treatment — Alternative G-2 would reduce the toxicity, mobility, and volume of groundwater COCs. Over a 30-year period, extraction and treatment would permanently and irreversibly remove an estimated 3,600 pounds (lb) of TCE, 1,900 lb of cis-1,2-dichloroethene (DCE), 3,300 lb of vinyl chloride, and 160 lb of 1,4-dioxane from groundwater. Most of these COCs would be sorbed onto GAC and spent GAC would be taken off-site for regeneration. The 1,4-dioxane and some other COCs would be destroyed by AOP. Vinyl chloride captured by the PPZ would be oxidized and destroyed. In addition, metals would be settled out into a sludge that would be disposed of off-site. Spent GAC would require off-site regeneration, and spent PPZ would require off-site disposal.

Short-term effectiveness — Alternative G-2 would reduce human health risks in the short term through groundwater use restrictions. Exposure of workers to contamination during installation of extraction wells and groundwater sampling would be minimized by compliance with federal Occupational Safety and Health Administration (OSHA) requirements, including wearing appropriate personal protective equipment (PPE) and adhering to site-specific health and safety procedures. Implementation of LUCs and monitoring would not adversely affect the surrounding community or the environment.

Slight risk would be posed to the surrounding community from transporting treatment chemicals to the treatment building or from transporting sludge, spent GAC, spent PPZ, and spent IE resin to off-site disposal. Transportation risks would be limited through adherence to U.S. Department of Transportation regulations. The effect of groundwater extraction on site-related wetlands is unknown; water levels in these wetlands will be monitored during groundwater extraction.

Groundwater RAO No. 1 would be attained as soon as the extraction wells and treatment system are activated. Groundwater RAO Nos. 2 and 3 would be achieved immediately upon implementation of LUCs and monitoring. The extraction and treatment system would be completed in approximately 18 months.

Implementability **—** Alternative G-2 is readily implementable. Several qualified contractors are available to install extraction wells and provide groundwater treatment equipment, such as metals removal systems and AOP units. Sampling and maintenance of monitoring wells could be readily accomplished. The resources, equipment, and materials these activities require are readily available. Design and implementation of this alternative's components must also consider the effects of soil remediation activities.

Administrative aspects of Alternative G-2, such as implementation of LUCs, would be relatively simple to implement. However, applying for and receiving the necessary permits may take time.

A permit to discharge treated effluent to the POTW must be obtained. The sanitary sewer authority is under a Consent Order, and the authority's acceptance of the relatively uncontaminated discharge would have to be confirmed. An off-site treatment system location is preferred, for ease of operation, because site access is limited by MDANG, airport operations, and Frog Mortar Creek. A suitable off-site location would have to be identified and either purchased or leased. Alternatively, a portion of the MDANG property along the property line could be designated as the treatment system location, eliminating the need to cross the MDANG property.

Sustainability **—** Alternative G-2 poses significant consequences affecting the sustainability factors listed above. The extraction and treatment system would use approximately 563,000 kilowatt-hour (kW-hr) of electrical power annually during its operational life, although

this rate would decrease over time as groundwater quality improves. Treatment, and thus energy use, can be expected to continue for several decades. The system's electrical energy usage may indirectly lead to greenhouse gas generation if that power is generated from fossil fuels. Renewable energy sources can be investigated during the system design phase. Production of chemicals used in treatment and in regenerating GAC would also contribute to energy use and greenhouse gas production.

Treatment consumes various chemicals, such as hydrogen peroxide, sodium hydroxide, and hydrochloric acid. Several waste streams would also be generated, including sludge from metals removal, spent GAC, spent IE resin, and spent PPZ. Of these streams, the GAC would be regenerated and reused. Regeneration would also destroy contaminants sorbed to the GAC. As noted above, costs would be incurred during construction, followed by annual expenditures for the duration of the remediation.

After remediation is complete, LUCs that would constrain or limit development could be lifted. Traffic from delivery trucks and waste transport trucks would increase under this alternative, but this does not appear to be a significant factor, nor would it be unusual, given the industrial/commercial nature of the general vicinity of the site. Noise may also increase, particularly during construction, but this too would be similar to current activities in the general vicinity of the site.

Cost — Estimated costs for Alternative G-2 are as follows:

- Capital cost: $12,000,000
- 30-year NPW of annual costs: $8,200,000
- 30-year NPW: $20,200,000
- 30-year current value: $37,000,000

Operating costs are based on a treatment system flow rate of 50 gpm. Operating costs directly related to contaminant concentrations, such as chemical use and GAC, were reduced in the NPW analysis by 25 percent in years six through 10 and by 50 percent thereafter, because contaminant concentrations will decrease over time. A detailed breakdown of estimated costs for this alternative is provided in Appendix F.

4.2.3 Alternative G-3: Hydraulic Control by Extraction, *ex situ* Treatment of Groundwater, Reinjection of Groundwater, Discharge to Publicly Owned Treatment Works/Surface Water, Monitoring, and Land Use Controls

4.2.3.1 Description

Alternative G-3 would consist of six major components: (1) hydraulic control of the plume by extraction, (2) *ex situ* treatment of groundwater, (3) reinjection of some of the treated groundwater to the aquifer, (4) discharge of treated groundwater to the POTW or surface water, (5) monitoring, and (6) LUCs. Components 1 through 4 are summarized below. See Appendix E for detailed descriptions of these components.

Component 1 (Alternative G-3): Hydraulic control — This component would install an array of groundwater extraction wells and piping as described above for Component 1 of Alternative G-2. As in Alternative G-2, the system would operate until groundwater contamination has been remediated. Extraction well locations are shown in Figure 4-5.

Component 2 (Alternative G-3):* Ex situ *treatment of groundwater — As in Alternative G-2, the total groundwater extraction rate would be approximately 40 gpm. The treatment system conceptual design is sized for 100 gpm because of uncertainties in groundwater extraction rates and to provide flexibility for future operations, but the system is assumed to operate at 50 gpm for costing purposes. The additional flow capacity would allow significant recirculation to facilitate *in situ* treatment of the HCAs as part of a future site remedy. This component would consist of installing a treatment system and operating it until groundwater remediation goals are met. The process is essentially the same as the treatment system in Alternative G-2, and is described below.

As shown in the PFD (see Figure 4-6), the extracted groundwater would enter the system at a feed tank, then flow through a metals removal system, filter unit, air stripper, advanced oxidation system, the liquid-phase GAC and IE units, and then exit the system. Sludge generated by the metals removal step would be thickened, dewatered, and disposed of off-site. This treatment system is the same as was described in Alternative G-2. A conceptual layout of the treatment building is shown in Figure 4-7. Design calculations for this component and a more detailed process description are provided in Appendix E.

In Alternative G-3, some of the treated groundwater would be injected through approximately six injection wells upgradient of the HCAs, as shown in Figure 4-5. Four wells would be screened in the upper zone and two wells in the intermediate zone. The total injection rate would be approximately 13 gpm. Before injection, sodium lactate (an electron-donor compound) would be added to promote bioremediation through reductive dechlorination. This will reduce concentrations of TCE, cis-1,2-DCE, and vinyl chloride, reduce the total loading of contaminants to the groundwater treatment system, and may shorten overall remediation time.

The sodium lactate feed system is described in Component 3 below. This portion of the alternative may be installed following initial installation of the extraction wells and the groundwater treatment system, potentially in conjunction with the soil/landfill waste remedy. Groundwater that is not reinjected would be discharged to the POTW or surface water, as described in Alternative G-2.

Considerations for locating the treatment system building are similar to those described in Component 2 of Alternative G-2. The treatment building under Alternative G-3 (estimated at 155 feet by 65 feet) would have a larger footprint than the one envisioned under Alternative G-2, and an area of approximately 200 feet by 130 feet would be needed to accommodate construction, parking, and deliveries. The tentative location is assumed to be off the Martin State Airport property. Influent, effluent, and intermediate points in the process will be routinely sampled to monitor treatment effectiveness and progress. These results will also be used to determine if the GAC needs to be replaced.

Component 3 (Alternative G-3): Reinjection of treated groundwater — Some groundwater would be reinjected near the HCAs under this alternative. The effects of reinjection are simulated in the groundwater model (see Appendix B). Reinjection would enhance the flushing rate of contaminants from these areas, and an electron-donor compound would be mixed with the reinjected treated groundwater to promote anaerobic reductive dechlorination of chlorinated VOCs (cVOCs).

Six injection wells would be placed in areas contaminated with cVOCs, as shown in Figure 4-5. Treated groundwater would not be reinjected in areas contaminated only with 1,4-dioxane, because the electron-donor compound is not effective in degrading 1,4-dioxane. Four wells

would be screened in the upper zone and two in the intermediate zone. The total flow rate to upper zone wells would be approximately 10 gpm; the total flow rate to the intermediate zone wells would be 3 gpm. The total injection rate would be approximately 13 gpm.

As noted, sodium lactate would be added to the reinjected treated groundwater as an electron-donor compound. Treated groundwater augmented with the electron-donor compound would be intermittently reinjected to the aquifer to allow the electron-donor compound to be flushed away from the wells, to minimize clogging. Absent reinjection, all treated groundwater would be discharged to the POTW. Reinjection facilities may be installed following initial installation of the extraction wells and the groundwater treatment system, potentially in conjunction with the soil/landfill waste remedy. No excess electron-donor compound is expected to reach Frog Mortar Creek because the containment wells would capture the electron-donor compound before it can reach the creek.

Component 4 (Alternative G-3): Discharge to POTW and surface water — This component is the same as Component 3 in Alternative G-2. Reporting would be required twice annually because the potential discharge rate of 100 gpm is greater than the 25,000 gpd threshold for a significant industrial user. Annual user fees are also required, in addition to sewage service charges. As with Alternative G-2, a surface water discharge permit would be obtained after two or three years of operation, once treatment system operating parameters have been established.

Component 5 (Alternative G-3): Monitoring — This component is essentially the same as Component 4 of Alternative G-2. Additional monitoring wells may need to be installed to monitor the effect of adding the electron-donor to the injection wells.

Component 6 (Alternative G-3): LUCs — This component is the same as Component 5 of Alternative G-2.

4.2.3.2 Detailed Analysis

Overall protection of human health and the environment — Alternative G-3 would protect human health and the environment. The extraction wells would prevent contaminated groundwater from entering Frog Mortar Creek. Extraction of groundwater from the leading edge of the plume and bioremediation of the HCAs would also gradually remediate the groundwater contamination. This would eventually reduce risk from exposure to contaminated

groundwater and protect future human receptors that may be exposed to contaminants during intrusive activities.

Monitoring protects human health and the environment by evaluating extraction effectiveness, remediation progress, and by detecting potential migration of contaminants in groundwater. Land use controls would likewise protect human health and the environment during the remediation period until PRGs are met. Restricting groundwater use would protect human health and the environment by avoiding unacceptable risks of exposure to contaminated groundwater. Exposure to VOCs via vapor intrusion would be controlled by requirements on building construction methods.

Compliance with ARARs and other guidance — Alternative G-3 would eventually comply with chemical-specific ARARs and other guidance through a combination of extraction, *in situ* and *ex situ* treatment, and plume migration toward the extraction system. Alternative G-3 would also comply with location- and action-specific ARARs and other guidance. The chemical-, location-, and action-specific ARARs and other guidance are described in Section 2.

Long-Term effectiveness and permanence — Alternative G-3 would provide long-term effectiveness and permanence. Extraction and bioremediation would effectively and permanently remove contaminants from groundwater. Extraction and *in situ* bioremediation are well-established methods of groundwater treatment. Many extraction systems reach a long-term steady-state groundwater concentration that is greater than the target treatment goal, which is usually an MCL.

Monitoring treatment progress would be an effective means of evaluating remediation progress and verifying that no groundwater COCs are migrating. Groundwater use restrictions would effectively prevent groundwater use until PRGs are met. Requirements for specific construction methods would effectively prevent exposure to VOCs via vapor intrusion. The controls proposed under this alternative are considered reliable. The treatment system design envisioned under this alternative provides significant flexibility for future expansion as part of the final remedial action.

Reduction of toxicity, mobility, or volume through treatment — Alternative G-3 would reduce the toxicity, mobility, and volume of groundwater COCs. Over a 30-year period, extraction, treatment, and bioremediation would permanently and irreversibly remove an estimated 3,700

lb of TCE, 1,900 lb of cis-1,2-DCE, 3,400 lb of vinyl chloride, and 160 lb of 1,4-dioxane from groundwater. Most of these COCs would be sorbed onto GAC or destroyed *in situ* via reductive dechlorination. Spent GAC would be taken off-site for regeneration. The 1,4-dioxane and some of the COCs would be destroyed by AOP. Vinyl chloride captured by the PPZ would be oxidized. In addition, metals will be settled out into a sludge that will be disposed off-site. Spent GAC would require off-site regeneration, and spent PPZ would require off-site disposal.

Short-term effectiveness — Alternative G-3 would reduce human health risks in the short term through implementation of groundwater use restrictions. Exposure of workers to contamination during installation of extraction wells, injection wells, and groundwater sampling would be minimized by compliance with OSHA requirements, including wearing appropriate PPE and adhering to site-specific health and safety procedures. Implementation of LUCs and monitoring would not adversely affect the surrounding community or the environment. Slight risk would be posed to the surrounding community from transporting treatment chemicals to the treatment building and transporting sludge, spent IE resin, spent GAC, and spent PPZ to an off-site regeneration or disposal site. Transportation-related risks would be limited by adherence to U.S. Department of Transportation regulations.

The effect of groundwater extraction on nearby wetlands is unknown. Water levels in the wetlands will be monitored during groundwater extraction. Groundwater RAO No. 1 would be attained as soon as the extraction wells and treatment system are activated. Groundwater RAO Nos. 2 and 3 would be achieved immediately upon implementation of LUCs and monitoring. The extraction and treatment system would be completed in approximately 18 months.

Implementability — Alternative G-3 would be readily implementable. Several qualified contractors are available to install extraction and injection wells and provide groundwater treatment equipment such as metals removal systems and AOP units. Sampling and maintenance of monitoring wells could also be readily accomplished. The resources, equipment, and materials required for these activities are all readily available. The design and implementation of this alternative's components must also consider the effects of soil remediation activities at the site.

Implementing administrative aspects of Alternative G-3, such as LUCs, would be relatively simple. A groundwater discharge permit from MDE would be required. However, applying for and receiving permits may take time. A permit to discharge treated effluent to the POTW would also be required. The sanitary sewer authority is under a Consent Order and would have to confirm their acceptance of the relatively uncontaminated treatment system discharge.

An off-site treatment system location is preferred, for ease of operation, because site access is limited by MDANG, airport operations, and Frog Mortar Creek. A suitable off-site location would have to be identified and either purchased or leased. Alternatively, a portion of the MDANG property along the property line could be designated as the treatment system location, eliminating the need to cross the MDANG property.

Sustainability — Alternative G-3 would pose several significant consequences affecting the sustainability factors listed above. The extraction and treatment system would use approximately 563,000 kW-hr of electrical power annually over its operational life, although this rate would decrease over time as groundwater quality improves. Treatment, and thus energy use, can be expected to continue for several decades. The system's electrical energy usage may indirectly lead to greenhouse gas generation if that power is generated from fossil fuels. Renewable energy sources can be investigated during the system design phase. The entire system would have the capacity to use approximately 778,000 kW-hr of power annually, if it operates at its maximum flow rate. Production of chemicals used in treatment and in regenerating GAC would also contribute to energy use and greenhouse gas production.

Treatment consumes chemicals, such as hydrogen peroxide, sodium hydroxide, and hydrochloric acid. Several waste streams would also be generated, including sludge from metals removal, spent GAC, spent IE resin, and spent PPZ. Of these streams, the GAC would be regenerated and reused. Regeneration would also destroy contaminants sorbed to the GAC. As noted above, costs would be incurred during construction, followed by annual expenditures for the duration of the remediation.

After remediation, LUCs that would constrain or limit development could be lifted. Traffic from delivery trucks and waste transport trucks would increase under this alternative, but this does not appear to be a significant factor, nor would it be unusual, given the

industrial/commercial nature of the vicinity of the site. Noise may also increase, particularly during construction, but this too would be similar to current activities in the vicinity of the site.

Cost — Estimated costs for Alternative G-3 are as follows:

- Capital cost: $12,900,000
- 30-year NPW of annual costs: $8,600,000
- 30-year NPW: $21,500,000
- 30-year current value: $38,700,000

Operating costs are based on a treatment system flow rate of 50 gpm. Operating costs directly related to contaminant concentrations, such as chemical use and GAC, were reduced in the NPW analysis by 25 percent in years six through 10 and by 50 percent thereafter, because contaminant concentrations will decrease over time. A detailed breakdown of estimated costs for this alternative is provided in Appendix F.

4.2.4 Alternative G-4: Hydraulic Control by Extraction, Extraction in High Concentration Areas, *ex situ* Treatment of Groundwater, Reinjection of Groundwater, Discharge to Publicly Owned Treatment Works/Surface Water, Monitoring, and Land Use Controls

4.2.4.1 Description

Alternative G-4 would consist of seven major components: (1) hydraulic control of the plume by extraction, (2) extraction of contaminated groundwater from the HCAs, (3) *ex situ* treatment of groundwater, (4) reinjection of some of the treated groundwater, (5) discharge of treated groundwater to the POTW or surface water, (6) monitoring, and (7) LUCs. Components 1 through 5 are summarized below. See Appendix E for detailed descriptions of these components.

Component 1 (Alternative G-4): Hydraulic control — This component would install an array of groundwater extraction wells and piping, as described for Component 1 in Alternative G-2. As in Alternative G-2, the system would operate until groundwater contamination has been remediated. Extraction well locations are shown in Figure 4-8.

Component 2 (Alternative G-4): Extraction of groundwater from the HCAs — This component would install groundwater extraction wells downgradient from the HCAs.

Extraction effects are simulated in the groundwater model (see Appendix B). Design calculations for this component are provided in Appendix E. Ten extraction wells would be sufficient to extract contaminated groundwater from the HCAs. Five wells would be screened in the upper zone (approximately 35 feet deep), two in the intermediate zone (approximately 65 feet deep), and three in the lower zone (approximately 90 feet deep). Each well screen would be at least 10 feet long.

The rate of groundwater extraction from the HCAs is estimated at 28 gpm. Six wells would extract groundwater contaminated with cVOCs, and 1,4-dioxane, and one well would extract groundwater contaminated only with 1,4-dioxane. These wells would be installed later because their locations could potentially interfere with soil remediation activities at the site. Extraction well locations are shown in Figure 4-8.

A submersible centrifugal pump equipped with level controls (to turn the pump on and off) would be installed in each groundwater extraction well under this alternative. The discharge line from each pump would have a flow meter, manual flow control valve, shut-off valve, and pressure gauges. Valves and instrumentation would be housed at each wellhead in a subsurface concrete vault with a hinged hatchway. Piping in the vault would be protected from freezing.

Each of these pumps would be connected to a piping network that would convey extracted groundwater to the pumping station. Extracted groundwater will be conveyed through double-walled pipes because the contaminated groundwater will pass through areas of uncontaminated groundwater. As with the hydraulic barrier extraction wells, the system would operate until the groundwater contamination has been remediated.

***Component 3 (Alternative G-4):* Ex situ *treatment of groundwater* —** The total groundwater flow-rate requiring treatment would be higher because of groundwater extracted from the HCAs. The process envisioned under this alternative would be essentially as was described in Alternative G-3 above. The total groundwater extraction rate would be approximately 70 gpm, based on the model, but the treatment system conceptual design is sized for 100 gpm because of uncertainties in groundwater extraction rates. This component would include the installation of a treatment system and operation of it as long as groundwater is being extracted.

As shown in the PFD (see Figure 4-9), extracted groundwater would enter the system at a feed tank, then flow through a metals removal system, filter unit, air stripper, advanced oxidation system, the liquid-phase GAC and IE units, and then exit the system. Sludge generated by the metals removal step would be thickened, dewatered, and disposed of off-site. The treatment system is as was described in Alternative G-3 above. Design calculations for this component are provided in Appendix E.

Component 4 (Alternative G-4): Reinjection of treated groundwater — This component is the same as Component 3 in Alternative G-3.

Component 5 (Alternative G-4): Discharge to POTW and surface water — This component is the same as Component 3 in Alternative G-2. Reporting would be required twice annually because the potential discharge rate of 100 gpm is greater than the 25,000 gpd threshold for a significant industrial user. Annual user fees are required in addition to sewage service charges.

Component 6 (Alternative G-4): Monitoring — This component is the same as Component 5 in Alternative G-3.

Component 7 (Alternative G-4): LUCs — This component is the same as Component 5 in Alternative G-2.

4.2.4.2 Detailed Analysis

Overall protection of human health and the environment — Alternative G-4 would protect human health and the environment. The extraction wells would prevent contaminated groundwater from entering Frog Mortar Creek. Extraction of groundwater at the leading edge of the plume and from the HCAs, and bioremediation at the HCAs would also gradually remediate the groundwater. This would eventually reduce risk from exposure to contaminated groundwater and protect future human receptors that may be exposed to contaminants during intrusive activities.

Monitoring protects human health and the environment by evaluating extraction effectiveness, remediation progress, and by detecting potential migration of contaminants in groundwater. Land use controls would likewise protect human health and the environment during the remediation period until PRGs are met. Restricting groundwater use would protect human

health and the environment by avoiding unacceptable risks of exposure to contaminated groundwater. Exposure to VOCs via vapor intrusion would be controlled by requirements placed on building construction methods.

Compliance with ARARs and other guidance — Alternative G-4 would eventually comply with chemical-specific ARARs and other guidance through a combination of extraction and treatment and plume migration toward the hydraulic containment extraction system. Alternative G-4 would also comply with location- and action-specific ARARs and other guidance. The chemical-, location-, and action-specific ARARs and other guidance are described in Section 2.

Long-term effectiveness and permanence — Alternative G-4 would provide long-term effectiveness and permanence. Extraction would effectively and permanently remove groundwater contaminants. Extraction is a well-established method of groundwater treatment. Many extraction systems reach a long-term steady-state groundwater concentration that is greater than the target treatment goal, which is usually an MCL.

Monitoring treatment progress would be an effective means of evaluating remediation progress and verifying that no groundwater COCs are migrating. Groundwater use restrictions would effectively prevent groundwater use until PRGs are met. Requirements for specific construction methods would effectively prevent exposure to VOCs via vapor intrusion. The controls proposed under this alternative are considered reliable. Since the HCA treatment would be defined before selection of the soil/landfill waste remedy (or the final groundwater remedy), this option is somewhat less flexible with respect to incorporation into a final groundwater remedy.

Reduction of toxicity, mobility, or volume through treatment — Alternative G-4 would reduce the toxicity, mobility, and volume of groundwater COCs. Over a 30-year period, extraction and treatment would permanently and irreversibly remove an estimated 3,900 lb of TCE, 2,000 lb of cis-1,2-DCE, 3,600 lb of vinyl chloride, and 170 lb of 1,4-dioxane from groundwater. Most of the COCs would be sorbed onto GAC or destroyed *in situ* via reductive dechlorination. Spent GAC would be taken off-site for regeneration. The 1,4-dioxane and some of the other COCs would be destroyed by AOP. Vinyl chloride captured by the PPZ would be oxidized.

Metals would be settled out into a sludge that would be disposed of off-site. Spent GAC would require off-site regeneration, and spent PPZ would require off-site disposal.

Short-term effectiveness — Alternative G-4 would reduce human health risks in the short term through implementation of groundwater use restrictions. Exposure of workers to contamination during installation of extraction wells, injection wells, and groundwater sampling would be minimized by compliance with OSHA requirements, including wearing appropriate PPE and adhering to site-specific health and safety procedures. Implementation of LUCs and monitoring would not adversely affect the surrounding community or the environment. Slight risk would be posed to the surrounding community from transporting treatment chemicals to the treatment building and transporting sludge, spent IE resin, spent GAC, and spent PPZ to an off-site regeneration or disposal site. Transportation-related risks would be limited by adherence to U.S. Department of Transportation regulations.

The effect of groundwater extraction on nearby wetlands is unknown. Water levels in the wetlands will be monitored during groundwater extraction. Groundwater RAO No. 1 would be attained as soon as the extraction wells and treatment system are activated. Groundwater RAO Nos. 2 and 3 would be achieved immediately upon implementation of LUCs and monitoring. The extraction and treatment system would be completed in approximately 18 months.

Implementability — Alternative G-4 would be readily implementable. Several qualified contractors are available to install extraction and injection wells and provide groundwater treatment equipment, such as metals removal systems and AOP units. Monitoring well sampling and maintenance could also be readily accomplished. The resources, equipment, and materials required for these activities are all readily available.

Implementing administrative aspects of Alternative G-4, such as LUCs, would be relatively simple. However, applying for and receiving permits may take time. A permit to discharge treated effluent to the POTW would also be required. The sanitary sewer authority is under a Consent Order and the permitting authority must confirm that the relatively uncontaminated discharge will be acceptable.

An off-site treatment system location is preferred, for ease of operation, because site access is limited by MDANG, airport operations, and Frog Mortar Creek. A suitable off-site location

would have to be identified and either purchased or leased. Alternatively, a portion of the MDANG property along the property line could be designated as the treatment system location, eliminating the need to cross the MDANG property.

Sustainability — Alternative G-4 would pose several significant consequences affecting the sustainability factors listed above. The extraction and treatment system would use approximately 778,000 kW-hr of electrical power annually over its operational life, although this rate would decrease over time as groundwater quality improves. Treatment, and thus energy use, can be expected to continue for several decades. The system's electrical energy usage may indirectly lead to greenhouse gas generation if that power is generated from fossil fuels. Renewable energy sources can be investigated during the system design phase. The production of the chemicals used for treatment and regeneration of GAC would also contribute to energy use and greenhouse gas production.

Treatment consumes chemicals, such as hydrogen peroxide, sodium hydroxide, and hydrochloric acid. Several waste streams would also be generated, including sludge from metals removal, spent GAC, spent IE resin, and spent PPZ. Of these streams, the GAC would be regenerated and reused. Regeneration would also destroy contaminants sorbed to the GAC. As noted above, costs would be incurred during construction, followed by annual expenditures for the duration of the remediation.

After remediation, LUCs that would constrain or limit development could be lifted. Traffic from delivery trucks and waste transport trucks would increase under this alternative, but this does not appear to be a significant factor, nor would it be unusual, given the industrial/commercial nature of the vicinity of the site. Noise may also increase, particularly during construction, but this too would be similar to current activities in the vicinity of the site.

Cost — Estimated costs for Alternative G-4 are as follows:

- Capital cost: $13,100,000
- 30-year NPW of annual costs: $11,700,000
- 30-year NPW: $24,800,000
- 30-year current value: $46,900,000

Operating costs are based on a treatment system flow rate of 100 gpm. Operating costs directly related to contaminant concentrations, such as chemical use and GAC, were reduced in the NPW analysis by 25 percent in years six through 10 and by 50 percent thereafter, because contaminant concentrations will decrease over time. A detailed breakdown of estimated costs for this alternative appears in Appendix F.

4.2.5 Alternative G-5: Hydraulic Control by Extraction, *ex situ* Treatment of Groundwater, *in situ* Bioremediation of High Concentration Areas, Discharge to Publicly Owned Treatment Works/Surface Water, Monitoring, and Land Use Controls

4.2.5.1 Description

Alternative G-5 would consist of six major components: (1) hydraulic control of the plume by extraction, (2) *ex situ* treatment of groundwater, (3) *in situ* bioremediation of groundwater in the HCAs, (4) discharge of treated groundwater to the POTW/surface water, (5) monitoring, and (6) LUCs. Components 1 through 4 are summarized below. See Appendix E for detailed descriptions of these components.

Component 1 (Alternative G-5): Hydraulic control — This component would include the installation of an array of groundwater extraction wells and piping, as described for Component 1 in Alternative G-2. As in Alternative G-2, the system would operate until the groundwater contamination has been remediated. Extraction well locations are shown in Figure 4-10.

Component 2 (Alternative G-5):* Ex situ *treatment of groundwater — This component is the same as Component 2 in Alternative G-3. Injection wells would not be required because reinjection is not part of this alternative. An IE unit would be required for future discharge to surface water. Figure 4-11 shows a PFD of the process.

Component 3 (Alternative G-5):* In situ *bioremediation of HCAs — This component would include the injection of an oil-based electron-donor compound, such as emulsified oil substrate (EOS) (provided by EOS Remediation, LLC), into groundwater through dedicated injection wells in the HCAs to promote biological reductive dechlorination of the cVOCs. Design calculations for this component appear in Appendix E. Modeling results for this component are provided in Appendix B.

Emulsified oil substrate would be injected into the subsurface along lines (barriers) perpendicular to the groundwater flow direction (see Figure 4-10). Spacing between the lines across the HCAs is based on the groundwater travel time of five years, the typical period of EOS effectiveness. Injection wells would be spaced 10 feet apart.

The estimated number of injection wells in each barrier and the quantity of EOS that would be injected are summarized below. A buffered EOS product would likely be required because of the groundwater's low alkalinity. A pilot study will confirm optimal well spacing and EOS application rate.

Under this alternative, EOS would be injected into the subsurface via permanent wells so that a subsequent injection can be made, if needed. A pump capable of pumping five to 10 gpm would be needed to ensure proper application of the EOS and to minimize application time. A subcontractor would provide the mixing and injection equipment. Injections would be completed in a relatively short period. The number of barriers and wells and the quantity of EOS required are summarized below.

Plume location (COC and zone)	Nearby well	Number of barriers	Number of wells per barrier	Total EOS added (lb)	Total water added (gallons)
TCE and DCE (Upper)	DMW11	4	10	8,100	10,000
TCE, (Intermediate)	DMW9	1	70	46,000	55,000
DCE (Intermediate)	DMW1	1	20	13,000	16,000
DCE and vinyl chloride (Upper)	MW20	10	40	80,000	95,000

As a conservative cost assumption, a second injection of EOS would be applied to half of the injection wells after five years. Appendix E includes cost information provided by EOS Remediation, LLC. Monitoring wells on both sides of each HCA would track EOS progress and effectiveness.

Component 4 (Alternative G-5): Discharge to POTW and surface water — This component is the same as Component 4 in Alternative G-2.

Component 5 (Alternative G-5): Monitoring — For the hydraulic control system and groundwater plume, this component is the same as Component 4 in Alternative G-2. An additional monitoring well would be installed on the downgradient side of each set of HCA barriers. Three new shallow wells and two new intermediate wells would also be installed (see Figure 4-10). In the first year, groundwater samples would be collected quarterly and analyzed for VOCs, oxidation-reduction potential (ORP), and iron. After the first year, samples would be collected and analyzed annually.

Component 6 (Alternative G-5): LUCs — This component is the same as Component 5 in Alternative G-2.

4.2.5.2 Detailed Analysis

Overall protection of human health and the environment — Alternative G-5 would protect human health and the environment. The extraction wells would prevent contaminated groundwater from entering Frog Mortar Creek. Extracting groundwater from the leading edge of the plume and *in situ* bioremediation of the HCAs would also gradually remediate the groundwater. This would eventually reduce risk from exposure to contaminated groundwater and protect future human receptors that may be exposed to contaminants during intrusive activities.

Monitoring would protect human health and the environment by evaluating extraction effectiveness and remediation progress, and by detecting potential contaminant migration through groundwater. Land use controls would likewise protect human health and the environment during the remediation period until PRGs are met. Restricting groundwater use would protect human health and the environment by avoiding unacceptable risks of exposure to contaminated groundwater. Exposure to VOCs via vapor intrusion would be controlled by requirements placed on building construction methods.

Compliance with ARARs and other guidance — Alternative G-5 would eventually comply with chemical-specific ARARs and other guidance through a combination of extraction and treatment, plume migration toward the extraction system, and *in situ* bioremediation. Alternative G-5 would also comply with location- and action-specific ARARs and other

guidance. The chemical-, location-, and action-specific ARARs and other guidance are described in Section 2.

Long-term effectiveness and permanence — Alternative G-5 would provide long-term effectiveness and permanence. Extraction and *in situ* bioremediation would effectively and permanently remove contaminants from groundwater. Both extraction and *in situ* bioremediation are well-established methods of groundwater treatment. Many extraction systems reach a long-term steady-state groundwater concentration that is greater than the target treatment goal, which is usually an MCL.

Monitoring treatment progress would be an effective means of evaluating remediation progress and verifying that no groundwater COCs are migrating. Groundwater use restrictions would effectively prevent groundwater use until PRGs are met. Requirements for specific construction methods would effectively prevent exposure to VOCs via vapor intrusion. The controls proposed under this alternative are considered reliable. Since the HCA treatment would be defined before selection of the soil/landfill waste remedy (or the final groundwater remedy), this option is somewhat less flexible with respect to incorporation into a final groundwater remedy.

Reduction of toxicity, mobility, or volume through treatment — Alternative G-5 would reduce the toxicity, mobility, and volume of COCs in groundwater. Over a 30-year period, extraction and treatment and *in situ* bioremediation would permanently and irreversibly remove an estimated 3,900 lb of TCE, 2,000 lb of cis-1,2-DCE, 3,600 lb of vinyl chloride, and 160 lb of 1,4-dioxane from groundwater. Most of the COCs would be sorbed onto GAC or destroyed *in situ* via reductive dechlorination. Spent GAC would be taken off-site for regeneration. The 1,4-dioxane and some of the other COCs would be destroyed by AOP. Vinyl chloride captured by the PPZ would be oxidized. Spent GAC would require off-site regeneration, and spent PPZ would require off-site disposal.

Short-term effectiveness — Alternative G-5 would reduce human health risks in the short term through implementation of groundwater use restrictions. Exposure of workers to contamination during installation of extraction wells and groundwater sampling would be minimized by compliance with OSHA requirements, including wearing appropriate PPE and adhering to site-specific health and safety procedures. Implementation of LUCs and monitoring would not

adversely affect the surrounding community or the environment. Slight risk would be posed to the surrounding community from transporting treatment chemicals to the treatment building and transporting sludge, spent IE resin, spent GAC, and spent PPZ to an off-site regeneration or disposal site. Transportation-related risks would be limited by adherence to U.S. Department of Transportation regulations.

The effect of groundwater extraction on nearby wetlands is unknown. Water levels in the wetlands will be monitored during groundwater extraction. Groundwater RAO No. 1 would be attained as soon as the extraction wells and treatment system are activated. Groundwater RAO Nos. 2 and 3 would be achieved immediately upon implementation of LUCs and monitoring. The extraction and treatment system would be completed in approximately 18 months.

Implementability — Alternative G-5 would be readily implementable, but installation of the injection wells must be coordinated with the soil remediation remedy. The proposed locations of the 140 injection wells will probably interfere with soil remediation activities, such as excavation or capping. Several qualified contractors are available to install injection and extraction wells, provide oil-based electron-donors, and provide groundwater treatment equipment such as metals removal systems and AOP units. Monitoring well sampling and maintenance could be readily accomplished. The resources, equipment, and materials for these activities are all readily available. Design and implementation of the components envisioned under this alternative must also consider the effects of soil remediation activities.

Implementing administrative aspects of Alternative G-5, such as LUCs, would be relatively simple. However, applying for and receiving permits may take time. A permit to discharge treated effluent to the POTW will have to be obtained. The sanitary sewer authority is under a Consent Order, and the permitting authority must confirm that the relatively uncontaminated discharge will be acceptable.

An off-site treatment system location is preferred, for ease of operation, because site access is limited by MDANG, airport operations, and Frog Mortar Creek. A suitable off-site location would have to be identified and either purchased or leased. Alternatively, a portion of the MDANG property along the property line could be designated as the treatment system location, eliminating the need to cross the MDANG property.

Sustainability — Alternative G-5 would pose several significant consequences that would influence the sustainability factors listed above. The extraction and treatment system would use approximately 563,000 kW-hr of electrical power annually over its operational life, although this usage rate would decrease with time as groundwater quality improves. Treatment will likely continue for several decades, with concomitant ongoing energy use. Electrical energy use will indirectly lead to greenhouse gas generation if that power is generated from fossil fuels. Renewable energy sources can be investigated during system design. The entire system would be capable of using approximately 778,000 kW-hr of power annually. Production and delivery of chemicals used for treatment, GAC regeneration, and *in situ* bioremediation would also contribute to energy use and greenhouse gas production.

Treatment consumes chemicals, such as hydrogen peroxide, sodium hydroxide, and hydrochloric acid. Several waste streams would be generated, including sludge from metals removal, spent GAC, spent IE resin, and spent PPZ. Of these streams, the GAC would be regenerated and reused. Regeneration would also destroy contaminants sorbed to the GAC.

As noted above, costs would be incurred during construction, followed by annual expenditures for the duration of the remediation. Land use controls that would constrain or limit development could be lifted after remediation. Traffic from delivery trucks and waste transport trucks would increase under this alternative, but this does not appear to be a significant factor, nor would it be unusual, given the industrial/commercial nature of the vicinity of the site. Noise may also increase, particularly during construction, but this too would be similar to current activities in the vicinity of the site.

Cost — Estimated costs for Alternative G-5 are as follows:

- Capital cost: $14,000,000
- 30-year NPW of annual costs: $8,800,000
- 30-year NPW: $22,800,000
- 30-year current value: $40,000,000

Operating costs are based on a treatment system flow rate of 50 gpm. The NPW analysis reduces operating costs directly related to contaminant concentrations, such as chemical use and GAC, by 25 percent in years six through 10 and by 50 percent thereafter, since contaminant

concentrations will decrease over time. A detailed breakdown of estimated costs for this alternative is provided in Appendix F.

4.2.6 Alternative G-6: Zero-Valent Iron Permeable Reactive Barrier, Monitoring, and Land Use Controls

4.2.6.1 Description

Alternative G-6 would consist of three major components: (1) installation of a ZVI PRB, (2) monitoring, and (3) LUCs.

Component 1 (Alternative G-6): Installation of a PRB — A ZVI PRB would be installed to mitigate migration of the cVOC plume toward Frog Mortar Creek (see Figure 4-12). The PRB would be installed along the downgradient edge of the plume, close to the shore of Frog Mortar Creek. The useful life of a ZVI PRB is 10 to 15 years. This estimate assumes a 15-year life before maintenance would be required to restore groundwater flow through the PRB. Groundwater velocity varies with depth. The velocity of organic compounds is slower than the surrounding groundwater because of sorption and desorption. The reduction in contaminant velocities can be estimated by calculating a retardation factor.

Of the primary contaminants (TCE, cis-1,2-DCE, and vinyl chloride), TCE will have the slowest velocity and so will be used to estimate the time for the plume to flow through the PRB. In the upper zone, TCE velocity is estimated at 0.006 feet per day, so the travel distance in 10 years would be 22 feet. In the intermediate zone, TCE velocity is estimated at 0.013 feet per day, so the travel distance in 10 years would be 47 feet. In the lower zone, TCE velocity is estimated at 0.05 feet per day, so the travel distance in 10 years would be 180 feet.

Comparing these distances to the length of the plume upgradient of the PRB (650–1,000 feet), the total treatment time would be 300 to 460 years in the upper zone, 140 to 210 years in the intermediate zone, and 36 to 55 years in the lower zone. The PRB in the upper zone would need to be replenished 30 to 46 times. The PRB in the intermediate and lower zones would only need to be replenished 14 to 21 and four to five times, respectively.

The PRB would be constructed using biopolymer supported trench excavations. The PRB would not need to be extended to the deep low permeability layer over the entire width of the plume because plume width decreases with depth. In the upper zone, the PRB would be approximately

1,100 feet long. In the intermediate zone, the PRB would be approximately 800 feet long, and in the lower zone, the PRB would be approximately 600 feet long. The ZVI and support matrix would then be pumped into the trench up to the depth of the water table. The balance of the trench would be filled with a non-reactive clean fill. The estimated width of each PRB is 2.5 feet, and the vertical thickness of ZVI through all three zones would be 65 to 70 feet.

Component 2 (Alternative G-6): Monitoring — This component includes sampling and analysis of groundwater from wells in the plume upgradient of the PRB and from wells on either side of the PRB, as described in Component 1. Monitoring wells in the plume that would be included in the monitoring program would include five existing three-well clusters between Taxiway Tango and Frog Mortar Creek, and two existing three-well clusters between the runway and Taxiway Tango. Five new three-well clusters (each downgradient of the PRB) and five existing three-well clusters (upgradient of the PRB) will monitor PRB performance. Samples will be collected and analyzed annually. Final selection of monitoring wells will be made in the design phase of the project, with the concurrence of relevant regulatory agencies.

Samples will be analyzed for VOCs, 1,4-dioxane, DRO, GRO, and metals. Monitoring wells would be sampled annually because contaminant concentrations are not expected to change quickly. Annual groundwater sampling and analysis reports will be submitted to the appropriate regulatory agencies. The groundwater monitoring program would be reviewed at least every five years to determine if changes in sampling frequency, analyses, or the wells that are sampled are needed.

Component 3 (Alternative G-6): LUCs — This component is the same as Component 5 in Alternative G-2.

4.2.6.2 Detailed Analysis

Overall protection of human health and the environment — Alternative G-6 would protect human health and the environment. As the plume passes through the PRB, *in situ* chemical reduction would significantly reduce concentrations of cVOCs, but concentrations of 1,4-dioxane, DRO, and GRO would be unaffected. The degree of metals removed, particularly cadmium, is uncertain. Cadmium, 1,4-dioxane, DRO, and GRO will eventually attenuate through natural physical processes. Diesel range organics and GRO may also attenuate through

biological processes. This would significantly reduce risk from exposure to contaminated groundwater and protect future human receptors that could be exposed to contaminants during intrusive activities. Contaminant concentrations downgradient of the PRB would be reduced by natural attenuation.

Monitoring would protect human health and the environment by evaluating the effectiveness of the *in situ* treatment and detecting changes in COC concentrations in the plume upgradient of the PRB. Land use controls would also protect human health and the environment during the remedial period until PRGs are met. Restricting the use of groundwater would protect human health and the environment by avoiding unacceptable risks of exposure to contaminated groundwater. Exposure to VOCs via vapor intrusion would be controlled by requirements on building construction methods.

Compliance with ARARs and other guidance — Alternative G-6 would eventually comply with chemical-specific ARARs and other guidance for cVOCs through a combination of *in situ* treatment and natural attenuation. The effect of the PRB on cadmium is uncertain, although cadmium concentrations on-site would eventually attenuate through dilution and dispersion. Concentrations of 1,4-dioxane, DRO, and GRO would be unaffected by the PRB and would eventually attenuate through dilution and dispersion, but the off-site consequences of low concentrations of these contaminants are uncertain. Alternative G-6 would also comply with location- and action-specific ARARs and other guidance. The chemical-, location-, and action-specific ARARs and other guidance are described in Section 2.

Long-term effectiveness and permanence — Alternative G-6 would provide long-term effectiveness and permanence. *In situ* treatment by the PRB would effectively and permanently remove cVOCs from groundwater as the plume flows through the PRB. However, as noted, the PRB would not affect concentrations of 1,4-dioxane, DRO, and GRO. A pilot-scale treatability study would be needed before designing the PRB. Further groundwater modeling would also be required to design the PRB.

Monitoring treatment progress would effectively evaluate remediation progress and verify that no COCs are migrating beyond the PRB. Administrative restrictions would effectively prevent groundwater use until PRGs are met. Requirements for specific construction methods would

effectively prevent exposure to VOCs via vapor intrusion. The controls proposed in this alternative are considered reliable.

This alternative provides expansion flexibility as part of the final groundwater remedial action because the HCAs and other parts of the plume can be treated without interfering with the PRB. However, the PRB would have to be installed before the soil/landfill waste remedy is implemented because of the disturbance at the ground surface that will be caused by PRB construction.

Reduction of toxicity, mobility, or volume through treatment — Alternative G-6 would reduce the toxicity, mobility, and volume of groundwater COCs. Over 30 years, *in situ* reduction would permanently and irreversibly remove an estimated 1,600 lb of TCE, 800 lb of cis-1,2-DCE, and 1,500 lb of vinyl chloride from groundwater. No 1,4-dioxane, DRO, or GRO would be removed. The PRB's effectiveness in removing metals such as cadmium is uncertain. No treatment residues would be generated by this alternative, although a large volume of excavated soil generated during installation will require disposal.

Short-term effectiveness — Alternative G-6 would reduce human health risks in the short term through groundwater use restrictions. Workers' exposure to contamination during installation of the PRB and groundwater sampling would be minimized by compliance with OSHA requirements, including wearing appropriate PPE and adhering to site-specific health and safety procedures. Implementation of LUCs and monitoring would not adversely affect the surrounding community or the environment.

Groundwater RAO No. 1 would be attained for cVOCs after the PRB is installed. Groundwater RAO Nos. 2 and 3 would be achieved immediately upon implementation of LUCs and monitoring. The PRB would be completed in approximately 12 months.

Implementability — Alternative G-6 would be difficult to implement. A limited number of qualified contractors are available for ZVI PRB installation. Installation of a PRB to this depth would be difficult and require specialized equipment.

A large area adjacent to the PRB would be needed to handle excavated and contaminated soil, which would need to be properly disposed of. Sampling and maintenance of monitoring wells

could be readily accomplished. Only a few contractors can perform this type of construction, and only a few sources of ZVI are available. Design and implementation of the components of this alternative must also consider the effect of soil remediation activities.

A bench-scale treatability study would be needed to confirm the effectiveness of these technologies at this site. Groundwater modeling would also be required to design the PRB. The administrative aspects of Alternative G-6, such as imposing LUCs, would be relatively simple to implement. However, applying for and obtaining permits may take time.

Sustainability — Alternative G-6 would pose several significant consequences affecting the sustainability factors listed above. Heavy construction equipment would generate greenhouse gases during initial installation and each subsequent PRB replacement. The PRB would have to be replaced numerous times until the plume has been remediated. However, long-term greenhouse gas generation would be minimal, and long-term electricity demand would be avoided. Production of the ZVI used in the PRB would contribute to energy use, as well as greenhouse gas production. A large volume of soil requiring off-site disposal would be generated during initial installation and each subsequent replacement of the PRB, but no waste streams would be generated during long-term operations.

The cVOCs would be destroyed as they pass through the PRB by reaction with the ZVI. As noted above, costs would be incurred during construction and replacement, followed by annual expenditures for the duration of the remediation. Although the site could be developed within the constraints of the LUCs, the types of development on top of the PRB and near construction equipment staging areas (for PRB replacement) would be limited by the presence of the PRB. Traffic from construction and waste transport would increase, but this would be a short-term effect during construction periods and would not create conditions significantly different from the normal industrial/commercial nature of the vicinity of the site. Noise may increase, particularly during construction, but this too would be similar to current activities near the site.

Cost — Estimated costs for Alternative G-6 are as follows:

- Capital cost: $13,300,000
- 30-year NPW of annual costs: $5,700,000

- 30-year NPW: $19,000,000
- 30-year current value: $33,500,000

A detailed breakdown of estimated costs for this alternative is provided in Appendix F.

Table 4-1

Summary of Key Features of the Alternatives - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

FS Alt No.	Name	GW Treatment System Size, gpm	Operating GW flow rate basis, gpm	Re-injection of Treated GW	HCA Extraction Wells	ISB of HCA
G-1	No Action	NA	NA	NA	NA	NA
G-2	Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW/Surface Water, Monitoring, and LUCs	50	50	No	No	No
G-3	Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW/Surface Water, Monitoring, and LUCs	100	50	Yes	No	No
G-4	Hydraulic Control by Extraction, Extraction of HCA, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW/Surface Water, Monitoring, and LUCs	100	100	Yes	Yes	No
G-5	Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of HCA, Discharge to POTW/Surface Water, Monitoring, and LUCs	100	50	No	No	Yes
G-6	ZVI PRB, Monitoring, and LUCs [No groundwater treatment]	NA	NA	NA	NA	NA

gpm - gallons per minute
GW - Groundwater.
HCA - High Concentration Areas
ISB - In-Situ Bioremediation (using dedicated injection system)
LUC - Land use control.
NA - Not Applicable.
POTW - Publicly Owned Treatment Works.
PRB - Permeable reactive barrier.
ZVI - Zero-valent iron.

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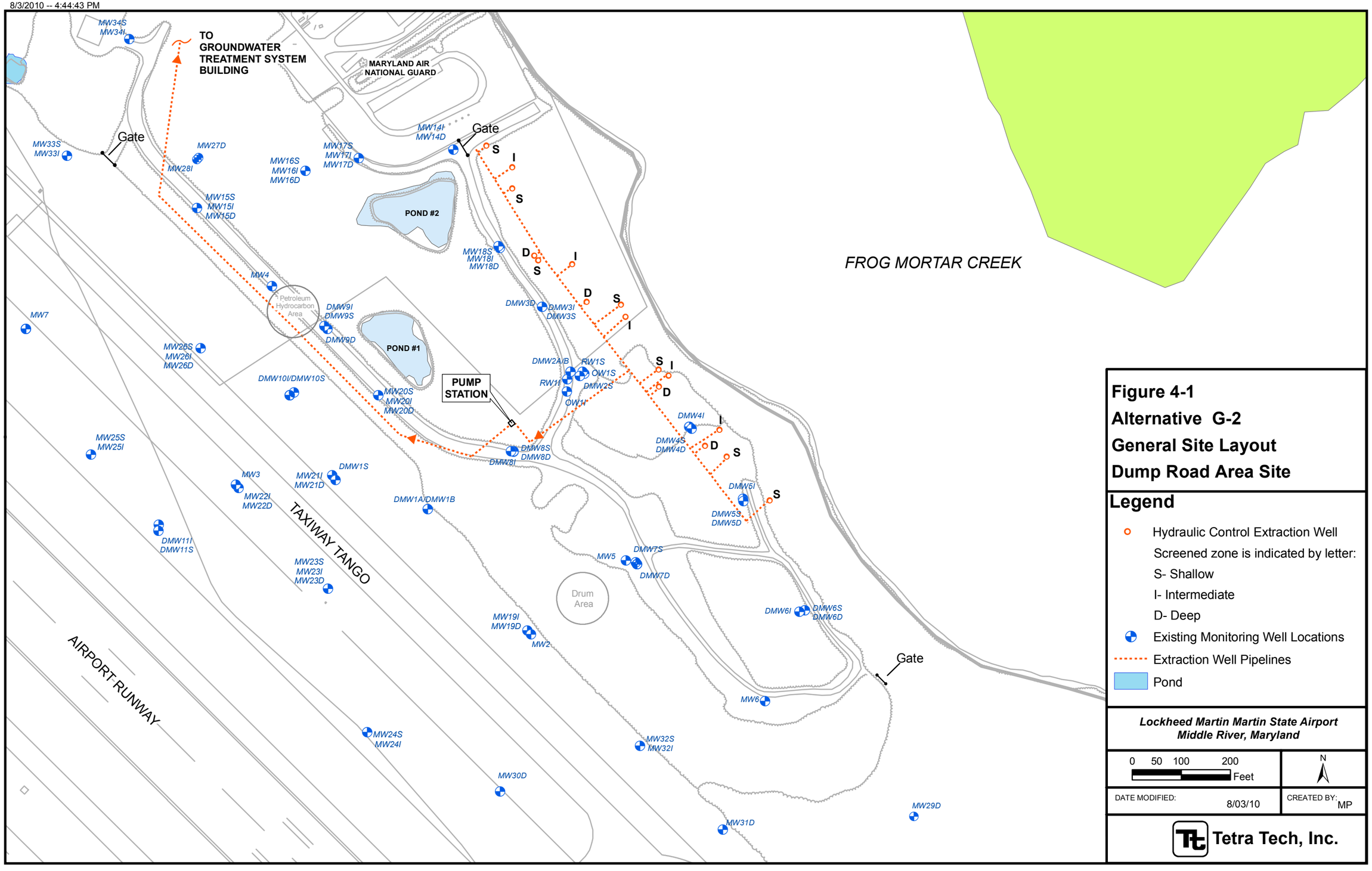

Figure 4-1
Alternative G-2
General Site Layout
Dump Road Area Site

Legend

- Hydraulic Control Extraction Well
  Screened zone is indicated by letter:
  S- Shallow
  I- Intermediate
  D- Deep
- Existing Monitoring Well Locations
- Extraction Well Pipelines
- Pond

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

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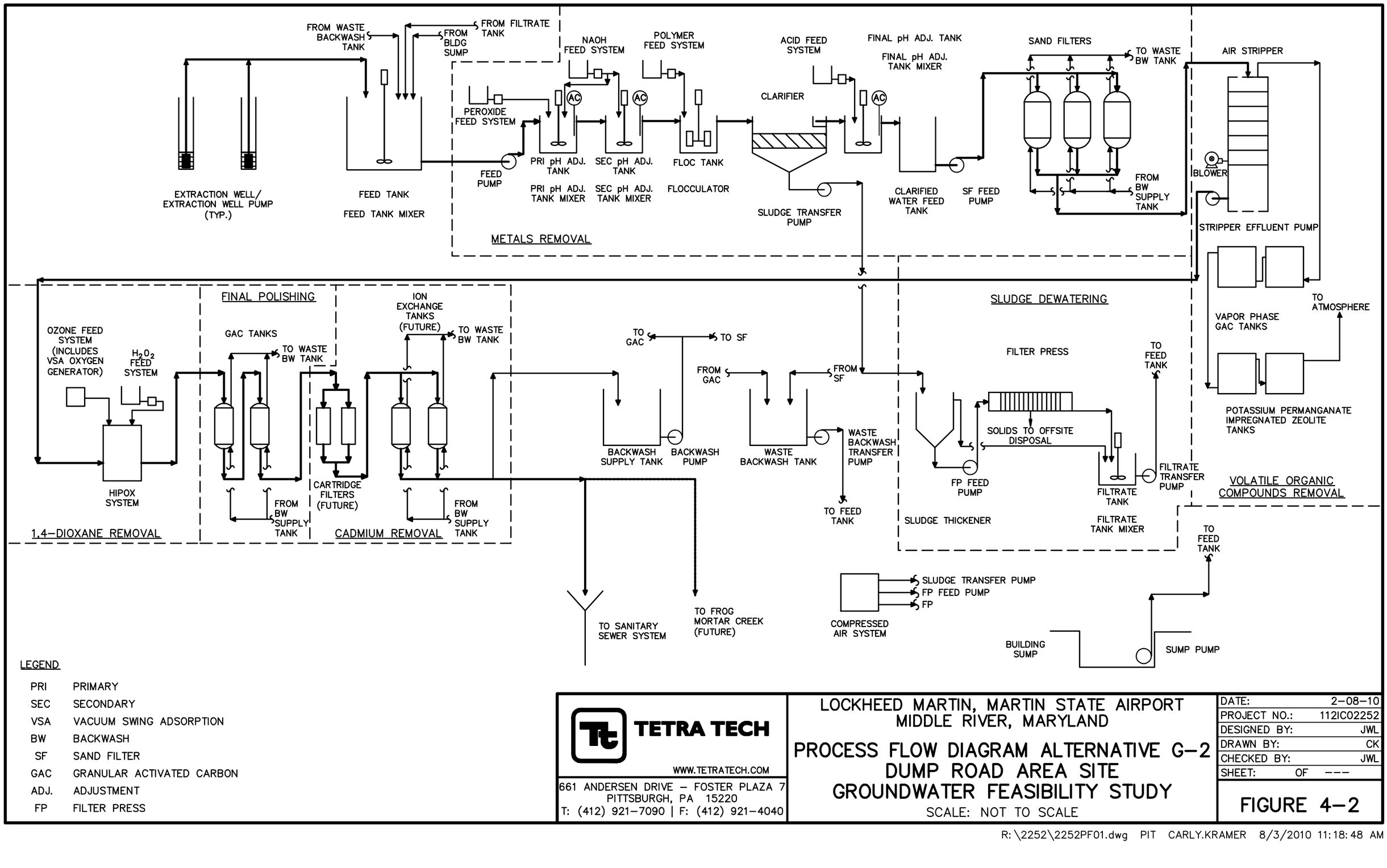

LEGEND

PRI	PRIMARY
SEC	SECONDARY
VSA	VACUUM SWING ADSORPTION
BW	BACKWASH
SF	SAND FILTER
GAC	GRANULAR ACTIVATED CARBON
ADJ.	ADJUSTMENT
FP	FILTER PRESS

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MIDDLE RIVER, MARYLAND

PROCESS FLOW DIAGRAM ALTERNATIVE G–2
DUMP ROAD AREA SITE
GROUNDWATER FEASIBILITY STUDY

SCALE: NOT TO SCALE

DATE:	2–08–10
PROJECT NO.:	112IC02252
DESIGNED BY:	JWL
DRAWN BY:	CK
CHECKED BY:	JWL
SHEET:	OF ---

FIGURE 4–2

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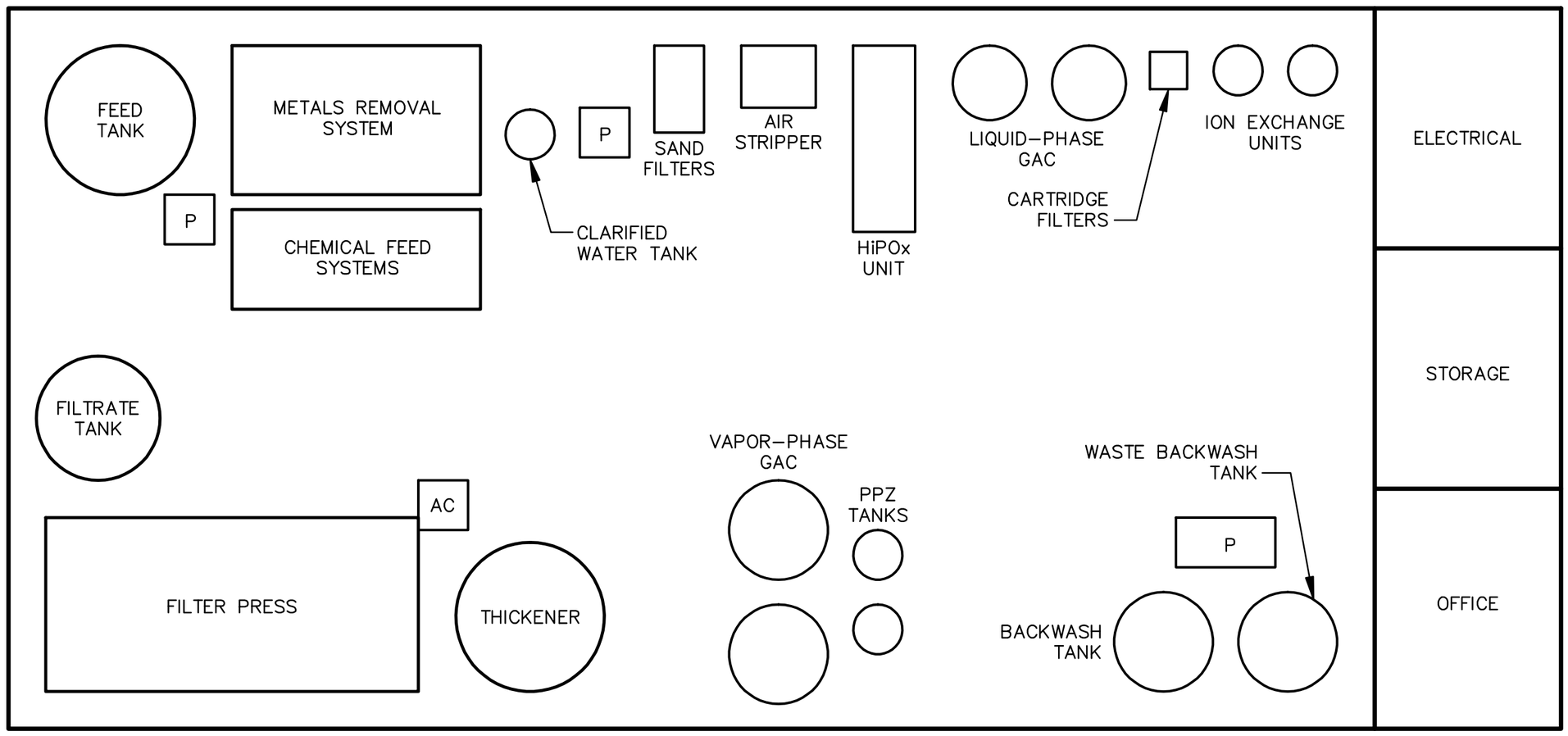

0 10 20

SCALE: 1" = 10'

LEGEND

P = PUMPS
AC = AIR COMPRESSOR
PPZ = POTASSIUM PERMANGANATE IMPREGNATED ZEOLITE

NOTE:

BUILDING DIMENSIONS ARE 60 FEET x 130 FEET

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CONCEPTUAL BUILDING LAYOUT ALTERNATIVE G–2 DUMP ROAD AREA SITE GROUNDWATER FEASIBILITY STUDY

SCALE: 1"=10'

DATE:	6–29–09
PROJECT NO.:	112G02199
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FIGURE 4–3

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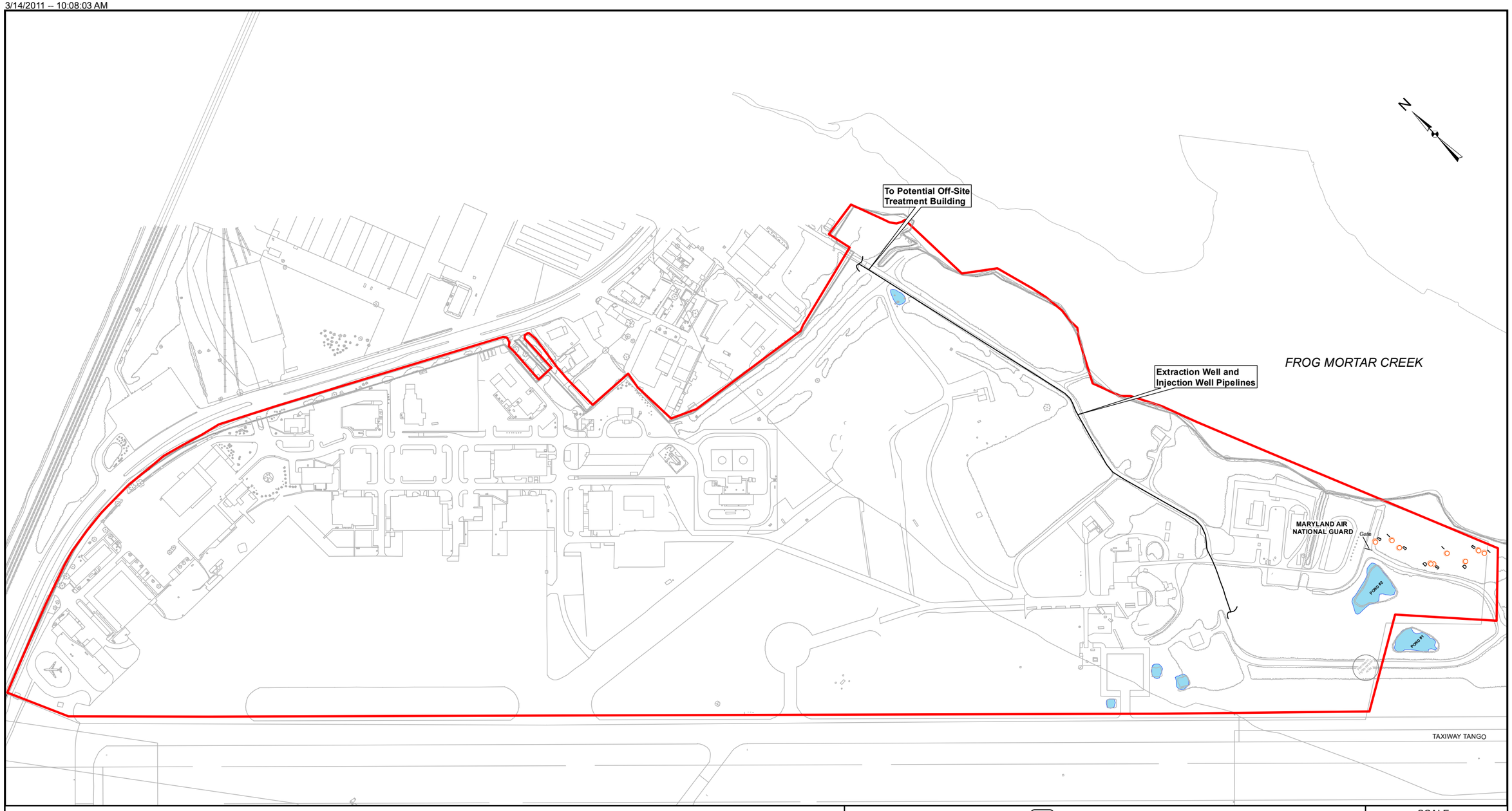

Legend

- Pond
- Maryland Air National Guard
- Hydraulic Control Extraction Well
  Screened zone is indicated by letter:
  S- Shallow D- Deep
  I- Intermediate

0 200 400 800 Feet

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PROPOSED GROUNDWATER TREATMENT
SYSTEM PIPELINE ROUTING
DUMP ROAD AREA SITE
LOCKHEED MARTIN, MARTIN STATE AIRPORT
MIDDLE RIVER, MARYLAND

SCALE	as shown
FILE	K:\GProject\MartinStateAirport-LMC\MapDocs\MXD\Maps\MSA FS Figure 4_6_revised 031411.mxd
REV	0
DATE	3/14/11
FIGURE NUMBER	4-4

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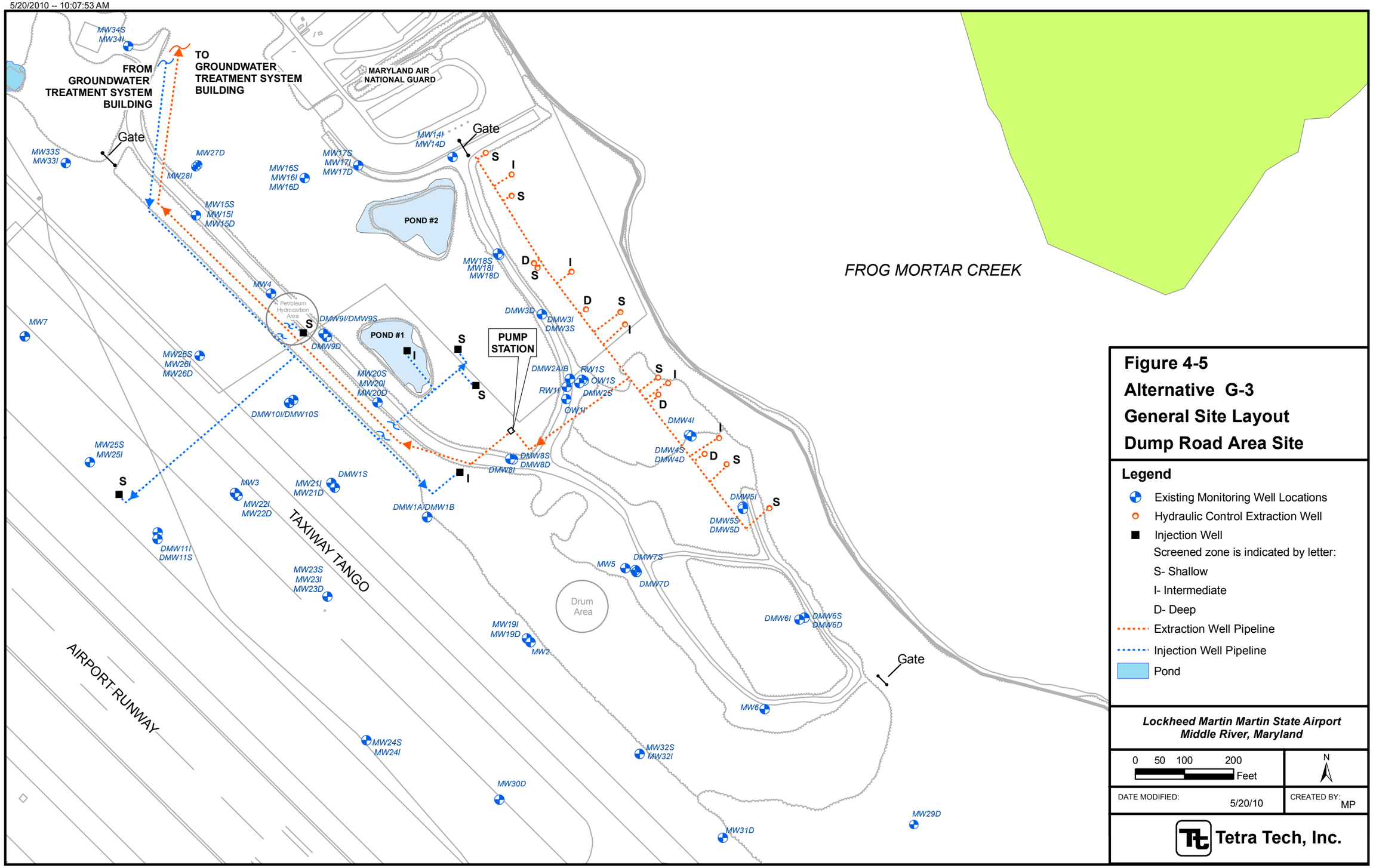

Figure 4-5
Alternative G-3
General Site Layout
Dump Road Area Site

Legend

- Existing Monitoring Well Locations
- Hydraulic Control Extraction Well
- Injection Well
- Screened zone is indicated by letter:
- S- Shallow
- I- Intermediate
- D- Deep
- Extraction Well Pipeline
- Injection Well Pipeline
- Pond

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

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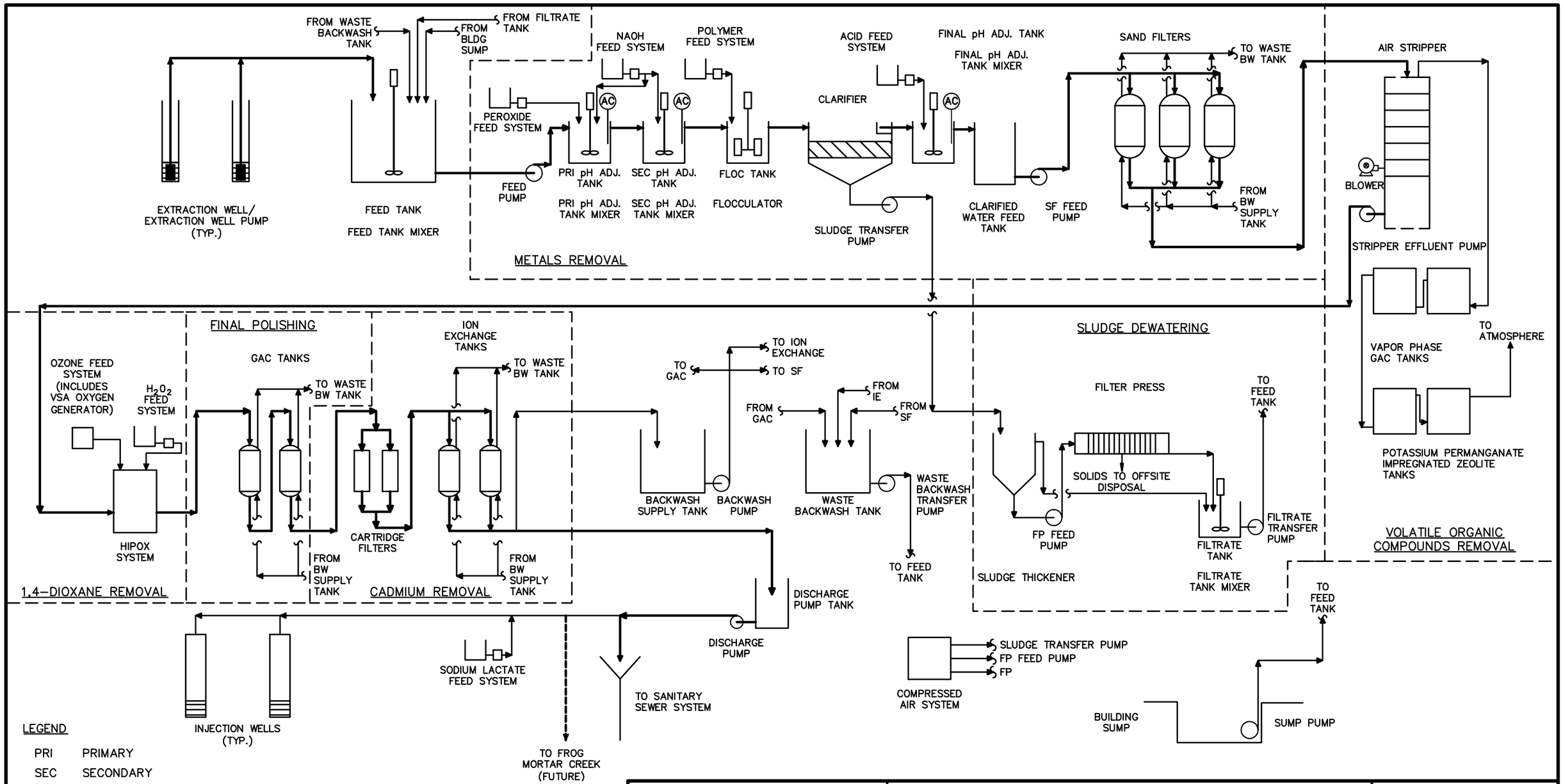

LEGEND

PRI	PRIMARY
SEC	SECONDARY
VSA	VACUUM SWING ADSORPTION
BW	BACKWASH
SF	SAND FILTER
IE	ION EXCHANGE
GAC	GRANULAR ACTIVATED CARBON
ADJ.	ADJUSTMENT
FP	FILTER PRESS

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PROCESS FLOW DIAGRAM ALTERNATIVE G–3 DUMP ROAD AREA SITE GROUNDWATER FEASIBILITY STUDY

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FIGURE 4–6

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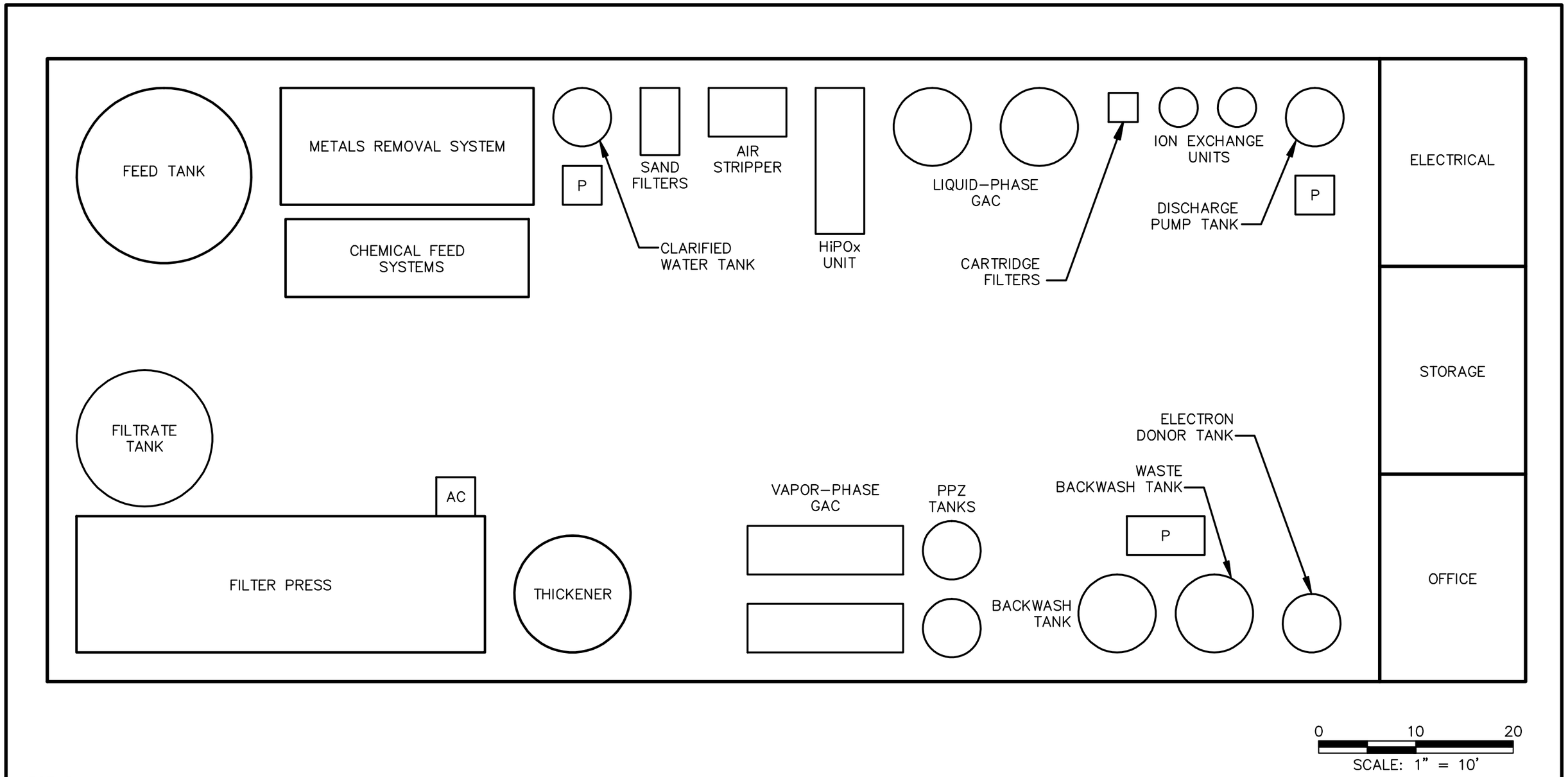

LEGEND

P = PUMPS
AC = AIR COMPRESSOR
PPZ = POTASSIUM PERMANGANATE IMPREGNATED ZEOLITE

NOTE:

BUILDING DIMENSIONS ARE 65 FEET x 155 FEET

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CONCEPTUAL BUILDING LAYOUT ALTERNATIVES G–3, G–4, AND G–5 DUMP ROAD AREA SITE GROUNDWATER FEASIBILITY STUDY

SCALE: 1"=10'

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FIGURE 4–7

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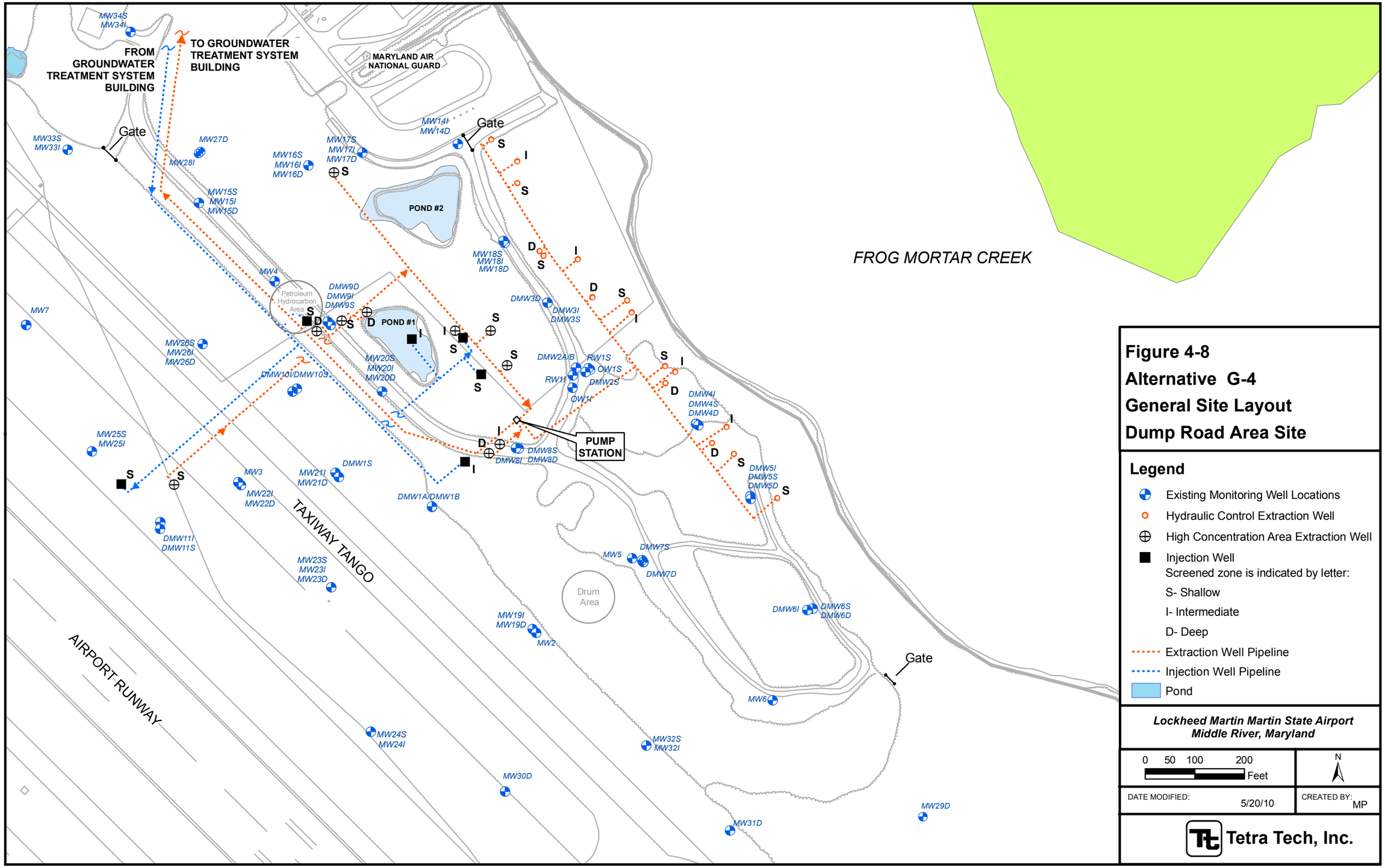

Figure 4-8
Alternative G-4
General Site Layout
Dump Road Area Site

Legend

- Existing Monitoring Well Locations
- Hydraulic Control Extraction Well
- High Concentration Area Extraction Well
- Injection Well
  Screened zone is indicated by letter:
  - S- Shallow
  - I- Intermediate
  - D- Deep
- Extraction Well Pipeline
- Injection Well Pipeline
- Pond

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

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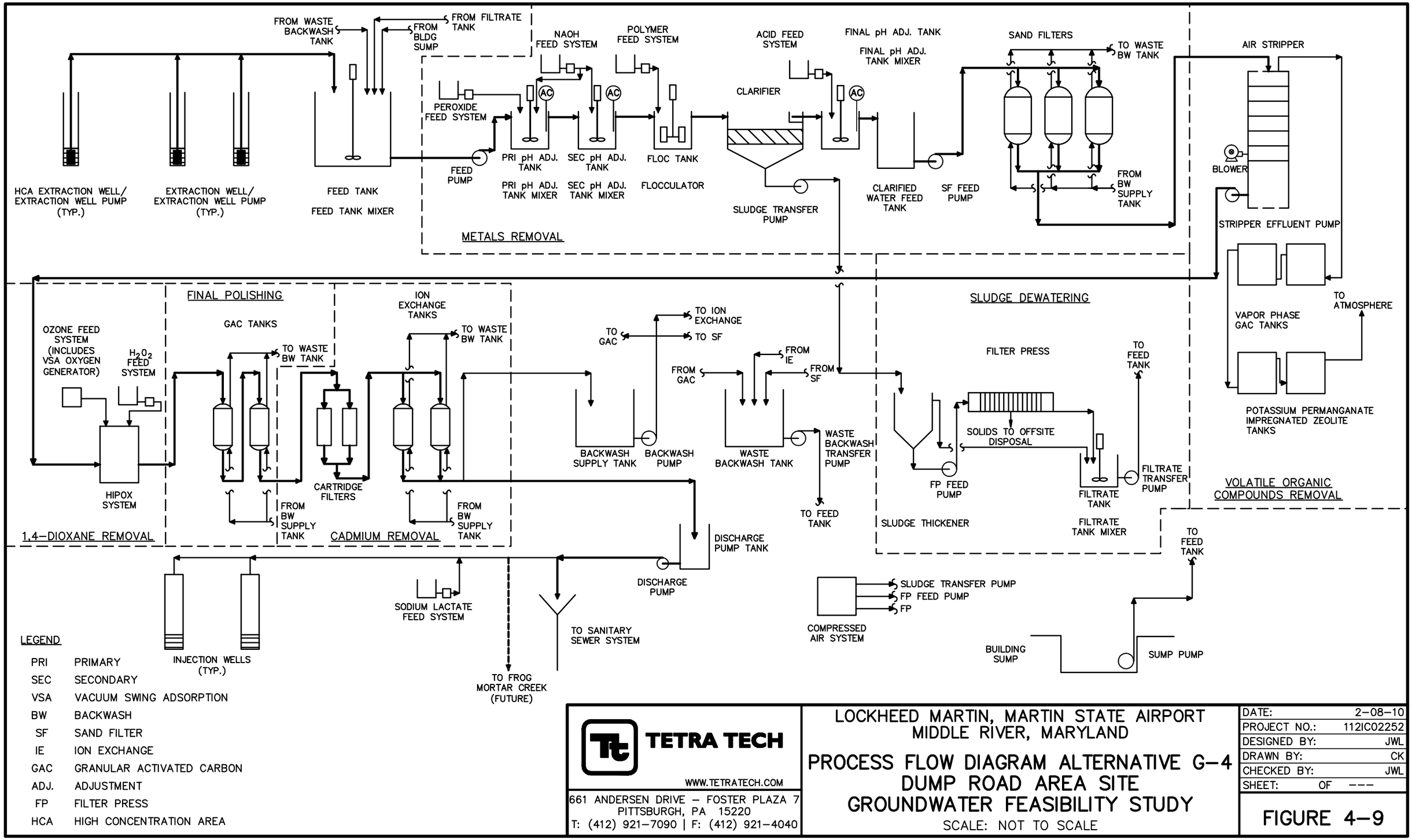

LEGEND

PRI	PRIMARY
SEC	SECONDARY
VSA	VACUUM SWING ADSORPTION
BW	BACKWASH
SF	SAND FILTER
IE	ION EXCHANGE
GAC	GRANULAR ACTIVATED CARBON
ADJ.	ADJUSTMENT
FP	FILTER PRESS
HCA	HIGH CONCENTRATION AREA

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PROCESS FLOW DIAGRAM ALTERNATIVE G–4 DUMP ROAD AREA SITE GROUNDWATER FEASIBILITY STUDY

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FIGURE 4–9

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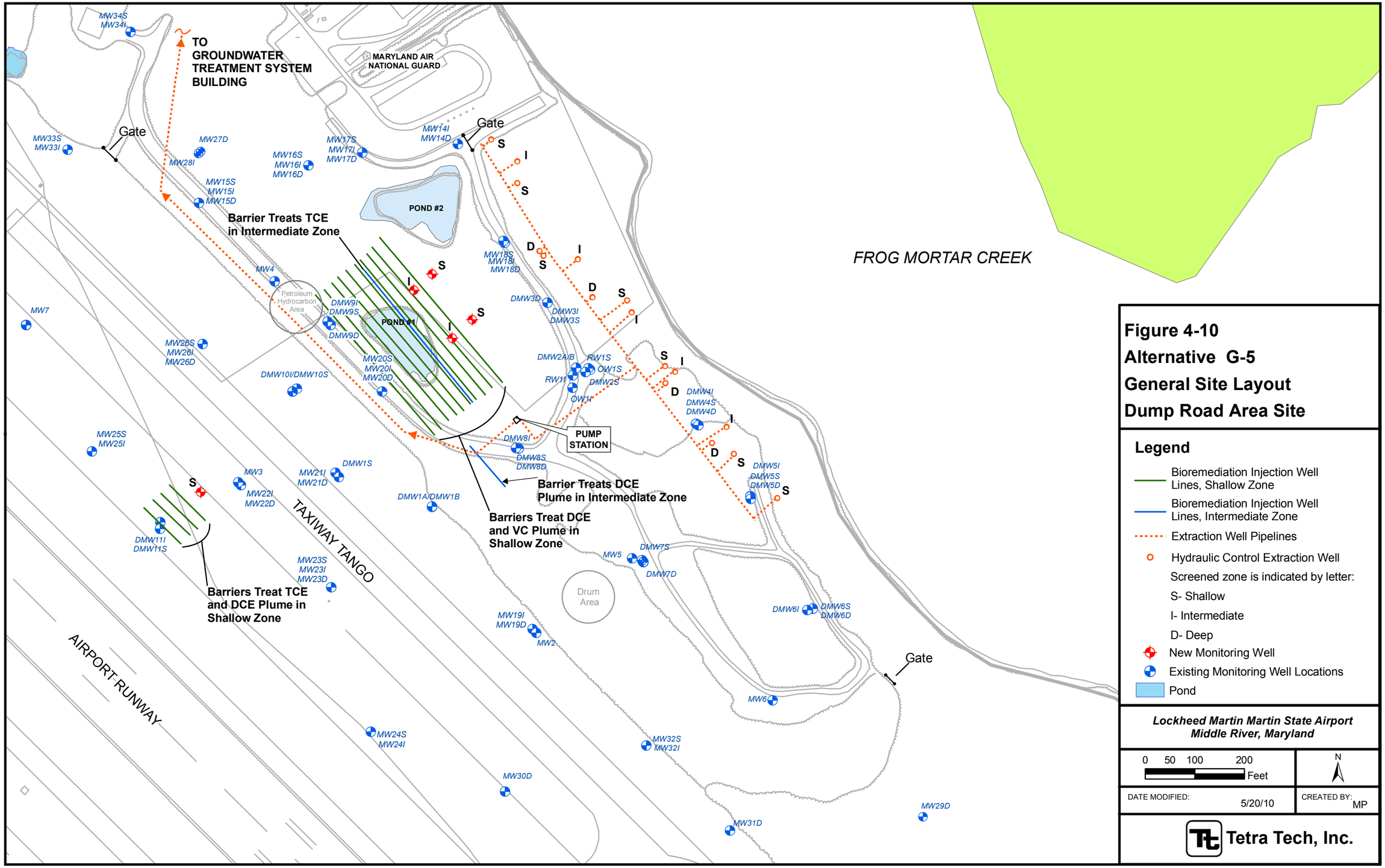

Figure 4-10
Alternative G-5
General Site Layout
Dump Road Area Site

Legend

- Bioremediation Injection Well Lines, Shallow Zone
- Bioremediation Injection Well Lines, Intermediate Zone
- Extraction Well Pipelines
- Hydraulic Control Extraction Well
- Screened zone is indicated by letter:
  - S- Shallow
  - I- Intermediate
  - D- Deep
- New Monitoring Well
- Existing Monitoring Well Locations
- Pond

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

DATE MODIFIED: 5/20/10

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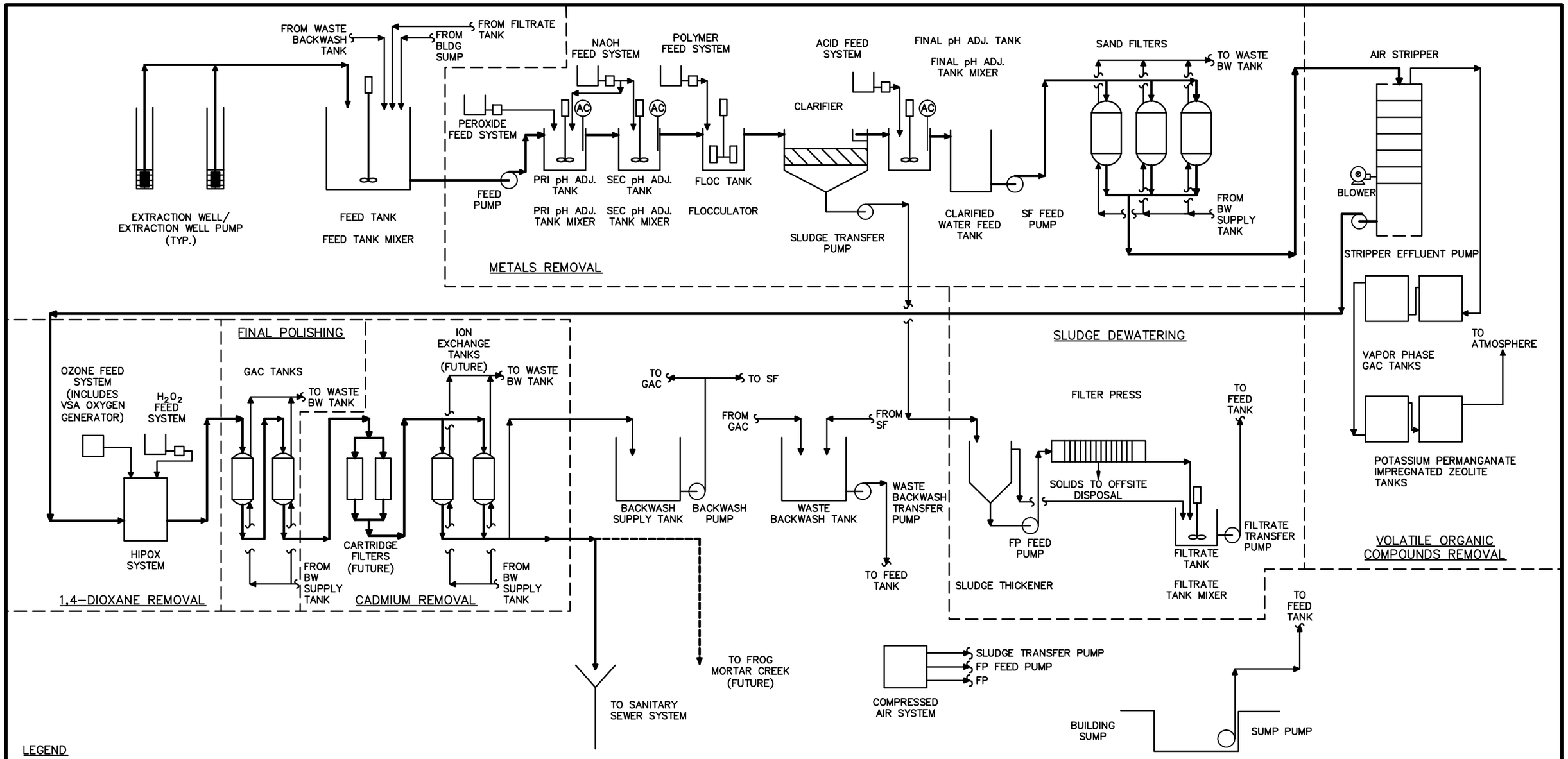

LEGEND

PRI	PRIMARY
SEC	SECONDARY
VSA	VACUUM SWING ADSORPTION
BW	BACKWASH
SF	SAND FILTER
GAC	GRANULAR ACTIVATED CARBON
ADJ.	ADJUSTMENT
FP	FILTER PRESS

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SCALE: NOT TO SCALE

DATE:	2–08–10
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FIGURE 4–11

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MW34S
MW34I
MARYLAND AIR NATIONAL GUARD
Gate
MW14I
MW14D
Gate
MW33S
MW33I
MW27D
MW28I
MW16S
MW16I
MW16D
MW17S
MW17I
MW17D
MW15S
MW15I
MW15D
POND #2
MW18S
MW18I
MW18D
FROG MORTAR CREEK
MW4
Petroleum Hydrocarbon Area
DMW9I/DMW9S
DMW9D
POND #1
DMW3I
DMW3S
DMW3D
MW7
MW26S
MW26I
MW26D
DMW2A/B
RW1S
OW1S
RW1I
DMW2S
OW1I
DMW10I/DMW10S
MW20S
MW20I
MW20D
DMW4I
DMW4S
DMW4D
MW25S
MW25I
DMW8I
DMW8S
DMW8D
MW3
MW21I
MW21D
DMW1S
(TCE U)
& DCE UW
MW22I
MW22D
DMW1A/DMW1B
DMW5I
DMW5S
DMW5D
ZVI PRB
TAXIWAY TANGO
DMW11I
DMW11S
MW23S
MW23I
MW23D
MW5
DMW7S
DMW7D
Drum Area
DMW6I
DMW6S
DMW6D
MW19I
MW19D
MW2
Gate
AIRPORT RUNWAY
MW6
MW24S
MW24I
MW32S
MW32I
MW30D
MW29D
MW31D

Figure 4-12
Alternative G-6
General Site Layout
Dump Road Area Site

Legend

- Existing Monitoring Well Locations
- New Monitoring Well Cluster
- ZVI PRB
- Pond

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

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DATE MODIFIED: 2/8/10

CREATED BY: MP

Tetra Tech, Inc.

Section 5
Comparative Analysis of Alternatives

The analyses for each of the groundwater alternatives presented in Section 4.0 of this Groundwater Feasibility Study (FS) are compared in this section. The comparison criteria are identical to those used for the detailed analysis of individual alternatives.

5.1 COMPARISON OF GROUNDWATER ALTERNATIVES BY CRITERIA

The following alternatives for groundwater are compared in this section:

- ***Alternative G-1***: No action
- ***Alternative G-2***: Hydraulic control by extraction, *ex situ* treatment of groundwater, discharge to publicly owned treatment works (POTW), monitoring, and land use controls (LUCs)
- ***Alternative G-3***: Hydraulic control by extraction, *ex situ* treatment of groundwater, reinjection of groundwater, discharge to POTW, monitoring, and LUCs
- ***Alternative G-4***: Hydraulic control by extraction, extraction in high concentration areas (HCAs), *ex situ* treatment of groundwater, reinjection of groundwater, discharge to POTW, monitoring, and LUCs
- ***Alternative G-5***: Hydraulic control by extraction, *ex situ* treatment of groundwater, *in situ* bioremediation of HCAs, discharge to POTW, monitoring, and LUCs
- ***Alternative G-6***: Zero-valent iron (ZVI) permeable reactive barrier (PRB), monitoring, and LUCs

5.1.1 Overall Protection of Human Health and the Environment

Alternatives G-2, G-3, G-4, and G-5 would all protect human health and the environment. Alternative G-2 offers site containment but does not address contaminant source areas. Alternatives G-4 and G-5 would provide the best protection because they also treat the HCAs.

Alternative G-3 provides the next best protection through reinjection of groundwater with an electron-donor compound to promote biological degradation of the HCAs. Alternative G-3 also offers the greatest flexibility to provide additional protection as part of a final groundwater remedy. In Alternative G-6, contaminants would continue to migrate off-site under this alternative because 1,4-dioxane, diesel range organics (DRO), and gasoline range organics (GRO) are not affected by the PRB. This could potentially affect downgradient users and allow contaminants to enter surface water.

Alternatives G-2, G-3, G-4, G-5, and G-6 would further reduce contaminant concentrations. Monitoring would be effective in detecting potential plume migration and in tracking remediation progress. Land use controls would protect human health until preliminary remediation goals (PRGs) are met by restricting groundwater use and mandating construction methods that will mitigate potential vapor intrusion into future buildings. Land use controls would significantly reduce risks from exposure to contaminated groundwater.

Alternative G-1 would provide no protection of human health and the environment. Groundwater contamination might migrate off-site under this alternative, and the potential for vapor intrusion into any future buildings is not considered. Potential migration of chemicals of concern (COCs) would not be detected under this alternative because no monitoring would be performed.

5.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternatives G-2, G-3, G-4, G-5, and G-6 would comply with location- and action-specific applicable or relevant and appropriate requirements (ARARs) and other guidance. Alternatives G-2, G-3, G-4, and G-5 would not immediately comply with chemical-specific ARARs and other guidance, but these alternatives would eventually achieve compliance as they attain PRGs through a combination of extraction and *ex situ* treatment and/or *in situ* treatment. Alternative G-6 would eventually comply with chemical-specific ARARs and other guidance for chlorinated volatile organic compounds (cVOCs) through a combination of *in situ* treatment and natural attenuation. The effect of the PRB on cadmium is uncertain, although cadmium concentrations on-site would eventually attenuate through dilution and dispersion. Concentrations of 1,4-dioxane, DRO, and GRO would be unaffected by the PRB and would eventually attenuate through dilution and dispersion.

Alternative G-1 would not comply with chemical-specific ARARs, and compliance with location-specific ARARs would be incidental. Although this alternative might eventually meet chemical-specific ARARs though natural attenuation, no monitoring would be conducted to confirm this. Action-specific ARARs or other guidance would not apply.

5.1.3 Long-Term Effectiveness and Permanence

Alternatives G-2, G-3, G-4, and G-5 would provide long-term effectiveness and permanence. Alternatives G-2, G-3, G-4, and G-5 provide essentially equal levels of long-term effectiveness and permanence through a combination of *ex situ* and *in situ* treatment and LUCs. As noted above, Alternative G-3 offers the greatest flexibility to provide additional effectiveness as part of a final groundwater remedy. Alternative G-6 would be less effective because 1,4-dioxane, DRO, and GRO would not be treated through the PRB. For all five alternatives, LUCs could be maintained until PRGs are met. All five alternatives require an extended period to reach PRGs. Operation and maintenance (O&M) would be required for an extended period to meet the PRGs.

Alternative G-1 would have no long-term effectiveness and permanence because contaminated groundwater would remain on-site. In the absence of LUCs, groundwater could be used and buildings could be built over the plume, potentially posing unacceptable risks to human receptors via vapor intrusion. Potential off-site migration of COCs would not be detected under this alternative because no groundwater monitoring would be conducted. Although COC concentrations might eventually decrease to PRGs through natural attenuation, no monitoring would verify this.

5.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives G-2, G-3, G-4, G-5, and G-6 would achieve reductions in COC toxicity and volume through treatment. Under Alternatives G-2, G-3, G-4, and G-5, COCs would be sorbed onto GAC, and spent GAC would be regenerated off-site. The 1,4-dioxane and some of the other COCs would be destroyed by the advanced oxidation process (AOP). Vinyl chloride captured by the potassium permanganate impregnated zeolite (PPZ) would be oxidized.

Additional reductions of contaminant toxicity and volume would also occur under Alternatives G-3, G-4, and G-5 through *in situ* biological degradation. Alternative G-6 eliminates cVOCs through reductive dechlorination, although 1,4-dioxane, DRO, and GRO are not affected and

the level of cadmium removal is uncertain. Metals removed in the treatment system under Alternatives G-2, G-3, G-4, and G-5 would be disposed of off-site. Each alternative would permanently and irreversibly remove contaminants as summarized below:

Alternative	TCE (lb)	cis-1,2-DCE (lb)	Vinyl chloride (lb)	1,4-Dioxane (lb)
Alternative G-2	3,600	1,900	3,300	160
Alternative G-3	3,700	1,900	3,400	160
Alternative G-4	3,900	2,000	3,600	170
Alternative G-5	3,900	2,000	3,600	170
Alternative G-6	1,600	800	1,500	0

Alternative G-6 would not generate treatment residues, but a large volume of excavated soil generated during installation would require disposal. Alternatives G-2, G-3, G-4, and G-5 would generate spent GAC, spent PPZ, spent ion exchange resin, and sludge that would require off-site management. Alternative G-1 would not achieve any reduction of toxicity, mobility, or volume of COCs through treatment. Reduction of contaminant toxicity and volume through natural attenuation might be achieved; however, under Alternative G-1, this reduction would neither be verified nor quantified.

5.1.5 Short-Term Effectiveness

Implementation of Alternatives G-2, G-3, G-4, and G-5 would result in a slight possibility of exposing site workers to contaminated groundwater during installation and maintenance of the groundwater collection and treatment system, as well as during sampling of new and existing monitoring wells. Alternatives G-2 and G-3 would result in the lowest short-term risk with the potential for exposure only during well installation, plant operation, and monitoring. As with Alternatives G-2 and G-3, Alternatives G-4 and G-5 would result in approximately the same level of short-term exposure during installation of additional wells (under Alternative G-4) and injection points (under Alternative G-5).

Alternative G-6 would pose the greatest potential for short-term exposure during groundwater sampling and excavation of contaminated saturated soil during PRB construction. However, these exposure risks could be effectively controlled by wearing appropriate PPE and compliance with appropriate site-specific health and safety procedures. Implementation of

Alternative G-6 could also pose a slightly higher risk to the surrounding community than would the other alternatives during the transport of contaminated soil excavated from the site and of clean sand and ZVI brought to the site. Implementation of Alternatives G-2, G-3, G-4, and G-5 could also pose a slight risk to the surrounding community as a result of transporting treatment chemicals to the treatment building and spent GAC, sludge, and/or IE resin from the site.

Alternatives G-2, G-3, G-4, G-5, and G-6 would achieve groundwater remedial action objective (RAO) Nos. 2 and 3 immediately upon implementation of LUCs and monitoring. Construction associated with Alternatives G-2, G-3, G-4, G-5, and G-6 would be completed in approximately 18 months. Groundwater RAO No. 1 would be attained upon startup of the hydraulic barrier entailed in Alternatives G-2, G-3, G-4, and G-5. For Alternative G-6, groundwater RAO No. 1 would be attained for cVOCs upon completion of the PRB. Whether RAO No. 1 would be attained for 1,4-dioxane, DRO, GRO, and cadmium is uncertain.

All alternatives can be expected to require operation for more than 50 years. Alternative G-6 would take the longest because of the long travel times for the plume to reach the PRB under natural groundwater gradients, and the expected need to rely on natural processes for some contaminants to achieve PRGs. The increased gradients due to groundwater extraction and treatment of HCAs under Alternatives G-2, G-3, G-4, and G-5 decrease the treatment duration as compared to Alternative G-6. Implementation of Alternative G-1 would not result in risks to site workers or adversely affect the surrounding community or environment because no activities would be performed. Alternative G-1 would not achieve RAOs, and though cleanup goals might eventually be attained through natural processes, this would not be verified because no sampling would be conducted.

5.1.6 Implementability

Alternative G-1 would be easiest to implement because it undertakes no action to address groundwater contamination at the site. Technical implementation of the various components of Alternatives G-2 and G-3 would be the next easiest to implement. Alternatives G-4 and G-5 would be slightly more difficult to implement because of the additional flow of groundwater to the treatment system and additional extraction wells envisioned under Alternative G-4 and the addition of EOS through injection wells envisioned under Alternative G-5. The large number of

injection wells envisioned under Alternative G-5 would also have to be coordinated with the soil/landfill waste remedy. Contractors and equipment are readily available for all four of these alternatives. All four would require long-term O&M.

Alternative G-6 would be the most difficult to implement because it would require specialized construction methods for the PRB trenches and specialized media (ZVI) to fill the trench. Only a few contractors do this type of construction, and only a few sources of ZVI are available. Alternatives G-2, G-3, G-4, G-4, and G-6 all require similar LUCs that would have to be implemented and maintained for the duration of treatment.

Several alternatives, if implemented, might affect use of the property. Alternative G-2 poses the fewest consequences because it involves only the installation of the hydraulic control extraction wells. Alternatives G-3, G-4, and G-5 would further affect site use because of the injection wells, the HCA extraction wells, and the EOS injection wells (respectively). Piping to and from the wells, and electrical supply to the wells, might also affect site use. Alternative G-6 would primarily affect site use during construction, but only the area of the PRB and the area immediately adjacent would be restricted. High concentrations of VOCs in the shallow groundwater will limit the type of building construction that can be allowed over the plume because of the potential for vapor intrusion.

A permit to discharge to the POTW will have to be obtained for Alternatives G-2, G-3, G-4, and G-5. This could prove difficult because of the sanitary authority's program to minimize the introduction of relatively clean water (such as groundwater infiltration) into the system. A permit for direct discharge to surface water could be more difficult to obtain because of the modeling, field testing, and calibration that would be required to estimate effluent limitations into the Frog Mortar Creek estuary or Stansbury Creek estuary. Discharge limitations to the POTW are much less restrictive compared to the limitations anticipated for a direct discharge. For Alternative G-6, a large volume of waste material would need to be managed and properly disposed of.

5.1.7 Sustainability

Alternative G-1 is the most sustainable of the alternatives evaluated, based on the factors considered for this criterion in this FS. No energy or resources would be consumed, no

greenhouse gases or waste would be generated, nor would costs or increases in negative social factors (such as traffic and noise) occur. However, an economic factor to consider is that site development would be limited because, with no controls in place under this alternative, potential exposure to contaminated groundwater or to contaminants volatilizing from groundwater into buildings could occur.

Alternative G-6 offers high to moderate sustainability. The passive process described in Alternative G-6 would use little electrical power in the long-term, but would entail significant energy use from construction vehicles during initial PRB installation and each subsequent PRB replacement. A large waste stream would also be generated during each PRB installation. The PRB would need to be replaced numerous times until the plume is remediated. Local effects, such as noise and traffic, would be limited to the construction period. The space occupied by the PRB could not be developed until remediation goals were met.

Alternatives G-2, G-3, G-4, and G-5 would have similar consequences for sustainability. All four alternatives use electrical power that contributes to greenhouse gas generation, but alternatives G-2 and G-5 would use the least. Electricity use under Alternative G-3 would initially be similar to that of Alternatives G-2 and G-5, but could increase to the same level as Alternative G-4. Alternative G-4 has the highest electrical energy use and highest contribution to greenhouse gas generation. Manufacture of the carbon substrate used for the *in situ* bioremediation component under Alternative G-5 would contribute additional greenhouse gases as compared to the other alternatives.

All four of these alternatives consume chemicals (such as hydrogen peroxide, sodium hydroxide, and hydrochloric acid) in the groundwater treatment system. Production of chemicals used to treat and regenerate GAC would also contribute to energy use and greenhouse gas production. Alternatives G-2 and G-5 would use the least amount of chemicals.

Chemical consumption under Alternative G-3 would initially be similar to that of Alternatives G-2 and G-5, but could increase to the same level as Alternative G-4, which uses the most. Alternatives G-3 and G-5 use similar quantities of electron-donor compound in the groundwater reinjection system. Production of the electron-donor compound would also contribute to energy use and greenhouse gas production. An electron-donor compound would

also be injected as part of Alternative G-4. The quantity of electron-donor compound under Alternative G-4 would be greater than what would be used under Alternatives G-3 and G-5, and production of the electron-donor compound would likewise contribute to energy use and greenhouse gas production.

All four groundwater treatment alternatives would generate similar quantities of waste and would destroy similar quantities of COCs in proportion to the amount of groundwater treated. All four would likewise pose similar noise and traffic impacts near the site. These alternatives would have the greatest effect on waste generation, COC destruction, traffic, and noise factors because of the higher groundwater treatment rates associated with Alternative G-4 and potentially with Alternatives G-3 and G-5,

5.1.8 Cost

Capital and O&M costs and the net present worth (NPW) of the alternatives evaluated above in this Groundwater FS are as follows:

Alternative	Capital	NPW of annual costs	NPW	Current value
G-1	$0	$0	$0 (30 years)	$0
G-2	$12,000,000	$8,200,000	$20,200,000 (30 years)	$37,000,000
G-3	$12,900,000	$8,600,000	$21,500,000 (30 years)	$38,700,000
G-4	$13,100,000	$11,700,000	$24,800,000 (30 years)	$46,900,000
G-5	$14,000,000	$8,800,000	$22,800,000 (30 years)	$40,000,000
G-6	$13,300,000	$5,700,000	$19,000,000 (30 years)	$33,500,000

Detailed cost estimates are provided in Appendix F.

5.2 SUMMARY OF COMPARATIVE ANALYSIS OF GROUNDWATER ALTERNATIVES

The comparative analysis of the groundwater remedial alternatives is summarized in Table 5-1.

5.3 SELECTION OF GROUNDWATER ALTERNATIVE

Alternative G-3 (hydraulic control by extraction, *ex situ* treatment of groundwater, reinjection of groundwater, discharge to POTW/surface water, monitoring, and LUCs) was selected as the interim remedial action to address groundwater contamination at the DRA Site. This alternative

meets the interim remedial action requirement in that it provides hydraulic containment to prevent migration of TCE, 1,4-dioxane, and cadmium to the surface water. It also provides additional groundwater treatment capacity so that the groundwater extraction system can be expanded in the future, particularly after the soil and landfill waste have been remediated.

Future expansion of this alternative could include groundwater recirculation and *in situ* bioremediation in the HCAs to provide some destruction of cVOCs, and such expansion could be designed for implementation in conjunction with the soil/landfill waste remedy. This alternative is economical and provides both effective treatment of all COCs and operational flexibility. Alternative G-3 is moderately sustainable, but this sustainability is comparable to the levels of Alternatives G-2, G-4, and G-5.

Additional investigations are being conducted in several of the HCAs. The purpose of these investigations is to better characterize and delineate the areas of the site with the highest contaminant concentrations in order to focus potential future remedial actions. The results of these investigations will be submitted in future documents and will be used to plan potential remedial actions conducted subsequent to this IRA. The HCAs to be investigated further include the vicinity of DMW-11S, the area in and around Pond 1, the Drum Area, and the vicinity of boring TA-1. Additionally, the surface water hydrology in the areas of Ponds 1 and 2 is being further studied to confirm that groundwater extraction would have a limited effect on water levels in these ponds and cause limited additional contaminant infiltration from pond sediments. Alternative G-3 contains sufficient flexibility to address these HCAs, including additional contaminant flux to the recovery wells, and the results of the investigations will be used to refine the design of the IRA.

Alternative G-2 was not selected primarily because it offers too little flexibility for future operations if higher flow rates or extraction of groundwater from other areas is required. In addition, the overall time to meet PRGs under Alternative G-2 is the second-longest. Alternative G-6 was not selected because 1,4-dioxane, DRO, and GRO would not be affected and the level of treatment of metals is uncertain. Alternative G-6 has the highest capital cost, and installation of the PRB to the required depth would be very difficult. Alternatives G-4 and G-5 were not selected because they require a commitment to a greater capital expenditure before the effects of the hydraulic barrier can be fully evaluated.

Alternatives G-4 and G-5 also include features such as additional extraction wells and injection wells that may need to be abandoned and re-installed as part of the soil and landfill waste remediation. Finally, after several years of Alternative G-3 system operation, components of Alternatives G-4 and/or G-5 could be optimally phased in using data and observations from the Alternative G-3 system operation and knowledge of the details of the final soil/landfill waste remedy. Therefore, Alternative G-3 was selected to provide hydraulic containment and to allow for a phased approach to remediation of other parts of the plume, such as the HCAs.

5.4 SUSTAINABILITY PRACTICES

Sustainability considerations were factored into determining the preferred remedial alternative. These considerations, in conjunction with Lockheed Martin's "Go Green" program, will also be applied in implementing that alternative. Sustainable practices in general are those that consider economic and natural resources, ecology, human health and safety, and quality of life. For remediation projects, sustainability means implementing projects in a manner that not only meets traditional remediation requirements (e.g., protection of human health and the environment and compliance with ARARs), but that also considers sustainable practices with a goal of minimizing the overall environmental "footprint."

Environmental footprint relates to the effects on environmental media and society that are the direct or indirect consequence of performing the remedial action. Minimizing the environmental footprint of a specific project might involve reducing toxic air and greenhouse gas emissions (e.g., carbon dioxide, methane, and nitrous oxide), reducing unnecessary or inefficient use of energy, promoting renewable energy over conventional sources, reducing soil erosion and nutrient depletion, reducing adverse effects to ecological receptors and ecosystems, and reducing water consumption or waste generation.

To improve the overall net environmental benefit of a remedial action, implementation of the selected remedial alternative will follow best management practices (BMPs) for sustainability. This includes resource management practices to minimize material demands, water consumption, energy usage, toxicity, and emissions of greenhouse gases and criteria pollutants. Considerations to encourage the sustainability of the remedial action may include items such as:

- Considering equipment material or construction during equipment specification. Selecting compatible materials that are recycled or have manufacturing processes that emit lower greenhouse gas and criteria pollutants, and require less energy and water demand.

- Using locally available resources to reduce transportation impacts.

- Installing variable frequency drives (as applicable) and high-efficiency motors on all major rotating equipment.

- If recovery of high concentration areas is conducted, pulsing of the wells may be conducted to reduce overall energy consumption.

- Optimizing the treatment system building's high-efficiency heating, ventilation, and air conditioning system and using high R-value rated insulation on building walls and roofing.

- Purchasing electricity from a renewable energy provider.

- Installing renewable energy sources (e.g., wind, solar, etc.) on-site and connecting directly to the treatment system's electrical source, and supplying surplus electricity to the power grid.

- Reducing process waste generation and landfilling by using reusable or recycled media (e.g., sand filter media and reactivated GAC).

- Continual optimization of the remedial system and groundwater monitoring program to ensure that equipment operates efficiently and treatment processes do not become redundant over time (e.g., GAC adsorption and AOP in series).

- Reducing overall effects on site water resources by discharging treated water to on-site surface water once adequate water quality information is confirmed and the discharge has been permitted.

Table 5-1

Summary of Comparative Analysis of Groundwater Remedial Alternatives - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Evaluation Criterion	Alternative G-1: No Action	Alternative G-2: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-3: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-4: Hydraulic Control by Extraction, Extraction of High Concentration Areas, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-5: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of High Concentration Areas, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-6: Zero-Valent Iron Permeable Reactive Barrier, Monitoring, and Land Use Controls
Overall Protection of Human Health and Environment	Would not be protective of human health or the environment because no action would occur. Migration of COCs would continue and remain undetected.	Would be protective of human health and the environment. Would be less protective than Alternatives G-3 through G-5 because there would be no early reduction of the HCAs. Same level of protection as Alternative G-6. LUCs would prevent exposure to the rest of the plume.	Would be protective of human health and the environment. Would be more protective than Alternatives G-2 and G-6 less protective than Alternatives G-4 and G-5 because there would be no early reduction of the HCAs. LUCs would prevent exposure to the rest of the plume.	Would be protective of human health and the environment. Would be more protective than Alternatives G-2, G-3, and G-6, because there would be early reduction of the HCAs. As protective as Alternative G-5 LUCs would prevent exposure to the rest of the plume.	Would be protective of human health and the environment. Would be more protective than Alternatives G-2, G-3, and G-6, because there would be early reduction of the HCAs. As protective as Alternative G-4 LUCs would prevent exposure to the rest of the plume.	Would be protective of human health and the environment. Would be slightly less protective than Alternatives G-3, G-4, and G-5 because there is no HCA treatment, no 1,4-dioxane, DRO, or GRO removal, and cadmium removal is uncertain. Also, less protective than Alternative G-2 because no 1,4-dioxane, DRO, or GRO are removed. High COC concentrations would persist until plume moves through the barrier. LUCs would prevent exposure to the rest of the plume.
Compliance with ARARs:						
Chemical-Specific	Would not comply	Would eventually comply	Would eventually comply	Would eventually comply	Would eventually comply	Would eventually comply for cVOCs, although compliance for 1,4-dioxane, DRO, GRO, and cadmium is uncertain.
Location-Specific	Would not comply	Would comply	Would comply	Would comply	Would comply	Would comply
Action-Specific	Not applicable	Would comply	Would comply	Would comply	Would comply	Would comply
Long-Term Effectiveness and Permanence	No long-term effectiveness and permanence because no action would occur. Contaminant reduction or migration would remain undetected.	Would be as permanent and effective as the other alternatives, although the remediation time will be longer because there is no HCA treatment. LUCs would prevent exposure. Long-term O&M is required.	Would be as permanent and effective as the other alternatives, although the remediation time will be longer because there is no HCA treatment. LUCs would prevent exposure. Long-term O&M is required.	Would be as permanent and effective as the other alternatives, although the remediation time will be shorter because there is HCA treatment. LUCs would prevent exposure. Long-term O&M is required.	Would be as permanent and effective as the other alternatives, although the remediation time will be shorter because there is HCA treatment. LUCs would prevent exposure. Long-term O&M is required.	Would be as permanent and effective for cVOCs as the other alternatives, although the remediation time will be longest because groundwater velocity under natural gradient is slow. The PRB would not affect DRO, GRO, or 1.4-dioxane. The PRB would reduce cVOCs, and LUCs would prevent exposure.

Table 5-1

Summary of Comparative Analysis of Groundwater Remedial Alternatives - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Evaluation Criterion	Alternative G-1: No Action	Alternative G-2: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-3: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-4: Hydraulic Control by Extraction, Extraction of High Concentration Areas, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-5: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of High Concentration Areas, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-6: Zero-Valent Iron Permeable Reactive Barrier, Monitoring, and Land Use Controls
Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment	Would not reduce contaminant toxicity, mobility or volume through treatment because no treatment would occur. Although some reductions would occur through natural attenuation, this would not be measured.	Would irreversibly and permanently reduce approximately 8,960 lb of COCs through advanced oxidation process.	Would irreversibly and permanently reduce approximately 9,160 lb of COCs through advanced oxidation process and in-situ biodegradation from electron donor addition to the injection wells.	Would irreversibly and permanently reduce approximately 9,670 lb of COCs through AOP and in-situ biodegradation from electron donor addition to the injection wells.	Would irreversibly and permanently reduce approximately 9,670 lb of COCs through advanced oxidation process and in-situ biodegradation.	Would irreversibly and permanently reduce approximately 3,900 lb of cVOCs through the PRB.
Short-Term Effectiveness	Would not result in any short-term risk to site workers or adversely impact the surrounding community or environment because no action would occur. The RAOs would never be achieved with the implementation of this alternative.	Would result in a possibility of exposing site workers to contaminated groundwater as a result of groundwater extraction, treatment, and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. Because of the long period of active treatment, this alternative has potential for short-term exposure. There would be a slight risk to the surrounding community or the environment. Groundwater RAO Nos. 1 and 3 would be achieved immediately upon implementation of LUCs and monitoring. RAO No. 2 would be met as soon as system was started up. Remediation time would up to 50 years and potentially longer. Construction activities would be completed in 12 months.	Would result in a possibility of exposing site workers to contaminated groundwater as a result of groundwater extraction, treatment, and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. Because of the long period of active treatment, this alternative has potential for short-term exposure. There would be a slight risk to the surrounding community or the environment. Groundwater RAO Nos. 1 and 3 would be achieved immediately upon implementation of LUCs and monitoring. RAO No. 2 would be met as soon as system was started up. Remediation time would up to 50 years and potentially longer. Construction activities would be completed in 12 months.	Would result in a possibility of exposing site workers to contaminated groundwater as a result of groundwater extraction, treatment, and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. Because of the long period of active treatment, this alternative has potential for short-term exposure. There would be a slight risk to the surrounding community or the environment. Groundwater RAO Nos. 1 and 3 would be achieved immediately upon implementation of LUCs and monitoring. RAO No. 2 would be met as soon as system was started up. Remediation time would up to 50 years and potentially longer. Construction activities would be completed in 12 months.	Would result in a possibility of exposing site workers to contaminated groundwater as a result of groundwater extraction, treatment, in-situ bioremediation chemical injection, and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. Because of the long period of active treatment, this alternative has potential for short-term exposure. There would be a slight risk to the surrounding community or the environment. Groundwater RAO Nos. 1 and 3 would be achieved immediately upon implementation of LUCs and monitoring. RAO No. 2 would be met as soon as system was started up. Remediation time would up to 50 years and potentially longer. Construction activities would be completed in 12 months.	Would result in a possibility of exposing site workers to contaminated groundwater as a result PRB installation and monitoring activities. This risk would be reduced through compliance with appropriate site-specific health and safety procedures. There would be a slight risk to the surrounding community and the environment during PRB construction. Groundwater RAO Nos. 1 and 3 would be achieved immediately upon implementation of LUCs and monitoring. RAO No. 2 would be met for cVOCs as soon as PRB is installed. Remediation time would up to 50 years and potentially longer. Construction activities would be completed within 12 months.

Table 5-1

Summary of Comparative Analysis of Groundwater Remedial Alternatives - DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Evaluation Criterion	Alternative G-1: No Action	Alternative G-2: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-3: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-4: Hydraulic Control by Extraction, Extraction of High Concentration Areas, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-5: Hydraulic Control by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of High Concentration Areas, Discharge to Publicly Owned Treatment Works / Surface Water, Monitoring, and Land Use Controls	Alternative G-6: Zero-Valent Iron Permeable Reactive Barrier, Monitoring, and Land Use Controls
Implementability	Technical and administrative implementation would be extremely simple because there would be no action to implement.	Easy to implement extraction, treatment, and monitoring. Less difficult to implement than Alternatives G-3 through G-6. LUCs would be relatively easy to develop and implement. Permit for discharge to POTW still needs to be negotiated. Use of property may be affected by extraction wells.	Easy to implement extraction, treatment, injection, and monitoring. More difficult to implement than Alternative G-2. Less difficult to implement than Alternatives G-4 through G-6. LUCs would be relatively easy to develop and implement. Permit for discharge to POTW still needs to be negotiated. Use of property may be affected by extraction and injection wells.	Easy to implement extraction, treatment, injection, and monitoring. More difficult to implement than Alternatives G-2 and G-3. Less difficult to implement than Alternatives G-5 and G-6. LUCs would be relatively easy to develop and implement. Permit for discharge to POTW still needs to be negotiated. Use of property may be affected by extraction, HCA, and injection wells.	Easy to implement extraction, treatment, injection, in-situ bioremediation, and monitoring. More difficult to implement than Alternatives G-2, G-3, and G-4. Less difficult to implement than Alternative G-6. LUCs would be relatively easy to develop and implement. Permit for discharge to POTW still needs to be negotiated. Use of property may be affected by extraction, in-situ bioremediation of HCA, and injection wells.	Difficult to install deep PRBs, but monitoring is easy to implement. Most difficult alternative. Bench-scale treatability testing would be required. LUCs would be relatively easy to develop and implement. Use of property may be affected by PRB. Management of excavated soil as hazardous waste requires RCRA TSDF permit. Corrective action may be triggered.
Sustainability	Would be highly sustainable. No energy or resources consumed. No GHG or wastes generated. No traffic or noise. Site development would be limited by the contaminated groundwater.	Would be moderately sustainable. Consumes energy and resources, and generates GHG and wastes. Slight increase in traffic and noise. More sustainable than G-3, G-4, and G-5.	Would be moderately sustainable. Consumes energy and resources, and generates GHG and wastes. Slight increase in traffic and noise. Less sustainable than G-2 and G-5. More sustainable than G-4.	Would be moderately sustainable. Consumes energy and resources, and generates GHG and wastes. Slight increase in traffic and noise. Less sustainable than G-2, G-3, and G-5.	Would be moderately sustainable. Consumes energy and resources, and generates GHG and wastes. Slight increase in traffic and noise. Less sustainable than G-2. More sustainable than G-3 and G-4.	Would be moderately to highly sustainable. Consumes energy and resources, and generates GHG and wastes during PRB installation. Slight increase in traffic and noise during construction periods.
Costs:						
Capital	$0	$12,000,000	$12,900,000	$13,100,000	$14,000,000	$13,300,000
NPW of Annual Costs	$0	$8,200,000 (30-Year)	$8,600,000 (30-Year)	$11,700,000 (30-Year)	$8,800,000 (30-Year)	$5,700,000 (30-Year)
NPW	$0	$20,200,000 (30-Year)	$21,500,000 (30-Year)	$24,800,000 (30-Year)	$22,800,000 (30-Year)	$19,000,000 (30-Year)
Current Value	$0	$37,000,000	$38,700,000	$46,900,000	$40,000,000	$33,500,000

ARAR - Applicable or Relevant and Appropriate Requirement.
COC - Chemical of concern.
DRO - Diesel range organics
GHG - Greenhouse gas.
GRO - gasoline range organics.
HCA - High concentration Area.
LUCs - Land use control.
NPW - Net present worth.
O&M - Operation and maintenance.
POTW - Publicly owned treatment works.
PRB - Permeable reactive barrier.
RAO - Remedial Action Objective.
RCRA - Resource Conservation and Recovery Act.
TSDF - Treatment, storage, and disposal facility.
VOC - Volatile organic compound.

Section 6
Future Actions

Implementation of the selected groundwater interim remedial action and subsequent final remedies for groundwater and soil/landfill waste at the DRA Site at Martin State Airport will require the following steps:

- The final version of the FS and a subsequent Proposed Plan for the groundwater interim remedial action will be submitted to the MDE for their review and approval. Requirements for subsequent document submittal will be described in a Consent Order for the site, once it has been completed. A Proposed Plan summarizing this feasibility study and identifying the selected alternative will then be prepared and distributed for public review.

- Design of the containment portion of Alternative G-3.

- Conduct additional investigations in the high concentration areas, including the vicinity of DMW-11S, Pond 1, the Drum Area, and the vicinity of boring PA-7.

- The containment portion of the interim remedial action for groundwater will be installed and operated and will initially discharge to the publicly owned treatment works. After that discharge has been fully characterized, a permit to discharge treated water to surface water will be obtained. The reinjection portion of the remedy will be installed in coordination with the final soil/landfill waste and groundwater remedies.

- The soil/landfill waste FS and final Groundwater FS will be completed in consultation with Maryland Aviation Administration (MAA) and Maryland Air National Guard (MDANG) and will be submitted for approval by MDE. What, if any, additional groundwater remedy is required will be determined at that time.

- Final remedies for site groundwater and soil/landfill waste will be designed and coordinated to eliminate potential interferences.

- The final groundwater and soil/landfill waste remedies will be implemented once the designs are complete.

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Section 7
References

1. Andreasen, D. C., 2007. "Optimization of Ground-Water Withdrawals in Anne Arundel County, Maryland, from the Upper Patapsco, Lower Patapsco, and Patuxent Aquifers Projected through 2044." *Maryland Geologic Survey Report of Investigations No. 77*.

2. Chapelle, F. M., 1985. "Hydrogeology, Digital Solute-Transport Simulation, and Geochemistry of the Lower Cretaceous Aquifer-System near Baltimore, Maryland." *Maryland Geological Survey Report of Investigations No. 43*. Maryland Geological Survey.

3. EPA (United States Environmental Protection Agency), 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*. EPA/540/G-89/004. October.

4. Fleck and Vroblesky (Fleck, W. B., and D. A. Vroblesky), 1996. "Simulation of Ground-Water Flow of the Coastal Plain Aquifers in Parts of Maryland, Delaware, and the District of Columbia." USGS Professional Paper 1404-J.

5. Glaser, J. D., 1969. "Petrology and Origin of Potomac and Magothy (Cretaceous) Sediments, Middle Atlantic Coastal Plain." *Maryland Geological Survey Reports of Investigations No. 11*. Maryland Geological Survey.

6. Hansen, H. J., 1969. "A Geometric Method to Subdivide the Patapsco Formation of Southern Maryland into Informal Mapping Units for Hydrogeologic Use." *Geological Society of America Bulletin.* Vol. 80, No. 2.

7. Tetra Tech (Tetra Tech, Inc.), 2004. *Final Data-Gap Investigation and Modeling Report, Martin State Airport, Middle River, Maryland*. May.

8. Tetra Tech, 2010a. *Groundwater Monitoring Report August–September 2009, Martin State Airport, Middle River, Maryland*. January.

9. Tetra Tech, 2010b. *Remedial Investigation Report, Martin State Airport, Middle River, Maryland*. May.

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APPENDIX A
SELECTED RI FIGURES AND TABLES

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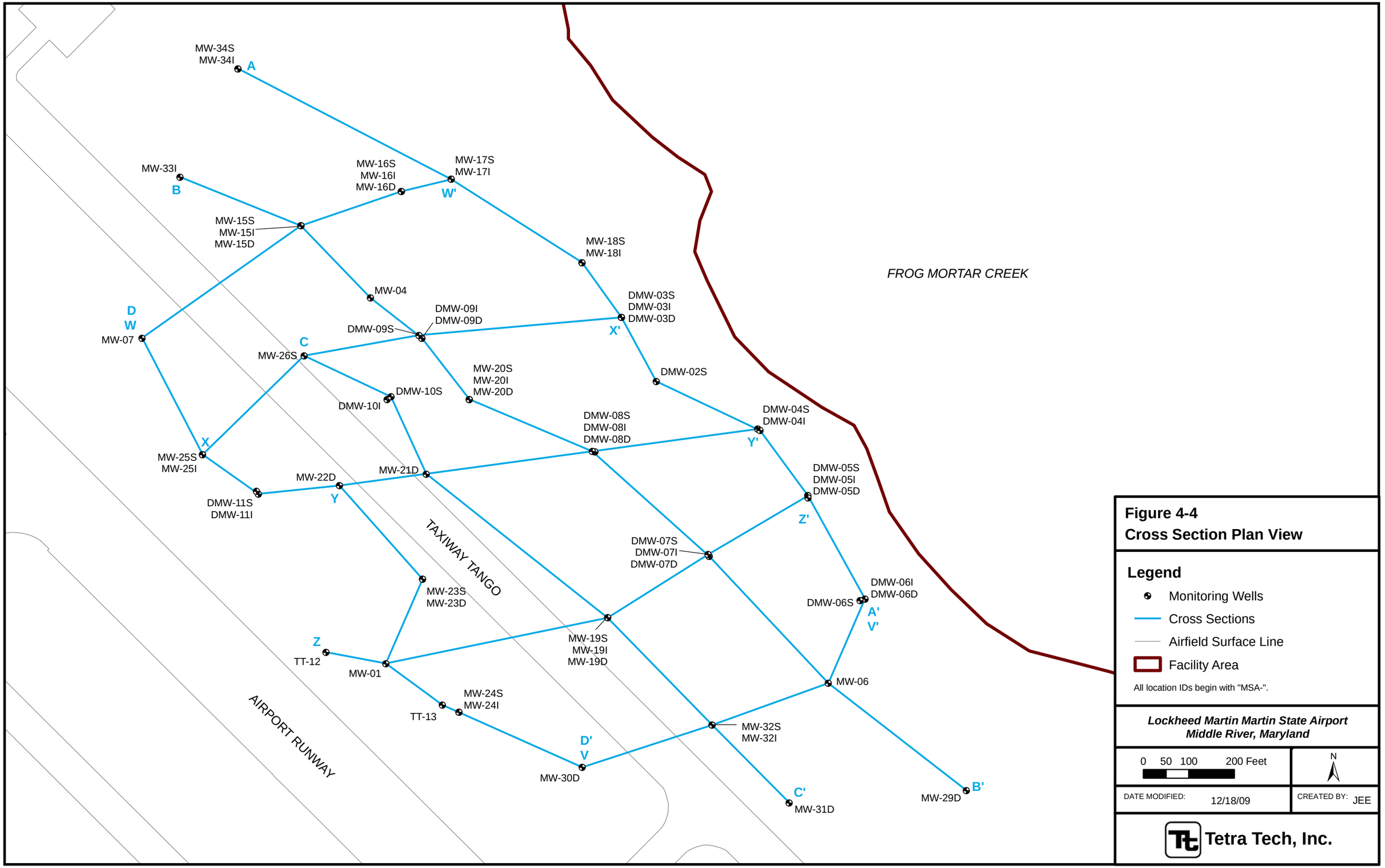

Figure 4-4
Cross Section Plan View

Legend

- Monitoring Wells
- Cross Sections
- Airfield Surface Line
- Facility Area

All location IDs begin with "MSA-".

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

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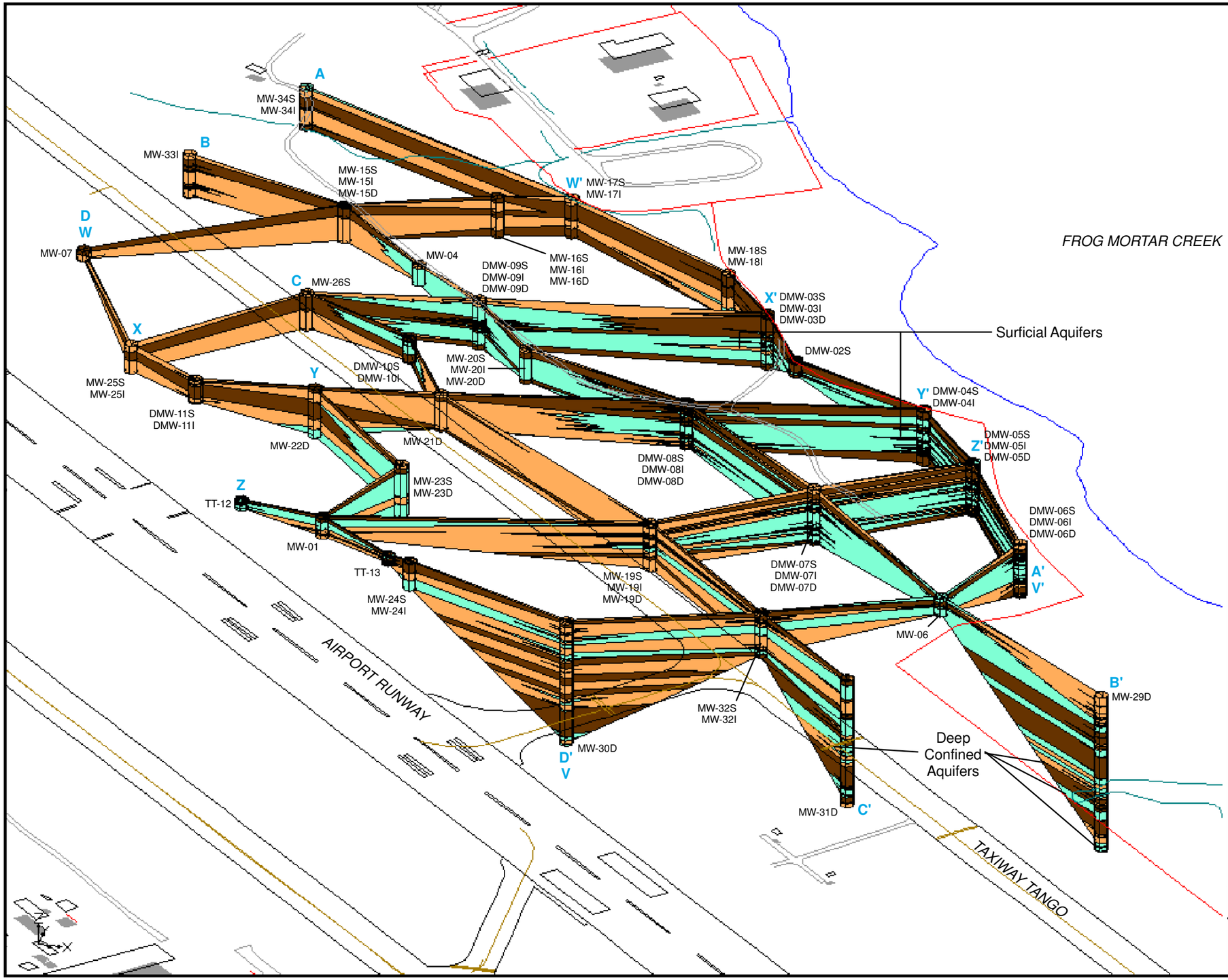

Figure 4-5
Fence Diagram

Legend

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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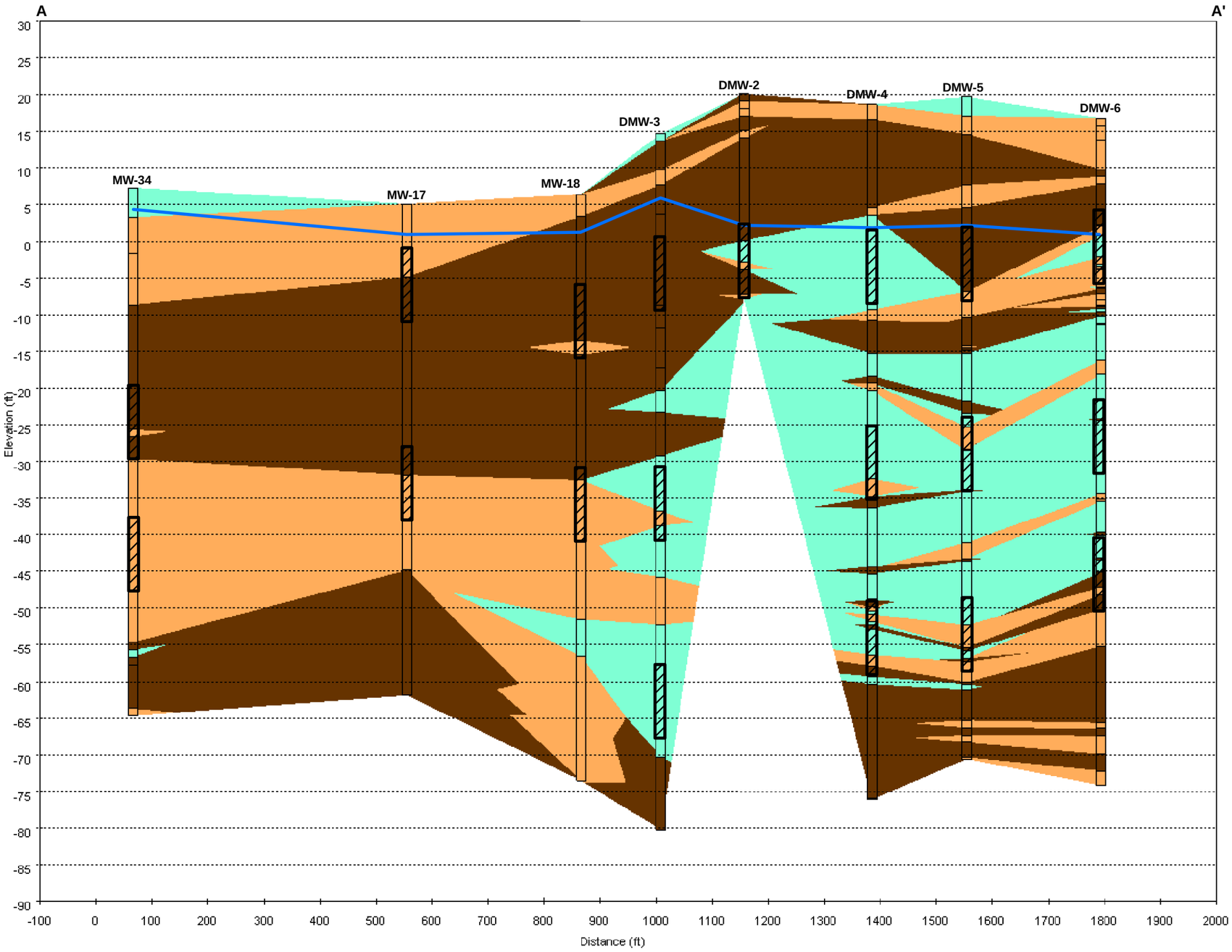

Figure 4-6
Hydrostratigraphic Cross Section
Transect A-A'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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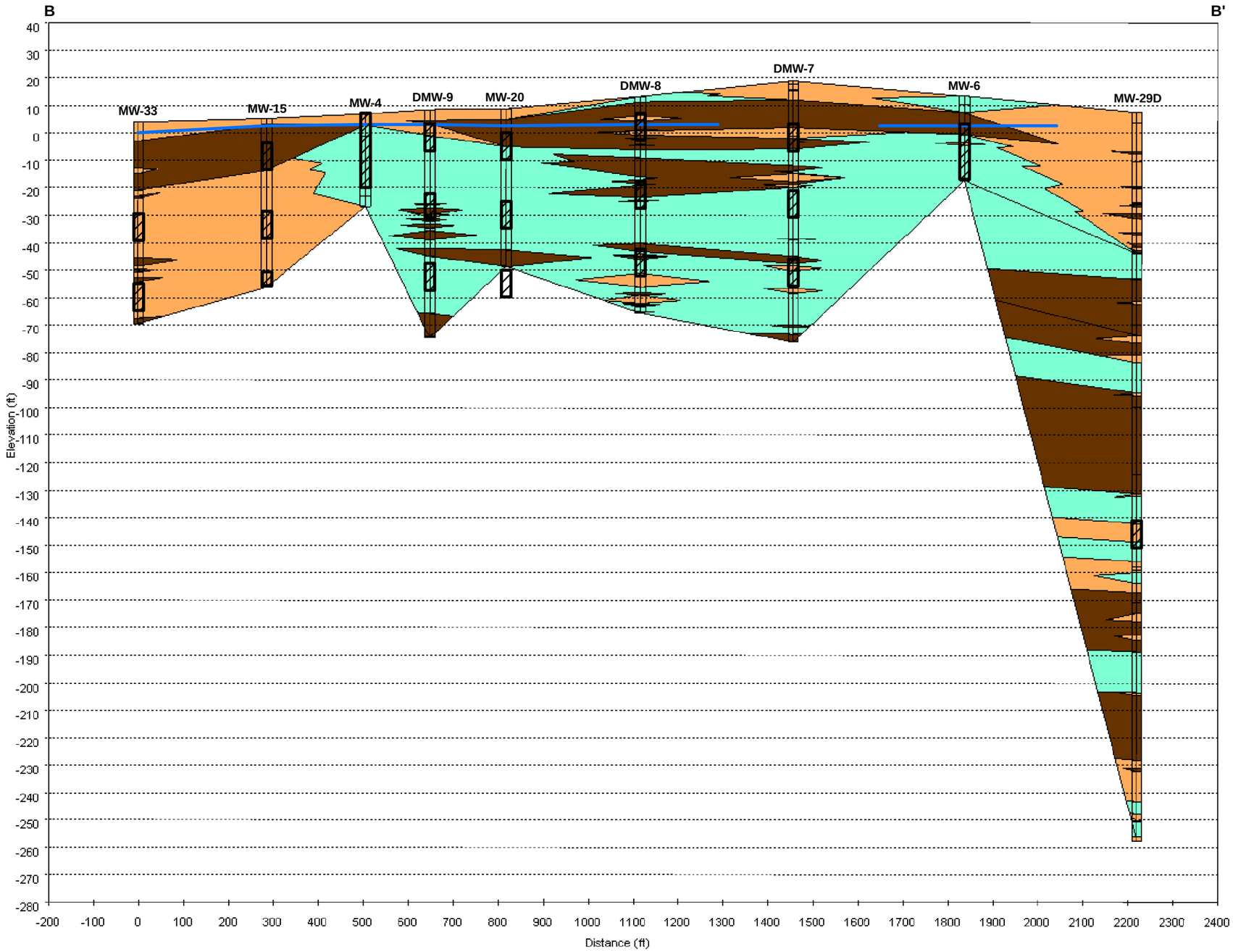

Figure 4-7
Hydrostratigraphic Cross Section
Transect B-B'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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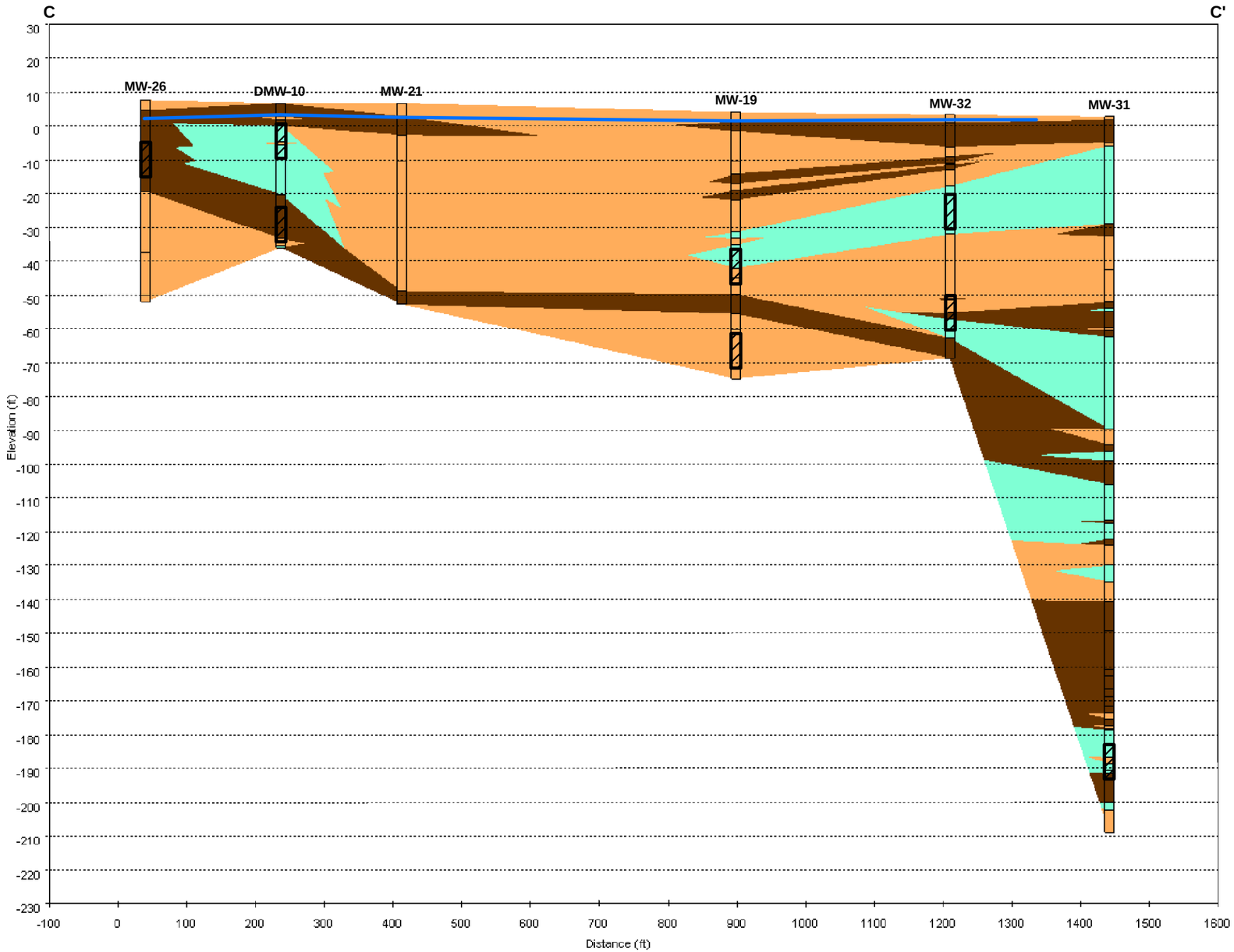

Figure 4-8
Hydrostratigraphic Cross Section
Transect C-C'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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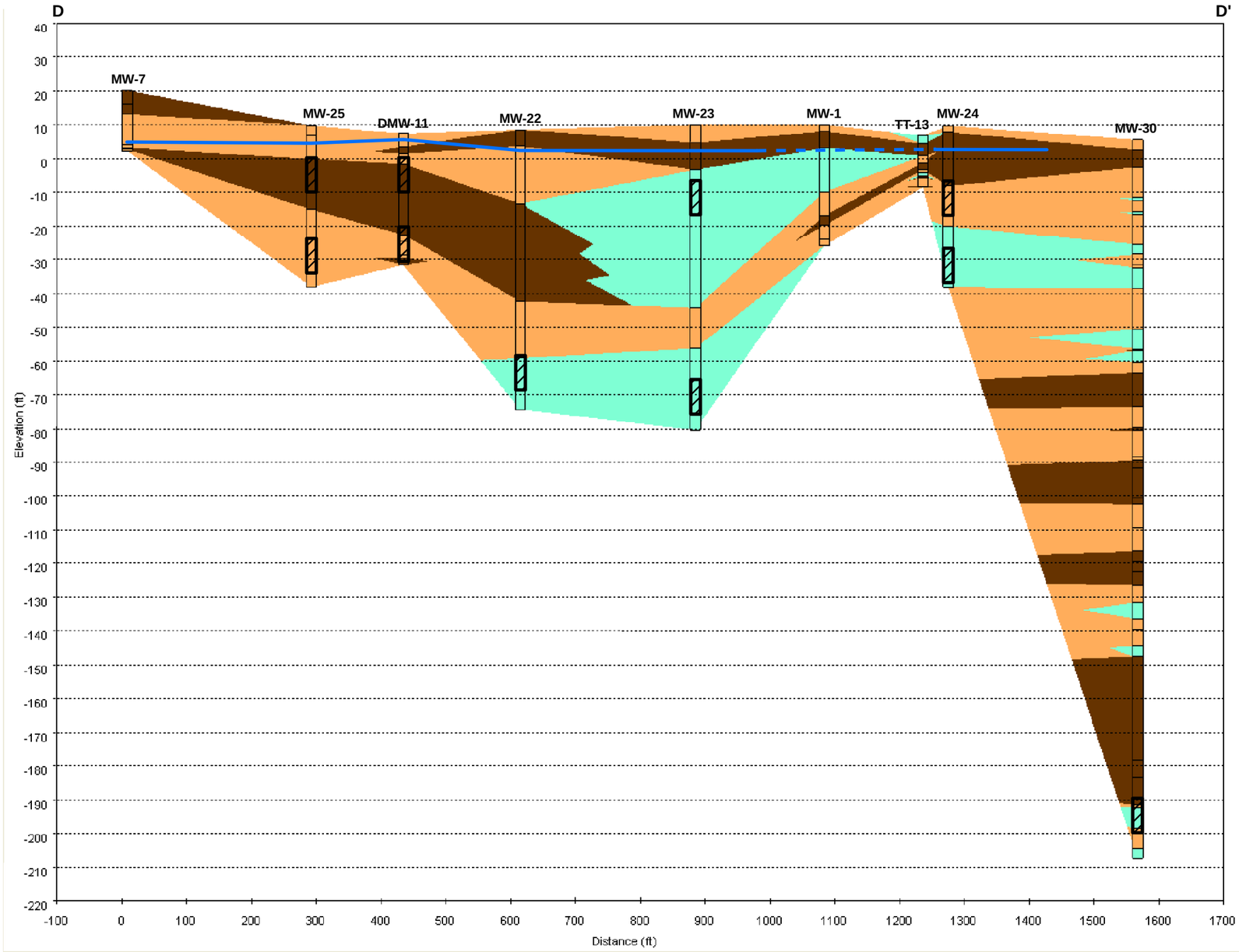

Figure 4-9
Hydrostratigraphic Cross Section
Transect D-D'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface (Dashed Where Inferred)

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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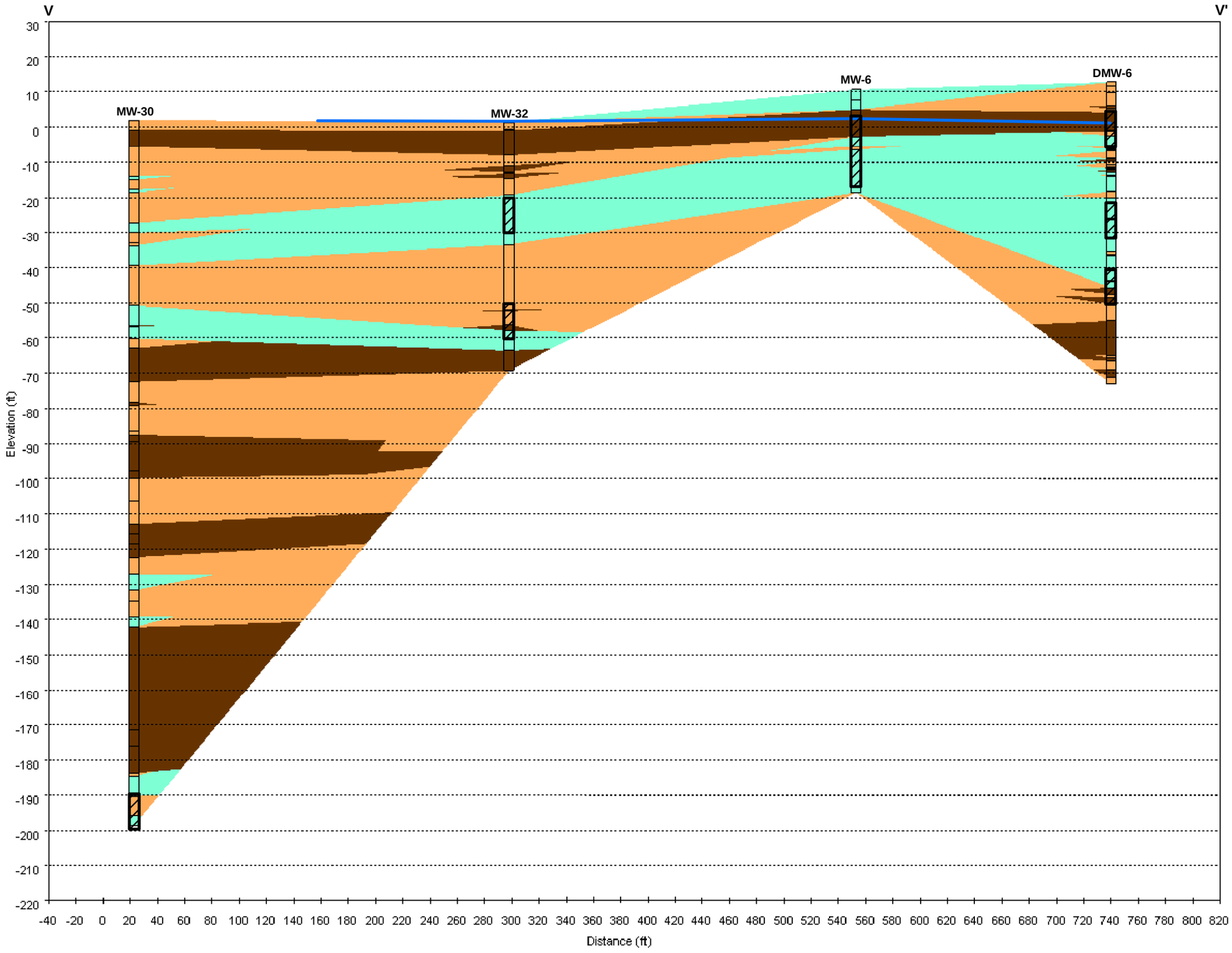

Figure 4-10
Hydrostratigraphic Cross Section
Transect V-V'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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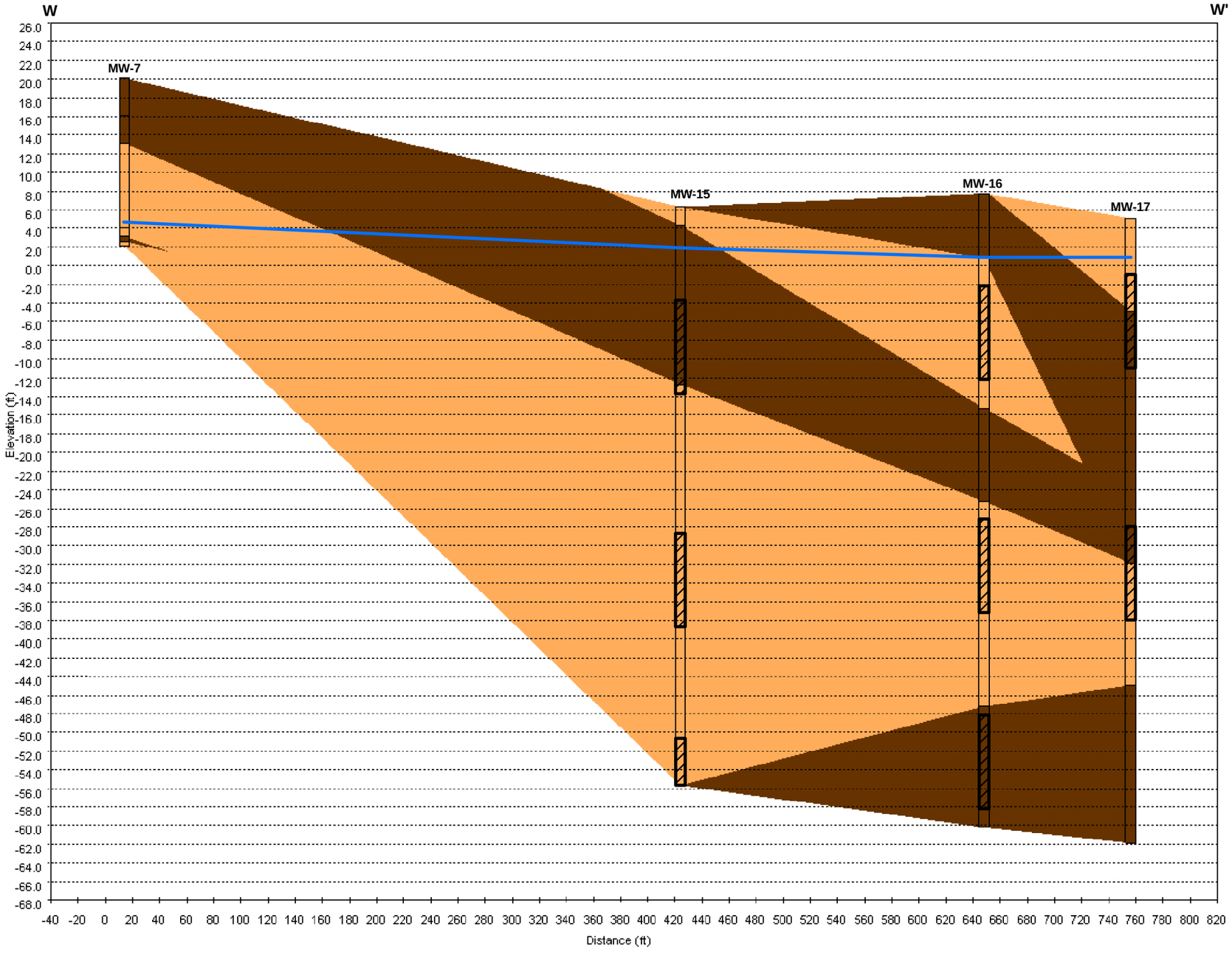

Figure 4-11
Hydrostratigraphic Cross Section
Transect W-W'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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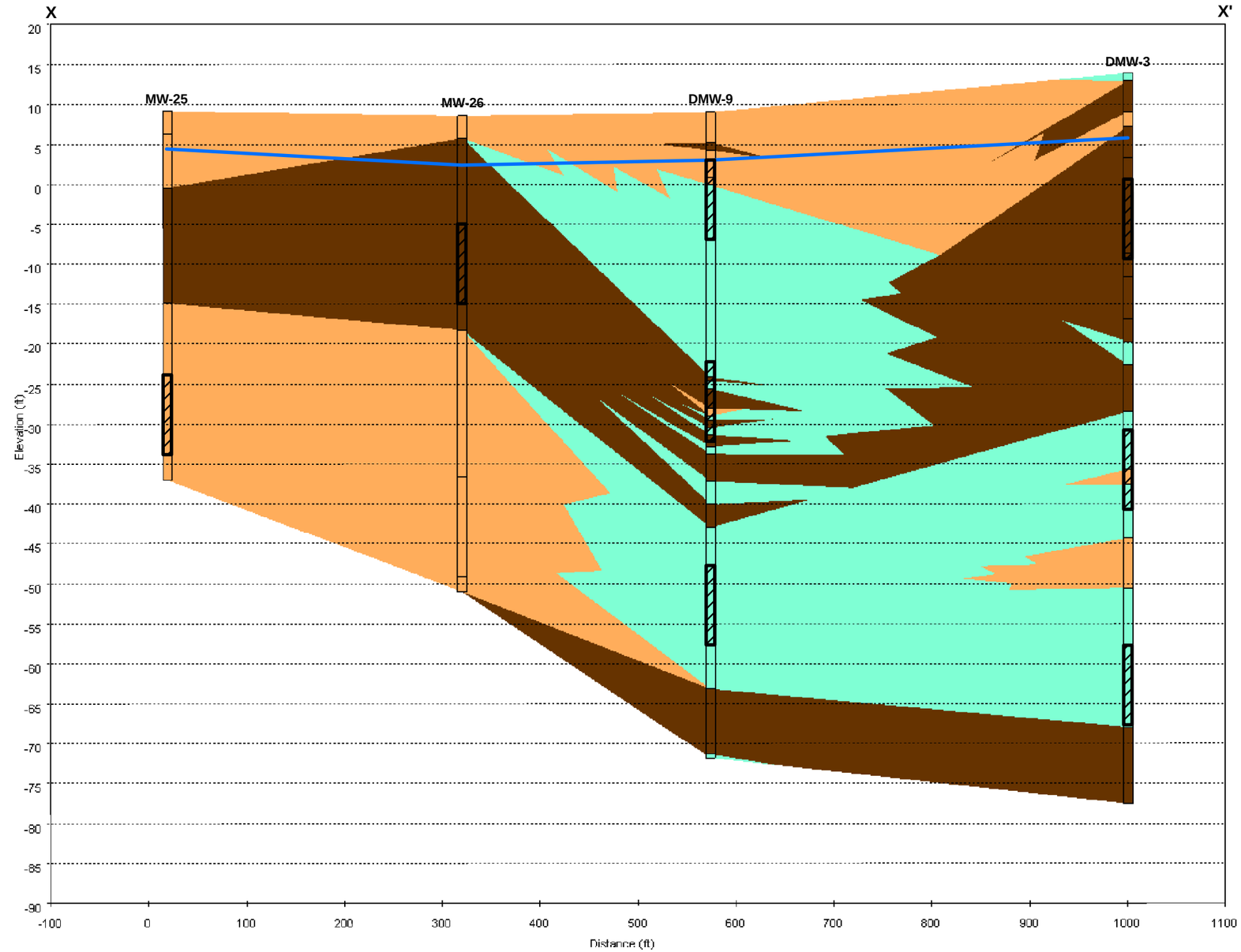

Figure 4-12
Hydrostratigraphic Cross Section
Transect X-X'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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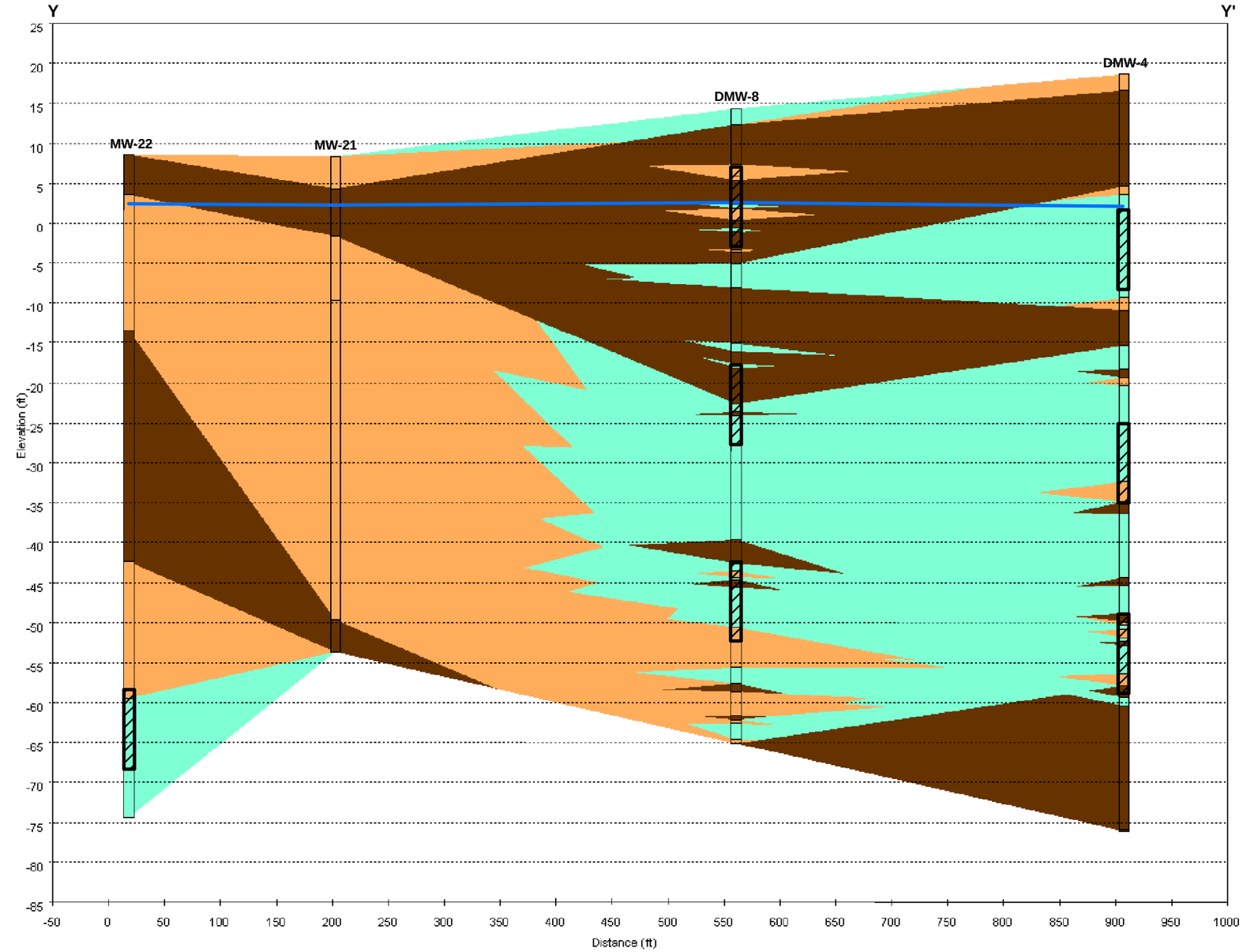

Figure 4-13
Hydrostratigraphic Cross Section
Transect Y-Y'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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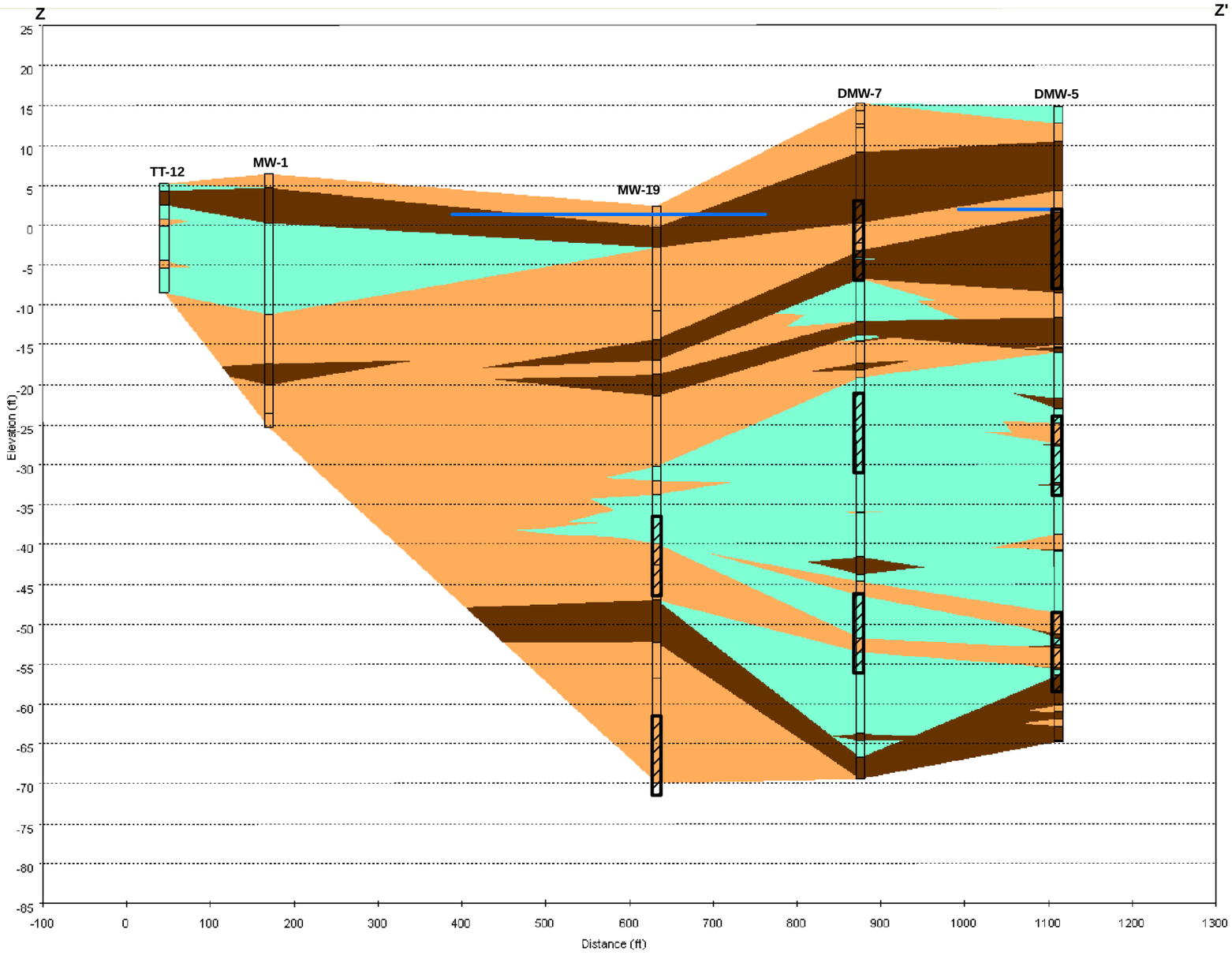

Figure 4-14
Hydrostratigraphic Cross Section
Transect Z-Z'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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MW34S
MW34I
MARYLAND AIR NATIONAL GUARD
Conrad's Ruth Villa
MW33S
MW33I
Gate
MW28I
MW27D
MW16S
MW16I
MW16D
MW17S
MW17I
MW17D
Gate
MW14I
MW14D
POND #2
MW15S
MW15I
MW15D
MW18S
MW18I
MW18D
FROG MORTAR CREEK
MW4
PETROLEUM HYDRO-CARBON AREA
MW7
MW26S
MW26I
MW26D
DMW9S
DMW9I
DMW9D
POND #1
DMW3S
DMW3I
DMW3D
DMW2A
DMW2B
RW1I
OW1I
RW1I
OW1I
DMW2S
DMW10S
DMW10I
MW20S
MW20I
MW20D
DMW8S
DMW8I
DMW8D
DMW4S
DMW4I
DMW4D
MW25S
MW25I
MW3
MW21I
MW21D
MW22I
MW22D
DMW1S
DMW5S
DMW5I
DMW5D
DMW11S
DMW11I
DMW1A
DMW1B
MW23S
MW23I
MW23D
MW5
DMW7S
DMW7I
DMW7D
DRUM AREA
DMW6S
DMW6I
DMW6D
MW19I
MW19D
MW2
MW1
AIRPORT RUNWAY
TAXIWAY TANGO
Gate
MW6
MW24S
MW24I
MW32S
MW32I
MW30D
MW29D
MW31D

Figure 5-14
CVOC Concentrations in Groundwater
(2007-2009 Maximum Concentration)

Legend

- Groundwater Well Location
- Ponds
- 0 - 5
- >=5 - 50
- >=50 - 500
- >=500 - 5000
- >= 5000

Ranges are based on Micrograms Per Liter (ug/l)

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

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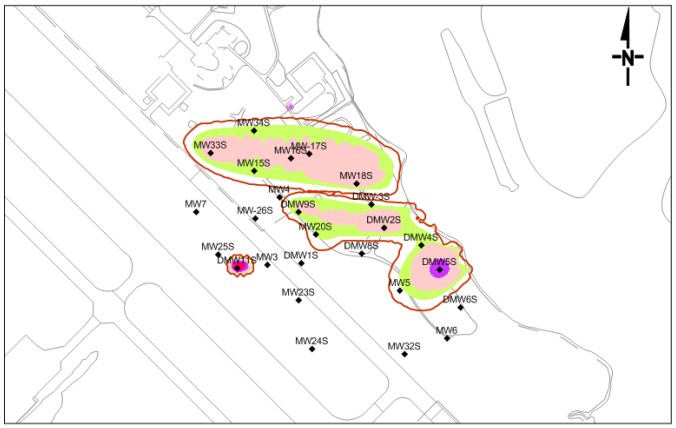
Figure 5-15
Contour Plots of TCE for the Upper, Intermediate, and Lower Surficial Aquifers - August - September 2009
Lockheed Martin, Martin State Airport, Middle River Maryland

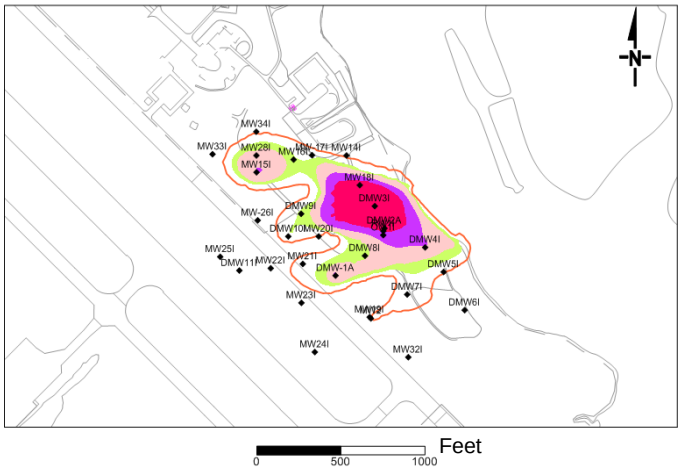
TCE - Upper Surficial Aquifer



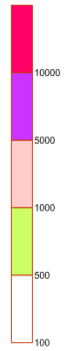
TCE Concentration ug/L



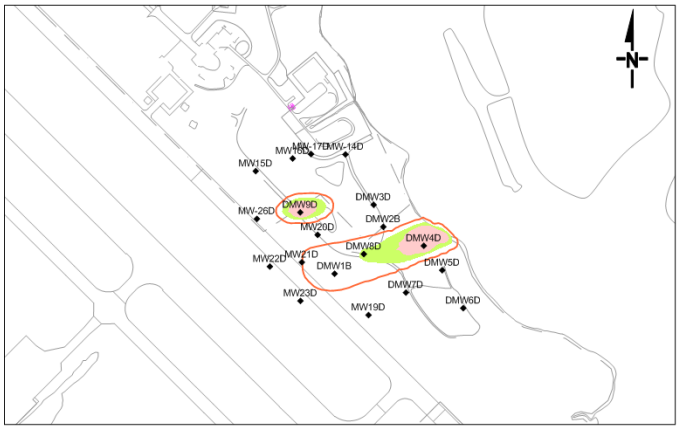
TCE - Intermediate Surficial Aquifer



TCE Concentration ug/L



TCE - Lower Surficial Aquifer



TCE Concentration ug/L

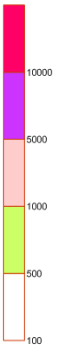
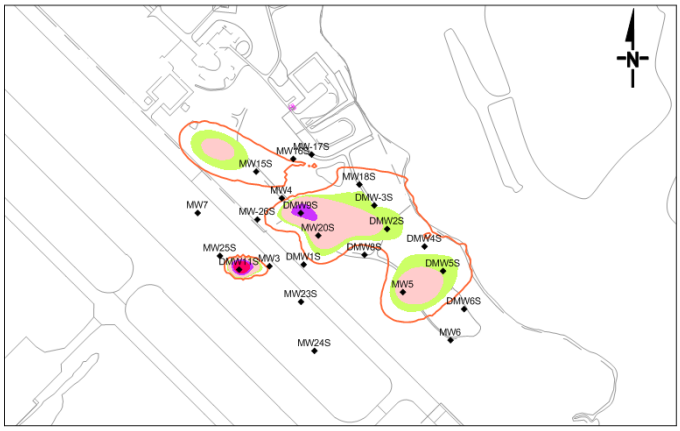
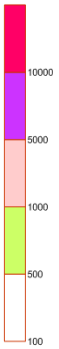


Figure 5-16
Contour Plots of cDCE for the Upper, Intermediate, and Lower Surficial Aquifers - August - September 2009
Lockheed Martin, Martin State Airport, Middle River Maryland

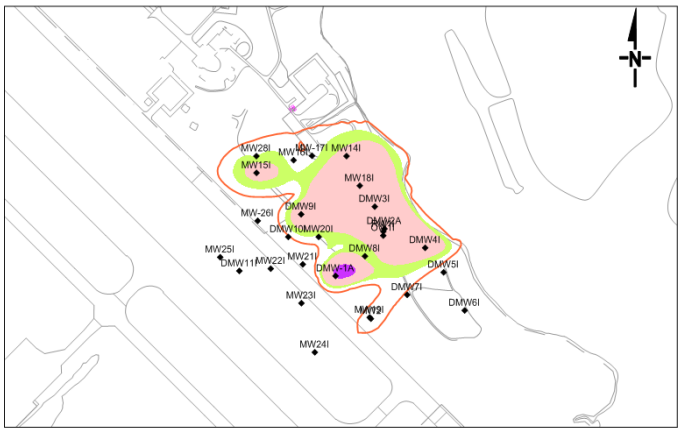
CIS-1,2-DCE - Upper Surficial Aquifer



cDCE Concentration ug/L



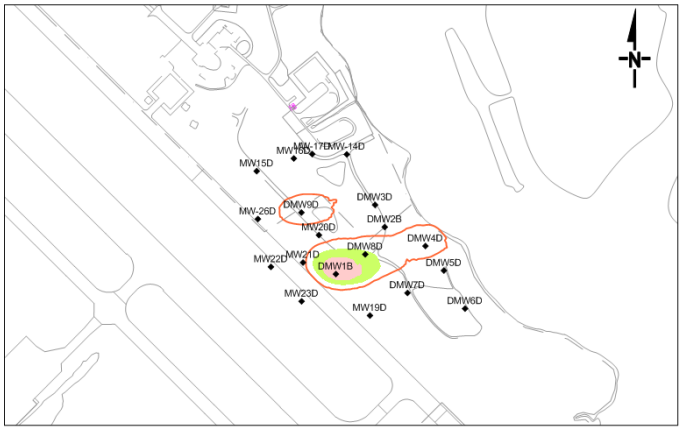
CIS-1,2-DCE - Intermediate Surficial Aquifer



cDCE Concentration ug/L



CIS-1,2-DCE - Lower Surficial Aquifer



cDCE Concentration ug/L

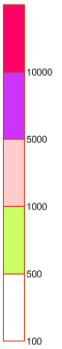
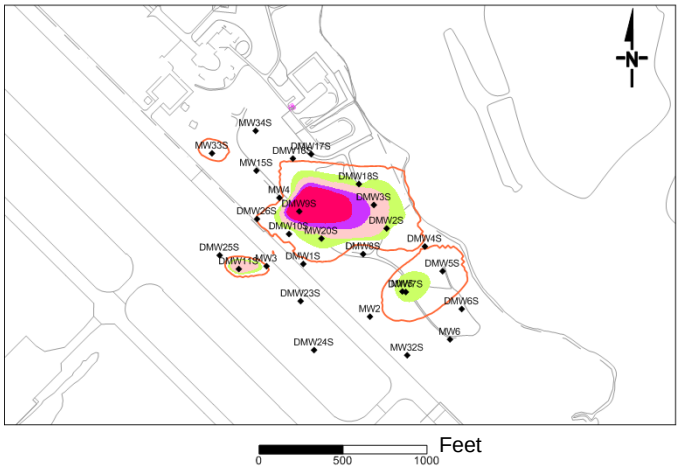
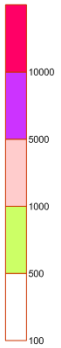


Figure 5-17
Contour Plots of Vinyl Chloride for the Upper, Intermediate, and Lower Surficial Aquifers - August - September 2009
Lockheed Martin, Martin State Airport, Middle River Maryland

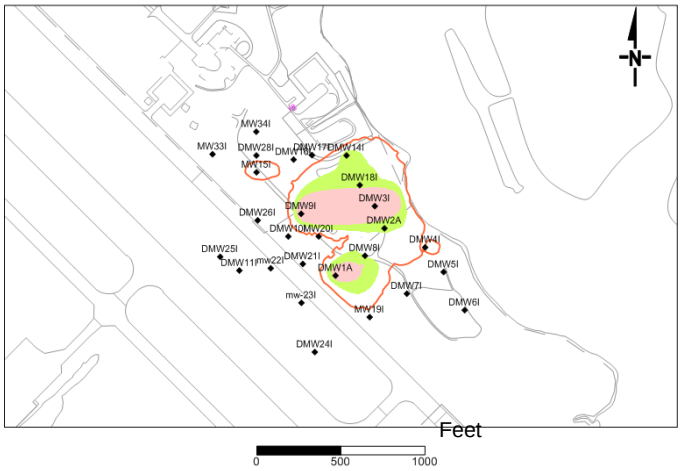
VINYL CHLORIDE - Upper Surficial Aquifer



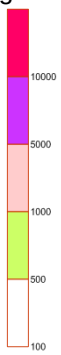
Vinyl Chloride Concentration ug/L



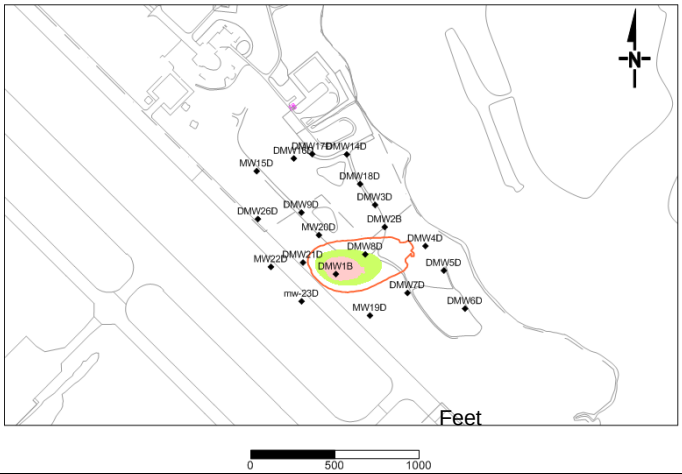
VINYL CHLORIDE - Intermediate Surficial Aquifer



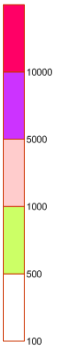
Vinyl Chloride Concentration ug/L



VINYL CHLORIDE - Lower Surficial Aquifer



Vinyl Chloride Concentration ug/L



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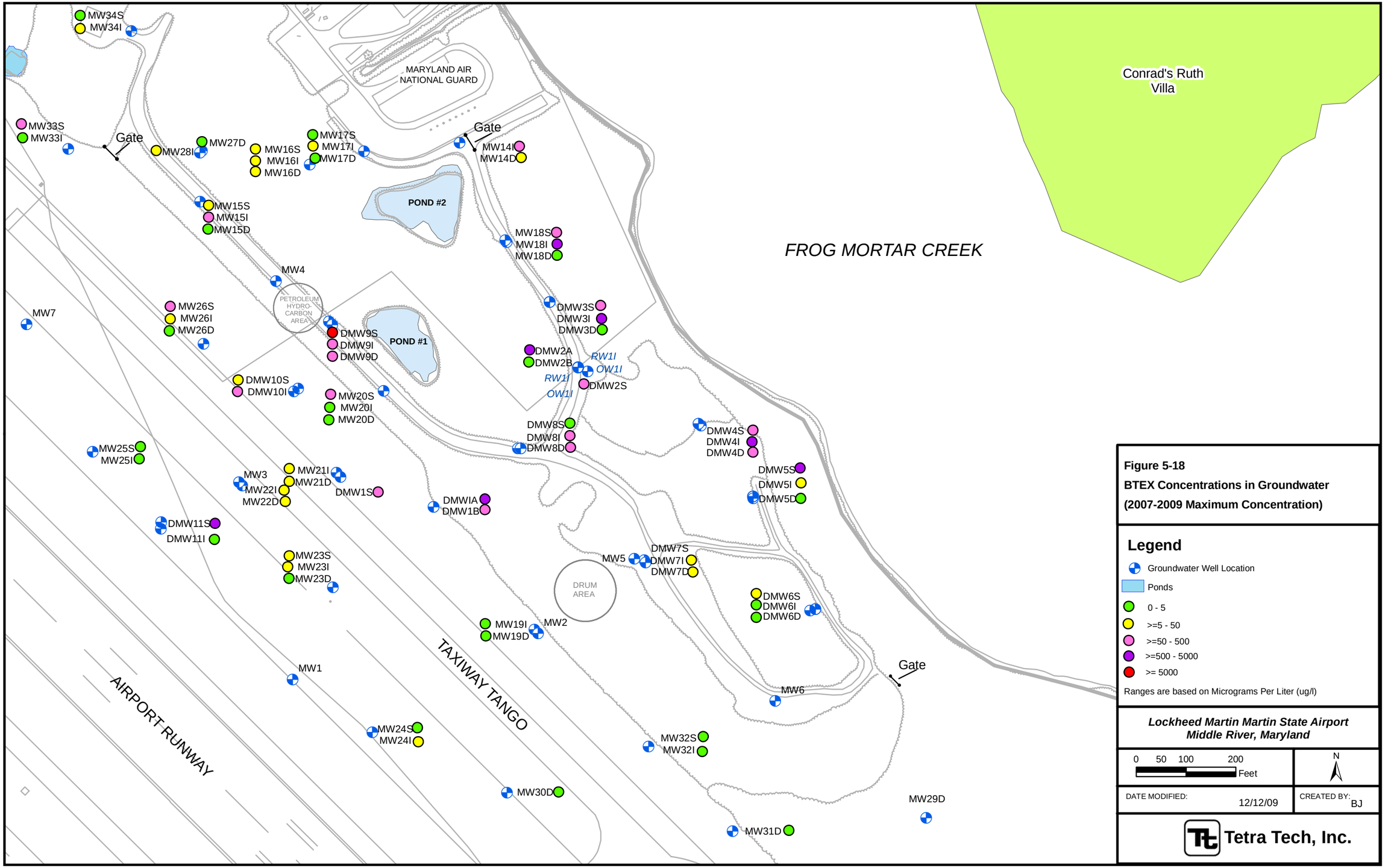


Figure 5-18
BTEX Concentrations in Groundwater
(2007-2009 Maximum Concentration)

Legend

- Groundwater Well Location
- Ponds
- 0 - 5
- >=5 - 50
- >=50 - 500
- >=500 - 5000
- >= 5000

Ranges are based on Micrograms Per Liter (ug/l)

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

DATE MODIFIED: 12/12/09

CREATED BY: BJ

Tetra Tech, Inc.

Map Document: (K:\GProject\MartinStateAirport-LMC\MapDocs\MXD\Maps\DIOXANE1, 4 Max 2007-2009.mxd)
3/9/2012 -- 4:05:46 PM

MW34S
MW34I
MW33S
MW33I
Gate
MW28I
MW27D
MW16S
MW16I
MW16D
MW17S
MW17I
MW17D
MARYLAND AIR NATIONAL GUARD
MW14I
MW14D
Gate
Conrad's Ruth Villa
POND #2
MW15S
MW15I
MW15D
MW18S
MW18I
MW18D
FROG MORTAR CREEK
MW4
PETROLEUM HYDRO-CARBON AREA
MW7
MW26S
MW26I
MW26D
DMW9S
DMW9I
DMW9D
POND #1
DMW3S
DMW3I
DMW3D
DMW2A
DMW2B
RW1S
OW1I
RW1I
OW1I
DMW2S
DMW10S
DMW10I
MW20S
MW20I
MW20D
DMW8S
DMW8I
DMW8D
DMW4S
DMW4I
DMW4D
DMW5S
DMW5I
DMW5D
MW25S
MW25I
MW21I
MW21D
MW3
MW22I
MW22D
DMW1S
DMW1A
DMW1B
DMW11S
DMW11I
MW23S
MW23I
MW23D
MW5
DMW7S
DMW7I
DMW7D
DRUM AREA
DMW6S
DMW6I
DMW6D
MW19I
MW19D
MW2
TAXIWAY TANGO
AIRPORT RUNWAY
MW1
Gate
MW6
MW24S
MW24I
MW32S
MW32I
MW30D
MW29D
MW31D

Figure 5-23
1,4-Dioxane Concentrations in Groundwater
(2007-2009 Maximum Concentration)

Legend

- Non Detect (DL <= 0.67 ug/l)
- Non Detect (DL > 0.67 ug/l; 1 or 1.3 ug/l))
- 0-0.67 (EPA RSL Tapwater; Risk= 1 E-06)
- >0.67-6.7 (1 E-05)
- >6.7-67 (1 E-04)
- >67 (>1 E-04)
- Groundwater Well Locations

Ranges are in Micrograms Per Liter (ug/l)
Risk levels (e.g., 1E-04) are in parentheses

DL= Detection Limit

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

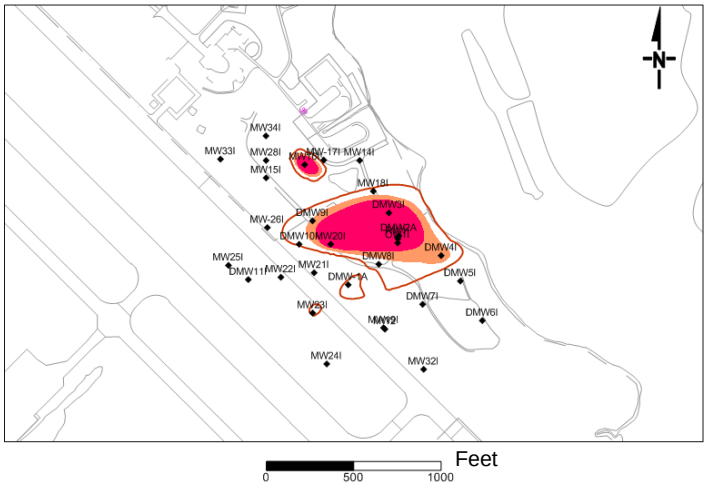
DATE MODIFIED: 3/9/12

CREATED BY: LR

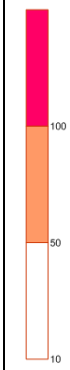
Tetra Tech, Inc.

Figure 5-24
Contour Plots of 1,4-Dioxane for the Upper, Intermediate, and Lower Surficial Aquifers – August - September 2009
Lockheed Martin, Martin State Airport, Middle River Maryland

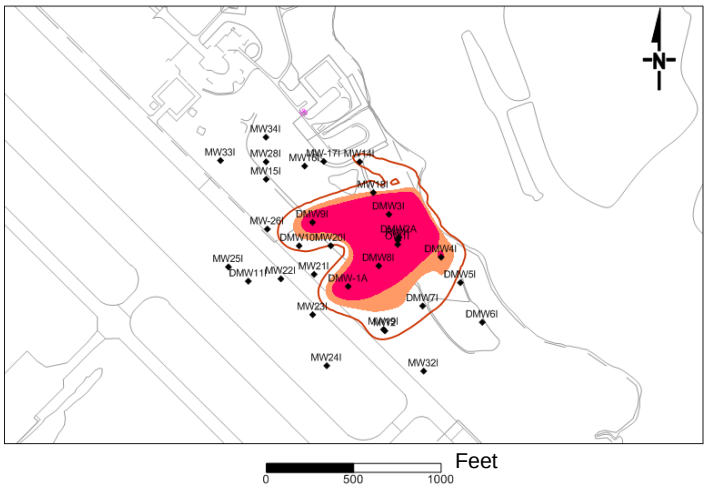
1,4 dioxane - Upper Surficial Aquifer



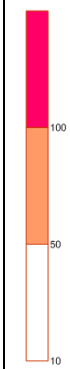
1,4 dioxane Concentration ug/L



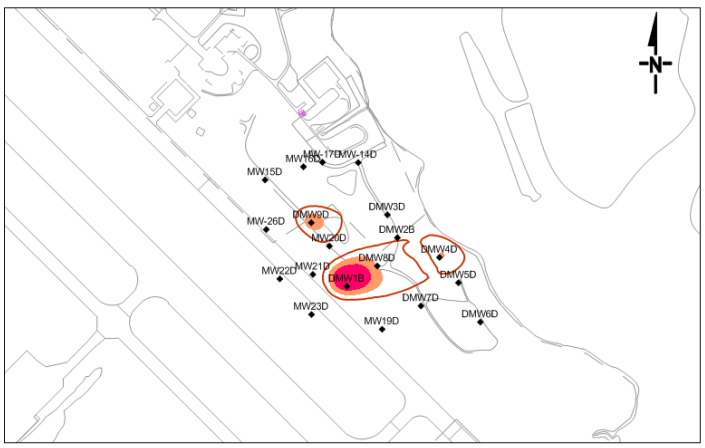
1,4 dioxane - Intermediate Surficial Aquifer



1,4 dioxane Concentration ug/L



1,4 dioxane - Lower Surficial Aquifer



1,4 dioxane Concentration ug/L

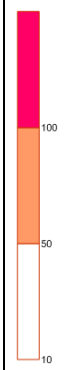


Table 4-3

Groundwater Levels and Elevations, Dump Road Area
Lockheed Martin Martin State Airport, Middle River, Maryland

Well ID	Aquifer Level	Elevation[1] Top of Well Casing NAVD88 Feet	Depth to Groundwater Top of Well Casing 10/14/2003 Feet	Groundwater Elevation[1] NAVD88 10/14/2003 Feet	Depth to Groundwater Top of Well Casing 12/1/2003 Feet	Groundwater Elevation[1] NAVD88 12/1/2003 Feet	Depth to Groundwater Top of Well Casing 9/30/2004 Feet	Groundwater Elevation[1] NAVD88 9/30/2004 Feet	Depth to Groundwater Top of Well Casing 12/10/2004 Feet	Groundwater Elevation[1] NAVD88 12/10/2004 Feet	Depth to Groundwater Top of Well Casing 6/25/2004 Feet	Groundwater Elevation[1] NAVD88 6/25/2004 Feet
DMW-1A	I	12.05	8.43	3.62	8.91	3.14	9.50	2.55	8.75	3.30	9.35	2.70
DMW-1B	D	12.04	8.81	3.23	9.54	2.50	9.65	2.39	9.11	2.93	9.57	2.47
DMW-1S	S	11.08	7.34	3.74	7.74	3.34	8.50	2.58	7.60	3.48	8.15	2.93
DMW-2A	I	21.65	19.37	2.28	20.92	0.73	20.13	1.52	20.20	1.45	2.75	18.90
DMW-2B	D	21.66	19.14	2.52	20.55	1.11	19.90	1.76	19.95	1.71	20.35	1.31
DMW-2S	S	21.75	19.31	2.44	20.53	1.22	20.60	1.15	20.43	1.32	20.49	1.26
DMW-3D	D	16.46	14.02	2.44	15.61	0.85	14.82	1.64	15.25	1.21	14.95	1.51
DMW-3I	I	16.45	14.03	2.42	15.53	0.92	14.85	1.60	15.23	1.22	14.90	1.55
DMW-3S	S	16.52	14.41	2.11	10.06	6.46	10.51	6.01	10.34	6.18	9.63	6.89
DMW-4D	D	20.44	18.32	2.12	20.11	0.33	19.00	1.44	19.45	0.99	19.50	0.94
DMW-4I	I	20.48	18.23	2.25	19.70	0.78	18.95	1.53	19.20	1.28	19.12	1.36
DMW-4S	S	20.52	18.55	1.97	20.15	0.37	19.25	1.27	19.70	0.82	19.60	0.92
DMW-5D	D	21.38	19.18	2.20	20.81	0.57	20.02	1.36	19.80	1.58	20.20	1.18
DMW-5I	I	21.39	19.13	2.26	20.68	0.71	19.95	1.44	19.75	1.64	20.15	1.24
DMW-5S	S	21.34	19.09	2.25	20.48	0.86	20.12	1.22	20.00	1.34	20.02	1.32
DMW-6D	D	18.51	16.29	2.22	17.76	0.75	17.25	1.26	17.15	1.36	17.70	0.81
DMW-6I	I	18.64	16.41	2.23	17.71	0.93	17.15	1.49	17.42	1.22	17.98	0.66
DMW-6S	S	18.62	16.20	2.42	17.72	0.90	17.09	1.53	17.35	1.27	17.75	0.87
DMW-7D	D	21.94	19.31	2.63	20.41	1.53	20.11	1.83	20.24	1.70	20.35	1.59
DMW-7I	I	21.90	19.28	2.62	20.49	1.41	20.20	1.70	20.42	1.48	20.47	1.43
DMW-7S	S	21.84	19.18	2.66	20.14	1.70	19.98	1.86	20.12	1.72	20.20	1.64
DMW-8D	D	16.35	13.64	2.71	14.65	1.70	14.31	2.04	14.60	1.75	14.36	1.99
DMW-8I	I	16.30	13.64	2.66	14.60	1.70	14.37	1.93	14.15	2.15	14.45	1.85
DMW-8S	S	15.80	12.38	3.42	11.86	3.94	14.20	1.60	12.50	3.30	13.05	2.75
DMW-9D	D	11.41	8.22	3.19	9.21	2.20	9.20	2.21	9.00	2.41	9.37	2.04
DMW-9I	I	11.40	7.95	3.45	9.18	2.22	9.16	2.24	8.82	2.58	9.11	2.29
DMW-9S	S	11.45	7.91	3.54	8.44	3.01	9.22	2.23	8.79	2.66	9.10	2.35
MW-1[2]	I	11.08	7.31	3.77	6.35	4.73	NA	NA	NA	NA	NA	NA
MW-10I	I	10.27	6.78	3.49	7.25	3.02	7.70	2.57	6.81	3.46	7.60	2.67
MW-10S	S	10.29	6.60	3.69	6.94	3.35	7.80	2.49	6.82	3.47	7.58	2.71
MW-11I	I	9.15	5.20	3.95	5.60	3.55	6.30	2.85	5.20	3.95	6.20	2.95
MW-11S	S	9.20	3.43	5.77	3.20	6.00	3.30	5.90	3.40	5.80	4.32	4.88
MW-14D	DD	11.56	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-14I	I	11.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-15D	D	8.77	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-15I	I	8.79	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-15S	S	8.60	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-16D	D	10.22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-16I	I	10.06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-16S	S	10.20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-17D	D	7.56	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-17I	I	7.68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-17S	S	7.61	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-18D	D	8.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-18I	I	8.91	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-18S	S	8.89	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-19D	D	7.94	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4-3

Groundwater Levels and Elevations, Dump Road Area
Lockheed Martin Martin State Airport, Middle River, Maryland
Page 2 of 4

Well ID	Aquifer Level	Elevation[(1)] Top of Well Casing NAVD88 Feet	Depth to Groundwater Top of Well Casing 10/14/2003 Feet	Groundwater Elevation[(1)] NAVD88 10/14/2003 Feet	Depth to Groundwater Top of Well Casing 12/1/2003 Feet	Groundwater Elevation[(1)] NAVD88 12/1/2003 Feet	Depth to Groundwater Top of Well Casing 9/30/2004 Feet	Groundwater Elevation[(1)] NAVD88 9/30/2004 Feet	Depth to Groundwater Top of Well Casing 12/10/2004 Feet	Groundwater Elevation[(1)] NAVD88 12/10/2004 Feet	Depth to Groundwater Top of Well Casing 6/25/2004 Feet	Groundwater Elevation[(1)] NAVD88 6/25/2004 Feet
MW-19I	I	7.90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-2	I	8.40	5.35	3.05	6.06	2.34	6.20	2.20	5.83	2.57	6.50	1.90
MW-20D	D	12.40	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-20I	I	12.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-20S	S	12.44	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-21D	D	10.78	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-21I	I	10.83	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-22D	D	11.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-22I	I	11.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-23D	D	10.03	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-23I	I	10.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-23S	S	10.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-24I	I	7.68	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-24S	S	7.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-25I	I	9.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-25S	S	9.69	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-26D	D	11.66	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-26I	I	11.67	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-26S	S	11.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-27D	DD	8.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-28I	I	8.65	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-29D	DD	11.43	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-3	S	11.19	7.23	3.96	7.25	3.94	8.65	2.54	7.40	3.79	8.27	2.92
MW-30D	DD	8.26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-31D	DD	6.95	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-32I	I	7.28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-32S	S	7.27	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-33I	I	10.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-33S	S	9.97	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-34I	I	7.37	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-34S	S	7.44	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-4	S	10.34	6.62	3.72	6.10	4.24	7.85	2.49	7.00	3.34	7.25	3.09
MW-5	S	22.65	19.99	2.66	21.10	1.55	20.96	1.69	21.00	1.65	21.05	1.60
MW-6	S	15.72	12.92	2.80	13.46	2.26	13.70	2.02	13.75	1.97	13.97	1.75
MW-7	S	10.90	5.78	5.12	6.86	4.04	7.36	3.54	5.73	5.17	6.70	4.20
OW1-I	I	18.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
OW1-S	S	19.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RW1-I	I	18.44	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RW1-S	S	19.09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TT-11[(2)]	S	11.16	6.45	4.71	5.60	5.56	NA	NA	NA	NA	NA	NA
TT-12[(2)]	S	11.51	6.39	5.12	5.79	5.72	NA	NA	NA	NA	NA	NA
TT-13[(2)]	S	9.55	4.31	5.24	4.23	5.32	NA	NA	NA	NA	NA	NA
TT-14[(2)]	S	10.31	4.81	5.50	3.96	6.35	NA	NA	NA	NA	NA	NA

Table 4-3

Groundwater Levels and Elevations, Dump Road Area
Lockheed Martin Martin State Airport, Middle River, Maryland

Well ID	Aquifer Level	Elevation[1] Top of Well Casing NAVD88 Feet	Depth to Groundwater Top of Well Casing 1/14/2008 Feet	Groundwater Elevation[1] NAVD88 1/14/2008 Feet	Depth to Groundwater Top of Well Casing 10/30/2008 Feet	Groundwater Elevation[1] NAVD88 10/30/2008 Feet	Depth to Groundwater Top of Well Casing 9/10/2009 Feet	Groundwater Elevation[1] NAVD88 9/10/2009 Feet	Depth to Groundwater Top of Well Casing 9/18/2009 Feet	Groundwater Elevation[1] NAVD88 9/18/2009 Feet	Depth to Groundwater Top of Well Casing 1/19/2010 Feet	r Elevation[1] NAVD88 1/19/2010 Feet
DMW-1A	I	12.05	9.70	2.35	10.30	1.75	9.92	2.13	NA	NA	8.70	3.35
DMW-1B	D	12.04	9.90	2.14	10.50	1.54	10.11	1.93	NA	NA	9.00	3.04
DMW-1S	S	11.08	8.60	2.48	8.10	2.98	8.81	2.27	NA	NA	7.65	3.43
DMW-2A	I	21.65	20.50	1.15	21.15	0.50	20.54	1.11	NA	NA	19.95	1.70
DMW-2B	D	21.66	20.30	1.36	21.00	0.66	20.35	1.31	NA	NA	19.60	2.06
DMW-2S	S	21.75	21.00	0.75	21.30	0.45	20.85	0.90	NA	NA	20.35	1.40
DMW-3D	D	16.46	15.15	1.31	15.90	0.56	15.26	1.20	NA	NA	14.65	1.81
DMW-3I	I	16.45	15.20	1.25	15.85	0.60	15.31	1.14	NA	NA	14.65	1.80
DMW-3S	S	16.52	NA	NA	12.40	4.12	11.79	4.73	NA	NA	8.45	8.07
DMW-4D	D	20.44	19.40	1.04	20.20	0.24	19.32	1.12	NA	NA	18.80	1.64
DMW-4I	I	20.48	19.50	0.98	20.05	0.43	19.36	1.12	NA	NA	18.70	1.78
DMW-4S	S	20.52	19.95	0.57	20.50	0.02	19.69	0.83	NA	NA	19.20	1.32
DMW-5D	D	21.38	20.40	0.98	21.10	0.28	20.38	1.00	NA	NA	19.70	1.68
DMW-5I	I	21.39	20.40	0.99	21.10	0.29	20.36	1.03	NA	NA	19.70	1.69
DMW-5S	S	21.34	20.50	0.84	20.95	0.39	20.39	0.95	NA	NA	19.80	1.54
DMW-6D	D	18.51	17.60	0.91	18.30	0.21	17.52	0.99	NA	NA	16.80	1.71
DMW-6I	I	18.64	17.60	1.04	18.30	0.34	17.56	1.08	NA	NA	16.80	1.84
DMW-6S	S	18.62	17.45	1.17	18.30	0.32	18.78	-0.16	NA	NA	16.85	1.77
DMW-7D	D	21.94	20.60	1.34	21.20	0.74	20.57	1.37	NA	NA	19.70	2.24
DMW-7I	I	21.90	20.70	1.20	21.25	0.65	20.61	1.29	NA	NA	19.80	2.10
DMW-7S	S	21.84	dry	dry	NA	NA	NA	NA	NA	NA	NA	NA
DMW-8D	D	16.35	14.80	1.55	15.35	1.00	14.79	1.56	NA	NA	14.00	2.35
DMW-8I	I	16.30	14.90	1.40	15.40	0.90	14.84	1.46	NA	NA	14.02	2.28
DMW-8S	S	15.80	13.90	1.90	14.30	1.50	14.44	1.36	NA	NA	12.23	3.57
DMW-9D	D	11.41	9.51	1.90	10.15	1.26	9.68	1.73	NA	NA	8.65	2.76
DMW-9I	I	11.40	9.35	2.05	9.80	1.60	9.59	1.81	NA	NA	8.25	3.15
DMW-9S	S	11.45	9.35	2.10	9.75	1.70	9.49	1.96	NA	NA	8.16	3.29
MW-1[2]	I	11.08	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-10I	I	10.27	7.80	2.47	8.45	1.82	8.87	1.40	NA	NA	6.95	3.32
MW-10S	S	10.29	7.90	2.39	8.30	1.99	8.06	2.23	NA	NA	6.90	3.39
MW-11I	I	9.15	33.20	-24.05	7.15	2.00	6.78	2.37	NA	NA	5.40	3.75
MW-11S	S	9.20	4.00	5.20	5.00	4.20	4.45	4.75	NA	NA	3.25	5.95
MW-14D	DD	11.56	7.60	3.96	8.25	3.31	7.71	3.85	NA	NA	7.00	4.56
MW-14I	I	11.72	10.60	1.12	11.20	0.52	10.72	1.00	10.32	1.40	10.15	1.57
MW-15D	D	8.77	6.26	2.51	7.00	1.77	6.61	2.16	5.5	3.27	5.43	3.34
MW-15I	I	8.79	6.30	2.49	7.02	1.77	6.63	2.16	5.55	3.24	5.43	3.36
MW-15S	S	8.60	5.80	2.80	6.83	1.77	6.66	1.94	4.95	3.65	4.65	3.95
MW-16D	D	10.22	7.90	2.32	8.70	1.52	8.26	1.96	7.3	2.92	7.19	3.03
MW-16I	I	10.06	7.80	2.26	8.50	1.56	8.11	1.95	7.1	2.96	7.01	3.05
MW-16S	S	10.20	8.40	1.80	9.10	1.10	9.26	0.94	8.49	1.71	8.35	1.85
MW-17D	D	7.56	18.00	-10.44	10.90	-3.34	5.88	1.68	4.9	2.66	4.40	3.16
MW-17I	I	7.68	5.60	2.08	6.30	1.38	6.12	1.56	5.65	2.03	5.22	2.46
MW-17S	S	7.61	6.00	1.61	9.35	-1.74	6.69	0.92	5.92	1.69	5.83	1.78
MW-18D	D	8.88	7.85	1.03	8.30	0.58	NA	NA	NA	NA	7.21	1.67
MW-18I	I	8.91	7.80	1.11	8.50	0.41	7.86	1.05	NA	NA	7.21	1.70
MW-18S	S	8.89	7.80	1.09	7.70	1.19	7.72	1.17	NA	NA	7.10	1.79
MW-19D	D	7.94	6.35	1.59	7.00	0.94	6.48	1.46	NA	NA	5.49	2.45

Table 4-3

Groundwater Levels and Elevations, Dump Road Area
Lockheed Martin Martin State Airport, Middle River, Maryland

Well ID	Aquifer Level	Elevation[1] Top of Well Casing NAVD88 Feet	Depth to Groundwater Top of Well Casing 1/14/2008 Feet	Groundwater Elevation[1] NAVD88 1/14/2008 Feet	Depth to Groundwater Top of Well Casing 10/30/2008 Feet	Groundwater Elevation[1] NAVD88 10/30/2008 Feet	Depth to Groundwater Top of Well Casing 9/10/2009 Feet	Groundwater Elevation[1] NAVD88 9/10/2009 Feet	Depth to Groundwater Top of Well Casing 9/18/2009 Feet	Groundwater Elevation[1] NAVD88 9/18/2009 Feet	Depth to Groundwater Top of Well Casing 1/19/2010 Feet	r Elevation[1] NAVD88 1/19/2010 Feet
MW-19I	I	7.90	6.80	1.10	7.05	0.85	6.48	1.42	NA	NA	5.50	2.40
MW-2	I	8.40	6.60	1.80	7.25	1.15	7.74	0.66	NA	NA	5.65	2.75
MW-20D	D	12.40	10.60	1.80	11.30	1.10	10.74	1.66	NA	NA	9.80	2.60
MW-20I	I	12.39	10.40	1.99	10.75	1.64	10.42	1.97	NA	NA	9.20	3.19
MW-20S	S	12.44	10.40	2.04	10.80	1.64	10.51	1.93	NA	NA	9.23	3.21
MW-21D	D	10.78	8.85	1.93	9.20	1.58	9.10	1.68	NA	NA	8.00	2.78
MW-21I	I	10.83	8.60	2.23	8.90	1.93	8.75	2.08	NA	NA	7.60	3.23
MW-22D	D	11.02	8.70	2.32	9.30	1.72	9.02	2.00	NA	NA	7.85	3.17
MW-22I	I	11.01	9.22	1.79	9.45	1.56	8.61	2.40	NA	NA	7.90	3.11
MW-23D	D	10.03	8.70	1.33	8.62	1.41	8.16	1.87	NA	NA	7.10	2.93
MW-23I	I	10.07	7.65	2.42	7.95	2.12	7.84	2.23	NA	NA	6.70	3.37
MW-23S	S	10.01	7.55	2.46	7.95	2.06	7.76	2.25	NA	NA	6.65	3.36
MW-24I	I	7.68	5.20	2.48	5.80	1.88	5.42	2.26	NA	NA	4.30	3.38
MW-24S	S	7.72	4.10	3.62	4.50	3.22	4.32	3.40	NA	NA	3.65	4.07
MW-25I	I	9.72	6.90	2.82	7.30	2.42	7.31	2.41	NA	NA	5.95	3.77
MW-25S	S	9.69	5.03	4.66	5.66	4.03	5.32	4.37	NA	NA	4.80	4.89
MW-26D	D	11.66	9.80	1.86	9.10	2.56	9.42	2.24	NA	NA	6.65	5.01
MW-26I	I	11.67	9.25	2.42	9.60	2.07	9.44	2.23	NA	NA	8.39	3.28
MW-26S	S	11.72	10.05	1.67	9.55	2.17	9.41	2.31	NA	NA	7.75	3.97
MW-27D	DD	8.39	NA	NA	6.02	NA	5.65	2.74	NA	NA	4.00	4.39
MW-28I	I	8.65	NA	NA	6.81	NA	6.57	2.08	5.45	3.20	5.40	3.25
MW-29D	DD	11.43	NA	NA	12.25	NA	11.89	-0.46	NA	NA	10.00	1.43
MW-3	S	11.19	8.65	2.54	9.00	2.19	8.79	2.40	NA	NA	7.70	3.49
MW-30D	DD	8.26	NA	NA	NA	NA	8.00	0.26	NA	NA	6.20	2.06
MW-31D	DD	6.95	NA	NA	NA	NA	7.47	-0.52	NA	NA	5.75	1.20
MW-32I	I	7.28	NA	NA	NA	NA	5.71	1.57	4.65	2.63	4.62	2.66
MW-32S	S	7.27	NA	NA	NA	NA	5.62	1.65	4.52	2.75	4.50	2.77
MW-33I	I	10.02	NA	NA	NA	NA	7.38	2.64	6.25	3.77	6.25	3.77
MW-33S	S	9.97	NA	NA	NA	NA	7.34	2.63	6.05	3.92	6.23	3.74
MW-34I	I	7.37	NA	NA	NA	NA	5.15	2.22	NA	NA	4.00	3.37
MW-34S	S	7.44	NA	NA	NA	NA	5.20	2.24	NA	NA	3.90	3.54
MW-4	S	10.34	7.50	2.84	8.25	2.09	8.15	2.19	NA	NA	5.45	4.89
MW-5	S	22.65	21.15	1.50	21.55	1.10	21.35	1.30	NA	NA	20.30	2.35
MW-6	S	15.72	14.30	1.42	15.00	0.72	14.46	1.26	NA	NA	13.15	2.57
MW-7	S	10.90	NA	NA	NA	NA	7.27	3.63	NA	NA	NA	NA
OW1-I	I	18.05	17.00	1.05	NA	NA	17.02	1.03	NA	NA	NA	NA
OW1-S	S	19.17	18.50	0.67	NA	NA	NA	NA	NA	NA	NA	NA
RW1-I	I	18.44	17.50	0.94	NA	NA	17.40	1.04	NA	NA	NA	NA
RW1-S	S	19.09	18.20	0.89	NA	NA	NA	NA	NA	NA	NA	NA
TT-11[2]	S	11.16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TT-12[2]	S	11.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TT-13[2]	S	9.55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TT-14[2]	S	10.31	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

1 Based on an October 2010 survey of all Dump Road Area wells
2 Well has been sealed and abandoned in accordance with state regulations and is no longer in use
NA - Not available or not measured
S - Upper surficial aquifer
I - Intermediate surficial aquifer
D - Lower surficial aquifer
DD - Deep confined aquifer or below the lower surficial aquifer
NAVD88 = North American Vertical Datum of 1988

Table 5-7

Distribution and Occurrence - Groundwater - 2007
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland
Page 1 of 4

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent							
SVOCs									
1,4-DIOXANE	**49/70**	**70%**	**0.19**	**0.96**	**0.35 J**	**1800**	**115**	**164**	**306**
MNA VOLATILES (mg/l)									
CARBON DIOXIDE	2/2	100%	-	-	220	630	425	425	NA(1)
ETHANE	12/12	100%	-	-	0.016 J	61	6.49	6.49	17.5
ETHENE	12/12	100%	-	-	0.02 J	2100	191	191	602
CARBON DIOXIDE	10/10	100%	-	-	34	600	208	208	166
METHANE	12/12	100%	-	-	0.23	1700	256	256	479
VOLATILES (ug/l)									
1,1,1-TRICHLOROETHANE	**9/65**	**14%**	**1**	**50**	**2.9**	**240**	**7.89**	**41.1**	**30.8**
1,1,2,2-TETRACHLOROETHANE	**1/65**	**2%**	**1**	**100**	**20**	**20**	**3.63**	**20.0**	**8.63**
1,1,2-TRICHLOROTRIFLUOROETHANE	1/65	2%	1	100	2.2 J	2.2 J	3.33	2.20	8.38
1,1-DICHLOROETHANE	**6/65**	**9%**	**1**	**50**	**0.62 J**	**83.3 J**	**4.18**	**19.4**	**11.9**
1,1-DICHLOROETHENE	**31/65**	**48%**	**1**	**50**	**0.47 J**	**222**	**13.0**	**25.1**	**36.0**
1,2,3-TRICHLOROBENZENE	5/65	8%	2	200	3	115	8.72	48.2	22.7
1,2,4-TRICHLOROBENZENE	**6/65**	**9%**	**2**	**200**	**1.8 J**	**689**	**28.3**	**253**	**118**
1,2,4-TRIMETHYLBENZENE	**12/65**	**18%**	**1**	**100**	**0.8 J**	**375**	**10.5**	**42.1**	**47.1**
1,2-DICHLOROBENZENE	8/65	12%	1	100	0.24 J	4.4 J	3.39	1.24	8.38
1,2-DICHLOROETHANE	**21/65**	**32%**	**1**	**100**	**0.63 J**	**129**	**11.3**	**27.6**	**27.0**
1,3,5-TRIMETHYLBENZENE	**16/62**	**26%**	**1**	**100**	**0.3 J**	**190**	**5.48**	**15.5**	**24.7**
1,3-DICHLOROBENZENE	4/65	6%	1	100	0.21 J	1.2	3.33	0.470	8.38
1,4-DICHLOROBENZENE	**4/65**	**6%**	**1**	**100**	**0.23 J**	**5**	**3.43**	**2.61**	**8.38**
2-BUTANONE	1/9	11%	10	250	18.9 J	18.9 J	56.0	18.9	53.4
2-HEXANONE	1/65	2%	5	500	1.4 J	1.4 J	16.6	1.40	41.9
4-ISOPROPYLTOLUENE	5/65	8%	1	100	0.43 J	9.9	3.53	3.06	8.40
4-METHYL-2-PENTANONE	1/65	2%	5	500	7.8	7.8	16.7	7.80	41.9
ACETONE	12/60	20%	10	1000	6.1 J	52	31.6	17.8	74.3
ACETYLENE	1/2	50%	0.5	0.5	1.2	1.2	0.725	1.20	NA(1)
BENZENE	**29/65**	**45%**	**1**	**100**	**0.42 J**	**491**	**13.6**	**25.3**	**61.0**
BROMODICHLOROMETHANE	**5/65**	**8%**	**1**	**100**	**0.21 J**	**0.78 J**	**3.32**	**0.424**	**8.38**
BUTANE	2/2	100%	-	-	0.15	0.28	0.215	0.215	NA(1)
CARBON DISULFIDE	13/65	20%	1	100	0.15 J	1.7	3.36	0.656	8.37
CARBON TETRACHLORIDE	**4/65**	**6%**	**1**	**100**	**5.2**	**333**	**10.3**	**114**	**43.1**
CHLOROBENZENE	**22/65**	**34%**	**1**	**100**	**0.25 J**	**283**	**10.6**	**26.3**	**38.6**
CHLOROETHANE	2/65	3%	1	100	0.32 J	0.61 J	3.33	0.465	8.38
CHLOROFORM	**33/65**	**51%**	**0.72**	**100**	**0.3 J**	**1870**	**49.4**	**92.6**	**239**

Table 5-7

Distribution and Occurrence - Groundwater - 2007
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent							
CHLOROMETHANE	1/65	2%	1	100	0.56 J	0.56 J	3.33	0.560	8.38
CIS-1,2-DICHLOROETHENE	**55/65**	**85%**	**1**	**1**	**0.25 J**	**38000**	**1981**	**2341**	**6586**
DICHLORODIFLUOROMETHANE	4/65	6%	1	100	0.78 J	5.5	3.50	3.67	8.37
DIISOPROPYL ETHER	6/65	9%	1	250	0.25 J	3.4	8.02	1.33	26.8
ETHYL TERT-BUTYL ETHER	1/65	2%	1	250	0.16 J	0.16 J	7.94	0.160	26.8
ETHYLBENZENE	**11/65**	**17%**	**1**	**100**	**0.48 J**	**2610**	**44.2**	**245**	**323**
ISOBUTANE	2/2	100%	-	-	0.065	0.082	0.074	0.074	NA(1)
ISOPROPYLBENZENE	14/65	22%	1	100	0.18 J	28.9 J	3.43	3.13	8.54
M+P-XYLENES	**18/65**	**28%**	**2**	**100**	**0.41 J**	**26000**	**409**	**1464**	**3224**
METHYLENE CHLORIDE	**30/65**	**46%**	**1**	**50**	**0.19 J**	**135**	**8.71**	**14.5**	**20.4**
NAPHTHALENE	**7/65**	**11%**	**2**	**200**	**2.4**	**63.3 J**	**6.46**	**17.4**	**15.2**
N-PROPYLBENZENE	7/65	11%	1	100	0.27 J	28.5 J	3.46	5.51	8.52
O-XYLENE	**25/65**	**38%**	**1**	**100**	**0.21 J**	**2500**	**43.5**	**107**	**310**
PROPANE	2/2	100%	-	-	0.05 J	0.43	0.240	0.240	NA(1)
PROPYLENE	2/2	100%	-	-	0.075	0.36	0.218	0.218	NA(1)
SEC-BUTYLBENZENE	1/65	2%	2	200	1.1 J	1.1 J	5.51	1.10	14.4
TERTIARY-BUTYL ALCOHOL	9/27	33%	10	10	4 J	53	11.7	25.1	13.2
TETRACHLOROETHENE	**30/65**	**46%**	**1**	**100**	**0.42 J**	**40.9**	**6.30**	**7.51**	**11.0**
TOLUENE	**28/65**	**43%**	**0.59**	**50**	**0.21 J**	**5900**	**139**	**318**	**787**
TOTAL XYLENES	**20/65**	**31%**	**3**	**300**	**0.63 J**	**28500**	**452**	**1449**	**3533**
TRANS-1,2-DICHLOROETHENE	**36/65**	**55%**	**1**	**50**	**0.25 J**	**376**	**22.1**	**37.4**	**66.5**
TRICHLOROETHENE	**54/65**	**83%**	**1**	**1**	**0.23 J**	**41100**	**2160**	**2600**	**5948**
TRICHLOROFLUOROMETHANE	1/65	2%	1	100	0.88 J	0.88 J	3.34	0.880	8.38
VINYL CHLORIDE	**44/65**	**68%**	**1**	**1**	**0.28 J**	**26200**	**735**	**1085**	**3325**
MISCELLANEOUS (mg/l)									
ALKALINITY	7/12	58%	4	4	8.1	440	77.7	132	147
CHLORIDE	12/12	100%	-	-	8.1	190	80.5	80.5	59.0
NITRATE	11/12	92%	0.5	0.5	1	15	2.85	3.09	3.94
NITRITE	**5/12**	**42%**	**0.5**	**0.5**	**1.4**	**2.1**	**0.838**	**1.66**	**0.747**
SULFATE	12/12	100%	-	-	3.1	1300	472	472	482
MISCELLANEOUS (S.U.)									
PH	3/3	100%	-	-	6.3	6.4	6.33	6.33	NA(1)
MISCELLANEOUS (ug/l)									
ACETYLENE	3/10	30%	0.5	0.5	0.18 J	2.1	0.423	0.827	0.590
BUTANE	7/10	70%	0.05	0.05	0.046 J	0.55	0.157	0.213	0.166
ISOBUTANE	5/10	50%	0.05	0.05	0.013 J	0.56	0.088	0.150	0.170

Table 5-7

Distribution and Occurrence - Groundwater - 2007
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent							
PERCHLORATE	**5/31**	**16%**	**0.8**	**8**	**2**	**8**	**1.99**	**3.80**	**1.45**
PROPANE	9/10	90%	0.05	0.05	0.03 J	0.36	0.109	0.118	0.103
PROPYLENE	7/10	70%	0.05	0.05	0.032 J	0.79	0.155	0.210	0.235
TOTAL METALS (mg/l)									
ANTIMONY	**35/62**	**56%**	**0.00005**	**0.002**	**0.0001**	**0.0017**	**0.0003**	**0.0004**	**0.0003**
ARSENIC	**59/62**	**95%**	**0.0005**	**0.006**	**0.001**	**0.028**	**0.006**	**0.006**	**0.006**
BARIUM	**62/62**	**100%**	**-**	**-**	**0.0039**	**44100**	**711**	**711**	**5601**
BERYLLIUM	**33/62**	**53%**	**0.0001**	**0.001**	**0.0001**	**0.0094**	**0.0010**	**0.002**	**0.002**
CADMIUM	**29/62**	**47%**	**0.0004**	**0.001**	**0.0003**	**0.997**	**0.047**	**0.100**	**0.157**
CHROMIUM	**58/62**	**94%**	**0.0002**	**0.0002**	**0.0003**	**0.889**	**0.027**	**0.028**	**0.114**
COBALT	**54/62**	**87%**	**0.0005**	**0.0005**	**0.0006**	**39200**	**632**	**726**	**4978**
COPPER	**61/62**	**98%**	**0.0003**	**0.0003**	**0.0003**	**0.297**	**0.022**	**0.022**	**0.046**
LEAD	**52/62**	**84%**	**0.00004**	**0.002**	**5E-05**	**0.228**	**0.007**	**0.008**	**0.029**
MERCURY	**17/62**	**27%**	**0.00003**	**0.0005**	**3E-05**	**0.0026**	**0.0002**	**0.0005**	**0.0004**
MOLYBDENUM	**40/62**	**65%**	**0.0005**	**0.002**	**0.0005**	**0.0265**	**0.004**	**0.006**	**0.005**
NICKEL	**62/62**	**100%**	**-**	**-**	**0.0004**	**0.226**	**0.037**	**0.037**	**0.049**
SELENIUM	**54/62**	**87%**	**0.001**	**0.006**	**0.0003**	**0.055**	**0.007**	**0.008**	**0.010**
SILVER	56/62	90%	0.001	0.001	0.0002	0.0012 L	0.0006	0.0006	0.0002
THALLIUM	**35/62**	**56%**	**0.00002**	**0.001**	**2E-05**	**0.0005**	**0.0002**	**0.0002**	**0.0002**
VANADIUM	**47/62**	**76%**	**0.00003**	**0.001**	**0.0001**	**0.0892**	**0.006**	**0.008**	**0.014**
ZINC	**60/62**	**97%**	**0.002**	**0.002**	**0.0014**	**1.78**	**0.137**	**0.141**	**0.273**
FILTERED METALS (mg/l)									
ANTIMONY	19/62	31%	0.0002	0.002	0.0003	0.0013	0.0007	0.0007	0.0004
ARSENIC	**58/62**	**94%**	**0.003**	**0.003**	**8E-05**	**0.0198**	**0.004**	**0.005**	**0.005**
BARIUM	**62/62**	**100%**	**-**	**-**	**0.003**	**0.313**	**0.048**	**0.048**	**0.051**
BERYLLIUM	**41/62**	**66%**	**0.0002**	**0.001**	**9E-05**	**0.0094**	**0.001**	**0.002**	**0.002**
CADMIUM	**28/62**	**45%**	**0.00001**	**0.001**	**7E-05**	**0.956**	**0.039**	**0.085**	**0.146**
CHROMIUM	**62/62**	**100%**	**-**	**-**	**0.0003**	**0.229**	**0.010**	**0.010**	**0.029**
COBALT	**60/62**	**97%**	**0.00002**	**0.005**	**0.0002**	**0.567**	**0.059**	**0.061**	**0.103**
COPPER	**55/62**	**89%**	**0.005**	**0.005**	**0.0004**	**0.136**	**0.011**	**0.012**	**0.021**
IRON	**12/12**	**100%**	**-**	**-**	**0.023 L**	**240**	**34.9**	**34.9**	**65.5**
LEAD	34/62	55%	0.0001	0.002	0.0001	0.0112	0.002	0.002	0.002
MERCURY	3/62	5%	0.00003	0.0005	4E-05	0.0001 L	0.0002	0.00008	0.0001
MOLYBDENUM	**44/62**	**71%**	**0.0001**	**0.002**	**0.0001**	**0.0223**	**0.003**	**0.004**	**0.005**
NICKEL	**61/62**	**98%**	**0.005**	**0.005**	**0.0004**	**0.235**	**0.035**	**0.036**	**0.048**
SELENIUM	**39/62**	**63%**	**0.005**	**0.005**	**0.0003**	**0.037 K**	**0.004**	**0.006**	**0.005**

Table 5-7

Distribution and Occurrence - Groundwater - 2007
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent							
SILVER	14/62	23%	0.00001	0.001	0.0003	0.0014 L	0.0004	0.0009	0.0004
THALLIUM	**15/62**	**24%**	**0.00001**	**0.001**	**0.0001**	**0.0004**	**0.0003**	**0.0002**	**0.0002**
VANADIUM	**59/62**	**95%**	**0.001**	**0.001**	**0.0001**	**0.0206**	**0.003**	**0.003**	**0.004**
ZINC	**57/62**	**92%**	**0.005**	**0.005**	**0.0003**	**0.822**	**0.098**	**0.106**	**0.159**

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.
Data Validation Qualifiers:
J = Estimated concentration
L = Result biased low
K = Result biased high
U = Analyte not detected at the analytical reporting limit
mg/kg = Milligrams per kilogram (i.e., parts per million)
ug/kg = Micrograms per kilogram (i.e., parts per billion)
Shaded line indicate analyte is a COPC.

Table 5-8

Distribution and Occurrence - Groundwater - 2008
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Location of Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent								
SEMIVOLATILES (ug/l)										
1,4-DIOXANE	**39/70**	**56%**	**0.49**	**4**	**0.54 J**	**590**	**DMW-16S-082108**	**41.3**	**73.8**	**103**
VOLATILES (ug/l)										
CIS-1,2-DICHLOROETHENE	**52/71**	**73%**	**0.17**	**2.5**	**0.34 J**	**36000**	**DMW-11S-081108**	**1283**	**1751**	**4725**
VINYL CHLORIDE	**43/71**	**61%**	**0.22**	**250**	**0.23 J**	**35000**	**DMW-9S-082208**	**880**	**1448**	**4224**
TRICHLOROETHENE	**39/71**	**55%**	**0.17**	**1200**	**0.36 J**	**29000**	**DMW-11S-081108**	**1741**	**3151**	**4883**
CHLOROFORM	**19/71**	**27%**	**0.16**	**1200**	**0.17 J**	**1000 J**	**DMW-11S-081108**	**43.7**	**80.8**	**142**
TOLUENE	**12/71**	**17%**	**0.13**	**500**	**0.32 J**	**4400**	**DMW-9S-082208**	**102**	**498**	**538**
TRANS-1,2-DICHLOROETHENE	**10/71**	**14%**	**0.19**	**1700**	**0.31 J**	**200**	**DMW-3S-082708**	**45.4**	**29.6**	**131**
1,1-DICHLOROETHENE	**9/71**	**13%**	**0.19**	**1700**	**0.31 J**	**76 J**	**DMW-4I-082508**	**42.2**	**20.5**	**129**
1,2-DICHLOROETHANE	**8/71**	**11%**	**0.22**	**1700**	**0.93 J**	**150 J**	**DMW-2A-082908 DMW-3I-082708**	**38.7**	**53.1**	**125**
CARBON DISULFIDE	7/71	10%	0.13	1700	0.29 J	0.95 J	DMW-17D-090508	43.0	0.599	129
CHLOROBENZENE	**7/71**	**10%**	**0.15**	**1700**	**0.22 J**	**720**	**DMW-1S-081808**	**62.8**	**210**	**161**
2-BUTANONE	6/71	8%	0.57	8300	0.66 J	1.4 J	DMW-23S-081108	214	0.917	645
BENZENE	**5/71**	**7%**	**0.13**	**1700**	**4.2**	**570 J**	**DMW-9S-082208**	**43.0**	**122**	**127**
METHYLENE CHLORIDE	**5/71**	**7%**	**0.33**	**1700**	**8.2 J**	**140 J**	**DMW-18I-090208**	**42.6**	**48.4**	**129**
1,2,4-TRIMETHYLBENZENE	**3/71**	**4%**	**0.12**	**1700**	**0.6 J**	**240 J**	**DMW-9S-082208**	**37.8**	**80.7**	**113**
CARBON TETRACHLORIDE	**3/71**	**4%**	**0.13**	**1700**	**0.7 J**	**430 J**	**DMW-10I-081508**	**48.5**	**150**	**137**
ETHYLBENZENE	**3/71**	**4%**	**0.17**	**1700**	**1.5 J**	**2100**	**DMW-9S-082208**	**64.7**	**714**	**269**
1,1,1-TRICHLOROETHANE	**2/71**	**3%**	**0.22**	**1700**	**4.5 J**	**78 J**	**DMW-4I-082508**	**42.6**	**41.3**	**129**
1,2,3-TRIMETHYLBENZENE	2/71	3%	0.0059	8300	0.11 J	1.1 J	MW26S-080708	147	0.605	617
1,2,4-TRICHLOROBENZENE	**2/71**	**3%**	**0.15**	**1700**	**650**	**730**	**DMW-3I-082708**	**53.8**	**690**	**165**
1,2-DICHLOROBENZENE	2/71	3%	0.13	1700	0.42 J	1.9 J	DMW-16S-082108	42.9	1.16	129
ISOPROPYLBENZENE	2/71	3%	0.13	1700	0.24 J	0.32 J	DMW-23S-081108	42.9	0.280	129
M+P-XYLENES	**2/71**	**3%**	**0.24**	**3300**	**0.33 J**	**15000**	**DMW-9S-082208**	**280**	**7500**	**1785**
NAPHTHALENE	**2/71**	**3%**	**0.24**	**1700**	**0.31 J**	**0.32 J**	**DMW-6D-082008**	**43.3**	**0.315**	**129**
O-XYLENE	**2/71**	**3%**	**0.14**	**1700**	**1.4 J**	**830 J**	**DMW-9S-082208**	**46.2**	**416**	**145**
TOTAL XYLENES	**2/71**	**3%**	**0.28**	**3300**	**0.33 J**	**16000**	**DMW-9S-082208**	**294**	**8000**	**1903**
1,3-DICHLOROBENZENE	1/71	1%	0.14	1700	0.63 J	0.63 J	DMW-16S-082108	43.0	0.630	129
1,4-DICHLOROBENZENE	**1/71**	**1%**	**0.13**	**1700**	**0.83 J**	**0.83 J**	**DMW-16S-082108**	**42.9**	**0.830**	**129**
4-ISOPROPYLTOLUENE	1/71	1%	0.12	1700	11	11	MW26S-080708	43.0	11.0	129
ACETONE	1/71	1%	1.1	8300	12	12	DMW-17D-090508	209	12.0	644
CHLOROETHANE	1/71	1%	0.29	1700	1.1 J	1.1 J	MW-23I-081808	43.5	1.10	129
N-PROPYLBENZENE	1/71	1%	0.14	1700	0.3 J	0.3 J	MW-23I-081808	43.0	0.300	129
SEC-BUTYLBENZENE	1/71	1%	0.13	1700	0.39 J	0.39 J	DMW-23S-081108	42.9	0.390	129

Table 5-8

Distribution and Occurrence - Groundwater - 2008
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Location of Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent								
TERT-BUTYLBENZENE	1/71	1%	0.13	1700	0.42 J	0.42 J	DMW-23S-081108	42.9	0.420	129
TETRACHLOROETHENE	**1/71**	**1%**	**0.29**	**1700**	**0.73 J**	**0.73 J**	**MW26D-080708**	**43.5**	**0.730**	**129**
TOTAL METALS (ug/l)										
BARIUM	**71/71**	**100%**	**-**	**-**	**5.5**	**1610**	**MW26S-080708**	**71.5**	**71.5**	**191**
MAGNESIUM	17/17	100%	-	-	592	199000	DMW-18S-090208	47265	47265	45865
MANGANESE	**71/71**	**100%**	**-**	**-**	**21**	**12000**	**MW-6-082608**	**2096**	**2096**	**2273**
COBALT	**70/71**	**99%**	**0.37**	**0.37**	**0.25**	**467**	**DMW-2A-082908**	**60.8**	**61.7**	**99.4**
ARSENIC	**69/71**	**97%**	**0.13**	**0.13**	**0.62**	**41.7**	**DMW-4I-082508**	**8.44**	**8.68**	**8.99**
IRON	**69/71**	**97%**	**30.5**	**118**	**66.6 K**	**275000**	**DMW-6S-082108**	**31790**	**32710**	**41080**
NICKEL	**69/71**	**97%**	**0.28**	**0.36**	**0.48**	**530**	**DMW-24S-081108**	**41.3**	**42.5**	**72.2**
CALCIUM	16/17	94%	1660	1660	1990	199000	DMW-18S-090208	70144	74476	57805
CHROMIUM	**62/71**	**87%**	**0.27**	**3.8**	**0.5 K**	**349 K**	**DMW-1A-081508**	**18.2**	**20.7**	**50.7**
VANADIUM	**54/71**	**76%**	**0.46**	**20**	**0.6**	**139 J**	**DMW-17D-090508**	**11.6**	**14.3**	**22.3**
SELENIUM	**50/71**	**70%**	**0.14**	**5**	**0.16 L**	**47.2**	**DMW-24S-081108**	**5.14**	**7.02**	**10.1**
LEAD	**49/71**	**69%**	**0.026**	**0.85**	**0.33**	**30**	**DMW-9I-082208**	**4.10**	**5.89**	**6.66**
COPPER	**45/71**	**63%**	**0.051**	**2.2**	**0.096 K**	**262**	**DMW-2A-082908**	**29.3**	**46.0**	**57.1**
ZINC	**44/71**	**62%**	**2.1**	**44.5**	**13.3**	**1780**	**DMW-24S-081108**	**133**	**211**	**248**
BERYLLIUM	**42/71**	**59%**	**0.012**	**1**	**0.016**	**9.3**	**DMW-4I-082508**	**1.30**	**2.16**	**2.11**
CADMIUM	**31/71**	**44%**	**0.0061**	**0.33**	**0.077 L**	**768**	**DMW-2A-082908**	**42.9**	**98.3**	**137**
MOLYBDENUM	**29/71**	**41%**	**0.12**	**2.7**	**0.17 K**	**9.2 K**	**DMW-27DEEP-080808**	**1.06**	**2.02**	**1.60**
CHROMIUM (HEXAVALENT)	**24/61**	**39%**	**0.002**	**0.04**	**0.002 L**	**0.25**	**DMW-17D-090508**	**0.016**	**0.028**	**0.037**
MERCURY	**16/71**	**23%**	**0.1**	**0.22**	**0.1**	**3.9**	**DMW-1B-081508**	**0.237**	**0.833**	**0.560**
ANTIMONY	15/71	21%	0.035	2	0.038 K	2.9	MW-4-081808	0.240	0.596	0.442
SILVER	5/71	7%	0.0026	1	0.058	0.35 K	DMW-4I-082508	0.105	0.188	0.188
THALLIUM	**1/71**	**1%**	**0.11**	**1**	**0.24 K**	**0.24 K**	**DMW-6I-082008**	**0.162**	**0.240**	**0.166**
FILTERED METALS (ug/l)										
MAGNESIUM	17/17	100%	-	-	418	183000	DMW-18S-090208	48406	48406	43806
MANGANESE	**71/71**	**100%**	**-**	**-**	**9.5**	**11900**	**MW-6-082608**	**2226**	**2226**	**2489**
BARIUM	**70/71**	**99%**	**2.9**	**2.9**	**6.4**	**1720**	**MW26S-080708**	**65.7**	**66.6**	**203**
COBALT	**69/71**	**97%**	**0.15**	**0.38**	**0.23**	**544**	**DMW-2A-082908**	**63.6**	**65.4**	**105**
ARSENIC	**68/71**	**96%**	**0.13**	**5**	**0.25**	**36**	**DMW-24S-081108**	**6.84**	**7.11**	**7.40**
NICKEL	**67/71**	**94%**	**0.22**	**0.38**	**0.65**	**542**	**DMW-24S-081108**	**42.0**	**44.5**	**75.1**
CALCIUM	**16/17**	**94%**	**1630**	**1630**	**2220**	**184000**	**DMW-18S-090208**	**70826**	**75201**	**55329**
IRON	**64/71**	**90%**	**5.2**	**79.3**	**156**	**284000**	**DMW-6S-082108**	**29930**	**33202**	**41784**
CHROMIUM	**45/71**	**63%**	**0.1**	**2.7**	**0.32 K**	**260 K**	**DMW-1A-081508**	**6.01**	**9.27**	**30.7**
SELENIUM	**44/71**	**62%**	**0.14**	**5**	**0.14**	**48.3**	**DMW-24S-081108**	**4.95**	**7.56**	**10.2**

Table 5-8

Distribution and Occurrence - Groundwater - 2008
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	Frequency of Detection		Mininum Non Detected	Maximum Non Detected	Mininum Detected	Maximum Detected	Location of Maximum Detected	Mean of All Samples	Mean of Positive Detects	Standard Deviation
	Number	Percent								
VANADIUM	**36/71**	**51%**	**0.46**	**20**	**0.47**	**82.4**	**DMW-24S-081108**	**4.74**	**6.03**	**10.6**
ZINC	**36/71**	**51%**	**1.5**	**42.8**	**10.8**	**1810**	**DMW-24S-081108**	**113**	**219**	**243**
BERYLLIUM	**35/71**	**49%**	**0.012**	**1**	**0.1**	**10.2**	**DMW-4I-082508**	**1.17**	**2.29**	**2.10**
COPPER	**25/71**	**35%**	**0.051**	**2.7**	**0.38 K**	**156**	**DMW-24S-081108**	**10.1**	**28.4**	**25.7**
CADMIUM	**23/71**	**32%**	**0.0061**	**1**	**0.076 L**	**787**	**DMW-1A-081508**	**33.2**	**102**	**126**
LEAD	23/71	32%	0.018	1	0.043	10.9	DMW-7I-082808	0.979	2.86	2.09
MOLYBDENUM	**17/71**	**24%**	**0.12**	**2**	**0.19 K**	**10.2**	**DMW-3S-082708**	**0.799**	**2.20**	**1.63**
MERCURY	7/71	10%	0.1	0.2	0.1 K	0.19	MW-5-082808	0.075	0.143	0.033
ANTIMONY	3/71	4%	0.035	2	0.089 K	0.18	DMW-6I-082008	0.135	0.121	0.291
THALLIUM	**1/71**	**1%**	**0.11**	**1**	**0.22 K**	**0.22 K**	**DMW-6I-082008**	**0.167**	**0.220**	**0.174**
MISCELLANEOUS (mg/l)										
ALKALINITY	11/17	65%	5	9.8	2.4	482	DMW-9S-082208	95.9	147	164
CHEMICAL OXYGEN DEMAND	15/17	88%	20	20	17.3	245	DMW-9S-082208	59.4	65.9	61.0
TOTAL ORGANIC CARBON	17/17	100%	-	-	0.5	43	DMW-18S-090208	11.5	11.5	12.4
MISCELLANEOUS (S.U.)										
PH	17/17	100%	-	-	4.1	6.6	DMW-16S-082108 DMW-18S-090208	5.40	5.40	0.919

Footnotes:
Bolded shaded indicates direct contact COPC.
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.
Data Validation Qualifiers:
J = Estimated concentration
L = Result biased low
K = Result biased high
U = Analyte not detected at the analytical reporting limit
mg/kg = Milligrams per kilogram (i.e., parts per million)
ug/kg = Micrograms per kilogram (i.e., parts per billion)
Shaded line indicate analyte is a COPC.

Table 5-9

Distribution and Occurrence - Groundwater - 2009
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	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)										
CIS-1,2-DICHLOROETHENE	46/65	71%	0.17	0.85	0.51 J	41000	MSA-DMW11S	1515	2141	5542
TRICHLOROETHENE	41/65	63%	0.17	280	0.3 J	36000	MSA-DMW11S	2115	3349	5693
1,4-DIOXANE	34/54	63%	1	1	0.75 L	1100	MSA-DMW3I	114	181	231
VINYL CHLORIDE	39/65	60%	0.22	55	0.32 J	56000	MSA-DMW9S	1222	2035	6954
1,2-DICHLOROETHANE	18/65	28%	0.22	370	0.26 J	160 J	MSA-DMW3I	13.7	22.2	35.3
TRANS-1,2-DICHLOROETHENE	17/65	26%	0.19	320	0.19 J	180 J	MSA-DMW11S	14.1	29.4	34.2
CHLOROFORM	15/65	23%	0.16	270	0.49 J	950	MSA-DMW11S	26.1	89.9	123
BENZENE	13/65	20%	0.13	93	0.35 J	570 J	MSA-DMW9S	14.6	54.0	70.8
1,1-DICHLOROETHENE	11/65	17%	0.19	320	0.24 J	160 J	MSA-DMW11S	11.7	28.8	30.1
CARBON DISULFIDE	8/65	12%	0.13	220	0.2 J	1.1	MSA-MW32I	5.89	0.690	15.7
CHLOROBENZENE	6/65	9%	0.15	250	0.33 J	560	MSA-MW20S	20.0	146	77.6
TOLUENE	6/65	9%	0.13	150	0.3 J	6500	MSA-DMW9S	132	1390	827
1,2,4-TRICHLOROBENZENE	5/65	8%	0.15	250	0.73 J	560	MSA-DMW3I	23.5	240	95.0
CARBON TETRACHLORIDE	3/65	5%	0.13	220	0.37 J	23 J	MSA-DMW9I	6.13	8.86	15.9
1,2-DICHLOROBENZENE	2/65	3%	0.13	220	0.36 J	1.2 J	MSA-MW16S	5.82	0.780	15.8
1,3-DICHLOROBENZENE	2/65	3%	0.14	230	0.4 J	0.75 J	MSA-MW23S	6.23	0.575	16.6
1,4-DICHLOROBENZENE	2/65	3%	0.13	220	0.37 J	0.45 J	MSA-MW16S	5.81	0.410	15.8
BROMODICHLOROMETHANE	2/65	3%	0.15	250	0.17 J	0.94 J	MSA-MW32I	6.71	0.555	18.1
ETHYLBENZENE	2/65	3%	0.17	120	27 J	2100	MSA-DMW9S	38.0	1064	260
M+P-XYLENES	2/65	3%	0.24	170	19	19000	MSA-DMW9S	300	9510	2356
O-XYLENE	2/65	3%	0.14	100	2.5	1400 J	MSA-DMW9S	26.0	701	173
TOTAL XYLENES	2/65	3%	0.28	200	21	21000	MSA-DMW9S	332	10511	2604
1,1,1-TRICHLOROETHANE	1/65	2%	0.22	370	68 J	68 J	MSA-DMW4I	10.6	68.0	27.6
1,2,3-TRIMETHYLBENZENE	1/65	2%	0.0059	9.8	0.056 J	0.056 J	MSA-MW32I	0.264	0.056	0.707
1,2,4-TRIMETHYLBENZENE	1/65	2%	0.12	86	210 J	210 J	MSA-DMW9S	7.03	210	26.8
2-BUTANONE	1/65	2%	0.57	950	0.94 J	0.94 J	MSA-MW32I	25.2	0.940	68.3
CHLORODIBROMOMETHANE	1/65	2%	0.18	300	0.57 J	0.57 J	MSA-MW32I	8.01	0.570	21.6
CHLOROMETHANE	1/65	2%	0.3	500	0.31 J	0.31 J	MSA-MW34S	13.3	0.310	35.9
ISOPROPYLBENZENE	1/65	2%	0.13	220	0.19 J	0.19 J	MSA-DMW1S	5.80	0.190	15.8
SEC-BUTYLBENZENE	1/65	2%	0.13	220	0.26 J	0.26 J	MSA-MW23S	5.80	0.260	15.8
TERT-BUTYLBENZENE	1/65	2%	0.13	220	0.36 J	0.36 J	MSA-MW23S	5.81	0.360	15.8
ETHENE	6/6	100%	-	-	1.6	36 J	MSA-MW14I	13.1	13.1	14.4
ETHANE	4/6	67%	0.27	0.27	0.95	31 J	MSA-MW14I	6.37	9.49	12.1
METHANE	6/6	100%	-	-	21	1000 J	MSA-MW14I	317	317	360

Table 5-9

Distribution and Occurrence - Groundwater - 2009
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	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								
SEMIVOLATILES (ug/l)										
DIETHYL PHTHALATE	1/6	17%	0.6	0.6	1.6	1.6	MSA-MW34S	0.517	1.60	0.531
TOTAL METALS (ug/l)										
BARIUM	**65/65**	**100%**	**-**	**-**	**3.1**	**539**	**MSA-MW26S**	**53.6**	**53.6**	**70.4**
CALCIUM	6/6	100%	-	-	43200	189000	MSA-MW14I	117750	117750	60092
MAGNESIUM	6/6	100%	-	-	31200	202000	MSA-MW18S	80267	80267	62176
MANGANESE	**65/65**	**100%**	**-**	**-**	**12.3**	**13400 J**	**MSA-MW6**	**2448**	**2448**	**2769**
POTASSIUM	6/6	100%	-	-	5050	42500 J	MSA-MW18S	15905	15905	14175
SILICA	6/6	100%	-	-	4270	30200	MSA-MW18S	17512	17512	10296
SODIUM	6/6	100%	-	-	44600	560000	MSA-MW18S	196600	196600	183500
COBALT	**61/65**	**94%**	**0.12**	**0.37**	**0.12**	**724**	**MSA-MW24S**	**81.6**	**87.0**	**135**
IRON	**61/65**	**94%**	**58.6**	**97.4**	**239**	**238000**	**MSA-MW24S**	**31142**	**33181**	**46327**
NICKEL	**61/65**	**94%**	**0.2**	**1**	**1.4 K**	**991**	**MSA-MW24S**	**57.9**	**61.6**	**128**
ARSENIC	**54/65**	**83%**	**0.12**	**0.93**	**0.28**	**82.2 J**	**MSA-DMW1B**	**8.34**	**10.00**	**15.4**
VANADIUM	**50/65**	**77%**	**0.29**	**0.6**	**0.62**	**116**	**MSA-MW24S**	**7.35**	**9.49**	**17.2**
CHROMIUM	**49/65**	**75%**	**0.36**	**1.7**	**0.84**	**303**	**MSA-DMW1A**	**14.0**	**18.5**	**42.7**
SELENIUM	**43/65**	**66%**	**0.14**	**1.1**	**0.16**	**149**	**MSA-MW24S**	**5.96**	**8.94**	**19.7**
ZINC	**43/65**	**66%**	**2.2**	**51.6**	**18.3 J**	**3150**	**MSA-MW24S**	**196**	**291**	**423**
COPPER	**41/65**	**63%**	**0.079**	**3.7**	**0.47**	**534**	**MSA-DMW6I**	**26.4**	**41.6**	**72.4**
LEAD	**39/65**	**60%**	**0.028**	**1.2**	**0.12 K**	**38**	**MSA-DMW9I**	**2.79**	**4.54**	**6.00**
BERYLLIUM	**36/65**	**55%**	**0.025**	**0.48**	**0.055**	**9.9**	**MSA-MW24S**	**1.10**	**1.95**	**2.05**
CADMIUM	**29/65**	**45%**	**0.014**	**0.43**	**0.073**	**1130**	**MSA-DMW1A**	**47.9**	**107**	**174**
MOLYBDENUM	**14/65**	**22%**	**0.2**	**1.8**	**0.97**	**4.3**	**MSA-DMW11I**	**0.794**	**2.43**	**1.00**
MERCURY	**10/65**	**15%**	**0.1**	**0.2**	**0.11 K**	**13.2**	**MSA-DMW4D**	**0.341**	**1.93**	**1.66**
ANTIMONY	**4/65**	**6%**	**0.043**	**0.82**	**0.51**	**1.7**	**MSA-DMW3S, MSA-DMW9I**	**0.160**	**1.12**	**0.297**
SILVER	2/65	3%	0.02	0.2	0.08 K	0.15 K	MSA-DMW4I	0.022	0.115	0.025
THALLIUM	**1/65**	**2%**	**0.072**	**0.78**	**0.2**	**0.2**	**MSA-MW14I**	**0.085**	**0.200**	**0.059**

Table 5-9

Distribution and Occurrence - Groundwater - 2009
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Chemical	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								
FILTERED METALS (ug/l)										
BARIUM	**65/65**	**100%**	**-**	**-**	**2.3**	**582**	**MSA-MW26S**	**49.6**	**49.6**	**75.9**
MANGANESE	**65/65**	**100%**	**-**	**-**	**11.8**	**12600**	**MSA-MW6**	**2474**	**2474**	**2808**
COBALT	**60/65**	**92%**	**0.11**	**0.39**	**0.078**	**692**	**MSA-MW24S**	**80.9**	**87.6**	**134**
NICKEL	**59/65**	**91%**	**0.3**	**1.3**	**1**	**942**	**MSA-MW24S**	**55.2**	**60.8**	**122**
IRON	**58/65**	**89%**	**4.7**	**73.9**	**175**	**222000**	**MSA-MW24S**	**29045**	**32548**	**45387**
ARSENIC	**51/65**	**78%**	**0.12**	**1.1**	**0.22 J**	**77.3**	**MSA-MW24S**	**6.38**	**8.10**	**11.5**
SELENIUM	**38/65**	**58%**	**0.14**	**1.2**	**0.15**	**139**	**MSA-MW24S**	**5.65**	**9.57**	**18.7**
ZINC	**37/65**	**57%**	**1.5**	**54.2**	**16.8 J**	**2860**	**MSA-MW24S**	**138**	**239**	**368**
CHROMIUM	**32/65**	**49%**	**0.19**	**1.3**	**0.83**	**171**	**MSA-DMW1A**	**4.99**	**9.82**	**21.3**
BERYLLIUM	**31/65**	**48%**	**0.025**	**0.6**	**0.073**	**10.4**	**MSA-DMW4I**	**1.00**	**2.05**	**2.03**
VANADIUM	**30/65**	**46%**	**0.29**	**0.6**	**0.6**	**141**	**MSA-MW24S**	**3.91**	**8.21**	**17.5**
COPPER	**27/65**	**42%**	**0.064**	**2.1**	**0.47**	**157**	**MSA-MW24S**	**12.2**	**29.0**	**27.6**
LEAD	24/65	37%	0.028	0.79	0.1 K	6.8	MSA-DMW4I	0.708	1.80	1.41
CADMIUM	**23/65**	**35%**	**0.014**	**0.41**	**0.041**	**1070**	**MSA-DMW1A**	**43.4**	**123**	**166**
MOLYBDENUM	**7/65**	**11%**	**0.2**	**2.2**	**0.48**	**2.6**	**MSA-DMW11I**	**0.426**	**1.97**	**0.623**
MERCURY	**4/65**	**6%**	**0.1**	**0.24**	**0.11 K**	**0.34**	**MSA-DMW4D**	**0.059**	**0.178**	**0.040**
MISCELLANEOUS (mg/l)										
ALKALINITY	4/6	67%	1.1	1.1	26	270	MSA-MW18S	80.0	120	103
CHLORIDE	6/6	100%	-	-	23.3 J	594	MSA-MW18S	207	207	211
DISSOLVED ORGANIC CARBON	6/6	100%	-	-	4	33	MSA-MW18S	11.3	11.3	10.8
HEXAVALENT CHROMIUM	14/42	33%	0.002	0.02	0.002 L	0.01	MSA-DMW11S	0.002	0.005	0.002
NITRATE-N	2/6	33%	0.023	0.023	0.1	2.8	MSA-DMW4D	0.491	1.45	1.13
SULFATE	6/6	100%	-	-	439	1600	MSA-MW18S	895	895	405
TOTAL DISSOLVED SOLIDS	6/6	100%	-	-	1100	3500	MSA-MW18S	1667	1667	922
MISCELLANEOUS (ug/l)										
PERCHLORATE	**14/59**	**24%**	**0.082**	**0.082**	**0.086 J**	**5.8**	**MSA-DMW4D**	**0.252**	**0.929**	**0.947**
PETROLEUM HYDROCARBONS (ug/l)										
DIESEL RANGE ORGANICS	13/23	57%	46	840	150	1300	MSA-MW20S	340	508	308
GASOLINE RANGE ORGANICS	22/23	96%	28	28	30 J	70000	MSA-DMW9S	4233	4425	14768

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.
Data Validation Qualifiers:
J = Estimated concentration
L = Result biased low
K = Result biased high
U = Analyte not detected at the analytical reporting limit
mg/kg = Milligrams per kilogram (i.e., parts per million)
ug/kg = Micrograms per kilogram (i.e., parts per billion)
Shaded line indicate analyte is a COPC.

Table 5-14

Summary of Metals Exceeding Maryland Groundwater Standards, 2007 Through 2009
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

Analyte	MDE Groundwater Standard[1] (ug/L)	Total Metals Samples			Filtered Metals Samples		
		Detections Exceeding Standards		Maximum Concentration (ug/L)	Detections Exceeding Standards		Maximum Concentration (ug/L)
		(Quantity)	(Percent)[2,3]		(Quantity)	(Percent)[2,3]	
Arsenic	10	42	21%	82.2 J	34	17%	77.3
Barium	2000	1	1%	44,100,000	0	0%	582
Beryllium	4	22	11%	9.9	23	12%	10.4
Cadmium	5	41	21%	1,130	34	17%	1,070
Chromium	100	8	4%	889	3	2%	260 K
Chromium (hexavalent)	100	NS	--	--	2	1%	250
Iron	2600	119	88%	275,000	120	81%	284,000
Lead	15	12	6%	228	0	0%	11.2
Manganese	73	122	90%	13,400 J	121	89%	12,600
Mercury	2	4	2%	13.2	0	0%	0.34
Nickel	73	39	20%	991	38	19%	942
Selenium	50	2	1%	149	1	1%	139
Vanadium	3.7	71	36%	139 J	33	17%	141
Zinc	1100	2	1%	3,150	1	1%	2,860

1 MDE Soil and Groundwater Standards, Interim Final, June 2008.
2 Total number of samples is 198 for listed analytes except filtered iron, total/filtered manganese and hexavalent chromium.
3 Total number of samples is 146 for hexavalent chromium, 148 for filterd iron and 136 for total iron and total/filtered manganese.
J = Estimated concentration below the contract required reporting limit.
K = Concentration is biased high
NS = Not sampled
ug/L = Micrograms per liter (i.e., parts per billion)

Table 5-15

Analytical Results for Groundwater Natural Attenuation Parameters
Dump Road
Lockheed Martin Martin State Airport, Middle River, Maryland

SAMPLE ID:	MSA-DMW4D-090309	MSA-DMW4I-090109	MSA-DMW4S-090309	MSA-MW14I-090809	MSA-MW18I-090109	MSA-MW18S-090109
LABORATORY ID:	A9I040243011	A9I020192010	A9I040243010	A9I090172002	A9I020192007	A9I020192006
SAMPLE DATE:	9/3/2009	9/1/2009	9/3/2009	9/8/2009	9/1/2009	9/1/2009
LOCATION:	MSA-DMW4D	MSA-DMW4I	MSA-DMW4S	MSA-MW14I	MSA-MW18I	MSA-MW18S
NATURAL ATTENUATION PARAMETERS (mg/l)						
ALKALINITY	1.1 U	1.1 U	73	110 J	26	270
CHLORIDE	123	94	105	23.3 J	305	594
DISSOLVED ORGANIC CARBON	4	7	8	10	6	33
ETHANE	0.27 U	0.27 U	3.3	31 J	2.7	0.95
ETHENE	1.6	4.3	2.5	36 J	26	8
METHANE	21	53	210	1000 J	390	230
NITRATE-N	2.8	0.1	0.023 U	0.023 U	0.023 U	0.023 UJ
NITRITE-N	0.012 U	0.012 U	0.012 U	0.012 U	0.012 U	0.012 UJ
ORTHOPHOSPHATE-P	0.044 UL	0.044 U	0.044 UL	0.044 U	0.044 U	0.044 U
SULFATE	723 L	1050	908 L	649 J	439	1600
TOTAL DISSOLVED SOLIDS	1200	1600	1500	1100	1100	3500

B - Analyte was detected but is considered to be a laboratory contaminant.

J - Positive value is considered estimated as a result of technical noncompliance.

L - Positive value is considered biased low as a result of technical noncompliance.

U - Not detected

mg/l - milligrams per liter

APPENDIX B
GROUNDWATER MODELING REPORT

DRAFT

MSA GROUNDWATER FEASIBILITY STUDY
APPENDIX B —
REFINEMENT AND CALIBRATION OF A GROUNDWATER FLOW MODEL AT THE "DUMP ROAD AREA SITE" AT MARTIN STATE AIRPORT

MIDDLE RIVER, MARYLAND

Prepared for:

Tetra Tech
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Prepared by:

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GEOTRANS, INC. PROJECT NO. 117-0512042

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ACRONYMS

bgs	below ground surface
C	Conductance
d	elevation of water level in drain
DCE	cis-1,2-dichloroethene
foc	fraction of organic carbon
FS	feasibility study
ft	Feet
gpm	gallons per minute
h	water level in grid cell (feet)
in.	inch(es)
IRA	interim remedial action
K_e	hydraulic conductivity
K_{oc}	partitioning coefficient
MRC	Middle River Complex
MSA	Martin State Airport
msl	mean sea level
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
Q	extraction rate
RAO	remedial action objective
RAP	remedial action plan
r_w	well radius (in feet)
TCE	Trichloroethene
USGS	United States Geological Survey
VC	vinyl chloride
VOC	volatile organic compound

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GLOSSARY

aquifer—Subsurface formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield usable quantities of water to wells and springs.

drawdown—A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused 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—The interconnected pore space through which fluids can pass, expressed as a percent of bulk volume. Part of the total porosity will be occupied by static fluid being held to mineral surfaces by surface tension; therefore, the effective porosity will be less than total porosity.

hydraulic conductivity—An aquifer characteristic related to its permeability. Hydraulic conductivity is a coefficient of proportionality describing the volumetric flow rate per unit area of water through a permeable medium, when the hydraulic gradient is unity.

hydraulic gradient—Slope of a water table or potentiometric surface. More specifically, change in the hydraulic head per unit of distance in the direction of the maximum rate of decrease.

model domain—The modeling area of interest bounded by model boundary conditions.

residual—The difference between the model-computed and field-measured values of a variable, such as hydraulic head or groundwater flow rate, at a specific time and location.

pumping test—A test to determine aquifer or well characteristics by pumping a well for a period of time and observing the change in hydraulic head in the aquifer. The results can be used to determine the capacity of the well and the hydraulic characteristics of the aquifer.

slug test—A test to determine aquifer or well characteristics by inducing a sudden pressure change in a well and observing the change in hydraulic head in the well as it returns to its original level. The results can be used to estimate the horizontal hydraulic conductivity of the screened portion of the aquifer.

storativity—The amount of water a given aquifer volume will absorb or expel per unit area when a unit change in hydraulic head is applied.

specific yield—A ratio representing the volumetric fraction of total bulk volume an aquifer will yield when all water is allowed to drain out under force of gravity. The specific yield is a property of unconfined aquifers.

steady-state model—A model of an aquifer system in equilibrium (or in balance) with respect to groundwater inflow and outflow. In a steady-state model simulation, the groundwater head and flux conditions do not change over time.

stratigraphy—Classifying rock and geologic materials into separate formations based on their physical, geochemical, geologic age, and other characteristics.

transient model (time-dependent)**—**A model of an aquifer system not in equilibrium with respect to groundwater inflow and outflow. In a steady-state model simulation, the groundwater head and flux conditions change over time.

1 INTRODUCTION AND MODELING OBJECTIVES

As part of the interim remedial action (IRA) feasibility study (FS) for the groundwater operable unit at the "Dump Road Area Site" at Martin State Airport (MSA) in Middle River, Maryland, this report summarizes the calibration and application of a groundwater flow model of the southeast portion of the airport (see **Figure 1**). This updated model refines previous groundwater flow modeling performed for the site (Tetra Tech, 2004). The primary focus of this refined model is to help develop an effective FS preliminary groundwater remedial system design to hydraulically capture high concentration zones of contaminants in groundwater at MSA.

In this updated model, the model domain was extended to be consistent with natural hydrogeologic boundaries and to assess the potential for contaminated groundwater to migrate beneath Frog Mortar Creek. In addition, the model was extended downward to include a deeper, confined, water-bearing zone. New hydrogeologic data collected after the earlier modeling effort— including groundwater elevation, groundwater sampling, stratigraphic boring, and pumping test data— were also incorporated into the updated flow and advective transport model.

The groundwater modeling efforts are defined based on the knowledge gained from prior modeling efforts and the availability of data collected during current site remedial investigation efforts. In summary, the modeling study includes the following primary tasks:

- refine the existing flow model using new site-specific data collected since 2004
- calibrate the flow model to both steady-state and transient-flow conditions
- apply the flow model to develop a conceptual remedial design for contaminated groundwater

The engineering team uses the model iteratively to develop technically sound remediation alternatives. Remedial approaches under consideration include plume control, plume capture, and ex-situ treatment of the extracted groundwater in order to meet remedial action objectives (RAOs) that include preventing migration of contaminated groundwater toward Frog Mortar Creek.

The primary contaminants driving the remedial action plan (RAP) approach include three volatile organic compounds (VOCs)— trichloroethene (TCE), cis-1,2-dichloroethene (DCE), and vinyl chloride (VC)— as well as 1,4-dioxane. The primary area of concern is shown by mapping

the groundwater concentrations of these VOCs and 1,4-dioxane (see **Figures 2 through 5**), based on groundwater sampling in September 2009. The likely sources of contamination include the following areas of concern:

- Taxiway Tango Median Anomaly Area
- Drum Area
- Two ponds on-site
- Petroleum Hydrocarbon Area (Handex, 1992; MES 1994; Tetra Tech, 2004)

These features guided the development of groundwater remediation scenarios, which were tested through groundwater model-based predictive simulations.

This report discusses refinements to the existing model and calibration of the flow model based on July 2010 water level data and a pumping test conducted in the intermediate zone of the surficial aquifer. After model calibration, the groundwater flow model was applied to determine appropriate locations for recovery wells and adequate pumping rates to prevent migration of upgradient contaminated groundwater toward Frog Mortar Creek. The model was also applied to examine the effects of additional pumping in high concentration zones of the contaminant plumes. Given its ability to simulate various extraction well configurations, this groundwater flow model is a useful and appropriate decision-analysis tool for this stage of the overall remediation project.

2 CONCEPTUAL MODEL

Groundwater modeling begins with defining goals and objectives, as listed in section 1, followed by the development of a conceptual model that forms the basis for the analytical techniques used to evaluate groundwater remediation alternatives. The conceptual model of a hydrogeologic system is a working description of the system's characteristics and dynamics. It consolidates site and regional hydrologic data into a set of assumptions and concepts that can be quantitatively evaluated (ASTM, 1996). The conceptual model is subsequently translated into a numerical representation to simulate groundwater, including modeling-based development, testing, and comparative evaluation of FS remediation options. This section describes the conceptual model developed for this project, with subsequent sections presenting the implementation and application of numerical groundwater-flow modeling for the analysis of remediation scenarios.

2.1 GEOLOGY

Martin State Airport is in the western shore of the Coastal Plain Physiographic Province. Geologic mapping of Baltimore County shows that MSA is underlain by the Potomac Group, a lower Cretaceous age interbedded gravel, sand, silt, and clay unit ranging in thickness from zero to 800 feet. The Potomac Group at MSA consists of three units (from the top down): the Patapsco Formation, the Arundel clay, and the Patuxent Formation. Sediments of the Potomac Group were deposited in a river delta environment (Hansen, 1969). Patapsco Formation deposits constitute fine to medium sand and silt beds characteristic of back swamps and flood-plain deposits. The Patapsco Formation, 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 ranging between 25–200 feet thick in the study area.

Previous (MES, 1994; Tetra Tech, 1999; 2002; 2004) and recent investigations at MSA indicate that the subsurface is characterized by interbedded zones of heterogeneous sand, silt, and clay deposits from the Patapsco Formation. Boring logs and cross-sections across MSA indicate relatively continuous layers of sand and gravel locally separated by silts and clays. These shallow permeable zones form the surficial aquifer. Both regional information (Andreasen, 2007; Fleck and Vroblesky, 1996; Chapelle, 1985) and recent deep borings at MSA indicate the

presence of a thick clay unit approximately 120 feet (ft) below MSA, which may be the top of the Arundel Formation. Interbedded sand zones in this clay unit form local, confined, water-bearing zones.

2.2 HYDROGEOLOGY

The hydrogeologic system beneath MSA consists of relatively continuous zones of sand and gravel that provide the primary pathways for groundwater flow and contaminant transport. These zones are interlayered with zones of lower permeability sediments, resulting in a relatively complex stratigraphic sequence. MSA data indicate that the surficial aquifer consists of three hydraulically connected monitoring zones: upper, intermediate, and lower. All zones contain lower conductivity lenses that result in horizontal and vertical anisotropy. In addition, the lower surficial unit is separated from the intermediate unit by a semi-confining layer. The surficial aquifer (part of the Patapsco Formation) is underlain at approximately 75 ft below mean sea level (msl) by a relatively thick clay unit that acts as a basal confining unit. Hydrostratigraphic cross-sections are presented along various transects in Addendum A. Deep borings at MSA indicate the presence of deeper sand zones, which are confined above and below by clay units most likely from the Arundel formation, which is a regionally extensive, thick, dense clay confining unit.

Water enters these units primarily via natural infiltration of precipitation (i.e., recharge) through the shallow fill materials before reaching the water table. From there, groundwater migrates along various pathways depending on location, with some groundwater flowing vertically downward to recharge units below the water table. Eventually almost all groundwater flows laterally through permeable zones before discharging to estuaries surrounding the peninsula on which MSA is located. In the Dump Road Area, the estuary of relevance is Frog Mortar Creek. Recharge of the deeper zones in the surficial aquifer occurs via low rates of downward leakage from the upper zone. In addition, the potential exists for groundwater in the lower surficial-aquifer zone, as well as in deeper flow zones, to flow eastward beneath and beyond Frog Mortar Creek.

Water level fluctuations have been measured through the use of recorders placed in selected monitoring wells and the tidal water bodies near the site. Water level fluctuations in the surficial aquifer result from surface water tidal fluctuations, with the greatest tidal influence generally occurring in the intermediate and deep surficial-aquifer zones. Frog Mortar Creek is

affected by tidal fluctuations with average amplitudes of approximately 1.2 ft (and thus a tidal range of about 2.4 ft). In the upper zone of the surficial aquifer, transducer data indicate that tidal fluctuation amplitudes decrease to less than 0.1 foot within a few hundred feet of Frog Mortar Creek. This damping effect is most likely due to the relatively high storage coefficient (i.e., "specific yield") of this unconfined zone. In other words, this layer zone is a water table aquifer in which its storage capacity is strongly correlated to the primary porosity of the formation. In the intermediate and deep zones, tidal fluctuations diminish less rapidly with distance from Frog Mortar Creek because of the semi-confined or confined conditions in these zones. Much less damping of the tidal signal occurs under these conditions because the aquifer units are fully saturated and under artesian pressure, with confined storage coefficient (i.e., "storativity") values significantly lower than in the shallow, water table zone.

Groundwater flow patterns at the site have been identified through the network of monitoring wells in which several rounds of water level measurements have been conducted, in addition to the continuously-recorded data from a select set of wells. Groundwater in the area generally flows eastward toward Frog Mortar Creek. **Figure 6** presents a water table map of the upper zone of the surficial aquifer based on water level data collected in July 2010, with elevations surveyed using the North American Vertical Datum of 1988 (NAVD88) and horizontal coordinates surveyed using North American Datum of 1983 (NAD83). **Figures 7** and **8** both indicate a similar flow direction in the intermediate and deep zones based on water level data collected in July 2010. At monitoring well clusters, the concurrently measured hydraulic heads indicate that groundwater vertical head differences in the surficial aquifer are generally downward in the upland areas and upward near Frog Mortar Creek.

2.3 AQUIFER HYDRAULIC CHARACTERISTICS

Slug testing at MSA yielded hydraulic conductivity estimates ranging from 1–68 ft/day in sand zones to 0.01–0.2 ft/day in clay zones (Tetra Tech, 2004; Tetra Tech 2010). Pumping tests were performed in both the shallow and intermediate zones of the surficial aquifer. For the shallow zone, only low pumping rates [less than one gallon per minute (gpm)] could be sustained, indicating a relatively lower hydraulic conductivity in the shallow zone. This is consistent with the greater amounts of clay in the shallow zone noted in boring logs.

For the intermediate zone, the pumping test was performed for three days at a rate of 10 gpm. Analyses of drawdown vs. time and drawdown vs. distance data from the intermediate zone-pumping test indicate an average horizontal hydraulic conductivity ranging from 42–140 ft/day, with a mean of 68 ft/day (Tetra Tech, 2010). Although no pumping tests have been performed in the deep zone, analyses of tidal data indicate a relatively higher hydraulic conductivity of 100 ft/day in this zone (GeoTrans, 2010), which is consistent with the observed presence of coarse-grained sediments in the lower zone of the surficial aquifer. Tidal fluctuations could not be used to estimate hydraulic conductivity in the upper and intermediate zones. The responses in the upper zone were diminished because of the higher storage coefficient in this unconfined zone. The responses were also diminished in the intermediate zone because of both the local presence of clay zones and the distance of the wells from Frog Mortar Creek.

2.4 SURFACE WATERS

The primary surface water drainages in the model vicinity are estuarine. Martin State Airport is bounded by Frog Mortar Creek to the east and Stansbury Creek to the west (see **Figure 1**). Dark Head Cove lies west and northwest of Stansbury Creek. Each of these creeks joins Middle River south of the airport. Middle River discharges into Chesapeake Bay to the east. South of Frog Mortar Creek is Seneca Creek, which also joins Middle River southeast of the airport.

Freshwater surface water features relevant to the model include two ponds, approximately 0.25 and 0.33 of an acre in size, respectively. The ponds are an area of concern in the RAP. The significantly higher elevation of water measured in these ponds in comparison to the water table elevation below them indicates that they are not well connected to shallow groundwater.

2.5 WATER BUDGET

Groundwater flow at the site is generated almost exclusively by the infiltration of precipitation and redirected storm runoff and snowmelt, leading to the recharge of the groundwater system. For this reason, development of the conceptual model focused on the identification and characterization of the processes affecting recharge. In addition, the conceptual

and numerical models assume that a single parameter called “net effective recharge” could be defined to incorporate all of the processes involved.

MSA topography is relatively flat, with a steeper slope near Frog Mortar Creek. The nature of the ground surface (much of which is paved or covered by buildings) creates a significant potential for precipitation runoff. Runoff from buildings and some or all of the paved areas is captured and conveyed through a storm-sewer system. In the area of interest, additional overland flow drains into locally perched ponds or Frog Mortar Creek. Therefore, the net effective recharge will be lower at MSA than in open areas that do not have runoff controls.

Areal variations in recharge rates are influenced by topography and surficial geology, including the presence or absence of paved surfaces. Precipitation in this area is approximately 44 inches (in.) per year (Tenbus and Fleck, 2001). Recharge is expected primarily in late winter and early spring, when evapotranspiration is minimal. Tenbus and Fleck (2001) estimated recharge rates between zero and nine inches per year at the nearby Graces Quarters site. Recharge rates applied in the associated groundwater model vary, based on whether the area is paved or unpaved. Recharge to the groundwater system where the ground surface at MSA is not covered by buildings or pavement is expected to be at the higher end of the 0–9 inches per year range referred to by Tenbus and Fleck (2001).

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3 NUMERICAL FLOW MODEL

Developing a numerical groundwater flow model entails transforming the conceptual model into a mathematical form. Fundamental components of the numerical groundwater flow modeling process conducted before model calibration include selection of an appropriate mathematical-solution basis, or code, development of a three-dimensional model grid, assignment of representative initial and boundary conditions for calibration and predictive-simulation purposes, and characterization of hydraulic properties (ASTM, 1996).

3.1 CODE SELECTION

The groundwater flow model was developed using *MODFLOW 200*0, a well documented, widely used and accepted code developed by the U.S. Geological Survey (USGS) (McDonald and Harbaugh, 1988; Harbaugh *et al.*, 2000).

3.2 MODEL GRID AND LAYERING

The site-specific model uses 15 layers to represent the groundwater system beneath MSA. The base of the model is approximately 120 ft below ground surface (bgs), which is where deep borings at MSA have encountered thick clays. These clays are likely the top of the Arundel clay confining-unit, which is represented in the model as an impermeable bottom edge, called a no-flow boundary. Table 1 summarizes model layering information.

The top and bottom elevations of each model layer are defined based both on regional trends of the geologic units and site-specific boring logs. The model grid shown in **Figure 9** is oriented at a rotation of approximately 45 degrees off true north, so that the columns are aligned parallel to northeast (NE) to southwest (SW), and the rows parallel to northwest (NW) to southeast (SE). The model domain includes the Middle River Complex (MRC), which is approximately a mile northwest of MSA. Given the distance between the MRC and MSA, different models are used to simulate local plume fate and transport characteristics at each site. At MSA, the model grid spacing varies from 25 ft in the area of interest to 100 ft at the outer regions of the model domain.

3.3 BOUNDARY CONDITIONS

Model boundaries are mathematical statements specifying the groundwater level (head), groundwater flux, or head-dependent flux at the boundaries of the model domain. Beginning with the top layer, this section discusses the boundary conditions specified for each of the layers in the numerical groundwater-flow model. Boundary conditions simulated in Layer 1 include net recharge, river leakage, and zero flux (no flow), as shown in **Figure 9**. The primary source of water to the model is from precipitation-derived recharge. As shown in **Figure 10**, uniform recharge rates equal to 8.4 inches per year for unpaved areas and 0.36 inch per year for paved areas are simulated in the model. The principal surface water drainages (including Frog Mortar Creek, Stansbury Creek, Dark Head Cove, Galloway Creek, and Seneca Creek) are simulated using river-boundary-conditions cells.

The lateral edges of the model grid were placed sufficiently far from the remediation site so that any groundwater pumping or injection would not affect groundwater conditions at the edges of the grid. In addition, the lateral sides of the grid were located either at a watershed divide, or along regional scale groundwater flow line – in both cases, groundwater can be assumed to flow neither in nor out of the model on these edges and thus they are termed no-flow boundaries. A no-flow boundary corresponding to the prevailing respective groundwater flow paths was placed along the northeastern and southeastern edges of the model. And, a no-flow boundary corresponding to the approximate position of a groundwater divide was assigned along the northwestern edge of the model.

Except for recharge, the boundary conditions for Layers 2 and 3 are similar to Layer 1 in that they include river leakage and zero flux conditions. Recharge is applied only to Layer 1. Head conditions and areal extent of the river cells in Layers 2 and 3 are identical to the Layer 1 specifications. Similarly, the no-flow boundary specifications in model Layers 2 and 3 are the same as for model Layer 1. The same types of boundary-condition settings are specified for Layers 4–15. In each of these layers, the entire perimeter of the model is designated as a no-flow boundary. Also, the bottom of Layer 15 is a no-flow boundary.

3.4 HYDRAULIC PROPERTIES

For groundwater flow modeling, the hydraulic properties to be specified include horizontal and vertical hydraulic conductivity, and storage coefficients [including specific yield for simulation of water table (unconfined) conditions and specific storativity for simulating confined situations]. In steady-state simulations, changes in storage are not simulated and thus the storage coefficients are needed only in transient simulations. Various sources of information guided the characterization of hydraulic properties. These include hydraulic tests conducted in a limited number of wells at the site, analyses of tidally-influenced water levels from selected monitoring wells instrumented with recorders, calibration results from prior site-specific modeling for Lockheed Martin and from regional scale modeling efforts by others, and site-specific geologic information from boring logs.

Initial values of hydraulic conductivity in the model were assigned using calibrated values from the previous groundwater flow model (Tetra Tech, 2004). These initial values are consistent with observed hydraulic conductivity values from slug testing (Tetra Tech, 2004; 2010). In addition, site boring-log data in combination with published, grain-size based hydraulic conductivity ranges were used to help assign hydraulic conductivity in the model.

Hydraulic testing results that were used to help improve modeling accuracy include data from multi-day pumping tests and short-term slug testing. Two recent pumping tests in the upper and intermediate zones (as described in section 2.3) provide the basis for estimating local values of horizontal and vertical hydraulic conductivities and confined and unconfined storage coefficients. The initial values in the model were modified as appropriate during model calibration to match the data from both of the new tests, as described in the next section.

In addition, supplemental slug testing and collection of tidally influenced water level data helped confirm horizontal hydraulic conductivity estimates from initial calibration testing, which is described in the next section. An analysis of the supplemental slug test data provided estimates ranging from 0.03–25 ft/day in the lower zone of the surficial aquifer. However, hydraulic conductivity estimates from slug tests tend to underestimate actual values, and the boring logs indicate relatively high permeability sediments in the lower zone of the surficial aquifer.

The analysis of the supplemental data on water level responses to surface water tidal fluctuations indicates a value of 100 ft/day for the horizontal hydraulic conductivity of the lower

zone of the surficial aquifer. This field-scale value in the lower zone prompted supplemental numerical model simulations to confirm the higher value. Last, the model's hydraulic conductivity distribution was compared to other relevant modeling efforts, including the USGS "Regional Aquifer System Analysis" (RASA) modeling of the Maryland Coastal Plain. The initial and calibrated hydraulic conductivities are consistent with the range of values reported by the USGS modelers for the geologic formations of interest.

4 FLOW MODEL CALIBRATION

4.1 INTRODUCTION

Calibration of a groundwater flow model entails adjusting hydraulic parameters, initial conditions, and boundary conditions within reasonable ranges to match measured and simulated hydraulic heads, flow rates, or other calibration targets (ASTM, 1996). For MSA, the flow model calibration consisted of simulating the following measured conditions:

- transient responses during two constant-rate pumping tests, one each in the intermediate and shallow zones of the surficial aquifer
- transient responses to tidal water level changes in the lower zone of the surficial aquifer
- approximate, steady-state conditions throughout all three vertical zones of the surficial aquifer, based on water level measurements collected on July 2, 2010

The quality of the steady-state calibration was assessed and quantified through statistical analysis of residuals (ASTM Standard D5981; Anderson and Woessner, 1992), which are the differences between the measured and simulated water levels on a well-by-well basis. Flow calibration criteria are based on the following statistical measures:

- a mean residual value near zero
- an absolute mean residual less than or equal to 10% of the observed range in water level elevations
- a standard deviation less than or equal to 20% of the observed range in water level elevations
- a random spatial distribution of the positive and negative residuals

To assist the assessment of calibration criteria, a plot of observed versus predicted water levels was used to examine the spread of points around the ideal line of a perfect calibration. In addition, horizontal and vertical flow directions in the model were examined for consistency with directions inferred from contour maps drawn using field data and from clustered monitoring wells where vertical-head differences were measured.

Calibration of a groundwater flow model to a single set of field measurements (assumed to represent steady-state conditions) does not provide the foundation for obtaining a unique solution. To reduce the problem of "non-uniqueness," the model should be tested against a different set of boundary conditions or stresses, labeled "verification" (ASTM, 1996). In

particular, non-uniqueness can be reduced through calibration to transient responses caused by measured groundwater flows (typically, extraction well pumping). Therefore, the groundwater flow model calibration focused on simulation of groundwater flow during constant-rate pumping tests in the shallow and intermediate zones of the surficial aquifer.

The objective of the transient calibration was to examine the model's ability to match both observed responses over time and final drawdowns at the test's end. Responses observed in well clusters help estimate both vertical and horizontal hydraulic conductivity values in the surficial aquifer. This simulation has the dual advantage of verification through matching to a second hydrologic condition, while also testing the model's ability to simulate the aquifer system's transient hydraulic response to carefully measured pumping stresses, thereby helping to reduce non-uniqueness. A second important calibration verification step involves transient simulation of tidal responses to estimate the hydraulic properties of the lower surficial zone. Because a pumping test had not yet been conducted in this unit, the tidal response data provided the foundation for testing and adjusting the model using what could be labeled a "naturally conducted" pumping test—i.e., the "pumping" action of the tidal waters in the estuaries surrounding the Martin State peninsula.

Calibration was conducted in sequence from initial steady-state calibration testing and adjustments for an improved match, followed by transient simulations for local area adjustments and model-domain-wide adjustments, and then re-simulation of steady-state conditions for final fine-tuning and consistency checking. In some cases, the transient and steady-state sequence of simulations was re-run to ensure full consistency and sufficient accuracy. Although the steady-state simulations are described before the reporting of the transient calibration efforts, calibration was iterative between the different types of runs. The final values of calibrated hydraulic properties are presented as part of the steady-state results because that simulation condition includes the largest number of observation wells; thus, a more thorough assessment of calibration matching can be provided than for the transient simulations.

4.2 STEADY-STATE FLOW

The July 2, 2010 water level data set was chosen for use as model calibration targets because of both the large number of wells measured in that round and the new elevation survey, which has provided a consistent set of measuring point elevations for calculating water level

elevations. In calibrating the model, hydraulic conductivities of the different materials were modified within reasonable ranges. In addition, the recharge rate was adjusted slightly during model calibration. The final distribution of hydraulic conductivity by model layer is presented in **Table 1**. Calibrated values for horizontal hydraulic conductivity in the upper, intermediate, and lower zones are consistent with available field data from slug tests, pumping tests, and tidal data. In general, the vertical hydraulic conductivity is estimated at one tenth of the horizontal hydraulic conductivity. Calibrated recharge rates were estimated at 8.4 inches per year (in/yr.) in the unpaved areas and 0.36 in/yr. in paved areas, as shown in **Figure 10**.

Simulated and observed July 2010 groundwater levels in all 80 wells monitored, and vertical gradients at well clusters, are presented in **Table 2**. **Table 3** presents a statistical summary of the model residuals (i.e., simulated minus observed head) for the 80 water level targets. The mean residual (-0.08 ft) is near zero, indicating that positive and negative residuals cancel out. In addition, the absolute mean residual is 0.34 ft, which is about one tenth of the difference between the minimum and maximum water level targets, and thus the calibration criterion is achieved.

Measured and simulated water levels are plotted relative to one another in **Figure 11**. The linear trend in this plot, the limited spread around the best-fit line, and the favorable residual statistics indicate that the model adequately represents MSA water levels. Simulated steady-state potentiometric surfaces and residuals in the upper zone (model Layers 1 and 6), intermediate zone (Layer 8), and lower zone (Layer 11) are presented in **Figure 12**. These plots indicate that simulated groundwater flow at MSA is predominantly to the east toward Frog Mortar Creek, which is consistent with the July 2010 observed data (**Figures 6-8**) and historical potentiometric surface maps for each zone (Tetra Tech, 2002; 2004).

In general, the residuals are relatively low in each layer, and their statistical measures are below the calibration criteria. The higher residuals in the runway area may be caused by local areas of preferential recharge or heterogeneities not represented in the model. In addition, simulated vertical head differences, including generally downward gradients in the upland areas and upward gradients near Frog Mortar Creek, are consistent with the field data overall (see **Table 2**). Further, the calibrated hydraulic conductivity values and recharge rates are within estimated field values for MSA. The agreement of the flow model with the observed prevailing

groundwater flow directions, based on field data, provides additional evidence of an adequately accurate calibration.

4.3 SIMULATION OF PUMPING TESTS

Tetra Tech conducted two constant-rate pumping tests, one each in the shallow and intermediate zones of the surficial aquifer. Although model simulations agree with observed drawdown for the low rate of pumping (less than 1 gpm) in the shallow zone, the transient model-calibration efforts focused on the higher pumping rate (10 gpm) during the 72-hour pumping test in the intermediate zone of the surficial aquifer. To verify the calibrated, steady-state groundwater flow model, the test was simulated using the groundwater flow model. Additional adjustments to the hydraulic conductivity values for the intermediate zone were made to improve the match to the drawdown data from this pumping test.

Measured and simulated drawdowns at wells monitored during the 72-hour pumping test are compared in **Table 4.** The comparison indicates that the model adequately simulates the effects of pumping according to the objectives established for this transient calibration exercise. This indicates that the flow model is a useful predictive tool for simulating new hydraulic stresses in the surficial aquifer within the area tested.

4.4 TIDAL INFLUENCE SIMULATION

A transient simulation of tidal responses in site monitoring wells was conducted to verify the calibrated, steady-state groundwater flow model. **Figure 13** shows the simulated versus observed hydraulic head changes at DMW4S, DMW4I, and DMW4D during tidal fluctuation from July 2–4, 2010. An examination of these plots indicates an excellent match between the model and the field data. The simulation period was divided into 12 stress periods, each representing a 6-hour period. The transient river-stage values were averaged over the same 6-hour intervals based on measured data in the Frog Mortar Creek Gage at Parkside Marina. The hydraulic conductivity values and storage coefficient of the lower zone were adjusted slightly to improve the match to the water level fluctuations. The calibrated values are presented in **Table 1** and were also used for the final calibrated steady-state model and pump test verification simulation. The ability of the model to match transient tidal variations in this important zone

where elevated contaminants are present in the surficial aquifer provides additional confidence in the application of the groundwater flow model for remedial design.

4.5 FLOW MODEL SENSITIVITY ANALYSIS

A sensitivity analysis was performed to evaluate the effects of changes in selected model parameters. One parameter at a time was varied while all other parameters were held constant. The tested model parameters were varied by 50% of the calibrated values. Results of the sensitivity analysis are shown in **Table 5**. These results were analyzed to identify the parameters that cause the greatest sensitivity when changed, and to confirm that their final calibrated values fall within the range of expected values according to the ranges set during conceptual model formulation, while also ensuring that calibration statistics would not be significantly improved.

Model results are most sensitive to the unpaved-area recharge rate, horizontal hydraulic conductivity values in the surficial aquifer, and especially the lower zone of the surficial aquifer. This is because the unpaved-area recharge is the source of all groundwater flow in the model, and most of the local site area's groundwater flow is occurring in the surficial aquifer, with horizontal hydraulic conductivity the primary property with regard to accurate simulation of the flow field. Hydraulic conductivity, when conducting steady-state simulations, can be adjusted in direct linear proportion to the prevailing recharge rate while still simulating the same flow field pattern of groundwater levels (this is the "non-uniqueness" concern cited above with regard to the need for conducting transient calibrations); thus, changes in hydraulic conductivity produce identical model-sensitivity results to the same, proportional changes in prevailing recharge rates.

Calibrated values for these parameters are consistent with values in the study area, as identified during the conceptual model formulation stage. In addition, no significant enough improvement would be achieved in the model calibration by adjusting these parameters to warrant making such changes. Thus, the model was accepted for use in performing predictive simulations, according to the objectives set forth at the beginning of the modeling process, and the model-calibration criteria established at the outset of numerical model development.

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5 REMEDIAL SCENARIO ANALYSES

The primary objective of these preliminary remedial-design-scenario analyses is to help identify and develop a remediation approach that will prevent migration of elevated concentrations of contaminants in groundwater toward Frog Mortar Creek. In addition, enhanced contaminant-mass removal was a secondary objective explored through predictive simulation modeling.

5.1 PREDICTIVE SIMULATION METHODOLOGY

Advective-particle tracking helped develop and evaluate the effectiveness of the hydraulic containment and contaminated-groundwater-capture scenarios described in the remedial alternatives analysis section of the FS. The overall predictive modeling process consisted of conducting groundwater flow simulations using the numerical groundwater-flow model described in section 4, followed by a companion particle-tracking simulation for determining whether sufficient capture is achieved. Iterative simulations were conducted, primarily to ensure adequate capture, and then to achieve efficiency in terms of limiting the induced inflow of brackish water from Frog Mortar Creek. The predictive simulations also included a scenario in which enhanced flushing of high-concentration groundwater was tested, involving the use of injection wells and additional extraction wells and higher extraction rates to compensate for the injected water. Using an initial starting point, particle tracking simulates the movement of a particle of groundwater through a groundwater flow field over time. Thus, particle tracking techniques are useful tools for evaluating groundwater flow directions, dissolved contaminant migration pathways, and evaluating hydraulic capture of groundwater recovery well systems.

Particle tracking is a simple form of contaminant transport analysis that does not include the effects of dispersion, retardation, and chemical reactions. Although plume dispersion could cause lateral spreading and thus lead to concern whether the lateral edges of the plume would be captured effectively, the final recommended scenarios include sufficient recovery well placement and pumping rates to account for this factor. In addition, the convergent flow produced by recovery well pumping would help offset the effect of lateral spreading.

The USGS particle-tracking code *MODPATH* (Pollock, 1989) was used to perform particle tracking in this modeling analysis. Using a groundwater flow field simulated with *MODFLOW*, *MODPATH* computes groundwater velocities in the three principal coordinate directions throughout the model domain, in each of the model-grid cells. Then, *MODPATH* uses the cell-by-cell 3D velocities as the basis for moving each simulated particle from one cell to the next. It does this by resolving the three velocities in each cell to a single velocity vector, and then uses these vectors to move the particles in the appropriate direction.

To compute these velocities, *MODPATH* requires study-area-specific values of effective porosity for converting *MODFLOW*-simulated specific discharge-values into groundwater velocities. The effective porosity represents a correction factor that accounts for the reduced flow area, as defined by the open pore space in which flow effectively occurs. Effective porosity can range as high as the porous medium's total porosity, but is typically a significant amount less than that. The results of the previously calibrated solute-transport model (Tetra Tech, 2004) led to the use of a value of 0.28 for effective porosity in these particle tracking analyses, whereas the geologic sediments' total porosity could range as high as 40 or 45%. Although the selected value of effective porosity directly influences the simulated velocities of particles, its value does not affect the size of the simulated capture zone.

For MSA, particle tracking was performed to help identify and simulate groundwater remediation options designed to achieve the objectives of plume control and capture. The particle tracking modeling was applied to simulate two categories of FS options:

- a hydraulic-barrier recovery well system at the downgradient extent of the contaminated groundwater area, along Frog Mortar Creek
- "focused," or "enhanced," extraction pumping in high concentration zones, in addition to the hydraulic-barrier recovery well system, as in the preceding option.

In the particle tracking analyses, particles were first initialized in grid cells throughout the extent of the VOC and 1,4-dioxane plumes. A containment scenario was then simulated under steady-state flow conditions using forward tracking to determine whether all particles in the upgradient plumes were captured by the recovery wells. Recovery well locations and their individual pumping rates were adjusted as necessary to achieve sufficient drawdowns to capture all of the particles within the target capture zone.

5.2 REPRESENTATION OF RECOVERY WELLS

The calibrated groundwater-flow model and its companion particle-tracking code were used to identify potential groundwater remediation scenarios that would successfully contain and capture contaminated groundwater. The target capture zones for contaminant plumes were the extent of TCE contamination in excess of 5 µg/L, vinyl chloride in excess of 2 µg/L, and 1,4-dioxane in excess of 6 µg/L. For hydraulic containment, extraction wells were placed near the downgradient end of the plumes, adjacent and parallel to the shoreline of Frog Mortar Creek.

Potential extraction wells were represented using the *MODFLOW* drain package. Water levels at the extraction wells were modeled as a fixed two-foot drawdown. Wells were assumed to have an effective diameter of one foot. Conductance and well efficiency were estimated as follows:

Conductance term—The conductance term (C) for each drain cell representing a fixed head well was calculated using the following equation [based on Prickett (1967) and Anderson and Woessner (1992)]:

$$C = 2K_e \pi b/\ln (\text{delta} \times/4.81 r_w) \quad (1)$$

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 are represented in the model as drains, the extraction rate (Q) achieved is effectively calculated by the model and controlled by the aquifer properties, as described in the equation:

$$Q = C (h - d) * \text{efficiency} \quad (2)$$

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% was applied to the wells.

5.3 HYDRAULIC-BARRIER WELLS ANALYSES

Numerous steady-state groundwater flow model simulations were performed to define effective and efficient recovery well locations and pumping rates for capturing the upgradient VOC and 1,4-dioxane plumes before their migration toward Frog Mortar Creek. Model simulations indicate that placing recovery wells only in the upper and intermediate zones of the

surficial aquifer would fail to capture contaminated groundwater in the lower zone of the surficial aquifer. Therefore, recovery wells were also included in the lower zone of the surficial aquifer in the hydraulic barrier wells analyses.

These model simulations indicate that upgradient plume capture can be achieved by placing seven wells in the upper zone, five in the intermediate zone, and four in the lower zone of the surficial aquifer. **Table 6** summarizes the injection and pumping rates by layer for this remedial scenario. The simulated total pumping rates were 12.2 gpm, 13.6 gpm, and 22.2 gpm, respectively, in the upper, intermediate, and lower zones of the surficial aquifer. Simulated steady-state hydraulic heads and recovery well locations are shown in **Figure 14** for the upper (Layer 1), intermediate (Layer 8), and lower (Layer 11) zones of the surficial aquifer. Forward particle tracking was conducted by placing particles in each cell and delineating the zone from which the particles would eventually be captured by the recovery wells. Examination of these simulated capture zones (**Figure 14**) and the extent of contaminated groundwater at MSA (**Figures 2 to 5**) indicates that these recovery wells establish a capture zone encompassing the mapped areas of MSA with VOC and 1,4-dioxane contamination, and thus the simulated scenario is sufficiently effective.

The model simulations also indicate that low rates (less than 1.6 gpm) of induced inflow from Frog Mortar Creek result from pumping, so capture of saline water is unlikely to be a problem for this hydraulic barrier pumping scenario. In essence, the simulations indicate that induced infiltration would be diluted by the pumped freshwater at a ratio of about 30:1. Also, Frog Mortar Creek is brackish (it ranges from about 25–50% of full seawater salinity), due to its position relatively far from the open ocean mouth of Chesapeake Bay, as well as its proximity to incoming freshwater flow from Middle River, the other local tributary streams and swales, and groundwater base-flow. Thus, the induced inflow already has much lower saline concentrations than ocean water, and therefore the recovery wells are predicted to produce groundwater that includes approximately 60:1 to 120:1 dilution of seawater salinity.

5.4 HIGH CONCENTRATION ZONE REMEDIATION ANALYSES

To increase mass-removal rates, a second overall scenario was developed in which additional recovery wells were placed in high concentration zones, along with injection wells placed upgradient of some of these pumping wells. Simulated steady-state hydraulic heads and

injection/recovery well locations are shown in **Figure 15**. **Table 6** summarizes injection and pumping rates by layer under this remedial scenario. Total simulated injection rates per layer are 10 gpm and 3 gpm in the upper and intermediate zones of the surficial aquifer, respectively. Total simulated pumping rates are 12.3 gpm, 21.3 gpm, and 34.3 gpm, respectively, in the upper, intermediate, and lower zones of the surficial aquifer.

Examination of the capture zones created by the simulated pattern of pumping and injection wells (**Figure 15**), in comparison to the initial extent of contaminated groundwater at MSA (**Figures 2 to 5**), indicates that this scenario would establish a capture zone that limits the upgradient VOCs and 1,4-dioxane from migrating toward Frog Mortar Creek. In comparison to the previous hydraulic barrier scenario (**Figure 14**), a higher amount of pumping under this scenario is needed to ensure adequate capture because of the effect of the injection wells on the groundwater-flow field. The higher net total pumping rate results in somewhat increased drawdowns near the recovery wells and an increase in the size of the capture zone (**Figure 15**). Model simulations also indicate that very limited amounts (less than 1.8 gpm) of induced inflow from Frog Mortar Creek would occur, so capture of saline water is very unlikely to be a problem for this pumping scenario, as was the case for the first scenario.

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6 SUMMARY AND DISCUSSION

This section summarizes the development, calibration, and application of a groundwater flow model to support the feasibility study and to help develop remediation alternatives to address volatile organic compounds (VOCs) and 1,4-dioxane contamination in groundwater at MSA in Middle River, Maryland. The remediation alternatives are based on the primary objectives of controlling and capturing contaminated groundwater at MSA to prevent its migration into off-site areas and toward Frog Mortar Creek. The primary results of this groundwater flow modeling analysis are summarized below, including recommendations.

The groundwater flow model was constructed and calibrated to both steady state and transient groundwater conditions at MSA. The simulated steady-state conditions are based on water level data collected on July 2, 2010. The simulated transient conditions are based on measured water level changes over time during two pumping tests and from various periods in which tidally induced fluctuations were measured in the surficial aquifer. Results of the groundwater-flow model calibration indicate that adequate calibration was achieved and that the groundwater flow model could be used to help design a remedial system to capture contaminated groundwater at MSA.

Viable FS-stage groundwater remedial scenarios for capturing MSA groundwater contaminated by VOCs and 1,4-dioxane were developed and tested through simulation modeling. The lateral and vertical extent of contaminated groundwater was established based on recent groundwater sampling. Two scenarios were analyzed using groundwater flow and advective-particle-tracking predictive modeling: (1) a stand-alone hydraulic barrier recovery well system, and (2) high concentration zone mass-removal, along with limited reinjection of treated groundwater, in conjunction with the first scenario. Results from modeling both scenarios indicate that the contaminated groundwater at MSA would be effectively controlled and captured; faster contaminant mass-removal could be achieved under the second scenario, although a net increase of recovery pumping would be needed to maintain sufficient capture, including a higher rate of recovery pumping from the lower aquifer layer.

For the hydraulic barrier scenario, numerous modeling simulations were performed to select sufficiently effective recovery well locations while also limiting the groundwater pumping rate and the induced infiltration of saline water from Frog Mortar Creek. This scenario includes

16 recovery wells arranged roughly perpendicular to the plume, adjacent and parallel to the shoreline of Frog Mortar Creek, with seven recovery wells in the upper zone, five in the intermediate zone, and four in the lower zone, and a total system-wide pumping rate of 48 gpm.

The second scenario combines the hydraulic barrier from the first scenario with focused injection and extraction for faster contaminant-mass reduction. This second scenario is designed to increase flushing rates while maintaining downgradient capture, so it includes the 16 hydraulic barrier recovery wells of the first scenario along with six injection wells and nine additional recovery wells located in high concentration zones: four injection/extraction well pairs in the upper zone, two pairs in the intermediate zone, and two individual recovery wells in the lower zone. The total injection rate under this scenario is 13 gpm, and the total pumping rate is 67.9 gpm, resulting in a net extraction rate of 54.9 gpm. The modeling analyses indicate that increased groundwater capture rates are needed, especially in the intermediate and lower surficial aquifer units, to offset the tendency for increased spreading due to the injection wells and to achieve the design objective for increasing the groundwater flushing rate.

The model results indicate that the hydraulic barrier wells, in both scenarios, form an effective hydraulic containment system without inducing significant brackish water inflow from Frog Mortar Creek. In the remedial scenario simulations, the model predicts that a very small percentage (approximately 3–5%) of the extracted groundwater would be from Frog Mortar Creek, and thus its salinity would be significantly diluted by fresh groundwater.

7 REFERENCES

Anderson, M. P. and W. W. Woessner, 1992. *Applied Groundwater Modeling: Simulation of Flow and Advective Transport*. San Diego: Academic Press, 381 pp.

Andreasen, D. C., 2007. "Optimization of Ground-Water Withdrawals in Anne Arundel County, Maryland, from the Upper Patapsco, Lower Patapsco, and Patuxent Aquifers Projected Through 2044." *Maryland Geologic Survey Report of Investigations No. 77*.

Aronson, D. and Howard, P. 1997. *Anaerobic Biodegradation of Organic Chemicals in Groundwater: A Summary of Field and Laboratory Studies* (SRC TR-96-0223F). Environmental Science Center, Syracuse Research Corporation, 6225 Running Ridge Road, North Syracuse, New York, pp. 13212-2509.

ASTM Standard D5981: "Standard Guide for Calibrating a Ground-Water-Flow Model Application."

Chapelle, F. H., 1985. "Hydrogeology, Digital Solute-Transport Simulation and Geochemistry of the Lower Cretaceous Aquifer System near Baltimore, Maryland." *U.S. Geological Survey Report of Investigations No. 43,* 120 pp.

Clement, T. P., 1997. *RT3D, A Modular Computer Code for Simulating Reactive Multispecies Transport in 3-Dimensional Groundwater Aquifers*, PNNL-SA-28967. Pacific Northwest National Laboratory, Richland, Washington.

Fleck, W. B., and Vroblesky D. A., 1996. "Simulation of Ground-Water Flow of the Coastal Plain Aquifers in Parts of Maryland, Delaware, and the District of Columbia." *U.S. Geological Survey Professional Paper 1404-J,* 41 pp.

GeoTrans, Inc. 2010. *Analysis of Tidal Data to Estimate Hydraulic Conductivity of the Lower Zone of the Surficial Aquifer*.

Handex Environmental Management, 1992. *Geophysical Survey Report, Taxiway Tango, Martin State Airport, Middle River, Maryland*.

Hansen, H. J. 1969. "A Geometric Method to Subdivide the Patapsco Formation of Southern Maryland into Informal Mapping Units for Hydrogeologic Use." *Geological Society of America Bulletin*. Vol. 80, No. 2, pp. 329-336.

Harbaugh, A. W., Banta, E. R., Hill, M. C., and McDonald, M. G., 2000. *MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model— User Guide to Modularization Concepts and the Ground-Water Flow Process*. U.S. Geological Survey Open-File Report 00-92. 121 pp.

Maryland Environmental Service, 1994. *Preliminary Investigation of the Taxiway Tango*. May.

Maryland Environmental Service, 1995. *Confirmation Investigation: Continuation of Phase I Taxiway Tango Site Investigation*. January.

McDonald, M. G. and A. W. Harbaugh, 1988. "*A Modular, Three-Dimensional, Finite Difference Ground-Water Flow Model.* U.S. Geological Survey Techniques of Water Resource Investigations (Book 6).

Pollock, D. W., 1989. *Documentation of Computer Programs to Compute and Display Pathlines Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model*. U.S. Geological Survey Open-File Report 89-381.

Prickett, T. A., 1967. "Designing Pumped-Well Characteristics into Electric Analog-Models," *Journal of Ground Water*. Vol. 17, No. 2, pp. 38–46.

Roberts, P. V., P. L. McCarty, M. Reinhard, and J. Schreiner, 1980. "Organic Contaminant Behavior during Groundwater Recharge." *Journal of Water Pollution*. Control Fed, 52(1), pp. 161–172.

Tenbus and Fleck, 2001. *Simulation of Ground-Water Flow and Transport of Chlorinated Hydrocarbons at Graces Quarters, Aberdeen Proving Ground, Maryland.* U.S. Geological Survey Water Resources Investigation Report 01-4106.

Tetra Tech, 2010. *Remedial Investigation Report, Martin State Airport, 701 Wilson Point Road, Middle River, Maryland*.

Tetra Tech, 2004. *Data Gap Investigation and Modeling Report, Martin State Airport, Middle River, Maryland*.

Tetra Tech, 2002. *Interim Data Summary Report, Martin State Airport, Middle River, Maryland*. October 4.

Tetra Tech, 2002. *Final Chemical-Delineation and Groundwater-Modeling Report, Martin State Airport, Middle River, Maryland.* December 27.

Tetra Tech, 2002. *Interim Data Summary Report, Martin State Airport, Middle River, Maryland.* March 15.

Tetra Tech, 2000. *Final Source Identification and Assessment Report, Martin State Airport, Middle River, Maryland*.

Tetra Tech, 1999. *Final Groundwater Monitoring Well Surveying and Sampling Report, Martin State Airport, Middle River, Maryland*.

Wiedemeier, T. H., H. S. Rifai, C. J. Newell, and J. T. Wilson, 1999. *Natural Attenuation of Fuels and Chlorinated Solvents in the Subsurface.* John Wiley & Sons, New York. 617 pp.

Zheng, C. and G. D. Bennett, 1995. *Applied Contaminant-Transport Modeling Theory and Practice*. van Nostrand Reinhold. 440 pp.

FIGURES

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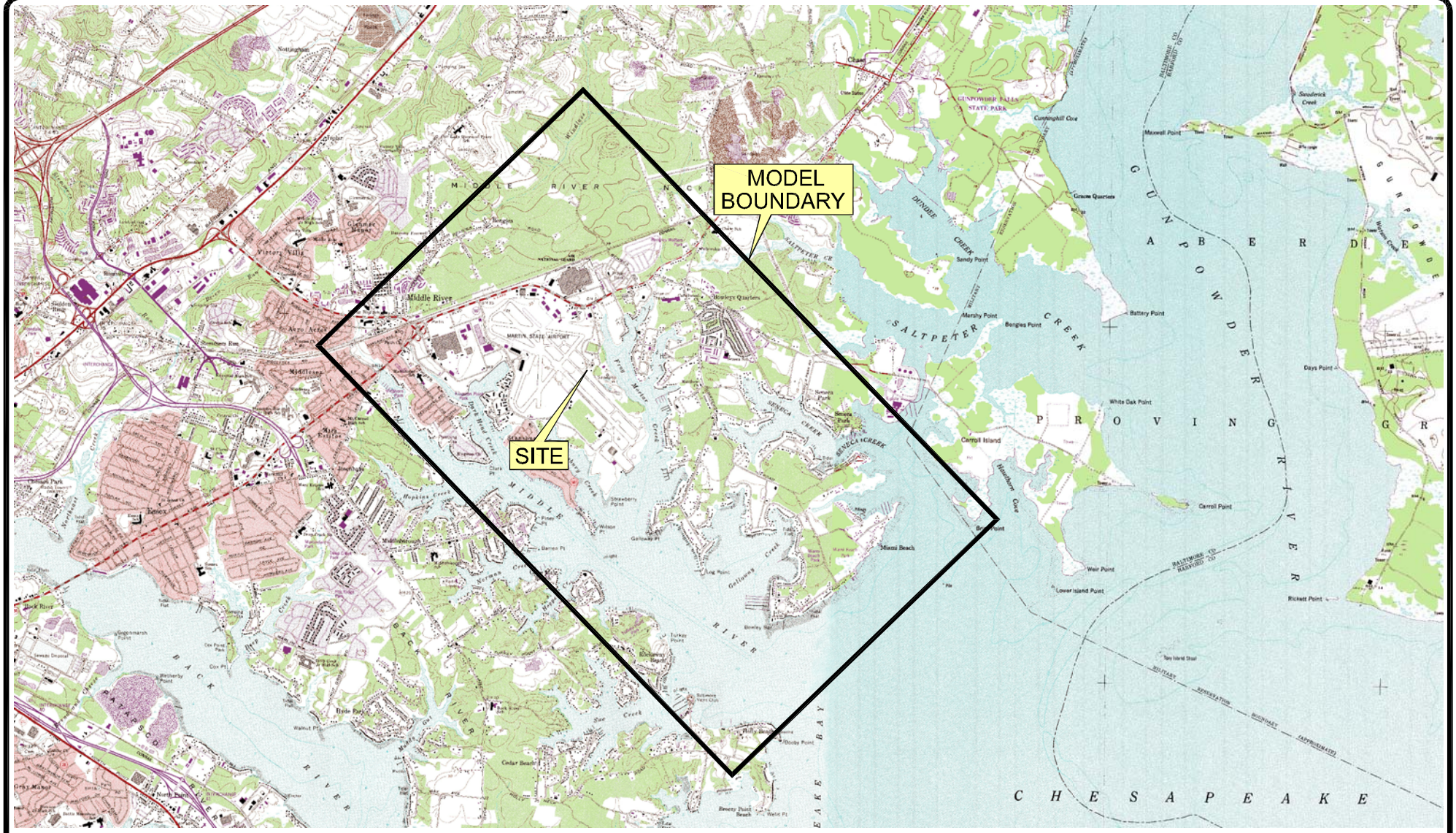

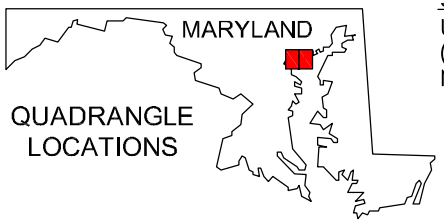

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TITLE:

SITE LOCATION MAP

LOCATION:

Martin State Airport, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

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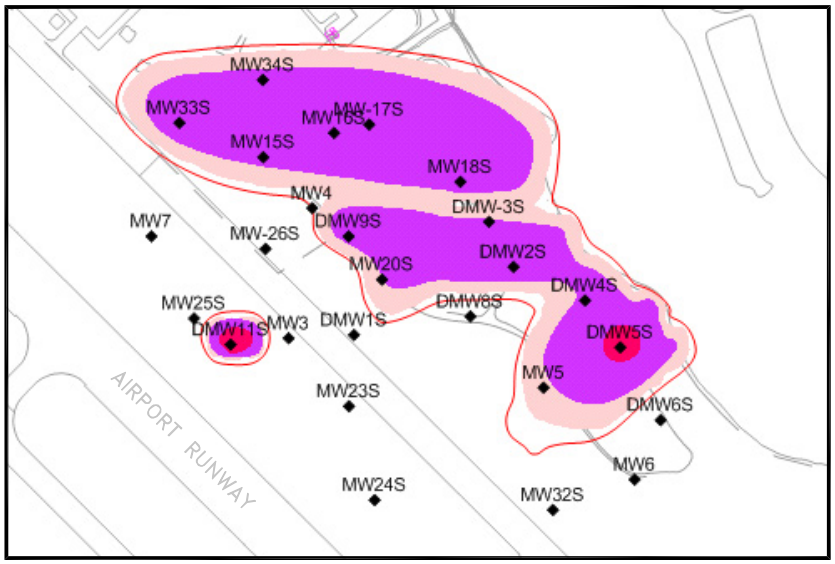
PROJECT#	117-0512055
DATE	12-15-10

FIGURE 1



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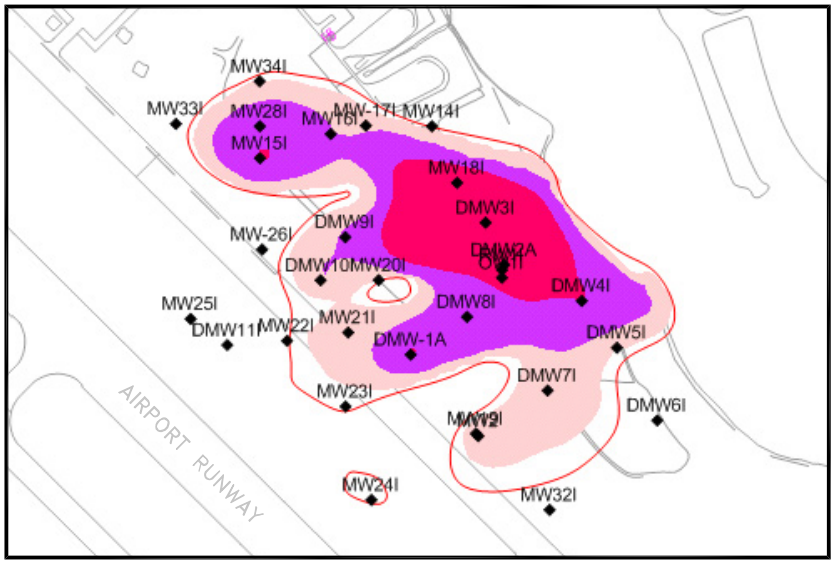

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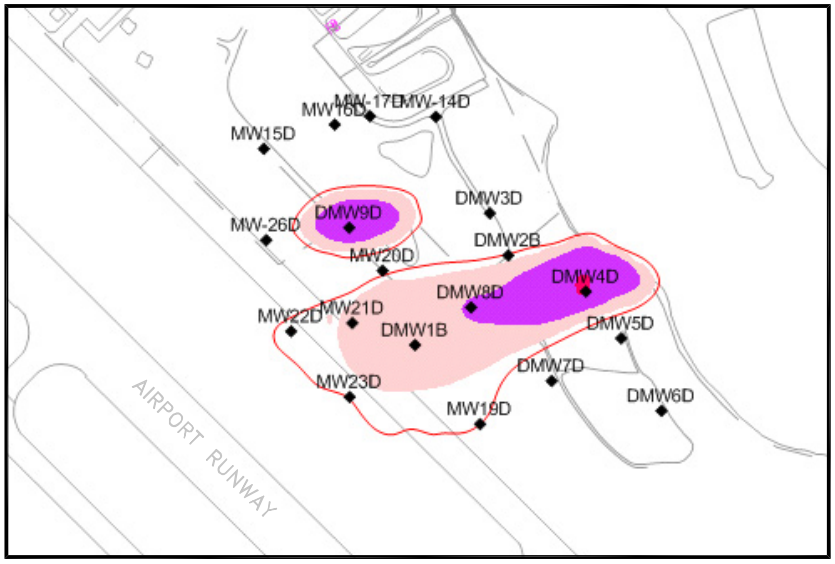

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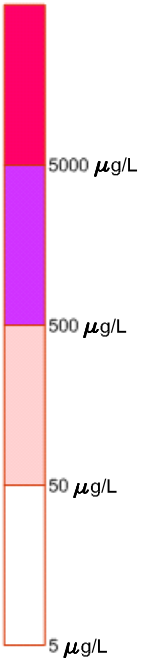

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TITLE: **DISTRIBUTION OF TCE IN UPPER, INTERMEDIATE, AND LOWER ZONES OF SURFICIAL AQUIFER, SEPTEMBER 2009**

LOCATION: **Martin State Airport, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

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FIGURE 2

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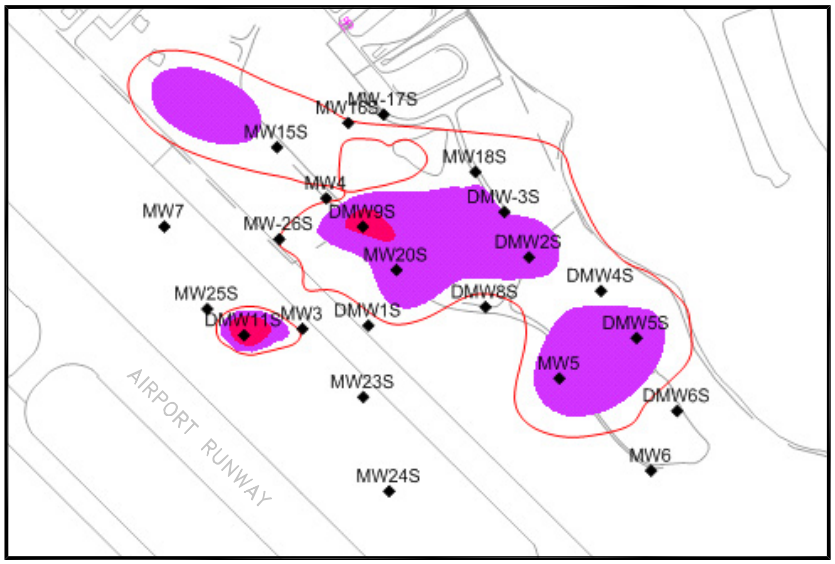

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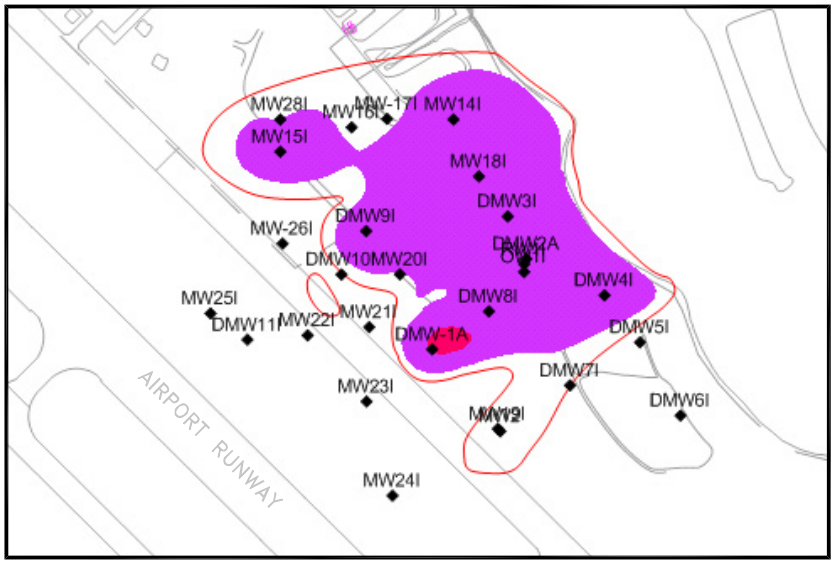

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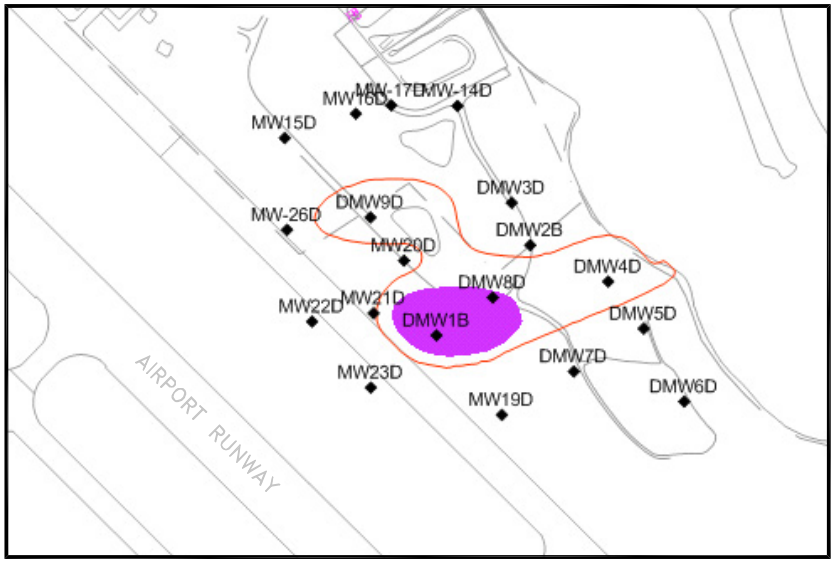

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LOCATION: **Martin State Airport, Maryland**

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FIGURE 3

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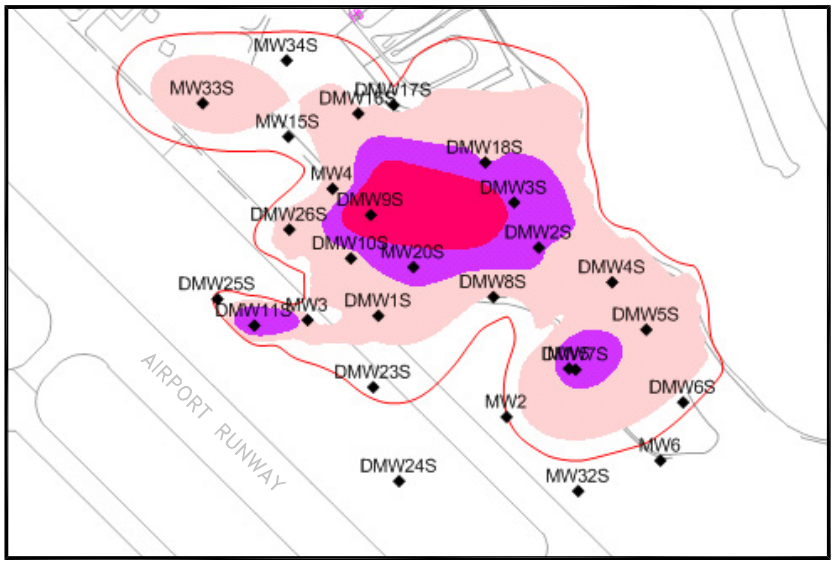

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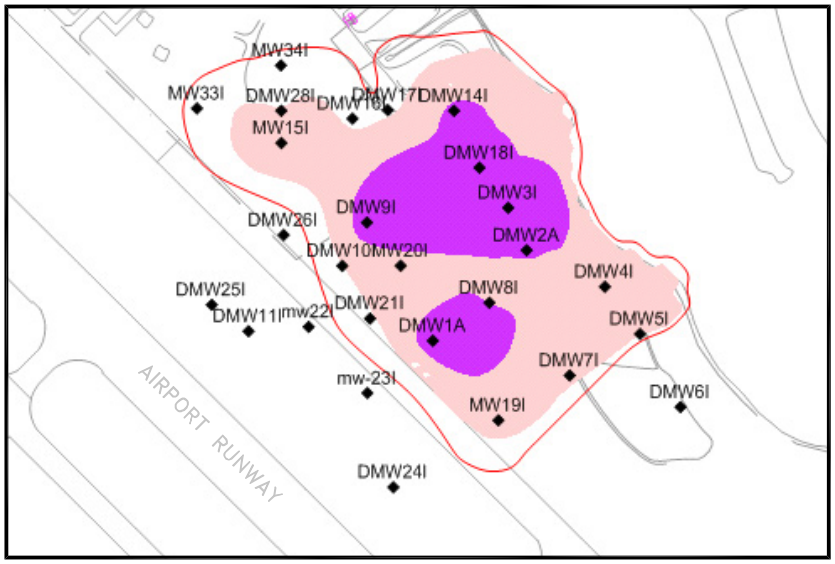

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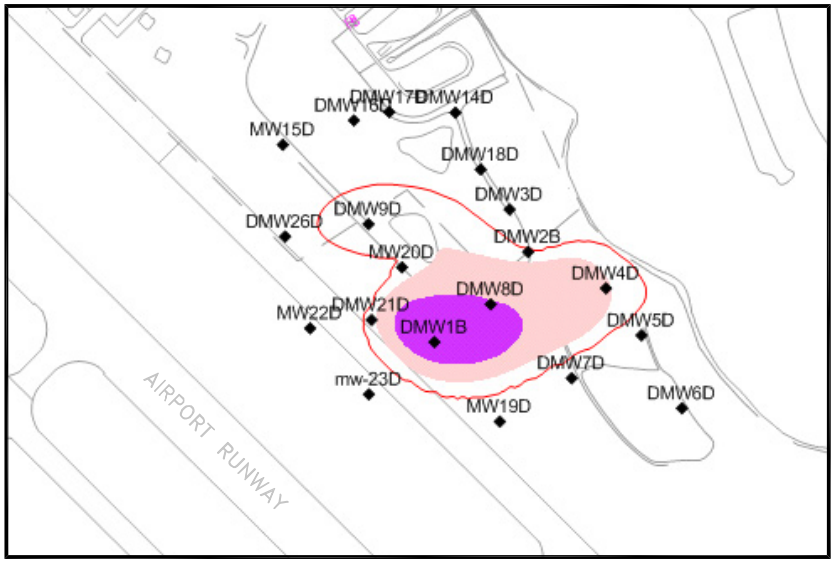

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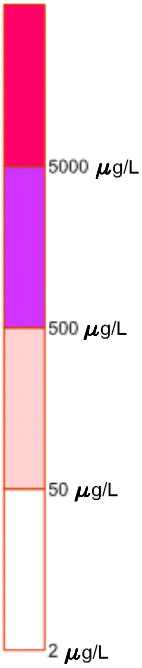

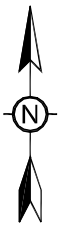

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LOCATION: **Martin State Airport, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

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FIGURE 4

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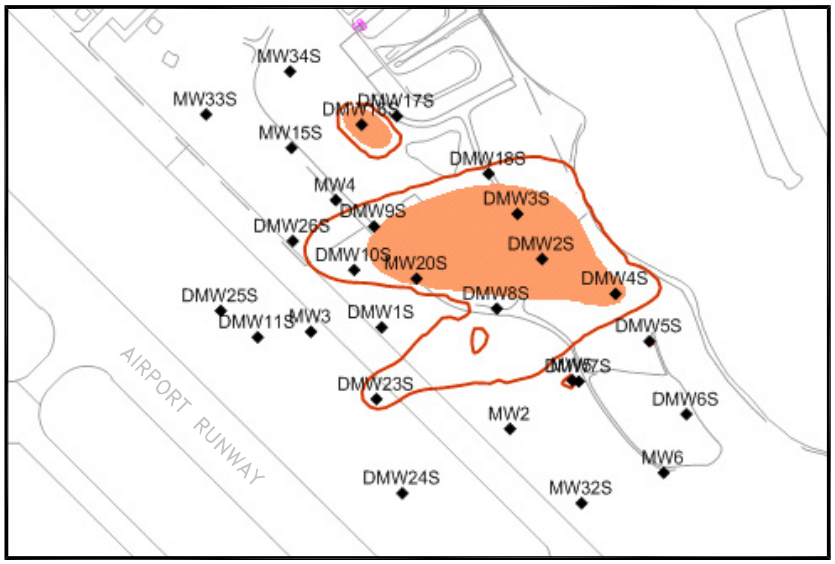

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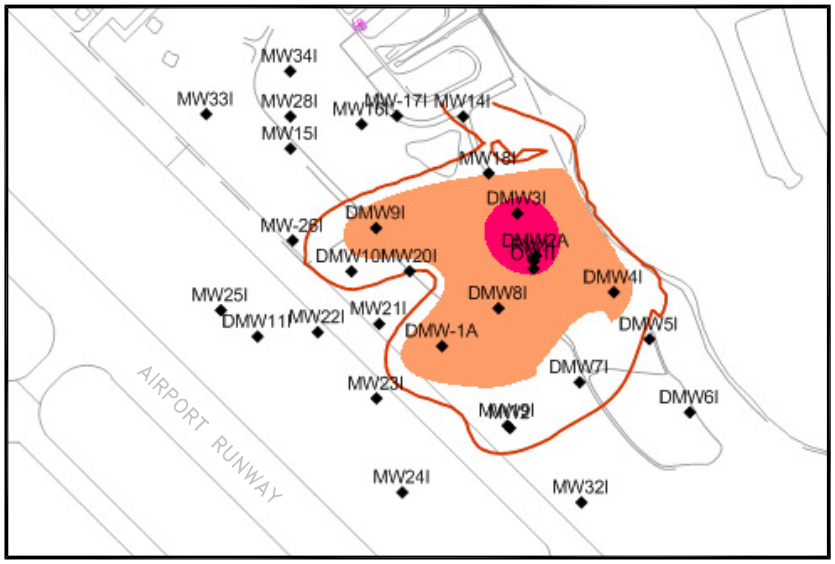

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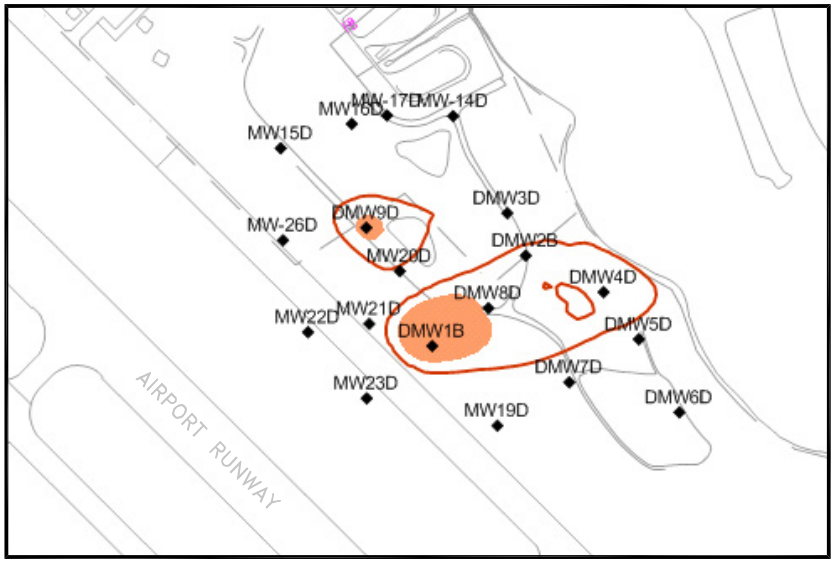

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LOCATION: **Martin State Airport, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

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FIGURE 5

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LEGEND

- GROUNDWATER MONITORING WELL OR PIEZOMETER LOCATION
- ABANDONED WELL
- GROUNDWATER ELEVATION CONTOUR CONTOUR INTERVAL = 0.5 OR 1 FOOT
- 1.79 GROUNDWATER ELEVATION FEET, MEAN SEA LEVEL
- MARYLAND AIR NATIONAL GUARD BOUNDARY
- POND

* Not used for contouring: well installed in clay and may represent perched groundwater.

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SCALE IN FEET

TITLE:

WATER TABLE MAP BASED ON GROUNDWATER LEVELS IN THE UPPER ZONE OF THE SURFICIAL AQUIFER, JULY 2010

LOCATION:

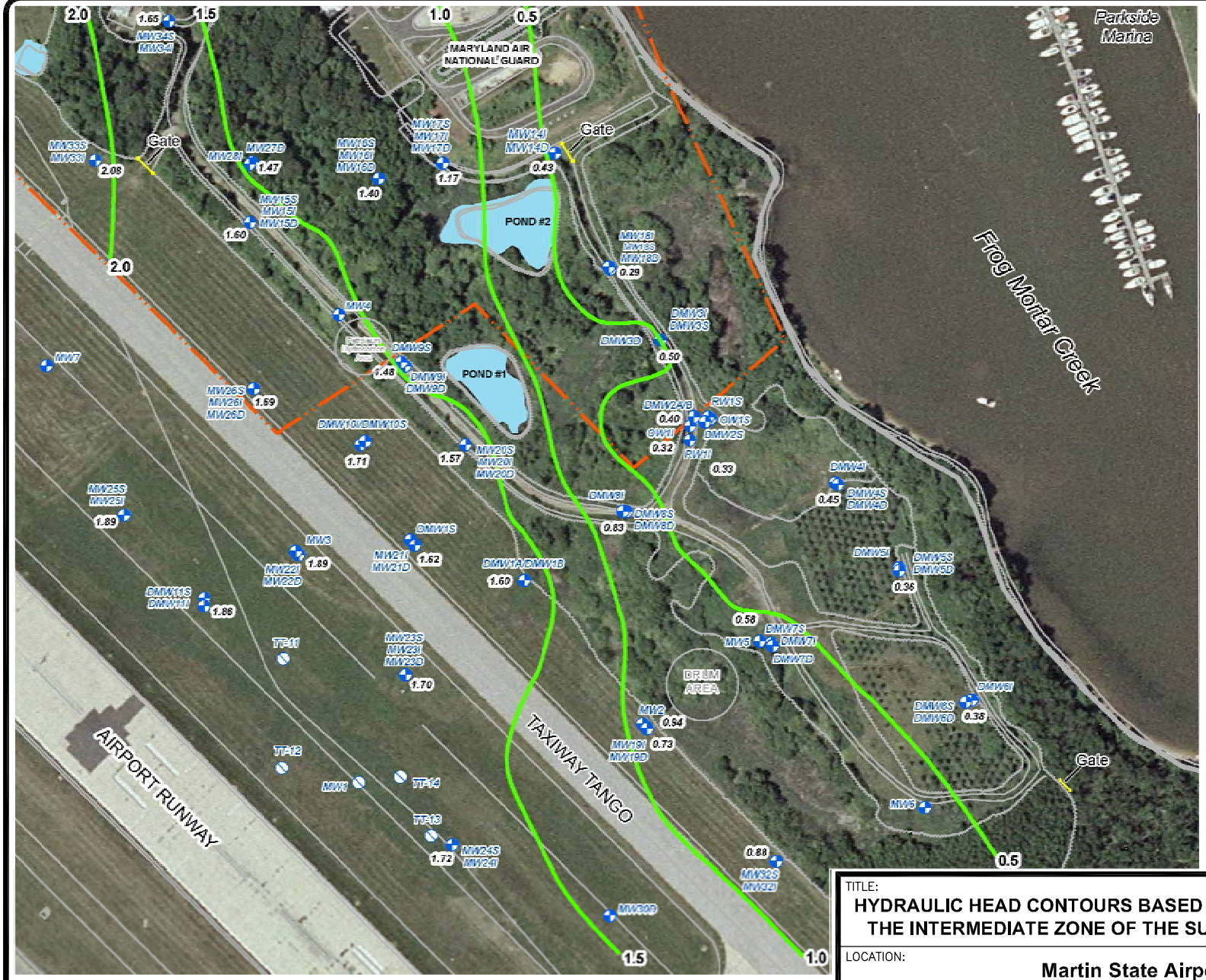
Martin State Airport, Maryland

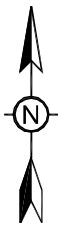
GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	12-15-10

FIGURE 6

P:\ACAD\0512-055-MSA\0512055013A.DWG





LEGEND

- GROUNDWATER MONITORING WELL OR PIEZOMETER LOCATION
- ABANDONED WELL
- GROUNDWATER ELEVATION CONTOUR CONTOUR INTERVAL = 0.5 FOOT
- 1.79 GROUNDWATER ELEVATION FEET, MEAN SEA LEVEL
- MARYLAND AIR NATIONAL GUARD BOUNDARY
- POND

0 250 500

SCALE IN FEET

TITLE:

HYDRAULIC HEAD CONTOURS BASED ON GROUNDWATER LEVELS IN THE INTERMEDIATE ZONE OF THE SURFICIAL AQUIFER, JULY 2010

LOCATION:

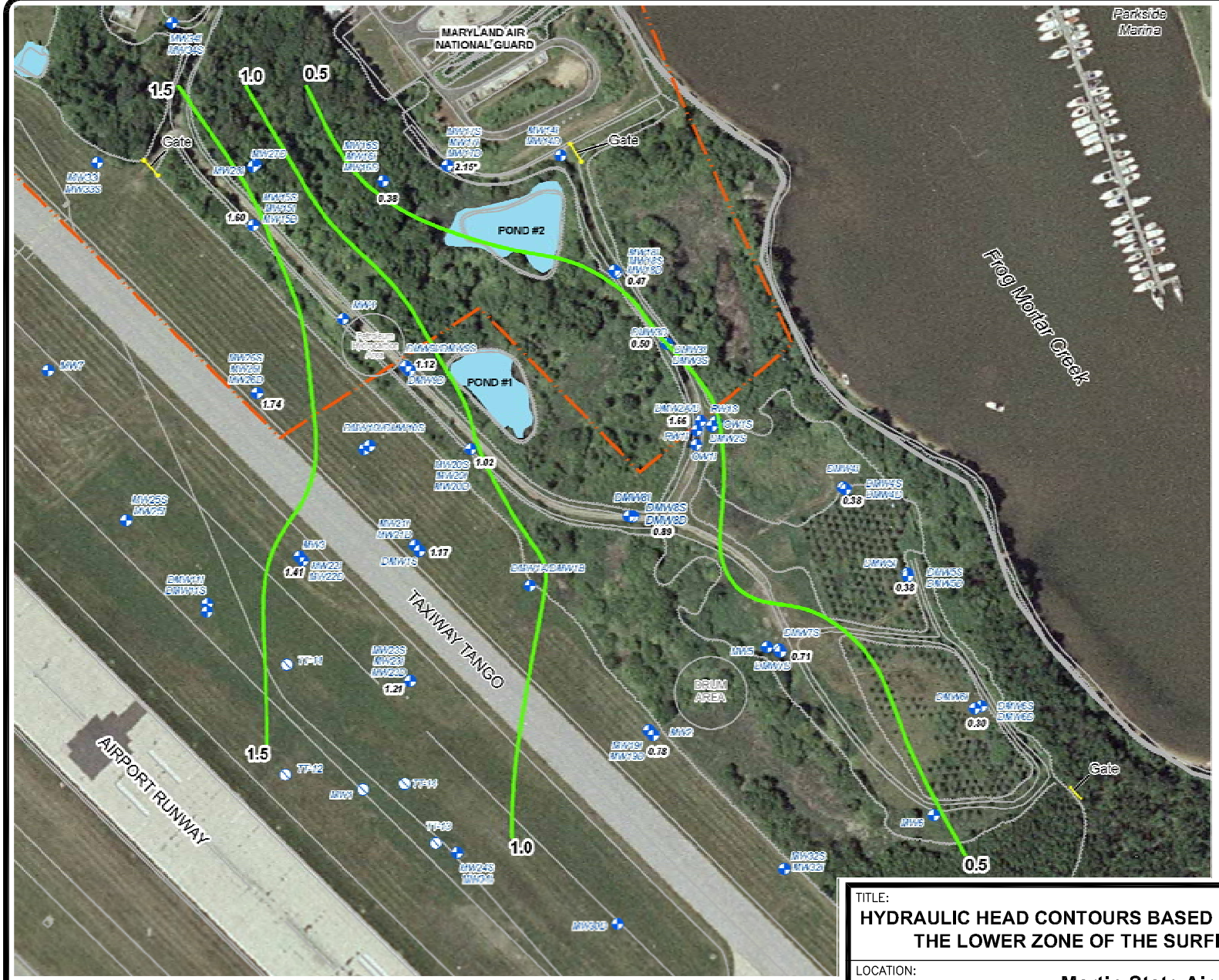
Martin State Airport, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	12-15-10

FIGURE 7

P:\ACAD\0512-055-MSA\0512055014A.DWG



N

LEGEND

- GROUNDWATER MONITORING WELL OR PIEZOMETER LOCATION
- ABANDONED WELL
- GROUNDWATER ELEVATION CONTOUR CONTOUR INTERVAL = 0.5 FOOT
- 1.79 GROUNDWATER ELEVATION FEET, MEAN SEA LEVEL
- MARYLAND AIR NATIONAL GUARD BOUNDARY
- POND

* Not used for contouring: well installed in clay and level may not represent sands of the lower surficial aquifer

TITLE:

HYDRAULIC HEAD CONTOURS BASED ON GROUNDWATER LEVELS IN THE LOWER ZONE OF THE SURFICIAL AQUIFER, JULY 2010

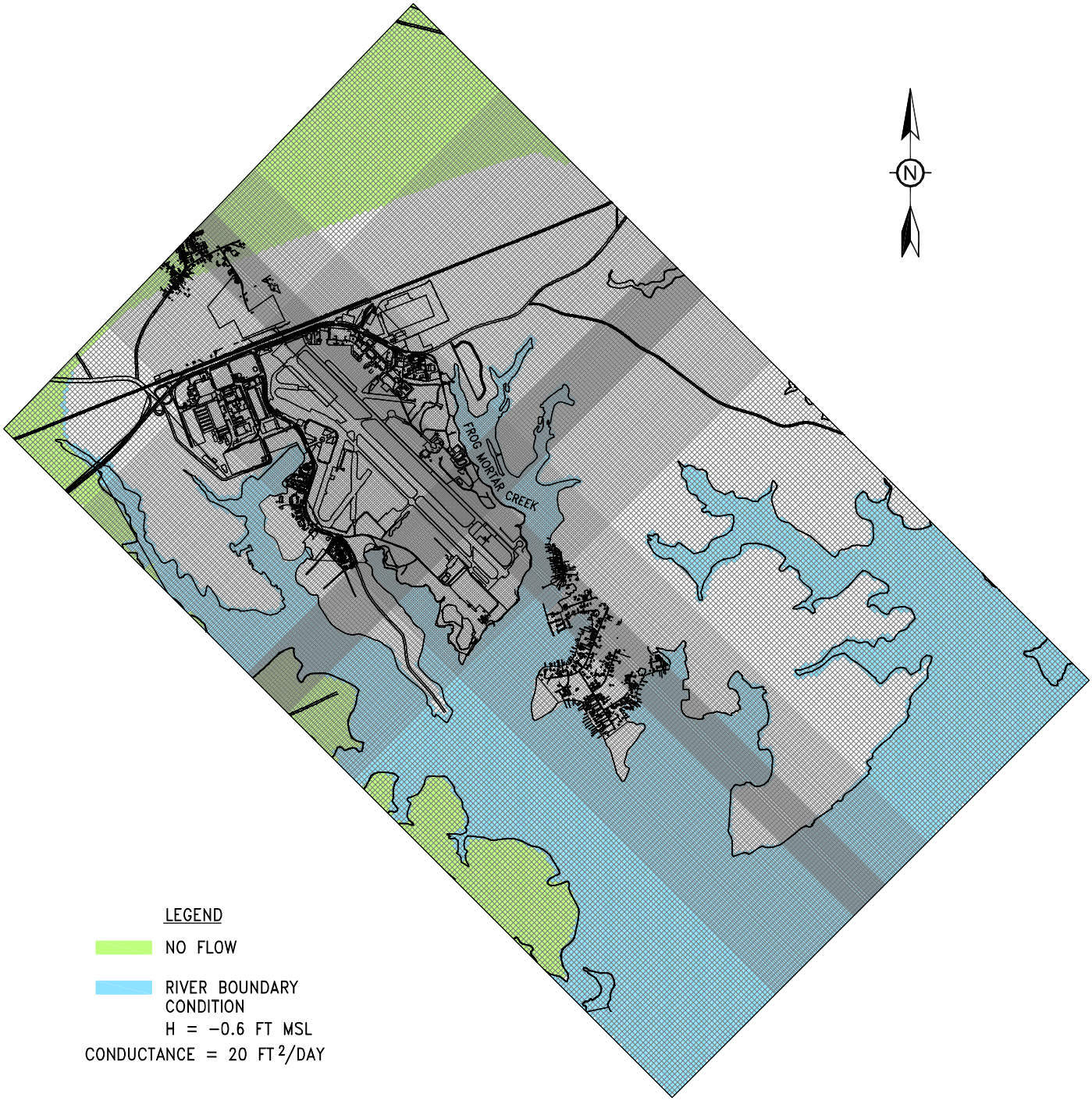
LOCATION:

Martin State Airport, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	12-15-10

FIGURE 8



LEGEND

NO FLOW

RIVER BOUNDARY CONDITION
H = −0.6 FT MSL
CONDUCTANCE = 20 FT²/DAY

NOTE:
RIVER BOUNDARY CONDITION IS ONLY IN LAYERS 1, 2, AND 3.

0 4000 8000
SCALE IN FEET

TITLE:
MODEL GRID AND BOUNDARY CONDITIONS

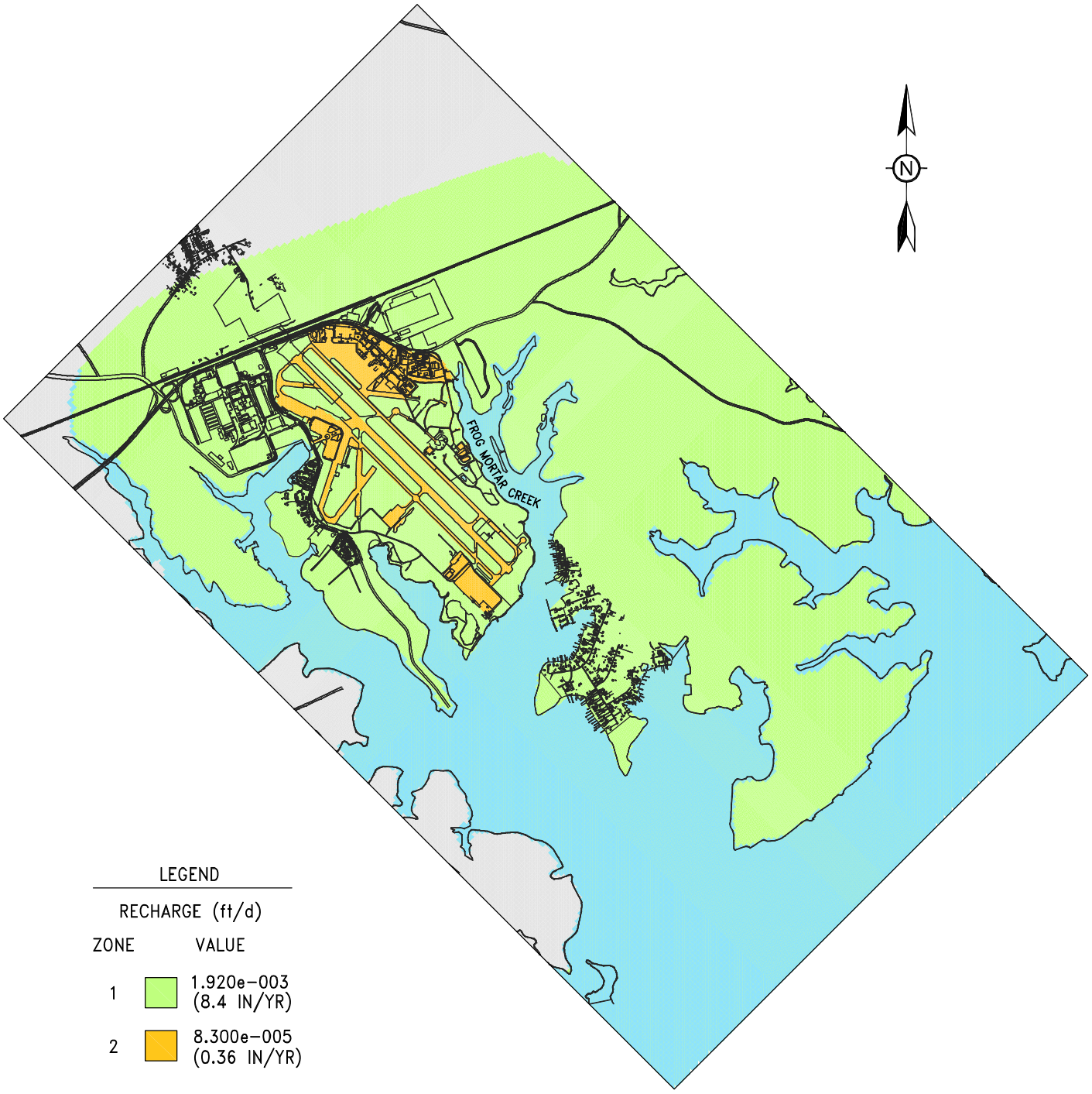
LOCATION:
Martin State Airport, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	12-15-10

FIGURE 9

P:\ACAD\0512-055-MSA\0512055007A.DWG



LEGEND

RECHARGE (ft/d)

ZONE	VALUE
1	1.920e-003 (8.4 IN/YR)
2	8.300e-005 (0.36 IN/YR)
	RIVER
	NO FLOW

0 4000 8000

SCALE IN FEET

TITLE: **SIMULATED DISTRIBUTION OF GROUNDWATER RECHARGE IN THE CALIBRATED MODEL**

LOCATION: **Martin State Airport, Maryland**

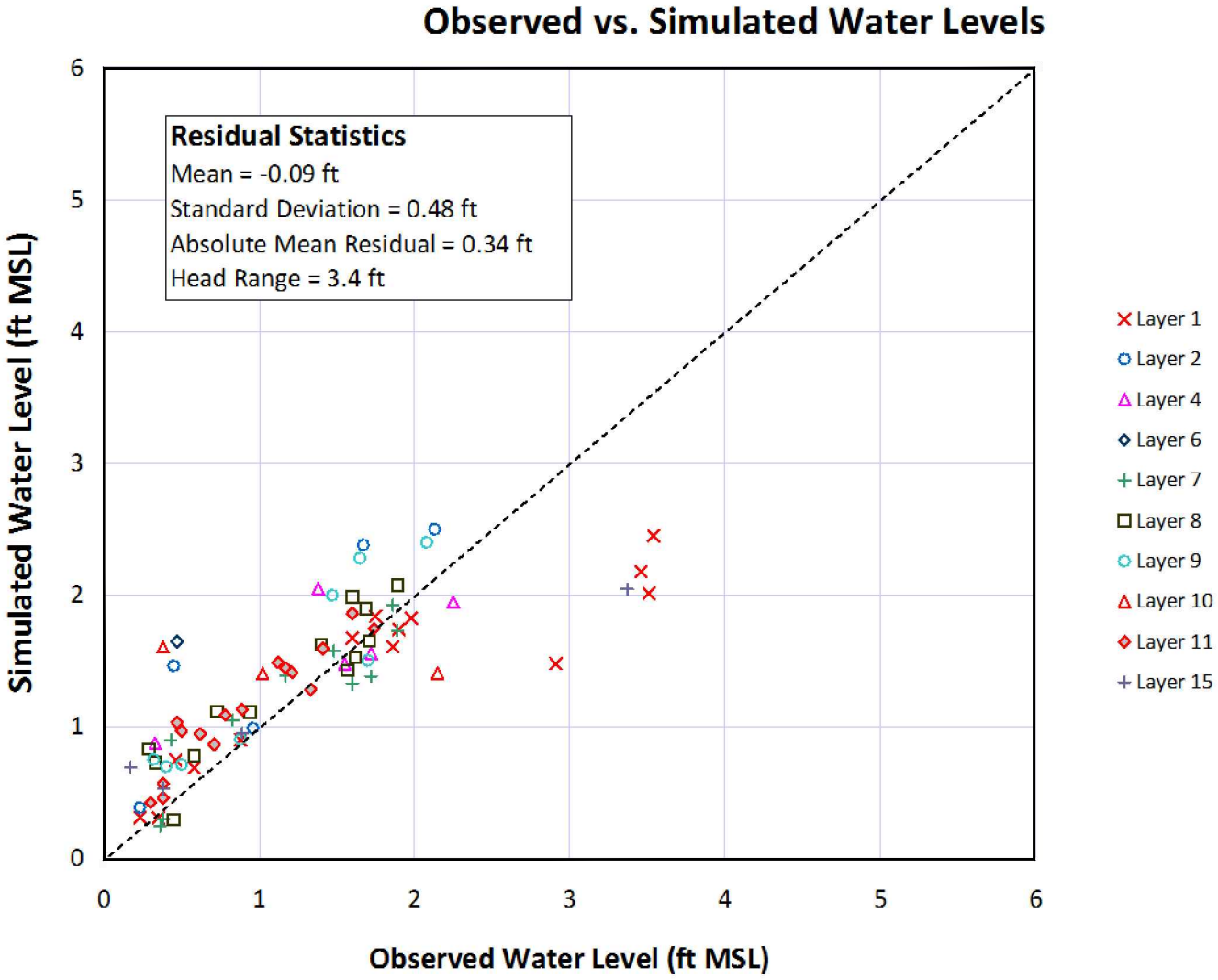
GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	12-15-10

FIGURE 10

P:\ACAD\0512-055-MSA\0512055008A.DWG

0512055009A.DWG



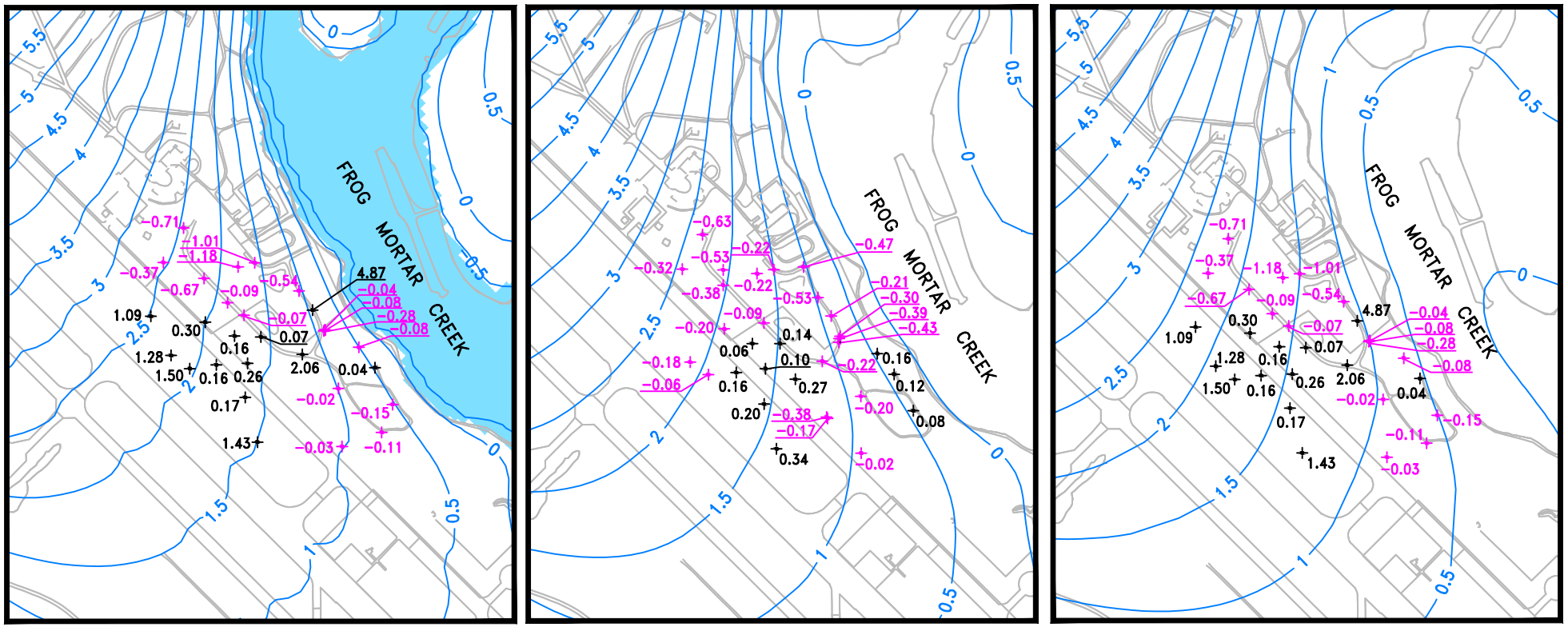
TITLE:	PLOT OF MEASURED VERSUS SIMULATED GROUNDWATER LEVELS, JULY 2010
LOCATION:	Martin State Airport, Maryland

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	2-1-11

FIGURE 11

0512055016A.DWG



NOTES:

1. RESIDUALS ARE FOR ALL MODEL LAYERS IN THE UPPER, INTERMEDIATE, AND LOWER ZONE.
2. SIMULATED HEADS ARE FOR MODEL LAYERS 1, 8, AND 11, RESPECTIVELY.
3. UPPER ZONE (LAYERS 1–6), INTERMEDIATE ZONE (LAYERS 7–9), AND LOWER ZONE (LAYERS 10,11).

N

0 1000 2000

SCALE IN FEET

LEGEND

—4— POTENTIOMETRIC CONTOUR (ft MSL)

0.76+ SIMULATED < OBSERVED RESIDUAL (FT)

−0.74+ SIMULATED > OBSERVED RESIDUAL (FT)

TITLE:

SIMULATED POTENTIOMETRIC SURFACE AND RESIDUALS IN UPPER SURFICIAL (LAYER 1), INTERMEDIATE SURFICIAL (LAYER 8), AND LOWER SURFICIAL (LAYER 11) AQUIFER

LOCATION:

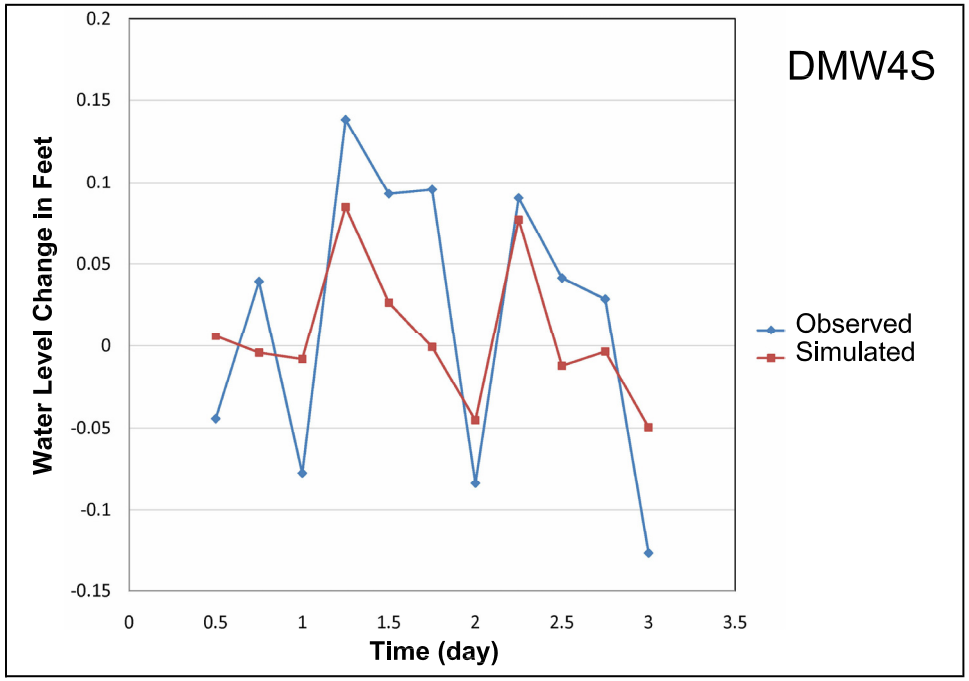
Martin State Airport, Maryland

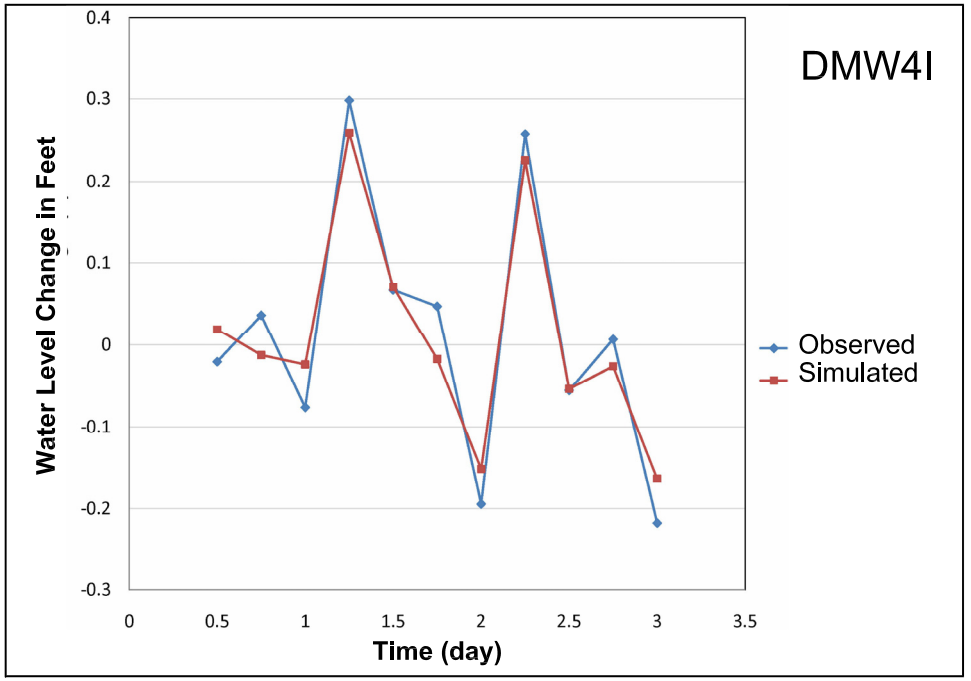
GeoTrans, Inc. A TETRA TECH COMPANY

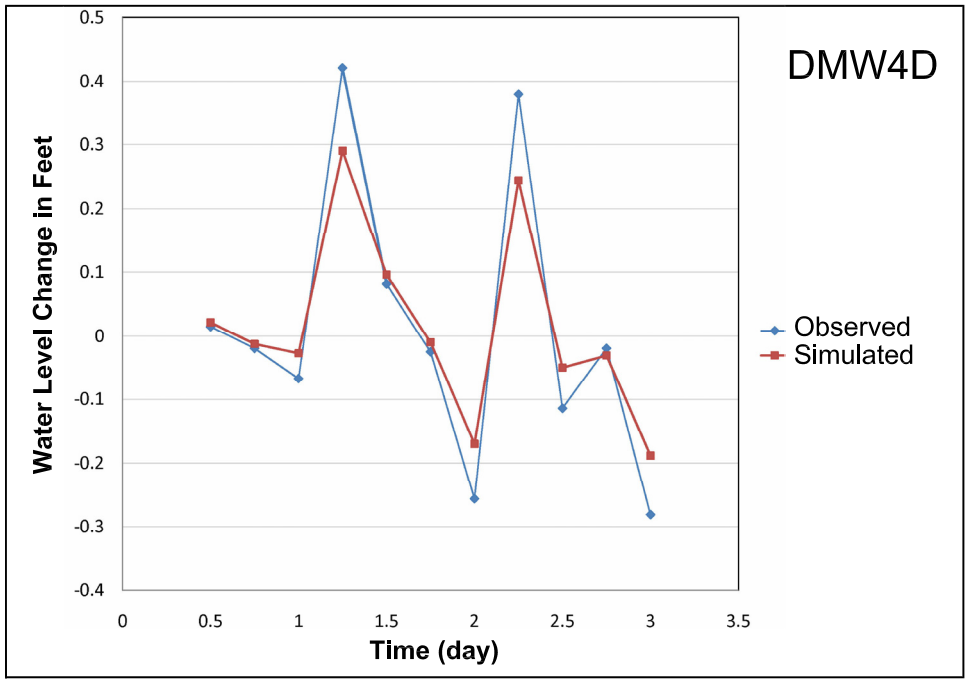
APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	2-1-11

FIGURE 12

P:\ACAD\0512-055-MSA\0512055017A.DWG







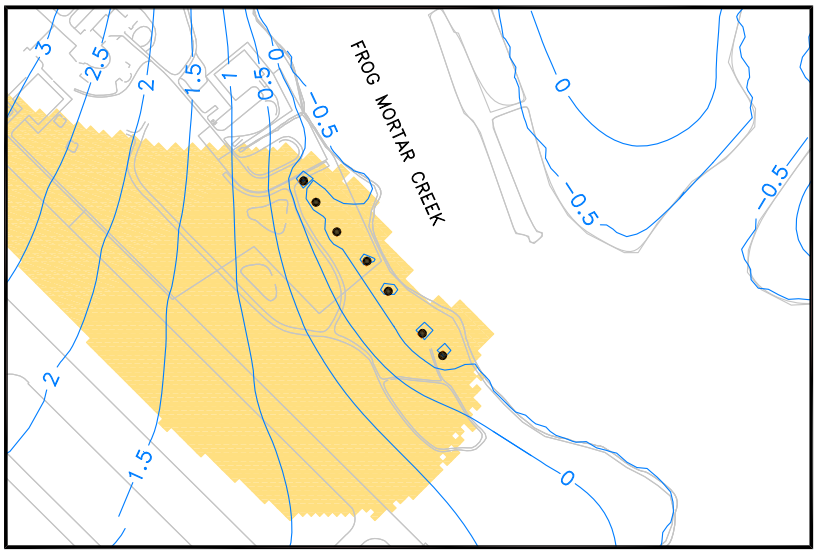
TITLE: **SIMULATED AND OBSERVED HYDRAULIC HEAD CHANGES AT DMW4S, DMW4I, AND DMW4D DURING TIDAL FLUCTUATION FROM JULY 2, 2010 TO JULY 4, 2010**

LOCATION: **Martin State Airport, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	1-14-11

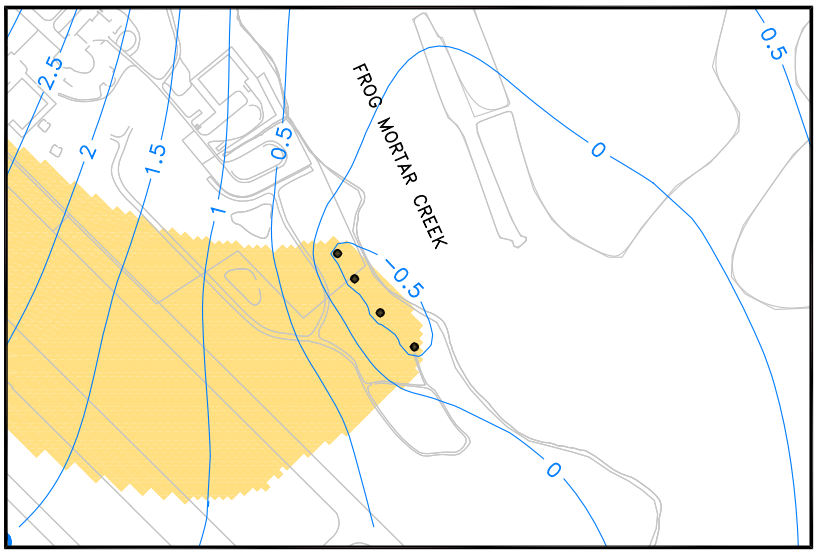
FIGURE **13**



UPPER ZONE



INTERMEDIATE ZONE



LOWER ZONE

LEGEND

- EXTRACTION WELL
- INJECTION WELL
- EXTENT OF CAPTURE ZONE
- RIVER
- — 3 — SIMULATED HEAD (FT MSL)

0 800 1600

SCALE IN FEET

TITLE: **PREDICTED CAPTURE ZONE IN HYDRAULIC BARRIER SCENARIO IN UPPER SURFICIAL (LAYERS 1 AND 6), INTERMEDIATE SURFICIAL (LAYER 8), AND LOWER SURFICIAL (LAYER 11) AQUIFER**

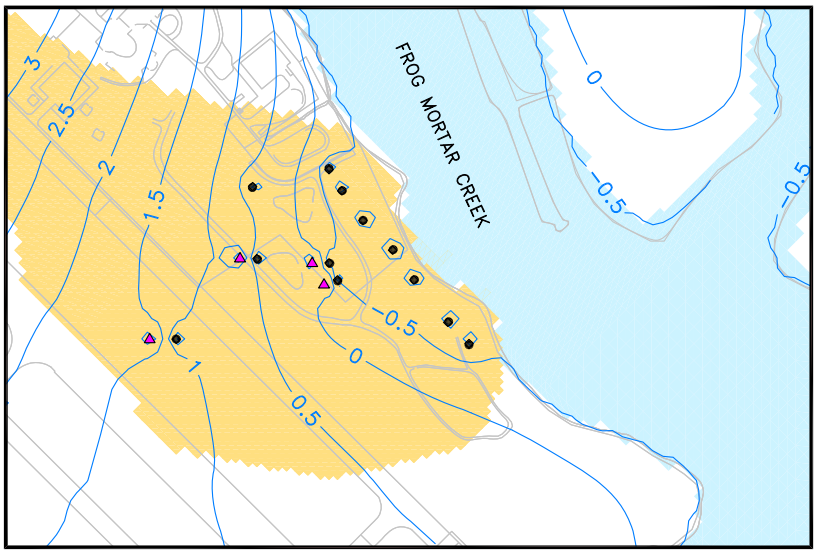
LOCATION: **Martin State Airport, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

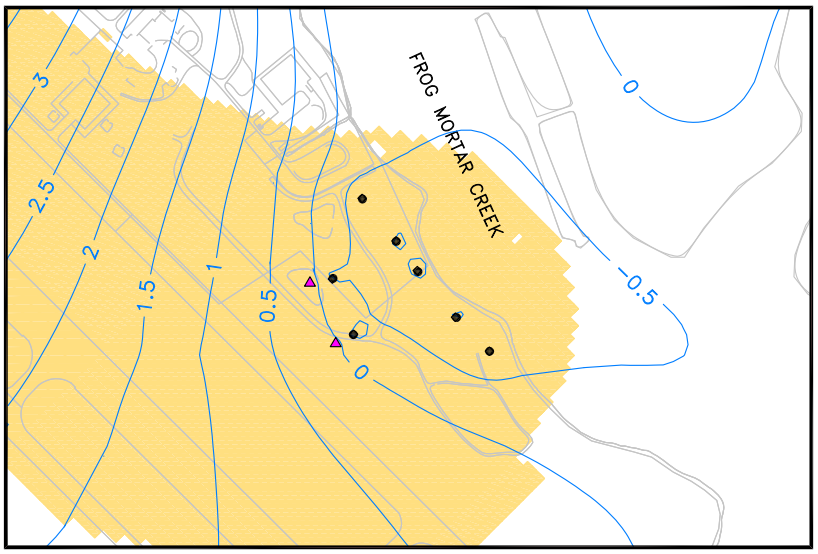
APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	12-15-10

FIGURE 14

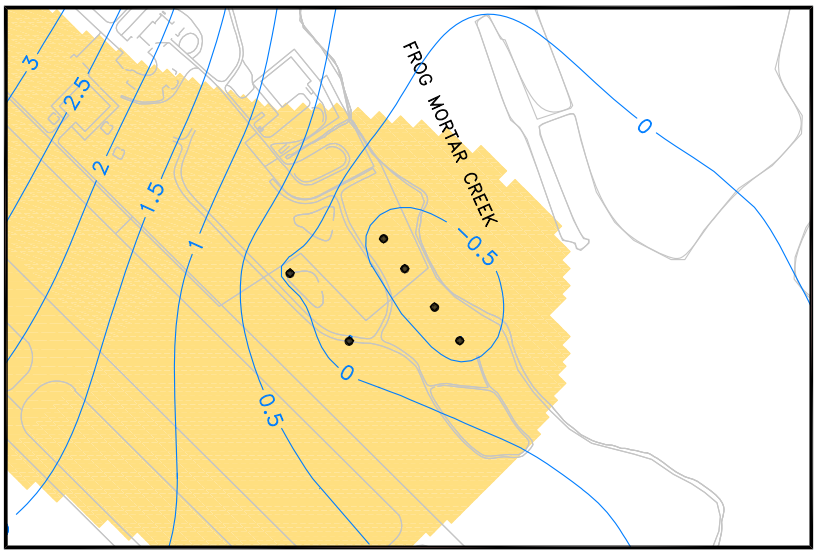
P:\ACAD\0512-055-MSA\0512055011A.DWG



UPPER ZONE



INTERMEDIATE ZONE



LOWER ZONE

N

LEGEND

- EXTRACTION WELL
- INJECTION WELL
- EXTENT OF CAPTURE ZONE
- RIVER
- —3— SIMULATED HEAD (FT MSL)

0 800 1600

SCALE IN FEET

TITLE: **PREDICTED CAPTURE ZONE IN HYDRAULIC BARRIER AND HIGH CONCENTRATION ZONE REMEDIATION SCENARIO IN UPPER SURFICIAL (LAYERS 1 AND 6), INTERMEDIATE SURFICIAL (LAYER 8), AND LOWER SURFICIAL (LAYER 11) AQUIFER**

LOCATION: **Martin State Airport, Maryland**

GeoTrans, Inc. A TETRA TECH COMPANY

APPROVED	DB
DRAFTED	CP
PROJECT#	117-0512055
DATE	1-14-11

FIGURE 15

P:\ACAD\0512-055-MSA\0512055018A.DWG

TABLES

Table 1. Summary of Groundwater Flow Model Parameter Values

Unit	Layer	Horizontal Hydraulic Conductivity K_h (ft/day)	Vertical Hydraulic Conductivity K_z (ft/day)	Specific Yield S_y	Specific Storage S_s (ft^{-1})
Upper	1	4	0.4	0.25	0.0001
	2	4.5	0.45		
	3	4.5	0.45		
	4	9	0.9		
	5	4.5	0.45		
	6	4.5	0.45		
Intermediate	7	20	2		0.0001
	8	20	2		
	9	20	2		
Lower	10	1.4	0.14		0.00001
	11	100	10		
Intermediate Aquitard	12	0.5	0.05		0.0001
	13	0.5	0.05		
	14	0.5	0.05		
Deep confined	15	40	4		0.0001

Note: The recharge rate for unpaved area is 0.00192 ft/day (8.4 in/yr); for the paved area is 0.000083 ft/day (0.36 in/yr).

Table 2. July 2, 2010 Measured Groundwater Elevations and Vertical Hydraulic Gradients Versus Simulated Values in the Calibrated Groundwater Flow Model

Well Name	X	Y	Layer	Observed WL	Computed WL	Residual	Observed Vertical Head Difference	Computed Vertical Head Difference
DMW-1S	1479310.5	604458.6	1	1.86	1.60	0.26		
DMW-1A	1479498.3	604398.6	7	1.6	1.33	0.27	0.2600	0.2798
DMW1B	1479498.3	604398.6	11	1.33	1.28	0.05	0.2700	0.0436
DMW-2S	1479807.5	604670.4	1	0.46	0.74	-0.28		
OW1-S	1479817.3	604674.9	4	0.6	0.68	-0.08	-0.1400	0.0647
RW1-S	1479813.4	604677.6	4	0.64	0.68	-0.04	-0.0400	-0.0065
DMW2A	1479789.4	604678.8	9	0.4	0.70	-0.30	0.2400	-0.0109
OW1-I	1479781.4	604638.0	9	0.32	0.75	-0.43	0.0800	-0.0543
OW1-S	1479817.3	604674.9	8	0.6	0.68	-0.08	-0.2800	0.0717
DMW-2B	1479789.4	604678.8	11	0.62	0.95	-0.33	-0.0200	-0.2678
DMW-3S	1479733.9	604804.9	1	5.66	0.79	4.87		
DMW-3I	1479731.1	604810.5	9	0.5	0.71	-0.21	5.1600	0.0759
DMW-3D	1479731.1	604810.5	11	0.5	0.97	-0.47	0.0000	-0.2529
DMW-4S	1480036.3	604563.0	1	0.23	0.31	-0.08		
DMW-4I	1480031.5	604566.0	8	0.45	0.29	0.16	-0.2200	0.0177
DMW-4D	1480031.5	604566.0	11	0.38	0.57	-0.19	0.0700	-0.2762
MW-4	1479180.8	604852.9	1	1.75	1.84	-0.09		
DMW-5S	1480141.1	604430.0	1	0.35	0.31	0.04		
DMW-5I	1480140.5	604431.1	7	0.36	0.24	0.12	-0.0100	0.0614
DMW-5D	1480140.6	604431.1	11	0.38	0.46	-0.08	-0.0200	-0.2134
DMW-6S	1480255.0	604190.5	2	0.23	0.38	-0.15		
DMW-6I	1480266.2	604193.6	7	0.38	0.30	0.08	-0.1500	0.0881
DMW-6D	1480266.2	604193.6	11	0.3	0.42	-0.12	0.0800	-0.1260
MW-6	1480184.7	604009.3	1	0.58	0.69	-0.11		
MW-7	1478680.4	604765.2	1	3.54	2.45	1.09		
MW-5	1479901.9	604294.7	1	0.88	0.90	-0.02		
DMW-7I	1479924.2	604287.2	8	0.58	0.78	-0.20	0.3000	0.1195
DMW-7D	1479924.2	604287.2	11	0.71	0.87	-0.16	-0.1300	-0.0884
DMW-8S	1479667.8	604516.6	1	3.2	1.14	2.06		
DMW-8I	1479673.6	604516.0	7	0.83	1.05	-0.22	2.3700	0.0924
DMW-8D	1479673.6	604516.0	11	0.89	1.13	-0.24	-0.0600	-0.0805
DMW-9S	1479286.9	604771.6	1	1.6	1.67	-0.07		
DMW-9I	1479293.4	604764.9	7	1.48	1.57	-0.09	0.1200	0.0964
DMW-9D	1479293.4	604764.9	11	1.12	1.49	-0.37	0.3600	0.0880
DMW-10S	1479225.8	604636.8	1	1.9	1.74	0.16		
DMW-10I	1479217.3	604630.7	8	1.71	1.65	0.06	0.1900	0.0868
DMW-11S	1478934.9	604424.2	1	3.51	2.01	1.50		
DMW-11I	1478930.8	604429.3	7	1.86	1.92	-0.06	1.6500	0.0899
MW-14I	1479550.7	605129.9	7	0.43	0.90	-0.47		

Well Name	X	Y	Layer	Observed WL	Computed WL	Residual	Vertical Head Difference	Vertical Head Difference
MW-15S	1479028.3	605011.0	4	1.38	2.05	-0.67		
MW-15I	1479028.3	605011.0	8	1.6	1.98	-0.38	-0.2200	0.0676
MW-15D	1479028.3	605011.0	11	1.6	1.86	-0.26	0.0000	0.1252
MW-16S	1479248.8	605086.4	6	0.47	1.65	-1.18		
MW-16I	1479248.8	605086.4	8	1.4	1.62	-0.22	-0.9300	0.0220
MW-16D	1479248.8	605086.4	10	0.38	1.60	-1.22	1.0200	0.0205
MW-17S	1479358.3	605112.7	2	0.45	1.46	-1.01		
MW-17I	1479358.3	605112.7	7	1.17	1.39	-0.22	-0.7200	0.0733
MW-17D	1479358.3	605112.7	10	2.15	1.41	0.74	-0.9800	-0.0178
MW-18S	1479645.1	604930.8	4	0.33	0.87	-0.54		
MW-18I	1479645.1	604930.8	8	0.29	0.82	-0.53	0.0400	0.0493
MW-2	1479708.3	604144.3	8	0.94	1.11	-0.17		
MW-19I	1479701.2	604152.7	8	0.73	1.11	-0.38	0.2100	-0.0067
MW-19D	1479701.2	604152.7	11	0.78	1.09	-0.31	-0.0500	0.0266
DMW-1S	1479310.5	604458.6	1	1.86	1.60	0.26		
MW-20S	1479397.9	604631.0	4	1.55	1.48	0.07	0.3100	0.1273
MW-20I	1479397.9	604631.0	8	1.57	1.43	0.14	-0.0200	0.0514
MW-20D	1479397.9	604631.0	10	1.02	1.40	-0.38	0.5500	0.0257
MW-21I	1479303.2	604467.8	8	1.62	1.52	0.10		
MW-21D	1479303.2	604467.8	11	1.17	1.44	-0.27	0.4500	0.0804
MW-3	1479107.2	604448.8	1	1.98	1.82	0.16		
MW-22I	1479112.8	604442.1	7	1.89	1.73	0.16	0.0900	0.0927
MW-22D	1479112.8	604442.1	11	1.41	1.59	-0.18	0.4800	0.1371
MW-23S	1479295.1	604237.1	4	1.72	1.55	0.17		
MW-23I	1479295.1	604237.1	9	1.7	1.50	0.20	0.0200	0.0525
MW-23D	1479295.1	604237.1	11	1.21	1.41	-0.20	0.4900	0.0908
MW-24S	1479375.2	603945.7	2	2.91	1.48	1.43		
MW-24I	1479375.2	603945.7	7	1.72	1.38	0.34	1.1900	0.0985
MW-25S	1478812.4	604510.1	1	3.46	2.18	1.28		
MW-25I	1478812.4	604510.1	8	1.89	2.07	-0.18	1.5700	0.1041
MW-26S	1479035.4	604726.4	4	2.25	1.95	0.30		
MW-26I	1479035.4	604726.4	8	1.69	1.89	-0.20	0.5600	0.0522
MW-26D	1479035.4	604726.4	11	1.74	1.74	0.00	-0.0500	0.1510
MW-29D	1480488.4	603774.8	15	0.38	0.53	-0.15		
MW-30D	1479645.7	603825.5	15	0.89	0.95	-0.06		
MW-31D	1480099.6	603747.8	15	0.17	0.69	-0.52		
MW-28I	1479027.9	605110.6	9	1.47	2.00	-0.53		
MW-27D	1479032.0	605114.3	15	3.37	2.04	1.33	-1.9000	-0.0467
MW-32S	1479926.5	603917.7	2	0.96	0.99	-0.03		
MW-32I	1479926.5	603917.7	9	0.88	0.90	-0.02	0.0800	0.0831
MW-33S	1478762.0	605115.6	2	2.13	2.50	-0.37		
MW-33I	1478762.0	605115.6	9	2.08	2.40	-0.32	0.0500	0.1000
MW-34S	1478893.8	605340.1	2	1.67	2.38	-0.71		
MW-34I	1478893.8	605340.1	9	1.65	2.28	-0.63	0.0200	0.0982

Table 3. Summary Statistics for Steady-State Flow Model Simulation for July 2010 Conditions

Model Layer	Unit	# Targets	Range of Water Levels (ft)	Residual Mean (ft)	Absolute Residual Mean (ft)	Residual Standard Deviation (ft)	Standard Deviation / Range
	Entire Model	**81**	**3.37**	**-0.09**	**0.34**	**0.48**	**0.14**
1	Upper Zone	14	3.31	0.38	0.41	0.64	0.19
2	Upper Zone	5	1.90	-0.45	0.45	0.40	0.21
3	Upper Zone	0	-	-	-	-	-
4	Upper Zone	7	1.92	-0.11	0.27	0.36	0.19
5	Upper Zone	0	-	-	-	-	-
6	Upper Zone	1	-	-1.18	1.18	-	-
7	Intermediate Zone	10	1.53	-0.01	0.20	0.25	0.16
8	Intermediate Zone	13	1.60	-0.17	0.24	0.23	0.14
9	Intermediate Zone	8	1.76	-0.28	0.33	0.27	0.15
10	Lower Zone	3	1.77	-0.29	0.78	0.99	0.56
11	Lower Zone	16	1.44	-0.23	0.24	0.16	0.11
12	Basal Confing Unit	0	-	-	-	-	-
13	Basal Confing Unit	0	-	-	-	-	-
14	Basal Confing Unit	0	-	-	-	-	-
15	Deep Confined Zone	4	3.20	0.15	0.41	0.81	0.25

Table 4. Comparison of Simulated and Measured Drawdown at the End of 72 Hour Pumping Test in the Intermediate Zone of the Surficial Aquifer.

Well ID	Actual Drawdown (Feet)	Simulated Drawdown (Feet)
OW-01I	1.18	1.28
DMW-2A	1.16	1.34
DMW-2B	0.54	0.55
DMW-3I	0.46	0.4
DMW-4I	0.39	0.17
DMW-8I	0.28	0.30

Table 5. Summary of Flow Model Sensitivity Analysis

Model Parameter	Multiplier	Normalized RSS
Recharge Rate (unpaved area)	0.5	1.99
Recharge Rate (unpaved area)	1.5	2.58
Recharge Rate (paved area)	0.5	1.00
Recharge Rate (paved area)	1.5	1.00
Horizontal Hydraulic Conductivity of Upper Zone	0.5	1.06
Horizontal Hydraulic Conductivity of Upper Zone	1.5	0.98
Horizontal Hydraulic Conductivity of Intermediate Zone	0.5	1.11
Horizontal Hydraulic Conductivity of Intermediate Zone	1.5	0.98
Horizontal Hydraulic Conductivity of Lower Zone	0.5	1.18
Horizontal Hydraulic Conductivity of Lower Zone	1.5	0.98
Vertical Hydraulic Conductivity of Upper Zone	0.5	1.11
Vertical Hydraulic Conductivity of Upper Zone	1.5	0.99
Vertical Hydraulic Conductivity of Intermediate Zone	0.5	1.04
Vertical Hydraulic Conductivity of Intermediate Zone	1.5	0.99
Vertical Hydraulic Conductivity of Lower Zone	0.5	1.10
Vertical Hydraulic Conductivity of Lower Zone	1.5	0.99
Vertical Hydraulic Conductivity Intermediate Aquitard (Layer 12, 13, and 14)	0.5	1.01
Vertical Hydraulic Conductivity Intermediate Aquitard (Layer 12, 13, and 14)	1.5	1.00
Horizontal Hydraulic Conductivity of Deep Confined Zone (Layer 15)	0.5	1.00
Horizontal Hydraulic Conductivity of Deep Confined Zone (Layer 15)	1.5	1.00
Vertical Hydraulic Conductivity of Deep Confined Zone (Layer 15)	0.5	1.00
Vertical Hydraulic Conductivity of Deep Confined Zone (Layer 15)	1.5	1.00

Note: Normalized RSS (residual sum of squares) is the new RSS divided by calibrated model RSS

Table 6. Summary of Injection and Pumping Rates by Model Layer for Each Remedial Scenario.

Scenario Description	Layer	Zone	Pumping Rate (gpm)	Pumping Rate by Zone (gpm)	Injection Rate (gpm)
Hydraulic Barrier Wells Along Frog Mortar Creek	Layer 2	Upper	1.5	12.2	
	Layer 3	Upper	1.6		
	Layer 4	Upper	3.2		
	Layer 5	Upper	1.6		
	Layer 6	Upper	4.3		
	Layer 7	Intermediate	1.8	13.6	
	Layer 8	Intermediate	6.0		
	Layer 9	Intermediate	5.8		
	Layer 11	Lower	22.2	22.2	
	Total			48.1	
Hydraulic Barrier Wells With High Concentration Zone Injection and Pumping	Layer 2	Upper	2.3	12.3	2.0
	Layer 3	Upper	2.3		2.0
	Layer 4	Upper	2.5		2.0
	Layer 5	Upper	2.4		2.0
	Layer 6	Upper	2.7		2.0
	Layer 7	Intermediate	7.2	21.3	1.0
	Layer 8	Intermediate	7.0		1.0
	Layer 9	Intermediate	7.0		1.0
	Layer 11	Lower	34.3	34.3	
	Total			67.9	

Addendum A —

Hydrostratigraphic Cross-Sections at MSA

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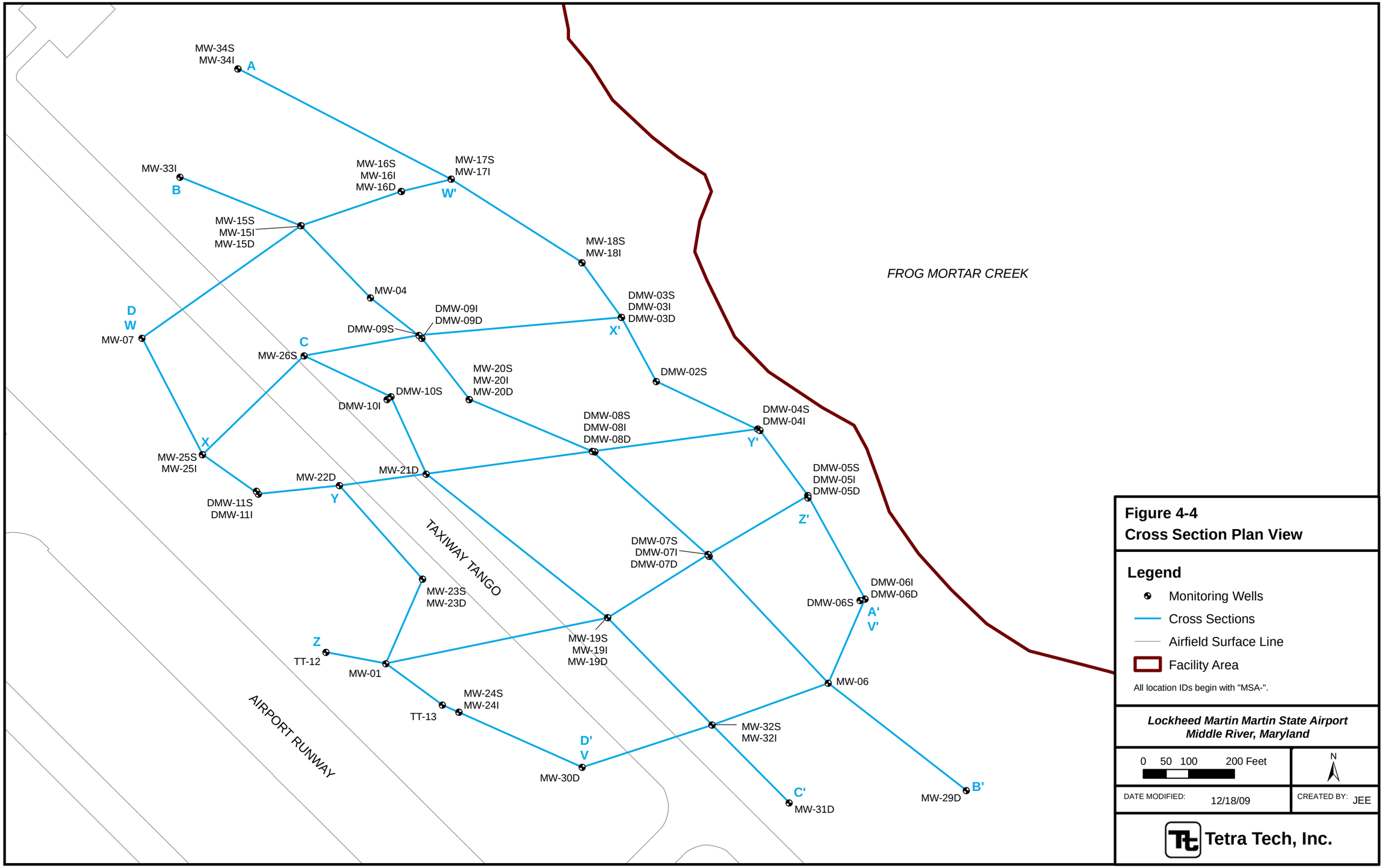

Figure 4-4
Cross Section Plan View

Legend

- Monitoring Wells
- Cross Sections
- Airfield Surface Line
- Facility Area

All location IDs begin with "MSA-".

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0 50 100 200 Feet

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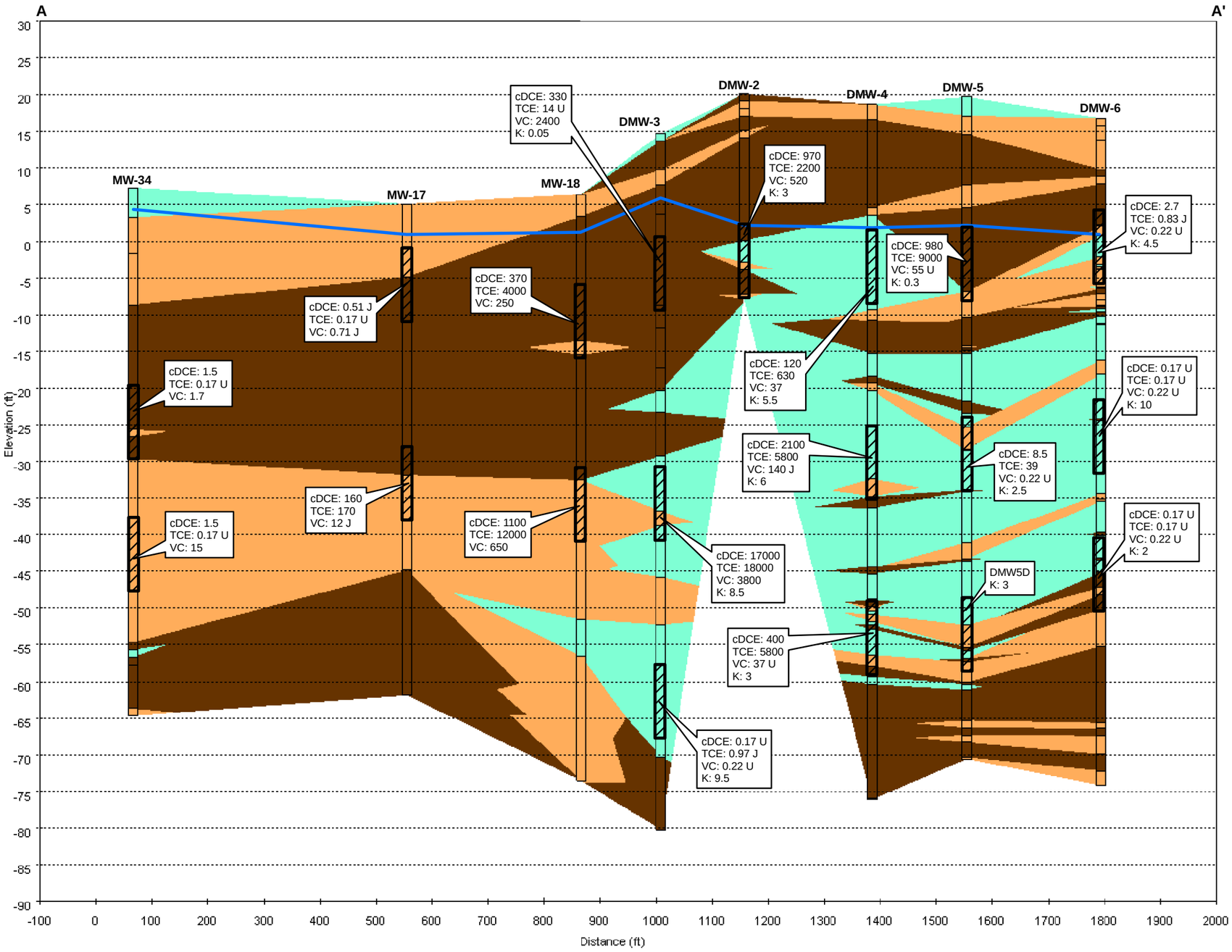

Figure 4-6
Hydrostratigraphic Cross Section
Transect A-A'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)
- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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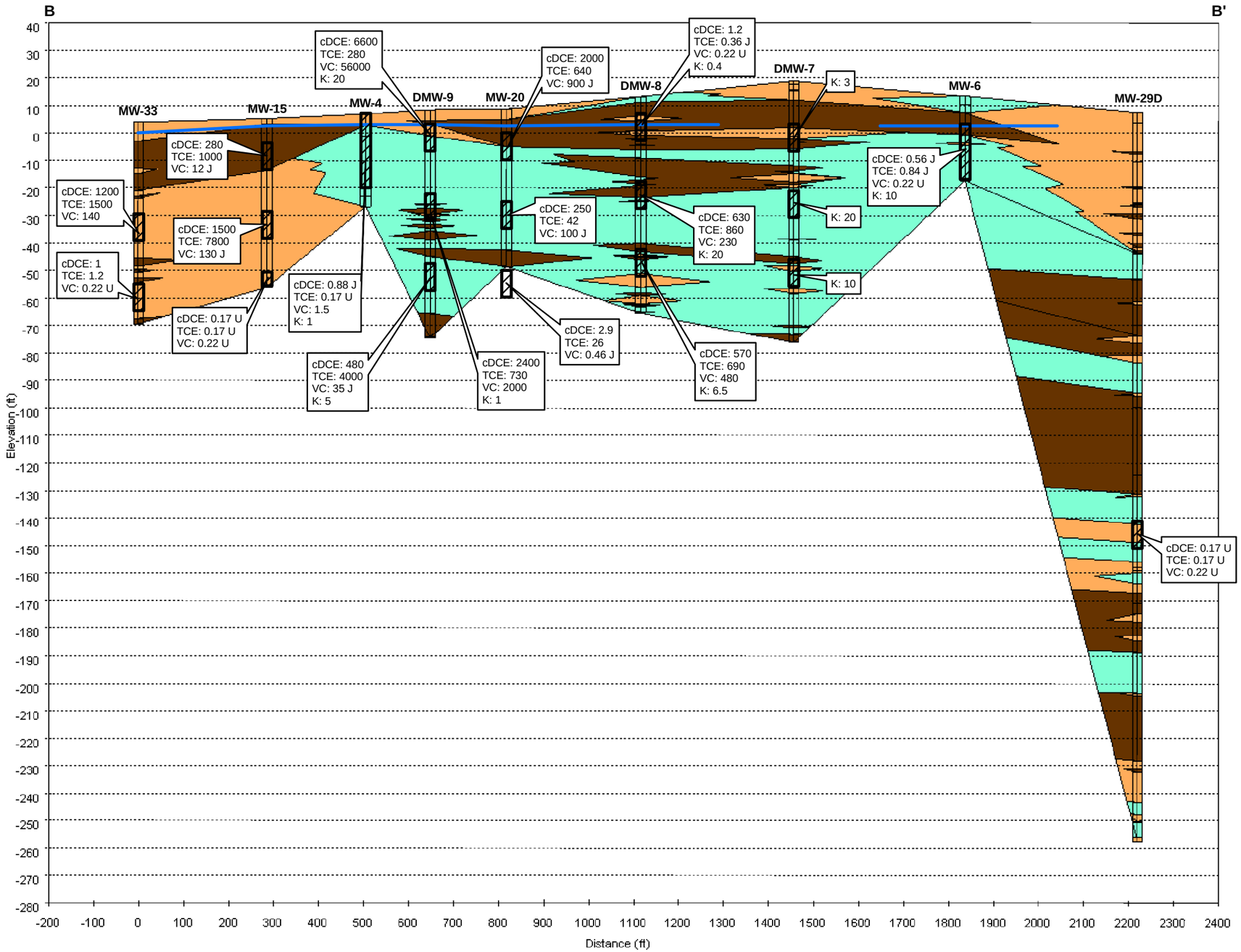

Figure 4-7
Hydrostratigraphic Cross Section
Transect B-B'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)

- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

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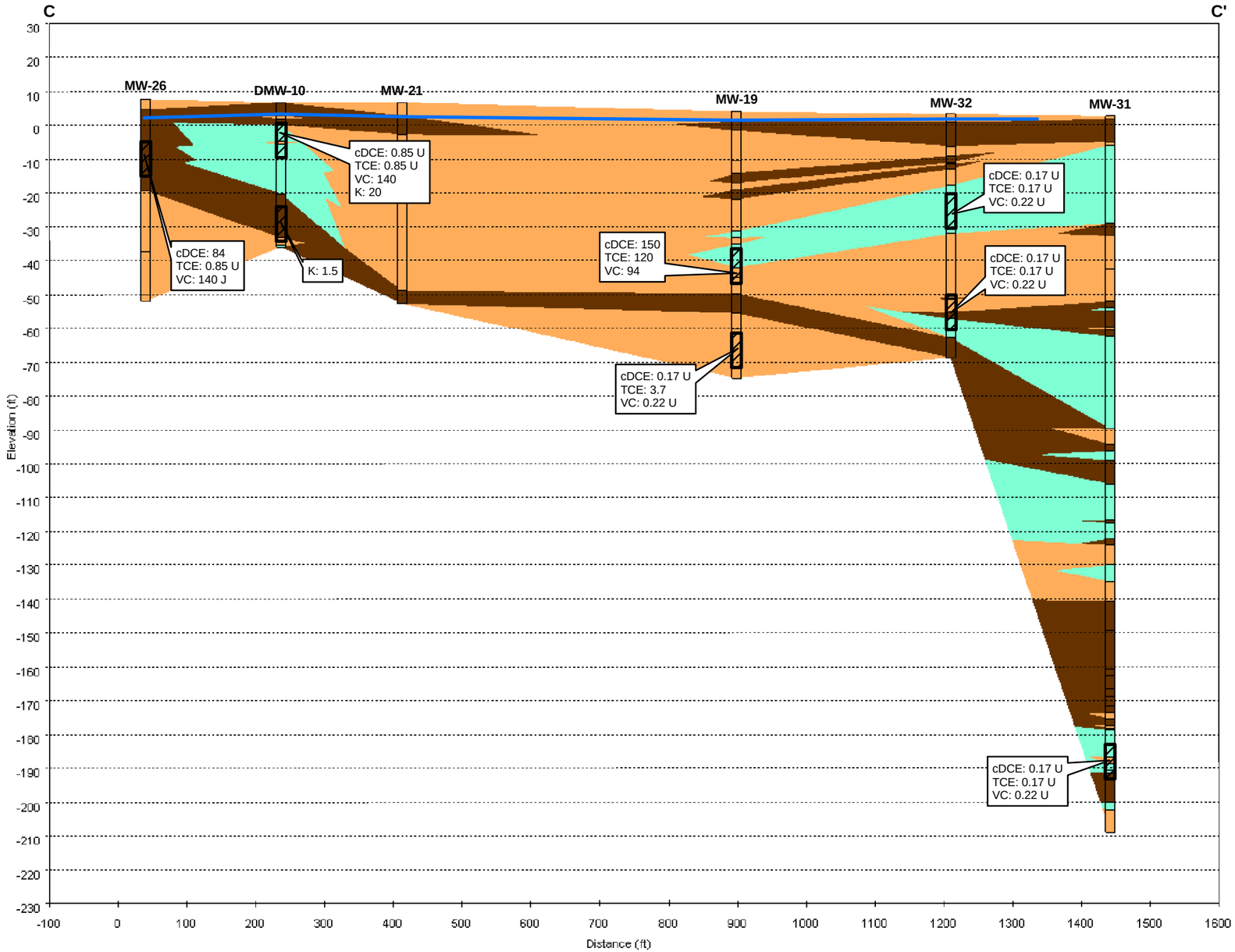

Figure 4-8
Hydrostratigraphic Cross Section
Transect C-C'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)

- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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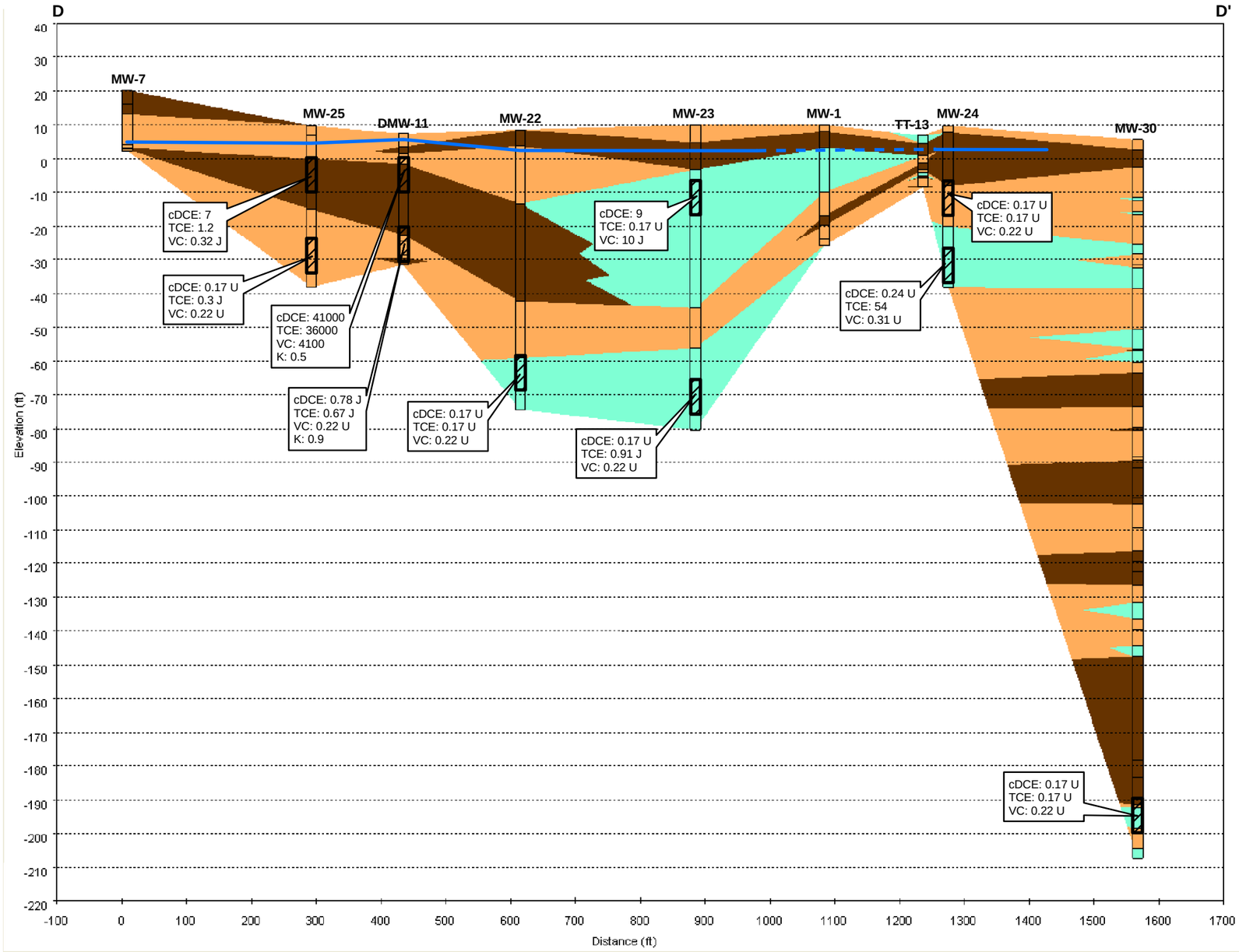

Figure 4-9
Hydrostratigraphic Cross Section
Transect D-D'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface (Dashed Where Inferred)
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)
- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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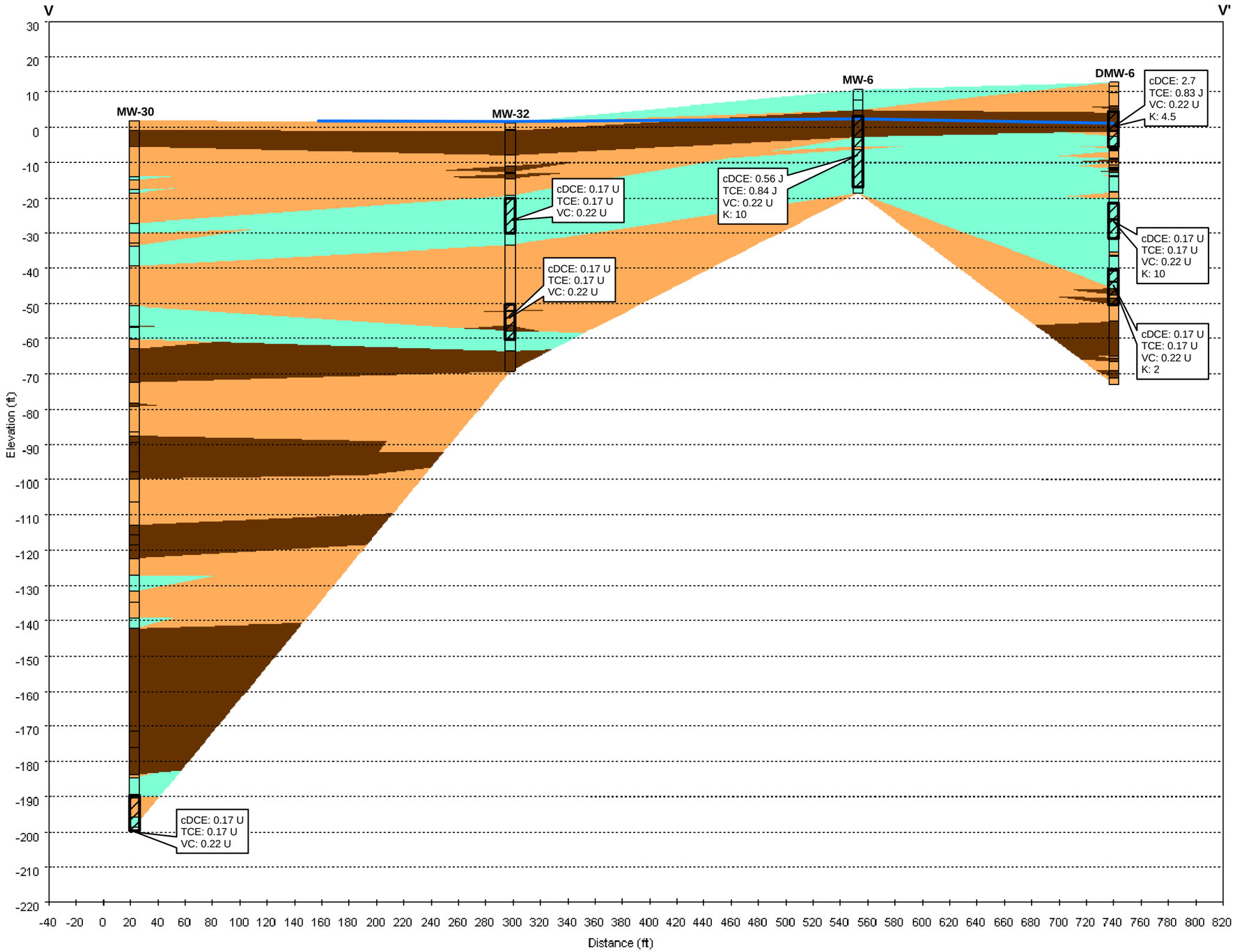

Figure 4-10
Hydrostratigraphic Cross Section
Transect V-V'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)
- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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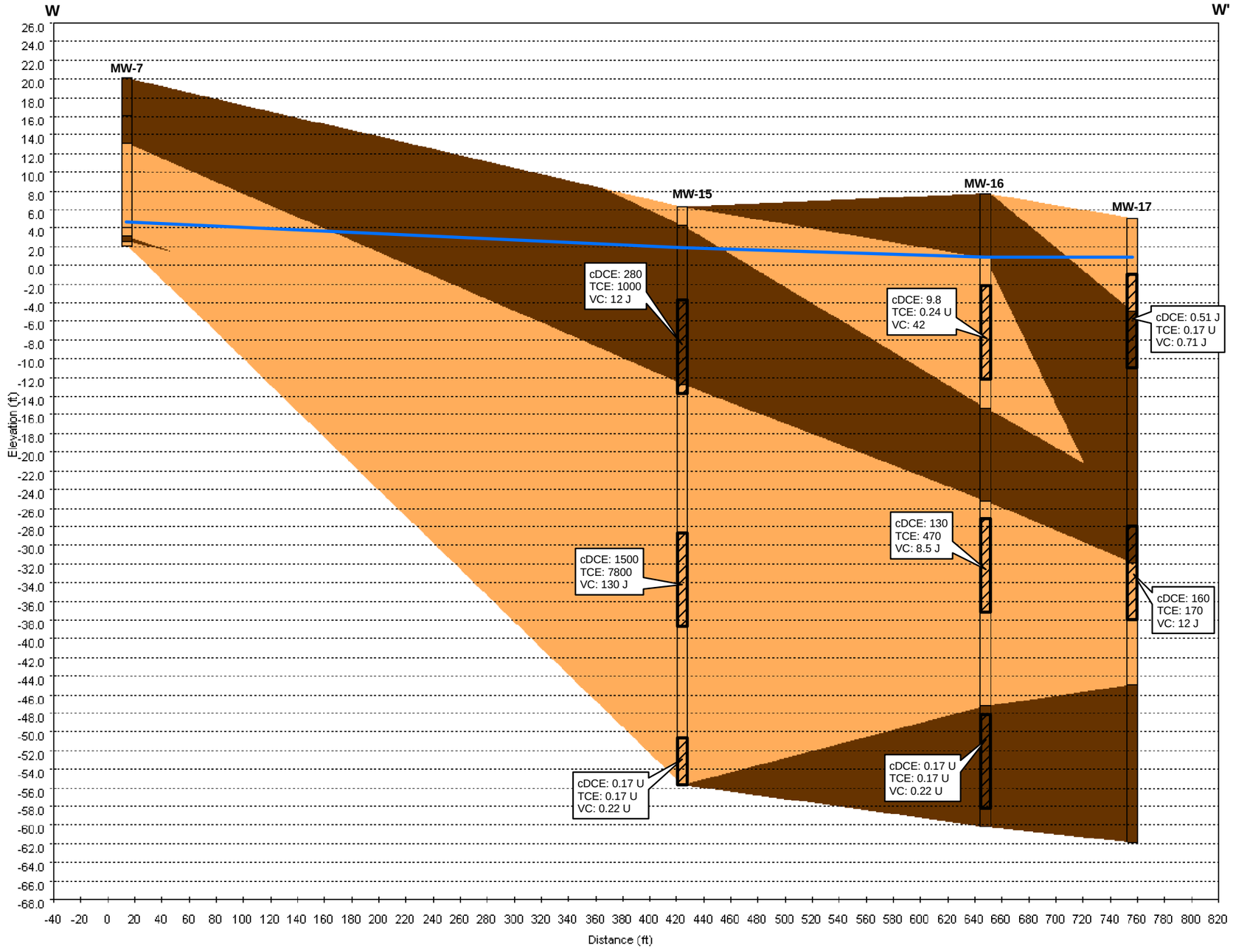

Figure 4-11
Hydrostratigraphic Cross Section
Transect W-W'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)
- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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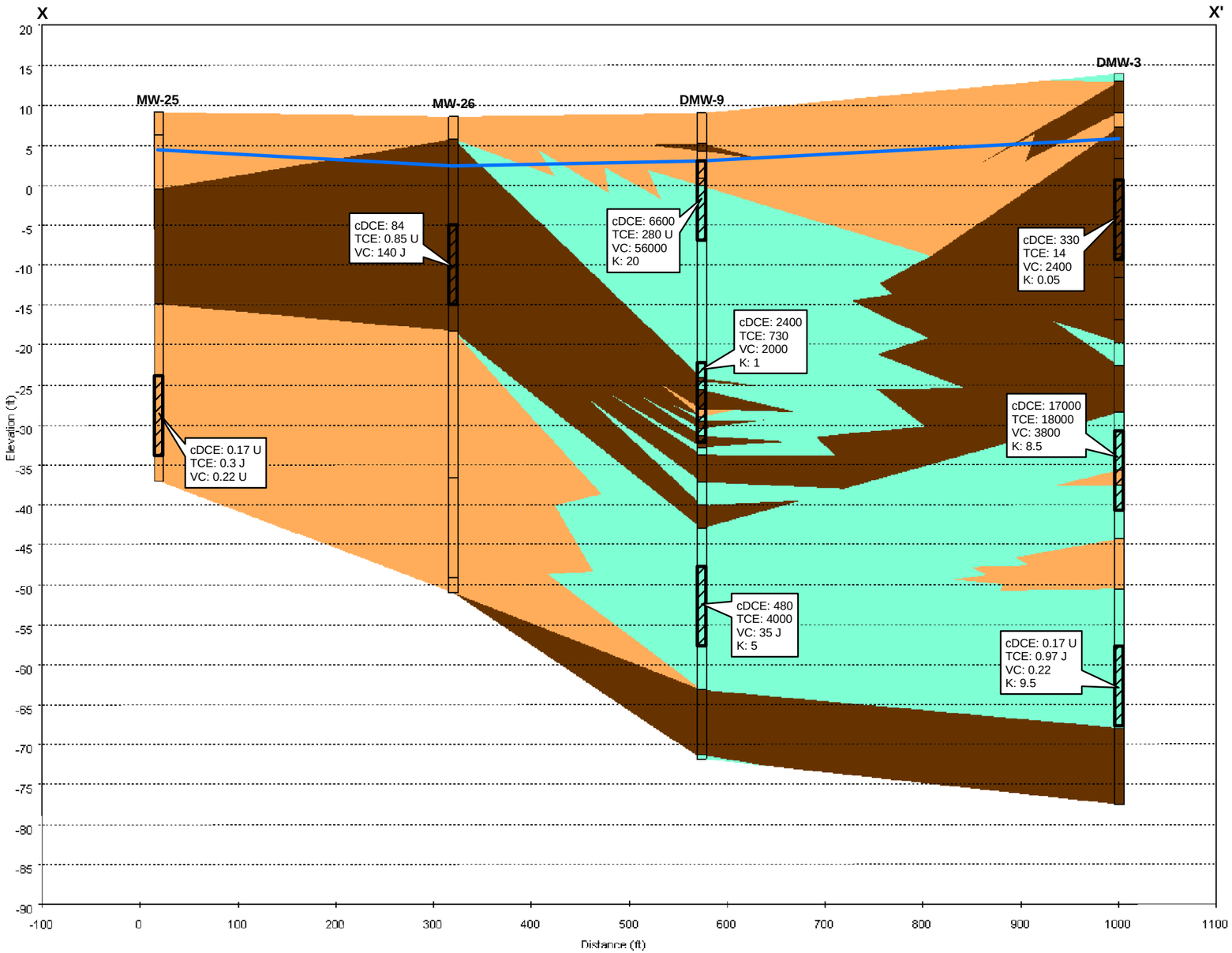

Figure 4-12
Hydrostratigraphic Cross Section
Transect X-X'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)
- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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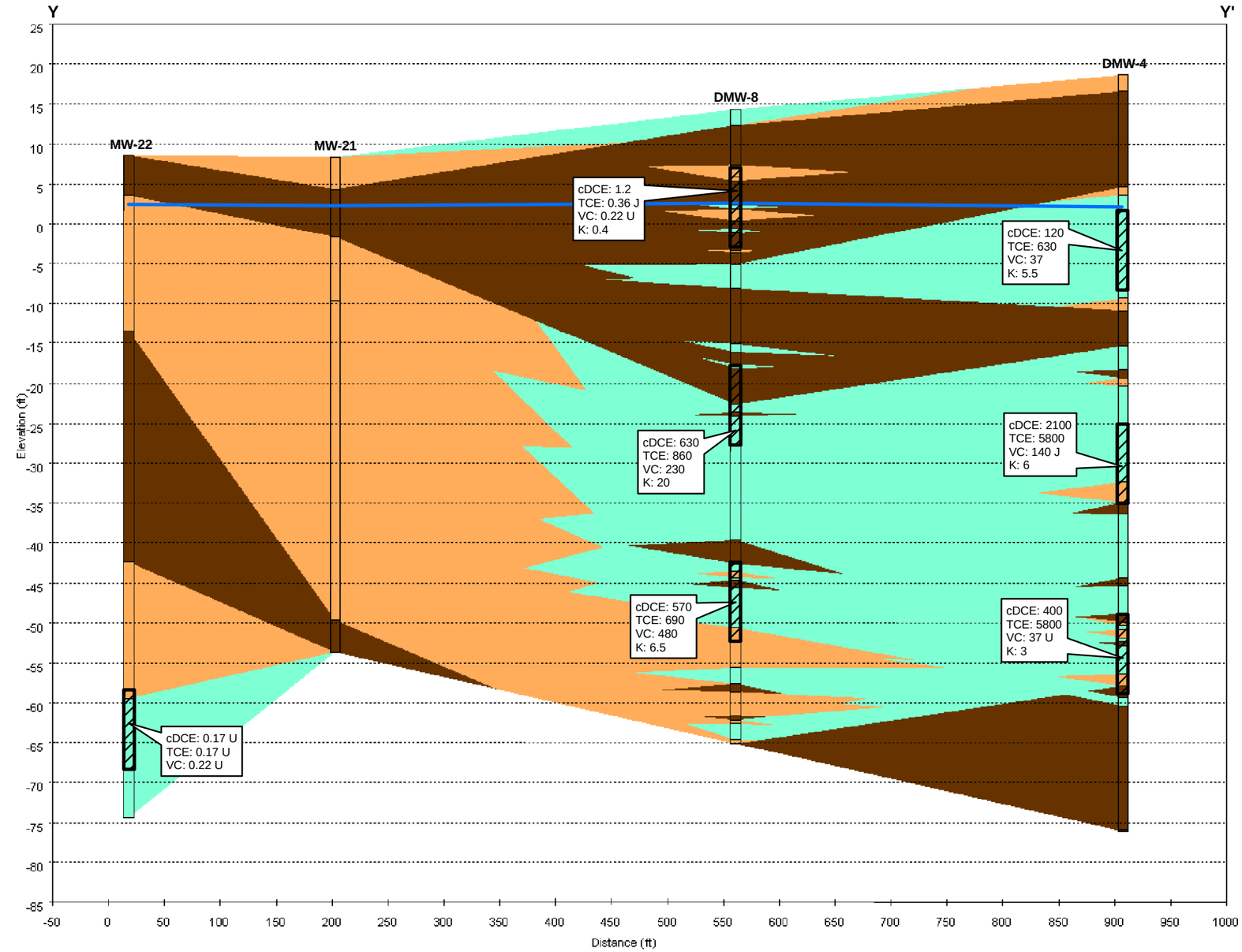

Figure 4-13
Hydrostratigraphic Cross Section
Transect Y-Y'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)

- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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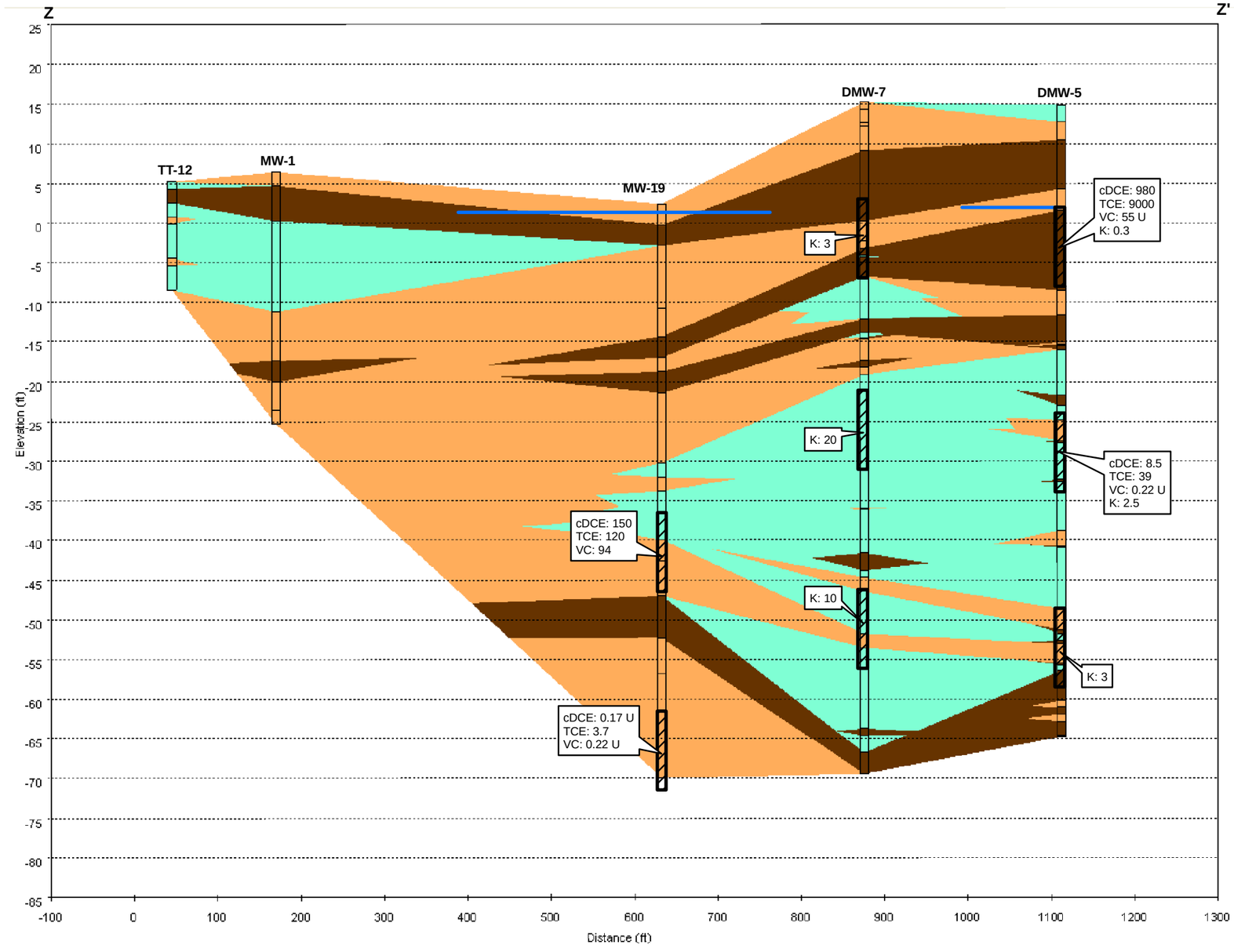

Figure 4-14
Hydrostratigraphic Cross Section
Transect Z-Z'

Legend

- Well Screen
- Soil / Well Boring
- Groundwater Surface
- **K** Hydraulic Conductivity (ft/day)

September 2009 Sampling Results

- **cDCE** cis-1,2-Dichloroethene Concentration (ug/L)
- **TCE** Trichloroethene Concentration (ug/L)
- **VC** Vinyl Chloride Concentration (ug/L)
- **J** Estimated Result
- **U** Result Below Detection Limit

Materials

- Higher Permeability (typically >10 ft/day): Sand and sand & gravel
- Medium Permeability (typically 1-10 ft/day): Mixture of sand, silt, and/or some clay
- Lower Permeability (typically <1 ft/day): Clay and silt & clay

Hydrostratigraphic units were interpreted from lithology information of boring logs and slug test results.

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APPENDIX C
CALCULATIONS OF CONTAMINATED MEDIA QUANTITIES

GROUNDWATER

LOCKHEED MARTIN
MARTIN STATE AIRPORT
DRA SITE FS
CONTAMINATED GROUNDWATER VOLUME AND CONTAMINANT MASS (FROM GW MODEL)
2/10/10

Volume of contaminated groundwater contaminated by each COC. The largest value was used in the text. These volumes over lap and are not additive.

Based on 5 ppb contour.

Compound	Initial Volume (ft3)
TCE	2.8E+07
DCE	2.0E+07
VC	2.3E+07
1,4 Dioxane	1.8E+07

Mass of contaminants, based on 5 ppb contour. 2009 data.

Compound	Initial Mass (lbs)
TCE	6.35E+03
DCE	3.28E+03
VC	5.84E+03
1,4 Dioxane	2.75E+02

Time (Year)	TCE Total Mass (lbs)					
	No Further Action	% dec.	Hydraulic Barrier Pumping Wells	% dec.	High Conc. and Hydraulic Barrier Pumping Wells	% dec.
0	6352		6352		6352	
10	5938	6.5	4621	27.2	4279	32.6
20	5598	11.9	3442	45.8	3138	50.6
30	5249	17.4	2703	57.4	2410	62.1

Notes:

1. TCE Half Life = 5.9 yr
2. TCE Retardation Factor is 6.9

APPENDIX D
SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

Screening of Technologies and Process Options

Information regarding identification, screening, and evaluation of the potential technologies and process options that may be applicable to the remedial alternatives for impacted groundwater in the Dump Road Area (DRA) Site are provided in this section. The primary objective of this phase of the Groundwater Feasibility Study (FS) is to develop an appropriate range of remedial technologies and process options to be used for developing the remedial alternatives. This includes the completion of the following analytical steps:

- Identification and screening of remedial technologies and process options
- Evaluation and selection of representative process options

A variety of technologies and process options are identified under each general response action (GRA) and screened. The screening is first conducted at a preliminary level to focus on relevant technologies and process options, and then the screening is conducted at a more detailed level based on certain evaluation criteria. Finally, process options are selected to represent the technologies that have passed the detailed evaluation and screening.

The evaluation criteria for detailed screening of technologies and process options that have been retained after the preliminary level screening are effectiveness, implementability, and cost. The following are descriptions of these evaluation criteria:

- Effectiveness
    - Protection of human health and the environment; reduction in toxicity, mobility, or volume; and permanence of the solution.
    - Ability of the technology to address the estimated areas or volumes of the contaminated media.
    - Ability of the technology to attain the preliminary remediation goals (PRGs) required to achieve the remedial action objectives (RAOs).

- Technical reliability (innovative versus well-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 (O&M) costs.

D.1 PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

The results of the identification and screening of remediation technologies and process options for groundwater at a preliminary stage based on implementation with respect to site-specific conditions and chemicals of concern (COCs) are provided in this section. The results of this preliminary screening process are summarized in Table 3-1. It presents the GRAs, identifies the technologies and process options, and provides a brief description of each process option followed by comments about the results of the screening process.

The following are the groundwater technologies and process options remaining for detailed screening.

General Response Action	Technology	Process Options
No Action	None	Not applicable
Limited Action	Land Use Controls (LUCs)	Groundwater use restrictions, construction restrictions
	Monitoring	Sampling and analysis
	Monitored Natural Attenuation	Sampling and analysis

General Response Action	Technology	Process Options
Containment	Vertical Barrier (Physical)	Cut-Off Walls, Grout Curtain, Sheet Piling
	Vertical Barrier (Hydraulic)	Extraction Wells
Removal	Groundwater Extraction	Extraction Wells
In-Situ Treatment	Biological	Enhanced bioremediation with an electron-donor compound
	Chemical	Permeable reactive barrier with zero-valent iron
Ex-Situ Treatment	Physical	Filtration
		Air stripping
		Liquid-phase granular activated carbon (GAC) adsorption
		Vapor-phase GAC adsorption
		Vapor-phase potassium permanganate impregnated zeolite adsorption
		Sedimentation
	Chemical	Coagulation/Flocculation
		Neutralization/pH adjustment
		Ion Exchange
		Advanced Oxidation
Disposal	Surface Discharge	Direct surface water discharge
		Indirect discharge to publicly owned treatment works (POTW)
	Subsurface Discharge	Reinjection

D.2 DETAILED SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

D.2.1 No Action

Because the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process is being used in this evaluation, the No Action alternative is being considered. No Action consists of maintaining the status quo at the site. The No Action

alternative is carried through the Groundwater FS to provide a baseline for comparison with other alternatives and their effectiveness in mitigating risks posed by site contaminants.

Effectiveness

No Action would not be effective in meeting the RAOs. Potential contaminant reduction through natural attenuation could not be evaluated, and off-site migration would not be monitored.

Implementability

There would be no implementability concerns because no action would be implemented.

Cost

There would be no costs associated with the No Action alternative.

Conclusion

No Action is retained because of National Oil and Hazardous Substances Pollution Contingency Plan (NCP) requirements, although it would not be effective.

D.2.2 Limited Action

The technologies considered under this GRA are LUCs, monitoring, and natural attenuation.

D.2.2.1 Land Use Controls

Land use controls (LUCs) would be developed through the implementation of a LUC Remedial Design (RD) to prevent the site and groundwater from being used in the future for purposes that are not consistent with the residual risk after implementation of the final remedy. Deed restrictions would be required to prevent the land from being developed and the groundwater from being used for potable purposes. Signage would be required to indicate the restrictions identified in the LUCs and to show the boundaries of the contamination. Environmental LUCs would be developed to meet the groundwater RAOs. Because the site is an airport, access is severely restricted.

Note that because of the presence of elevated concentrations of volatile organic compounds (VOCs) in groundwater, LUCs that place restrictions on construction of buildings over the plume would also be required. The restrictions would require special construction methods such as vented foundations for buildings to control vapor intrusion.

Effectiveness

Groundwater use restrictions would be effective in combination with source control activities. These controls would minimize potential human health risks associated with exposure to contaminated groundwater. Routine site inspections would be required to confirm that LUCs are being followed. Because of the long time required for natural attenuation and the potential for off-site migration, a LUCs-only alternative would not be feasible.

Implementability

Land use controls would be readily implementable. Resources are readily available for the preparation of deed restrictions.

Cost

Costs of LUCs would be low.

Conclusion

Land use controls are retained in combination with other process options for the development of groundwater remedial alternatives.

D.2.2.2 Monitoring

Sampling and analysis of groundwater would be used to evaluate migration of COCs. Monitoring would also be used to monitor potential natural attenuation or the progress of active groundwater remediation.

Effectiveness

Monitoring would not of itself reduce the toxicity, mobility, or volume of COCs in groundwater, but it would allow the observation and evaluation of potential migration of COCs and the reductions in their concentrations through natural attenuation or active remediation.

Implementability

A groundwater monitoring program could be readily implemented and is routinely performed at other sites. Monitoring well installation would need to comply with state and local regulations.

Cost

Capital and O&M costs of monitoring would be low.

Conclusion

Monitoring is retained in combination with other process options for the development of groundwater remedial alternatives.

D.2.2.3 Monitored Natural Attenuation

Monitored natural attenuation (MNA) would consist of monitoring groundwater quality to determine the extent to which naturally occurring processes such as biodegradation, abiotic transformation, dispersion, and dilution would reduce concentrations of COCs over time. For this purpose, new monitoring wells would be installed. In the chlorinated volatile organic compound (cVOC) plume, samples from new and existing wells would be regularly collected and analyzed for natural attenuation parameters such as oxidation-reduction potential (ORP), dissolved oxygen (DO), pH, alkalinity, temperature, conductivity, total organic carbon (TOC), ferrous and total iron, sulfur compounds (sulfide and sulfate), nitrogen compounds (nitrite and nitrate), orthophosphate, chloride, and metabolic gases (methane, ethane, ethene, and carbon dioxide), as well as for the cVOCs themselves.

Natural attenuation processes may also affect concentrations of inorganic contaminants. Dispersion and dilution would reduce concentrations over time. As metals migrate to zones with different geochemistry, metals may precipitate or sorb onto soil particles.

In the 2009 annual sampling event (Tetra Tech, 2010a), groundwater samples were collected from six wells and analyzed to evaluate whether anaerobic reductive dechlorination of cVOCs was occurring at the site and whether site conditions could be enhanced by adding electron-donor and/or pH adjustment to stimulate anaerobic reductive dechlorination. Evidence indicated that slow or incomplete reductive dechlorination of lower order cVOCs may be occurring in the lower surficial aquifer zone.

Effectiveness

Naturally occurring processes could reduce low concentrations of trichloroethene (TCE) and other organic contaminants in groundwater over the long term. Based on the results of samples collected during previous investigations, natural anaerobic reductive dechlorination is occurring at the site but not to a significant degree. Monitored natural attenuation may be applied at the fringe area of a plume where concentrations are low and suspected source areas are controlled or no longer migrating toward this area. More typically, MNA is applied after suspected source areas have been removed and residual cVOC groundwater concentrations are less than 100 µg/l.

Groundwater monitoring would provide an effective means of evaluating the concentrations of COCs in groundwater and of assessing the rate of decrease of these concentrations. Monitoring of indicator parameters would be used to evaluate the potential effectiveness of the reductive dechlorination process.

Implementability

Monitored natural attenuation would be easy to implement. Monitoring groundwater quality and periodically reviewing site conditions could readily be performed, and the necessary resources are available to provide these services.

Cost

Capital and O&M costs for MNA would be low.

Conclusion

Because of the relatively high concentrations of COCs, MNA is not anticipated to be effective and will not be a significant component for any of the alternatives. Changes in contaminant concentrations and the effects of natural attenuation will be observed coincidentally as part of the long-term monitoring program for the site. Monitored natural attenuation is eliminated as a specific process option for the development of groundwater remedial alternatives.

D.2.3 Containment

The only technologies retained for this GRA are physical vertical barriers and hydraulic barriers.

D.2.3.1 Physical Barriers

Low permeability vertical barriers include cut-off walls, grout curtains, and sheet piles that are used to minimize the horizontal migration of contaminants, especially in the saturated zone. These barriers are placed around wastes or contaminated areas. Low permeability vertical barriers extend from the ground surface to at least the bottom depth of the contamination or to the confining layer of the aquifer. The type of barrier selected depends on site-specific conditions. To be most effective, a barrier generally needs to be "keyed" 2 to 3 feet into a low permeability layer, such as clay or bedrock.

Conventional cut-off walls are most often constructed using the slurry trenching method. This is a two-step process. First, a hydraulic excavator or clamshell excavates soil, forming a trench with sidewalls supported by the weight of a bentonite slurry. Excavated or imported soil with low permeability is then mixed with bentonite slurry outside of the trench to form a low permeability soil/bentonite mixture to be used in the trench as backfill material. The soil/bentonite backfill is typically pushed into the bentonite slurry filled trench to displace the bentonite slurry thus forming the soil/bentonite vertical cut-off wall. Alternatively, Portland cement may be mixed with the bentonite slurry if a higher strength is required and greater permeability is acceptable. Walls are generally 2 to 4 feet thick and installed to depths of 50 feet or less with a hydraulic excavator and to depths greater than 50 feet with a clamshell.

Grout curtains are installed by pressure injection of grout composed of Portland cement and bentonite. The injection creates a column of grout and columns are injected side by side and overlapped or are spaced closely to create a continuous wall. Grout curtains can readily be installed to depths of 100 feet and depths of 200 feet have even been installed. Grout curtains may be installed by methods such as deep soil mixing using augers and pressure grouting.

Sheet piling of steel or plastic can be installed by driving or vibrating methods, depending on the soil conditions. Individual sheets have interlocking joints on each side that fit into the adjoining sheet. The joints are sealed with hydrophilic rubber, grout, or polymer, but are subject to leakage. Steel sheet pile is subject to corrosion. The maximum sheet piling installation depth is 70 to 80 feet.

Effectiveness

The use of low permeability vertical barriers is effective in controlling the horizontal migration of contaminants. Cut-off walls are more commonly used than grout curtains and sheet piling. The geotechnical properties of the backfill material must be considered in the design of a physical barrier. Barriers are most effective when keyed into a confining layer. The required service life of the barrier must be considered during design. Long service lives will require a thicker or lower permeability barrier.

Although the barrier prevents migration of contaminants, additional technologies are usually required to treat the groundwater behind the barrier and maintain the groundwater level to minimize the gradient across the barrier.

Implementability

The use of low permeability vertical barriers could cause an increase in groundwater elevations upgradient of the barrier. Maintenance of the integrity of low permeability vertical barriers is difficult over the long term, and groundwater monitoring may be required to ensure that the barrier remains effective. An excessive depth to the confining layer may cause problems with constructability. The depth to the Arundel clay varies from 80 to 100 feet. This depth is greater than the typical maximum depth for cut-off walls constructed using hydraulic excavators and

may exceed the limit for driven sheet piles. Specialty equipment such as a clamshell may be required for construction of a low permeability barrier installed to this depth.

Because of high concentrations of COCs in the groundwater in the vicinity of a proposed barrier, some of the excavated soil and groundwater could be classified as Toxicity Characteristic Leaching Procedure (TCLP) hazardous waste, which would require managing the waste according to hazardous waste regulations.

Cost

A physical barrier was modeled to evaluate the level of groundwater extraction that would be required compared to the level of groundwater extraction needed for a hydraulic barrier (see Section D.2.3.2). The model results show that the pumping rate would be similar to the rate needed for a hydraulic barrier, and a groundwater treatment system would be essentially the same size for both cases. Thus, the cost of a physical barrier alternative would be much higher than the cost of a similar hydraulic barrier alternative because of the additional cost of the physical barrier. The groundwater model results are included in Appendix B.

The costs are high for cut-off walls, sheet piling, and grout curtains. Long-term O&M costs are low.

Conclusion

Cut-off walls, grout curtains, and sheet piles will be eliminated primarily because they would not be effective as there is no cost benefit for a physical barrier compared to a hydraulic barrier. In addition, sheet piles may not be implementable to the presumed installation depth due to subsurface obstructions, such as buried debris.

D.2.3.2 Hydraulic Barrier

Hydraulic barriers use groundwater extraction composed of a series of wells that are used to intercept and extract contaminated groundwater at the leading edge of the plume. The wells used in the hydraulic capture system are designed and located to provide optimum efficiency in attaining hydraulic containment of the contaminant plume. Extraction wells are further described below in Section D.2.4.1.

Effectiveness

Groundwater extraction is a well-established and well-proven technology for the containment of groundwater contaminant plumes. This technology is reliable and minimal effects on human health and the environment would be expected during implementation. The extraction system and related components must be operated and maintained until the site groundwater contaminant concentrations have met PRGs. Modeling was conducted to determine the number, depth, and placement of monitoring wells (see Appendix B).

Although the hydraulic barrier prevents migration of contaminants, additional technologies are required to treat the extracted groundwater.

Implementability

This technology uses readily available equipment and techniques and has been widely used in remedial actions. Implementation of this technology would require long term operation and maintenance. Maintenance would require periodic replacement of mechanical components and well inspections. Local and state permits might be required for installation of additional extraction wells.

Concentrations of TCE and vinyl chloride are greater than the TCLP leachate criteria, so untreated groundwater must be managed as a hazardous waste. Treatment of groundwater in a system that conforms to the requirements of a Resource Conservation and Recovery Act (RCRA) wastewater treatment unit can also be performed to exclude the system from RCRA permitting requirements.

Cost

Capital and O&M costs for groundwater extraction would be moderate, depending on the extent of the contaminant plume and aquifer characteristics.

Conclusion

Plume containment through groundwater extraction is retained in combination with other process options for the development of remedial alternatives.

D.2.4 Removal

The only technology and process option for groundwater removal considered under this GRA is groundwater extraction with wells.

D.2.4.1 Extraction Wells

Wells would be installed in the surficial aquifer and screened below the water table to access the groundwater. Pumping would be used to extract the water as it collects in the wells and bring it to the surface. The process of extraction would create a hydraulic gradient that would induce flow of groundwater into the well. For hydraulic containment, extraction wells would be placed in the path of migration of a contaminant plume to intercept and contain the plume. Extraction wells placed within the contaminated plume could be used to clean the aquifer by removing the contaminated groundwater and flushing the saturated zone. The flushing action would occur when water from upgradient (clean) areas (or from reinjection) replaces the extracted contaminated groundwater and causes more contaminants to desorb from saturated zone soil. Thus, theoretically, the saturated zone soil would progressively lose contaminants until the concentrations in groundwater are at acceptable levels. The selection of the appropriate well system depends on the depth of contamination and the hydrologic and geologic characteristics of the aquifer.

Vertical extraction wells are commonly used. Wells are screened within the contaminated zone, and multiple wells are installed to capture or intercept the plume. The number of wells needed to capture or intercept a plume is a function of the characteristics of the aquifer, such as hydraulic conductivity, aquifer thickness, and the width of the plume.

Horizontal wells can also be installed through the contaminated zone to capture or intercept the plume. A single, long horizontal well can often be used to capture or intercept a plume. Horizontal wells are often used where surface structures, such as buildings or roads prevent the installation of vertical wells. As with vertical wells, the effectiveness of a horizontal well depends on the characteristics of the aquifer.

Extraction pumps are typically submersible, electrically operated, centrifugal pumps or pneumatically operated ejector pumps. For shallow groundwater extraction (depths up to 10

feet), surface pumps may be used. Centrifugal pumps are not practical for use at low extraction rates, less than 1 gallon per minute (gpm), and in such cases, pneumatic ejector pumps are preferred.

Effectiveness

Extraction wells could be effective for intercepting and containing the migration of contaminant plumes and extracting the groundwater from the high concentration areas such as the plumes at the DRA Site. The locations and screening depths of the wells are important criteria that must be taken into consideration in achieving adequate capture of the contaminant plume. Extraction wells are a well-established and well-proven technology for the removal of contaminated groundwater and the containment of groundwater contaminant plumes. Although the initial effectiveness of this technology for contaminant mass capture is high, it has often been shown to decrease over time. This decrease is generally due to one or more factors, including the presence of preferential flow pathways due to aquifer heterogeneity, contaminant adsorption to aquifer materials, diffusion of contaminants into the pore spaces of low permeability materials, and creation of stagnation zones due to pumping operations. This technology is reliable, and minimal effects on human health and the environment would be expected during implementation.

The concentrations of contaminants in groundwater in plumes being treated with extraction systems often reach a steady-state concentration greater than the target goal, typically a Maximum Contaminant Level (MCL).

Because horizontal wells consist of one long continuous screen, variations in permeability of the aquifer cannot be easily accommodated. Because horizontal wells are generally parallel to bedding planes, they are less effective in heterogeneous formations. Conversely, with a line of vertical wells, the extraction rate from each well can be adjusted as needed to account for different contaminant concentrations and/or well yield.

Implementability

Vertical extraction wells are relatively easy to install, while horizontal wells are more difficult to install and require specialized equipment. Pumps are widely available for a variety of flow rates and aquifer conditions. Implementation of this technology would require long-term O&M. Well

screens would require regular inspection and well flushing to remove fine-grained material that may clog the wells. Pumps would also require regular preventive maintenance. Installation of extraction wells would need to comply with state and location regulations. Extracted groundwater would require treatment prior to disposal/discharge. Placement of vertical wells and piping may interfere with current or future site operations. Horizontal wells are less likely to interfere with future site use.

Concentrations of TCE and vinyl chloride are greater than the TCLP leachate criteria, so untreated groundwater must be handled as a hazardous waste.

Cost

The capital and O&M costs of extraction wells are low although the costs of the treatment plant are high, especially considering the variety of COCs and their differing treatment processes. The costs of horizontal wells are typically higher than the costs of vertical wells.

Conclusion

Because the groundwater plume will be contained, extraction wells are retained for the development of groundwater remedial alternatives. Due to the heterogeneity of the site, only vertical wells will be considered to accommodate potential differences in hydraulic conductivity and allow for changes in extraction rates. Multiple vertical extraction wells will also allow for variation in pumping, improving capture of groundwater with the highest levels of contamination.

D.2.5 In-Situ Treatment

The technologies considered under this GRA are enhanced bioremediation of the high concentration areas (HCAs) and permeable reactive barriers (PRBs).

D.2.5.1 In-Situ Enhanced Bioremediation

In-situ enhanced bioremediation involves the use of microorganisms, primarily bacteria, actinomycetes, and fungi, to breakdown hazardous organic compounds into nontoxic or less toxic forms. In-situ enhanced bioremediation includes biostimulation and bioaugmentation.

Biostimulation consists of using an electron-donor compound to cause anaerobic reductive dechlorination or an oxygen-release compound (ORC®) to enhance aerobic processes and the growth of indigenous microorganisms and natural biodegradation processes. Anaerobic and aerobic processes can be applied in sequence, such as applying an anaerobic process in the source area and then promoting aerobic conditions downgradient. Bioaugmentation consists of using a bacterial culture to increase the naturally occurring microorganism population and to provide organisms specifically targeted to the degradation of COCs.

For the DRA Site, in-situ biostimulation would consist of an electron-donor compound such as a lactate or emulsified oil substrate (EOS) to enhance the anaerobic dechlorination of TCE and other cVOCs. The TCE can be transformed to ethene, carbon dioxide, chloride, and water through anaerobic biological process.

In-situ bioaugmentation could consist of injecting a specialized bacterial culture, such as *Dehalococcoides* (DHC), to enhance the dechlorination of TCE if indigenous microorganisms are not sufficient.

The electron-donor compound and/or bacterial culture would be injected into the VOC plumes using multiple direct push technology (DPT) injection points or permanent injection wells. Injection via DPT is simple to implement and can be used over large areas.

Effectiveness

Biostimulation with an electron-donor compound and bioaugmentation with the use of DHC are fairly well-proven technologies for the complete dechlorination of non-degraded chlorinated solvents (e.g., TCE) from groundwater. The effectiveness of these technologies, particularly in cases of very high contaminant concentrations, still typically needs to be demonstrated through site-specific treatability testing.

Implementability

In-situ enhanced bioremediation could be implemented at the DRA Site. Many qualified contractors would be available for the implementation of this technology. Because of the relatively large surface area and considerable plume depth, application of an electron-donor

compound and bacterial culture would best be accomplished through DPT injection. Placement of future injection points may interfere with future site uses.

Cost

Capital and O&M costs for in-situ enhanced bioremediation would be moderate to high.

Conclusion

In-situ enhanced bioremediation is retained in combination with other processes options for the development of groundwater remedial alternatives.

D.2.5.2 Permeable Reactive Barriers

Permeable reactive barriers involve emplacement of reactive materials in the subsurface to intercept a contaminant plume, provide a flow path through the reactive media, and transform the contaminant(s) into environmentally acceptable forms in order to attain PRGs downgradient of the barrier. Barriers can be constructed with materials that remove contaminants through chemical reactions or with materials that promote degradation of organics through biological activity.

Permeable reactive barriers have been used to treat a wide range of groundwater contaminants, including cVOCs and non-cVOCs such as benzene, toluene, ethybenzene and xylenes (BTEX), and inorganics such as hexavalent chromium. Iron metal [zero valent-iron (ZVI)] is the most common reactive medium used in PRBs for the treatment of cVOCs such as TCE. For barriers that promote biological degradation, organic materials that provide electron donors for an extended period of time, such as mulch or emulsified oil, are used.

Permeable reactive barriers using ZVI are generally built in two basic configurations: funnel-and-gate and continuous. The funnel-and-gate PRB uses impermeable walls (sheet pilings, slurry walls, etc.) as a “funnel” to direct the contaminant plume into a “gate” containing the reactive media, whereas the continuous PRB completely intercepts the plume flow path with reactive media. Because PRBs are not designed to contain groundwater movement, but to intercept groundwater contaminants, the permeability of the reactive medium must be at least equal to or greater than the permeability of the surrounding aquifer to avoid diversion of the groundwater

flow path. This is particularly necessary with the funnel-and-gate design where the cross-section of the permeable zones is restricted. Because the emplacement of reactive material generally requires excavation, both types of PRBs have typically been limited to relatively shallow depths of approximately 50 feet bgs. However, the use of alternative technologies, such as slurry injection and hydrofracturing, may help to overcome some of these emplacement limitations.

For deep barrier emplacements, such as necessary at the DRA Site, PRBs using emulsified oil electron donor substrate would be installed using injection techniques. Emulsified oil substrate material must typically be replaced at intervals of 5 years, so if multiple injections are anticipated, then permanent injection wells must be installed. To provide good distribution of the substrate, injection well screen lengths are usually limited to 10 feet.

Placement of PRBs must consider both groundwater and contaminant velocity and lifespan of the reactive material in the PRB. For this site, a single PRB located near the banks of Frog Mortar Creek would be used. A ZVI PRB would need to be replaced at 15 year intervals, and the electron donor substrate barriers would need to be replaced at 5 year intervals. Because of the relatively slow plume velocity, approximately 55 to 460 years would be required for the contaminants to flow through the barriers (see Section 4.2.6 of the FS for additional details).

Effectiveness

A ZVI PRB would be effective for the in-situ treatment of TCE and other chlorinated organic compounds. Some metal removal may also occur. Petroleum hydrocarbons and 1,4-dioxane would not be affected by the ZVI. The barrier may plug over time; therefore, the duration of the effectiveness of the ZVI is difficult to predict.

An electron donor (ED) substrate PRB would be effective for the in-situ treatment of TCE and other chlorinated organic compounds, although the degradation of TCE to ethene may not be complete. Some metal removal is likely, primarily because of reducing conditions. Petroleum hydrocarbons and 1,4-dioxane would probably not be affected by the ED. Because of the slow groundwater velocity, multiple injections will be needed.

Implementability

Installation of a ZVI PRB would be difficult because of the depth of the aquifer to be treated. Installation methods would be similar to those for a physical barrier except that a biodegradable polymer would be used to stabilize the trench. A large quantity of waste material will be generated. Alternative methods of installations, such as high-pressure jetting or deep soil mixing may need to be considered. The number of competent contractors available to implement these specialized techniques would also be relatively limited.

Installation of an ED barrier would be simpler using conventional well installation techniques and slurry injection equipment. Multiple well clusters would be required to provide full depth coverage and ED distribution.

Once installed, the O&M requirements of PRBs would be minimal and would be essentially limited to the monitoring of groundwater quality to verify performance with routine inspections to verify continued integrity of the structure. However, periodic replacement of the ZVI and ED would be required.

Because of the high concentrations of COCs in the groundwater in the vicinity of a proposed barrier, some of the excavated soil and groundwater would be classified as TCLP hazardous waste and would have to be managed as a hazardous waste.

Cost

Capital cost of installation of deep PRBs would be high. O&M costs would be low.

Conclusion

Zero-valent iron PRBs are retained for the development of groundwater remedial alternatives. Because the TCE may not be completely degraded and there may be multiple injections required, ED PRBs are eliminated from further consideration.

D.2.6 Ex-Situ Treatment

The technologies and process options considered under this GRA include filtration, air stripping, liquid-phase granular activated carbon (GAC) adsorption, vapor-phase GAC adsorption,

vapor phase potassium permanganate impregnated zeolite (PPZ), sedimentation, coagulation/flocculation, neutralization/pH adjustment, ion exchange, and advanced oxidation.

D.2.6.1 Filtration

Filtration uses a porous medium to remove solid particles from a liquid or gas. This technology is generally used as a groundwater pretreatment to remove suspended material before other treatment processes and/or for the final cleaning or polishing of treated effluent to remove metals that are sorbed to suspended solids.

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 enhanced by pressure on the inlet side or by drawing a vacuum on the filter outlet.

Most types of liquid filters, except those utilizing 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. Disposable filters would be disposed at an off-site landfill.

Effectiveness

Filtration is a very well-proven technology for the removal of fines from groundwater that might otherwise undermine the efficiency of downstream treatment technologies such as liquid-phase GAC adsorption and for meeting low cleanup goals that could be affected by metals concentrations associated with suspended solids.

Implementability

Filtration would be readily implementable. Treatment 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 low.

Conclusion

Filtration is retained for the development of groundwater remedial alternatives in combination with other process options for the development of groundwater remedial alternatives.

D.2.6.2 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-liter per mole (atm-L/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. However, air stripping is not very effective for the removal of 1,4-dioxane.

A countercurrent packed tower or 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. In packed towers, loosely fitted packing material serves to increase the air/water interface area to provide maximum mass transfer. In tray towers, water flows down through a tower equipped with perforated trays that allow air to pass upward through the water. Key factors that influence process performance include air-to-water ratio, height of packing and type of packing material, number of trays, operating temperature, surface hydraulic loading, and contact time.

Effectiveness

Air stripping is a well-proven and reliable technology that would be effective for removing TCE and other VOCs from the DRA Site groundwater, but 1,4-dioxane and metals cannot be removed by this process. Removal efficiencies greater than 99 percent could theoretically be achieved for the cVOCs. Because air stripping only removes the contaminants from the water and concentrates them in an exhaust gas, this gas would have to be further treated to meet air

discharge regulations prior to release to the atmosphere by such means as vapor-phase GAC adsorption, catalytic oxidation, or thermal destruction.

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 packing material. Typical causes of clogging include suspended solids, and iron concentrations, and slightly soluble salts such as calcium carbonate.

Cost

Capital cost for air stripping would be low. O&M costs would be low to moderate depending on influent contaminant concentrations and the degree of removal required.

Conclusion

Air stripping is retained for the development of groundwater remedial alternatives in combination with other process options for the development of groundwater remedial alternatives. Because 1,4-dioxane is not removed by air stripping, an additional process would be needed.

D.2.6.3 Liquid-Phase Granular Activated Carbon Adsorption

Granular activated carbon is a frequently applied technology for the removal of contaminants from water. Liquid-phase GAC adsorption is principally used for removal of organic compounds and is more effective for less polar and less soluble compounds. Liquid-phase 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 contaminated groundwater passes 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 spent GAC must then either be regenerated or disposed.

Typical GAC adsorption treatment systems include atmospheric or pressurized columns operating in series and/or parallel configuration. Liquid-phase GAC columns are typically designed with backwashing capability to minimize solids fouling that would increase GAC replacement frequency. Factors such as pH and temperature of the influent, empty bed contact time (EBCT), surface area to volume ratio of the activated carbon, and solubility of the organic compound will affect the carbon adsorption process.

Effectiveness

Liquid-phase GAC adsorption is a well-proven reliable technology that would be effective for removing of many organic compounds, including TCE. However, GAC does not effectively remove 1,4-dioxane. Treatability testing might be required to confirm GAC adsorption efficiency. Because of the relatively high costs of GAC replacement, a preceding process, such as air stripping or advanced oxidation, is typically used to remove cVOCs to a very low level, so GAC would be used as a polishing step.

Implementability

Liquid-phase GAC adsorption would be readily implementable. Treatment systems are commercially available from a wide variety of manufacturers and can be readily ordered to almost any specification. There are a sufficient number of qualified vendors that provide GAC adsorption units. As previously mentioned, it is anticipated that pretreatment with filtration would be required. As it becomes saturated, GAC would have to be periodically replaced, and the spent GAC would have to be disposed. Treatability testing might be required to determine the anticipated frequency of GAC replacement.

Cost

The capital cost for liquid-phase GAC adsorption would be low, and O&M costs would be moderate to high based on expected GAC consumption.

Conclusion

Liquid-phase GAC adsorption is retained for the development of groundwater remedial alternatives, in combination with other process options.

D.2.6.4 Vapor-Phase Granular Activated Carbon Adsorption

Granular activated carbon adsorption is a frequently applied technology for the removal of contaminants from air. The GAC process adsorbs most organic compounds to some extent but is more effective for the less polar and less soluble compounds. Granular activated carbon adsorption involves the physical attraction of organic solute molecules to exchange sites on the internal pore surface areas of the specially treated (activated) carbon grains. As the contaminated vapor passes through one or more vessels containing GAC, the organic molecules 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 atmospheric columns operating in series and/or parallel configuration. Factors such as temperature and relative humidity of the inlet stream, EBCT, and surface area to volume ratio of the activated carbon will affect the carbon adsorption process.

Effectiveness

Vapor-phase GAC adsorption is a well-proven reliable technology that would be effective for removing most of the COCs from the off-gas from the air stripper to meet the requirements of air discharge regulations. Removal efficiency exceeding 99 percent is possible depending on the compound and system operating parameters such as retention time. However, vinyl chloride is poorly sorbed by GAC.

Implementability

Granular activated carbon adsorption would be readily implementable. There are a sufficient number of qualified vendors that provide vapor-phase GAC adsorption units.

Spent GAC containing concentrated organic contaminants would have to be regenerated, incinerated, or disposed in a hazardous waste landfill. Thermal, steam, and solvent treatments are the most common types of GAC regeneration technologies, and these are typically conducted off-site.

Cost

Capital cost for GAC adsorption would be low and O&M costs would range from moderate to high, depending on the carbon usage rate, which is a function of influent contaminant concentration.

Conclusion

Because air stripping has been retained as a process option, vapor-phase GAC adsorption is also retained for the development of groundwater remedial alternatives.

D.2.6.5 Potassium Permanganate Impregnated Zeolite

Because GAC is not very effective in removing vinyl chloride from air, PPZ can be used. Potassium permanganate impregnated zeolite is effective in the removal of vinyl chloride and other chlorinated ethenes.

As the contaminated vapor passes through one or more vessels containing PPZ, the cVOCs are oxidized by the potassium permanganate. After all potassium permanganate is consumed, the zeolite must then be disposed as a hazardous waste and replaced with new PPZ. Typical PPZ adsorption treatment systems operate in series and/or parallel configurations.

Effectiveness

Treatment of vapor streams contaminated with VOCs with PPZ is a relatively recent technology, although it is well established for other industries. Potassium permanganate impregnated zeolite would be effective for removing most of the vinyl chloride from the off-gas from the air stripper to meet the requirements of air discharge regulations. Removal efficiency exceeding 95 percent is possible.

Implementability

Potassium permanganate impregnated zeolite adsorption would be readily implementable. There are a sufficient number of qualified vendors that provide vapor-phase PPZ adsorption units.

Spent PPZ would have to be disposed in a non-hazardous waste landfill. Unlike GAC, PPZ cannot be regenerated.

Cost

Capital cost for PPZ adsorption would be moderate and O&M costs would range from moderate to high, depending on the PPZ rate, which is a function of influent contaminant concentration.

Conclusion

Because air stripping has been retained as a process option, PPZ adsorption is also retained for the development of groundwater remedial alternatives.

D.2.6.6 Neutralization/pH Adjustment

Neutralization/pH adjustment is a process for achieving appropriate pH levels for removal of contaminants, primarily metals. This is generally accomplished by adding acidic compounds to balance alkaline solutions or vice versa.

Effectiveness

Neutralization/pH adjustment is generally effective for the removal of certain contaminants, mostly inorganics, by bringing them out of solution. For the DRA Site, neutralization/pH adjustment would not of itself be effective for the removal of all COCs in groundwater. However, this technology might be required prior to discharge of treated groundwater, or in advance of certain other treatment technologies, to prevent fouling or to improve treatment effectiveness.

Implementability

Neutralization/pH adjustment would be readily implementable. This technology is widely used, and numerous qualified equipment vendors and contractors offer these types of equipment and services. There can be safety issues associated with storing and handling pH adjustment compounds.

Cost

Capital and O&M costs for neutralization/pH adjustment would be low.

Conclusion

Neutralization/pH adjustment is retained because of high metals concentrations in the groundwater that must be removed prior to further treatment and discharge. This process would be used in combination with other treatment process options.

D.2.6.7 Coagulation/Flocculation and Sedimentation

Coagulation/flocculation is a process that consists of adding certain chemical reagents that result in the agglomeration of small suspended solids particles into larger ones, thus increasing significantly the effectiveness of sedimentation. This step is typically applied after chemical precipitation.

Sedimentation is a process that removes the suspended solids from a liquid by producing quiescent hydraulic conditions. This allows gravity to settle out the unstable solids from suspension. This technology may be used in conjunction with precipitation. Two slightly different sedimentation options are used including clarification (to typically produce a sludge that is 2 to 8 percent solids) and thickening (to typically further concentrate clarification sludges to 8 to 15 percent solids). Sludge would be further processed in a dewatering unit, such as a plate and frame filter press, so that the solids could be disposed off-site.

Effectiveness

Coagulation/flocculation and sedimentation would not of themselves be effective for the removal of COCs from groundwater at the DRA Site. However, these technologies would be effective for the removal of excessive concentrations of suspended solids (such as iron and manganese compounds) that would otherwise undermine the efficiency of COC removal technologies such as air stripping and GAC adsorption. Therefore, coagulation/flocculation is often required following a neutralization/pH adjustment step. Based on characterization of the groundwater, pretreatment would be required not only for iron and manganese removal, but also for the removal of other metals, such as cadmium.

Implementability

Coagulation/flocculation and sedimentation would be readily implementable. Numerous qualified equipment vendors and contractors offer this type of equipment and services.

Cost

Capital and O&M costs for coagulation/flocculation and sedimentation would be low.

Conclusion

Coagulation/flocculation and sedimentation are retained because of the high suspended solids concentrations from iron and manganese compounds (and other metals) that will be precipitated from the groundwater.

D.2.6.8 Ion Exchange

Ion exchange would consist of pumping the groundwater to be treated through a bed of a special resin medium capable of capturing ions from the groundwater and exchanging these with the ions populating the active sites of the resin medium. There are two main categories of ion exchange resins, including cationic resins, with active sites populated with positive ions (cations), and anionic resins, with active sites populated with negative ions (anions). Ion exchange is capable of reducing metals concentrations to very low levels that may be required for a discharge to Frog Mortar Creek and meeting MCLs of certain metals, such as cadmium, prior to reinjection.

Cationic resins are most often used with either sodium (Na^+) or hydrogen (H^+) ions populating their active sites. Anionic resins are most often used with either chloride (Cl^-) or hydroxyl (OH^-) ions populating their active sites. Once most of the original ions on the active sites have been replaced with those captured from the groundwater being treated, the ion exchange resin is said to be saturated and is temporarily taken out of service for regeneration. This regeneration consists of flushing the resin with a concentrated solution of the original ion to reverse the exchange process and repopulate the active sites with this original ion. Typically, cationic resins are regenerated with either sodium chloride, if operating in the sodium cycle, or sulfuric or hydrochloric acid, if operating in the hydrogen cycle. Anionic resins are regenerated with sodium chloride, if operating in the chloride cycle, or with caustic soda (sodium hydroxide), if operating

in the hydroxyl cycle. The regeneration process generates a waste brine residue that contains the ions removed from the treated groundwater and a surplus of the regenerating ions. This waste brine must be neutralized and undergo some form of treatment, such as evaporation, prior to disposal. Ion exchange resins can be regenerated on-site or off-site.

Effectiveness

Ion exchange is a well-proven process for the removal of inorganic compounds down to extremely low concentrations that may be required for surface water discharge or re-injection to the groundwater.

Implementability

Ion exchange would be simple to implement. Treatability testing would be required to verify that metals can be removed down to surface discharge limits and MCLs. The resources, equipment, and materials necessary for such an implementation are readily available. Typical ion exchange systems are fully automatic and require minimum operating supervision. Maintenance requirements would consist of routine inspection of the resin bed and periodic replacement of damaged or lost resin. Since suspended solids interfere with the performance of most ion exchange resins, pretreatment would most likely be required.

As previously mentioned, the ion exchange units would have to be regularly regenerated with sodium chloride brine or an acid solution that would generate a waste fluid requiring off-site disposal. Alternatively, resins can be regenerated off-site.

Cost

Capital and O&M costs for ion exchange would be high.

Conclusion

Ion exchange is retained in combination with other process options for the development of remedial alternatives.

D.2.6.9 Advanced Oxidation

Advanced oxidation processes (AOPs) use a controlled combination of either ozone or hydrogen peroxide with ultraviolet (UV) light or UV light in the presence of a catalyst to induce photochemical oxidation of organic compounds. Ultraviolet radiation is electromagnetic (EM) energy with wavelengths that fall between those of visible light and X-ray radiation on the EM spectrum. Ultraviolet energy is capable of breaking down or rearranging a molecular structure, depending on the dissociation energies of the chemical bonds within the structure. The combination of ultraviolet radiation with ozone or hydrogen peroxide or in the presence of a catalyst results in the oxidation of organic contaminants at a rate many times faster than that obtained from applying UV light alone. An alternative process uses ozone and hydrogen peroxide without UV light to accomplish the destruction of organic chemicals.

A typical, continuous flow hydrogen peroxide/ozone and UV system consists of an oxygen or air source, an ozone generator or hydrogen peroxide feed system, a UV/oxidation reactor, and an ozone decomposer. Flow patterns and configurations are designed to maximize exposure of the wastewater to the UV radiation, which is supplied by an arrangement of UV lamps. Typical reactor designs range from mechanically agitated reactors to spray, packed, and tray type towers. If ozone is utilized, reactor gases are passed through a catalytic ozone decomposer that converts remaining ozone to oxygen and destroys any residual VOCs.

A catalytic process (Photo-Cat by Purifics, Inc.) consists of multiple UV lights in reactor tubes, through which the wastewater flows. The catalyzed process generates radicals that react with and oxidize contaminants. No chemicals are added in this process.

Similarly, an ozone-hydrogen peroxide system (such as HiPOx® by APTwater, Inc.) consists of an oxygen source, an ozone generator, a hydrogen peroxide feed system, a reactor, and an ozone decomposer. Flow patterns and configurations are designed to maximize exposure of the wastewater to the oxidizing chemicals. Reactor gases are passed through a catalytic ozone decomposer that converts remaining ozone to oxygen and destroys any residual VOCs.

Effectiveness

Advanced oxidation with hydrogen peroxide/ozone and/or UV technology has been proven effective for the destruction of halogenated organic compounds, benzene derivatives, various aliphatic hydrocarbons, and specifically, 1,4-dioxane. Removal effectiveness varies greatly depending on the contaminant of concern. For the DRA Site groundwater, chlorinated alkenes such as TCE, cis-1,2-DCE, and 1,4-dioxane, along with petroleum-related compounds would be readily destroyed.

Implementability

Advanced oxidation processes would be readily implementable. However, only a few vendors currently offer this technology. Recent improvements have been made by vendors of this technology to minimize energy usage and reduce UV lamp fouling problems. However, because of the high iron and manganese concentrations, systems using UV lights may have high maintenance requirements and costs. With this treatment, no toxics are emitted to the atmosphere or adsorbed onto media that require further treatment or disposal.

Cost

Capital costs of AOPs would be moderate to high. O&M costs vary significantly depending on flow rate, and contaminant type and concentration.

Conclusion

The advanced oxidation process with ozone and hydrogen peroxide is retained in combination with other process options for the development of remedial alternatives, primarily for the removal of 1,4-dioxane. Ultraviolet light systems have the propensity to foul, and require pretreatment for solids removal. For the purposes of this Groundwater FS, the HiPOx® system is described in the process descriptions, although other processes can be used.

D.2.7 Disposal

The technologies and process options considered under this GRA includes surface water discharge, indirect discharge, and reinjection.

D.2.7.1 Direct Surface Discharge

Direct surface discharge would consist of disposing of treated groundwater by discharging it directly to a surface water body such as Frog Mortar Creek. Because of distance, a discharge to another surface water body is not feasible. In addition, for the groundwater treatment system to qualify for the RCRA wastewater treatment unit exemption, a permitted direct (or indirect) discharge is necessary.

Because of the poor mixing in the tidal portion of Frog Mortar Creek, effluent limitations are expected to be very low, close to surface Water Quality Criteria (WQC), without significant dilution. Frog Mortar Creek is considered to be fresh water by Maryland Department of the Environment (MDE), so fresh water quality criteria would be considered. This portion of Frog Mortar Creek is tidal and not considered to be usable as a drinking water source, so human health WQC based on consumption of organisms only is applicable. Effluent limitations would need to be developed using a model acceptable to MDE and then model assumptions would need to be calibrated by field tests. Note that WQC for a few parameters (for example, cadmium) are less than MCLs, so additional treatment, such as ion exchange may be needed to meet the surface water effluent limitations compared to the groundwater cleanup goals. Table D-1 lists the contaminants and the corresponding WQC. To maximize mixing the discharge with the surface water, the discharge would likely be through a submerged diffuser along the bottom of Frog Mortar Creek.

Effectiveness

Direct surface discharge of treated groundwater would be an effective means of disposal. However, appropriate on-site treatment would be required prior to discharge to satisfy applicable water quality criteria and the requirements of a National Pollutant Discharge Elimination System (NPDES) permit.

Implementability

Direct surface discharge to Frog Mortar Creek would be easy to implement; however, achieving the stringent WQC will be more difficult. Because the DRA Site is in close proximity to the creek, transfer distances would be relatively short and it is likely that existing storm sewers

might be used for this purpose. In addition, the discharge would have to meet the requirements of an NPDES permit. Because of the relatively small drainage area of Frog Mortar Creek and the poor mixing typical of tidal portions of the creek, effluent limitations will probably be very stringent. A submerged, multiport diffuser would likely be needed for the discharge to meet effluent limitations. As noted above, effluent limitations would need to be calculated using a state-approved model, and the model would need to be field calibrated and verified.

Cost

The capital and O&M costs of direct surface discharge would be low.

Conclusion

Direct surface discharge is retained as a contingency for the development of groundwater remedial alternatives.

D.2.7.2 Indirect Discharge

This technology would consist of discharging the treated groundwater to a local publicly owned treatment works (POTW) where it would undergo either the full or incremental treatment required for discharge. In addition, for the groundwater treatment system to qualify for the RCRA wastewater treatment unit exemption, a permitted indirect (or direct) discharge is necessary. Local limits for the discharge to the POTW system are much less stringent than MCLs or surface water effluent limitations. The limitations for industrial discharges to the City of Baltimore POTW are summarized in Table D-2.

Effectiveness

Indirect discharge to a POTW would be an effective method of disposal of the treated groundwater. The POTW would provide the necessary polishing treatment for ultimate discharge to surface water.

Implementability

Although the POTW appears to have the capacity to handle the flow, the county sanitary sewer system may be unwilling to accept the flow. The sewer system is under a Consent Order with the United States Environmental Protection Agency (EPA)/Department of Justice (DOJ)/MDE regarding overflows from the sanitary system, and elimination of excess inflows and infiltration from the system. The sewer authority is trying to eliminate groundwater and rainwater from entering the sewers, and the addition of a relatively clean groundwater stream may be counterproductive to their goal. Thus, acceptance of the discharge by the sanitary sewer authority may need to be negotiated.

Cost

Capital and O&M costs for indirect discharge to a POTW would be moderate to high, depending on the distance to the sewer tie-in and the service and annual fees charged by the sewer authority to accept the treated water.

Conclusion

Indirect discharge is retained for further consideration although there may be significant administrative implementability issues. Because of uncertainties in estimating surface water discharge effluent limitations at this time, treated groundwater could be discharged to the POTW for the first few years of operation until flow rates, influent, and effluent quality are better characterized. Then, a surface water discharge permit can be obtained based on actual site operating data.

D.2.7.3 Reinjection

Reinjection consists of disposing treated groundwater back into the original aquifer from which it was removed through infiltration galleries or reinjection wells. Based on the relatively shallow groundwater table at the DRA Site, infiltration galleries may be an acceptable option. Reinjection may be used to improve contaminant remediation by creating artificial hydraulic gradients that direct groundwater toward extraction wells. Reinjection can be coupled with extraction wells to create a closed system in which pumping and injection rates balance one another. The groundwater would need to be treated to meet groundwater MCLs prior to injection. Other groundwater quality parameters, such as total dissolved solids concentration, must also be

considered. In addition, the groundwater can be amended with an electron donor prior to reinjection to promote in-situ reductive dechlorination.

Effectiveness

Reinjection via infiltration galleries or injection wells is an effective means of disposing of the volumes of water generated by a groundwater pumping/treatment system. Infiltration galleries offer the advantage of decreasing groundwater remediation time by increasing groundwater flow through the aquifer. The vertical infiltration of treated groundwater through the vadose zone will create elevated groundwater conditions (i.e., groundwater mounding) in the vicinity of the infiltration gallery, requiring detailed flow modeling to ensure that the design of the infiltration gallery can accommodate these changes to water levels within the aquifer. Injection well systems must be designed to minimize potential for clogging the wells and galleries with suspended solids. The effectiveness of reinjection depends on hydraulic conductivity, aquifer thickness, and hydraulic gradient/aquifer recharge rate. This method of disposal would require treatment of the water to meet groundwater MCLs for all contaminants.

Implementability

Installation of an infiltration gallery system or injection well system for underground injection is implementable using established procedures. Vendors and equipment for installation are commercially available. Reinjected water could potentially force contaminated groundwater into less-contaminated areas. Periodic groundwater monitoring would be needed to assess the impacts of reinjection. Infiltration galleries will require a larger area than injection wells. The placement of infiltration galleries, injection wells, and associated piping could restrict development and use of the site and complicate the soil FS yet to come.

Using reinjection as the sole method of groundwater disposal would eliminate exemption from permitting under RCRA as a wastewater treatment unit.

Cost

Costs for construction and O&M of a reinjection system would be low to moderate.

Conclusion

Reinjection (infiltration gallery or wells) is retained for the development of groundwater remedial alternatives, but only in conjunction with a permitted direct and/or indirect discharge. This process will be used in combination with other technologies such as extraction and ex-situ treatment.

D.3 SELECTION OF REPRESENTATIVE TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER

The following technologies and process options, under the GRAs as noted, were retained for the development of groundwater containment remedial alternatives:

- No Action
- Limited Action: LUCs, Monitoring
- Containment: Hydraulic Barrier
- Removal: Extraction
- In-Situ Treatment: Enhanced Bioremediation, ZVI PRB
- Ex-Situ Treatment: Filtration, Air Stripping, Liquid-Phase GAC Adsorption, Vapor-Phase GAC Adsorption, Vapor-Phase PPZ Adsorption, Neutralization/pH Adjustment, Coagulation/Flocculation and Sedimentation, Ion Exchange, Advanced Oxidation
- Disposal: Indirect Discharge to POTW, Reinjection, Direct Discharge

The purpose of this FS is to evaluate containment of contaminated groundwater, which must consider the overall depth of the contaminated groundwater (approximately 90 feet) and wide variety of contaminants (for example, cVOCs, metals, and 1,4-dioxane). Therefore, the number of processes and technologies that can be applied is limited. The primary objective of containment is particularly limiting, and contaminant removal technologies that might be applied throughout the plume were not considered. All remediation technologies and processes will be revisited when the FS for the site-wide groundwater remedy is prepared.

Table D-1

Water Quality Criteria
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Parameter	WQC Aquatic Life (ug/L)	WQC HH (ug/L)	MCL (ug/L)
Organic Compounds			
1,1- Dichloroethene	-	32	7
1,2-Dichloroethane	-	370	5
1,2,4-Trichlorobenzene	-	940	70
1,3,5-Trimethylbenzene	-	-	-
1,4-Dioxane	-	-	-
Benzene	-	510	5
Chloroform	-	4,700	80 (as TTHMs)
cis-1,2-Dichloroethene	-	-	70
Ethylbenzene	-	29,000	700
Naphthalene	-	-	-
Tetrachloroethene	-	33	5
Toluene	-	200,000	1,000
Trichloroethene	-	300	5
Vinyl chloride	-	5,300	2
Xylenes	-	-	10,000
Inorganics			
Arsenic	150	41	10
Barium	-	2,000 (DW+O)	2,000
Beryllium	-	4 (DW+O)	4
Cadmium	0.25	5 (DW+O)	5
Chromium	-/ 74 / 11	100 (DW+O)	100
Copper	9	1,300 (DW+O)	1,300 (AL)
Iron	-	-	-
Mercury	0.77	-	2

Table D-1

Water Quality Criteria
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Parameter	WQC Aquatic Life (ug/L)	WQC HH (ug/L)	MCL (ug/L)
Manganese	-	-	-
Nickel	52	4,600	-
Lead	2.5	-	15 (AL)
Selenium	5	4,200	50
Silver	3.2	-	-
Vanadium	-	-	-
Zinc	120	26,000	-

WOC - Water Quality Criteria
WQC Aquatic life - fresh water, lowest of chronic and acute.
WQC HH - Human health, consumption of organisms only (unless noted).
DW+O - Human health, based on drinking water and consumption of organisms. No WQC for consumption of organisms only.
MCL - Maximum Contaminant Level
AL - Action Level
TTHMs - Total Trihalomethanes
For metals, dissolved metals are shown.
Max concentrations from June 2008 (Tetra Tech, 2008) and May 2009 (Tetra Tech, 2009) reports.
Mean Concentrations are from June 2008 (Tetra Tech, 2008).
For chromium, the WQC AL values are for total/III/VI
"-" indicates not criteria.

Table D-2

Baltimore County Industrial Wastewater Discharge Standards
DRA Site Groundwater Feasibility Study
Lockheed Martin, Martin State Airport
Middle River, Maryland

Parameter	Limit (mg/L)
Cadmium	0.21
Chromium	6.89
Copper	6.59
Lead	6.81
Mercury	0.01
Nickel	2.82
Silver	1.20
Zinc	17.85
Fats, Oils, and Grease (FOG)	100.0
Total Petroleum Hydrocarbons	100.0
Total Toxic Organics	2.13
pH	6.0 to 10.0 SU

mg/L – milligram(s) per liter.
SU – Standard units.

APPENDIX E
PRELIMINARY DESIGN CALCULATIONS AND PROCESS DESCRIPTIONS

APPENDIX E

PRELIMINARY DESIGN CALCULATIONS AND PROCESS DESCRIPTIONS

GROUNDWATER COMPOSITION DESIGN BASIS

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater Treatment system – Design basis for untreated groundwater to treatment system		CHECKED BY:	DATE: 2/1/10

The composition of the untreated groundwater to the treatment system was based on the locations of the extraction wells from the model. The composition was estimated based on the monitoring wells close to the proposed extraction wells. If an extraction well is near two monitoring wells, then the results of the two well will be averaged. See attached sketch.

Extraction Well – Shallow	Monitoring wells
S1	MW14S
S2	MW14S + DMW18S
S3	DMW18S + DMW3S
S4	DMW2S + DMW3S
S5	DMW2S + DMW4S
S6	DWM4S + DMW5S
S7	DWM5S

Extraction Well – intermediate	Monitoring wells
I1	MW14I + DMW18I
I2	DMW3I
I3	DMW3I + DMW2A
I4	DMW2A + DMW4I
I5	DWM4I

Extraction Well – Deep	Monitoring wells
D1	DMW18D + DMW3D
D2	DMW3D + DMW2B
D3	DMW2B + DMW4D
D4	DMW4D

GROUNDWATER DESIGN BASIS - SECOND PUMPING SCHEME
DUMP ROAD SITE
LOCKHEED MARTIN - MARTIN STATE AIRPORT
MIDDLE RIVER, MARYLAND

Extraction well No.	S1							I2		S3		D1
LOCATION	**14S**	**14I**	**14D**	**18S**	**18I**	**18D**	**3S**	**3I**	**3D**	**AVE 18S 3S**	**AVE**	**AVE 18D 3D**
SAMPLE DATE												
SAMPLE ID												
MATRIX												
SAMPLE CODE												
Volatile Organics (ug/L)												
1,1,1-TRICHLOROETHANE	1	11	1	20	73	1	18	110	1	19	91.5	1
1,1-DICHLOROETHENE	1	28	1	20	63	1	16	95	1	18	79	1
1,2,4-TRICHLOROBENZENE	2	7.5	1	29	92	0.25	12	730	1	21	411	0.63
1,2-DICHLOROETHANE	1	11	1	30	78	1	18	160	1	24	119	1
BENZENE	1	11	1	16	43	1	11	65	1	14	54	1
BTEX	0	11						210	0.4		210	0.4
CHLOROBENZENE	0.21	270	1	19	50	1	12	75	1	16	63	1
CHLOROFORM	1	8	1	3.7	53	0.58	13	100	0.49	8	77	0.5
CIS-1,2-DICHLOROETHENE	1	1700	1	370	1100	0.43	550	17000	1	460	9050	0.7
METHYLENE CHLORIDE	1	16	1	8.2	140	1	90	500	1	49	320	1
NAPHTHALENE	2	12	1	20	80	0.3	20	120	1	20	100	0.7
TOLUENE	0.42	6.5	1	16	43	1	11	210	0.4	14	127	0.7
TOTAL CHLORINATED VOCS	0	2750	0	4620	13750	7.33	4950	38800	0.97	4785	26275	4.2
TRANS-1,2-DICHLOROETHENE	1	12	1	20	63	1	200	95	1	110	79	1
TRICHLOROETHENE	1	50	1	4000	12000	6.9	14	18000	0.97	2007	15000	3.9
VINYL CHLORIDE	1	1000	1	250	650	1	4400	4300	1	2325	2475	1
Volatile Organics - SIM (ug/L)												
1,4-DIOXANE	0.59	130	0.33	150	350	1	480	1100	0.33	315	725	0.7
Petroleum Hydrocarbons (ug/L)												
DIESEL RANGE ORGANICS	100	100	100	320	100	100	440	100	100	380	100	100
GASOLINE RANGE ORGANICS	100	100	100	1700	100	100	120	100	100	910	100	100
Inorganics (ug/L)												
ANTIMONY	30	0.035	0.33	2	0.07	2	1.7	0.33	0.5	1.9	0.2	1.3
ARSENIC	16	24.4	19.6	3.1	19.4	0.83	15.4	4	1.2	9.3	12	1.0
BARIUM		16	25.6	52.3	70.1	11.1	92.9	12.9	107	72.6	41.5	59.1
BERYLLIUM	3	0.037	0.71	0.2	7.3	0.02	0.23	0.19	1.1	0.2	3.7	0.6
CADMIUM	2	0.027	0.25	0.077	129	0.1	0.88	478	0.51	0.5	303.5	0.3
CALCIUM		189000	1660	199000	66000	1990	0	0	0	99500	33000	995
CHROMIUM	59	1.3	22.9	3.2	9.3	0.27	17.1	6.5	3.6	10.2	7.9	1.9
COBALT	0.00	14.3	13.9	88.7	330	6.6	2.3	203	74.4	45.5	266.5	40.5
COPPER	73	0.22	37.2	1.1	245	0.62	40.6	68.4	20.5	20.9	156.7	10.6
IRON		73500	11100	163000	64300	888	21600	60500	1620	92300	62400	1254
LEAD	6	0.064	2.6	0.48	2.5	0.07	25.1	3.9	4.3	12.8	3.2	2.2
MAGNESIUM		31200	592	202000	61500	763		0	0	2E+05	30750	381.5
MANGANESE		2230	47.3	4420	5490	50.6	440	5720	559	2430	5605	304.8
MERCURY	2.9	0.1	0.83	0.2	0.11	0.2	0.2	0.74	0.42	0.2	0.4	0.3
MOLYBDENUM		0.91	3	0.51	0.82	2	7.2	0.38	1.3	3.9	0.6	1.7
NICKEL	10	8.6	21.3	58.2	200	10	9.4	52.4	86.7	33.8	126.2	48.4
POTASSIUM		11300		42500	5880					42500	5880	
SELENIUM	10	0.43	1.1	0.76	20.6	5	0.32	3.4	0.67	0.5	12	2.8
SILICA		4270		30200	11600					30200	11600	
SILVER	4	0.033	0.044	1	0.02	1	0.15	0.025	0.033	0.6	0.02	0.5
SODIUM		44600		560000	2E+05					6E+05	2E+05	
THALLIUM	20	0.2	0.18	1	1	1	0.12	0.46	0.45	0.56	0.73	0.7
VANADIUM		0.72	31.6	3	12.8	20	13.6	11.8	2	8.3	12.3	11
ZINC	20	2.9	31.1	65	363	16.3	165	282	132	115	322.5	74.2
Filtered Inorganics (ug/L)												
ANTIMONY	20	0.25	0.081	2	2	2	0.36	0.12	0.4	1.2	1.1	1.2
ARSENIC	10	23.6	7.9	2.8	8	0.85	18.7	4.1	0.84	10.8	6.1	0.8
BARIUM	0	14.5	8.1	49.7	67.2	11.5	99.5	10.2	103	74.6	38.7	57.3
BERYLLIUM	4	0.047	0.26	0.24	2.8	0.02	0.025	0.18	0.99	0.1	1.5	0.5
CADMIUM	2	0.027	0.24	1	81.1	0.08	0.023	76.9	0.32	0.5	79	0.2
CALCIUM		181000	1630	184000	68400	2220		0		2E+05	34200	2220
CHROMIUM	5	0.92	1.8	2	1.9	0.2	1.4	2.1	1.3	1.7	2	0.8
COBALT		13.7	14.3	107	333	6.9	0.68	208	72.6	53.8	270.5	39.8
COPPER	10	0.082	4.6	0.49	22.2	0.11	0.63	25.1	2.6	0.6	23.7	1.4
IRON		70900	4020	138000	43600	800	1240	60300	1120	69620	51950	960
LEAD	6	0.072	0.18	1	0.33	0.04	1	2	0.24	1	1.2	0.1
MAGNESIUM		27700	418	183000	63400	839		0		2E+05	31700	839
MANGANESE		2200	50.3	4180	5560	50.9	330	5690	556	2255	5625	303.5
MERCURY	0.06	0.1	0.2	0.2	0.2	0.2	0.2	0.14	0.2	0.2	0.2	0.2
MOLYBDENUM		0.89	0.4	2	2	2	10.2	0.23	1.2	6.1	1.1	1.6
NICKEL	5	6.7	21.8	72.2	200	10.1	0.65	51.8	84.6	36.4	125.9	47.4
SELENIUM	20	0.48	5	0.77	14	5	0.22	3.6	0.44	0.5	8.8	2.7
THALLIUM	6	0.22	1	1	0.27	1	0.2	0.36	0.19	0.6	0.3	0.6
VANADIUM		0.64	2.9	1.9	2.7	20	1.9	7	0.62	1.9	4.9	10.3
ZINC	6	3.5	54.2	85.6	356	16.7	8.5	267	119	47.1	311.5	67.9
Miscellaneous Parameters												
ALKALINITY MG/L		110	4.9	355	55.1	8.8				355	55	9
CHEMICAL OXYGEN DEMAND MG/L		42	20	168	56.9	20				168	57	20
CHLORIDE MG/L		23.3		594	305					594	305	
HEXAVALENT CHROMIUM MG/L		0.02	0.04	0.002	0.02	0.02	0.02	0.02	0.004	0.011	0.020	0.012
NITRATE-N MG/L		0.023		0.023	0.023					0.023	0.023	
PERCHLORATE UG/L		0.082	0.082	0.082	0.13		0.082	0.082	0.082	0.082	0.106	0.082
PH S.U.		6.1	5.7	6.6	5.9	5.5				6.6	5.9	5.5
SULFATE MG/L		649		1600	439					1600	439	
TOTAL DISSOLVED SOLIDS MG/L		1100		3500	1100					3500	1100	

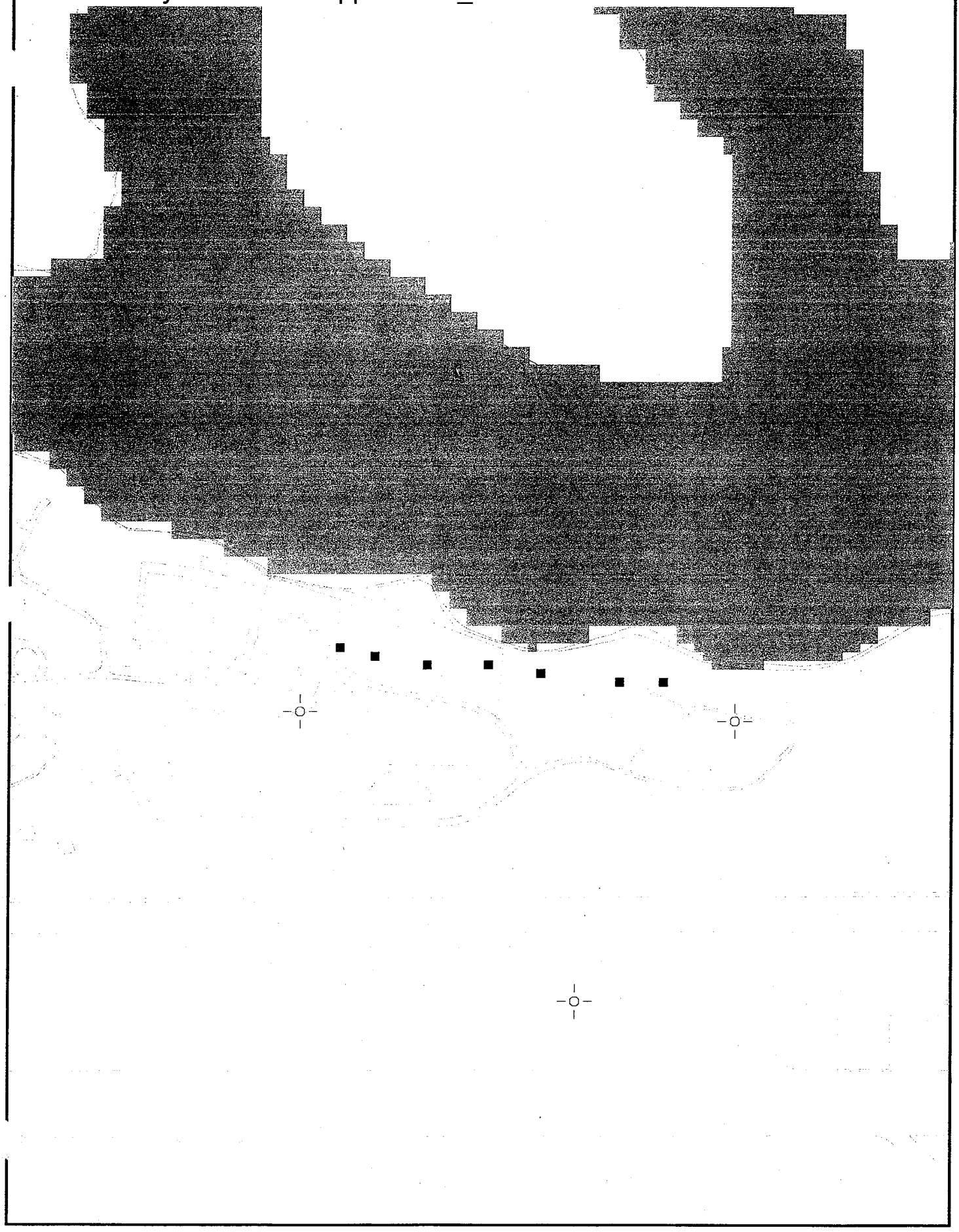
GROUNDWATER DESIGN BASIS - SECOND PUMPING SCHEME
DUMP ROAD SITE
LOCKHEED MARTIN - MARTIN STATE AIRPORT
MIDDLE RIVER, MARYLAND

01/18/10

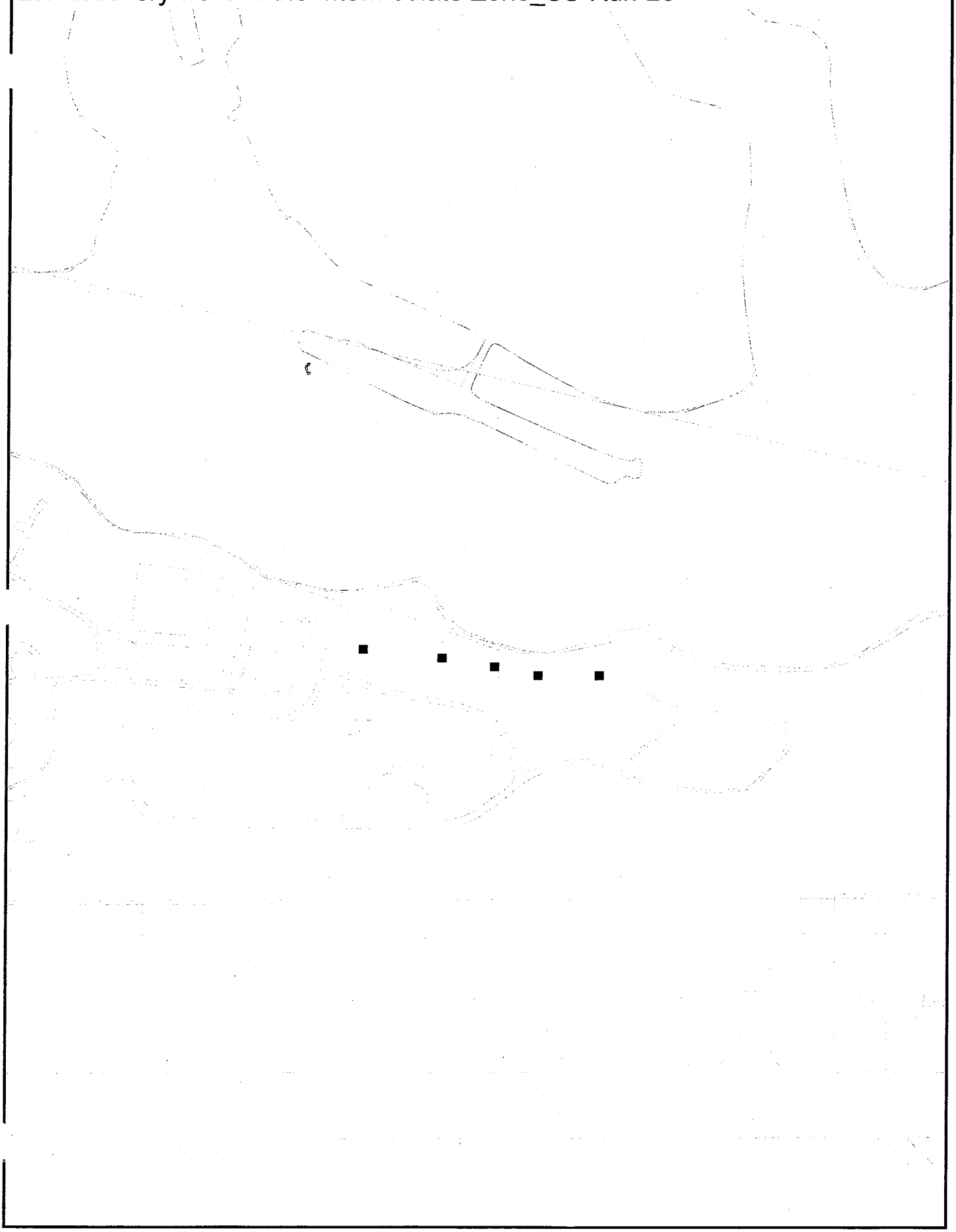
Extraction well No.					I5	D4	S5	I4	D3	S7						S2	S4
LOCATION	**2S**	**2A**	**2B**	**4S**	**4I**	**4D**	**AVE**	**AVE**	**AVE**	**5S**	**5I**	**5D**	**6S**	**6I**	**6D**	**4S**	**2S**
SAMPLE DATE							**2S**	**2A**	**2B**							**18S**	**3S**
SAMPLE ID							**4S**	**4I**	**4D**							**AVE**	**AVE**
MATRIX																	
SAMPLE CODE																	
Volatile Organics (ug/L)																	
1,1,1-TRICHLOROETHANE	18	110	1	4.4	78	37	11.2	94	19	55	0.22	1	0.22	0.22	0.22	12.2	18
1,1-DICHLOROETHENE	16	95	1	27	83	32	21.5	89	16.5	48	0.19	1	0.19	0.19	0.19	23.5	16
1,2,4-TRICHLOROBENZENE	12	650	1	3	25	25	7.5	337.5	13	38	0.15	1	0.15	0.15	0.15	16	12
1,2-DICHLOROETHANE	18	150	1	16	37	37	17	93.5	19	55	0.93	1	0.22	0.22	0.22	23	18
BENZENE	11	65	1	2.6	22	22	6.8	43.5	11.5	32	0.35	1	0.13	0.13	0.13	9.3	11
BTEX			0								0.35						
CHLOROBENZENE	12	75	1	3	25	25	7.5	50	13	38	0.15	1	0.33	0.15	0.15	11	12
CHLOROFORM	11	89	1	3.2	27	27	7.1	58	14	40	1.3	1	0.16	0.16	0.16	3.45	12
CIS-1,2-DICHLOROETHENE	1000	5000	4.5	170	2100	400	585	3550	202.3	980	53	1	3.6	0.17	0.17	270	775
METHYLENE CHLORIDE	27	500	1	21	55	140	24	277.5	70.5	250	0.33	1	0.33	0.33	0.33	14.6	58.5
NAPHTHALENE	20	120	1	4.8	40	40	12.4	80	20.5	60	0.24	1	0.24	0.24	0.32	12.4	20
TOLUENE	11	65	1	2.6	22	22	6.8	43.5	11.5	32	0.13	1	0.13	0.13	0.13	9.3	11
TOTAL CHLORINATED VOCS	3730	25840	6.6	1518	8674	6200	2624	17257	3103	9980	176.6	1.1	3.6				
TRANS-1,2-DICHLOROETHENE	16	95	0.36	3.8	32	32	9.9	63.5	16.18	48	2.5	1	0.19	0.19	0.19	11.9	108
TRICHLOROETHENE	2200	20000	2.1	1300	7300	5800	1750	13650	2901	9000	120	1.1	0.83	0.17	0.17	2650	1107
VINYL CHLORIDE	530	840	1	48	140	37	289	490	19	55	3.6	1	0.22	0.22	0.22	149	2465
Volatile Organics - SIM (ug/L)																	
1,4-DIOXANE	250	890	1	120	120	75	185	505	38	41	2.9	1	1	1	1	135	365
Petroleum Hydrocarbons (ug/L)																	
DIESEL RANGE ORGANICS	310	100	100	270	100	100	290	100	100	290	100	100	420	100	100	295	375
GASOLINE RANGE ORGANICS	980	100	100	310	100	100	645	100	100	3500	100	100	39	100	100	1005	550
Inorganics (ug/L)																	
ANTIMONY	0.04	0.71	0.45	0.2	0.53	0.2	0.122	0.62	0.325	0.038	0.49	0.07	0.9	0.45	0.16	1.1	0.8715
ARSENIC	12.6	7.7	3.1	4.4	41.7	24	8.5	24.7	13.55	17.1	14	0.13	6.8	4.5	3.3	3.75	14
BARIUM	15.1	37.9	32.1	13.8	21.5	29.3	14.45	29.7	30.7	13.7	34.2	10.1	52.9	15.4	56.4	33.05	54
BERYLLIUM	4.7	1.2	0.32	1.2	9.5	3.8	2.95	5.35	2.06	4.7	2.4	0.12	0.051	5.8	0.75	0.7	2.465
CADMIUM	242	777	1	49.9	56.6	24.4	146	416.8	12.7	4.9	23.3	0.04	0.061	37.8	0.81	24.989	121.44
CALCIUM		27600		118000	115000	67300	###	71300	67300	77900	76700					158500	0
CHROMIUM	4	45.1	42.1	6.7	70.3	15	5.35	57.7	28.55	158	11.9	0.52	1.2	15.7	11.4	4.95	10.55
COBALT	247	573	3.6	72.4	150	162	159.7	361.5	82.8	88.5	74.5	4.1	6.4	70.4	27.6	80.55	124.65
COPPER	55.3	262	20.5	21.7	142	80.3	38.5	202	50.4	59.7	214	1.2	2	534	18.8	11.4	47.95
IRON	66.6	48200	5240	49400	15300	3930	24733	31750	4585	25900	32600	30.5	275000	###	2800	106200	10833
LEAD	1	13.9	11	4.9	13.5	7.1	2.95	13.7	9.05	4.3	19.6	0.03	0.63	16	3.1	2.69	13.05
MAGNESIUM		27800		76500	72900	57900	76500	50350	57900	53700	43800					139250	
MANGANESE	6500	9940	45.8	6210	8010	6300	6355	8975	3173	4560	2580	24.2	2240	4430	774	5315	3470
MERCURY	0.1	0.56	0.29	0.1	0.12	13.2	0.1	0.34	6.745	0.1	0.1	0.1	0.1	0.1	2.6	0.15	0.15
MOLYBDENUM	0.23	1.6	0.97	0.72	2.2	1.2	0.475	1.9	1.085	3.4	0.82	0.12	1	3.7	1.3	0.615	3.715
NICKEL	112	143	13.2	33.4	113	117	72.7	128	65.1	78.6	65.2	5.7	5.7	82.3	37.3	45.8	60.7
POTASSIUM				20700	10000	5050	20700	10000	5050							31600	
SELENIUM	33.8	9.4	0.48	4.4	41.7	36.2	19.1	25.55	18.34	39.2	30.5	0.2	0.43	3.6	2	2.58	17.06
SILICA				11800	28700	18500	11800	28700	18500							21000	
SILVER	0.02	0.27	0.11	0.02	0.35	0.096	0.02	0.3	0.1	0.02	0.033	0	0.025	0.04	0.02	0.51	0.085
SODIUM		0		170000	124000	###	###	62000	###							365000	
THALLIUM	0.34	0.39	0.13	0.11	0.5	0.23	0.2	0.4	0.2	0.25	0.24	0.11	0.17	0.24	0.13	0.555	0.23
VANADIUM	0.46	44.8	15.2	4.6	66.9	10.6	2.5	55.9	12.9	11.7	4.9	0.46	1.1	2.9	7.1	3.8	7.03
ZINC	303	534	38.8	153	512	498	228	523	268.4	211	328	16.3	7.6	835	111	109	234
Filtered Inorganics (ug/L)																	
ANTIMONY	0.04	0.12	0.08	0.074	0.095	0.043	0.06	0.1	0.06	0.067	0.055	0.04	0.29	0.18	0.04	1.037	0.2015
ARSENIC	12.3	5.1	5	4.4	27.1	20.8	8.4	16.1	12.9	17.1	13.1	0.13	6.8	3.8	0.77	3.6	15.5
BARIUM	14.3	13.2	8.3	10.5	14.6	20.7	12.4	13.9	14.5	13.4	34	10.2	53.6	11.9	54.3	30.1	56.9
BERYLLIUM	4.3	1.3	0.07	1.3	10.4	4.2	2.8	5.9	2.1	4.9	2.6	0.11	0.025	6.8	0.72	0.77	2.1625
CADMIUM	238	762	0.8	6.6	59.6	26.5	122.3	410.8	13.7	4.6	3.4	0.06	0.014	9.9	0.73	3.8	119.01
CALCIUM		33900		95000	119000	72100	95000	76450	72100	77400	81500					139500	
CHROMIUM	3.5	7.7	0.39	0.97	11.7	2.8	2.2	9.7	1.6	9.3	10	0.18	0.66	4.5	1.4	1.485	2.45
COBALT	248	589	1.2	83.3	171	174	165.7	380	87.6	90.9	79.2	3.9	6.5	76.4	29	95.15	124.34
COPPER	55.2	56	5.1	3	111	67.8	29.1	83.5	36.5	10.2	4.6	1.3	0.49	66	20.7	1.745	27.915
IRON	59.6	44900	6	47900	15000	224	23980	29950	115	26000	34500	5.6	284000	###	156	92950	649.8
LEAD	0.91	4.2	0.41	1.2	10.1	1.9	1.1	7.2	1.2	3.1	4.6	0.02	0.13	6.4	2	1.1	0.955
MAGNESIUM		31800		74100	90900	62500	74100	61350	62500	53500	47300					128550	
MANGANESE	6510	10700	9.5	7150	8760	6960	6830	9730	3485	4690	2800	22.7	2340	4850	838	5665	3420
MERCURY	0.1	0.2	0.2	0.1	0.1	0.34	0.1	0.2	0.3	0.1	0.1	0.14	0.1	0.1	0.17	0.15	0.15
MOLYBDENUM	0.23	2	0.13	0.23	0.23	0.23	0.2	1.1	0.2	0.23	0.2	0.12	0.23	0.19	0.36	1.115	5.215
NICKEL	111	142	4.1	37.8	134	125	74	138	65	80	70	5.5	2.5	85.8	39.2	55	55.825
SELENIUM	33	9.2	5	4	44	37.4	18.5	26.6	21.2	38.6	32.7	0.22	1.3	4.1	2.3	2.385	16.61
THALLIUM	0.32	0.27	0.17	0.11	0.32	0.21	0.2	0.3	0.2	0.22	0.17	0.11	0.12	0.22	0.11	0.555	0.26
VANADIUM	0.46	13.3	20	0.46	4.6	0.46	0.5	9.0	10.2	12.2	3.8	0.46	0.7	1.6	0.46	1.18	1.18
ZINC	301	533	21	134	517	374	217.5	525	197.5	212	236	16	7.1	398	127	109.8	154.75
Miscellaneous Parameters																	
ALKALINITY MG/L		2.4		73	5	5	73	3.7	5	5	5					214	
CHEMICAL OXYGEN DEMAND MG/L		54.4		42	59.3	27.2	42	56.9	27.2	34.6	27.2					105	
CHLORIDE MG/L				105	94	123	105	94	123							349.5	
HEXAVALENT CHROMIUM MG/L	0.02	0.004	0.007	0.003	0.02	0.005	0.01	0.01	0.006	0.002	0.02	0.02	0.13	0.02	0.02	0.0025	0.02
NITRATE-N MG/L				0.023	0.1	2.8	0.02	0.1	2.8							0.023	
PERCHLORATE UG/L	0.12	0.11		0.082	4.6	5.8	0.1	2.4	5.8	0.63	0.082		0.082	0.08	0.1	0.082	0.101
PH S.U.		4.6		5.4	4.2	4.2	5.4	4.4	4.2	4.3	4.4					6	
SULFATE MG/L				908	1050	723	908	1050	723							1254	
TOTAL DISSOLVED SOLIDS MG/L				1500	1600	1200	1500	1600	1200							2500	

Extraction well No.	S6	I1	I3	D2	ALL	GW CRIT	WQC	WQC x 5	Design Basis 1.5 x All well Ave	max all wells	max Ave wells	max/DB
LOCATION	**4S**	**14I**	**3I**	**3D**	**ALL**							
SAMPLE DATE	**5S**	**18I**	**2A**	**2B**	**WELL**							
SAMPLE ID	**AVE**	**AVE**	**AVE**	**AVE**	**AVE**							
MATRIX												
SAMPLE CODE												
Volatile Organics (ug/L)												
1,1,1-TRICHLOROETHANE	29.7	42	110	1	40	200	200 HH	1000	60	500	110	1.8
1,1-DICHLOROETHENE	37.5	45.5	95	1	39	7	0.57	2.85	**58**	500	95	1.6
1,2,4-TRICHLOROBENZENE	20.5	49.75	690	1	124	70	260	1300	186	730	730	3.9
1,2-DICHLOROETHANE	35.5	44.5	155	1	45	5	3.8	19	**68**	160	160	2.4
BENZENE	17.3	27	65	1	22	5	22	110	**5**	500	**5**	1.0
BTEX												
CHLOROBENZENE	20.5	160	75	1	33	100	680 HH	3400	50	270	160	3.2
CHLOROFORM	21.6	30.5	94.5	0.745	28	80	80	400	42	100	100	2.4
CIS-1,2-DICHLOROETHENE	575	1400	11000	2.75	2456	70	-	-	**3685**	17000	17000	4.6
METHYLENE CHLORIDE	135.5	78	500	1	135	5	46 HH	230	**10**	540	**10**	1.0
NAPHTHALENE	32.4	46	120	1	39	0.65	-	-	**21**	500	**21**	1.0
TOLUENE	17.3	24.75	137.5	0.7	35	1000	6500	32500	53	500	210	4.0
TOTAL CHLORINATED VOCS												
TRANS-1,2-DICHLOROETHENE	25.9	37.5	95	0.68	43	100	700 HH	3500	64	200	110	1.7
TRICHLOROETHENE	5150	6025	19000	1.535	5897	5	2.5	12.5	**8845**	20000	19000	2.1
VINYL CHLORIDE	51.5	825	2570	1	857	2	20	100	**1286**	4400	4300	3.3
Volatile Organics - SIM (ug/L)												
1,4-DIOXANE	80.5	240	995	0.665	262	6.1	-	-	**393**	1100	1100	2.8
Petroleum Hydrocarbons (ug/L)												
DIESEL RANGE ORGANICS	280	100	100	100	182	47	-	-	**273**	440	380	1.4
GASOLINE RANGE ORGANICS	1905	100	100	100	595	47	-	-	**892**	3500	3500	3.9
Inorganics (ug/L)												
ANTIMONY	0.119	0.0525	0.52	0.475	2	6	5.6	28	2	1.9	30	12.5
ARSENIC	10.75	21.9	5.85	2.15	14	10	10	50	**20**	41.7	41.7	2.0
BARIUM	13.75	43.05	25.4	69.55	35	2000	2000	10000	52	107	72.6	1.4
BERYLLIUM	2.95	3.6685	0.695	0.71	3	4	4	20	4	9.5	9.5	2.3
CADMIUM	27.4	64.514	627.5	0.755	126	5	0.25	1.25	**188**	777	627.5	3.3
CALCIUM	97950	127500	13800	0	67670	-	-	-	67670	199000	158500	2.3
CHROMIUM	82.35	5.3	25.8	22.85	35	100	11	55	**53**	158	158	3.0
COBALT	80.45	172.15	388	39	136	11 RSL	-	-	**204**	573	388	1.9
COPPER	40.7	122.61	165.2	20.5	72	1300	9	45	**108**	534	202	1.9
IRON	37650	68900	54350	3430	36108	300	-	-	**54162**	275000	106200	2.0
LEAD	4.6	1.282	8.9	7.65	7	15	2.5	12.5	**11**	25.1	13.7	1.3
MAGNESIUM	65100	46350	13900	0	59731	-	-	-	89596	202000	202000	2.3
MANGANESE	5385	3860	7830	302.4	4799	50	-	-	**7199**	9940	8975	1.2
MERCURY	0.1	0.105	0.65	0.355	2	2	0.77	3.85	**2**	13.2	13.2	8.0
MOLYBDENUM	2.06	0.865	0.99	1.135	2	180 RSL	-	-	2	7.2	3.855	2.3
NICKEL	56	104.3	97.7	49.95	71	73	52	260	106	200	128	1.2
POTASSIUM	20700	8590			17132	-	-	-	25698	42500	42500	1.7
SELENIUM	21.8	10.515	6.4	0.575	16	50	5	25	**24**	41.7	41.7	1.7
SILICA	11800	7935			19682	-	-	-	19682	30200	30200	1.5
SILVER	0.02	0.0265	0.1475	0.0715	0	100	3.5	17.5	0.4	4	4	9.3
SODIUM	170000	103300	0		179230	-	-	-	268845	560000	560000	2.1
THALLIUM	0.18	0.6	0.425	0.29	2	-	1.7	8.5	1.6	20	1.6	1.0
VANADIUM	8.15	6.76	28.3	8.6	17	3.7	-	-	**17**	66.9	66.9	3.9
ZINC	182	182.95	408	85.4	246	5000	120	600	**369**	835	523	1.4
Filtered Inorganics (ug/L)												
ANTIMONY	0.0705	1.125	0.12	0.2405	2	6	5.6	28	1.6	20	1.6	1.0
ARSENIC	10.75	15.8	4.6	2.92	11	10	10	50	11	27.1	27.1	2.4
BARIUM	11.95	40.85	11.7	55.65	27	2000	2000	10000	41	103	74.6	1.8
BERYLLIUM	3.1	1.4235	0.74	0.5315	3	4	4	20	3	10.4	10.4	3.8
CADMIUM	5.6	40.564	419.45	0.56	82	5	0.25	1.25	**122**	762	419.45	3.4
CALCIUM	86200	124700	16950		81971	-	-	-	81971	184000	184000	2.2
CHROMIUM	5.135	1.41	4.9	0.845	4	100	11	55	6	11.7	11.7	2.0
COBALT	87.1	173.35	398.5	36.9	152	11 RSL	-	-	**229**	589	398.5	1.7
COPPER	6.6	11.141	40.55	3.85	29	1300	9	45	**44**	111	111	2.5
IRON	36950	57250	52600	563	31141	300	-	-	46711	284000	92950	2.0
LEAD	2.15	0.201	3.1	0.325	3	15	2.5	12.5	4	10.1	10.1	2.6
MAGNESIUM	63800	45550	15900		64807	-	-	-	97210	183000	183000	1.9
MANGANESE	5920	3880	8195	282.75	5071	50	-	-	**7607**	10700	9730	1.3
MERCURY	0.1	0.15	0.17	0.2	0	2	0.77	3.85	0.2	0.34	0.1	0.6
MOLYBDENUM	0.23	1.445	1.115	0.665	1	180 RSL	-	-	1.3	10.2	6.1	4.6
NICKEL	58.9	103.35	96.9	44.35	73	73	52	260	**110**	200	138	1.3
SELENIUM	21.3	7.24	6.4	2.72	17	50	5	25	**25**	44	44	1.7
THALLIUM	0.165	0.245	0.315	0.18	1	-	1.7	8.5	0.7	6	6	9.0
VANADIUM	6.33	1.67	10.15	10.31	6	3.7	-	-	**6**	20	12.2	2.1
ZINC	173	179.75	400	70	220	5000	120	600	**330**	533	525	1.6
Miscellaneous Parameters												
ALKALINITY MG/L	39	82.55	2.4		67				67	355	355	5.3
CHEMICAL OXYGEN DEMAND MG/L	38.3	49.45	54.4		57				57	168	168	3.0
CHLORIDE MG/L	105	164.15			195				195	594	594	3.1
HEXAVALENT CHROMIUM MG/L	0.0025	0.02	0.012	0.0055	0		0.011	0.055	**0.01**	0.13	0.02	1.9
NITRATE-N MG/L	0.023	0.023			1				0.7	2.8	2.8	4.3
PERCHLORATE UG/L	0.356	0.106	0.096	0.082	1				1.4	5.8	5.8	4.3
PH S.U.	4.85	6	4.6		5				5	6.6	6.6	1.3
SULFATE MG/L	908	544			973				973	1600	1600	1.6
TOTAL DISSOLVED SOLIDS MG/L	1500	1100			1744				1744	3500	3500	2.0

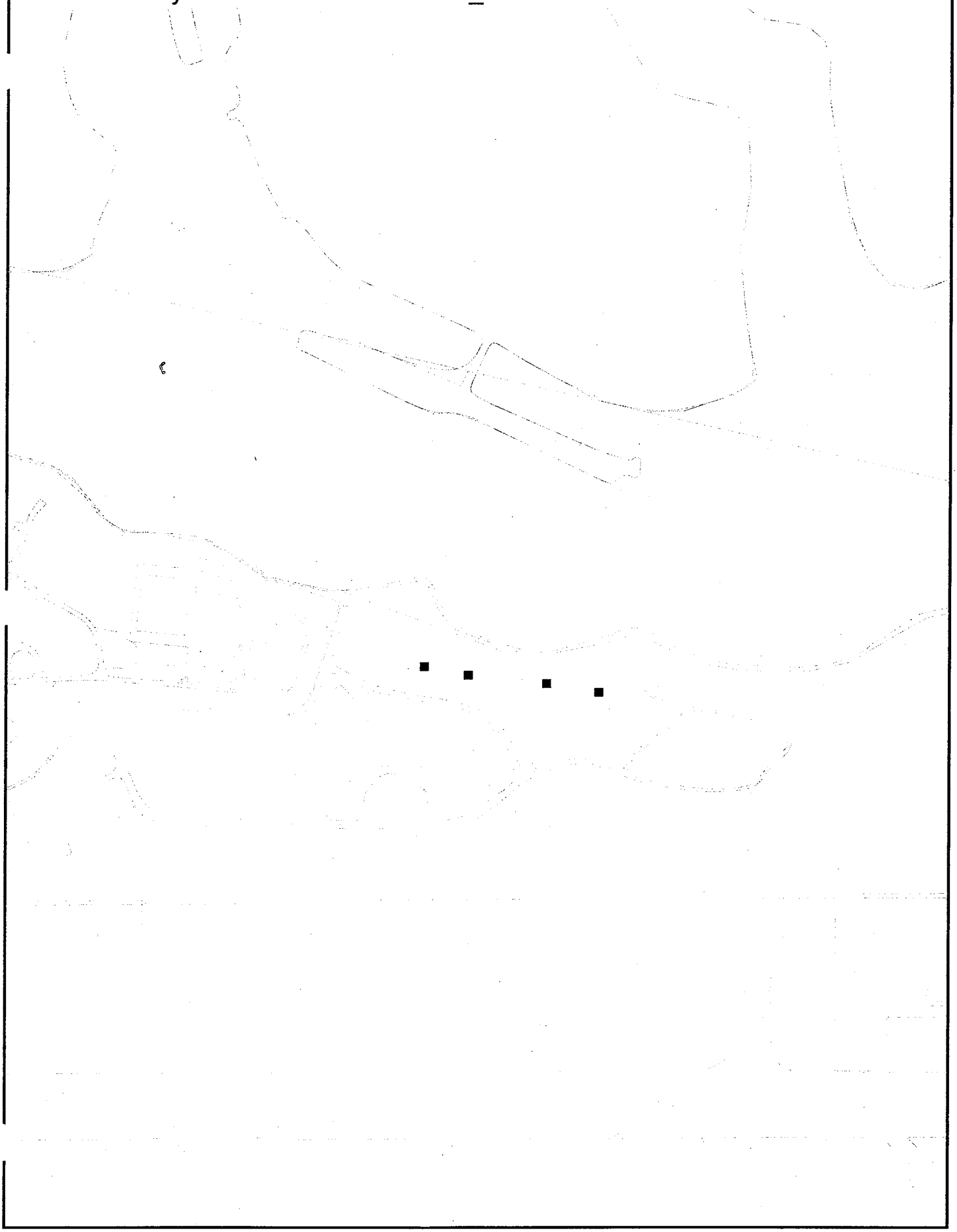
L2: Recovery wells in the Upper Zone_SS-Run-26



L8: Recovery wells in the Intermediate Zone_SS-Run-26



L11: Recovery wells in the Lower Zone_SS-Run-26



Map Document: (K:\GProject\MartinStateAirport-LMC\MapDocs\MXD\Maps\Groundwater monitoring well locs Nov2008 1 30 09.mxd)
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1/4/09

MARYLAND AIR NATIONAL GUARD

Gate

Gate

Gate

POND #2

POND #1

Petroleum Hydrocarbon Area

Drum Area

FROG MORTAR CREEK

MSA- Gage 01

TAXIWAY TANGO

AIRPORT-RUNWAY

MW34S MW34I
MW33S MW33I
MW27D
MW28I
MW16S MW16I MW16D
MW17S MW17I MW17D
MW14I MW14D
MW15S MW15I MW15D
MW18S MW18I MW18D
MW4
MW7
DMW9I/DMW9S
DMW9D
MW26S MW26I MW26D
DMW10I/DMW10S
MW20S MW20I MW20D
DMW3I DMW3S
DMW3D
DMW2A/B
RW1S OW1S
RW1I
OW1I
DMW2S
DMW4I
DMW8I
DMW8S DMW8D
MW25S MW25I
MW3
MW21I MW21D
DMW1S
MW22I MW22D
DMW1A/DMW1B
DMW5I
DMW5S DMW5D
DMW11I DMW11S
TT-11
MW23S MW23I MW23D
MW5
DMW7S
DMW7D
DMW6I
DMW6S DMW6D
MW19I MW19D
MW2
TT-12
TT-14
MW1
TT-13
MW24S MW24I
MW6
MW32S MW32I
MW30D
MW29D
MW31D

Figure 3-1
Groundwater Monitoring Well and Staff Gage Locations

Legend

- Sampled Groundwater Monitoring Well Location
- Installed Well Locations Aug - Sept 09
- Staff Gage Location
- Well Not Sampled
- Ponds

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

DATE MODIFIED: 11/12/09

CREATED BY: MP

Tetra Tech, Inc.

20 scale:
2.1 = 200'

GROUNDWATER TREATMENT SYSTEM AND VENDOR QUOTES

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 3
SUBJECT: Groundwater treatment – Estimate sludge generation		CHECKED BY: CAM	DATE: 4/9/10

Alternative G-2 (aka N-2)

Solids generation

Solids will be generated during the pH adjustment and oxidation step. The majority of the solids will be from the precipitation of iron, manganese, and magnesium. Additional solids may result from sulfate compounds. Although other metals are present (such as cadmium), their concentrations are so low compared to iron, manganese, magnesium, and calcium, they don't need to be calculated individually. Flow rate is 50 gpm. Fe and Mg will precipitate by hydroxide reactions. Ca will react with available alkalinity (about 60 mg/L as CaCO3 is available). Mn will precipitate as an oxide after oxidation.

Assume:

$Fe\ (III) + 3\ OH^- \rightarrow Fe\ (OH)_3$ (MW = 107)

$Mn(II) \rightarrow MnO_2$ (MW = 87)

$Mg + 2\ OH^- \rightarrow Mg\ (OH)_2$ (MW = 58)

$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$ (MW = 100)

Base inorganic concentrations of filtered results because over time, no suspended solids will be generated by the wells. Use average concentrations times a factor of 1.5 rather than maximums. These cations will generally be consistent in concentrations.

Fe – 47,000 ug/L MW = 56

Mn – 7,600 ug/L MW = 55

Mg – 97,000 ug/L MW = 24

Ca – 82,000 ug/L MW = 40

Flow rate = Q = 50 gpm

Estimate $Fe\ (OH)_3$ rate:

50 gal/min x 1,440 min/day x 3.785 L/gal x 47,000 ug Fe/L x 107 ug $Fe\ (OH)_3$ /56 ug Fe x 1 g/10^6 ug x 1 lb/454 g = 54 lb $Fe\ (OH)_3$ /day

Estimate MnO2 rate:

50 gal/min x 1,440 min/day x 3.785 L/gal x 7,600 ug Mn/L x 87 ug MnO2 /55 ug Mn x 1 g/10^6 ug x 1 lb/454 g = 7 lb MnO2 /day

Estimate $Mg\ (OH)_2$ rate:

From literature, typical endpoint Mg concentration from cold lime softening is 60 mg/l Mg as CaCO3. But the conditions will not be ideal for softening (shorter residence time), so assume 120 mg/L as CaCO3.

To convert Mg concentration of ion to equivalent as CaCO3, multiply Mg concentration by 4.12. (from Permutit Data Book)

Similarly, to convert Mg as CaCO3 to Mg, divide the equivalent by 4.12.

So, final concentration of Mg assumed to be 120 mg/L as CaCO3/4.12 = ~30 mg/L Mg.

Amount of Mg precipitated (volume basis) = 97 mg/L – 30 Mg/L = 67 Mg/L.

Estimate Mg $(OH)_2$ rate:

50 gal/min x 1,440 min/day x 3.785 L/gal x 67 Mg mg/L x 58 mg MgOH2 /24 mg Mg x 1 g/10^3 mg x 1 lb/454 g = 97 lb Mg(OH)2 /day

Estimate CaCO3 rate

Assume that the alkalinity at 60 mg/L as CaCO3 precipitates the same equivalent of calcium.

Equivalent weight of Ca is 2.5.

60 mg/L Ca x 1/2.5 = 24 mg/L Ca

MW CaCO3 – 100

24 mg/L Ca x 100 mg CaCO2/40 mg Ca = 60 mg/L CaCO3 precipitates

50 gal/min x 1,440 min/day x 3.785 L/gal x 60 CaCO3 mg/L x 1 g/10^3 mg x 1 lb/454 g = 36 lb CaCO3 /day

Total = 54 + 7 + 36 + 97 = 194 lb/day

To account for other solids, use 200 lb/day solids

Sludge flow rates
Assume sludge from clarifier is 0.5% solids.
Assume sludge from thickener is 4% solids.
Assume sludge from filter press is 30% solids.

Estimate volumetric sludge rate from clarifier:

200 lb solids/day x 1 lb sludge/0.005 lb solid x 1 gal/8.34 lb = 4,800 gal/day

Estimate volumetric sludge rate from thickener underflow:

200 lb solids/day x 1 lb sludge/0.04 lb solid x 1 gal/8.34 lb = 600 gal/day

Estimate sludge rate from filter press:

(Assume typical concentration of 25 lb solids per cubic feet of dewatered sludge)

200 lb solids/day x 1 ft3 dewatered sludge/25 lb solids = 8 ft3/day

[Use 8 ft3/day for filter press sizing]

These rates apply to Alternatives G-2, G-3, and G-5. For Alternative G-4, the rates will be scaled directly to the flow rate (100 gpm).

pH ADJUSTMENT/WASTEWATER NEUTRALIZATION

H_2SO_4 (100%)	HCl (100%)	pH	NaOH (100%)	$Ca(OH)_2$ (100%)
49 g/L	36.5 g/L	0	40 g/L	37 g/L
4.9 g/L	3.65 g/L	1	4.0 g/L	3.7 g/L
0.49 g/L	0.365 g/L	2	0.4 g/L	0.37 g/L
49 mg/L	36.5 mg/L	3	40 mg/L	37 mg/L
4.9 mg/L	3.65 mg/L	4	4.0 mg/L	3.7 mg/L
0.49 mg/L	0.365 mg/L	5	0.4 mg/L	0.37 mg/L
0.049 mg/L	0.0365 mg/L	6	0.04 mg/L	0.037 mg/L
		7		
0.049 mg/L	0.0365 mg/L	8	0.04 mg/L	0.037 mg/L
0.49 mg/L	0.365 mg/L	9	0.4 mg/L	0.37 mg/L
4.9 mg/L	3.65 mg/L	10	4.0 mg/L	3.7 mg/L
49 mg/L	36.5 mg/L	11	40.0 mg/L	37 mg/L
0.49 g/L	0.365 g/L	12	0.4 g/L	0.37 g/L
4.9 g/L	3.65 g/L	13	4.0 g/L	3.7 g/L
49 g/L	36.5 g/L	14	40 g/L	37 g/L

Note: pH_o and pH_f mean initial and final pH, respectively. Units used in table must be corrected in calculations.

Calculation of:

Acid Requirement:

- If $pH_o > 7.0$ and $7.0 \leq pH_f < pH_o$, subtract the acid requirement for pH_f from that for pH_o.
- If $pH_o > 7.0$ and $pH_f \leq 7.0$, add the acid requirement for pH_f to that for pH_o.
- If $pH_o < 7.0$ and $pH_f < pH_o$, subtract the acid requirement for pH_o from that for pH_f.

Base Requirement:

- If $pH_o \geq 7.0$ and $pH_f > pH_o$, subtract the base requirement for pH_o from that for pH_f.
- If $pH_o \leq 7.0$ and $pH_f > 7.0$, add the base requirements.
- If $pH_o < 7.0$ and $pH_o < pH_f < 7.0$, subtract the base requirement for pH_f from that for pH_o.

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Sand Filter – Back wash rate		CHECKED BY: CAH	DATE: 4/9/10

Estimate the backwash flow rates to be used for preliminary sizing of backwash tanks. Base calculation on 50 gpm. (Alternatives G-2, G-3, and G-5)

Assume typical sand filter feed rate of 5 gpm/ft2 (per Siemens quote)

Three sand filters, each 2.5 feet in diameter. (Same filters for 50 and 100 gpm case)

Per Siemens quote, use backwash rate per filter of 40 gpm for 16 minutes.

Estimated backwash volume is 633 gallons, use 800 gallon per backwash, per filter.

Volume of BW:

Although not typical, assume that all three sand filters were backwashed in succession, so volume is 3 x 800 = 2,400 gallons

Backwash of GAC and IE will be needed occasionally when fresh material is added, but will be of shorter duration and lower flow rate, so assume an additional 2,000 gallons volume.

V = 2,400 + 2,000 = 4,400 gal

V = 4,400 gal x 1 ft3/7.481 gal = 588 ft3

Assume a tank diameter (D) of 8 feet.

$V = \pi D^2 H/4$, where H is tank height

$588\ ft3 = \pi 8^2 H/4 \rightarrow H = 12$ feet

$\pi\ 8^2 12/4 \times 7.481\ gal/ft3 = 4{,}500\ gal$ (OK)

These dimensions will be used for Backwash Storage Tank and Waste Backwash Storage Tank.

Estimate return rate of waste backwash (800 gallons) to Feed Tank for different durations:

20 hour – rate = 800 gallons/(20 hr x 60 min/hr) = 0.7 gpm
12 hour – rate = 800 gallons/(12 hr x 60 min/hr) = 0.1 gpm

Use flow rate of 1 gpm.

Same size BW tanks and pumps for 100 gpm and 50 gpm case.

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 2
SUBJECT: Groundwater treatment – Feed Tank		CHECKED BY: CAH	DATE: 4/9/10

Estimate size of Feed Tank for 50 gpm case.

Purpose of Feed Tank is to provide some nominal equalization, mixing of internal streams (such as waste backwash), and level control for the feed pump.

For tank height assume:

- 1 foot to maintain flooded pump suction
- 1 foot of freeboard above LAH
- Place low level switch (pump off) 1 foot above flooded suction level
- Place high level switch (pump on) 1 foot below LAH
- Start with 4 to 6 feet for pump control and to minimize cycling of feed pump.
- Allow 3,000 gallons surge capacity for miscellaneous backwash and water from dewatering.

Try tank 12 feet D and 12 feet H (4 feet for first 4 items above, and 8 feet for working volume and surge).

Check minimum pump operating volume (on-off) per Flygt article. Minimum condition, where 1/2 Qo equals Q in has been substituted in the Flygt article equation:

Min Volume (gal) = $60/(N\Phi) \times (Qo/4)$

Where:
N = number of pumps in automatic alternation system = 1
Φ = allowable motor starts per hour = 8 (assumed, typical is 10)
Qo = flow out of pump = 50 gpm

Min Volume (gal) = $60/(1 \times 8) \times (50/4) = 94$ gal

94 gal x 1 ft3/7.481 gal = 12.6 ft3

At 12 ft D, the change in height is:

12.6 Ft3/$12^2\pi/4$ ft2 = 0.1 ft, so there is enough change in height in the initial assumption above.

Check for surge volume change in height:

3,000 gal x 1 ft3/7.481 gal x $1/12^2\pi/4$ ft2 = 3.5 feet, so here is sufficient height and volume for tank operation.

Total height (excluding height between pump start and pump stop): 1 + 1 + 1 + 1 + 3.5 = 7.5

For uncertainties at this stage, allow 4 more feet = 7.5 + 4 = 11/5 feet, use 12 feet.

Feed Tank – 12 feet D x 12 feet H, 10,200 gal

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 2 of 2
SUBJECT: Groundwater treatment – Feed Tank		CHECKED BY: CAH	DATE: 4/9/10

Size for 100 gpm case:

Target volume for approximately 100 gpm/50 gpm x 10,200 gal = 20,400 gal.

Maintain same height

Try 18 feet D

$V = 18^2\pi/4 \times 12 \times 7.481$ gal/ft3 = 22,800 gallons (Okay)

$V_1 = \frac{60}{N\phi}\left[0.25\,Q_2\right]$ // AT $N=1$ and $\phi=5$, $V_1 = 3Q_2$ or 3 minutes.

Pump Starts Per Hour

Now we have gotten to the point where the permissible number of starts per hour of the pump selected becomes an important factor. One of the advantages of submersible pumps is their substantially greater start capability than dry pit pumps. Flygt pumps, for example, normally operate with 10 starts per hour, and it is permissible to utilize up to 15 starts per hour for specific applications where sump volumes must be maintained at a minimum. In addition to adhering to the manufacturer's recommendations for maximum pump starts per hour, it is also imperative to consider the recommendations of the starting equipment manufacturer to assure that the number of starts permitted by the latter does not exceed the number of starts capability of the contactors. The electrical control equipment must be compatible with the pump motors. Specifying a single source for pumps, motors, and controls assures such compatibility.

The number of starts per hour, together with the number of pumps used in the station, will determine the minimum sump capacity, and this will be our next consideration. To determine the required volume, we begin by calculating the minimum pumping volume per cycle, which is determined by the turn-on and shut-off points in the pit.

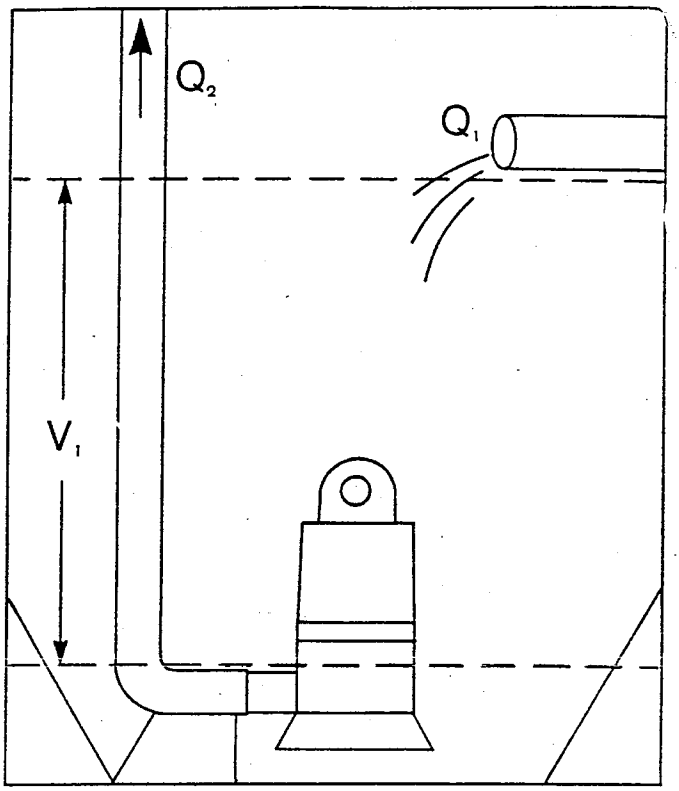
The formula for determining the minimum pumping volume per cycle is $V_1 = \frac{60}{N\phi}\left[\frac{Q_1}{Q_2}(Q_2-Q_1)\right]$. V_1 stands for the required minimum pumping volume per cycle, N is the number of pumps alternating in the system, ϕ is the permissible number of starts per hour per pump, Q_1 is the rate of influent flow in gallons per minute, and Q_2 is the rate of pump discharge in gallons per minute.

Now this formula can be reduced in terms of time (T), which is a determinant of volume V_1. By taking the first differential of the equation containing both V_1 and T and equating it to zero, we determine that minimum pumping volume per cycle occurs when Q_1 is ½ of Q_2 (or when the inflow to the station is ½ the pump capacity). To repeat, these calculations will provide us with the requirements for the minimum volume permitted by the number of starts per hour. Any volume below the minimum will necessitate more starts per hour and possibly exceed the capacity of the pump. If we apply the formula to a duplex pump station with one pump operating as an alternating active standby, and calculate on the basis of 10 starts per hour, then V_1 becomes .75 of Q_2 or the required operating minimum volume between pump turn-on and shut-off is ¾ of the pump capacity.

A final refinement of the preliminary selection of pumps, pumping station depth, and its diameter or area is now in order. Utilizing the preliminary sump depth assumption, the shutoff point for the pump selected, the diameter or area assigned for the pump station, and having calculated the required minimum volume, it is now possible to determine if the assumed pump station depth selected agrees with requirements. If the assumed sump volume is excessive or inadequate, the pump station depth can be altered to suit the requirements. It then becomes necessary to make corrections to the head curve as well as the other considerations to end up with a properly designed pumping station. If the sump volume has been determined as excessive, diminution of wet well depth can provide significant savings in station construction.

Final Design

With all the pump and pumping station details established, we are now at the final design stage. The final design includes the layout of the pumps, controls, and valves, as well as the miscellaneous accessories. It also includes final setting of the turn-on and shut-off of the pumps and the alarm system.



Minutes "on" $= t_1 = \frac{V_1}{Q_2-Q_1}$ Minutes "off" $= t_2 = \frac{V_1}{Q_1}$

Complete cycle $= t_1 + t_2 = t_3$

Single pump (of "N" pumps) cycles/hr. $= \phi$

$$\phi = \frac{60}{t_3 \cdot N} = \frac{60}{NV_1}\left[\frac{Q_1}{Q_2}(Q_2-Q_1)\right]$$

Required pumping vol./cycle $= V_1$

$$V_1 = \frac{60}{N\phi}\left[\frac{Q_1}{Q_2}(Q_2-Q_1)\right]$$

For 2 pumps and 10 cy./hr./pump $V_1 = 0.75\,Q_2$

Important factors to be considered in the layout are the location of the pumps and the pump discharge relative to the inflow sewer. The liquid level controls should be placed in a quiescent area away from the incoming flow or protected in one of several ways from direct impingement.

Another item is the location of the check valves in the system. Certain states require an external chamber for the valves so that maintenance department personnel need not enter the wet well to service the valves.

Final design will also include considerations for future needs such as possible increased capacity. In the latter instance, the control panel should be large enough to accommodate future larger breakers and starting equipment if necessary.

The type of alarm system must also be selected and designed into the control system. Options include a local or a remote alarm system. Local systems generally make use of bells, horns, and lights. A remote system will require a means of transmitting the signal from the local station to a location such as the treatment plant or a police or fire station.

I have attempted in this relatively short paper to outline certain of the basic considerations to be followed in the design of small and medium size submersible pump stations. A refinement in detail would require a much longer paper. However, I believe that the major factors for consideration have been touched on sufficiently to alert pump station designers to possible major items where care should be exercised to assure a safe, dependable and economical submersible pump station.

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system. Clarified Water Feed Tank and Discharge Pump Tank size.		CHECKED BY: CAH	DATE: 4/9/10

Estimate the size of the Clarified Water Feed Tank for 50 gpm case. This will also be the size of the Discharge Pump Feed Tank.

Purpose of tank is to provide working volume for pump. Assume on-off operation of pump.

For tank height assume:

- 1 foot to maintain flooded pump suction
- 1 foot of freeboard above LAH
- Place low level switch (pump off) 1 foot above flooded suction level
- Place high level switch (pump on) 1 foot below LAH
- Use 2 to 4 feet for pump control and working volume.

Small diameter tank.

Check pump operating volume (on-off) per Flygt article

Min Volume (gal) = $60/(N\Phi) \times (Qo/4)$

Where:
N = number of pumps in automatic alternation system = 1
Φ = allowable motor starts per hour = 8 (assumed, typical is 10)
Qo = flow out of pump = 50 gpm

Min Volume (gal) = 60/(1 x8) x (50/4) = 94 gal

94 gal x 1 ft3/7.481 gal = 12.6 ft3

Try 4 ft D, and check a working height of 4 feet:

$V = 4^2\pi/4 \times 4 \times 7.481$ gal/ft3 = 376 gallons (Okay)

Tank will be 4 feet D x 8 feet high

Tank $V = 4^2\pi/4 \times 8 \times 7.481$ gal/ft3 = 750 gallons

This is for both the Clarified Water Feed Tank and Discharge Pump Feed Tank.

Calculate 100 gpm case

Scale volume to flow rate

Target volume is 100 gpm/50 gpm x 750 gal = 1,500 gal

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 2 of 2
SUBJECT: Groundwater treatment system. Clarified Water Feed Tank and Discharge Pump Tank size.		CHECKED BY: CAH	DATE: 4/9/10

Use same H to maintain hydraulics

Try 6 feet D x 8 feet H:

Tank V = $6^2\pi/4$ x 8 x 7.481 gal/ft3 = 1,690 gallons.

Tetra Tech NUS			STANDARD CALCULATION SHEET
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 2
SUBJECT: Groundwater treatment system. Air Stripper size and Vapor-Phase GAC		CHECKED BY: CAM	DATE: 4/9/10

Air Stripper
Estimate the size of the air stripper for the 50 gpm and 100 gpm cases.

Air stripper sizes were estimated using QED Environmental model at their website. The stripper was sized so that the effluent VOC concentrations would be less than MCLs so that the AOP system would only be treating the 1,4-dioxane.

Based on the model output and information from the QED website (attached) the characteristics of the air strippers are as follows:

50 gpm case

EZ-Tray 8.6 with 6 trays, 75 gpm maximum flow rate, 420 cfm blower with 5 hp motor.

100 gpm case

EZ-Tray 16.6 with 6 trays, 150 gpm maximum flow rate, 850 cfm blower with 7.5 hp motor.

Vapor-Phase GAC

The QED stripper model output provides a vapor stream composition, and this information was put into a spreadsheet (attached) to estimate the GAC requirement. GAC usage was calculated for a daily, monthly, and annual rates. Based on this, the monthly rate was selected.

The GAC system will have two GAC tanks, each containing sufficient GAC for 1 month operation.

Per the spreadsheet, for 50 gpm, the GAC rate is 4,000 lb/month, so there will be two tanks, each containing 4,000 lb GAC.

For 100 gpm, the GAC rate is 9,000 lb/month, so there will be two tanks, each containing 9,000 lb GAC.

Electric Heater for Vapor to GAC

Need electric heater to raise temperature of air stripper discharge to 80% relative humidity (RH).

Assume air temperature equals water temperature, about 50 F.

Using a psychrometric chart:

Enthalpy (BTU/lb dry air) at 50 F, 100 % RH = 20.4
Follow line of constant moisture:
Enthalpy (BTU/lb dry air) at 56.5 F, 80 % RH = 22.0

Δenthalpy (BTU/lb dry air) = 1.6

Specific weight of dry air (from chart) = 13 ft3/lb dry air = 0.077 lb dry air/Ft3

Tetra Tech NUS			STANDARD CALCULATION SHEET
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 2 of 2
SUBJECT: Groundwater treatment system. Air Stripper size and Vapor-Phase GAC		CHECKED BY: CAH	DATE: 4/9/10

Q air = 420 scfm (because pressure change is very small, this can be used.)

1 kw = 0.9478 BTU/sec

Power = 420 ft3/min x 1 min/60 sec x 0.077 lb air/ft3 x 1.6 BTU/lb air x 1 kw/(0.9478 BTU/sec) = 0.91 kw

Assume 75% efficiency: 0.91/0.75 = 1.2 kw, round to 2 kw.

For 100 gpm case, use 4 kw.

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system. Potassium permanganate impregnated zeolite		CHECKED BY: CAH	DATE: 4/9/10

Estimate the usage rate of potassium permanganate impregnated zeolite (PPIZ) to remove vinyl chloride from air stripper offgas. Estimate quantity for 50 gpm case and double those values for 100 gpm case.

Per Carbonair, the loading rate of vinyl chloride on PPOZ is 1.4% by weight. The vinyl chloride reacts with and consumes the PP, and the spent zeolite is disposed of as a non-hazardous waste.

From the vapor-phase GAC spreadsheet, the vinyl chloride rates are:

50 gpm – 44.6 lb/mo

100 gpm – 89.2 lb/mo

1.4% loading equals 1.4 lb vinyl chloride (VC)/100 lb PPIZ.

50 gpm

44.6 lb VC/mo x 100 lb PPIZ/1.4 lb VC = 3,186 lb/mo, use 3,000 lb/month.

100 gpm

89.2 lb VC/mo x 100 lb PPIZ/1.4 lb VC = 6,370 lb/mo, use 6,000 lb/month.

At 60 lb/ft3, estimate the tank size.

50 gpm

3,000 lb x ft3/60 lb = 50 ft3

$V = 4^2\pi/4 \times 6 = 75$ ft3 → 4 feet diameter x 6 feet high

100 gpm

6,000 lb x ft3/60 lb = 100 ft3

$V = 6^2\pi/4 \times 6 = 170$ ft3 → 6 feet diameter x 6 feet high

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system – Liquid-phase GAC estimate		CHECKED BY: CAH	DATE: 4/9/10

Estimate liquid-phase GAC requirement based on design flows and concentrations. Note that concentrations will significantly decrease with time and that air stripper and AOP system will destroy/remove most of the organic compounds.

Size for 50 gpm.

Post-AOP concentrations will be MCLs, although GRO and DRO may be high.

Use average DRO and GRO for design basis. Assume 25% removal by the air stripper and AOP.

Untreated water:

DRO – 300 µg/L
GRO – 900 µg/L

Post AOP (based on 25% removal)

DRO – 0.75 x 300 µg/L = 225 µg/L
GRO – 0.75 x 900 µg/L = 675 µg/L

Mass Rate

DRO

225 µg DRO/L x 50 gal/min x 1,440 min/day x 3.785 L/gal x 1 g/10^6 µg x 1 lb/454 g = 0.14 lb GRO/day

GRO

675 µg DRO/L x 50 gal/min x 1,440 min/day x 3.785 L/gal x 1 g/10^6 µg x 1 lb/454 g = 0.4 lb DRO/day

Total = 0.14 + 0.4 = 0.54 lb/day, use 0.6 lb/day

GAC Volume
Check volume based on empty bed contact time (EBCT)

Base on 20 minute EBCT

50 gal/min x 20 min = 1,000 gallons (assume 2 tanks)

Mass of GAC per tank

1,000 gal x 1 ft3/7.481 gal x 30 lb GAC/ft3 = 4,000 lb GAC

Estimate replacement rate at 10 lb GAC per lb DRO/GRO

4,000 lb GAC x 1 lb DRO-GRO/10 lb GAC x 1 day/0.6 lb DRO-GRO = 660 days

This is more than sufficient. Actual change out will occur more frequently, and as a safety factor, the change-out rate is assumed to be semi-annual.

For the 100 gpm case, the tanks will be larger for a higher EBCT (Two tanks at 2,000 gallons each with 8,000 lb GAC per tank.)

Tetra Tech NUS			STANDARD CALCULATION SHEET
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater Treatment – Thickener size		CHECKED BY: CAH	DATE: 4/9/10

Estimate the size of the thickener. Assume that this will be a small diameter unit for inorganic solids, and a plain tank without a rake will be sufficient.

The thickener thickens sludge from 0.5% to 4% by gravity.

Thickener will be able to hold 10 days of 4% sludge (for weekly filter press runs)

(See Sludge generation calculations for quantity estimation.)

Volume 0.5% sludge = 4,800 gal/day

Volume 4% sludge = 600 gal/day

Mass solids rate = 200 lb/day

Typical sizing factor for iron sludge is 2 to 10 lb per ft2-day. Use the low end of the range: 2 lb/ft2-day

200 lb/day x ft2-day/2 lb = 100 ft2

$A = \pi D^2/4 = 100$ ft2 → D = 11.3 ft, use 12 feet.

Assume 12 feet high (1 foot freeboard)

Assume pumping to thickener would be intermittent. Use 1 pumping cycle per hour for 15 minutes per cycle:

Q = 4,800 gal/24 cycles x 1 cycle/15 minutes = 13.3 gpm (use 15 gpm) as the flow rate for the sludge transfer pump

Check sludge inventory:

Volume per foot:

$V = \pi D^2 H/4 \times 7.481 = \pi 12^2 1/4 \times 7.481$ gal/ft3 = 846 gal/foot

Ten days of 4% sludge = 10 x 600 gal/day = 6,000 gal

Assume 9 feet of height is available:

Sludge storage volume = $\pi D^2 H/4 \times 7.481 = \pi 12^2 9/4 \times 7.481$ gal/ft3 = 7,600 gal (this is sufficient)

Overall: 12 feet Dia x 12 feet high, 10,000 gal

<u>For 100 gpm case</u>

Use the same height for hydraulics. Scale area to flow rate.

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
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SUBJECT: Groundwater Treatment – Thickener size		CHECKED BY: CAH	DATE: 4/9/10

Area = 100 gpm/50 gpm x 100 ft 2 = 200 ft2

$A = \pi D^2/4 = 200$ ft2 → D = 15.9 ft, use 16 feet.

Overall: 16 feet Dia x 12 feet high, 18,000 gal

(These sizes are similar to Siemens quoted equipment.)

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system – Filtrate Tank		CHECKED BY: CAH	DATE: 4/9/10

Estimate size of Filtrate Tank for 50 gpm case. This receives overflow from thickener and filtrate from filter press. The tank also provides pump control (on and off) for Filtrate Transfer Pump.

Size based on 7 days of 4% sludge. This water volume will be conservatively estimated to be the thickened sludge flow rate. Assume entire flow as water.

Sludge rate is 600 gal/day

600 gal/day x 7 day = 4,200 gallons. Use 4,400 gallons.

Tank needs to be low in height to receive water by gravity from thickener overflow and from the filter press. Thickener is 12 feet high, and filter press will be mounted on an elevated platform, 8 to 10 feet above the flow.

10 feet D x 8 feet H

$V = 10^2\pi/4 \times 8 \times 7.481$ gal/ft3 = 4,700 gallons (Okay)

Filtrate Transfer Pump will be sized to match Sludge Transfer Pump = 15 gpm.

<u>100 gpm case</u>

Scale according to flow rates. Use 8 feet height.

V = 100 gpm/50 gpm x 4,700 gal = 9,400 gal

14 feet D x 8 feet H

$V = 14^2\pi/4 \times 8 \times 7.481$ gal/ft3 = 9,200 gallons (Okay)

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system – Filter Press Pump and Filter press		CHECKED BY: CAH	DATE: 4/9/10

Estimate size of filter press:

Assume 8 ft3 day of dewatered sludge (see separate calculation).

Assume press is operated weekly, so 7 days of sludge is processed.

V = 7 day x 8 ft3/day = 56 ft3

Provide capability for 10 days:

V = 10 day x 8 ft3/day = 80 ft3

Estimate size of Filter Press Feed Pump

Size for pumping 7 days of 4% sludge in 4 hours

7 days x 600 gal / (4 x 60 minutes) = 17.5 gpm use 20 gpm

Use an air-operated double diaphragm pump.

For 100 gpm case, scale to flow rate:

100 gpm/50 gpm x 80 ft3 = 160 Ft3

(Siemens quote had a 25 Ft3 unit, so cost estimate will be increased for a larger filter press.)

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system – Building Sump		CHECKED BY: CAH	DATE: 4/9/10

Estimate size of Building sump.

Sump is intended to capture small spills and miscellaneous small drains. Contents would be pumped to Feed Tank. A major spill would be contained entirely within the building.

Assume 8 feet x 8 feet and 6 feet deep. Opening would be covered by a steel grating.

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 5
SUBJECT: Groundwater treatment system – Pump sizes		CHECKED BY: CAH	DATE: 4/9/10

Estimate pump sizes for wastewater pumps in the groundwater treatment system for 50 gpm case.

1. Feed Pump

Transfers water from the Feed Tank to the Metals Removal Step

Pressure losses and static head:

Item	Δh, feet
Static head – based on estimated height of clarifier	20 feet
Piping losses: 4" Sch 80 PVC (0.21ft/100feet). Assume 150 equivalent feet of piping. Δh = 150 feet x 0.21 ft/100 ft =	0.3
Meters (flow meter) assume 5 psi = 12 feet	12
Total	32.3

Use ΔH = 40 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (50 gpm x 40 feet)/(3,960 x 0.7) = 0.72 → use 1 hp

100 gpm case:

Pump hp = (100 gpm x 40 feet)/(3,960 x 0.7) = 1.4 → use 1.5 hp

2. Clarified Water Pump

Transfers water from Clarified water Tank through Sand Filters, to Air Stripper.

Pressure losses:

Item	Δh, feet
Static head – based on estimated height of Air Stripper	10
Sand Filter: Use 10 psi. 10 psi x 2.3 feet/psi = 23 feet	23
Total	33

Use ΔH = 40 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (50 gpm x 40 feet)/(3,960 x 0.7) = 0.7 → use 1 hp

100 gpm case:

Pump hp = (100 gpm x 40 feet)/(3,960 x 0.7) = 1.5 → use 2 hp

3. Stripper Effluent Pump

Transfers water from Stripper Effluent sump through HiPOx, GAC, IE, and into BW supply tank and Discharge Pump Tank.

Pressure losses:

Item	Δh, feet
Static head – based on estimated height of backwash supply tank	10
HiPOx: Use 15 psi. 15 psi x 2.3 feet/psi = 35 feet	35
GAC: Use 10 psi. 10 psi x 2.3 feet/psi = 23 feet	23
IE tank: Use 5 psi. 5 psi x 2.3 feet/psi = 12 feet	12
Total	80

Use ΔH = 90 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (50 gpm x 90 feet)/(3,960 x 0.7) = 1.6 → use 3 hp

100 gpm case:

Pump hp = (100 gpm x 90 feet)/(3,960 x 0.7) = 3.2 → use 5 hp

4. Backwash Pump

Backwashes sand filter.

Per vendor, flow rate is 40 gpm

Pressure losses:

Item	Δh, feet
Static head – estimated	12
Tank – assume 10 psi: 10 psi x 2.3 feet/psi = 23 feet	23
Miscellaneous piping losses. Assume 5 feet	5
Total	40

Use ΔH = 40 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (40 gpm x 40 feet)/(3,960 x 0.7) = 0.6 → use 1 hp

100 gpm case:

Same filters are used, so pump is the same.
Pump hp = (40 gpm x 40 feet)/(3,960 x 0.7) = 0.6 → use 1 hp

5. Waste Backwash Pump

Transfers waste backwash from Waste Backwash Tank to the Feed Tank.

Assume 1 gpm.

Pressure losses:

Item	Δh, feet
Static head	12
Miscellaneous piping losses. Assume 5 feet	5
Total	17

Use ΔH = 20 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (1 gpm x 20 feet)/(3,960 x 0.7) = 0.07 → use 0.5 hp

100 gpm case:

Use the same size. 0.5 hp.

6. Sump Pump

Transfers water Building Sump to Feed Tank.

Assume 10 gpm.

Pressure losses:

Item	Δh, feet
Static head – bottom of sump to floor	10
Static head – Floor to top of Feed Tank	12
Miscellaneous piping losses. Assume 5 feet	5
Total	27

Use ΔH = 30 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (10 gpm x 30 feet)/(3,960 x 0.7) = 0.1 → use 0.5 hp

100 gpm case:

Use the same size. 0.5 hp.

7. Filtrate Transfer Pump

Transfers water from Filtrate Tank to Feed Tank.

Assume 15 gpm.

Pressure losses:

Item	Δh, feet
Static head	12
Miscellaneous piping losses. Assume 5 feet	5
Total	17

Use ΔH = 20 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (15 gpm x 20 feet)/(3,960 x 0.7) = 0.1 → use 0.5 hp

100 gpm case:

Pump hp = (15 x (100/50) gpm x 20 feet)/(3,960 x 0.7) = 0.2 → use 0.5 hp

7. Discharge Water Pump

Transfers water Discharge Tank to Sanitary sewer tie-in near road and injects water into injection wells. Size for injection.

Length of pipe is 3,900 feet
Assume 200 equivalent feet for fittings
Total; equivalent length is 4,100 feet

Assume 4" dia Sch 80 PVC, Δh = 0.21ft/100 feet

Assume 10 psi for injection = 10 psi x 2.3feet/psi = 23 feet

Pressure losses:

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SUBJECT: Groundwater treatment system – Pump sizes		CHECKED BY: CAH	DATE: 4/9/10

Item	Δh, feet
Static head	0 feet
Piping losses: Δh = 4,100 feet x 0.21 ft/100 ft = 8.6, use 10 foot	10
Meter (flow meter) assume 5 psi = 12 feet	12
Injection losses	23
Total	45

Use ΔH = 50 feet

Estimate motor horsepower (assume 70% efficiency)
Pump hp = (50 gpm x 50 feet)/(3,960 x 0.7) = 0.9 → use 1.5 hp

100 gpm case:

Pump hp = (100 gpm x 50 feet)/(3,960 x 0.7) = 1.8 → use 2 hp

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater Treatment system - Mixers		CHECKED BY: CAH	DATE: 4/9/10

Estimate mixer sizing for 50 gpm case, from vendor catalogue and Siemens quote.

Mixer	Tank Volume, Gal	Mixer HP (50 GPM)	Mixer HP (100 GPM)
Feed Tank	10,000	10	10
Primary pH adj. Tank	-	0.5	0.5
Secondary pH adj. Tank	-	0.5	0.5
Flocculator	-	0.5	0.5
Final pH Adj. Tank	1,000	0.5	1
Filtrate Tank	4,700	5	7.5

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater Treatment System – Air Compressor		CHECKED BY: CAH	DATE: 4/9/10

Air Compressor only needs to provide service to the sludge transfer pump, filter press feed pump, and filter press.

Assume a 100 psig unit that provides 50 scfm.

Tetra Tech NUS			STANDARD CALCULATION SHEET
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 3
SUBJECT: Groundwater treatment system – Chemical feed rates		CHECKED BY: CAH	DATE: 4/9/10

Estimate chemical addition rates for 50 gpm case. For 100 gpm, rates will be increase by factor of 100/50 = 2.

1. Hydrogen peroxide (H_2O_2) for iron and manganese oxidation. Iron and manganese are assumed to be reduced. (See sludge calculations for Fe and Mn concentrations.).

For Fe(II) to Fe(III)

$2 Fe^{+2} + H_2O_2 + 4 OH^- \rightarrow 2 Fe(OH)_3$

From US Peroxide Website, the H_2O_2 rate for the iron (50 gpm and 47,000 ug/L) is 8.5 lb/day, use 9 lb/day

For Mn(II) to Mn(VI)

1 mole of H_2O_2 oxidizes 2 mole e^-

So 1 mole H_2O_2 oxidizes 1 mole Mn(II) to Mn(VI)

MW H_2O_2 = 34, MW Mn = 55

Concentration Mn = 7,600 µg/L

H_2O_2 for Mn:

50 gal/min x 1,440 min/day x 7,600 ug/L x 3.785 L/gal x g/10^6 ug x 1 lb/454 g x 34 lb H_2O_2/55 lb Mn = 3 lb H_2O_2/day

Total = 9 + 3 = 12 H_2O_2 lb/day

(100 gpm case is 2 x 12 = 24 H_2O_2 lb/day)

2. NaOH

Base this on chart to adjust pH from 6 to 11 for Cd removal, fast Fe oxidation, and precipitation of other metals.

pH from 6 to 7 needs 0.04 mg NaOH/L
pH from 7 to 11 needs 40 mg NaOH/L

Total for pH adjustment – 40.04 mg NaOH/L

50 gal/min x 1,440 min/day x 40.04 mg NaOH /L x 3.785 L/gal x g/10^3 mg x 1 lb/454 g = 24 NaOH lb/day

Additional hydroxide for Fe and Mg precipitation. (See Sludge estimate calculation.)

Estimated $Fe(OH)_3$ – 54 lb/day (MW = 107) (from sludge calculation)

Estimated Mg(OH)2 – 97 lb/day (MW = 58) (from sludge calculation)

MW NaOH = 40

NaOH for Fe(OH)3:
54 lb Fe(OH)3/day x (3 x 17 lb OH)/107 lb Fe(OH)3 x 40 lb NaOH/17 lb OH = 60 lb NaOH/day

NaOH for Mg(OH)2:

97 lb Mg(OH)2/day x (2 x 17 lb OH)/58 lb Mg(OH)2 x 40 lb NaOH/17 lb OH = 133 lb NaOH/day

Total NaOH = 24 + 60 + 133 = 220 lb/day

At 50% solution (s.g. = 1.2):

220 lb/day x 1 lb solution/0.5 lb NaOH x 1 gal/(8.34 x 1.2) lb = 44 gal/day NaOH 50% solution

(100 gpm case is 2 x 220 = 440 lb NaOH/day and 2 x 44 = 88 gal/day NaOH 50% solution)

3. HCl

Base this on chart to adjust pH from 11 to 7.

pH from 11 to 7 needs 36.5 mg HCl/L

50 gal/min x 1,440 min/day x 36.5 mg HCl /L x 3.785 L/gal x g/10^3 mg x 1 lb/454 g = 22 lb HCl/day

At 35% solution (s.g. = 1.2):

22 lb/day x 1 lb solution/0.35 lb HCl x 1 gal/(8.34 x 1.2) lb = 6.3 gal/day HCl 35% solution

(100 gpm case is 2 x 22 = 44 lb HCl/day and 2 x 6.3 = 12.6 gal/day HCl 35% solution)

4. Polymer (for coagulation and flocculation)

Assume typical concentration of 10 ppm.

50 gal/min x 1,440 min/day x 8.34 lb/gal x 10 lb polymer/10^6 lb water = 6 lb polymer/day

(100 gpm case is 6 x 2 = 12 lb/day)

5. H2O2 and ozone for HiPOx

See HiPOx Quote.



Full-Service Chemical Treatment Programs for Municipal an

H_2O_2 Calculator

Determine your hydrogen peroxide requirements for the treatment of 15 different reactants.

Reactant:	Iron (II)	
Reactant Concentration:	47	(mg/L)
Waste Flow:	72000	(gallons / day)

Submit

Notes: Calculations are based on continuous flow. If more than one type of reactive contaminant is present, enter the contaminants separately and add the H2O2 requirements together.

Calculated lbs per day of Reactant:	28.2 lbs / day
Calculated lbs per day of H_2O_2 (100%):	8.5 lbs / day
Calculated H_2O_2 Requirement (50%):	1.7 gallons / day
Hourly Dosing Requirement (50% H_2O_2):	0.07 gallons / hour
Monthly Usage (50% H_2O_2):	50.8 gallons / month
List Price per gallon (50% H_2O_2):	$3.45 per gallon (full truck load, FOB manufacturer's site)
Cost per day (based on above list price):	$5.85 per day
Reaction Equation(s):	$2\ Fe^{2+} + H_2O_2 + 4\ OH^- \rightarrow 2\ Fe(OH)_3$ (ferrous iron + hydrogen peroxide → ferric acid)

Theoretical Weight Ratio: 0.3 lbs H_2O_2 (100%) per lb Fe^{2+}

Process Notes:

Reaction occurs within seconds at neutral to alkaline pH

The ferric hydroxide product may be removed by precipitation or filtration

Manganese (II) may be removed concurrently through a similar conversion to MnO_2

Note: This information is provided for preliminary evaluation purposes only. The estimates are based upon theoretical requirements of H_2O_2 using 100% efficiency of reaction. Actual requirements may vary depending on the specific composition of the waste and the conditions under which the reaction is performed. It is user's responsibility to familiarize himself with the safe handling of H_2O_2 and to ensure that no patents or licenses are being infringed upon in practicing this reaction.

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Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 2
SUBJECT: Estimate Chemical storage containers		CHECKED BY: CAH	DATE: 5/26/2010

Estimate chemical containers, drum or totes.

H2O2

50 gpm – 12 lb/day
100 gpm – 24 lb/day

assume 35% H2O2

1 drum = 55 gal x 8.34 lb/gal x 0.35 = 160 lb H2O2

50 gpm: 160 lb/(12 lb/day) = 13 days per drum
100 gpm: 160 lb/(24 lb/day) = 7 days per drum

Use drum

NaOH

50 gpm – 12 gal/day at 50%
100 gpm – 24 gal/day at 50%

assume tote tank at 300 gal

50 gpm: 300 gal/(44 gal/day) = 7 days per tote
100 gpm: 300 gal/(88 gal/day) = 3.5 days per tote

Need to use a large tote tank, say 500 gal.

50 gpm: 500 gal/(44 gal/day) = 11 days per tote
100 gpm: 500 gal/(88 gal/day) = 6 days per tote

HCl

50 gpm – 6.3 gal/day at 35%
100 gpm – 12.6 gal/day at 35%

assume tote tank at 300 gal

50 gpm: 300 gal/(6.3 gal/day) = 48 days per tote
100 gpm: 300 gal/(12.6 gal/day) = 24 days per tote

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 2 of 2
SUBJECT: Estimate Chemical storage containers		CHECKED BY: CAH	DATE: 5/26/2010

Polymer

Use a 55 gal drum

6 lb/day ~ 0.8 gal/day

55 gal/(0.8 gal/day) = 68 days

H2O2 for HiPOx

50 gpm – 3 gal/day at 35%
100 gpm – 6 gal/day at 35%

assume tote tank at 300 gal

50 gpm: 300 gal/(3 gal/day) = 100 days per tote
100 gpm: 300 gal/(6 gal/day) = 50 days per tote

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 2
SUBJECT: Groundwater Treatment system – Estimate of piping quantity for estimate.		CHECKED BY: CAH	DATE: 4/9/10

Estimate piping quantity based on preliminary layout sketch.

For 50 gpm, the velocity in 2" PVC is 5.5 ft/sec, which is greater than the recommended maximum velocity of 5 ft/sec. Therefore, assume 4" schedule 80 PVC. At 100 gpm, velocity through 4" pipe is 2.87 ft/sec.

The cost of a fitting (for example a T or elbow) is about the same as 10 feet of piping. So a fitting unit cost will be based on 10 feet of PVC.

Price valves as ball valves.

Assume 3 fittings into and out of each piece of equipment (on each line).

Assume 1 valve on each line into and out of each piece of equipment.

Assume 1 fitting between each piece of equipment.

For estimating length, use layout for horizontal and assume 10 feet vertical for each piece of equipment.

Horizontal piping
Main process flow – 300 feet
Backwash – 190 feet
Sludge - 170 feet
Air – 200 feet (steel)

Total = 860 feet, use 1,000 feet

Vertical piping
10 feet x 60 items of equipment = 600 feet

Total = 1,000 + 600 = 1,600 feet

Fittings

(60 +20) x 3 + 25 x 1 = 265, use 300.

Valves

60 x 2 = 120

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 2 of 2
SUBJECT: Groundwater Treatment system – Estimate of piping quantity for estimate.		CHECKED BY: CAH	DATE: 4/9/10

Assume there will be some 2" piping:

300 feet
50 fittings
20 valves

Assume there will be some 6" piping:

100 feet
10 fittings
5 valves

For air duct work from stripper through GAC and zeolite, assume:

100 feet
20 fittings
10 valves

Tetra Tech NUS		*STANDARD CALCULATION SHEET*	
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 2
SUBJECT: Groundwater Treatment system – Extraction well, injection well, and other long pipe lines		CHECKED BY: CAH	DATE: 4/9/10

1. Estimate length of piping for hydraulic control extraction wells.

Assume a common header, then individual take-offs to each well. Assume that common header will run close to the wells.

From figure, the Main Header length is 4,050 feet (as 4"diameter double wall pipe.)

Assume that each well has a 25 foot long 1" diameter double wall line.

For 16 wells, this is 16 x 25 feet = 400 feet.

2. Estimate length of injection well piping from building to injection wells. Single wall pipe.

Assume a main header with individual lines to each well. From sketch, the Main Header length is 3,900 feet.

Total length of 1-inch lines to each well is 950 feet.

3. Estimate additional length of piping for HCA extraction wells (This is added to Item 1, for appropriate Alternatives).

Assume a common header, then individual take-offs to each well. Assume that common header will run close to the wells.

From figure, the Main Header length is 1,600 feet (as 2"diameter double wall pipe.)

Assume that each well has a 25 foot long 1" diameter double wall line.

For 16 wells, this is 16 x 25 feet = 400 feet.

4. Estimate length of piping to sanitary sewer connection. Single wall pipe.

Assume the tie-in point is along side street.

The Header length is assumed to be 400 feet. Assume 4" Polyethylene

5. Estimate length of piping to surface water outfall. Single wall pipe.

The Header length is assumed to be 400 feet. Assume 4" Polyethylene

6. Estimate length of piping to supply potable water to treatment building. Single wall pipe.

Assume the tie-in point is along side street.

The Header length is 300 feet. Assume 2" Polyethylene.

Tetra Tech NUS		*STANDARD CALCULATION SHEET*	
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system – extraction well pumps		CHECKED BY: CAH	DATE: 5/19/10

Estimate size of extraction well pumps.

Estimate size by starting with average rate, then providing for 2X flow rate for a typical pump.

Flow rate of 50 gpm total and 16 wells

50 gpm/16 wells x 2 = 6 gpm

For well depths, assume these values (similar to line A-A' of cross-section).

Shallow – 35 feet
Intermediate – 65 feet
Deep – 90 feet

Assume 4" main header to pump station and 1" well line. Assume 1-inch line is 25 feet long.

Length of 4" line is 500 feet (average), and at 50 gpm, line losses are 0.21 feet/100 feet.

For 4", add 10 feet of length for each fitting and assume 10 fittings.

Total equivalent L = 500 + 10 x 10 = 600 feet

Δh = 600 x 0.21 feet/100 feet = 1.3 feet, use 2 feet

Size 1-inch line for deepest well. Length = 25 + 90 = 115 feet. At 6 gpm, line loss is 5 feet per 100 feet.

For 1", add 3 feet of length for each fitting and assume 20 fittings.

Total equivalent L = 115 + 20 x 3 = 175 feet

Δh = 175 x 5 feet/100 feet = 9 feet

Static h
Assume 4 feet drawdown and 20 feet depth to water

= 4 + 20 = 24 feet

Assume top of pump station is near grade.

H static = 24 feet

Total h = 2 + 9 +24 = 35 feet

Hp = (6 gpm x 35 feet)/(3960 x 0.5) = 0.11, use 0.5 hp.

Tetra Tech NUS			*STANDARD CALCULATION SHEET*
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 2
SUBJECT: Pump Station for Extraction Wells		CHECKED BY: CAH	DATE: 5/26/2010

Based on Flygt paper.

Calculate vault size

Vworking = 60/(NΦ) [Q1/Q2(Q2-Q1)]

Size for 100 gpm

Min working volume is for Q1 = ½ Q2

Although there will be 2 pumps, size for N=1.

Assume Φ = 8 (typical)

V (gal) = 60/(1 x 8)[50/100(100-50)] = 188 gal

= 25.2 ft3, use 26 ft3

Depth:

Allow 2 feet for submergence of pumps.
Allow 3 feet for pipe burial.
Allow 1 foot for LAH.

Assume 6 feet x 6 feet vault

Working Depth = 26 ft3/(6 feet x 6 feet) = 0.7 feet, use 1 foot.

Total depth = 2 + 3 +1 +1 = 7 feet, use 8 feet

Estimate pump

Pipeline is 4-inch PE; length is 4,000 feet

Add 200 additional feet for fittings, etc.

Static h = depth of station + height of Feed Tank = 8 + 12 = 20 feet

For 50 gpm, Δh = 0.21 feet /100 feet
For 100 gpm, Δh = 0.76 feet /100 feet

50 gpm:

hdyn = 4,200 feet x 0.21 feet/100 feet = 9 feet

hstatic = 20 feet

total h = 20 + 9 = 29 feet

hp = (50 x 29)/3,960 x 0.7) = 0.52, use 1 hp

100 gpm:

hdyn = 4,200 feet x 0.76 feet/100 feet = 32 feet

hstatic = 20 feet

total h = 20 + 32 = 52 feet

hp = (100 x 52)/3,960 x 0.7) = 1.9, use 3 hp

Tetra Tech NUS			STANDARD CALCULATION SHEET
CLIENT: Lockheed Martin – Martin State Airport – DRA Site FS	FILE No:	BY: JWL	PAGE: 1 of 1
SUBJECT: Groundwater treatment system – estimate of ED for injection wells		CHECKED BY: CAH	DATE: 4/9/10

Estimate quantity and rate of ED (sodium lactate) to feed into injected water.

The groundwater that will be affected by the injection wells is assumed to be the area affected per the initial groundwater modeling (see attached figures). Assume that the thickness is 20 feet for each injection well.

In Alternative G-3, the distribution of the ED will only be affected by the hydraulic barrier pumping gradient. In Alternative G-4, DE distribution will also be affected by the extraction wells in the HCAs. It is assumed that in Alternative G-4, this will indirectly affect the amount of ED that can be injected to avoid drawing the ED into the extraction well. For Alternative G-4, it may be beneficial to not activate the HCA extraction wells until the ED has substantially degraded.

Injection wells are in the Upper and Intermediate zones only (Designated I-A, I-B, U-A, U-B, U-C, and U-D on the sketches. Because of the slow groundwater velocity in the shallow zone, distribution of the ED may be limited. However, injection will locally increase the gradient and the velocity will increase.

For estimating purposes, assume that the velocity increase in about 2x. From the model and previous calculations, the normal velocities under pumped conditions (from the hydraulic barrier) are 22 feet/year and 91 feet/year for the shallow and intermediate zones, respectively. For the injection case, (Alternative G-4), assume this is 2 x 22 feet/yr, or about 40 feet/yr. For the intermediate case, the velocity is 2 x 91, or about 200 feet/yr.

The contour lines from the model output suggest an affected area of about 140 feet in diameter (see sketches), or a radius of 70 feet.

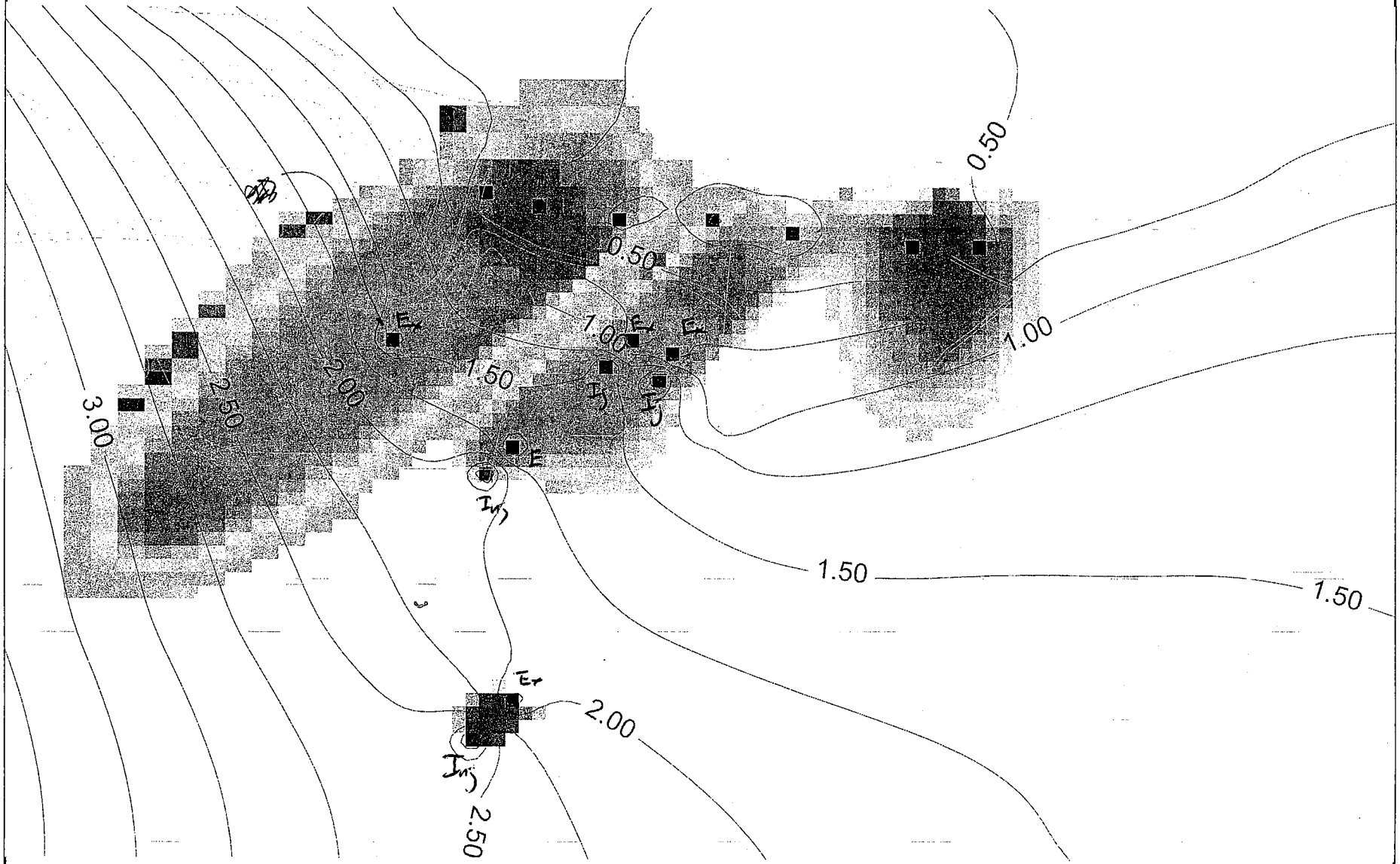
Thus, for the shallow zone, the time for travel across the radius is approximately 70 feet/(40 feet/year) = 1.75 years, or about 2 years. Thus, the duration of injection is will only be about 2 years, at which time, the HCA extraction wells will begin drawing in the sodium lactate.

It is also unlikely that the lactate can remain effect for that long. Thus, for estimating purposes, only 2 years of chemical injection will be assumed.

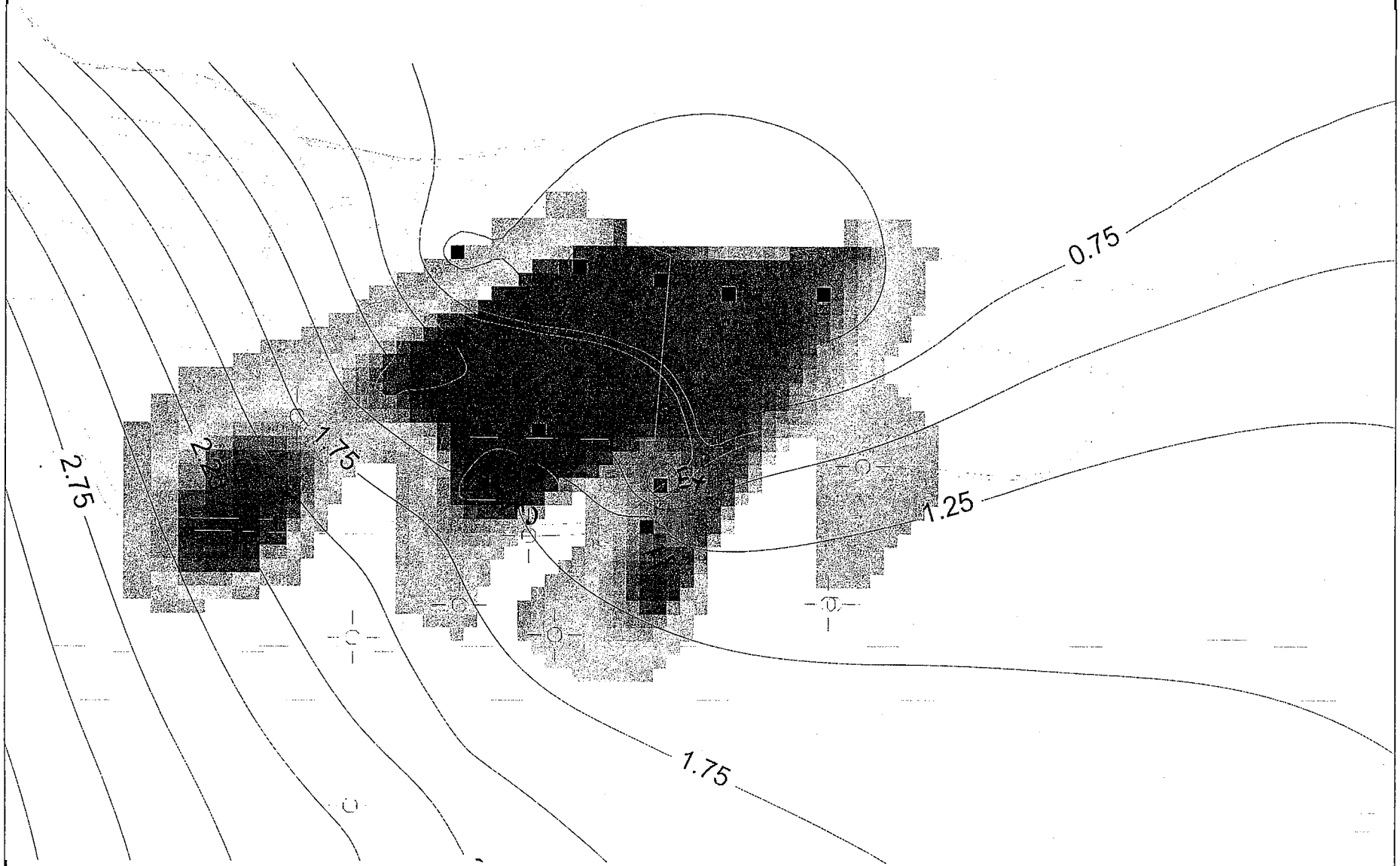
The attached spreadsheet summarizes the estimation of the quantity of sodium lactate to treat the groundwater near each injection well. The sulfate concentration is very high near several of the injection wells and the sulfate controls the amount of ED to be added. The amount of sodium lactate was estimate for each zone and a low sulfate concentration and a high sulfate concentration. The low sulfate concentration is more typical of the intermediate zone, and the sodium lactate loading was estimated based on high sulfate concentrations in the shallow zone and low concentrations in the intermediate zone.

Run	Unit	groundwater velocity (ft/d)	1,4d diox velocity (ft/d)	TCE retardation	TCE velocity (ft/d)
No pumping	Upper	0.02 - 0.06	0.02 - 0.06	6.9	0.0029 - 0.0086
	Intermediate	0.06 - 0.12	0.06 - 0.12	6.9	0.0087 - 0.017
	Lower	0.3 - 0.5	0.3 - 0.5	6.9	0.043 - 0.072
pumping	Upper	0.05 - 0.08	0.05 - 0.08	6.9	0.0072 - 0.012
	Intermediate	0.25	0.25	6.9	0.036
	Lower	0.6 - 0.95	0.6 - 0.95	6.9	0.087 - 0.14

Upper Surficial (Layer 6) Heads and TCE for Injection and Pumping Scenario ESA-1



Intermediate Surficial (Layer 8) Heads and TCE for Injection and Pumping Scenario ESA-1



LMC MARTIN STATE AIRPORT
ED ESTIMATE
1/29/2010

Estimate ED requirement based on hydrogen estimates.

4 shallow injection wells
2 Intermediate injection wells

Hydrogen demand, no SF	lb
Shallow - High Sulfate	504
Shallow - Low Sulfate	173
Intermediate - High Sulfate	751
Intermediate - Low Sulfate	255

Hydrogen in sodium lactate, lb H/lb SL	0.045

	lb	lb/day
SL requirement, high sulfate	78,231	214
SL requirement, low sulfate	26,674	73

Mix Shallow high sulfate and Intermediate low sulfate

SL requirement	56,176	154

SUBSTRATE CALCULATION SHEET - LMC - DRA - ED Addition for Re-injection - Shallow

1. Treatment zone dimensions	Units	Value
Length (perpendicular to GW flow)	feet	140
Width	feet	140
Saturated thickness	feet	20
Treatment zone cross section (vertical)	square feet	2,800
Treatment zone volume	cubic feet	392,000
Treatment zone pore volume	gallons	879,766
Design performance period	years	1

2. Treatment zone hydrogeologic properties

Total porosity		0.3	
Effective porosity		0.28	per GW model
Average hydraulic conductivity	ft/day	4.5	
Average hydraulic gradient	ft/ft	0.0085	Adjusted to meet 50 ft/yr, below
Average seepage velocity through treatment zone	ft/day	0.136607	
Average seepage velocity through treatment zone	ft/year	49.86161	(Use 50 ft/yr)
Average groundwater flux through treatment zone	gal/yr	292,444	
Soil bulk density	gm/cm3	1.8	per GW model
Soil fraction organic carbon (foc)		0.005	default

3. Initial treatment cell electron-acceptor demand (one pore volume)

A. Aqueous phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	14.67	7.9	1.9	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	400	2933.84	10.6	276.8	8
Carbon dioxide	10	73.35	5.5	13.3	8
Subtotal				**292.0**	

B. Solid phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Mn(IV)	9	66.01	27.5	2.4	1
Fe(III)	50	366.73	55.9	6.6	1
Subtotal				**9.0**	

C. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	36	264.05	21.7	12.2	6
cis-1,2-DCE	41	300.72	24	12.5	4
Vinyl chloride	56	410.74	31	13.2	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**37.9**	

D. Sorbed contaminant electron acceptors

Cs = Koc x foc x Cw	Koc, ml/g	Cs, mg/kg	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	263	0	0.00	20.6	0.0	8
TCE	107	19.26	829.16	21.7	38.2	6
cis-1,2-DCE	45	9.23	397.15	24	16.5	4
Vinyl chloride	3	0.84	36.16	31	1.2	2
Carbon tetrachloride	224	0.00	0.00	25.4	0.0	8
Chloroform	63	0.00	0.00	12.3	0.0	6
1,1,1-TCA	105	0.00	0.00	22	0.0	6
1,1-DCA	30	0.00	0.00	25	0.0	4
1,1-DCE	65	0.00	0.00	24	0.0	4
Subtotal					**55.9**	

4. Treatment Cell Electron Acceptor Flux (per year)

A. Soluble native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	4.88	7.9	0.6	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	400	975.24	10.6	92.0	8
Carbon dioxide	10	24.38	5.5	4.4	8
Subtotal				**97.1**	

B. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	36	87.77	21.7	4.0	6
cis-1,2-DCE	41	99.96	24	4.2	4
Vinyl chloride	56	136.53	31	4.4	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**12.6**	

Total Demand		**504.5**

5. Design Factors on total Demand

Factor (2 to 10)	1

Total Demand (Design)		**504**

Shaded is entered for each project.
Blue is given.

SUBSTRATE CALCULATION SHEET - LMC - DRA - ED Addition for Re-injection - Intermediate

1. Treatment zone dimensions	Units	Value
Length (perpendicular to GW flow)	feet	140
Width	feet	140
Saturated thickness	feet	20
Treatment zone cross section (vertical)	square feet	2,800
Treatment zone volume	cubic feet	392,000
Treatment zone pore volume	gallons	879,766
Design performance period	years	1

2. Treatment zone hydrogeologic properties

Total porosity		0.3	
Effective porosity		0.28	per GW model
Average hydraulic conductivity	ft/day	20	
Average hydraulic gradient	ft/ft	0.008	Adjusted to meet 200 ft/yr, below
Average seepage velocity through treatment zone	ft/day	0.5714286	
Average seepage velocity through treatment zone	ft/year	208.57143	(Use 200 ft/yr)
Average groundwater flux through treatment zone	gal/yr	1,223,293	
Soil bulk density	gm/cm3	1.8	per GW model
Soil fraction organic carbon (foc)		0.005	default

3. Initial treatment cell electron-acceptor demand (one pore volume)

A. Aqueous phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	14.67	7.9	1.9	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	400	2933.84	10.6	276.8	8
Carbon dioxide	10	73.35	5.5	13.3	8
Subtotal				**292.0**	

B. Solid phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Mn(IV)	9	66.01	27.5	2.4	1
Fe(III)	50	366.73	55.9	6.6	1
Subtotal				**9.0**	

C. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	14.4	105.62	21.7	4.9	6
cis-1,2-DCE	13.6	99.75	24	4.2	4
Vinyl chloride	3.4	24.94	31	0.8	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**9.8**	

D. Sorbed contaminant electron acceptors

Cs = Koc x foc x Cw	Koc, ml/g	Cs, mg/kg	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	263	0	0.00	20.6	0.0	8
TCE	107	7.70	331.66	21.7	15.3	6
cis-1,2-DCE	45	3.06	131.74	24	5.5	4
Vinyl chloride	3	0.05	2.20	31	0.1	2
Carbon tetrachloride	224	0.00	0.00	25.4	0.0	8
Chloroform	63	0.00	0.00	12.3	0.0	6
1,1,1-TCA	105	0.00	0.00	22	0.0	6
1,1-DCA	30	0.00	0.00	25	0.0	4
1,1-DCE	65	0.00	0.00	24	0.0	4
Subtotal					**20.8**	

4. Treatment Cell Electron Acceptor Flux (per year)

A. Soluble native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	20.40	7.9	2.6	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	400	4079.44	10.6	384.9	8
Carbon dioxide	10	101.99	5.5	18.5	8
Subtotal				**406.0**	

B. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	14.4	146.86	21.7	6.8	6
cis-1,2-DCE	13.6	138.70	24	5.8	4
Vinyl chloride	3.4	34.68	31	1.1	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**13.7**	

Total Demand		**751.2**

5. Design Factors on total Demand

Factor (2 to 10)	1

Total Demand (Design)		**751**

Shaded is entered for each project.
Blue is given.

SUBSTRATE CALCULATION SHEET - LMC - DRA - ED Addition for Re-injection - Shallow - Lower sulfate

1. Treatment zone dimensions	Units	Value
Length (perpendicular to GW flow)	feet	140
Width	feet	140
Saturated thickness	feet	20
Treatment zone cross section (vertical)	square feet	2,800
Treatment zone volume	cubic feet	392,000
Treatment zone pore volume	gallons	879,766
Design performance period	years	1

2. Treatment zone hydrogeologic properties

Total porosity		0.3	
Effective porosity		0.28	per GW model
Average hydraulic conductivity	ft/day	4.5	
Average hydraulic gradient	ft/ft	0.0085	Adjusted to meet 50 ft/yr, below
Average seepage velocity through treatment zone	ft/day	0.136607	
Average seepage velocity through treatment zone	ft/year	49.86161	(Use 50 ft/yr)
Average groundwater flux through treatment zone	gal/yr	292,444	
Soil bulk density	gm/cm3	1.8	per GW model
Soil fraction organic carbon (foc)		0.005	default

3. Initial treatment cell electron-acceptor demand (one pore volume)

A. Aqueous phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	14.67	7.9	1.9	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	40	293.38	10.6	27.7	8
Carbon dioxide	10	73.35	5.5	13.3	8
Subtotal				**42.9**	

B. Solid phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Mn(IV)	9	66.01	27.5	2.4	1
Fe(III)	50	366.73	55.9	6.6	1
Subtotal				**9.0**	

C. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	36	264.05	21.7	12.2	6
cis-1,2-DCE	41	300.72	24	12.5	4
Vinyl chloride	56	410.74	31	13.2	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**37.9**	

D. Sorbed contaminant electron acceptors

Cs = Koc x foc x Cw	Koc, ml/g	Cs, mg/kg	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	263	0	0.00	20.6	0.0	8
TCE	107	19.26	829.16	21.7	38.2	6
cis-1,2-DCE	45	9.23	397.15	24	16.5	4
Vinyl chloride	3	0.84	36.16	31	1.2	2
Carbon tetrachloride	224	0.00	0.00	25.4	0.0	8
Chloroform	63	0.00	0.00	12.3	0.0	6
1,1,1-TCA	105	0.00	0.00	22	0.0	6
1,1-DCA	30	0.00	0.00	25	0.0	4
1,1-DCE	65	0.00	0.00	24	0.0	4
Subtotal					**55.9**	

4. Treatment Cell Electron Acceptor Flux (per year)

A. Soluble native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	4.88	7.9	0.6	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	40	97.52	10.6	9.2	8
Carbon dioxide	10	24.38	5.5	4.4	8
Subtotal				**14.3**	

B. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	36	87.77	21.7	4.0	6
cis-1,2-DCE	41	99.96	24	4.2	4
Vinyl chloride	56	136.53	31	4.4	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**12.6**	

Total Demand		**172.6**

5. Design Factors on total Demand

Factor (2 to 10)	1

Total Demand (Design)		**173**

Shaded is entered for each project.
Blue is given.

SUBSTRATE CALCULATION SHEET - LMC - DRA - ED Addition for Re-injection - Intermediate - Low Sulfate

1. Treatment zone dimensions	Units	Value
Length (perpendicular to GW flow)	feet	140
Width	feet	140
Saturated thickness	feet	20
Treatment zone cross section (vertical)	square feet	2,800
Treatment zone volume	cubic feet	392,000
Treatment zone pore volume	gallons	879,766
Design performance period	years	1

2. Treatment zone hydrogeologic properties

Total porosity		0.3	
Effective porosity		0.28	per GW model
Average hydraulic conductivity	ft/day	20	
Average hydraulic gradient	ft/ft	0.008	Adjusted to meet 200 ft/yr, below
Average seepage velocity through treatment zone	ft/day	0.571429	
Average seepage velocity through treatment zone	ft/year	208.5714	(Use 200 ft/yr)
Average groundwater flux through treatment zone	gal/yr	1,223,293	
Soil bulk density	gm/cm3	1.8	per GW model
Soil fraction organic carbon (foc)		0.005	default

3. Initial treatment cell electron-acceptor demand (one pore volume)

A. Aqueous phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	14.67	7.9	1.9	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	100	733.46	10.6	69.2	8
Carbon dioxide	10	73.35	5.5	13.3	8
Subtotal				**84.4**	

B. Solid phase native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Mn(IV)	9	66.01	27.5	2.4	1
Fe(III)	50	366.73	55.9	6.6	1
Subtotal				**9.0**	

C. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	14.4	105.62	21.7	4.9	6
cis-1,2-DCE	13.6	99.75	24	4.2	4
Vinyl chloride	3.4	24.94	31	0.8	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**9.8**	

D. Sorbed contaminant electron acceptors

Cs = Koc x foc x Cw	Koc, ml/g	Cs, mg/kg	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	263	0	0.00	20.6	0.0	8
TCE	107	7.70	331.66	21.7	15.3	6
cis-1,2-DCE	45	3.06	131.74	24	5.5	4
Vinyl chloride	3	0.05	2.20	31	0.1	2
Carbon tetrachloride	224	0.00	0.00	25.4	0.0	8
Chloroform	63	0.00	0.00	12.3	0.0	6
1,1,1-TCA	105	0.00	0.00	22	0.0	6
1,1-DCA	30	0.00	0.00	25	0.0	4
1,1-DCE	65	0.00	0.00	24	0.0	4
Subtotal					**20.8**	

4. Treatment Cell Electron Acceptor Flux (per year)

A. Soluble native electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
Oxygen	2	20.40	7.9	2.6	4
Nitrate	0	0.00	10.2	0.0	5
Sulfate	100	1019.86	10.6	96.2	8
Carbon dioxide	10	101.99	5.5	18.5	8
Subtotal				**117.3**	

B. Soluble contaminant electron acceptors

	C, mg/L	mass, lb	Stoic demand, wt/wt H2	Hydrogen demand, lb	Electron equiv per mole
PCE	0	0.00	20.6	0.0	8
TCE	14.4	146.86	21.7	6.8	6
cis-1,2-DCE	13.6	138.70	24	5.8	4
Vinyl chloride	3.4	34.68	31	1.1	2
Carbon tetrachloride	0	0.00	25.4	0.0	8
Chloroform	0	0.00	12.3	0.0	6
1,1,1-TCA	0	0.00	22	0.0	6
1,1-DCA	0	0.00	25	0.0	4
1,1-DCE	0	0.00	24	0.0	4
Subtotal				**13.7**	

Total Demand	**255.0**

5. Design Factors on total Demand

Factor (2 to 10)	1

Total Demand (Design)	**255**

Shaded is entered for each project.
Blue is given.

SIEMENS

Siemens Water Technologies Corp.

BUDGETARY PROPOSAL TO SUPPLY A

METALS PRECIPITATION SYSTEM WITH FILTER PRESS

FOR

TETRA TECH NUS, INC

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Bob Hall
Siemens Water Technologies

Proposal No. 1002007
February 2, 2010

SIEMENS

1. OVERVIEW

This budgetary proposal has been prepared to assist you to develop equipment cost estimates for your wastewater treatment system project. Siemens Water Technologies (herein referred to as Siemens) appreciates the opportunity to offer our services and looks forward to working closely with you as your project moves forward.

We have based our budgetary estimate on the information provided and on comparing this application to similar installations successfully completed by Siemens. At this stage our estimate is for equipment only but can be expanded to include process later as the project develops. A comprehensive system recommendation and proposal can be developed once more complete design parameters have been provided and specific requirements are identified for the metals precipitation portion of the project. A final proposal should be based on bench testing of actual wastewater, comprehensive wastewater source profiling, technology treatability testing and perhaps site pilot testing.

We are providing pricing on the clarifier, neutralizer, filtration and sludge dewatering portion of your request. We have not included the ion exchange service portion or the carbon tank portion of your request. Other Siemens Business units offer those products and services.

2. BASIS FOR DESIGN

Mechanical Specification	Description
Maximum Flow Rate	80 gpm
Concentrated Acids	None
Concentrated Bases	None

2.1. Clarifications and Exceptions

- The above specifications are preliminary. Listed are design and performance requirements of the wastewater treatment system offered in this quotation. Site specific conditions that exceed these parameters would require this design recommendation to be modified. Prior to developing a full proposal and complete wastewater treatment system recommendation, it will be necessary to develop an accurate and comprehensive site specification.

- Siemens' equipment is built to Seismic Zone 2 unless otherwise stated. Seismic design calculations are not included.

3. EQUIPMENT LIST

3.1. TotalTreat® Continuous Precipitation System
Model No. CPS-100-2-SA

One modular, epoxy painted, carbon steel constructed multi-chamber unit. The prepackaged unit contains the following treatment equipment:

First Stage Reaction Chamber

- 1,070-gallon capacity
- Single-speed, gear drive agitator with 316 stainless steel wetted parts (Brawn or equal)
- pH probe (Hach or equal)
- Two chemical metering pumps (LMI or equal)

Second Stage Reaction Chamber

- 1,070-gallon capacity
- Single-speed, gear drive agitator with 316 stainless steel wetted parts (Brawn or equal)
- pH probe (Hach or equal)
- Three chemical metering pumps (LMI or equal)

Flocculation Chamber

- 770-gallon capacity
- Polypropylene and stainless steel constructed paddlewheel type agitator
- Low speed, gear type agitator drive motor (Bodine or equal)

Clarifier Chamber

- 3,690-gallon capacity
- Settling modules with Chevron shaped tube packing
- One air operated diaphragm pump for sludge recycle (ARO or equal)

Sludge Age Chamber Feed Pump

- One air operated diaphragm pump (ARO or equal)
- Cast iron construction
- Santoprene elastomers

Effluent Clearwell

- 850-gallon capacity

Sludge Age Chambers

- Two 1,340-gallon capacity tanks
- Two single point, float type, PVC and polypropylene constructed level switches
- One air operated diaphragm pump to decant clear water (ARO or equal)
- One air operated diaphragm pump to transfer sludge to the sludge surge tank (ARO or equal)

Operator Access Platforms

- Two platforms with handrail and toeplate
- Carbon steel construction
- Access ladders

3.2. Neutralization System
Model No. NSP-1500

- One 1,500-gallon capacity, heavy-duty, HDPE constructed reaction tank
- One heavy-duty mixer (Brawn or equal)
- One pH monitor/transmitter (Hach or equal)
- Two chemical metering pumps (LMI or equal)
- Skid-mounting

3.3. Equalization Tank
Model No. EQ-1500-HDPE

- One 1,500-gallon capacity, heavy-duty, HDPE constructed, dome top collection tank
- Manway
- Inlet connection
- Pump suction connection

3.4. Transfer Pump System (Duplex)
Model No. PSH-150-D

- Duplex, horizontal centrifugal pumps, stainless steel constructed
- 150 gpm capacity at 150 ft total discharge head
- 230/460-VAC, 3-Phase, TEFC motors
- Pump discharge flow meter
- Pump discharge pressure gauge
- Level switches for pump on/off control
- Pump skid with Schedule-80 PVC piping and shutoff valves

3.5. Hydrus Backwashing Sand Filters
Model No. HF-330m

- 150 gpm service flow
- 60 gpm service flow during backwash
- Three Hydrus non-electric control valves
- Three FRP media vessels, 30" Dia x 72" H
- 125 psi non-code vessels
- 9 ft^3 of filter media (per vessel)
- Automatic backwash based on pressure drop
- 40 gpm backwash flow
- Piping manifold with bypass valve
- 2" flanged inlet and outlet connections
- 2" threaded drain connections
- Smart Start controller
- Differential pressure switch
- Three cartridge filters for effluent polishing

3.6. Sludge Holding Tank
Model No. 50-71100-3

- 10,000-gallon capacity, vertical, cylindrical, FRP tank
- Conical bottom
- Internal baffles
- Overflow nozzle
- Flanged bottom nozzle

3.7. Air Diaphragm Filter Press Feed Pump System (Simplex)
Model No. PS2.0C-S-AD

- Simplex, air operated diaphragm pump, cast iron constructed (ARO or equal)
- 80 gpm capacity at 50 ft total discharge head
- Level switches for pump on/off control
- Pump skid with Schedule-80 PVC piping

3.8. Filter Press
Model No. JP-25-800

- 25 cu ft filter cake capacity
- 1.26-inch cake thickness
- 100 psi filtration capacity
- Center feed
- Four corner filtrate discharge connection
- Set of gasketed polypropylene plates

- Air blowdown manifold
- Two dumpsters
- Plate shifter
- Painted steel skeleton
- Automatic pump control

4. PROCESS CONTROLS

The Siemens Water Technologies standard control system consists of a PLC (Programmable Logic Controller) and HMI (Human Machine Interface) graphical display as the main components providing system automation and operator monitoring of the water treatment system.

The HMI display is provided as the central location for an operator to visually monitor equipment status, alarm messaging, and process pH, flow, and level values. The adjustment of process set-points is performed via the HMI. The HMI will allow Hand/Off/Auto (or On/Off) control of devices and display interlock statuses. The HMI also displays all alarm conditions.

Alarms are also annunciated with an alarm horn that can be silenced.

The control system includes all engineering, programming, instrumentation, and documentation for the system. A main panel contains the PLC, HMI, programming receptacle, and alarming. Power distribution, motor starters, emergency stop pushbuttons, relays, remote I/O, and other control hardware are located remotely at each treatment module being controlled. 10% spare I/O capacity is provided, with spares wired to terminal blocks.

The Siemens Simatic S7-300 series PLC is used as the standard controller with a monochromatic 5.7" Siemens HMI. Communication is over a Profibus network to the Siemens ET200 remote I/O. Transformers, power supplies, disconnects, circuit breakers, and motor starters are Siemens or equivalent. Relays and terminal blocks are Phoenix or equivalent. Fuses and fuse blocks are Bussmann or equivalent. Enclosures are Hoffman Type 4X fiberglass.

5. DRAWINGS AND DOCUMENTATION

The following mechanical and electrical drawings are included with the system:

General Arrangement Drawing – Shows the overall general arrangement for the system with dimensions to locate equipment.

Piping and Instrumentation Diagram(s) - Provides a flow schematic illustrating the treatment equipment. Equipment is shown with the instrumentation, valves, pipe sizes and materials of construction.

Equipment Arrangement Drawings for the System Modules - Each equipment arrangement drawing will show overall equipment dimensions, access and maintenance clearance requirements, shipping and operating weights, equipment coatings or lining specifications, anchoring details, piping connections and utility requirements.

Control Panel Enclosure Layout - A dimensioned front elevation of the Electrical Control Panel, which details door-mounted component locations and identification. This document also includes part number references for component identification. Depending on system size and complexity, the Nameplate Schedule or Sub-Panel Layout may also be included on this drawing in lieu of a separate drawing.

Control Panel Sub-Panel Layout - A dimensioned layout drawing detailing each control component's description, part number reference, and location on the sub-panel. This information may be incorporated into the Control Panel Enclosure Layout drawing depending on enclosure size.

Electrical Schematic Diagrams - This drawing provides a schematic representation of all circuitry contained within the Electrical Control Panel including internal and field termination points, PLC I/O wiring, and wire numbering.

Nameplate Schedule - Lists individual nameplates for control panel devices. This includes nameplate text, material type, size and mounting methods. Depending on system size, this information may be incorporated into one of the Control Panel Layout drawings.

Electrical Bill of Materials - A spreadsheet listing of all components contained in the Control Panel design. Each component is assigned a bill of material number allowing its reference to the Control Panel Layout drawings.

Operating and Maintenance Manuals - Include installation instructions for utilities and piping connections to the system. It includes operating procedures, maintenance instructions and vendor manuals for the equipment furnished.

Notes: All copies described above are in triplicate. Additional copies may be obtained at an additional cost. All drawings and documentation will be submitted for information only. All drawings and documentation will be completed in Siemens' standard format. All drawings and documentation will be completed in English.

6. SYSTEM INSTALLATION

6.1. Overview

The wastewater treatment system presented in this document has been designed as a modular system. It is comprised of individual modular subsystems that are designed to connect to each other. Each module (subsystem) will be piped, wired and assembled at the Siemens manufacturing facility (to the extent possible). At the conclusion of manufacturing, a Functional Operating Test will be performed. Following QC testing, the modules will be partially dismantled and packed for shipping.

A typical installation requires equipment off-loading, placement, reassembly, interconnection of piping and wiring between subsystems, utility hook-ups and process piping/wiring to the treatment system (as required by the layout).

The interconnecting piping and wiring connections between subsystem modules are the responsibility of the customer (or their installing contractor).

6.2. System Unloading and Placement

Receiving, unloading and setting the system modules in place at the installation location (including any required leveling/grouting/lagging as required by site conditions), is the responsibility of the customer or the customers contractor. Siemens will provide layout drawings to assist the customer in the correct placement and locating of the system components. During the placement of the system, platforms and access ladders (or stairs) may require reassembly.

6.3. Reassembly of Modular Subsystem Components

The Siemens Wastewater Treatment System is assembled at the factory as modular subsystems. This is done to simplify the field installation and minimize the labor required to fully commission the system. When the system arrives at the installation site it will have been partially dismantled from its factory assembled condition. Components such as mixers, instrumentation probes, ladders, stairways and platforms will have been secured for shipment. The customer will be responsible for remounting and reassembly of these items.

6.4. Utilities, Interconnecting Piping/Wiring and Process Piping Installation

The customer or the customer's contractor will be responsible for connecting utilities, piping feed lines to the system, providing and installing interconnecting piping and wiring, and connecting discharge lines from the system. The customer is responsible for all process piping lines from the customer's facility to the WTS. The customer is responsible for utility installation including: power drops, water lines and air connections to designated points within the boundaries of the WTS.

The customer is also responsible for supplying and installing the piping connections and control wiring connections between the modular subsystems.

6.5. Codes and Fees

The Siemens wastewater treatment system will be designed and assembled to the standards and codes identified in the Basis for Design section of this document. Any codes, regulations or standards that apply to any portion of the project that differ with those standards offered by Siemens, are not included in Siemens' scope of work for this project.

Fees associated with permits, licenses, inspections etc., are the responsibility of the customer and are not included in Siemens' scope of work. They are not included in the price for the system presented in this document.

7. START-UP AND OPERATOR TRAINING

Start-up and operator training have not been included in the budgetary price. Start-up and operator training can be provided at our standard per diem rate of $1,250.00 per 8-hour day per person, plus all out of pocket travel and living expenses. Travel and living expenses will be charged at net cost plus a 5% handling fee.

8. BUDGETARY PRICE $322,500.00

The price in this proposal is budgetary and intended for estimating and planning purposes only. The design of the system and the price estimate are based on preliminary design information and subject to change and revision. This budgetary proposal is not intended to be used as an offer for purchase or as a binding commercial proposal.

Recent market conditions have resulted in exceptionally volatile prices for both stainless and carbon steels. Supply conditions are such that producers have instituted surcharges, which they apply at the time of actual shipment of the steel. This means that the cost for steel used for developing the prices in this quotation are not firm. As a result of this policy, it has become necessary for Siemens to pass along any escalation in the cost of carbon and stainless steels. The price escalation will be calculated by indexing the cost of the steel based on the London Metals Exchange from the date that this proposal is issued to the date that the steel is actually received.

9. SHIPPING SCHEDULE

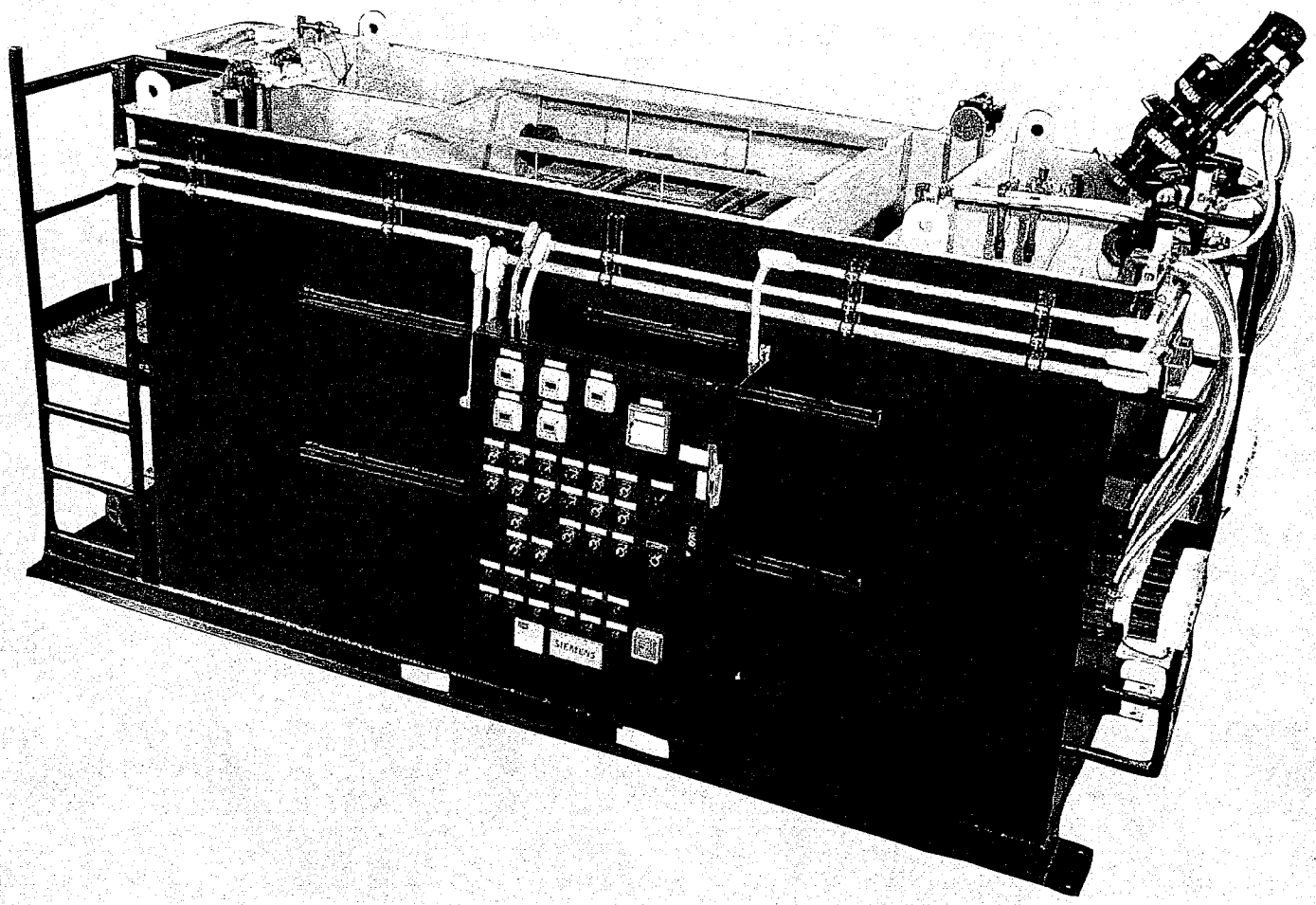
The system would be shipped approximately 14 to 20 weeks from the time of an accepted order. Shipping charges are not included in the estimated price of this budgetary proposal.

10. EQUIPMENT WARRANTY

Siemens warrants all equipment for a maximum period of 18 months from date of shipment or 12 months from the date of installation. This warranty would cover all defects in materials and workmanship. Excluded are membranes, ion exchange resins, instrumentation electrodes, pump seals and consumables.

11. CONFIDENTIALITY AGREEMENT

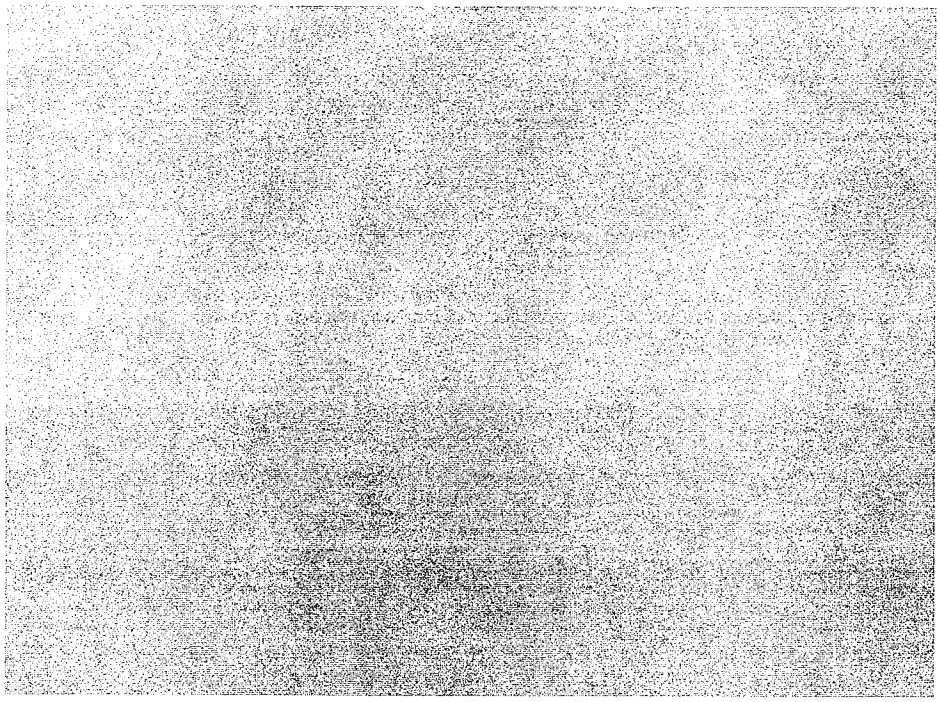
This budgetary proposal is confidential and contains proprietary information. It is not to be disclosed to a third party without the written consent of Siemens.

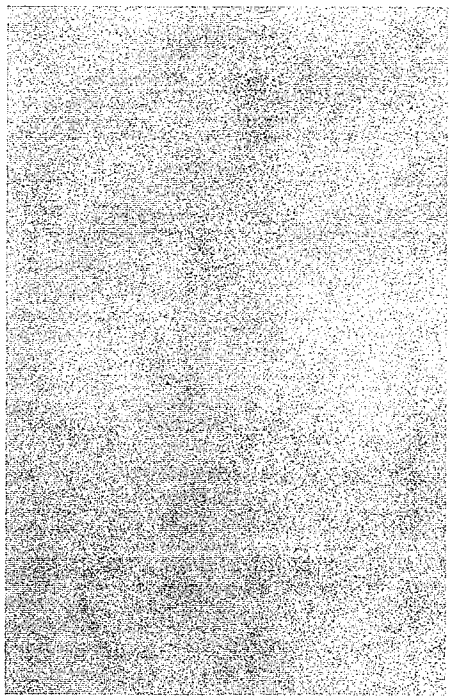


TotalTreat® Continuous Precipitation System (CPS)

Water Technologies

SIEMENS





TotalTreat® Continuous Precipitation System (CPS)

Introduction

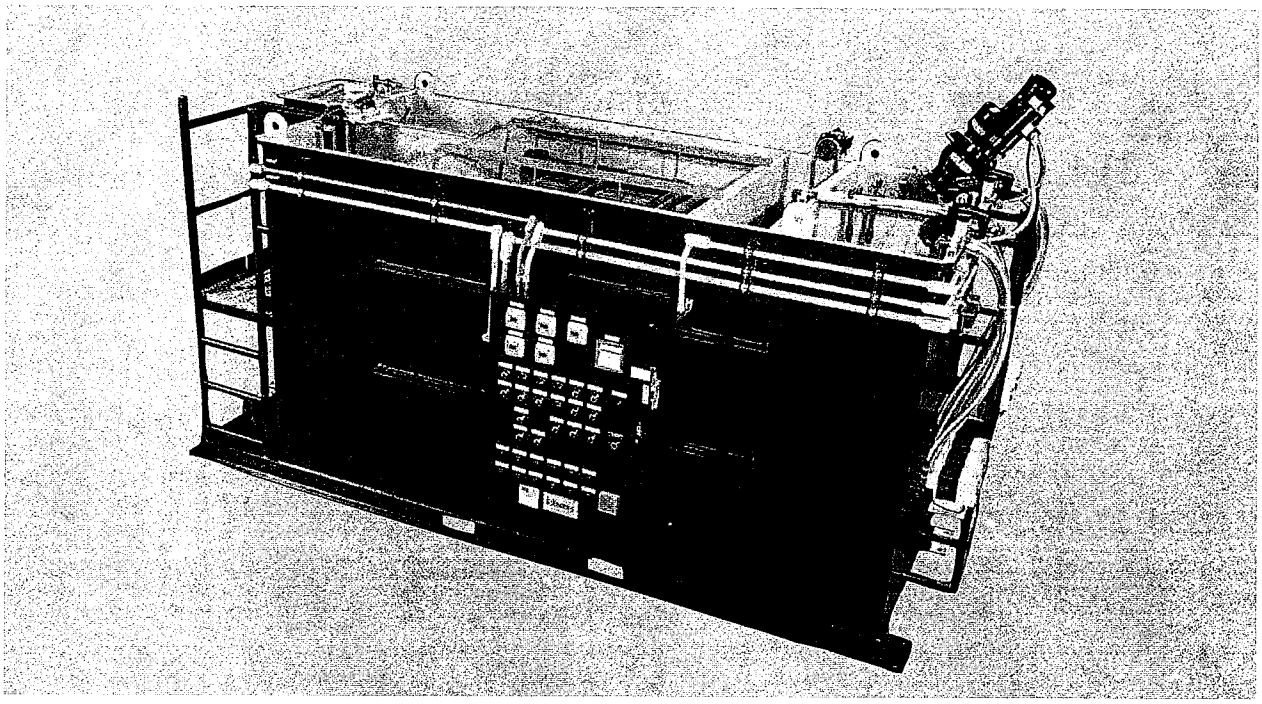
The TotalTreat® Continuous Precipitation System (CPS) has a compact, skid-mounted design that performs a continuous flow chemical precipitation process. The CPS incorporates two chemical process reaction chambers, a flocculation chamber, an inclined tube separator for solids separation, two sludge thickening chambers, and an effluent sampling/pumping chamber, all on one skid. The CPS has been used in a wide range of applications for wastewater treatment. Some markets/industries where the CPS is commonly used are: microelectronics, petrochemical, printed circuit board manufacturing, metal finishing/plating, industrial laundries, and landfill leachate/ground water remediation.

Features/Benefits

- Process guarantee ensures specified effluent pH/contaminant levels
- Compact design for small footprint requirement
- Skid-mounted, factory assembled and tested to ensure trouble-free installation
- PLC controls for low operating costs and safety interlocks
- Dual sludge thickening chambers for improved filter press operation
- 60° inclined tube settling modules for clarification
- Integral platforms for operator access
- Epoxy coated carbon steel materials of construction for superior corrosion resistance

Typical CPS Applications

- Hydrofluoric (HF) Acid Wastewater Treatment
- Grinding Slurry
- Chemical Mechanical Polishing (CMP) Slurry
- Arsenic Wastewater
- Heavy Metals (Cu, Ni, Pb, etc.)
- Hexavalent Chrome Wastewater
- Suspended Solids



Process Description

Waste flow from the facility is captured in an influent collection tank (separate equipment). During times of high flow or equipment maintenance, this tank provides flow equalization and normalization. The collected waste is transferred to the first reaction chamber of the CPS via a transfer pump.

The first stage reaction chamber is designed as a stirred tank reactor utilized for the neutralization and precipitation of the influent waste. Reagents, based on the specific waste water being treated, are added to the reaction chamber via metering pumps. The reagent addition is proportionally controlled by the system controller. The effluent flows by gravity from the first stage reaction chamber into the second stage reaction chamber of the CPS.

The second stage reaction chamber is also designed as a stirred tank reactor and is utilized for pre-clarification pH adjustment using chemical reagents. Reagents are added to the reaction chamber, via metering pumps, to complete the required process chemistry. The contents of chamber two gravity overflow into the flocculation chamber.

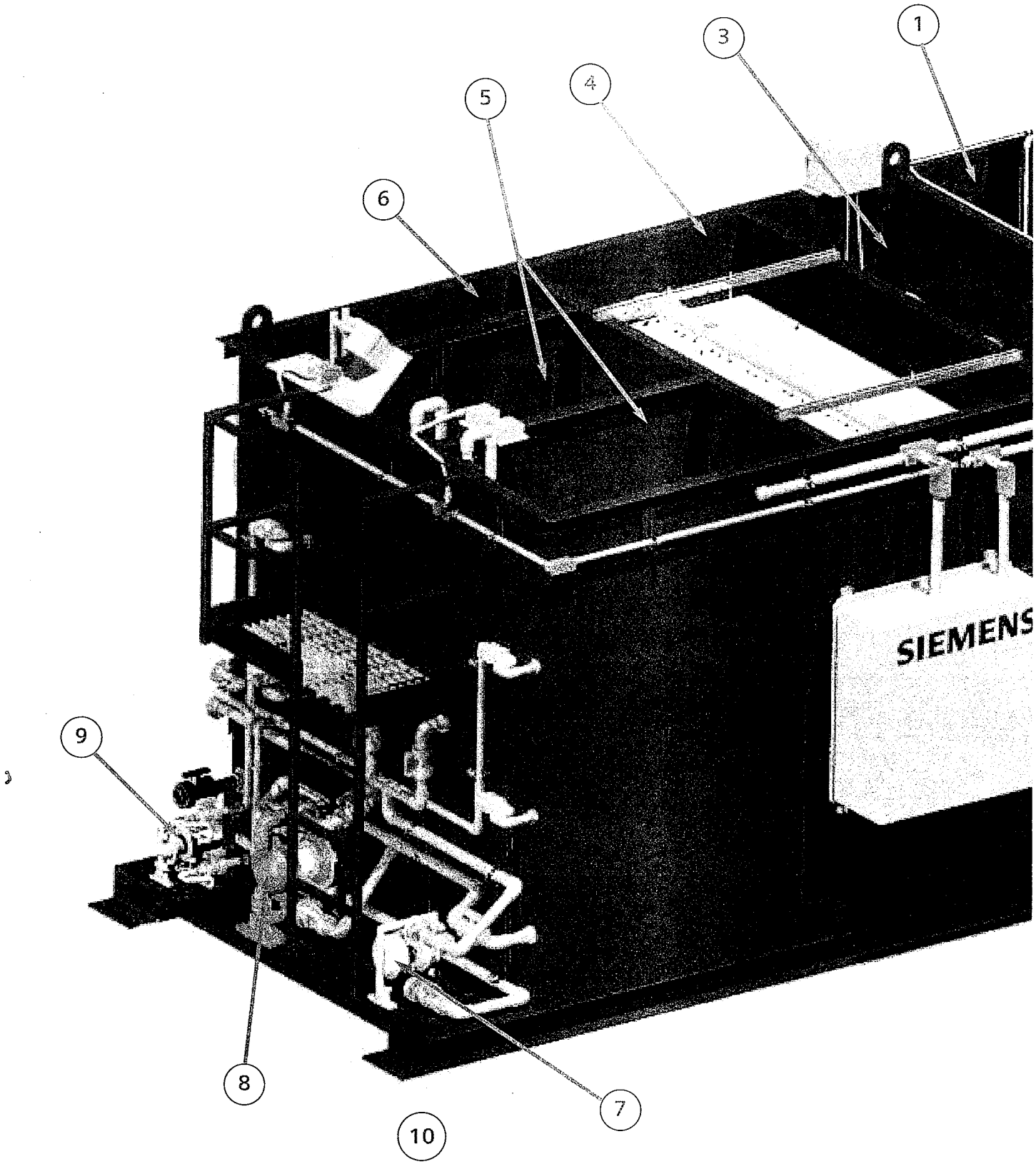
The flocculation chamber, also designed as a stirred tank reactor, is utilized for flocculation of the solid precipitates, using a low-shear paddle wheel mixer. To encourage the coagulation of the particles formed in chambers one and two into larger and faster settling particles, anionic polymer is added via a metering pump. The precipitate from the flocculation chamber flows by gravity into the clarification chamber.

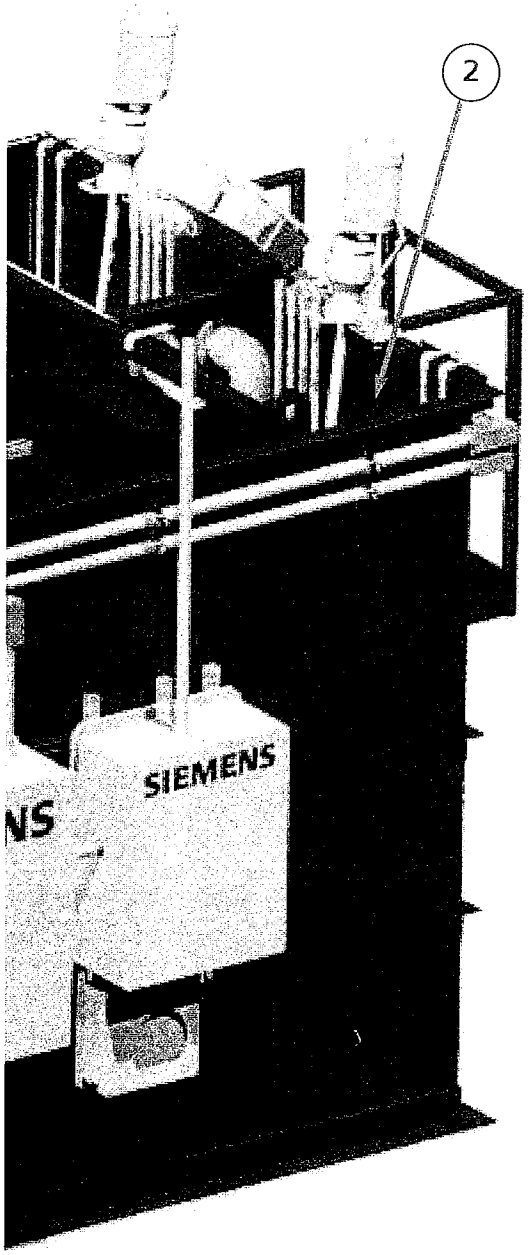
The clarification chamber is designed as an up-flow, inclined tube type clarifier, which allows gravity settling of the precipitate. This chamber is fitted with chevron style, inclined tube modules that provide the settling surface area required and create the laminar flow environment necessary for effective clarification. The precipitate enters the clarifier and settles to the chamber bottom where it is automatically pumped to the sludge thickening chambers. The precipitate-free effluent emerges from the top of the clarifier through a set of weirs and flows by gravity to the effluent clearwell chamber.

Two internal sludge thickening chambers are supplied with the CPS. These chambers are used to thicken the sludge to one to three percent solids prior to filter press dewatering. This thickening time improves the performance and reduces cycle time of the filter press. Two sludge thickening chambers are utilized to allow one to be filled while the other is thickening. Influent sludge valves direct the sludge from the clarifier to the desired thickening chamber. Clear decant from the sludge thickening chambers is transferred back to the influent collection tank via a decant valving manifold for reprocessing.

Prior to being sent to drain, the clarified water gravity flows to the effluent clearwell. An optional final pH transmitter and recorder is used to measure and record the effluent water quality. Effluent from the clearwell is either pumped, via an optional centrifugal transfer pump, or gravity overflows to the drain connection point.

TotalTreat® CPS Equipment Description





1.First Stage Reaction Chamber
Equipped with a mixer, two chemical metering pumps and a pH (optional ORP) probe, this chamber is used to pre-treat incoming wastewaters. Typically, lowering the pH and adding a coagulant in this step, helps treat metals that are tied up with chelating (complexing) agents.

2. Second Stage Reaction Chamber
As in the previous chamber, this chamber is equipped with a mixer, pH probe and two chemical metering pumps. The pH is evaluated in this chamber to induce the precipitation of insoluble metal hydroxides.

3. Flocculation Chamber
Once the metal hydroxides are precipitated, a polymer is added in this chamber, which allows the small precipitated hydroxides to slowly mix with the polymer. The small particles grow into larger solids which can be easily removed in the clarifier.

4. Clarifier Chamber
Solids that are formed in the flocculation chamber are removed in the clarifier chamber. Inclined tube modules are placed in the clarifier to provide the necessary surface area and laminar flow for effective solids removal.

5. Sludge Thickening Chambers
The underflow or dilute sludge from the clarifier is pumped to one of the two sludge thickening chambers. The sludge is allowed to gravity settle which increases the solids concentration to 1 to 3% prior to being dewatered. High level alarms and manual decant valves are provided.

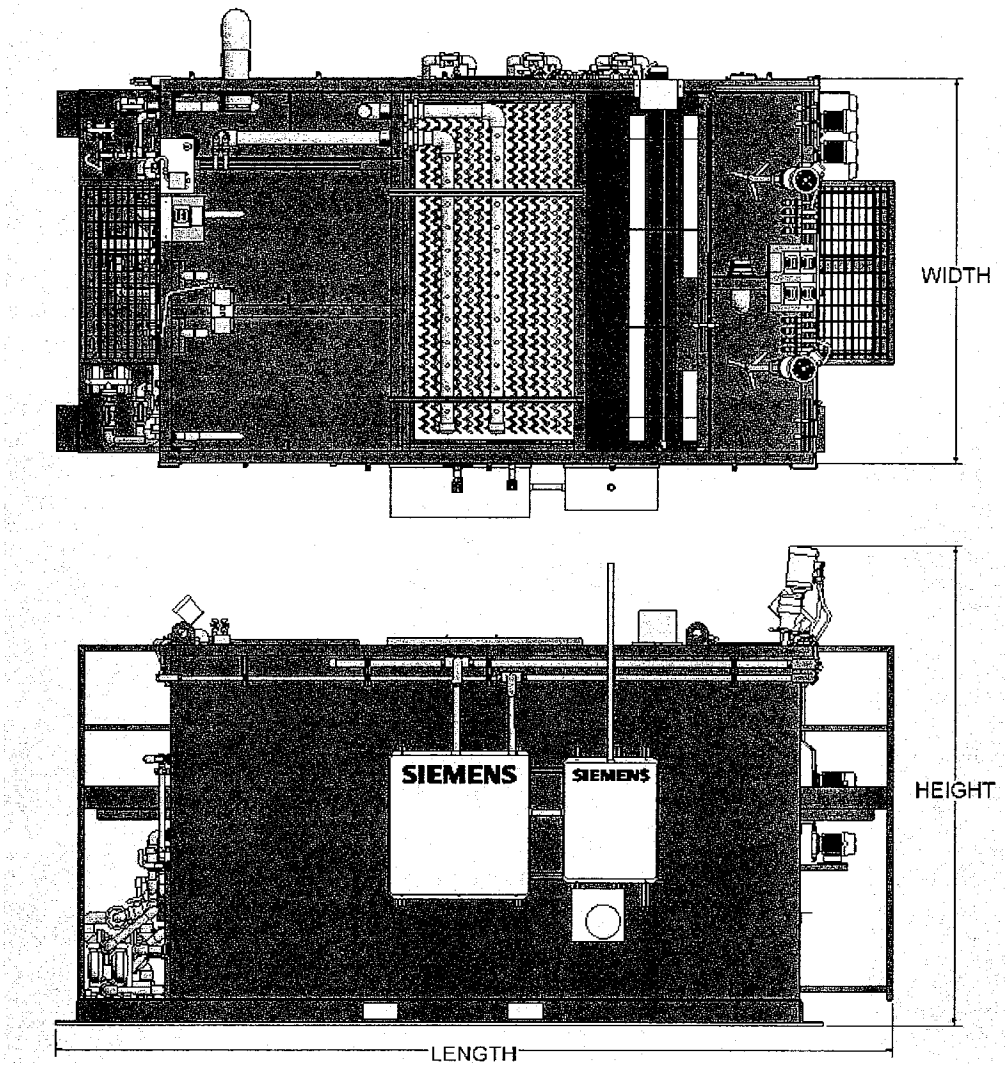
6. Effluent Clearwell Chamber
The clarified effluent is collected in the effluent clearwell chamber. With optional equipment, the pH can be monitored and the waste can be pumped to its final destination. Gravity flow is the standard means of effluent discharge from this chamber.

7. Sludge Transfer Pump
This pump is used to transfer the dilute sludge from the bottom of the clarifier chamber to one of the two sludge thickening chambers.

8. Optional Filter Press Feed Pump
Thickened sludge from the sludge thickening chambers is transferred via this pump to an optional dewatering device, such as a filter press.

9. Optional Decant Pump
An optional small air-operated diaphragm pump can be provided to transfer the decant from the sludge thickening chambers back to the influent collection tank.

10. Modular Design
The system is fully skid-mounted and includes mixers, pH probes, polymer mixing paddlewheel, inclined tube modules, sludge transfer pumps, instrumentation and PLC controller. The system is fully piped, wired and equipped for operation.



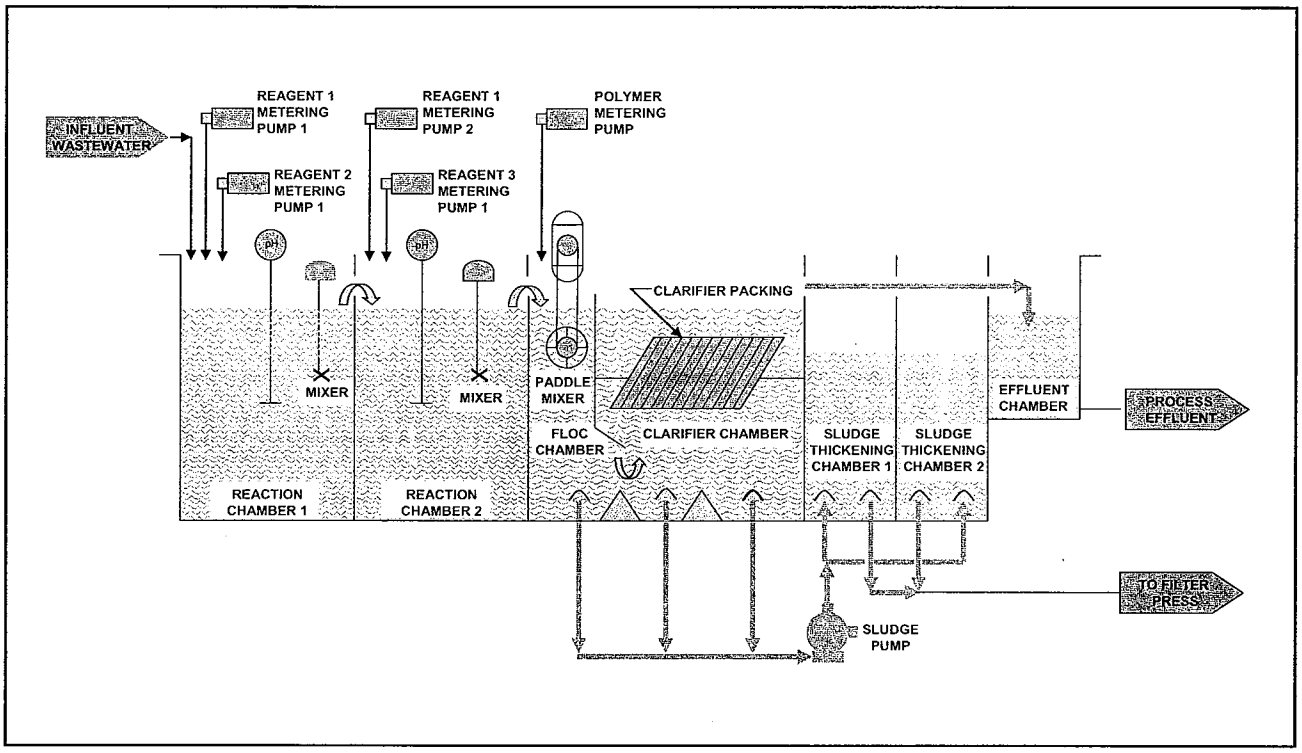
Technical Information

CONTINUOUS PRECIPITATION SYSTEMS		
MODEL*	FLOW RATE**	OVERALL DIMENSIONS (L x W x H)
CPS-10-2-SA	10 gpm (2.3 m^3/h)	11'-6" x 7'-2" x 8'-5" (3.5 m x 2.2 m x 2.0 m)
CPS-30-2-SA	30 gpm (6.8 m^3/h)	16'-1" x 7'-2" x 9'-0" (5.0 m x 2.2 m x 2.7 m)
CPS-50-2-SA	50 gpm (11.4 m^3/h)	18'-5" x 11'-1" x 10'-7" (5.6 m x 3.3 m x 3.2 m)
CPS-100-2-SA	100 gpm (22.7 m^3/h)	25'-10" x 10'-10" x 11'-7" (7.9 m x 3.3 m x 3.5 m)

** Epoxy Coated Carbon Steel is the standard material of construction.*

*** Assumes <500 ppm influent suspended solids and temperature of 40°F<T<120°F (4°C<T<50°C).*

Process Flow Diagram



OPTIONAL EQUIPMENT	
Item	**Description**
Influent Flow Equalization Tank & Transfer Pump	Tank sized for 60 minutes retention at the rated flow
Solids Dewatering Filter Press	Recessed chamber filter press used to dewater the process sludge generated by the CPS unit
Reagent Mix Tanks	Used for preparation and storage of the chemical reagents
Effluent Flow Meter and Recorder	Paddle wheel type flow meter used to measure and record the treated wastewater flow to the drain connection
Instruments	Reaction chamber ORP transmitters/probes, effluent pH transmitter/probe with recorder, and dual pH/ORP transmitters/probes
Inclined Plate Separator	Packing of FRP construction
Effluent Media Filter	Sand or multi-media filter used to ensure effluent suspended solids limits (<20 ppm) are met
Influent Collection Liftstations	Used to collect individual waste streams that are not able to gravity flow, and transfer the wastewater to the influent collection tank

TotalTreat is a trademark of Siemens, its subsidiaries or affiliates.

The information provided in this brochure contains merely general descriptions or characteristics of performance which in actual case of use do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in the terms of contract.

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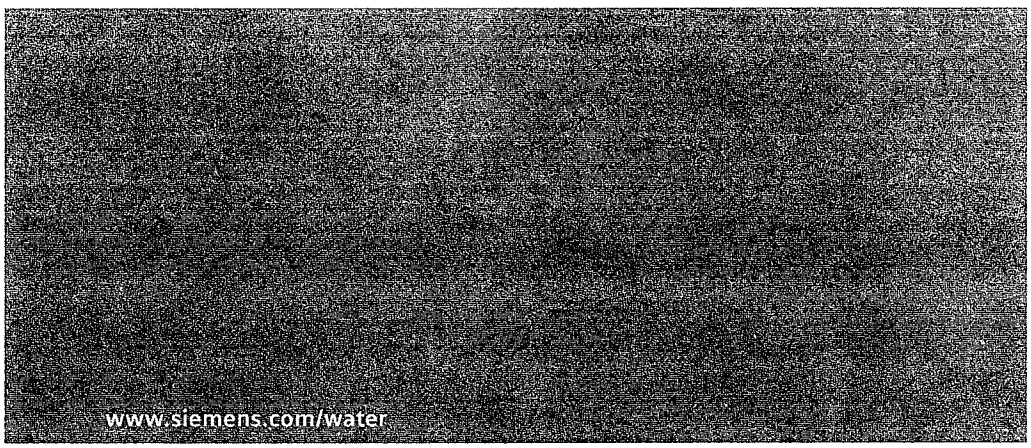


Water Technologies

Neutralization System

Fiberglass and HDPE Construction

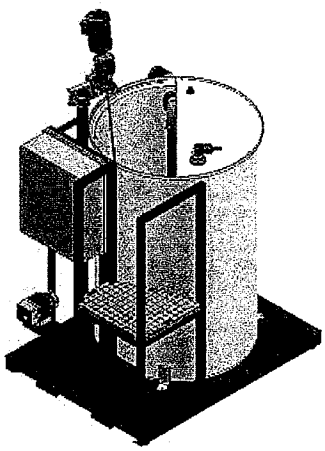
SIEMENS

The Neutralization NS (fiberglass tanks) and NSP (HDPE tanks) systems are typically used as final pH adjustment steps following conventional wastewater treatment or microfiltration systems. They include one reaction tank that is skid-mounted or supplied with a catwalk frame and completely piped and wired. The systems are designed to adjust the pH either up, down or both.

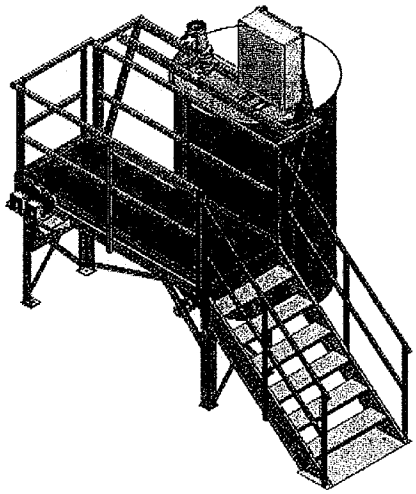
The basic neutralization system configuration has the tank equipped with one Brawn mixer, one LMI chemical feed pump, one GLI pH probe and one GLI pH transmitter. On NS/NSP systems less than 1,000 gallon (3.8 m3) capacity, the units are completely skid-mounted.

The skid frame supports the mixer, probes and chemical pump. An additional chemical metering pump is available as an option. The electrical control box, piping manifolds, conduit and wiring harnesses are also attached to this frame. When necessary, steps are supplied for operator access to the system.

NSP-500



NSP-1000



FEATURES

- Fully assembled at the factory
- Factory tested
- Units are either skid-mounted or catwalk integrated
- Units are match marked for ease of reassembly
- Rapid installation assured by skidded assemblies and mistake proof electrical connections

Neutralization System

Fiberglass and HDPE Construction

NEUTRALIZATION SYSTEM						
Model Number	**NS/NSP-250**	**NS/NSP-500**	**NS/NSP-1000**	**NS/NSP-1500**	**NS/NSP-2000**	**NS/NSP-3000**
Number of Tanks	One	One	One	One	One	One
Tank Material	FRP/HDPE	FRP/HDPE	FRP/HDPE	FRP/HDPE	FRP/HDPE	FRP/HDPE
Tank Volume	250 gallons 0.95 m^3	500 gallons 1.9 m^3	1,000 gallons 3.8 m^3	1,500 gallons 5.7 m^3	2,000 gallons 7.6 m^3	3,000 gallons 11.4 m^3
Type	Vertical Cylindrical	Vertical Cylindrical	Vertical Cylindrical	Vertical Cylindrical	Vertical Cylindrical	Vertical Cylindrical
Method of Construction	Skidded	Skidded	Catwalk-Mounted	Catwalk-Mounted	Catwalk-Mounted	Catwalk-Mounted
Recommended Through-Put	20 gpm 4.5 m^3/hr	40 gpm 9.1 m^3/hr	80 gpm 18.2 m^3/hr	125 gpm 28.4 m^3/hr	165 gpm 37.5 m^3/hr	240 gpm 54.5 m^3/hr
Mixers	1/4 HP, 120/1/60, TEFC	1/3 HP, 460/3/60, TEFC	1/2 HP, 460/3/60, TEFC	1 HP, 460/3/60, TEFC	1 HP, 460/3/60, TEFC	2 HP, 460/3/60, TEFC
VALVES AND PIPING CONNECTIONS						
Outlet Connection	3" Male Pipe Stub	4" Male Pipe Stub	4" Male Pipe Stub	4" Male Pipe Stub	6" Male Pipe Stub	8" Male Pipe Stub
Drain Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve
INSTRUMENTS						
pH Monitors	GLI pH Indicator Transmitter	GLI pH Indicator Transmitter	GLI pH Indicator Transmitter	GLI pH Indicator Transmitter	GLI pH Indicator Transmitter	GLI pH Indicator Transmitter
pH Probe	GLI Temperature Compensated	GLI Temperature Compensated	GLI Temperature Compensated	GLI Temperature Compensated	GLI Temperature Compensated	GLI Temperature Compensated
Recorder	One (1) Channel Circular Chart Recorder w/Digital Display	One (1) Channel Circular Chart Recorder w/Digital Display	One (1) Channel Circular Chart Recorder w/Digital Display	One (1) Channel Circular Chart Recorder w/Digital Display	One (1) Channel Circular Chart Recorder w/Digital Display	One (1) Channel Circular Chart Recorder w/Digital Display
PLC	Siemens	Siemens	Siemens	Siemens	Siemens	Siemens
SKID						
Mounting	Each tank is mounted on its own skid. Skids are interlocked for ease of reassembly.	Each tank is mounted on its own skid. Skids are interlocked for ease of reassembly.	Tanks are floor mounted with mixers and all other components mounted off the catwalks.	Tanks are floor mounted with mixers and all other components mounted off the catwalks.	Tanks are floor mounted with mixers and all other components mounted off the catwalks.	Tanks are floor mounted with mixers and all other components mounted off the catwalks.
Paint	Near white metal sandblast + 2-3 mil primer + 3-5 mil finish	Near white metal sandblast + 2-3 mil primer + 3-5 mil finish	Near white metal sandblast + 2-3 mil primer + 3-5 mil finish	Near white metal sandblast + 2-3 mil primer + 3-5 mil finish	Near white metal sandblast + 2-3 mil primer + 3-5 mil finish	Near white metal sandblast + 2-3 mil primer + 3-5 mil finish
Dimensions (L x W x H)	80" x 55" x 85" 2,032 x 1,397 x 2,159 mm	80" x 55" x 110" 2,032 x 1,397 x 2,794 mm	100"x 120" x 145" 2,540 x 3,048 x 3,683 mm	100" x 135" x 145" 2,540 x 3,429 x 3,683 mm	100" x 145" x 145" 2,540 x 3,683 x 3,683 mm	100" x 150" x 170" 2,540 x 3,810 x 4,318 mm
Shipping Weight	879 lbs 399 kg	1,266 lbs 574 kg	2,445 lbs 1109 kg	2,550 lbs 1,156 kg	2,717 lbs 1,232 kg	3,191 lbs 1,447 kg
Operating Weight	2,964 lbs 1,344 kg	5,438 lbs 2,467 kg	10,785 lbs 4,892 kg	15,060 lbs 6,831kg	19,397 lbs 8,798 kg	28,211 lbs 12,796 kg

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Water Technologies

Equalization and Water Storage Tanks

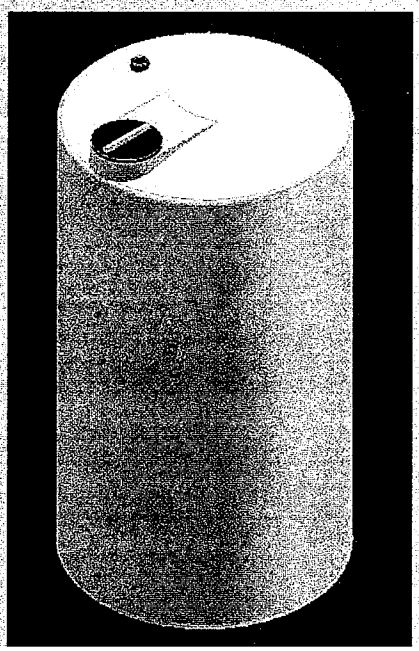
SIEMENS

The Equalization and Water Storage Tanks are specifically designed to be used with the transfer pump system. The tanks are used to provide the proper holding capacity before a wastewater treatment system or to hold purified water from an ion exchange or reverse osmosis system.

The tanks are available in either high density polyethylene (HDPE) or fiberglass (FRP). The tank can be supplied as either open top construction features or with a dome/cover.

The tanks come complete with a level control and all of the associated bulk head fittings.

EQ 1500



FEATURES

- Non-corrosive construction (HDPE or FRP)
- Level control included
- Sold as stand alone
- Integrate with other wastewater products

Equalization and Water Storage Tanks

SPECIFICATIONS

Model Number	EQ-250-HDPE	EQ-500-HDPE	EQ-1000-HDPE	EQ-1500-HDPE	EQ-3200-HDPE	EQ-6500-HDPE	EQ-9000-HDPE	EQ-10000-HDPE	EQ-12000-HDPE
Tank Volume	250 gallons 0.95 m³	500 gallons 1.9 m³	1,000 gallons 3.8 m³	1,500 gallons 5.7 m³	3,200 gallons 12.1 m³	6,500 gallons 24.6 m³	9,000 gallons 34.0 m³	10,000 gallons 37.9 m³	12,000 gallons 45.4 m³
Material of Construction	HDPE Dome Top	HDPE Dome Top	HDPE Dome Top	HDPE Dome Top	HDPE Dome Top	HDPE Dome Top	HDPE Dome Top	HDPE Dome Top	HDPE Dome Top
Discharge Nozzle	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection
Drain Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve
Level Control	Float	Float	Float	Float	Float	Float	Float	Float	Float
Dimensions (Dia. x H)	43" x 59" 1,092 x 1,499 mm	45-1/2" x 82-3/4" 1,156 x 2,102 mm	64-1/2" x 88-1/4" 1,638 x 2,242 mm	64" x 126-1/2" 1,626 x 3,213 mm	95-3/4" x 116-3/4" 2,432 x 2,965 mm	120" x 152-1/4" 3,048 x 3,867 mm	141" x 145" 3,581 x 3,683 mm	141" x 159" 3,581 x 4,039 mm	141" x 192" 3,581 x 4,877 mm
Manway	8	16	16	16	16	16	16	16	16
Shipping Weight	100 lbs 45 kg	120 lbs 54 kg	220 lbs 100 kg	365 lbs 166 kg	660 lbs 299 kg	1,595 lbs 723 kg	1,940 lbs 880 kg	2,310 lbs 1,048 kg	3,100 lbs 1,406 kg
Operating Weight	2,185 lbs 991 kg	4,290 lbs 1,946 kg	8,560 lbs 3,883 kg	12,875 lbs 5,840 kg	27,348 lbs 12,405 kg	58,307 lbs 26,448 kg	77,000 lbs 34,927 kg	85,710 lbs 38,877 kg	103,180 lbs 46,802 kg

Model Number	EQ-500-FRP	EQ-1000-FRP	EQ-1500-FRP	EQ-3200-FRP	EQ-6500-FRP	EQ-9000-FRP	EQ-10000-FRP	EQ-12000-FRP
Tank Volume	500 gallons 1.9 m³	1,000 gallons 3.8 m³	1,500 gallons 5.7 m³	3,200 gallons 12.1 m³	6,500 gallons 24.6 m³	9,000 gallons 34.0 m³	10,000 gallons 37.9 m³	12,000 gallons 45.4 m³
Material of Construction	FRP Open Top w/cover	FRP Open Top w/cover	FRP Dome Top	FRP Dome Top	FRP Dome Top	FRP Dome Top	FRP Dome Top	FRP Dome Top
Discharge Nozzle	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection	Determined by pump selection
Drain Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve
Level Control	Float	Float	Float	Float	Float	Float	Float	Float
Dimensions (Dia. x H)	42" x 66" 1,067 x 1,676 mm	60" x 84" 1,524 x 2,134 mm	72" x 84" 1,829 x 2,134 mm	96" x 108" 2,438 x 2,743 mm	96" x 210" 2,438 x 5,334 mm	120" x 186" 3,048 x 4,724 mm	120" x 210" 3,048 x 5,334 mm	144" x 168" 3,658 x 4,267 mm
Shipping Weight	230 lbs 104 kg	406 lbs 186 kg	560 lbs 254 kg	947 lbs 430 kg	1,596 lbs 724 kg	1,813 lbs 822 kg	1,988 lbs 902 kg	2,390 lbs 1,084 kg
Operating Weight	4,400 lbs 1,996 kg	8,746 lbs 3,967 kg	13,070 lbs 5,928 kg	27,635 lbs 12,535 kg	55,806 lbs 25,313 kg	76,873 lbs 34,869 kg	85,388 lbs 38,731 kg	102,470 lbs 46,479 kg

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Water Technologies

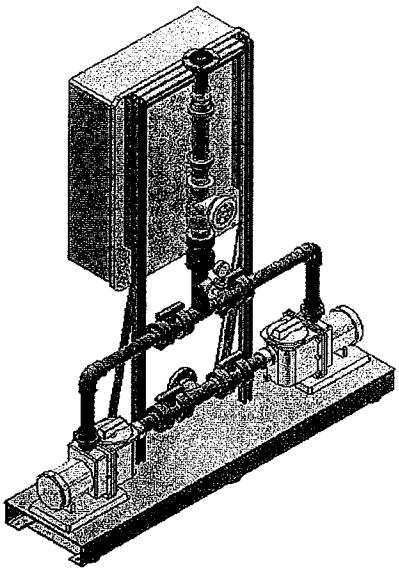
Transfer Pump Systems (PS-S and PS-D Series)

Low Pressure, Simplex and Duplex

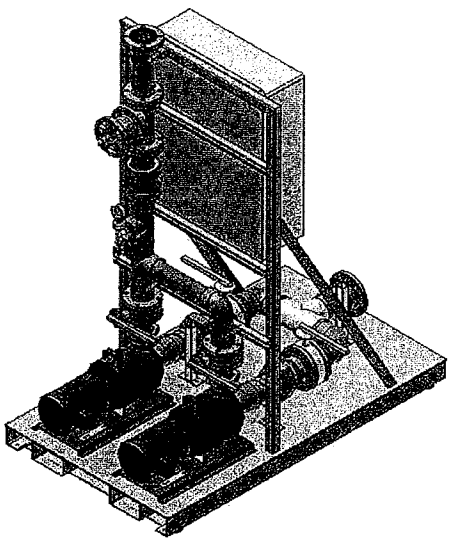
SIEMENS

The Transfer Pump Systems are specifically designed to be used with an existing collection tank or sump tank. The pumps are sized to provide 50 feet of head at the design flow rate. The pump, valves, flow indicator, flow control valve and control panel are mounted on a corrosion resistant painted steel skid. The system can be purchased as a stand alone item or used in conjunction with other standard products. When integrating with other standard products modules, the Transfer Pump System simply interlocks with the other modules. The interconnecting piping (if within 3 feet of the next module) is also provided with the system. On larger horsepower pumps, an electrical drop may be necessary.

PS-10 through PS-50



PS-75 through PS-200



FEATURES

- NEMA-4X electrical enclosure
- Rotometer to indicate flow
- Adjustable diaphragm valve to control flow
- Isolation ball valve to service the pump
- TEFC pump motor
- Pre-piped
- Pre-wired
- Factory tested
- Sold as stand alone
- Integrate with other wastewater products

Transfer Pump Systems (PS-S and PS-D Series)

Low Pressure, Simplex and Duplex

PUMPS									
Model Number	PS-10-S/D	PS-30-S/D	PS-50-S/D	PS-75-S/D	PS-100-S/D	PS-150-S/D	PS-200-S/D	PS-250-S/D	PS-300-S/D
Number of Pumps	One/Two	One/Two	One/Two	One/Two	One/Two	One/Two	One/Two	One/Two	One/Two
Manufacturer	Serfilco	Serfilco	Serfilco	Serfilco	Serfilco	Serfilco	Serfilco	Serfilco	Serfilco
Type	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal
Material of Construction	Noryl	Noryl	Noryl	Polyester	Polyester	Polyester	Polyester	Stainless Steel	Stainless Steel
Capacity	10 gpm @ 50' head 2.3 m^3/hr @149 kPa	30 gpm @ 50' head 6.8 m^3/hr @ 149 kPa	50 gpm @ 50' head 11.4 m^3/hr @ 149 kPa	75 gpm @ 50' head 17.0 m^3/hr @ 149 kPa	100 gpm @ 50' head 22.7 m^3/hr @ 149 kPa	150 gpm @ 50' head 34.1 m^3/hr @ 149 kPa	200 gpm @ 50' head 45.4 m^3/hr @ 149 kPa	250 gpm @ 50' head 56.8 m^3/hr @ 149 kPa	300 gpm @ 50' head 68.1 m^3/hr @ 149 kPa
Motor	1.0 HP, 460/3/60, TEFC	1.5 HP, 460/3/60, TEFC	2 HP, 460/3/60, TEFC	3 HP, 460/3/60, TEFC	3 HP, 460/3/60, TEFC	5 HP, 460/3/60, TEFC	5 HP, 460/3/60, TEFC	7.5 HP, 460/3/60, TEFC	7.5 HP, 460/3/60, TEFC
VALVES									
Suction	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type
Discharge	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type	One/Two PVC Ball Type
Discharge Check Valve	One PVC Check Valve	One PVC Check Valve	One PVC Check Valve	One PVC Check Valve	One PVC Check Valve	One PVC Check Valve	One PVC Check Valve	One PVC Check Valve	One PVC Check Valve
Discharge Throttle Valve	Diaphragm Type	Diaphragm Type	Diaphragm Type	Diaphragm Type	Diaphragm Type	Diaphragm Type	Diaphragm Type	Diaphragm Type	Diaphragm Type
Connection	2"	2"	2"	3"	3"	4"	4"	4"	4"
INSTRUMENTS									
Pressure	One Discharge Pressure Gauge	One Discharge Pressure Gauge	One Discharge Pressure Gauge	One Discharge Pressure Gauge	One Discharge Pressure Gauge	One Discharge Pressure Gauge	One Discharge Pressure Gauge	One Discharge Pressure Gauge	One Discharge Pressure Gauge
Flowmeter	Rotometer	Rotometer	Rotometer	Rotometer	Paddlewheel	Paddlewheel	Paddlewheel	Paddlewheel	Paddlewheel
Level Control	Float	Float	Float	Float	Float	Float	Float	Float	Float
SKID									
Mounting	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base	Pumps and piping mounted on steel base
Paint	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish	White metal sandblast + 2-3 mil primer + 3-5 mil finish
Dimensions (L x W x H)	60"x 18"x 80" 1,524 x 457 x 2,032 mm	60"x 18"x 80" 1,524 x 457 x 2,032 mm	60"x 18"x 80" 1,524 x 457 x 2,032 mm	72"x 42"x 86" 1,829 x 1,067 x 2,032 mm	72"x 42"x 86" 1,829 x 1,067 x 2,032 mm	72"x 42"x 86" 1,829 x 1,067 x 2,032 mm	72"x 42"x 86" 1,829 x 1,067 x 2,032 mm	72"x 42"x 86" 1,829 x 1,067 x 2,032 mm	72"x 42"x 86" 1,829 x 1,067 x 2,032 mm
Shipping Weight	475 lbs 215 kg	475 lbs 215 kg	475 lbs 215 kg	989 lbs 449 kg	1,020 lbs 463 kg	1,080 lbs 490 kg	1,200 lbs 544 kg	1,700 lbs 771 kg	1,800 lbs 816 kg
Operating Weight	500 lbs 227 kg	500 lbs 227 kg	500 lbs 227 kg	1,014 lbs 460 kg	1,045 lbs 474 kg	1,105 lbs 474 kg	1,225 lbs 556 kg	1,725 lbs 782 kg	1,825 lbs 828 kg

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HYDRUS

HF 330m OD Macrolite® Filter

Design Specifications

Flow Rate at 10 gpm/ft^2	147 gpm
Nominal Clean-Bed Pressure Drop	7.5 psid
Pressure Range	35 – 125 psig
Temperature Range	35 – 120° F
Total Suspended Solids	≤ 30 mg/L

System Components

Media Vessel (qty) Size	(3) 30" x 72"
Media Vessel Construction	Wrapped Polyethylene
Empty Bed Volume	25.0 ft^3
Media Type	M2 Macrolite®
Media Volume (per tank)	8 ft^3
Under Bedding Weight (per tank)	300 pounds
Total Bed Depth	20"
Free Board	41"
Riser Tube	2.0" PVC
Upper Distributor	0.012" Slots, Engineered Plastic Material
Lower Distributor	0.012" Slots, Polyethylene Hub and Laterals
Backwash Control	7-Day Controller
Backwash Type	Countercurrent
Unfiltered Water Bypass During Backwash	No
Water Used for Backwash	Filtered Water

Connections

Inlet / Outlet Connections	E-Clip Adapter
Drain Connection	E-Clip Adapter
Power, Valve	None
Power, Control Box	12 VDC

Part Numbers

System (quantity)	(3) H12281
Smart Start Controller	12137
Differential Pressure Switch	59256

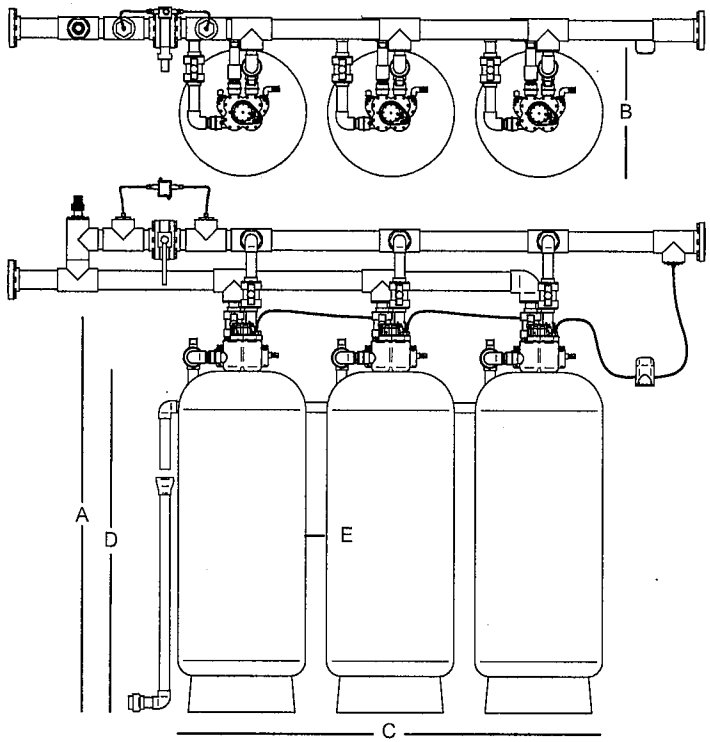
Backwash Specifications (per tank)

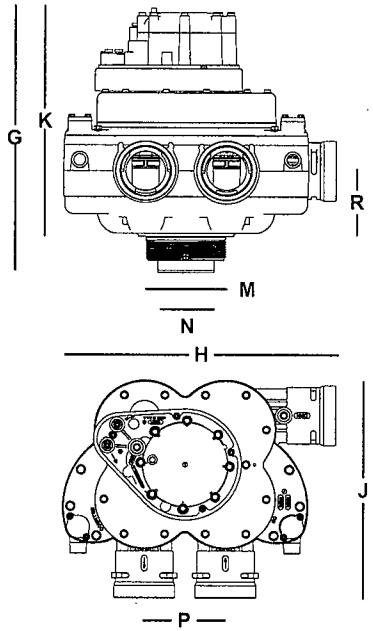
Sequence	Flow	Time	Volume
Backwash	39 gpm	12 minutes	468 gallons
Settle	N/A	1.5 minutes	N/A
Purge	39 gpm	4 minutes	156 gallons
Total	N/A	17.5 minutes	633 gallons

Dimensions and Weight

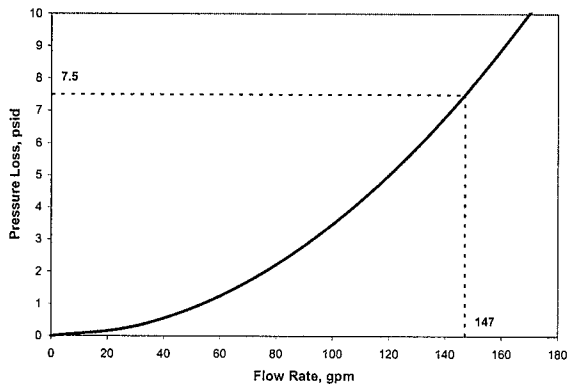
System

Overall Height	(A)	95.5"
Overall Depth	(B)	30"
Overall Width	(C)	98.0"
Tank Height	(D)	83.8"
Inter-Tank Spacing	(E)	4"
Shipping Weight		3,343 pounds
Operating Weight		**6,094** pounds





System Flow Performance



Valve

Overall Height	(G)	13.25"
Overall Width	(H)	14"
Overall Depth	(J)	11"
Installed Height	(K)	11.5"
Tank Thread	(M)	4-8 UN
Riser Tube (OD)	(N)	2.8"
Inlet/Outlet Centerline	(P)	4.06
Inlet/Outlet/Drain Center Installed Height	(R)	3.34
Valve Weight		14.3 pounds

Kinetico water systems

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HYDRUS HF 330m OD Macrolite® Filter

Operating Profile
The filter shall remove suspended solids to a nominal rating of 5 micron. Ceramic based non-consumable media shall be used for the filtration process. The system shall provide filtered water through the use of a multiplex configuration. System backwashes shall be initiated based on the time of day. The programmable timer shall allow backwashes to be programmed over a 7-day period.

Backwash Control Valve
The backwash control valve shall be top mounted (top of media tank), and manufactured from non-corrosive materials. Control valve shall not weight more than 15 lbs. Control valve shall operate using a minimum outlet pressure of 25 psi. Pressure shall be used to drive all valve functions. Control valve shall incorporate three operational cycles including; service, backwash, and purge. Service cycle shall operate in a down-flow direction. The backwash cycle shall be up-flow and purge shall be down-flow. Control valve shall contain a backwash flow control.

Media Tanks
The tanks shall be designed for a maximum working pressure of 125 psi and hydrostatically tested at 300 psi. Tanks shall be made of polypropylene and reinforced with a fiberglass wrapping. Tank shall have a 4" threaded top opening. Tank shall be NSF approved. Upper diffuser system shall be of a slot design. Lower distribution system shall be of hub and lateral design. Distribution system shall provide even distribution of backwash water and the collection of processed water.

Filtering Media
Each system shall use ceramic based filter media capability of operating in an average service flow of 10 gpm per square foot of media. The media shall be solid and of a proper particle size, 40-70 mesh. Backwash shall produce a minimum of 50% bed expansion at a nominal flow rate of 8 gpm per square foot of media.

Kinetico®
water systems

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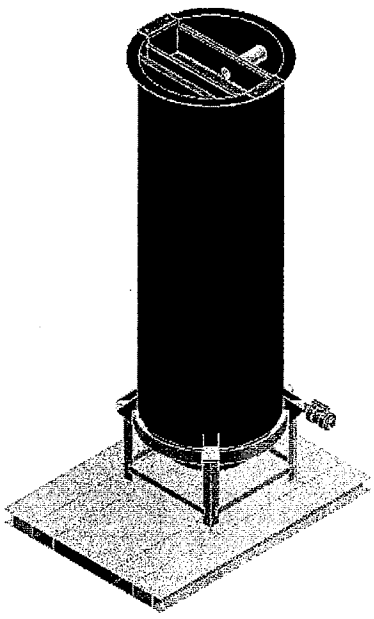
Water Technologies

Sludge Thickening System (50 Series)

SIEMENS

The Sludge Thickening System is designed to take low concentrated sludge (1-2% solids) and increase the sludge concentration to 4-5% solids by means of gravity settling. Sludges from a Memtek® Microfilter System, a solids separator (clarifier) or a TotalTreat® Continuous Precipitation System system that does not incorporate an integrated sludge aging tank can be further thickened by using a Sludge Thickening System. The system is operated in a continuous mode. It includes a coned bottom FRP tank, FRP inlet baffle, effluent weir trough and a flanged sludge withdrawal nozzle.

50 Series



FEATURES

- Non-corrosive FRP construction
- Sold as stand alone
- Integrate with other wastewater products

Sludge Thickening System (50 Series)

SLUDGE THICKENING SYSTEM									
Model Number	50-7105-3	50-7108-3	50-7112-3	50-7118-3	50-7125-3	50-7130-3	50-7135-3	50-7140-3	50-7145-3
Tank Volume	500 gallons 1.9 m^3	800 gallons 3.0 m^3	1,200 gallons 4.5 m^3	1,800 gallons 6.8 m^3	2,500 gallons 9.5 m^3	3,000 gallons 11.4 m^3	3,500 gallons 13.3 m^3	4,000 gallons 15.1 m^3	4,500 gallons 17.0 m^3
Effluent Nozzle	3" Flanged	3" Flanged	3" Flanged	3" Flanged	3" Flanged	3" Flanged	4" Flanged	4" Flanged	4" Flanged
Sludge Withdrawal Nozzle	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged
Drain Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve	2" True Union Ball Valve
Dimensions (Dia. x H)	3'-0" x 10'-8" 914 x 3,251 mm	4'-0" x 10'-8" 1,219 x 3,251 mm	5'-0" x 10'-8" 1,524 x 3,251 mm	6'-0" x 10'-8" 1,829 x 3,251 mm	7'-0" x 10'-8" 2,134 x 3,251 mm	8'-0" x 10'-8" 2,438 x 3,251 mm	8'-0" x 13'-9" 2,438 x 4,191 mm	9'-0" x 13'-6" 2,743 x 4,115 mm	9'-0" x 14'-6" 2,743 x 4,420 mm
Shipping Weight	432 lbs 196 kg	560 lbs 254 kg	722 lbs 328 kg	834 lbs 378 kg	955 lbs 433 kg	1,095 lbs 497 kg	2,640 lbs 1,197 kg	2,726 lbs 1,237 kg	2,800 lbs 1,270 kg
Operating Weight (lbs)	5,935 lbs 2,692 kg	9,815 lbs 4,452 kg	14,315 lbs 6,493 kg	18,985 lbs 8,612 kg	23,880 lbs 10,832 kg	28,665 lbs 13,002 kg	37,640 lbs 17,073 kg	42,725 lbs 19,380 kg	47,800 lbs 21,682 kg

Model Number	50-7150-3	50-7155-3	50-7160-3	50-7165-3	50-7170-3	50-7180-3	50-7190-3	50-71100-3
Tank Capacity (gallons)	5,000 gallons 18.9 kg	5,500 gallons 20.8 kg	6,000 gallons 22.7 kg	6,500 gallons 24.6 kg	7,000 gallons 26.5 kg	8,000 gallons 30.3 kg	9,000 gallons 34.0 kg	10,000 gallons 37.9 kg
Effluent Nozzle	4" Flanged	4" Flanged	4" Flanged	4" Flanged	4" Flanged	4" Flanged	4" Flanged	4" Flanged
Sludge Withdrawal Nozzle	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged	2" Flanged
Dimensions (Dia. x H)	10'-0" x 14'-0" 3,048 x 4,267 mm	10'-0" x 15'-0" 3,048 x 4x572 mm	11'-0" x 14'-6" 3,353 x 4,420 mm	11'-0" x 15'-3" 3,353 x 4,648 mm	12'-0" x 15'-0" 3,658 x 4,572 mm	12'-0" x 16'-2" 3,658 x 4,928 mm	12'-0" x 17'-4" 3,658 x 5,283 mm	12'-0" x 18'-6" 3,658 x 5,639 mm
Shipping Weight	3,280 lbs 1,488 kg	3,370 lbs 1,529 kg	3,980 lbs 1,805 kg	4,050 lbs 1,837 kg	4,465 lbs 2,025 kg	4,975 lbs 2,257 kg	5,490 lbs 2,490 kg	6,000 lbs 2,722 kg
Operating Weight	53,280 lbs 24,167 kg	58,370 lbs 26,476 kg	63,980 lbs 29,021 kg	69,050 lbs 31,321 kg	74,465 lbs 33,777 kg	84,965 lbs 38,540 kg	95,465 lbs 43,302 kg	106,000 lbs 48,081 kg

The information provided in this literature contains merely general descriptions or characteristics of performance which in actual case of use do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in the terms of the contract.

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Water Technologies

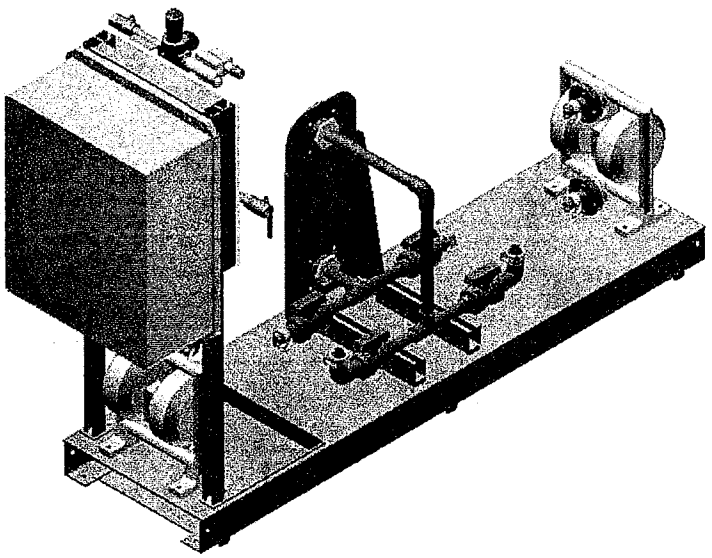
Air Diaphragm Pump Systems

Simplex and Duplex

SIEMENS

The Air Diaphragm Pump Systems are specifically designed to be used with an existing collection tank or sump. The pumps are sized to provide 50 feet of head at the design flow rate. The air diaphragm pump, valves and control panel are mounted on a corrosion resistant painted steel skid. The system can be purchased as a stand alone item or used in conjunction with other standard products. When integrating with other standard products modules, the Air Diaphragm Pump System simply interlocks with the other modules. The interconnecting piping (if within 3 feet of the next module) is also provided with the system.

PS1.OP



FEATURES

- Isolation ball valve to service the pump
- Pre-piped
- Pre-wired
- Factory tested
- Sold as stand alone
- Integrate with other wastewater products

Air Diaphragm Pump Systems

Simplex and Duplex

PUMPS									
Model Number	PS0.5C	PS0.5P	PS1.0C	PS1.0P	PS1.5C	PS1.5P	PS2.0C	PS2.0P	PS3.0C
Number of Air Diaphragm Pumps	One/Two		One/Two		One/Two		One/Two		One/Two
Manufacturer	Aro		Aro		Aro		Aro		Aro
Type	Double Diaphram, Air Operated		Double Diaphram, Air Operated		Double Diaphram, Air Operated		Double Diaphram, Air Operated		Double Diaphram, Air Operated
Material of Construction	Cast Iron	Polypro	Double Diaphram, Air Operated	Polypro	Cast Iron	Polypro	Cast Iron	Polypro	Cast Iron
Flow rate	3-12 gpm 0.68-2.7 m^3/hr	3-12 gpm 0.68-2.7 m^3/hr	12-35 gpm 2.7-7.9 m^3/hr	10-40 gpm 2.2-9.0 m^3/hr	40-80 gpm 9.0-18.2 m^3/hr	40-110 gpm 9.0-25.0 m^3/hr	60-150 gpm 13.6-34.0 m^3/hr	40-120 gpm 9.0-27.2 m^3/hr	120-210 gpm 27.2-47.7 m^3/hr
VALVES									
Suction	2" True Union Ball Valve		2" True Union Ball Valve		2" True Union Ball Valve		3" Butterfly Valve		4" Butterfly Valve
Discharge	2" True Union Ball Valve		2" True Union Ball Valve		2" True Union Ball Valve		3" Butterfly Valve		4" Butterfly Valve
Connection	2"		2"		2"		3"		4"
INSTRUMENTS									
Level Control	Float		Float		Float		Float		Float
SKID									
Mounting	Pumps and piping mounted on steel base		Pumps and piping mounted on steel base		Pumps and piping mounted on steel base		Pumps and piping mounted on steel base		Pumps and piping mounted on steel base
Paint	White metal sandblast + 2-3 mil primer + 3-5 mil finish		White metal sandblast + 2-3 mil primer + 3-5 mil finish		White metal sandblast + 2-3 mil primer + 3-5 mil finish		White metal sandblast + 2-3 mil primer + 3-5 mil finish		White metal sand-blast + 2-3 mil primer + 3-5 mil finish
Dimensions (L x W x H)	80" x 20" x 57" 2,032 x 508 x 1,448 mm		80" x 20" x 57" 2,032 x 508 x 1,448 mm		80" x 20" x 57" 2,032 x 508 x 1,448 mm		82" x 50" x 54" 2,083 x 1,270 x 1,372 mm		82" x 50" x 54" 2,083 x 1,270 x 1,372 mm
Shipping weight	500 lbs 227 kg		500 lbs 227 kg		500 lbs 227 kg		800 lbs 227 kg		800 lbs 227 kg

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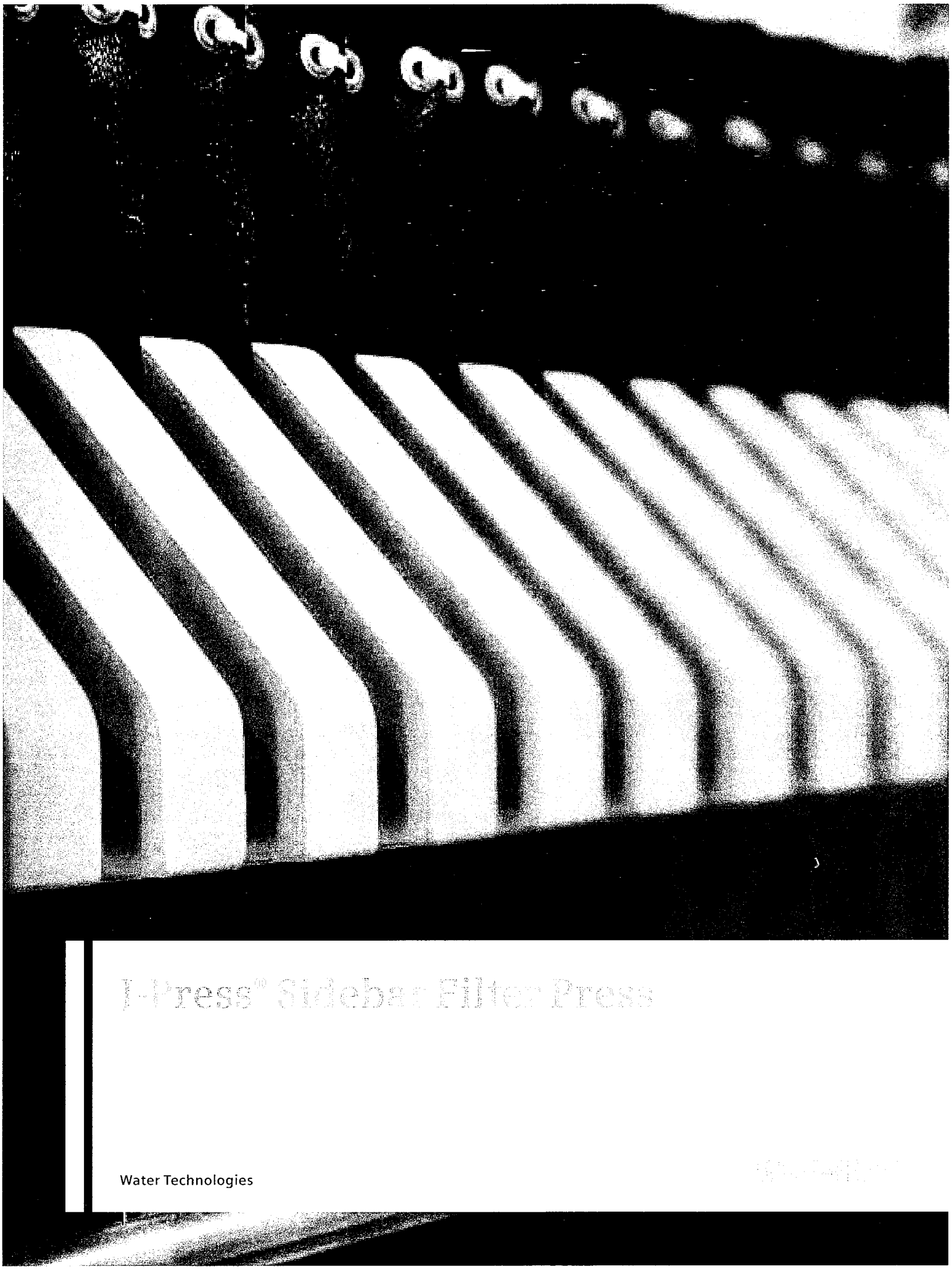
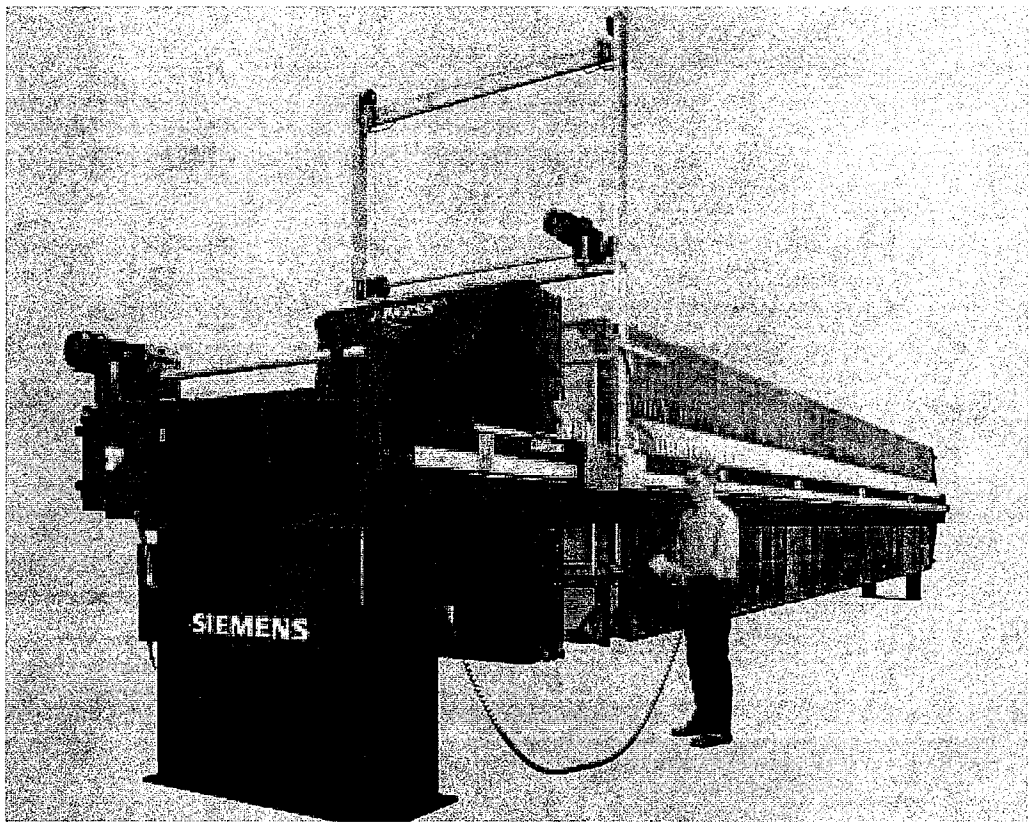
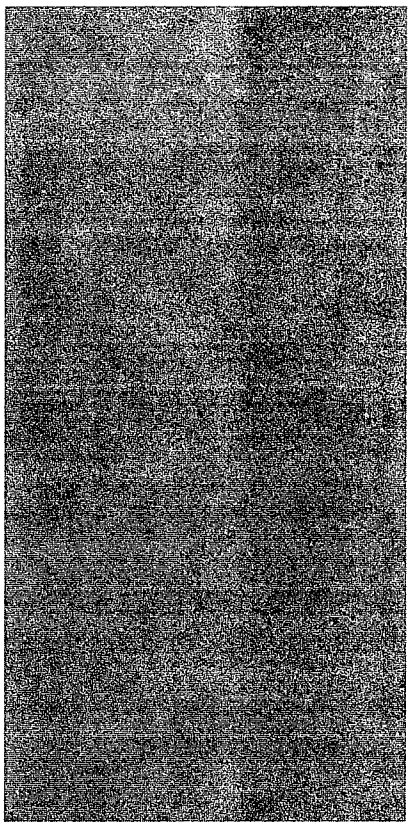


I-Press® Sidebar Filter Press

Water Technologies

J-Press® Filter Press – The Industry Standard





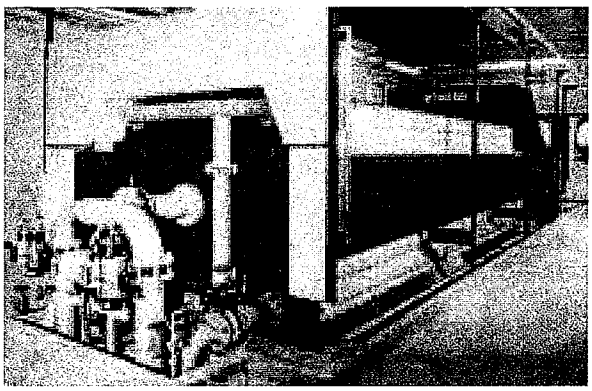
1.5m x 2.0m Fully automatic with automatic cloth washer.

Liquid/Solid Separation Process

The J-Press® sidebar filter press is the cost-effective solution for producing high solids filter cake with extremely high clarity in the liquid effluent. Considered by industry professionals as the premier sidebar filter press, the J-Press® filter press combines rugged construction, precision engineering, ease of operation and a wide range of features and options to tackle the most difficult dewatering problems.

The J-Press® filter press is one of the most versatile dewatering devices on the market, being used in a wide variety of industrial and municipal applications. The J-Press® filter press can be used to recover both solids and liquids from a waste or process stream. With superior materials of construction, the J-Press® filter press is especially useful in the dewatering of aggressive acid and alkali suspensions.

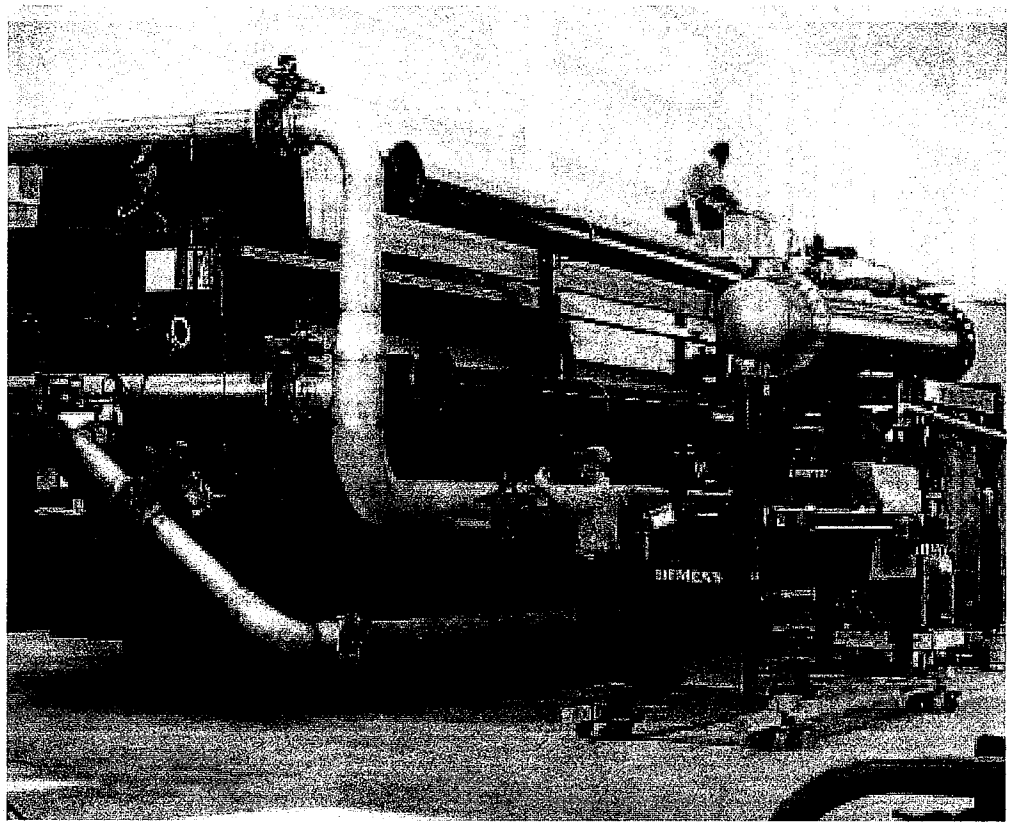
Available in a wide range of sizes and styles, the J-Press® filter press can be configured to provide a dewatering solution to most all process flows from as little as 25 gallons to 1,000,000 gallons per day. It produces consistent results under varying influent conditions.



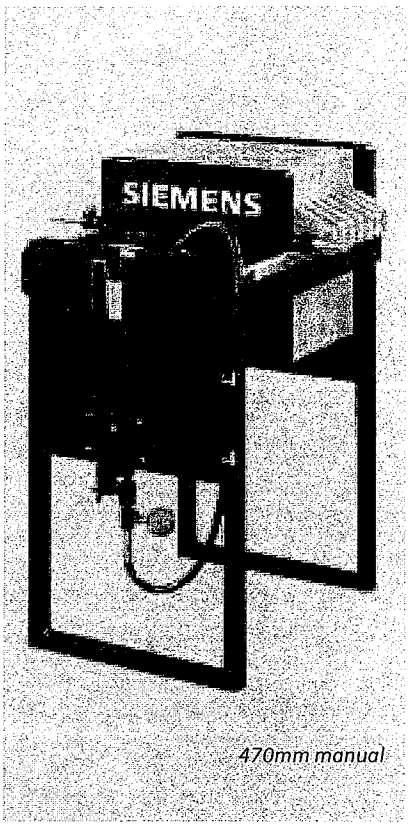
1500mm fully automatic with automatic cloth washer.

CWB Certification

The Canadian Welding Bureau acknowledges that Siemens Water Technologies is certified to CSA Standard W47.1.



The J-Press® filter press can be configured with highly sophisticated manifolds, controls and cake discharge systems, such as this 2.0m x 2.0m J-Press® filter press built for a prominent municipal wastewater treatment plant.



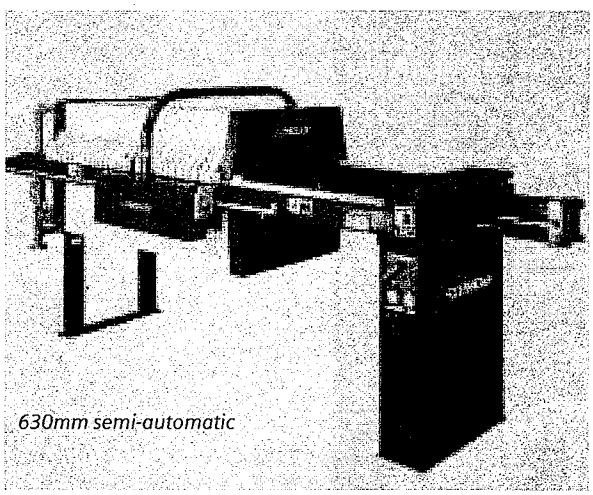
470mm manual

Siemens sidebar presses are available in sizes ranging from 250mm to 2.0m designs, with working pressure ratings of 100psi (7bar) and 225psi (16bar).

J-Press® Filter Press, The Industry Leader

In 1978, JWI revolutionized the industry with the introduction of the J-Press® filter press. The J-Press® filter press was the first to feature, in a single design, a self compensating air/hydraulic closure system for ease of maintenance, gasketed filter plates for virtually leak free dewatering, semi-automatic plate shifting for labor savings and safety, automatic pump controls for unattended operation and a superior paint system that provided the highest level of protection from corrosion. The J-Press® filter press quickly set the benchmark for filter press performance.

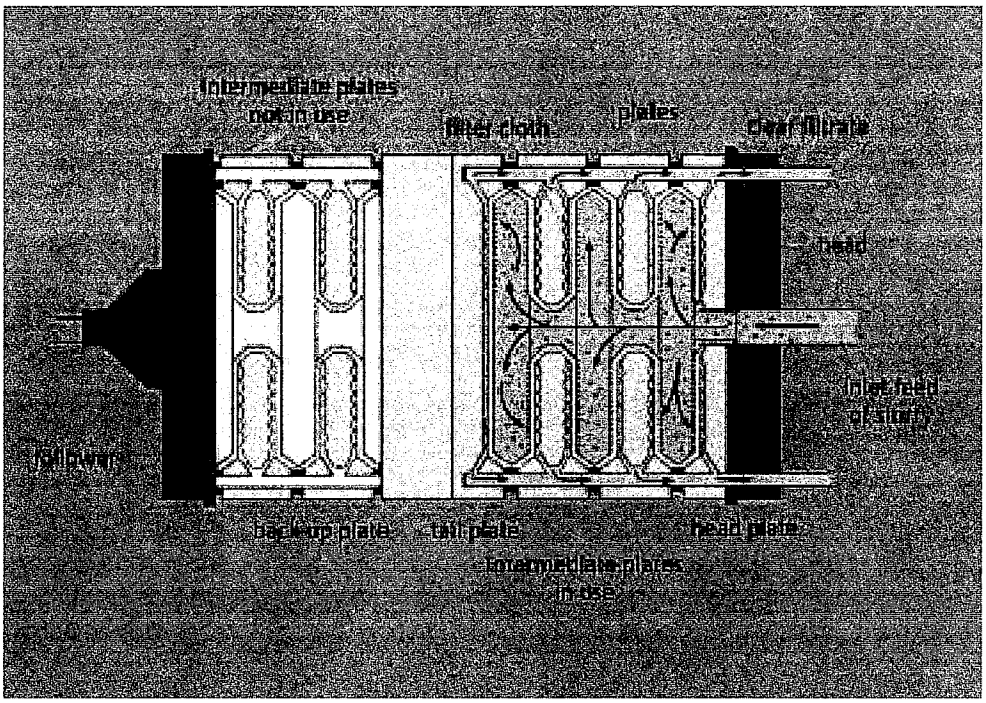
In the ensuing years, the J-Press® filter press evolved, offering options for fully automatic plate shifting, automatic cloth washing, PLC controls and a full complement of ancillary slurry processing and cake handling systems. Being the industry standard, the J-Press® line of filter presses is now the most versatile on the market today, from a manual 250mm pilot press that processes less than 2 lbs of dry solids per batch, to the monster 2.0m fully automatic press that can produce over 10,000 lbs of dry solids per cycle.



630mm semi-automatic

ISO 9001:2000 QMS

The quality management system governing the manufacture of the J-Press® sidebar filter press is ISO 9001:2000 certified.



Because the J-Press® filter press is a batch dewatering system, the press capacity can be easily adjusted by the changing the effective volume of the filter pack. A back-up plate, in conjunction with the tail plate, can be inserted to reduce the number of chambers used during dewatering.

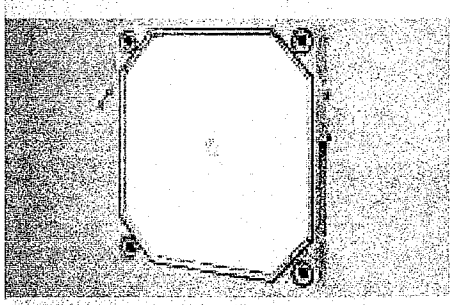
Uniform, Consistent Cake Solids

The J-Press® filter press is simple to operate. A single switch activates the pneumatic or electrically actuated hydraulic system. The plate stack forms a series of chambers, each covered with a filter cloth. With the plate stack clamped tightly in place, a solids-laden slurry is pumped, under pressure, into the plate chambers through a central feed connection.

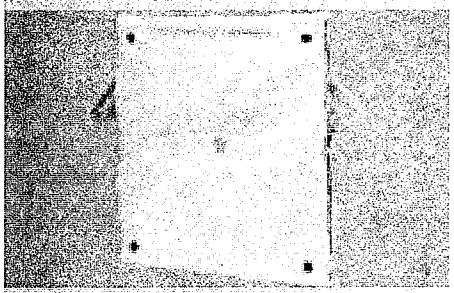
The plate chambers fill uniformly with solids while the pump pressure and flow keep the solids deposited on the vertical surfaces of the plate chambers. Liquid passes through the filter cloths as clean filtrate flows to the end of the press where it is collected at a common manifold.

The solids continue to fill the plate chambers and are compacted in the press by the feed pump until the chambers are completely full. The feed cycle is discontinued and an air blow down is initiated for 5-15 minutes to remove any freestanding water within the cake and the press. The hydraulic closure of the press is then retracted, the individual filter elements are separated and the solids are discharged as "dry" filter cake to an appropriate receptacle or conveyance system.

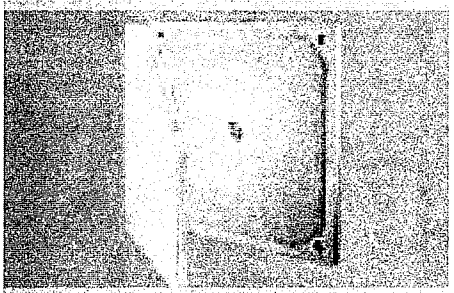
The J-Press® filter press may also be equipped with diaphragm (or membrane) squeeze plates that allow for a mechanical compression of the filter cake, yielding higher dry solids before the cake is discharged from the filter press.



Gasketed plates form a tight seal due to o-rings around the recessed chamber and filtrate discharge eyes, allowing for a virtually leak free operation.



Filter clothes are available for all gasketed and non-gasketed plates (above); material and weave pattern are selected for your specific performance requirements.



Diaphragm (or membrane) plates feature flexible drainage surfaces that expand to exert additional pressure on the filter cake, further reducing moisture.

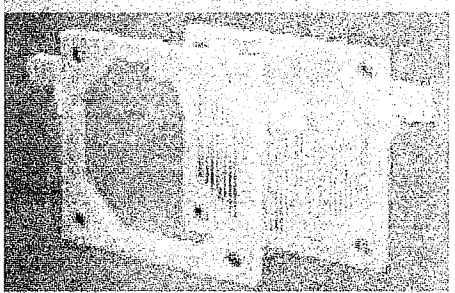
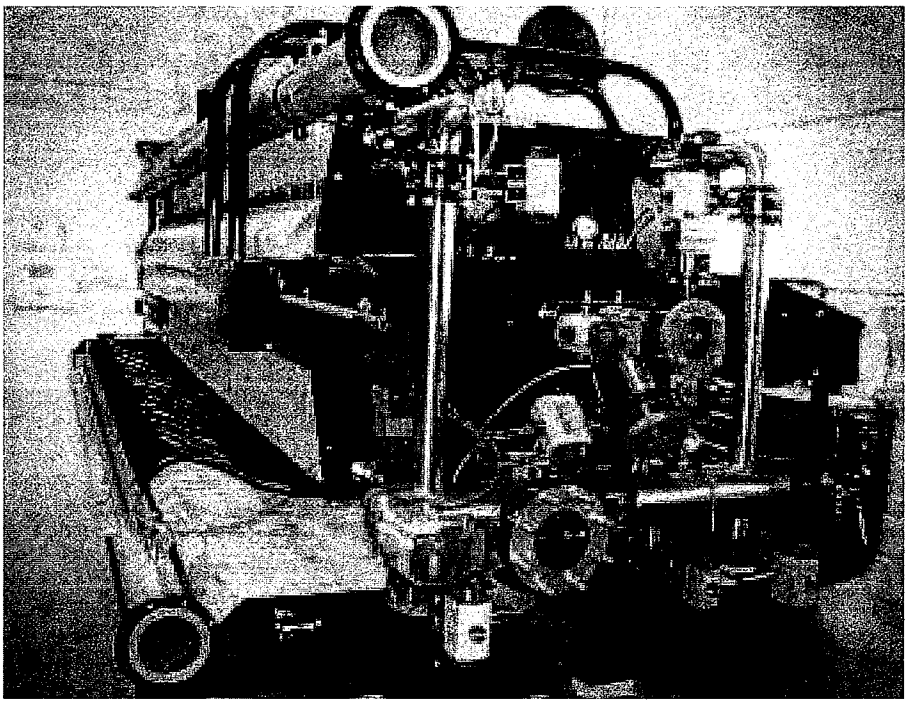
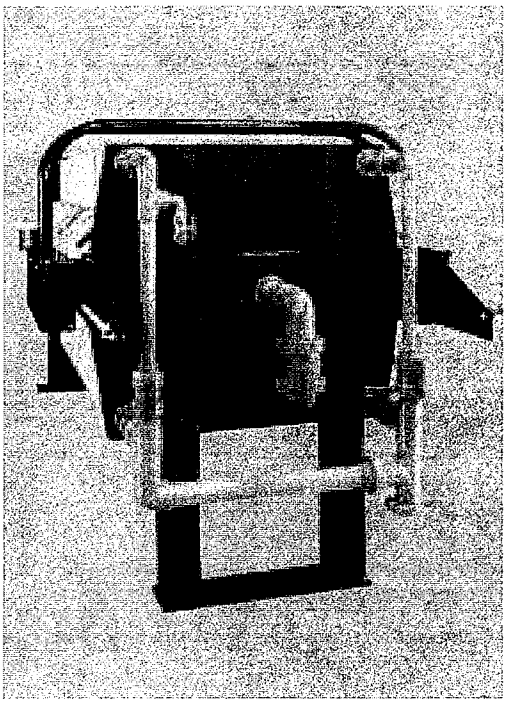


Plate and frame filter packs are available for polishing applications.





J-Press® feed and discharge manifolds are available in a variety of materials from PVC (above right) to stainless steel (above) to suit the application.

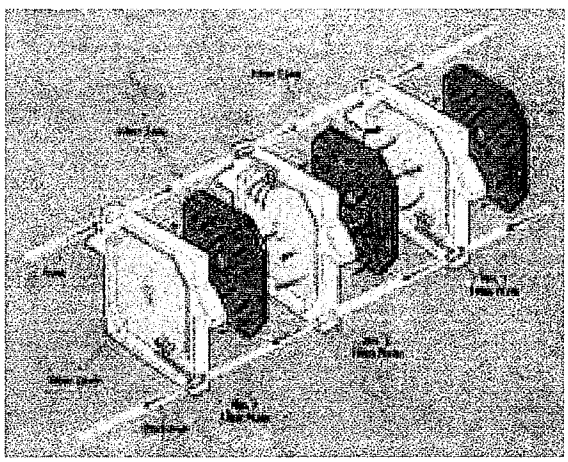
Superior Filter Plate Technology

Adding to the versatility of the J-Press® filter press is the large selection of filter plates available from Siemens. Based upon the process operating demands, filter plates are selected for each specific application. Filter plates are available in corrosion resistant polypropylene, PVDF and nylon. Plates can be configured as gasketed or non-gasketed, diaphragm (membrane) squeeze, or plate and frame designs.

Like the J-Press® filter press itself, the filter plates can be designed to withstand operating pressures up to 225 psi (16 bar).

Cake Wash or Air Blowdown

The inherent flexibility of the J-Press® filter press makes it ideal for recovering solids, liquids or both. In processes where the filter cake may need treatment prior to discharge, the J-Press® cake wash/air blowdown manifold can be used to force wash liquid through the cake. The manifold consists of piping and valves connecting the four corner filtrate ports into a common discharge pipe. By closing the appropriate valves, a wash liquid is pumped through the filter cake, and discharged out the diagonally opposed port. This can be followed by a compressed air blowdown, further removing moisture from the cake and filter plate drainage channels.



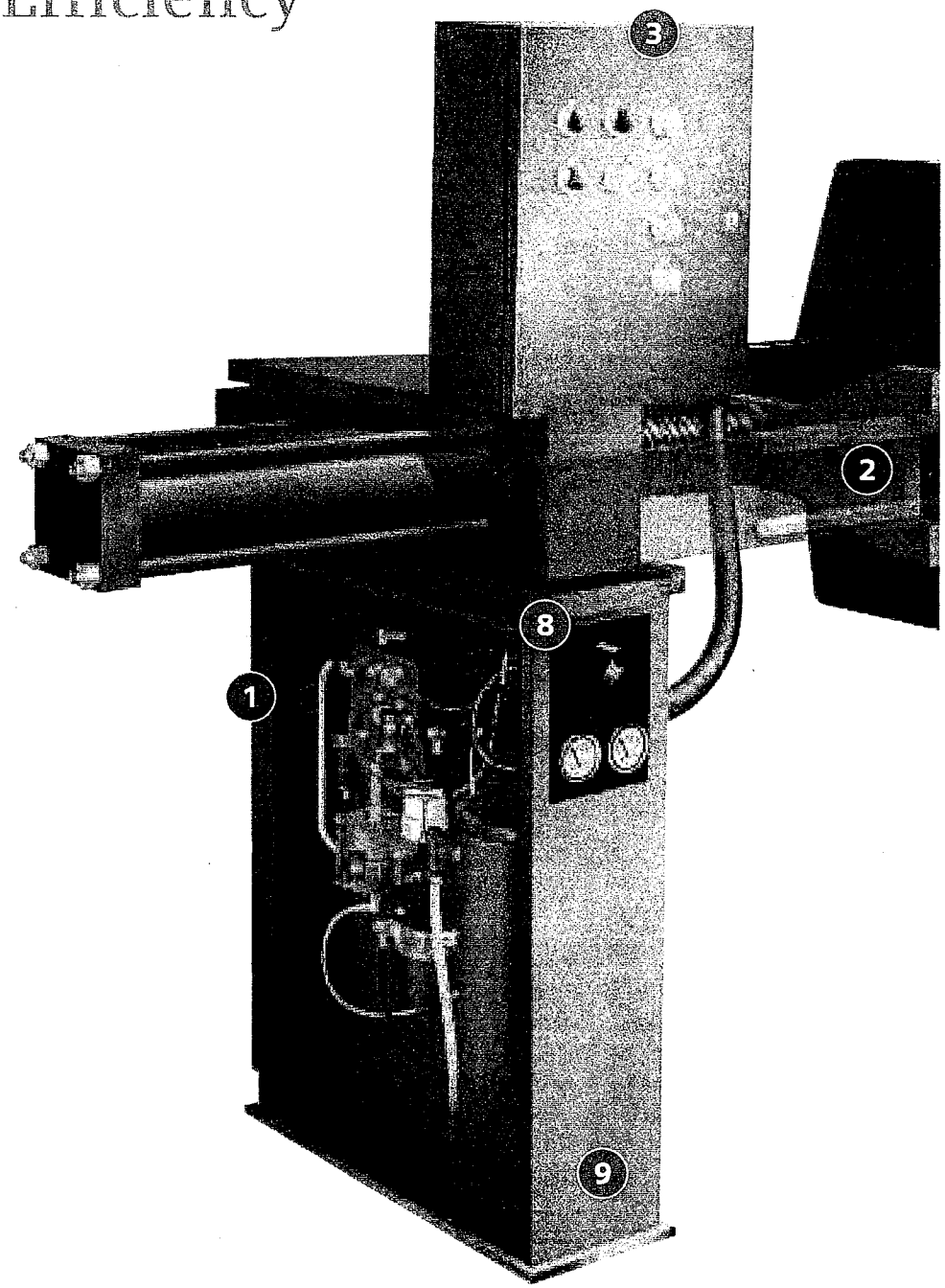
Engineered Performance and Operating Efficiency

1. Modularized Hydraulic Closure Systems — Available with either pneumatic or electric power, the modular power pack delivers up to 5,000 psi of hydraulic pressure to the hydraulic cylinder. The unit automatically compensates for thermal expansion and contraction of the filter pack due to changes in process temperature. Designed to minimize power consumption, the power pack features color coded connections for quick and easy removal and replacement during service and maintenance. The hydraulic pump and associated components are fully enclosed in a steel cabinet for protection from contamination and accidental damage, yet are easily accessible for maintenance through the full width cabinet door.

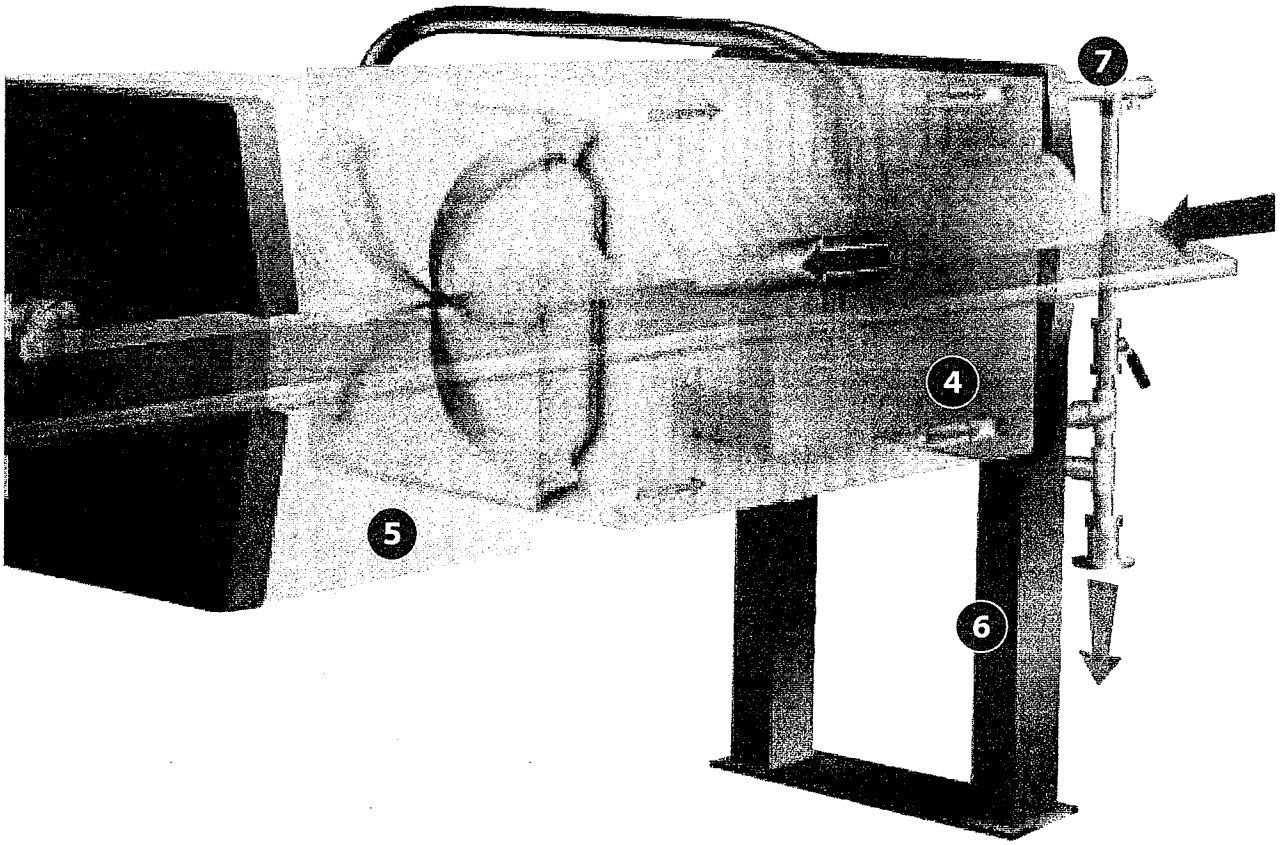
2. Future Expandability — The J-Press® filter press can be equipped with an optional expansion piece for future expansion of operating capacity with no need for costly sidebar replacements or frame exchanges. Expanding the capacity is as easy as adding additional filter plates.

3. Automatic Pump Control System (APCS) — For smaller presses, the APCS automatically controls the filling cycle, gradually increasing the feed pressure of the slurry feed pump to ensure a uniform formation of filter cake in the filter plate chambers. The uniform cake formation enhances the dewaterability of the incoming slurry. The APCS includes a hydraulic pressure safety device that shuts down the feeding cycle if a loss in hydraulic pressure occurs. For larger presses, filter press filling is controlled by a PLC.

4. Plate Shifter/Cloth Washing — The J-Press® filter press is available with either semi-automatic or fully automatic plate shifting systems (depending on size). The semi-automatic plate shifter is an operator driven plate shifting device that reduces manpower requirements during cake discharge. Further reductions in manpower are available with fully automatic shifting systems. The patented Siemens pry, bump and weigh system offers the additional advantage of positive cake discharge from each chamber further reducing the requirement for operator interface with the filter press during cake discharge.



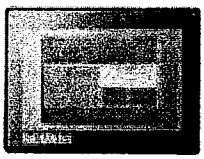
A cloth washing system can also be added to the automatic plate shifting system to provide a periodic high pressure cleaning cycle for the filter cloths. Operating in as little as 20 seconds per plate, the automatic high pressure cloth washing system can restore the porosity of the filter cloths to like new condition. Washing the cloths at regular intervals not only improves performance but prolongs the working life of the cloth as well.



5. Numerous Filter Pack Options — A wide selection of filter plate materials and styles makes the J-Press® filter press one of the most versatile dewatering devices on the market. With materials of construction ranging from polypropylene to PVDF and nylon, the J-Press® filter press can be designed to handle virtually any feed slurry no matter how corrosive or chemically aggressive. Filter plates are available in recessed gasketed, recessed non-gasketed and diaphragm (or membrane) squeeze designs that can dewater everything from the easiest metal hydroxide slurry to difficult organic solids. The J-Press® filter press can readily adapt to changes in product and process applications by simply changing the filter cloths or the filter plates, giving the system great operational flexibility.

6. Robust Frame Construction — The J-Press® filter press is a ruggedly built unit made of fabricated steel plate. Precision alignment and machining of the structural components provide for even distribution of all pressures and stresses generated during operation. Frame strength is based upon the filter press operating pressure of either 100 psi (7 bar) or 225 psi (16 bar).

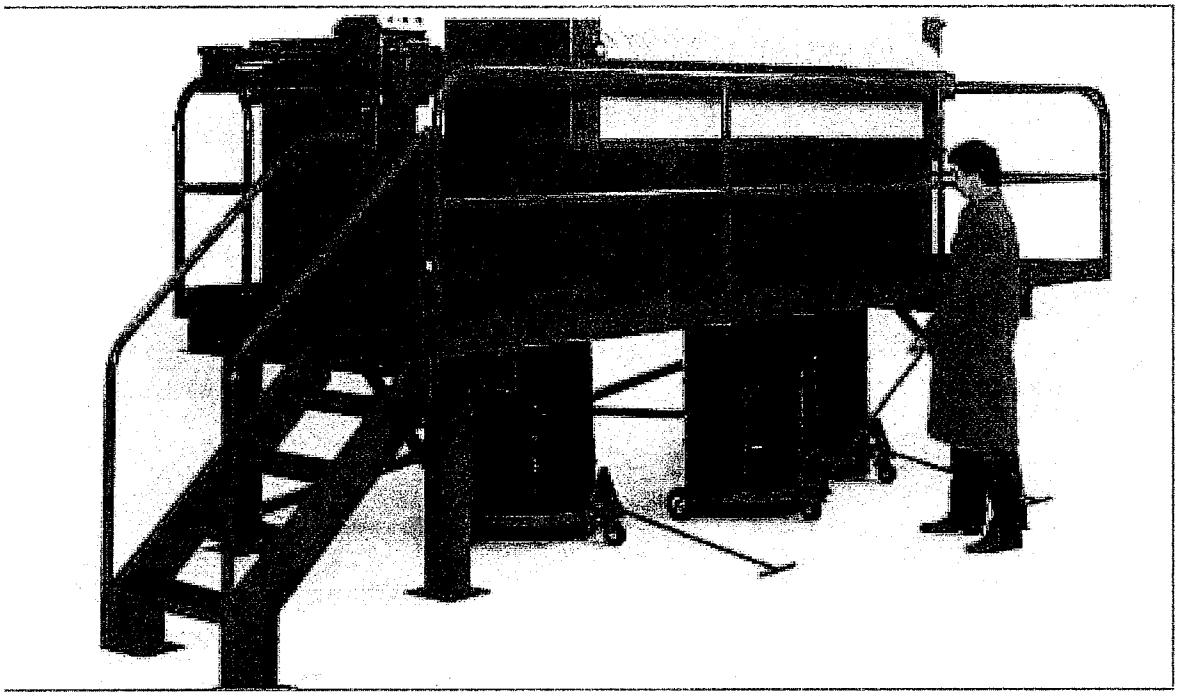
7. Manifold Piping — Like the filter plates, manifold piping is supplied in a variety of non-metallic and metallic materials suited to meet the rigors of the application. Manifolds can also be configured in a variety of inlet, discharge and valve options to maximize the versatility of the filter press. With the appropriate manifold, a filter press can be designed to perform both pre and post dewatering operations that enhance both the dewaterability of the material and the quality of the final cake.

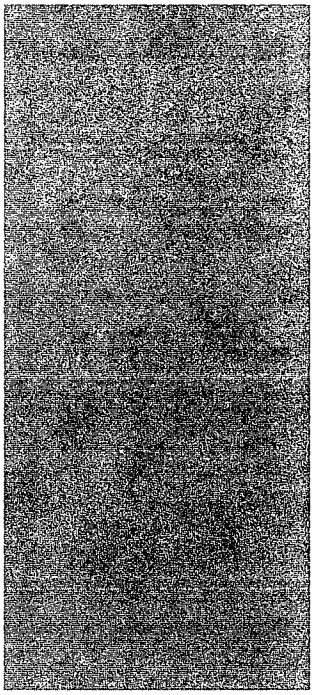


8. Control Systems — Filter press control can be as simple as a single switch for opening and closing to as complex as a fully integrated PLC with Ethernet or wireless capabilities for remote monitoring and operation. The PLC system provides the most advanced and complete press operation available, from automatic feed pressure adjustment, to cycle frequency, cake discharge, cloth wash and air blowdown.

9. Superior Paint System — Each J-Press® filter press is sandblasted to an SSPC-10 near white finish before being primed and finished with a high quality, single coat aliphatic polyurea, fast clad DTM urethane paint system that results in a durable, chemically resistant finish averaging 6-9 mils in thickness (other paint systems are available on request).

Material Handling Systems

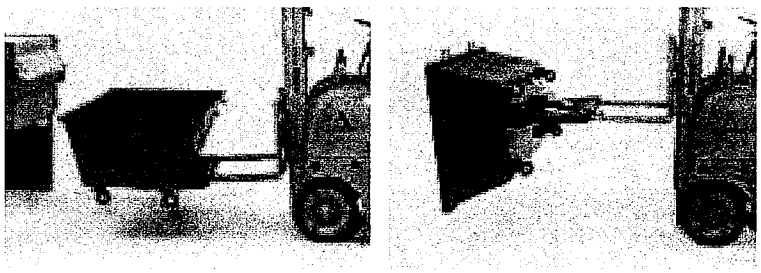




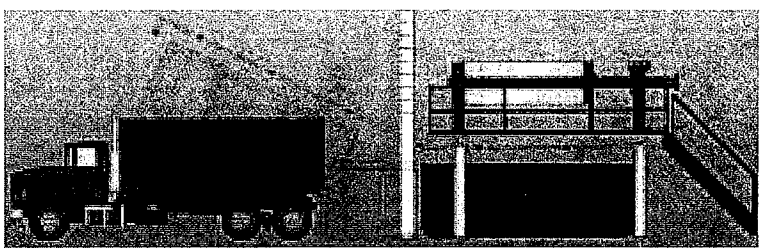
The J-Press® filter press is available with a wide range of material handling solutions for small or large volume cake discharge.

The J-Press® filter press installation can be configured to accommodate a wide range of material handling systems for discharged cake. Dumpsters, equipped with casters and self-dumping forklift mounts are the most common method for smaller presses. The drum disposal system, also for smaller presses, allows easy removal of discharged cake. This system includes a series of chutes that catch the filter cake as it falls from the press and directs it into 55-gallon (200L) drums. The J-Press® filter press is typically mounted on a platform, with catwalks, railings and stairs.

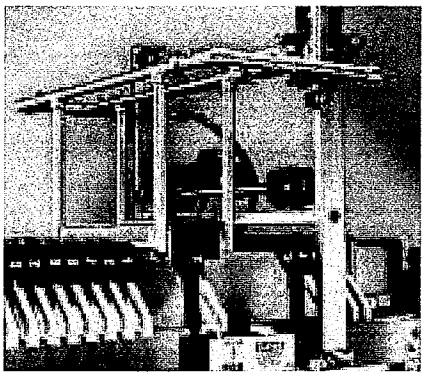
For larger presses, or presses that require transfer to downstream drying systems, Siemens can engineer a belt or screw conveyance as an integrated component of your process configuration. Roll-off container and truck-loading systems are also available. Your Siemens representative works closely with you to design, install and support the most efficient handling system for your specific needs.



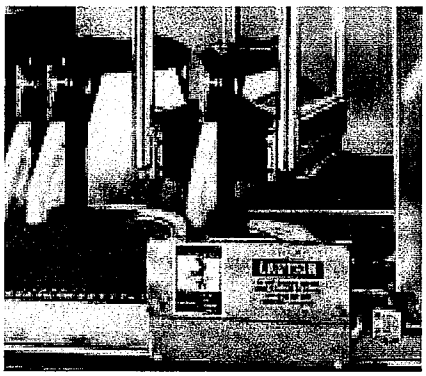
Self-dumping dumpsters



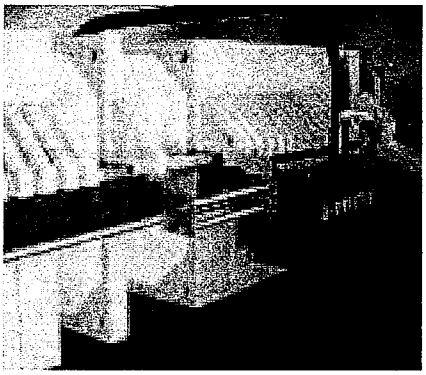
Full Range of Features and Options



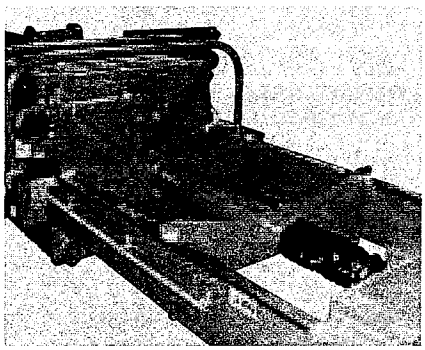
Fully automatic cloth washer



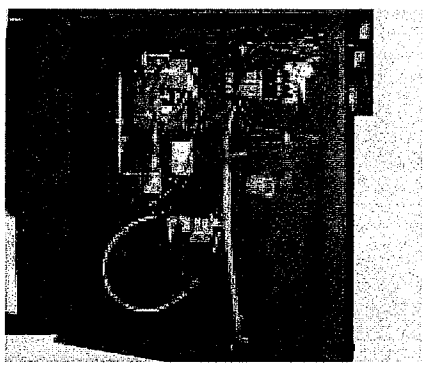
Fully automatic plate shifter



Semi-automatic plate shifter



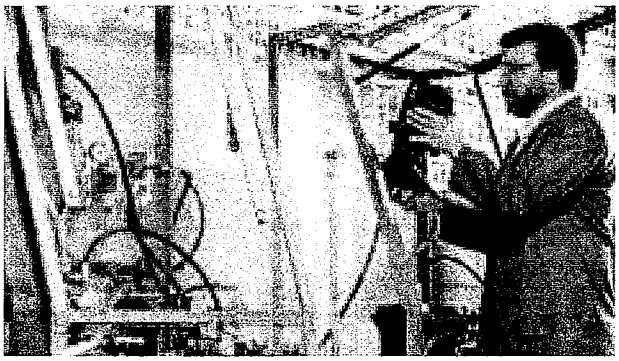
Optional expansion allows you to build your press to meet future needs, then increase capacity simply by adding additional filter plates.

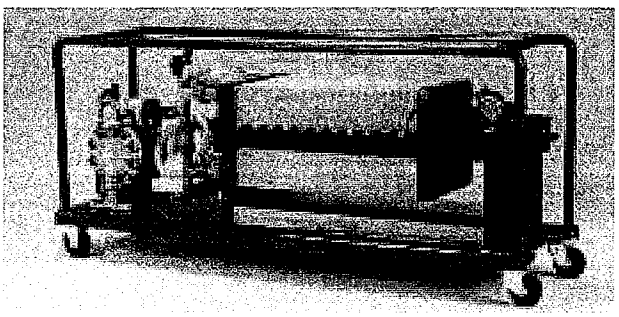


Exclusive integrated hydraulic circuit technology automatically compensates for varying pressures and temperatures. The enclosed steel cabinet and leak-free design minimize maintenance.

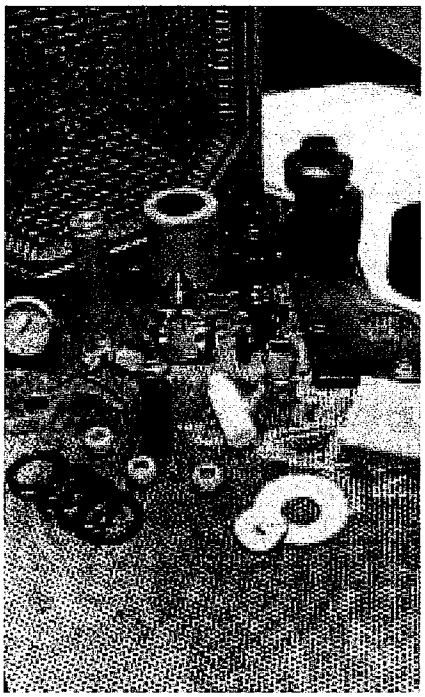
Siemens has the expertise and engineering capabilities to manufacture filter presses to meet the demands of your particular operation. Adaptability to applications, processes and capacities is the underlying value of J-Press® filter press. Features include:

- Full range of capacities: 250mm to 2.0m x 2.0m
- Low and high pressure: 100 psi (7 bar), 225 psi (16 bar), higher pressure available – consult factory
- Standard plate packs:
  Non-Gasketed Plates
  Gasketed Plates
  Diaphragm Squeeze Plates
  Plate and Frame
- Stainless Steel Sidebar Covers
- Closure Systems:
  Manual
  Automatic Closure (Air/Hydraulic)
  Automatic Closure (Electric/Hydraulic)
- Control Systems:
  Standard Control Panel
  Automatic Pump Control System
  PLC Control
- Standard Manifolds:
  Air Blow Down Manifold
  Double End Feed Manifold
  Core Blow Down Manifold
  Cake Wash Manifold
  Precoat Manifold (other configurations available — consult factory)
- Expansion options available for future capacity
- Plate Shifting:
  Air Operated Semi-Auto Plate Shifter
  Automatic Pry Shifter
  Automatic Pry Shifter and Bump
  Automatic Pry Shifter, Bump and Weigh (ACDDS)
  Multi-Plate Pull
- Automatic Cloth Washing
- Material handling:
  Filter Cake Dumpster
  Extended Legs and Chute
  Platform, Drum Disposal System
  Platform, Roll-off Container System
- Cake Conveyors
- Drip Trays:
  Manual
  Automatic
- Spread Leg Design:
- Safety:
  Splash Curtain
  Safety Guard
  Safety Light Curtains
  Deadman Control Button
  Safety Tripwire
  Hyd. Clamp Pressure/Feed Pump Interlock
  Hyd. Control System/Press Pressure Interlock
  Hyd. Clamp Pressure/Squeeze System Interlock
- Custom Paint Systems:
  Nicklad® Coating





Portable pilot filter press





Our large parts distribution center ensures that many parts are available for same day shipment.

Laboratory Services — an Informed Decision is the Best Decision

Siemens maintains a fully-staffed, state-of-the-art laboratory for determining the most effective liquid/solids separation techniques for your specific application. Capabilities range from feasibility testing of your materials to providing portable pilot units for on-site testing. This customer-focused resource produces tangible results. We can determine the most effective feed pressures, fill times, filter media and sludge conditioning.

In addition to ensuring a better informed equipment purchase, this valuable service is also available to help you maintain maximum performance of your J-Press® filter press.

An Ongoing Investment in Your Satisfaction

Preventative Maintenance Services We can customize a cost-effective program for your specific equipment, application, and environment that translates into lower maintenance cost and years of worry-free operation.

Parts Repair Service Our professional service staff can quickly and reliably answer your technical questions and troubleshoot your specific requirements, schedule parts shipments, and arrange for an on-site service call. Our factory-trained and qualified service engineers travel throughout the world to help ensure equipment runs efficiently. From basic maintenance to complex Program Logic Control (PLC) interfaces and beyond, we have the experience and capability.

Refurbishment Services We can provide a partial or complete rehabilitation of your equipment to a warranted like-new condition, at your site or ours.

For more information on our Aftermarket Services, call 800.245.3006.

Aftermarket Services

- Factory-based customer service support
- Expert technical consulting
- Same-day shipment on many service and spare parts
- Worldwide repair and preventative maintenance services
- Emergency support services
- Equipment retrofits, upgrades, and refurbishments
- Training
- Testing, evaluative and customized services



Specification/Selection Charts

The following formula may be used for establishing J-Press® filter press volume (ft^3) (L) for most dewatering applications:

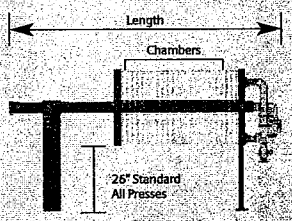
$$\text{Total Filter Press Volume } (ft^3)\ (L) = \frac{\text{Total volume of product feed (gallons) (liters)} \times \text{\% solids concentration of product feed*} \times \text{8.34 (lbs per gallon of water) (1kg/L) (density of water)} \times \text{specific gravity of feed slurry}}{\text{Density of wet filter cake** (lbs/ft}^3\text{)(kg/L)} \times \text{\% dry solids content of filter cake*}} \quad \text{or} \quad \frac{\text{lbs (kg) dry solids}}{\text{cake density (lbs/ft}^3\text{)(kg/L) x \% cake solids}}$$

* % concentration should be expressed in decimal form (e.g. 2% = .02).

**Density of wet filter cake = Specific gravity of wet filter cake x the density of water

For dewatering applications where feed solids are less than 1%, the dewatering area is the controlling parameter rather than volume. For such applications, contact Siemens for size recommendations. Also, for advice on sizing for any application, contact Siemens or our authorized representative.

PRESS	MEASUREMENT	MINIMUM	MAXIMUM
250mm	Volume (ft^3)	0.1	0.4
	Volume (L)	2.8	11.3
Height 15" (381mm)	Length (in)	24.0	38.0
Width 18.5" (470mm)	Length (mm)	607.0	975.0
470mm	Volume (ft^3)	0.5	4.0
	Volume (L)	14.2	113.0
Height 45.8" (1162mm)	Length (in)	41.0	93.0
Width 33.0" (838mm)	Length (mm)	1041.0	2362.0
630mm	Volume (ft^3)	2.0	8.0
	Volume (L)	57.0	227.0
Height 51.0" (1299mm)	Length (in)	85.0	129.0
Width 36.0" (916mm)	Length (mm)	2168.0	3277.0
800mm	Volume (ft^3)	8.0	25.0
	Volume (L)	227.0	708.0
Height 58.0" (1473mm)	Length (in)	122.0	196.0
Width 43.5" (1105mm)	Length (mm)	3099.0	4978.0
1000mm	Volume (ft^3)	25.0	55.0
	Volume (L)	708.0	1558.0
Height 66.5" (1689mm)	Length (in)	175.0	260.0
Width 51.5" (1308mm)	Length (mm)	4445.0	6604.0
1200mm	Volume (ft^3)	50.0	125.0
	Volume (L)	1416.0	3540.0
Height 74.5" (1892mm)	Length (in)	217.0	356.0
Width 60.0" (1524mm)	Length (mm)	5512.0	9042.0
1500mm	Volume (ft^3)	130.0	270.0
	Volume (L)	3682.0	7646.0
Height 95.7" (2432mm)	Length (in)	313.0	500.0
Width 74.9" (1903mm)	Length (mm)	7950.0	12,700.0
1.5 x 2.0M	Volume (ft^3)	275.0	350.0
	Volume (L)	7788.0	9912.0
Height 136.6" (3470mm)	Length (in)	430.0	507.0
Width 79.0" (2007mm)	Length (mm)	10,922.0	14,097.0
2.0 x 2.0M	Volume (ft^3)	300.0	600.0
	Volume (L)	8496.0	16,992.0
Height 106.0" (2692mm)	Length (in)	405.0	562.0
Width 137.0" (3480mm)	Length (mm)	10,287.0	14,275.0



Notes:

- *Based on 32mm cake thickness, 100psi (7bar).*
- *Additional sizes and capacities available — consult factory.*
- *All dimensions are approximate and should only be used for reference.*
- *Dimensions do not include optional equipment such as plate shifters, cloth washers or piping manifolds.*



www.siemens.com/water

Tetra Tech

Foster Plaza 7
Pittsburgh, PA 15220
(412) 921-7231
(412) 921-4040 Fax

Ion Exchange Treatment of
Groundwater

Proposal # 283231

Prepared By:

SIEMENS

Monday, February 1, 2010

SIEMENS

Siemens Water Technologies Corp.
Monday, February 1, 2010
Proposal # 283231

Joe Logan
Foster Plaza 7
661 Andersen Drive
Pittsburgh, PA 15220

Proposal # 283231

Dear Joe:

Siemens is pleased to provide Tetra Tech with this proposal for portable Wastewater Ion Exchange Service.

Based on information you have provided, we have proposed a system that will meet your technical requirements simply and economically.

1.0 Siemens - A Leader in Environmental Service

Siemens through its Environmental Services facility is the only company in the United States that has the technology, and more importantly, all of the necessary permits to regenerate resins from any industrial rinse water process, including those that are determined to be a hazardous waste. These two factors - technology and permitting - enable Siemens to provide Tetra Tech Nus with the peace of mind, knowing that you are in full compliance with federal, state and local regulations.

Here are some very important points to consider before choosing Siemens:

- Pursuant to MN Rule 7045.0452, Subpart 3c, Siemens has all the appropriate permits to accept and process your wastes.
- All Siemens Ion Exchange tanks are approved as transportable hazardous waste containers by the US Department of Transportation.
- Siemens is an approved carrier for transportation of Hazardous Waste.
- Siemens can provide manifesting of all waste transported by Siemens.
- Siemens can provide the proper labels for marking hazardous ion exchange resin containers.

We are certain that you will agree that our unique service will provide your business with many operating advantages compared to other methods of handling your wastewater.

We look forward to providing our quality products and services to Tetra Tech. If you have any questions, please contact me at 813-620-0900.

Sincerely,

Jay Dwyer
Technical Sales Representative
Siemens

2.0 Basis of Design

No sample was provided; therefore, all recommendations are estimates based on the following information. A feed water sample to the ion exchange tanks is required to properly size and specify the type of media tanks required for your application. From this sample Siemens will do engineering and prepare a proposal, which will include an annual budget (Exhibit C to the Service Contract). If a water sample has not been analyzed by Siemens at the time of this proposal because wastewater was not available or there was not access to the wastewater, any estimates in this proposal are budgetary and the design should be considered preliminary.

2.1 Treatment Goal:

Ion exchange treatment post-WWT and carbon to discharge standards for cadmium

2.2 Influent Parameters:

Peak Flowrate = 80gpm

2.3 Effluent Quality Requirements

Cadmium = <5ppb

If any of this information is inaccurate, please contact me immediately.

3.0 Proposed System and Operating Parameters

3.1 Siemens will provide the following system components:

Ion Exchange Tanks - Rental Tanks:
Two (2) 60 cu ft special cation tanks, one online and one standby

Ion exchange tanks will be used to remove dissolved cadmium. Siemens does not sell the exchange tanks.

Hoses:
One (1) set inlet/outlet hoses, 3" EPDM 150psi-rated, and 3" stainless steel fittings

3.2 This treatment system is designed to run within the following parameters:

TANKS MUST BE PLACED POST-CARBON to protect resin from oxidizers or oils/grease
Maximum operating temperature of 120°F
Minimum flow rate of 50gpm, Maximum flow rate of 150gpm
Maximum pressure of 100psig (Maximum pressure of 50psig @> 110°F)
Influent pH range of 3 to 8 S.U.

4.0 Scope of Work

4.1 Siemens Responsibilities

- Under normal operating conditions, Siemens will have available fresh replacement ion exchange and carbon tanks ready for delivery to Tetra Tech. All fresh tanks delivered are non-hazardous.
- Siemens will pick up all spent tanks from Tetra Tech's facility and transport the spent tanks to Siemens's, Roseville, Minnesota facility for processing.
- All tanks will be processed at Siemens's fully permitted RCRA Part B facilities.
- All tanks will be verified for proper flow and pressure tested for leaks and returned to the fresh tank float.
- Siemens maintains consistent resin quality through rigorous quality assurance testing and resin replacement as required.

4.2 Customer Responsibilities

- Any pre or post ion exchange pH adjust (if required)
- Any pre or post filtration as required, a maximum of 20 micron cartridge pre-filtration is required with all ion exchange systems.
- All plumbing to and from the process and discharge point within 5 feet of the ion exchange tanks.
- All permits, permit fees, and inspections as required.
- If applicable, work schedules indicating times during which interruption in normal service are permissible. All labor rates quoted in this proposal are for straight time, non-union labor.
- Suitable drains.
- Suitable lighting for all equipment.
- All electrical power as required to within 5 feet of the equipment, including overload protection.
- Any double containment required for the system.
- Free and clear access to treatment site.
- Dock access and material handling equipment capable of safely handling specified ion exchange tanks.
- Regulated plant air supply (if required).
- City or DI water supply (if required).
- System operation, including maintenance and water quality monitoring.

5.0 Compensation to Processor (refer to Exhibit C)

6.0 Getting Started

It is required that the following documents be accurately completed and signed, where applicable, and returned to Siemens prior to delivery of equipment.

6.1 - **Signed** Siemens Waste Treatment Service Agreement (See Section 8)
6.2 - **Signed** Waste Profile Sheet (Exhibit A)
6.3 - Siemens Lab Analysis (Exhibit B) - **Sample required before tanks can be returned to Siemens**
6.4 - PO for System Installation or Parts **(Please Reference EXHIBIT C)**
6.5 - Blanket PO for Rent, Regeneration and Transportation **(Please Reference EXHIBIT C)**

7.0 Delivery

Shipment will occur within 10 working days after receipt of the completed documents in Section 6.0.

For all direct shipments by third-party transporters, freight will be billed at actual cost plus $85.

8.0 WASTE TREATMENT, METAL RECOVERY, WATER RE-USE PROCESSING, TRANSPORTATION AND DISPOSAL SERVICES AGREEMENT

This agreement is entered into this _____day of _____by and between Siemens Water Technologies Corp.. ("Processor") and Tetra Tech ("Generator").

WHERAS, Processor has a facility located at 2430 Rose Place, Roseville, MN. ("Processor's Facility") and the necessary licenses and permits to recover, treat, transfer, transport, and temporarily store (collectively "Handle") certain regulated and unregulated hazardous/industrial waste; and

WHEREAS, Generator desires Processor to Handle certain waste material generated by Generator at its facility at Foster Plaza 7, 661 Andersen Drive, Pittsburgh, P ("Generator's address") which waste material is described in the Waste Profile Sheet included in Exhibit A, attached hereto and made a part hereof.

NOW, THEREFORE, the parties agree as follows:

I. Processor Services

1.1 Processor shall handle the Waste Material in a careful, workmanlike, and lawful manner, and in accordance with all applicable state and federal regulations.

II. Compensation for Services

2.1 Compensation to Processor shall be as specified in Exhibit C attached hereto and made a part hereof.
2.2 Generator shall pay Processor within ten (10) days after the date of each invoice. Generator shall pay interest on any unpaid balance at the rate of one and one-half percent (1-1/2%) per month, commencing upon the expiration of such thirty (30) day period.
2.3 Processor may adjust prices specified in Exhibit C on the Agreement's anniversary date or with thirty (30) days notice.

III. Waste Analysis

3.1 For all Waste Material to be Handled by Processor, Generator shall: (1) provide a detailed written physical and chemical description or analysis of the waste material (the waste profile sheet included in Exhibit A), (2) package, mark, label and placard each shipment and provide to Processor appropriate shipping documents, manifests, or other such documentation as prescribed by Processor, or required by law , and (3) maintain all records with respect to the Waste Material as required by law.
3.2 Generator shall immediately communicate to Processor any changes in the composition of the Waste Material and any additional information obtained by Generator at any time during the term of this Agreement indicating that the Waste Material may present a hazard or risk to persons or the environment which is not set forth in Exhibits A or B (if included with this agreement) or was not generally known as of the date of this Agreement.
3.3 At any time and at its own expense, Processor shall have the right to perform analysis of Waste Material delivered by Generator hereunder. IV.

Nonconforming Waste Material

4.1 Waste Material shall be considered nonconforming if: (1) it has constituents, characteristics, components or properties not specified in Exhibits A or B (if included with this agreement), (2) it has constituents, characteristics, components or properties designated as unacceptable to the Processor in Exhibit D, or (3) if constituents therein exceed designated concentration levels specified in Exhibits A or B.
4.2 If Processor determines within thirty (30) days after delivery of Waste Material from Generator's Facility that the Waste Material is nonconforming pursuant to 4.1 above, Processor shall immediately notify Generator, and shall, at Processor's election, either arrange with Generator for the satisfactory disposition of such Waste Material upon mutually agreeable terms and conditions, or reject and return such nonconforming Waste Material to Generator without further obligation. If Processor elects to reject and return the Waste Material, Generator shall promptly arrange for its return and shall pay reasonable charges for Processor's Handling and time involved up to the time of the return.
4.3 At any time, Processor may, upon reasonable grounds to believe that Waste Material furnished by Generator is nonconforming, so notify Generator and require that Generator have a sample or samples thereof chemically analyzed by a qualified, reputable, independent laboratory acceptable to Processor. The results of such chemical analysis shall be furnished to Processor. If the chemical analysis demonstrates that the Waste Material is not nonconforming, Processor shall pay the costs of the analysis. If the chemical analysis demonstrate that the waste material is nonconforming, Generator shall pay the cost of the analysis.
4.4 Any waste containing any of the Prohibited Wastes as specified in the Processor's RCRA Part B Operating Permit, and in Exhibit D to this agreement shall be considered non-conforming.

V. Ion Exchange Resin

5.1 Processor shall supply to Generator such ion exchange resin canisters as the parties determine are appropriate after inspection and analysis by Processor of Generator's process and waste. Generator shall be responsible for utilizing each canister only on the process for which it is intended. Generator acknowledges the necessity of segregating rinse tank wastes as agreed with Processor. Generator agrees to monitor its use of the canisters and employ a fresh canister promptly as each canister's resin is exhausted. Any and all costs (including increased processing costs or replacement costs) incurred by Processor's Facility as a result of Generator's intentionally wrought or negligent use of any ion exchange resin canister shall be solely the responsibility of Generator; provided such costs shall not exceed the replacement cost of such ion exchange resin and/or canister.
5.2 Processor will conduct periodic ion exchange capacity tests on resin processed at Processor's Facility, and all canisters supplied to Generator, at the time of delivery, shall contain resin having an acceptable ion exchange capacity.
5.3 Resin canisters supplied hereunder shall be free from defects in material and workmanship. Processor shall not be liable for any incidental or consequential damages for any breach of warranty. PROCESSOR MAKES NO WARRANTY, EXPRESS OR IMPLIED, EXCEPT AS IS EXPRESSLY SET FORTH HEREIN. Processor's liability and Generator's exclusive remedy are expressly limited to removal from Generator's Facility and disposal of any defective canister and replacement thereof with another resin canister within a reasonable time period.

VI. Title

6.1 Title to and liability for conforming Waste Material shall pass from Generator to Processor when the loading operation of the Waste Material onto vehicles provided by the Processor has been completed and said vehicles are ready to leave the facility of the Generator. If transportation is provided by the Generator, then title passes from Generator to Processor when unloaded at Processor's site.

6.2 Title and liability for non-conforming Waste Material shall at all times remain with the Generator, unless, upon the discovery that the Waste Material is non-conforming, Processor agrees in writing to perform services under this Agreement.

6.3 Should Processor revoke acceptance of any nonconforming Waste Material as provided in IV above, title to and liability for such Waste Material shall revest in Generator at the time such revocation is communicated to Generator, regardless of who has physical possession of such Waste Material. Processor shall take all reasonable steps appropriate to protect the Waste Material until Generator can properly retake possession thereof.

6.4 Processor shall have title to all materials recovered from Generator's waste material.

VII. Collection and Transportation

7.1 The party providing transportation for the Waste Material from Generator's Facility to Processor's Facility shall comply with all federal, state, and local statutes, rules, regulations and ordinances applicable to the moving, handling, securing and transporting of such Waste Material. Generator is legally responsible to provide the proper Department of Transportation and Resource Conservation and Recovery Act shipping papers and labels, and/or any other such papers and labels required by applicable law, which shall accompany the Waste Material. Processor will assist Generator in determining proper labeling and shipping documentation.

7.2 Generator shall provide safe, satisfactory roadways and approaches to the point of loading at Generator's Facility. To the extent that Waste Material to be shipped from Generator's Facility is contained in canisters, totes or drums, Generator shall be solely responsible for loading the Waste Material onto vehicles provided by Processor, and Generator assumes full risk of loss to all equipment and premises of both parties, to the extent that such loss results from the negligence of its employees, officers, agents or subcontractors ("Generator Personnel"). To the extent that Processor's employees, officers, agents or subcontractors ("Processor's Personnel") engage in loading of canisters of Waste Material or in connecting of piping from Generator's process equipment to vehicles supplied by Processor, Processor assumes full risk of loss to all equipment and premises of both parties, to the extent that such loss results from the negligence of Processor's Personnel. Each of Generator and Processor shall indemnify, defend and hold harmless the other (and in the case of Processor, its partners and affiliates) from any and all costs and expenses (including attorney's fees) relating to: (1) liability, claims and demands arising from personal injury or death of personnel of any persons, including the other party's employees, officers, agents, or subcontractors, arising out of the negligence of Generator's Personnel or Processor's Personnel respectively while engaged in such loading activities, and (2) loss or damage to any property arising out of or in any manner connected with such loading activities.

7.3 To the extent that Processor Personnel enter Generator's Facility in performance of services hereunder, Generator shall ensure such Processor Personnel a safe working environment.

7.4 If an emergency should occur at Generator's Facility while Processor Personnel are on the premises, Generator shall make available to such Processor Personnel its emergency services, including first aid, to the same extent that emergency services would be available to an employee, agent or subcontractor of Generator at the same facility.

VIII. Insurance, Liability, Indemnification

8.1 Processor shall maintain adequate general liability insurance; Worker's Compensation Insurance in accordance with the laws of the State of Minnesota; adequate automobile personal injury and property damage insurance; and environmental insurance covering bodily injury and property damage caused to third parties by a sudden accidental occurrence in such amounts as may be legally required.

8.2 Processor shall indemnify, save harmless and defend Generator against any and all claims, liabilities, penalties, forfeitures, suits and costs and expenses incident thereto (including costs of investigation, defense, settlement and reasonable attorney's fees), resulting from death or bodily injuries to any person, destruction or damage to any property, contamination of or adverse effects on the environment, or any violation of governmental regulations or orders to the extent such results from the imposition of strict liability with respect to Waste Material delivered to Processor by Generator.

8.3 Generator shall indemnify, save harmless and defend Processor against any and all claims, liabilities, penalties, forfeitures, suits and the costs and expenses incident thereto (including costs of investigation, defense, settlement and reasonable attorney's fees), resulting from death or bodily injuries to any person, destruction or damage to any property, contamination of or adverse effects on the environment, or any violation of governmental regulations or orders to the extent (1) such is caused by the negligence or intentional wrongdoing of Generator or any of its agents or employees, (2) such is caused by Generator's delivery to Processor of nonconforming Waste Material.

IX. LIMITATION OF LIABILITY

9.1Notwithstanding anything else to the contrary, Processor shall not be liable for any consequential, incidental, special, punitive or other indirect damages, and Seller's total liability arising at any time from the sale or use of the Processor's services shall not exceed the purchase price paid for processors services. These limitations apply whether the liability is based on the contract, tort, strict liability or any other theory.

X. Representations and Warranties

10.1 Processor warrants and represents to Generator that: (1) it will during the term hereof possess the equipment, plant and employee resources required to perform this Agreement; and (2) it will be at all times while the services hereunder are being performed by it, duly licensed and authorized to Handle the Waste Material; and (3) it will comply with all applicable federal, state and local laws, regulation, rules, orders, decisions and ordinances pertaining to its Handling of the Waste Material.

10.2 Generator warrants and represents to Processor that: (1) the composition of all Waste Material to be delivered to Processor conforms to Exhibits A and B; (2) Generator will during the term of this Agreement communicate to Processor any and all changes in the composition of its Waste Material and any additional potential hazards and risks associated with the Waste Material learned of by Generator; and (3) Generator will hold clear title to all Waste Material to be transferred hereunder; and (4) the Waste Material will conform to the shipping papers and labels which accompany it; and (5) Generator is under no legal restraint or order and shall be under no legal restraint or order which would prohibit transfer by it of possession or title of the Waste Material to Processor for Handling; and (6) Generator will comply with all applicable federal, state and local laws, regulations, rules, orders, decisions and ordinances pertaining to its activities pursuant to this Agreement. XI. Excuse of Performance

11.1 The parties agree that any delay or failure of either party to perform its obligations hereunder, except for the payment of money for services already rendered, shall be excused if and to the extent caused by acts of God, strikes, action of regulatory agencies (including loss by Processor of any license, permit or other authorization

necessary for fulfilling its obligations hereunder), fire, flood, windstorm, explosion, riot, war, sabotage or other cause or causes beyond reasonable control of the party affected ("Force Majeure"), provided that prompt notice of such delay is given by such party to the other and each of the parties hereto shall be diligent in attempting to remove such cause or causes. In the event that the Force Majeure is not rectified within thirty (30) days of the date of such notice, each of the parties shall have the right to terminate this Agreement effective immediately upon written notice to the other party.

XII. Term of Agreement

12.1 The term of this agreement shall be from the date hereof and automatically renewed on the anniversary date thereof for a like period until such time as either party terminates the agreement in accordance with the provisions contained herein.

XIII. Termination of Agreement

13.1 Either party may terminate this Agreement if the other party (1) has been adjudicated a bankrupt, or (2) has filed a voluntary petition in bankruptcy, or (3) has made an assignment for the benefit of creditors, or (4) a receiver has been appointed for such party.
13.2 Furthermore, either party may terminate this Agreement without cause by giving the other party thirty (30) days written notice of termination.

IN WITNESS WHEREOF, the parties have caused this Agreement to be executed by the duly authorized representatives.

Siemens Water Technologies Corp.

NAME: _____

SIGNATURE: _____

TITLE: _____

DATE: _____

GENERATOR

NAME: _____

SIGNATURE: _____

TITLE: _____

DATE: _____

Generator acknowledges that Processor is required to comply with applicable export laws and regulations relating to the sale, exportation, transfer, assignment, disposal and usage of the services provided under the Contract, including any export license requirements. Purchaser agrees that such services shall not at any time directly or indirectly be used, exported, sold, transferred, assigned or otherwise disposed of in a manner which will result in non-compliance with such applicable export laws and regulations. It shall be a condition of the continuing performance by Processor of its obligations hereunder that compliance with such export laws and regulations be maintained at all times. GENERATOR AGREES TO INDEMNIFY AND HOLD PROCESSOR HARMLESS FROM ANY AND ALL COSTS, LIABILITIES, PENALTIES, SANCTIONS AND FINES RELATED TO NON-COMPLIANCE WITH APPLICABLE EXPORT LAWS AND REGULATIONS.

EXHIBITS:

Exhibit A: Waste Profile Sheet
Waste profile sheets to be provided after receipt and analysis of a feed water sample.

Exhibit B: Siemens Lab Report
A feed water sample to the ion exchange tanks is required to properly size and specify the type of media tanks required for your application. From this sample Siemens will do engineering and prepare a proposal, which will include an annual budget (Exhibit C to the Service Contract). If a water sample has not been analyzed by Siemens at the time of this proposal because wastewater was not available or there was not access to the wastewater, any estimates in this proposal are budgetary and the design should be considered preliminary.

Exhibit C: Quotation for Compensation to Processor

Exhibit D: Prohibited Wastes

EXHIBIT C

QUOTATION FOR COMPENSATION TO PROCESSOR

Proposal # 283231
Monday, February 1, 2010

INITIAL INSTALLATION AND ACCESSORIES

Part Number	Description	Quantity	Unit	Rate	Amount
RSLABSDI	RECOVERY SERV SDI LAB ANALYSIS FEE	1	EA	$ 625.00	$ 625.00
WXSCC6000CNWFR	WX TANK 60 CUBIC FOOT SELECTIVE MEDIA STEEL	2	EA	$ 17,311.00	$ 34,622.00
HOSES	INLET AND OUTLET HOSE	1	SET	$ 2,000.00	$ 2,000.00
				TOTAL START UP COSTS	**$ 37,247.00**

TANK RENTAL

Part Number	Description	Quantity	Unit	Rate	Amount
WXRENTAL	RENTAL OF WWIX 60CF SCC TANK	2	EA	$ 1,000.00	$ 2,000.00
				MONTHLY RENTAL TOTAL	**$ 2,000.00**
				ANNUAL RENTAL TOTAL	**$ 24,000.00**

RESIN REGENERATION & MEDIA PROCESSING

All tanks will be changed out based on quality or a minimum of every six (6) months

Part Number	Description	Qty/Yr	Unit	Rate	Amount
WXSCC6000CNWFR	WX TANK 60 CUBIC FOOT SELECTIVE MEDIA STEEL	2	EA	$ 17,311.00	$ 34,622.00
				ESTIMATED RESIN TOTAL	**$ 34,622.00**
				ESTIMATED 1st YEAR TOTAL:	**$ 95,869.00**

Usage estimates above are based on lab analysis and/or industry knowledge. It is important to remember that ion exchange loading rates can vary significantly based on any process changes made or fluctuations in influent contaminant concentrations.

TRANSPORTATION

Customer shall pay to Siemens shipping and transportation charges as determined at the time of each shipment.

Notes:

1. Siemens requires a hard copy Purchase Order in the amount listed as 'ESTIMATE' - 1st Year Total.
2. Media Processing and Transportation charges will be incurred as tanks are delivered.
3. All annual quantities of units in Media Processing and Transportation sections are estimates.
4. All charges are plus any applicable taxes. This quote is good for 90 days.

EXHIBIT D
PROHIBITED WASTES

1. Waste Oil

Waste Oil of any kind including but not limited to waste hydraulic oil, waste emulsified oil, waste cutting oil, oil laden metal shavings, oil laden "floor dry" compounds, grinding swarf, waste cooling or cutting oils, transformer oil, waste lubricants, used oil coating baths, water soluble oils and paint strippers, unless previously approved by Processor.

2. Organic Solvents

Organic solvents of any kind including but not limited to: trichloroethane, trichloroethylene, dichloromethane (methylene chloride), naptha, kerosene, gasoline, alcohols, methylethyl ketone (MEK), acetone, benzene, toluene, tetrachloroethane and carbon tetrachloride, unless previously approved by Processor.

3. Toxic Organics

Toxic organic compounds of any kind, which contain toxic organics higher than nominal concentration. Toxic organics shall be defined as those compounds listed in 40 CFR 433.11, as it may be amended. The CRTF will not accept contamination in wastes by TTO in concentration equal to or greater than 2.13 mg/L. Concentrated toxic organics will not be accepted for treatment at the CTRF. Specific examples of unacceptable toxic organics include but are not limited to: vapor degreasing compounds (chlorinated hydrocarbons), cresylic acid emulsion cleaners, and vapor degreaser sludge.

4. Radioactive Materials

Any material exhibiting radioactivity above background levels, including artificial radioisotopes and naturally occurring radioisotopes; any material which is exposed to radioisotopes or radiation which becomes radioactive from such exposure; radiation sources used for thickness gauging; and equipment used to contain radiation sources.

5. Reactive Compounds

Any compounds which cause or could possibly cause undesirable reactions when mixed with other wastes in either Generator's holding tanks or the Processor's holding tanks and chemicals that are unstable alone or that can react with common contaminants listed for each Waste Category to cause a highly exothermic reaction or release explosive gases. Prohibited compounds include but are not limited to reducing agents in chrome or sulfate copper etch wastes, oxidizing agents in chelated wastes; and powerful reducing or oxidizing agents of any type other than those specifically listed as acceptable in Exhibit A. Examples of unacceptable reactive compounds are: hydrazine, sodium hydrosulfite, sodium borohydride,chlorate compounds and perchlorate compounds (other than ion exchange resin used to remove perchlorates from wastewater).

6. Mercury

Elemental mercury and all compounds of mercury.

7. Scrap Metals

All solid scrap including but not limited to: circuit board scrap, scrap or ruined plating work, drums, equipment or components (tanks, liners, etc.), anodes, anode baskets and chemical containers, unless previously approved by Processor.

8. Particulate Material

Particulate material larger than 1/4 inch in diameter in any liquid waste is unacceptable to the Processor. Such material includes but is not limited to: lost parts in process bath dumps (screws, nuts, etc.); cigarette butts, mop strings and rags in floor wash water; and sludge or crystal particles that may not be broken up by the agitation caused by pumping.

HiPOx Preliminary and Budgetary Estimate
P2461 Tetra Tech Baltimore No.2

Description	P2461 Tetra Tech Baltimore #2			
Condition	Case 1: 50 gpm, 1,4-Dioxane Removal		Case 2: 100 gpm, 1,4-Dioxane Removal	
Flow Rate (gpm)	50		100	
Design Criteria				
Contaminant	1,4-Dioxane		1,4-Dioxane	
Influent Concentration (ug/l)	725		725	
Treatment Target Concentration (ug/l)	6.1		6.1	
Ozone				
Ozone Concentration (wt %)	10		10	
Applied Ozone Dose (mg/l)	35.4		35.4	
Ozone Demand (ppd)	21.3		42.5	
Unit Energy Consumption (kWh/lb O3)	6.00		6.00	
Annual Energy Consumption (kWh/yr)	46587		93174	
Unit Energy Cost ($/kWh)	$0.10		$0.10	
Annual Energy Cost ($/yr)	$4,659		$9,317	
Oxygen	**w/LOX**		**w/LOX**	
Oxygen Flow Rate (scfm)	1.62		3.25	
Annual Oxygen Consumption (100 scf)	8529		17058	
Unit Oxygen Cost ($/100 scf)	$0.80		$0.80	
Annual LOX Cost ($/yr)	$6,823		$13,646	
Oxygen	**w/VSA**		**w/VSA**	
Power Consumption (kW)	2.5		5.0	
Annual Energy Consumption (kWh/yr)	21958		43916	
Unit Energy Cost (S/kWh)	$0.10		$0.10	
Annual Energy Cost ($/yr)	$2,196		$4,392	
Hydrogen Peroxide				
Hydrogen Peroxide Dose (mg/l)	15.8		15.8	
Hydrogen Peroxide Concentration (wt %)	35		35	
Hydrogen Peroxide Usage (gpd)	2.9		5.7	
Annual Hydrogen Peroxide Usage (gal/yr)	1047		2094	
Unit Hydrogen Peroxide Cost ($/gal)	$3.50		$3.50	
Annual Hydrogen Peroxide Cost ($/yr)	$3,664		$7,328	
Consumable Costs	**w/LOX**	**w/VSA**	**w/LOX**	**w/VSA**
Annual Energy Cost ($/yr)	$4,659	$6,854	$9,317	$13,709
Annual Oxygen Cost ($/yr)	$6,823	$0	$13,646	$0
Annual Hydrogen Peroxide Cost ($/yr)	$3,664	$3,664	$7,328	$7,328
Total ($/yr)	**$15,146**	**$8,323**	**$30,291**	**$16,645**
Total ($/1000 gal)	$0.576	$0.317	$0.576	$0.317
Captial Equipment Costs	**w/LOX**	**w/VSA**	**w/LOX**	**w/VSA**
Total Sale Price	**$237,437**	**$277,787**	**$327,322**	**$377,759**

Notes:

1. This is a preliminary and budgetary estimate. Bench testing and further scope definition is necessary for a firm estimate/proposal.
2. All equipment will be pre-assembled as much as possible and provided in skid-mounted subassemblies.
3. Containerization of most of the equipment is available as an option for an additional price.
4. Consumable costs assume 100% utilization for 365 days per year.

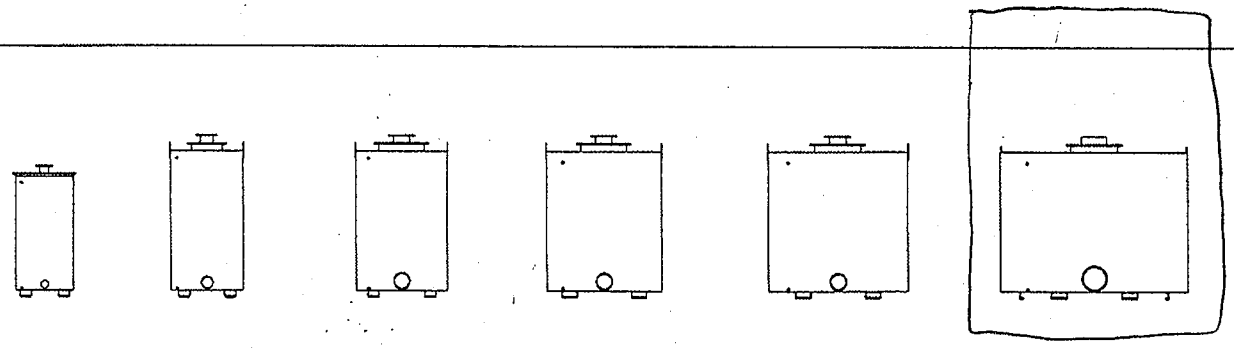
50 gpm case: 420 cfm
100 gpm case: 850 cfm.

CARBONAIR
www.carbonair.com

GPC Round Series Carbon Vessels

Carbonair's gas phase carbon absorbers are designed to provide an efficient and economical means to control odor, toxic vapors, and corrosive gases. Several types of activated carbons are available for a variety of applications. 50 SPM

Specifications*



Model	GPC 5R	GPC 7R	GPC 13R	GPC 20R	GPC 28R	GPC 50R
Flow Range (cfm)	40 - 380	76 - 500	120 - 800	200 - 1800	240 - 2200	480 - 4000
Carbon Capacity (lb)	500	1000	1500	2000	3000	5000
Vessel Diameter or Plot Size	2'-6"	3'-2"	4'	5'	6'	8'
Vessel Height	**5'-7"**	**7'-0"**	**7'-0"**	**7'-0"**	**7'-3"**	**7'-0"**
Bed Area (ft^2)	4.9	7.9	12.6	19.6	28.3	50
Empty Weight (lb)	550	790	1090	1425	1795	3970
Operating Weight (lb)	1050	1790	2590	3425	4795	8970
Influent Connection (NPS)**	4"	6"	8"	8"	8"	12"
Effluent Connection (NPS)**	4"	6"	8"	8"	8"	12"

Design Features

- **Welded steel construction**
- **Fork pockets for easy lifting**
- **Corrosion resistant acrylic polyurethane coated interior and exterior**
- **Steel grate and stainless steel screen**
- **Access port**

Options

- ☐ Influent/effluent sample and pressure taps
- ☐ Influent/effluent ducting
- ☐ Humidity control
- ☐ Discharge stack
- ☐ Blowers
- ☐ Complete line of granular activated carbon

Service Centers

FLORIDA
4710 Dignan Street
Jacksonville, FL 32254
800.241.7833
904.387.4465
904.387.5058 Fax

MINNESOTA
7500 Boone Ave N #101
Brooklyn Park, MN 55428
800.526.4999
763.315.4771
763.315.4614 Fax

TEXAS
4889 Hunter Rd. Bldg 1-C
San Marcos, TX 78666
800.893.5937
512.392.0085
512.392.0066 Fax

VIRGINIA
4003 West Main Street
Salem, VA 24153
800.204.0324
540.380.5913
540.380.5920 Fax

*Specifications subject to change without notice.

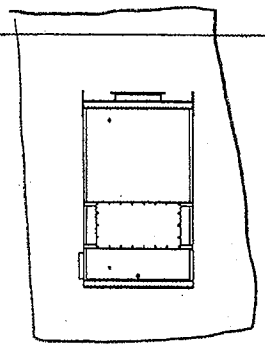
CARBONAIR
www.carbonair.com

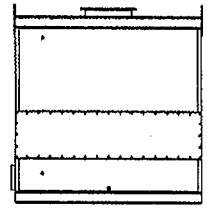
1000 scfm

GPC Series Carbon Vessels

Carbonair's gas phase carbon absorbers are designed to provide an efficient and economical means to control odor, toxic vapors, and corrosive gases. Several types of activated carbons are available for a variety of applications.

Specifications*





Model	GPC 70	GPC 120
Flow Range (cfm)	700 - 7000	1200 - 12,000
Carbon Capacity (lb)	10,000	13,500
Vessel Diameter or Plot Size	**5'-0" x 16'-0"**	**8'-0" x 16'-6"**
Vessel Height	8'-5"	8'-6"
Bed Area (ft²)	70	119
Empty Weight (lb)	5850	9250
Operating Weight (lb)	15,850	22,750
Influent Connection (NPS)**	**12 3/4" (2)**	**12 3/4" (2)**
Effluent Connection (NPS)**	**12 3/4" (2)**	**12 3/4" (2)**

Design Features

- **Welded steel construction**
- **Corrosion resistant acrylic polyurethane coated interior and exterior**
- **Steel grate and stainless steel screen**
- **Access port**

Options

- ☐ Influent/effluent sample and pressure taps
- ☐ Influent/effluent ducting
- ☐ Humidity control
- ☐ Discharge stack
- ☐ Blowers
- ☐ Complete line of granular activated carbon

Service Centers

FLORIDA
4710 Dignan Street
Jacksonville, FL 32254
800.241.7833
904.387.4465
904.387.5058 Fax

MINNESOTA
7500 Boone Ave N #101
Brooklyn Park, MN 55428
800.526.4999
763.315.4771
763.315.4614 Fax

TEXAS
4889 Hunter Rd. Bldg 1-C
San Marcos, TX 78666
800.893.5937
512.392.0085
512.392.0066 Fax

VIRGINIA
4003 West Main Street
Salem, VA 24153
800.204.0324
540.380.5913
540.380.5920 Fax

*Specifications subject to change without notice.

TETRA TECH
BALTIMORE NO. 2
4/9/2010

	Design Basis #2	Cleanup Goal	50 gpm Mass lb/hr	50 gpm Mass lb/day	50 gpm Mass lb/mo	50 gpm Mass ton/yr	100 gpm Mass lb/hr	100 gpm Mass lb/day	100 gpm Mass lb/mo	100 gpm Mass ton/yr	GAC Loading lb/100 lb GAC	50 gpm lb GAC/mo	50 gpm ton GAC/mo	100 gpm lb GAC/mo	100 gpm ton GAC/mo
Volatile Organics (ug/L)															
1,1,1-TRICHLOROETHANE	94	200	0.0024	0.056	1.7	0.01	0.0047	0.113	3.4	0.02	6	28		56	
1,1-DICHLOROETHENE	**89**	3	0.0022	0.053	1.6	0.01	0.0045	0.107	3.2	0.02	**6**	27		53	
1,2,4-TRICHLOROBENZENE	411	70	0.0103	0.247	7.4	0.05	0.0206	0.494	14.8	0.09	6	123		247	
1,2-DICHLOROETHANE	**119**	5	0.0030	0.071	2.1	0.01	0.0060	0.143	4.3	0.03	6	36		71	
BENZENE	**5**	5	0.0001	0.003	0.1	0.00	0.0003	0.006	0.2	0.00	**12**	1		2	
CHLOROBENZENE	270	100	0.0068	0.162	4.9	0.03	0.0135	0.324	9.7	0.06	6	81		162	
CHLOROFORM	77	80	0.0019	0.046	1.4	0.01	0.0038	0.092	2.8	0.02	6	23		46	
CIS-1,2-DICHLOROETHENE	**9050**	70	0.2264	5.434	163.0	0.99	0.4529	10.869	326.1	1.98	**7**	2,329		4,658	
METHYLENE CHLORIDE	**10**	5	0.0003	0.006	0.2	0.00	0.0005	0.012	0.4	0.00	6	3		6	
NAPHTHALENE	**21**	0.65	0.0005	0.013	0.4	0.00	0.0011	0.025	0.8	0.00	20	2		4	
TOLUENE	127	1000	0.0032	0.076	2.3	0.01	0.0063	0.152	4.6	0.03	12	19		38	
TRANS-1,2-DICHLOROETHENE	110	100	0.0028	0.066	2.0	0.01	0.0055	0.132	4.0	0.02	**7**	28		57	
TRICHLOROETHENE	**15000**	5	0.3753	9.007	270.2	1.64	0.7506	18.014	540.4	3.29	**20**	1,351		2,702	
VINYL CHLORIDE	**2475**	2	0.0619	1.486	44.6	0.27	0.1238	2.972	89.2	0.54	**0**				
Volatile Organics - SIM (ug/L)															
1,4-DIOXANE	**725**	6.1													
Petroleum Hydrocarbons (ug/L)															
DIESEL RANGE ORGANICS	**420**	47	0.0105	0.252	7.6	0.05	0.0210	0.504	15.1	0.1	20	38		76	
GASOLINE RANGE ORGANICS	**3500**	47	0.0876	2.102	63.1	0.38	0.1751	4.203	126.1	0.8	20	315		631	

Total	4,404	2.2	8,808	4.4

QED Air Stripper Model ver. 2.01

4/9/2010

Site Data

Name: J Logan

e-mail: joe.logan@tetratech.com

Project: Baltimore

Units: English

Altitude: 10 ft

Air Temp: 55 F

Flow: 50 gpm

Water Temp: 55 F

Stripper: EZ-Tray 8.x - Click for details

Stripper Air Flow: 420 cfm

Stripper Max Flow: 75 gpm

Water Results

Contaminant	Influent (ppb)	Target (ppb)	4-Tray Results (ppb)	4-Tray % Removal	6-Tray Results (ppb)	6-Tray % Removal
1,1,1-trichloroethane	94	200	< 1	100.000	< 1	100.000
1,1-dichloroethane	119	5	< 1	100.000	< 1	100.000
1,1-dichloroethylene	89	3	< 1	100.000	< 1	100.000
1,2,4-trichlorobenzene	411	70	62.7	84.745	32.3	92.141
benzene	6	5	< 1	100.000	< 1	100.000
c-1,2-dichloroethylene	9050	70	27.8	99.693	1.6	99.982
chlorobenzene	270	100	3.0	98.889	< 1	100.000
chloroform (trichloromethane)	81	80	< 1	100.000	< 1	100.000
methylene chloride	10	5	< 1	100.000	< 1	100.000
t-1,2-dichloroethylene	110	100	< 1	100.000	< 1	100.000
toluene	127	1000	< 1	100.000	< 1	100.000
trichloroethylene (TCE)	15000	5	16.2	99.892	< 1	100.000
vinyl chloride (chloroethylene)	2475	2	< 1	100.000	< 1	100.000

Air Results

Contaminant	4-Tray (ppmV)	4-Tray (lb/hr)	6-Tray (ppmV)	6-Tray (lb/hr)
1,1,1-trichloroethane	0.2630	0.00235	0.2631	0.00235
1,1-dichloroethane	0.4467	0.00296	0.4488	0.00298
1,1-dichloroethylene	0.3427	0.00223	0.3428	0.00223
1,2,4-trichlorobenzene	0.7167	0.00872	0.7792	0.00948
benzene	0.0285	0.00015	0.0287	0.00015
c-1,2-dichloroethylene	34.7486	0.22588	34.8496	0.22654
chlorobenzene	0.8856	0.00668	0.8945	0.00675
chloroform (trichloromethane)	0.2502	0.00200	0.2530	0.00202
methylene chloride	0.0421	0.00024	0.0435	0.00025
t-1,2-dichloroethylene	0.4221	0.00274	0.4236	0.00275

toluene	0.5118	0.00316	0.5144	0.00318
trichloroethylene (TCE)	42.5803	0.37514	42.6249	0.37553
vinyl chloride (chloroethylene)	14.7831	0.06195	14.7859	0.06196

Notes

Copyright -- QED Treatment Equipment, PO Box 3726, Ann Arbor, MI 48106.

PH-> 1-800-624-2026 or 1-734-995-2547, FX-> 1-734-995-1170. E-mail->info@qedenv.com. WEB->www.qedenv.com.

The QED modeler estimates unit performance for the listed contaminants.
Results assume -

1. *dissolved-phase contaminant within a water matrix*
2. *clean stripper air*
3. *no surfactants, oil, grease or other immiscible phase(s) in the influent*
4. *unit operated within the given parameters and as instructed in the O&M manual*

Stripper performance shall meet or exceed either the required effluent concentration(s) or effluent estimates, whichever is greater, for the conditions supplied and assumes the influent concentrations of each contaminant are less than 25% solubility in water. QED makes no claim of the model's accuracy beyond the 25% solubility in water limit.

Contact Us

Fill out your contact and project information and click Send to have a QED Treatment application specialist contact you.

Name - J Logan

Company - Company

Phone - Phone **Fax -** Fax

e-mail - joe.logan@tetratech.com **Project -** Baltimore

Application Notes

Send Reset

Save Data

Use the following URL to reconstruct your data form for future remodeling

with changes. This URL can be saved in any text file for record keeping and later retrieval. This run's URL:

```
http://64.9.214.199/cgi-bin/remodel.pl?
u=e&tw=55&ta=55&f=50&a=10&s=8.x&n=J+Log&e=joe.logan@tetratech.com&p=B
alti&c=9,94;15,119;16,89;21,411;63,6;81,9050;88,270;91,81;150,10;178,
110;186,127;189,15000;195,2475;
```

QED Air Stripper Model ver. 2.01

4/9/2010

Site Data

Name: J Logan

e-mail: joe.logan@tetratech.com

Project: Baltimore

Units: English

Altitude: 10 ft

Air Temp: 55 F

Flow: 100 gpm

Water Temp: 55 F

Stripper: EZ-Tray 16.x - Click for details

Stripper Air Flow: 850 cfm

Stripper Max Flow: 150 gpm

Water Results

Contaminant	Influent (ppb)	Target (ppb)	4-Tray Results (ppb)	4-Tray % Removal	6-Tray Results (ppb)	6-Tray % Removal
1,1,1-trichloroethane	94	200	< 1	100.000	< 1	100.000
1,1-dichloroethane	119	5	< 1	100.000	< 1	100.000
1,1-dichloroethylene	89	3	< 1	100.000	< 1	100.000
1,2,4-trichlorobenzene	411	70	61.5	85.036	31.4	92.360
benzene	6	5	< 1	100.000	< 1	100.000
c-1,2-dichloroethylene	9050	70	27.1	99.701	1.6	99.982
chlorobenzene	270	100	3.0	98.889	< 1	100.000
chloroform (trichloromethane)	81	80	< 1	100.000	< 1	100.000
methylene chloride	10	5	< 1	100.000	< 1	100.000
t-1,2-dichloroethylene	110	100	< 1	100.000	< 1	100.000
toluene	127	1000	< 1	100.000	< 1	100.000
trichloroethylene (TCE)	15000	5	15.8	99.895	< 1	100.000
vinyl chloride (chloroethylene)	2475	2	< 1	100.000	< 1	100.000

Air Results

Contaminant	4-Tray (ppmV)	4-Tray (lb/hr)	6-Tray (ppmV)	6-Tray (lb/hr)
1,1,1-trichloroethane	0.2599	0.00470	0.2600	0.00471
1,1-dichloroethane	0.4415	0.00593	0.4435	0.00596
1,1-dichloroethylene	0.3387	0.00446	0.3387	0.00446
1,2,4-trichlorobenzene	0.7107	0.01750	0.7720	0.01901
benzene	0.0282	0.00030	0.0283	0.00030
c-1,2-dichloroethylene	34.3426	0.45180	34.4398	0.45308
chlorobenzene	0.8754	0.01337	0.8840	0.01350
chloroform (trichloromethane)	0.2474	0.00401	0.2500	0.00405
methylene chloride	0.0416	0.00048	0.0430	0.00050
t-1,2-dichloroethylene	0.4172	0.00549	0.4186	0.00551

toluene	0.5058	0.00632	0.5084	0.00636
trichloroethylene (TCE)	42.0806	0.75029	42.1235	0.75106
vinyl chloride (chloroethylene)	14.6093	0.12391	14.6120	0.12393

Notes

Copyright -- QED Treatment Equipment, PO Box 3726, Ann Arbor, MI 48106.

PH-> 1-800-624-2026 or 1-734-995-2547, FX-> 1-734-995-1170. E-mail->info@qedenv.com. WEB->www.qedenv.com.

The QED modeler estimates unit performance for the listed contaminants.
Results assume -

1. *dissolved-phase contaminant within a water matrix*
2. *clean stripper air*
3. *no surfactants, oil, grease or other immiscible phase(s) in the influent*
4. *unit operated within the given parameters and as instructed in the O&M manual*

Stripper performance shall meet or exceed either the required effluent concentration(s) or effluent estimates, whichever is greater, for the conditions supplied and assumes the influent concentrations of each contaminant are less than 25% solubility in water. QED makes no claim of the model's accuracy beyond the 25% solubility in water limit.

Contact Us

Fill out your contact and project information and click Send to have a QED Treatment application specialist contact you.

Name - J Logan

Company - Company

Phone - Phone

Fax - Fax

e-mail - joe.logan@tetratech.com

Project - Baltimore

Application Notes

Send Reset

Save Data

Use the following URL to reconstruct your data form for future remodeling

with changes. This URL can be saved in any text file for record keeping and later retrieval. This run's URL:

```
http://64.9.214.199/cgi-bin/remodel.pl?
u=e&tw=55&ta=55&f=100&a=10&s=16.x&n=J+Log&e=joe.logan@tetratech.com&p
=Balti&c=9,94;15,119;16,89;21,411;63,6;81,9050;88,270;91,81;150,10;17
8,110;186,127;189,15000;195,2475;
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ENGINEERING DATA SHEET
BLOWERS: ALL MODELS FOR AIR STRIPPERS

REF — ITEMS and SPECIFICATIONS

2.1.1, 2.2.2.2 2.3.2.2 — EZ-STACKER STRIPPER BLOWERS

Model No.	Type*	Used on Stripper	Electrical Specifications	Max CFM	Motor HP
805188	R	2.4P	115-230V/1PH/TEFC	145	2.0
805189	R	2.4P	115-230V/1PH/EXP	145	2.0
805190	R	2.4P	230/460V/3PH/TEFC	145	2.0
805191	R	2.4P	230/460V/3PH/EXP	145	2.0
805192	R	2.6P	115-230V/1PH/TEFC	180	3.0
805193	R	2.6P	115-230V/1PH/EXP	180	3.0
805194	R	2.6P	230/460V/3PH/TEFC	180	3.0
805195	R	2.6P	230/460V/3PH/EXP	180	3.0
807034	P	4.4P,4.6P	230/460V/3PH/TEFC	600	5.0
807035	P	4.4P,4.6P	230/1PH/TEFC	600	5.0
807036	P	4.4P,4.6P	230/460V/3PH/EXP	600	5.0

* R-Regenerative type, P-Pressure type

2.1.1, 2.2.2.2 2.3.2.2 — EZ-TRAY STRIPPER BLOWERS

Model No.	Type*	Used on Stripper	Electrical Specifications	Max CFM	Motor HP
807034	P	4.4,6.4,8.4	230/460V/3PH/TEFC	600	5.0
807035	P	4.4,6.4,8.4	115-230V/1PH/TEFC	600	5.0
807036	P	4.4,6.4,8.4	230/460V/3PH/EXP	600	5.0
807037	P	12.4,16.4	230/460V/3PH/TEFC	1100	7.5
807038	P	12.4,16.4	230V/1PH/TEFC	1100	7.5
807039	P	12.4,16.4	230/460V/3PH/EXP	1100	7.5
807040	P	24.4	230/460V/3PH/TEFC	2200	15.0
807041	P	24.4	230/460V/3PH/EXP	2200	15.0
807139	P	4.6,6.6,8.6	230/460V/3PH/TEFC	500	5.0
807140	P	4.6,6.6,8.6	115-230V/1PH/TEFC	500	5.0
807141	P	4.6,6.6,8.6	230/460V/3PH/EXP	500	5.0
807142	P	12.6,16.6	230/460V/3PH/TEFC	1000	7.5
807143	P	12.6,16.6	230V/1PH/TEFC	1000	7.5
807144	P	12.6,16.6	230/460V/3PH/EXP	1000	7.5
807145	P	24.6	230/460V/3PH/TEFC	1700	15.0
807146	P	24.6	230/460V/3PH/EXP	1700	15.0

* P-Pressure type

(Note: To use this Data Sheet in a specification, either reproduce the whole table above and indicate which model number is being specified, or include only the data for the model selected.)

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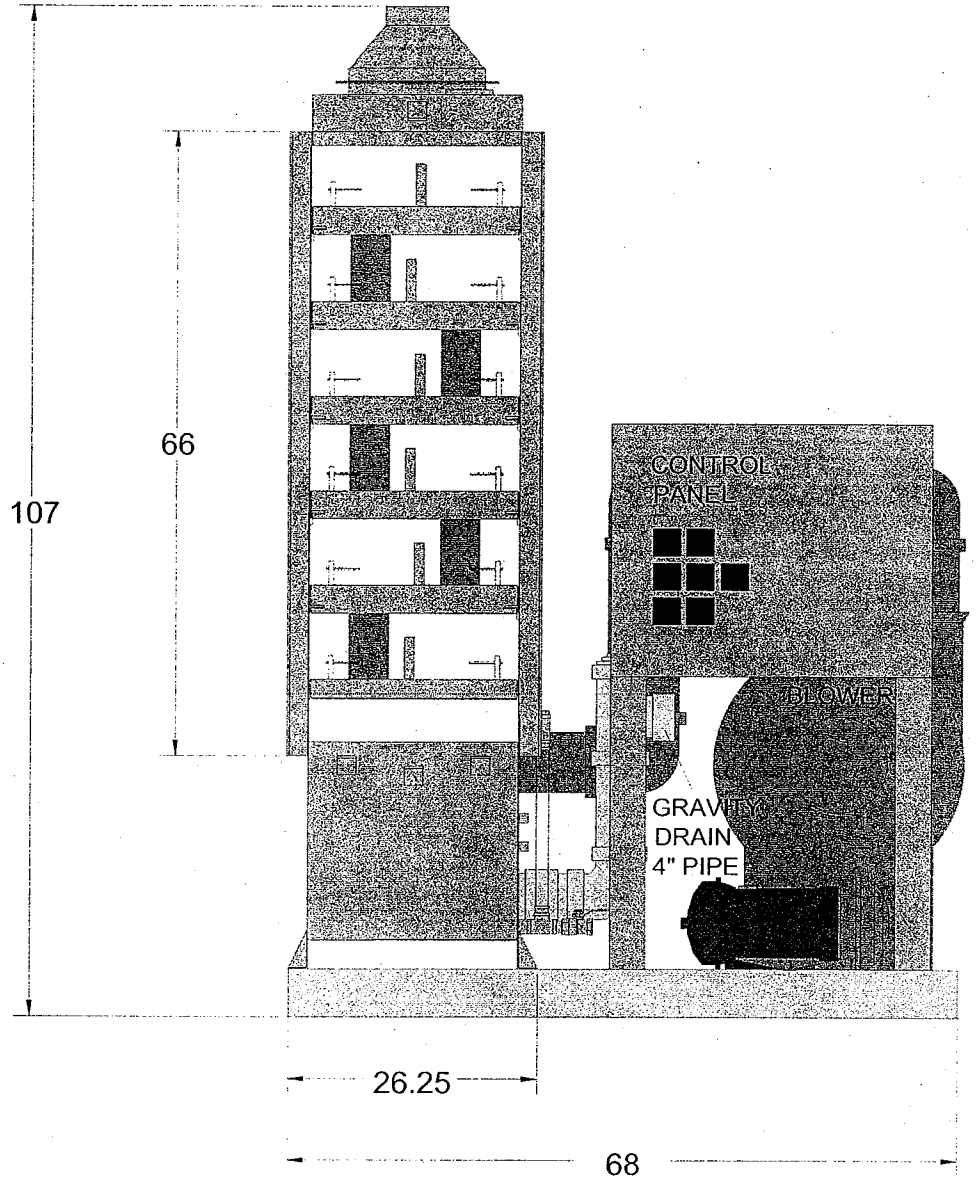
QED EZ-Tray Model 8.6 - Front View



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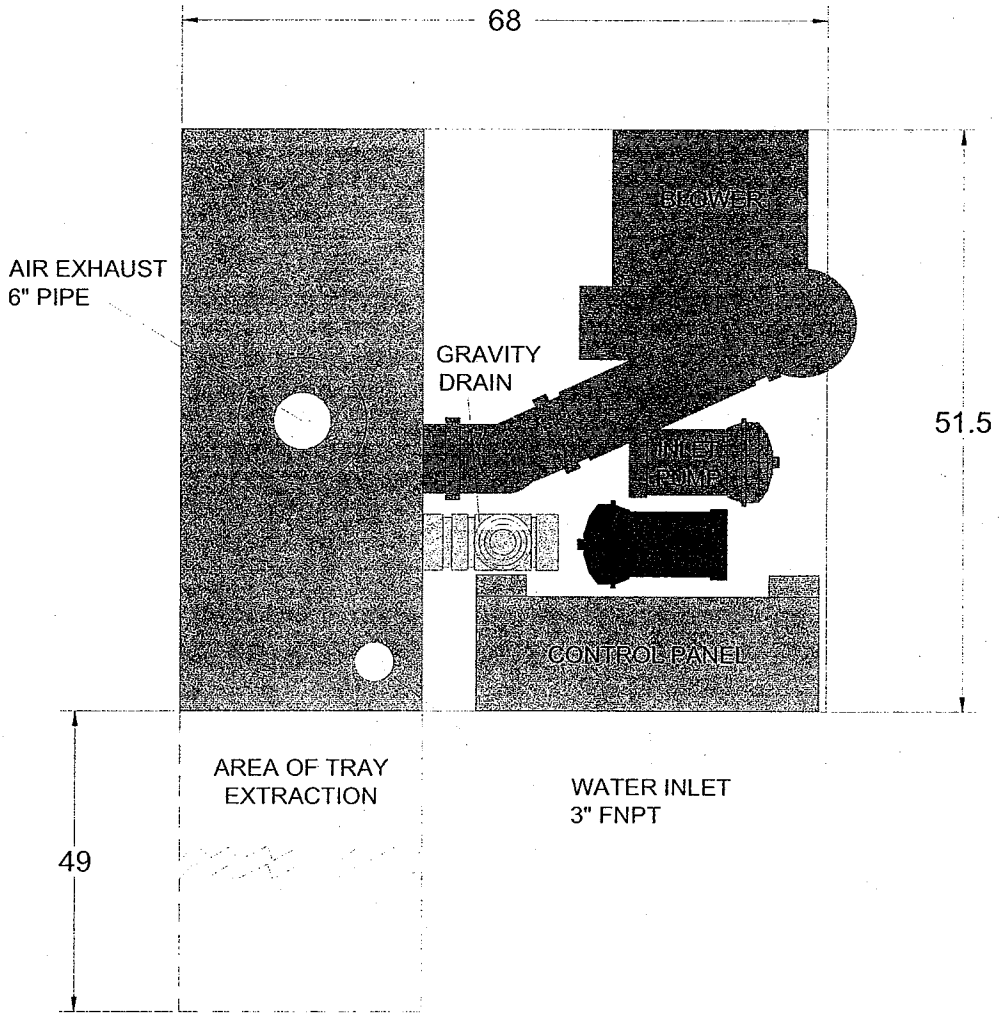
QED EZ-Tray Model 8.6 - Top View



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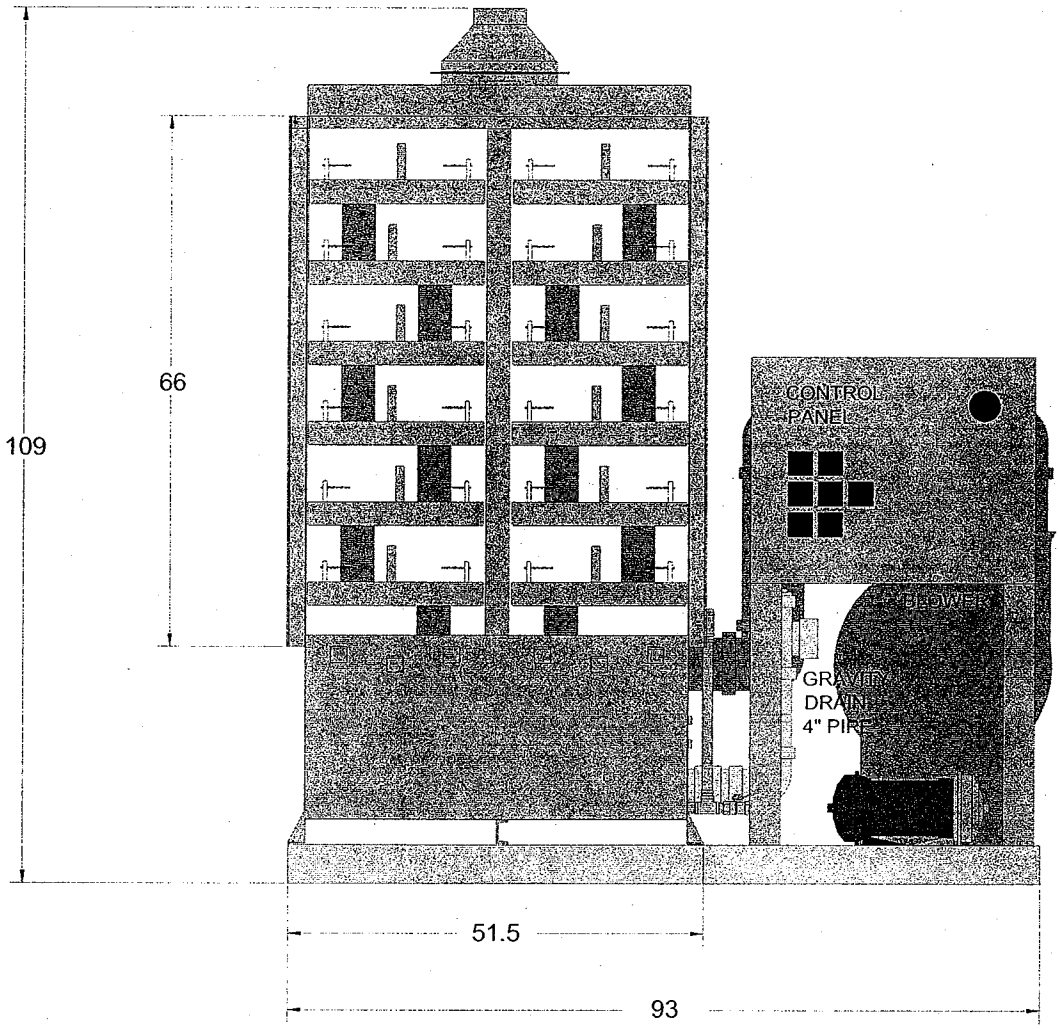
QED EZ-Tray Model 16.6 - Front View



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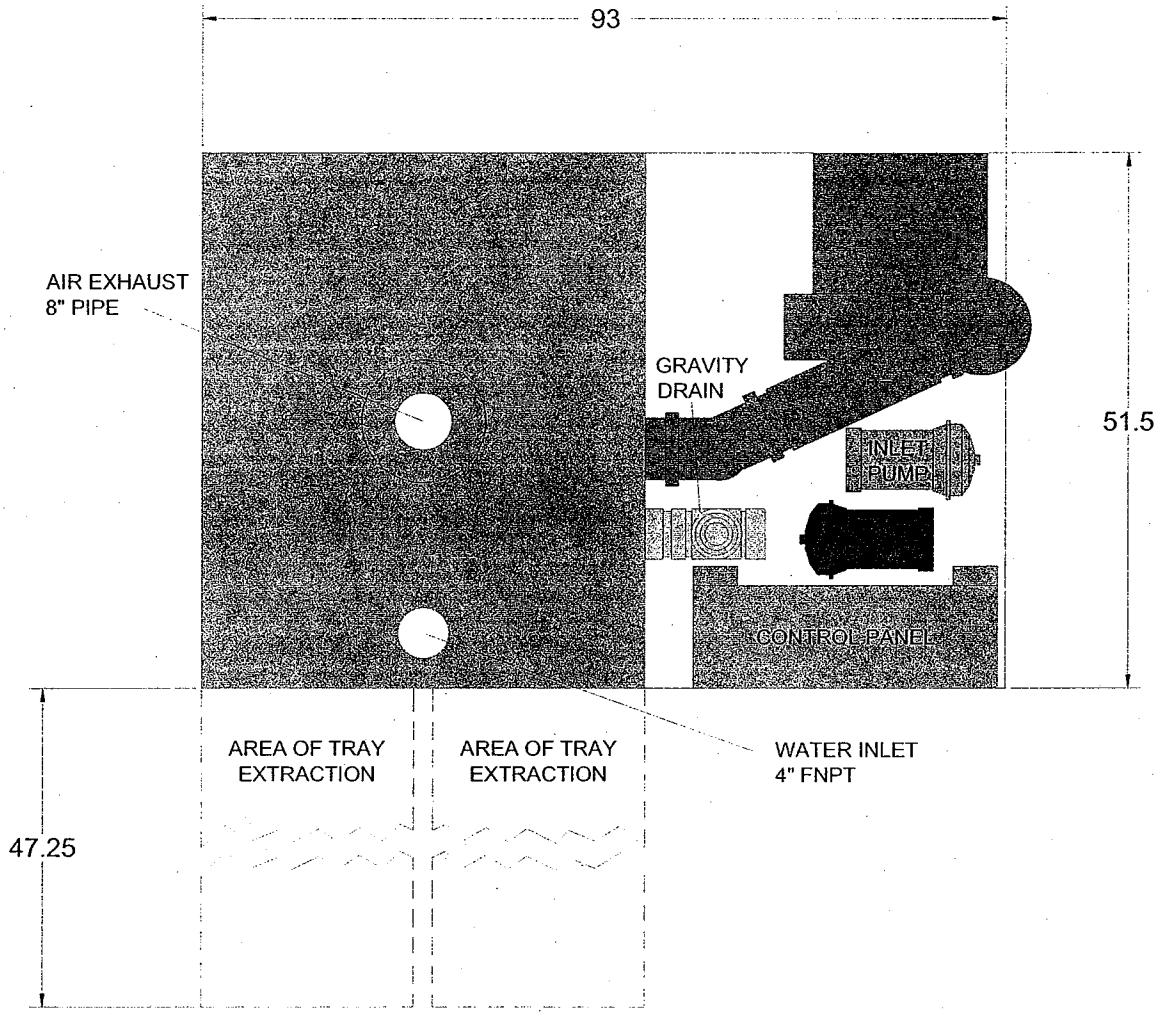
QED EZ-Tray Model 16.6 - Top View



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GROUNDWATER TREATMENT SYSTEM PROCESS DESCRIPTIONS

PROCESS DESCRIPTION - ALTERNATIVE G-2

Component 1: Hydraulic Control

This component would consist of installing an array of groundwater extraction wells and operating this array for a period of up to 50 years. Modeling results for this component are provided in Appendix B. Design calculations for this component are provided in Appendix D

Based on the results of groundwater modeling, sixteen extraction wells at various extraction depths would be sufficient to intercept the contaminated groundwater before it reaches Frog Mortar Creek. Seven wells would be screened within the upper zone (approximately 35 feet deep), five wells would be screened within the intermediate zone (approximately 65 feet deep), and four would be screened within the lower zone (approximately 90 feet deep). Each well screen would be a minimum of 10 feet long. The total groundwater extraction rate is estimated to be 40 gpm. The locations of the extraction wells are shown on Figure 4-1.

Groundwater extraction wells would be installed at depths ranging from approximately 35 to 90 feet bgs. A submersible centrifugal pump equipped with level controls to turn the pump on and off would be installed in each groundwater extraction well. The discharge line from each pump would be provided with a flow meter, flow control valve, shut-off valve, and pressure gauges. Valves and instrumentation would be housed in a subsurface concrete vault with a hinged hatchway. Piping within the vault would be protected from freezing.

Each of these pumps would be connected to a piping network that would convey the extracted groundwater to a pump station on-site (see Figure 4-1). From there, the groundwater would be pumped to an off-site treatment system located near Eastern Boulevard. Because the concentrations of TCE and vinyl chloride in many of the wells the extracted groundwater will be conveyed through double walled piping.

Component 2: Ex-Situ Treatment of Groundwater

Based on recent groundwater modeling, the total groundwater extraction rate was estimated to be approximately 40 gpm. The treatment system conceptual design is sized for a maximum instantaneous flow of 50 gpm. This component would consist of installing an on-site treatment

system and operating the system as long as groundwater is being extracted. As shown on Figure 4-2, the extracted groundwater would enter the system at a feed tank; then flow through a metals removal system, filter unit, air stripper, advanced oxidation system, the liquid-phase GAC unit; and exit the system from the GAC unit. Sludge generated by the metals removal step would be thickened, dewatered, and disposed off-site. The treatment system is described further below and a process flow diagram (PFD) of the system is shown on Figure 4-2. A conceptual layout of the treatment building is shown on Figure 4-3. Design calculations for this component are provided in Appendix C. The following description is typical and the description of the final system will depend on the vendor-specific equipment selected.

The purpose of the Feed Tank is to provide control of water flow through the treatment system. The tank would also blend the groundwater from the various extraction wells to dampen variations in the quality of the influent to treatment system. In addition, side streams from the wastewater treatment system process will also be sent to the Feed Tank. The Feed Tank could also be used to provide additional treatment, as may be required, such as pH adjustment. The Feed Tank would be a nominal 10,000 gallon capacity.

The groundwater flow would be pumped by the Feed Pump, a 50 gpm centrifugal pump, to the metals removal system. The groundwater enters a 600-gallon Primary pH Adjustment Tank equipped with a 0.5 horsepower (hp) Adjustment Tank Mixer. In this tank, the pH is adjusted to 10 with caustic soda (12 gallons per day of 50 percent solution), and hydrogen peroxide (3.5 gallons per day of 35 percent solution) is added for the oxidation and precipitation of iron and manganese. The groundwater then enters a 600-gallon Secondary pH Adjustment Tank equipped with a 0.5 hp mixer. In this tank, the pH is adjusted to 11 with caustic soda for the precipitation of other metals, such as cadmium. The groundwater then flows into the Flocculation Tank equipped with a 0.5 hp flocculation mixer and mixed with a polymer (approximately 6 lb/day) to coagulate and flocculate the suspended solids. The groundwater then flows into the Clarifier where solids settle out. The Clarifier would be equipped with tube settlers. The clarified effluent flows into a Final pH Adjustment Tank where hydrochloric acid (3 gallons per day of 35 percent solution) is added to return the pH back into the range of 6 to 9 for discharge after final treatment. The Final pH Adjustment Tank would be 1,000 gallons with a 1 hp mixer. Chemicals would be stored in drums or tote tanks, depending on usage rates.

Neutralized groundwater flows by gravity into the Clarified Water Feed Tank (750 gallons), from which it is pumped through to the air stripper treatment system by the Clarified Water Pump (3 hp). The clarified water is pumped directly to the air stripper then through a sand filter. Groundwater flows to the top of an air stripper where the groundwater would then cascade down through the multiple trays of a low-profile-type air stripper unit where a countercurrent of air would volatilize the VOCs, and the treated groundwater would be collected in a sump at the bottom of the air stripper unit. The air stripper unit would include four trays and be equipped with a 420 cubic feet per minute (cfm) centrifugal blower to provide the necessary countercurrent of air. Another pump would convey the treated groundwater to the AOP and GAC units.

The sand filter will remove the balance of the suspended solids (including precipitated iron and manganese), as well as any particulate generated in the stripper. By removing suspended solids, the Sand Filter will also remove metals so that discharge limitations are met. There would be three Sand Filter tanks in parallel, two on-line and one off-line. As solids accumulate, the pressure drop in the Sand Filter increases. When a pre-set pressure drop is reached, the off-line sand filter will automatically be brought on line while the original sand filter is taken off-line. The off-line Sand Filter will be backwashed, as described further below.

For the purposes of this GW/FS, the HiPOx system is described in the process description although other processes can be used. Water from the air stripper enters the HiPOx unit where ozone and hydrogen peroxide are added to the groundwater to oxidize organic compounds. Ozone is generated by an ozone generator that uses a stream of oxygen produced by a vacuum swing absorption (VSA) system Excess ozone is oxidized in the HiPOx unit prior to venting. The treated groundwater then flows through the GAC system.

A GAC system is provided to polish the groundwater, to remove remaining DRO and GRO compounds, and to provide contingency treatment in the event that the AOP unit is malfunctioning. There are two GAC Tanks, each containing 4,000 pounds (lb) GAC, in series in a lead-lag configuration. When the GAC in the lead tank reaches capacity (based on analytical testing of the influent and effluent), the flow will be switched to the lag tank while the first tank

is taken off-line so that the GAC can be replaced with fresh GAC. After the GAC is replaced, the GAC Tank is put back on-line in the lag position.

Following GAC treatment, the treated water flows to the discharge piping to an existing sewer that is connected to the sanitary sewer system. A flow meter and totalizer measures the total discharge to the POTW.

The gas exhausting from the top of the air stripper unit would pass through an offgas treatment unit to remove volatilized contaminants prior to venting to atmosphere. The offgas treatment unit would consist of an electric heater followed by two vapor-phase GAC adsorption units, each holding 4,000 lb of GAC and operating in parallel or series followed by two PPZ adsorption units, each holding 3,000 lb of PPZ. The purpose of the exhaust gas heater would be to reduce the relative humidity of the air stripper unit off gas from near 100 percent to approximately 50 percent to allow efficient operation of the vapor-phase GAC adsorption units. The majority of the VOCs in the extracted vapors would be removed by the lead vapor-phase GAC adsorption unit, with the lag unit provided for polishing purposes. Upon exhaustion of the carbon of the lead vapor-phase GAC unit, it would be taken out for disposal or regeneration. The lag vapor-phase GAC adsorption unit would then be placed in the lead position and a fresh unit would be placed in the lag position. Because vinyl chloride is poorly sorbed by GAC, PPZ is used. The vinyl chloride is oxidized by the potassium permanganate. The PPZ units are in a parallel configuration only due to their high capacity and long bed life. Upon exhaustion of the PPZ unit, it would be taken out for disposal.

For discharge to surface water, the contaminant concentrations must also conform to WQCs. For cadmium, the PRG is 5 µg/L, and conventional treatment by pH adjustment, clarification, and filtration cannot meet this level. To meet the cadmium requirement, an ion exchange (IE) unit would be provided following the GAC unit. Cartridge filters would be required upstream of the IE system to prevent clogging of the IE resin and to further remove metals sorbed onto fine suspended solids that pass through the sand filters. There would be two tanks each containing 60 ft^3 of cationic IE resin. One tank would be on line and the second tank would be on standby. The effluent would be routinely monitored for cadmium, and as the concentration approached the PRG, the tank would be taken offline, and the standby tank would be brought into service. The

resin would be regenerated off-site by a resin regeneration service. For a small system such as this, the resin and tank would be removed from the site and replace with another tank filled with fresh resin. The new tank would be backwashed to remove fines, and the tank would be placed in standby mode.

Part of the treated water will be diverted to a Backwash Supply Tank (5,000 Gallons). This tank would be equipped with level switches to divert treated water into the tank when it is not full. When the tank is full, all treated water flows to the sanitary sewer. The Backwash Supply Tank is sized to provide sufficient water for one backwash cycle each of a Sand Filter and GAC Tank.

When a Sand Filter requires backwash, the Backwash Pump is activated and 40 gpm flows upward through the sand filter, suspending the sand, and carrying the solids out of the sand filter to the Waste Backwash Tank. Each backwash cycle requires approximately 800 gallons of water. After backwash is complete, the Backwash Pump is stopped, and the Sand Filter is ready to be used when the next on line Sand Filter reaches capacity.

Similarly, when the GAC in a GAC Tank is replaced, fines are generated during transfer of the GAC, and these are removed by backwashing. When a GAC Tank requires backwash, the Backwash Pump is activated and 50 gpm flows upward through the GAC tank carrying the fines out of the tank to the Waste Backwash Tank.

Because the backwash is a relatively large volume of water generated over a short period of time, the waste backwash water is directed to the Waste Backwash Tank (5,000 Gallons) so that it can be fed into the treatment system at a low rate. The water in the Waste Backwash Tank is metered back to the Feed Tank by the Waste Backwash Transfer Pump over a 20-hour period at approximately 1 gpm.

Settled sludge (approximately 200 lb/day of dry solids) in the Clarifier is periodically transferred to a 10-foot diameter Sludge Thickener Tank by a 15 gpm Clarified Underflow Pump. In the Sludge Thickener the solids content of the sludge is increased by gravity sedimentation from approximately 0.5 percent (by weight) to approximately 4 percent (by weight). Thickened sludge is periodically transferred from the bottom of the Thickener to an 80 cubic feet (ft^3) recessed plate type Filter Press by a 60 gpm Filter Press Feed Pump. In the Filter Press, the solids content

of the thickened sludge is increased from approximately 4 percent by weight to 25- to 35 percent (by weight) to form a solid cake which would be stored in a roll-off container and later hauled away for appropriate disposal. Supernatant water from the Thickener and filtrate water from the Filter Press are collected in the 4,700-gallon Filtrate Tank and returned from there to the Feed Tank by a 15 gpm Filtrate Transfer Pump.

A compressed air system will be used to operate air-operated diaphragm pumps for Sludge Transfer, Filter Press Feed, and other air-operated equipment.

The DRA site is bordered by the taxiways and runways, the MDANG property, and Frog Mortar Creek which makes access for routine maintenance difficult, so the location of the treatment building is planned to be off of the Martin State Airport property. The estimated size of the building is 130 feet by 60 feet, and an area of approximately 180 feet by 120 feet would be needed to accommodate construction, parking, and deliveries. The tentative location is assumed to be along Lynbrook Road at the Martin State Airport property line (see Figure 4-4). Figure 4-4 also shows an alternative location along the property line approximately 800 feet to the west. The properties would need to be purchased or leased. The Groundwater Treatment Plant Building will be designed to contain spills within the building. Spilled water will flow or be directed into the building sump and transferred by a Sump Pump to the Feed Tank.

Influent, effluent, and intermediate locations in the process will be sampled routinely to monitor the effectiveness and progress of the treatment. These results will also be used to determine if GAC needs to be replaced.

Component 3: Discharge to POTW and Surface Water

Treated groundwater would be initially discharged to the Baltimore County sanitary sewer system and treated at the City of Baltimore Back River Wastewater Treatment Plant. The discharge from the groundwater treatment system would be pumped and tied into an existing sanitary sewer near the proposed treatment building. The discharge to the sanitary sewer would be metered and routinely sampled to comply with Baltimore County Industrial Wastewater Discharge Standards. The design discharge rate of 50 gpm is greater than the 25,000 gallons per

day (gpd) threshold for a significant industrial user, so reporting is required twice per year and annual user fees are required in addition to sewage service charges.

After the extraction and treatment system has been in operation for 2 to 3 years, the extraction flow rates, groundwater concentrations, and treated water concentrations will be well established. Using the data from plant operation, an NPDES permit application for a discharge to surface water can be prepared. This will include developing an MDE-approved estuary model to calculate effluent limitations, field calibration of the model, and obtaining effluent limitations from the MDE. The treated water would be discharged to surface water through a submerged multiple diffuser outfall.

PROCESS DESCRIPTION - ALTERNATIVE G-3

Component 1: Hydraulic Control

This component would consist of installing an array of groundwater extraction wells and piping as described for Component 1 in Alternative G-2. As in Alternative G-2, the system would operate up to 50 years. The locations of the extraction wells are shown on Figure 4-5.

Component 2: Ex-Situ Treatment of Groundwater

As in Alternative G-2, the total groundwater extraction rate is approximately 40 gpm, but because of uncertainties in the groundwater extraction rates and to provide flexibility for future operation, the treatment system conceptual design is sized for 100 gpm, although the system is assumed to operate at 50 gpm. The additional flow capacity would allow significant recirculation to facilitate in-situ treatment of the HCAs. This component would consist of installing an on-site treatment system and operating this system for up to 50 years, and the process is essentially the same as the treatment system in Alternative G-2, and is described below.

As shown on Figure 4-6, the extracted groundwater would enter the system at a feed tank, then flow through a metals removal system, filter unit, air stripper, advanced oxidation system, the liquid-phase GAC unit, IE unit; and exit the system. Sludge generated by the metals removal step would be thickened, dewatered, and disposed off-site. The treatment system is described further below and a PFD of the system is shown on Figure 4-6. A conceptual layout of the treatment building is shown on Figure 4-7. Design calculations for this component are provided in Appendix C. The following description closely follows Alternative G-2, but has been modified to reflect the larger size of the equipment for the higher design flow rate.

The purpose of the Feed Tank is to provide control of water flow through the treatment system. The tank would also blend the groundwater from the various extraction wells to dampen variations in the quality of the influent to treatment system. In addition, side streams from the wastewater treatment system process will also be sent to the Feed Tank. The Feed Tank could also be used to provide additional treatment, as may be required, such as pH adjustment. The Feed Tank would be sized at 23,000 gallons.

The groundwater flow would be pumped by the Feed Pump, a 100 gpm centrifugal pump to the metals removal system. The groundwater enters a 1,200-gallon Primary pH Adjustment Tank equipped with a 0.5 hp Adjustment Tank Mixer. In this tank, the pH is adjusted to 10 with caustic soda (24 gallons per day of 50 percent solution) and hydrogen peroxide (7 gallons per day of 35 percent solution) is added for the oxidation and precipitation of iron and manganese. The groundwater then enters a 1,200-gallon Secondary pH Adjustment Tank equipped with a 0.5 hp mixer. In this tank, the pH is adjusted to 11 with caustic soda for the precipitation of other metals, such as cadmium. The groundwater then flows into the Flocculation Tank equipped with a 0.5 hp flocculation tank mixer and mixed with a polymer (approximately 12 lb/day) to coagulate and flocculate the suspended solids. The groundwater then flows into the Clarifier where solids settle out. The Clarifier would be an equipped with tube settlers. The clarified effluent flows into a Final pH Adjustment Tank where hydrochloric acid (6 gallons per day of 35 percent solution) is added to return the pH back into the range of 6 to 9 for subsequent discharge. The Final pH Adjustment would be 2,000 gallons with a 1 hp mixer. Chemicals would be stored in drums or tote tanks, depending on usage rates.

Neutralized groundwater flows by gravity into the Clarified Water Feed Tank (1,500 gallons), from which it is pumped through the rest of the treatment system by the Clarified Water Pump (5 hp). The clarified water is pumped directly to the air stripper then through a sand filter. Groundwater flows to the top of an air stripper where the groundwater would then cascade down through the multiple trays of a low-profile-type air stripper unit where a countercurrent of air would volatilize the VOCs, and the treated groundwater would be collected in a sump at the bottom of the air stripper unit. The air stripper unit would include four trays and be equipped with a 850 cfm centrifugal blower to provide the necessary countercurrent of air. Another pump would convey the treated groundwater to the AOP and GAC units.

The sand filter will remove the balance of the suspended solids (including precipitated iron and manganese), as well as any particulate generated in the stripper. By removing suspended solids, the Sand Filter will also remove metals so that discharge limitations are met. There would be three Sand Filter tanks in parallel, two on-line and one off-line. As solids accumulate, the pressure drop in the Sand Filter increases. When a pre-set pressure drop is reached, the off-line

sand filter will automatically be brought on line while the original sand filter is taken off-line. The off-line Sand Filter will be backwashed, as described further below.

For the purposes of this GW/FS, the HiPOx system is described in the process description although other processes can be used. Water from the air stripper enters the HiPOx unit where ozone and hydrogen peroxide are added to the groundwater to oxidize organic compounds. Ozone is generated by an ozone generator that uses a stream of oxygen produced by a vacuum swing absorption (VSA) system Excess ozone is oxidized in the HiPOx unit prior to venting. The treated groundwater then flows through the GAC system.

A GAC system is provided to polish the groundwater, to remove remaining DRO and GRO compounds, and to provide contingency treatment in the event that the AOP unit is malfunctioning. There are two GAC Tanks, each containing 8,000 lb GAC, in series in a lead-lag configuration. When the GAC in the lead tank reaches capacity (based on analytical testing of the influent and effluent), the flow will be switched to the lag tank and while the first tank is taken off-line so that the GAC can be replaced with fresh GAC. After the GAC is replaced, the GAC Tank is put back on-line in the lag position.

For re-injection of the treated groundwater, the contaminant concentrations must meet the groundwater PRGs, and for discharge to surface water, the contaminant concentrations must also conform to WQCs. For cadmium, the PRG is 5 µg/L, and conventional treatment by pH adjustment, clarification, and filtration cannot meet this level. To meet the cadmium requirement, an IE unit would be provided following the GAC unit. Cartridge filters would be required upstream of the IE system to prevent clogging of the IE resin and to further remove metals sorbed onto fine suspended solids. There would be two tanks each containing 60 ft^3 of cationic IE resin. One tank would be on-line and the second tank would be on standby. The effluent would be routinely monitored for cadmium, and as the concentration approached the PRG, the tank would be taken off-line, and the standby tank would be brought into service. For a small system such as this, the resin and tank would be removed from the site and replaced with another tank filled with fresh resin. The new tank would be backwashed to remove fines, and the tank would be placed in standby mode.

Following IE treatment, part of the treated water would be pumped through the discharge piping to an existing Baltimore County sanitary sewer system and treated at the City of Baltimore Back River Wastewater Treatment Plant, and the rest is pumped to the injection wells. Flow meters and totalizers measure the discharge to the POTW and to the injection wells.

The gas exhausting from the top of the air stripper unit would pass through an offgas treatment unit to remove volatilized contaminants prior to venting to atmosphere. The offgas treatment unit would consist of an electric exhaust gas dryer followed by two vapor-phase GAC adsorption units, each holding 9,000 lb of GAC and operating in series and lead/lag configuration, which would be followed by two PPZ adsorption units, each holding 6,000 lb of PPZ. The purpose of the exhaust gas dryer would be to reduce the relative humidity of the air stripper unit off gas from near 100 percent to approximately 50 percent to allow efficient operation of the vapor-phase GAC adsorption units. The majority of the VOCs in the extracted vapors would be removed by the lead vapor-phase GAC adsorption unit, with the lag unit provided for polishing purposes. Upon exhaustion of the carbon of the lead vapor-phase GAC unit, it would be taken out for disposal or regeneration. The lag vapor-phase GAC adsorption unit would then be placed in the lead position and a fresh unit would be placed in the lag position. Because vinyl chloride is poorly sorbed by GAC, PPZ is used. The vinyl chloride is oxidized by the potassium permanganate. Like the GAC, the PPZ units are in a lead/lag configuration. Upon exhaustion of the PPZ of the lead unit, it would be taken out for disposal.

Part of the treated water will be diverted to a Backwash Supply Tank (5,000 Gallons). This tank would be equipped with level switches to divert flow into the tank when it is not full. When the tank is full, all treated water flows to the sanitary sewer. The Backwash Supply Tank is sized to provide sufficient water for one backwash cycle each of a Sand Filter and GAC Tank.

When a Sand Filter requires backwash, the Backwash Pump is activated and 40 gpm flows upward through the sand filter, suspending the sand, and carrying the solids out of the sand filter to the Waste Backwash Tank. After backwash is complete, the Backwash Pump is stopped, and the Sand Filter is ready to be used when the on line Sand Filter reaches capacity.

Similarly, when the GAC in a GAC Tank is replaced, fines are generated during transfer of the GAC, and these are removed by backwashing. When a GAC Tank requires backwash, the

Backwash Pump is activated and 40 gpm flows upward through the GAC tank, carrying the fines out of the tank to the Waste Backwash Tank.

Because the backwash flow rate is significantly larger in proportion to the groundwater extraction rate, the waste backwash water is directed to the Waste Backwash Tank (5,000 Gallons). The water in the Waste Backwash Tank is metered back to the Feed Tank by the Waste Backwash Transfer Pump over a 20-hour period at approximately 1 gpm.

Settled sludge (approximately 400 lb/day dry solids) in the Clarifier is periodically transferred to a 16-foot diameter Sludge Thickener Tank by a 15 gpm Clarified Underflow Pump. In the Thickener the solids content of the sludge is increased by gravity sedimentation from approximately 0.5 percent (by weight) to approximately 4 percent (by weight). Thickened sludge is periodically transferred from the bottom of the Thickener to a 160 ft^3 recessed plate type filter press by a 100 gpm Filter Press Feed Pump. In the Filter Press, the solids content of the thickened sludge is increased from approximately 4 percent by weight to 25- to 35 percent (by weight) to form a solid cake which would be stored in a roll-off container and later hauled away for appropriate disposal. Supernatant water from the Sludge Thickener-Decanting Tank and filtrate water from the Filter Press are collected in the 9,200-gallon Filtrate Tank and returned from there to the Feed Tank by a 25 gpm Filtrate Transfer Pump.

Some of the treated groundwater would be injected through approximately six injection wells located upgradient of the HCAs, as shown on Figure 4-5. Four wells would be screened in the shallow zone and two wells would be screened in the intermediate zone. The total injection rate would be approximately 13 gpm. Prior to injection, sodium lactate, an electron donor, would be added to promote bioremediation through reductive dechlorination. This will reduce concentrations of TCE, cis-1,2-DCE, and vinyl chloride, reduce the total loading of contaminants on the groundwater treatment system, and may shorten the overall time for remediation. The estimated feed rate of sodium lactate is 150 lb/day. The sodium lactate feed system is described below in Component 3. This portion of the alternative may be installed following the initial installation of the extraction wells and the groundwater treatment system, potentially in conjunction with the soil remedy.

Groundwater that is not re-injected would be discharged to the POTW or surface water, as described in Alternative G-2.

A compressed air system will be used to operate air-operated diaphragm pumps for Sludge Transfer, Filter Press Feed, and other air-operated equipment.

The DRA site is bordered by the taxiways and runways, the MDANG property, and Frog Mortar Creek which makes access for routine maintenance difficult, so the location of the treatment building is assumed to be off of the Martin State Airport property. The estimated size of the building is 155 feet by 65 feet, and an area of approximately 200 feet by 130 feet would be needed to accommodate construction, parking, and deliveries. The tentative location is assumed to be along Lynbrook Road at the Martin State Airport property line (see Figure 4-4). Figure 4-4 also shows an alternative location along the property line approximately 800 feet to the west. The properties would need to be purchased or leased. Other potential locations to be considered include the MSA/MDANG property along Lynbrook Road adjacent to the property line or on the MDANG property near the DRA Site. The Groundwater Treatment Plant Building will be designed to contain spills within the building. Spilled water will flow or be directed into the building sump and transferred by a Sump Pump to the Feed Tank.

Influent, effluent, and intermediate locations in the process will be sampled routinely to monitor the effectiveness and progress of the treatment. These results will also be used to determine if GAC needs to be replaced.

Component 3: Reinjection of Treated Groundwater

Some of the groundwater would be reinjected in the vicinity of the HCAs. The reinjection would enhance the flushing rate of contaminants from these areas, and an ED would be mixed with the injected groundwater to promote anaerobic reductive dechlorination of the cVOCs. There would be six injection wells in areas contaminated with cVOCs, as shown on Figure 4-5. There would be no reinjection of groundwater in areas contaminated only with 1,4-dioxane. Four wells would be screened in the shallow zone, and two wells would be screened in the intermediate zone. The total flow rate to shallow zone wells would be approximately 10 gpm, and the total flow rate to

the intermediate zone wells would be 3 gpm. The total injection rate would be approximately 13 gpm.

As noted, sodium lactate would be added to the injected groundwater at a rate of approximately 150 lb/day. Sodium lactate solution would be prepared in a 500 gallon tank and injected into the injection well piping at approximately 4 gallons per hour. The injection of groundwater and electron donor would be intermittent to allow for the ED to be flushed away from the wells to minimize clogging of the wells. When there is no reinjection, all treated groundwater would be discharged to the POTW. This portion of the alternative may be installed following the initial installation of the extraction wells and the groundwater treatment system, potentially in conjunction with the soil remedy.

Component 4: Discharge to POTW and Surface Water

This component is the same as Component 3 in Alternative G-2. Because the potential discharge rate of 100 gpm is greater than the 25,000 gpd threshold for a significant industrial user, reporting would be required twice per year and annual user fees are required in addition to sewage service charges. Per Alternative G-2, a surface water discharge permit would be obtained at a later date.

PROCESS DESCRIPTION - ALTERNATIVE G-4

Component 1: Hydraulic Control

This component would consist of installing an array of groundwater extraction wells and piping as described for Component 1 in Alternative G-2. As in Alternative G-2, the system would operate for up to 50 years. The locations of the extraction wells are shown on Figure 4-8.

Component 2: Extraction of Groundwater from the HCAs

This component would consist of installing groundwater extraction wells downgradient from the HCAs and operating them for up to 50 years. Modeling results for this component are provided in Appendix B. Design calculations for this component are provided in Appendix D.

Seven extraction wells would be sufficient to extract contaminated groundwater from the HCAs. Three wells would be screened within the upper zone (approximately 35 feet deep), two wells would be screened within the intermediate zone (approximately 65 feet deep), and two would be screened within the lower zone (approximately 90 feet deep). Each well screen would be a minimum of 10 feet long. The groundwater extraction rate from the HCAs is estimated to be 28 gpm. Six wells extract groundwater contaminated with cVOCs, and 1,4-dioxane, and one well extracts groundwater contaminated only with 1,4-dioxane. The locations of the extraction wells are shown on Figure 4-8.

A submersible centrifugal pump equipped with level controls to turn the pump on and off would be installed in each groundwater extraction well. The discharge line from each pump would be provided with a flow meter, manual flow control valve, shut-off valve, and pressure gauges. Valves and instrumentation would be housed in a subsurface concrete vault at each wellhead with a hinged hatchway. Piping within the vault would be protected from freezing.

Each of these pumps would be connected to a piping network that would convey the extracted groundwater to the pump station. Because the concentrations of TCE and vinyl chloride in many of the wells are greater than the TCLP criteria, and because the contaminated groundwater will be conveyed through clean areas, the extracted groundwater will be conveyed through double walled pipes.

As with the hydraulic barrier extraction wells, the system would operate for up to 50 years.

Component 3: Ex-Situ Treatment of Groundwater

Because of the groundwater extracted from the HCAs, the total groundwater flow rate requiring treatment will be higher, and the process will be essentially as described in Alternative G-3. Based on the model, the total groundwater extraction rate is approximately 70 gpm, but because of uncertainties in the groundwater extraction rates, the treatment system conceptual design is sized for 100 gpm. This component would consist of installing an on-site treatment system and operating this system as long as groundwater is extracted. As shown on Figure 4-9, the extracted groundwater would enter the system at a feed tank, then flow through a metals removal system, filter unit, air stripper, advanced oxidation system, the liquid-phase GAC unit, IE unit; and exit the system. Sludge generated by the metals removal step would be thickened, dewatered, and disposed off-site. The treatment system is as described for Alternative G-3 and a PFD of the system is shown on Figure 4-9. Design calculations for this component are provided in Appendix C.

Component 4: Reinjection of Treated Groundwater

This component is the same as Component 3 in Alternative G-3.

Component 5: Discharge to POTW and Surface Water

This component is the same as Component 3 in Alternative G-2. Because the potential discharge rate of 100 gpm is greater than the 25,000 gpd threshold for a significant industrial user, reporting would be required twice per year and annual user fees are required in addition to sewage service charges.

PROCESS DESCRIPTION - ALTERNATIVE G-5

Component 1: Hydraulic Control

This component would consist of installing an array of groundwater extraction wells and piping as described for Component 1 in Alternative G-2. As in Alternative G-2, the system would operate for up to 50 years. The locations of the extraction wells are shown on Figure 4-10.

Component 2: Ex-Situ Treatment of Groundwater

This component is the same as Component 2 in Alternative G-3. No reinjection is included in this alternative, so injection wells would not be required. An IE unit would be required for future discharge to surface water. Figure 4-11 shows a PFD of the process.

Component 3: In-Situ Bioremediation of HCAs

This component would consist of injecting an oil-based electron donor, such as EOS (EOS Remediation LLC), into the groundwater through dedicated injection wells in the HCAs to promote biological reductive dechlorination of the cVOCs. Design calculations for this component are provided in Appendix D. Modeling results for this component are provided in Appendix B.

EOS would be injected into the subsurface along lines (barriers) perpendicular to the groundwater flow direction (see Figure 4- 10). The spacing between the lines across the HCAs was based on the groundwater travel time in 5 years, the typical length of time that EOS remains effective. Thus, short plumes or plumes with relatively high velocity may be treated with a single barrier at the downgradient edge of the plume, and longer plumes or plumes with relatively slow velocity would require multiple barriers along the length of the plume. The spacing between the injection wells would be 10 feet. The estimated number of injection wells in each barrier and the quantity of EOS injected is summarized below. Because of the low alkalinity of the groundwater, a buffered EOS product is expected to be required. A pilot study would be performed to confirm well spacing and EOS application rate.

Under this alternative, EOS would be injected into the subsurface via permanent wells so that a subsequent injection can be made at a later date, if needed. A pump capable of a pumping rate of

5 to 10 gpm would be necessary to ensure the proper application of the EOS and to minimize application time. A subcontractor would provide the mixing and injection equipment, and the injections would be completed in a relatively short period of time.

Plume Location (COC, Zone, and nearby well)	Number of Barriers	Number of Wells per Barrier	Total EOS Added, lb	Total Water Added, gallons
TCE Upper (DMW11)	4	10	8,100	10,000
TCE Intermediate (DMW9)	1	70	46,000	55,000
DCE Intermediate (DMW1)	1	20	13,000	16,000
Vinyl Chloride Upper (MW20)	10	40	80,000	95,000

As a conservative cost assumption, a second injection of EOS would be applied to half of the injection wells after 5 years. Appendix C includes the cost information provided by EOS Remediation, Inc. Monitoring wells on both sides of each HCA would be used to monitor the progress and effectiveness of the EOS.

Component 4: Discharge to POTW and Surface Water

This component is the same as Component 4 in Alternative G-2.

PRB SYSTEM AND VENDOR QUOTE

LOCKHEED MARTIN
MARTIN STATE AIRPORT
DRA FS
PRB
2/10/10

The PRB must also consider the groundwater and COC travel time. The longest distance to travel is from the DMW11 cluster (shallow depth only). For the main plume, the distance is from the edge of the taxiway for all depths.

From a figure, the distance from DMW11 to the PRB is about 1,000 feet.

From the edge of the taxiway to the PRB, the distance is approximately 650 feet.

This information was used for the attached spreadsheet that estimates the number of times maintenance must be performed (at 10 year intervals).

Because of the slow groundwater velocities and TCE velocity, a long period of time is required for treatment, particularly in the shallow zone.

LOCKHEED MARTIN
MARTIN STATE AIRPORT - DUMP ROAD AREA SITE
PRB - GENERAL CALCULATIONS
TREATMENT TIME
1/28/2010

Estimate groundwater travel distance for each groundwater zone for a 10 year period.
Base this on TCE velocity from model, (No pumping)

TCE velocity	ft/d	ft/y	ft/10-yr
VTCE Shallow (U)	0.006	2.19	22
VTCE Intermediate (I)	0.013	4.7	47
VTCE Deep (L)	0.05	18.25	183

Groundwater velocity		
ft/d	ft/y	ft/10-yr
0.04	14.6	146
0.09	32.85	328.5
0.4	146	1,460

Distance from cluster DMW-11 to PRB, feet	1,000
Distance from taxiway edge to PRB, feet	650

Number of 10-year periods to cover distances:

DMW-11 to PRB	TCE based	GW Vel based	Total time TCE based years
VTCE Shallow (U)	46	7	457
VTCE Intermediate (I)	21	3	211
VTCE Deep (L)	5	0.7	55

Taxiway to PRB	TCE based	GW Vel based	TCE based years
VTCE Shallow (U)	30	4	297
VTCE Intermediate (I)	14	2	137
VTCE Deep (L)	4	0.4	36

Run	Unit	groundwater velocity (ft/d)	1,4d diox velocity (ft/d)	TCE retardation	TCE velocity (ft/d)
No pumping	Upper	0.02 - 0.06	0.02 - 0.06	6.9	0.0029 - 0.0086
	Intermediate	0.06 - 0.12	0.06 - 0.12	6.9	0.0087 - 0.017
	Lower	0.3 - 0.5	0.3 - 0.5	6.9	0.043 - 0.072
pumping	Upper	0.05 - 0.08	0.05 - 0.08	6.9	0.0072 - 0.012
	Intermediate	0.25	0.25	6.9	0.036
	Lower	0.6 - 0.95	0.6 - 0.95	6.9	0.087 - 0.14

Table 1. Summary of Groundwater Flow and Solute Transport Model Parameter Values

Flow Model Parameter Values

Unit	Layer	Unit	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Sy	S
Upper	1	Upper	4.5	4.5	0.45	0.25	
	2	Upper	4.5	4.5	0.45		
	3	Upper	4.5	4.5	0.45		
	4	Upper	9	9	0.9		
	5	Upper	4.5	4.5	0.45		
	6	Upper	4	4	0.4		
Intermed.	7	Intermed.	5	5	0.5		0.0001
	8	Intermed.	20	20	2		
	9	Intermed.	20	20	2		
Lower	10	Lower	1.4	1.4	0.14		1.00E-05
	11	Lower	100	100	10		
Intermed aquitard	12	Intermed aquitard	0.5	0.5	0.05		0.0001
	13	Intermed aquitard	0.5	0.5	0.05		
	14	Intermed aquitard	0.5	0.5	0.05		
Deep confined	15	Deep confined	30	30	3		0.0001

Note: The recharge rate for unpaved area is 0.00152 ft/day (6.7 in/yr) ; for the paved area is 1e-005 ft/day (0.044 in/yr).

Transport Model Parameter Values

Bulk density (lb/ft^3)	Effective Porosity	Kd (ft^3/lb)			Dispersivity (ft)			R			Half Life (yr)		
		TCE	DCE	VC	D_L	D_H	D_V	TCE	DCE	VC	TCE	DCE	VC
110	0.28	0.9	0.18	0.1	32.8	3.28	0.328	6.9	2.2	1.6	5.9	12	4.2

Notes: 1) DCE/TCE yield 0.738; DCE/VC yield 0.644
2) 1,4 dioxane assumed to undergo no degradation

enviro**metal** technologies inc.
an Adventus company

Revised PRB Design

To: Joseph W. Logan, Tetra Tech NUS, Inc., joe.logan@tetratech.com

From: Andrzej Przepiora, Mike Duchene, EnviroMetal Technologies Inc.

Date: 27 January 2010

Re: **Revised Design for a Potential Application of a Granular Iron PRB at a Site in Baltimore, MD – 32276.88**

EnviroMetal Technologies Inc. (ETI) has prepared a revised cost estimate for using a granular iron permeable reactive barrier (PRB) for groundwater remediation at a site in Baltimore, MD, based on updated design parameters (Table 1) received from Tetra Tech NUS Inc. on 22 January 2010.

To date, granular iron PRBs have been installed at over 150 sites in the United States, Canada, Europe, Japan, and Australia. The earliest commercial applications in California and Belfast, Ireland have been in operation for the past 15 years. These installations have performed consistently with the expectation that they will continue to perform for another 5 to 10 years without any maintenance.

Using data from these sites, we have prepared a preliminary cost estimate for an *in-situ* PRB system at the site. Further detailed design information would be required in order to refine this cost estimate.

PRB Technology Implementation

ETI's typical approach to applying our PRB technology involves an initial review of hydrogeologic data and site visit/meeting. Treatability testing with site groundwater may be undertaken to obtain design parameters for use in the field application, however for more common volatile organic compounds (VOCs), ETI's database of degradation rates can be used. ETI then acts as part of the design and implementation team to assist with the PRB installation. ETI assistance is provided on a professional time and expense basis for this work. For a description of ETI's involvement and cost, please refer to Attachment A and Table 2.

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Web page: www.eti.ca

Cost Estimate for PRB Application

Figure 1 shows the design of the proposed iron PRB, which includes distinct aquifer zones with varying groundwater velocities and VOC concentrations. The dimensions of each zone, along with the anticipated VOC concentrations, groundwater velocity are shown in Figure 1. The residence time (RT) for each zone was determined using ETI's database of half-lives and the site cleanup targets (Figure 1, Table 1). Using the RT and the groundwater flow velocity, the theoretical iron thickness (IT) was determined (the theoretical iron thickness are in parentheses in Figure 1). Granular iron is mixed with similar grain size native sand, as a bulking agent, where the construction thickness may be wider than the required iron amount. To ensure that the contaminants contact iron as they pass through the PRB and recognizing that there may be some segregation during mixing and placement, ETI's recommends that the iron/sand mixture contains minimum of 20 percent by volume. Therefore, we have assumed that the PRB will be installed in a 2.5 ft wide trench and backfilled with 20% iron/sand mix resulting in a 100% iron thickness equivalent of 0.5 ft. As seen on Figure 1, the equivalent iron thickness of 0.5 will apply to all sections of the PRB.

The total volume and cost of iron needed for the Upper Aquifer, Intermediate Aquifer and Lower Aquifer are shown in Table 1.

The simplest configuration that could be applied to this site is a continuous wall. An installation method that could be considered for construction of continuous PRB to a depth of 81 ft is biopolymer slurry trenching.

Biopolymer Trenching - Installation of a treatment zone of iron using biopolymer (biodegradable) slurry is similar to constructing a conventional impermeable slurry wall. The biopolymer slurry used is typically guar based. As the trench is excavated, the biopolymer slurry provides stability to the trench walls. Granular iron can then be placed into the trench through the slurry. After some time, the biopolymer slurry breaks down (i.e. become less viscous) allowing groundwater to flow through the iron treatment zone. The assumed cost of installing a continuous iron wall by this method is $\$30/ft^2$. A mobilization/ demobilization cost of about $100,000 was assumed.

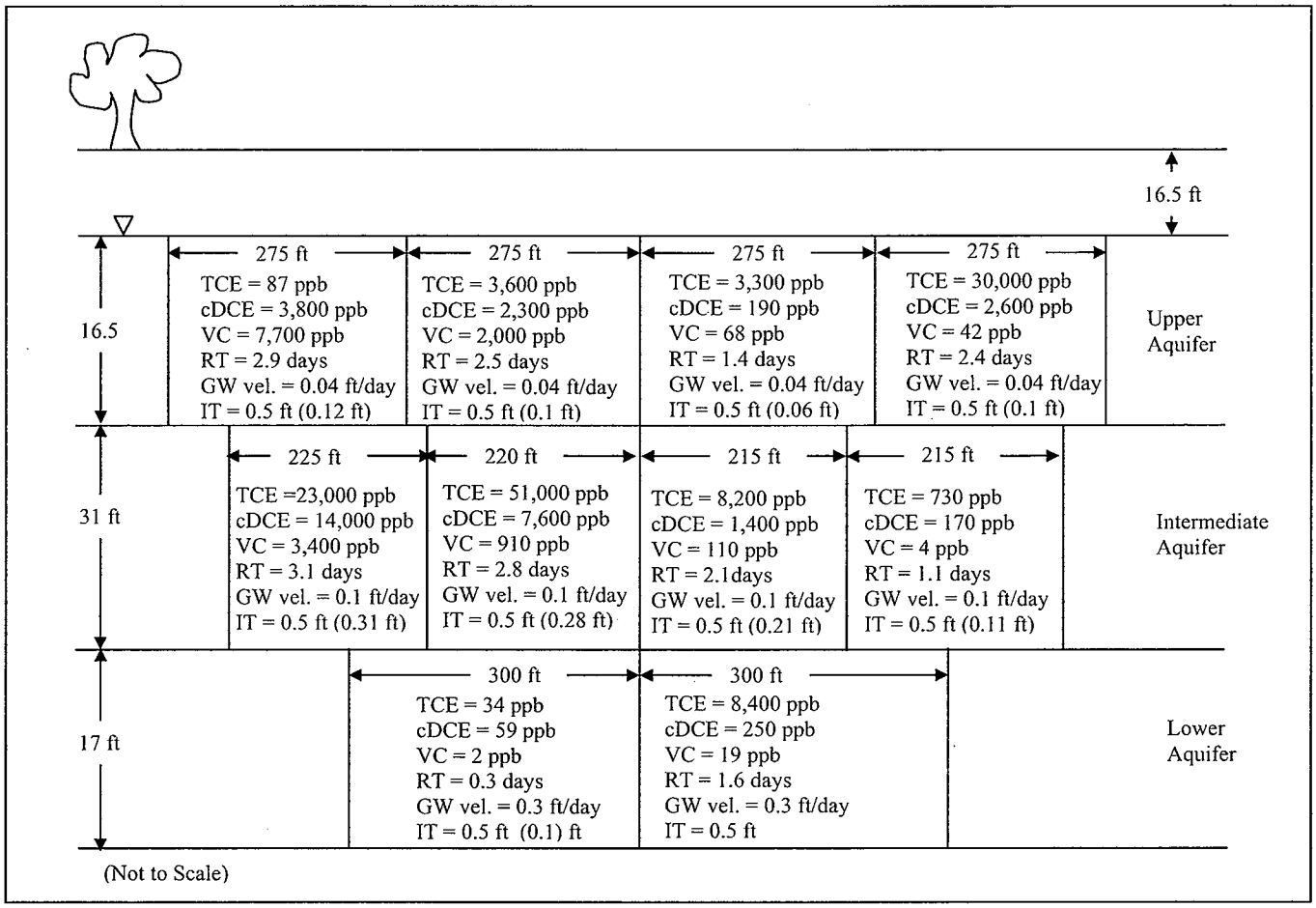


Figure 1: Conceptual design for the proposed PRB (RT - residence time, IT - iron thickness).

Table 2 summarizes the installation costs discussed above. Refinement of these costs will require more detailed site information. The site license fee for use of the patented technology is typically 15% of capital cost (construction and delivered iron costs). The site lines fee would be at least 12% for project of this magnitude. Costs for activities such as site preparation, permitting, site construction management, soil disposal, etc., which are not included in the above estimate, should also be taken into account.

Table 1: Summary of PRB Design Parameters

Parameters	**Conceptual Design Value**		
Organic Parameters [a]	**Anticipated Influent Concentration** [a] **(µg/L)**		**Regulatory Limit** [a] **(µg/L)**
TCE	34 – 51,000		10
cDCE	59 – 14,000		1,100
VC	2 – 7,700		4
Residence time (days)	**0.3 – 3.1**		
	Upper	Intermediate	Lower
Groundwater Velocity (ft/day)	0.04	0.1	0.3
Dimensions [a]			
PRB width (ft)	1,100	875	600
Depth to Plume Bottom (ft)	33	64	81
Saturated Plume Thickness (ft)	16.5	31	17
Required Iron Amount and Cost (US$)			
Practical Iron Flow-Through Thickness [b] (ft)	0.5 [c]	0.5 [c]	0.5 [c]
Granular Iron Volume (ft^3)	9,075	13,563	5,100
Granular Iron Amount [d] (ton)	681	1,017	383
Delivered Granular Iron Cost [e] (US$750/ton)	$510,000	$763,000	$287,000

[a] Provided by Tetra Tech NUS Inc.
[b] Iron thickness is directly proportional to groundwater flow velocity
[c] Assumes a trench width of 2.5 ft and a 20% iron by volume with the balance mixed with sand
[d] Assuming a bulk density for the iron material of 0.075 ton/ft^3
[e] Based on current iron costs

Table 2: PRB Cost Estimate for a Site in Baltimore, MD

PRB Implementation	**Estimated Cost (US$)**
ETI Assistance with Data Assessment, Field Design and Implementation [a]	$8,000 - $10,000
Bench Scale Testing [b]	$20,000
Estimated Contractors Installation Cost:	
Delivered Iron Material	$1,560,000
Iron/Sand Mixing	$100,000
Mobilization/Demobilization	$100,000
Construction [c] (73,625 ft^2 @ $30/$ft^2$)	$2,210,000
Subtotal	**$3,970,000**
ETI's License Fee (12% minimum)	$476,400
TOTAL	**$4,446,400**

Detailed cost estimates can be provided upon request.

[a] Based on professional time and expenses.
[b] Costs of sample collection and shipment are not included.
[c] Based on cost data from other sites. Would need to be refined based on a more complete review of site data and quotation from construction contractors. Does not include costs for activities such as site preparation/restoration, permitting, soil/water disposal, site construction management, etc.

IN-SITU BIOREMEDIATION AND VENDOR QUOTE

LOCKHEED MARTIN
MARTIN STATE AIRPORT
DRA FS
In-Situ Bioremediation of HCAs
1/28/10

High concentration areas (HCAs) are treated by EOS in Alternative G-5. Because remediation does not need to be immediate, the HCAs will be treated using a barrier approach rather than a grid approach.

The barriers will be assumed to last 5 years.

There are 6 HCA that have TCE, cis-1,2-DCE and or vinyl chloride (VC). Of these, two HCAs overlap other HCAs, so only 4 areas need to be treated.

Groundwater velocities and retardation factors were the same as those used in the model.

The attached spreadsheet shows the TCE velocity for each groundwater zone. TCE was used because it is the slowest of the three COCs. The table shows the velocity and the distance covered in 5 years (as ft/5-yr).

For was area, the length and width was measured from the figures. Each length (distance parallel to the groundwater flow) was compared to the 5-year travel distance. If the length was longer than the 5-year travel distance, then the length was divided into segments, each of which is the length of the 5-year travel distance. Barriers were then drawn the width of each area spaced according to the 5-year travel distance.

MARYLAND SITE
IN-SITU BIOREMEDIATION - NUMBER OF BORINGS
1/22/2010

Estimate number of borings for each area.
Use flow-through approach, rather than grid.
Assume 5-year travel gap between injection lines, based on TCE velocity. (Conservative because velocity of DCE and VC will be faster.)

TCE velocity	ft/d	ft/y	ft/5-yr
VTCE Shallow (U)	0.01	3.65	18
VTCE Intermediate (I)	0.036	13.1	66
VTCE Deep (L)	0.1	36.5	183

Assume borings at 15' spacing.
Assume permanent injection wells with 10' screens for distribution.

Area Name	Depth interval	Thickness of interval, feet	Length, feet	# of 5-year intervals	Number of rows	Width, feet	Number of boring locations	Number of wells	Depth of wells, Feet	Notes
TCE Upper	U	10	100	5.5	4	100	27	27	20	
TCE Intermediate	I	20	150	2.3	1	350	23	47	30 and 40	
DCE Upper West	U	10	100	5.5	NA	150	NA	NA	NA	captured by TCE U
DCE Upper East	U	10	100	5.5	NA	150	NA	NA	NA	captured by VC U
DCE Intermediate	I	20	150	2.3	1	100	7	13	45 and 55	
VC Upper	U	10	200	11.0	10	400	267	267	20	

# of 5-Year intervals = Length/[(ft/5-yr) for that interval]
Number of rows is # of intervals less 1. Round down.
Number of boring locations is no. of rows x [(width)/15' (Spacing)]
Number of wells is number of borings times thickness/10'

AquaBupH requirement

Per vendor, typical range is 1.5 to 2 lb/cy of saturated soil
Estimate, use 1.75 lb/cy, then check with EOS tool spreadsheet.
Per vondor, quantity of AquaBupH is 1.25 x EOS.

Area Name	Thickness of interval, feet	Length, feet	Width, feet	Vol, ft3	Vol, cy	Estimated lb EOS	lb EOS (EOS Tool), per row	Number of rows	Total lb EOS (EOS Tool)	Total lb Aqua- bupH (at 1.25 EOS)
TCE Upper	10	100	100	100,000	3,704	6,481	1,615	4	6,460	8,075
TCE Intermediate	20	150	350	1,050,000	38,889	68,056	36,945	1	36,945	46,181
DCE Intermediate	20	150	100	300,000	11,111	19,444	10,479	1	10,479	13,099
VC Upper	10	200	400	800,000	29,630	51,852	6,360	10	63,600	79,500
Total						145,833			117,484	**146,855**

Drums (at 420 lb/drum)	350

Run	Unit	groundwater velocity (ft/d)	1,4d diox velocity (ft/d)	TCE retardation	TCE velocity (ft/d)
No pumping	Upper	0.02 - 0.06	0.02 - 0.06	6.9	0.0029 - 0.0086
	Intermediate	0.06 - 0.12	0.06 - 0.12	6.9	0.0087 - 0.17
	Lower	0.3 - 0.5	0.3 - 0.5	6.9	0.043 - 0.072
pumping	Upper	0.05 - 0.08	0.05 - 0.08	6.9	0.0072 - 0.012
	Intermediate	0.25	0.25	6.9	0.036
	Lower	0.6 - 0.95	0.6 - 0.95	6.9	0.087 - 0.14

0 0.017

Table 1. Summary of Groundwater Flow and Solute Transport Model Parameter Values

Flow Model Parameter Values

Unit	Layer	Unit	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Sy	S
Upper	1	Upper	4.5	4.5	0.45	0.25	
	2	Upper	4.5	4.5	0.45		
	3	Upper	4.5	4.5	0.45		
	4	Upper	9	9	0.9		
	5	Upper	4.5	4.5	0.45		
	6	Upper	4	4	0.4		
Intermed.	7	Intermed.	5	5	0.5		0.0001
	8	Intermed.	20	20	2		
	9	Intermed.	20	20	2		
Lower	10	Lower	1.4	1.4	0.14		1.00E-05
	11	Lower	100	100	10		
Intermed aquitard	12	Intermed aquitard	0.5	0.5	0.05		0.0001
	13	Intermed aquitard	0.5	0.5	0.05		
	14	Intermed aquitard	0.5	0.5	0.05		
Deep confined	15	Deep confined	30	30	3		0.0001

Note: The recharge rate for unpaved area is 0.00152 ft/day (6.7 in/yr) ; for the paved area is 1e-005 ft/day (0.044 in/yr).

Transport Model Parameter Values

Bulk density (lb/ft^3)	Effective Porosity	Kd (ft^3/lb)			Dispersivity (ft)			R			Half Life (yr)		
		TCE	DCE	VC	D_L	D_H	D_V	TCE	DCE	VC	TCE	DCE	VC
110	0.28	0.9	0.18	0.1	32.8	3.28	0.328	6.9	2.2	1.6	5.9	12	4.2

Notes: 1) DCE/TCE yield 0.738; DCE/VC yield 0.644
2) 1,4 dioxane assumed to undergo no degradation

P:\GIS\LOCKHEED_MSA\MAPDOCS\MXD\PLAN_VIEW_SEP2009_G.MXD 12/21/09 JEE

-I SB.

MW-34S
MW-34I
A
MW-33I
B
MW-16S
MW-16I
MW-16D
MW-17S
MW-17I
W'
MW-15S
MW-15I
MW-15D
MW-18S
MW-18I
VC-U
DCE U-E
NCU)
MW-04
TCE I
DMW-03S
DMW-03I
DMW-03D
D
W
MW-07
DMW-09I
DMW-09D
DMW-09S
X'
C
MW-26S
MW-20S
MW-20I
MW-20D
DMW-02S
DMW-10S
DMW-10I
DMW-08S
DMW-08I
DMW-08D
DMW-04S
DMW-04I
Y'
X
MW-25S
MW-25I
MW-21D
MW-22D
Y
DMW-11S
DMW-11I
U
TCE
DCE U-W
DCE I
DMW-05S
DMW-05I
DMW-05D
Z'
TAXIWAY TANGO
DMW-07S
DMW-07I
DMW-07D
DMW-06I
DMW-06D
DMW-06S
A'
V'
MW-23S
MW-23D
MW-19S
MW-19I
MW-19D
Z
TT-12
MW-01
MW-06
MW-24S
MW-24I
TT-13
AIRPORT RUNWAY
MW-32S
MW-32I
D'
V
MW-30D
C'
MW-31D
MW-29D
B'

FROG MORTAR CREEK

Figure 4-4
Cross Section Plan View

Legend

- Monitoring Wells
- Cross Sections
- Airfield Surface Line
- Facility Area

All location IDs begin with "MSA-".

Lockheed Martin Martin State Airport
Middle River, Maryland

0 50 100 200 Feet

N

DATE MODIFIED: 12/18/09

CREATED BY: JEE

Tetra Tech, Inc.

1/22/10

EOS Remediation, Inc.

EOS® BARRIER DESIGN WORKSHEET

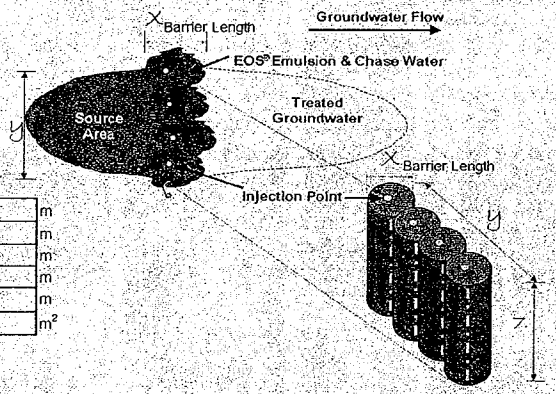
U.S. Version 2.1e, Rev. Date: February 6, 2008
www.EOSRemediation.com

Help

Site Name:	Baltimore
Location:	TCE U - one line
Project No.:	

Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list) | EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here



Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Treatment Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	15	ft	4.6	m
Width of treatment area perpendicular to groundwater flow, "y"	100	ft	30.5	m
Minimum depth to contamination	5	ft	1.5	m
Maximum depth of contamination	15	ft	4.6	m
Treatment thickness, "z"	10	ft	3.0	m
Treatment zone cross-sectional area, $A = y * z$	1,000	ft^2	92.9	m^2

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Silty Sand			
Total Porosity (accept default or enter n)	0.28	(decimal)		
Effective Porosity (accept default or enter n_e)	0.17	(decimal)		
Soil bulk density, (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.91	g/cc	119	lbs / ft^3

Hydraulic Characteristics

Hydraulic Conductivity (accept default or enter K)	4.5	ft/day	1.6E-03	cm/sec
Hydraulic Gradient (accept default or enter i)	0.0025	ft/ft		

Note: Since the hydraulic gradient ($i = dh/dx$) is negative, we ask you to enter "-i" in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i) / n_e$	0.07	ft/day	0.020	m/day
Groundwater flow rate through treatment zone, $Q = -KiA$	84.15	gallons/day	318.56	L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)		60	typical values 60 to 180 days, see comment	
Calculated Contact Length (x) = $\tau * V_x$	Suggested Minimum	5.0	ft	1.5 m

Treatment zone volume	15,000	ft^3	424.8	m^2
Treatment zone groundwater volume (volume * effective porosity)	19,074	gallons	72,208	L

Section D: Design Lifespan For One Application

	7	year(s)	typical values 5 to 10 years
Estimated total groundwater volume treated over design life	234,077	gallons	886,140 L

Section E: Electron Acceptors

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e⁻ equiv / mole	Stoichiometry *Contaminant/H₂ (wt/wt H_2)*	Hydrogen Demand ($g\ H_2$)
Dissolved Oxygen (DO)	0 to 8	2	32.0	4	7.94	223.2935801
Nitrate Nitrogen (NO_3^- - N)	1 to 10		62.0	5	12.30	
Sulfate (SO_4^{2-})	10 to 500	400	96.1	8	11.91	29753.50878
Tetrachloroethene (PCE), C_2Cl_4			165.8	8	20.57	
Trichloroethene (TCE), C_2HCl_3		36	131.4	6	21.73	1468.300736
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$		41	96.9	4	24.05	1510.927935
Vinyl Chloride (VC), C_2H_3Cl		4.1	62.5	2	31.00	117.1825138
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym-tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_2CHCl_2			99.0	4	24.55	
loroethane, C_2H_5Cl			64.9	2	32.18	
rchlorate, ClO_4^-			99.4	8	12.33	
Hexavalent Chromium, Cr[VI]			52.0	3	17.20	

User added								
User added								
User added								

Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e⁻ equiv./ mole	Stoichiometry *Contaminant-/ H_2 (wt/wt H_2)*	Hydrogen Demand ($g\ H_2$)	DOC Released *(moles)*
Estimated Amount of Fe^{2+} Formed	10 to 100	50	55.8	1	55.41	799.6605126	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	162.5725047	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	4453.845768	
Target Amount of DOC to Release	60 to 100	100	12.0				7377.74

Design Safety Factor: 2.0 typical values 1 to 3

Calculations assume:

1.) all reactions go to completion during passage through emulsified edible oil treated zone; and,

2.) perfect reaction stoichiometry.

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand	169.6	pounds
DOC Released	842.4	pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss

1,615 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "z_e" (typically less than 40%): 0.25

For Additional Information on Effective Thickness, Click Here

Weight of sediment to be treated: 446,672 lbs

Sorptive Capacity of Soil (accept default or enter site specific value): 0.0020 lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material[1]

- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

[1]Default values provided based on laboratory studies completed by NCSU

For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material

893 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project: 4 drums

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EOS® BARRIER DESIGN WORKSHEET

U.S. Version 2.1e, Rev. Date: February 6, 2008
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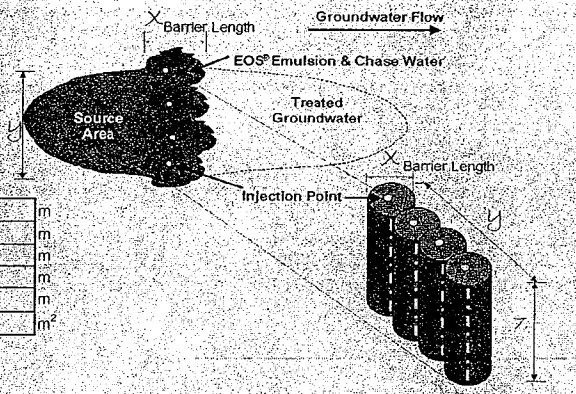
Help

Site Name:	Baltimore
Location:	TCE I - 1 line
Project No.:	

Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list): EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here



Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Treatment Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	15	ft	4.6	m
Width of treatment area perpendicular to groundwater flow, "y"	350	ft	106.7	m
Minimum depth to contamination	20	ft	6.1	m
Maximum depth of contamination	40	ft	12.2	m
Treatment thickness, "z"	20	ft	6.1	m
Treatment zone cross-sectional area, A = y * z	7,000	ft²	650.3	m²

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Silty Sand			
Total Porosity (accept default or enter *n*)	0.28	(decimal)		
Effective Porosity (accept default or enter n_e)	0.17	(decimal)		
Soil bulk density: (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.91	g/cc	119	lbs / ft³

lic Characteristics

ulic Conductivity (accept default or enter *K*)	20	ft/day	7.1E-03	cm/sec
Hydraulic Gradient (accept default or enter *i*)	0.002	ft/ft		

Note: Since the hydraulic gradient ($i = dh/dx$) is negative, we ask you to enter -*i* in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i)/n_e$	0.24	ft/day	0.072	m/day
Groundwater flow rate through treatment zone, $Q = -KiA$	2094.40	gallons/day	7,928.72	L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)	60	typical values 60 to 180 days, see comment		
Calculated Contact Length (x) = τ * V_x	14.1	ft	4.3	m

Treatment zone volume	105,000	ft³	2,973.3	m³
Treatment zone groundwater volume (volume * effective porosity)	133,518	gallons	505,456	L

Section D: Design Lifespan For One Application

Estimated total groundwater volume treated over design life	7	year(s)	typical values 5 to 10 years	
	5,484,710	gallons	20,763,328	L

Section E: Electron Acceptors

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e⁻ equiv./ mole	Stoichiometry *Contaminant/H₂* (wt/wt H_2)	Hydrogen Demand ($g H_2$)
Dissolved Oxygen (DO)	0 to 8	2	32.0	4	7.94	5232.035715
Nitrate Nitrogen (NO_3^- - N)	1 to 10		62.0	5	12.30	
Sulfate (SO_4^{2-})	10 to 500	400	96.1	8	11.91	697160.3056
Tetrachloroethene (PCE), C_2Cl_4			165.8	8	20.57	
Trichloroethene (TCE), C_2HCl_3		14.4	131.4	6	21.73	13761.61712
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$		13.6	96.9	4	24.05	11743.38409
Vinyl Chloride (VC), C_2H_3Cl		3.4	62.5	2	31.00	2276.943917
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym-tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_2CHCl_2			99.0	4	24.55	
ethane, C_2H_5Cl			64.9	2	32.18	
orate, ClO_4^-			99.4	8	12.33	
Hexavalent Chromium, Cr[VI]			52.0	3	17.20	

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Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e- equiv./ mole	Stoichiometry *Contaminant / H_2* (wt/wt H_2)	Hydrogen Demand (g H_2)	DOC Released (moles)
Estimated Amount of Fe^{2+} Formed	10 to 100	50	55.8	1	55.41	18737.00246	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	3809.268276	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	104358.9346	
Target Amount of DOC to Release	60 to 100	100	12.0				172869.27

Design Safety Factor: 2.0 typical values 1 to 3

Calculations assume:

1.) all reactions go to completion during passage through emulsified edible oil treated zone; and,

2.) perfect reaction stoichiometry.

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand	3,775.7	pounds
DOC Released	19,738.9	pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss

36,945 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "z_e" (typically less than 40%): 0.25

For Additional Information on Effective Thickness, Click Here

Weight of sediment to be treated: 3,126,704 lbs

ive Capacity of Soil (accept default or enter site specific value): 0.0020 lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material[1]

- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

[1]Default values provided based on laboratory studies completed by NCSU

For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material

6,253 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project: 88 drums

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EOS® BARRIER DESIGN WORKSHEET

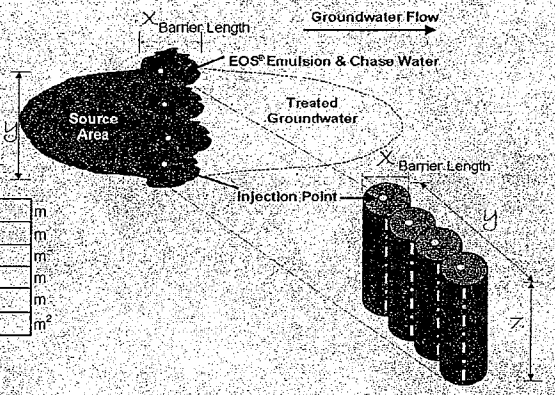
U.S. Version 2.1e, Rev. Date: February 6, 2008
www.EOSRemediation.com

Help

Site Name:	Maryland
Location:	DCE intermediate - 1 line
Project No.:	

Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list) | EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here



Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Treatment Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	15	ft	4.6	m
Width of treatment area perpendicular to groundwater flow, "y"	100	ft	30.5	m
Minimum depth to contamination	35	ft	10.7	m
Maximum depth of contamination	55	ft	16.8	m
Treatment thickness, "z"	20	ft	6.1	m
Treatment zone cross-sectional area, A = y * z	2,000	ft^2	185.8	m^2

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Silty Sand			
Total Porosity (accept default or enter n)	0.28	(decimal)		
Effective Porosity (accept default or enter n_e)	0.17	(decimal)		
Soil bulk density, (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.91	g/cc	119	lbs / ft^3

Hydraulic Characteristics

Hydraulic Conductivity (accept default or enter K)	20	ft/day	7.1E-03	cm/sec
Hydraulic Gradient (accept default or enter i)	0.002	ft/ft		

Note: Since the hydraulic gradient ($i = -dh/dx$) is negative, we ask you to enter i in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i)/n_e$	0.24	ft/day	0.072	m/day
Groundwater flow rate through treatment zone, $Q = -KiA$	598.40	gallons/day	2,265.35	L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)	60	typical values 60 to 180 days, see comment		
Calculated Contact Length (x) = $\tau * V_x$	14.1	ft	4.3	m

Treatment zone volume	30,000	ft^3	849.5	m^3
Treatment zone groundwater volume (volume * effective porosity)	38,148	gallons	144,416	L

Section D: Design Lifespan For One Application

	7	year(s)	typical values 5 to 10 years	
Estimated total groundwater volume treated over design life	1,567,060	gallons	5,932,379	L

Section E: Electron Acceptors

Inputs	Typical Value	GW Conc (mg/L)	MW (g/mole)	e⁻ equiv./ mole	Stoichiometry *Contaminant/H₂* (wt/wt H_2)	Hydrogen Demand (g H_2)
Dissolved Oxygen (DO)	0 to 8	2	32.0	4	7.94	1494.867347
Nitrate Nitrogen (NO_3 - N)	1 to 10		62.0	5	12.30	
Sulfate (SO_4^{2-})	10 to 500	400	96.1	8	11.91	199188.6587
Tetrachloroethene (PCE), C_2Cl_4			165.8	8	20.57	
Trichloroethene (TCE), C_2HCl_3		7.7	131.4	6	21.73	2102.469282
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$		6.8	96.9	4	24.05	1677.626298
Vinyl Chloride (VC), C_2H_3Cl		1.7	62.5	2	31.00	325.2777024
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym-tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_3CHCl_2			99.0	4	24.55	
hloroethane, C_2H_5Cl			64.9	2	32.18	
rchlorate, ClO_4			99.4	8	12.33	
Hexavalent Chromium, Cr[VI]			52.0	3	17.20	

User added				
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Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc (mg/L)	MW (g/mole)	e equiv./ mole	Stoichiometry *Contaminant / H_2 (wt/wt H_2)*	Hydrogen Demand *(g H_2)*	DOC Released *(moles)*
Estimated Amount of Fe^{2+} Formed	10 to 100	50	55.8	1	55.41	5353.429276	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	1088.362364	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	29816.83846	
Target Amount of DOC to Release	60 to 100	100	12.0				49391.22

Design Safety Factor: 2.0 typical values 1 to 3

Calculations assume:

1.) all reactions go to completion during passage through emulsified edible oil treated zone; and,

2.) perfect reaction stoichiometry

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand	1,061.9	pounds
DOC Released	5,639.7	pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss

10,479 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "z_e" (typically less than 40%): 0.25

For Additional Information on Effective Thickness, Click Here

Weight of sediment to be treated: 893,344 lbs

Sorptive Capacity of Soil (accept default or enter site specific value): 0.0020 lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material†

- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

†Default values provided based on laboratory studies completed by NCSU

For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material

1,787 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project: 25 drums

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EOS® BARRIER DESIGN WORKSHEET

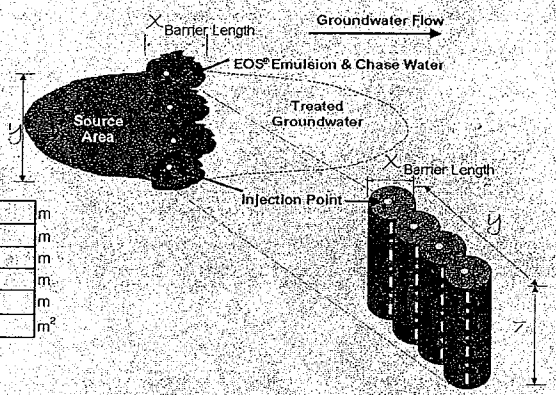
U.S. Version 2.1e, Rev. Date: February 6, 2008
www.EOSRemediation.com

Help

Site Name:	Maryland
Location:	VC Upper 1 line
Project No.:	

Step 1: Select a Substrate from the EOS® Family of Bioremediation Products

Substrate Selected (pick from drop down list) | EOS® 598B42 (Preferred for Chlorinateds)
For Product Literature Click Here



Step 2: EOS® Consumption During Contaminant Biodegradation / Biotransformation

Section A: Treatment Area Dimensions

Length of treatment area parallel to groundwater flow, "x"	15	ft	4.6	m
Width of treatment area perpendicular to groundwater flow, "y"	400	ft	121.9	m
Minimum depth to contamination	10	ft	3.0	m
Maximum depth of contamination	20	ft	6.1	m
Treatment thickness, "z"	10	ft	3.0	m
Treatment zone cross-sectional area, A = y * z	4,000	ft²	371.6	m²

Section B: Groundwater Flow Rate / Site Data

Soil Characteristics

Nominal Soil Type (pick from drop down list)	Silty Sand			
Total Porosity (accept default or enter n)	0.28	(decimal)		
Effective Porosity (accept default or enter n_e)	0.17	(decimal)		
Soil bulk density, (1-n)*2.65 g/cc (accept calculated or enter dry bulk density)	1.91	g/cc	119	lbs / ft³

Hydraulic Characteristics

Hydraulic Conductivity (accept default or enter K)	4.5	ft/day	1.6E-03	cm/sec
Hydraulic Gradient (accept default or enter i)	0.0025	ft/ft		

Note: Since the hydraulic gradient ($i = dh/dx$) is negative, we ask you to enter -i in the EOS® Design Tool so that you can enter a positive number for convenience.

Non-reactive Transport Velocity, $V_x = -(K \times i) / n_e$	0.07	ft/day	0.020	m/day
Groundwater flow rate through treatment zone, $Q = -KiA$	336.60	gallons/day	1,274.26	L/day

Section C: Calculated Contact Length

Contact time (τ) between oil and contaminants (accept default or enter τ)		60	typical values 60 to 180 days, see comment	
Calculated Contact Length (x) = τ * V_x	Suggested Minimum	5.0	ft	1.5 m

Treatment zone volume	60,000	ft³	1,699.0	m²
Treatment zone groundwater volume (volume * effective porosity)	76,296	gallons	288,832	L

Section D: Design Lifespan For One Application

	7	year(s)	typical values 5 to 10 years
Estimated total groundwater volume treated over design life	936,309	gallons	3,544,561 L

Section E: Electron Acceptors

Inputs	Typical Value	GW Conc. (mg/L)	MW (g/mole)*	e⁻ equiv./ mole	Stoichiometry *Contaminant/H₂* (wt/wt H_2)	Hydrogen Demand (g H_2)
Dissolved Oxygen (DO)	0 to 8	2	32.0	4	7.94	893.1743206
Nitrate Nitrogen (NO_3^- - N)	1 to 10		62.0	5	12.30	
Sulfate (SO_4^{2-})	10 to 500	400	96.1	8	11.91	119014.0351
Tetrachloroethene (PCE), C_2Cl_4			165.8	8	20.57	
Trichloroethene (TCE), C_2HCl_3		0.2	131.4	6	21.73	32.62890524
cis-1,2-dichloroethene (c-DCE), $C_2H_2Cl_2$		6.6	96.9	4	24.05	972.8901826
Vinyl Chloride (VC), C_2H_3Cl		56	62.5	2	31.00	6402.16661
Carbon tetrachloride, CCl_4			153.8	8	19.08	
Chloroform, $CHCl_3$			119.4	6	19.74	
sym-tetrachloroethane, $C_2H_2Cl_4$			167.8	8	20.82	
1,1,1-Trichloroethane (TCA), CH_3CCl_3			133.4	6	22.06	
1,1-Dichloroethane (DCA), CH_2CHCl_2			99.0	4	24.55	
Chloroethane, C_2H_5Cl			64.9	2	32.18	
Perchlorate, ClO_4^-			99.4	8	12.33	
Hexavalent Chromium, Cr[VI]			52.0	3	17.20	

User added								
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Section F: Additional Hydrogen Demand and Carbon Losses

Generation (Potential Amount Formed)	Typical Value	GW Conc. (mg/L)	MW (g/mole)	e⁻ equiv./ mole	Stoichiometry *Contaminant / H_2 (wt/wt H_2)*	Hydrogen Demand *(g H_2)*	DOC Released *(moles)*
Estimated Amount of Fe^{2+} Formed	10 to 100	50	55.8	1	55.41	3198.642051	
Estimated Amount of Manganese (Mn^{2+}) Formed		5	54.9	2	27.25	650.290019	
Estimated Amount of CH_4 Formed	5 to 20	10	16.0	8	1.99	17815.38307	
Target Amount of DOC to Release	60 to 100	100	12.0				29510.96

Design Safety Factor: 2.0 typical values 1 to 3

Calculations assume:

1.) all reactions go to completion during passage through emulsified edible oil treated zone; and,

2.) perfect reaction stoichiometry

EOS® Requirement Calculations Based on Hydrogen Demand and Carbon Losses

Stoichiometric Hydrogen Demand	656.3	pounds
DOC Released	3,369.7	pounds

EOS® Requirement Based on Hydrogen Demand and Carbon Loss

6,360 lbs

Step 3: EOS® Requirement Based on Attachment by Aquifer Material

Soil Characteristics

Effective treatment thickness, "Z_e" (typically less than 40%): 0.25

For Additional Information on Effective Thickness, Click Here

Weight of sediment to be treated: 1,786,688 lbs

orptive Capacity of Soil (accept default or enter site specific value): 0.0020 lbs EOS® / lbs sediment

EOS® Attachment by Aquifer Material[1]

- Fine sand with some clay 0.001 to 0.002 lbs EOS® / lbs soil
- Sand with higher silt/clay content 0.002 to 0.004 lbs EOS® / lbs soil

[1]Default values provided based on laboratory studies completed by NCSU

For Additional Data, Click Here

EOS® Requirement Based on Oil Entrapment by Aquifer Material

3,573 lbs

Summary – How much EOS® do you need?

Suggested Quantity of EOS® for Your Project: 16 drums

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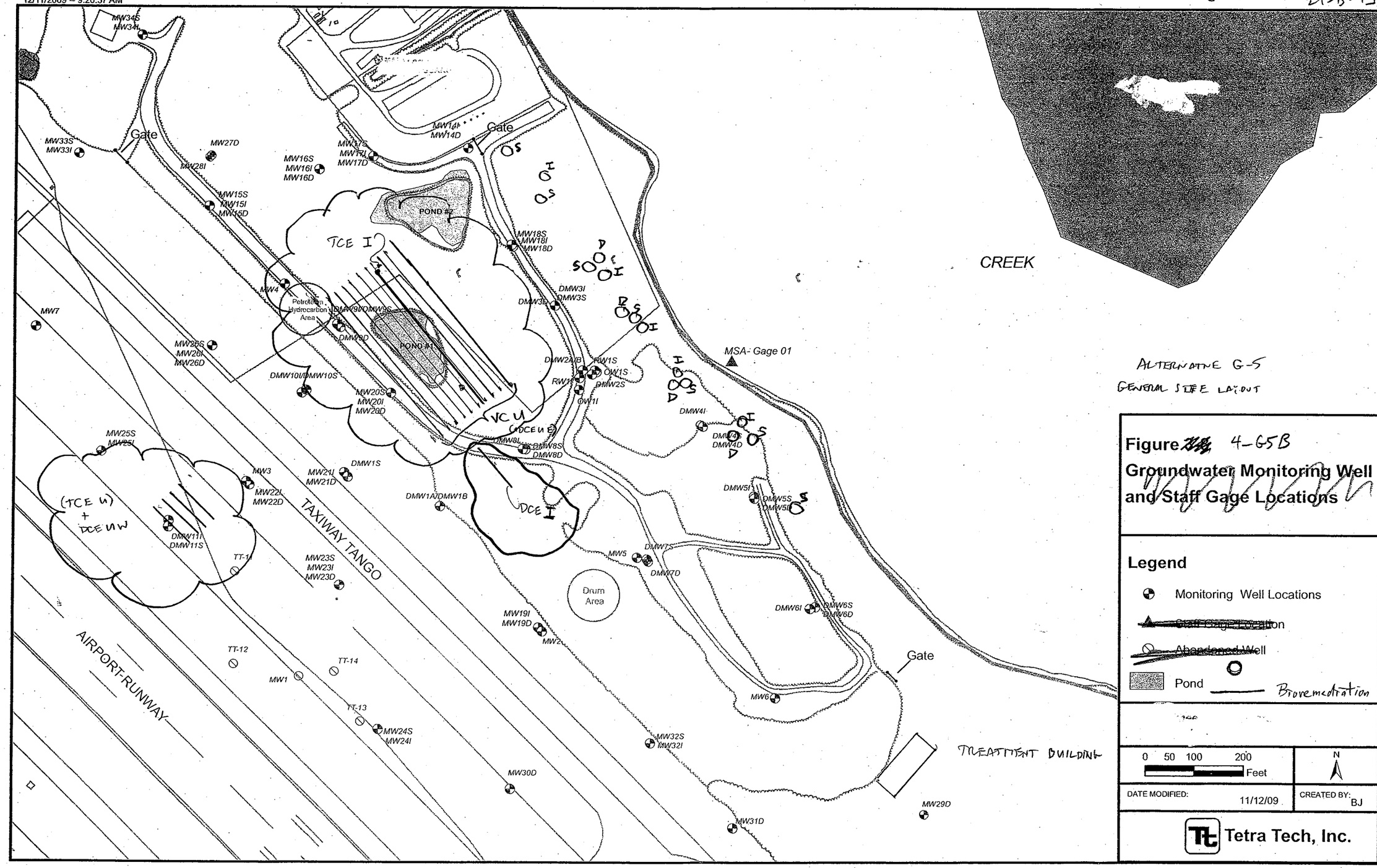
†Exclusive license agreement with Solutions-IES under U.S. Patent # 6,398,960, European Union Patent # EP 1 315 675 and several other pending international patents.
††EOS® is a registered trademark of EOS Remediation, Inc.

Map Document: (K:\GProject\...ad Fig 3-8_12 10 2009.mxd)
12/11/2009 -- 9:20:57 AM

Hydraulic Control Wells
- ISB Barrier lines.

G-5 [ISB-1]



SENT TO EOS

ALTERNATIVE G-5
GENERAL SITE LAYOUT

Figure 4-G5B
Groundwater Monitoring Well and Staff Gage Locations

Legend

- Monitoring Well Locations
- ~~Staff Gage Location~~
- ~~Abandoned Well~~
- Pond
- Bioremediation injection well lines

0 50 100 200 Feet

N

DATE MODIFIED: 11/12/09

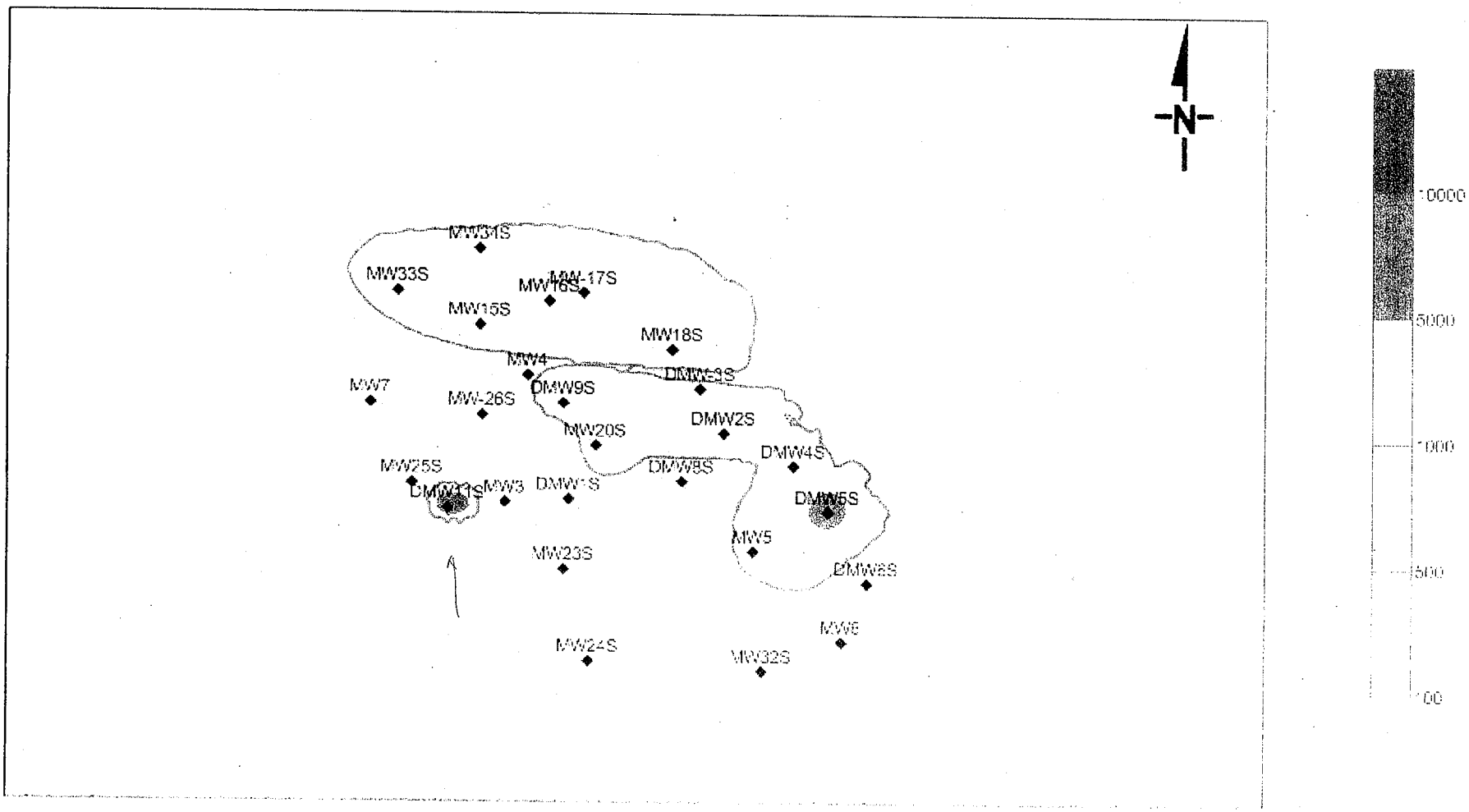
CREATED BY: BJ

Tetra Tech, Inc.

HIGH CONCENTRATION AREAS

JJB

TCE - Upper Surficial Aquifer



L
W

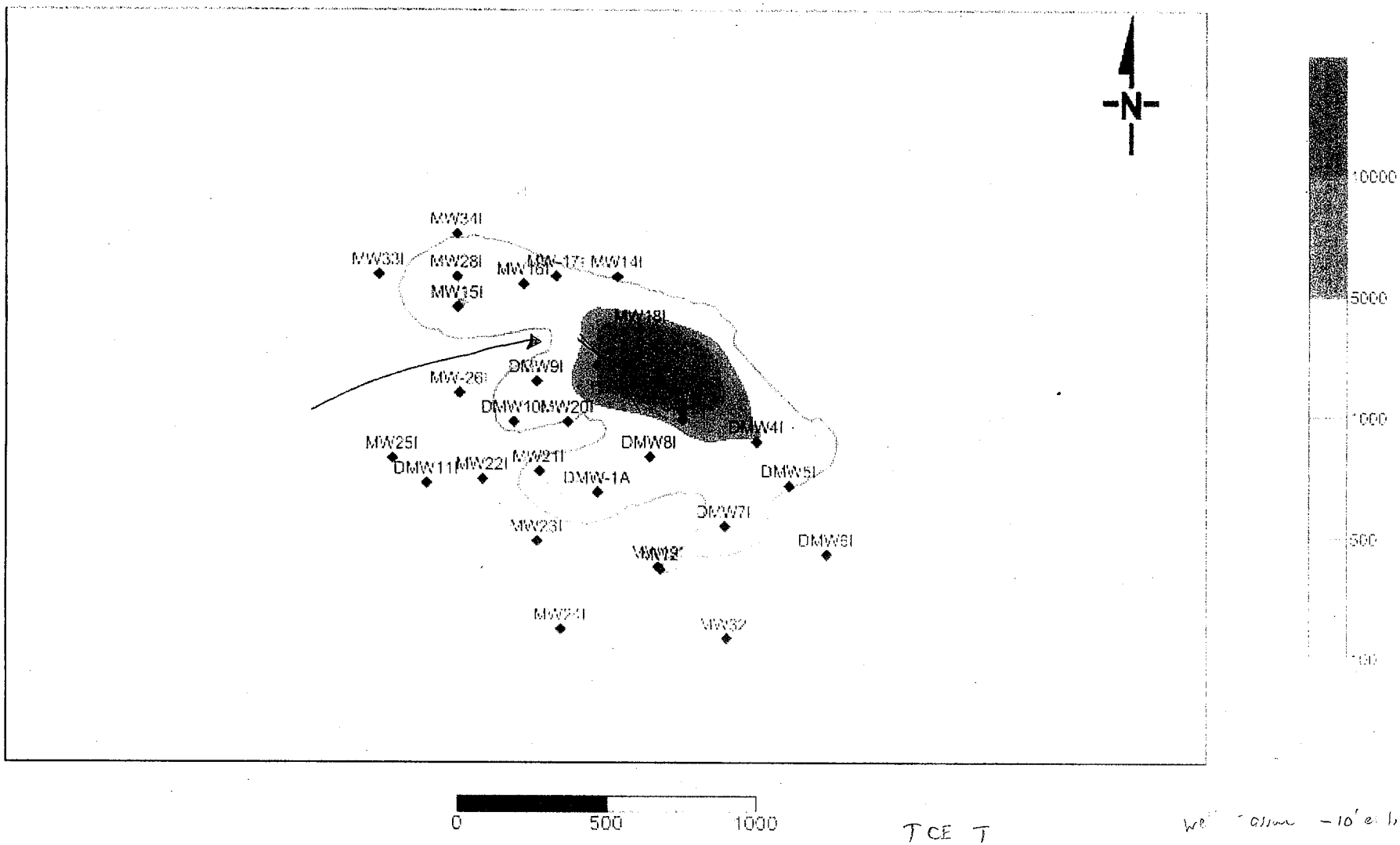
0 500 1000

TCE U
L 100'
W 100'

Based on MW 25
water [illegible] el 0 to el = 10
TD ~ 20

(4)

TCE - Intermediate Surficial Aquifer



TCE I

L 150'

W 350'

well assume -10' et b -30'

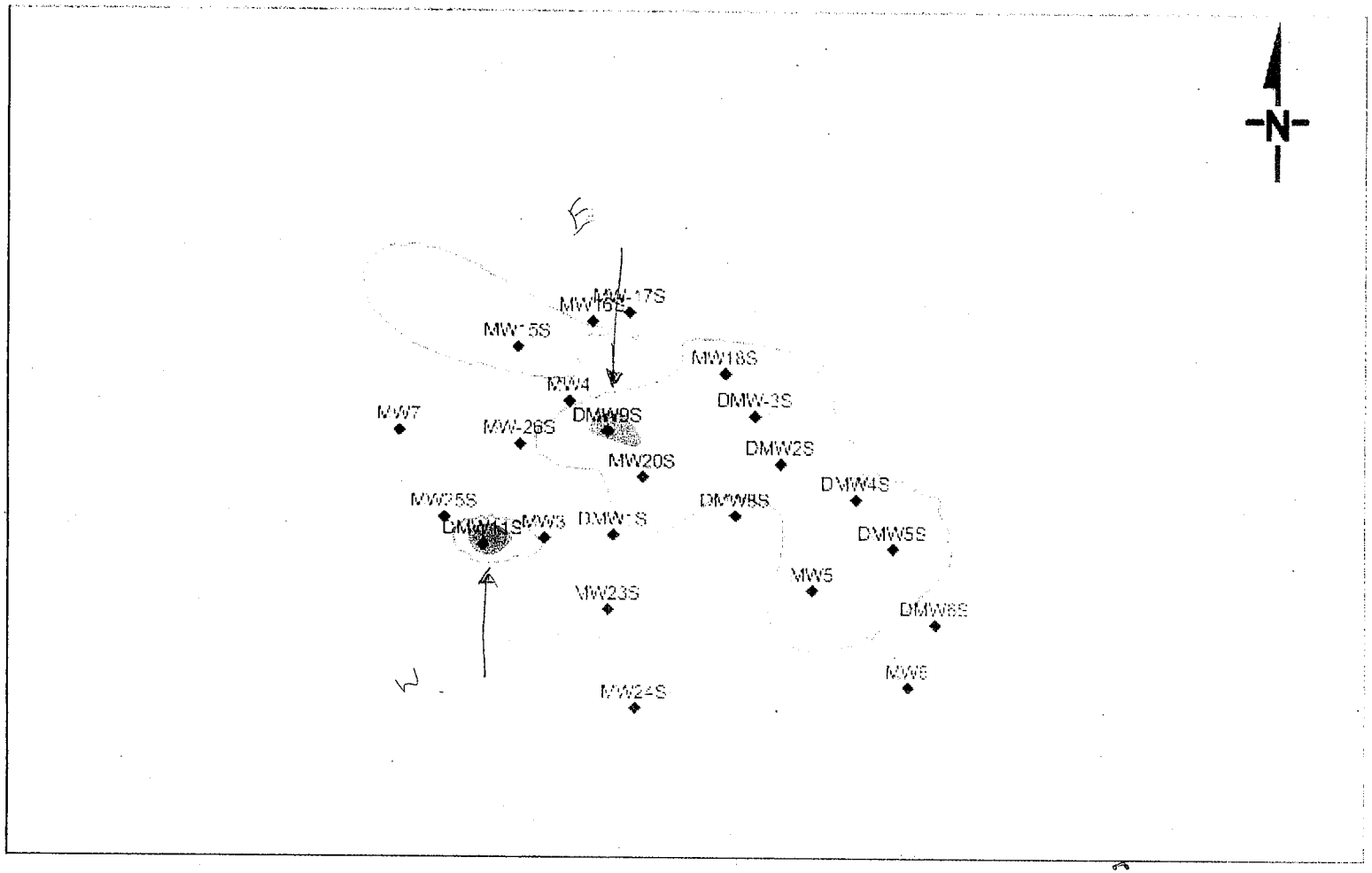
TD

~~8~~ 40'

From File

(1)

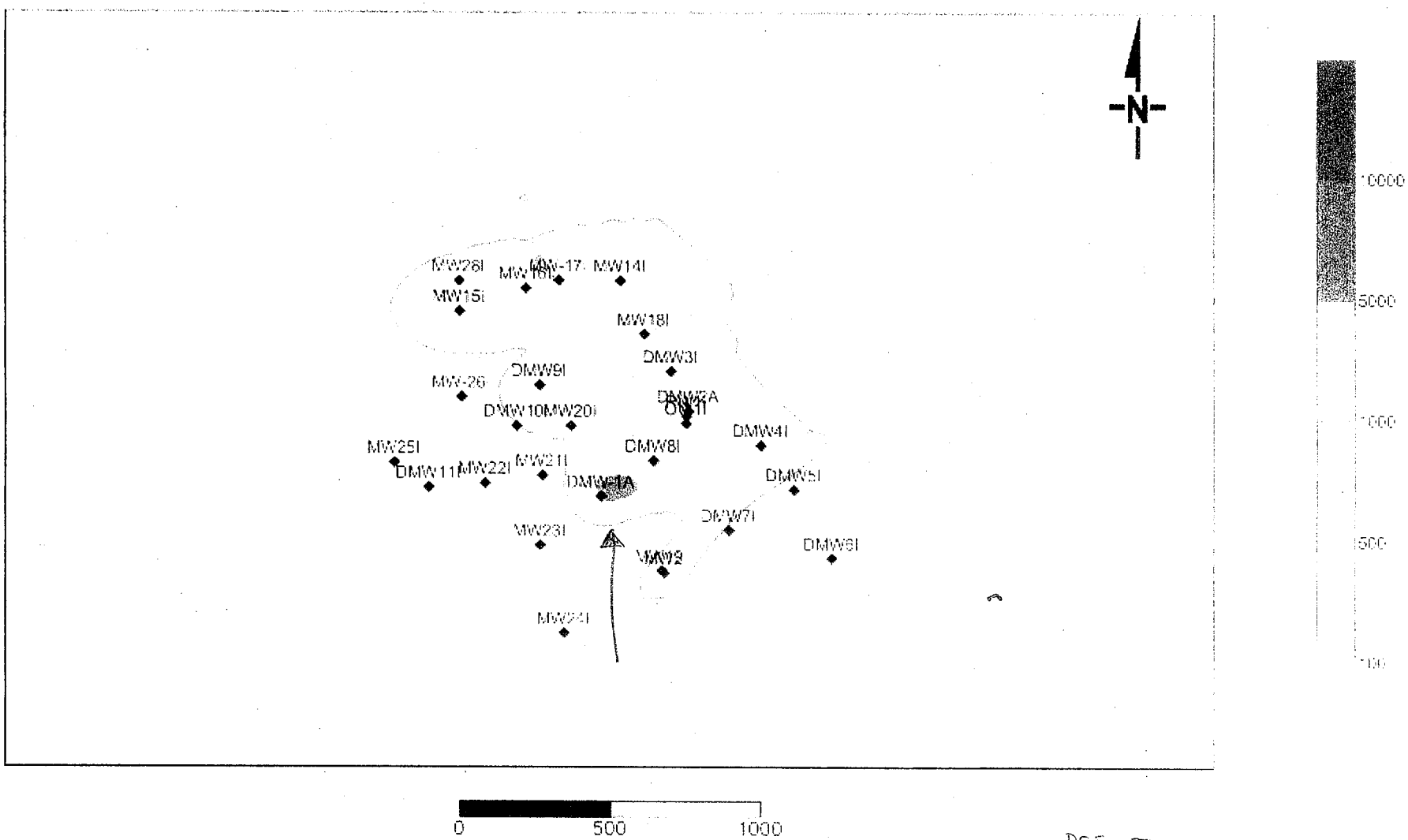
CIS-1,2-DCE - Upper Surficial Aquifer



DCE U - Bad Wet L - 100' W 150'

DCE M - FAIR L - 100' W 150'

CIS-1,2-DCE - Intermediate Surficial Aquifer



DCE I

L 150'

W 100'

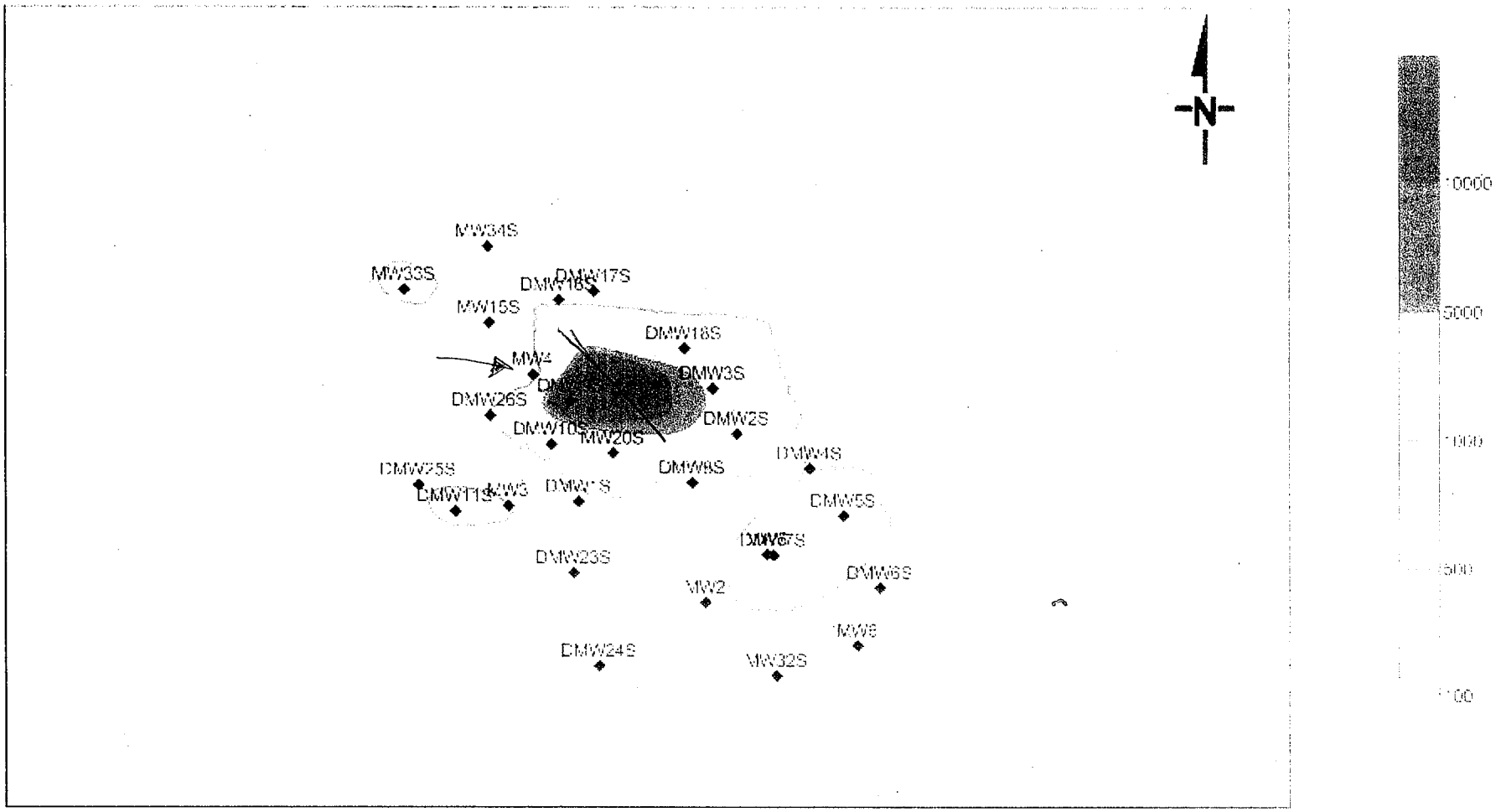
Assume

-39 ft h-sq ✓

✓ TD = 55' ✓

(1)

VINYL CHLORIDE - Upper Surficial Aquifer



VC - U

L 200'

W 400'

-10 elev 0 el

TD = 20'

(10)

From Fig

Logan, Joe

From: Mark Kluger [mkluger@dajak.com]
Sent: Friday, January 22, 2010 9:03 AM
To: Logan, Joe
Cc: Tim Parker; Gary Birk
Subject: RE: EOS/AquabupH estimate

Because AquaBupH contains less oil a pound than EOS 598B42, EOS Remediation typically recommends that you use 25% more AquaBupH than EOS 598B42. Thus, you would inject about 148,000 of AquaBupH into your matrix. The cost would be about $320,000 excluding shipping and taxes, if applicable.

dajak
Characterization & Remediation Technologies

Mark Kluger
302-655-6651 (office)
302-494-6050 (mobile)
www.dajak.com

From: Logan, Joe [mailto:Joe.Logan@tetratech.com]
Sent: Friday, January 22, 2010 7:42 AM
To: Mark Kluger
Subject: EOS/AquabupH estimate

Hi Mark

I used the EOS Tool to estimate a quantity of AquaBupH. (I used the EOS598B42 "setting". Please let me know if this is appropriate.)

My estimated total quantity is118,000 lb. (And this was in the same order of magnitude of the 1.5 - 2 lb/cy value that you suggested.)

What would be the cost for this. The site is in Maryland, near Baltimore.

Thanks

Joe

Joseph W. Logan, Jr. | **Process Engineer**
Direct: 412.921.7231 | Main: 412.921.7090 | Personal Fax: 412.921.4040
joe.logan@tetratech.com

Tetra Tech NUS, Inc. | Environmental Engineering
661 Andersen Drive Foster Plaza 7 | Pittsburgh, PA 15220 | www.ttnus.com

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No virus found in this incoming message.
Checked by AVG - www.avg.com
Version: 9.0.730 / Virus Database: 271.1.1/2637 - Release Date: 01/21/10 14:34:00

APPENDIX F
COST ESTIMATES

ALTERNATIVE F-2:

HYDRAULIC CONTROLS BY EXTRACTION, EX-SITU TREATMENT OF GROUNDWATER, DISCHARGE TO POTW, MONITORING, AND LUCS

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-2: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW, Monitoring, and LUCs
Capital Cost

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
1 PROJECT PLANNING & DOCUMENTS											
1.1 Bench Testing	1	ls	$30,000.00				$30,000	$0	$0	$0	$30,000
1.2 Land Finders Fee	1	ls	$100,000.00				$100,000	$0	$0	$0	$100,000
2 MOBILIZATION AND DEMOBILIZATION											
2.1 Site Support Facilities (trailers, phone, electric, etc.)	1	ls		$1,000.00		$3,500.00	$0	$1,000	$0	$3,500	$4,500
2.2 Equipment Mobilization/Demobilization								$40,000	$20,000	$40,000	$100,000
3 FIELD SUPPORT AND SITE ACCESS											
3.1 Office Trailer	12	mo				$360.00	$0	$0	$0	$4,320	$4,320
3.2 Field Office Equipment, Utilities, & Support	12	mo		$470.00			$0	$5,640	$0	$0	$5,640
3.3 Storage Trailer	12	mo				$92.50	$0	$0	$0	$1,110	$1,110
3.4 Survey Support	15	day	$1,075.00				$16,125	$0	$0	$0	$16,125
3.5 Site Superintendent	252	day		$164.00	$384.64		$0	$41,328	$96,929	$0	$138,257
3.5.1 Resident Engineering (1.5 persons)	0	day		$164.00	$307.68		$0	$0	$0	$0	$0
3.6 Site Health & Safety and QA/QC	252	day		$164.00	$307.68		$0	$41,328	$77,535	$0	$118,863
3.7 Underground Utility Clearance	1	ls	$10,000.00				$10,000	$0	$0	$0	$10,000
3.8 Access Road & Parking	500	sy		$15.50	$1.05	$1.94	$0	$7,750	$525	$970	$9,245
3.9 Clearing and Grubbing	3	acre	$10,000.00				$30,000	$0	$0	$0	$30,000
3.10 Directional Drill Under Taxiway Tango	0	ls	$50,000.00				$0	$0	$0	$0	$0
4 DECONTAMINATION											
4.1 Decontamination Services	12	mo		$1,220.00	$2,245.00	$1,550.00	$0	$14,640	$26,940	$18,600	$60,180
4.2 Temporary Equipment Decon Pad	1	ls		$1,500.00	$2,000.00	$300.00	$0	$1,500	$2,000	$300	$3,800
4.3 Decon Water	2,000	gal		$0.20			$0	$400	$0	$0	$400
4.4 Decon Water Storage Tank, 6,000 gallon	12	mo				$771.00	$0	$0	$0	$9,252	$9,252
4.5 Clean Water Storage Tank, 4,000 gallon	12	mo				$693.00	$0	$0	$0	$8,316	$8,316
4.6 Disposal of Decon Waste (liquid & solid)	12	mo	$985.00				$11,820	$0	$0	$0	$11,820
5 EXTRACTION SYSTEM											
5.1 Install Extraction Wells, 16 wells	930	lf	$100.00				$93,000	$0	$0	$0	$93,000
5.1.1 Well Development (1 day/well)	16	days	$1,500.00	$164.00	$307.68		$24,000	$2,624	$4,923	$0	$31,547
5.2 Extraction Well Head/Vault (incl controls and other det	16	ea	$5,000.00				$80,000	$0	$0	$0	$80,000
5.3 Insulate/Heat Trace Well Head, 16 wells	160	lf		$5.87	$3.89		$0	$939	$622	$0	$1,562
5.4 Submersible Pump w/ Controls, 0.5 hp	16	ea		$1,000.00	$236.00		$0	$16,000	$3,776	$0	$19,776
5.5 Well Piping, 1" dia. PVC Sch 80	930	lf		$1.70	$3.25		$0	$1,581	$3,023	$0	$4,604
5.6 Pump Station	1	ea		$30,000.00	$1,800.00	$400.00	$0	$30,000	$1,800	$400	$32,200
5.7 Pump Station Pumps, 50 gpm, 3 hp	2	ea		$781.20	$200.00		$0	$1,562	$400	$0	$1,962
5.8 Transfer Piping, 1" dia. PVC Sch 80, Double Wall	0	lf		$12.44	$15.69		$0	$0	$0	$0	$0
5.9 Transfer Piping Fittings, 1" dia. PVC Sch 80, Double W	0	ea		$124.40	$156.90		$0	$0	$0	$0	$0
5.10 Transfer Piping Valves, 1" dia. PVC Ball	0	ea		$30.30	$18.10		$0	$0	$0	$0	$0
5.11 Transfer Piping, 2" dia. PVC Sch 80, Double Wall	400	lf		$20.23	$20.88		$0	$8,092	$8,352	$0	$16,444
5.12 Transfer Piping Fittings, 2" dia. PVC Sch 80, Double W	128	ea		$202.30	$208.80		$0	$25,894	$26,726	$0	$52,621
5.13 Transfer Piping Valves, 2" dia. PVC Ball	64	ea		$70.50	$24.50		$0	$4,512	$1,568	$0	$6,080
5.14 Transfer Piping, 4" dia. PVC Sch 80, Double Wall	4,050	lf		$22.14	$31.72		$0	$89,667	$128,466	$0	$218,133
5.15 Transfer Piping Fittings, 4" dia. PVC Sch 80, Double W	128	ea		$221.40	$317.20		$0	$28,339	$40,602	$0	$68,941
5.16 Transfer Piping Valves, 4" dia. PVC Ball	4	ea		$610.00	$37.50		$0	$2,440	$150	$0	$2,590
5.17 Backhoe/Loader	40	day			$343.60	$387.60	$0	$0	$13,744	$15,504	$29,248
5.18 Site Labor (3 laborers)	120	day			$264.80		$0	$0	$31,776	$0	$31,776
6 TREATMENT SYSTEM											
6.1 Equipment Building, 155' by 65'	7,800	sf	$125.00				$975,000	$0	$0	$0	$975,000
6.2 Property Acquisition	26,875	sf	$20.00				$537,500	$0	$0	$0	$537,500
6.3 Equipment Building Foundation	179	cy	$400.00				$71,600	$0	$0	$0	$71,600
6.4 Water Supply Pipe, 2" Polyetheylene	300	lf		$2.49	$5.06	$1.17	$0	$747	$1,518	$351	$2,616
6.5 Water Supply Valves & Meters	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
6.6 Feed Tank, 10,200 gallons	1	ea		$15,300.00	$1,440.00		$0	$15,300	$1,440	$0	$16,740
6.7 Feed Tank Foundation	5	cy	$400.00				$2,000	$0	$0	$0	$2,000
6.8 Feed Tank Mixer, 10 hp	1	ea		$6,600.00	$1,245.00		$0	$6,600	$1,245	$0	$7,845
6.9 Feed Pump, 50 gpm, 1.5 hp	2	ea		$781.20	$200.00		$0	$1,562	$400	$0	$1,962
6.10 Piping, 2" PVC Sch 80	300	lf		$3.93	$13.65		$0	$1,179	$4,095	$0	$5,274
6.11 Pipe Fittings, 2" PVC Sch 80	50	ea		$39.30	$136.50		$0	$1,965	$6,825	$0	$8,790
6.12 Piping Valves, 2" dia. PVC Ball	20	ea		$76.50	$24.50		$0	$1,530	$490	$0	$2,020
6.13 Piping, 4" PVC Sch 80	1,600	lf		$11.15	$16.30		$0	$17,840	$26,080	$0	$43,920
6.14 Pipe Fittings, 4" PVC Sch 80	300	ea		$111.50	$163.00		$0	$33,450	$48,900	$0	$82,350
6.15 Piping Valves, 4" dia. PVC Butterfly	120	ea		$733.26	$43.00		$0	$87,991	$5,160	$0	$93,151
6.16 Piping, 6" PVC Sch 80	100	lf		$24.50	$19.75		$0	$2,450	$1,975	$0	$4,425
6.17 Pipe Fittings, 6" PVC Sch 80	10	ea		$245.00	$197.50		$0	$2,450	$1,975	$0	$4,425
6.18 Piping Valves, 6" dia. PVC Butterfly	5	ea		$879.94	$65.00		$0	$4,400	$325	$0	$4,725
6.19 Air Stripper Piping	100	lf		$24.50	$19.75		$0	$2,450	$1,975	$0	$4,425
6.20 Air Stripper Fittings	20	ea		$245.00	$197.50		$0	$4,900	$3,950	$0	$8,850
6.21 Air Stripper Valves	10	ea		$879.94	$65.00		$0	$8,799	$650	$0	$9,449
Metals Removal Package	1	ls		$293,000.00	$134,032.50		$0	$293,000	$134,033	$0	$427,033
- Primary pH Adjustment Tank, 600 gallons	1	ea									
- Primary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- Secondary pH Adjustment Tank, 600 gallons	1	ea									
- Secondary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- H2O2 Feed System, 20 lb/day	1	ea									
- NaOH Feed System, 24 lb/day; 5 gal/day	1	ea									
- Floc Tank, 400 gallons	1	ea									
- Floc Mixer, 0.5 hp	1	ea									
- Polymer Feed system, 6 lb/day	1	ea									
- Clarifier, 2,000 gallons	1	ea									
- Sludge Transfer Pump, 15 gpm, AODD	2	ea									
- Final pH Adjustment Tank, 1,000 gallons	1	ea									
- Final pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- Acid (HCl) Feed System, 22 lb/day: 6.3 gal/day	1	ea									
- Clarified Water Feed Tank, 750 gallons	1	ea									
- SF Feed Pump, 50 gpm, 5 hp	2	ea									
- Sand Filter, 2.5' dia. by 6' high	3	ea									
- Cartridges Filters, 10 micron	2	ea									
- Thickener, 12' dia. by 15' high	1	ea									
- FP Feed Pump, 60 gpm, AODD	2	ea									
- Filter Press, 130 cf	1	ea									
6.22 Air Stripper, 6 Tray, 420 cfm	1	ea		$35,000.00	$3,500.00		$0	$35,000	$3,500	$0	$38,500
6.23 Air Stripper Effluent Pump, 50 gpm, 3 hp	2	ea		$781.20	$200.00		$0	$1,562	$400	$0	$1,962
6.24 Vapor-Phase GAC System	2	ea		$5,000.00	$1,200.00		$0	$10,000	$2,400	$0	$12,400
6.25 PPI Zeolite System	2	ea		$2,000.00	$500.00		$0	$4,000	$1,000	$0	$5,000
6.26 HiPOx System	1	ea		$280,000.00	$1,360.00		$0	$280,000	$1,360	$0	$281,360
6.27 Ion Exchange System, 60 cf resin; 450 gallons	2	ea		$2,700.00	$0.00		$0	$5,400	$0	$0	$5,400
6.28 Liquid Phase GAC System, 4,000 lbs.	2	ea		$28,000.00	$2,076.00		$0	$56,000	$4,152	$0	$60,152
6.29 Backwash Supply Tank, 4,500 gallons	1	ea		$6,750.00	$750.00		$0	$6,750	$750	$0	$7,500
6.30 Backwash Supply Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.31 Backwash Pump, 40 gpm, 1 hp	2	ea		$735.00	$122.00		$0	$1,470	$244	$0	$1,714
6.32 Waste Backwash Tank, 4,500 gallon	1	ea		$6,750.00	$750.00		$0	$6,750	$750	$0	$7,500
6.33 Waste Backwash Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.34 Waste Backwash Transfer Pump, 1 gpm, 0.5 hp	2	ea		$339.60	$84.00		$0	$679	$168	$0	$847
6.35 Filtrate Tank, 4,700 gallons	1	ea		$7,050.00	$698.00		$0	$7,050	$698	$0	$7,748
6.36 Filtrate Tank Foundation	4	cy	$400.00				$1,600	$0	$0	$0	$1,600
6.37 Filtrate Tank Mixer, 5 hp	1	ea		$5,500.00	$1,073.00		$0	$5,500	$1,073	$0	$6,573
6.38 Filtrate Transfer Pump, 15 gpm, 0.5 hp	2	ea		$339.60	$84.00		$0	$679	$168	$0	$847
6.39 Air Compressor System, 50 scfm, 100 psi	1	ea		$8,900.00	$1,450.00		$0	$8,900	$1,450	$0	$10,350
6.40 Sump Pump, 10 gpm, 0.5 hp	2	ea		$283.20	$83.50		$0	$566	$167	$0	$733
6.41 Discharge Pump Tank, 750 gallons	0	ea		$1,500.00	$163.00		$0	$0	$0	$0	$0
6.42 Discharge Pump, 50 gpm, 1.5 hp	0	ea		$535.20	$133.00		$0	$0	$0	$0	$0
6.43 ED Tank, 500 gallon	0	ea		$1,225.00	$311.40		$0	$0	$0	$0	$0
6.44 ED Tank Mixer & Stand, 0.5 hp	0	ea		$1,666.00	$415.20		$0	$0	$0	$0	$0
6.45 ED Feed Pump, 4 gallons/hr	0	ea		$1,500.00	$415.20		$0	$0	$0	$0	$0
6.46 Discharge Pipe (POTW and SW), 4" Polyetheylene	800	lf		$11.00	$16.00	$1.17	$0	$8,800	$12,800	$936	$22,536
6.47 Outfall Diffuser	1	ls	$50,000.00				$50,000	$0	$0	$0	$50,000
6.48 Utility Service Line	1	ls		$59,808.50	$15,691.40		$0	$59,809	$15,691	$0	$75,500
6.49 Electrical and Controls	1	ls		$223,785.00	$109,790.00		$0	$223,785	$109,790	$0	$333,575
6.50 System Start-Up and Testing	1	ls		$3,000.00	$65,550.00		$0	$3,000	$65,550	$0	$68,550
7 MONITORING WELL INSTALLATION											
7.1 Well Installation (4 wells)	290	lf	$45.00				$13,050	$0	$0	$0	$13,050
7.2 Protective Well Casing & Apron	4	ea	$750.00				$3,000	$0	$0	$0	$3,000
8 INJECTION WELLS											
8.1 Well Installation (6 wells)	0	lf	$100.00				$0	$0	$0	$0	$0
8.2 Injection Well Head/Vault (incl controls and other detai	0	ea	$5,000.00				$0	$0	$0	$0	$0

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-2: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW, Monitoring, and LUCs
Capital Cost

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
8.3 Main Header Pipe, 2" PVC	0	lf		$1.97	$5.64		$0	$0	$0	$0	$0
8.4 Main Header Pipe Fittings, 2" PVC	0	ea		$19.70	$56.40		$0	$0	$0	$0	$0
8.5 Piping Valves, 2" dia. PVC Ball	0	ea		$76.50	$24.50		$0	$0	$0	$0	$0
8.6 Well Piping, 1" dia. PVC	0	lf		$0.76	$2.35		$0	$0	$0	$0	$0
8.7 Pipe Fittings, 2" PVC	0	ea		$7.60	$23.50		$0	$0	$0	$0	$0
8.8 Piping Valves, 1" dia. PVC Ball	0	ea		$30.30	$18.10		$0	$0	$0	$0	$0
9 WASTE DISPOSAL											
9.1 Decon Fluids	1,100	gal	$1.00				$1,100	$0	$0	$0	$1,100
9.2 Well Development Water (5,000 gal/well)	80,000	gal	$1.00				$80,000	$0	$0	$0	$80,000
9.3 Drill Cuttings (12-inch dia boreholes, non-haz)	25	cy	$100.00				$2,500	$0	$0	$0	$2,500
9.4 Soil Excavate (2700 lf, 3'x4' trench, non-haz)	880	cy	$100.00				$88,000	$0	$0	$0	$88,000
10 IMPORTED CLEAN FILL											
10.1 Import and place clean backfill	880	cy	$25.00				$22,000	$0	$0	$0	$22,000
10.2 Stabilize and restore disturbed areas (3 acres)	101,000	sy	$8.00				$808,000	$0	$0	$0	$808,000
Subtotal							$3,055,695	$1,577,552	$953,004	$103,559	$5,689,810
Overhead on Labor Cost @ 30%									$285,901		$285,901
G & A on Labor, Material, Equipment, & Subs Cost @ 10%							$305,570	$157,755	$95,300	$10,356	$568,981
Tax on Materials and Equipment Cost @ 6%								$94,653		$6,214	$100,867
Total Direct Cost							$3,361,265	$1,829,960	$1,334,206	$120,128	$6,645,559
Indirects on Total Direct Cost @ 25%											$1,661,390
Profit on Total Direct Cost @ 10%											$664,556
Subtotal											$8,971,504
Health & Safety Monitoring @ 2%											$179,430
Subtotal											$9,150,935
Record Drawings and Completion Report 1%											$91,509
Feasibility Study Level Costs											$9,242,444
Design Cost											$831,820
Engineering Contingency 20%											$1,848,489

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site

Alternative G-2: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 1 through 5

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$87,718	$87,718	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	8,000	lbs	$2.00	$16,000	
4	Vapor Phase GAC Replacement	48,000	lbs	$2.00	$96,000	
5	PPI Zeolite Replacement	36,000	lbs	$2.25	$81,000	
6	PPI Zeolite Disposal	18	ton	$66.00	$1,188	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (12 lbs/day)	4,380	lbs	$2.00	$8,760	
	b) NaOH (220 lbs/day)	80,300	lbs	$0.35	$28,105	
	c) Polymer (6 lbs/day)	2,190	lbs	$1.00	$2,190	
	d) Hydrochloric Acid (22 lbs/day)	8,030	lbs	$0.80	$6,424	
	e) Hydrogen Peroxide - HiPOx (2.1 gal/day)	1,059	gal	$3.50	$3,705	
8	Sludge Disposal	86	ton	$65.00	$5,590	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	3513	1K cf	$35.89	$126,082	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	1	year	$3,000.00	$3,000	
11	Sanitary Sewer Analysis	2	ea	$450.00	$900	
12	NPDES Analysis	0	ea	$350.00	$0	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	0	year	$24,000.00	$0	
	b) resin	0	year	$35,000.00	$0	
14	Cartridge Filters, 25 micron	0	ea	$3.91	$0	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$739,661**	

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site

Alternative G-2: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 6 through 10

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$87,718	$87,718	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	6,000	lbs	$2.00	$12,000	
4	Vapor Phase GAC Replacement	36,000	lbs	$2.00	$72,000	
5	PPI Zeolite Replacement	27,000	lbs	$2.25	$60,750	
6	PPI Zeolite Disposal	13.5	ton	$66.00	$891	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (9 lbs/day)	3,285	lbs	$2.00	$6,570	
	b) NaOH (165 lbs/day)	60,225	lbs	$0.35	$21,079	
	c) Polymer (5 lbs/day)	1,643	lbs	$1.00	$1,643	
	d) Hydrochloric Acid (17 lbs/day)	6,023	lbs	$0.80	$4,818	
	e) Hydrogen Peroxide - HiPOx (1.6 gal/day)	794	gal	$3.50	$2,779	
8	Sludge Disposal	65	ton	$65.00	$4,225	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$18,000.00	$18,000	
	b) resin	1	year	$26,250.00	$26,250	
14	Cartridge Filters, 25 micron	98	ea	$3.91	$383	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$596,305**	

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site

Alternative G-2: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 11 through 30

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$87,718	$87,718	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	4,000	lbs	$2.00	$8,000	
4	Vapor Phase GAC Replacement	24,000	lbs	$2.00	$48,000	
5	PPI Zeolite Replacement	18,000	lbs	$2.25	$40,500	
6	PPI Zeolite Disposal	9	ton	$66.00	$594	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (6 lbs/day)	2,190	lbs	$2.00	$4,380	
	b) NaOH (110 lbs/day)	40,150	lbs	$0.35	$14,053	
	c) Polymer (3 lbs/day)	1,095	lbs	$1.00	$1,095	
	d) Hydrochloric Acid (11 lbs/day)	4,015	lbs	$0.80	$3,212	
	e) Hydrogen Peroxide - HiPOx (1.0 gal/day)	529	gal	$3.50	$1,852	
8	Sludge Disposal	43	ton	$65.00	$2,795	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$12,000.00	$12,000	
	b) resin	1	year	$17,500.00	$17,500	
14	Cartridge Filters, 25 micron	65	ea	$3.91	$254	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$519,153**	

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-2: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW, Monitoring, and LUCs

Annual Cost

Item	Item Cost year 1	Item Cost years 2 - 3	Item Cost years 4 - 30	Notes
Site Inspection: Visit	$1,620	$1,620	$1,620	One-day visit to verify LUC RD
Site Inspection: Report	$1,680	$1,680	$1,680	
Groundwater Sampling	$57,440	$28,720	$14,360	Labor and supplies to collect samples from 40 wells using a crew of two, quarterly year 1, semi-annual years 2 & 3, annual years 4-30.
Groundwater Sampling Analysis/Water	$61,600	$30,800	$15,400	Analyze groundwater samples
Sampling Report	$33,600	$16,800	$8,400	
TOTAL	**$155,940**	**$79,620**	**$41,460**	

LOCKHEED MARTIN
Martin State Airport
Dump Road Area Site
Middle River, Maryland

Alternative G-2: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Discharge to POTW, Monitoring, and LUCs

Present Worth Analysis

Year	Capital Cost	Operation & Maintenance Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth	Current Value 2% inflation
0	$11,922,753			$11,922,753	1.000	$11,922,753	11,922,753
1		$739,661	$155,940	$895,601	0.935	$837,387	913,513
2		$739,661	$79,620	$819,281	0.873	$715,232	852,380
3		$739,661	$79,620	$819,281	0.816	$668,533	869,428
4		$739,661	$41,460	$781,121	0.763	$595,995	845,511
5		$739,661	$41,460	$781,121	0.713	$556,939	862,421
6		$596,305	$41,460	$637,765	0.666	$424,751	718,227
7		$596,305	$41,460	$637,765	0.623	$397,328	732,591
8		$596,305	$41,460	$637,765	0.582	$371,179	747,243
9		$596,305	$41,460	$637,765	0.544	$346,944	762,188
10		$596,305	$41,460	$637,765	0.508	$323,985	777,432
11		$519,153	$41,460	$560,613	0.475	$266,291	697,052
12		$519,153	$41,460	$560,613	0.444	$248,912	710,993
13		$519,153	$41,460	$560,613	0.415	$232,654	725,213
14		$519,153	$41,460	$560,613	0.388	$217,518	739,717
15		$519,153	$41,460	$560,613	0.362	$202,942	754,511
16		$519,153	$41,460	$560,613	0.339	$190,048	769,601
17		$519,153	$41,460	$560,613	0.317	$177,714	784,993
18		$519,153	$41,460	$560,613	0.296	$165,941	800,693
19		$519,153	$41,460	$560,613	0.277	$155,290	816,707
20		$519,153	$41,460	$560,613	0.258	$144,638	833,041
21		$519,153	$41,460	$560,613	0.242	$135,668	849,702
22		$519,153	$41,460	$560,613	0.226	$126,699	866,696
23		$519,153	$41,460	$560,613	0.211	$118,289	884,030
24		$519,153	$41,460	$560,613	0.197	$110,441	901,711
25		$519,153	$41,460	$560,613	0.184	$103,153	919,745
26		$519,153	$41,460	$560,613	0.172	$96,425	938,140
27		$519,153	$41,460	$560,613	0.161	$90,259	956,903
28		$519,153	$41,460	$560,613	0.150	$84,092	976,041
29		$519,153	$41,460	$560,613	0.141	$79,046	995,561
30		$519,153	$41,460	$560,613	0.131	$73,440	1,015,473
		$17,062,889	$1,434,600				36,940,210

TOTAL PRESENT WORTH $20,180,489

Dump Road Area Groundwater Containment System Design Costs

Feasibility Study Level Capital Costs (Excluding Contingency)	$9,242,444
Total Design Costs @ 9% of FS Level Capital Costs *(excluding contingency)*	$831,820
30% Design Cost (Procurement EESHBDF-02384_R631) @ 26% of Line 6	$216,273
60% Design Cost @ 44% of line 6	$366,001
90% Design Cost @ 20% of line 6	$166,364
100% Design Cost @ 10% of line 6	$83,182

ALTERNATIVE F-3:

HYDRAULIC CONTROLS BY EXTRACTION, EX-SITU TREATMENT OF GROUNDWATER, RE-INJECTION OF GROUNDWATER, DISCHARGE TO POTW, MONITORING, AND LUCS

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-3: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Capital Cost

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Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
1 PROJECT PLANNING & DOCUMENTS											
1.1 Bench Testing	1	ls	$30,000.00				$30,000	$0	$0	$0	$30,000
1.2 Land Finders Fee	1	ls	$100,000.00				$100,000	$0	$0	$0	$100,000
2 MOBILIZATION AND DEMOBILIZATION											
2.1 Site Support Facilities (trailers, phone, electric, etc.)	1	ls		$1,000.00		$3,500.00	$0	$1,000	$0	$3,500	$4,500
2.2 Equipment Mobilization/Demobilization								$40,000	$30,000	$40,000	$110,000
3 FIELD SUPPORT AND SITE ACCESS											
3.1 Office Trailer	12	mo				$360.00	$0	$0	$0	$4,320	$4,320
3.2 Field Office Equipment, Utilities, & Support	12	mo		$470.00			$0	$5,640	$0	$0	$5,640
3.3 Storage Trailer	12	mo				$92.50	$0	$0	$0	$1,110	$1,110
3.4 Survey Support	15	day	$1,075.00				$16,125	$0	$0	$0	$16,125
3.5 Site Superintendent	252	day		$164.00	$384.64		$0	$41,328	$96,929	$0	$138,257
3.5.1 Resident Engineering (1.5 persons)	0	day		$164.00	$307.68		$0	$0	$0	$0	$0
3.6 Site Health & Safety and QA/QC	252	day		$164.00	$307.68		$0	$41,328	$77,535	$0	$118,863
3.7 Underground Utility Clearance	1	ls	$10,000.00				$10,000	$0	$0	$0	$10,000
3.8 Access Road & Parking	500	sy		$15.50	$1.05	$1.94	$0	$7,750	$525	$970	$9,245
3.9 Clearing and Grubbing	3	acre	$10,000.00				$30,000	$0	$0	$0	$30,000
3.10 Directional Drill Under Taxiway Tango	1	ls	$50,000.00				$50,000	$0	$0	$0	$50,000
4 DECONTAMINATION											
4.1 Decontamination Services	12	mo		$1,220.00	$2,245.00	$1,550.00	$0	$14,640	$26,940	$18,600	$60,180
4.2 Temporary Equipment Decon Pad	1	ls		$1,500.00	$2,000.00	$300.00	$0	$1,500	$2,000	$300	$3,800
4.3 Decon Water	2,000	gal		$0.20			$0	$400	$0	$0	$400
4.4 Decon Water Storage Tank, 6,000 gallon	12	mo				$771.00	$0	$0	$0	$9,252	$9,252
4.5 Clean Water Storage Tank, 4,000 gallon	12	mo				$693.00	$0	$0	$0	$8,316	$8,316
4.6 Disposal of Decon Waste (liquid & solid)	12	mo	$985.00				$11,820	$0	$0	$0	$11,820
5 EXTRACTION SYSTEM											
5.1 Install Extraction Wells, 16 wells	930	lf	$100.00				$93,000	$0	$0	$0	$93,000
5.1.1 Well Development (1 day/well)	16	days	$1,500.00	$164.00	$307.68		$24,000	$2,624	$4,923	$0	$31,547
5.2 Extraction Well Head/Vault (incl controls and other det	16	ea	$5,000.00				$80,000	$0	$0	$0	$80,000
5.3 Insulate/Heat Trace Well Head, 16 wells	160	lf		$5.87	$3.89		$0	$939	$622	$0	$1,562
5.4 Submersible Pump w/ Controls, 0.5 hp	16	ea		$1,000.00	$236.00		$0	$16,000	$3,776	$0	$19,776
5.5 Well Piping, 1" dia. PVC Sch 80	930	lf		$1.70	$3.25		$0	$1,581	$3,023	$0	$4,604
5.6 Pump Station	1	ea		$30,000.00	$1,800.00	$400.00	$0	$30,000	$1,800	$400	$32,200
5.7 Pump Station Pumps, 100 gpm, 3 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
5.8 Transfer Piping, 1" dia. PVC Sch 80, Double Wall	0	lf		$12.44	$15.69		$0	$0	$0	$0	$0
5.9 Transfer Piping Fittings, 1" dia. PVC Sch 80, Double W	0	ea		$124.40	$156.90		$0	$0	$0	$0	$0
5.10 Transfer Piping Valves, 1" dia. PVC Ball	0	ea		$30.30	$18.10		$0	$0	$0	$0	$0
5.11 Transfer Piping, 2" dia. PVC Sch 80, Double Wall	400	lf		$20.23	$20.88		$0	$8,092	$8,352	$0	$16,444
5.12 Transfer Piping Fittings, 2" dia. PVC Sch 80, Double W	128	ea		$202.30	$208.80		$0	$25,894	$26,726	$0	$52,621
5.13 Transfer Piping Valves, 2" dia. PVC Ball	64	ea		$70.50	$24.50		$0	$4,512	$1,568	$0	$6,080
5.14 Transfer Piping, 4" dia. PVC Sch 80, Double Wall	4,050	lf		$22.14	$31.72		$0	$89,667	$128,466	$0	$218,133
5.15 Transfer Piping Fittings, 4" dia. PVC Sch 80, Double W	128	ea		$221.40	$317.20		$0	$28,339	$40,602	$0	$68,941
5.16 Transfer Piping Valves, 4" dia. PVC Ball	4	ea		$610.00	$37.50		$0	$2,440	$150	$0	$2,590
5.17 Backhoe/Loader	40	day			$343.60	$387.60	$0	$0	$13,744	$15,504	$29,248
5.18 Site Labor (3 laborers)	120	day			$264.80		$0	$0	$31,776	$0	$31,776
6 TREATMENT SYSTEM											
6.1 Equipment Building, 155' by 65'	10,075	sf	$125.00				$1,259,375	$0	$0	$0	$1,259,375
6.2 Property Acquisition	26,875	sf	$20.00				$537,500	$0	$0	$0	$537,500
6.3 Equipment Building Foundation	256	cy	$400.00				$102,400	$0	$0	$0	$102,400
6.4 Water Supply Pipe, 2" Polyetheylene	300	lf		$2.49	$5.06	$1.17	$0	$747	$1,518	$351	$2,616
6.5 Water Supply Valves & Meters	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
6.6 Feed Tank, 23,000 gallons	1	ea		$30,000.00	$3,200.00		$0	$30,000	$3,200	$0	$33,200
6.7 Feed Tank Foundation	6	cy	$400.00				$2,400	$0	$0	$0	$2,400
6.8 Feed Tank Mixer, 15 hp	1	ea		$8,200.00	$1,465.00		$0	$8,200	$1,465	$0	$9,665
6.9 Feed Pump, 100 gpm, 1.5 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
6.10 Piping, 2" PVC Sch 80	300	lf		$3.93	$13.65		$0	$1,179	$4,095	$0	$5,274
6.11 Pipe Fittings, 2" PVC Sch 80	50	ea		$39.30	$136.50		$0	$1,965	$6,825	$0	$8,790
6.12 Piping Valves, 2" dia. PVC Ball	20	ea		$76.50	$24.50		$0	$1,530	$490	$0	$2,020
6.13 Piping, 4" PVC Sch 80	1,600	lf		$11.15	$16.30		$0	$17,840	$26,080	$0	$43,920
6.14 Pipe Fittings, 4" PVC Sch 80	300	ea		$111.50	$163.00		$0	$33,450	$48,900	$0	$82,350
6.15 Piping Valves, 4" dia. PVC Butterfly	120	ea		$733.26	$43.00		$0	$87,991	$5,160	$0	$93,151
6.16 Piping, 6" PVC Sch 80	100	lf		$24.50	$19.75		$0	$2,450	$1,975	$0	$4,425
6.17 Pipe Fittings, 6" PVC Sch 80	10	ea		$245.00	$197.50		$0	$2,450	$1,975	$0	$4,425
6.18 Piping Valves, 6" dia. PVC Butterfly	5	ea		$879.94	$65.00		$0	$4,400	$325	$0	$4,725
6.19 Air Stripper Piping	100	lf		$29.40	$19.75		$0	$2,940	$1,975	$0	$4,915
6.20 Air Stripper Fittings	20	ea		$352.80	$197.50		$0	$7,056	$3,950	$0	$11,006
6.21 Air Stripper Valves	10	ea		$1,055.93	$65.00		$0	$10,559	$650	$0	$11,209
Metals Removal Package	1	ls		$347,000.00	$134,032.50		$0	$347,000	$134,033	$0	$481,033
- Primary pH Adjustment Tank, 1,100 gallons	1	ea									
- Primary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- Secondary pH Adjustment Tank, 1,100 gallons	1	ea									
- Secondary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- H2O2 Feed System, 32 lb/day	1	ea									
- NaOH Feed System, 38 lb/day; 8 gal/day	1	ea									
- Floc Tank, 770 gallons	1	ea									
- Floc Mixer, 0.5 hp	1	ea									
- Polymer Feed system, 10 lb/day	1	ea									
- Clarifier, 3,700 gallons	1	ea									
- Sludge Transfer Pump, 15 gpm, AODD	2	ea									
- Final pH Adjustment Tank, 1,500 gallons	1	ea									
- Final pH Adjustment Tank Mixer, 1 hp	1	ea									
- Acid (HCl) Feed System, 35 lb/day: 10 gal/day	1	ea									
- Clarified Water Feed Tank, 1,100 gallons	1	ea									
- SF Feed Pump, 80 gpm, 5 hp	2	ea									
- Sand Filter, 2.5' dia. by 6' high	3	ea									
- Cartridges Filters, 10 micron	2	ea									
- Thickener, 14' dia. by 12' high	1	ea									
- FP Feed Pump, 80 gpm, AODD	2	ea									
6.22 - Filter Press, 130 cf	1	ea									
6.23 Air Stripper, 6 Tray, 850 cfm	1	ea		$55,000.00	$4,000.00		$0	$55,000	$4,000	$0	$59,000
6.24 Air Stripper Effluent Pump, 100 gpm, 3 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
6.25 Vapor-Phase GAC System	2	ea		$8,000.00	$1,200.00		$0	$16,000	$2,400	$0	$18,400
6.26 PPI Zeolite System	2	ea		$3,000.00	$500.00		$0	$6,000	$1,000	$0	$7,000
6.27 HiPOx System	1	ea		$380,000.00	$1,360.00		$0	$380,000	$1,360	$0	$381,360
6.28 Ion Exchange System, 60 cf resin; 450 gallons	2	ea		$2,700.00	$0.00		$0	$5,400	$0	$0	$5,400
6.29 Liquid Phase GAC System, 8,000 lbs.	2	ea		$42,000.00	$2,076.00		$0	$84,000	$4,152	$0	$88,152
6.30 Backwash Supply Tank, 5,000 gallons	1	ea		$7,500.00	$750.00		$0	$7,500	$750	$0	$8,250
6.31 Backwash Supply Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.32 Backwash Pump, 40 gpm, 1 hp	2	ea		$735.00	$122.00		$0	$1,470	$244	$0	$1,714
6.33 Waste Backwash Tank, 5,000 gallon	1	ea		$7,500.00	$750.00		$0	$7,500	$750	$0	$8,250
6.34 Waste Backwash Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.35 Waste Backwash Transfer Pump, 1 gpm, 0.5 hp	2	ea		$339.60	$84.00		$0	$679	$168	$0	$847
6.36 Filtrate Tank, 9,000 gallons	1	ea		$13,500.00	$1,410.00		$0	$13,500	$1,410	$0	$14,910
6.37 Filtrate Tank Foundation	4	cy	$400.00				$1,600	$0	$0	$0	$1,600
6.38 Filtrate Tank Mixer, 7.5 hp	1	ea		$6,300.00	$1,240.00		$0	$6,300	$1,240	$0	$7,540
6.39 Filtrate Transfer Pump, 30 gpm, 0.5 hp	2	ea		$499.00	$96.00		$0	$998	$192	$0	$1,190
6.40 Air Compressor System, 50 scfm, 100 psi	1	ea		$8,900.00	$1,450.00		$0	$8,900	$1,450	$0	$10,350
6.41 Sump Pump, 10 gpm, 0.5 hp	2	ea		$283.20	$83.50		$0	$566	$167	$0	$733
6.42 Discharge Pump Tank, 1,500 gallons	1	ea		$3,000.00	$450.00		$0	$3,000	$450	$0	$3,450
6.43 Discharge Pump, 100 gpm, 2 hp	2	ea		$535.20	$133.00		$0	$1,070	$266	$0	$1,336
6.44 ED Tank, 500 gallon	1	ea		$1,225.00	$311.40		$0	$1,225	$311	$0	$1,536
6.45 ED Tank Mixer & Stand, 0.5 hp	1	ea		$1,666.00	$415.20		$0	$1,666	$415	$0	$2,081
6.46 ED Feed Pump, 4 gallons/hr	2	ea		$1,500.00	$415.20		$0	$3,000	$830	$0	$3,830
6.47 Discharge Pipe (POTW and SW), 4" Polyetheylene	800	lf		$11.00	$16.00	$1.17	$0	$8,800	$12,800	$936	$22,536
6.48 Outfall Diffuser	1	ls	$50,000.00				$50,000	$0	$0	$0	$50,000
6.49 Utility Service Line	1	ls		$59,808.50	$15,691.40		$0	$59,809	$15,691	$0	$75,500
6.50 Electrical and Controls	1	ls		$286,083.76	$176,543.40		$0	$286,084	$176,543	$0	$462,627
6.51 System Start-Up and Testing	1	ls		$3,000.00	$65,550.00		$0	$3,000	$65,550	$0	$68,550
7 MONITORING WELL INSTALLATION											
7.1 Well Installation (4 wells)	290	lf	$45.00				$13,050	$0	$0	$0	$13,050
7.2 Protective Well Casing & Apron	4	ea	$750.00				$3,000	$0	$0	$0	$3,000
8 INJECTION WELLS											
8.1 Well Installation (6 wells)	270	lf	$100.00				$27,000	$0	$0	$0	$27,000
8.2 Injection Well Head/Vault (incl controls and other detai	6	ea	$5,000.00				$30,000	$0	$0	$0	$30,000

LOCKHEED MARTIN
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Alternative G-3: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Capital Cost

	Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
8.3	Main Header Pipe, 2" PVC	3,860	lf		$1.97	$5.64		$0	$7,604	$21,770	$0	$29,375
8.4	Main Header Pipe Fittings, 2" PVC	12	ea		$19.70	$56.40		$0	$236	$677	$0	$913
8.5	Piping Valves, 2" dia. PVC Ball	4	ea		$76.50	$24.50		$0	$306	$98	$0	$404
8.6	Well Piping, 1" dia. PVC	950	lf		$0.76	$2.35		$0	$722	$2,233	$0	$2,955
8.7	Pipe Fittings, 2" PVC	60	ea		$7.60	$23.50		$0	$456	$1,410	$0	$1,866
8.8	Piping Valves, 1" dia. PVC Ball	8	ea		$30.30	$18.10		$0	$242	$145	$0	$387
9	**WASTE DISPOSAL**											
9.1	Decon Fluids	2,200	gal	$1.00				$2,200	$0	$0	$0	$2,200
9.2	Well Development Water (5,000 gal/well)	160,000	gal	$1.00				$160,000	$0	$0	$0	$160,000
9.3	Drill Cuttings (12-inch dia boreholes, non-haz)	50	cy	$100.00				$5,000	$0	$0	$0	$5,000
9.4	Soil Excavate (2700 lf, 3'x4' trench, non-haz)	1,800	cy	$100.00				$180,000	$0	$0	$0	$180,000
10	**IMPORTED CLEAN FILL**											
10.1	Import and place clean backfill	1,800	cy	$25.00				$45,000	$0	$0	$0	$45,000
10.2	Stabilize and restore disturbed areas (3 acres)	21,100	sy	$8.00				$168,800	$0	$0	$0	$168,800
	Subtotal							$3,037,670	$1,899,765	$1,061,806	$103,559	$6,102,801
	Overhead on Labor Cost @ 30%									$318,542		$318,542
	G & A on Labor, Material, Equipment, & Subs Cost @ 10%							$303,767	$189,977	$106,181	$10,356	$610,280
	Tax on Materials and Equipment Cost @ 6%								$113,986		$6,214	$120,199
	Total Direct Cost							$3,341,437	$2,203,728	$1,486,529	$120,128	$7,151,822
	Indirects on Total Direct Cost @ 25%											$1,787,956
	Profit on Total Direct Cost @ 10%											$715,182
	Subtotal											$9,654,960
	Health & Safety Monitoring @ 2%											$193,099
	Subtotal											$9,848,059
	Record Drawings and Completion Report 1%											$98,481
	Feasibility Study Level Costs											$9,946,540
	Design Cost											$895,189
	Engineering Contingency 20%											$1,989,308

LOCKHEED MARTIN
Martin State Airport
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Alternative G-3: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 1 through 5

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$100,541	$100,541	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	8,000	lbs	$2.00	$16,000	
4	Vapor Phase GAC Replacement	48,000	lbs	$2.00	$96,000	
5	PPI Zeolite Replacement	36,000	lbs	$2.25	$81,000	
6	PPI Zeolite Disposal	18	ton	$66.00	$1,188	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (12 lbs/day)	4,380	lbs	$2.00	$8,760	
	b) NaOH (220 lbs/day)	80,300	lbs	$0.35	$28,105	
	c) Polymer (6 lbs/day)	2,190	lbs	$1.00	$2,190	
	d) Hydrochloric Acid (22 lbs/day)	8,030	lbs	$0.80	$6,424	
	e) Hydrogen Peroxide - HiPOx (2.1 gal/day)	1,059	gal	$3.50	$3,705	
8	Sludge Disposal	86	ton	$65.00	$5,590	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	3513	1K cf	$35.89	$126,082	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	1	year	$3,000.00	$3,000	
11	Sanitary Sewer Analysis	2	ea	$450.00	$900	
12	NPDES Analysis	0	ea	$350.00	$0	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	0	year	$24,000.00	$0	
	b) resin	0	year	$35,000.00	$0	
14	Cartridge Filters, 25 micron	0	ea	$3.91	$0	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$752,484**	
21	Electron Donor Addition (injection)	54750	lbs	$2.00	**$109,500**	for year one and year two only

LOCKHEED MARTIN
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Alternative G-3: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 6 through 10

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$100,541	$100,541	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	6,000	lbs	$2.00	$12,000	
4	Vapor Phase GAC Replacement	36,000	lbs	$2.00	$72,000	
5	PPI Zeolite Replacement	27,000	lbs	$2.25	$60,750	
6	PPI Zeolite Disposal	13.5	ton	$66.00	$891	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (9 lbs/day)	3,285	lbs	$2.00	$6,570	
	b) NaOH (165 lbs/day)	60,225	lbs	$0.35	$21,079	
	c) Polymer (5 lbs/day)	1,643	lbs	$1.00	$1,643	
	d) Hydrochloric Acid (17 lbs/day)	6,023	lbs	$0.80	$4,818	
	e) Hydrogen Peroxide - HiPOx (1.6 gal/day)	794	gal	$3.50	$2,779	
8	Sludge Disposal	65	ton	$65.00	$4,225	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$18,000.00	$18,000	
	b) resin	1	year	$26,250.00	$26,250	
14	Cartridge Filters, 25 micron	98	ea	$3.91	$383	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$609,128**	

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Alternative G-3: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 11 through 30

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$100,541	$100,541	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	4,000	lbs	$2.00	$8,000	
4	Vapor Phase GAC Replacement	24,000	lbs	$2.00	$48,000	
5	PPI Zeolite Replacement	18,000	lbs	$2.25	$40,500	
6	PPI Zeolite Disposal	9	ton	$66.00	$594	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (6 lbs/day)	2,190	lbs	$2.00	$4,380	
	b) NaOH (110 lbs/day)	40,150	lbs	$0.35	$14,053	
	c) Polymer (3 lbs/day)	1,095	lbs	$1.00	$1,095	
	d) Hydrochloric Acid (11 lbs/day)	4,015	lbs	$0.80	$3,212	
	e) Hydrogen Peroxide - HiPOx (1.0 gal/day)	529	gal	$3.50	$1,852	
8	Sludge Disposal	43	ton	$65.00	$2,795	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$12,000.00	$12,000	
	b) resin	1	year	$17,500.00	$17,500	
14	Cartridge Filters, 25 micron	65	ea	$3.91	$254	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$531,976**	

LOCKHEED MARTIN
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Dump Road Area Site

Alternative G-3: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Annual Cost

Item	Item Cost year 1	Item Cost years 2 - 3	Item Cost years 4 - 30	Notes
Site Inspection: Visit	$1,620	$1,620	$1,620	One-day visit to verify LUC RD
Site Inspection: Report	$1,680	$1,680	$1,680	
Groundwater Sampling	$57,440	$28,720	$14,360	Labor and supplies to collect samples from 40 wells using a crew of two, quarterly year 1, semi-annual years 2 & 3, annual years 4-30.
Groundwater Sampling Analysis/Water	$61,600	$30,800	$15,400	Analyze groundwater samples
Sampling Report	$33,600	$16,800	$8,400	
TOTAL	**$155,940**	**$79,620**	**$41,460**	

LOCKHEED MARTIN
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Alternative G-3: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Present Worth Analysis

Year	Capital Cost	Operation & Maintenance Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth	Current Value 2% inflation
0	$12,831,036			$12,831,036	1.000	$12,831,036	12,831,036
1		$861,984	$155,940	$1,017,924	0.935	$951,759	1,038,283
2		$861,984	$79,620	$941,604	0.873	$822,021	979,645
3		$752,484	$79,620	$832,104	0.816	$678,997	883,036
4		$752,484	$41,460	$793,944	0.763	$605,780	859,391
5		$752,484	$41,460	$793,944	0.713	$566,082	876,579
6		$609,128	$41,460	$650,588	0.666	$433,292	732,668
7		$609,128	$41,460	$650,588	0.623	$405,316	747,321
8		$609,128	$41,460	$650,588	0.582	$378,642	762,268
9		$609,128	$41,460	$650,588	0.544	$353,920	777,513
10		$609,128	$41,460	$650,588	0.508	$330,499	793,063
11		$531,976	$41,460	$573,436	0.475	$272,382	712,996
12		$531,976	$41,460	$573,436	0.444	$254,606	727,256
13		$531,976	$41,460	$573,436	0.415	$237,976	741,801
14		$531,976	$41,460	$573,436	0.388	$222,493	756,637
15		$531,976	$41,460	$573,436	0.362	$207,584	771,770
16		$531,976	$41,460	$573,436	0.339	$194,395	787,205
17		$531,976	$41,460	$573,436	0.317	$181,779	802,949
18		$531,976	$41,460	$573,436	0.296	$169,737	819,008
19		$531,976	$41,460	$573,436	0.277	$158,842	835,388
20		$531,976	$41,460	$573,436	0.258	$147,947	852,096
21		$531,976	$41,460	$573,436	0.242	$138,772	869,138
22		$531,976	$41,460	$573,436	0.226	$129,597	886,521
23		$531,976	$41,460	$573,436	0.211	$120,995	904,251
24		$531,976	$41,460	$573,436	0.197	$112,967	922,336
25		$531,976	$41,460	$573,436	0.184	$105,512	940,783
26		$531,976	$41,460	$573,436	0.172	$98,631	959,598
27		$531,976	$41,460	$573,436	0.161	$92,323	978,790
28		$531,976	$41,460	$573,436	0.150	$86,015	998,366
29		$531,976	$41,460	$573,436	0.141	$80,854	1,018,333
30		$531,976	$41,460	$573,436	0.131	$75,120	1,038,700
		$17,666,585	$1,434,600				38,604,724

TOTAL PRESENT WORTH **$21,445,871**

Dump Road Area Groundwater Containment System Design Costs

Feasibility Study Level Capital Costs (Excluding Contingency)	$9,946,540
Total Design Costs @ 9% of FS Level Capital Costs *(excluding contingency)*	$895,189
30% Design Cost (Procurement EESHBDF-02384_R631) @ 26% of Line 6	$232,749
60% Design Cost @ 44% of line 6	$393,883
90% Design Cost @ 20% of line 6	$179,038
100% Design Cost @ 10% of line 6	$89,519

ALTERNATIVE FF4:

HYDRAULIC CONTROLS BY EXTRACTION, EXTRACTION OF HCA, EX-SITU TREATMENT OF GROUNDWATER, RE-INJECTION OF GROUNDWATER, DISCHARGE TO POTW, MONITORING, AND LUCS

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-4: Hydraulic Controls by Extraction, Extraction of HCA, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Capital Cost

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
1 PROJECT PLANNING & DOCUMENTS											
1.1 Bench Testing	1	ls	$30,000.00				$30,000	$0	$0	$0	$30,000
1.2 Land Finders Fee	1	ls	$100,000.00				$100,000	$0	$0	$0	$100,000
2 MOBILIZATION AND DEMOBILIZATION											
2.1 Site Support Facilities (trailers, phone, electric, etc.)	1	ls		$1,000.00		$3,500.00	$0	$1,000	$0	$3,500	$4,500
2.2 Equipment Mobilization/Demobilization								$40,000	$27,000	$40,000	$107,000
3 FIELD SUPPORT AND SITE ACCESS											
3.1 Office Trailer	12	mo				$360.00	$0	$0	$0	$4,320	$4,320
3.2 Field Office Equipment, Utilities, & Support	12	mo		$470.00			$0	$5,640	$0	$0	$5,640
3.3 Storage Trailer	12	mo				$92.50	$0	$0	$0	$1,110	$1,110
3.4 Survey Support	15	day	$1,075.00				$16,125	$0	$0	$0	$16,125
3.5 Site Superintendent	252	day		$164.00	$384.64		$0	$41,328	$96,929	$0	$138,257
3.5.1 Resident Engineering (1.5 persons)	0	day		$164.00	$307.68		$0	$0	$0	$0	$0
3.6 Site Health & Safety and QA/QC	252	day		$164.00	$307.68		$0	$41,328	$77,535	$0	$118,863
3.7 Underground Utility Clearance	1	ls	$10,000.00				$10,000	$0	$0	$0	$10,000
3.8 Access Road & Parking	500	sy		$15.50	$1.05	$1.94	$0	$7,750	$525	$970	$9,245
3.9 Clearing and Grubbing	3	acre	$10,000.00				$30,000	$0	$0	$0	$30,000
3.10 Directional Drill Under Taxiway Tango	1	ls	$50,000.00				$50,000	$0	$0	$0	$50,000
4 DECONTAMINATION											
4.1 Decontamination Services	12	mo		$1,220.00	$2,245.00	$1,550.00	$0	$14,640	$26,940	$18,600	$60,180
4.2 Temporary Equipment Decon Pad	1	ls		$1,500.00	$2,000.00	$300.00	$0	$1,500	$2,000	$300	$3,800
4.3 Decon Water	2,000	gal		$0.20			$0	$400	$0	$0	$400
4.4 Decon Water Storage Tank, 6,000 gallon	12	mo				$771.00	$0	$0	$0	$9,252	$9,252
4.5 Clean Water Storage Tank, 4,000 gallon	12	mo				$693.00	$0	$0	$0	$8,316	$8,316
4.6 Disposal of Decon Waste (liquid & solid)	12	mo	$985.00				$11,820	$0	$0	$0	$11,820
5 EXTRACTION SYSTEM											
5.1 Install Extraction Wells, 23 wells	1,350	lf	$100.00				$135,000	$0	$0	$0	$135,000
5.1.1 Well Development (1 day/well)	23	days	$1,500.00	$164.00	$307.68		$34,500	$3,772	$7,077	$0	$45,349
5.2 Extraction Well Head/Vault (incl controls and other det	23	ea	$5,000.00				$115,000	$0	$0	$0	$115,000
5.3 Insulate/Heat Trace Well Head, 16 wells	230	lf		$5.87	$3.89		$0	$1,350	$895	$0	$2,245
5.4 Submersible Pump w/ Controls, 0.5 hp	23	ea		$1,000.00	$236.00		$0	$23,000	$5,428	$0	$28,428
5.5 Well Piping, 1" dia. PVC Sch 80	1,350	lf		$1.70	$3.25		$0	$2,295	$4,388	$0	$6,683
5.6 Pump Station	1	ea		$30,000.00	$1,800.00	$400.00	$0	$30,000	$1,800	$400	$32,200
5.7 Pump Station Pumps, 100 gpm, 3 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
5.8 Transfer Piping, 1" dia. PVC Sch 80, Double Wall	0	lf		$12.44	$15.69		$0	$0	$0	$0	$0
5.9 Transfer Piping Fittings, 1" dia. PVC Sch 80, Double W	0	ea		$124.40	$156.90		$0	$0	$0	$0	$0
5.10 Transfer Piping Valves, 1" dia. PVC Ball	0	ea		$30.30	$18.10		$0	$0	$0	$0	$0
5.11 Transfer Piping, 2" dia. PVC Sch 80, Double Wall	1,600	lf		$20.23	$20.88		$0	$32,368	$33,408	$0	$65,776
5.12 Transfer Piping Fittings, 2" dia. PVC Sch 80, Double W	128	ea		$202.30	$208.80		$0	$25,894	$26,726	$0	$52,621
5.13 Transfer Piping Valves, 2" dia. PVC Ball	64	ea		$70.50	$24.50		$0	$4,512	$1,568	$0	$6,080
5.14 Transfer Piping, 4" dia. PVC Sch 80, Double Wall	4,050	lf		$22.14	$31.72		$0	$89,667	$128,466	$0	$218,133
5.15 Transfer Piping Fittings, 4" dia. PVC Sch 80, Double W	128	ea		$221.40	$317.20		$0	$28,339	$40,602	$0	$68,941
5.16 Transfer Piping Valves, 4" dia. PVC Ball	4	ea		$610.00	$37.50		$0	$2,440	$150	$0	$2,590
5.17 Backhoe/Loader	40	day			$343.60	$387.60	$0	$0	$13,744	$15,504	$29,248
5.18 Site Labor (3 laborers)	120	day			$264.80		$0	$0	$31,776	$0	$31,776
6 TREATMENT SYSTEM											
6.1 Equipment Building, 155' by 65'	10,075	sf	$125.00				$1,259,375	$0	$0	$0	$1,259,375
6.2 Property Acquisition	26,875	sf	$20.00				$537,500	$0	$0	$0	$537,500
6.3 Equipment Building Foundation	256	cy	$400.00				$102,400	$0	$0	$0	$102,400
6.4 Water Supply Pipe, 2" Polyetheylene	300	lf		$2.49	$5.06	$1.17	$0	$747	$1,518	$351	$2,616
6.5 Water Supply Valves & Meters	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
6.6 Feed Tank, 23,000 gallons	1	ea		$30,000.00	$3,200.00		$0	$30,000	$3,200	$0	$33,200
6.7 Feed Tank Foundation	6	cy	$400.00				$2,400	$0	$0	$0	$2,400
6.8 Feed Tank Mixer, 15 hp	1	ea		$8,200.00	$1,465.00		$0	$8,200	$1,465	$0	$9,665
6.9 Feed Pump, 100 gpm, 1.5 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
6.10 Piping, 2" PVC Sch 80	300	lf		$3.93	$13.65		$0	$1,179	$4,095	$0	$5,274
6.11 Pipe Fittings, 2" PVC Sch 80	50	ea		$39.30	$136.50		$0	$1,965	$6,825	$0	$8,790
6.12 Piping Valves, 2" dia. PVC Ball	20	ea		$76.50	$24.50		$0	$1,530	$490	$0	$2,020
6.13 Piping, 4" PVC Sch 80	1,600	lf		$11.15	$16.30		$0	$17,840	$26,080	$0	$43,920
6.14 Pipe Fittings, 4" PVC Sch 80	300	ea		$111.50	$163.00		$0	$33,450	$48,900	$0	$82,350
6.15 Piping Valves, 4" dia. PVC Butterfly	120	ea		$733.26	$43.00		$0	$87,991	$5,160	$0	$93,151
6.16 Piping, 6" PVC Sch 80	100	lf		$24.50	$19.75		$0	$2,450	$1,975	$0	$4,425
6.17 Pipe Fittings, 6" PVC Sch 80	10	ea		$245.00	$197.50		$0	$2,450	$1,975	$0	$4,425
6.18 Piping Valves, 6" dia. PVC Butterfly	5	ea		$879.94	$65.00		$0	$4,400	$325	$0	$4,725
6.19 Air Stripper Piping	100	lf		$29.40	$19.75		$0	$2,940	$1,975	$0	$4,915
6.20 Air Stripper Fittings	20	ea		$352.80	$197.50		$0	$7,056	$3,950	$0	$11,006
6.21 Air Stripper Valves	10	ea		$1,055.93	$65.00		$0	$10,559	$650	$0	$11,209
Metals Removal Package	1	ls		$347,000.00	$134,032.50		$0	$347,000	$134,033	$0	$481,033
- Primary pH Adjustment Tank, 1,100 gallons	1	ea									
- Primary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- Secondary pH Adjustment Tank, 1,100 gallons	1	ea									
- Secondary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- H2O2 Feed System, 32 lb/day	1	ea									
- NaOH Feed System, 38 lb/day; 8 gal/day	1	ea									
- Floc Tank, 770 gallons	1	ea									
- Floc Mixer, 0.5 hp	1	ea									
- Polymer Feed system, 10 lb/day	1	ea									
- Clarifier, 3,700 gallons	1	ea									
- Sludge Transfer Pump, 15 gpm, AODD	2	ea									
- Final pH Adjustment Tank, 1,500 gallons	1	ea									
- Final pH Adjustment Tank Mixer, 1 hp	1	ea									
- Acid (HCl) Feed System, 35 lb/day: 10 gal/day	1	ea									
- Clarified Water Feed Tank, 1,100 gallons	1	ea									
- SF Feed Pump, 80 gpm, 5 hp	2	ea									
- Sand Filter, 2.5' dia. by 6' high	3	ea									
- Cartridges Filters, 10 micron	2	ea									
- Thickener, 14' dia. by 12' high	1	ea									
- FP Feed Pump, 80 gpm, AODD	2	ea									
6.22 - Filter Press, 130 cf	1	ea									
6.23 Air Stripper, 6 Tray, 850 cfm	1	ea		$55,000.00	$4,000.00		$0	$55,000	$4,000	$0	$59,000
6.24 Air Stripper Effluent Pump, 100 gpm, 3 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
6.25 Vapor-Phase GAC System	2	ea		$8,000.00	$1,200.00		$0	$16,000	$2,400	$0	$18,400
6.26 PPI Zeolite System	2	ea		$3,000.00	$500.00		$0	$6,000	$1,000	$0	$7,000
6.27 HiPOx System	1	ea		$380,000.00	$1,360.00		$0	$380,000	$1,360	$0	$381,360
6.28 Ion Exchange System, 60 cf resin; 450 gallons	2	ea		$2,700.00	$0.00		$0	$5,400	$0	$0	$5,400
6.29 Liquid Phase GAC System, 8,000 lbs.	2	ea		$42,000.00	$2,076.00		$0	$84,000	$4,152	$0	$88,152
6.30 Backwash Supply Tank, 5,000 gallons	1	ea		$7,500.00	$750.00		$0	$7,500	$750	$0	$8,250
6.31 Backwash Supply Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.32 Backwash Pump, 40 gpm, 1 hp	2	ea		$735.00	$122.00		$0	$1,470	$244	$0	$1,714
6.33 Waste Backwash Tank, 5,000 gallon	1	ea		$7,500.00	$750.00		$0	$7,500	$750	$0	$8,250
6.34 Waste Backwash Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.35 Waste Backwash Transfer Pump, 1 gpm, 0.5 hp	2	ea		$339.60	$84.00		$0	$679	$168	$0	$847
6.36 Filtrate Tank, 9,000 gallons	1	ea		$13,500.00	$1,410.00		$0	$13,500	$1,410	$0	$14,910
6.37 Filtrate Tank Foundation	4	cy	$400.00				$1,600	$0	$0	$0	$1,600
6.38 Filtrate Tank Mixer, 7.5 hp	1	ea		$6,300.00	$1,240.00		$0	$6,300	$1,240	$0	$7,540
6.39 Filtrate Transfer Pump, 30 gpm, 0.5 hp	2	ea		$499.00	$96.00		$0	$998	$192	$0	$1,190
6.40 Air Compressor System, 50 scfm, 100 psi	1	ea		$8,900.00	$1,450.00		$0	$8,900	$1,450	$0	$10,350
6.41 Sump Pump, 10 gpm, 0.5 hp	2	ea		$283.20	$83.50		$0	$566	$167	$0	$733
6.42 Discharge Pump Tank, 1,500 gallons	1	ea		$3,000.00	$450.00		$0	$3,000	$450	$0	$3,450
6.43 Discharge Pump, 100 gpm, 2 hp	2	ea		$535.20	$133.00		$0	$1,070	$266	$0	$1,336
6.44 ED Tank, 500 gallon	1	ea		$1,225.00	$311.40		$0	$1,225	$311	$0	$1,536
6.45 ED Tank Mixer & Stand, 0.5 hp	1	ea		$1,666.00	$415.20		$0	$1,666	$415	$0	$2,081
6.46 ED Feed Pump, 4 gallons/hr	2	ea		$1,500.00	$415.20		$0	$3,000	$830	$0	$3,830
6.47 Discharge Pipe (POTW and SW), 4" Polyetheylene	800	lf		$11.00	$16.00	$1.17	$0	$8,800	$12,800	$936	$22,536
6.48 Outfall Diffuser	1	ls	$50,000.00				$50,000	$0	$0	$0	$50,000
6.49 Utility Service Line	1	ls		$59,808.50	$15,691.40		$0	$59,809	$15,691	$0	$75,500
6.50 Electrical and Controls	1	ls		$286,083.76	$176,543.40		$0	$286,084	$176,543	$0	$462,627
6.51 System Start-Up and Testing	1	ls		$3,000.00	$65,550.00		$0	$3,000	$65,550	$0	$68,550
7 MONITORING WELL INSTALLATION											
7.1 Well Installation (4 wells)	290	lf	$45.00				$13,050	$0	$0	$0	$13,050
7.2 Protective Well Casing & Apron	4	ea	$750.00				$3,000	$0	$0	$0	$3,000
8 INJECTION WELLS											
8.1 Well Installation (6 wells)	270	lf	$100.00				$27,000	$0	$0	$0	$27,000
8.2 Injection Well Head/Vault (incl controls and other detai	6	ea	$5,000.00				$30,000	$0	$0	$0	$30,000

LOCKHEED MARTIN
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Alternative G-4: Hydraulic Controls by Extraction, Extraction of HCA, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Capital Cost

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
8.3 Main Header Pipe, 2" PVC	3,860	lf		$1.97	$5.64		$0	$7,604	$21,770	$0	$29,375
8.4 Main Header Pipe Fittings, 2" PVC	12	ea		$19.70	$56.40		$0	$236	$677	$0	$913
8.5 Piping Valves, 2" dia. PVC Ball	4	ea		$76.50	$24.50		$0	$306	$98	$0	$404
8.6 Well Piping, 1" dia. PVC	950	lf		$0.76	$2.35		$0	$722	$2,233	$0	$2,955
8.7 Pipe Fittings, 2" PVC	60	ea		$7.60	$23.50		$0	$456	$1,410	$0	$1,866
8.8 Piping Valves, 1" dia. PVC Ball	8	ea		$30.30	$18.10		$0	$242	$145	$0	$387
9 WASTE DISPOSAL											
9.1 Decon Fluids	2,000	gal	$1.00				$2,000	$0	$0	$0	$2,000
9.2 Well Development Water (5,000 gal/well)	145,000	gal	$1.00				$145,000	$0	$0	$0	$145,000
9.3 Drill Cuttings (12-inch dia boreholes, non-haz)	35	cy	$100.00				$3,500	$0	$0	$0	$3,500
9.4 Soil Excavate (2700 lf, 3'x4' trench, non-haz)	1,600	cy	$100.00				$160,000	$0	$0	$0	$160,000
10 IMPORTED CLEAN FILL											
10.1 Import and place clean backfill	1,600	cy	$25.00				$40,000	$0	$0	$0	$40,000
10.2 Stabilize and restore disturbed areas (3 acres)	19,140	sy	$8.00				$153,120	$0	$0	$0	$153,120
Subtotal							$3,067,790	$1,933,314	$1,089,305	$103,559	$6,193,969
Overhead on Labor Cost @ 30%									$326,792		$326,792
G & A on Labor, Material, Equipment, & Subs Cost @ 10%							$306,779	$193,331	$108,931	$10,356	$619,397
Tax on Materials and Equipment Cost @ 6%								$115,999		$6,214	$122,212
Total Direct Cost							$3,374,569	$2,242,645	$1,525,027	$120,128	$7,262,369
Indirects on Total Direct Cost @ 25%											$1,815,592
Profit on Total Direct Cost @ 10%											$726,237
Subtotal											$9,804,199
Health & Safety Monitoring @ 2%											$196,084
Subtotal											$10,000,283
Record Drawings and Completion Report 1%											$100,003
Feasibility Study Level Costs											$10,100,286
Deign Cost											$909,026
Engineering Contingency 20%											$2,020,057

LOCKHEED MARTIN
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Operation and Maintenance Cost for Years 1 through 5

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	778,000	kWh	$0.12	$93,360	
2	System Maintenance	1	ls	$103,544	$103,544	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	16,000	lbs	$2.00	$32,000	
4	Vapor Phase GAC Replacement	96,000	lbs	$2.00	$192,000	
5	PPI Zeolite Replacement	72,000	lbs	$2.25	$162,000	
6	PPI Zeolite Disposal	36	ton	$66.00	$2,376	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (12 lbs/day)	8,760	lbs	$2.00	$17,520	
	b) NaOH (220 lbs/day)	160,600	lbs	$0.35	$56,210	
	c) Polymer (6 lbs/day)	4,380	lbs	$1.00	$4,380	
	d) Hydrochloric Acid (22 lbs/day)	16,060	lbs	$0.80	$12,848	
	e) Hydrogen Peroxide - HiPOx (2.1 gal/day)	2,081	gal	$3.50	$7,284	
8	Sludge Disposal	175	ton	$65.00	$11,375	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	7025	1K cf	$35.89	$252,127	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	1	year	$3,000.00	$3,000	
11	Sanitary Sewer Analysis	2	ea	$450.00	$900	
12	NPDES Analysis	0	ea	$350.00	$0	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	0	year	$24,000.00	$0	
	b) resin	0	year	$35,000.00	$0	
14	Cartridge Filters, 25 micron	0	ea	$3.91	$0	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$1,156,364**	
21	Electron Donor Addition (injection)	54,750	lbs	$2.00	**$109,500**	for year one and year two only

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Operation and Maintenance Cost for Years 6 through 10

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	778,000	kWh	$0.12	$93,360	
2	System Maintenance	1	ls	$103,544	$103,544	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	12,000	lbs	$2.00	$24,000	
4	Vapor Phase GAC Replacement	72,000	lbs	$2.00	$144,000	
5	PPI Zeolite Replacement	54,000	lbs	$2.25	$121,500	
6	PPI Zeolite Disposal	27.0	ton	$66.00	$1,782	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (9 lbs/day)	6,570	lbs	$2.00	$13,140	
	b) NaOH (165 lbs/day)	120,450	lbs	$0.35	$42,158	
	c) Polymer (5 lbs/day)	3,285	lbs	$1.00	$3,285	
	d) Hydrochloric Acid (17 lbs/day)	12,045	lbs	$0.80	$9,636	
	e) Hydrogen Peroxide - HiPOx (1.6 gal/day)	1,561	gal	$3.50	$5,463	
8	Sludge Disposal	130	ton	$65.00	$8,450	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$18,000.00	$18,000	
	b) resin	1	year	$26,250.00	$26,250	
14	Cartridge Filters, 25 micron	196	ea	$3.91	$766	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$824,974**	

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Operation and Maintenance Cost for Years 11 through 30

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	778,000	kWh	$0.12	$93,360	
2	System Maintenance	1	ls	$103,544	$103,544	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	8,000	lbs	$2.00	$16,000	
4	Vapor Phase GAC Replacement	48,000	lbs	$2.00	$96,000	
5	PPI Zeolite Replacement	36,000	lbs	$2.25	$81,000	
6	PPI Zeolite Disposal	18	ton	$66.00	$1,188	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (6 lbs/day)	4,380	lbs	$2.00	$8,760	
	b) NaOH (110 lbs/day)	80,300	lbs	$0.35	$28,105	
	c) Polymer (3 lbs/day)	2,190	lbs	$1.00	$2,190	
	d) Hydrochloric Acid (11 lbs/day)	8,030	lbs	$0.80	$6,424	
	e) Hydrogen Peroxide - HiPOx (1.0 gal/day)	1,041	gal	$3.50	$3,642	
8	Sludge Disposal	88	ton	$65.00	$5,720	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$12,000.00	$12,000	
	b) resin	1	year	$17,500.00	$17,500	
14	Cartridge Filters, 25 micron	130	ea	$3.91	$508	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$685,581**	

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site

Alternative G-4: Hydraulic Controls by Extraction, Extraction of HCA, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Annual Cost

Item	Item Cost year 1	Item Cost years 2 - 3	Item Cost years 4 - 30	Notes
Site Inspection: Visit	$1,620	$1,620	$1,620	One-day visit to verify LUC RD
Site Inspection: Report	$1,680	$1,680	$1,680	
Groundwater Sampling	$57,440	$28,720	$14,360	Labor and supplies to collect samples from 40 wells using a crew of two, quarterly year 1, semi-annual years 2 & 3, annual years 4-30.
Groundwater Sampling Analysis/Water	$61,600	$30,800	$15,400	Analyze groundwater samples
Sampling Report	$33,600	$16,800	$8,400	
TOTAL	**$155,940**	**$79,620**	**$41,460**	

LOCKHEED MARTIN
Martin State Airport
Dump Road Area Site
Middle River, Maryland

Alternative G-4: Hydraulic Controls by Extraction, Extraction of HCA, Ex-Situ Treatment of Groundwater, Re-injection of Groundwater, Discharge to POTW, Monitoring, and LUCs
Present Worth Analysis

Year	Capital Cost	Operation & Maintenance Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth	Current Value 2% inflation
0	$13,029,368			$13,029,368	1.000	$13,029,368	13,029,368
1		$1,265,864	$155,940	$1,421,804	0.935	$1,329,387	1,450,240
2		$1,265,864	$79,620	$1,345,484	0.873	$1,174,608	1,399,842
3		$1,156,364	$79,620	$1,235,984	0.816	$1,008,563	1,311,636
4		$1,156,364	$41,460	$1,197,824	0.763	$913,940	1,296,563
5		$1,156,364	$41,460	$1,197,824	0.713	$854,049	1,322,494
6		$824,974	$41,460	$866,434	0.666	$577,045	975,745
7		$824,974	$41,460	$866,434	0.623	$539,788	995,260
8		$824,974	$41,460	$866,434	0.582	$504,264	1,015,165
9		$824,974	$41,460	$866,434	0.544	$471,340	1,035,469
10		$824,974	$41,460	$866,434	0.508	$440,148	1,056,178
11		$685,581	$41,460	$727,041	0.475	$345,345	903,984
12		$685,581	$41,460	$727,041	0.444	$322,806	922,064
13		$685,581	$41,460	$727,041	0.415	$301,722	940,505
14		$685,581	$41,460	$727,041	0.388	$282,092	959,316
15		$685,581	$41,460	$727,041	0.362	$263,189	978,502
16		$685,581	$41,460	$727,041	0.339	$246,467	998,072
17		$685,581	$41,460	$727,041	0.317	$230,472	1,018,033
18		$685,581	$41,460	$727,041	0.296	$215,204	1,038,394
19		$685,581	$41,460	$727,041	0.277	$201,390	1,059,162
20		$685,581	$41,460	$727,041	0.258	$187,577	1,080,345
21		$685,581	$41,460	$727,041	0.242	$175,944	1,101,952
22		$685,581	$41,460	$727,041	0.226	$164,311	1,123,991
23		$685,581	$41,460	$727,041	0.211	$153,406	1,146,471
24		$685,581	$41,460	$727,041	0.197	$143,227	1,169,400
25		$685,581	$41,460	$727,041	0.184	$133,776	1,192,788
26		$685,581	$41,460	$727,041	0.172	$125,051	1,216,644
27		$685,581	$41,460	$727,041	0.161	$117,054	1,240,977
28		$685,581	$41,460	$727,041	0.150	$109,056	1,265,796
29		$685,581	$41,460	$727,041	0.141	$102,513	1,291,112
30		$685,581	$41,460	$727,041	0.131	$95,242	1,316,935
		$23,837,314	$1,434,600				46,852,405

TOTAL PRESENT WORTH **$24,758,344**

Dump Road Area Groundwater Containment System Design Costs

Feasibility Study Level Capital Costs (Excluding Contingency)	$10,100,286
Total Design Costs @ 9% of FS Level Capital Costs *(excluding contingency)*	$909,026
30% Design Cost (Procurement EESHBDF-02384_R631) @ 26% of Line 6	$236,347
60% Design Cost @ 44% of line 6	$399,971
90% Design Cost @ 20% of line 6	$181,805
100% Design Cost @ 10% of line 6	$90,903

ALTERNATIVE F-5:

HYDRAULIC CONTROLS BY EXTRACTION, EX-SITU TREATMENT OF GROUNDWATER, IN-SITU BIOREMEDIATION OF HCA, DISCHARGE TO POTW, MONITORING, AND LUCS

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-5: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of HCA, Discharge to POTW, Monitoring, and LUCs
Capital Cost

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
1 PROJECT PLANNING & DOCUMENTS											
1.1 Bench Testing	1	ls	$30,000.00				$30,000	$0	$0	$0	$30,000
1.2 Land Finders Fee	1	ls	$100,000.00				$100,000	$0	$0	$0	$100,000
2 MOBILIZATION AND DEMOBILIZATION											
2.1 Site Support Facilities (trailers, phone, electric, etc.)	1	ls		$1,000.00		$3,500.00	$0	$1,000	$0	$3,500	$4,500
2.2 Equipment Mobilization/Demobilization								$50,000	$30,000	$50,000	$130,000
3 FIELD SUPPORT AND SITE ACCESS											
3.1 Office Trailer	12	mo				$360.00	$0	$0	$0	$4,320	$4,320
3.2 Field Office Equipment, Utilities, & Support	12	mo		$470.00			$0	$5,640	$0	$0	$5,640
3.3 Storage Trailer	12	mo				$92.50	$0	$0	$0	$1,110	$1,110
3.4 Survey Support	15	day	$1,075.00				$16,125	$0	$0	$0	$16,125
3.5 Site Superintendent	252	day		$164.00	$384.64		$0	$41,328	$96,929	$0	$138,257
3.5.1 Resident Engineering (1.5 persons)	0	day		$164.00	$307.68		$0	$0	$0	$0	$0
3.6 Site Health & Safety and QA/QC	252	day		$164.00	$307.68		$0	$41,328	$77,535	$0	$118,863
3.7 Underground Utility Clearance	1	ls	$10,000.00				$10,000	$0	$0	$0	$10,000
3.8 Access Road & Parking	500	sy		$15.50	$1.05	$1.94	$0	$7,750	$525	$970	$9,245
3.9 Clearing and Grubbing	3	acre	$10,000.00				$30,000	$0	$0	$0	$30,000
3.10 Directional Drill Under Taxiway Tango	1	ls	$50,000.00				$50,000	$0	$0	$0	$50,000
4 DECONTAMINATION											
4.1 Decontamination Services	12	mo		$1,220.00	$2,245.00	$1,550.00	$0	$14,640	$26,940	$18,600	$60,180
4.2 Temporary Equipment Decon Pad	1	ls		$1,500.00	$2,000.00	$300.00	$0	$1,500	$2,000	$300	$3,800
4.3 Decon Water	2,000	gal		$0.20			$0	$400	$0	$0	$400
4.4 Decon Water Storage Tank, 6,000 gallon	12	mo				$771.00	$0	$0	$0	$9,252	$9,252
4.5 Clean Water Storage Tank, 4,000 gallon	12	mo				$693.00	$0	$0	$0	$8,316	$8,316
4.6 Disposal of Decon Waste (liquid & solid)	12	mo	$985.00				$11,820	$0	$0	$0	$11,820
5 EXTRACTION SYSTEM											
5.1 Install Extraction Wells, 16 wells	930	lf	$100.00				$93,000	$0	$0	$0	$93,000
5.1.1 Well Development (1 day/well)	16	days	$1,500.00	$164.00	$307.68		$24,000	$2,624	$4,923	$0	$31,547
5.2 Extraction Well Head/Vault (incl controls and other det	16	ea	$5,000.00				$80,000	$0	$0	$0	$80,000
5.3 Insulate/Heat Trace Well Head, 16 wells	160	lf		$5.87	$3.89		$0	$939	$622	$0	$1,562
5.4 Submersible Pump w/ Controls, 0.5 hp	16	ea		$1,000.00	$236.00		$0	$16,000	$3,776	$0	$19,776
5.5 Well Piping, 1" dia. PVC Sch 80	930	lf		$1.70	$3.25		$0	$1,581	$3,023	$0	$4,604
5.6 Pump Station	1	ea		$30,000.00	$1,800.00	$400.00	$0	$30,000	$1,800	$400	$32,200
5.7 Pump Station Pumps, 100 gpm, 3 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
5.8 Transfer Piping, 1" dia. PVC Sch 80, Double Wall	0	lf		$12.44	$15.69		$0	$0	$0	$0	$0
5.9 Transfer Piping Fittings, 1" dia. PVC Sch 80, Double W	0	ea		$124.40	$156.90		$0	$0	$0	$0	$0
5.10 Transfer Piping Valves, 1" dia. PVC Ball	0	ea		$30.30	$18.10		$0	$0	$0	$0	$0
5.11 Transfer Piping, 2" dia. PVC Sch 80, Double Wall	400	lf		$20.23	$20.88		$0	$8,092	$8,352	$0	$16,444
5.12 Transfer Piping Fittings, 2" dia. PVC Sch 80, Double W	128	ea		$202.30	$208.80		$0	$25,894	$26,726	$0	$52,621
5.13 Transfer Piping Valves, 2" dia. PVC Ball	64	ea		$70.50	$24.50		$0	$4,512	$1,568	$0	$6,080
5.14 Transfer Piping, 4" dia. PVC Sch 80, Double Wall	4,050	lf		$22.14	$31.72		$0	$89,667	$128,466	$0	$218,133
5.15 Transfer Piping Fittings, 4" dia. PVC Sch 80, Double W	128	ea		$221.40	$317.20		$0	$28,339	$40,602	$0	$68,941
5.16 Transfer Piping Valves, 4" dia. PVC Ball	4	ea		$610.00	$37.50		$0	$2,440	$150	$0	$2,590
5.17 Backhoe/Loader	40	day			$343.60	$387.60	$0	$0	$13,744	$15,504	$29,248
5.18 Site Labor (3 laborers)	120	day			$264.80		$0	$0	$31,776	$0	$31,776
6 TREATMENT SYSTEM											
6.1 Equipment Building, 155' by 65'	10,075	sf	$125.00				$1,259,375	$0	$0	$0	$1,259,375
6.2 Property Acquisition	26,875	sf	$20.00				$537,500	$0	$0	$0	$537,500
6.3 Equipment Building Foundation	256	cy	$400.00				$102,400	$0	$0	$0	$102,400
6.4 Water Supply Pipe, 2" Polyetheylene	300	lf		$2.49	$5.06	$1.17	$0	$747	$1,518	$351	$2,616
6.5 Water Supply Valves & Meters	1	ls	$3,000.00				$3,000	$0	$0	$0	$3,000
6.6 Feed Tank, 23,000 gallons	1	ea		$30,000.00	$3,200.00		$0	$30,000	$3,200	$0	$33,200
6.7 Feed Tank Foundation	6	cy	$400.00				$2,400	$0	$0	$0	$2,400
6.8 Feed Tank Mixer, 15 hp	1	ea		$8,200.00	$1,465.00		$0	$8,200	$1,465	$0	$9,665
6.9 Feed Pump, 100 gpm, 1.5 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
6.10 Piping, 2" PVC Sch 80	300	lf		$3.93	$13.65		$0	$1,179	$4,095	$0	$5,274
6.11 Pipe Fittings, 2" PVC Sch 80	50	ea		$39.30	$136.50		$0	$1,965	$6,825	$0	$8,790
6.12 Piping Valves, 2" dia. PVC Ball	20	ea		$76.50	$24.50		$0	$1,530	$490	$0	$2,020
6.13 Piping, 4" PVC Sch 80	1,600	lf		$11.15	$16.30		$0	$17,840	$26,080	$0	$43,920
6.14 Pipe Fittings, 4" PVC Sch 80	300	ea		$111.50	$163.00		$0	$33,450	$48,900	$0	$82,350
6.15 Piping Valves, 4" dia. PVC Butterfly	120	ea		$733.26	$43.00		$0	$87,991	$5,160	$0	$93,151
6.16 Piping, 6" PVC Sch 80	100	lf		$24.50	$19.75		$0	$2,450	$1,975	$0	$4,425
6.17 Pipe Fittings, 6" PVC Sch 80	10	ea		$245.00	$197.50		$0	$2,450	$1,975	$0	$4,425
6.18 Piping Valves, 6" dia. PVC Butterfly	5	ea		$879.94	$65.00		$0	$4,400	$325	$0	$4,725
6.19 Air Stripper Piping	100	lf		$29.40	$19.75		$0	$2,940	$1,975	$0	$4,915
6.20 Air Stripper Fittings	20	ea		$352.80	$197.50		$0	$7,056	$3,950	$0	$11,006
6.21 Air Stripper Valves	10	ea		$1,055.93	$65.00		$0	$10,559	$650	$0	$11,209
Metals Removal Package	1	ls		$347,000.00	$134,032.50		$0	$347,000	$134,033	$0	$481,033
- Primary pH Adjustment Tank, 1,100 gallons	1	ea									
- Primary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- Secondary pH Adjustment Tank, 1,100 gallons	1	ea									
- Secondary pH Adjustment Tank Mixer, 0.5 hp	1	ea									
- H2O2 Feed System, 32 lb/day	1	ea									
- NaOH Feed System, 38 lb/day; 8 gal/day	1	ea									
- Floc Tank, 770 gallons	1	ea									
- Floc Mixer, 0.5 hp	1	ea									
- Polymer Feed system, 10 lb/day	1	ea									
- Clarifier, 3,700 gallons	1	ea									
- Sludge Transfer Pump, 15 gpm, AODD	2	ea									
- Final pH Adjustment Tank, 1,500 gallons	1	ea									
- Final pH Adjustment Tank Mixer, 1 hp	1	ea									
- Acid (HCl) Feed System, 35 lb/day: 10 gal/day	1	ea									
- Clarified Water Feed Tank, 1,100 gallons	1	ea									
- SF Feed Pump, 80 gpm, 5 hp	2	ea									
- Sand Filter, 2.5' dia. by 6' high	3	ea									
- Cartridges Filters, 10 micron	2	ea									
- Thickener, 14' dia. by 12' high	1	ea									
- FP Feed Pump, 80 gpm, AODD	2	ea									
6.22 - Filter Press, 130 cf	1	ea									
6.23 Air Stripper, 6 Tray, 850 cfm	1	ea		$55,000.00	$4,000.00		$0	$55,000	$4,000	$0	$59,000
6.24 Air Stripper Effluent Pump, 100 gpm, 3 hp	2	ea		$883.20	$210.00		$0	$1,766	$420	$0	$2,186
6.25 Vapor-Phase GAC System	2	ea		$8,000.00	$1,200.00		$0	$16,000	$2,400	$0	$18,400
6.26 PPI Zeolite System	2	ea		$3,000.00	$500.00		$0	$6,000	$1,000	$0	$7,000
6.27 HiPOx System	1	ea		$380,000.00	$1,360.00		$0	$380,000	$1,360	$0	$381,360
6.28 Ion Exchange System, 60 cf resin; 450 gallons	2	ea		$2,700.00	$0.00		$0	$5,400	$0	$0	$5,400
6.29 Liquid Phase GAC System, 8,000 lbs.	2	ea		$42,000.00	$2,076.00		$0	$84,000	$4,152	$0	$88,152
6.30 Backwash Supply Tank, 5,000 gallons	1	ea		$7,500.00	$750.00		$0	$7,500	$750	$0	$8,250
6.31 Backwash Supply Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.32 Backwash Pump, 40 gpm, 1 hp	2	ea		$735.00	$122.00		$0	$1,470	$244	$0	$1,714
6.33 Waste Backwash Tank, 5,000 gallon	1	ea		$7,500.00	$750.00		$0	$7,500	$750	$0	$8,250
6.34 Waste Backwash Tank Foundation	3	cy	$400.00				$1,200	$0	$0	$0	$1,200
6.35 Waste Backwash Transfer Pump, 1 gpm, 0.5 hp	2	ea		$339.60	$84.00		$0	$679	$168	$0	$847
6.36 Filtrate Tank, 9,000 gallons	1	ea		$13,500.00	$1,410.00		$0	$13,500	$1,410	$0	$14,910
6.37 Filtrate Tank Foundation	4	cy	$400.00				$1,600	$0	$0	$0	$1,600
6.38 Filtrate Tank Mixer, 7.5 hp	1	ea		$6,300.00	$1,240.00		$0	$6,300	$1,240	$0	$7,540
6.39 Filtrate Transfer Pump, 30 gpm, 0.5 hp	2	ea		$499.00	$96.00		$0	$998	$192	$0	$1,190
6.40 Air Compressor System, 50 scfm, 100 psi	1	ea		$8,900.00	$1,450.00		$0	$8,900	$1,450	$0	$10,350
6.41 Sump Pump, 10 gpm, 0.5 hp	2	ea		$283.20	$83.50		$0	$566	$167	$0	$733
6.42 Discharge Pump Tank, 1,500 gallons	1	ea		$3,000.00	$450.00		$0	$3,000	$450	$0	$3,450
6.43 Discharge Pump, 100 gpm, 2 hp	2	ea		$535.20	$133.00		$0	$1,070	$266	$0	$1,336
6.44 ED Tank, 500 gallon	1	ea		$1,225.00	$311.40		$0	$1,225	$311	$0	$1,536
6.45 ED Tank Mixer & Stand, 0.5 hp	1	ea		$1,666.00	$415.20		$0	$1,666	$415	$0	$2,081
6.46 ED Feed Pump, 4 gallons/hr	2	ea		$1,500.00	$415.20		$0	$3,000	$830	$0	$3,830
6.47 Discharge Pipe (POTW and SW), 4" Polyetheylene	800	lf		$11.00	$16.00	$1.17	$0	$8,800	$12,800	$936	$22,536
6.48 Outfall Diffuser	1	ls	$50,000.00				$50,000	$0	$0	$0	$50,000
6.49 Utility Service Line	1	ls		$59,808.50	$15,691.40		$0	$59,809	$15,691	$0	$75,500
6.50 Electrical and Controls	1	ls		$286,083.76	$176,543.40		$0	$286,084	$176,543	$0	$462,627
6.51 System Start-Up and Testing	1	ls		$3,000.00	$65,550.00		$0	$3,000	$65,550	$0	$68,550
7 MONITORING WELL INSTALLATION											
7.1 Well Installation (4 wells)	290	lf	$45.00				$13,050	$0	$0	$0	$13,050
7.2 Protective Well Casing & Apron	4	ea	$750.00				$3,000	$0	$0	$0	$3,000
8 INJECTION WELLS - ISB											
8.1 Well Installation	12,250	lf	$45.00				$551,250	$0	$0	$0	$551,250
8.2 Protective Well Casing & Apron	530	ea	$125.00				$66,250	$0	$0	$0	$66,250

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Capital Cost

	Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
8.3	Injection Labor and Equipment	14	day			$794.40	$200.00	$0	$0	$11,122	$2,800	$13,922
8.4	EOS	1	ls		$320,000.00			$0	$320,000	$0	$0	$320,000
9	**WASTE DISPOSAL**											
9.1	Decon Fluids	1,100	gal	$1.00				$1,100	$0	$0	$0	$1,100
9.2	Well Development Water (5,000 gal/well)	80,000	gal	$1.00				$80,000	$0	$0	$0	$80,000
9.3	Drill Cuttings (12-inch dia boreholes, non-haz)	25	cy	$100.00				$2,500	$0	$0	$0	$2,500
9.4	Soil Excavate (2700 lf, 3'x4' trench, non-haz)	880	cy	$100.00				$88,000	$0	$0	$0	$88,000
10	**IMPORTED CLEAN FILL**											
10.1	Import and place clean backfill	880	cy	$25.00				$22,000	$0	$0	$0	$22,000
10.2	Stabilize and restore disturbed areas (3 acres)	10,600	sy	$8.00				$84,800	$0	$0	$0	$84,800

Subtotal	$3,315,570	$2,220,198	$1,046,595	$116,359	$6,698,723
Overhead on Labor Cost @ 30%			$313,979		$313,979
G & A on Labor, Material, Equipment, & Subs Cost @ 10%	$331,557	$222,020	$104,660	$11,636	$669,872
Tax on Materials and Equipment Cost @ 6%		$133,212		$6,982	$140,193
Total Direct Cost	$3,647,127	$2,575,430	$1,465,233	$134,976	$7,822,767
Indirects on Total Direct Cost @ 25%					$1,955,692
Profit on Total Direct Cost @ 10%					$782,277
Subtotal					$10,560,736
Health & Safety Monitoring @ 2%					$211,215
Subtotal					$10,771,950
Record Drawings and Completion Report 1%					$107,720
Feasibility Study Level Costs					$10,879,670
Design Cost					$870,374
Engineering Contingency 20%					$2,175,934

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-5: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of HCA, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 1 through 5

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$100,541	$100,541	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	8,000	lbs	$2.00	$16,000	
4	Vapor Phase GAC Replacement	48,000	lbs	$2.00	$96,000	
5	PPI Zeolite Replacement	36,000	lbs	$2.25	$81,000	
6	PPI Zeolite Disposal	18	ton	$66.00	$1,188	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (12 lbs/day)	4,380	lbs	$2.00	$8,760	
	b) NaOH (220 lbs/day)	80,300	lbs	$0.35	$28,105	
	c) Polymer (6 lbs/day)	2,190	lbs	$1.00	$2,190	
	d) Hydrochloric Acid (22 lbs/day)	8,030	lbs	$0.80	$6,424	
	e) Hydrogen Peroxide - HiPOx (2.1 gal/day)	1,059	gal	$3.50	$3,705	
8	Sludge Disposal	86	ton	$65.00	$5,590	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	3513	1K cf	$35.89	$126,082	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	1	year	$3,000.00	$3,000	
11	Sanitary Sewer Analysis	2	ea	$450.00	$900	
12	NPDES Analysis	0	ea	$350.00	$0	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	0	year	$24,000.00	$0	
	b) resin	0	year	$35,000.00	$0	
14	Cartridge Filters, 25 micron	0	ea	$3.91	$0	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$752,484**	
21	Re-Application of EOS for Year 5	1	ls	$233,745.00	**$233,745**	

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-5: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of HCA, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 6 through 10

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$100,541	$100,541	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	6,000	lbs	$2.00	$12,000	
4	Vapor Phase GAC Replacement	36,000	lbs	$2.00	$72,000	
5	PPI Zeolite Replacement	27,000	lbs	$2.25	$60,750	
6	PPI Zeolite Disposal	13.5	ton	$66.00	$891	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (9 lbs/day)	3,285	lbs	$2.00	$6,570	
	b) NaOH (165 lbs/day)	60,225	lbs	$0.35	$21,079	
	c) Polymer (5 lbs/day)	1,643	lbs	$1.00	$1,643	
	d) Hydrochloric Acid (17 lbs/day)	6,023	lbs	$0.80	$4,818	
	e) Hydrogen Peroxide - HiPOx (1.6 gal/day)	794	gal	$3.50	$2,779	
8	Sludge Disposal	65	ton	$65.00	$4,225	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$18,000.00	$18,000	
	b) resin	1	year	$26,250.00	$26,250	
14	Cartridge Filters, 25 micron	98	ea	$3.91	$383	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$609,128**	

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-5: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of HCA, Discharge to POTW, Monitoring, and LUCs
Operation and Maintenance Cost for Years 11 through 30

	Item	Quantity	Unit	Unit Cost	Subtotal	Notes
Treatment System per year						
1	Energy - Electric	563,000	kWh	$0.12	$67,560	
2	System Maintenance	1	ls	$100,541	$100,541	5% of Installed Equipment Cost
3	Liquid Phase GAC Replacement	4,000	lbs	$2.00	$8,000	
4	Vapor Phase GAC Replacement	24,000	lbs	$2.00	$48,000	
5	PPI Zeolite Replacement	18,000	lbs	$2.25	$40,500	
6	PPI Zeolite Disposal	9	ton	$66.00	$594	assume non-hazardous
7	Treatment Plant Chemicals					
	a) Hydrogen Peroxide - Fe/Mn Oxidation (6 lbs/day)	2,190	lbs	$2.00	$4,380	
	b) NaOH (110 lbs/day)	40,150	lbs	$0.35	$14,053	
	c) Polymer (3 lbs/day)	1,095	lbs	$1.00	$1,095	
	d) Hydrochloric Acid (11 lbs/day)	4,015	lbs	$0.80	$3,212	
	e) Hydrogen Peroxide - HiPOx (1.0 gal/day)	529	gal	$3.50	$1,852	
8	Sludge Disposal	43	ton	$65.00	$2,795	4,000 cf per year @ 70 lb/cf
9	Sanitary Sewer Fees	0	1K cf	$35.89	$0	1,000 cubic feet @ $35.89
10	Sanitary Sewer Annual Fees	0	year	$3,000.00	$0	
11	Sanitary Sewer Analysis	0	ea	$450.00	$0	
12	NPDES Analysis	12	ea	$350.00	$4,200	monthly sampling @ 1 location
13	Ion Exchange Replacement					
	a) tanks	1	year	$12,000.00	$12,000	
	b) resin	1	year	$17,500.00	$17,500	
14	Cartridge Filters, 25 micron	65	ea	$3.91	$254	
15	Process Monitoring (VOCs, 1,4-D, metals), Aqueous	48	ea	$350.00	$16,800	monthly sampling @ 4 locations
16	Process Monitoring (VOCs), Vapor	36	ea	$150.00	$5,400	monthly sampling @ 3 locations
17	Potable Water	50,000	gal	$0.20	$10,000	
18	Miscellaneous Services (sanitation, rubbish)	1	ls	$1,000.00	$1,000	
19	Treatment Plant Operator	2,496	hours	$65.00	$162,240	48 hours per week
20	Quarterly Reports	4	ea	$2,500.00	$10,000	
				Total	**$531,976**	

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site

Alternative G-5: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of HCA, Discharge to POTW, Monitoring, and LUCs
Annual Cost

Item	Item Cost year 1	Item Cost years 2 - 3	Item Cost years 4 - 30	Notes
Site Inspection: Visit	$1,620	$1,620	$1,620	One-day visit to verify LUC RD
Site Inspection: Report	$1,680	$1,680	$1,680	
Groundwater Sampling	$57,440	$28,720	$14,360	Labor and supplies to collect samples from 40 wells using a crew of two, quarterly year 1, semi-annual years 2 & 3, annual years 4-30.
Groundwater Sampling Analysis/Water	$61,600	$30,800	$15,400	Analyze groundwater samples
Sampling Report	$33,600	$16,800	$8,400	
TOTAL	**$155,940**	**$79,620**	**$41,460**	

LOCKHEED MARTIN
Martin State Airport
Dump Road Area Site
Middle River, Maryland
Alternative G-5: Hydraulic Controls by Extraction, Ex-Situ Treatment of Groundwater, In-Situ Bioremediation of HCA, Discharge to POTW, Monitoring, and LUCs
Present Worth Analysis

Year	Capital Cost	Operation & Maintenance Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth	Current Value 2% inflation
0	$13,925,977			$13,925,977	1.000	$13,925,977	13,925,977
1		$986,229	$155,940	$1,142,169	0.935	$1,067,928	1,165,013
2		$986,229	$79,620	$1,065,849	0.873	$930,487	1,108,910
3		$752,484	$79,620	$832,104	0.816	$678,997	883,036
4		$752,484	$41,460	$793,944	0.763	$605,780	859,391
5		$752,484	$41,460	$793,944	0.713	$566,082	876,579
6		$609,128	$41,460	$650,588	0.666	$433,292	732,668
7		$609,128	$41,460	$650,588	0.623	$405,316	747,321
8		$609,128	$41,460	$650,588	0.582	$378,642	762,268
9		$609,128	$41,460	$650,588	0.544	$353,920	777,513
10		$609,128	$41,460	$650,588	0.508	$330,499	793,063
11		$531,976	$41,460	$573,436	0.475	$272,382	712,996
12		$531,976	$41,460	$573,436	0.444	$254,606	727,256
13		$531,976	$41,460	$573,436	0.415	$237,976	741,801
14		$531,976	$41,460	$573,436	0.388	$222,493	756,637
15		$531,976	$41,460	$573,436	0.362	$207,584	771,770
16		$531,976	$41,460	$573,436	0.339	$194,395	787,205
17		$531,976	$41,460	$573,436	0.317	$181,779	802,949
18		$531,976	$41,460	$573,436	0.296	$169,737	819,008
19		$531,976	$41,460	$573,436	0.277	$158,842	835,388
20		$531,976	$41,460	$573,436	0.258	$147,947	852,096
21		$531,976	$41,460	$573,436	0.242	$138,772	869,138
22		$531,976	$41,460	$573,436	0.226	$129,597	886,521
23		$531,976	$41,460	$573,436	0.211	$120,995	904,251
24		$531,976	$41,460	$573,436	0.197	$112,967	922,336
25		$531,976	$41,460	$573,436	0.184	$105,512	940,783
26		$531,976	$41,460	$573,436	0.172	$98,631	959,598
27		$531,976	$41,460	$573,436	0.161	$92,323	978,790
28		$531,976	$41,460	$573,436	0.150	$86,015	998,366
29		$531,976	$41,460	$573,436	0.141	$80,854	1,018,333
30		$531,976	$41,460	$573,436	0.131	$75,120	1,038,700
		$17,915,075	$1,434,600				39,955,659

TOTAL PRESENT WORTH $22,765,447

Dump Road Area Groundwater Containment System Design Costs

Feasibility Study Level Capital Costs (Excluding Contingency)	$10,879,670
Total Design Costs @ 8% of FS Level Capital Costs *(excluding contingency)*	$870,374
30% Design Cost (Procurement EESHBDF-02384_R631) @ 26% of Line 6	$226,297
60% Design Cost @ 44% of line 6	$382,964
90% Design Cost @ 20% of line 6	$174,075
100% Design Cost @ 10% of line 6	$87,037

ALTERNATIVE F-6:

ZVI-PRB, MONITORING, AND LUCS [NO GROUNDWATER TREATMENT]

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-6: ZVI-PRB, Monitoring, and LUCs [No groundwater treatment]
Capital Cost

Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
1 PROJECT PLANNING & DOCUMENTS											
1.1 Bench Testing	1	ls	$38,000.00				$38,000	$0	$0	$0	$38,000
1.2 Land Finders Fee	1	ls	$100,000.00				$100,000	$0	$0	$0	$100,000
2 MOBILIZATION AND DEMOBILIZATION											
2.1 Site Support Facilities (trailers, phone, electric, etc.)	1	ls		$1,000.00		$3,500.00	$0	$1,000	$0	$3,500	$4,500
2.2 Equipment Mobilization/Demobilization								$60,000	$30,000	$60,000	$150,000
3 FIELD SUPPORT AND SITE ACCESS											
3.1 Office Trailer	9	mo				$360.00	$0	$0	$0	$3,240	$3,240
3.2 Field Office Equipment, Utilities, & Support	9	mo		$470.00			$0	$4,230	$0	$0	$4,230
3.3 Storage Trailer	9	mo				$92.50	$0	$0	$0	$833	$833
3.4 Survey Support	10	day	$1,075.00				$10,750	$0	$0	$0	$10,750
3.5 Site Superintendent	189	day		$164.00	$384.64		$0	$30,996	$72,697	$0	$103,693
3.5.1 Resident Engineering (1.5 persons)	0	day		$164.00	$307.68		$0	$0	$0	$0	$0
3.6 Site Health & Safety and QA/QC	189	day		$164.00	$307.68		$0	$30,996	$58,152	$0	$89,148
3.7 Underground Utility Clearance	1	ls	$10,000.00				$10,000	$0	$0	$0	$10,000
3.8 Access Road & Parking	500	sy		$15.50	$1.05	$1.94	$0	$7,750	$525	$970	$9,245
3.9 Clearing and Grubbing	1	acre	$10,000.00				$10,000	$0	$0	$0	$10,000
3.10 Directional Drill Under Taxiway Tango	0	ls	$50,000.00				$0	$0	$0	$0	$0
4 DECONTAMINATION											
4.1 Decontamination Services	3	mo		$1,220.00	$2,245.00	$1,550.00	$0	$3,660	$6,735	$4,650	$15,045
4.2 Temporary Equipment Decon Pad	1	ls		$1,500.00	$2,000.00	$300.00	$0	$1,500	$2,000	$300	$3,800
4.3 Decon Water	3,000	gal		$0.20			$0	$600	$0	$0	$600
4.4 Decon Water Storage Tank, 6,000 gallon	3	mo				$771.00	$0	$0	$0	$2,313	$2,313
4.5 Clean Water Storage Tank, 4,000 gallon	3	mo				$693.00	$0	$0	$0	$2,079	$2,079
4.6 Disposal of Decon Waste (liquid & solid)	3	mo	$985.00				$2,955	$0	$0	$0	$2,955
5 MONITORING WELL INSTALLATION											
5.1 Well Installation (15 wells)	2,700	lf	$45.00				$121,500	$0	$0	$0	$121,500
5.2 Protective Well Casing & Apron	15	ea	$750.00				$11,250	$0	$0	$0	$11,250
6 PRB Installation											
6.1 Subcontractor Labor & Equipment	1	ls	$2,440,000.00				$2,440,000	$0	$0	$0	$2,440,000
6.2 PRB Materials	2,080	ton		$750.00			$0	$1,560,000	$0	$0	$1,560,000
6.3 Field Oversight	100	day	$414.00				$41,400	$0	$0	$0	$41,400
6.4 Waste Characterization	30	ea	$785.00	$30.00	$50.00	$30.00	$23,550	$900	$1,500	$900	$26,850
6.5 Waste Transportation and Disposal, Subtitle C	5,200	ton	$235.00				$1,222,000	$0	$0	$0	$1,222,000
6.6 Topsoil, 4" thick	55	cy		$23.00	$1.68	$4.21	$0	$1,265	$92	$232	$1,589
6.7 Seed Area	4,840	sy	$3.48				$16,843	$0	$0	$0	$16,843
6.8 License Fee - 12%	1	ls	$484,968.00				$484,968	$0	$0	$0	$484,968
7 WASTE DISPOSAL (other than PRB)											
7.1 Decon Fluids	1,000	gal	$1.00				$1,000	$0	$0	$0	$1,000
7.2 Well Development Water (5,000 gal/well)	75,000	gal	$1.00				$75,000	$0	$0	$0	$75,000
7.3 Drill Cuttings (12-inch dia boreholes, non-haz)	24	cy	$100.00				$2,400	$0	$0	$0	$2,400

Subtotal		$4,611,616	$1,702,897	$171,701	$79,016	$6,565,230
Overhead on Labor Cost @	30%			$51,510		$51,510
G & A on Labor, Material, Equipment, & Subs Cost @	10%	$461,162	$170,290	$17,170	$7,902	$656,523
Tax on Materials and Equipment Cost @	6%		$102,174		$4,741	$106,915
Total Direct Cost		$5,072,778	$1,975,361	$240,381	$91,659	$7,380,178
Indirects on Total Direct Cost @	25%					$1,845,045
Profit on Total Direct Cost @	10%					$738,018
Subtotal						$9,963,241
Health & Safety Monitoring @	2%					$199,265
Subtotal						$10,162,505
Record Drawings and Completion Report	1%					$101,625
Feasibility Study Level Costs						$10,264,130
Design Cost						$923,772
Engineering Contingency	20%					$2,052,826

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-6: ZVI-PRB, Monitoring, and LUCs [No groundwater treatment]
Capital Cost

	Item	Quantity	Unit	Unit Cost Subcontract	Unit Cost Material	Unit Cost Labor	Unit Cost Equipment	Extended Cost Subcontract	Extended Cost Material	Extended Cost Labor	Extended Cost Equipment	Subtotal
1	**PROJECT PLANNING & DOCUMENTS**											
1.1	Bench Testing	1	ls	$38,000.00				$38,000	$0	$0	$0	$38,000
1.2	Land Finders Fee	1	ls	$100,000.00				$100,000	$0	$0	$0	$100,000
2	**MOBILIZATION AND DEMOBILIZATION**											
2.1	Site Support Facilities (trailers, phone, electric, etc.)	1	ls		$1,000.00		$3,500.00	$0	$1,000	$0	$3,500	$4,500
2.2	Equipment Mobilization/Demobilization								$60,000	$30,000	$60,000	$150,000
3	**FIELD SUPPORT AND SITE ACCESS**											
3.1	Office Trailer	9	mo				$360.00	$0	$0	$0	$3,240	$3,240
3.2	Field Office Equipment, Utilities, & Support	9	mo		$470.00			$0	$4,230	$0	$0	$4,230
3.3	Storage Trailer	9	mo				$92.50	$0	$0	$0	$833	$833
3.4	Survey Support	10	day	$1,075.00				$10,750	$0	$0	$0	$10,750
3.5	Site Superintendent	189	day		$164.00	$384.64		$0	$30,996	$72,697	$0	$103,693
3.5.1	Resident Engineering (1.5 persons)	0	day		$164.00	$307.68		$0	$0	$0	$0	$0
3.6	Site Health & Safety and QA/QC	189	day		$164.00	$307.68		$0	$30,996	$58,152	$0	$89,148
3.7	Underground Utility Clearance	1	ls	$10,000.00				$10,000	$0	$0	$0	$10,000
3.8	Access Road & Parking	500	sy		$15.50	$1.05	$1.94	$0	$7,750	$525	$970	$9,245
3.9	Clearing and Grubbing	1	acre	$10,000.00								$10,000
3.10	Directional Drill Under Taxiway Tango	0	ls	$50,000.00								$0
4	**DECONTAMINATION**											
4.1	Decontamination Services	3	mo		$1,220.00	$2,245.00	$1,550.00	$0	$3,660	$6,735	$4,650	$15,045
4.2	Temporary Equipment Decon Pad	1	ls		$1,500.00	$2,000.00	$300.00	$0	$1,500	$2,000	$300	$3,800
4.3	Decon Water	3,000	gal		$0.20			$0	$600	$0	$0	$600
4.4	Decon Water Storage Tank, 6,000 gallon	3	mo				$771.00	$0	$0	$0	$2,313	$2,313
4.5	Clean Water Storage Tank, 4,000 gallon	3	mo				$693.00	$0	$0	$0	$2,079	$2,079
4.6	Disposal of Decon Waste (liquid & solid)	3	mo	$985.00				$2,955	$0	$0	$0	$2,955
5	**MONITORING WELL INSTALLATION**											
5.1	Well Installation (15 wells)	2,700	lf	$45.00				$121,500	$0	$0	$0	$121,500
5.2	Protective Well Casing & Apron	15	ea	$750.00				$11,250	$0	$0	$0	$11,250
6	**PRB Installation**											
6.1	Subcontractor Labor & Equipment	1	ls	$2,440,000.00				$2,440,000	$0	$0	$0	$2,440,000
6.2	PRB Materials	2,080	ton		$750.00			$0	$1,560,000	$0	$0	$1,560,000
6.3	Field Oversight	100	day	$414.00				$41,400	$0	$0	$0	$41,400
6.4	Waste Characterization	30	ea	$785.00	$30.00	$50.00	$30.00	$23,550	$900	$1,500	$900	$26,850
6.5	Waste Transportation and Disposal, Subtitle C	5,200	ton	$235.00				$1,222,000	$0	$0	$0	$1,222,000
6.6	Topsoil, 4" thick	55	cy		$23.00	$1.68	$4.21	$0	$1,265	$92	$232	$1,589
6.7	Seed Area	4,840	sy	$3.48				$16,843	$0	$0	$0	$16,843
6.8	License Fee - 12%	1	ls	$484,968.00				$484,968	$0	$0	$0	$484,968
7	**WASTE DISPOSAL (other than PRB)**											
7.1	Decon Fluids	0	gal	$1.00				$0	$0	$0	$0	$0
7.2	Well Development Water (5,000 gal/well)	0	gal	$1.00				$0	$0	$0	$0	$0
7.3	Drill Cuttings (12-inch dia boreholes, non-haz)	0	cy	$100.00				$0	$0	$0	$0	$0

Subtotal	$4,523,216	$1,702,897	$171,701	$79,016	$6,486,830
Overhead on Labor Cost @ 30%			$51,510		$51,510
G & A on Labor, Material, Equipment, & Subs Cost @ 10%	$452,322	$170,290	$17,170	$7,902	$647,683
Tax on Materials and Equipment Cost @ 6%		$102,174		$4,741	$106,915
Total Direct Cost	$4,975,538	$1,975,361	$240,381	$91,659	$7,282,938
Indirects on Total Direct Cost @ 25%					$1,820,735
Profit on Total Direct Cost @ 10%					$728,294
Subtotal					$9,831,967
Health & Safety Monitoring @ 2%					$196,639
Subtotal					$10,028,606
Record Drawings and Completion Report 1%					$100,286
Feasibility Study Level Costs					$10,128,892
Engineering Contingency 20%					$2,025,778

LOCKHEED MARTIN
Martin State Airport
Middle River, Maryland
Dump Road Area Site
Alternative G-6: ZVI-PRB, Monitoring, and LUCs [No groundwater treatment]

Annual Cost

Item	Item Cost year 1	Item Cost years 2 - 3	Item Cost years 4 - 30	Notes
Site Inspection: Visit	$1,620	$1,620	$1,620	One-day visit to verify LUC RD
Site Inspection: Report	$1,680	$1,680	$1,680	
Groundwater Sampling	$79,840	$39,920	$19,960	Labor and supplies to collect samples from 40 wells using a crew of two, quarterly year 1, semi-annual years 2 & 3, annual years 4-30.
Groundwater Sampling Analysis/Water	$84,000	$42,000	$21,000	Analyze groundwater samples
Sampling Report	$33,600	$16,800	$8,400	
TOTAL	**$200,740**	**$102,020**	**$52,660**	

LOCKHEED MARTIN
Martin State Airport
Dump Road Area Site
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Alternative G-6: ZVI-PRB, Monitoring, and LUCs [No groundwater treatment]
Present Worth Analysis

Year	Capital Cost	Operation & Maintenance Cost	Annual Cost	Total Year Cost	Annual Discount Rate at 7%	Present Worth	Current Value 2% inflation
0	$13,240,728			$13,240,728	1.000	$13,240,728	13,240,728
1		$25,000	$200,740	$225,740	0.935	$211,067	230,255
2		$25,000	$102,020	$127,020	0.873	$110,888	132,152
3		$25,000	$102,020	$127,020	0.816	$103,648	134,795
4		$25,000	$52,660	$77,660	0.763	$59,255	84,062
5		$100,000	$52,660	$152,660	0.713	$108,847	168,549
6		$25,000	$52,660	$77,660	0.666	$51,722	87,458
7		$25,000	$52,660	$77,660	0.623	$48,382	89,207
8		$25,000	$52,660	$77,660	0.582	$45,198	90,991
9		$25,000	$52,660	$77,660	0.544	$42,247	92,811
10		$100,000	$52,660	$152,660	0.508	$77,551	186,092
11		$25,000	$52,660	$77,660	0.475	$36,889	96,560
12		$25,000	$52,660	$77,660	0.444	$34,481	98,492
13		$25,000	$52,660	$77,660	0.415	$32,229	100,461
14		$25,000	$52,660	$77,660	0.388	$30,132	102,471
15		$12,154,670	$52,660	$12,207,330	0.362	$4,419,054	16,429,459
16		$25,000	$52,660	$77,660	0.339	$26,327	106,611
17		$25,000	$52,660	$77,660	0.317	$24,618	108,743
18		$25,000	$52,660	$77,660	0.296	$22,987	110,918
19		$25,000	$52,660	$77,660	0.277	$21,512	113,136
20		$100,000	$52,660	$152,660	0.258	$39,386	226,845
21		$25,000	$52,660	$77,660	0.242	$18,794	117,707
22		$25,000	$52,660	$77,660	0.226	$17,551	120,061
23		$25,000	$52,660	$77,660	0.211	$16,386	122,462
24		$25,000	$52,660	$77,660	0.197	$15,299	124,911
25		$100,000	$52,660	$152,660	0.184	$28,089	250,455
26		$25,000	$52,660	$77,660	0.172	$13,358	129,958
27		$25,000	$52,660	$77,660	0.161	$12,503	132,557
28		$25,000	$52,660	$77,660	0.150	$11,649	135,208
29		$25,000	$52,660	$77,660	0.141	$10,950	137,912
30		$25,000	$52,660	$77,660	0.131	$10,173	140,670
		$13,179,670	$1,826,600				33,442,694

TOTAL PRESENT WORTH $18,941,901

Dump Road Area Groundwater Containment System Design Costs

Feasibility Study Level Capital Costs (Excluding Contingency)	$10,264,130
Total Design Costs @ 9% of FS Level Capital Costs *(excluding contingency)*	$923,772
30% Design Cost (Procurement EESHBDF-02384_R631) @ 26% of Line 6	$240,181
60% Design Cost @ 44% of line 6	$406,460
90% Design Cost @ 20% of line 6	$184,754
100% Design Cost @ 10% of line 6	$92,377