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Remedial Action Plan Addendum

Lockheed Martin Tallevast Site

Tallevast, Florida

July 14, 2009

ARCADIS

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Lockheed Martin
Tallevast Site

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Executive Summary

Environmental stewardship is an important aspect of Lockheed Martin Corporation's commitment to the communities in which we operate. Accordingly, the Corporation has assumed responsibility for the assessment and cleanup of environmental impacts from the Lockheed Martin Tallevast Site (also known as the former American Beryllium Company site) located at 1600 Tallevast Road in Tallevast, Manatee County, Florida.

The assessment and cleanup activities are being conducted pursuant to the requirements detailed in Consent Order No. 04-1328 executed by and between Lockheed Martin and the Florida Department of Environmental Protection, effective July 28, 2004.

Lockheed Martin presents this revised Remedial Action Plan Addendum to outline and explain the remedial approach selected for impacted soil and groundwater on and around the site. Alternatives were evaluated not only for their technical feasibility and regulatory compliance, but also their ability to minimize disturbance of the citizens and natural resources of the Tallevast community.

This *Remedial Action Plan (RAP) Addendum* reflects retained elements of the original May 2007 RAP and the September 2008 RAP as well as the responses to comments from the Florida Department of Environmental Protection. Incorporated in this submittal are:

- Extensive new system design information gathered by Lockheed Martin to address agency comments and community concerns
- Input provided directly by the community and by independent technical experts representing the community

Both items were used to support the selection of a technically sound remedial approach. Details are described in this *RAP Addendum*.

Background

Lockheed Martin acquired ownership of the former American Beryllium Company facility through its 1996 acquisition of Loral Corporation. Lockheed Martin ceased operations at this facility in late 1996, and in 2000, sold the

facility to BECSD, LLC, which leased the facility to Wire Pro Inc. (WPI) until January 2007. In January 2007 WPI was sold to Cooper Industries, Inc., which leased the facility until operations ceased in June 2007. Lockheed Martin leased the property from BECSD from July 2007 until June 30, 2009 when ownership of the property was reacquired.

The facility is located in Tallevast, a small unincorporated community situated between the cities of Sarasota and Bradenton, Florida, in southwestern Manatee County. Land use in the area is predominantly single-family residential homes and churches, light commercial and industrial development, and heavy manufacturing. The facility is zoned for heavy manufacturing and is bounded by Tallevast Road to the north; 17th Street Court East to the east; a golf course, undeveloped and residential areas to the south; and an abandoned industrial facility to the west.

Assessments of the site indicated the presence of contaminants impacting the groundwater and soil. Groundwater contaminants that were detected above required cleanup levels are:

- 1,4-dioxane
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- Cis-1,2-Dichloroethene (cis-1,2-DCE)
- 1,1-Dichloroethene (1,1-DCE)
- 1,1-Dichloroethane (1,1-DCA)
- Vinyl Chloride
- Methylene Chloride
- Bromodichloromethane
- Dibromochloromethane
- 1,1,1-Trichloroethane

These contaminants are compounds (and their associated breakdown components) found in common industrial solvents historically used at the site.

Of these contaminants, 1,4-dioxane is the most challenging for a groundwater restoration program because it is more mobile than the other contaminants in groundwater, is the least biodegradable by indigenous subsurface microbes, and many commonly employed groundwater treatment technologies are ineffective for treating it. Consequently, it is the dominant factor in defining the area of the plume and the duration of the projected cleanup.

In addition to the groundwater contaminants listed above, polycyclic aromatic hydrocarbons (PAHs) and metals (arsenic, copper, chromium, and beryllium) were detected in soils at the facility. Standard tests of leachability were performed that indicate that these substances are not in a form or in sufficient quantity to represent a threat of off-site transport by percolation of surface water or groundwater. Furthermore, as long as an adequate exclusion barrier is maintained to sequester the contaminated soil from human exposure, there is no undue incremental risk to health or the environment.

Underlying the site are three aquifer systems – the "Surficial Aquifer System", the "Intermediate Aquifer System," and the "Floridan Aquifer". The shallowest ("Surficial Aquifer System") is a single hydrogeologic unit that is a primary water-bearing zone. The middle ("Intermediate Aquifer System") is a multi-layered system comprised of 12 separate and discernible hydrogeologic units or layers containing four (4) primary water-bearing zones. The lowest ("Floridan Aquifer System") is a single hydrogeologic unit and is a primary water-bearing zone. Extensive testing of the subsurface conditions have shown that only the upper-most four (4) water bearing zones (one shallowest "Surficial Aquifer System" zone and upper-most three "Intermediate Aquifer System" zones) are impacted by site-related contamination.

The deepest water-bearing zone of the "Intermediate Aquifer System", and the deeper "Floridan Aquifer" appear to be unaffected by the contamination. These aquifer systems and the associated geology and hydrogeology are described in detail in the *RAP Addendum*. The extent to which the aquifers contain contaminants, their relationship to each other, and their use and proximity to the community is detailed as well.

In 2006, Lockheed Martin installed an interim groundwater extraction and treatment system at the facility for contaminant removal from the on-facility source area and to reduce the possibility of further spread of contamination while a more complete solution was investigated and designed. Also in 2006, Lockheed Martin implemented a program to close the private water supply wells at the site to prevent people from drinking or using impacted groundwater and to eliminate conduits through which contaminants might seep into an uncontaminated part of the aquifer system. An important parallel effort investigated the potential for soil vapor intrusion impacts from both soil and groundwater. This study confirmed that vapor intrusion exposure was not a concern either on the facility or in the community.

To more effectively manage the cleanup and communicate with the Tallevast community, Lockheed Martin leased the entire facility in July 2007 and in June 2009, purchased it back from BECSD, LLC.

<u>Remedial Action Plan Addendum</u>

The comprehensive remedial actions detailed in this *RAP Addendum* were developed through a systematic process grounded in an appropriate balancing of state, community, and corporate interests. This development included the following:

- Establishment of objectives
- Determination of remedial system requirements from analytical and test data
- Evaluation of remedial alternatives
- Selection and justification of remedial approach and plan implementation

All of these steps were informed by open communication with the community and its experts, environmental remediation experts retained by Lockheed Martin, and interaction with the Florida Department of Environmental Protection. On February 11, 2009, Lockheed Martin provided written responses to comments submitted by the community and other interested parties regarding the previous Remedial Action Plan. Where appropriate and practical, the *RAP Addendum* incorporates changes to address concerns or constructive observations from these comments. This *RAP Addendum* is based on assessments of the facility, assessments of the site geology and hydrogeology, characterization of the nature and extent of soil and groundwater impacts, an evaluation of remedial technologies, and forecasts of time required to complete the remedy.

Remedial Objectives

Lockheed Martin has established objectives for both soil and groundwater at the site.

Soil

The *RAP Addendum* proposes a single objective for soil:

- Reduce the potential for exposure to COCs present in soil at the Facility

This will be accomplished with institutional and engineering controls that prohibit certain uses of the property and protect the health and safety of on-site workers and the surrounding community with barriers that prevent direct exposure.

Groundwater

The *RAP Addendum* proposes the following objectives for groundwater at the site:

- Reduce the potential for human exposure to COCs in groundwater
- Hydraulically control groundwater containing COCs in concentrations greater than the groundwater cleanup target levels (GCTLs) as listed in Chapter 62-777 of the F.A.C.
- Actively extract and treat the groundwater plume until concentrations are below GCTLs
- Minimize community and natural resource disturbance.

As described in this plan, these will be accomplished via active remedial measures.

With these objectives in mind, Lockheed Martin established design criteria for the remedial measures proposed. A key element in the establishment of design criteria was the development of a detailed, three-dimensional groundwater model to enable reasonable prediction of groundwater movement and its effects on the contaminant plume. From this it was possible to evaluate the effectiveness of the remediation system and estimate cleanup timeframes from a variety of perspectives and under various assumed circumstances.

Data from the Comprehensive Sampling Event in March/April 2009 were used to simulate the effects of different configurations of extraction points and pumping rates to select the most effective means to: 1) control the possible spread of contamination; 2) affect the rate at which contaminants would be removed; and 3) minimize impact to surface water and wetland resources. The model was calibrated using actual results from on site aquifer pumping tests and tracer tests to validate the modeled distribution of groundwater contaminants.

The nature and extent of environmental impact to the site soil and groundwater have been thoroughly defined by the extensive investigation and design data collection activities conducted by Lockheed Martin. This information, in conjunction with the three-dimensional groundwater modeling tool, make possible the design and implementation of the remedial measures evaluated and selected.

A broad range of remedial alternatives were evaluated and the final design is a combination of measures that, in total, meet the defined objectives. The selection process emphasized overall protection of human health and the environment and compliance with Florida State regulations.

Selected Remedial Approach

Soil

The selected approach for soil at the facility is:

- Institutional and Engineering Controls: Soils at the site will be left in place and managed through institutional and engineering controls commonly used throughout Florida for sites undergoing remediation. Access to the facility will be restricted by fencing and on-site security. Visitors to the facility and employees will be protected from exposure by barriers that cover the impacted soils. Inappropriate modifications to the facility will be prevented through deed restrictions that include mandates for appropriate soil management practices to protect against human exposure.

Groundwater

The selected remedial approach for groundwater uses the same fundamental treatment technologies employed in the interim extraction and treatment system now in operation. Elements include:

- Expanded Groundwater Extraction System: The existing groundwater recovery system will be expanded to capture and extract the contaminated groundwater within the impacted aquifer zones. A total of 77 extraction wells and four (4) trenches are proposed.
- Groundwater Treatment System: A new groundwater treatment system will be constructed to process the full flow and contaminant loading expected from the expanded extraction well network.
- Focused Pumping in the Source Areas on the Facility: An array of closely spaced extraction and injection wells will be installed in the on-facility areas that contain the greatest mass of contaminants.
- Expanded Monitoring Program: An expanded monitoring program is proposed to evaluate the capture and removal of the groundwater plume in all affected aquifer zones.

The groundwater plume will be actively extracted and treated until concentrations are below target levels set forth by the State of Florida.

The water treatment system will consist of multiple elements including iron removal, advanced oxidation, and granular activated charcoal. The design provides for significant contaminant mass removal in the first 5 years of system operation.

Plan elements will be implemented as described in several stages. Upon receiving State approval, Lockheed Martin will initiate preparations for construction, install the equipment and systems described herein, and operate the facility until cleanup is complete.

To ensure proper and safe operation of the groundwater extraction and treatment systems Lockheed Martin will incorporate the following features into the design:

- Redundant treatment unit operations and warning systems

- Regular inspections and testing of fail-safes
- Continuous manned operations

Also provided are sampling and analysis activities to confirm system performance over time. Effectiveness will be monitored by periodic sampling and analysis to track performance of the system.

This *RAP Addendum* is the culmination of substantial work conducted by Lockheed Martin, its contractors, the local community's technical experts, and the State to design the best solution for mitigating exposure to on-facility soil and restoration of groundwater at the former American Beryllium Company site. Lockheed Martin is committed to this endeavor and its ultimate successful execution.

Engineer Certification

This Remedial Action Plan Addendum for the Lockheed Martin Tallevast Site (also known as the former American Beryllium Company site) located at 1600 Tallevast Road in Manatee County, Florida, has been prepared in accordance with good scientific and engineering practices by individuals under my direct supervision and me. The system substantially meets or exceeds the objectives stated in this report. No other warranty is implied or intended.

Guy T. Kaminski, PE
Florida License No. 41048

Date July 14, 09

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Acronyms, Abbreviations, and Units of Measurement

ABC	American Beryllium Company
AF	Arcadia Formation
AF Gravels	Upper AF Gravels Unit in the Intermediate Aquifer System
AOP	advanced oxidation process
APT	Applied Process Technology, Inc.
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BBL	Blasland, Bouck & Lee, Inc.
bgs	below ground surface
CAP	Corrective Action Plan
CDM	Camp Dresser & McKee
CEB	chemically enhance backwash
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm/s	centimeters per second
CO_2	carbon dioxide
CPT	cone penetrometer test
cis-1,2-DCE	cis-1,2- dichloroethene
COC	contaminants of concern
CRV	catalyst recovery unit
CTL	cleanup target level
cy	cubic yards
CVOC	chlorinated volatile organic compound
1,1-DCA	1,1-dichloroethane
1,1-DCE	1,1-dichloroethene
DNA	Deoxyribonucleic acid
DO	dissolved oxygen
DOP	detailed operating procedure
DOT	Department of Transportation
DPE	dual-phase extraction
EBD	enhanced biological degradation
ECD	electron capture detector
ERH	electrical resistive heating
FAA	Federal Aviation Administration

F.A.C.	Florida Administrative Code
Facility	Lockheed Martin Tallevast Facility
Floridan	Upper Floridan Aquifer
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FID	flame-ionization detector
FLUCFCS	Florida Land Use, Cover, and Forms, Classification System
FOCUS	Family Oriented Community, United, Strong
Forum LLC	Forum
FRP	fiberglass reinforced plastic
ft	feet
ft^2	square feet
ft^3	cubic feet
ft bgs	feet below ground surface
ft/day	feet per day
ft^3/day	cubic feet per day
ft/ft	feet per foot
ft/msl	feet mean sea level
FOCUS	Family Oriented Community United Strong
g/kg	gram(s) per kilogram
g/L	gram(s) per liter
G-11 Aquifer	Class of groundwater designated as potable water use
GAC	granular activated carbon
GCTL	groundwater cleanup target level
GeoTrans	GeoTrans, Inc.
gph	gallons per hour
gpm	gallons per minute
gpm/ft^2	gallons per minute per square foot
GRAs	General Response Actions
GWMR	2008 Groundwater Monitoring Report
GSFD	gallons per square foot per day
h	head
H_2O_2	hydrogen peroxide
HAPs	hazardous air pollutants
HCL	hydrochloric acid
HDPE	high-density polyethylene
IAS	Intermediate Aquifer System
IDE	industrial direct exposure
IDR	*Interim Data Report*

IDW	investigation derived waste
IRA	Interim Remedial Action
IRAP	*Interim Remedial Action Plan*
IRM	Interim Remedial Measure
ISCO	*in situ* chemical oxidation
ISR	interim source removal
ITRC	Interstate Technology Regional Council
IUD	industrial user discharge
J&E	Johnson & Ettinger
K	vertical hydraulic conductivity
K_d	soil/groundwater partitioning coefficient
K_v	vertical hydraulic conductivity
kW	kilowatt
lbs	pounds
lbs/day	pounds per day
L/kg	liters per kilogram
Lockheed Martin	Lockheed Martin Corporation
Lower AF Sands System	Lower AF Sands unit within the Intermediate Aquifer
LPGAC	liquid phase granular activated carbon
Lpm	liters per minute
Lpm/Kw	liters per minute per kilowatt
LSAS	Lower Shallow Aquifer System
LTG	leachability-to-groundwater
MCC	motor control center
MCHD	Manatee County Health Department
MCUO	Manatee County Utility Operations Department Office of Industrial Compliance
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µS	microSiemens
MDL	method detection limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mi^2	square miles
MIP	membrane interface probe
NaOCl	sodium hypochlorite
NaOH	sodium hydroxide
NAM	natural attenuation monitoring
NFA	no further action

MNA	monitored natural attenuation
msl	mean sea level
NAPL	non-aqueous phase liquid
NOD	Natural Oxidant Demand
MIP	membrane interface probe
O_3	ozone
O&M	operation and maintenance
OMM	operation, maintenance, and monitoring
ORR	operational readiness review
PAH	polycyclic aromatic hydrocarbons
PCE	tetrachloroethene
PCR	polymerase chain
PES	polyethersulfone
Photo-Cat	photocatalytic
PID	photo-ionization detector
ppb	parts per billion
ppm	parts per million
PPE	personal protective equipment
psi	pounds per square inch
POTW	publicly owned treatment works
PLC	programmable logic controller
PRF	Peace River Formation
Purifics	Purifics ES, Inc.
PVC	polyvinyl chloride
PVP	polyvinylpyrrolidone
Q	flow rate
QA/QC	quality assurance/quality control
RAO	Remedial Action Objective
RAP	*Remedial Action Plan*
RAWP	*Remedial Action Work Plan*
RCA	Root Cause Analysis
RCRA	Resource Conservation and Recovery Act
RDE	Residential Direct Exposure
RO	reverse osmosis
ROI	radius of influence
rpm	revolutions per minute
RW	reference wetland
S&P Sands	Salt & Pepper Sands in the Intermediate Aquifer System
SAPA	*Site Assessment Plan Addendum*
SARA	*Site Assessment Report Addendum*

SARA 2	*Site Assessment Report Addendum 2*
SARA 3	*Site Assessment Report Addendum 3*
SAS	Surficial Aquifer System
SCTL	soil cleanup target level
SIM	selective ion monitoring
Site	The “Site” consists of both the Tallevast Facility and the surrounding area’s groundwater impacted by contaminants of concern (COCs)
SOD	soil oxidant demand
SOP	standard operating procedure
SPLP	synthetic precipitation leaching procedure
SRCO	Site Rehabilitation Completion Order
S.U.	standard units
SVOC	semi-volatile organic compounds
SWFWMD	Southwest Florida Water Management District
TCE	trichloroethene
TDH	total dynamic head
TDS	total dissolved solids
Tetra Tech	Tetra Tech, Inc.
TiO_2	titanium dioxide
TMP	transmembrane pressure
TOC	total organic carbon
1,1,1-TCA	1,1,1-Trichloroethane
UF	ultra-filtration system
TBWSA	Tampa Bay Water Supply Authority
TPH	total petroleum hydrocarbons
TPOC	temporary point of compliance
TW	target wetland
UIC	underground injection control
USAS	Upper Surficial Aquifer System
USD	undifferentiated surficial deposit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
UV	ultraviolet
UVOx	ultraviolet oxidation
VPGAC	vapor phase granular activated carbon
VFD	variable frequency drive
VOC	volatile organic compound
W	watt

WAP	wetlands assessment procedure
WMP	wetlands monitoring plan
WPI	Wire Pro, Inc.

Tables

Figures

Appendices

1. Introduction

A Remedial Action Plan (RAP) describes the basis upon which a remedial alternative has been selected for a site. A summary of historic investigation activities, results of pilot or bench studies, rationale for remedy selection/rejection using evaluation criteria, design details for the selected remedy, and an outline of the performance monitoring are included to provide a clear picture of the reasoning used to reach the conclusion that the selected remedial alternative is most appropriate.

Lockheed Martin Corporation (Lockheed Martin) has conducted extensive investigations, collected significant design data, and participated in meaningful and regular interactions with stakeholders during development of the RAP for the area surrounding and including the Lockheed Martin Tallevast Facility [also known as the former American Beryllium Company (ABC) Facility] (the Facility) located at 1600 Tallevast Road in Tallevast, Manatee County, Florida (Figures 1-1 and 1-2). The “site” consists of both the Tallevast Facility (referred to as the “Facility” or “on-facility” portion of the Site) and the surrounding area’s groundwater that is impacted by contaminants of concern (COCs) (referred to as the “off-facility” portion of the Site).

This *RAP Addendum* is a revision of the RAP submitted to Florida Department of Environmental Protection (FDEP) in August 2008 and contains changes to the 2008 RAP that were made to address FDEP comments received via letter dated March 16, 2009, community concerns, and changes to the remedial design contemplated since submitting the 2008 RAP. Information that was developed for and included in the 2008 RAP that has not been revised or included in this *RAP Addendum* includes the field logs, laboratory analytical reports, potentiometric surface and contaminant distribution figures for sampling events conducted in 2007 and 2008. The extensive remedial design investigation conducted in 2007 and 2008 was in response to FDEP comments dated July 27, 2007 on the original RAP submitted to FDEP in May 2007. FDEP had suggested a three-dimensional groundwater flow and transport model be developed for the Site versus the multi-layered two-dimensional model provided in the 2007 RAP. This *RAP Addendum* summarizes the previous RAP and associated design investigations as well as summarizing the Site assessment and interim remedial actions.

The previous investigations and development of this *RAP Addendum* were conducted pursuant to the requirements detailed in Consent Order No. 04-1328 executed by and between Lockheed Martin and FDEP, effective July 28, 2004. These activities comply with applicable sections of Chapter 62-780, Florida Administrative Code (F.A.C.), and Section 376.30701 of the Florida Statutes (*Application Of Risk-Based Corrective Action Principles To Contaminated Sites)*.

Previous investigations and RAP design data collection at the Facility and surrounding area include more than 400 soil samples from more than 1,400 boring locations, and groundwater samples from more than 275 monitoring and 11 extraction wells. COCs in soil identified in previous investigations include polycyclic aromatic hydrocarbons (PAHs), tetrachloroethene (PCE), total petroleum hydrocarbons (TPH), arsenic, beryllium, copper, and chromium. COCs identified in groundwater include:

- 1,4-dioxane
- Trichloroethene (TCE)
- Tetrchloroethene (PCE)
- Cis-1,2-dichloroethene (cis-1,2-DCE)
- 1,1-Dichloroethene (1,1-DCE)
- 1,1-Dichloroethane (1,1-DCA)
- Vinyl chloride
- Methylene chloride
- Bromodichloromethane
- Dibromochloromethane
- 1,1,1-Trichloroethane (1,1,1-TCA)

Information from these extensive efforts has guided the selection of remedial alternatives for:

- Soil at the Facility
- Groundwater beneath the Facility and the Site.

This *RAP Addendum* presents a summary assessment of the Facility, an assessment of Site geology and hydrogeology, characterization of the nature and extent of soil and groundwater impacts, an evaluation of remedial technologies, and details of the selected remedial measures to address impacts to soil on the Facility and to groundwater Site-wide.

1.1 Remedial Action Objectives

Specific remedial action objectives (RAOs) for both soil and groundwater were developed to focus remedy selection. Remedies satisfying the RAOs while minimizing impacts to the community were given preference. The RAOs are described below for both media.

Soil

The RAO for soil is:

- Reduce the potential for exposure to COCs present in soil at the Facility

The soil COCs and their respective cleanup target levels (CTLs) are listed here:

Soil Contaminants of Concern	Residential Soil Cleanup Target Level (µg/kg)	Industrial Soil Cleanup Target Level (µg/kg)	Leachability Based on Groundwater Criteria Soil Cleanup Target Level (µg/kg)
Arsenic	2,100	12,000	*
Beryllium	120,000	1,400,000	63,000
Chromium	210,000	470,000	38,000
Copper	150,000	89,000,000	*
PAH **	100	700	***
Tetrachloroethene (PCE)	8,800	18,000	30
Total Petroleum Hydrocarbons	460,000	2,700,000	340,000

Notes:

1) * — Site-specific based on Synthetic Precipitation Leaching Procedure (SPLP) analysis
2) ** — As represented by Benzo(a)pyrene equivalents
3) *** — Leachability values for individual carcinogenic polycyclic aromatic hydrocarbons are available
4) µg/kg— microgram(s) per kilogram

Groundwater

RAOs for groundwater are to:

- Reduce the potential for human exposure to COCs in groundwater
- Hydraulically control groundwater containing COCs in concentrations greater than the groundwater cleanup target levels (GCTLs) as listed in Chapter 62-777 of the F.A.C.
- Actively extract and treat the groundwater plume until concentrations are below GCTLs
- Minimize community and natural resource disturbance

The groundwater COCs and their respective GCTLs are here:

Groundwater Contaminants of Concern	Groundwater Cleanup Target Levels for G-II Aquifer (µg/L)
1,4-dioxane	3.2
Tetrachloroethene (PCE)	3
Trichloroethene (TCE)	3
Cis-1,2- dichloroethene (cis-1,2-DCE)	70
1,1-dichloroethene (1,1-DCE)	7
1,1-dichloroethane (1,1-DCA)	70
Vinyl chloride (VC)	1
1,1,1-Trichloroethane (1,1,1-TCA)	200
Methylene Chloride	5
Bromodichloromethane	0.6
Dibromochloromethane	0.4

Notes:

1) G-II Aquifer— Class of groundwater designated by the Florida Department of Environmental Protection as potable water use, groundwater in aquifers that have a total dissolved solids content of less than 10,000 milligrams per liter (mg/L), unless otherwise classified by the Commission
2) µg/L— microgram(s) per liter

1.2 History

Lockheed Martin acquired ownership of the former ABC Facility through its 1996 acquisition of Loral Corporation, the parent company of ABC. Plant operations were discontinued in late 1996. Between 1997 and 2000, Lockheed Martin prepared the property for sale and initiated Site investigations. In early 2000, Lockheed Martin sold the property and its improvements to BECSD, LLC, who in turn leased the Facility to WPI Sarasota Division, Inc. (WPI), a privately owned manufacturing company. In March 2007, WPI subsequently was sold to Cooper Industries, Inc., which assumed the lease of the Facility and continued the same manufacturing processes until operations ceased in June 2007. Lockheed Martin leased the Facility from BECSD, LLC in July 2007 and in June 2009, purchased it from BECSD, LLC.

From 1962 until 1996, the Facility was owned by Loral Corporation and operated by ABC as an ultra-precision machine parts manufacturing plant where metals were milled, lathed, and drilled into various components. Some of the components were finished by electroplating, anodizing, and ultrasonic cleaning. Chemicals used and wastes generated at the Facility included oils, fuels, solvents, acids, and metals. A detailed description of the Facility operations is presented in the *Phase I Environmental Assessment* report (Tetra Tech, Inc. [Tetra Tech], 1997a). Additional information can be found in the *Site Assessment Report Addendum* (SARA) (Tetra Tech, 2005a).

Areas of potential environmental concern at the Facility included an underground storage tank/aboveground storage tank (UST/AST) area near the southeast corner of Building 1; an area on the east and northeast side of Building 5, where five sumps were located; a hazardous materials storage area in the southeast corner of Building 5; and the wastewater treatment pond located to the south of the buildings. In the UST/AST area, two 1,500-gallon ASTs historically were used to store fuel oil, a 1,000-gallon AST was used to store solvents, and a 550-gallon UST was used to store gasoline.

Anecdotal information purported that a production well was once present in an area formerly occupied by Building 5 (see Figure 1-3 for a Facility Site Plan), which is also near the former sump area. Construction and operational details for this purported well (e.g., exact location, depth, open or screened intervals, diameter, pumping rate) cannot be located, nor any records of how this purported well may have been decommissioned, although verbal reports indicate that the well casing was cut off below the surface and buried beneath the floor slab of an addition to Building 5. All information regarding this purported well is based on conversations with former ABC employees. Lockheed Martin has conducted, and will continue to conduct, investigations to locate this purported production well.

The first Site *RAP* was submitted to FDEP on May 4, 2007. FDEP commented on that document in a letter dated July 27, 2007 and asked Lockheed Martin to submit a RAP addendum by October 1. In a letter to FDEP dated September 11, 2007, Lockheed Martin requested an extension to that deadline, citing the need to conduct additional design-related studies to adequately respond to FDEP's comments. Lockheed Martin proposed that interim deliverables could be submitted to demonstrate adequate progress toward compiling the revised *RAP*. FDEP granted the extension request in an October 2, 2007 letter formally requiring Lockheed Martin to submit five proposed interim deliverables. These were submitted to FDEP as follows:

- *Supplemental Field Activity Interim Data Report* (*IDR*), February 22, 2008 (ARCADIS 2008b)
- *Groundwater Flow and Transport Model, Interim Report— Conceptual Model, Numerical Model, and Preliminary Flow Calibration*. March 19, 2008 (GeoTrans 2008a)
- *In situ Pilot Study IDR*, April 25, 2008 (ARCADIS 2008d)
- *Groundwater Model Hydraulic Containment IDR*, April 30, 2008 (GeoTrans 2008b)
- *Groundwater Model Solute Transport IDR*, July 9, 2008 (GeoTrans 2008c)

In addition to interim deliverables, meetings were held with FDEP and members of a local organization known as "Family Oriented Community, United, Strong" (FOCUS) to review the technical details and progress of the interim submittals and to encourage input into the overall RAP process before submitting the revised *RAP*. FOCUS and its representatives have provided information and assistance to the Tallevast community relative to the Site investigation and cleanup. Eleven meetings were held with FDEP, FOCUS, and/or FOCUS' technical representative between August 24, 2007 and July 17, 2008.

Subsequent to the submittal of the interim deliverables, a revised *RAP* was submitted to FDEP on August 29, 2008 (ARCADIS, 2008g). Since the submittal of the 2008 *RAP*, Lockheed Martin has met regularly with FOCUS and their advisors. FDEP commented on the August 2008 *RAP* in a letter dated March 16, 2009 (see Appendix A). FDEP requested that a "revised final *RAP*" be submitted within 120 days of the letter (or July 14, 2009). This 2009 *RAP Addendum* addresses comments and questions set forth in the March 16, 2009 FDEP letter requesting additional information.

1.3 Remedial Actions Completed to Date

Lockheed Martin has planned and completed several voluntary remedial actions over the past eight years to proactively address Site contaminants and potential risks posed to the public. These actions include:

- Source removal action completed in 2001
- Private Well Closure Program initiated in 2006
- Voluntary Groundwater Interim Remedial Action (IRA) (operating), initiated in 2006
- Interim Source Removal (ISR) for groundwater impacted by a surface release in August 2008

These activities are summarized in Section 3.2.

2. Site Characteristics

This section discusses pertinent information regarding the physical characteristics of the Facility and the surrounding area, the topographic setting and drainage, and the regional hydrology, geology and hydrogeology.

2.1 Site Location and Land Use

The Facility is located at 1600 Tallevast Road, between the cities of Sarasota and Bradenton, in southwestern Manatee County, Florida. Land use in the area is predominantly single-family residential homes, churches, light commercial and industrial development, and heavy manufacturing. A large percentage of the ground cover in the area includes grass fields, a golf course, and residential landscaping. The Facility is located in the northwest quarter of Section 31, Township 35 South, Range 18 East, as shown on the Bradenton, Florida United States Geological Survey (USGS) 7½-minute quadrangle (Figure 1-1).

2.2 Physical Setting

The Facility encompasses an area slightly larger than five acres and is zoned for heavy manufacturing by Manatee County (Tetra Tech 1997a). It is bounded by Tallevast Road to the north, 17th Street Court East to the east, a golf course, undeveloped land, and residential areas to the south, and an abandoned industrial facility to the west (Figures 1-2 and 1-3).

Five primary buildings (Buildings 1 through 5), covering a surface area of approximately 66,000 square feet (ft^2), have been located in the central portion of the Facility. Buildings 4 and 5 were removed in December 2008. Buildings 1, 2, and 3 remain, although Building 3 is scheduled for removal before implementation of this *RAP Addendum*. Surface cover consists of a landscaped stormwater retention pond surrounded by grass on the west side of the Facility, asphalt paved parking areas south of the retention pond and south and east of the buildings, and grass in the southwestern portion of the Facility adjoining the asphalt surface. A concrete swale is located in the driveway between the main buildings (Buildings 1 and 2) to the west and Building 3 and Buildings 4/5 foundations to the east. The swale is a stormwater pathway, sloping to a grassy area at the southern end of the paved parking area. The stormwater retention pond on the west side of the Facility was reportedly constructed in approximately 1960. A Facility map is provided on Figure 1-3.

Properties adjoining and near the Facility include the Sarasota-Bradenton International Airport to the southwest, a golf course/driving range adjoining the Facility to the south, an abandoned industrial facility (formerly operated at various times by ABC, Spindrift, and Wellcraft) adjoining the Facility to the west, a CITGO gas station approximately 500 feet northwest of the Facility, and a north-south trending spur of the Seminole Gulf Railroad that intersects Tallevast Road approximately 200 feet east of the Facility. Aside from these features, surrounding properties are primarily single-family residences. Several small churches and the Tallevast Community Center are also nearby.

2.3 Topographic Setting

The Facility sits on a gently sloping plain known as the Gulf Coastal Lowlands at an elevation of approximately 30 feet above mean sea level (msl). The Facility is approximately 1.5 miles east (inland) of Sarasota Bay and approximately six miles from the Gulf of Mexico. The land surface close to the Facility has very little relief and slopes gently in a radial pattern away from the Facility (see Figure 1-1). The land surface declines from approximately 30 feet above msl at the Facility to 25 feet above msl to the west near the intersection of Tallevast Road and 15th Street East. Farther west, land surface elevations decrease to approximately 15 feet above msl just north of the Sarasota-Bradenton International Airport. Elevation contours show a very gentle slope from approximately 30 feet above msl at the Facility to 25 feet above msl approximately 2,000 feet north, northeast, southeast, and southwest of the Facility.

2.4 Regional and Site Hydrology

The Site is located in the Sarasota Bay watershed within Florida’s Southern Coastal Watershed. The Southern Coastal Watershed includes numerous estuaries, wetlands, and small coastal streams that are tidally influenced over much of their length, and a few longer stream/canal systems with predominantly freshwater habitats (SWFWMD, 2002). The Sarasota Bay watershed drains more than 200 square miles within Manatee, Sarasota, and Charlotte Counties (Kish, et. al, 2008). In the area of the Site, the Braden River watershed, a sub-basin of the Manatee River watershed, borders the Sarasota Bay watershed to the east.

The Site is located along the drainage divide between two stream/canal systems, Bowlees Creek and Pearce Canal, within the Sarasota Bay watershed. Bowlees Creek, a major tributary of Sarasota Bay, is located approximately 1.25 miles northwest of Tallevast. The Pearce Canal is located southeast (0.75 mile) and east (one mile) of Tallevast. A topographical high runs north-south through the Facility. Surface water on the western portion of the Facility flows west toward the Bowlees Creek and the improved drainage features around the Bradenton-Sarasota airport, both of which drain to Sarasota Bay. Surface water on the easternmost portion of the Facility flows toward the Pearce Canal. The Pearce Canal drains both south into the Sarasota Bay watershed and north into the Braden River watershed (DelCharco and Lewelling, 1997). The drainage divide along the Pearce Canal is located about one mile north of the Manatee/Sarasota County line, which is approximately where the canal crosses US 301, approximately one mile southeast of the Facility (Tampa Bay Regional Planning Council, 1986).

A number of small surface water bodies lie within a half-mile radius of the Facility, as shown on Figure 1-1. Several shallow swales also convey surface runoff to the street and stormwater channels. In addition, a number of wetlands have been identified by the Florida Department of Transportation Florida Land Use, Cover, and Forms, Classification System (FLUCFCS) near the Site. These wetlands are shown in Figure 2-1.

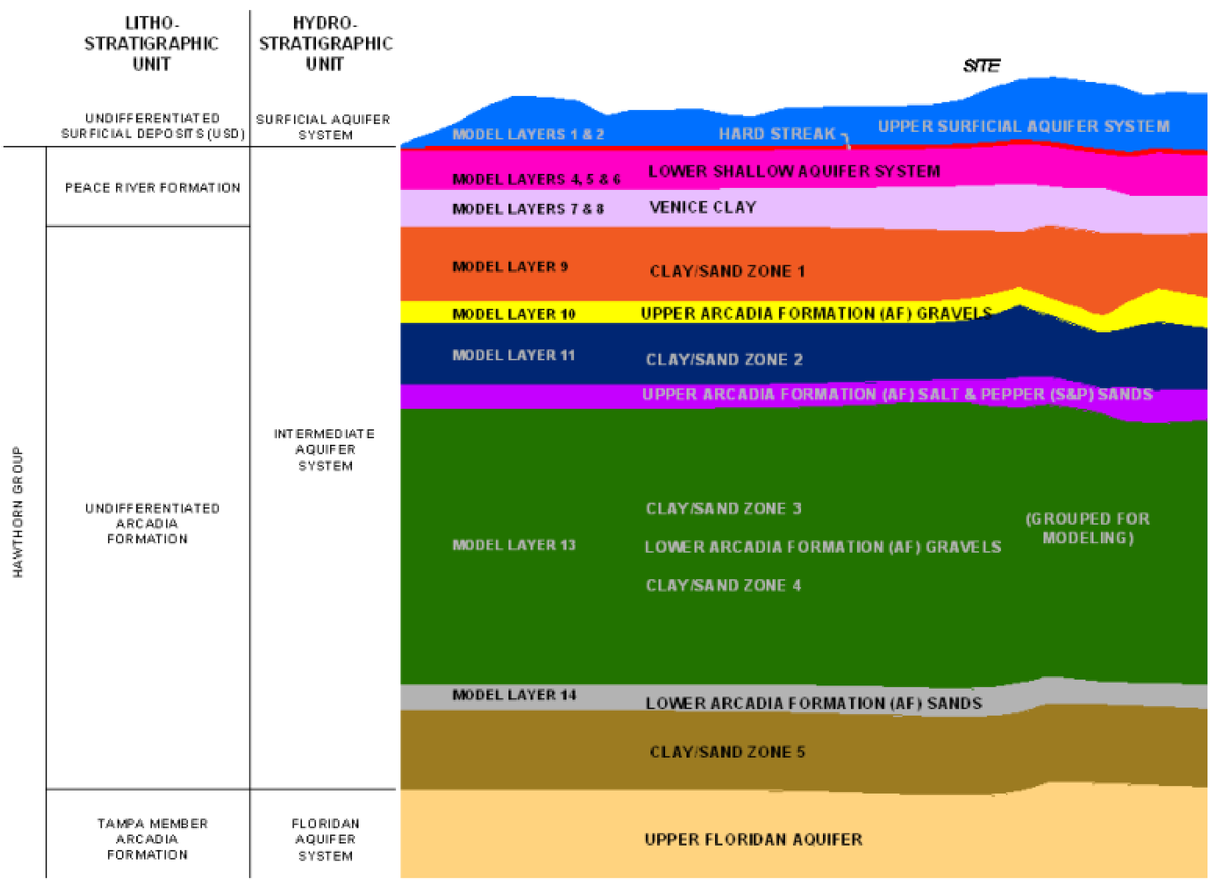
2.5 Regional Geology and Hydrogeology

In January 1995, the Southwest Florida Water Management District (SWFWMD) published a report entitled *ROMP TR-7 Oneco Monitor Well Site, Manatee County, Florida*, which describes the drilling and testing of a well completed to a reported depth of 1,715 feet (ft) below ground surface (bgs) at a location approximately 2.5 miles north of the Facility in southwestern Manatee County (SWFWMD, 1995). The nomenclature used in the 1995 SWFWMD report to describe subsurface sediments is typically used to describe consolidated carbonate formations in the Site area and is therefore used for this Site.

The regional geology consists of three main lithostratigraphic units, which are further subdivided into hydrogeologic units and water-bearing zones for monitoring purposes. Figure 2-2, below, illustrates the generalized geologic cross-section. Figure 2-3 provides a detailed stratigraphic column. From the surface downward, the geologic units underlying southern Manatee County consist of the following:

- Undifferentiated Surficial Deposits (USD) (Pleistocene to Recent)
- The Hawthorn Group, consisting of the Peace River Formation (PRF) and the Arcadia Formation (AF) (Miocene to Pliocene) — the AF consists of an upper undifferentiated section and the lower Tampa Member.
- A thick sequence of marine carbonates (limestone and dolomite) exists below the PRF and AF (not shown in the Figure 2-2 conceptual geologic cross-section) and includes the Suwannee Limestone (Oligocene), Ocala Limestone (Eocene) and the Avon Park Formation (Eocene).

Figure 2-2. Conceptual Geologic Cross-Section



The main geologic units listed above are further subdivided into the local hydrogeologic units and water-bearing zones listed below. More detailed descriptions are presented on Figure 2-3.

- Surficial Aquifer System (SAS) — the unconfined surficial aquifer overlying the Hawthorn Group.
  - Upper Surficial Aquifer System (USAS) — the unconfined surficial aquifer, consisting of unconsolidated Pleistocene to recent siliciclastic sand units with up to 20 percent fines.

- Intermediate Aquifer System (IAS) and Confining Units– the confined aquifers and confining units overlying the Upper Floridan Aquifer (Floridan). This aquifer system is made up of strata from the Hawthorn Group, which comprise the PRF and the AF.
  - Lower Shallow Aquifer System (LSAS) — the uppermost portion of the PRF, the top of which is indurated limestone/calcareous rock known locally as the Hard Streak. The LSAS consists of a series of interbedded limestone, clay, and carbonate mudstone units. The LSAS is generally encountered around 30 ft bgs. Previously, the LSAS was defined as the Lower Surficial Aquifer System, and was considered part of the SAS. However, recent carbonate content and rock coring data indicate characteristics more consistent with the IAS. The unit itself has not changed since previous reports; rather, additional data support an updated understanding of its relationship to overlying and underlying aquifer systems.

  - Venice Clay — the lower portion of the PRF, consisting of siliciclastic to calcareous clays with a distinctive greenish-grey to olive color.

  - Clay/Sand Zone 1 — the uppermost sub-unit of the AF, consisting of a series of low permeability carbonate mudstones.

  - Upper AF Gravels (AF Gravels) — a fractured to vuggy carbonate unit approximately 100 ft bgs in the AF. This unit is significantly more permeable than the overlying and underlying AF units, and is usually identified in drilling logs as “wet.” Hereafter, the term AF Gravels is only used to refer to the Upper AF Gravels.

- Clay/Sand Zone 2 a subunit of the AF, consisting primarily of low permeability carbonate mudstones.

- Salt & Pepper (S&P) Sands— a sub unit of the AF characterized by increased sand content and dark phosphatic sand grains, which give it a black and white speckled (salt and pepper) appearance. The S&P Sands are more permeable than the overlying and underlying units but less permeable than the AF Gravels. It is generally found approximately 145 ft bgs and is up to 12 feet thick.

- Clay/Sand Zone 3 & 4 and Lower AF Gravel — a sub-unit of the AF, consisting of low permeability calcareous mudstones overlying and underlying a somewhat higher permeability carbonate (Lower AF Gravel).

- Lower AF Sands — a sub-unit of the AF containing an increased percentage of sand sized particles and located approximately 280 ft bgs.

- Clay/Sand Zone 5 — a sub-unit of the AF consisting of a series of calcareous mudstones.

In addition to the SAS and IAS, the underlying Floridan (Oligocene) is monitored in a limited number of locations across the Site. The Floridan consists of the Tampa Member of the AF, the Suwannee and Ocala Limestones, and the upper part of the Avon Park Formation (Tetra Tech, 2005a). The Floridan is a series of limestone to dolomite units that are used for local water supply and irrigation. The groundwater modeling conducted for the *RAP Addendum*, as described in Section 9 below, provides additional descriptions of the hydraulic characteristics of each geologic unit simulated, including the USAS through the Lower AF Sands.

3. Previous Investigations and Voluntary Remedial Actions

Previous investigations and remedial activities conducted at the Site since 1996 include the following:

- *Phase I Environmental Site Assessment* (Tetra Tech, December 1996 to January 1997)
- *Preliminary Site Investigation* (Tetra Tech, August 1997)
- *Phase I Environmental Site Assessment* (Law Engineering and Environmental Services, Inc., December 1999 to January 2000)
- Contamination Notification to the FDEP (January 2000)
- *Contamination Discovery Report* (Tetra Tech, July 2000)
- *Contamination Assessment* (Tetra Tech, January and February 2001)
- *Interim Remedial Action — Source Removal* (Tetra Tech, September and October 2001)
- *Supplemental Groundwater Assessment* (Tetra Tech, December 2001 to January 2002)
- *Contamination Assessment Delineation Investigation* (Tetra Tech, December 2002 through March 2003)
- *Post-Contamination Assessment Monitoring* (Tetra Tech, September and December 2003, March 2004)
- *Residential Well Sampling and Geophysical Logging* (Tetra Tech, May through July 2004)
- *Preliminary Contamination Assessment* (FDEP Site Investigation Section, June 2004)
- *Site Assessment Report Addenda* (*SARA*)
  - *SARA* — Tetra Tech, November 2004 to January 2005
  - *SARA 2* — Tetra Tech, April to August 2005
  - *SARA 3* — BBL, August 2005 to April 2006
- *Remedial Action Work Plan Implementation* (BBL, September and October 2005)
- *Interim Remedial Action Plan* (*IRAP*) (BBL, 2006)

- *Private Well Closures* (ARCADIS BBL, Early 2006)
- *Interim Remedial Action System* (ARCADIS BBL, 2006)
- *Vapor Intrusion Assessment* (ARCADIS BBL, 2007)
- *Ambient Air Monitoring* (ENVIRON, November 2007 to February 2008)
- ISR (ARCADIS, August to October 2008)
- *IRA Corrective Action Plan* (ARCADIS, September 2008)
- *Soil Vapor Sampling* (ARCADIS, February 2009)
- *Private Well Closures* (ARCADIS, March 2009)

Activities conducted before 2005 are summarized in the January 2005 *SARA* (Tetra Tech, 2005a), with more recent assessment activities summarized below [based on the August 2005 *SARA 2* (Tetra Tech, 2005d) report and the April 2006 *SARA 3* report (BBL, 2006a)]. Activities are grouped by type, where applicable.

3.1 Site Assessment Report Addenda

Lockheed Martin voluntarily entered into a Consent Order with FDEP in July 2004 ordering Lockheed Martin to initiate Site assessment and remediation activities. Since then, Lockheed Martin has prepared a series of *Site Assessment Report Addenda*, which are described in the sections below.

3.1.1 *Site Assessment Report Addendum* (January 2005)

Lockheed Martin proposed expanded Site assessment activities in the October 2004 *Site Assessment Plan Addendum* (*SAPA*; Tetra Tech, 2004). Following FDEP approval of the *SAPA*, Lockheed Martin carried out these proposed activities in late 2004 to early 2005, documenting the work in the *Site Assessment Report Addendum (SARA)*, submitted to FDEP on January 31, 2005 (Tetra Tech, 2005a). The *SARA* provides additional confirmation that multiple hydrostratigraphic systems have been affected by Site COCs, including: TCE, PCE, 1,1-DCE, 1,1-DCA, cis-1,2-DCE, and 1,4-dioxane. All of these COCs are chemical ingredients (and their associated breakdown components) of common industrial solvents used historically at the Facility.

Initially, 1,4-dioxane was not identified as a Site-related COC and was not listed as such in the Consent Order. In response to a suggestion from FDEP, Lockheed Martin analyzed groundwater samples for 1,4-dioxane as part of the Site assessment activities. These activities determined that 1,4-dioxane was present in groundwater across the Site at concentrations above GCTLs, so 1,4-dioxane was designated a COC. The *SARA* defined the COCs for groundwater and recommended additional assessment activities to better define the vertical and lateral extent of these groundwater impacts. Lockheed Martin conducted additional assessment activities in early 2005, which are documented in two *Interim Data Reports* submitted to FDEP on March 10, 2005 and April 14, 2005 (Tetra Tech, 2005b, c). Representatives of FOCUS conducted their own independent testing contemporaneously with the 2005 *SARA* assessments. On May 30, 2005, Lockheed Martin received a letter from FDEP commenting on the *SARA* and its compliance with Chapter 62-780, F.A.C.

3.1.2 *Site Assessment Report Addendum 2* (August 2005)

SARA 2 (Tetra Tech, 2005d) was submitted to FDEP on August 5, 2005. It summarizes additional Site assessment data collected between approximately April–August 2005 through the additional assessment activities recommended in the January 2005 *SARA*. Results and conclusions of *SARA 2* are summarized below:

- Site-specific COCs in groundwater identified in the Consent Order include PCE, TCE, 1,1-DCE, 1,1-DCA, and cis-1,2-DCE. Subsequent to issuance of the Consent Order, 1,4-dioxane was added as a site-specific COC in groundwater.
- Concentrations of one or more COCs were found above GCTLs in the USAS and LSAS.
- Private wells that previously provided water are no longer in use. Public water service has been extended to all private well users within the affected groundwater area. Thus, exposure to contaminated groundwater has been eliminated.
- Groundwater in the upper 10 feet of the saturated zone (i.e., USAS) contains very low concentrations of COCs; however, groundwater deeper than 10 ft bgs in the USAS was found to contain elevated COC concentrations.

Based on Site assessment data collected through August 2005, *SARA 2* recommended that a *RAP* be prepared for the Site to address COC exceedances in the USAS, LSAS, and IAS. In an October 5, 2005 letter, FDEP directed Lockheed Martin to augment the *SARA 2* with specific additional activities and information, and to submit *SARA 3*.

3.1.3 *Site Assessment Report Addendum 3* (April 2006)

In response to comments from FDEP, FOCUS, and other stakeholders, Lockheed Martin completed comprehensive Site assessment activities, which were presented in the *SARA 3* (BBL, 2006a). *SARA 3* was submitted to FDEP on April 26, 2006 and summarized additional Site assessment data collected between approximately August 2005 and April 2006. Specific elements of the *SARA 3* assessment and field activities included well drilling, logging, installation, development, surveying, sampling, surface geophysical investigations, hydraulic conductivity testing, both on-facility and off-facility soil sampling, and assessment of potential receptors and exposure pathways. FDEP approved *SARA 3* on September 25, 2006, thus indicating that Site characterization was complete. A brief description of the *SARA 3* results and conclusions are presented below.

3.1.3.1 Groundwater Assessment

During development of *SARA 3*, more than 100 additional monitoring wells were installed to further delineate the nature and extent of groundwater COCs above GCTLs. The monitoring wells were installed under two work plans dated November 23, 2005 and December 16, 2005 (BBL, 2005c and 2005d). The wells installed under the first work plan investigated the nature and extent of groundwater impacts surrounding an irrigation well east of the Facility that FOCUS had previously sampled. The second work plan incorporated a proposal to install additional monitoring well clusters at various perimeter locations. As the monitoring well installation programs progressed into early 2006, additional step-out monitoring well locations were identified and installed, as necessary. Installation and sampling of the expanded monitoring well network led to the following conclusions regarding COC distribution in groundwater:

- The horizontal and vertical extent of COCs above GCTLs in Site groundwater has been delineated. The maximum horizontal extent for all COCs above GCTLs in all transmissive zones beneath the Site was identified as approximately 1,200 feet north, 2,800 feet east, 1,600 feet south, and 800 feet west of the Facility. The vertical extent of COCs above GCTLs in Site groundwater was limited to approximately 200 ft bgs within the uppermost four water-bearing zones.

- Groundwater in the Lower AF Sands and the Floridan did not contain Site COCs above GCTLs.
- The most frequently detected COC in Site groundwater samples was 1,4-dioxane, which also had the largest areal distribution in Site groundwater.
- Nonaqueous phase liquid (NAPL) has never been observed directly in any soil or groundwater samples collected during Site assessments. However, NAPL could potentially exist within the former Facility boundaries in a limited portion of the USAS near the southeast corner of Building 5.

3.1.3.2 Soil Assessment

The *SARA 3* soil assessment included an evaluation of Site-related COCs, historical soil management practices, Facility chemical usage, and previous and recent Site investigations. This information was considered in conjunction with the results of soil sampling conducted in residential areas in the Tallevast community, as well as soil sampling conducted at representative reference/background locations. In a letter dated September 25, 2006, FDEP concluded that no further action is warranted for off-facility soils, and on-facility soils can be addressed using engineering and/or institutional controls, in accordance with Chapter 62-780, F.A.C. The *SARA 3* soil assessment reached the following conclusions regarding the nature and extent of soil contamination at the Facility:

- Beryllium, copper, and chromium are the soil COCs at the Facility.
- Chromium and beryllium were detected at levels exceeding respective leachability-to-groundwater (LTG) Soil Cleanup Target Levels (SCTLs). Subsequent leachability testing using United States Environmental Protection Agency (USEPA) Methods 1312 and 6010B for beryllium indicated that the soil was not leachable. Copper was retained as a COC for Facility soils because the concentration in one location exceeded the residential direct exposure (RDE) SCTL of

150 milligrams per kilogram (mg/kg), though the detection was below the industrial direct exposure (IDE) SCTL of 89,000 mg/kg.

- Arsenic and PAHs were also detected at the Facility at concentrations exceeding the RDE SCTLs at certain locations. Research of previous operations and chemical usage indicates that neither arsenic nor PAHs were used in the manufacturing or processing operations at the Facility. These soils will be addressed as part of the *RAP Addendum*.
- One isolated detection of PCE exceeded the LTG SCTL in an on-facility soil sample (HA-016 in the upper depth horizon). The frequency of detection (one of 48 samples) and the lack of detection at deeper intervals suggest that the presence of PCE is limited and temporary in soils.

Arsenic, beryllium, copper, chromium, PAHs, TPH, and PCE are addressed below in this *RAP Addendum*.

3.1.3.3 Groundwater Elevation Measurements and Continuous Water Level Monitoring

Depth to groundwater was measured in monitoring wells from April 10–13, 2006 and converted to groundwater elevations in feet mean sea level (ft msl). Groundwater elevations were then contoured for the wells in the USAS, LSAS, AF Gravels, S&P Sands, Lower AF Sands, and Floridan. In addition, continuous groundwater level monitoring was conducted at 19 monitoring wells between November 4, 2005 and January 11, 2006. The purpose of this continuous groundwater level monitoring program was to provide data for use in evaluating the degree of hydraulic connection between hydrostratigraphic units as well as the potential influence, if any, on groundwater levels and hydraulic gradients due to off-site pumping wells. Results of these Facility investigations indicate the following:

- Groundwater levels in the USAS, LSAS, AF Gravels, and S&P Sands respond to both barometric pressure changes and rainfall events.
- Potentiometric mounding observed in the USAS is likely associated with recharge.
- Surface water elevations in ponds measured during *SARA 3* appear to be connected to the USAS water table, and were therefore contoured using the USAS water levels. Lower units are not in direct hydraulic communication with surface water bodies.

- Groundwater extraction occurs at undetermined locations near the Site. This may influence groundwater levels and associated hydraulic gradients.
- The direction of the vertical hydraulic gradient between the USAS and the LSAS, and between the LSAS and the AF Gravels, was downward throughout the monitoring period at the locations monitored.
- The direction of the vertical gradient between the S&P Sands and the AF Gravels was upward throughout the monitoring period at the locations monitored.

3.1.3.4 Fate and Transport

The *SARA 3* document reviewed the naturally occurring fate and transport processes governing COC migration in Site groundwater, including advection, dilution, dispersion, adsorption and retardation, *in situ* biodegradation, and molecular diffusion. All of these processes are present to some extent in Site groundwater, and their combined effect on COC migration rates and directions is to attenuate COC concentrations over time and distance. Evidence also indicated that biotic and abiotic degradation of chlorinated volatile organic compounds (CVOCs) in Site groundwater is occurring via reductive dechlorination processes. Evidence of reductive dechlorination occurring in portions of all monitored zones includes the presence of CVOC daughter products (cis-1,2-DCE, 1,1-DCE, 1,1-DCA, ethene, and ethane) and the presence of reducing geochemical conditions (i.e., iron reducing, sulfate reducing, and methanogenic). Overall, the *SARA 3* data demonstrate that natural attenuation processes are occurring for CVOCs in the Site's transmissive zones.

3.1.3.5 Potential Receptors and Exposure Pathways

Potential receptors and exposure pathways were evaluated during development of *the SARA 3*, including consideration of potential human and ecological receptors, as summarized below.

Human receptors — Given the mixed industrial/commercial/residential nature of land use near the Site, potential human receptors include workers and residents. These receptor groups may be exposed to site-specific COCs present in groundwater, soil, sediment, air, fish, and produce. Exposure pathways may be via ingestion, inhalation, and dermal contact. The *SARA 3* presented data that addressed each of these receptor populations and potential exposure pathways.

The principal exposure pathway for human receptors is ingestion of impacted groundwater withdrawn from private water supply wells. [Note that many of the wells that were identified and successfully located in the field have since been taken out of service, and potable water is now supplied to the community from a public water supply, thus eliminating this exposure pathway (see Section 3.2.2 for further discussion).] Other pathways and associated environmental media were also considered in the *SARA 3*. Exposure to COCs in surface water is not considered a complete pathway because no COCs were detected in surface water or the shallow groundwater (which discharges to surface water). Inhalation via the vapor intrusion pathway was likewise not considered a significant exposure pathway, because COC concentrations in the ambient air were presumed low, due to the lack of COCs in the shallow groundwater. Results from vapor intrusion studies and ambient air sampling, discussed in Section 3.3, confirm this.

Ecological receptors — The Facility supports a variety of ecological receptors that may be exposed to Site COCs present in groundwater and soil via direct contact, incidental ingestion, direct uptake, and the consumption of contaminated prey. However, the magnitude of actual exposure is likely to be small because:

- Concentrations of COCs in primary exposure media are relatively low or nonexistent.
- Exposure pathways are likely incomplete.

Thus, impacts to ecological populations at the Facility and in the surrounding areas are considered negligible.

3.2 Voluntary Interim Remedial Actions

Since 1996, Lockheed Martin has planned and completed several voluntary interim remedial actions to proactively and aggressively address Site contaminants. These IRAs include a source removal action, private well closures, and operation of a groundwater extraction and treatment system. These IRAs are described below.

3.2.1 Soil Source Removal Action

As reported in the *Site Assessment Report Addendum* (Tetra Tech, Inc., 2005a), a September 2001 source removal action was conducted to remove soil with elevated TPH concentrations from the Facility's Building 5 sump area (soils beneath the building were not excavated). The remedial excavation encompassed a surface area of approximately 2,400 ft^2 (see Figure 1-3, Facility Map) and extended to a depth of 5 ft bgs. A total of 538 tons of impacted soil was excavated and 14 confirmation soil samples were collected from the excavation. After excavation, confirmation soil samples indicated that all accessible impacted soils had been removed. TPH was detected in one sample above FDEP SCTLs; however, further excavation would have undermined the structural integrity of Building 4. Details of the soil removal action are presented in an *Interim Remedial Action Report* (Tetra Tech, 2001). TPH in Site soils will be addressed in this *RAP Addendum*.

3.2.2 Private Well Closures

In early 2006, Lockheed Martin implemented a program to abandon private domestic supply wells within the study area and connect the users to the municipal water supply system (Manatee County Utilities). The goal of the program is to eliminate the potential for exposure to groundwater and to limit potential cross-connection between vertically distinct aquifer zones. More than 100 private wells, with depths ranging from 24 to 440 feet, have been identified in the general area around the Facility (Table 3-1). Figure 3-1 presents the locations of these wells, which include irrigation, industrial supply, and former potable water use wells.

Information about these wells was provided in the *Supplemental Field Activity IDR* (ARCADIS BBL, 2007b) and the *Community Well Closure Program Well Closure Report* (ARCADIS, 2009e), including known or assumed well depths, current or former use, current status (abandoned or active), and the most recent sampling date. Lockheed Martin has worked with the Manatee County Environmental Management Department and local well owners to properly abandon former water supply wells and reduce the number of open hole wells at the Site. Since beginning the private well closure program in 2006 through June 2009, 49 wells have been abandoned. Other private wells were closed before February 2006. The *Supplemental Field Activity IDR* summarizes these efforts through February 2008. The *Community Well Closure Program Well*

Closure Report summarizes the wells closed in March 2009. Lockheed Martin will continue efforts to abandon any remaining wells near the Site. Historical analytical results from private wells are provided in Tables B-1 and B-2 of Appendix B. Private well closures help achieve the first RAO listed for groundwater in Section 1.1 above, namely, to reduce the potential for human exposure to COCs in groundwater.

3.2.3 Groundwater Interim Remedial Action

3.2.3.1 Remedial Action Work Plan (July 2005)

The overall Site remediation plan for both on- and off-facility groundwater contamination was established with FDEP's approval of the *Remedial Action Work Plan* (*RAWP*) (Tetra Tech, 2005e) submitted in July 2005. The *RAWP* describes pre-design activities (including completion of remediation pilot studies) necessary to support a comprehensive remedial design for both on- and off-facility areas including:

- Aquifer pumping tests in the USAS and LSAS (see Section 3.2.3.2.1)
- Pilot test of an ultraviolet oxidation (UVOx) advanced oxidation process (AOP) to destroy COCs in groundwater (see Section 3.2.3.2.2)
- Bench-scale test of another AOP technology to destroy COCs in groundwater (see Section 3.2.3.2.2)
- *In situ* biodegradation treatability study (see Section 4.4.1)

These pre-design activities (excluding the *in--situ* biodegradation treatability study) were summarized in the revised *IRAP* (BBL, 2006b).

3.2.3.2 Interim Remedial Action Plan (February 2006)

To expedite the remedial process, Lockheed Martin submitted a *Basis of Design — Interim Remedial Action* (BBL, 2005b) to FDEP on December 2, 2005. This document proposed a groundwater pumping and treatment system to facilitate the control and remediation of impacted groundwater in the on-facility source area and near the Facility. A revised *IRAP* was submitted to FDEP in February 2006, detailing the design, installation, operation, and monitoring of the groundwater pump and treat system at the Facility. The revised *IRAP* also provided Site assessment and pre-design investigation data, as well as design analyses. The pump and treat system is used to expedite mass removal and COC destruction and hydraulically contain the source area. The objectives of the IRA groundwater extraction and treatment system include the following:

- Provide on-facility hydraulic control of groundwater in the USAS and LSAS impacted with the highest concentrations of COCs.
- Remove a significant amount of COC mass from the groundwater plume.
- Provide additional hydrogeologic information near the Site to help design the full-scale groundwater remedy described below in Section 10 of this *RAP Addendum*.
- Destroy COCs in extracted groundwater before discharge to the on-site sanitary sewer system, using technologies that will neither result in air emissions nor disrupt the aesthetic qualities of the neighborhood.

Lockheed Martin implemented this revised *IRAP* at the Facility as an initial phase of active groundwater remediation while the *SARA 3* activities were being completed. The following sections briefly describe the pre-design investigation data presented in the *IRAP*.

3.2.3.2.1 Upper Surficial Aquifer System and Lower Shallow Aquifer System Pumping Tests (September 2005)

In accordance with the *RAWP*, Tetra Tech conducted two pumping tests at the Facility in September 2005 to collect site-specific pre-design hydrogeological data to support the preparation of the *RAP*. One 48-hour pumping test was conducted in the USAS and another 24-hour pumping test was conducted in the LSAS. Specifically, pumping test data were used to:

- Design the groundwater extraction wells and estimate groundwater extraction rates for the USAS and LSAS.
- Provide a preliminary estimate of the extent of the capture zones in the USAS and LSAS that would be created during the operation of an interim remedial action.
- Provide a design basis for the groundwater extraction treatment system.

The results of these tests indicate that hydraulically developed five-inch diameter wells with a minimum of five feet of screen could produce 3–5 gallons per minute (gpm). The complete results of the pumping tests were presented and evaluated in the revised *IRAP* (BBL, 2006b).

3.2.3.2.2 Treatability Studies

Bench-scale and pilot testing of treatment technologies were conducted to determine the most efficient and cost-effective AOP technology for the treatment of COCs present in groundwater at the Site. UVOx and ozone/hydrogen peroxide oxidation were evaluated as potential AOP technologies. Based on the test results UVOx was selected as the AOP technology for the IRA system. The following sections briefly summarize the results of the pilot and bench-scale studies used in the technology selection.

3.2.3.2.2.1 Ultraviolet Oxidation Pilot Study

Purifics ES, Inc. (Purifics) conducted an on-facility pilot test using the UVOx treatment process, which includes a patented, closed-loop, titanium dioxide (TiO_2), slurry-based photocatalytic (Photo-Cat) technology. Periodic samples were collected during the pumping tests (described above) for COC analysis. Samples were collected both before and after groundwater was treated with the on-facility UVOx pilot system and analyzed for COCs. Other organic and inorganic constituents in Site groundwater were investigated to assess whether they would interfere with the UVOx process, reduce treatment efficiency, or even prohibit its use. If such adverse conditions were found to have existed, modifications to the treatment process, such as adding pre- and/or post-treatment of the extraction water, would have been considered. The pilot test verified the effectiveness of the UVOx treatment process in treating 1,4-dioxane and volatile organic compounds (VOCs) in groundwater at the Facility. The pilot test also provided baseline design and operating parameters for the IRA treatment system. Design information and operating data, along with analytical data from KB Labs, Inc., were collected and reported in the *IRAP* (BBL, 2005a).

3.2.3.2.2.2 Ozone and Peroxide Oxidation Bench-Scale Study

To evaluate the effectiveness of ozone and peroxide oxidation technologies, Applied Process Technology, Inc. (APT) conducted a study using HiPOx™.

This technology is a continuous, in-line, at-pressure AOP to destroy waterborne VOCs and 1,4-dioxane. A 2.5-gallon sample of extracted water obtained during the pumping tests (described above) was used in bench-scale tests of ozone and peroxide oxidation using the HiPOx process. This process uses ozone (O_3) and hydrogen peroxide (H_2O_2) chemistry in a uniquely designed oxidation reactor. Reactants are injected directly into the water stream in precisely controlled ratios and locations, generating hydroxyl radicals, which are powerful oxidizers. These hydroxyl radicals attack the bonds in the organic molecules, progressively oxidizing those compounds and any resulting intermediate byproducts until the basic atoms ultimately recombine into benign end products of carbon dioxide (CO_2), water, and salts.

To confirm efficacy and to design a full-scale system for a particular application, a bench-scale reactor was used to validate HiPOx performance. Having been proven effective in treating the Site COCs, the HiPOx data were then used to model the design and performance of a full-scale system. A test report prepared by APT, including analytical data from Accutest Laboratories, was presented in the *IRAP* (BBL, 2005a).

3.2.4 Interim Remedial Action System Installation and Operation

As described in the *IRAP* (BBL, 2006b), remediation of groundwater at the Site began with the installation of the IRA groundwater extraction and treatment system. System construction began on July 24, 2006, with initial system start-up and testing on August 23, 2006. Additional construction and start-up testing continued until October 2, 2006.

3.2.4.1 Overview of the 2006 Interim Remedial Action Groundwater Extraction and Treatment System

The location of the 2006 IRA groundwater extraction and treatment system is shown on the Facility site plan (Figure 1-3). Except for the influent tank, treatment equipment was housed inside the treatment system building. The AOP is a photo-catalytic ultraviolet (UV) light VOC-destruction system operating at a flow rate of approximately 20–25 gpm and capable of operating up to a maximum flow rate of 75 gpm. Per the *IRAP*, groundwater was initially extracted from six on-facility extraction wells: three screened in the USAS (EW-103, EW-105, and EW-109) and three screened in the LSAS (EW-104, EW-106, and EW-110).

On February 4, 2008, four additional extraction wells were brought online, two in the USAS (EW-101 and EW-107) and two in the LSAS (EW-102 and EW-108), to improve hydraulic control and COC extraction rates at the Site. Extraction well EW-109, which was capturing low concentrations of Site COCs, was taken offline in February 2008. The locations of the additional extraction wells were selected based on an evaluation of the capture zone achieved by the original six extraction wells during the initial operating period. Two of these additional extraction wells (EW-101 and EW-108) are 6-inch diameter recovery wells (known previously as EXU-1 screened in the USAS, and EXL-1 screened in the LSAS) that were previously installed for pumping tests conducted in 2005 (BBL, 2006b).

Each extraction well generally yielded average flows of less than 5 gpm due to limited aquifer yields. Flow was measured and monitored with in-line flow meters. The wells discharged into a 20,000-gallon influent tank. Water inside the influent tank was circulated through an aeration system to oxidize iron. Groundwater from the influent tank was initially pumped through bag filter canisters to remove oxidized iron. Effluent from the iron removal filters was then acidified to a pH of approximately 3.0 standard units (S.U.), using sulfuric acid. The acidified water was filtered a second time through two additional sets of dual filter canisters.

After filtration, the COCs in the groundwater were treated via the Photo-Cat water treatment system, destroying the COCs by oxidation using a TiO_2 catalyst and UV light. The TiO_2 catalyst was completely removed from the treated groundwater and recycled back to the reactor before sending the treated groundwater through granular activated carbon (GAC). Following treatment through GAC, the treated groundwater was neutralized using sodium hydroxide and then discharged through an on-site connection to the sanitary sewer. The IRA groundwater extraction and treatment system also had a control system with built-in alarms and automatic shut-offs.

3.2.4.1.1 Permitting and Construction

All requisite permits were obtained for the construction of the treatment system as follows:

- Temporary Use Permit # 06070197
- Industrial Factory Permit # 06061725

- Pollutant Storage Tank Permit # 06061730
- Non-Structural Fence Permit # 06061731

All permits were reviewed and approved in the following Departments of Manatee County: Permitting, Zoning, Infrastructure, Health, Environmental Management, Fire, Impact Fees, Utilities, Plan Review, Plans Examiner, Electrical Review, Mechanical Review, and Plumbing Review. An Industrial User Discharge (IUD) permit was obtained to discharge treated water through an on-site connection to the sanitary sewer. Manatee County issued IUD permit #IW0025S, effective August 10, 2006. This permit was last revised on April 4, 2008. A Notice of Commence was issued by Manatee County on July 24, 2006. Construction of the IRA groundwater extraction and treatment system began on July 25, 2006 and system testing began on August 23, 2006, although construction continued until October 2, 2006. The following inspections were performed by Manatee County during the construction: Monolithic, Building Anchor Bolt, Building Footing, Plumbing Sewer, Plumbing Water Service, Electrical Rough In, Electrical Permanent Power Temporary Use, Electrical Final, and Building Final.

3.2.4.1.2 Treatment System Operations

Initial IRA groundwater extraction and treatment system testing began on August 23, 2006. Until the system was completed, water recovered from the extraction system was pumped to a temporary holding tank and was removed from the Site by tanker truck for appropriate off-site disposal. Approximately 63,000 gallons were extracted and disposed in this fashion.

Disposal of treated water to the sanitary sewer began on October 5, 2006. Through August 3, 2008, approximately 8.1 million gallons of groundwater were recovered and treated, resulting in about 126 pounds of COCs being removed from the subsurface. Descriptions of the IRA groundwater extraction and treatment system performance are provided in periodic Operation, Maintenance, and Monitoring (OMM) reports provided to FDEP.

3.2.4.2 Interim Source Removal for Interim Remedial Action System

On August 3, 2008, the IRA groundwater extraction and treatment system was shut down due to an accidental discharge resulting from an overflow of the influent storage tank containment. As described in the December 19, 2008

Interim Source Removal (ISR) Report (ARCADIS, 2008k) submitted to FDEP, soil and groundwater samples were collected at 30 locations to delineate the lateral and vertical extent of resultant impacts. From August 8 to September 3, 2008, 104 soil and 140 groundwater samples were collected to be analyzed for VOCs and 1,4-dioxane. As described in the *ISR Report*, a soil remedy was not required based on the soil analytical results. The groundwater results indicated that Site related COCs were present in the shallowest groundwater in the immediate vicinity of the release and within Facility boundaries.

An ISR system was installed in accordance with Rule 62-780.500(3) of the F.A.C. to extract groundwater from the 5 to 9 ft bgs interval beneath an approximately 1,000 ft^2 area. Groundwater was pumped from 15 shallow extraction wells and collected in a double-walled steel storage tank for transportation off-site for proper disposal. Double containment was provided for all recovered groundwater piping. Four sets of nested pairs of monitoring wells were also installed near the extraction wells. Operation of the ISR system started on September 24, 2008 and continued for 30 days until October 23, 2008, as allowed by Rule 62-780.500(3) F.A.C. About 74,760 gallons of groundwater were extracted during ISR system operation and transported off-site for disposal.

The ISR Report concluded the ISR system effectively reduced groundwater concentrations at all 15 extraction and eight monitoring wells, reaching non-detect levels at the method detection limit (MDL) within 30 days. Sample results at the eight monitoring wells 32 days following shut down also showed that pre-existing COCs were not affected by operation of the ISR system. The ISR Report concluded that the objectives of the ISR were achieved and recommended that no further action was necessary.

With FDEP approval, the aboveground portions of the ISR system were demolished on February 16–18, 2009. The ISR groundwater extraction and monitoring wells were abandoned on February 23–24, 2009. These activities are summarized on April 10, 2009 *ISR Demolition Report* (ARCADIS, 2009b) submitted to FDEP.

3.2.4.3 Treatment System Improvements and Re-Start

In response to the August 3, 2008 release, a *Corrective Action Plan* (CAP) (ARCADIS 2008i) for the IRA groundwater extraction and treatment system was submitted to FDEP on October 28, 2008. Improvements to the treatment system were constructed in accordance with the *CAP*, which was approved on November 3, 2008. On January 29, 2009, a *Final Incident Corrective Action Report* (ARCADIS, 2009a) was submitted to FDEP to document this milestone. This report also included an *OMM Manual* (ARCADIS 2006, revised 2009), Record Drawings of the as-built system, and *Contingency Plan*. The improvements outlined below were intended to improve the reliability of the IRA groundwater extraction and treatment system.

Corrective Action Plan Improvements

- Replaced the existing influent tank/containment dike system with a 17,640 gallon double-wall tank
- Used triple-redundant level switches/alarms for monitoring the primary tank level as well as the interstitial space between the inner and outer tanks, and for shutting down the entire system in the event of a high level in the primary tank or a detection of liquid in the interstitial space
- Wiring or programming level control switches and other critical controls to fail on loss of continuity (fail open), so that the system will shut down on a loss of signal from any of the control switches
- Implemented a redundant interlock system so that the system will shut down even if the existing programmable logic controller (PLC) system fails
- Relocated the aeration recirculation equipment and valves to a secure, controlled area inside the treatment building rather than at the influent tank inside a containment dike
- Used 316L Schedule 40 welded stainless steel for the aeration recirculation piping and influent groundwater piping inside the building, building sump transfer piping, and all process piping between the building and influent tank. This piping is pressure-rated in excess of 2,000 pounds per square inch (psi), and is more resistant to damage from external forces than the polyvinyl chloride (PVC) or the hose that was previously used
- Dual containment of the stainless steel piping between the building and the double-wall influent tank, using clear PVC pipe to allow leak observation. Instrumentation was also installed to monitor for any liquid collecting in the containment piping

- Used lockable valves
- Installed two aerators in parallel so one can be removed for cleaning while the system remains operable
- Used a centrifugal pump capable of producing a recirculation flow rate of 15 gpm at an estimated 101 feet of total dynamic head (TDH) with the pump shutoff head at approximately 140 feet TDH or 60 psi
- Replaced the metal curb at the north roll-up door with concrete curbing for improved containment within the building
- Improvements to the building, equipment, and electrical system surge suppression and grounding network

Additional Improvements

- Replaced the existing 10-well influent manifold made of Schedule 80 PVC and included flexible hose connections between the buried influent piping and the PVC manifold. This manifold was reconstructed using Schedule 40 welded stainless steel piping, valves, and braided and stainless steel flexible fittings to be consistent with the other new piping in the treatment Facility.
- Replaced the influent flow meters during reconstruction of the influent manifold. The replacement flow meters are constructed with stainless steel bodies, were sized for the anticipated flows from the recovery wells, and are powered by a 24 volt power supply.
- Replaced the existing pressure gauges (local, manual readout only) on the influent manifold with pressure indicating transmitters that provide both local pressure readings and transmit that information to the PLC.
- Installed dedicated drain lines from select process equipment to the building sump, to facilitate equipment maintenance.

As these modifications were being deployed, they were documented by means of Record Drawings, and the system *OMM Manual* and the *Contingency Plan* were revised to address comments from FDEP and to be consistent with the system as constructed. Furthermore, the standard operating procedures (SOPs) included in the *OMM Manual* were reformatted and supplemented with more detail. These changes were designed to provide the system operations staff with detailed step-by-step instructions on routine operations and include sign-off verification spaces to document that procedures were followed.

Following FDEP approval, the IRA groundwater extraction and treatment system was restarted on May 4, 2009. In addition to the improvements described above, an operator is now on-site 24-hours per day, seven days per week to monitor critical operating parameters. During May–June 2009, approximately 1.4 million gallons of groundwater from the 10 extraction wells were treated and discharged to the on-site sanitary sewer under the Manatee County IUD Permit. An OMM Report for May 2009 was submitted to FDEP on June 29, 2009 (ARCADIS 2009c) and quarterly reporting will resume in August 2009.

3.3 Soil Vapor and Vapor Intrusion Sampling

The following soil vapor sampling studies and/or vapor intrusion pathway assessments have been completed at the Site.

- Manatee County Health Department (MCHD) and Florida Department of Health (FDOH) indoor air sampling in four buildings near the Facility in 2004, with a subsequent report by the Agency for Toxic Substances and Disease Registry (ATSDR);
- Soil vapor and groundwater sampling conducted by Tetra Tech on behalf of Lockheed Martin in 2004, results of which were reported in the *SARA* (Tetra Tech, 2005a)
- Indoor air sampling conducted by Tetra Tech in Facility buildings, results of which were reported in the 2005 *Vapor Intrusion Sampling Report* (Tetra Tech, 2005f)
- Soil vapor and indoor air sampling conducted by BBL on behalf of Lockheed Martin in 2007, results of which were reported in the *Vapor Intrusion Assessment Report* (ARCADIS BBL, 2007a)
- Soil vapor, indoor air, and ambient air sampling conducted by ARCADIS on behalf of Lockheed Martin in 2009, results of which were reported in the *Soil Vapor Sampling Report* (ARCADIS, 2009d)

The results of these analyses and the multiple lines of evidence presented in these reports supported the decision to eliminate the vapor intrusion pathway from further consideration for additional assessment or potential risk mitigation.

4. Remedial Design Data

Design data were collected from October 2006 through May 2009. These activities are described briefly in the next sections, with additional details provided as appendices where appropriate. Most of this information was collected in response to FDEP comments on the original *RAP* submitted in 2007 and comments on the August 2008 *RAP*. The design data collected include:

- Groundwater Monitoring
- Subsurface Investigations:
  - Monitoring well and piezometer Installation
  - Geotechnical borings
  - Membrane Interface Probe (MIP) and cone penetrometer investigations
  - Pond and ditch sediment characterization
- Aquifer Testing
  - Specific capacity testing (June 2006)
  - Slug and pump testing — Winter 2007-2008
- Bench- and Field-Scale Testing
  - *In situ* biostimulation and bioaugmentation treatability study
  - Bench-scale testing
  - *In situ* pilot studies
- Other Activities

4.1 Groundwater Monitoring Events

Seven groundwater monitoring events have been completed to support the RAP development and design. These events included obtaining samples and measuring water levels in varying numbers of wells, since several new wells were installed in 2008. In addition, private water supply wells were sampled during some events. In many cases, private water supply wells are no longer available for sampling because they have been abandoned.

Three groundwater monitoring events were conducted between October 2006 and February 2007 to support the development of the RAP submitted in May 2007. These events are summarized below. Results and evaluation were provided in the May 2007 *RAP*.

- *October 2006* — F.A.C. Chapter 62-780 requires collection of groundwater data no more than 270 days before submittal of a *RAP*. In advance of the May 2007 *RAP* submission, groundwater levels were measured and samples collected for analysis from 102 monitoring wells during October 2006. The samples were analyzed for VOCs (including 1,4-dioxane) using USEPA Method 8260. 1,4-dioxane was also analyzed using Method USEPA 8270.
- *December 2006* — Subsequent to the October 2006 groundwater sampling effort, FDEP approved USEPA Method 8260 to analyze 1,4-dioxane in groundwater using heated purge and isotope dilution. Thus, monitoring wells and available private wells were re-sampled for all COCs, and 1,4-dioxane was analyzed for using Method 8260. Water levels were also measured during this monitoring event. The COC distribution maps associated with this event were provided in Appendix D of the August 2008 *RAP*.
- *February 2007* — On February 20, 2007, depth to groundwater was measured in all monitoring wells and samples were collected from three monitoring wells installed between December 2006 and February 2007. The potentiometric surface maps associated with this measurement event were provided in Appendix D of the August 2008 *RAP*.

Three groundwater monitoring events were conducted between December 2007 and February 2008 to support development of the revised *RAP* submitted in August 2008.

- *December 2007*— In November 2007, the IRA system was shut down to prepare for aquifer testing as described in Section 4.3. After groundwater levels in each zone had stabilized following the shutdown, a comprehensive water level measurement event was conducted in December 2007. The potentiometric surface maps associated with this measurement event were presented in the 2008 *Groundwater*

Monitoring Report (GWMR) (ARCADIS, 2008f), and were included in the August 2008 *RAP*.

- *January 2008* — A comprehensive water level measurement event was conducted in January 2008, after the aquifer testing described in Section 4.3. The potentiometric surface maps associated with this measurement event were presented in the 2008 *GWMR*, and were included in the August 2008 *RAP*.
- *January–February 2008* — A comprehensive groundwater sampling event was conducted following the January 2008 water level measurement event to provide analytical results within 270 days of submittal of the revised *RAP*, as required by rule. COC distribution maps associated with this sampling event were presented in the 2008 *GWMR*, and were included in the August 2008 *RAP*. Historical monitoring and extraction well analytical results are presented in Tables B-3 through B -5 of Appendix B of this *RAP Addendum*. Historical groundwater elevations are presented in Table B-6 of Appendix B. Laboratory analytical data for the 2006 and 2007 sampling events were provided in Appendix E of the August 2008 *RAP*. Laboratory analytical data for the 2008 sampling event were provided in the 2008 GWMR.

One groundwater monitoring event was conducted following submittal of the August 2008 *RAP* to support development of this *RAP Addendum*. This event was comprised of the following five activities:

- *March/April 2009 Annual Sampling* — A comprehensive groundwater sampling event was conducted in conjunction with obtaining water level measurements to provide analytical results not more than 270 days prior to submittal of this *RAP Addendum*, as required by rule. The COC distribution maps and potentiometric surface maps associated with this sampling event are presented and discussed below in Section 5 of this *RAP Addendum* and are also in the 2009 *GWMR*, included here as Appendix C. Historical analytical results and groundwater elevations are presented in Tables B-3 through B-6 of Appendix B of this *RAP Addendum*. Laboratory analytical data for the 2009 sampling event are also provided in Appendix C.
- *March/April 2009 IRAP Sampling* — Quarterly monitoring of the 44 IRA wells (including the 10 extraction wells) is required by the *OMM Manual*

(ARCADIS, 2006, revised 2009). The IRA well sampling was conducted as an element of the annual event. Results for the IRA wells were reported in the *IRA Monitoring Report* (ARCADIS 2009c) submitted on May 26, 2009 and are included in Tables B-3, B-4, and B-5 of Appendix B. Lab data packages are included in Appendix C.

- *March/April 2009 Blended Water RAP Design Data Sampling* — Groundwater samples were collected from a series of 16 monitoring wells and analyzed for additional design parameters, to help estimate the influent properties of this blended groundwater to the RAP treatment system. Total and dissolved iron and manganese were measured in 148 monitoring wells using USEPA Method 6010B. Field testing for total iron using Hach kits was conducted on an additional 30 monitoring wells. Analytical results for the blended water parameters and the total/dissolved iron and manganese are summarized in Tables B-7 and B-8 of Appendix B, respectively. Laboratory data packages are included in Appendix C.
- *March//April 2009 In situ Chemical Oxidation (ISCO)-Underground Injection Control (UIC) Sampling* — The April 2008 ISCO pilot study requires ongoing monitoring of metals to comply with UIC requirements. The ISCO-UIC periodic monitoring was conducted at the same time as the other March/April 2009 sampling events. Thirty-one wells (including the 10 extraction wells) were monitored for metals, bromide, sulfate, and total dissolved solids (TDS). Analytical results for the ISCO UIC parameters are summarized in Tables B-9A through B-9D of Appendix B. Laboratory data packages are included in Appendix C.
- *March/April 2009 Soil Gas Parameter Groundwater Sampling* — A soil vapor sampling program was completed in February 2009. Lockheed Martin agreed to add additional parameters to the annual groundwater sampling event in 2009 to compare compounds detected in soil gas to groundwater. Samples from 46 on-facility wells were analyzed for the detected soil gas parameters, in addition to the compounds normally reported under USEPA Method 8260. Analytical results for the soil gas parameters are summarized below in Table B-10 of Appendix B and Table 2-4 of the 2009 *GWMR*, included here as Appendix C. Laboratory data packages are also included in Appendix C.

Data in this section were used to evaluate historical trends, refine and update the groundwater model, and help identify private well use at the southwest perimeter of the Site. Recent analytical data were used to produce updated plume maps and finalize the design of the groundwater recovery system described in this *RAP Addendum*.

4.2 Subsurface Investigations

In response to FDEP's comments on the May 2007 *RAP* and to provide data for a revised *RAP* in 2008, a number of subsurface investigations were performed to identify specific potential treatment areas, provide information for groundwater flow and contaminant transport modeling, and test remedial alternatives. Subsurface investigations included the following:

- Monitoring well installation
- Geotechnical boring advancement
- MIP and cone penetrometer (CPT) boring advancement
- Pond and ditch sediment characterization

Each subsurface investigation is summarized in the sections below.

4.2.1 Monitoring Well Installation

Several monitoring wells were installed over the course of RAP design data collection. Table 3-1 lists monitoring well locations, installation dates, zone, usage, and status (former or current). Figure 4-1 shows monitoring well locations. The different monitoring well installation events are described in more detail below.

4.2.1.1 2006-2007 Monitoring Well Installation Event

The Forum, LLC (Forum), a local property development corporation, filed a petition dated October 19, 2006 for an administrative hearing regarding final agency action on the *SARA 3* (BBL, 2006a) to delineate groundwater impacts on the Forum property, located approximately 2,800 feet east of the Facility. A September 12, 2006 letter from Forum recommends installation of four well clusters on Forum property to complete the assessment. Lockheed Martin proposed installing two AF Gravels wells on the Forum property. After discussions with Forum, the parties agreed on two monitoring well locations and Forum recalled their petition. The two AF Gravels wells (MW-249 and MW-250) were installed on January 31, 2007. Boring log and well construction information for these wells were provided in Appendix F of the August 2008 *RAP*.

A new Floridan monitoring well (MW-251) was installed along the east side of 15^{th} Street East in April 2007, approximately 500 feet north of Tallevast Road to provide additional information regarding the potentiometric surface in the Floridan. The monitoring well construction details and stratigraphic description log, geophysical log, and groundwater sampling log for MW-251 were provided in Appendix F of the August 2008 *RAP*.

These three wells (MW-249, MW-250 and MW-251) were sampled in spring 2007 and were sampled for the 2008 and 2009 *GWMR*. The results of groundwater sampling and gauging are summarized in Appendix B, Tables B-3 and B-4. The potentiometric surface and COC distribution maps are included in the 2009 *GWMR* data presented in Section 5 above and in Appendix C below.

In early June 2006, an AF Gravels recovery well (EW-UAFG-1) was installed at the Facility for specific capacity testing. Boring log and well construction information were provided in Appendix F of the August 2008 *RAP*.

4.2.1.2 2007-2008 Monitoring Well Installation Event

From November to December 2007, three new wells were installed at the Facility in accordance with Lockheed Martin's Proposed Field Activities Scope of Work dated October 5, 2007. MW-252 (S&P Sands) and MW-253 (AF Gravels) were installed just north of Building 3 to complete a monitoring well cluster that includes MW-19 (Lower AF Sands) to monitor water levels (potential influence) during the aquifer testing program conducted in the AF Gravels on-facility (see Section 4.3 below). Well MW-254 (USAS) was installed in the parking lot south of Building 5 to evaluate the relative level of COC concentrations in groundwater near borings, to provide qualitative information about elevated chlorinated COCs (see Section 4.2.3, below). The monitoring well construction information is summarized in Table 3-1. The boring logs were provided in Appendix F of the August 2008 *RAP*. Information in the boring logs confirms the depth and nature of the geology identified in previous investigations. These wells were sampled and gauged as part of the 2009 *GWMR* activities. The results of historic groundwater sampling and gauging are summarized in Appendix B, Tables B-3, B-4, B-5, and B-6. The potentiometric surface and COC distribution maps including data collected from these wells, are provided in Section 5.

4.2.1.3 Piezometer Installation

Seven piezometers were installed as part of Lockheed Martin's Proposed Pumping Test Scope of Work dated November 16, 2007 (Lockheed Martin, 2007b). They were installed in the LSAS to provide additional information on LSAS water levels during the aquifer testing program being conducted in the AF Gravels on the Facility (see Section 4.3). The piezometers were designated PZ-LSAS-1 through PZ-LSAS-7. The monitoring well construction information is summarized in Table 3-1. The boring logs are provided in Appendix F of the August 2008 *RAP*. The boring log information confirms the depth and nature of the USAS, the Hard Streak, and the LSAS as identified in previous investigations. The piezometers were gauged and sampled as part of the 2009 *GWMR*, and the potentiometric surface and COC distribution maps including data collected from these wells are provided in Section 5.

4.2.2 Geotechnical Borings

Six deep (approximately 175 to 180 ft bgs) and four shallow (approximately 40 to 50 ft bgs) geotechnical borings were drilled at the locations shown on Figure 4-2 to recover soil samples for laboratory analysis. Data from these analyses were used to estimate the aquifer parameters for the groundwater contaminant fate and transport model (presented in Section 9 and Appendix D). The deep borings are GT-D-1, GT-D-2, GT-D-3, GT-D-4, GT-D-5, and GT-D-6. The shallow borings are GT-S-7, GT-S-8, GT-S-9, and

GT-S-10. Soil samples were retrieved at various depths shown in Table 4-1 and analyzed for the following:

- Total organic carbon (TOC) by USEPA Method 9060 corrected for carbonate carbon (inorganic carbon) either by direct measurement (American Society for Testing and Materials [ASTM] D513 Method B) and mathematical subtraction or removal by acidification (USEPA Lloyd Kahn Method)
- VOCs, including the full VOC list, by 8260B and 1,4-dioxane by 8260C selective ion monitoring (SIM), heated purge, isotope dilution
- Vertical hydraulic conductivity (K_v) by ASTM D 5084 (Flexible Wall Permeameter)
- Soil adsorption (soil/groundwater partitioning coefficient [K_d]) of TCE and 1,4-dioxane using batch-type procedures outlined in technical resource document: EPA-530/SW-87/006-F (see Section 4.4.2)
- Porosity by ASTM D 854
- Bulk density by ASTM D 2937
- Particle size distribution by ASTM D 422/4464
- Moisture content by ASTM D 2216

Depending on lithology type, degree of consolidation, and sub-surface drilling conditions, the following methods were used for collection of subsurface samples:

- Unlined 2-inch diameter split-spoon sampling
- Lexan-lined 2-inch and 3-inch diameter split-spoon sampling
- Brass sleeve-lined 3-inch diameter split-spoon sampling
- Dual-tube split-barrel HQ-wireline coring (Layne-Christensen model)
- Triple-tube split-barrel HQ-wireline coring (Boart Longyear model)

Hollow-stem augers were used to advance boreholes within the surficial aquifer units and into the upper portion of the Venice Clay unit. The HQ-wireline and spin casing were used to advance the boreholes through the Venice Clay and underlying units. Upon termination of the borings at their total depths, each borehole was grouted using a tremie pipe to introduce grout from the bottom of the boring to land surface to seal the borehole and prevent possible cross contamination in the aquifer system. Materials that were retrieved via coring were archived in labeled wooden core boxes located at the Facility.

The geologic logs of the soil borings were provided in Appendix F of the August 2008 *RAP*. Table 4-1 provides the survey data for the geotechnical borings. Tables B-4, B-5, and B-6 of Appendix B of the 2008 *RAP* summarizes laboratory analytical data for the geotechnical borings. The actual laboratory data reports were provided in Appendix E of the August 2008 *RAP*.

4.2.3 Membrane Interface Probe and Cone Penetrometer Investigation

A MIP survey was conducted from November 2007 through March 2008 in three Site areas to evaluate the distribution of contaminants in soil and characterize areas that may be appropriate to implement source control/treatment measures. These areas are identified as Area A on the Facility, Area B east of the Facility, and Area C south of the Facility. These areas were selected based on a review of the COC analytical results from USAS monitoring wells sampled in 2007 and earlier. Area A (on-facility) was selected because it had the highest total chlorinated COC concentrations in the Site area. Area B was selected because it appeared to have the highest chlorinated COC concentrations off-facility and had the highest PCE results detected in the USAS on-site. Area C was selected primarily to confirm that the vertical distribution of chlorinated COC concentrations in this area were similar to those observed from the MIP study in Areas A and B. The MIP locations are presented on Figure 4-2.

MIP is a tool in which a heated probe is driven at a set rate (e.g., one foot per minute) into the subsurface, using a vehicle-mounted unit. The probe is equipped with the following sensors:

- Soil conductivity sensor, a lithology indicator, since conductivity increases approximately as an inverse response to soil particle size
- Electron Capture Detector (ECD), which responds to analytes with electro-negative functional groups, such as halogens - this is the primary means by which the MIP detects chlorinated solvents; however, 1,4-dioxane is not detected by this method

- Flame-Ionization Detector (FID), which responds to organic molecules
- Photo-Ionization Detector (PID), which responds to molecules containing double carbon bonds

The information from these devices is captured in digital format and translated into graphical output, facilitating interpretation of soil types and the presence of compounds of interest. MIP data are only qualitative, and simply indicate the presence or absence of the COCs. One-hundred-thirteen MIP borings were advanced on the Facility, 31 were advanced on the property directly east of the Facility, and 17 were advanced on the next property east (Figure 4-2). In addition, single MIP borings were advanced adjacent to MW-74 and in the road right-of-way on 17th Street East, south of the Facility. Confirmation borings logged for soil lithology were advanced at three on-facility MIP locations. The borehole logs were provided in Appendix F of the August 2008 *RAP*.

To confirm soil lithology in select locations, cone penetrometer borings were advanced as described in Appendix G of the August 2008 *RAP*. Approximately 12 borings were attempted using a CPT tool attached ahead of the MIP tool to obtain additional information on the lithology simultaneously as MIP results were obtained. The CPT measures resistance on its tip and its sleeve, as well as pore pressure as the tool advances, to determine the relative amount of sand and fines (clay and silt) in the subsurface. The CPT requires a more constant drive pressure to advance the tool than does the MIP tool alone.

The limitations of the CPT drive pressure prevented full penetration of the USAS to the Hard Streak and was abandoned. The few borings that could be advanced to the Hard Streak using the CPT confirmed the lithology observed using the soil conductivity probe and the visual logging done at select MIP borings. Table 4-1 provides the survey data for the MIP boring locations. MIP printouts were provided in Appendix G of the August 2008 *RAP*.

Confirmation groundwater and soil samples were collected from boring and depth intervals with elevated MIP response to assess the chemical composition and magnitude of impacts. The analytical results from the collected soil and groundwater samples were provided in Tables G-1, G-2, G-3 and G-4 of Appendix G of the August 2008 *RAP*. The details of the MIP investigation were provided in Appendix G of the August 2008 *RAP*. The primary findings of the investigation are summarized below, grouped by location.

Area A — Facility

Several conclusions regarding the relative distribution of VOCs at the Facility resulted from the MIP investigation (see Figure 4-3):

(1) Compared to other responses across the Facility, ECD response data indicate elevated levels of VOCs in the southeastern parking area, an area to the north that previously included several sumps, and along an alley separating Buildings 1 and 2 from Buildings 3, 4 and 5.

(2) Soil conductivity data suggest that elevated levels of VOCs appear to be associated with an interbedded zone at depth and distributed vertically. Soil conductivity data at the Facility indicate that the USAS consists of sands and silty sands to approximately 20 ft bgs, but that soils from approximately 20 ft bgs to the Hard Streak are interbedded with silty clay and clay. This interbedded zone overlying the Hard Streak has lower hydraulic conductivity than upper portions of the USAS. In most locations, significant ECD response (and by inference, VOC concentrations) was associated with this interbedded zone.

(3) Four locations (MIP-39, 41, 42, 43 and 44) along a sewer line in the alleyway between Buildings 1 and 2, and Buildings 3, 4 and 5 exhibited a maximum ECD response above the interbedded zone.

Discrete groundwater sampling confirms that the areas listed above have the highest concentrations of COCs. COCs detected at concentrations greater than GCTLs in the discrete groundwater sampling included 1,1,1-TCA, 1,1-DCE, cis-1,2-DCE, TCE, 1,1-DCA, PCE, and 1,4-dioxane.

Area B — Southeast of the Facility

Area B was chosen for evaluation based on historical groundwater monitoring data. MIP data regarding distribution of VOCs at Area B off-facility locations support the following conclusions:

(1) The same pattern of higher response in the interbedded zone observed in Area A (at the Facility) was also observed in Area B. However, in Area B the higher response tended to be in the upper

portion of the interbedded zone rather than in the lower portion (as was observed in Area A).

(2) In contrast to the ECD response observed at the Facility, the ECD response in Area B did not exceed the detector maximum in any location.

(3) FID and PID response profiles do not coincide with ECD response profiles. FID and PID responses were observed in the interval between 10 and 20 ft bgs, which is shallower than the interval where ECD response occurred.

COC concentrations based on confirmatory groundwater sampling in Area B differ from those recorded in Area A (the Facility):

(1) Total VOC concentrations detected in groundwater samples collected from Area B were more than an order of magnitude lower than concentrations detected in Area A.

(2) In Area B groundwater samples, 1,4-dioxane was detected at higher concentrations than in Area A. In Area B, the 1,4-dioxane concentrations were detected at similar levels to the VOC concentrations.

Area C — South of the Facility

Area C locations were chosen for evaluation based on historical groundwater monitoring data indicating the presence of VOCs and 1,4-dioxane at concentrations greater than GCTLs. The MIP investigation, however, indicated no significant detector responses or unusual conditions in Area C.

4.2.4 Pond and Ditch Sediment Characterization

Two sediment/soil cores were retrieved from each of the 22 pond or ditch locations shown on Figure 4-2 and identified in Table 4-1. The characteristics of ponds and ditches in the groundwater flow model (presented in Section 9 and Appendix D below) represent the results of these sample analyses. Table 4-1 also provides survey data for the sampled locations. One sediment/soil core at each location was recovered from the sediment/water interface to a depth of approximately three feet below the pond bottom or refusal, whichever was encountered first. Observation of the material in the core was recorded, and the sediment logs were provided in Appendix F of the August 2008 *RAP*.

Two samples, one from the top half and one from the bottom half of the core, were collected for grain size analysis using ASTM Method D 422/4464. If the material in the core was stratified, then the grain size samples were collected from the top two to three strata observed in the core. A second core from each location was retrieved from the sediment/water interface to a depth of approximately one to two feet below the pond bottom and sent to the laboratory for vertical Kv by ASTM Method D 5084. Depth of water at each boring location was recorded. Table C-4 in Appendix C of the August 2008 *RAP* summarized the results of Kv testing. The laboratory data packages including grain size data curves were provided in Appendix E of the August 2008 *RAP*.

4.3 Aquifer Testing

Two sets of aquifer tests were performed during the RAP development. The first aquifer testing event focused on specific capacity testing of various monitoring wells and occurred in June 2006. The second aquifer testing event focused on longer-term testing of AF Gravels wells and interactions among monitored aquifer zones. Details of all testing activities were provided in Appendix H of the August 2008 *RAP*.

4.3.1 Specific Capacity Testing (June 2006)

The primary purpose of these specific capacity tests was to supplement prior hydraulic conductivity data in the USAS, LSAS, AF Gravels, and S&P Sands units to support the groundwater modeling discussed in Section 9. Results were added to previous hydraulic conductivity data from packer tests and used to develop hydraulic conductivity arrays for groundwater modeling. During June 2006, nine specific capacity tests were performed at the newly installed AF Gravels recovery wells and at eight other select monitoring wells. Testing was performed at three wells screened within the USAS (off-facility wells MW-27, MW-67, and MW-74), at two wells in the LSAS (off-facility wells MW-82 and MW-93), two wells in the AF Gravels (off-facility well MW-131 and on-facility well EW-UAFG-1), and two wells in the S&P Sands unit (off-facility wells MW-44 and MW-165).

After the specific capacity tests were completed, groundwater samples from the discharge line of the pump assembly were collected at test wells MW-27, MW-44, MW-67, MW-74, MW-82, MW-93, and MW-131. These post-test groundwater samples were analyzed for VOCs by USEPA Method 8260 and for 1,4-dioxane by USEPA Method 8270. A groundwater sample was not collected at test well MW-165 because it did not produce enough groundwater to perform a sustained four-hour specific capacity test. Appendix H of the August 2008 *RAP* presents a graphical and tabulated summary of the specific capacity test data and analysis.

4.3.2 Slug Testing and Pump Testing - Winter 2007-2008

Between November 2007 and January 2008, aquifer testing was performed to gather additional hydraulic information in support of RAP development. This section briefly summarizes the results of these tests, the objectives of which include:

- Provide quantitative hydraulic data to incorporate into the groundwater flow and contaminant transport model
- Determine the degree of hydraulic connection between the LSAS and AF Gravels units, under controlled test conditions with measured flow rates
- Attempt to produce responses that could help identify the location of the former Facility production well, thought to be beneath one of the Facility buildings [the potentiometric map offered insufficient resolution to indicate the location of the former production well]

Activities in support of these goals include:

- Installation of seven piezometers in the upper LSAS to enable additional groundwater monitoring of the aquifer pumping tests (see Section 4.2.1.3 for more details)
- Installation of continuous water level logging devices (transducers) both on-facility and off-facility
- Shut down of the IRA system

- Slug testing
- Specific capacity testing
- 24-hour aquifer pumping tests
- Seven-day aquifer pumping test
- Monitoring of the IRA system startup and the radius of influence (ROI) of the expanded system (with the addition of wells EW-101, 102, 107, and 108) was evaluated

Appendix H of the August 2008 *RAP* describes aquifer testing methods, electronic raw data generated by transducers, and an analysis of results. Appendix D describes how the results were used in groundwater flow and contaminant transport modeling.

4.3.2.1 Interim Remedial Action System Shutdown

The IRA system was shut down on November 13, 2007 to allow groundwater systems to recover to static water level conditions before testing, and to evaluate the IRA system's radius of influence. Recovery was observed in the LSAS and the USAS zones. The observable zone of influence was measured from the centerline of the extraction array to the estimated point where less than 0.1 foot of response to system shutdown was observed in transducer data. Drawdown maps used in the analysis are provided in Appendix H of the August 2008 *RAP*.

- *USAS* — The IRA system's observable zone of influence in the USAS, based on the data gathered from transducers, extended approximately 150 feet from the extraction wells.
- *LSAS* — The IRA system's observable zone of influence in the LSAS, based on the data gathered from pressure transducers, extended beyond the monitored wells to the north, west, and east. This represents a radius of over 600 feet in these directions. The zone of influence was inconclusive to the south.

Data from the IRA system shutdown indicate that the IRA zone of influence just before shutdown was smaller in the USAS than in the LSAS.

4.3.2.2 Arcadia Formation Gravels Aquifer Testing

The AF Gravels aquifer testing evaluated five different wells located on the Facility screened in the AF Gravels zone. During each test, transducers were installed in the pumped well and in 51 additional monitoring and stilling wells at and near the Facility. A detailed description of aquifer testing methods and data was included in Appendix H of the August 2008 *RAP*. GeoTrans analyzed the data to estimate aquifer parameters (such as hydraulic conductivity and storativity) and apply these parameters to the groundwater model presented in Appendix D. The following briefly describes the key information generated by the aquifer test as they pertain to RAP development (results grouped by test):

- *Slug Test in DW-1*— A slug test on well DW-1 aimed to determine whether the hydraulic conductivity at that location was sufficiently high to justify further testing. This slug test resulted in a calculated hydraulic conductivity value of 1.3 X 10^{-5} centimeters per second (cm/s), using the Bouwer and Rice (1976) method for slug test analysis. This hydraulic conductivity value is quite low compared to results from other AF Gravels wells; thus, well DW-1 does not appear to be in direct communication with the other AF Gravels wells. This is further supported by the lack of significant response by well DW-1 to extraction at other AF Gravels wells. FDEP was notified in a memo dated December 12, 2007 that testing would no longer be conducted in well DW-1. Appendix H of the August 2008 *RAP* contains a detailed description of the analytical methods used and results of this testing.
- *Specific Capacity Tests —* Specific capacity testing on four other on-facility AF Gravels wells sought to determine appropriate extraction rates for longer-term aquifer pumping tests. One hour specific capacity tests were done on wells MW-134, IWI-1, MW-127, and EW-UAFG-1. Pumping rates ranged from 1.3 to 5.6 gpm. Even with the relatively short duration of the pumping events, all four AF Gravels wells responded hydraulically to each event, indicating that this zone is spatially well-connected, at least in the tested area. The lack of observable hydraulic response in well DW-1 (though located between wells that responded) indicates it likely is not part of the same unit. The observed drawdown for each test is tabulated in Appendix H, Table H-5 of the August 2008 *RAP*.

- *24-Hour Pumping Tests* — A series of 24-hour pump tests assessed hydraulic response to extended pumping in the AF Gravels. Wells IWI-1, MW-127, and MW-134 were pumped separately for 24 hours, and then allowed to recover for at least 24 hours before beginning extraction at the next well. Pumping rates ranged from 2.0 to 2.5 gpm. The 24-hour pumping tests produced observable responses in all the monitored AF Gravels wells, as well as in many of the monitored LSAS wells. This indicates that groundwater extraction in one hydraulic zone can produce a response in another zone of the Hawthorn, even though they are separated by significant confining layers. Observed drawdown for each test is tabulated in Appendix H, Table H-5 of the August 2008 *RAP*.
- *Seven-Day Pumping Test* — A seven-day pump test likewise assessed hydraulic response to long-term pumping in the AF Gravels. Well EW-UAFG-1 was pumped for one week and then allowed to recover for seven days. Drawdown was observed in the USAS (only at MW-36), the LSAS, and the AF Gravels units. Monitored wells in zones underlying the AF Gravels (such as the S&P Sands) showed no response to pumping from the AF Gravels. The approximate maximum drawdown for each monitored location is provided in Appendix H, Table H-5 of the August 2008 *RAP*. Figures 3-3A to 3-3C from the 2008 *GWMR* were also included in Appendix H of the August 2008 *RAP* to illustrate drawdown contours. A brief description of the drawdown results is provided below.
  - *USAS* — In the USAS, only the closest well (MW-36) to EW-UAFG-1 showed a measurable, though extremely small, response (0.5 inch).
  - *Uppermost LSAS* — The uppermost LSAS responded significantly less to pumping in the AF Gravels than did the lower portions of the LSAS, indicating that the vertical hydraulic conductivity of the LSAS is significantly lower than the horizontal hydraulic conductivity. Boring logs point to the presence in the LSAS of (1) very finely laminated and vertically stratified zones and (2) clay rich lenses, which together hinder vertical flow. The transducer-instrumented piezometers and wells were in the uppermost portion of the LSAS: PZ-LSAS-1 through 7, EW-104, EW-106, and

EW-110.The maximum adjusted drawdown of 0.75 foot was at well EW-106.

- o *Lower LSAS* — All instrumented wells in this zone responded to extraction at EW-UAFG-1, with adjusted drawdown responses ranging from 0.64 to 2.32 feet. A response of 0.89 foot was observed in well MW-91, nearly 700 feet away from EW-UAFG-1.

- o *AF Gravels* — *All instrumented wells in this zone responded to extraction at EW-UAFG-1, with adjusted drawdown responses ranging from 35.6 feet at the pumped well to 1.81 feet at well MW-133, nearly 700 feet away from EW-UAFG-1.*

The drawdown measured in the LSAS during the AF Gravels aquifer testing indicates that pressure responses are transmitted upward through the Venice Clay into the LSAS. The persistent and sizeable response observed in the LSAS during the AF Gravels aquifer testing suggests that a natural connection may exist between the units, in addition to the connection due to the boreholes of private wells, many of which were abandoned before these tests. These presumed natural connections may be caused by local zones of higher vertical hydraulic conductivity due to natural variations in lithology in the carbonate rocks of the Hawthorn Formation. This hydraulic connection is represented in the GeoTrans model simulation (Appendix D).

4.3.2.3 Interim Remedial Action System Startup

The IRA system was re-started on February 4, 2008, approximately three weeks after the cessation of pumping at well EW-UAFG-1. The four new IRA extraction wells (EW-101, 102, 107, and 108) were operational at system startup. The effect of adding these new extraction wells was determined by comparing the recovery observed after the original IRA system was shut down in November 2007 to the drawdown observed from the startup of the new IRA system in February 2008. The addition of the new extraction wells significantly expanded the IRA system's influence both laterally and vertically, as outlined below.

- *USAS* — Data from the transducers suggest that the IRA-system's observable zone of influence in the USAS extends approximately 450 feet from the extraction wells. This approximately triples the radius of influence as compared to the previous effect of IRA system operation.

- *LSAS* — Data from pressure transducers suggest that the IRA system's observable zone of influence in the LSAS extends beyond the monitored wells to the north, west, and east. This represents a radius greater than 700 feet. In addition, drawdown at the farthest monitoring points was more than double the amount of recovery observed after the IRA system shutdown.
- *AF Gravels* — With the addition of the new IRA system wells, the AF Gravels experienced drawdown due to IRA system operation. The radius of influence in the AF Gravels is estimated between 200 to 300 feet from the center of LSAS pumping, indicating that extraction in the LSAS influences the gradient between units to a larger extent than previously estimated.

2008 *GWMR* Figures 3-2A to 3-2C, included in Appendix H of the August 2008 *RAP*, present the November 2007 IRA system shutdown recovery data, and Appendix H of the August 2008 *RAP*, Figures H-8 to H-9 presents the February 2008 IRA system start-up drawdown data.

4.3.2.4 Value of Hydraulic-Stress Changes to Model Calibration and Verification

The groundwater hydraulic response data collected from December 2007 through April 2008 provides a strong foundation for improving the calibration of the groundwater flow model (discussed more fully in Section 9), including testing the model against several significant changes in hydraulic stresses due to sudden, programmed changes, either from extraction well pumping (discussed above) or injection well recharge (discussed in Section 4.4.3 below). The following activities induced measurable water level responses across all of the aquifer units where remediation efforts are focused.

- *LSAS and USAS tracer tests*— In these tests, solutions were injected at rates sufficiently high to cause substantial water level changes in these two units and adjacent layers. Transient water level data from these tests were used to refine estimated values for the horizontal and vertical hydraulic conductivities of the USAS, LSAS, and AF Gravels units, as well as the vertical hydraulic conductivities of the Hard Streak and the Venice Clay or Clay/Sand Zone 1 confining units. In addition, the groundwater quality data from these tests provides the primary basis for estimating the mobile porosity of the contaminated aquifer units.

- <u>*IRA system pumping changes.*</u> These changes provided several sets of hydraulic--stress data. The changes included full system shut--down for running the AF Gravels pumping test, re-start following the test, and subsequent on/off cycling of selected IRA extraction wells during the LSAS and USAS tracer tests. Analyses of water level responses to these pumping changes helped improve estimates of the vertical hydraulic conductivity of the lower permeability clay zone within the LSAS and of the Venice Clay or Clay/Sand Zone 1 confining unit, and for the horizontal hydraulic conductivity of the shallower and deeper portions of the LSAS. In particular, the observed higher yields of EW-108 and significant water level responses in nearby monitoring wells during the on/off pumping cycle provides the basis for estimates of horizontal hydraulic conductivity for the deeper portion of the LSAS.

These hydraulic stress-change periods serve as the foundation for verifying the accuracy of the groundwater flow model for simulating remediation pumping effectiveness, and for representing the seepage through confining units with sufficient accuracy for predictive modeling purposes. Thus, the data from these hydraulic changes were used to confirm the ability of the model to simulate stressed pumping conditions in the USAS, LSAS, and AF Gravels geologic units at the Facility, as described in more detail in the Modeling Report (Appendix D), and as summarized in Section 9 below.

4.4 Bench- and Field-Scale Testing

As part of the *RAP* preparation, several field- and bench-scale studies were conducted with the goal of directly testing the effectiveness of remedial options and to characterize certain site-specific aquifer properties that would influence the effectiveness of remedial options. These studies included the following:

- *In situ* biostimulation and bioaugmentation treatability study
- Bench-scale natural-oxidant-demand (NOD) testing
- Partitioning-coefficient testing

- *In situ* chemical oxidation bench-scale treatability study
- *In situ* pilot studies, including tracer injection tests and chemical oxidation pilot tests

4.4.1 *In situ* Biostimulation and Bioaugmentation Treatability Study

Preliminary treatability testing was conducted in October 2005 to determine the potential effectiveness of biostimulation (i.e., the addition of a biodegradable substrate to act as an electron donor in the reductive dechlorination process) and biostimulation/bioaugmentation (i.e., the addition of a specific microbial consortium known to facilitate complete reductive dechlorination). Specific deoxyribonucleic acid (DNA) analyses were performed to assess the potential presence of *Dehalococcoides ethanogenes,* a microorganism known to facilitate reductive dechlorination. The preliminary treatability testing included a bench-scale microcosm assessment and analysis of groundwater samples from monitoring wells MW-37, MW-39, IWI-1, and IWI-2 for key biogeochemical parameters. A detailed description of these tests and their results was included in Appendix I of the August 2008 *RAP*.

In-well microcosms were constructed using select amendments, including biodegradable substrate and/or an engineered consortium of dehalorespiring bacteria. Groundwater sampling associated with biotreatability testing included the analysis of field parameters (i.e., pH, temperature, specific electrical conductivity, dissolved oxygen, turbidity, and oxidation reduction potential), analysis for chlorinated VOCs, dissolved light hydrocarbon gases (i.e., ethene, ethane, and methane), and anions (i.e., nitrate, nitrite, sulfate, phosphate, chloride, lactate, and bromide), and DNA analyses using the polymerase chain reaction (PCR) method. *In situ* testing was done using down-hole, retrievable microcosms, including one or more of the following components: (1) diffusive groundwater sampler, (2) degradable substrate, and/or (3) dehalorespiring microbial consortium.

These bench and field tests found that:

- DNA expression of indigenous Dehalococcoides sp. was not detected in ambient groundwater samples; however, in situ testing revealed detectable levels of Dehalococcoides sp. in one control microcosm where no additional amendments were provided, and in two microcosms containing only electron donor amendment, which suggests that dechlorinating bacteria are present in Site groundwater and can be stimulated in the presence of an excess electron donor. Although Dehalococcoides sp. has been selected for focused study in assessing reductive dechlorination, Dehalococcoides sp. alone cannot completely dechlorinate PCE to ethane in energy-conserving metabolism reactions. A microbial consortium is required to facilitate complete reductive dechlorination (Suthersan and Payne, 2005).

- The presence of cis-1,2-DCE (a PCE and TCE dechlorination product) in Facility groundwater indicates that natural reductive dechlorination is occurring. Reduction of PCE and TCE to cis-1,2-DCE can readily occur through primary fermentation reactions that occur under marginally reducing conditions in the presences of degradable carbon compounds, found naturally in Site groundwater (e.g., humic and fulvic naturally-occurring organic acids). However, dechlorination of the lower chlorinated ethenes requires molecular hydrogen, which is present at elevated concentrations under strongly reducing conditions (i.e., sulfate-reducing and methanogenic dominated biogeochemical reactions) [Suthersan and Payne, 2005]. Biogeochemical analytical results collected from the control microcosms show that ambient groundwater is strongly reducing at select locations in the study area. Specifically, low sulfate and elevated methane concentrations are observed in the control microcosms IWI-1 and IWI-2, suggesting that sulfate reduction and methanogenesis are the dominant biogeochemical process at these locations. Under strongly reducing conditions, chlorinated ethenes can undergo reductive dechlorination, (as was observed in this series of biotreatability studies), or can be reduced through abiotic pathways. Abiotic reactions with reduced solid surfaces (mostly ferrous sulfides and other "green rust" minerals), can reduce chlorinated ethenes and produce chloroacetylene and acetylenes as reaction products (Suthersan and Payne, 2005).

The presence of ethene (the end product of reductive dechlorination) in control (IWI-2) and electron donor amendment microcosms (MW-37, MW-39, and IWI-2) demonstrates that complete reductive dechlorination occurs, to some extent, and that the dechlorination process can be enhanced through biostimulation of indigenous bacteria through the addition of excess organic carbon to the subsurface.

4.4.2 Bench-Scale Testing

The following bench-scale tests were completed to assess remedial alternatives and to provide information on solute transport model parameters: NOD testing, soil/groundwater partitioning coefficient (K_d) testing, and *in situ* chemical oxidation treatability studies.

4.4.2.1 Bench-Scale Natural Oxidant Demand Testing

Bench-scale NOD testing evaluated the oxidant demand of the aquifer materials. ARCADIS carried out the tests using soil and groundwater samples collected from the Facility. Sodium persulfate served as the oxidant. Test methodology and results were included in Appendix J of the August 2008 *RAP*. Results of the NOD testing are summarized as follows:

- Following seven days of chemical oxidation treatments, the NOD values were between 29 and 40 grams of sodium persulfate per kilogram of saturated soil (g/kg). A typical NOD value is approximately 1 g/kg.
- The high NOD exerted by Site soils from the USAS and LSAS is likely associated with a relatively high concentration of naturally occurring organic material, typically associated with shallow soils in Florida and reduced mineralogy.
- Reduced divalent metals (e.g., ferrous iron) are naturally present in the USAS, providing a certain level of persulfate activation.

4.4.2.2 Partitioning Coefficient Testing

The ARCADIS Treatability Laboratory performed a batch-type soil adsorption treatability study to determine the site-specific range in soil/groundwater partitioning coefficient (K_d) for TCE using 12 soil samples collected over a range of depths (13 to 154 ft bgs) and locations (GT-D-1, GT-D-2, GT-D-3, GT-D-5, and GT-D-6). Sample locations are shown on Figure 4-2. The soil samples represent multiple hydraulic units, including the LSAS, USAS, AF Gravels, and S&P Sands, and were selected as samples of minimally impacted soil. The K_d study was based on USEPA's "Batch-Type Procedures for Estimating Soil Adsorption of Chemicals," (EPA.530-SW-87-006-F). ARCADIS also referred to "Natural Attenuation of Chlorinated Volatile Organic

Compounds in a Freshwater Tidal Wetland, Aberdeen Proving Ground, Maryland," (USGS Water Resources Investigations Report 97-4171, page 27).

Soil samples were air-dried and screened using a 2-millimeter diameter sieve size. Various soil to water ratios were established for each soil sample, including 1:4, 1:6, 1:7, 1:8, and 1:10. The K_d vessels were filled with deionized water spiked with a target concentration of 2 mg/L TCE, then agitated for 48 hours. After agitation, the samples were analyzed to determine aqueous TCE concentration. Multiple samples of TCE-spiked water without soil were subjected to the same treatments to establish baseline TCE concentrations and to serve as volatilization controls.

After completing these analyses, an average K_d was calculated for each soil sample using the laboratory results for each soil to water ratio. The average K_d values for each aquifer were as follows:

USAS:	0.97 liters per kilogram (L/kg)
LSAS:	1.00 L/kg
AF Gravels:	1.04 L/kg
S&P Sands:	1.48 L/kg

These data suggest that Site soils possess relatively limited capacity to adsorb TCE. A detailed report on this treatability study was included in the August 2008 *RAP* as Appendix K.

Several parameters were defined and loaded into numerical models to simulate groundwater flow and solute fate and transport (see Appendix D, "Groundwater Modeling Report," below, and the summary in Section 9 of this *RAP Addendum*). These parameters include fraction of organic carbon (foc), partitioning coefficient (K_{oc}), soil/groundwater partitioning coefficient (K_d), effective porosity, bulk density, retardation coefficient, and dispersivity. Values for these parameters were then used in the contaminant mass, fate, and transport modeling simulations presented in Table 16 of Appendix D. As noted in that table, a number of these parameters and variables (e.g., foc, total porosity, and bulk density) were measured in samples collected at the deep geotechnical borings completed in late 2007 (ARCADIS, 2008b).

Data from these borings augmented results from the batch test, providing improved indicators of TCE sorption in the field. The bench tests primarily enhanced the exposed surface area of the soil and sediment grains, in contrast to the more limited exposure of these grains under *in situ* conditions. For example, sediment grains in the sandy USAS are tightly packed, whereas more heterogeneous arrangements, packing, and semi-consolidation of sediments is typical of the IAS units (LSAS, AF Gravels, and S&P Sands, as well as confining units, such as the Hard Streak, Venice Clay, and Clay/Sand Zones 1, 2, and 3). Based on the field collected and laboratory tested samples from the geotechnical borings, the following distribution coefficients for TCE were used in the groundwater models described in Appendix D:

USAS:	0.69 L/Kg
Hard Streak & LSAS:	0.22 L/Kg
Venice Clay:	0.85 L/Kg
Clay/Sand Zone 1:	0.50 L/Kg
AF Gravels:	0.14 L/Kg
Clay/Sand Zone 2:	0.32 L/Kg
S&P Sands:	0.36 L/Kg
Clay/Sand Zone 3:	0.31 L/Kg

4.4.2.3 In Situ *Chemical Oxidation Bench-Scale Treatability Study*

Camp Dresser & McKee (CDM) performed an *in situ* chemical oxidation bench-scale treatability study to evaluate the efficacy of *in situ* chemical oxidation using sodium persulfate to treat 1,4-dioxane and chlorinated compounds found at the Site. CDM conducted the bench-scale study in two separate phases:

- Phase I — Chemistry, Persulfate Activation, and Metals Test
- Phase II — Optimal Oxidant Dosage Evaluation

Soil samples for the treatability study were collected from different locations near the Site. Phase I has been completed and is discussed in Appendix L ("*In Situ* Chemical Oxidation Bench-Scale Treatability Study Report") of the August

2008 *RAP*. Bench-testing data generated June 1, 2008 is also included in this report. Results of the Phase I study indicate the following:

- Naturally-activated persulfate effectively oxidizes chlorinated compounds and 1,4-dioxane. This natural-activation method was sustainable in USAS samples with both low and high oxidant dosages (1 percent and 5 percent), but appears sustainable only in LSAS samples with higher applied oxidant-dosage.
- Iron activation offers no contaminant removal advantages over natural activation.
- Alkaline activation reduces oxidant effectiveness with respect to removing cis-1,2-DCE, TCE, and PCE, but increases effectiveness with respect to 1,4-dioxane removal.
- pH changes associated with persulfate consumption or alkaline activation resulted in elevated metal concentrations. These concentrations were generally attenuated upon neutralization except in the cases of arsenic and nickel.
- The soil oxidant demand (SOD) ranged from 0 to 42 g/kg (g persulfate/kg soil) for USAS samples and from 8.4 to 70 g/kg for LSAS samples.

4.4.3 *In Situ Pilot Studies*

The *In Situ Pilot Study Work Plan* (*Work Plan*) of January 22, 2008 (ARCADIS, 2008a) proposed a series of *in situ* pilot studies, including two tracer injection tests and one chemical oxidation pilot test. The studies were performed in the USAS and LSAS to evaluate the implementability and effectiveness of *in situ* chemical oxidation and to obtain information for full-scale *in situ* remedial design (if that approach is ultimately selected for implementation at the Facility). Details of the *in situ* pilot studies are presented in Appendix L of the August 2008 *RAP*. The following sections briefly describe the methodology and conclusions from these studies. Figure 4-4 indicates the locations of *in situ* pilot-study locations and associated wells.

4.4.3.1 Chemical Oxidation Pilot Testing and Tracer Testing Wells

Pursuant to the In Situ *Pilot Study Work Plan*, the following well sets were installed for the tracer test and chemical oxidation pilot test on the Facility:

- USAS tracer testing wells: one injection well (IW-1) and 30 monitoring wells designated with the prefix "T-."
- USAS chemical oxidation pilot testing wells: one injection well (IW-2) and 20 monitoring wells designated with the prefix "CO-."
- LSAS tracer testing wells: one injection well (TL-INJ) and six monitoring wells designated with the prefix "TL-."

Installation of the oxidation and tracer-test wells confirmed the presence of the Hard Streak and USAS interbedded-zone immediately above the Hard Streak, as well as confirming the nature and thickness of the LSAS in this tight grid of well points. The details of the installation, sampling, specific locations, and use of these wells are provided in Appendix L of the August 2008 *RAP*. Monitoring well construction information is summarized in Table 3-1, and the boring logs are provided in Appendix L of the August 2008 *RAP*.

4.4.3.2 Tracer Tests

The tracer testing methodology involved injection by gravity drainage of water augmented with fluorescein dye and bromide into the tracer testing injection wells. The injection locations were IW-1 in the USAS, and TL-INJ in the LSAS. The tracer injection dates were:

- USAS tracer test: March 24–27, 2008
- LSAS tracer test: March 31–April 2, 2008

The tracer study concluded that (1) the sustainable rate of injection into the USAS is approximately 1.4 gpm at 4 psi; (2) Mobile porosity of the USAS ranges between 0.14 and 0.47, with an average of 0.28; and (3) groundwater velocity estimates based on preliminary tracer breakthrough data are approximately 0.32 foot/day for the USAS and 4.2 feet/day for the LSAS under pumping conditions. These estimates were based on information available at the time of testing. The tracer injection study shows that oxidant injection is possible in both the USAS and LSAS. Tracer injections into the LSAS required the operation of nearby extraction wells to allow for injection without increasing pressures, which would risk fracturing the formation. Further, preferential flow within the LSAS makes it difficult to ensure that an oxidant can reliably be placed in contact with the contaminants to ensure effective treatment.

4.4.3.3 Chemical Oxidation Pilot Test

A sodium persulfate chemical oxidation pilot test was conducted in the USAS using well IW-2. Injection took place from April 15–19, 2008. Conclusions of that study are summarized below.

- Approximately 4,400 gallons of oxidant had to be injected into the USAS to achieve a working strength reagent concentration within a 7-foot horizontal radius of influence.
- The chemical oxidation pilot test generally achieved approximately 60 percent to greater than 95 percent reduction in VOC and 1,4-dioxane concentrations at the pilot study's performance monitoring wells; however, some wells showed stable or increasing concentrations following oxidant injection. Multiple injections of oxidant would be required to treat persistent portions of the aquifer and attain a greater mass reduction.
- The USAS has sufficient buffering and natural attenuation capacity to both neutralize the acidity generated by oxidant (persulfate) decomposition and attenuate mobilized metals generated from oxidant injection.

4.5 Other Activities

4.5.1 Staff Gauge Installation

Staff gauges were installed in nine surface water bodies to determine if these features connect to the USAS. To ensure consistent elevation data, new and existing staff gauges were surveyed in spring 2008. The locations of staff gauges are depicted on Figure 4-1. The staff gauge construction details and survey information are provided in Table 4-1.

4.5.2 Stilling Well Installation

Stilling wells were also installed in five surface water bodies to monitor the potential connection of surface water bodies to the USAS. The stilling wells were constructed of PVC well screen and equipped with transducers to measure water levels. A stilling well dampens momentary fluctuations in the surface of the surface-water body. Stilling wells installed before spring of 2008 were surveyed at the same time as the staff gauges. One stilling well was installed in the golf course pond to enable long-term monitoring, but it was not in place during the spring 2008 survey (see Section 13.5). It will be included in future surveys. Figure 4-1 illustrates the locations of stilling wells and Table 4-1 provides survey information.

4.5.3 Updated Elevation Survey

Newly installed Site monitoring wells, IRA extraction wells, stilling wells, staff gauges, geotechnical borings, MIP borings, and chemical oxidation test/tracer test wells were surveyed by a Florida-licensed, professional surveyor and mapper, using both horizontal and vertical control. Locations and elevations were also surveyed. Current survey data are provided in Tables 3-1 and 4-1.

4.5.4 On-Facility Pond Sediment Sampling

Five sediment grab samples were collected from the on-facility stormwater pond in November 2008 to compare previous sediment sampling results to current conditions. Samples collected with a Ponar™ dredge were analyzed for VOCs, 1,4-dioxane, mercury, and 20 metals. The 2008 analytical results were similar to those of 2004 and considered representative of stormwater retention ponds. This sampling effort and data assessment were presented in the *On-Facility Pond Sediment Sampling Report* (ARCADIS, 2008j). Analytical results from this sampling event are also included in Table B-11 of Appendix B of this *RAP Addendum*. The findings indicate no further action is necessary at the pond.

4.5.5 Wetlands Assessment

This *RAP Addendum* presents a remedial alternative that could potentially affect wetlands near the Site. To evaluate the effects of the chosen remedy on these wetlands, Lockheed Martin has initiated a wetlands assessment plan for areas near the Site. Initial assessments of wetlands near the Site were completed in June 2008 and June 2009. The results of these assessments and the plan for conducting ongoing assessments are presented in Section 13.6 and Appendix G. These assessments recommended continued monitoring of water levels and vegetation in eight transects of these wetlands.

4.5.6 Synthetic Precipitation Leaching Procedure Update

To define the extent of soil exceeding cleanup criteria (presented in Section 7.1), all soil data reported in past investigations was reviewed and summarized. During this effort beryllium and chromium were detected above default LTG SCTLs in soil samples HA-006 and HA-007; however, the laboratory reported only SPLP results for beryllium from these two samples in the *SARA* 2 report. The laboratory was asked to report the SPLP results for chromium and they have provided a revised report, a copy of which is included in Appendix B. Results for beryllium and chromium are summarized in Table 4-2 below.

Table 4-2: SPLP Results for Soil Samples HA-006 and HA-007

Parameter	Sample	SPLP Result (µg/L)	GCTL (µg/L)
Be	HA-006	0.74 U	4
	HA-007	2.2 I	
Cr	HA-006	8.5 U	100
	HA-007	8.5 U	

Be = beryllium

Cr = chromium

U = parameter is not detected,

I = value is reported between the method detection limit (MDL) and practical quantitation limit (PQL).

4.5.7 Long-Term Transducer Installation

As part of long-term continuous groundwater elevation monitoring at the Site, 36 pressure transducers and one barometric pressure transducer were installed in summer 2008. Figure 4-5 shows their locations. Table 4-3 provides additional information on these pressure transducers and the overall monitoring network, including the rationale behind the selection of these well locations. Since then, they have continuously recorded data hourly, and that information has been downloaded quarterly. These data were entered into a database, and a preliminary evaluation was performed to determine if the data were suitable for use in the groundwater modeling effort (see Appendix D). Preliminary evaluation of the transducer data identified off-facility groundwater extraction influences, which precipitated the additional well search described in Section 4.5.8. After the transducer data analyses and associated quality control have been finalized, they will be submitted to FDEP in a separate report.

4.5.8 Field Identification of Nearby Pumping Influences and Pond Characterization

The influence of water supply well pumping on the groundwater flow system is a concern for the RAP design because several permitted and operating supply wells lie within the area of the Site and that of the larger groundwater model. Small to moderate pumping rates in the confined units of the IAS (specifically the LSAS, AF Gravels, and S&P Sands) have been observed to create moderate to large cones of depression. Therefore, characterization of supply well pumping in the Site and model area remains an important aspect of plume remediation. This characterization effort includes identification and closure of wells within the Site area, identification and characterization of supply wells beyond the Site that may influence the RAP design, collection of water level data at strategic monitoring locations, and groundwater flow modeling that accounts for the effects of supply well pumping and helps confirm the characterization information.

Preliminary analysis of these transducer data indicates previously unidentified groundwater extraction influences in the northwest and southwest portions of the Site that warrant further investigation. A door-to-door search in the northwest quadrant revealed only wells that are used minimally or infrequently. Transducer data from the southwest area shows the characteristic on/off cycling of a single supply well (PW-127). The data point to a nearby well that is used to replenish the decorative pond (TL-1) along 15^{th} St. E. As appropriate, the effects of water supply well pumping are included in the groundwater modeling described in Section 9. Additional wells identified during this well search have been added to Figure 3-1 and Table 3-1. Attempts to close specific wells that may affect remediation efforts are ongoing.

To enhance modeling accuracy, Site personnel surveyed the condition and water level of all stormwater and decorative ponds within a three-quarter mile radius of the Facility. These personnel also checked each pond to attempt to determine if it was lined or unlined. This field reconnaissance information was used in the simulation of the March/April 2009 conditions to confirm the accuracy of the model.

5. Summary of Recent Groundwater Conditions

The most recent water quality and potentiometric surface evaluation was performed as part of the 2009 *GWMR,* included below as Appendix C of this *RAP Addendum*. It includes the results of a comprehensive static water level monitoring event (on March 16-18, 2009, with follow-up monitoring March 23 through April 2 and April 13) and a single comprehensive groundwater sampling event (March/April 2009). All accessible monitoring wells were included in these events. Thus, the 2009 *GWMR* data represent current groundwater conditions at the Site (both on-facility and off-facility). Chapter 62-780 , F.A.C., requires that groundwater data be collected no more than 270 days prior to submittal of a RAP. The 2009 *GWMR* data satisfy this requirement and form the basis for the groundwater modeling. The 2009 *GWMR* also includes a detailed evaluation of both potentiometric surfaces and groundwater quality data.

For reference, historic water level data and groundwater analytical results summary tables are presented in Appendix B. The potentiometric and analytical data contour maps from the 2009 *GWMR* in Appendix C are also included as figures in this *RAP Addendum* and are specifically referenced in the sections below. Information regarding the groundwater monitoring network (including private wells) is presented in Table 3-1. The monitoring well network is illustrated in Figure 4-1. A graphical representation of the 2006, 2007, and 2008 water level data and groundwater analytical data contours was provided in the August 2008 *RAP* (Appendix D and Figures 5-1A through 5-11G in the August 2008 *RAP*).

5.1 Potentiometric Surfaces

The 2009 *GWMR* presents potentiometric surface maps and analysis for the USAS, uppermost LSAS, lower LSAS, AF Gravels, S&P Sands, Lower AF Sands, and Floridan aquifer zones. The following sections briefly summarize its main points related to potentiometric surfaces, which are discussed in detail in the 2009 *GWMR* (included as Appendix C below).

5.1.1 Upper Surficial Aquifer System Potentiometric Surface

Figure 5-1 shows the USAS potentiometric surface in March/April 2009. Surface water elevations in ponds and stilling wells were contoured with the

USAS groundwater elevations, where appropriate, since the surface water bodies are believed to act as recharge and discharge points to the USAS. Groundwater elevations ranged from 10.94 to 24.55 ft msl in March and April 2009. The USAS potentiometric surface during these measurement events showed a groundwater high beneath the Facility and extending onto the golf course. The horizontal component of groundwater flow was, therefore, radial, away from the Facility with a gradient ranging from 0.003 to 0.007 feet per foot (ft/ft). The average vertical downward gradient from the USAS to the lower LSAS at the Facility and across the monitored area was 0.3 ft/ft. Some features of the USAS potentiometric surface are:

- A groundwater high beneath the southern portion of the Facility and the northeastern portion of the golf course which is likely due to increased recharge at the golf course.
- A localized groundwater high beneath Pond TW-6 (Stilling Well 3) may be due to the pond collecting surface water drainage and thus acting as a recharge feature.
- Potentiometric lows near some ponds and the Tallevast Road ditch. Stilling well and monitoring well groundwater elevation data indicate that the Tallevast Road ditch acts as discharge zones for the USAS.
- During a field reconnaissance of local ponds, higher than ambient water levels were observed in ponds (e.g., pond TL-1, shown in Figure 5-1) that appear to have been (or are known to have been) artificially maintained. Some surface water features may be lined to allow artificial maintenance of water levels: therefore, water levels on staff gauges in these features may not represent the water table. Other surface water features appear to be unlined (e.g., TL-1) and maintained which affects local groundwater flow patterns.

5.1.2 Upper Portion of the Lower Shallow Aquifer System Potentiometric Surface

Figure 5-2 shows the potentiometric surface of the upper portion of the LSAS in March 2009.As indicated in Sections 4.3.2.2 and 4.3.2.4 above, monitoring of water levels and hydraulic responses during pumping tests or IRA pumping changes have demonstrated that the upper portion of the LSAS at the Facility responds differently than the lower portion. Therefore, water level contours are displayed for the upper portion separately (see Section 5.1.3 below for the lower portion). Hydraulic heads in the upper portion of the LSAS range from 21.83 to 23.64 ft msl as measured during the March 2009 monitoring event. Limited data points are available in the uppermost LSAS. The available data indicate that the general flow direction during the March 2009 measurement event was toward the north across the Site, with a slight groundwater depression near the corner of Building 5. The wells in this zone are screened just below the Hard Streak (which forms the interface between the USAS and LSAS), and the downward gradient from the USAS to the uppermost portion of the LSAS was approximately 0.20 ft/ft as measured from MW-38 to PZ-LSAS-2.

5.1.3 Lower Portion of the Lower Shallow Aquifer System Potentiometric Surface

Figure 5-3 shows the potentiometric surface of the lower portion of the LSAS in March/April 2009. The hydraulic heads in the lower portion of the LSAS ranged from 4.28 to 22.09 ft msl in March/April 2009. The highest head was on the golf course at well MW-87. The lowest contoured hydraulic head was at well MW-246, located in the northwest corner of the contoured area. The horizontal component of groundwater flow was again radial, away from the Facility. The horizontal gradient ranged from approximately 0.003 to 0.007 ft/ft, depending on direction. The average vertical gradient was approximately 0.1 ft/ft downward to the AF Gravels.

Some features of the lower portion of the LSAS potentiometric surface include:

- A groundwater high beneath the golf course likely due to increased recharge. This is also an indication of hydraulic connection between the USAS and the LSAS in this area.
- A groundwater high west of pond TW-6 that may be due to increased recharge from the pond itself.
- A groundwater low in the southwest corner of the map area that appears to be due to groundwater extraction from a private well in the area, used to maintain water levels in a decorative pond (TL-1).

5.1.4 Arcadia Formation Gravels Potentiometric Surface

Figure 5-4 shows the potentiometric surface for the AF Gravels, as measured in March/April 2009. Hydraulic heads in the AF Gravels ranged from -1.07 to

11.72 ft msl in March/April 2009. The lowest head was at well MW-221, located in the southwest corner of the contoured area (southeast of the airport). The highest head occurred at the Facility and at well MW-232 located north of the Facility. Here, too, the horizontal component of groundwater flow was radial, away from the Facility. The horizontal gradient ranged from approximately 0.004 to 0.007 ft/ft, with the strongest gradients toward the southwest. Horizontal gradients were shallower towards the east and south. At the Facility, the vertical gradient was downward from the AF Gravels to the S&P Sands throughout most of the mapped area, ranging approximately 0.01 to 0.1 ft/ft. However, the vertical gradients are upward from the S&P Sands to the AF Gravels in the extreme western and eastern portions of the contoured area away from the Facility. The main features of the AF Gravels' potentiometric surface include:

- A groundwater high beneath the Facility and north of the Facility, with horizontal radial flow, away from these areas.
- An apparent cone of depression in the southwest contoured area. The cone of depression appears to be due to groundwater extraction from a private well (PW-127, see Figure 3-1) in the area, used to maintain water levels in a decorative pond (TL-1).
- Groundwater elevations in the northwest portion of the Site are lower than the northeast and southeast portions which may be due to water supply pumping.

5.1.5 Salt & Pepper Sands Potentiometric Surface

Figure 5-5 shows the potentiometric surface of the S&P Sands as measured in March/April 2009. The hydraulic heads in the S&P Sands ranged from -1.92 (April event) to 9.51 ft msl (March event). The lowest heads were consistently in the southwest corner of the contoured area, and the highest heads were in the eastern portion of the contoured area. The horizontal component of groundwater flow was toward the west and southwest, with a depression to the southwest of the Facility. The horizontal gradient ranged from approximately 0.001 to 0.009 ft/ft, with the strongest observed gradients from the Facility toward the southwest. The vertical gradient at the Facility was slightly upward from the Lower AF Sands, at approximately -0.03 ft/ft. Across the contoured area as a whole, the average vertical gradient was slightly upward from the

Lower AF Sands to the S&P Sands, at -0.01 ft/ft. The main features of the S&P Sands potentiometric surface are:

- A groundwater low, southwest of the Facility, apparently due to groundwater extraction from a private well (PW-127, Figure 3-1) in the area to maintain water levels in a decorative pond (TL-1).
- A groundwater high, east of the Facility. Previous reports and the potentiometric-surface map indicate that the Facility and immediate vicinity are located in or west of a regional recharge area between discharge boundaries (ARCADIS BBL 2007c, GeoTrans 2008a).

5.1.6 Lower Arcadia Formation Sands Potentiometric Surface

Figure 5-6 shows the Lower AF Sands potentiometric surface as measured in March/April 2009. Groundwater elevations in the Lower AF Sands ranged from 8.55 to 11.84 ft msl in March/April 2009. Additional water levels taken in April 2009 northeast of the Facility (at a property located at the corner of Tallevast Road and Route 301), showed a high of 12.47 ft msl in the center of the property, decreasing radially from that property. The horizontal component of groundwater flow near the Facility is toward the northwest with a gradient of between 0.0001 and 0.001 ft/ft. The vertical gradient is downward to the Floridan Aquifer System and increases from west to east across the Site. While the vertical gradient is downward from the Lower AF to the Floridan, the vertical gradient between the Lower AF and the overlying unit is upward. The main feature of the Lower AF Sands potentiometric surface is the overall lower lateral gradient as compared to shallower units.

5.1.7 Upper Floridan Aquifer Groundwater Potentiometric Surface

Figure 5-7 shows potentiometric data for the Floridan collected in March/April 2008. Based on the monitoring data from these two events, groundwater flows primarily to the east-northeast. The horizontal gradient was 0.0007 ft/ft to the east-northeast. Horizontal groundwater flow direction in the Floridan significantly differs from the overlying units in the SAS and IAS, indicating limited or no connection between these units.

5.1.8 Summary

The March/April 2009 sampling event was conducted during a period of significant drought conditions, exacerbating the already occurring dry season. This resulted in decreased water elevations in all of the monitored geologic layers and many of the surface water features. Regional groundwater extraction for water supply purposes from the AF Gravels, S&P Sands, and the Floridan also decreased groundwater elevations. As a result, decreased water levels were observed in these aquifer zones between the January/February 2008 groundwater sampling event and during the month between March 17 and April 13, 2009. Elevated water levels were observed in some ponds that appear (or are known) to be artificially maintained.

- Groundwater elevations generally decreased by 0.67 to 3.58 ft in the USAS monitoring wells between January/February 2008 and March/April 2009. The decrease in 75 percent of the wells was greater than 2 ft.
- Groundwater elevations generally decreased by 0.82 to 6.15 ft in the LSAS monitoring wells between January/February 2008 and March/April 2009. The decrease in 68 percent of the wells was more than 2 ft.
- Groundwater elevations generally decreased by 0.87 to 6.79 ft in the AF Gravels monitoring wells between January/February 2008 and March/April 2009. The decrease in 85 percent of the wells was more than 3 ft. The greatest decrease (5.27 to 14.02 ft) was observed southwest of the Site, where the apparent cone of depression is located.
- Groundwater elevations generally decreased by 0.95 to 5.36 ft in the S&P Sands monitoring wells between January/February 2008 and March/April 2009. The greatest decrease (4.22 to 12.38 ft) was observed southwest of the Site, where the apparent cone of depression is located.
- Groundwater elevations in the Lower AF Sands monitoring wells generally decreased by 0.01 to 1.42 ft between January/February 2008 and March/April 2009. The decrease in 64 percent of the wells was more than 0.50 ft. A slight increase (0.37 ft) was observed in MW-217.
- Groundwater elevations decreased by 2.46 to 3.53 ft in the Floridan monitoring wells between January/February 2008 and March/April 2009.

5.2 Horizontal and Vertical Distribution of Contaminants of Concern

Testing of subsurface conditions to date shows that the uppermost four water-bearing zones (USAS, LSAS, AF Gravels, and S&P Sands) contain COCs above GCTLs (resulting in a vertical extent of approximately 200 ft bgs or less). Figures 5-8A through 5-14C illustrate the distribution of each COC in each groundwater hydrostratigraphic zone. All figures were plotted using the contouring interval of the GCTL, 10×GCTL, 100×GCTL, and 1000×GCTL, as appropriate. The distribution of COCs is also fully described in the 2009 *GWMR* (included in Appendix C below). Analytical data from the March/April 2009 sampling event are presented in Tables 2-3 and 2-4 in Appendix C**.**

5.2.1 Contaminants of Concern Distribution in the Upper Surficial Aquifer System

The distribution of each COC in the USAS is shown on Figures 5-8A through F. In addition, Figure 5-8G superimposes the extent of COC concentrations above GCTL in the USAS. Representation of the 1,4-dioxane GCTL boundary extended further to the northeast of the Facility in 2009 as compared to 2008. This change is based on detections of this constituent in MW-62 and MW-65, as well as the removal of MW-14S, MW-16S, and MW-17S from contouring to create a more conservative contour. Representation of the 1,4-dioxane and 1,1-DCE GCTL boundaries south of the Facility are smaller in 2009 as compared to 2008. This change is primarily based on reduced detections of 1,1-DCE in MW-25 and of 1,4-dioxane detections in MW-75. Appendix C includes a more detailed description of these conditions.

5.2.2 Contaminants of Concern Distribution in the Lower Shallow Aquifer System

The distribution of each COC in the LSAS is shown on Figures 5-9A through F. In addition, Figure 5-9G superimposes the extent of COC concentrations above GCTL in the LSAS. Only slight variations in GCTL boundary conditions occurred from 2008 to 2009. Overall, both representations are similar. Concentrations of TCE in the on-facility piezometers have increased. Appendix C includes a more detailed description of these conditions.

5.2.3 Contaminants of Concern Distribution in the Arcadia Formation Gravels

The distribution of each COC in the AF Gravels is shown on Figures 5-10A through F. Figure 5-10G superimposes the extent of COC concentrations above GCTL in the AF Gravels. In the northeast and southeast portions of the Site, the 1,4-dioxane GCTL boundary line contours in 2009 show reductions in the surface area affected by this constituent as compared to 2008 results. A non-detect result at MW-248 in 2009 (above GCTL in 2008) was the primary reason for changing the boundary representation in the southeast. The change in the representation of the disconnected 1,4-dioxane plume boundary to the northeast is based on a non-detect result for the private well located at 2411 Tallevast Road (above GCTL in 2008). A reduction in the representation of the TCE GCTL boundary was made to the northeast due to a decrease in the TCE concentration detected at MW-135. TCE concentrations in MW-134 and EW-UAFG-1 (on the Facility) have increased. Appendix C offers a more detailed description of these conditions.

5.2.4 Contaminants of Concern Distribution in the Salt & Pepper Sands and Clay/Sand Zone 3 & 4

The distribution of each COC in the S&P Sands is shown on Figures 5-11A through F. Figure 5-11G superimposes the extent of COC concentrations above GCTL in the S&P Sands. For this unit, the representation of the 1,4-dioxane GCTL boundary changed due to a decrease in concentration at MW-23 (to the south) and an increase in concentration at MW-45 (to the north). New detections of 1,1-DCE (on-facility) and 1,1-DCA (off-facility) in 2009 also changed representations of the GCTL boundary for this unit. Although IWI-2 is located in Clay/Sand Zone 3 & 4, it has been included on the S&P Sands maps because it is screened at the very top of the Clay/Sand Zone 3 & 4 (approximately 5 to 10 feet deeper than monitoring wells screened within the S&P Sands) and it is the only well in this unit with COC detections greater than GCTLs. Concentrations of 1,4-Dioxane and TCE have increased in IWI-2 from 2008 to 2009. Appendix C provides a more detailed description of these conditions.

5.2.5 Contaminants of Concern Distribution in the Lower Arcadia Formation Sands and Upper Floridan Aquifer

No COCs were detected above GCTLs in either the Lower AF Sands or the Floridan. The 2009 analytical results for these wells are presented in Table 2-3 of Appendix C.

5.2.6 Additional VOC Compounds

Review of the March/April 2009 Annual Event results and the soil gas parameter groundwater results indicate the following four compounds were detected at least once at concentrations greater than their GCTL:

- Vinyl chloride was detected in three LSAS (Figure 5-12A), one S&P Sands, and one Clay/Sand Zone 3 & 4 (Figure 5-12B) well(s).

- Bromodichloromethane and Dibromochloromethane were detected at concentrations greater than its GCTL in one off-facility AF Gravels well (Figure 5-13).

- Methylene chloride was detected at concentrations greater than its GCTL in three USAS (Figure 5-14A), eight LSAS (Figure 5-14B), and three AF Gravels (Figure 5-14C) wells located on-facility.

5.2.7 Summary

On a Site-wide basis, when considering the outer GCTL boundary of all COCs across all 4 of the impacted layers (as depicted in Figures 5-8A through 5-14 and Appendix C), there is little variation between the 2008 and 2009 depictions. The outer boundaries lie close to each other and they are defined by the same perimeter pairs of monitoring wells in all cases but one. The one exception is found at the far east/northeastern edge of the 2008 and 2009 boundaries, and is defined by fluctuating, near-GCTL concentrations of 1,4-dioxane in the AF Gravels layer.

The overall distribution of COCs in groundwater during March/April 2009 is similar to that observed during the January 2008 event, which was used previously during development of the August 2008 *RAP* (ARCADIS, 2008g). As a result, this *RAP Addendum* focuses on essentially the same areas as those described in the August 2008 *Revised RAP*.

6. Updated Site Conceptual Model

As additional Site investigations have been performed, the Site Conceptual Model has progressively evolved and become more detailed. As a result, some hydrostratigraphic units have been subdivided to more accurately represent observed subsurface conditions and thus enable the 3-dimensional computer model to better reflect groundwater flow and contaminant fate and transport near the Site.

6.1 Site Geology

The updated Site geologic understanding is described in Section 2.5, and additional detail is provided in the *Groundwater Modeling Report* presented as Appendix D. Figure 2-2, provided below, illustrates the Site's generalized geologic cross-section.

Figure 2-2. Conceptual Geological Cross-Section

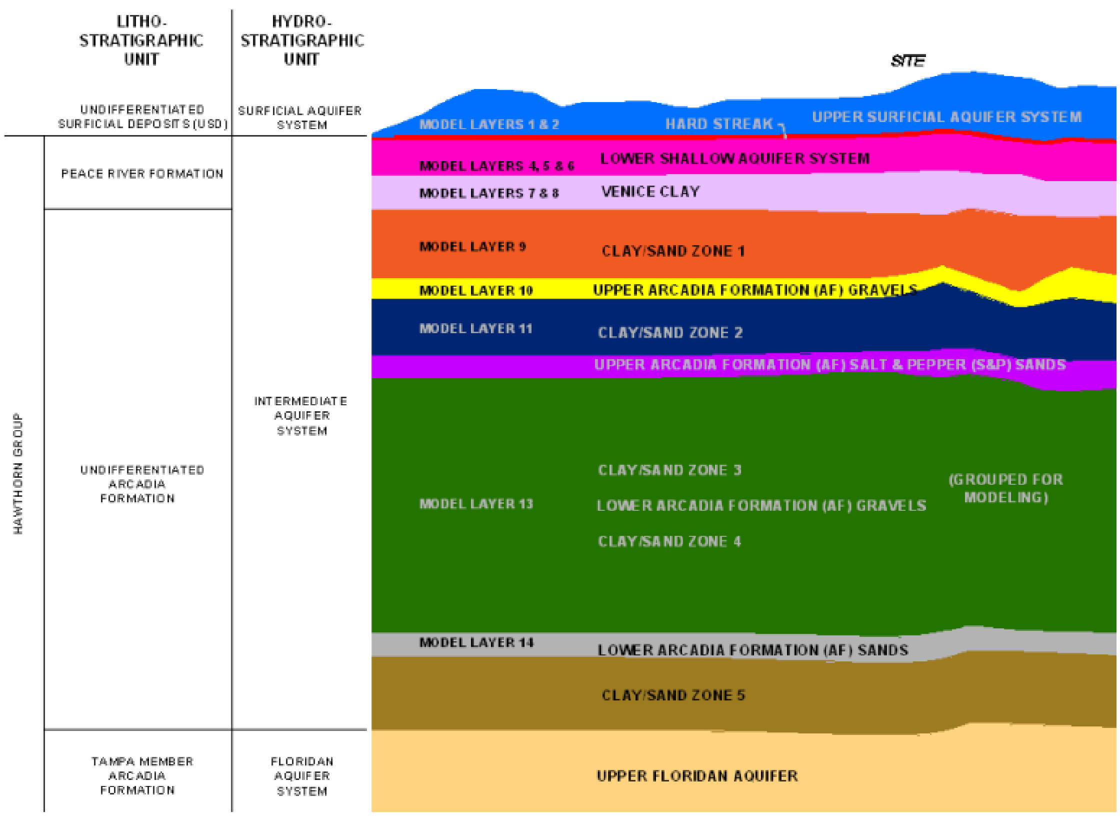


Figure 2-3 provides a detailed stratigraphic column. Summarized below are several recent updates to investigators' geologic understanding of the setting that will specifically affect the assessment and selection of a remedial alternative:

- The bottom portion (approximately the 5-foot interval above the Hard Streak) of the USAS is more clayey and finely laminated than the overlying portions, and therefore has lower hydraulic conductivity than the overlying sediment. The MIP data collected at the Facility also indicates that this lower portion of the USAS contains elevated concentrations of some COCs.
- The Hard Streak represents the top of the Hawthorn Group. The LSAS and underlying units are part of the Hawthorn Group (which includes the PRF and AF), and are partially to fully consolidated units.
- The LSAS is heterogeneous and finely laminated vertically, resulting in a very low vertical hydraulic conductivity through some portions of the unit. Horizontal hydraulic conductivity varies throughout the unit. The highest horizontal hydraulic conductivity is at the bottom of the unit, and there is a conductive zone in the upper portion of the unit.
- Apparently both natural and anthropogenic connections exist between transmissive units.

6.2 Site Hydrogeology

From a hydrogeological perspective, the various geologic units within the SAS and IAS (above the Floridan) can be divided into two groups according to each unit's individual abilities to transmit groundwater. One group consists of more permeable (more transmissive) units, and the other consists of those units that have relatively low permeability and are likely to represent an impediment to the horizontal and vertical movement of groundwater. The more permeable units consist of the USAS, the LSAS, the AF Gravels, the S&P Sands and the Lower AF Sands (see Figure 2-2). Note that throughout the Site these units may vary slightly in thickness and ability to transmit water.

The lower permeability units consist of the Hard Streak, the Venice Clay, the Clay/Sand Zone 1, the Clay/Sand Zone 2, and the Clay/Sand Zone 3 & 4. In addition, portions of the LSAS seem to represent a significant barrier to vertical flow due to heterogeneity and finely laminated nature. Based on the significant downward gradient between the base of the USAS and the underlying, more permeable portions of the LSAS, the Hard Streak represents an impediment to downward groundwater flow, although natural fracturing or anthropogenic features such as water wells may breach it locally. Another indication that the Hard Streak acts as an impediment to vertical flow is that the remainder of the

LSAS is hydraulically confined. In addition, the middle portion of the LSAS acts as a confining, low permeability zone that causes the upper portion of the LSAS to respond differently than the lower portion. Although each of these low-permeability units represents an impediment to groundwater flow, particularly vertical groundwater flow, hydraulic testing of the various units indicates slight and variable hydraulic connectivity across these units.

Vertical hydraulic gradients are generally downward until the AF Gravels are encountered. The gradient between the S&P Sands and the AF Gravels may be either upward or downward depending on location, seasonal variations, and possibly regional groundwater use patterns. The vertical gradient appears to be generally upward from the Floridan to the Lower AF Sands, and from the Lower AF Sands to the S&P Sands. However, a downward gradient is present from the USAS and LSAS to the Floridan.

6.3 Fate and Transport

The important physical and chemical processes affecting the fate and transport of COCs in groundwater at the Site are advection, hydrodynamic dispersion, sorption, and degradation. These processes cause changes in both the mass and distribution of dissolved constituents in groundwater.

The mass and distribution of COCs, provide the basis for evaluating the current situation and for predicting the fate and transport of COCs. TCE and 1,4-dioxane were selected for detailed evaluation because they define the furthest extent of GCTLs laterally and vertically, and they represent both s highly soluble/mobile(1,4-dioxane) and recalcitrant (TCE) COCs respectively.

Of the general fate and transport parameters, advection generally dominates the others, especially for conservative chemicals such as 1,4-dioxane. In the USAS, groundwater flows laterally away from the Facility and golf course area where the water table “high” is located. Thus the distribution of contaminated groundwater follows this pattern, in general. Distribution of COCs in the USAS also indicates that recharge patterns and surface water features influence plume migration. For example, the enhanced recharge due to golf course irrigation and the presence of the golf course pond and on-facility pond may have led to the lower COC concentrations in those areas. Another example is the apparent influence on the northwest lobe of the plume by the Tallevast Road ditch, which is directing the plume toward that feature.

The vertical advective pathway is also important in the USAS because groundwater seeps downward through the Hard Streak and into the upper portion of the LSAS. Evidence for this pathway is found on-facility where the highest concentrations of TCE are present in the upper portion of the LSAS. The lower LSAS contains TCE and 1,4-dioxane concentrations in areas that are generally similar to the USAS pattern.

Advection within the LSAS layer corresponds to the patterns seen in the USAS. The LSAS generally flows out laterally from the site area, away from the Facility toward discharge areas, while it also loses some of its groundwater to downward leakage. Exceptions include the absence of significant measured COC concentrations southeast of the Facility in the LSAS, and lesser migration laterally northeast and north/northwest of the Facility. This may be the result of vertical impediments to advection due to the Hard Streak and middle LSAS confining units.

Similar patterns of advection occur in the AF Gravels and S&P Sands layers, but the primary mechanism of COC delivery to these two layers is likely via open boreholes because advection vertically downward through the thick and low permeability confining layers is very slow. Once the COCs reach these deeper layers, advection causes radial spreading that is less than in the USAS and LSAS layers. In the AF Gravels the exceptions to this are:

- The influence of water supply pumping on advective patterns and plume spreading, evident in the lobe to the east along Tallevast Road
- Spreading toward the south and the northwest, possibly the result of water supply pumping in those areas.

Some of the observed spreading of dissolved contaminants in the study area is the result of hydrodynamic dispersion processes. Hydrodynamic dispersion is a physical process in which dissolved constituents spread at the macroscopic level both away from the center of mass of the plume, in directions that are both transverse and longitudinal to the dominant flow direction. In groundwater velocity fields such as at this study area, effects of hydrodynamic dispersion are less important than primary advection. In addition, seasonal and climatic changes as well as variations in water well pumping can cause contaminant plumes to spread laterally away from the average flow path, thus imparting perceived additional “dispersion.” The development of the plume lobes in the contaminated layers at the site display characteristic effects of dispersion, given the lateral spreading, but advection dominates. Values of dispersion parameters appropriate for the hydrogeologic setting are used in the numerical modeling, based on experience with similar sites and COCs.

Sorption and desorption processes affect the migration of COCs in the groundwater at the site. Hydrophobic organic constituents, such as chlorinated solvents tend to adhere to organic matter, and move more slowly than the groundwater flow velocity. Because relatively high levels of total organic carbon are present in soil at the Site, adsorption is an important chemical process for chlorinated solvents. However, 1,4-dioxane does not readily adsorb and thus is highly mobile. Sorption/desorption is quantified using a retardation factor, "R", that is evaluated and cited here as part of the conceptual model specifically for TCE, because of its utility in predicting future concentrations. The R value is a function of the distribution coefficient, described above in Section 4.4.2.2, and several physical parameters of the porous media, including density and porosity. These parameters vary by geologic layer. The conceptual model identifies "R" values for TCE by layer, as follows:

- *USAS*: 5.8
- *Hard Streak and LSAS*: 2.3
- *Venice Clay*: 4.2
- *Clay/ Sand Zone 1*: 3.8
- *AF Gravels*: 1.6
- *Clay/Sand Zone 2*: 2.4
- *S&P Sands*: 2.9
- *Clay/Sand Zone 3*: 2.8

These values indicate, for example, that TCE migrates 5.8 times more slowly than the prevailing groundwater velocity in the USAS, but only 1.6 times more slowly in the AF Gravels layer.

Degradation is another significant fate process for some of the COCs at the site, TCE in particular. This factor represents biological and chemical processes that decrease the mass of dissolved constituents including biodegradation, photolysis, oxidation-reduction, and hydrolysis. Chlorinated solvents typically degrade in anaerobic conditions, which are generally present at the Site, and the presence of daughter products such as cis-1,2-DCE, 1,1-DCE, and 1,1-DCA indicate that degradation is occurring. In addition, the biostimulation and bioaugmentation treatability study, described in Section 4.4.1, indicated that bacteria responsible for biodegrading chlorinated solvents have been detected in Site groundwater. Of the two primary COCs, TCE and 1,4-dioxane, TCE is subject to degradation and is included in the predictive assessment. Because 1,4-dioxane degrades slowly, and its degradation rate is not well understood, degradation of 1,4-dioxane was not considered a significant process.

For the simulations presented in this report, TCE was assigned a two year half-life. This value was selected based on prior experience at similar sites and literature-reported investigations. Note that in the conceptual fate and transport model, and its subsequent incorporation into the numerical model (see Section 9.3), the TCE half-life only applies to the *dissolved* phase of TCE. Degradation of TCE in the sorbed phase is assumed not to occur. Consequently, the effective half-life is equal to the half-life in the dissolved phase (2.0 yrs) times the retardation coefficient. The resulting effective half-life values for each of the contaminated aquifer layers are as follows:

- *USAS*: 11.6 years
- *LSAS*: 4.6 years
- *AF Gravels*: 3.2 years
- *S&P Sands*: 5.8 years

Numerical fate and transport modeling facilitated the further assessment of Site COCs in groundwater and evaluation of the effects of both physical and chemical processes on proposed remediation efforts. A discussion of the groundwater model and the results of this evaluation are presented in Section 9.

6.4 Distribution of the Contaminants of Concern

Potential historical COC source areas at the Facility include:

- A 1,000-gallon above ground storage tank used for solvent storage near the southeast corner of Building 1
- An area on the east and northeast side of former Building 5 where five sumps were located, and
- A hazardous material storage area in the southeast corner of former Building 5

The MIP study identified four areas on the Facility with relatively high levels of COC concentrations (Figure 4-3):

- The southeastern parking area
- An area below the former sumps east of former Buildings 4 and 5
- Two locations along the alley separating Buildings 1 and 2 from Buildings 3 and former Buildings 4 and 5

The larger distribution of COCs in the subsurface is a function of all the elements of the conceptual model discussed above. These generally include the following common understandings:

- COCs entered the USAS from leaking sewer lines and sumps on the Facility
- Lateral flow occurs in a generally radial pattern within the aquifer zones —including the USAS, LSAS, AF Gravels, and S&P Sands— due to the groundwater "high" at or near the Facility, and lower hydraulic heads away from the Facility (which in some areas/zones are caused by water supply wells)
- Vertical seepage/leakage through drilled boreholes/wells.
- Vertical seepage through confining units, including the Hard Streak and the middle portion of the LSAS

The extent of COC migration in the S&P Sands and the top of the Clay/Sand Zones 3 & 4 is a much smaller area (limited to the vicinity of the Facility) than the area of COC migration in the overlying, more permeable USAS, LSAS and AF Gravels. The lack of COCs detected in samples collected from the Clay/Sand Zones 1 & 2 suggests that COC migration through these confining units is through anthropogenic features (well bore holes) or discrete natural pathways. Groundwater sample results from permeable units below the Clay/Sand Zones 3 & 4 indicate that COCs have not migrated below these confining units, as no samples from these units were above GCTLs. This may be due to the low number of private wells that have been completed through the Clay/Sand Zones 3 & 4, as well as the consistency and thickness of these confining units.

7. Identification of General Response Actions and Remedial Technologies and Process Options

Applicable soil and groundwater standards, the extent of exceedances of those standards, and general response actions, remedial technologies or process options capable of addressing those exceedances are presented below.

7.1 Soil and Groundwater Cleanup Standards

In accordance with Chapter 62.780, F.A.C, the cleanup standards for soil are the default residential, commercial/industrial standards; the LTG SCTLs and groundwater cleanup standards are the default GCTLs (as referenced in Chapter 62.777, F.A.C.).

7.2 Extent of Soil Exceeding Cleanup Standards

The extent of soil that will be addressed by this *RAP* is limited to the Facility, as discussed in the *SARA 3* (BBL, 2006a). Soil samples collected on-facility that exceed the default residential, commercial/industrial, or LTG SCTLs are summarized in Table 7-1 and shown on Figures 7-1 through 7-7. The following is a summary of the COCs exceeding the default SCTLs in soil samples collected on the Facility:

RESIDENTIAL SCTLS

- Arsenic
- Beryllium
- Copper

- PAHs (expressed as benzo(a)pyrene equivalents)
- TPH

COMMERCIAL/INDUSTRIAL SCTLS

- PAHs (expressed as benzo(a)pyrene equivalents)

LEACHABILITY TO GROUNDWATER (LTG) SCTLS

- Beryllium
- Chromium
- PCE

These compounds will be addressed by the selected soil remedy.

7.3 Extent of Groundwater Exceeding Cleanup Standards

The extent of groundwater that will be addressed by the *RAP* includes all areas exceeding the GCTLs in each of the four primary water bearing zones (USAS, LSAS, AF Gravels and S&P Sands). These areas are outlined on Figures 5-8G, 5-9G, 5-10G, and 5-11G. The following summarizes the COCs exceeding the GCTLs in groundwater on the Site:

- 1,4-dioxane
- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- Cis-1,2-dichloroethene (cis-1,2-DCE)
- 1,1-Dichloroethene (1,1-DCE)
- 1,1-Dichloroethane (1,1-DCA)
- Vinyl chloride (VC)
- Methylene chloride
- Bromodichloromethane
- Dibromochloromethane
- 1,1,1-Trichloroethane

7.4 General Response Actions

General Response Actions (GRAs) are broad remediation approaches capable of achieving the Site RAOs. Some response actions are sufficiently broad to meet the remedial objectives alone, but usually combinations of response actions are required to address varied site conditions and meet all the remediation objectives. The identification of GRAs involved a focused review of available literature, including the following documents:

- *Guidance for Conducting Remedial Investigations and Feasibility Studies Under Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) (USEPA, 1988)
- *Treatment Technologies* (USEPA, 1991)
- *Remediation Technologies Screening Matrix and Reference Guide, Version 3* (Federal Remedial Technologies Roundtable, 1997)
- *Technical and Regulatory Guidance for* In Situ *Chemical Oxidation of Contaminated Soil and Groundwater* (Interstate Technology Regulatory Council [ITRC], 2005)
- *Treatment Technologies for 1,4-Dioxane: Fundamentals and Field Applications* (USEPA, 2006)

These documents, along with remedial technology vendor information, applicable regulatory requirements, and other available information, were reviewed to identify the GRAs and their remedial technologies or process options that are potentially applicable for addressing COCs in soil and groundwater and the RAOs. General response actions and their remedial technologies and process options were also selected to address on-facility groundwater containing COCs at the highest concentrations (hot spots). The GRAs and their remedial technologies and process options are listed below by media (soil, Site-wide groundwater, and groundwater hot spots):

SOIL

- No further action (NFA)
- Institutional controls
- Engineering controls
- Monitoring

- Removal
  - Excavation

GROUNDWATER –– Site-wide

- No further action
- Institutional controls
- Engineering controls
- Monitoring
- Natural attenuation monitoring (NAM)
- *In situ* treatment
  - Enhanced biological degradation (EBD)
  - In situ chemical oxidation (ISCO)
  - Electrical resistive heating (ERH)
- Groundwater recovery
  - Horizontal extraction wells
  - Extraction trenches
  - Vertical extraction wells
  - Dual-phase extraction (DPE)
- *Ex situ* treatment
  - Air stripping
  - Liquid phase granular activated carbon (LPGAC)
  - Advanced Oxidation Process (AOP)
- Vapor treatment
  - Vapor phase granular activated carbon (VPGAC)
- Groundwater discharge
  - Discharge to publicly owned treatment works (POTW)
  - Recharge galleries and extraction wells

GROUNDWATER –– Hot spots

- *In situ* treatment
  - Enhanced biological degradation (EBD)
  - In situ chemical oxidation (ISCO)
  - Electrical resistive heating (ERH)
- Groundwater recovery
  - Focused groundwater extraction and injection wells
  - Dual-phase extraction (DPE)
- Removal
  - Excavation

7.5 Description of the GRAs, Remedial Technologies and Process Options

A description of potentially applicable remediation technologies and process options is provided here:

SOIL

No Further Action - No further action (NFA) without controls, Risk Management Options I, as specified in Rule 62-780.680(1), F.A.C., is not an acceptable remedial option for the soils identified in Section 7.2 because Site conditions do not meet the criteria specified in the rule. However, NFA with institutional and engineering controls, Risk Management Options Level II as defined in Rule 62-780.680 (2), F.A.C., may be an acceptable remedial option to address the extent of soils identified in Section 7.2. This option was proposed in the *SARA 3* and the previous *RAPs*. In accordance with this rule, the remedial option is acceptable provided that institutional and engineering controls protect human health, public safety, and the environment and they are agreed to by the current real-property owner(s) that will be affected by them. Other conditions that must be met (i.e., demonstrated to FDEP) for this to be an acceptable remedial process option include:

1. No free product is present and no fire or explosive hazard exists as a result of a release, as specified in Rule 62-780.680(2)(a) F.A.C.,

2. COC concentrations in soil do not exceed the default commercial/industrial SCTLs, as specified in Rule 62-780.680(2)(b)1a. F.A.C.

3. If an engineering control preventing human exposure (for example, permanent cover material or a minimum of two feet of soil) is implemented, the COC concentrations in the soil below the permanent cover may exceed the direct exposure SCTLs, as specified in Rule 62-780.680(2)(b)1b. F.A.C.

4. Direct leachability testing results can demonstrate that leachate concentrations do not exceed the GCTLs, as specified in Rule 62-780.680(2)(b)2b. F.A.C.

5. If an engineering control that prevents infiltration (for example, permanent impermeable cover material) is implemented, concentrations of COCs in the soil below the impermeable cover may exceed the LTG SCTLs, as specified in Rule 62-780.680(2)(b)2c. F.A.C.

6. Previous Site assessments, remedial action investigations, and other remedial efforts summarized in Sections 3 and 4 indicate that no free product is present. In addition, as the *SARA 2* concluded, leachability testing of soil samples that contained beryllium and chromium above the default LTG SCTLs produced leachate concentrations below the beryllium and chromium GCTLs (Table 4-2). These soil samples do not exist below a permanent cover. Accordingly, this remedial option is acceptable provided that (1) institutional controls are implemented to address soil with COCs above default residential SCTLs and (2) engineering controls, such as a permanent cover, are implemented to prevent exposure to or infiltration of the remaining soil that is above the default commercial/industrial or LTG SCTLs, respectively.

Institutional Controls— Non-engineering measures (usually, but not always, legal controls) intended to affect human activities in such a way as to prevent or reduce exposure to contamination. The legal mechanism, the “institutional control,” contains restrictions or prohibitions such as land and resource use restrictions and well drilling prohibitions. Generally, the institutional control itself may be in the form of a restrictive covenant, modified consent order, or conservation easement. Each of these documents must be properly recorded with the appropriate county's land records to help ensure proper notice and effectiveness of the control. As indicated above, institutional controls are necessary to meet the requirements under Risk Management Option II Lockheed Martin has provided FDEP draft terms of a restrictive covenant as a potential remedy to address Facility soils containing COCs above the default residential SCTL.

Engineering Controls— Engineering controls, such as impermeable barriers (i.e., caps), slurry walls, or other controls are designed to limit access and exposure to contamination, or are designed to eliminate further contaminant migration. Where an engineering control is necessary, institutional controls may need to be imposed to ensure that engineering controls are properly monitored and maintained, and that the FDEP has access to inspect the engineering controls. As indicated above, engineering controls are necessary to meet the requirements under Risk Management Option II. Existing asphalt pavement or building slabs, as well as new pavement or building slabs, are considered to prevent exposure to or infiltration of the remaining soil that is above the default commercial/industrial or LTG SCTLs, respectively. A soil cap has not been considered because it would require removing the soil that contains COCs above the default SCTLs so two feet of clean fill can be placed without raising the grade at the Facility. Removal of this soil would render the cap unnecessary. A fence encircling the Facility is another engineering control considered to limit unauthorized access and further reduce potential exposure to soil on the Facility.

Monitoring— Monitoring requirements for an active soil-treatment remedy that may be implemented on-site are specified in Rule 62-780.700, F.A.C. No active soil-treatment remedy is proposed to address soil identified in Section 7.2, so soil monitoring is not considered further.

Removal— Soil containing COCs above default SCTLs may be removed from the Facility using conventional excavation equipment and procedures, thereby eliminating direct exposure or potential for leaching to groundwater. Excavated soil is characterized, transported to and disposed of in a licensed disposal Facility. A soil management plan that outlines dust control, material handling, and transportation procedures is typically implemented during excavation, handling, and transport, to reduce potential exposure to or spread of the contaminated soil. More than 200 large dump-truck loads would have to be transported from the Facility if soil above the default residential SCTL were to be removed. However, several dump truck loads may be all that is required to remove soil at one or two sample locations where COCs are above the default commercial/industrial or LTG SCTLs. The ultimate soil volume in either case would depend on confirmatory sampling results.

GROUNDWATER— Site-wide

No Further Action— Current Site conditions do not meet the criteria specified in Rule 62-780.680, F.A.C. to implement NFA with or without controls for groundwater, principally because groundwater contains COCs above the GCTLs. Active groundwater treatment options are being considered with the goal to achieve site conditions that meet the NFA criteria set forth in Rule 62-780.680, F.A.C.

Institutional Controls— A restrictive covenant prohibiting installation of water-supply wells on the Facility that would affect the groundwater plume is considered so as not to adversely affect an active groundwater remedy or pose a risk of exposure.

Engineering Controls— Engineering controls such as slurry walls and sheet piling to eliminate further migration of the groundwater plume are not considered further because they are not practical to install or maintain to effect containment of such a large and deep plume. Lockheed Martin is conducting a private well closure program to abandon private supply wells to limit access and exposure to contaminated groundwater as well as reduce the potential for further migration of the contamination.

Monitoring— Monitoring (sampling monitoring wells and measuring water levels) is ongoing to evaluate the performance and effectiveness of the IRA system. Monitoring requirements to evaluate the performance and effectiveness of an active groundwater treatment remedy and to periodically redefine the plume are specified in Rule 62-780.700, F.A.C. Monitoring will be retained as a process option to be implemented for an active groundwater remedial alternative in the *RAP*.

Natural Attenuation with Monitoring— NAM may be an acceptable remedial strategy for site rehabilitation depending on the individual site characteristics, and provided that human health, public safety, and the environment are protected, as specified in Rule 62-780.690, F.A.C. Current Site conditions may not meet the criteria prescribed in the rule as necessary to implement NAM. Principally, data available in the scientific literature suggest 1,4-dioxane does not degrade or else has a very long half-life, and the existing Site data do not appear to cover a sufficiently long time period to adequately demonstrate 1,4-dioxane attenuation. Otherwise, it may be possible to demonstrate NAM is an appropriate remedial strategy. This process option is considered further in section 8.

In Situ Treatment— As discussed in Section 4, a tracer study injected bromide and fluorescein dye into the USAS and LSAS to evaluate the implementability and effectiveness of *in situ* chemical oxidation and to obtain information for full-scale *in situ* remedial design at the Site or Facility. The tracer injection study showed that injection is possible in both the USAS and LSAS, but that LSAS injection required operation of nearby extraction wells to provide space in the confined aquifer for the injected fluid. It also revealed significant preferential flow paths within the LSAS, making it difficult to ensure that the injected chemical would have adequate contact with COCs, thereby limiting the effectiveness of *in situ* treatment. As a result, *in situ* treatment is only considered for the USAS.

Three *in situ* technologies were considered for site-wide plume treatment: EBD, ISCO, and ERH. Note that *in situ* treatment over the entire area of the groundwater plume in the USAS would require 10,000 to 20,000 injection or heating points installed on approximately 15 to 20 ft centers. This is based on tracer test findings that the effective injection radius in the USAS is approximately 7.5 feet.

Enhanced Biological Degradation— As discussed in Section 4.4.1, EBD may be an effective method to reduce CVOCs. Addition of an electron donor stimulates specific microbes that enhance the reductive dechlorination of CVOCs. Stimulating enhanced reductive dechlorination would have no significant effect on degrading 1,4-dioxane concentrations. *In situ* EBD of 1,4-dioxane has not been reliably demonstrated at full-scale. Since most of the groundwater plume contains both 1,4-dioxane and CVOCs, and model simulations presented in Section 9 indicate the overall cleanup time is controlled by 1,4-dioxane, treatment using EBH is unlikely to have a significant effect on overall cleanup time. This remedial technology is considered further in Section 8.

In situ Chemical Oxidation (ISCO)— *In situ* chemical oxidation involves the introduction of a chemical oxidant into the subsurface to break down the CVOCs and 1,4-dioxane into less harmful chemical species, typically carbon dioxide, water, and chlorides. Several different reagents are effective at treating the Site CVOCs and 1,4-dioxane, including Fenton's reagent (peroxide and iron), peroxide plus ozone, and activated persulfate. The formation of the hydroxyl radical from peroxide using either iron, ozone, or the persulfate radical is necessary to oxidize 1,4-dioxane. Before submitting the *RAP* in 2008, persulfate was selected for bench and pilot scale testing. Fenton's reagent and peroxide plus ozone were not selected because far more of the oxidant is consumed by the natural soil oxygen demand (i.e. carbonates) than activated persulfate. Accordingly, activated persulfate is much less likely to dissolve the large amount of carbonate present in the Hard Streak or clays.

As presented in Section 4.4, the results from the bench and pilot scale tests with activated persulfate indicate that it effectively treated the COCs in the subsurface and achieved an effective injection radius of approximately 7.5 ft. Test results also indicate that multiple injections would be required to reduce concentrations below GCTLs. The pilot study revealed that injection of persulfate temporarily mobilized naturally occurring metals (arsenic and chromium) in the formation. The mobilization of these metals was not observed beyond the zone of injection. Based on the pilot scale test, treatment of the entire plume in the USAS wide would require a total activated persulfate injection volume well in excess of a million gallons. Adequate precautions must be taken when handling, mixing, and transporting powerful oxidants. This remedial technology is considered further in Section 8.

Electrical Resistive Heating (ERH)— ERH enhances the removal of COCs in the subsurface by heating the subsurface sufficiently to volatilize the compounds and recover them with a vacuum extraction system. Although this technology is effective at removing CVOCs, it is less effective at removing 1,4-dioxane, because a large percentage of the mass is removed via the vapor stream. The CVOCs have a significantly higher vapor pressure and are less soluble than 1,4-dioxane. Treatment of the entire plume in the USAS would pose an extremely large energy demand. This remedial technology is considered further in Section 8.

Groundwater Recovery— is an established remedial technology that would remove contaminated groundwater for above-ground treatment and later discharge. Groundwater may be extracted using vertical extraction wells, horizontal extraction wells, and/or extractions trenches. Horizontally drilled extraction wells were not considered because targeting the relatively thin water bearing zones that contain contaminated groundwater is very difficult.

Extraction Trenches— Shallow extraction trenches are relatively easy to install and may be more effective at groundwater removal than vertical wells because they are capable of connecting more transmissive channels and zones within a heterogeneous aquifer. A Dewind - trenching machine is being considered as the method for constructing extraction trenches in the USAS. The trenching machine can install a trench, extraction pipeline, and backfill in one operation and should be capable of reaching the bottom of the USAS in most areas without extensive benching (i.e., excavation to place trenching equipment before excavating the trench). One excavation is relatively quick (up to 200 feet per day (ft/day)), reducing construction time compared to other trenching technologies. An approximately 50-ft-wide unobstructed path is necessary to dig an extraction trench.

Trench construction into the LSAS could not be practically done with a one pass trencher because the Hard Streak would slow down the cutting, significant benching would be required to reach the LSAS, and it would be very difficult to ensure that the finished LSAS trench is adequately isolated from USAS. Driving sheet-piling is a more conventional method for installing a deep trench and ensuring its isolation from shallower zones; however, the Hard Streak would resist sheet-pile driving or make installation of other isolation walls difficult and time consuming, and produce a large volume of construction waste. As a result, extraction trenches are only considered for use in the USAS and not in any of the deeper water bearing zones.

Extraction trenches may be preferable in areas where large continuous lobes of relatively higher COC concentrations are encountered, such as the southwest and southeast portions of the USAS plume. The extraction trenches can reduce the number of wells necessary for hydraulic capture and mass removal, thereby reducing the number of associated extraction appurtenances such as pumps and pump controls. Accordingly, the same benefits offered by extraction trenches can also be disadvantages, because trenches offer less operational control of the groundwater extraction system over the life of the Site rehabilitation process (e.g., a portion of the trench cannot be shut off once a portion of the plume is cleaned up).

Vertical Extraction Wells— Vertical extraction wells are preferred for the LSAS and deeper zones because of the extraction trench construction difficulties described above. Within the USAS, using wells for extraction is preferred over trenches in areas where COC concentrations are lower and more sporadic or irregular in distribution, such as north of Tallevast Road, because pumping rates at each well can be individually controlled to optimize capture and control drawdown. Wells can be shut off as more distant areas of the plume with low COC concentrations are cleaned up. Extraction wells also require less space and produce less construction waste to install than extraction trenches.

Dual Phase Extraction— DPE, also known as multi-phase extraction, uses a high vacuum system to remove both contaminated groundwater and soil vapor. Fluid/vapor extraction systems depress the water table so that water flows faster to the extraction well. Although DPE dewaters the aquifer, volatile contaminants can also be removed by extracting the soil vapor. Once above ground, the extracted vapors and groundwater are treated. This technology is difficult to implement because it requires a large volume of groundwater to be removed to subject the source of USAS contamination to vapor extraction. Most contamination in the USAS exists below 20 feet or more of clean or relatively uncontaminated groundwater. Once the clean layer of groundwater is removed, CVOCs will migrate to the shallow soil zone, thus increasing the potential to complete the soil vapor pathway to a potential receptor. Large decreases in the shallow water table can also increase the risk of differential settling creating problems for structures. This technology is extremely difficult to implement and would present an unacceptable level of risk if implemented Site-wide; therefore it is not retained for further consideration to treat the Site-wide groundwater plume.

Ex Situ **Treatment**

Extracted groundwater may be treated above ground using one of the following treatment processes.

Air Stripping— Air is passed countercurrent through extracted groundwater. Using with low vapor-pressures, chemicals are stripped from the water and released into the air stream. The counter current flow may be achieved using a blower or compressor to pass air from one end of a tower packed with porous media or perforated trays while groundwater is pumped through from the other end. The air stream must be treated for the first month of operation, and air emission treatment must continue if the emission exceeds 5.5 pounds/day for any single pollutant or 13.7 pounds/day for total pollutants. This technology is very effective at removing CVOCs from groundwater but ineffective at removing 1,4-dioxane because of its low vapor pressure and high solubility. This remedial technology is considered further in Section 8.

Liquid Phase Granular Activated Carbon (LPGAC)— Liquid phase granular activated carbon adsorbs relatively small quantities of soluble organics and some inorganic compounds. Adsorption occurs when molecules adhere to the internal walls of pores in carbon particles produced by thermal activation. 1,4-dioxane is a very soluble compound not easily adsorbed by carbon; as a result LPGAC is inefficient as a primary treatment method to remove 1,4-dioxane. However, LPGAC can be used to polish groundwater to remove very low levels of contaminants that remain following a more effective primary treatment method. Discharge from the existing IRA Photo-Cat system is pumped through LPGAC canisters to remove residual 1,1-DCA and polish the Photo-Cat effluent before discharging the water to the sanitary sewer. LPGAC is further evaluated in Section 8.

Advanced Oxidation Process (AOP)— These technologies were screened in the *IRAP* (BBL, 2006b) and two were pilot tested: (1) photo-catalytic oxidation (i.e., a Photo-Cat unit manufactured by Purifics) and (2) ozone and peroxide (i.e., a HiPOx unit manufactured by APT), as discussed in Section 3.2.3. The Photo-Cat unit was selected for the IRA because it demonstrated effective treatment of the COCs during the pilot test, and the process does not generate significant air emissions. The IRA Photo-Cat system has operated since the fall of 2006 and has demonstrated substantial reduction of all COCs, although its effectiveness at treating 1,1-DCA is limited. For the purposes of screening remedial technologies, AOP is evaluated later in this *RAP*. This technology accomplishes the reduction by permanently destroying most of the COC mass in the groundwater.

Vapor Treatment Using Vapor Phase Granular Activated Carbon (VPGAC)— Similar to LPGAC, VPGAC adsorbs organic emissions by venting tank head space, through vacuum extraction, or by air stripping exhausts through activated carbon. Regardless of the emission rate of pollutants, VGAC is retained as a remedial technology to treat exhaust from the storage and treatment of tank head-space and/or exhausts from vacuum extraction or air stripping, should any of these latter technologies be selected as part of the final selected remedial action.

Groundwater Disposal

Discharge to POTW— Currently, the IRA system discharges treated groundwater to the Manatee County wastewater treatment facility via the sanitary sewer, under permit IW 0025S. A new permit may be issued to allow the discharge/disposal of treated groundwater to the POTW for the *RAP*. This technology was retained for any remedy that includes extraction and treatment of groundwater because it is relatively easy to implement and provides a means to dispose of recovered groundwater, to hydraulically control the plume and thus reduce COCs below the GCTLs. This technology will further reduce the potential for exposure over the short-term, because any residual COCs in the treatment system effluent would be discharged to the sanitary sewer that exists below the surface and then further treated by the POTW. It is possible that untreated groundwater could be discharged directly to the POTW provided it is approved by FDEP and MCUO. Discharge of untreated groundwater directly to the sanitary sewer for treatment at the POTW is retained for further evaluation in Section 8.

Recharge Galleries and Injection Wells— Perforated pipe or well screen installed in a horizontal trench or vertical borehole is used to return treated groundwater to the aquifer. Given the size and location of the plume within four different water bearing zones, it would be very difficult to use recharge galleries and injection wells in conjunction with extraction wells and trenches to control the Site-wide plume. However, localized areas may be targeted for recharge with little risk of spreading the plume. Recharge galleries are retained as part of any remedial alternative that would extract groundwater from the USAS and potentially increase drying of wetland and/or ponds.

GROUNDWATER— Hot spots

As noted in section 4.2.3, four areas of highest COC concentrations (i.e., hot spots) were identified on the Facility. Six treatment technologies are considered below to target these areas to accelerate contaminant mass removal. Note that these areas represent a small portion of the overall mass present in the Site-wide plume, and removing this mass does not affect the overall cleanup times projected in the groundwater flow and transport model simulations summarized in Section 9.

In Situ Treatment— Similar to Site-wide plume remediation, EBD, ISCO and ERH were considered for treating the hot spots on the Facility. While each of these may be more practical to implement in a much smaller area, they share similar drawbacks. EBD is not proven effective at treating or removing 1,4-dioxane. ERH also has limited effectiveness at removing 1,4-dioxane, and to heat the USAS aquifer would require high energy use. ISCO has been pilot tested and shown effective. However, it would require multiple injections with an estimated total volume of oxidant in excess of 100,000 gallons, which must be carefully handled and managed. ISCO may also mobilize metals that may be recovered by the groundwater recovery system and removed from the groundwater before the discharge of treated groundwater.

Groundwater Recovery

Dual Phase Extraction— Dual-phase extraction may be more practical to implement in hot-spots on-facility than noted above for Site-wide groundwater treatment; however, it still requires significant dewatering of the USAS to target the contaminants present in the bottom of the USAS. This would increase the potential for CVOCs to migrate into the shallow soil zone, increasing the risk of exposure via the soil vapor pathway and increasing the potential for differential settling that may cause structural problems to Facility buildings.

Focused Groundwater Extraction and Injections Wells— Groundwater extraction wells placed in the center of hot spots can target the highest groundwater concentrations and accelerate mass removal. Adding injection wells to reintroduce treated groundwater along the edges of the larger hot spots would further accelerate mass removal by increasing gradient and groundwater flow at these locations.

Removal

Excavation— Removing soil with a high mass of CVOCs sorbed to soil can often be effective in reducing concentrations in groundwater. Given that areas of relatively high concentrations of COCs exist at the base of the USAS, excavation is generally less efficient at addressing these areas than *in situ* techniques because a large amount of soil and groundwater that is clean or has relatively low concentrations of COCs must be removed to reach the deeper soil having relatively high concentrations. Excavation techniques had been evaluated before submitting the 2008 *RAP*. Conventional excavation with sloped sidewalls was eliminated because the perimeter of the excavation would extend beyond the boundary of Buildings 1 and 2 as well as of the Facility. Sheet-piling was also eliminated because, even if it were possible to drive through the Hard Streak, which is questionable, it would cause communication between the USAS and LSAS. The retained excavation-technology is augering, which requires driving a caisson, a slow and often noisy method.

7.6 General Response Actions, Remedial Technologies, and Process Options Retained for Detailed Evaluation

Based on the preceding discussion, the following GRAs, remedial technologies, and process options (listed by media) will be retained for detailed evaluation in Section 8:

SOIL

- No further action
- Institutional controls
- Engineering controls
- Removal
    - Excavation

GROUNDWATER— Site-wide

- No further action
- Natural attenuation monitoring (NAM)
- *In situ* treatment
    - Enhanced biological degradation (EBD)
    - *In situ* chemical oxidation (ISCO)
    - Electric resistive heating (ERH)
- Groundwater recovery
    - Extraction wells
    - Extraction trenches
- *Ex situ* treatment
    - Air stripping
    - Liquid phase granular activated carbon (LPGAC)
    - Advanced Oxidation Process (AOP)
- Vapor treatment (retained for remedial scenarios, not evaluated in Section 8)

  - o Vapor phase granular activated carbon (VPGAC)

- Groundwater discharge
  - o Discharge of untreated groundwater to publicly owned treatment works (POTW)
  - o Recharge galleries and extraction wells (retained for remedial scenarios, not evaluated in Section 8)

GROUNDWATER— Hot Spots

- *In situ* treatment
  - o Enhanced biological degradation (EBD)
  - o *In situ* chemical oxidation (ISCO)
  - o Electric resistive heating (ERH)
- Groundwater recovery
  - o Focused groundwater extraction and injection wells
  - o Dual-phase extraction (DPE)
- Removal
  - o Excavation

8. Selection of Preferred Remedial Alternative

In accordance with the criteria provided in Rule 62-780.700 F.A.C., potentially applicable GRAs, remediation technologies, and process options were evaluated on the basis of feasibility, implementability, long-term human health and environmental effects, short-term human health and environmental effects, operability, maintainability, reliability, cleanup time, and cost effectiveness. A summary of the evaluation is provided in Table 8-1.

8.1 Description of Process for Ranking Alternatives

Each of the evaluation criteria were subdivided into five characteristic components against which the attributes of each technology can be compared on a normalized basis. These characteristic components are generally accepted interpretations of each of the evaluation criteria derived from historical practice in Florida and referenced against published guidance from the USEPA.

These characteristic criteria components were structured so that true/false logic can be applied when the specific technology attributes are evaluated against the statement. In other words, if a specific technology attribute is true (or more true than false) with respect to a particular criterion characteristic, it is assigned a “1”; if it is false (or more false than true), it is assigned a “0”. After the five characteristic versus technology attributes were evaluated for the criterion under consideration, the respective ones and zeros in all five columns were added together to give a raw score for that particular technology with respect to that specific criterion. Then the raw criteria scores were summed to obtain a raw technology score. However, comparison of these raw technology scores just portrayed distinctions among approaches with all evaluation criteria given exactly equal emphasis.

In order to illuminate the specific emphases applied by Lockheed Martin in selection of a preferred alternative, weighting factors were assigned to each of the evaluation criteria in accordance to relative significance. The range of weighting factors was from one to five, with 5 representing the greatest emphasis. This range was selected as broad enough to afford graded distinctions between the criteria, but not so large that it created an exaggerated separation in weighted composite scores.

Once the raw scores by criterion were obtained, these were multiplied by assigned weighting factors and summed to give the weighted composite scores for each alternative. Table 8.1 contains both the raw scores and the weighted scores to clearly demonstrate how the criteria given the greatest emphasis affect the preferred remedy. Note that both the raw scores and the weighted score yield roughly the same set of preferred technologies.

Basic conceptual information for each alternative was compiled with respect to each of the attributes. To the extent practicable without preparing fully developed designs for each, the alternatives were normalized to a comparable set of performance measures.

Characteristic Components by Criterion

The following are the interpretations applied to each of the evaluation criteria listed in Rule 62-780.700*(3)(d)2.a. through g., F.A.C.* These are structured as statements against which applicable technology attributes can be assessed using “true/false” logic. Since relatively few environmental remediation measures can be asserted effective in an absolute sense, evaluating them entails making relative comparisons among the spectrum of technologies considered. Consequently, a determination that a technology attribute is “true” for the “Implementability” component of “minimum disruption of the community” should not be construed as meaning that an absolute minimum can be achieved, but rather, selection of this particular technology would allow approaching the achievable minimum more closely than other technologies under consideration.

Summation of binary comparisons does not eliminate all subjectivity in ranking various options. However, in contrast to having evaluators assign numbers on a scale of one to 10, it forces a more uniform consideration of yes/no thresholds that are more amenable to quantification and less dependent on the differences in the personal biases of evaluators.

Feasibility

The simplest measure of feasibility is “Will it work?” In this context, the applicable characteristics for ranking among alternatives are:

- Stops further spread of the plume
- Treats, removes or otherwise addresses all the COCs
- Has no significant collateral impacts, either from construction or operation
- Leaves minimal residual contamination upon completion
- Extinguishes future risks

Implementability

The characteristic components evaluated with regard to implementability are:

- Historically acceptable to regulator
- Reasonably addresses third-party concerns

- Does not require access to numerous parcels of private property
- Does not cause significant disruption of community or locale
- Does not require extraordinary measures to sustain

Long-Term Human Health and Environmental Effects

Characteristic components of this criterion are:

- Direct human exposure pathways are precluded
- Post-remediation residual contamination is below harmful levels, or isolated
- Concurrent effects (e.g., air emissions) can be controlled
- Further dispersion of contaminants during or after remediation is unlikely
- COCs are destroyed, not moved to another place

Short-Term Human Health and Environmental Effects

Characteristic components of this criterion are:

- Does not create temporary exposure pathways
- Does not disperse COCs during processing into air, surface water, or soil
- Does not require significantly invasive methods to construct or implement
- Large quantities of dangerous or potentially harmful chemicals are not required
- Potentially dangerous methods are not required

Operability

The characteristic components of operability are:

- Process is easy to control
- Has a wide range of treatment capabilities and processing rates
- All necessary performance parameters are within the control-span of the system/operator

- All necessary performance parameters can be measured quickly enough to enable appropriate response and adjustment
- Single component failures do not propagate damage to other dependent operations or system

Maintainability

Component characteristics of maintainability are:

- The system can be properly maintained without requiring highly specialized tools, rigging, or heavy equipment (cranes, drill rigs)
- The components requiring service can be easily reached and worked on without requiring access permission or removal of other structures or equipment
- System troubleshooting and repair can be done without enlisting highly trained or uniquely skilled specialists
- Can maintenance be properly performed without requiring extraordinary measures (closing a runway or road, relocating residents)?
- Can maintenance or repair be accomplished without the need to shut down the complete system?

Reliability

Component characteristics of reliability are:

- No complex sequences of interdependent components required
- The system and components are rugged and durable enough to withstand extreme weather, neglected maintenance, or inadvertent improper operation
- The process is insensitive to changes in groundwater composition (e.g., unexpectedly high concentrations of iron) or characteristics of the substrate
- Process performance does not hinge on a single (not necessarily reliable) component
- Early indicators of component failure can be readily monitored

Cleanup Time

The component characteristics of the relative time to achieve cleanup are:

- Limited basis for third parties to delay start up
- Lengthy interruption of operation unlikely
- Reasonable confidence that cleanup times can be predicted
- Does not cause conditions that would require lengthy post remediation monitoring
- No major unknowns that, if encountered, could cause indefinite delay

Cost Effectiveness

The characteristic components of cost effectiveness are:

- The ratio of capital cost to mass of contaminant ultimately removed (or sequestered) in dollars per pound ($/lb) is less than the statistical median of the cost effectiveness ratios of the technologies considered
- The ratio of life-cycle operating cost to mass of contaminant ultimately removed (or sequestered) in $/lb is less than the statistical median of the cost effectiveness ratios of the technologies considered
- The ratio of life-cycle maintenance cost to mass of contaminant ultimately removed (or sequestered) in $/lb is less than the statistical median of the cost effectiveness ratios of the technologies considered
- The ratio of life-cycle monitoring cost to mass of contaminant ultimately removed (or sequestered) in $/lb is less than the statistical median of the cost effectiveness ratios of the technologies considered
- The ratio of decontamination and decommissioning cost to mass of contaminant ultimately removed (or sequestered) in $/lb is less than the statistical median of the cost effectiveness ratios of the technologies considered

Order of magnitude costs estimates of capital, operation, maintenance, monitoring, as well as decommissioning and demolition are provided in Appendix H for each evaluated technology or process option. The estimated cost for each of the attributes listed above is also summarized on Table 8-2. Estimated costs that are less than the median cost are represented in bold text on Table 8-2.

Weighting Factors

These evaluation criteria were given weighting factors that reflect the level of emphasis in selecting a preferred alternative. Long-term and short-term human health and environmental effects were given the greatest emphasis and weighted at 5; time to achieve cleanup and feasibility were assigned a weighting factor of 4; all remaining criteria were assigned a weighting factor of 3.

8.2 Discussion of Ranking Considerations

SOIL

No Further Action (NFA)

No further action without controls as a process option for soil has a low composite score (ranking) because it does not remove mass or reduce migration of COCs nor do conditions on the Facility currently exist that are protective of human health or the environment. Since current conditions on the Facility do not meet the criteria set forth in Rule 62-780.680(1), F.A.C., it would not be approved by FDEP and is unlikely to be acceptable to the community. It is also not cost effective because it gains no improvements in site conditions but requires expenditures to pursue. NFA without controls ranks very low and is not retain as part of the selected remedial alternative.

Institutional and Engineering Controls

Institutional and engineering controls are feasible to implement on the Facility because it is property under the control and ownership of Lockheed Martin. Thus, a restrictive covenant can be lodged to limit further activities on the Facility. Engineered barriers (a cover) can be constructed and maintained to prevent potential future exposure to COCs in soil and prevent leaching COCs from soil and into groundwater. Institutional and engineering controls have a high composite score and are retained as part of the selected remedial alternative.

Removal

Excavation of soil on the Facility has a lower composite score than institutional and engineering controls primarily because it creates more disruption and short-term risk to implement. As indicated in Section 7, if excavation on Facility was implemented to address soil above default residential SCTLs most of the surface soil on Facility would have to be removed. As a result, excavation is not retained as the major element of any remedial strategy for soil on the Facility. However, some soil excavation is contemplated to install groundwater recovery and treatment systems and a soil management plan would be implemented to minimize potential short-term risk as a result there of.

GROUNDWATER – Site-wide

No Further Action (NFA)

The proposed active groundwater remedial alternative is intended to implement an active remedy to achieve Site conditions that meet the no further action criteria set forth in Rule 62-780.680, F.A.C. Those Site conditions do not currently exist. NFA at this time is not protective of human health or the environment; it is not implementable because it is deemed unlikely to receive either regulatory or community acceptance; it is not operable, maintainable, or reliable; and it is not cost effective because it gains no improvements in site conditions but requires expenditures to pursue.

Natural Attenuation with Monitoring

Natural attenuation with monitoring (NAM) alone, or as part of an active remedial strategy, is not regarded as feasible for this Site because it does not meet the NAM requirements set forth in Rule 62-780.690, F.A.C. As a result it is not considered implementable because of the low probability of either regulatory or community acceptance. Current data do not indicate adequate natural attenuation of 1,4-dioxane and as such this would not likely be a cost effective strategy nor would it meet the RAO to hydraulically control the plume.

***In Situ* Treatment**

Enhanced biological degradation (EBD), *in situ* chemical oxidation (ISCO), and electrical resistive heating (ERH) all have low composite scores. They are not feasible for Site-wide plume treatment because they are impractical to implement over a large area. For example, they require a very large number of closely spaced injection or heating points to fully treat the COCs in the USAS (10,000 and 20,000 points on 20 to 15 foot centers). These technologies are not feasible for treating the lower confined aquifers because the preferential flow within these aquifer zones significantly reduces their efficacy. None of the *in situ* technologies can be affirmatively controlled after injection, and residual contamination may remain if preferential pathways develop in the subsurface. This could cause short-circuiting, or bypass of large volumes of material. Deep injection points are difficult to maintain and are not reliable for achieving uniform distribution. Where the oxidant or biological stimulant fully reaches all contaminants, cleanup times are accelerated as compared to other means, but both are accompanied by the possibility that the injection itself could seal off parts of the water bearing zone in a manner that would inhibit future injections and possibly make extraction more difficult. The large number of injection points and the quantities of injectant required to implement Site-wide *in situ* methods render this approach cost ineffective.

Groundwater Recovery

Extraction and treatment of groundwater yields the greatest composite score because it is the most protective of human health and the environment in both the short and long term, is implementable because it produces the most sustainable ultimate result and can be constructed without necessitating extensive access to private property. It is practical to operate and maintain, and is both reliable and cost effective.

Vertical extraction wells - Vertical extraction wells have the highest overall score because they are effective at removing groundwater containing COCs in all four units.

Trench extraction — Trenches are also only implementable in the USAS; however, trenches have a much greater composite score than DPE. Trenches in the USAS are nearly equal in score as vertical extraction wells because they are somewhat more effective at removing COCs in certain portions of the plume. Trenches are less implementable than vertical extraction wells because they require large construction equipment to install, create more disruption and produce more construction waste.

***Ex Situ* Treatment**

Air Stripping – Air stripping did not score as high as other *ex situ* treatment technologies because it produces a collateral vapor stream that requires treatment and does not address1,4-dioxane.

Liquid Phase Granular Activated Carbon (LPGAC) – LPGAC scores higher as an auxiliary treatment technology than it does as a primary system. It is effective for removal of VOCs, of limited value in removing 1,4 dioxane, and ineffective in removing dissolved metals. It poses no hazard to human health or the environment, it is easy to construct, easy to operate and maintain, is very reliable and cost effective.

Advanced Oxidation Process (AOP) –This technology obtained a high composite score because it is very effective at reducing the COCs in groundwater to below GCTLs, it is simple to operate, easy to maintain, has demonstrated a high degree of reliability, poses the least threat to human health and the environment, and is cost effective. Further, this technology reduces contamination by permanently destroying most of the COC mass in the groundwater.

Groundwater Disposal

Discharge to POTW— This technology scores high for disposal of treated water but low for disposal of contaminated groundwater.

Groundwater Hot Spots

***In Situ* Treatment**

Enhanced biological degradation (EBD), *in situ* chemical oxidation (ISCO), and electrical resistive heating (ERH) are more feasible for hot spot treatment than the site-plume because they require much less infrastructure, chemical/energy and are less intrusive. In small areas of high concentrations of COCs, *in situ* methods are sometimes preferred, however, all of the same criteria must be considered. Generally, *in situ* methods do not by themselves arrest the spread of contaminants and can produce adverse collateral impacts (e.g. mobilization of metals) thereby reducing their feasibility, may exacerbate short term human health and environmental effects, can be difficult to control and maintain, are not always reliable, and aren't necessarily the most cost effective approach. Furthermore, there have been instances in which the subsurface formation is affected in a way that makes subsequent efforts to remove or treat groundwater more difficult.

Groundwater Recovery

Groundwater extraction focused in the center of hot spots accelerates mass removal and arrests the further spread of the higher concentration mass. Adding wells around the perimeter of the hot spots to inject treated groundwater will further accelerate the rate of mass recovery in hot spots. Focused extraction and injection scores higher than *in situ* technologies because it does not mobilize metals, involves no hazardous materials, and is easier to operate and maintain.

Dual-phase extraction scores lower than focused extraction and injection because it requires a much larger volume of groundwater to be removed for it to be effective, thus increasing the potential risk to differential settling and short-term exposure. It also produces an additional waste stream that must be treated.

Excavation

Excavation can be an effective technology for reducing/removing small areas/volumes that act as sources of groundwater impacts (i.e., they contain COCs in the sorbed phase at relatively high concentrations). Because areas of relatively high concentrations of COCs exist at the base of the USAS, excavation is generally less efficient at addressing these areas than treatment or removal techniques targeting this interval. This is because a large amount of clean soil must be excavated and handled in order to remove the deeper interval having the highest COC concentrations. The depth also adds to the complexity of the excavation and increases the potential to cause structural problems for existing buildings. As a result, excavation does not score high as a remedial technology.

Excavation will be necessary when constructing the treatment building and installing extraction trenches, wells, and utilities. The materials management plan in Section 11.5 will be implemented to manage excavated soil. This plan also provides details on how to safely excavate and handle any unexpected source material that may be encountered in the field.

8.3 Formulation of the Recommended Alternative

The limited nature and extent of COCs in soil, the limited mobility of the soil COCs (PAHs and metals), and the location of these areas (restricted to the on-facility property) enabled identification of a single protective and minimally intrusive alternative for soils. The specific alternative selected for soils is described in Section 8.3.1. In contrast, the nature and extent, and fate and transport, of COCs in groundwater are more complex than in soils. The mixture of contaminants (1,4-dioxane, chlorinated alkenes, and chlorinated alkanes) and their presence in various hydrostratigraphic units at the Site limit the number of technologies that can potentially be used to successfully treat them. Potentially available *in situ* technologies reviewed earlier in Section 8 include biological degradation, chemical oxidation, and resistive heating. These technologies were considered for source area treatment but were eliminated as an option to treat the entire plume for the following reasons:

- Current documentation of a biological degradation pathway for 1,4-dioxane (the COC that exists over the greatest areal extent at the Site) is insufficient.

- Each technology requires extensive delivery systems (e.g., nutrients, oxidants, heat).

- Based on chemical oxidation pilot studies, delivery systems at approximately 20-foot centers would be required to successfully implement the technology. This translates into placing thousands of delivery points throughout the nearby residential community, which would unacceptably disturb the community.

- The large number of delivery points increases the potential for cross-contaminating hydrostratigraphic units. Minimizing delivery points will minimize this potential.

- A significant increase in potential short-term risk due to handling large quantities of a strong oxidant on properties with unrestricted access.

The treatment technologies considered for 1,4-dioxane and other COCs included AOP, LPGAC, and air stripping. AOP was selected as the primary treatment option because it treats most of the COCs, especially those present in the highest concentrations. LPGAC was retained as secondary treatment of CVOCs to polish treated waters. LPGAC was not selected as a primary treatment technology because it does not effectively remove 1,4-dioxane from the groundwater. Nor was air stripping retained as a potential treatment technology, because it does not effectively remove 1,4-dioxane and because it would transfer the COCs to the air phase, where they would require additional treatment before discharge to the atmosphere. The specific elements of preferred groundwater remedy are described further in Section 8.3.2.

8.3.1 Soils Retained Alternative

FDEP approved the *SARA 3* (BBL, 2006a) in a September 25, 2006 letter, in which the agency acknowledged that Lockheed Martin would address on-facility soil through a combination of engineering and institutional controls, in accordance with Rule 62-780.680(2) F.A.C. Institutional controls include a "Declaration of Restrictive Covenant" for the Facility prohibiting certain uses of the property and requiring appropriate soil management disposal practices to protect the health and safety of on-facility workers. Fencing around the Facility and existing or new buildings or pavement constitute the engineering control. FDEP concluded in its approval letter that no further action is required for soil beyond the former ABC Facility property. Lockheed Martin understands that a final "Site Rehabilitation Completion Order" (SRCO) for the Site will not be issued until all impacted media achieve media cleanup goals.

8.3.2 Groundwater Retained Alternative

The remedial technologies identified for groundwater include:

- Hydraulic containment of groundwater in the upper four water-bearing zones containing COCs at concentrations greater than GCTLs, using extraction wells and trenches
- Treatment of extracted groundwater using AOP, with GAC polishing
- Discharge of treated groundwater to the POTW and recharge galleries
- Groundwater recharge using infiltration galleries around wetlands, where groundwater withdrawal from the USAS may impact such areas
- Focused pumping and injection of treated groundwater in on-facility areas of highest COC concentrations in the USAS

Focused flushing in the USAS will also produce the beneficial effect of promoting flushing in the LSAS. Injecting treated water into the USAS will create a mound surrounding the injection wells, and the injection will generally maintain USAS water levels higher than with extraction only. The mounding and the generally higher water levels in the USAS will particularly be reflected in the upper part of the LSAS, because the Hard Streak allows sufficient hydraulic communication between the lower USAS and upper LSAS. This connection is indicated through the monitoring of hydraulic pumping changes, as well as through long-term tracking of groundwater levels as part of the regular site monitoring program.

The mounding and generally higher water levels will, in essence, drive contaminated groundwater toward the extraction wells with a higher gradient than without injection, not only in the USAS but also in the LSAS. Complementing this effect, the focused flushing area is situated beneficially with respect to the zone of highest COC concentrations in the LSAS, as shown by the sampling of the PZ-LSAS series of monitoring wells. The high concentration LSAS zone is effectively surrounded and covered by LSAS extraction wells that mimic the arrangement of USAS extraction wells for the USAS focused flushing design. The high concentration zone in the upper LSAS is likely the result of the hydraulic communication between the lower USAS and the upper LSAS, through the Hard Streak layer. This is in the same zone where the MIP investigation identified sufficiently elevated contaminant levels to warrant definition of the largest of the four USAS enhanced remediation areas.

Although the data indicate communication across the Hard Streak, the USAS injection and extraction wells will not be extended down into the LSAS. That would represent cross-connection of two distinctly different hydrogeologic formations. Injection of treated groundwater into the LSAS, separately from injection into the USAS, will not be included in the groundwater remediation system. Injection into the LSAS would increase the downward gradient from this unit into the lower aquifer layers, exacerbating cross-contamination through open or leaking boreholes. This is because almost all of the water supply wells in the area are cased through the USAS into at least the LSAS, and then open hole below that point. Of particular concern is the former on-facility production well, due to its location within the more highly impacted zone in the LSAS (and the USAS). Therefore, one of the most important goals of the groundwater pumping is to create as much drawdown as possible in the LSAS unit, especially in the more highly contaminated zone on-facility, so that the downward gradients are controlled adequately. Assembly and layout of the groundwater technologies was based in part on information generated from the three-dimensional groundwater model and evaluating existing IRA treatment data. Development of the groundwater model and its use in the development of the preferred alternative are discussed in Section 9 and Appendix D.

9. Groundwater Modeling

GeoTrans, Inc. (GeoTrans) developed, calibrated, and used a three-dimensional computer model of groundwater flow, complemented by solute transport modeling, to simulate the recommended groundwater remedial alternative, support the design of the alternative, and estimate remediation time frames. *MODFLOW-2000* (Harbaugh, et al, 2000a and 2000b) was used to simulate groundwater flow and *MT3DMS* V 5.2 (Zheng C., 2006) was used to simulate solute transport. Groundwater flow and solute transport modeling was used to evaluate potential groundwater extraction scenarios in the Surficial and Intermediate Aquifer Systems at the Site. The model enabled the project team to simulate various potential extraction and focused injection and/or extraction scenarios, thereby refining selection of the recommended remediation alternative. This included assessing the extent of hydraulic capture and rate of COC removal under each scenario, so as to determine an effective strategy for the prevention of further migration of COCs, the effective location and number of extraction points and focused injection/extraction on-facility, and rapid removal of significant portions of groundwater-borne contaminant mass. The model also facilitated evaluation of scenarios to mitigate potential groundwater drawdown impacts to surface water and wetlands in the area. To achieve the general objectives described above, the following specific modeling objectives were developed:

- Reduce the potential for human exposure to COCs in groundwater
- Hydraulically control groundwater containing COCs in concentrations greater than the GCTLs as listed in Chapter 62-777 of the F.A.C.
- Actively extract and treat the groundwater plume until concentrations are below GCTLs
- Minimize community and natural resource disturbance

In identifying effective hydraulic containment scenarios, numerous extraction well and trench configurations were evaluated during this and previous *RAP* submittals. In developing the scenarios, the goal was to keep extraction rates relatively low (less than 250 gpm) to avoid excessive drawdown of ponds and wetlands while maintaining hydraulic control of groundwater containing COCs in excess of GCTLs. Both extraction wells and extraction trenches (horizontal wells) were considered for use in the recommended alternative. In addition, limited reinjection was introduced in 2009 simulation modeling to facilitate enhanced source area cleanup. The recommended alternative presented herein reflects adjustments, changes, and improvements in extraction well layouts relative to those presented in the Task 3 interim report (GeoTrans, 2008b), the Task 4 interim report (GeoTrans, 2008c), and Appendix M of the 2008 *RAP*. Areas within the groundwater model that have been refined during development of this *RAP Addendum* include:

- Completion of sensitivity analyses for TCE (reasonableness and conservativeness of the “effective half-life”)
- Simulation of recharge trenches for hydroperiod maintenance of wetlands
- Accounting for private water supply well pumping influences
- Predicting the effectiveness of focused flushing on-facility to treat areas of higher concentration
- Predictions accounting for a span of three years between RAP submittal and RAP start up

The following sections summarize the key points of model construction and results as these relate to remedial alternative selection. The details of model construction, calibration, and predictive scenarios are provided as Appendix D, “Groundwater Flow and Solute Transport Model.”

9.1 Model Construction and Calibration Information

The model consists of 14 layers as shown on Figure 2-2. The five relatively permeable units (USAS, LSAS, AF Gravels, S&P Sands, and Lower AF Sands) are represented using layers 1 to 3. The USAS was divided into two layers: an upper, more permeable layer, and a lower, less permeable layer, representing the bottom five feet of the unit. The LSAS was divided into three layers so the model could simulate significant vertical head differentials observed in wells screened at different depths in the LSAS. The remaining permeable zones (AF Gravels, S&P Sands, and Lower AF Sands) are each represented by a single model layer. The Venice Clay is simulated using two layers to facilitate the solute transport modeling. All other less permeable units are represented by a single model layer.

The groundwater flow model was subjected to a several step calibration and confirmation or validation process:

1) The model was initially calibrated in steady-state mode using groundwater elevation data collected on December 28, 2006. Overall calibration statistics indicated that the residual standard deviation was less than 10 percent of the observed range in target hydraulic head values.

2) Next, the groundwater flow model was calibrated in transient mode to drawdown observed during the seven-day aquifer pumping test conducted in January 2008 at well EW-UAFG-1 (see Section 4.3.2.2). Again, the overall residual standard deviation was less than 10 percent of the observed range in target drawdown values.

3) The model was subjected to additional qualitative checks using tracer testing and IRA system performance data obtained in spring 2008.

4) A sensitivity analysis was performed to further improve the model calibration statistics. No significant improvement was achieved through the parameter perturbations applied.

5) The final groundwater flow model was successfully checked against March/April 2009 groundwater elevation data, and off-facility water supply pumping influences were included, improving the model's fit to measured data and confirming that it can accurately simulate this additional new data set.

The groundwater flow model was therefore considered adequately calibrated and verified to meet its objectives. Details of model calibration and validation, including tables and plots of the residuals, a description of the sensitivity analysis procedure, and summaries of the qualitative and quantitative validation checks are provided in Appendix D.

In the solute transport model, the TCE and 1,4-dioxane distributions from the 2009 *GWMR* (Appendix C) were initialized into the USAS, LSAS, AF Gravels, and S&P Sands. These compounds were selected for modeling because their combined extent represents the largest extent of COCs in the USAS, LSAS, AF Gravels, and S&P Sands units. In addition, the two compounds are representative of sorptive and non-sorptive compounds, and of degrading and non-degrading compounds. The relevant 2009 *GWMR* figures illustrating these distributions are provided in Section 5. COC mass was also initialized into the Hard Streak using concentrations detected in the USAS. Next, the model's ability to accurately predict mass removal was tested by simulating the February, March, and April 2008 IRA system operation, and comparing the resulting mass removal rates to the actual observed mass removal rates. Details of this process are provided in Appendix D.

9.2 Hydraulic Containment Results

A primary goal for the model was to evaluate hydraulic containment alternatives and their ability to develop a capture radius extending at least as far as the maximum extent of COCs in excess of GCTLs (based on the most recent groundwater sampling event in March/April 2009) (Appendix C). The model was used to evaluate the performance of different combinations of extraction wells in all units to be pumped, of extraction trenches in the USAS, and of focused flushing with the addition of injection wells on-facility in the USAS, to arrive at the most appropriate combination of these technologies. In addition, a portion of the treated groundwater was simulated as being infiltrated in galleries adjacent to wetland/ponds, which would need to have their water level hydroperiods maintained.

The success of each of the various hydraulic containment scenarios tested was evaluated using particle tracking analysis. Particles were first initialized in grid cells corresponding to the exterior boundary of the target capture zone in the model layer(s) representing individual hydrostratigraphic units. The containment scenario was then simulated under steady-state flow conditions, and the associated travel pathways of the particles were determined over a period sufficient to achieve a steady-state capture zone. The extraction alternative was adjusted as necessary to capture all of the particles within the target capture zone. The target capture zones for each hydrostratigraphic unit are displayed in Figures 9-1 through 9-4, which demonstrate that for the design extraction system, hydraulic capture extends at least 100 feet beyond the

GTCL of the composite plume. Particle-tracking analyses were also performed to verify the success of each hydraulic containment scenario.

Figure 2-1 presents wetlands and ponds in the Site area. Three wetlands/ponds could be affected by the drawdown in the USAS. To mitigate impact to surface water bodies and wetlands, simulations were run with strategically placed injection trenches or wells which would recharge treated groundwater back into the USAS, to prevent dewatering near ponds, drainage ditches, wetlands, and other strategic locations (see Appendix G for details of how the potential for dewatering will be evaluated). Since the ponds on the golf course are manmade, the assumption was made that these could be lined if necessary. In contrast, it was assumed that the three wetland/pond locations indicated on Figure 9-5 would be artificially recharged via infiltration trenches to maintain their water level hydroperiods.

The recommended groundwater management alternative, consisting of groundwater extraction and recharge, is summarized in the tables below. The scenario includes extraction in all four targeted aquifers, limited on-facility re-injection for enhanced flushing in the USAS, and recharge of groundwater near the three locations indicated on Figure 9-5. Approximately 200 gpm will be extracted at full system operation. Approximately 10 gpm will be reinjected at the Facility, and 48 gpm will be recharged at the pond/wetland areas during system operation.

Table 9-1: Proposed Remedial Action Alternative Extraction and Recharge System

Extraction Wells and Trenches

Unit	Number of extraction wells/Trenches	Extraction Rate (gpm)
USAS	4 trenches	145
	37 (5 from IRA)	
LSAS	27 (5 from IRA)	30
AF Gravels	11	17
S&P Sands	2	4
	77 wells (10 from IRA)	196

Injection Wells

Unit	Number of injection wells	Injection Rate (gpm)
USAS	5	10

Recharge Galleries

Pond or Wetland Designation	Infiltration rate (gpm)
TW-6	34
TL-1	10
TW-18	4
	48

gpm = gallons per minute

Extraction rate = total for all remediation systems, including IRA extraction wells.

All injection wells are located on-facility, for enhanced source area flushing.

9.3 Contaminants of Concern Mass Removal Results

Solute transport modeling was used to predict and evaluate the mass removal and remediation periods for TCE and 1,4-dioxane in the USAS, LSAS, AF Gravels, and S&P Sands model layers. Fate and transport modeling was performed using the finite-difference code *MT3DMS*. This code accounts directly for advective transport, hydrodynamic dispersion, diffusion, and sorption of COCs.

The model was used to predict and evaluate the remediation timeframes associated with the hydraulic containment program, determine the rate of mass removal and distribution of TCE and 1,4-dioxane and predict the amount of time to achieve GCTLs in each unit. Initial concentrations were assigned based on the measured distributions of TCE and 1,4-dioxane from the 2009 groundwater monitoring annual sampling round, resulting in 219 pounds of TCE and 163 pounds of 1,4-dioxane initially. Of these initial amounts, 120 pounds of TCE were simulated as sorbed to the porous media but only 12 pounds of 1,4-dioxane.

Two time-segments were defined for predictive simulation of hydraulic capture and plume extraction – an initial 3-year period with the IRA system running (see Section 9.4 below for more information on this simulation), and a subsequent period with the full RAP system operational. The groundwater flow model- simulated the anticipated IRA system pumping for the initial 3-year period, using recently measured average rates as the presumed operational values. The solute transport model simulated that same 3-year period, with the COC concentrations from the end of this simulation used as the initial concentrations for full RAP system implementation simulation.

The groundwater flow model was then used to simulate the hydraulic responses of the groundwater flow system to the full RAP system, including focused flushing with injection-extraction in on-facility “hot spot” areas and control of wetland-pond water levels through groundwater recharge of treated effluent. Progressive shut-down of extraction wells and trenches was simulated, in 5-year increments, to help reduce the time to reach GCTLs by avoiding creation of stagnation points. The flow fields simulated in the flow model were used by the solute transport model for predicting the rate of plume capture and mass extraction.

The model-predicted times to achieve GCTLs following RAP system start up are summarized in Table 9-2 below.

Table 9-2. Summary of Model-Predicated Times to Achieve GCTLs

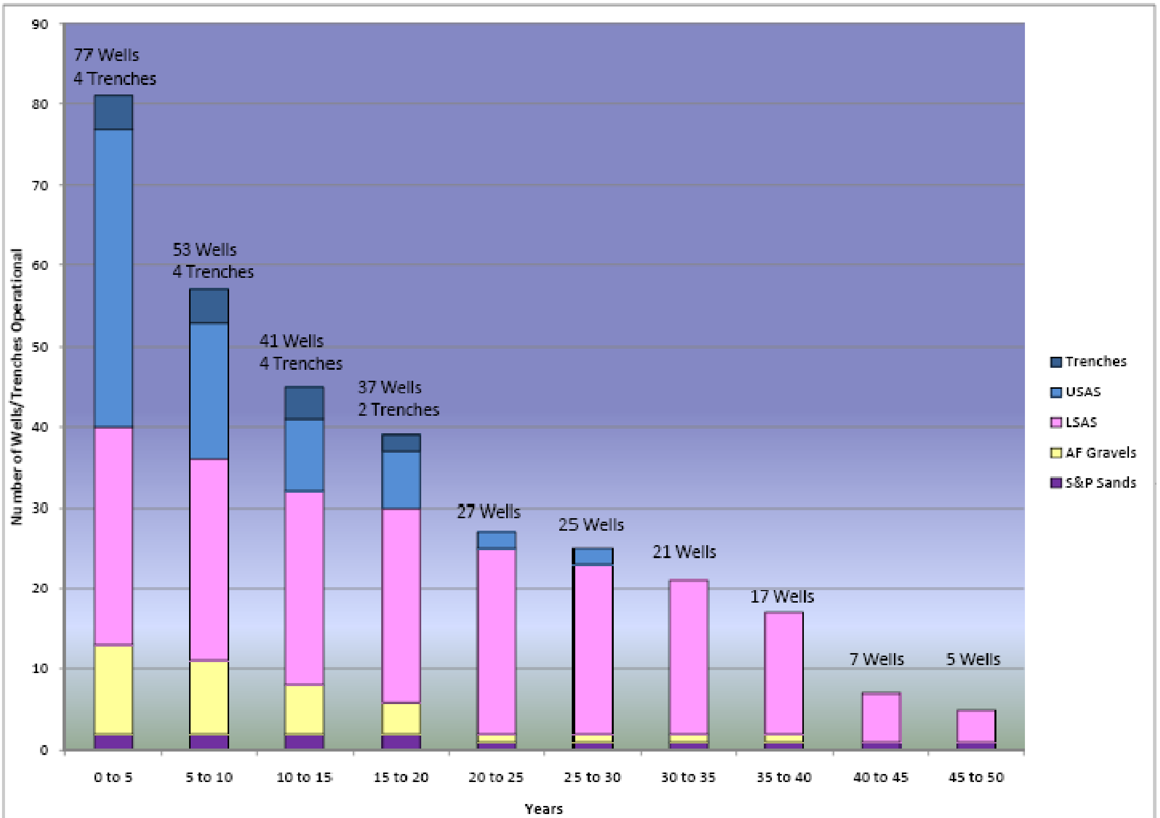
			Time to Achieve GCTL (years)			
Compound	**GCTL (µg/L)**	**Unit**	**Entire Model**	**On Facility**	**Golf Course**	**Off Facility**
TCE	3	USAS	31	22	9	31
		LSAS	26	26	21	23
		AF Gravels	19	19	7	14
		S&P Sands	23	23	1	8
1,4-Dioxane	3.2	USAS	25	8	10	25
		LSAS	48	48	47	48
		AF Gravels	39	38	39	26
		S&P Sands	37	37	12	34

Under the recommended remedial alternative, TCE is predicted to be below its GCTL (3 µg/L) in all permeable units in approximately 31 years; 1,4-dioxane in 48 years. 1,4-dioxane in the LSAS will take the longest to remove; in the other three units, GCTLs are predicted to be achieved in 39 years or less. Modeling observations include:

- Significant portions of the contaminant mass are predicted to be removed within the first five years of extraction.
- Focused flushing within the most impacted groundwater area on-facility produce adequate “hot spot” remediation.
- Shutting off select wells and collection trenches as the cleanup proceeds decreases the time to reach GCTLs in comparison to running all extraction wells and trenches for the full duration.

As shown in Table 21B of Appendix D, the model simulation for the proposed recovery and treatment system predicts that approximately 67 percent of the TCE and 53 percent of the 1,4-dioxane mass would be removed in the first five years of the system operation, and about 85 percent of the TCE and 71 percent of the 1,4-dioxane would be removed 10 years after start up.

The model simulation of the proposed recovery and treatment system indicates a significant number of recovery locations (trenches and wells) will be shut down much sooner than 48 years as areas of the plume are reduced below GCTLs as illustrated below.



In addition, test-simulations were conducted to evaluate how predicted cleanup times change in response to changes in the following:

1. The effective porosity of the low permeability zones
2. Recharge rate from golf course irrigation
3. Half-life of TCE
4. Natural recharge rate
5. Absence of the simulated open borehole at the Facility

The test simulations did not produce any increase in the overall cleanup time, even when the half-life of dissolved TCE was increased (doubled) to four years.

9.4 Simulation of Transport Between 2009 and 2012

Once the recommended remedial alternative is approved by FDEP, approximately 2–2.5 years will be needed to construct the system and begin operations. Predicting the time to remedy the TCE and 1,4-dioxane in the groundwater system needs to consider the change between the distribution of these compounds today (2009) and when the system becomes operational. Therefore, a flow and solute transport simulation was performed to represent plume conditions from March 2009 (the most recent annual groundwater monitoring event) until three years later (March 2012).

Average hydrologic conditions were assumed for the full three-year period. In addition, the IRA system was assumed to pump at the rates sustained in June 2009 (18.7 gpm, total). An off-facility pumping well (PW-127) associated with pond TL-1 was simulated at an average rate of 4.75 gpm, the estimated annual average as described in the 2009 *Groundwater Flow and Solute Transport Model* (Appendix D). Initial concentrations for the three-year solute transport simulation used the values measured in March 2009, as depicted in the 2009 *Groundwater Flow and Solute Transport Model* (Appendix C). The simulated TCE and 1,4-dioxane concentrations for the March 2012 conditions served as the initial (Year 0) concentrations for all of the RAP system predictive simulations.

Simulated distributions of TCE and 1,4-dioxane in each of the four units at the end of this three-year period are presented in Figures 9-7 through 9-16. Each COC contaminated water bearing unit is depicted, and both the upper and lower zones in the LSAS are displayed. These maps show the following features and simulation results that can be compared quantitatively:

- The GCTL line, as depicted in the 2009 *Annual Groundwater Monitoring Report* (Appendix C)
- The simulated (March 2012) GCTL line, as presented in the 2009 *Groundwater Flow and Solute Transport Model* (Appendix D)
- Proposed RAP effectiveness monitoring well network, as described in Section 13 of this *RAP Addendum*
- Simulated extent of hydraulic capture, as displayed in Appendix D

Figures 9-7 through 9-16, indicate that only in two units do the predicted 2012 GCTL boundaries extend beyond the 2009 boundaries: 1,4-dioxane in the USAS (Figure 9-7), and 1,4-dioxane and TCE in the upper portion of the LSAS (Figures 9-9 and 9-10). As these three figures show, the 2012 predicted GCTL extents still fall well within the groundwater recovery system's predicted capture zones. Of these three predicted 2012 extents, only 1,4-dioxane in the upper portion of the LSAS (Figure 9-9) may extend beyond the existing most downgradient monitoring well (MW-105) currently proposed for annual sampling (see Section 13). Past sampling events have indicated that no COCs have been detected in MW-105. If detectable concentrations of COCs are ultimately found in MW-105, remedial action monitoring well(s) and location(s) can be proposed during the annual reporting event, to install monitoring well(s) further downgradient, if necessary.

9.5 Groundwater Modeling Future Use

The selected remedial strategy involves groundwater extraction focused along the areas with higher COC concentrations, to minimize the time needed to reach GCTLs, while continuously maintaining containment. The model will be used particularly during implementation and operation of the RAP system, to evaluate remediation progress and further improve the extraction strategy as the area of groundwater above GCTLs decreases.

10. Remedial Action Design

An overview of the selected remedial alternative was presented in Section 8 and evaluated with respect to FDEP criteria. For soils, "No Further Action with Controls" is the selected remedial alternative. For groundwater, the existing IRA groundwater recovery, treatment, and discharge system will be replaced with an expanded system that will include 77 extraction wells and four trenches to recover impacted groundwater throughout the Site. The groundwater treatment system incorporates the following elements:

- A more robust pretreatment approach to remove metals, including oxidation, metals precipitation, media filtration, and membrane filtration
- Advanced oxidation to destroy organic contaminants
- Granular activated carbon adsorption polishing to remove organics

- Discharge of treated groundwater to the POTW, on-facility injection, wells, and off-facility recharge galleries
- Reverse osmosis water-polishing as needed to recharge nearby off-facility wetlands

This design philosophy is consistent with recent upgrades to the IRA system, including the following:

- Multiple redundant level sensing and system shutoff to prevent overflow
- Wiring/programming these sensing systems and other critical controls to fail on loss of continuity (fail open) so appropriate systems will shut down upon a loss of signal from the control switches
- Implementation of redundant programmable logic controller (PLC) systems
- Use 316L Schedule 40 stainless steel for primary process piping

Various other distinct changes (as compared with the 2008 *RAP* submission) that have been incorporated into the treatment process design include:

- Locating treatment process equipment, storage tanks, and chemical tanks in a single, stand-alone building instead of in multiple buildings or outside.
- Adding provisions for operator offices, a wet chemistry water quality lab, restroom/change rooms, a tool room/repair shop, storage areas, and support facilities to allow continuous 24/7 staffed operation inside the treatment building.
- Designing the building foundation for containment, with the capacity to hold 110 percent of the process water and liquid chemicals contained in the building at any time.
- Designing treatment processes with multiple, smaller units to facilitate future changes in groundwater extraction rates.
- Using a two-stage precipitation process, rather than a single-stage, to remove metals more effectively and efficiently.
- Using cone-bottomed tanks instead of a lamella clarifier for settling, and to facilitate solids removal.

- Incorporating ultra-filtration rather than cartridge filtration, following media filtration and before the AOPs.
- Using sulfuric acid to adjust pH rather than liquid carbon dioxide, and thereby allowing removal of the liquid carbon dioxide storage tank.
- Significantly reducing the volume of liquid acid and caustics by operating at near-neutral pH through the AOP
- Using larger capacity AOP units that will not require any provision for series operation, resulting in less heat gain through the AOPs and consequently allowing removal of the heat exchanger and cooling tower.
- Adding a third liquid-phase activated carbon adsorber to each carbon vessel train, for additional polishing and to provide more operational flexibility during carbon changeout.
- Incorporating reverse osmosis to polish the effluent, if necessary, for water being recharged off-facility, near wetlands.

The remainder of this section presents the design of the separate components and describes how they are integrated into a combined remedy.

10.1 Soil Remedial Actions

This RAP addresses only on-facility soils, as discussed in the *SARA 3* (BBL, 2006a). The residential, commercial/industrial, or LTG SCTLs that are exceeded in soil samples collected on-facility are summarized in Table 7-1 and on Figures 7-1 through 7-7. To satisfy the requirements for a "No Further Action with Controls," Lockheed Martin proposes to implement and maintain both engineering (fencing and cover) and institutional (restrictive covenant) controls. An existing chain-link fence encircles the Facility (i.e., the property) and access is restricted by locked gates. Engineering controls are required wherever soil concentrations exceed commercial/industrial or LTG SCTLs. Existing buildings and paved areas will be maintained, replaced, or expanded as a cover of shallow soil where COCs are detected above soil CTLs, thus requiring engineering controls. Figure 10-1 presents the locations of soil CTL exceedances for industrial/commercial use or soil leaching to groundwater criteria, the type of cover currently present at those locations, and the planned future cover necessary to maintain engineering control. Any future alterations to the existing building or paving footprint will be done with the concurrence of FDEP. Draft terms of the restrictive covenant will likely be as follows:

a) Generally, there shall be no agricultural use of the Facility, including forestry, fishing, and mining; no hotels or lodging; no recreational uses, including amusement parks, parks, camps, museums, zoos, or gardens; no residential uses; and no educational uses, such as elementary and secondary schools, or day care services.

b) Excavation is not prohibited within the Facility, provided that any contaminated soils that are excavated are removed and properly disposed of pursuant to Chapter 62-780, F.A.C. (or subsequent Site cleanup criteria rule(s)) and in accordance with the soil management plan described in Section 11. Reasonable construction methods and techniques shall be employed to minimize risk of exposure. Nothing herein shall limit or conflict with any other legal requirements regarding construction methods and techniques that must be followed to minimize risk of exposure while working on the Facility.

c) Engineering controls currently in place or planned to minimize infiltration in soil areas containing COCs at concentrations greater than industrial/commercial use or leachability criteria must be restored if they are disturbed.

d) To monitor the restrictions contained herein, FDEP or its respective successors and assigns shall have access to the Facility at reasonable times and with reasonable notice to the owner.

10.2 Groundwater Remedial Action

The proposed remedial action plan would replace the existing IRA groundwater recovery, treatment, and discharge systems for the Site with an expanded system. The design criteria/details of the new system are provided in this section and are shown in drawings as described below:

Figure 10-2 Extraction Well and Extraction Trench Locations— an overall Site plan showing the extraction network.

Figure 10-3	Yard Piping Plan— extraction, discharge and recharge locations including the conveyance network.
Figure 10-4	On-Facility Yard Piping Plan— extraction and recharge locations including the conveyance network.
Figure 10-5	On-Facility Trench Sections— sections and typical details for utility trenches.
Figure 10-6	Extraction Well Construction Details— typical detail of an extraction well.
Figure 10-7	Injection Well Construction Details— typical detail of an injection well for on-site recharge of treated groundwater.
Figure 10-8	Extraction Trench Construction Details— typical detail of an extraction trench.
Figure 10-9	Extraction System Vault Details— typical details for extraction well and extraction trench vaults.
Figure 10-10	Recharge and Injection System Vault Details— typical details for recharge trench and injection well vaults.
Figure 10-11	Treatment Process Block Diagram
Figures 10-12 through 10-15	Process Flow-Diagram (Sheet #1 through Sheet #4)— major components of groundwater treatment system.
Figure 10-16 and 10-17	Mass Balance (Sheets #1 and #2)— flow rates, COC concentration changes, and general water quality changes through treatment process.
Figures 10-18 through 10-28	Piping and Instrumentation Diagram (Sheet #1 through Sheet #10) and Legend Sheet— major components of groundwater treatment system including valves, meters, and other instrumentation for process control.
Figure 10-29	Site Plan— orientation of process building to other buildings, features, and the Facility boundary.

10.2.1 Extraction System Design

The proposed extraction and recharge system consists of:

- Four extraction trenches and 37 extraction wells installed in the USAS, to the top of the Hard Streak. Of the 37 wells, five will replace existing USAS extraction wells that will be subsequently abandoned.
- Twenty-seven LSAS extraction wells. Of the 27 wells, five will replace existing LSAS extraction wells that will be subsequently abandoned.
- Eleven AF Gravels extraction wells, including an existing AF Gravels extraction well on-facility.
- Two S&P Sands extraction wells.
- Five on-facility injection points installed in the USAS, to recharge treated groundwater and flush the USAS source area.
- Three off-facility recharge galleries installed in the USAS near potentially affected wetlands, where treated groundwater can be recharged to sustain the hydroperiods of those wetlands.

The proposed extraction network is shown on Figure 10-2. Greater detail is depicted on Figures 10-3 and 10-4, which include general utility trench routing. Typical utility trench sections, extraction well and trench details, injection well and recharge gallery details, extraction system vault details, and recharge system vault details are shown on Figures 10-5 through 10-10.

Upper Surficial Aquifer System

Groundwater extraction will be achieved using a combination of vertical wells and horizontal trenches. A Dewind-type trenching machine will be used to construct the trenches because it can rapidly excavate trenches to the required dimensions, thereby minimizing short-term exposures and construction disruptions. The five existing IRA USAS extraction wells will be properly abandoned by a Florida-licensed driller. New extraction wells will be installed near the location of the respective abandoned extraction well, using the well construction proposed in this *RAP*. This will allow the existing system to be used as long as possible while construction of the full-scale RAP system is completed. Additionally, the proposed extraction-well construction described in Section 10.2.1.2 below offers a number benefits over the existing extraction well design, including:

- Stainless-steel continuous wire-wrapped screens to provide better connectivity to the aquifer formation than the slotted well screens now used. Continuous wire-wrapped screens typically have an open area more than double that of slotted screens.
- The USAS extraction wells will have 5-foot screens located just above the Hard Streak, rather than the longer well-screen used in the IRA USAS wells. The longer well screens can promote oxidation of iron from water cascading down the inside of the well screen.

The location of the four USAS extraction trenches and 37 vertical extraction wells planned for installation in the USAS are on Figure 10-2. On-facility USAS extraction wells are also shown on Figure 10-4.

Lower Shallow Aquifer System

The 27 LSAS extraction wells will have well screens placed beneath the USAS but above the Venice Clay. The annular space in these wells will be sealed from the surface to the top of the LSAS, isolating the wells from the USAS. The five existing IRA LSAS extraction wells will be properly abandoned by a Florida-licensed driller. New extraction wells will be installed near the location of the respective abandoned extraction wells. As discussed above for the USAS extraction wells, replacing the existing LSAS wells with new wells will allow the existing system to be used as long as possible until construction of the full-scale RAP system is completed. The 27 LSAS extraction wells are also shown on

Figure 10-2 and on-facility LSAS extraction wells are also shown on Figure 10-4.

AF Gravels

The 11 AF Gravels extraction wells are planned for the locations shown on Figure 10-2. One of these wells is in place. Appropriate construction methods will be used to inhibit potential hydraulic communication between geologic units. Wherever possible, wells have been nested with USAS or LSAS extraction wells so that common trenching and header lines can be used.

S&P Sands

The two S&P Sands extraction wells are planned for the locations shown on Figure 10-2. Appropriate construction methods will likewise be used in these wells to inhibit potential hydraulic communication between water bearing units. The screen length and depth will be selected based on the boring logs. The length of screen will be selected so that it will extend approximately 5 to 10 feet below the base of S&P Sands zone to ensure adequate influence and capture at the top of the Clay/Sand Zone 3 & 4.

10.2.1.1 Capture Zone

Figures 9-1 through 9-4 show predicted capture zones in the USAS, LSAS, AF Gravels, and S&P Sands. Hydraulic groundwater modeling estimated that a total extraction of approximately 200 gpm from four extraction trenches and 77 extraction wells in the four targeted hydrostratigraphic zones would be needed to produce the interpreted capture zone boundaries discussed above. The model also predicts the approximate contribution from the individual aquifer units (see Section 9.2 and Appendix D). The actual capture zones developed within the USAS, LSAS, AF Gravels, and S&P Sands units during RAP operations will be monitored regularly, using groundwater level measurements obtained as detailed in the effectiveness monitoring discussed in Section 13.

10.2.1.2 Extraction Well Construction

USAS extraction wells will be installed with hollow-stem auger technique, using an auger with a minimum inside diameter of 10.25-inches. LSAS, A&F Gravels, and S&P Sands extraction wells will be installed with mud-rotary technique, using a bit with a minimum 10-inch outside diameter. The initial borehole will be made to the top of the Hard Streak. The auger will be of adequate size to allow mud-rotary bit access. At drilling locations where COCs are present in a shallow aquifer at higher concentrations than the aquifer targeted for extraction well completion, an isolation casing will be set before drilling into the deeper aquifer. Data from nearby monitoring wells will be used to evaluate whether an isolation casing is necessary. All extraction wells in the LSAS, AF Gravels, and S&P Sands will be installed with a five-foot sump to collect sediments and prevent occlusion of the well screen. The extraction wells in the USAS will not include a sump, to avoid breaching the Hard Streak. The sump will be sealed from the well screen using a fine sand seal. All wells will be installed with a properly sized filter-pack, extending from the lower fine sand seal to two feet above the top of well screen. A two-foot fine sand seal with then be installed. Bentonite grout will be used to seal the well from the top of the upper fine sand seal to ground surface.

On-facility extraction wells will be individually plumbed back to the treatment building and manifolded together. The manifold will be similar to that used in the current IRA system, and include a pressure gauge, sample port, flow meter, and control valves. Because this instrumentation is contained in the treatment building, the on-facility vaults will be 18-inch square vaults with lockable H-20 rated steel covers. Off-facility extraction wells will be constructed with a larger, lockable H-20 rated well vault. The off-facility wells will be manifolded in the field; therefore, each vault will be large enough to contain a pressure gauge, sample port, flow meter, and control valves.

All extraction wells will use the following construction materials:

- Casing materials will be schedule 80 PVC, 6-inch minimum diameter.
- Well screen materials will be stainless steel, continuous wrap screen, 6-inch minimum diameter.
- Well screen slot size and filter pack will be determined in the field based on sieve analysis of samples collected in the well screen zone at the extraction well location.

Additional construction details are shown on Figures 10-6 and 10-9.

10.2.1.3 Extraction Trench Construction

Extraction trenches will be installed with a Dewind type trencher and used to extract groundwater from the USAS aquifer only. The extraction trench will be installed to the top of the Hard Streak. The depth to the top of the Hard Streak will be identified using borings installed every 50 feet along the centerline of the proposed trench location before its installation. Samples collected during boring installation will undergo sieve analysis. Data from the sieve analysis will be used to size the permeable backfill for the extraction trench. Samples for pre-characterization of waste will also be collected and analyzed during the boring program. Details of the pre-characterization of wastes are provided in Section 11.

In the first pass, the trencher will install a high-density polyethylene (HDPE) SDR-17 (minimum) well screen (6-inch diameter) and casing (8-inch diameter) as well as the permeable backfill. The well screen will be installed at the bottom of the trench and the permeable backfill will be installed above the top of the well screen to near the land surface in an initial pass. A clean out will be installed at one end of the trench and an HDPE extraction sump (8-inch minimum diameter) will be installed at the other. A submersible pump and pressure transducer will be installed within the vertical section of the extraction sump. The extraction sump will be completed with a lockable, H-20-rated well vault, which will house the flow meter, sample port, pressure gauge, and control valves. A second pass by the trencher along the same trench will then install a fine-sand seal above the permeable backfill, to within three feet of the land surface. The fine-sand seal will reduce water extraction from the highly conductive and less contaminated zones in the upper USAS, and increase extraction rates on the more moderately conductive but relatively elevated contaminated zones of the lower USAS. Finally, the upper three feet of the trench will be restored to the surface with native fill. Additional construction details are shown on Figures 10-8 and 10-9.

10.2.1.4 Extraction Pumps

Electric submersible pumps are proposed for use in all extraction wells and trenches, which will be powered by a variable-frequency drive (VFD). The VFD will regulate pump speed based on output from a pressure transducer in the extraction well, regulating the groundwater recovery rate to maintain a specified water level in the well. Where multiple extraction wells are located within 300 to 400 feet of each other, the VFDs for those wells may be co-located in a single electrical cabinet so that the above-ground equipment may be minimized. Data from the VFD and water level transducer, in addition to flow rate and total volume of groundwater extracted from each extraction well and trench, will be logged at the central control panel located at the treatment facility. Design details are provided below.

Equipment

1. Submersible Well Pumps

USAS Well Pumps	(P-2001 - P-2037)
LSAS Well Pumps	(P-3001— P-3027)
AF Gravels Well Pumps	(P-4001— P-4011)
S&P Sands Well Pumps	(P-5001 and P-5002)
Manufacturer:	Grundfos, or equal
Model:	5S05-13
Type:	Electric Submersible
Quantity:	77
Horsepower:	0.5 – 0.75
Flow Rate:	1.6 gpm @ 175 ft total dynamic head (TDH) to 2.0 gpm @ 200 ft TDH

2. Submersible Well Pumps

USAS Extraction Trenches	(P-2101— P-2104)
Manufacturer:	Grundfos, or equal
Model:	25S15-9
Type:	Electric Submersible
Quantity:	4
Horsepower:	1.5
Flow Rate:	20 gpm @ 185 ft TDH

10.2.1.5 Transmission System Construction

Groundwater from extraction wells and trenches will be conveyed to the treatment facility within sub-grade dual-containment piping. All such dual-containment piping from will be made of HDPE pipe. Carrier piping will have a minimum 160 psi pressure-rating (SDR-11) and the containment piping will have a minimum 100 psi pressure-rating (SDR-17). All pipe and fitting joints will be butt-welded. The containment and carrier piping will be pressure-tested before the system is commissioned. Groundwater conveyance system routing from the extraction wells and trenches to the treatment system is depicted on Figure 10-3 for the off-facility extraction wells and trenches, and on Figure 10-4 for the on-facility extraction wells.

10.2.1.6 Utilities Trench Installation

Utility trenches between the treatment facility and the extraction wells, trenches, recharge galleries, remote electrical control panels are depicted on Figure 10-3. Utility trenches between the treatment facility and the on-facility extraction wells are depicted on Figure 10-4. These trenches will contain some or all of the following utility conduits:

1. Dual containment piping to convey groundwater to the treatment building
2. Single-wall piping to convey treated water to discharge to the POTW, on-facility injection wells, and off-facility recharge galleries
3. Electrical power (230V 3 phase)
4. Electrical control (24VDC)
5. Optical fiber communication

Generally, process water lines (dual-containment piping) will be installed below electrical and optical fiber conduits. The top of the dual-containment piping will typically be installed at least two feet below ground surface, while the top of electrical power, controls, and communication conduits will all be installed at least 18 inches below ground surface. A magnetic marking tape will be installed above the conduits, and the trench will be backfilled to the surface. Above-grade trench surfaces will be restored with original cover upon completion.

10.2.1.7 Influent Concentrations

The remediation system's estimated combined influent concentrations are based on groundwater analytical results obtained during the March 2009 monitoring well sampling event. Calculation of the “flow-weighted” influent concentration was performed as follows:

1) Sixteen existing monitoring wells distributed across the area of the plume were selected for sampling and analysis for an extended list of compounds and metals covering the range of potential discharge criteria (e.g., POTW, groundwater recharge, and surface water recharge).

2) The groundwater model was used to establish the expected extraction locations and flow rates for each aquifer zone.

3) The expected extraction well locations were compared to the locations of the 16 monitoring wells that were sampled.

4) Based on the number of extraction wells near a given monitoring well, a flow-weighted average from each planned extraction point was derived using the data from the monitoring well nearest in proximity.

5) The projected flow-weighted average and the derived concentrations were used to calculate a representative COC loading from each extraction point.

6) Tabular combination of flows from all extraction points yielded the expected influent concentration for each aquifer zone, and the combined influent.

7) The data (for individual monitoring wells, the expected influent concentrations by aquifer zone, and the total combined influent concentrations) were compared to GCTLs and surface water criteria to identify parameters potentially requiring treatment.

The results of these calculations are presented in Table 10-1 below. The calculation is provided in Appendix E.

Table 10-1: Remediation System Combined Influent Concentrations

Parameter	Estimated Concentration (µg/L)
TCE	630
1,4-dioxane	140

1,1-DCA	40
PCE	40
cis-1,2-DCE	30
1,1-DCE	90
Total Iron	9,200
Total Aluminum	180

Based on these analytical results, the key constituents to be removed by the treatment system design were identified as TCE, 1,4-dioxane, 1,1-DCA, iron, and aluminum. TCE and 1,4-dioxane were identified as the key constituents based on concentrations that constrain the design of the AOP, since TCE concentrations are expected to be the highest encountered at the treatment system, and 1,4-dioxane is recalcitrant to other treatment processes. 1,1-DCA is generally not completely treated by AOP but can be treated with the use of GAC. However, 1,1-DCA is a relatively poor adsorber to GAC and, has therefore been used as a design constraint for sizing the GAC vessels. Although additional VOCs are present in the groundwater, they are detected at relatively low concentrations and are effectively treated by the AOP. Removal of iron, aluminum, and other metals is necessary for efficient AOP operation, to prevent fouling from precipitation on the catalyst, and also to meet surface water criteria.

Influent concentrations are predicted to be lower for the RAP system than the IRA system, because the RAP recovery system will withdraw more groundwater from areas having lower overall concentrations. The IRA system recovers smaller volumes of groundwater with higher contaminant concentrations (i.e., from the SAS unit below the Facility, which is near a source area). Further, the influent concentrations are expected to decrease over time, based on mass removal due to operation of the groundwater recovery system and natural degradation.

10.2.2 Groundwater Treatment System

The groundwater treatment system is described in this section. This design incorporates the following elements:

- A robust pretreatment approach to removing metals, including oxidation, metals precipitation, media filtration, and membrane filtration
- Advanced oxidation to destroy organic contaminants
- Granular activated carbon adsorption polishing to remove residual organics
- Discharge of treated groundwater to the POTW, on-facility injection wells, and off-facility recharge galleries
- Reverse osmosis water polishing, as needed, for water recharged off-facility near wetlands

Figure 10-11 shows the configuration of these elements and secondary, support processes, such as chemical feed and solids management systems. The systems described below were designed to treat a nominal flow rate of 200 gpm, as predicted by the model, plus a 50 percent operating margin. This results in a maximum design flow rate of 300 gpm for the system. The primary process tanks in the system are designed with multiple-redundant level sensing systems, consistent with those used in the upgraded IRA system. Additional tank design philosophy incorporated herein includes:

- Vertical cylindrical tanks to minimize the footprint of indoor installation and allow direct conversion of water level to volume (i.e., straight sidewalls result in a direct correlation of water depth to volume)
- A 1-to-1 horizontal width to-vertical height ratio where possible to provide a low center of gravity and minimize tipping potential
- A minimum of one-foot of free-board above the working tank level
- Cone tank bottoms, expected to collect solids
- Sloped bottoms on tanks where solids may, but are not intended to, collect, to facilitate draining and cleaning
- Provide domed covers on tanks to contain vapors and provide additional structural strength

Design data, including calculations and equipment literature, is presented in Appendix E. Proposed treatment system details (including process flow diagrams, piping and instrumentation diagrams, the site plan, and general arrangement plan) are shown on Figures 10-12 through 10-30.

10.2.2.1 Pretreatment Metals Removal

The metals removal pretreatment system for the RAP system will consist of a multi-phase process to remove aluminum, iron, and other metals. The system will consist of pH adjustment, oxidation, gravity settling, primary multimedia filtration, and secondary ultra-filtration. This pretreatment system is expected to consistently reduce concentrations of metals below both the GCTLs and the IUD permit levels. Iron concentrations are expected to consistently remain below 0.3 mg/L, which will increase the performance of the AOP (used to destroy VOCs and semivolatile organic compounds (SVOCs)). Operating the AOP with iron concentrations at these low levels will reduce the potential for iron to precipitate and will allow the AOP to operate at close to neutral pH.

10.2.2.1.1 Aluminum Oxidation and Settling

The extraction system will convey groundwater to the first stage of the metals removal process, which is focused on aluminum. Groundwater is conveyed to the primary tank splitter box. The splitter box will feature two weirs evenly dividing the groundwater flow into two primary settling tanks, where aluminum oxidation and settling will occur. Aluminum will be oxidized through pH adjustment and the addition of aerated water. A diaphragm metering pump (P-700A) will be used to accurately dose sodium hydroxide into the process water, which will then flow through an inline static mixer to uniformly disperse the sodium hydroxide through the water. A pH sensor downstream of the static mixer will measure the resulting pH and these data will be transmitted to the PLC. The pH of the water will be adjusted to approximately 7.0 S.U. to specifically target the oxidation of aluminum.

A centrifugal pump (P-150A/B) will then circulate water from the filter feed tank (T-200) to the primary settling tank splitter box. Water will be aerated through an inline aeration system, similar to that used in the IRA system and described in more detail in Section 10.2.2.1.3. The dissolved oxygen content in the water will be increased to approximately 6.0 mg/L, thereby providing an oxidant for the aluminum oxidation process.

The splitter box will be made of fiberglass reinforced plastic (FRP) and its associated gates will be made of stainless steel. The primary settling tanks will cone-bottom, made of FRP, with a storage capacity of 7,470 gallons each. The primary settling tanks are sized to permit adequate settling of solids precipitated in the tanks, and to equalize groundwater flows from the various quadrants and aquifer zones undergoing extraction.

The primary settling tanks will be installed in the treatment building and, if a breach should occur, their entire volume will be contained within the building's secondary containment. The tanks will be equipped with a high level alarm that will shut down the extraction well pumps upon activation, and a high/high emergency shut-off switch that will shut down the entire treatment system when activated.

Equipment

1. Sodium Hydroxide Metering Pump (P-700A)

Manufacturer:	Grundfos, or equal
Model:	DME 12-6 A-PP/E/C-F-21RRB
Type:	Diaphragm
Quantity:	1
Flow Rate:	0.0032 gallons per hour (gph) - 3.17 gph @ 85 psi

2. Static Mixer (SM-100)

Manufacturer:	Koflo, or equal
Model:	275
Type:	4-inch, 6 Element Low Pressure Loss Flange-Mounted Static Mixer
Material of Construction (body):	316L Stainless Steel
Material of Construction (mixer):	316L Stainless Steel
Quantity:	1

3. Primary Settling Tank Splitter Box (T-100)

Manufacturer:	Plasti-Fab, Inc., or equal
Model:	custom
Type:	Dual Weir
Storage Capacity:	270 gallons (minimum)
Materials of Construction (Basin):	Fiberglass Reinforced Plastic
Materials of Construction (Gates):	316L Stainless Steel
Quantity:	1

4. Primary Settling Tanks (T-110A and T-110B)

Manufacturer:	Belding Tank, or equal
Model:	C-CKV
Type:	Vertical Cone Bottom
Storage Capacity:	7,470 gallons (minimum)
Materials of Construction:	Fiberglass Reinforced Plastic
Quantity:	2

10.2.2.1.2 Iron Oxidation and Settling

The second stage of the RAP metals removal process oxidizes and settles iron. The system will consist of aeration, pH adjustment, solids contacting/mixing, and gravity settling. Process water will flow via gravity from the primary settling tanks to the solids contact tank. Aerated water, sodium hydroxide, and iron solids will be introduced into the solids contact tank. Process water from the solids contact tank will then flow to the secondary settling tank splitter box that evenly divides the groundwater stream into two secondary settling tanks. Solids created in the solids contact tank will settle in these tanks and the clarified water will flow via gravity to the filter feed tank.

A diaphragm metering pump (P-700B) will accurately dose sodium hydroxide into the process water. Sodium hydroxide mixing will take place in the solids contact tank with a paddle-type tank mixer (M-120). A pH sensor in the solids contact tank will measure the resulting pH, and these data will be transmitted to the PLC. The pH of the water will be adjusted to approximately 8.5 S.U., to specifically target the oxidation of iron.

A centrifugal pump (P-150A/B) will circulate water from the filter feed tank (T-200) to the solids contact tank. Water will be aerated through an inline aeration system, similar to that used in the IRA system and described in more detail in Section 10.2.2.1.3. The dissolved oxygen content of the water will be increased to approximately 6.0 mg/L, thereby providing an oxidant for the iron oxidation process.

A positive displacement pump (P-140A/B) will circulate concentrated solids from the bottom of the secondary settling tanks to the solids contact tank. Recycling these solids will increase the iron concentration in the solids contact tank to promote co-precipitation of metals. The solids content in the solids contact tank will also be increased, thereby improving floc settling characteristics in the settling tanks.

The solids contact tank, splitter box, and secondary settling tanks will be of FRP construction. The solids contact tank will have a 3,390-gallon storage capacity and sized to provide adequate contact time to flocculate iron solids. The solids contact tank will be fitted with a mixer to adequately mix the sodium hydroxide, reduce solids settling, and improve floc formation. Construction of the secondary settling tank splitter box will be identical to that of the primary settling/splitter box. Each secondary settling tank will be cone-bottom and have a 7,470-gallons storage capacity. The secondary settling tanks are sized to allow the solids precipitated in them to adequately settle.

The solids contact tank, splitter box, and secondary settling tanks will be installed in the treatment building; should a breach occur, their entire volume would be contained in the building's secondary containment. The tanks will be equipped with a high level alarm that will, upon activation, shut down the extraction well pumps, as well as a high/high emergency shut-off switch that will, if activated, shut down the entire treatment system.

Equipment

1. Sodium Hydroxide Metering Pump (P-700B)

Manufacturer:	Grundfos, or equal
Model:	DME 12-6 A-PP/E/C-F-21RRB
Type:	Diaphragm
Quantity:	1
Flow Rate:	0.0032gph— 3.17gph @ 85 psi

2. Solids Contact Tank (T-120)

Manufacturer:	Belding Tank, or equal
Model:	C-CKV
Type:	Vertical Cone Bottom
Storage Capacity:	3,390 gallons
Materials of Construction:	Fiberglass Reinforced Plastic
Mixer:	28-inch diameter, dual paddle
Quantity:	1

3. Secondary Settling Tank Splitter Box (T-130)

Manufacturer:	Plasti-Fab, Inc., or equal
Model:	custom
Type:	Dual Weir
Storage Capacity:	270 gallons (minimum)
Materials of Construction (Basin):	Fiberglass Reinforced Plastic
Materials of Construction (Gates):	316L Stainless Steel
Quantity:	1

4. Secondary Settling Tanks (T-140A and T-140B)

Manufacturer:	Belding Tank, or equal
Model:	C-CKV
Type:	Vertical Cone Bottom
Storage Capacity:	7,470 gallons (minimum)
Materials of Construction:	Fiberglass Reinforced Plastic
Quantity:	2

10.2.2.1.3 Aeration System

A continuous recirculation and inline aeration system will increase the dissolved oxygen content of the process water in the aluminum and iron oxidation and settling systems. Increasing dissolved oxygen in the process water will oxidize aluminum and iron. As mentioned previously, oxidation of aluminum and iron will occur in separate treatment processes, at specific pH levels to target efficient oxidation of the desired metals.

The aeration system will consist of two end-suction centrifugal pumps and two inline aerators. During normal operations, one pump and two aerators will be used and the second pump will be in stand-by. The pumps will use a clean water seal flush system to reduce solids fouling of the pump seal, thereby reducing maintenance requirements for and increasing the reliability of the pump. The aerators used will be similar to those of the IRA system: Purifics aerator housings, Model P7A-802 or approved equivalent. The aerators will be constructed of 316L stainless steel and use a ceramic aerator. Water flows through the aerators and is entrained with micro air bubbles, which efficiently dissolve into the process water. The aerators require cleaning approximately quarterly. Aerators must be removed from the process line to be cleaned, which requires approximately one day. A third aerator will be on-facility and installed in place of the aerator being cleaned. Aerator cleaning will not require the treatment system to shut down.

Aerated water will be divided between the primary settling tank splitter box (T-100) and the solids contact tank (T-120). Anticipated flow rates to T-100 and T-120 are approximately 10 gpm and 20 gpm, respectively. This aeration system is designed to increase the dissolved oxygen content of the process water in those tanks to approximately 6 mg/L.

Equipment

1. In-Line Aerator (A-150A and A-150B)

Manufacturer:	Purifics
Model:	P7A-802
Type:	Inline Ceramic-Membrane
Air-Flow Rate:	1.75 cubic feet per minute (cfm) (maximum)
Water-Flow Rate:	26.4 gpm (maximum)
Quantity:	3 (2 installed, 1 spare)

2. Aerator Recirculation Pump (P-150A and P-150B)

Manufacturer:	Goulds Pump, or equal
Model:	1ST1G5B4F
Type:	End Suction Centrifugal
Quantity:	2
Horsepower:	2
Flow Rate:	30 gpm @ 108ft TDH

10.2.2.2 Filtration System

After passing through the iron oxidation and settling phases of the treatment system, process water will flow via gravity from the secondary settling tanks to the filter feed tank. Three pumps, in parallel, will pump process-water in the filter-feed tank through the filtration system. Each pump will feed a filtration train consisting of a media filter and an ultra-filtration unit. Each filtration train is designed to operate at a maximum flow rate of 100 gpm. During normal operations, when the treatment system flow-rate is approximately 200 gpm, only two of the three filtration trains will be in use; the third will remain in standby. However, during high flow conditions, when the treatment system flow rate is above 200 gpm, all three skids will be used.

The filter feed tank will be made of FRP, with a 3,340-gallon capacity. The tank's exterior base will be flat; however, the interior tank base will be sloped toward the pump suction, so solids will not accumulate on the tank bottom.

End-suction centrifugal pumps will pump water from the tank through the filtration system. The pumps will use a clean water seal/flush system to reduce solids fouling the pump seal, thereby reducing pump maintenance and increasing pump reliability.

Equipment

1. Filter Feed Tank (T-200)

Manufacturer:	Belding Tank, or equal
Type:	Vertical w/sloped interior base
Model:	C-CFV
Storage Capacity:	3,340 gallons
Materials of Construction:	Fiberglass Reinforced Plastic
Quantity:	1

2. Filter Feed Pumps (P-200A, P-200B and P-200C)

Manufacturer:	Goulds Pumps, or equal
Model:	10SH2L52B0
Type:	End Suction Centrifugal w/ Continuous Clean Water Seal/Flush
Quantity:	3
Horsepower:	10
Flow Rate:	100 gpm @ 169ft TDH

10.2.2.2.1 Media Filters

Three 54-inch diameter media filters (F-210A/B/C) will provide primary filtration. Each is designed to typically operate at 100 gpm, which results in a surface loading rate of 6.3 gpm/ft^2 to the vessels. During normal operations, when treatment system flow is approximately 200 gpm, only two filters will be used and the third vessel will in stand-by. Normal operations, the stand-by vessel would be brought online if back-pressure in the vessels met the 20 psi threshold for backwashing. During high flow conditions, when the treatment system flow rate is above 200 gpm, all three filters will be used. The backwash procedure during high flow conditions (with all three vessels operating) requires a brief reduction in overall treatment flow rate, since one of the filter skids will have to be shut down to permit backwashing.

As previously noted, the filters will use an automatic backwash system that will activate when the differential pressure across a vessel reaches approximately 20 psi. Backwash pumps (P-210A/B) will provide filtered water for backwashing from the AOP feed tank (T-300). Effluent created by backwashing will be discharged to the backwash surge tank (T-800) and treated through the solids handling system (as described in Section 10.2.2.8.1).

The media filters are designed to remove suspended particulates greater than 10 microns in size. The filter media will have a dimension of roughly 20×40 mesh, and consist of manganese dioxide coated anthracite that is self-regenerated by the high dissolved oxygen content in the feed water. This media will react with any remaining dissolved iron and thus precipitate the metal from the liquid, which will be captured in the media bed. The filters are expected to remove iron concentrations in the process water to below 0.3 mg/L.

Backwashing media filters will be done when the differential pressure across the filter vessel is approximately 20 psi, signifying diminished filter performance. Backwashing will be an automated process that will reverse flow through the media filter bed for approximately 15 minutes once daily for each vessel. Backwashing removes accumulated particulates from the media and evenly redistributes filter media in the bed. The recommended backwashing flow rate for a 54-inch diameter filter with 20×40 mesh manganese dioxide coated anthracite media is approximately 400 gpm, which equates to a backwash loading rate of 25 gpm/ft^2.

Equipment:

1. Media Filters (F-210A, F-210B and F-210C)

Manufacturer:	Yardney, or equal
Model:	MM-5460-3A
Flow Rate:	150 gpm each (maximum)
Maximum Working Pressure:	80 psi
Materials of Construction:	Epoxy-Coated Carbon Steel
Quantity:	3 (vendor supplied skid)

2. Media

Manufacturer:	Layne Christensen Company
Model:	LayneOx
Screen Size:	20 x 40 mesh (US sieve)
Bed Depth:	36 to 48 inches

3. Media Filter Backwash Pumps (P-210A and P-210B)

Manufacturer:	Goulds Pumps, or equal
Model:	6SH2N52E0
Type:	End-Suction Centrifugal
Quantity:	2
Horsepower:	20
Flow Rate:	400 gpm @ 117ft TDH

10.2.2.2.2 Ultra-filtration System

Following primary filtration through the media filters, process water will flow to the ultra-filtration (UF) filters to catch fine particulates. The filter feed pump (P-400A/B/C) will be capable of providing adequate pressure both at the media filters and the UF system. Each ultra-filtration unit has two vessels. Each of these will have four filter elements (or membranes), totaling eight elements per train. Each UF train is designed to typically operate at 100 gpm. Each membrane or filter element will have approximately 432 ft^2 of surface area, resulting in a flux rate of 41 gallons per square foot per day (GSFD). Typical flux rates vary from 20 to 80 GSFD, depending on feed water quality. During normal operations, when the treatment system flow is approximately 200 gpm, only two UF trains will be used and the third train will be placed in standby.

The UF system is backwashed to maintain membrane performance in both permeate capacity and quality. The backwash pumps will be centrifugal, each equipped with a VFD. The UF backwash and chemically-enhanced backwash (CEB) skid provide and maintain a pressurized flow of UF-permeated water to the membranes. During a CEB, chemicals are automatically added to this stream to remove the material that has accumulated from the raw feed water, to enhance system performance, and condition the membranes to maintain optimal operating conditions. A typical backwash sequence would occur hourly, while a CEB would normally occur daily. A typical backwash sequence would be for the pump to ramp up (15 sec) to the design backwash flow rate at high flux (150 GSFD) for 30 seconds and pump to ramp down to zero flow (15 sec).

Two different CEB cycles are typically implemented. CEB1A is executed with a mixture of sodium hydroxide (NaOH) + sodium hypochlorite (NaOCl), and CEB1B is executed with hydrochloric acid (HCl). CEB1A and CEB1B are executed consecutively, as follows:

- Backwash cycle: Pump to ramp up (15 sec) to design backwash flow rate at high flux (150 GSFD) for 30 seconds and pump to ramp down (15 sec).
- CEB1A chemical dosing and pump flow at moderate flux (75 GSFD) for 65 seconds to flood the membranes with solution, soak for 10 minutes (pump off), pump ramp up to high flux backwash for 70 seconds to flush out chemicals, and pump ramp down to moderate flux (75 GSFD).
- CEB1B chemical dosing with pump flow at moderate flux (75 GSFD) for 65 seconds to flood the membranes with solution, soak for 10 minutes (pump off), pump ramp up to high flux backwash for 70 seconds to flush out chemicals, and pump ramp down and shut-off

The dose rate for each chemical used in the CEB process will likely be 200 parts per million (ppm) per chemical. The flow rate during chemical injection is 180 gpm. Therefore, chemical usage per CEB will be approximately

0.3 pounds (per chemical), or approximately 0.03 gallons per cleaning. Each chemical will be injected into the system via a small air diaphragm pump or a Liquid Metronics, Inc. metering pump.

During high flow conditions, when the treatment system flow rate is above 200 gpm, all three UF trains will be used. The typical backwash procedure during high flow conditions, with all three vessels operating, should not affect operation due to the short duration of the process (approximately one minute). A CEB during high flow conditions will require certain lock out timers and a reduction in flow for 20 minutes for each train.

The UF system will use an automatic backwash system that will be initiated when the differential pressure across the train reaches a preset pressure, or based on a preset amount of operating time. The UF will use backwash pumps (P-230A/B) to provide clean water from the AOP feed tank (T-300) for backwashing. Backwash solids water created during backwashing will be discharged to the backwash surge tank (T-800) and treated through the solids-handling system as described in Section 10.2.2.8.1. The UF membranes are designed to remove suspended particulates greater than 0.01 to 0.1 microns in size. The filters are expected to remove iron concentrations in the process water to approximately 0.01 mg/L.

Equipment:

1. Ultra-filtration System (F-230A, F-230B and F-230C)

Manufacturer:	Crown Solutions, or equal
Model:	CUF-3-862-100 X-Flow
Backwash Skid:	PS-2-360-CEB
Flow Rate:	100 gpm each (maximum)
Membranes:	Polyethersulfone (PES) and Polyvinylpyrrolidone (PVP)
Quantity:	3 trains (vendor supplied skid)

2. Ultra-Filter Backwash Pumps (P-230A and P-230B)

Manufacturer:	Goulds Pumps, or equal
Model:	22SH2P52H0
Type:	End Suction Centrifugal
Quantity:	2
Horsepower:	25
Flow rate:	400 gpm @ 138 ft TDH

10.2.2.3 Advanced Oxidation

After metals oxidation, settling, and filtration; the VOCs and 1,4-dioxane in the groundwater will be treated via an AOP. Based on performance during the field pilot test and during existing equipment operations, three Photo-Cat 10 DDL AOP units manufactured by Purifics will be used for the RAP system. The Purifics AOP system creates hydroxyl radicals when titanium dioxide (TiO_2) slurry is activated by UV light in the AOP reactor. The hydroxyl radicals drive a series of reactions which destroy the VOCs and 1,4-dioxane in the groundwater. This photo-catalytic process oxidizes most volatile and SVOC COCs in the groundwater, resulting in benign end-products such as CO_2, H_2O, and salts. No daughter-products of the COCs (e.g., vinyl chloride) are generated during this process. The Photo-Cat system is designed to treat TCE and 1,4-dioxane to less than 3 µg/L and 3.2 µg/L, respectively; which is at or below the discharge limits established by the POTW and which achieves the existing GCTLs for each compound.

The current IRA AOP system operates at a reduced pH to prevent iron from precipitating during treatment. The IRA iron removal system only reduces iron concentrations to between 2 to 5 mg/L; therefore, pH adjustment is required to keep the remaining iron dissolved. Sulfuric acid is added to reduce the pH of the process water after the iron removal system. A diaphragm metering pump accurately doses sulfuric acid into the feed water, which then flows through an inline static mixer to uniformly disperse the acid through the water. A pH sensor downstream of the static mixer will measure the resulting pH and transmit those data to a PLC. After the AOP process, the pH is raised to a minimum of 6.0 S.U (to meet the discharge permit requirements) by adding sodium hydroxide prior to discharging the water to the sanitary sewer.

The metals removal system proposed in the *RAP* is intended to reduce iron to below 0.3 mg/L, thereby reducing iron interference with the AOP and allowing the system to run at a near-neutral pH. For the RAP system, a sulfuric acid feed system will reduce the pH close to neutral during normal operations. The amount of acid required for this has been calculated to be approximately 3 gpd of 98 percent sulfuric acid, based on the anticipated influent water quality (see Appendix E). In addition, the system will be capable of reducing the influent pH below 3.0 S.U., operating in a closed loop with the Photo-Cat system should catalyst cleaning be required. Catalyst cleaning is not expected to be required more than once monthly. The cleaning process is designed to be performed on one Photo-Cat unit in a closed loop recirculation, while the two remaining Photo-Cat units remain operational. Water created during the catalyst cleaning process will be neutralized to approximately 7.0 S.U. and transferred back to the head of the treatment plant for reprocessing.

The AOP system will be designed to operate continuously with minimal operator attention. The process is fully automated, sealed, and generates no waste stream or air emissions. The system will contain a fully integrated PLC-based operating system that controls all aspects of AOP system controls and alarms, including system shutdowns. The AOP PLC will receive run-permission from the PLC that controls the overall treatment train. The AOP system is comprised of three parallel 100-gpm units that, in combination, treat water at a flow rate up to 300 gpm (an approximately 50 percent operating margin over the anticipated flow rate of 200 gpm). Process water will feed to the AOP from the AOP feed tank. The AOP feed system will use three end-suction centrifugal feed pumps; however, only a single pump will be used for pumping. The others will be stand-by pumps. Two of these are sized to operate in the 150 to 300 gpm flow rate range, while the third is sized to operate in the 75 to 150 gpm flow rate range. Typical operations are expected to be within the 150 to 300 gpm range, so two pumps would be available for that system flow rate. Treatment system flow rates below 150 gpm are not expected to be typical, but are likely during plant start-up and in the future when extraction wells are taken off-line as cleanup criteria are achieved; therefore no standby pump for this flow range was provided.

Specific rate constants for COC destruction were developed during IRA system operations and have been shown to be typically lower than those developed during initial AOP pilot testing. The differences in rate constants are thought to result from different groundwater quality observed during the pilot test, compared to groundwater quality typically treated during IRA system operations. Specifically, the concentration of iron in the groundwater influent experienced during most of the IRA system's operation has been approximately one order of magnitude greater than the iron concentrations seen during the pilot-scale tests. Note too that the IRA AOP system is not being operated to generate contaminant destruction curves; rather, the unit is being operated to maximize contaminant destruction. Calculating rate constants based on the performance of this system will result in conservative rate constants because the calculation is based on a large number of non-detect effluent data for the system. For purposes of the RAP, the rate constants developed during IRA system operations have been used to size the AOP.

The IRAP operational rate constants for TCE, 1,4-dioxane and 1,1-DCA are 17.55, 14.92 and 3.09 liters per minute/kilowatt (Lpm/kW), respectively. Calculations of the rate constants are shown in Table 10-2A. As stated previously, TCE and 1,4-dioxane are used specifically to size the AOP, since TCE concentrations are expected to be the highest experienced at the treatment system and 1,4-dioxane is recalcitrant to other treatment processes. 1,1-DCA will not be used to size the AOP since 1,1-DCA and other chlorinated ethanes have long rates of reaction with most oxidants, including the hydroxyl radicals produced in this AOP. However, calculated 1,1-DCA removal through the AOP is used to determine GAC influent concentrations of 1,1,-DCA.

Concentrations of constituents in the influent expected during full-scale operations are outlined in Section 10.2.1.7. As shown in Table 10-2B, a 365 kilowatt (kW) Photo-Cat unit will be sufficient for the destruction of COCs, based on the estimated flow rate and concentrations for the RAP system. The two existing AOP units will be replaced with three new units. All three photo-cat units will be installed in parallel, with each unit being capable of treating process water at a flow rate of 100 gpm. For the RAP system, the major differences to the AOP units will be the power of the lamps and the hydraulic capacity of the units. The current IRA system uses 75 watt (W) lamps; however, for the RAP system, 190 W lamps will be used. Hydraulically, each unit will be capable of flow rates of at least 100 gpm as compared to 75 gpm used in the IRA design. The final AOP system will be capable of treating 300 gpm of groundwater with a TCE concentration of approximately 840 µg/L and 1,4-dioxane concentrations of approximately 385 µg/L to an effluent concentration of 3 µg/L or less for both compounds. These concentrations are 33 percent and 178 percent greater than the expected initial concentrations of TCE and 1,4-dioxane, respectively. This calculation is provided in Appendix E.

The water temperature increase through the AOP process was evaluated at the average design condition (100 gpm flow rate through each unit) and at a reduced flow rate condition that would produce a greater temperature rise through the unit. The reduced flow condition evaluated assumes that the average design flow rate (200 gpm) was treated using the 3 AOPs resulting in a flow rate of 67 gpm through each unit. Under these two conditions, the anticipated temperature rise through the AOPs ranges from 5 to 12 degrees Fahrenheit. The influent temperature is expected to range from 75 to 85 degrees Fahrenheit, depending on the time of year. Therefore, effluent should be well below the POTW-established discharge limit of 104 degrees Fahrenheit.

The configuration of the AOP units in the 2008 *RAP* allowed operation either with four units in parallel or as two trains of two units in series. In the series configuration, the heat added by two successive passes caused the temperature of the effluent water to rise above the POTW discharge limit, so a heat rejection system (involving a heat exchanger and cooling tower) were added to enable full compliance when operating in this mode. This plan uses larger capacity AOP units that will not require any provision for series operation. Thus, no operating configuration could cause discharge temperatures to rise to the POTW discharge limit. Consequently, the heat exchanger and cooling tower have been removed from this plan.

Equipment

1. Advanced Oxidation Process Units (PC-310A, PC-310B, PC-310C)

Manufacturer:	Purifics
Model:	Photo-Cat 10DDL
Power requirements:	121.8 kW
Quantity:	3

2. AOP Feed Tank (T-300)

Manufacturer:	Belding Tank, or equal
Model:	C-CFV
Type:	Vertical w/ sloped interior base
Capacity:	12,050 gallons
Materials of Construction:	Fiberglass Reinforced Plastic
Quantity:	1

3. High Flow AOP Feed Pump (P-300A and P-300B)

Manufacturer:	Goulds Pumps, or equal
Model:	3196 STi 2x3-10 (7.25" IMP)
Type:	End Suction Centrifugal
Quantity:	2
Horsepower:	30
Flow Rate:	300 gpm @ 189 ft TDH

4. Low Flow AOP Feed Pump (P-300C)

Manufacturer:	Goulds Pumps, or equal
Model:	3196 STi 1.5x3-6 (5.625" IMP)
Type:	End Suction Centrifugal
Quantity:	1
Horsepower:	10
Flow Rate:	150 gpm @ 122 ft TDH

5. Sulfuric Acid Metering Pump (P-710A, P-710B) (continuous acidification and catalyst cleaning)

Manufacturer:	Grundfos, or equal
Model:	DME 8-10 A-PV/V/C-F-21RRB
Type:	Diaphragm
Quantity:	2
Flow Rate:	0.002 gph - 1.98 gph @ 145psi

6. Static Mixer (SM-300)

Manufacturer:	Koflo, or equal
Model:	400
Type:	6 Element Low Pressure Loss Flange Mounted Static Mixer
Material of Construction (body):	PVDF Lined 316L Stainless Steel
Material of Construction (mixer):	PVDF
Quantity:	1

7. AOP Effluent Pumps (P-310A, P-310B and P-310C)

Manufacturer:	Goulds Pumps, or equal
Model:	7SH2L52D0
Type:	End Suction Centrifugal
Quantity:	3
Horsepower:	10

Flow Rate: 125 gpm @ 152 ft TDH

10.2.2.4 Granular Activated Carbon Vessels

Two parallel trains of lead-lag GAC units will be used as a polishing step following the AOP. The main function of these units is to remove any residual VOCs (mainly 1,1-DCA) not destroyed in the AOP. Flow from the AOP units will be split equally between the trains. Each train will be sized to fully process half of the treatment plant maximum design flow rate (with an appropriate processing margin). These trains will operate continuously any time the AOP system is operating. The design is configured to allow change-out of beds without shutting down the system by diverting flow around the exhausted bed.

Each train is comprised of three GAC beds in series with piping/valving to enable any of the vessels to operate as the lead bed. Each bed is hydraulically capable of accepting the full flow through the train. Rather than keeping one bed in idle standby while the other two in the train are on-line, the trains are configured so that during normal operation, flow will be directed through all three beds. This minimizes the potential for bacterial growth in the standby bed and prevents settling/compaction of the bed. In this configuration, the first vessel in the flow path is designated as ‘lead’, the second vessel in the flow path is designated as ‘intermediate’, and the last in the flow path as ‘lag’. The intermediate bed primarily provides on-line reserve capacity during bed change-out after exhaustion of the lead bed. When inter-stage sampling indicates exhaustion of the bed in the lead position, it is valved out of service and the train is reconfigured to temporarily operate with two beds in service. The intermediate bed is placed in the lead position and the lag bed remains in the lag position. Then the exhausted bed is drained, the spent carbon is removed, the vessel is inspected, and refilled with fresh carbon. The new carbon will be soaked for a minimum of 24 hours and backwashed to remove fine particulates before being placed in operation. After performing system checks to ensure all ports and access points have been properly closed, this vessel is then valved back into the train in the lag position; the bed that in the former configuration had been intermediate until the change-out now remains in the lead position; and the former lag bed is now intermediate. This sequence is repeated each time breakthrough is observed on whichever vessel is in the lead position. This ensures that the freshest GAC is always in the lag position and serves as the last barrier against inadvertent contaminant release. The vessels will always be rotated in a round-robin order (e.g., A-B-C then to B-C-A then to C-A-B then to A-B-C). Valve changes will be automated and initiated by the operator using the primary PLC.

The LPGAC vessels (F-400A/B/C and F410A/B/C) will be comprised of six Siemens model PV5000 liquid-phase carbon adsorbers, or equal each with 5,000 pounds of virgin acid-washed coconut carbon. The carbon vessels are six feet in diameter and sized to operate at the maximum continuous operating flow rate of 150 gpm, which will result in a surface loading rate of approximately 5.3 gallons per minute per square foot (gpm/ft^2) to the carbon vessels.

1,1-DCA was used to size the carbon vessels since it is a relatively poor adsorber to carbon and is anticipated to be consistently present at detectable concentrations as compared to the other COCs potentially in the process water subsequent to advanced oxidation. Based on the projected 1,1-DCA influent concentrations (Table 10-2C), the breakthrough of 1,1-DCA is estimated to occur after approximately 22 days of operation if the design maximum 300 gpm of water is processed through two 5,000 pound carbon vessels (Appendix E). This translates to approximately 30 days of operation at a nominal flow rate of 200 gpm through two 5,000 pound carbon vessels.

The LPGAC vessels will use an automatic backwash system that will be initiated when the fresh carbon has been placed in the vessel and allowed to soak for a minimum of 24 hours and when the differential pressure across a vessel is approximately 20 psi. The vessels will use backwash pumps (P-400A/B) to provide treated water from the effluent tank (T-500) for backwashing. Effluent created during backwashing will be filtered through bag filters (F-420A/B/C/D) and recirculated back to the effluent tank. During normal and high flow operations, when the treatment system flow is approximately 200 gpm and 300 gpm, respectively; process water will be diverted through a single set of LPGAC vessels in series during the backwash procedure. The maximum surface loading rate to the vessels during a high flow condition will be approximately 10.6 gpm/ft^2. The temporary high loading rate to the vessels is expected to last approximately 20 minutes and will have minimal to no effect on carbon performance during that time.

Equipment

1. GAC Vessel (F-400A/B/C, and F-410A/B/C)

Manufacturer:	Siemens, or equal
Model:	PV5000
Carbon Capacity:	5,000 pounds (lbs)/each
Carbon Type:	Acid-Washed Coconut
Max. Pressure:	125 psi
Quantity:	6

2. GAC Backwash Pump (P-400A, P-400B)

Manufacturer:	Goulds Pumps, or equal
Model:	8SH2M52E0
Type:	End-Suction Centrifugal
Quantity:	2
Horsepower:	15
Flow Rate:	280 gpm @ 113ft TDH

3. GAC Backwash Effluent Bag Filter Canister (F-420A, F-420B, F-420C and F-420D)

Manufacturer:	Rosedale, or equal
Model:	82-30-3F-1-150-S316-V-S-PB-D-C
Type:	High Capacity Bag Filter Housing
Max. Flow Rate:	440 gpm
Max. Pressure:	150 psi
Quantity:	4

4. Backwash Effluent Bag Filters

Manufacturer:	Water Solutions, or equal
Model:	GDPO 529 2A
Micron Rating:	19 microns @ 98 percent

10.2.2.5 Effluent Tank

Treated groundwater from the liquid phase GAC vessels will be transferred into an effluent tank before discharge to the POTW, or on-facility injection wells. Treated water discharged from the effluent tank may require pH adjustment to meet discharge requirements. A diaphragm metering pump (P-700C) will be used to accurately dose sodium hydroxide into the effluent stream, which will then flow through an inline static mixer to disperse the sodium hydroxide uniformly through the water. A pH sensor located downstream of the static mixer will be used to measure the resulting pH and the data will be transmitted to the PLC. The pH of the water will be adjusted to approximately 7.0 S.U. before discharge. The effluent tank will also provide storage capacity for LPGAC backwash water use, water softener and reverse osmosis system feed, water softener regenerant, and brine solution make-up.

The effluent tank will be a flat bottom tank, with storage capacity of 8,500 gallons. The tank will be installed within the treatment building, and its entire volume will be contained within the secondary containment of the building, should a breach occur. Transfer pump operation for flows into and out of the tank will be controlled by a level sensor in the tank.

Equipment

1. Effluent Tank (T-500)

Manufacturer:	Belding Tank, or equal
Model:	C-CFV
Type:	Vertical
Storage Capacity:	8,500 gallons
Materials of Construction:	Fiberglass Reinforced Plastic

2. Discharge Pumps (P-500A, P-500B)

Manufacturer:	Goulds Pumps, or equal
Model:	27SH2M52A0
Type:	End-Suction Centrifugal
Quantity:	2

Horsepower:	15
Flow Rate:	300 gpm @ 92ft TDH

3. On-Facility Injection Well Feed Pump (P-510)

Manufacturer:	Goulds Pumps, or equal
Model:	1SVD1E5C0H
Type:	End-Suction Centrifugal
Quantity:	1
Horsepower:	1
Flow Rate:	10 gpm @ 109ft TDH

4. Sodium Hydroxide Metering Pumps (P-700C, P-700D)

Manufacturer:	Grundfos, or equal
Model:	DME 12-6 A-PP/E/C-F-21RRB
Type:	Diaphragm
Quantity:	2
Flow Rate:	0.0032 gph— 3.17gph @ 85psi

5. Static Mixer (SM-500)

Manufacturer:	Koflo, or equa
Model:	275
Type:	4-inch 6 Element Low Pressure Loss Flange Mounted Static Mixer
Material of Construction (body):	316L Stainless Steel
Material of Construction (mixer):	316L Stainless Steel
Quantity:	1

10.2.2.6 Reverse Osmosis System

Effluent to be recharged close to wetlands may need to be treated via reverse osmosis (RO) to achieve surface-water quality standards. The hydraulic groundwater modeling estimated that a total recharge rate of approximately 47 gpm would be required to minimize groundwater table drawdown in three wetland areas in the vicinity of the groundwater extraction system. Consistent with the design of the other treatment processes, the RO system has been designed to produce treated water at a maximum rate 50 percent greater than the nominal recharge rate predicted by the groundwater model, or approximately 75 gpm.

Using cross-flow filtration, RO can remove (rejecting) 99 percent of the heavy metals in the treated groundwater. In this configuration, pressurized feed water flows across a membrane, with a portion of the feed permeating it. The balance of the feed sweeps parallel to the surface of the membrane and exits the system without being filtered.

To implement RO as a treatment strategy, the feed water to the RO system must first have the hardness (calcium and magnesium) removed. Hard water will quickly foul the RO membranes and require frequent membrane cleaning or replacement. Therefore, the RO system will consist of a twin alternating softener to remove hardness, followed by the RO membrane unit.

The softening system will have two softener vessels, with one vessel in-service and the second one in standby until a preset amount of water (measured in gallons) is processed or when hardness break-through is detected. At that time, the second vessel enters service and the first vessel is regenerated; thus, the flow of soft water is uninterrupted. Automatic regeneration cycles will be controlled by the PLC control system located on the RO skid. Regeneration cycles will occur based on totalized flow, manually initiated by the operator, or by detecting hardness breakthrough. Only one vessel will be regenerated at a time.

Each softener vessel is designed to typically operate at 100 gpm. The design flow rate to the softeners is 25 percent higher than the design permeate flow rate from the RO system. In cross-flow filtration, part of the feed stream does not permeate the medium but retains and increases the amount of ions, organics, and suspended particles, which are rejected by the membrane. This is referred to as the concentrate or reject stream. The design reject flow is 25 gpm; therefore, the total effluent flow from the softeners to the RO unit will be 100 gpm. Each vessel will contain 30 cubic feet (ft^3) of resin. The exchange capacity of the resin will be 24,000 grains/ft^3. The expected hardness of the influent water is 18.5 grain/gallon. The softeners will likely regenerate once every eight hours of operation. The softeners can be set to automatically regenerate based on volume throughput, time interval, or hardness break-through (determined via in-line analysis). The softeners are designed to remove the hardness concentration to 0.01 mg/L or less. Effluent from the softener system will feed the suction side of the high pressure RO pumps.

The RO system design will consist of one single-pass RO system, with a 2×1 array (two membrane housings on the first stage and one housing on the second stage). Each housing will contain six membranes (18 membranes total). The RO is designed to produce 75 gpm of purified water based on the expected influent groundwater metals concentration, a water temperature of 95 degrees Fahrenheit, and 1200 microSiemens (µS) conductivity. The design surface area of the RO membranes is 400 ft^2 and operating nominally at 15 GSFD. Typical design flux rates range from 13 to 25 GSFD.

Equipment:

1. Water Softener Feed Pumps (P-600A, P-600B)

Manufacturer:	Goulds Pumps, or equal
Model:	4SH2K52C0
Type:	End-Suction Centrifugal
Quantity:	2
Horsepower:	7.5
Flow Rate:	100 gpm @ 125 ft TDH

2. Twin Alternating Water Softening System (F-600A, F-600B)

Manufacturer:	Crown Solutions, or equal
Model:	TSSZ-1500-3P
Flow Rate:	100 gpm each
Vessel	42” diameter × 60” side shell
Resin:	Purolite C100E
Quantity:	2

3. RO Feed Pump (P-640)

Manufacturer:	Goulds Pumps, or equal
Model:	4SVD1M560H
Type:	End-Suction Centrifugal
Quantity:	1

Horsepower:	15
Flow Rate:	100 gpm @ 330 ft TDH

4. Reverse Osmosis System (RO-640A/B/C)

Manufacturer:	Crown Solutions. or equal
Model:	CRO-863-75
Flow Rate:	100 gpm
Array:	2×1
Recovery:	60–75 percent
Membranes:	Hydranautics, CPA5
Rejection Rate:	99 percent for heavy metals
Quantity:	1

5. Wetlands Recharge Pump (P-660)

Manufacturer:	Goulds Pumps, or equal
Model:	10SH2K52D0
Type:	End-Suction Centrifugal
Quantity:	1
Horsepower:	7.5
Flow Rate:	70 gpm @ 174 ft TDH

6. POTW Waste Pump (P-620)

Manufacturer:	Goulds Pumps, or equal
Model:	1STH5A4F
Type:	EndSuction Centrifugal
Quantity:	1
Horsepower:	3
Flow Rate:	45 gpm @ 106 ft TDH

10.2.2.7 pH Adjustment Systems

Two chemical injection systems will be used for pH adjustment of process water. Sodium hydroxide will be used in three locations as follows:

- Aluminum oxidation and settling system
- Iron oxidation and settling system
- Final pH adjustment of treated water effluent discharge to the POTW and on-site injection wells

Increasing the pH of the process water in the metals oxidation and settling systems will promote oxidation of the desired metals in those systems, and the treated effluent may require pH adjustment to meet discharge requirements. Sulfuric acid will be used to reduce the pH of process water before treatment through the AOP system and for AOP catalyst cleaning.

The sodium hydroxide system will use two 330-gallon HDPE storage totes, two 330-gallon HDPE transfer totes, and five diaphragm chemical metering pumps. Four of the five pumps will be used during treatment system operation and the fifth pump will be used as standby. The pumps and storage totes will be located within a containment area sized to hold a minimum of 1,500 gallons or 110 percent of the total volume of storage totes. Containment will be provided by a 1-foot high concrete curb. The floor and curb will be sealed using an industrial coating system compatible with sodium hydroxide. Additional splash protection will be provided by installing a 4-foot tall clear Plexiglas divider on top of the curbing on three sides of the containment. The only side without the Plexiglas splashguard will be for delivery from the loading dock.

The sulfuric acid system will use one 330-gallon HDPE storage tote, one 330-gallon HDPE transfer tote, and two diaphragm chemical metering pumps. Only a single pump will be used during treatment system operations, specifically for pH reduction prior to the AOP system. A second pump will be used specifically for catalyst cleaning. The pumps and storage totes will be located within a containment area sized to hold a minimum of 750 gallons or 110 percent of the total volume of storage totes. Containment will be provided by a 1-foot high concrete curb. The floor and curb will be sealed using an industrial coating system compatible with sulfuric acid. Additional splash protection will be provided by installing a 4-foot tall clear Plexiglas divider on top of the curbing on three sides of the containment. The only side without the Plexiglas splashguard will be for delivery from the loading dock.

Chemical will be transferred from temporary transfer totes to permanently installed storage totes. Transfer totes will be received at the treatment facility as required and placed on the chemical transfer dock, adjacent to the storage totes and within the chemical containment area. Chemicals will then be transferred from tote to tote using dedicated pumps and piping.

Equipment:

1. Chemical Storage Totes (T-700A, T-700B, T-700C, T-700D, T-710A, and T-710B)

Manufacturer:	Snyder Tanks, or equal
Model:	68445
Capacity:	330 gallons (maximum)
Materials of Construction:	1.9 SPGR HDLPE
Quantity:	6

2. Sodium Hydroxide Pumps (P-700A, P-700B, P-700C,P-700D, and P-700E)

Manufacturer:	Grundfos, or equal
Model:	DME 12-6 A-PP/E/C-F-21RRB
Type:	Diaphragm
Quantity:	5
Flow Rate:	0.0032 gph— 3.17 gph @ 85 psi

3. Sulfuric Acid Metering Pumps (P-710A and P-710B)

Manufacturer:	Grundfos, or equal
Model:	DME 8-10 A-PV/V/C-F-21RRB
Type:	Diaphragm
Quantity:	2
Flow Rate:	0.002 gph - 1.98 gph @ 145psi

10.2.2.8 Secondary Treatment Processes

Secondary treatment processes are those processes that are not specifically used for the treatment of the process water. These include the solids handling system, the seal water system, the compressed air system, and the vapor phase carbon system.

10.2.2.8.1 Solids Handling System

The solids handling system will consist of all equipment used to thicken solids produced from the aluminum and iron oxidation and settling systems as well as backwash effluent from the media filtration and ultra-filtration systems. Solids settled in the primary and secondary settling tanks, T-110A/B and T-140A/B, will be transferred using electric-driven positive displacement pumps, P-110A/B and P-140A/B to the solids thickening tank (T-1700). The solids thickening tank will be constructed of FRP and will have a capacity of 7,470 gallons. The tank is designed to be of adequate size to allow for settling and thickening of solids.

Coagulant aids will be injected into the solids process stream from T-110A/B and T-140A/B, before T-810. The coagulant aids will be used to form a solids floc that will more readily settle in the tank and therefore thicken before further processing. The coagulant aids will be injected using diaphragm chemical metering pumps, P-830A/B. Two pumps are used in the design; however, only one pump will be used for pumping and the second will be in standby. A static mixer will be used to disperse the coagulant aid into the solids process stream.

Solids produced during media filtration and ultra-filtration backwashing will be transferred initially to the backwash surge tank (T-810). The backwash surge tank is used to limit high flow turbulent conditions into the solids thickening tank. The backwash surge tank will be constructed of FRP and will have a capacity of 3,340 gallons. The exterior base of the tank will be flat; however, the interior base of the tank will be sloped to the pump inlet such that solids will not accumulate on the bottom of the tank. Backwash effluent will be transferred to T-810 using two end suction centrifugal pumps (P-800A/B), however only a single pump will be used for pumping. The other pump will be used as a stand-by pump. The pumps will use a clean water seal flush system to reduce solids fouling of the pump seal thereby reducing maintenance requirements for and improving the reliability of the pump. A coagulant aid will be injected into the solids process stream from T-800 before T-810. The coagulant aid will be used for the same purpose as mentioned previously. P-830A/B will be used to inject the coagulant aid into the process stream.

Thickened solids in T-810 will be transfer to a plate and frame style filter press for further thickening and drying. Solids will be transferred from T-810 using two double diaphragm pneumatic pumps (T-810A/B). Two pumps are used in the design; however, only a single pump will be used for pumping while the second is kept in standby. Tank T-810 will use a gravity overflow system that will be transfer clarified water back to the filter feed tank (T-200). The filter press will use a pre-coat system that will pump a diatomaceous earth and potable water slurry to the filter press before solids processing. The pre-coat system is used to allow good separation of solids from the filter plates during solids cake removal. The pre-coat slurry will be contained in a 300-gallon mix tank and transferred to the filter press via two double diaphragm pneumatic pumps (P-840A/B), however, only a single pump will be used for pumping while the second pump is in standby. Solids will accumulate on the filter plate screens during pumping and thicken to approximately 35 percent solids. Supernatant from the filter press will be transferred to T-810. The filter press will be operated until the influent pressure is approximately 50 psi, at which time P-810A/B will be shut down and solids will be further dried with compressed air. At the completion of solids drying, the filter cake will contain approximately 40 percent solids. The filter press will be opened and the filter cakes will fall into the solids hopper and be transferred into 55-gallon drums. The drums will be temporarily stored inside the Building in a designated area. Filter cakes produced during this process will be properly profiled for disposal offsite at a licensed Facility in accordance with appropriate regulations.

Equipment:

1. Settling Tank Solids Transfer Pumps (P-110A, P-110B, P-140A, P-140B)

Manufacturer:	Moyno, or equal
Model:	1000 BIC Single Stage
Type:	Progressive Cavity Positive Displacement
Quantity:	4
Horsepower:	0.5–0.75
Speed:	400–600 revolutions per minute (rpm)
Flow Rate:	5.5–8.5 gpm @ 50ft TDH

2. Filter Press Feed Pumps (P-810A and P-810B)

Manufacturer:	Warren Rupp, or equal
Model:	SA1-A-DV-4-SS
Type:	Pneumatic Double Diaphragm
Quantity:	2
Flow Rate:	10 gpm @ 90ft TDH

3. Solids Thickening Tank (T-810)

Manufacturer:	Belding Tank, or equal
Model:	C-CKV
Type:	Vertical-Cone Bottom
Storage Capacity:	7,470 gallons (minimum)
Materials of Construction:	Fiberglass Reinforced Plastic
Quantity:	1

4. Backwash Surge Tank (T-800)

Manufacturer:	Belding Tank, or equal
Model:	C-CFV
Type:	Vertical w/ sloped interior base
Storage Capacity:	8,240 gallons
Materials of Construction:	Fiberglass Reinforced Plastic
Quantity:	1

5. Surge Transfer Pumps (P-800A, P-800B)

Manufacturer:	Goulds Pumps, or equal
Model:	1ST1E5E4F
Type:	End-Suction Centrifugal
Quantity:	2
Horsepower:	1
Flow Rate:	30 gpm @ 51ft TDH

6. Filter Press (FP-820)

Manufacturer:	Siemens, or equal
Model:	800mm J-Press
Type:	Plate & Frame
Capacity:	20 cu-ft (minimum)
Materials of Construction:	Various
Quantity:	1

7. Coagulant Aid Storage Tank (T-830)

Manufacturer:	Various
Model:	HDPE Drum
Capacity:	55 gallons (minimum)
Materials of Construction:	HDPE
Quantity:	1

8. Coagulant Aid Metering Pumps (P-830A, P-830B)

Manufacturer:	Grundfos, or equal
Model:	DME 8-10 A-PV/V/C-F-21RRB
Type:	Diaphragm
Quantity:	2
Flow Rate:	0.002 gph - 1.98 gph @ 145 psi

9. Static Mixer (SM-800)

Manufacturer:	Koflo, or equal
Model:	365
Type:	2-inch 6 Element Low Pressure Loss Flange Mounted Static Mixer
Material of Construction (body):	316L Stainless Steel
Material of Construction (mixer):	316L Stainless Steel
Quantity:	1

10. Pre-Coat Tank (T-840)

Manufacturer:	Snyder Tanks, or equal
Model:	586000N-L
Type:	Vertical Open Top Mix Tank
Capacity:	330 gallons (minimum)
Materials of Construction:	HDPE
Quantity:	1

11. Pre-Coat Mixer (M-840)

Manufacturer:	Lightning, or equal
Model:	EV5P25
Type:	11.2-inch Diameter Propeller
Horsepower:	0.5
RPM:	350
Quantity:	1

12. Pre-Coat Feed Pumps (P-840A and P-840B)

Manufacturer:	Warren Rupp, or equal
Model:	SA1-A-DV-4-SS
Type:	Pneumatic Double-Diaphragm
Quantity:	2
Flow Rate:	10 gpm @ 90ft TDH

10.2.2.8.2 Seal Water System

A clean water seal/flush system will be used on centrifugal pumps for water containing a high concentration of precipitated solids. Those pumps are the aeration recirculation pumps (P-150A/B); the filter feed pumps (P-200A/B/C) and the backwash solids pumps (P-800A/B). The seal water system will use water from the effluent tank (T-500). Water from the effluent tank will be pumped using two end suction centrifugal pumps into a process water distribution system. Pressure in the system will be maintained using a bladder tank (T-1000). Two pumps are used in the design; however, only one pump will be operated at a time and the second pump will be in standby. The pumps will be controlled with a pressure switch to maintain a desired pressure range in the system. The bladder tank will be constructed of carbon steel and will use a butyl-rubber bladder. The bladder tank will have an approximate capacity of 264 gallons.

Equipment:

1. Bladder Tank (T-1000)

Manufacturer:	Roy E. Hanson Mfg, or equal
Model:	TB-264-R
Storage Capacity:	264 gallons
Materials of Construction (vessel):	Carbon Steel
Materials of Construction (bladder):	Butyl-rubber
Operating Pressure Range:	100–115 psi
Quantity:	1

2. Process Water Feed Pump (P-1000A and P-1000B)

Manufacturer:	Goulds Pumps, or equal
Model:	1SVD1G5F0H
Type:	Horizontal Multi-Stage Centrifugal
Quantity:	2
Horsepower:	2
Flow Rate:	10 gpm @ 260ft TDH

10.2.2.8.3 Compressed Air System

A compressed air system will operate all pneumatic systems, including all double-diaphragm pneumatic pumps, the bladder tank recharge system, and all pneumatic valves. The air compressor system will use a rotary screw compressor, a refrigerated air dryer, and a receiver tank. The receiver tank will be constructed of carbon steel and will have a capacity of 120 gallons.

Equipment:

1. Air Compressor (AC-900)

Manufacturer:	Atlas Copco, or equal
Model:	SF8 HP
Type:	Oil-less Scroll Compressor
Horsepower:	10
Performance:	24 cfm @ 145psi
Quantity:	1

2. Refrigerated Air Dryer (AD-900)

Manufacturer:	Atlas Copco, or equal
Model:	Integral to Compressor
Quantity:	1

10.2.2.8.4 Vapor Phase Carbon

Vapor phase granular activated carbon (VPGAC) vessels will treat vapors from all non-pressurized vessels containing water not treated through the AOP system. These tanks include the primary and secondary settling tanks (T-110A/B and T-140A/B), the primary and secondary splitter boxes (T-100 and T-130), the solids contact tank (T-120), the filter feed tank (T-300), the AOP feed tank (T-300), the backwash surge tank (T-800) and the solids thickening tank (T-810). The vapor treatment system will use two VPGAC vessels in series for vapor treatment. The exhaust side of the primary vessel will be periodically monitored with a vapor analyzer and replaced if warranted.

Equipment:

1. Vapor Phase Carbon Vessels (F-1100A and F-1100B)

Manufacturer:	CarbonAir, or equal
Model:	GPC-5R
Carbon Capacity:	500 pounds (lbs)/each
Carbon Type:	Virgin-Coal Based
Max. Pressure:	75 psi

10.2.2.9 Treatment System Building and Containment

The groundwater treatment system equipment will be housed in a new, free-standing building constructed to the north of the existing IRA treatment building. The structure will be concrete, tilt-wall construction in accordance with applicable local and State of Florida building codes. Spread footers will support the foundations for the building, tanks, and equipment. This will minimize the necessary excavation and disturbance of Site soils. Any soils removed for building construction will be managed in accordance with the soil management plan described in Section 13.

The general arrangement of major process equipment within the building is shown in Figure 10-30. East-west and north-south cross-sections through the building are shown in Figures 10-31 and 10-32, respectively. The treatment equipment, tanks, and chemical storage will be located inside the new building. The building will be approximately 100 feet wide by 150 feet long. The foundation of the building will form the containment for holding 110 percent of the process water and liquid chemicals contained with the building structure at any time. The estimated volume of the required containment is approximately 110,000 gallons. This containment volume is achieved using a 16-inch curb around the primary process floor plus installing a 4-foot deep collection basin beneath the loading dock area. This collection basin is designed to accommodate the volume of all plausible leaks and minor overflows, is easily observed, and is equipped with a fully redundant, independent system of alarm/shutoffs.

10.2.3 Disposition of Effluent

Currently, treated groundwater from the IRA system is discharged to the Manatee County POTW through an on-facility connection to the sanitary sewer under IUD permit #IW0025S. A request for modification to this permit will be sought for discharging all groundwater proposed to be recovered as part of this RAP and treated with the system detailed above. Based on on-going discussions with Manatee County, the total flow for the discharge proposed in this RAP does not present any capacity or treatment problems for the POTW.

While the POTW discharge permit for the entire flow will be sought, at times, a portion of the treated effluent may be routed to on-facility injection wells for flushing the source area and to off-facility recharge galleries for maintaining wetlands hydroperiods. The design flow rate for the off-facility recharge galleries is 75 gpm. Recharge galleries are planned in three locations as shown on Figure 10-3. Flow rate into the galleries is calculated using Darcy's law and is detailed below.

$$Q = KhA$$

Where:

Q = flow rate (cubic feet per day [ft^3/day])

K = vertical hydraulic conductivity (ft/day)

h = head or potential causing flow (ft)

A = cross-sectional area of flow (ft^2)

Hydraulic conductivity used for the calculation was 0.7 ft/day, the same value used by the groundwater model for the upper portion of the USAS aquifer. The head value used for the calculation was 2.5 ft, which assumes water in the trench will be above the effective groundwater table by 2.5 ft. This is a reasonable design value since during wet periods when high water levels are naturally present in the wetlands, no water will likely be sent to the recharge galleries, and during dry periods, 2.5 feet of head differential will be present. Based on the calculation, approximately 1,590 linear feet of gallery (5 ft width) will be constructed to handle the design flow for the recharge system. Field verification of natural percolation rates in the recharge areas will be performed prior to construction.

Discharge to recharge galleries and injection wells is expected to be subject to underground injection control permitting. The design anticipates that the water to be recharged near wetlands will need to meet both GCTLs and surface-water quality criteria while the water recharged to on-facility injection wells will only need to meet GCTLs. The following are the current effluent limitations for Manatee County Utility Operations (MCUO) IUD permit #IW 0025S. The expectation is that Manatee County would not require the addition of any parameters or more restrictive effluent limits. Also shown in this table are the GCTLs and surface water quality criteria which are the anticipated effluent criteria for various recharge locations.

Table 10-3: Effluent Limitations for MCUO ID Permit #IW 0025S, GCTLs, and Surface Water Quality Criteria

Parameter	Unit	MCUO IUD Permit #IW 0025S Effluent Limitation	GCTL	Surface Water Quality Criteria
pH	SU	5–11.5	--	--
1,4-dioxane	mg/L	Report	0.0032	0.120
TCE	mg/L	0.003	0.003	0.0807
PCE	mg/L	0.003	0.003	0.00885
1,1-DCE	mg/L	0.007	0.007	0.0032
1,1-DCA	mg/L	0.07	0.07	--
cis-1,2-DCE	mg/L	0.07	0.07	--
Vinyl chloride	mg/L	0.001	0.001	0.0024
Metals				
Aluminum	mg/L	Report	0.2	0.013
Arsenic	mg/L	2.51	0.01	0.050
Beryllium	mg/L	0.004	0.004	0.00013
Cadmium	mg/L	0.73	0.005	0.0012[2]
Chromium	mg/L	9.90	0.1	0.011
Copper	mg/L	28.48	1	0.0101[2]
Nickel	mg/L	11.08	0.1	0.0565[2]
Lead	mg/L	1.87	0.015	0.0036[2]
Zinc	mg/L	4.78	5	0.1299[2]
Sodium	mg/L	NA	160	--
Other Parameters 1/				
Chloride	mg/L	NA	250	--
Sulfate	mg/L	NA	250	--
TDS	mg/L	NA	500	--

[1]— Secondary water-quality standard, Chapter 62--550 F.A.C.

2 – Calculated based on estimated hardness of receiving water.

NA— not applicable

"- - " = no criteria

10.2.4 Process and Instrumentation

The groundwater extraction and treatment system will be designed to run continuously. The control system will be a redundant PLC system, which will monitor key treatment system parameters such as tank level, process flow rate, differential pressure across media filters, ultra-filtration units, and RO units, AOP system alarms, high pressure at liquid phase GAC vessels and pump operation. To provide additional factors of safety, each of the control switches will be electrically wired or programmed to fail on loss of continuity (fail open) so that appropriate system components will shut down on a loss of signal from the switch.

The influent tank and other tank systems will be equipped with multiple-redundant level sensors. The primary device in each tank will be an ultrasonic level device that will provide an indication of tank level. Level transmitters will control the operation of the process pumps and will also signal high and low level alarms to the PLC. The filtration units will be equipped with pressure transmitters at the influent and effluent of each unit. The PLC will calculate the differential pressure across the filters and initiate backwash cycles. The AOP system will be equipped by the manufacturer with applicable process instrumentation and alarms. The AOP parameters will be monitored via the PLC control system. The GAC vessels will have pressure transmitters to monitor fouling of the carbon and samples will be taken as prescribed in Section 13, at a minimum, to assess carbon breakthrough. Furthermore, the redundant alarms for each location will be wired/programmed to shut down the system through an independent relay system that does not rely on the primary PLC system. A second PLC will be used for this relay system to provide redundancy. Therefore, in the event of a failure of the primary PLC, the system will still shutdown.

Detailed piping and instrumentation diagrams are provided as Figures 10-18 through 10-28. Additionally, Table 10-4 provides a description of the control logic and alarm sequences.

10.2.5 Air Emissions

No significant air emissions will be generated by this treatment system. Slight emissions from untreated groundwater in the settling tanks and pump tanks prior to the AOP could be expected through the tank vents; however, the expected emissions have been calculated to be less than the allowable limits of 5.5 and 13.7 pounds a day (lbs/day) for individual and aggregate hazardous air pollutants (HAPs). In fact, if the total expected concentration of TCE (630 µg/L) were to volatilize and the treatment system was operating at the maximum flow rate of 300 gpm, the total mass of TCE volatilized would be approximately 2.3 lb/day, nearly 100 percent below the allowable limit. Regardless, the tank vents will be piped to will send vapor collected from the tanks to VPGAC vessels. Two VPGAC vessels will be used in series for vapor treatment. The exhaust side of the primary vessel will be monitored with a vapor analyzer periodically. The vessels will be replaced at least annually.

10.3 Cleanup Target Levels

Cleanup target levels for COCs in Site groundwater are specified in Chapter 62-777, F.A.C. as follows:

Chemical of Concern	G-II GCTL (µg/L)
PCE	3
TCE	3
cis-1,2-DCE	70
1,1-DCE	7
1,1-DCA	70
1,4-dioxane	3.2

10.4 Remedy Performance Measurement

The performance of the selected remedy will be measured by its ability to:

1) Reduce the COC mass in the USAS, LSAS, AF Gravels and S&P Sands units with the goal of achieving G-II GCTLs site-wide to the extent technically feasible.

2) Hydraulically contain the groundwater plume site-wide.

The first performance goal, COC mass removal, can be evaluated by periodically measuring groundwater extraction rates and COC concentrations in extracted groundwater prior to treatment and COC concentrations in monitoring wells to observe changes in plume extent and concentration. This information can be used to estimate and monitor COC mass removal rates of the pump and treat system and estimate remaining plume mass. Initial COC mass removal rates in the pump and treat system will be relatively fast, and will decrease over time until concentrations in source area groundwater are low.

The second performance goal, hydraulic containment of the site-wide plume, can be evaluated by periodically measuring groundwater and surface water elevations at the Site (including water levels within the extraction points) and preparing potentiometric surface maps based on the field data. Hydraulic gradients that are inward toward the pump and treat system and the inward gradients that encompass areas where COC concentrations in groundwater exceed GCTLs indicate that the pump and treat system is achieving this performance goal. Monitoring groundwater from perimeter sentry wells for COCs will also provide assurance that containment has been achieved.

10.5 Temporary Point of Compliance

Lockheed Martin has identified the boundary of the current groundwater plume (exceedances of GCTLs) as extending beyond the Facility. The presence of the GCTL exceedances beyond the Facility will require that a temporary point of compliance (TPOC) be established. Requirements associated with establishment of the TPOC are discussed below.

10.5.1 TPOC Plan

Lockheed Martin requests that a TPOC be established at the outermost extent of the GCTL exceedances based on the March/April 2009 groundwater monitoring event data. All properties that are crossed by the boundary or are wholly within the boundary would be considered subject to the Rule 62-780.220(3) F.A.C. TPOC notification requirements described in Section 10.5.2 below. The boundary of all COC GCTL lines in each affected aquifer was projected to the ground surface. The outermost edge of these lines was composited and used to establish the proposed TPOC line. The proposed line is shown on Figure 10-33.

10.5.2 TPOC Administrative Requirements

In requesting a TPOC beyond the Facility, Lockheed Martin will comply with the notice requirements of Rule 62-780.220(3) F.A.C. Specifically, Lockheed Martin will provide:

- Actual notice
- Constructive notice
- Copies of notices made

Actual notice will be made in writing and be mailed via “Certified Mail, Return Receipt Requested” to the Manatee County Health Department and all owners of record (per county property tax office records) within the proposed TPOC. The notice will include the following and conform to the FDEP template for notice:

- Type of action to be taken (i.e., establish the TPOC)
- Description of the Facility location with the owner’s name and Facility address
- Description of the Site, including a map of the TPOC line and categories of COCs present (matching the “families” of COCs listed in the *Institutional Controls Registry*)
- Location of where relevant documents about the Site can be inspected (e.g., Lockheed Martin Facility, offices of FOCUS, FDEP offices, etc.)
- Contact information for the FDEP project manager
- Statement regarding public comment period (“Persons receiving this notice shall have the opportunity to comment on the Department’s proposed action within 30 days of receipt of the notice.”)

“Constructive notice” requires that all of the information in the actual notice be made generally available by:

- Publishing the notice one time in a standard-size newspaper of general circulation with dimensions at least two columns wide by 10 inches long with a headline in a type no smaller than 18-point font and the body of the notice in a type no smaller than 10-point font

- Including a statement in the notice indicating the 30-day deadline by which comments must be received (30 days from the date of publication in the newspaper).
- Conforming to the FDEP template
- Including the same map of the TPOC line as described above and the list of addresses affected by the notice

Copies of both the actual and constructive notice will be provided to the FDEP as proof of compliance with this rule.

Additionally, every five years notice concerning the status of the Site rehabilitation will be made in the same manner (active and constructive notice) to the affected parties within the TPOC line. If an owner within the original TPOC line has been separately notified that their property is no longer affected, then it is not required to provide them the five-year status update notice. The TPOC process outlined above is part of a sequence of events that must occur to formally establish the TPOC. A generic description of the sequence of events is:

- Lockheed Martin submits the *RAP* with proposed TPOC for FDEP review
- If FDEP finds the *RAP* and TPOC acceptable, FDEP provides Lockheed Martin with notice of its intent to approve the *RAP* after the TPOC notice process is completed
- Lockheed Martin initiates the TPOC process described above
- Lockheed Martin demonstrates to FDEP its compliance with the notice requirements (e.g., provide FDEP with a copy of the notice, date each addressee receives notice or date of refusal/unclaimed status, provide proof of publishing newspaper notice within seven days of publication
- Lockheed Martin forwards affected party comments (if any) on the notices to FDEP for resolution
- FDEP develops the *RAP* approval order after TPOC notice period is complete

10.6 Cessation Criteria

The groundwater pump and treat system will operate until it can be demonstrated that conditions satisfy the "No Further Action" criteria set forth in Rule 62-780.680, F.A.C. (generally speaking, GCTLs have been achieved). As discussed in Section 10.2.1, the groundwater hydraulic model, in conjunction with the groundwater solute model, were used to evaluate and design an expanded groundwater extraction system that achieves RAOs effectively and efficiently. Though groundwater recovery and treatment systems are known to take a considerable amount of time to achieve cleanup standards, as entropy would suggest, typically longer than the problem has existed, groundwater recovery and treatment is a very effective means of controlling the groundwater plume and reducing COC concentrations. The model simulation of the proposed recovery and treatment system predicts that approximately 50 percent and 64 percent of mass of 1,4-dioxane and TCE, respectively, would be removed within the first five years of extraction system operation, while approximately 66 percent of the 1,4-dioxane and 83 percent of the TCE mass would be removed within 10 years of beginning groundwater extraction operation. The model predicts that the COCs will meet the RAOs in the entire plume (concentrations below the GCTLs) in approximately 48 years. Further, the model simulation indicates a significant number of recovery wells in the proposed recovery system will be shut down much sooner than that, as areas of the plume are reduced below GCTLs. Procedures for shutting down extraction locations are detailed in Section 13.5.

11. RAP Construction

This section outlines the process of RAP construction. A schedule for these activities is presented in Section 14. Waste handling, characterization, and disposal are discussed below in Section 11.3.

11.1 Site Preparation Activities

Site preparation activities are required to be completed prior to construction. The Site preparation will include survey, utility identification, and obtaining access agreements for construction. A full survey of the area described in Figure 10-2 (approximately 250 acres) will be conducted. The survey will include obtaining horizontal and vertical controls of property lines, utilities (e.g., gas, overhead electric, underground electric, telephone, fiber optic, sanitary sewer, stormwater), edge of pavement, fence lines, drainage ditch centerlines, and stormwater structures. Topography will also be surveyed in areas where extraction, treatment, and discharge appurtenances will be installed (e.g., extraction wells/trenches, power drops and infiltration galleries). This baseline survey, which will take at least two months to complete, will be critical to establishing the Site plan for completing the final design, identifying areas for utility clearance, and establishing properties that will require access for system components that will be constructed off-facility.

11.2 IRA System Operations

IRA extraction and treatment system operations are expected to continue until the RAP system construction is substantially complete.

11.3 Construction Elements

Key elements of the construction include.

- Building 3 will be removed before the start of the RAP construction.
- Receive required approvals and permits from relevant federal, state and local government agencies including, but limited to, Manatee County Building department permits, SWFWMD permit and Federal Aviation Administration (FAA) permit
- Submit notice of construction activities to FDEP per Rule 62-780.220, F.A.C.
- Notify utility owners of upcoming work and locations in which temporary installation may be necessary
- Complete utility clearance
- Mobilization
- Set up support and exclusion zones (e.g., trailers to support construction personnel and fencing to restrict access to construction areas)

- Prepare area for treatment facility building construction, including removing existing concrete slabs or asphalt in new building foundation area to prepare area for concrete placement
- Build treatment facility, including treatment building and equipment installation
- Install and develop extraction and injection wells
- Install extraction trenches
- Install recharge galleries
- Install pipe and electrical conduit trenches from extraction system to treatment facility
- Pressure test piping
- Conduct treatment system shake-down using potable water to confirm operation of each component to establish acceptance to proceed with start-up as describe in Section 12

11.3.1 Waste Material Handing and Characterization

Soils and waste materials that will require handling as part of RAP activities at the Site are expected to include the following:

- Drill cuttings from extraction and injection well installation
- Soil generated from building foundation excavation
- Soil generated from utility trench installation for transmission piping and electrical conduits
- Soil generated from recharge gallery installation
- Soil generated from extraction trench installation which will include dry soils excavated from above the water table (vadose zone) and wet soils excavated from below the water table
- Water from well development, extraction trench installation, and other construction-related activities including stormwater

Before disposal, soil and groundwater waste characterization will be completed in accordance with Resource Conservation and Recovery Act (RCRA) procedures. The waste will be characterized based on existing Site waste profiles or *in situ* sampling results as much as possible to obtain approval from the disposal facilities before performing the RAP. Pre-characterization of waste will minimize storage of waste materials while awaiting analytical results before disposal. However, any visually stained or odiferous soils that are encountered during any excavation will be segregated from other material. Depending on the volume, these soils will be temporarily stored in a 55-gallon drum or covered, lined roll-off pending investigation into the source of the material and additional waste characterization, if necessary.

The nature and sampling frequency for each type of waste material is described below.

Drill Cuttings

Seventy-seven extraction wells and five injection wells will be installed as part of implementation of the selected remedy. Drill cuttings generated during extraction and injection well installation will be placed in either Department of Transportation (DOT) approved 55-gallon drums or a covered, lined roll-off. Based on the extensive waste characterization of previous drill cuttings, these materials will be managed as non-hazardous waste based on existing waste profiles. Off-site disposal will be at a Lockheed Martin approved facility.

Foundation Excavation

The spread footer foundation for the approximately 14,200 square feet treatment system building will be excavated to a depth of about 1.5 feet. Foundation excavation soils will be pre-characterized at a rate of one sample per 500 cubic yards (cy) of soil excavated. Since approximately 800 cy of soil will be removed, two composite samples consisting of four discrete grab samples each will be collected from each half of the foundation excavation area. These samples will be collected to a depth of 1.5 feet before the start of excavation and analyzed in accordance with RCRA procedures. Asphalt and concrete at the surface will first be removed and directly loaded into roll-offs or dump trailers. The asphalt and concrete will be targeted for off-site recycling at a Lockheed Martin approved facility. Excavated soil will be directly loaded either into covered, lined roll-offs or dump trailers. Soils will be managed as hazardous or non-hazardous waste based on pre-excavation characterization results described above. Off-site disposal will be at a licensed facility approved by Lockheed Martin.

Utility Trench Excavation

About 15,000 linear feet of utility trench containing transmission piping and electrical conduit runs will be installed as part of extraction well, extraction trench and recharge gallery installation activities. Each trench will be approximately two feet deep, with the width varying based on the number of pipes or conduit in a particular trench.

Utility trench excavation soils will be pre-characterized at a rate of one composite sample per 1,000 linear feet of trenching. Since there is about 15,000 linear feet of utility trenching, which is approximately 3,500 cy of excavated soil based on an average trench width of three feet, 15 composite samples consisting of three discrete grab samples each will be collected. These samples will be collected to a depth of two feet before the start of excavation and analyzed in accordance with RCRA procedures.

Asphalt and concrete at the surface will first be removed and directly loaded into roll-offs or dump trailers. The asphalt and concrete will be targeted for off-site recycling at a licensed recycling facility approved by Lockheed Martin.

Excavated soils will be directly loaded into roll-offs or dump trailers. Soils will be managed as hazardous or non-hazardous based on pre-excavation characterization results described above. Off-site disposal will be at a licensed landfill approved by Lockheed Martin.

Recharge Gallery Excavation

Three recharge galleries with a combined length of at least 1,540 feet will be installed as part of remedial activities. Each trench will be about five feet wide and four feet deep. Soils generated from infiltration gallery excavation activities are anticipated to include dry soils excavated from above the water table (vadose zone). The excavated soil will be backfilled with off-site materials.

Recharge gallery excavation soils will be pre-characterized at a rate of one composite sample for each of the three infiltration galleries. Approximately 400 cy of soil will be excavated from each recharge gallery and each composite sample will consist of four discrete grab samples. These samples will be collected to a depth of four feet before the start of excavation and analyzed in accordance with RCRA procedures.

The excavated soil will be directly loaded into covered, lined roll-offs or dump trailers and managed as hazardous or non-hazardous waste based on pre-excavation characterization results described above. Off-site disposal will be at a licensed landfill approved by Lockheed Martin.

Extraction Trench Excavation

Four extraction trenches ranging in length from 300 feet long to 380 feet long will be installed using a trenching machine as part of remedial activities. Each trench will be about 1.5 feet wide and roughly 30 feet deep. Soils generated from digging extraction trenches will include dry soils (excavated from above the water table) and wet soils (excavated from below the water table). The water table varies by location and seasonally but is generally about 4–38 ft bgs. Soil excavated from the top three feet will be re-used as native backfill material and the bottom approximately 27 feet of the collection trench will be backfilled with clean backfill. Extraction trench dry and wet soils will be pre-characterized before excavation of the extraction trench as described below. Samples will be analyzed in accordance with RCRA procedures.

Approximately 500 cy of wet extraction trench soils will be generated from the 3 to 30 ft bgs interval at each trench. These soils will be pre-characterized before collection trench installation by collecting two composite samples from each trench. Each composite sample will consist of five discrete grab samples obtained from the 3 to 10, 10 to 15, 15 to 20, 20 to 25 and 25 to 30 ft bgs intervals at the planned location of each collection trench.

All excavated wet soils will be managed as hazardous or non-hazardous waste based on pre-excavation characterization results described above. Off-site disposal will be at a licensed landfill approved by Lockheed Martin.

Soils from the surface to 3 ft bgs excavated from above the water table (including topsoil, gravel and other surficial soils) will be directly stockpiled adjacent to the trench and reused as surface backfill following the extraction trench excavation.

Soils from 3 to 30 ft bgs excavated from below the water table will be wet and, therefore, handled separately from dry soils. Wet soils will be loaded into a filter box or similar equipment to facilitate dewatering before off-site disposal.

The filter box will consist of a roll-off fitted with floor and sidewall screens covered with a filter cloth to allow gravity migration of water into a collection sump. The collection sump will be fitted with drains to facilitate dewatering. Collected water will be managed along with other construction water as described below.

Following dewatering, stabilizing agents such as granular absorbents or Portland cement may be blended with the wet soils. The purpose of the stabilizing agent is to attain the moisture content requirements of the disposal facility.

Construction Water

Construction water will be generated from a number of sources including water from well development, extraction trench installation, and other construction-related activities including stormwater. Stormwater diversions will be used to minimize the volume of stormwater that runs into excavation areas. However, stormwater that enters active excavation areas that must be removed to continue the excavation activities will be pumped to a temporary storage tank. Similarly, water generated from the extraction trench installations will also be collected in a temporary storage tank. Depending on the volume being generated, water generated from other construction-related activities, including well development, will be collected in DOT-approved 55-gallon drums or temporary storage tanks. Construction water will be managed as hazardous or non-hazardous waste based on waste profiles for the Site.Off-site disposal will be at a licensed disposal facility approved by Lockheed Martin.

11.3.2 Waste Disposal

Asphalt and concrete at the surface will be targeted for off-site recycling at a Lockheed Martin approved facility. A bill-of-lading will be maintained for each container sent off-site for recycling.

Soil, water and other waste removed from areas characterized as non-hazardous will be transported and disposed of off-site by Lockheed Martin approved waste transporters at a Lockheed Martin approved non-hazardous waste disposal facility.

Hazardous waste generation is not anticipated during implementation of this project. In the unlikely event hazardous waste is generated, it will be segregated from non-hazardous waste. The hazardous waste will be transported and disposed of off-site by Lockheed Martin approved waste transporters at a Lockheed Martin approved hazardous waste disposal facility.

A waste manifest will be maintained for each container sent off-site for non-hazardous or hazardous waste disposal. Ancillary waste materials that may be generated during implementation of this project, such as personal protective equipment (PPE) or investigation-derived waste (IDW), will be disposed of as non-hazardous or hazardous waste based on the characterization of the materials being generated along with this ancillary waste.

12. Groundwater Recovery and Treatment System Start-up, Operation, Maintenance and Monitoring

This section provides details on the start-up, operation, maintenance and monitoring of the groundwater recovery and treatment system outlined in Section 10. The RAP has been designed with redundancy of equipment and controls to optimize operational efficiency and facilitate system maintenance. Start-up of the RAP system will be carefully sequenced to positively verify that all facilities, equipment, and controls are properly working in accordance with the design. Outlined in this section is an overview of the system start-up along with a summary of the operation, maintenance, and monitoring (OMM) activities for the RAP system. Before start-up, a detailed OMM Manual will be prepared to include manufacturer literature along with SOPs and Detailed Operating Procedures (DOPs) for the RAP system. The RAP Contingency Plan is provided in Appendix F.

12.1 System Start-up

The RAP system start-up will consist of two phases. The first phase includes a number of activities that will be completed prior to actual start-up activities in the field. The second phase will include the field portion of the start-up. Each step of the start-up will be scripted and then positively verified to confirm completion. The start-up activities are described below.

Before start-up, the following representative activities will be completed to confirm that the construction activities are complete and RAP system is ready for operations:

- Prepare a detailed *OMM Manual* including SOPs and DOPs.
- Train operators including classroom review and field testing of SOPs and DOPs to confirm operators are knowledgable on all aspects of the RAP system.
- Check utilities— electrical, controls, communication, and potable water.
- Check and test electrical equipment— transformers, switch gear, control panels, electrical panels, motors and motor control center (MCC).
- Test building controls— ventilation and lighting.
- Test operation of instrumentation, system alarms and interlocks to confirm proper operation.
- Calibrate all pH sensors.
- Confirm new media, bags, membranes, etc. in associated vessels.
- Confirm presence of catalyst and check the lamps in the Photo-Cat units.
- Confirm necessary spare parts are stocked at Facility.
- Notify suppliers of carbon, acid, caustic and other supplies of restart and potential schedule for service.
- Notify the analytical laboratory of restart and schedule for required analyses.

Conduct the Operational Readiness Review (ORR) with all system operators and necessary staff to ensure that the system and operators are ready for startup.

- Complete a dry run of the initial system startup procedures in the field.
- Reset flow totalizers to zero.

- Notify Manatee County that discharge is ready to begin

Following completion of the activities described above, start-up of the RAP system will begin. Operating personnel will be on-site 24 hours per day, 7 days per week throughout the start-up. The start-up will be sequenced to first confirm operation of the treatment system using extracted groundwater from select wells and then bring on line additional extraction wells plus the extraction trenches, infiltration galleries and injection wells. The general start-up sequence is summarized below.

- The on-site extraction wells will be started one at a time. The treatment system will be started up in recycle mode (no discharge) at a flow rate of about 100 gpm (50 percent of the average design flow rate). The wells will continue to operate until all main process piping is full and process tanks reach their operating levels. The treatment system will continue to be operated in recycle mode and samples will be collected throughout the system to confirm general conformance with design parameters. A sample will also be taken from the effluent tank with the system still in recycle to confirm compliance with the discharge permit limitations.
- Upon receipt of analytical result that confirm design and discharge standards, the treatment system will be configured to discharge treated groundwater. The on-site extraction wells will again be started and the treatment system restarted at about 100 gpm. The extraction wells and trenches located to the southwest of the Site will then be started one at a time until the total groundwater influent flow rate is about 100 gpm. At least one set of samples will be collected throughout the treatment system and from the effluent at 100 gpm to confirm continued conformance with the design parameters and discharge permit limitations.
- Upon receipt of acceptable analytical results, additional extraction wells and trenches will be started one at a time until the total groundwater influent flow rate is about 200 gpm. The sequence for bringing the additional extraction wells and trenches will be those located southeast, northeast, north, and northwest of the Site. The treatment-system flow rate will be increased to about 200 gpm. At least one set of samples will be collected throughout the treatment system and from the effluent at

200 gpm to confirm continued conformance with the design parameters and discharge permit limitations.

- Upon receipt of acceptable analytical results, any remaining extraction wells and trenches will be started one at a time in the same order outlined above. The treatment-system flow rate will be increased to no higher than the design maximum of 300 gpm. At least one set of samples will be collected throughout the treatment system and from the effluent at this flow rate to confirm continued conformance with the design parameters and discharge permit limitations.
- Upon receipt of acceptable analytical results, the five on-Site injection wells and three infiltration galleries will be brought on-line for at least one hour to confirm proper operation. Continued operation of the injection wells and infiltration galleries following this initial start-up will be based on hydrogeologic conditions (e.g., season, drawdowns) at that time.

As start-up progresses and groundwater drawdown developed in the extraction areas, on-going adjustments to pump flow rates may be necessary to maximize drawdown at acceptable extraction pump cycling rates. While the exact timing to complete each step outlined above will be based on many factors, at a minimum, the sampling and analysis outline in Section 12.3 will be completed. Additional sampling may be conducted based on action field conditions.

12.2 Operation and Maintenance Activities

Operations and maintenance (O&M) activities described in this section will promote proper operation of the remedial action. Operators will be on-site 24 hours per day, seven days per week whenever the RAP system is operating. The operator will maintain records throughout the treatment system to verify performance and document proper treatment system O&M. The operator will also perform and document maintenance tasks on treatment system components. Maintenance on system components will be documented on a Facility Maintenance Log. For detailed instruction on performing preventative maintenance on system components, Site personnel will refer to the *RAP System OMM Manual*, manufacturer’s O&M manuals and vendor literature that will be stored at the treatment facility.

Maintenance will be generally involve routine activities, preventive action or equipment repairs. Operating personnel will be trained to complete all three types of maintenance activities, although subcontractor personnel may be used for specific services such as well maintenance or electrical troubleshooting.

One key element of on-going OMM will be a quality assurance/quality control (QA/QC) process to verify that operating and maintenance procedures are being followed and are effective. The process will include a configuration-change-control program to manage and approve/disapprove any design modification or operating change before they occur. If change is proposed to address a potential deficiency, problem, and/or failure, then a root cause analysis (RCA) may be performed. In summary, potential changes will be carefully considered before implementation, and these changes will be documented. This O&M QA/QC process will be periodically audited to confirm the continued effectiveness or to make process adjustments.

Specific O&M activities for the RAP system are summarized below.

12.2.1 Routine Operation and Maintenance

Operating personnel will, at a minimum, perform the following routine O&M activities— 24/7, expand, QC:

- Inspect piping/tanks for leaks and spills
- Inspect groundwater treatment system transfer pumps during normal operation, and check for leaks, unusual noises, or general indications of poor performance
- Inspect seal water system during normal operations, and check for leaks and record pressures
- Record instantaneous and totalized system flow rates
- Record tank operating levels
- Record metals removal system pH levels
- Record effluent system pH levels
- Record advanced oxidation operating data
- Record media filter, ultra-filter and carbon vessel pressures

- Monitor inventory of critical spare parts
- Complete a Daily Shift Operations Log Sheet

The above-described routine O&M activities will be conducted at least daily to document operating conditions. Operating personnel will be trained to use the data being collected to make process adjustment to keep treatment equipment within the designed operating ranges. Operating personnel will also perform additional O&M activities on a less frequent basis such as once per month. Examples of monthly O&M activities are as follows:

- Visually inspect all tanks/equipment, associated piping, and containment for leaks, cracks, chips, exterior corrosion, or other damage
- Visually verify proper operation of instrumentation, including confirming they are free of obstructions and local transmitter displays match displays at the PLC operator interface
- Inspect/test the eye wash/safety shower units and fire extinguishers

Lastly, operating personnel will perform a structured test of all critical alarms at least once per quarter to confirm alarms are functioning in accordance with the design. Additional maintenance requirements/activities will be described in the Facility O&M manuals and manufacturer's O&M manuals that will be stored at the treatment facility. Specific O&M activities for major RAP system components are described below.

12.2.2 Extraction Well Operation and Maintenance

Iron may potentially oxidize within the extraction wells or within the extraction pumps themselves. Pump selection and well design have been considered to minimize the likelihood of iron oxidation in the extraction wells or pumps; however, in the case of reduced yield from a well, maintenance to that well will be necessary. Groundwater volume extracted from the individual extraction wells will be monitored and assessed monthly. A reduction of groundwater extraction rates greater than 50 percent will warrant maintenance. Initially the pump will be inspected and cleaned if necessary. If no appreciable effect from pump cleaning is noticed, then the well will be redeveloped. Extraction well redevelopment may involve the use of chemicals such as dilute sulfuric acid, citric acid or bleach while surging the well. Groundwater and the chemicals in the well will then be pumped out into an above-ground holding tank until redevelopment is completed. Frequency of extraction well maintenance will be determined through operational experience.

12.2.3 Extraction System Line Operation and Maintenance

Precipitated iron may build up within the extraction system pipeline, reducing overall extraction-system flow rate. Increased pressure along the pipeline, reduced overall flow-rate from the extraction wells and high power usage at individual wells can indicate that the pipeline is becoming clogged. To reduce the effect of precipitated iron within the extraction system pipeline, cleanouts will be installed strategically along the extraction system pipeline. When reduced performance of the extraction system pipeline is observed, a high-pressure water jet will be introduced to the pipeline through the cleanouts and used to break-up precipitated iron within the pipeline. After line jetting is completed, water will be pumped through the extraction system by restarting the extraction wells. This will remove the dislodged precipitated iron from the extraction system by entraining it with the overall flow from the extraction system. Water collected from the extraction system after line jetting will be discharged to the primary settling tanks. Waste produced during the line maintenance will contain high levels of iron and will therefore be metered into the treatment stream or characterized and disposed of off-site at a Lockheed Martin approved facility. Frequency of line maintenance will be determined through operational experience.

12.2.4 Splitter Box Operation and Maintenance

The primary and secondary splitter boxes may require adjustment to maintain flows split evenly between the tanks. The splitter box weirs will be inspected monthly for buildup of precipitates and cleaned as necessary.

12.2.5 Settling Tank Operation and Maintenance

The primary and secondary settling tanks have been designed to reduce the likelihood of sediments and precipitated metal solids build-up. To maintain the operability of these tanks the following maintenance items will be performed at the frequency described. The settling tank solids transfer pumps (P-110A, P-110B, P-140A and P-140B) will be checked daily to confirm their proper operation. The tank should be visually inspected yearly, at a minimum, for sediment buildup and pumped out as necessary. The frequency of tank cleaning will be determined by operational experience.

To assess metals-removal performance in the primary and secondary settling tanks, influent and effluent water samples will be analyzed for aluminum and iron concentrations using a field colorimetric analyzer. The settler performance samples will be collected weekly, at a minimum, and adjustments made to pH operating levels if necessary. Dissolved oxygen concentrations will be checked weekly to assure required levels in the settling tanks are met; adjustment to the aeration system flow rate to respective tanks will be made if required.

12.2.6 Solids Contact Tank Operation and Maintenance

The solids contact tank is also designed to reduce the likelihood of sediment and precipitated metal solids build-up. To maintain the operability of this tank the tank mixer will be inspected weekly to confirm its proper operation. In addition, the secondary settling tank solids transfer pump (P-140A) will be checked weekly to confirm its proper operation.

The iron concentration of water in the solids contact will be assessed weekly with the use of a field colorimetric analyzer and the solids transfer pump P-140A operation will be adjusted if required.

12.2.7 Aeration System Operation and Maintenance

Operational data will be collected from the aeration system daily. Operational data will include water pressure influent to the aerators, air pressure influent to the aerators, flow rate of aerated water and flow rate of air. These operational data will be assessed to maintain the acceptable operation of the aeration system.

The in-line aerators will require cleaning approximately once every quarter. A high influent air or water pressure to the aerators is an indication that an aerator cleaning may be necessary. Cleaning will require the aerator to be removed from its service location and be soaked in an acid solution for approximately 12 hours. The actual schedule of aerator cleaning will be determined through operational experience.

12.2.8 Media Filter System Operation and Maintenance

Operational data will be collected from the media filter system daily. Operational data will include influent and effluent pressure of the media vessels, feed water flow rate and backwash flow rate.

Media filters will be monitored for typical number of backwash cycles; a large change from typical operations will denote a potential upstream issue with the metals oxidation and settling system. The effluent from the media filters will be tested weekly with a colorimetric field test kit to verify iron removal to design specifications.

12.2.9 Ultra-Filtration System Operation and Maintenance

Operational data will be collected daily from the Ultra-filtration system. Operational data will include temperature of the feed water, backwash flow rate, volume of water used during a backwash cycle, feed water flow rate, volume of filtrate produced between cleaning cycles, pressure at the top and bottom of the filter, and permeate pressure. This data will be used to calculate Transmembrane Pressure (TMP) of the system. This is the effective pressure for forcing water through the membrane. A clean membrane will have a relatively low TMP, whereas a fouled membrane will have a relatively high TMP, depending on the severity of fouling. When TMP reaches 15-20 psi a chemical cleaning will occur. Furthermore, a temperature compensated specific flux for the membranes will be calculated. This value is used to further determine membrane performance based on a relative temperature. In relation to startup conditions, a significantly high flux rate may indicate chemical degradation of the membrane, whereas a low flux may indicate fouling. When this value reaches 7–9 gsfd/psi, a chemical cleaning is recommended. Finally, the percent recovery will be calculated. All of these values and calculations will provide insight as to system and membrane performance and assist in determining membrane-cleaning frequency. Membrane cleaning will consist of an hourly backwash cycle and a daily chemically enhanced backwash cycle.

12.2.10 Solids Thickening and Dewatering Operation and Maintenance

The coagulant aid feed system will be checked daily to assure its proper operation during solids pumping to the solids thickening tank. Supernatant from the solids thickening tank will be sampled daily and visually inspected for high levels of floc, which would denote potential over dosing of coagulant aid.

The plate and frame style filter press will be inspected weekly for proper operation. It is anticipated that the filter press will operate approximately every other day or as necessary to convert the thickened sludge into filter cake. Supernatant from the filter press will be visually inspected for solids on a weekly basis to assure filter competency. The filter press pre-coat and feed pumping systems will be inspected for leaks and proper operation. Filter cakes will be assessed for adequate separation from the filters on completion of pressing. The sludge hopper will be visually inspected daily for leaks.

12.2.11 Advanced Oxidation System Operation and Maintenance

The advanced oxidation unit will require replenishment of chemicals, catalyst cleaning, and lamp replacement. The frequency of these maintenance activities will be determined by operational experience. UV lamps are expected to require replacement every two years. The catalyst will be inspected at least weekly to determine if cleaning is necessary. The differential pressure across the AOP catalyst recovery unit (CRU) will be checked daily to determine if a CRU cleaning is required. The differential pressure, which will determine if a cleaning is necessary, will be determined through operational experience. Catalyst and CRU clearings consist of recirculating acids and/or bases through the photo-cat reactor and CRU. Effluent created during cleanings is discharged to the Process Tank (T-1300), where it is neutralized and transferred to the Primary Settling Tanks.

12.2.12 Liquid-Phase Granular Activated Carbon Operation and Maintenance

LPGAC vessels are designed to adsorb VOCs that may remain after AOP treatment. As evident from operation of the IRA system, LPGAC primarily removes 1,1-DCA that is not destroyed by the AOP system. As the number of available sites for adsorption decreases, breakthrough of VOCs can occur. Six LPGAC vessels will be installed in a double train lead/intermediate/lag fashion. Carbon vessels are sized to operate at the maximum design flow rate of 300 gpm and will be normally operated with the flow split between two parallel trains of vessels. Each train will be operated with three vessels in series during normal operations.

An effective means of detecting VOC breakthrough is through sampling. If sampling indicates VOC concentrations approaching the permitted discharge limits, at the discharge side of the primary (lead) carbon vessel, that primary carbon vessel will be taken offline and the train is reconfigured to temporarily operate with two beds in service. The intermediate bed is placed in the lead position and the lag bed remains in the lag position. Then the exhausted bed is drained, the spent carbon is removed, the vessel is inspected, then refilled with fresh carbon. The new carbon will be soaked for a minimum of 24 hours and backwashed to remove fine particulates before being placed in operation.

After performing system checks to ensure all ports and access points have been properly closed, this vessel is then valved back into the train in the lag position; the bed that in the former configuration had been intermediate until the change-out now remains in the lead position; and the former lag bed is now intermediate. This sequence is repeated each time breakthrough is observed on whichever vessel is in the lead position. This ensures that the freshest GAC is always in the lag position and serves as the last barrier against inadvertent contaminant release.

The frequency of carbon exchanges is expected to be approximately every 60 days; however, actual carbon exchange frequency will be determined through operational experience.

12.2.13 Reverse Osmosis System Operation and Maintenance

Operational data will be collected daily from the RO system. Operational data will include temperature of the feed water, conductivity of the feed water, permeate and reject streams, interstage, and feed water pressure, and feed water, permeate and reject flow rate. This data will be used to calculate salt passage, salt rejection, net drive pressure, flux rate, and permeate recovery. These values are used to determine membrane performance based on a relative temperature in relation to startup conditions. All of these values and calculations will provide insight as to system and membrane performance and assist in determining membrane cleaning frequency. Membrane cleaning will consist of a circulation of chemically enhanced water through membranes as determined necessary (usually once every three to four months).

12.2.14 Vapor-Phase Granular Activated Carbon Operation and Maintenance

The VPGAC vessels are designed to adsorb VOCs that may volatilize from non-pressurized tanks in the treatment system. VPGAC vessels will be installed in a lead/lag fashion such that there is one lead carbon vessel and one lag carbon vessel in use at all times, except during carbon change out. An effective means of detecting VOC breakthrough is through sampling. If sampling indicates VOC concentrations approaching thresholds requiring air permits at the discharge side of the primary (lead) carbon vessel, the lead GAC vessel will be removed from the treatment train and carbon will be exchanged in this vessel. The lag carbon vessel will be moved to the lead position. Carbon will be exchanged in the offline vessel within one week of detected break-through, at which time the vessel will be placed in the lag position.

12.2.15 Centrifugal Pump Operation and Maintenance

Many pumps in the treatment system are used in a duplex fashion, where one pump is in operation and the other in standby. The operational and standby pumps will be alternated each month. Pump seals will be inspected monthly for signs of leaks and repaired if warranted. Motor bearings will be greased once every six months, or as recommended by the manufacturer. Vibration testing will be completed annually.

12.2.16 Compressor Air System Operation and Maintenance

The air compressor and air dryer system will be inspected weekly to assure proper operation. Automatic drains will be tested weekly. Pneumatic system piping will be checked for leaks annually.

12.2.17 Seal Water System Operation and Maintenance

Operational data will be collected from the seal water system daily. Operational data will include seal water tank pressure, seal water tank feed pump pressure, seal water regulated pressure line and the seal water pressure at the individual pumps serviced. Operational data will be used to assess operational condition of the seal water system and make adjustments if required.

12.2.18 System Alarms and Response

System operation set points for various process parameters will be set by the system operator. The PLC will monitor these parameters and alert the operator of changes in the system operation. The following parameters will be monitored for both “informational” and “process maintenance” conditions:

- High differential pressure across the media filter units
- High differential pressure across the ultra filter units
- High differential pressure across the lead LPGAC vessel
- High differential pressure across the intermediate LPGAC vessel
- High differential pressure across the lag LPGAC vessel

Shutdown alarms are triggered under the following conditions:

- High or low pH to the primary settling tanks T-110A/B
- High or low pH to the solids contact tank T-120
- High or low feed pressure to the media filter units
- High turbidity in the effluent from the ultra filters
- High or low feed pressure to the AOP units
- AOP fault
- High effluent pressure
- Low effluent pressure
- High high-level alarm in tanks T-110A/B, T-120, T-140A/B, T-200, T-300, T-500, T-620, T-660, T-800, T-810 and T-1200
- Low low-level alarm in tanks T-110A/B, T-120, T-140A/B, T-200, T-300, T-500, T-620, T-660, and T-800
- Power loss
- High-level alarm at Building floor sensors

Specifically, the AOP system will shut down under any of the following alarm conditions:

- Influent fault— No feed water to the AOP
- Effluent fault— Water cannot be discharged from the AOP
- Air pressure— Loss of air pressure to the system
- Acidification fault— Actual pH is outside of specified pH range
- Neutralization fault— Same as for acidification
- TiO2 slurry feed return fault— Insufficient TiO2 slurry return to the influent
- Ballast temperature fault— Temperature switch in the ballast cabinets will fault if there is overheating due to failure of the ballast cooling fan

All alarms and system operation will be accessible via remote telemetry using the treatment system computer and *PCAnywhere* software. The PLC, computer, and *PCAnywhere* software may be used to remotely investigate, correct, reset, and document any alarm conditions that occur. The system will never be controlled remotely. Any process adjustments will be conducted by on-facility personnel. For detailed treatment system alarm procedures involving the primary treatment components including the setting tanks, media and ultra-filtration systems, AOP, LPGAC, and RO system, Facility O&M personnel will refer to the Facility *O&M Manual* and the manufacturers' O&M manuals that will be stored at the treatment system.

12.3 Sampling and Analysis

In accordance with Rule 62-780.700(3)(g), F.A.C., treatment system effluent samples will be collected on the following frequency:

- The first three days during the first week
- Weekly for the next three weeks
- Monthly for the next two months
- Quarterly thereafter

In addition to the COCs, other parameters to be analyzed in the proposed effluent samples are expected to remain the same as those required by the current IUD permit # IW 0025S listed in Section 10.2.3. If the parameter list or methods are modified in the final permit issued by MCUO, then the treatment system monitoring will be changed accordingly.

To evaluate the operational performance of the treatment system, operational samples will also be collected from the combined influent (T-100 influent), mid-process (before lead GAC vessel) and post-lead GAC vessel at a frequency necessary to optimize the treatment system and monitor its performance. The samples collected post-lead GAC vessel will be used to determine CVOC breakthrough.

Samples will also be collected from operating recovery wells and trenches on the following frequency:

- Weekly for the first month
- Monthly for the next two months
- Quarterly for the next two years
- Semi-annually thereafter.

The extraction well and trench samples will be analyzed for COCs and may include other parameters as necessary to evaluate the operational performance of the treatment system. In accordance with Rule 62-780.700(3)(g)(1), F.A.C., COCs that do not exceed the CTLs in samples from the extraction wells or trenches for two consecutive sampling events with a sampling frequency not less than quarterly may be excluded from subsequent monitoring events. For extraction wells or trenches that meet this condition, a recommendation to terminate monitoring, if sought, will be provided in the operation, maintenance and monitoring reports submitted to FDEP and monitoring will not be discontinued until FDEP has concurred with the recommendation.

The treatment system sampling schedule for operation, maintenance and monitoring is outlined in Table 12-1.

12.4 Reporting

In addition to the above information, the percentage of system operation time and the treatment efficiency will be reported in operation, maintenance and monitoring reports as detailed in Section 13.7 below.

Within 120 days of initiating the operation (after shake down) of the RAP system, Lockheed Martin will provide FDEP with two signed and sealed sets of As-Built Drawings. The As-Built Drawings will include all construction and equipment design specifications of the installed active remediation system(s) and any operational parameters different from those in the approved RAP.

13. Effectiveness Monitoring

13.1 Overview

In accordance with Rule 62-780.700(3)(g), F.A.C., effectiveness monitoring of the groundwater recovery system will consist of measuring water levels at staff gauges, stilling wells and monitoring wells in addition to collecting groundwater samples from monitoring wells. Water levels will provide a means of determining hydraulic capture of the plume and groundwater samples will provide a means for evaluating cleanup progress and ensure the edges of the plumes (TPOCs) are adequately monitored.

The list of staff gauges, stilling wells and designated monitoring wells in the effectiveness-monitoring program is provided in Tables 13-1 and 13-2 and is depicted on Figures 13-1 and 13-2. All the monitoring wells listed in Table 13-1 will be sampled annually during active remediation to redefine the plume and fully evaluate the effectiveness and efficiency of the remediation system as required by Rule 62-780.700(3)(g)3, F.A.C. These monitoring wells will also be sampled annually before active remediation, during construction of the proposed groundwater remediation system, to ensure it will capture the extent of COCs in groundwater exceeding GCTLs and ensure the edges of the plume (TPOCs) are adequately monitored. A subset of monitoring wells, as noted on Tables 13-1, will be sampled quarterly for the first year and semi-annually thereafter to adequately monitor the cleanup progress during active remediation as required by Rule 62-780.700(3)(g)2, F.A.C. Monitoring wells currently in the quarterly IRAP monitoring program are part of this subset of wells that will continue to be monitored.

Groundwater samples will be collected using previously approved sampling methods and shipped to a certified laboratory for analysis of site-specific COCs identified in Section 1 using USEPA Method 8260 SIM, which is modified with heated purge and isotope dilution for 1,4-dioxane.

Table 12-1 summarizes the schedule for the effectiveness monitoring groundwater recovery system per Rule 62-780.700(3)(g), F.A.C.

In accordance with FDEP meetings on June 26 and July 1, 2008, wetlands and manmade lakes whose water levels may be potentially affected by the drawdown caused by the groundwater extraction system will be monitored for potential changes in hydroperiod and vegetation composition. FDEP has requested that potentially affected wetlands be evaluated using the Wetland Assessment Procedure (WAP) (SFWMD, March 2005).

13.2 Monthly Groundwater Monitoring

Water levels will be measured in the monitoring wells listed in Table 13-2 and shown on Figure 3-2 at least once a month during the first six months after the RAP groundwater pump and treat system is fully operational. The purpose of this portion of the monitoring program is to monitor the development of the groundwater capture zones in the USAS, LSAS, AF Gravels and S&P Sands to verify that the groundwater recovery system is providing hydraulic control site-wide and to monitor the influence groundwater recovery has on deeper units. The data will be used to prepare potentiometric surface contour maps and delineate capture zones in the USAS and LSAS, AF Gravels and S&P Sands. As described in Section 13.7, monthly monitoring reports will be submitted to FDEP showing the results. After six months of monthly monitoring, water levels will be collected quarterly and semi-annually as discussed in Sections 13.3 and 13.4.

13.3 Quarterly Groundwater Monitoring

Groundwater samples will be collected from the monitoring wells listed in Table 13-1 quarterly during the first year after the RAP groundwater pump and treat system is operational. Additionally, during the last quarterly sampling event, groundwater samples will be collected from the annual monitoring wells. The purpose of the groundwater sampling will be to monitor the COC mass removal rates, changes in COC concentrations over time, and the extent of the capture zones. The data will be used to estimate COC mass removal rates, evaluate changes in COC concentrations over time, prepare potentiometric surface contour maps, and delineate capture zones in the USAS and LSAS. As described in Section 13.7, quarterly-monitoring results will be summarized and submitted to FDEP in an annual report. The sampling event conducted during the last quarter will be used to redefine the plume. After one year of quarterly monitoring, groundwater samples and water level measurements will be collected on a semi-annual basis as discussed in Section 13.4.

13.4 Semi-Annual Groundwater Monitoring

After one year of quarterly groundwater sampling, groundwater samples will be collected from monitoring wells semi-annually. Groundwater samples will be collected from the monitoring wells listed in Table 13-1 during the first semi-annual event each year and from all monitoring wells during the last semi-annual event each year.

The purpose of the semi-annual groundwater monitoring program will be to monitor COC mass removal rates, changes in COC concentrations over time during operation of the RAP, and the extent of the capture zones. The data will be used to evaluate changes in COC concentrations over time, prepare potentiometric surface contour maps, and delineate capture zones in the USAS, LSAS, AF Gravels and S&P Sands. The sampling event conducted during the last semi-annual event each year will be used to establish the new limits of the plume. As described in Section 13.7, an annual monitoring report will be submitted to FDEP summarizing the monitoring results.

13.5 Additional Monitoring

13.5.1 Recovery Well/Trench Shut Down Post-Active Remediation Monitoring

This section describes the process for shutting down portions of the groundwater recovery system in areas of the plume where COCs no longer exceed GCTLs. The groundwater solute and transport model simulation of the selected remedy, presented in Appendix D, predicts that COCs in different areas of the plume will be reduced to below GCTLs at different times in the future. It will be beneficial to shut down certain recovery wells and/or trenches in areas of the plume where COCs no longer exceed GCTLs. A recommendation to shut down a recovery well/trench will be submitted to FDEP. If COCs in the monitoring wells within the area of the plume affected by the recovery well/trench do not exceed CTLs in samples from two consecutive sampling events with a sampling frequency not less than quarterly, Lockheed Martin may recommend that this recovery well/trench be shut down. If FDEP concurs, the recovery well/trench will be shut down and a post-active remediation monitoring plan for that portion of the plume will be implemented similar to the requirements set forth in Rule 62-780.750, F.A.C.

After shutdown, the recovery well/trench and affected monitoring wells will be sampled quarterly for a period of at least one year. The recovery system will be maintained in an inactive but operational status during the period the four quarterly sampling events are conducted. If the results of at least the last two sampling events do not exceed the GCTLs, then the recovery well/trench will remain off. If the results indicate that the action levels are exceeded, then an alternate proposal will be submitted, which may include, but not be limited to, restarting the recovery well/trench. If any non-COC parameters, such as metals, appear elevated in extraction wells or trenches due to the groundwater extraction process, and concentrations appear to remain elevated during the last two quarters of the post-active remediation sampling events, then the elevated parameters will be sampled quarterly until two consecutive sampling events indicate they are no longer elevated.

13.5.2 Long-Term Monitoring Transducer Installation

As part of long-term continuous groundwater elevation monitoring, 36 pressure transducers and one barometric pressure transducer were installed during the weeks of May 19 and 26, 2008. A transducer was also installed at the stilling well at the golf course pond. The pressure transducers have been recording data on an hourly basis. Data from the transducers have been downloaded on a quarterly basis. Figure 4-5 shows the wells where transducers have been installed for long-term monitoring purposes. Table 4-3 provides additional information on the monitoring network in which pressure transducers were installed including the rationale behind the selection of the wells.

The locations, number, and distribution of long-term monitoring transducers will be periodically re-evaluated. The current distribution was selected to help characterize inter-relationships and gradients between geologic units on-facility and off-facility. In addition, the wide lateral spread of monitoring locations was intended to allow evaluation of potential regional groundwater flow trends as opposed to local effects of groundwater extraction.

Most transducers have been in place for approximately one year at the date of this RAP submittal. A database containing the transducer data has been established, and it is anticipated that the results of transducer monitoring will be provided to the FDEP on an annual basis. It is expected that any intended changes in the long term transducer monitoring network will be proposed in the yearly transducer monitoring report, and will be implemented during the quarter following report submittal.

Maintenance will be performed on transducers quarterly as needed. Maintenance is expected to include changing desiccant caps, checking calibration if there appears to be a problem, raising or lowering the instrument in the well if needed based on water level changes, and transducer or cable replacement if necessary. If a transducer is observed to malfunction and cannot be fixed, it will be replaced with a comparable unit to maintain the robustness of the monitoring network.

13.5.3 Monitoring Well Redevelopment

A number of wells were redeveloped to ensure continued usefulness. A yearly re-evaluation of monitoring well total depth will be performed to determine which, if any, of the wells display evidence of silt accumulation requiring redevelopment. Seventeen monitoring wells were redeveloped to maintain a relatively silt-free screened interval. The wells redeveloped in 2008 were: IWI-2, MW-19, MW-22, MW-33, MW-MW-39, MW-49, MW-50, MW-77, MW-94, MW-95, MW-97, MW-155, MW-165, MW-177, MW-187, MW-202, and MW-243.

Before redevelopment, the total depth and depth to water were measured in each well. Then, depending on the depth of the monitoring well, either an inertial or submersible pump was used for removal of the fine particles at the bottom of the well. For monitoring wells greater than 150 feet deep, a Waterra inertial lift pump was used. The monitoring well was pumped at the highest sustainable rate until the groundwater was relatively clear of sediment, or the well was pumped dry. If the well was pumped dry, it was allowed time to recharge, and then pumped again until the groundwater was relatively clear of sediment. After allowing the well to recharge, total depth of the well and depth to water were measured again. A similar procedure will be followed in future well redevelopment activities.

13.6 Wetland Monitoring

The details of the wetland monitoring program are presented in the *Wetlands Monitoring Plan* (WMP) included in Appendix G. The focus of the WMP is on collecting and comparing water level and vegetative data along transects within eight wetlands: four reference wetlands (RW) and four target wetlands (TW). Eight nearby wetlands were initially assessed in June 2008 and again in 2009, and eight were selected for the program based upon applicable wetland standards and criteria described within the March 2005 *Wetland Assessment Procedure (WAP) Instruction Manual for Isolated Wetlands*; published by the SWFWMD and the Tampa Bay Water Supply Authority (TBWSA). Historic and present wetland morphologies for each assessed wetland are described in Appendix G. Figure 13-3 shows the eight wetlands and transects along which water level and vegetation will be monitored.

13.6.1 Hydroperiod, Vegetative, and Soil Condition Monitoring at Wetlands

Initial hydroperiod and vegetative monitoring will take place at the monitoring wells and staff gauges installed along transects within each of the eight wetlands. Quarterly water level data downloads will take place with annual monitoring taking place during May or June of each successive year for a total of five years. Monitoring will take place along each transect as defined in the WAP (2005) and will include photo-documentation and water level data from the staff gauge and the piezometer well from each wetland. Wetland photo-documentation will include digital photographs taken at the staff gauge, NP-6 marker, and NP-12 marker in each cardinal direction. Changes in wetland characteristics, wildlife and wildlife activity, and the vegetation composition and zonation will be documented.

Soil conditions will be assessed during the initial wetland evaluation and every five years thereafter. In addition to water level assessment along the established transects, assessment of soil conditions will be carefully conducted throughout the assessment area and wetland to evaluate soil conditions. Evidence of subsidence including compaction, tree root exposure, fire, and soil fissures will be documented in addition to signs of soil oxidation.

13.6.2 Critical Action Levels for Further Evaluation

Surface water depths and elevations recorded at the staff gauges and piezometer wells in each wetland after operating the groundwater remedy will be compared to baseline conditions recorded prior to remedy implementation. If water level elevations are below 50 percent of the baseline normal pool or seasonal low for three consecutive monitoring periods within a target wetland, but not within the reference wetlands, then FDEP would be contacted to determine if a mitigation plan needs to be implemented.

During groundwater remediation, vegetation composition and structure along the transect in each wetland will be monitored and compared to baseline vegetation conditions. If the total relative abundance of obligate and facultative wet species within a vegetative layer is less than 75 percent for consecutive monitoring periods within a target wetland, but not within the reference wetlands, then FDEP would be contacted to determine if a mitigation plan needs to be implemented. If the vegetative structure (i.e., canopy density or vegetation health) measured on photographs changes by more than 50 percent for consecutive monitoring periods within a target wetland, but not within the reference wetlands, then FDEP would be contacted to determine if a mitigation plan needs to be implemented.

13.6.3 Reporting and Schedule

Implementation of the monitoring plan will begin upon approval by FDEP. Quarterly (January, April, July, and October) water level monitoring will take place and visual assessments annually for the five year monitoring period. After five years, the monitoring plan will be re-evaluated with FDEP to determine whether it needs to continue or be modified. If monitoring demonstrates that wetland impacts are occurring due to groundwater withdrawals, then a mitigation plan will be developed for submittal to FDEP.

Quarterly water level data and annual visual assessments will be compiled into an annual report submitted to FDEP. The report shall include narrative descriptions, figures and tables that show:

- locations of wetlands and man-made lakes
- locations of staff gauges, piezometer wells, and photostations

- water elevation data recorded for current and past five monitoring quarters and baseline data
- photographic data recorded for current and past five monitoring quarters and baseline data
- dominant vegetation species data with indicator status for current and past five monitoring quarters and baseline data
- an evaluation of the critical action levels for hydroperiod and vegetation

13.6.4 Potential Mitigation Measures

If there are impacts to the hydroperiod or vegetation of wetlands or manmade lakes that exceed the critical action levels, then FDEP would be contacted to determine if a mitigation plan needs to be implemented. If FDEP notifies Lockheed Martin that a mitigation plan is required it shall be submitted to FDEP for review and approval within 30 days of the notification. If there are impacts to the hydroperiod or vegetation of wetlands that exceed the critical action levels within the plume area, possible mitigation would be augmentation of the groundwater with treated water that has met FDEP approval or Floridan aquifer groundwater from a newly drilled well. If there are impacts to the hydroperiod or vegetation of a wetland or man-made lake that exceed the critical action levels outside the plume area, but within the cone of depression, possible mitigation would be augmentation of the groundwater from newly drilled local Floridan aquifer well(s) with treated water that has met FDEP approval.

13.7 Monitoring Reports

As discussed in Sections 13.2 through 13.4 and shown in Table 12-1, groundwater monitoring data and groundwater treatment process data will be summarized in the remedial action status report entitled operation, maintenance and monitoring (OMM) report to be submitted to FDEP. The OMM Report will be provided at least annually as required by Rule 62-780.700(13) F.A.C. and will include the following:

- A summary of the data requested in Rule 62-780.700(12)(a) through (k), F.A.C., as applicable. These items include:

a) Water level data collected from all designated wells, piezometers, and staff gauge locations each time monitoring wells and recovery wells are sampled.

b) If encountered, the total volume of free product recovered and the thickness and horizontal extent of free product during the reporting period until free product recovery is completed. As noted in this RAP Addendum and earlier reports, free product has never been encountered and is not expected; however, if it is encountered in the future, details of its presence will be reported.

c) Total volume of groundwater recovered from each recovery well during each month of the operating period for the first year and quarterly thereafter.

d) Concentrations of applicable contaminants based on analyses performed on the effluent from the groundwater treatment system, daily for the first three days with a 24-hour turnaround on analytical results of the samples collected the first two days, weekly for the next three weeks, monthly for the next two months and quarterly thereafter. Applicable contaminants include the COCs in all effluent samples. Concentrations of metals required by the MCUO permit will also be reported quarterly.

e) Concentrations of applicable contaminants based on analyses performed on the untreated groundwater from individual recovery wells and trenches, weekly for the first month, monthly for the next two months, quarterly for the next two years, and semiannually thereafter. Applicable contaminants include the COCs.

f) Analytical data from all monitoring wells sampled during the remediation year to monitor rehabilitation progress during active remediation, including all applicable information required by Rule 62-780.300(2), F.A.C.

g) Operational parameters for *in situ* systems (not applicable to this RAP Addendum as no *in situ* systems are proposed)

h) Operational parameters for biological systems (not applicable to this RAP Addendum as no biological systems are proposed)

i) Concentrations of recovered vapors from a vacuum extraction system (not applicable to this RAP), and post-treatment air emissions if air treatment is provided, weekly for the first month, monthly for the next two months, and quarterly thereafter; influent and effluent samples will be monitored for contaminants using appropriate analytical methods pursuant to Chapter 62-160, F.A.C.

j) Percentage of system operation time and treatment efficiency for all operating treatment systems including the dates when the Site was visited and whether the system was operating upon arrival at the Site and upon departure from the Site

k) Results of analyses of soil samples taken to verify that the applicable NFA or NAM criteria are met (not applicable to this RAP as NFA or NAM are not being sought as active soil remediation is not being conducted)

- All applicable information required by Rule 62-780.300(2), F.A.C., specifically:

a) Laboratory reports that include all information specified in Rule 62-160.340(2), F.A.C., and are in the format specified in Chapter 62-160, F.A.C. (Soil analytical results shall be reported on a dry-weight basis.)

b) Copies of the completed chain of custody record form(s) [Form 62-780.900(3) or an equivalent chain of custody form that includes all the items required by Form 62-780.900(3)]

c) Copies of the completed chain of custody record form(s) [Form 62-780.900(3) or an equivalent chain of custody form that includes all the items required by Form 62-780.900(3)]Copies of the completed water sampling log form(s) pursuant to Chapter 62-160, F.A.C.

Results from screening tests or on-site analyses including:

- Conclusions as to the effectiveness of the active remediation for the specified period covered in the status report.
- Recommendations to continue or discontinue the operation of the treatment system.

- A completed Form 62-780.900(5), summarizing the information from annual remedial action tasks.
- Graphs of groundwater COC concentrations versus time for select monitoring locations.

Further details provided in the annual OMM reports will include:

- Measurements and analytical data will be provided in summary tables
- Groundwater elevation contour maps
- Maps posting groundwater COC analytical results in the USAS, LSAS, AF Gravels and S&P Sands monitoring wells
- Actual capture zones of the RAP will be estimated by contouring groundwater elevation data and determining the location of hydraulic stagnation points, and shown on Site maps
- COC mass removal rates will be estimated and tabulated

Analysis of the data and figures listed above will be provided. Any recommendations to modify the operation of the Facility will also be provided and the recommendations will be based on, but not limited to, the analysis of the data above, if warranted.

14. RAP Implementation Timeline

A timeline of implementation has been developed for the principal milestones necessary to achieve an operational remedy.

Duration After Prior Activity	***Activity***
Start date	RAP approval
3 months	Bidding and contractor selection
3 months	Pre-construction planning and contractor Mobilization (permits, work plans, utility clearances, etc.)
18 months	Construction
2 months	System startup and testing

This schedule results in a total estimated timeframe of 26 months from RAP approval to have the proposed remedy operational and begin the RAP monitoring program as detailed on Table 12-1.

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