CORRECTIVE MEASURES STUDY REPORT

FOR

COMPLIANCE CLEANUP SITES CC-A11 AND CC-A12

FORT BELVOIR, VIRGINIA

DEPARTMENT OF THE ARMY
U.S. ARMY GARRISON, FORT BELVOIR
DIRECTORATE OF PUBLIC WORKS
ENVIRONMENTAL AND NATURAL RESOURCES DIVISION
FORT BELVOIR, VA 22060

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FORT BELVOIR, VIRGINIA

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L ....micrograms per liter
amsl..................above mean seal level
bgs....................below ground surface
BMP..................Best Management Practice
CC ....Compliance Cleanup
CERCLA...........Comprehensive Environmental Response, Compensation, and Liability Act
CFR ....Code of Federal Regulations
CMA ....Corrective Measures Alternative
CMI...................Corrective Measures Implementation
CMIWP.............Corrective Measures Implementation Work Plan
CMO ....Corrective Measures Objective
CMS ....Corrective Measures Study
COI ....Contaminant of Interest
DCE..................Dichloroethene
DCR-NHP.........Department of Conservation and Recreation, Natural Heritage Program
DERP ....Defense Environmental Restoration Program
DHC..................*Dehalococcoides sp*
DNAPL ....Dense Non-Aqueous Phase Liquid
DO ....Dissolved Oxygen
DoD ....Department of Defense
ET.....................Evapotranspiration
FBNA................Fort Belvoir North Area
ft ....foot/feet
FTBL.................Fort Belvoir
H_2......................Hydrogen
INRMP..............Integrated Natural Resources Management Plan
ISCO.................In Situ Chemical Oxidation
ISEB ....In Situ Enhanced Bioremediation
LEL ....Lower Explosive Limit
LFG ....Landfill Gas
LTM ....Long-Term Monitoring
LUC ....Land Use Control
LUCIP...............Land Use Control Implementation Plan
MCL..................Maximum Contaminant Level
MNA ....Monitored Natural Attenuation
MRS ....Munitions Response Site
MSW.................Municipal Solid Waste
mV ....millivolts
NPDES.............National Pollutant Discharge Elimination System
NRCS ....Natural Resource Conservation Service
O&M ....Operation and Maintenance
O_2 ....Oxygen
ORP..................Oxidation-Reduction Potential
PCE ....Tetrachloroethene
POL ....Petroleum, Oil, and Lubricants
PRB ....Permeable Reactive Barrier
PtR ....Proton Reduction
RCRA ....Resource Conservation and Recovery Act
RFA ....RCRA Facility Assessment
RFI....................RCRA Facility Investigation
RGO ....Remedial Goal Option
Shaw ....Shaw Environmental, Inc.
SVE ....Soil Vapor Extraction

SWMU..............Solid Waste Management Unit
TCE..................Trichloroethene
TOC..................Total Organic Carbon
US EPA............U.S. Environmental Protection Agency
USACE.............U.S. Army Corps of Engineers
USCS...............Unified Soil Classification System
VC....................Vinyl Chloride
VDEQ...............Virginia Department of Environmental Quality
VDGIF..............Virginia Department of Game and Inland Fisheries
VOC..................Volatile Organic Compound
VSI....................Visual Site Inspection
WWTP..............Wastewater Treatment Plant
ZVI....................Zero Valent Iron

EXECUTIVE SUMMARY

This report presents the results of the Corrective Measures Study (CMS) performed at Compliance Cleanup (CC) sites CC-A11 and CC-A12 located at U.S. Army Garrison Fort Belvoir (FTBL) located in southeastern Fairfax County, Virginia.

The Poe Road Landfill (CC-A11) and Accotink Landfill (CC-A12) are inactive, covered sanitary and construction debris landfills located adjacent to each other within the Accotink Bay Wildlife Refuge directly south of Poe Road. The Poe Road landfill operated from 1967 to 1977 and the Accotink Landfill operated from 1956 to 1973. Both landfills were closed with a soil cover generally at least 2 feet (ft) thick, but slightly less in some areas as measured during the Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI). Due to their mutual proximity, CC-A11 and CC-A12 are being addressed as a single site encompassing approximately 40 acres.

Current and reasonably anticipated future land-use conditions were evaluated via a human health risk screening during the RFI, which found no potential concerns for residential and industrial exposure to soil (surface and subsurface), sediment, and surface water. The risk evaluation did reveal unacceptable risk results for groundwater with tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride (VC) as the primary concern. The risk evaluation conservatively evaluated exposure to groundwater as a tap water source in accordance with the corrective action module of FTBL's Part B Hazardous Waste Permit (VA7213720082) Module IV (Attachment/Section KK—Hazardous Constituent Sampling List and Risk Based Concentration Screening). However, groundwater is not used as a tap water source at FTBL. The ecological risk screening evaluation identified no risks to ecological receptors.

The following corrective measures objectives (CMOs) were developed for the site to address landfill waste and contaminants in groundwater at CC-A11 and CC-A12, located within the sensitive habitat of the Accotink Bay Wildlife Refuge:

- Reduce infiltration of surface waters into the waste, thereby reducing leachate production;
- Isolate the wastes from receptors (i.e., humans, animals, environment) and control movement by wind or water;
- Control landfill gas (LFG) and odor emissions;
- Promote surface water runoff, and minimize erosion;
- Remain effective for at least 30 years;
- Be protective of endangered, threatened, and sensitive species and habitat;
- Utilize Best Management Practices (BMPs) of U.S. Environmental Protection Agency's (US EPA) defined core elements of green remediation;
- Prevent use of groundwater containing PCE, TCE, or VC in concentrations exceeding maximum contaminant levels (MCLs); and,
- Contain the PCE, TCE, and VC solute plume to below MCLs at the point of compliance (defined as Accotink Creek) within 30 years. It should be noted that this CMO appears to have already been met based on RFI sampling.

All potential technologies that may be used to achieve the CMOs were identified and preliminarily evaluated for potential further consideration as part of corrective measures alternatives (CMAs). Upon consideration of various containment technologies, the existing forested cover at CC-A11 and CC-A12 was acknowledged to be performing at least to some degree as an evapotranspiration (ET) cover that relies on minimization of vertical infiltration of water via enhanced evaporation and transpiration of rainfall. The soil and vegetative mass captures and temporarily stores precipitation, then releases the water back to the atmosphere either by transpiration through vegetation or by direct evaporation from the soil and vegetative surfaces. ET covers have been demonstrated and well documented to be effective and reliable cover systems that have been installed at more than 200 landfill sites across the U.S. Further, ET cover systems have been found effective in phytoremediation of volatile organic compounds (VOCs), metals, pesticides, solvents, explosives, crude oil, polycyclic aromatic hydrocarbons, and landfill leachates (US EPA, 1999).

With consideration of the existing forested cover, four CMAs were developed and evaluated to address landfill waste and groundwater at CC-A11 and CC-A12, as follows:

- Alternative 1 – No Action includes no proposed measures to be employed at CC-A11 and CC-A12. It is evaluated to provide a baseline for comparison.
- Alternative 2 – Engineered RCRA Cap System, Long-Term Monitoring (LTM), Monitored Natural Attenuation (MNA), and Land Use Controls (LUCs) includes:
  - Removal of all vegetation within the entire landfill limits (see **Figures 5-3 and 5-4**);
  - Addition of select fill and re-grading of landfill surface to attain required sloping for surface water runoff;
  - Placement of low permeability soil and topsoil to achieve the minimum 24-inch thickness;
  - Restoration of vegetation;
  - LFG venting;
  - LUCs to protect the cover system and contained waste;
  - Groundwater monitoring for MNA; and,
  - LTM to verify cover and LUC effectiveness.
- Alternative 3 – Engineered ET Cover System, LTM, MNA, and LUCs includes:
  - Removal of all vegetation within the delineated limits of landfill soil cover thickness measuring less than 24 inches (see **Figures 5-5 and 5-6**);
  - Placement of select fill, as required, and topsoil to achieve the minimum 24-inch soil cover thickness;
  - Restoration of native vegetation in disturbed areas to achieve a modeled water budget to minimize infiltration of rainfall into waste;
  - LFG venting;
  - LUCs to protect the cover system and contained waste;
  - Groundwater monitoring for MNA; and,
  - LTM to verify cover and LUC effectiveness.
- Alternative 4 – Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs includes:
  - Delineation of areas within landfill limits with no vegetation or insufficient vegetation (see **Figures 5-7 and 5-8**) for preliminary determination);
  - Removal or relocation of existing vegetative debris in vegetative enhancement areas;
  - Enhancement of existing soils in vegetative enhancement areas either by addition or amendment;
  - Planting of native trees and groundcover;
  - LFG venting;
  - LUCs to protect the cover system and contained waste;
  - Groundwater monitoring for MNA; and,
  - LTM to verify cover and LUC effectiveness.

All alternatives (other than No Action) utilize MNA to achieve CMOs for groundwater. Samples collected for MNA will be evaluated to determine if natural attenuation through reductive dechlorination, phytoremediation, dispersion, dilution, volatilization, and sorption is occurring at a sufficient rate. There currently is limited data available for MNA, but the anaerobic conditions and presence of breakdown products suggest that natural attenuation processes are occurring. The CMO of containing the plume to below MCLs at Accotink Creek within 30 years appears to have already been met based on RFI sampling. Therefore, MNA is the only groundwater technology included with the alternatives.

In compliance with the FTBL RCRA permit and the RCRA Subpart S guidance documents, each of these four alternatives was evaluated according to the following considerations:

- Control of the sources of releases so as to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment;
- Overall protection of human health and the environment;
- Compliance with standards and criteria for all media based on state and federal regulations and requirements;
- Long-term reliability and effectiveness, including an evaluation of the persistence, toxicity, and mobility of the hazardous substances and constituents, and their propensity to bioaccumulate;
- Short-term effectiveness and potential for human exposure;
- Feasibility of using the technology;
- Capital and Operation and Maintenance (O&M) Costs; and,
- State, US EPA, and community acceptance.

As summarized in **Table 6-1**, Alternatives 2, 3, and 4 all control source releases, comply with standards and criteria, provide long-term effectiveness, and are feasible to implement. However, the removal of mature forested areas in Alternative 3 poses a concern regarding the root systems of the trees. Removal of the root systems is not recommended due to the potential for disturbing and exposing buried waste. Leaving them in place poses a concern regarding decomposition of the roots, subsidence of the cover, ponding of water, and preferential infiltration pathways.

Alternatives 2, 3, and 4 all contribute some short-term impacts to the environment associated with removal of vegetation and associated disruption of wildlife habitat and impacts to traffic. However, the extent of disturbance varies greatly, with Alternative 2 disturbing approximately 70 acres to install the RCRA cap, Alternative 3 disturbing approximately 20 acres of partly forested area to add fill, to Alternative 4 disturbing approximately 10 poorly vegetated acres. The smaller and less vegetated footprint of construction for Alternative 4 will:

- Reduce disturbance to site soils, vegetation, and ecosystems/habitats;
- Reduce the footprint of existing cover temporarily destabilized, thereby reducing the volume of surface water infiltration that would occur until re-vegetation matures;
- Reduce potential disturbance of landfill waste;
- Reduce noise and air emissions generated by heavy earthmoving equipment, and site traffic volumes;
- Reduce potential impacts to nearby water bodies including sedimentation, nutrient loading, and overall water quality;
- Require less material consumption (e.g., equipment fuel and oil, soils and soil amendments imported from off-site sources, new trees and shrubs from off-site sources, water, etc.); and,
- Reduce waste generation (e.g., clearing/grubbing debris, field supplies, etc.).

The smaller footprint of construction associated with Alternative 4 supports many BMPs outlined in the US EPA's *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (US EPA, 2008). Alternative 4 will also be more feasible to implement in regards to obtaining permits to perform construction in wetlands and sensitive environmental habitats. Further, Alternative 4 is not anticipated to pose issues with long-term effectiveness since the existing landfill covers have become generally well vegetated and both appear to have met performance standards for containment since the landfills ceased operations in the 1970s.

The capital and 30-year present value costs to implement Alternative 4 are also lower than Alternatives 2 and 3, as shown below. The O&M costs are primarily for groundwater sampling to support MNA, and are assumed to continue annually for 30 years which may not be necessary given that groundwater currently meets CMOs.

CC-A11 and CC-A12	**1**	**2**	**3**	**4**
	No Action	**Engineered RCRA Cap, LTM, MNA, and LUCs**	**Engineered ET Cover System, LTM, MNA, and LUCs**	**Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs**
Capital Cost	$0	$13.7M	$1.9M	$1.1M
O&M Costs	$0	$1.4M	$1.4M	$1.4M
Total Present Worth	$0	$14.8M	$3.0M	$2.2M

In consideration of these criteria, Alternative 4 Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs is the preferred alternative to address landfill waste and groundwater at CC-A11 and CC-A12. Compared to Alternatives 2 and 3, this alternative provides the best combination of control of source releases, protection of human health and the environment, long-term reliability, and short-term effectiveness. It meets CMOs, complies with applicable standards, is the most feasible to implement and has the lowest cost.

1.0 INTRODUCTION

Shaw Environmental, Inc. (Shaw), a CB&I company, was tasked by the U.S. Army Corps of Engineers (USACE), Baltimore District to perform a Corrective Measures Study (CMS) at Solid Waste Management Unit (SWMU) A-11 (Poe Road Landfill) and A-12 (Accotink Landfill) at U.S. Army Garrison Fort Belvoir (FTBL) located in southeastern Fairfax County, Virginia (**Figure 1-1**). This work was performed under Contract No. W912DR-10-D-0014, Delivery Order 02.

The U.S. Army Garrison FTBL is evaluating these sites and other locations on the Main Post identified in the Resource Conservation and Recovery Act (RCRA) Hazardous Waste Permit (VA7213720082) Module IV, issued by the Commonwealth of Virginia, Department of Environmental Quality (VDEQ). This process required the performance of a RCRA Facility Investigation (RFI) to investigate evidence of releases of hazardous substances at SWMUs identified in the permit and other areas of concern. Based on the results of the Phase I RFI (Tidewater, 2009, 2010) and Phase II RFI (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011a,b) performed for SWMU A-11 (Poe Road Landfill) and A-12 (Accotink Landfill), a CMS was recommended for both sites. SWMU A-11 and SWMU A-12 are hereafter referred to by their Army Environmental Database – Restoration module names as Compliance Cleanup (CC) sites CC-A11 and CC-A12, respectively.

1.1 CMS PURPOSE

The purpose of this CMS is to fulfill the requirements of the RCRA corrective action process and meet Department of Defense (DoD) and Army requirements as specified in Defense Environmental Restoration Program (DERP) guidance documents (DoD, 2012; U.S. Army, 2004). Specifically, as stated in the final RCRA corrective action plan (US EPA, 1994), the CMS shall "identify and evaluate potential remedial alternatives for the releases that have been identified at a facility." This CMS report builds on the results of the Phase I and Phase II RFIs performed at CC-A11 and CC-A12. CC-A11 and CC-A12 are both inactive landfills which are reported to have received municipal waste and construction debris.

1.2 CMS APPROACH

The following approach is utilized in this CMS report to meet the purpose stated above:

- Discuss the current conditions, site history, site description, and summary of previous investigations. This information was presented in detail in the Phase II RFI reports for CC-A11 and CC-A12 (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011a,b), and is summarized in Section 2.0 of this CMS.
- List the corrective measures objectives (CMOs). The CMOs for CC-A11 and CC-A12 are established in Section 3.0 of this CMS.
- Screen technologies that can be used to develop corrective measures alternatives (CMAs) and to meet the CMOs. The technology screen is summarized in Section 4.0 of this CMS.
- Develop the CMAs for the landfill cover system and groundwater. Based on the technology screen and the data collection, the feasible landfill cover and groundwater technologies are arranged into CMAs presented in Section 5.0.
- Perform a detailed evaluation of the CMAs and provide recommendations. Evaluations and recommendations are outlined in Section 6.0.

2.0 SITE BACKGROUND

2.1 FORT BELVOIR SITE DESCRIPTION AND HISTORY

The U.S. Army Garrison FTBL is located in southeastern Fairfax County, Virginia, approximately 15 miles southwest of Washington, D.C. FTBL's military history dates to the early 1900s, when the facility was known as Camp Belvoir and used as an Army rifle range and training camp. The post was re-named Fort Humphreys in 1922, and became Fort Belvoir in 1935. Since 1935, FTBL has supported major U.S. military operations throughout the world.

The Main Post of FTBL consists of approximately 8,200 acres situated between I-95 and the Potomac River (**Figure 2-1**). An additional 800-acre Parcel, known as the Fort Belvoir North Area (FBNA), is located west of I-95. U.S. Route 1 divides the Main Post into two distinct geographical areas, referred to as North Post and South Post. As shown on **Figure 2-1**, CC-A11 (Poe Road Landfill) and CC-A12 (Accotink Landfill) are approximately adjacent to each other and located on the western side of South Post.

FTBL's primary function has been as an administrative and logistics support center for the Army and as a host for over 100 tenant organizations from various government branches (including all branches of the armed services). It currently employs more than 39,000 civilian and military personnel with a proposed increase to 42,000 by the end of 2012, and provides support services for over 200,000 military personnel, dependents, and retirees in the region.

2.2 POE ROAD LANDFILL (CC-A11) SITE HISTORY AND OPERATIONS

CC-A11, also known as the Poe Road Landfill, was first identified in 1988 during the RCRA Facility Assessment (RFA) conducted by A.T. Kearney (1988) and was found to include approximately 20 acres. Based on historical aerial photographs, the area was in use for multiple purposes from 1937 until 2007. Initially, the southern portion was used for the target and impact area of the Accotink Creek Range which was active from 1944 until approximately 1962. SWMU A-11 is documented to have received municipal waste and construction debris only. Waste was received at CC-A11 between 1967 and 1977; and, debris was placed in below grade trenches and covered with soil.

2.3 ACCOTINK LANDFILL (CC-A12) SITE HISTORY AND OPERATIONS

CC-A12, also known as the Accotink Landfill, was also identified during the 1988 RFA (A.T. Kearney, 1988). The SWMU occupies approximately 20 acres which was in operation between 1956 and 1973 for the disposal of construction debris and municipal waste. This SWMU also overlaps portions of two munitions response sites (MRSs), the Grenade Court and Small Arms Range Complex. Accotink Bay and wetlands were filled with debris until ordered to stop by Congressional inquiry. The landfill operations moved up to the Poe Road Landfill (A.T. Kearney, 1988).

2.4 TOPOGRAPHY AND HYDROLOGY

As shown on **Figure 2-2**, CC-A11 (Poe Road Landfill) and CC-A12 (Accotink Landfill) are approximately adjacent to each other, directly south of Poe Road. The elevations at CC-A11 vary from approximately 145 feet (ft) above mean sea level (amsl) at the southernmost point, sloping generally to the north and east towards Accotink Creek to an elevation of 20 ft amsl at the northeast toe of the landfill along Poe Road. There are two main drainage swales located within CC-A11: one that drains the northernmost portion of the landfill, and one that bisects the landfill. There are areas of standing water reported along the bisecting drainage swale. Two natural springs have also been observed: one which percolates through a completed section of the northeastern section, and the other through the southwestern portion and discharging to the Accotink Creek drainage ditch in the vicinity of Poe Road.

Compared to CC-A11, the topography for CC-A12 is relatively flat, ranging from 50 ft amsl at a high point in the south, sloping abruptly to the southwest and southeast to 15 ft amsl, and more gradually to the northeast to 10 ft amsl. A surface water drainage feature cuts across the western side of CC-A12 and flows north across Poe Road into Accotink Creek.

For both sites, all surface water drainage eventually reaches Accotink Creek, which subsequently flows to the south and feeds Accotink Bay and ultimately the Potomac River.

2.5 SITE SOIL

The Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service) surveyed FTBL Main Post soils in 1982. The NRCS soil survey described and delineated 19 named soil series within FTBL. The survey data have been incorporated into the FTBL Geographic Information System. In addition to the 19 named soil series, there are areas of mixed waterborne sediments (Entisols) and tidal marsh (Histosols) that are not sufficiently defined to be classified as series (Horne, 2001). Of the area included in the survey, 1,898 acres are described as urban built-up, and 587 acres are cut and fill. Fill material is generally of unknown source but is likely to be material selected for high structural stability following placement.

Table 2-1 lists the soils mapped within CC-A11 and CC-A12, which consists of three distinct soil types, including keyport, matapeake, and mixed alluvium. For each soil type present, **Table 2-1** provides soil name; drainage and problem classes; whether they are highly erodible or subject to flooding; and foundation support rating. The problem class ranks the installation's soils with respect to the degree of difficulty they present in building site development, including the construction of buildings with and without basements; local roads and streets; shallow excavations; small commercial buildings; and lawns and landscaping. Soils classified as problem class A are severe and present significant, unfavorable constraints to development and require substantial design work, increased construction costs, and increased maintenance work, with lesser problems associated with classes B and C in that order. Each class is further defined below.

Table 2-1
CC-A11 and CC-A12 Soils

Soil Name (series-phase)	Drainage Class	Problem Class	Highly Erodible	Flooding	Foundation Support
Keyport	MWD	B	No	No	Fair
Matapeake	WD	C	Yes	No	Generally favorable
Mixed Alluvium	PD	A	No	Yes (Jan-Dec)	Poor

MWD = Moderately Well Drained
PD = Poorly Drained
WD = Well Drained

2.5.1 Site Soils at CC-A11

The results of the Phase I RFI soil boring investigations for CC-A11 (Tidewater, April 2010) indicate the following two soil stratum encountered from top down just outside the landfill boundaries at CC-A11:

- Stratum I – encountered in all soil borings, described as native material, occurring at ground surface to a depth ranging from approximately 8 to 14 ft below ground surface (bgs), and comprised of clay and silt matrices with varying amounts of sand and gravel. The Unified Soil Classification System (USCS) classifications given range from ML to SC with colors ranging from brownish yellow to gray to greenish gray.
- Stratum II – encountered in all soil borings, described as native material, occurring at a depth ranging from approximately 8 to 14 ft bgs and terminating at a depth of approximately 25 ft bgs, and comprised of clayey fine to medium sands. The USCS classifications given range from CL to SC with colors ranging from pale brown to gray and greenish gray.

2.5.2 Site Soils at CC-A12

The results of the Phase I RFI soil boring investigations for CC-A12 (Tidewater, October 2009) indicate the following three soil stratum encountered from top down just outside the landfill boundaries at CC-A12:

- <u>Stratum I</u> – encountered in all soil borings, occurring at ground surface to a depth ranging from approximately 6 to 10 ft bgs, and comprised of clay, silt and sand matrices with varying amounts of sand and gravel. The USCS classifications given ranges from OL to CL to SC to SW with colors ranging from brownish yellow to dark brown to gray and greenish gray.
- <u>Stratum II</u> – encountered in all soil borings, described as native material, occurring at a depth ranging from approximately 6 to 10 ft bgs and terminating at a depth of approximately 24 ft bgs, and comprised of clayey fine to medium sands, and sandy clays. The USCS classification given ranges from CL to SC to SM with colors ranging from brown to greenish gray to olive brown.
- <u>Stratum III</u> – encountered in two soil borings (A12-SB04, and -SB07), occurring at a depth of approximately 14 ft bgs and terminating at boring depth of 25 ft bgs, and comprised of fine to medium sands with some gravels. The USCS classification given ranges from SC to SW with colors ranging from greenish gray to bluish gray.

2.6 SITE GEOLOGY

Fairfax County is divided into two physiographic provinces: the Coastal Plain and the Piedmont Plateau (Hobson, 1996). The fall line, which runs north to south through Virginia, crosses Fairfax County and forms the boundary between the resistant, metamorphic rocks of the Piedmont and the softer, sedimentary rocks of the Coastal Plain (Terwilliger, 1991).

FTBL's Main Post lies below the fall line within the high and low Coastal Plain Terraces of the Coastal Plain Physiographic Province, which are two of the five Fairfax County province subsections. There are several geologic formations associated with the Coastal Plain Physiographic Province, including the Potomac Formation, Bacons Castle Formation, Shirley Formation, and Alluvium and Pliocene sand and gravel (Hobson, 1996). The Potomac Formation outcrops along the slopes leading down to the Potomac River shoreline on the Main Post.

The Coastal Plain Physiographic Province consists of unconsolidated sand, silt, and clay underlain by residual soil and weathered crystalline rocks. Most of the Coastal Plain Physiographic Province deposits in the FTBL area consist of a sequence of unconsolidated sediments that belong to the Potomac Group (Hobson, 1996). The Potomac Group is characterized by lens-shaped deposits of interbedded sand, silt, clay, and gravel, primarily of non-marine origin. The Potomac Group is approximately 600 ft thick beneath most of FTBL (Law Engineering and Environmental Services, 1995, as cited in DIS-ENRD, 2001a).

FTBL's uplands are underlain by sands, silts, and clays of riverine origin. Uplands underlain by sands and silts tend to be more stable than those underlain by clays. Uplands that are underlain by clayey soils form undulating and rolling hills where the dominant land-forming process is mass wasting, which includes downhill creep, landslides, slumping, and rockfalls. Lowlands and valley bottoms are typically underlain with sediments deposited by moving water (Horne, 2001). The dominant land-forming process in these lower areas is active riverine erosion and deposition during overbank flooding. Surface drainage is commonly poor due to the shallow water table. Drainage usually occurs as surface runoff, with runoff greatest on the steeper slopes. The extent of runoff increases with construction activity and the removal of vegetation, which in turn increases the rate of erosion and the probability of creep and slumping.

Soil borings advanced during previous investigations at CC-A11 consisted of clay and silt matrices with varying amounts of sand and gravel (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011a). At CC-A12, soils consisted of silts and sands to clays with varying amounts of gravel (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011b). Homogeneous non-native soils were also encountered at both SWMUs and were apparently used as landfill cap material.

2.7 SITE HYDROGEOLOGY

FTBL is located near the northeastern-trending physiographic boundary known as the Fall Line that separates the eastern edge of the Appalachian Piedmont Upland Province and the western edge of the Atlantic Coastal Plain Province (IT Corporation, 1990). The Piedmont Province consists primarily of Precambrian metamorphic and Cambrian igneous rock formations, whereas the Coastal Plain is characterized by softer sedimentary formations.

Drainage usually occurs as surface runoff, with runoff greatest on the steeper slopes. Limited extent water bearing aquifers have been detected at various locations at FTBL (A.T. Kearney, 1988). The perched aquifers vary greatly in size and distribution due to more permeable localized lithology. The groundwater flow patterns for these localized unconfined perched aquifers (when present) are expected to generally follow surface water drainage.

FTBL is underlain by three subsurface aquifers: Lower Potomac, Middle Potomac, and Bacons Castle Formation. These three aquifers are within the Potomac Group and consist of unconsolidated sediments characteristic of the Coastal Plain. The Lower Potomac aquifer, the primary aquifer in eastern Fairfax County, contains potable water below FTBL. This aquifer is approximately 100 ft thick and is located approximately 100 ft deep in the FTBL Area (A.T. Kearney, 1988). The aquifer lies between a layer of crystalline bedrock and a clay wedge containing sandy clays and interbedded layers of sand. The aquifer is recharged by surface infiltration north and west of FTBL and regional flow is to the southeast.

The Middle Potomac aquifer consists of interbedded lenses of differing thicknesses of sand, silt, and clay, but its confining unit is not present in the vicinity of FTBL. The Bacons Castle Formation is the shallowest aquifer of the three. It receives recharge from and discharges to surface water bodies on the installation.

Based on regional hydrogeology information and the data obtained from the Phase II RFI investigation, the water table aquifer at CC-A11 and CC-A12 is likely a laterally perched aquifer. **Figure 2-3** illustrates the groundwater elevations for both sites. Groundwater at CC-A11 was found to be located approximately 4 to 29 ft below ground (12 to 37 ft amsl) and flowing to the northeast towards Accotink Creek. At CC-A12, groundwater was identified at 1 to 22 ft below ground (2 to 17 ft amsl) and flowing to the northeast and east toward Accotink Creek.

2.8 ENDANGERED, THREATENED, AND SENSITIVE SPECIES

CC-A11 and CC-A12 are located within the Accotink Bay Wildlife Refuge which is home to many sensitive species present at FTBL.

According to the FTBL Integrated Natural Resources Management Plan (INRMP) (DIS-ENRD, 2001a), there is one federally listed threatened/state-listed endangered animal species (bald eagle), one federally listed threatened species (Small Whorled Pogonia), one state-listed endangered species (peregrine falcon), and one state-listed threatened species (wood turtle) known to be present at FTBL. Additionally, seven Virginia state rare animal species and four Virginia state rare plant species have been identified on the Installation. The inventory also identifies 16 state watch-list animal species and three state watch-list plant species. Two additional state-listed threatened species have been sighted historically on FTBL, but were not identified during the three most recent annual bird surveys conducted prior to publication of the INRMP. Of these, all inhabit FTBL except the peregrine falcon, which migrates through the area seasonally. The INRMP also lists 128 Virginia and Natural Heritage ranked species that occur on the installation.

Bald eagle populations have continued to grow in Virginia and across the country. The bald eagle was removed from the Federal List of Endangered and Threatened Wildlife in the contiguous 48 states on June 28, 2007. The continued recovery of bald eagle populations in Virginia led the Virginia Department of Game and Inland Fisheries (VDGIF) to remove the bald eagle from the Virginia state list of threatened and endangered species effective January 1, 2013.

The Small Whorled Pagonia (*Isotria medeoloides*) is federally listed as a threatened species and also Virginia state-listed as endangered. The species is a member of the orchid family and grows between 10 and 14 inches tall depending on the time of year, 10 inches when flowering and 14 inches when bearing fruit (USFWS, 2011). The species can be found in 17 eastern states and parts of Canada. Preferred habitat consists of older stands of mature hardwoods, such as beech, birch, maple, oak, and hickory, with a relatively open understory.

The wood turtle (*Clemmys insculpta*) is a state-listed threatened species found primarily in mesic deciduous woodlands in and near clear creeks in Fairfax County. The wood turtle is very mobile and is a highly terrestrial species that typically uses creeks for hibernacula and mating (DIS-ENRD, 2001a). In 1998, two wood turtles were observed on FTBL, a female along Dogue Creek near the Jackson Miles Abbott Wetland Refuge, and a male along Accotink Creek near U.S. Route 1. In 1999, a different male was observed along Accotink Creek in the Accotink Bay Wildlife Refuge Huntley Meadows Park, to the northeast of the Jackson Miles Abbott Wetland Refuge. This Refuge has a population of wood turtles that has been monitored for several years. The recent sightings of three different individuals within the Dogue Creek and Accotink Creek corridors on FTBL indicate that this species is established on post (DIS-ENRD, 2001a).

The peregrine falcon (*Falco peregrinus*) is a state-listed endangered species. The peregrine falcon occurs along the Accotink Creek/Accotink Bay stream corridor during fall migration. This area of FTBL provides valuable foraging habitat for migratory falcons. Falcons have been recorded on FTBL during the last three fall migrations (DIS-ENRD, 2001b).

In accordance with the FTBL INRMP, localized rare species studies may be needed to support specific installation projects. The results of these surveys are coordinated with the VDGIF and Department of Conservation and Recreation, Natural Heritage Program (DCR-NHP), and maintained in the FTBL installation GIS. A biological survey is assumed to be required for all Alternatives involving vegetative removal activities to assess for the presence of sensitive species, particularly the Small Whorled Pagonia and wood turtle.

2.9 CC-A11 AND CC-A12 PREVIOUS INVESTIGATION FINDINGS

Five previous studies and/or investigations have been conducted at the site. In 1998, A.T. Kearney conducted an RFA at the site to evaluate releases of hazardous waste or hazardous waste constituents and to implement corrective actions as necessary. A SWMU Study was conducted in 1992 by CH2M HILL. A Visual Site Inspection (VSI) for the Main Post was conducted by Tetra Tech in September 2005 and document in the VSI Report (Tetra Tech, 2008). The VSI indicated that environmental investigations were warranted for CC-A11 and CC-A12, and FTBL conducted a Phase I RFI at the site in 2009. As a result of the Phase I RFI recommendations, a Phase II RFI was conducted in 2011.

2.9.1 RCRA Facility Assessment, A.T. Kearney, 1988

In 1988, the U.S. Environmental Protection Agency (US EPA) contracted A.T. Kearney to perform a Phase II RFA at FTBL. This facility assessment identified 202 SWMUs at FTBL Main Post and FBNA. The RFA identified Sites A-11 and A-12 as being SWMUs, which can be defined as any discernible waste management unit at a RCRA facility from which hazardous constituents might migrate, regardless of whether the unit was intended for the management of solid and/or hazardous waste (CH2M HILL, 1992).

SWMU A-11 was described in the RFA as a 20-acre unit which managed both construction debris and municipal waste from 1968 until 1977. No records of releases prior to the RFA were identified. During the RFA, a leachate seep was observed at the eastern landfill boundary; and, an installation representative reported that seeps were common at all facility landfills. The RFA noted that natural springs flowed through northeastern and southwestern portions of the closed landfill, both draining into a ditch that ultimately discharged to Accotink Creek.

SWMU A-12 was also identified as a 20-acre unit which received construction debris and municipal waste. This landfill was in use from 1956 until 1973. Although the landfill reportedly accepted only non-hazardous waste, the RFA reported that material uncovered in 1975 indicated that hazardous constituents may also have been disposed of at SWMU A-12. Additional information on the nature of hazardous material uncovered was not provided in the RFA. An undated release of spontaneously igniting substance occurred during grading operations and was pushed into Accotink Creek. No additional information was provided.

Results of the RFA determined that further investigation of SWMUs A-11 and A-12 was warranted.

2.9.2 Solid Waste Management Unit Study, CH2M Hill, 1992

Because FTBL was an “interim status” RCRA facility, it was subject to the corrective action program. CH2M HILL was tasked to conduct a study to identify SWMUs and to review the draft RFA prepared by US EPA Region III. The main objective of the SWMU Study was to review and verify the information provided in the RFA SWMU descriptions, conduct a site visit to each of the SWMUs, and make preliminary determinations about the need for further action including; additional sampling, the need for an RFI, or source/contaminant removal. The CH2M HILL study resulted in the addition of 24 newly identified SWMUs, bringing the total number of SWMUs at FTBL to 248.

No releases or seeps were observed around the perimeter of the A-11 landfill during the August 1991 site visit. During the October 1991 site visit conducted at A-12, the area had become heavily vegetated and contained hiking trails. A surrounding pine forest was considered to represent the approximate horizontal extent of waste. The wet areas and area in proximity to Accotink Creek did not show signs of having been impacted (i.e., discoloration).

As a result of the SWMU Study, an RFI was recommended at SWMUs A-11 and A-12 as a result of site conditions, the potential presence of hazardous constituents, and a documented release at A-12.

2.9.3 Visual Site Inspection Report Main Post, Tetra Tech, 2008

A VSI was conducted by Tetra Tech to determine current conditions at SWMUs on the Main Post. A site inspection team prepared a site description of each SWMU by reviewing historical documentation, identifying site features, past use, known releases, previous studies, and chemicals of concern. This information was reviewed and a summary of recommendations was developed for each SWMU, as documented in the 2008 report (Tetra Tech, 2008).

The VSI for SWMU A-11 was conducted in September 2005 and the vegetation was identified as a mix of old field vegetation and dense thickets of trees (Virginia pine, black locust, and various hardwoods). Surface debris was not observed and the landfill cover was reported to be stable without significant erosion. No stained soils or unusual odors were recorded. The VSI documented the results of previous investigations, including the observation of leachate in 1973 from the then active landfill and despite (unknown) corrective measures a small amount of leachate was still observed in 1984.

The VSI of SWMU A-12 was conducted in September 2005 and the vegetation was identified as a mix of old field vegetation and areas of trees (loblolly pine and black locust). The VSI site description of SWMU A-12 confirmed that Grenade Court (FTBL-007-R-01) and Small Arms Range Complex (FTBL-001-R-01) MRSs were previously located at this site. Historical aerial photographs reviewed during the VSI identified petroleum, oil, and lubricants (POL) storage on either side of the landfill entrance and four large tanks with berms were located at the south side of Poe Road: one tank on the west side of the entrance and the other four on the east side. No tanks were observed during the site visit; although, concrete debris was identified to the west of the entrance and scattered throughout the site.

The VSI recommended that further environmental investigations were warranted for SWMUs A-11 and A-12.

2.9.4 Phase I RCRA Facility Investigation Reports

Based on previous investigations, FTBL conducted Phase I RFIs at SWMUs A-11 and A-12 (Tidewater, 2009, 2010). The Phase I RFI activities included the collection of soil, groundwater, surface water, and sediment samples. Each sample collected was analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds, target analyte list, and pesticides.

The Phase I soil gas survey included the installation of five landfill gas (LFG) probes at SWMU A-11 and the collection of soil gas data during three monitoring events. The Phase I RFIs at SWMUs A-11 and A-12 revealed limited impacts to soils, groundwater, surface water, and sediment. The primary contaminants of interest (COIs) are metals and chlorinated solvents in groundwater and the presence of LFGs (methane).

Based on incomplete landfill delineations and analytes detected during the Phase I RFIs, Phase II RFIs were recommended and approved by US EPA and VDEQ.

2.9.5 Phase II RCRA Facility Investigation Reports

Phase II RFIs (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011a,b) were conducted to complete the landfill delineation begun during the Phase I RFI and to evaluate soil gas, subsurface soils, groundwater, and surface soil at SWMUs A-11 and A-12. At each site, the following field activities occurred:

- Further Evaluation of Groundwater – Three monitoring wells at SWMU A-11 and four monitoring wells at SWMU A-12 were installed and sampled.
- Evaluation of LFG Migration – Three additional probes were installed at each of the SWMU A-11 and SWMU A-12 landfills, with collection of data over three monitoring rounds from all Phase I and II probes.
- Evaluation of Landfill Cap Thickness – Ten shallow borings at SWMU A-11 and 20 at SWMU A-12 were advanced on the top surface of the landfill to further evaluate the clean fill landfill cap thickness. These borings were in addition to those advanced during the Phase I RFI. At SWMUs A-11 and A-12, waste was occasionally encountered at depths of less than 24 inches.
- Further Delineation of Horizontal Limits of the Landfill – Six test pits were excavated along the southern, southeastern, and western boundary of SWMU A-11, and six test pits were excavated along the northern and southern boundaries of the SWMU A-12 landfill.

In addition, the Phase II RFIs evaluated risk to human health receptors. The human health risk ratio evaluations found that there were no potential concerns for residential or industrial exposure to soil. Risk results for groundwater are above the levels of concern. It should be noted that this is a conservative evaluation for SWMUs A-11 and A-12 because groundwater is not used as a drinking water source.

The results of the 2011 Phase II RFI LFG monitoring at SWMU A-11 indicated elevated methane (above the lower explosive limit [LEL] of 5 percent by volume) on the western boundary of the landfill in an area that abuts a steep hill. This hill may have acted as a natural buffer for potential gas migration to the west. Elevated levels on the southeastern portion of the landfill in an area that bridges into SWMU A-12 and, if so, any potential gas migration in this direction (i.e., southeast/east) would flow to SWMU A-12.

The results of the 2011 Phase II RFI LFG monitoring at SWMU A-11 identified no measurable concentrations of methane in any of the LFG probes during the three monitoring events. During the second monitoring round though, the ambient temperature was below freezing and the ground was frozen which may potentially have affected the LFG monitoring readings.

Based on the results of the Phase II RFI and human health and ecological risk screening, a CMS was recommended to address groundwater concerns and cover thickness deficiencies.

3.0 CORRECTIVE MEASURES OBJECTIVES

As described in US EPA's Advance Notice of Proposed Rulemaking: *Corrective Action for Releases from Solid Waste Management Units at Hazardous Waste Management Facilities* (US EPA 1996a), commonly known as "Subpart S," the main objective of a corrective measures program is to stabilize all releases and perform site cleanup in a timely manner, with the underlying fundamental goal of controlling or eliminating unacceptable risks to human health and the environment.

The US EPA specifies that the objective of a CMS is to identify and evaluate potential remedial alternatives (US EPA, 1996a). The US EPA advises, however, that the CMS does not necessarily have to address all potential remedies for every corrective action facility, but instead focus on realistic remedies tailored to the extent, nature, and complexity of releases and contamination at a given facility (US EPA, 1996a). US EPA expects that certain combinations of site-specific conditions be addressed by similar corrective measures approaches (presumptive remedy initiative), and by using the most practicable alternatives (US EPA, 1996a). Specifically, US EPA's expectations include the following:

- Use treatment to address principal threats such as contamination that is highly toxic, highly mobile, or cannot be reliably contained.
- Use engineering controls for wastes that can be reliably contained, pose relatively low long-term threats, or for which treatment is impracticable.
- Use a combination of methods (e.g., treatment, engineering controls and institutional controls), as appropriate, to achieve protection.
- Use institutional controls primarily to supplement engineering controls to prevent or limit exposure; institutional controls will not often be the sole corrective measure.
- Consider using innovative technology.
- When restoration of groundwater is not practicable, prevent or minimize further plume migration, prevent exposure to groundwater, and evaluate further risk reduction. Control or eliminate sources of groundwater contamination.
- Remediate contaminated soil as necessary to prevent or limit direct contact exposure, and prevent the transfer of unacceptable concentrations from soil to other media.

In cases where a presumptive remedy has been developed by US EPA, the CMS should confirm that the presumptive remedy is appropriate to the facility-specific conditions. In addition, during the CMS, one or more remedial alternatives should be evaluated based on site-specific conditions and a preferred remedial alternative selected as the remedy. As part of the CMS, performance standards, including media cleanup levels, points of compliance and compliance timeframes should be developed.

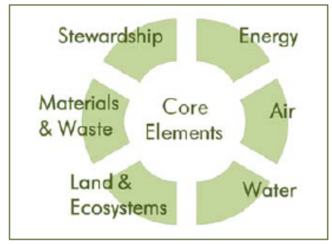
3.1 ESTABLISHMENT OF CORRECTIVE MEASURES OBJECTIVES FOR LANDFILL WASTE

This section establishes the CMOs for landfill waste at CC-A11 and CC-A12. RCRA Subtitles C and D are the controlling federal laws for closure and capping of hazardous waste and municipal solid waste (MSW) landfills, respectively, in operation after Subtitles C and D became effective. Concerning the remediation of older closed landfill units that do not meet RCRA standards, an evaluation and demonstration can be made to the US EPA for an existing or proposed alternative cover system. Municipal landfills are a type of site where treatment of the waste may be impracticable because of the size and heterogeneity of the contents. Because treatment usually is impracticable, US EPA generally considers containment to be the appropriate response action, or the "presumptive remedy," for the source areas of the landfill sites.

3.1.1 US EPA's Presumptive Remedy

US EPA's "presumptive remedy" initiative looks for remedies that are appropriate for specific site types and/or contaminants. Its objective is to streamline site investigations and make remedy selection speedier and more predictable. The Presumptive Remedy for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Municipal Landfill Sites (US EPA, 1993) was written to address CERCLA sites, but also provides useful guidance for the RCRA corrective actions at the FTBL landfills. The presumptive remedy for municipal landfill sites relates primarily to containment of the landfill mass and collection and/or treatment of LFG. In addition, measures to control landfill leachate, affected groundwater at the perimeter of the landfill, and/or upgradient groundwater that is causing saturation of the landfill mass may be implemented as part of the presumptive remedy to be protective of human health and the environment.

3.1.2 Sustainable Practices



During the evaluation of CMAs, sustainable practices, as outlined in US EPA's *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (US EPA, 2008) were considered as part of the CMS. Specifically, certain Best Management Practices (BMPs) of US EPA's defined core elements of green remediation for integration into the CMS should be considered.

- Land and Ecosystem Impacts:
  - Use minimally invasive technologies;
  - Use passive energy technologies such as bioremediation and phytoremediation as primary remedies or "finishing steps," where possible and effective;
  - Minimize soil and habitat disturbance;
  - Minimize bioavailability of contaminants through adequate contaminant source and plume controls; and,
  - Reduce noise and lighting disturbance.
- Air Emissions:
  - Minimize use of heavy equipment to reduce fuel consumption, and particulate and dust emissions;
  - Use cleaner fuels and retrofit diesel engines to operate heavy equipment, when possible;
  - Minimize land disturbance and excavations to reduce overall dust emissions;
  - Reduce atmospheric release of toxic or priority pollutants (ozone, particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead); and,
  - Minimize dust export of contaminants.
- Water Consumption and Water Quality Protection:
  - Minimize fresh water consumption and maximize water reuse during daily operations and treatment processes;
  - Reclaim treated water for beneficial use such as irrigation;
  - Avoid disturbance to existing vegetation and use native vegetation where needed to reduce need for irrigation; and,
  - Prevent impacts such as nutrient loading on water quality in nearby water bodies.
- Material Consumption and Waste Generation:
  - Use technologies designed to minimize waste generation;
  - Re-use materials whenever possible;
  - Recycle materials generated at or removed from the site whenever possible;
  - Minimize natural resource extraction and disposal; and,
  - Use passive sampling devices producing minimal waste, where feasible.

- Energy Requirements:
  - Consider use of optimized passive-energy technologies (with little or no demand for external utility power) that enable all remediation objectives to be met;
  - Look for energy efficient equipment and maintain equipment at peak performance to maximize efficiency;
  - Periodically evaluate and optimize energy efficiency of equipment with high energy demands; and,
  - Consider installing renewable energy systems to replace or offset electricity requirements otherwise met by the utility.
- Long-Term Monitoring (LTM) and Environmental Stewardship:
  - Reduce emission of CO2, N2O, CH4, and other greenhouse gases contributing to climate change;
  - Integrate an adaptive management approach into long-term controls for a site;
  - Install renewable energy systems to power long-term cleanup and future activities on redeveloped land;
  - Use passive sampling devices for LTM, where feasible; and,
  - Solicit community involvement to increase public acceptance.

3.1.3 Landfill Cover System Corrective Measures Objectives

After consideration of the US EPA's presumptive remedy guidance and sustainable practices (discussed above) as applied to CC-A11 and CC-A12 and their location within the sensitive Accotink Bay Wildlife Refuge (as discussed in Section 2.9), the primary goal of the landfill cover system for CC-A11 and CC-A12 is containment of the underlying waste mass with the following objectives:

- Reduce infiltration of surface waters into the waste, thereby minimizing leachate production;
- Isolate the wastes from receptors (i.e., humans, animals, environment) and control movement by wind or water;
- Control LFG and odor emissions;
- Promote surface water runoff, and minimize erosion;
- Remain effective for at least 30 years;
- Be protective of endangered, threatened, and sensitive species and habitat; and,
- Utilize BMPs of US EPA's defined core elements of green remediation.

3.2 ESTABLISHMENT OF CORRECTIVE MEASURES OBJECTIVES FOR GROUNDWATER

CMOs are developed in this section for contaminated groundwater at CC-A11 and CC-A12. CMOs are media-specific cleanup objectives that are developed during the CMS to protect human health and the environment. CMOs consist of site-specific, media-specific, and location-specific goals for protecting human health and the environment based upon consideration of risk-based remedial goal options (RGOs) and RCRA performance standards. CMOs facilitate consideration of all practicable remedial alternatives, and specify the following:

- Relevant exposure route(s) and receptor(s);
- COIs to be addressed; and,
- Chemical concentration limits specific to COIs, environmental media, and specific locations at the site, referred to as risk-based RGOs.

The following sections discuss RGOs and RCRA performance standards for groundwater at CC-A11 and CC-A12 and present the resulting CMOs. These CMOs provide the basis for identification, detailed analysis, and selection of corrective action alternatives.

3.2.1 Receptors and Chemicals of Concern

Current and reasonably anticipated future land-use conditions were evaluated during the Phase II RFI via a human health risk screening that included current and future industrial use (FTBL workers and contractors), in addition to potential residential use. Based upon the results of the risk ratio evaluation, there are no potential concerns for residential and industrial exposure to soil (surface and subsurface), sediment, and surface water. The human health risk evaluation determined that there are potential concerns for CC-A11 and CC-A12 groundwater; although, it should be noted that the risk evaluation conservatively evaluated exposure to groundwater as a tap water source in accordance with the corrective action module of FTBL's Part B Hazardous Waste Permit (VA7213720082) Module IV (Attachment/Section KK—Hazardous Constituent Sampling List and Risk Based Concentration Screening). However, groundwater is not used as a tap water source at FTBL.

At CC-A11, potentially unacceptable carcinogenic risk was identified, with arsenic, benzo(a)pyrene, dibenz(a,h)anthracene, tetrachloroethene (PCE), trichloroethene (TCE), and vinyl chloride (VC) as the primary contributors (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011a). However, arsenic, benzo(a)pyrene, and dibenz(a,h)anthracene only exceeded screening levels at one location, so there is no definable plume and risks from these chemicals do not represent a "site-wide" human health concern. Potential non-cancer hazard was also identified for iron and manganese; however, these metals are naturally-occurring elements and are commonly found on FTBL in excess of the screening criteria (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011a). Therefore, PCE, TCE, and VC are the COIs identified for CC-A11 groundwater. These COIs were detected primarily in the southern half of CC-A11 in wells MW04, MW06, and MW10 (see **Figure 2-2**).

At CC-A12, potentially unacceptable carcinogenic risk was identified, with arsenic, PCE, and VC as the primary contributors (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011b). However, arsenic, PCE, and VC only exceeded screening levels at one location, so there is no definable plume and risks from these chemicals do not represent a "site-wide" human health concern. Potential non-cancer hazard was also identified for cobalt, iron, and manganese; however, these are naturally-occurring elements and the concentrations found at CC-A12 are consistent to slightly higher than naturally-occurring levels (ECC, EA Engineering, Science and Technology, Inc. and Tidewater, Inc., 2011b). Therefore, there are no COIs for CC-A12 groundwater.

The ecological risk screening evaluation concluded that although metals have been detected above ecological screening criteria in surface waters, the surface water sources sampled do not represent aquatic habitats for ecological receptors, and the metals do not pose a risk to ecological receptors in surface water. None of the COIs for groundwater (TCE and VC) were detected in surface water and sediment samples that were collected during RFI sampling.

3.2.2 RCRA Performance Standards

RCRA performance standards identified for contaminated groundwater at CC-A11 and CC-A12 include drinking water regulations and health advisories (US EPA, 1996a), RCRA, and state primary drinking water regulations as amended June 7, 2004. MCLs established under the Safe Drinking Water Act are potential groundwater standards for remediation of current or potential sources of drinking water. Virginia water quality standards for groundwater are the MCLs given in the state primary drinking water regulations. Although groundwater at A-11/A-12 is not a drinking water source, nor is it likely to be, MCLs will be considered as potential remedial goals for any groundwater remedial actions (Virginia Anti-Degradation Policy, Section 9VAC25-280-30).

3.2.3 Point of Compliance

Under RCRA, the point of compliance concept provides a distinct boundary where specified levels of groundwater quality must be achieved. The point of compliance, as described in 40 CFR

264.95(a), is a “vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units.”

The hydraulically downgradient limit of the waste management area is essentially defined by Accotink Creek located toward the northeast of the landfills (**Figure 2-3**).

3.2.4 Corrective Measures Objectives for Groundwater

From the receptor scenarios and consideration of RCRA performance standards, RGOs were selected for PCE, TCE and VC in CC-A11 groundwater, as shown in **Table 3-1**.

Table 3-1
Remedial Goal Options

Contaminant of Interest	Maximum Groundwater Concentration (µg/L)	Groundwater Cleanup Goal (MCL) (µg/L)
PCE	9.6	5
TCE	60	5
Vinyl Chloride	18	2

MCL = Maximum Containment Level

As presented in **Table 3-1**, the MCLs are selected as the RGOs for the COIs in the shallow aquifer beneath CC-A11. The extent of contamination in the shallow aquifer is limited to wells MW04, MW06, and MW10 (see **Figure 2-2**). To ensure that potential receptors are adequately protected from contact with contaminated groundwater from the shallow aquifer, the following are the CMOs:

- Prevent use of groundwater containing PCE, TCE, or VC in concentrations exceeding MCLs; and,
- Contain the PCE, TCE, and VC solute plume to below MCLs at the point of compliance (defined as Accotink Creek) within 30 years. It should be noted that this CMO appears to have already been met based on RFI sampling.

4.0 IDENTIFICATION AND SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES

This section identifies potential technologies that may be used to achieve the CMOs for containment of waste and contaminated groundwater at CC-A11 and CC-A12. A brief description is given for each technology along with an assessment of its potential application to the site.

4.1 GENERAL CORRECTIVE MEASURES TECHNOLOGIES

This section identifies and screens general technologies that may be used to achieve the CMOs for landfill waste and contaminated groundwater at CC-A11 and CC-A12.

4.1.1 Land Use Controls

Land use controls (LUCs) consist of physical and/or legal measures to restrict potential means of human exposure to site contamination by means including direct contact or consumption. CC-A11 and CC-A12 are within the boundary of an active military facility and LUCs that include limited landfill access, restrictive boundary fencing, and signs may already be in place. LUCs alone will not meet the site CMOs and therefore are not retained for development as a “stand-alone” alternative. LUCs set in place specifically for CC-A11 and CC-A12 that limit exposure pathways from soil and groundwater will be **retained** in conjunction with all remedial options and as a component of the final remedy. Program components may include the following:

- **Physical Controls:** Physical controls include, but are not limited to, containment structures (i.e., cover system), access barriers such as fences, and signs.
- **Institutional/Administrative Controls:** These controls include governmental controls such as zoning, permits, and site use restrictions; proprietary controls such as easements and covenants; legal enforcement tools such as administrative orders and consent decrees; and informational devices such as deed notices, registries, and advisories. For FTBL, the Master Plan controls land use and is the appropriate means of documenting LUCs.
- **Monitoring and Maintenance:** These components include periodic monitoring and maintenance of the selected corrective measures options and corresponding stewardship controls (whether physical or institutional/administrative).
- **Information Management:** A successful stewardship program is dependent on retaining all necessary records about the site’s history and residual contamination. Information that must be retained should include history of the site, the contaminants of concern, the selected corrective measures options, the use of controls along with their monitoring and maintenance records, and any other information judged necessary for succeeding generations to understand the nature and extent of any residual contamination.
- **Periodic Assessment:** Periodic assessments are performed to determine whether the selected corrective measures options and stewardship controls continue to operate as designed, and to ascertain whether new technologies might exist to eliminate any remaining residual contamination in a safe and cost-effective manner.
- **Controlling Authority:** Long-term protection of human health and the environment necessitates that a controlling authority be established with responsibility for overall stewardship program management and guidance.

4.1.2 Long-Term Monitoring

LTM provides a method for identifying spatial and temporal changes in the extent contamination and to determine that LUCs are effective. An LTM program for the contaminated groundwater could be implemented to provide a method for identifying spatial and temporal changes in the extent of groundwater contamination. LTM also could be implemented to ensure landfill cover systems are maintained and LUCs are effective. LTM alone will not meet the site’s CMOs and therefore is not retained for development as a “stand-alone” alternative. LTM will be **retained** as a component of all remedial alternatives as a means to measure the long-term effectiveness of the alternative.

4.2 LANDFILL WASTE CONTAINMENT TECHNOLOGIES

Containment using cover or cap systems is the presumptive remedy for landfill waste. Containment technologies introduced below are intended to prevent exposure to waste and to minimize the downward percolation of surface water through the soil cover into the underlying waste. By minimizing infiltration into the waste, the potential for further movement of contaminants into groundwater and subsequently into Accotink Creek is reduced. The applicable technologies considered in this document are:

- Soil Cover;
- Engineered RCRA Cap; and,
- Engineered Evapotranspiration (ET) Cover System.

4.2.1 Soil Cover Addition

Soil cover is considered as a potential technology to contain waste as a presumptive remedy. Under the RCRA program at FTBL, the Army and US EPA have been using a typical standard of 24 inches of soil cover to determine at least in part, the need for corrective measures at various FTBL legacy landfills. Landfills with no identified risk and at least 24 inches of soil cover have been proposed for corrective measures consisting of LUCs only. Therefore, soil cover of at least 24 inches has been accepted as a containment technology for legacy landfills at FTBL. The 24-inch thickness is a relevant standard based on typical reference in prescribed landfill closure requirements.

The RFI evaluated soil cover thickness at CC-A11 and CC-A12 and found that the majority of the landfill has at least 24 inches of soil cover and therefore already meets the relevant standard. At CC-A11, 67 percent of the 30 RFI soil borings demonstrated soil cover of at least 24 inches, while 87 percent demonstrated soil cover of at least 18 inches. At CC-A12, 60 percent of the 20 RFI soil borings demonstrated soil cover greater than 24 inches, while 85 percent demonstrated soil cover greater than 18 inches. Addition of topsoil, and where necessary select fill, was considered as a potential technology for landfill areas currently having less than 24 inches of soil cover.

Much of CC-A11 and CC-A12 landfills are vegetated with tulip poplar mesic, mixed hardwood forest, Virginia pine forest, and loblolly pine forest, as shown on **Figures 4-1 and 4-2**. Addition of soil cover would require removal of all vegetation, including trees, prior to placing soil. If trees are not removed prior to adding soil, there would be potentially significant levels of tree mortality by adding more than 2-4 inches of topsoil over root systems at one time (International Society of Arboriculture, 2005). Even if done gradually over time, there is significant risk of tree mortality each time heavy equipment is used within forested areas. Topsoil addition in a forest setting requires transportation, placement, and grading of large material quantities over a broad area using, by necessity, heavy equipment causing soil compaction and potential damage to root systems. Equipment is available that would cast the topsoil up to 100 ft; however, it would need to be done gradually over time and would be difficult to apply in a uniform manner in a densely forested area. Oaks and conifers, the most common types of trees at FTBL, are particularly sensitive to construction activity. Trees that are damaged or weakened by such activity are more susceptible to disease, insect infestations, and toppling during strong wind events (http://www.sustland.umn.edu/implement/protecting_trees.html http://extension.missouri.edu/p/G6885). Therefore, addition of soil cover is not recommended unless all trees are removed from the targeted area.

Removing mature trees to attain a 24-inch soil cover may be counterproductive. Mature forested areas of the landfills are currently reducing rainfall infiltration into the waste (see ET Cover Systems below). Removing forested areas to add soil cover would at least temporarily destroy wildlife habitat and remove the natural ET cover, thus increasing infiltration. Removing trees would require creating a road system through the landfill for equipment access and removal of timber. Trees would be cut at the ground surface and stumps would be ground. The root systems would be left in place because removing them would involve potentially disturbing and exposing landfill waste which poses additional hazards to workers, the surrounding community, and the environment. Leaving the root systems in place prevents inadvertent excavation of waste; however, the root mass will subsequently decay, producing additional LFG and creating subsidence, standing water, and preferential infiltration pathways. Therefore, the benefit of removing mature trees to add soil cover is questionable and should be weighed against the drawbacks.

Soil cover as a technology is **retained** for further consideration if at least 24 inches of cover is already in place. If not, adding soil is beneficial in non-forested areas where access can be achieved without tree removal, but the benefits of removing forest to add soil should be weighed against the consequence of habitat destruction and residual root masses if left in place.

4.2.2 Engineered RCRA Cover System

An engineered RCRA Subtitle D cover system would provide containment via a compacted soil layer which would restrict vertical infiltration of surface waters into the waste mass. The RCRA Subtitle D cover system, which is applicable to the closure of MSW landfills, would consist of a vegetative soil layer of no less than 6 inches overlying a compacted low permeability soil barrier of no less than 18 inches.

To construct engineered RCRA cover systems at CC-A11 and CC-A12, both landfills would be stripped of existing vegetative cover including all trees within landfill limits. Both sites would be re-graded to provide positive drainage (minimum 5 percent slopes) followed by installation of the 24-inch-thick soil cover and re-vegetation with grass. Clearing of both landfills would require that trees be replaced elsewhere at FTBL at a rate of two trees for every removed tree exceeding 4 inches in diameter. Potential wetlands would need to be identified and delineated with permits obtained prior to any clearing or ground disturbance.

US EPA has indicated that a nominal 2-ft soil cover is acceptable containment for a legacy landfill containing primarily municipal type solid waste and demolition debris. However, the RFI has identified several areas within the landfills where the soil cover is less than 2 ft. This technology has been **retained** for further evaluation and alternative development.

4.2.3 Engineered Evapotranspiration Cover System

An engineered ET cover system would provide containment of waste and minimization of vertical infiltration of water via enhanced evaporation and transpiration of rainfall. The soil and vegetative mass would capture and temporarily store precipitation, then release the water either by transpiration through vegetation or by direct evaporation from the soil and vegetative surfaces.

Computer modeling could be used to evaluate alternative ET cover systems for implementation in areas at CC-A11 and CC-A12 where existing cover is less than 24 inches. ET cover systems would be modeled to assess their relative performance. Modeling would take into consideration the proposed soil characteristics, plants, climate, and the impact on hydrology and water balance. Implementation of the approved ET cover system would require, in general, the following tasks be performed:

- Stakeout of areas with less than 24 inches of cover;
- Installation of erosion controls just outside the limits of ET cover construction;
- Clearance of vegetation and grinding of stumps in place for equipment access, erosion controls, and ET cover construction;
- Addition/amendment of the existing soil profile per the ET cover design;
- Establishment of native ground cover and trees in accordance with the approved ET cover system design; and,
- Removal of erosion controls and restoration of resulting ground disturbance.

An engineered ET cover system must meet the following minimum criteria: 1) support rapid and prolific root growth in all parts of the soil cover; and 2) hold enough water to minimize water movement beneath the cover during extreme or critical design periods. Engineered ET cover systems include various combinations of soils and vegetation, and are categorized as one of three types:

- *Monolithic:* A single soil layer system — precipitation water is stored in one layer of soil and later removed through ET.

- *Capillary break:* A two soil layer system to increase the water storage capacity of the cover — a layer of fine soil over a layer of coarser material (e.g., sand or gravel). Capillary force causes the layer of fine soil overlying the coarser material to hold more water than if there were no change in particle size between the layers.
- *Dry barrier:* The dry barrier cover uses wind-driven airflow through a layer of coarse material to remove water from a storage layer.

Due to climate conditions, only the monolithic and capillary break - type ET cover systems have been considered for CC-A11 and CC-A12.

ET covers have been demonstrated and well documented to be effective and reliable cover systems. ET cover systems use “natural” climatic and vegetation ET conditions to minimize the vertical infiltration of liquid into the underlying waste mass thereby minimizing further leachate production and potential impacts on groundwater. ET cover systems have been installed at more than 200 landfill sites across the U.S. (includes pilot and full scale installations) under the review of the US EPA’s Technology Innovation Office. The US EPA’s “CLU-IN” website for information on the cleanup of contaminated sites, provides an online database of these ET cover project sites (http://cluin.org/products/altcovers). ET cover systems have been found to be a superior alternative to conventional landfill covers in certain cases. Further, ET cover systems have been found effective in phytoremediation of VOCs, metals, pesticides, solvents, explosives, crude oil, polycyclic aromatic hydrocarbons, and landfill leachates (US EPA, 1999). ET cover systems are increasingly being considered for use at MSW and hazardous waste landfill sites, and radioactive waste sites (Barnswell and Dwyer, 2011; WSRC, 2007).

A summary of monolithic ET cover project landfill sites having similar climate, soil, and vegetation conditions to that of FTBL has been provided in **Appendix B** to demonstrate applicability and suitability of this proposed remedy. Data presented in **Appendix B** was obtained from the US EPA’s CLU-IN website and from communications made with US EPA Office of Research and Development staff.

Four landfill sites have ET projects installed by Ecolotree, Inc., with 2 ft or less soil cover. Three of the sites, located in St. Louis, MO, Marion, IA, and Detroit, MI, are identified on the CLU-IN website. A fourth 12-acre site near Williamsburg, VA, was installed in two phases during 2012 and has not yet been added to the CLU-IN website. The initial 5-acre area at the Williamsburg project is well established and the trees are thriving. All four of the referenced sites have a seasonal and humid climate similar to that at FTBL.

Given that the measures included in this technology would be protective of human health and the environment, this alternative is **retained** for further evaluation.

4.3 GROUNDWATER REMEDIATION TECHNOLOGIES

The COIs identified in Section 3.0 are PCE, TCE, and VC in groundwater at CC-A11. Therefore, groundwater remediation technologies to address these contaminants are evaluated.

4.3.1 Groundwater Extraction

Extraction wells can be utilized to contain the groundwater plume and remove contaminated groundwater from the shallow aquifer at CC-A11 for ex situ treatment. Extraction wells (recovery wells) are effective in removing contaminated groundwater and contaminant mass from the contaminated zone. Contaminant mass reduction is principally achieved by increased VOC mobility and removal. Once extracted, the groundwater would undergo ex situ treatment prior to disposal. Ex situ treatment options for the extracted groundwater include:

- **Air Stripping.** Air stripping volatilizes VOCs from the extracted groundwater by passing the contaminated water through an air stripping tower. This process is an efficient technology that may not require separate vapor phase treatment, depending on the concentration and mass of the off-gas and site-specific emission restrictions.
- **Activated Carbon.** Passing contaminated groundwater through a bed of activated carbon can be used to treat the extracted groundwater. The hydrophobic COI chemicals preferentially partition to the carbon, resulting in an effluent free of contaminants.

Potential disposal options for the treated groundwater include discharge to FTBL wastewater treatment plant (WWTP), point-source discharge through a permitted National Pollutant Discharge Elimination System (NPDES) outfall, Virginia's Pollutant Discharge Elimination System outfall, irrigation ponds, irrigation, off-site WWTP, and underground injection. Based on site location, the most likely treated water disposal options are the NPDES outfall permit or underground reinjection.

Groundwater extraction can also be coupled to with groundwater reinjection to implement technologies such as In Situ Enhanced Bioremediation (ISEB, detailed in Section 4.3.4 below) and surfactant flushing. The injection of a surfactant or co-solvent into the subsurface can increase the mobility of VOCs. Once the VOCs are mobilized, a groundwater extraction system is used to remove the VOCs and the surfactant or co-solvent from the subsurface. Groundwater extraction also can provide a hydraulic barrier to contaminant migration, preventing future spreading.

The source of the contaminated groundwater is poorly defined at CC-A11 due to the lack of wells within the landfill boundaries. The complete identification and capture of the plume may be impractical. Groundwater capture relies on the solubility and mobility of the COIs in the subsurface which are recalcitrant to flow with the groundwater often requiring decades for regulatory standard to be met. Groundwater extraction may not be practical or feasible for CC-A11; therefore, the technology is **eliminated** from alternative development.

4.3.2 Vertical Barriers

This remedial technology involves using different process options for containment of the groundwater plume. Such process options include grout curtains, slurry walls, and sheet piling. These walls typically are installed along the trailing edge of a plume to divert uncontaminated groundwater around a contaminated source area. However, there is no asymmetry across the vertical barrier and no flow of the topographic disturbance. In time, some studies have shown that groundwater will flow around the vertical barrier thereby not containing groundwater flow beneath the landfill. Vertical barriers are **eliminated** from further consideration.

4.3.3 Monitored Natural Attenuation

The natural attenuation processes such as dilution, dispersion, volatilization, sorption, biodegradation, and chemical reactions will reduce contaminant concentrations in the site groundwater over time (US EPA, 1996b). Intrinsic biodegradation is the most important component of naturally-occurring reduction of chlorinated hydrocarbon, such as PCE and TCE, because it is usually the only destructive component of the process. Anaerobic reductive dechlorination is the biodegradation process in which bacteria conduct respiration (breathe) as each chlorine atom on a chlorinated hydrocarbon is replaced with hydrogen. The reductive dechlorination of TCE to ethene proceeds through a series of hydrogenolysis reactions, with each reaction becoming progressively more difficult to carry out. A common observation is that TCE is reductively dechlorinated under relatively mild reducing conditions; whereas, dichloroethene (DCE) and VC require increasingly stronger reducing conditions [i.e., dissolved oxygen (DO) levels <0.5 mg/L; oxidation-reduction potential (ORP) of <-100] to be dechlorinated (Mohn and Tiedje, 1992). In addition to anaerobic degradation, DCE and VC may undergo aerobic biodegradation in the presence of elevated DO concentrations. The aerobic oxidation of cis-DCE does not produce VC and therefore where aerobic DCE degradation occurs, VC is not produced or accumulated.

Monitored natural attenuation (MNA) is a risk management strategy that evaluates and demonstrates that ongoing natural processes are controlling plume migration and/or will lead to site restoration within a reasonable timeframe (e.g., ~30 years). Under this option, periodic groundwater monitoring is required to measure the reductions achieved due to natural attenuation and to validate that the natural attenuation process continue to contribute to site restoration. Detection of TCE, cis-1,2-DCE, and VC at some sampling locations indicates that bioremediation of COIs in the form of reductive dechlorination may be occurring in CC-A11 groundwater. Groundwater physical parameters collected during the RFI indicate that anaerobic conditions exist supportive of reductive dechlorination processes in the groundwater beneath both of the landfills.

Therefore, natural attenuation will be **retained** as a component of all remedial alternatives as a means to measure the long-term effectiveness of the alternative.

4.3.4 In Situ Enhanced Biodegradation (ISEB)

Bioremediation through reductive dechlorination is a well-documented, biologically catalyzed anaerobic process that can result in the complete dechlorination of PCE and its daughter products (TCE, DCE, and VC). This natural process is a component of natural attenuation; however, the rate of PCE reduction may be unacceptably slow and the process is usually limited by the lack of an electron donor or biodegradable organic carbon source. In addition, sequential biodegradation of PCE and TCE will result in the production of VC which has a lower cleanup standard than its parent products. As a result, the MNA approach has a potential for creating a VC plume. ISEB accelerates the reductive dechlorination process by providing a readily fermented organic carbon source, such as molasses, lactate or emulsified vegetable oil, that provides food for microbial cell growth. The addition of a microbial culture capable of completing PCE/TCE degradation for ISEB results in a lower likelihood of transient accumulation of VC as compared to MNA alone.

Carbon sources can be injected in a grid pattern to target specific source areas, recirculated through a series of injection and extraction wells to sweep the reagent across large distances or under sensitive surface structures, or placed in barrier walls to treat groundwater as it migrates through the wall. Carbon source selection is dependent on the method of reagent delivery and the type of treatment zone desired.

- **Dissolved carbon sources** such as molasses, and sodium lactate, cheese whey, and ethanol are used where the subsurface allows for high injection flow rates and large injection well spacing. These carbon sources typically are consumed in the subsurface within 180 days. Multiple injections are often required to maintain optimal in situ organic carbon (food) concentrations over the duration of the treatment.
- **Durable carbon sources** such as HRC (Regenesis), emulsified vegetable oil products such as EOS (Solutions IES), Newman zone (RNAS) and EDS (Tersus) are hydrophobic and designed to stay within the vicinity of the initial injection. These durable carbon compounds ferment slowly releasing a low concentration of organic carbon to the aquifer over 3 to 5 years.

Bioaugmentation is often coupled with ISEB to provide a robust microbial culture known to perform reductive dechlorination. Fermentation of the carbon source produces a pool of hydrogen gas (H_2) necessary for the replacement of chloride to complete the dechlorination. While many dechlorinating microorganisms have been identified, only one, *Dehalococcoides sp* (DHC), is capable of completely reducing PCE and TCE to ethene. DHC is not ubiquitous at all sites contaminated with chlorinated ethenes. Several sites lacking this microorganism exhibit incomplete dechlorination and accumulation of DCE or VC. Several stable, natural microbial consortia containing DHC are commercially available including KB-1 (Sirem) and Shaw's SDC-9 consortia.

The levels of VOC contamination are considered low enough at CC-A11 that microbes may not have any competitive advantage for the nutrients added. In addition, ISEB may mobilize and increase the concentrations of arsenic in groundwater which has been detected at levels greater than its MCL. Since the plume does not progress far beyond the landfill boundaries before reaching the point of compliance, the injection points would need to be installed inside the landfill, which may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. Due to the potential adverse effect on arsenic in groundwater, and the blind treatment of a large undefined source area within a landfill possibly mobilizing additional contamination, ISEB is **eliminated** from further consideration.

4.3.5 Proton Reduction with SDC-9™ Bioaugmentation

The Proton Reduction (PtR) is a developing technology that provides a non-carbon source electron donor for the implementation of ISEB. A series of paired cathodes and anodes are installed on a grid working at low voltage to produce H_2 and oxygen (O_2), respectively. The excess H_2 migrates with groundwater away from the cathode and is used by anaerobic microbes as an electron donor in reductive dechlorination processes while the O_2 may be used by aerobic microbes to consume fuel compounds. The PtR would be coupled with bioaugmentation to ensure the presence of a robust microbial population capable of complete reductive dechlorination. PtR is suitable for treating remote sites where accessing or maintaining electrical feeds is cost prohibitive. In some climates, a solar panel can be installed to power the in situ PtR wells.

As a developing technology, the technology's treatment effectiveness and efficiency on CC-A11 groundwater concentrations are unknown. As with ISEB, the installation of cathodes inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. Due to the potential adverse effect of a blind treatment of a large undefined source area within a landfill possibly mobilizing additional contamination, PtR is **eliminated** from further consideration.

4.3.6 Combination Biological/Chemical Technologies

Zero valent iron (ZVI) can be used as a standalone reagent to chemically drive reductive dechlorination of most chlorinated solvents such as PCE. ZVI has been used predominantly in the application of permeable reactive barriers (PRBs) discussed in the following section. ZVI also has been used in combination with durable carbon sources to achieve bio/chemical reduction of PCE. EHC® technology is integrated carbon and ZVI source that yields redox potentials (Eh) as low as -500 millivolts (mV). The Eh produced by EHC is significantly lower than that achieved when using either organic carbon sources (i.e., lactate, molasses) or reduced metal alone. Eh potentials in this range facilitate chemical PCE reduction with less formation of bioremediation daughter products such as DCE and VC.

Emulsified ZVI, developed by NASA, is a surfactant-stabilized, biodegradable emulsion that forms microscopic liquid-oil membrane spheres that have a core consisting of ZVI particles suspended in water. As a result of the liquid oil sphere hydrophobic nature, the emulsified ZVI droplets enhance the destruction of chlorinated dense non-aqueous phase liquid (DNAPL) in source zones by creating intimate contact between the DNAPL and the nano- or microscale iron particles. The emulsified ZVI liquid-oil membrane contains vegetable oil and surfactant, which provides a long-term electron donor carbon source that can stimulate further degradation of TCE via anaerobic biodegradation.

Biological/chemical in situ reduction can be employed in source area treatment zones and/or the plume perimeter. Pneumatic fracturing and injection, hydraulic fracturing, and injection via direct-push rigs have been used successfully to introduce biological/chemical reagents to the groundwater or soil source area. However, the installation of injection points inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. Biological/chemical treatments may mobilize and increase the concentrations of arsenic in groundwater which has been detected at levels greater than its MCL. The installation of injection points inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. Due to the potential adverse effect on arsenic in groundwater, and the blind treatment of a large undefined source area within a landfill possibly mobilizing additional contamination, the use of biological/chemical treatments is **eliminated** from further consideration.

4.3.6.1 Permeable Reactive Barriers

Passive treatment walls, also known as PRBs, are typically installed across the migration path of a plume to destroy contaminants as groundwater passes through the barrier. PRB material promotes either a biological and/or chemical reaction destroying the contaminant. PRBs can be created using solid- or liquid-phase carbon substrate amendments (e.g., mulch and emulsified oil, respectively) and/or ZVI. The contaminants are concentrated and either degraded or retained in the barrier material, which may need to be replaced periodically.

PRBs can be installed as permanent or semi-permanent units. The most commonly used PRB configuration is that of a continuous trench in which a treatment reagent (i.e., ZVI, Mulch) is mixed with a porous material such as sand or gravel and is backfilled. The trench is cut perpendicular to and intersects the groundwater plume. Another frequently used configuration is the funnel and gate, in which low-permeability walls (the funnel) direct the groundwater plume toward a permeable treatment zone (the gate). Funnel and gate PRBs use collection trenches, funnels, or complete containment to capture the plume and pass the groundwater, by gravity or hydraulic head, through a treatment barrier.

ZVI PRB walls can be constructed using either a long stick excavator, with a slurry to support the trench walls, or a one pass trencher (http://www.dewindonepasstrenching.com/). Mulch and granular ZVI wall are typically installed using trenching techniques and are limited to depths of less than 75 ft bgs.

Emulsified oil and/or nano-scale ZVI walls are typically installed using either permanent or temporary groundwater wells and injection technologies, allowing for deeper installation depths. Both carbon substrate and ZVI PRBs promote reductive dechlorination of PCE sequentially to TCE, DCE, to VC, and finally to innocuous ethene.

The PRB is a robust technology typically used when there is an imminent risk to human health or the environment. Due to the relatively low concentrations of contaminants and associated risks, the PRB is **eliminated** from further consideration.

4.3.6.2 Phytoremediation

Phytoremediation is the use of plant based approaches to contain, degrade, or eliminate contaminants from soil, groundwater, surface water, or sediments. Phytotechnologies include phytosequestration, rhizodegradation, phytohydraulics, phytoextraction, phytodegradation, and phytovolatilization. Using a grid of hybrid poplar trees across the site to control and accelerate the degradation of PCE in groundwater and soil is a common phytoremediation approach. During the warm months, the normal water uptake of the trees would perform like groundwater extraction pumps (phytohydraulics) containing the groundwater and arresting the further migration of the plume. If possible, the trees would be arranged so that the plume would not migrate beyond the phytohydraulic capture zone during the winter months when the trees are dormant. In addition to hydraulic control, the trees will take up dissolved VOCs (phytoextraction), release a portion to the atmosphere (phytovolatilization), or biodegrade a portion in the root zone (rhizodegradation). Hybrid poplars are favored because of their fast growth, deep roots, ability to pump water, and adaptability to a variety of conditions. To implement this phytoremediation approach, the site would be cleared of existing trees to allow for the maximum sun exposure for the hybrid popular grid.

While phytoremediation is a low maintenance remedial technology, typically 3 to 5 years are required for the phytoremediation system to mature to its full remediation capacity. Large portions of CC-A11 are already covered with various mature hardwoods and conifers that may be functioning to remove VOCs from the subsurface. Removal of these trees to replace them with poplars that would mature in 3 to 5 years is not recommended, especially since the mature root systems of the existing trees are likely in contact with landfill waste. Thus, phytoremediation is **eliminated** from further development as a remedial technology. Although an engineered phytoremediation approach is not recommended, existing phytoremediation processes, if contributing to site restoration, will continue and be captured as an unidentified component of natural attenuation.

4.3.7 In Situ Chemical Oxidation

In Situ Chemical Oxidation (ISCO) entails the injection of chemical oxidants into the subsurface to destroy the contaminants by converting them to innocuous breakdown products. Oxidants are not selective, as they oxidize both the contaminants and natural organic compounds found in the subsurface. Commonly, application of ISCO involves multiple injection events. The periods between injection events are typically on the order of months to a year. Hundreds of ISCO remedies have been implemented at chlorinated solvent sites. Groundwater recirculation, pneumatic fracturing and injection, hydraulic fracturing, and injection via direct-push rigs have been used successfully to introduce ISCO reagents to the groundwater or soil source area.

Oxidants commonly applied in situ include potassium or sodium permanganate, persulfate, ozone, and hydrogen peroxide in the form of Fenton's Reagent. Each of these oxidants has advantages and limitations. Potassium permanganate ($KMnO_4$) treatment is the most commonly deployed oxidant for in situ PCE treatment. $KMnO_4$ offers the following advantages over other oxidants for PCE treatment:

- Quickly and completely oxidizes chlorinated ethenes to innocuous end products over a wide pH range. Reaction half lives are between 1 minute (trans-1,2-DCE) to 4 hours (PCE) (Yan and Schwartz, 2000).
- Colored solution (purple) makes it easy to track the injection influence or the degree of treatment.

- Chemically stable in groundwater – stays in solution until it is reacted and therefore can penetrate into the least permeable lithologies.
- No off-gas treatment required.
- Minimal energy and equipment requirements.

ISCO will increase the ORP and change the chemistry of the subsurface which can have adverse effects on surface water ecology. Application of ISCO may be problematic as it will require the injection points to be installed inside the landfill. Installation of injection points inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. In addition, the application of an oxidizer into landfill waste could release other contaminants such as hexavalent chromium, and end the apparent reductive dechlorination processes naturally occurring. Due to the potential adverse effect of an oxidizer releasing additional contaminants into the groundwater and ending the current natural reductive dechlorination, ISCO is **eliminated** from further consideration.

4.3.8 In Situ Thermal Treatment/Soil Vapor Extraction

In situ thermal treatment heats the subsurface in an attempt to accelerate the volatilization of contaminants. Contaminant mobility is enhanced through one or more of the following mechanisms:

- Volatilization due to increased vapor pressure;
- Dissolution due to increased solubility;
- Liquid flow due to reduced viscosity and/or density;
- Desorption due to decreased solid-phase adsorption and organic matter absorption;
- Molecular diffusion in aqueous and gaseous phase due to increased diffusion coefficients;
- Boiling of the interstitial groundwater and dissolved contaminants; and,
- Steam stripping and steam distillation.

In the vadose zone, rising steam and contaminant vapors are collected by conventional soil vapor extraction (SVE) wells. A condenser is used to separate contaminant-laden condensate from the contaminant-laden vapor. Standard air phase (e.g., catalytic incineration with scrubbers) and water treatment technologies (e.g., tray strippers, carbon, or oxidation) are then employed to treat the discharges.

For VOCs, the dominant removal mechanism is volatilization. Steam is injected in injection wells beneath the targeted treatment zone, optimally bringing the entire treatment zone to the boiling point of water. Steam injection can displace mobile contaminants in front of the steam and vaporize residual volatile contaminants. Condensation will occur at the advancing thermal front, creating a bank of contaminants in front of the advancing steam. Volatile contaminants can thus be recovered in both dissolved and vapor phases. Mobilization of DNAPL may also occur as a result of the lowered interfacial tensions due to the increase in temperature.

There is no evidence that DNAPL may be present, and the source area in the landfill is undefined; therefore, in situ thermal treatment coupled with SVE is **eliminated** from further consideration.

4.4 CORRECTIVE MEASURES ALTERNATIVE DEVELOPMENT

Table 4-1 includes a summary of the preceding technologies and the rational for their retention or elimination. The following technologies were retained for alternative development to meet the CMOs for both the landfill cover system and groundwater in the shallow aquifer underlying the landfill:

- LUCs;
- LTM;
- Soil Cover;

- Engineered RCRA Cap System;
- Engineered ET Cover System; and,
- MNA.

As discussed above, many of the technologies (i.e., LUCs, LTM, MNA) are supporting technologies that are not "stand-alone." To address PCE, TCE, and VC in groundwater, MNA is the only technology that was retained. With the presence of PCE breakdown products more prevalent than PCE, and the anaerobic conditions in the aquifer, natural attenuation appears to be a reasonable and effective solution for the site.

The primary waste containment technologies were assembled into CMAs as listed below, each augmented as appropriate with supporting technologies:

- Alternative 1 – No Action;
- Alternative 2 – Engineered RCRA Cap System, LTM, MNA, and LUCs;
- Alternative 3 – Engineered ET Cover System, LTM, MNA, and LUCs; and,
- Alternative 4 – Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs.

Each of these alternatives is fully described and evaluated in Section 5.0.

Table 4-1
Fort Belvoir CMS Summary of Technologies

Technology	Summary	Rationale	Retained/Eliminated
No Action	The no action alternative would not meet the CMOs and contains no remedial measures, engineering or administrative controls, or monitoring of contaminated media. Contaminants would be allowed to migrate with time through dispersion and diffusion.	No Action is a baseline against which the adequacies of other remedial alternatives are compared.	Retained
Land-Use Controls	LUCs consist of physical and/or legal measures that restrict potential exposure routes for human contact with site contamination. CC-A11 and CC-A12 are within the boundary of an active military facility and LUCs such as limited Base access, restrictive boundary fencing, and associated signage are currently present.	LUCs alone will not meet the CMOs.	Retained[1]
Long-Term Monitoring	LTM provides a method for identifying spatial and temporal changes in the extent of contamination and to determine that LUCs are effective.	An LTM program for the contaminated groundwater could be implemented, but will not by itself meet the CMOs.	Retained[2]
Soil Cover	Addition of soil to the existing cap to create uniform cap of at least 24 inches in depth.	Soil cover is considered as a potential technology to contain waste as a presumptive remedy. The RFI evaluated soil cover thickness at CC-A11 and CC-A12 and found that the majority of the landfill has at least 24 inches of soil cover and therefore already meets the relevant standard. Addition of topsoil in forested areas while leaving the forest intact poses a high risk of tree mortality due both to placement of topsoil over tree roots as well as due to ground compaction caused by heavy equipment delivering and spreading large quantities of topsoil around the trees.	Retained
Engineered RCRA Cover System	An engineered RCRA Subtitle D cover system would provide containment via a compacted soil layer which would restrict vertical infiltration of surface waters into the waste mass.	To construct engineered RCRA cover systems at CC-A11 and CC-A12, both landfills would be stripped of existing vegetative cover including all trees within landfill limits. Clearing of both landfills would require that trees be replaced elsewhere at FTBL at a rate of two trees for every removed tree exceeding 4 inches in diameter. Potential wetlands would need to be identified and delineated with permits obtained prior to any clearing or ground disturbance.	Retained
Engineered Evapotranspiration Cover System	An engineered ET cover system would provide containment of waste and minimization of vertical infiltration of water via enhanced evaporation and transpiration of rainfall. The soil and vegetative mass would capture and temporarily store precipitation, then release the water either by transpiration through vegetation or by direct evaporation from the soil and vegetative surfaces.	ET covers have been demonstrated and well documented to be effective and reliable cover systems. ET cover systems use “natural” climatic and vegetation ET conditions to minimize the vertical infiltration of liquid into the underlying waste mass thereby minimizing further leachate production and potential impacts on groundwater.	Retained
Groundwater Extraction	Extraction wells (recovery wells) are effective in removing contaminated groundwater and contaminant mass from the contaminated zone. Contaminant mass reduction is principally achieved by increased VOC mobility and removal. Once extracted, the groundwater would undergo ex situ treatment (air stripping and activated carbon) prior to disposal.	Once the VOCs are mobilized, a groundwater extraction system is used to remove the VOCs and the surfactant or co-solvent from the subsurface. Groundwater extraction also can provide a hydraulic barrier to contaminant migration, preventing future spreading. The source of the contaminated groundwater is poorly defined at CC-A11 and CC-A12, and the complete identification and capture of the plume may be impractical. Groundwater capture relies on the solubility and mobility of the COIs in the subsurface which are recalcitrant to flow with the groundwater often requiring decades for regulatory standard to be met.	Eliminated
Vertical Barriers	Use of grout curtains, slurry walls, and sheet piling to divert uncontaminated groundwater around a contaminated source area.	There is no asymmetry across the vertical barrier and no flow of the topographic disturbance. In time, some studies have shown that groundwater will flow around the vertical barrier thereby not containing groundwater flow beneath the landfill.	Eliminated
Monitored Natural Attenuation	MNA is a risk management strategy that evaluates and demonstrates that ongoing natural processes are controlling plume migration and/or will lead to site restoration within a reasonable timeframe (e.g. ~30 years).	Detection of TCE, cis-1,2-dichloroethene (DCE), and VC at some sampling locations indicates that bioremediation of COIs in the form of reductive dechlorination may be occurring in CC-A11 and CC-A12 groundwater. Groundwater physical parameters collected during the RFI indicate that anaerobic conditions exist supporting of reductive dechlorination processes in the groundwater beneath both of the landfills.	Retained[3]
In Situ Enhanced Bioremediation	ISEB accelerates the reductive dechlorination process by providing a readily fermented organic carbon source, such as molasses, lactate or EVO, that provide food for microbial cell growth. Fermentation of the carbon source produces a pool of hydrogen gas (H_2) necessary for the replacement of chloride to complete the dechlorination. Bioaugmentation is often coupled with ISEB to provide a robust microbial culture (DHC) known to perform reductive dechlorination.	The levels of VOC contamination are low. These low concentrations may not allow for microbes to have any competitive advantage for the nutrients. In addition, ISEB may mobilize and increase the concentrations of arsenic in groundwater which has been detected at levels greater than its MCL. The installation of injection points inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. There is also the potential adverse effect on arsenic in groundwater.	Eliminated
Proton Reduction with SDC-9™ Bioaugmentation	The PtR is a developing technology that provides a non-carbon source electron donor for the implementation of ISEB. A series of paired cathodes and anodes are installed on a grid working at low voltage to produce H_2 and O_2, respectively. The excess H_2 migrates with groundwater away from the cathode and is used by anaerobic microbes as an electron donor in reductive dechlorination processes while the O_2 may be used by aerobic microbes to consume fuel compounds.	As a developing technology, the technology’s treatment effectiveness and efficiency on CC-A11 and CC-A12 source area concentrations are unknown.	Eliminated

Table 4-1
Fort Belvoir CMS Summary of Technologies

Technology	Summary	Rationale	Retained/Eliminated
Biological/Chemical Technologies	ZVI can be used as a standalone reagent to chemically drive reductive dechlorination of most chlorinated solvents such as PCE. Emulsified ZVI is a surfactant-stabilized, biodegradable emulsion that forms microscopic liquid-oil membrane spheres that have a core consisting of ZVI particles suspended in water. As a result of the liquid oil sphere hydrophobic nature, the emulsified ZVI droplets enhance the destruction of chlorinated DNAPL in source zones by creating intimate contact between the DNAPL and the nano- or microscale iron particles.	The installation of injection points inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. Biological/chemical treatments may mobilize and increase the concentrations of arsenic in groundwater which has been detected at levels greater than its MCL. The installation of injection points inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants.	Eliminated
Permeable Reactive Barriers	PRBs are typically installed across the migration path of a plume to destroy contaminants as groundwater passes through the barrier. PRB material promotes either a biological and/or chemical reaction destroying the contaminant. Mulch and granular ZVI wall are typically installed using trenching techniques and are limited to depth of less than 75 ft bgs. Emulsified oil and/or nano-scale ZVI walls are typically installed using injection technologies, allowing for deeper installation depths.	The PRB is a robust technology typically used when there is an imminent risk to human health or the environment. At CC-A11 and CC-A12, concentrations of contaminants and associated risks are relatively low.	Eliminated
Phytoremediation	Site phytoremediation would consist of installing a grid of hybrid poplar trees across the site to control and accelerate the degradation of PCE in groundwater and soil. Another potential phytoremediation scheme for the PCE plume treatment would be to construct a riparian corridor consisting of heavy layers of peat or other high carbon material to intercept and retard PCE migration and wetland plants to foster the PCE treatment through rhizodegradation, phytoextraction, and phytovolatilization prior to communication with surface water.	While phytoremediation is a low maintenance remedial technology, typically 3 to 5 years are required for the phytoremediation system to mature to full remediation capacity. In addition, PCE taken into plant tissue is an exposure risk for wildlife that feeds on the plant tissues and once in the food chain can lead to bioaccumulation in predator species.	Eliminated
In Situ Chemical Oxidation	ISCO entails the injection of chemical oxidants into the subsurface to destroy the contaminants by converting them to innocuous breakdown products. ISCO will increase the oxidation-reduction and change the chemistry of the subsurface which can have adverse effects on surface water ecology.	Application of ISCO may be problematic as it will require the injection points to be installed inside the landfill. Installation of injection points inside the landfill may provide preferential pathways for water to enter the landfill with the potential of mobilizing additional contaminants. In addition, the application of an oxidizer into landfill waste could release other contaminants such as hexavalent chromium, and end the apparent reductive dechlorination processes naturally occurring.	Eliminated
In Situ Thermal Treatment/Soil Vapor Extraction	ISTT heats the subsurface in an attempt to accelerate the volatilization of contaminants. In the vadose zone, rising steam and contaminant vapors are collected by conventional SVE wells. A condenser is used to separate contaminant-laden condensate from the contaminant-laden vapor. Standard air phase (e.g., catalytic incineration with scrubbers) and water treatment technologies (e.g., tray strippers, carbon, or oxidation) are then employed to treat the discharges.	There is no evidence that DNAPL may be present, and the PCE source area in the landfill is undefined.	Eliminated

[1] LUCs that limit exposure pathways to soil and groundwater are retained in conjunction with all remedial alternatives and as a component of the final remedy.
[2] LTM is retained as a component of all remedial alternatives as a means to measure long-term effectiveness of the alternative.
[3] MNA is retained as a component of all remedial activities as a means to measure the long-term effectiveness of the alternative.

bgs	below ground surface
CMO	corrective measure objective
DCE	dichloroethene
DHC	*Dehalococcoides sp*
DNAPL	dense non-aqueous phase liquid
EVO	emulsified vegetable oil
ISCO	in situ chemical oxidation
ISEB	in situ enhance bioremediation
ISTT	in situ thermal treatment
LTM	long-term monitoring
LUC	land-use control
MNA	monitored natural attenuation
PCE	tetrachloroethene
PRB	permeable reactive barrier
PtR	proton reduction
RCRA	Resource Conservation and Recovery Act
SDC-9™	Shaw Dechlorinating Culture
SVE	soil vapor extraction
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
VC	vinyl chloride
VOC	volatile organic compound
ZVI	zero valent iron

5.0 EVALUATION OF CORRECTIVE MEASURES ALTERNATIVES FOR LANDFILL WASTE

This section contains a detailed evaluation of the CMAs that address the CMOs for the landfill waste and groundwater at Poe Road Landfill (CC-A11) and the Accotink Landfill (CC-A12) at FTBL. The CMAs evaluated to address waste containment were selected after a screening of technologies in Section 4.0, and include:

- Alternative 1 – No Action;
- Alternative 2 – Engineered RCRA Cap System, LTM, MNA, and LUCs;
- Alternative 3 – Engineered ET Cover System, LTM, MNA, and LUCs; and,
- Alternative 4 – Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs.

The differences in these alternatives focus on various approaches for the overlying cover of landfill waste to comply with containment as a Presumptive Remedy. The following elements are common to CMAs 2 through 4:

- The existing waste mass will remain undisturbed;
- LTM and environmental stewardship will be required to ensure continued performance of the cover system;
- MNA will be required to ensure that the groundwater CMOs for CC-A11 and CC-A12 are being met; and,
- Institutional controls (i.e., land use/site access restrictions) that are protective of human health and environment will be required.

In compliance with the FTBL RCRA permit and Subpart S guidance documents, each alternative is evaluated according to the following considerations:

- Control of the sources of releases so as to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment;
- Overall protection of human health and the environment;
- Compliance with standards and criteria for all media based on state and federal regulations and requirements;
- Long-term reliability and effectiveness, including an evaluation of the persistence, toxicity, and mobility of the hazardous substances and constituents, and their propensity to bioaccumulate;
- Short-term effectiveness and potential for human exposure and environmental effects;
- Feasibility of using the technology;
- Capital and Operation and Maintenance (O&M) Costs; and,
- State, US EPA, and community acceptance.

5.1 ALTERNATIVE 1 – NO ACTION

5.1.1 Description

No Action is included as a baseline for comparison purposes only. It contains no remedial measures, engineering or administrative controls, or monitoring of contaminated groundwater. Alternative 1 provides a description of current conditions to compare to the potential effects of the proposed Alternatives 2, 3, and 4. The Final Phase II RFI Report (June 2011) provides an overall description of the general site conditions including the existing soil cover system and vegetation that it supports. The existing cover systems would remain in their existing condition with no improvements. The approximate landfill soil cover limits and the landfill areas having less than 24 inches of cover thickness are shown on **Figures 5-1 and 5-2**.

5.1.2 Control of Source Releases

There are no active disposal operations at CC-A11 or CC-A12 and contaminants are no longer being released at the site. However, the contamination in the waste, constituting the source area, presents a potential source of contamination to groundwater. The No Action alternative does not include any measures to mitigate or monitor the further migration of contaminants.

5.1.3 Protection of Human Health and the Environment

The No Action alternative would allow the landfill covers to remain in their current condition with no changes in landfill soil cover thickness, vegetative cover, or methane control. Although there are no current unacceptable risks, the No Action alternative provides no protection in the future against unacceptable use of the land and underlying groundwater and no monitoring to ensure unacceptable impacts to surface water are not occurring. No additional protection of human health and the environment would result from implementation of this alternative.

5.1.4 Compliance with Applicable Standards for Management of Wastes

No applicable standards for the management of wastes would be triggered with the implementation of the No Action alternative. However, the No Action alternative would not address areas of the landfill with exposed waste (although none have been identified) or areas with less than 24 inches of soil cover as a relevant standard.

Per FTBL's Part B Hazardous Waste permit (VA7213720082) Module IV (Attachment/Section MM–Correctives Measures Study requirement), compliance with state and federal standards and criteria may be established by risk-based assessment of human health and the environment and the establishment of risk-based action levels. The Phase II RFI established that the only risk to human health would be if groundwater were used as a drinking water source, which is not expected to occur, even under the No Action alternative.

5.1.5 Long-Term Reliability and Effectiveness

The No Action alternative would not involve any active waste removal, soil or groundwater treatment, or further waste containment. Therefore, the No Action alternative would not actively contribute to achieving the CMOs for the soil cover or the groundwater underlying CC-A11 and CC-A12 landfills. Existing established vegetation at the two landfill sites contributes to ET which in turn may inhibit surface water infiltration through the underlying waste, introduction of contaminants into groundwater, and long-term mobility of any groundwater contaminants. The No Action alternative would not reduce the mobility, toxicity, or mass of contaminants beyond natural attenuation processes.

5.1.6 Short-Term Effectiveness

The Phase II RFI risk evaluation indicated that human exposure to surface water, sediment, surface soil, and subsurface soil is not a concern. The ecological risk evaluation determined that neither terrestrial nor aquatic organism populations are at risk. The only unacceptable risk to human health is associated with use of groundwater as a tap water source, which is considered unlikely given that FTBL does not use groundwater as a source of potable water.

5.1.7 Feasibility

The No Action alternative is technically feasible but potentially not administratively implementable because it does not maintain protectiveness in the future.

5.1.8 Cost

There are no costs associated with this alternative.

5.1.9 State, US EPA, and Community Acceptance

State, US EPA, and community acceptance will be determined after completion of the Statement of Basis and Public Comment Period. At this time, the Army knows of no State or Community concerns regarding the acceptability of the alternative.

5.2 ALTERNATIVE 2 – ENGINEERED RCRA CAP SYSTEM, LTM, MNA, AND LUCS

5.2.1 Description

Alternative 2 proposes the installation of an engineered RCRA Subtitle D cap system to meet current RCRA standards regarding MSW landfill containment and inadequate landfill soil cover thickness. The approximate limits of the waste area to be capped is illustrated on **Figures 5-3 and 5-4**. The proposed RCRA cap system would function as a containment measure to do the following:

- Minimize infiltration of precipitation/surface waters into the underlying waste mass, thereby minimizing leachate production and percolation of leachate from waste to groundwater;
- Isolate wastes from receptors (i.e., humans, animals, environment);
- Control LFG and potential odor emissions;
- Promote surface water runoff, and minimize erosion; and,
- Prevent occurrence of vectors and other nuisances.

The engineering and design of Alternative 2 would require determination of appropriate cover soils, grass species, and any necessary modifications to the existing site grading and surface water drainage; a short-term monitoring and maintenance plan to be utilized until vegetation has been fully established; and, a long-term monitoring and maintenance plan.

A pre-design survey and reconnaissance would be performed as necessary to delineate the landfill especially along the southeast and southwest limits as noted in the April 2010 RFI. Potential wetlands would need to be identified and delineated with permits obtained prior to any clearing or ground disturbance. A Corrective Measures Implementation Work Plan (CMIWP) would present investigative results, engineering design, and operational approach for the RCRA cap system and would, at a minimum, address the following:

- Existing topography and proposed grading;
- Anticipated limits of disturbance and tree removal inventory;
- Access routes and traffic control plan;
- Soil erosion and sediment control design;
- Sensitive receptor inventory to include wetlands, bodies of water, critical habitat;
- Any construction restrictions such as Virginia's Bald Eagle Protection Guidelines;
- Permit requirements;
- Landfill design details;
- Anticipated sources of construction materials such as protective cover soil and topsoil;
- LFG control and monitoring;
- LTM;
- MNA;
- Site restoration plan to include a construction mitigation plan; and,
- LUCs.

The RCRA cap system would require clearing and grubbing of all vegetation to just beyond the delineated landfill limits and additional clearing and grubbing for erosion controls, staging areas, and access roads. Approximately 70 acres of forest and meadow would be cleared at CC-A11 and CC-A12 for cap construction including approximately 3 to 5 acres for erosion controls, site access, and support areas. The extent of clearing would be clearly demarcated in the field to limit unnecessary clearing and to minimize disturbance beyond the limits of construction. An inventory of impacted vegetation would be prepared prior to site disturbance for use in preparing a tree mitigation plan. Trees greater than 4 inches in diameter that are removed would require replacement with two trees either within the limits of disturbance or elsewhere within FTBL.

This alternative would be initiated only after establishment of approved site access and approval of installed soil erosion and sediment control devices. All activities would be closely coordinated with FTBL and permitted as needed to minimize impact on the environment and surrounding community. This will require mandatory wetland and wildlife surveys.

Soil erosion and sediment control measures would be installed, inspected, and approved in conjunction with site clearing in accordance with the approved plan. All cleared materials would be logged or chipped with final disposition determined by FTBL. Waste materials and debris observed on the landfill surface would be removed with final disposition to be determined by FTBL. Handling and segregation of the materials would be dependent on final disposition such as recycling or disposal in a landfill.

The resulting landfill surface would require re-grading and compaction to provide sufficient slopes for drainage and a base for placement of an 18-inch-thick low permeability soil layer and a 6-inch-thick vegetative support layer. Potential sources of suitable fill and topsoil within FTBL would be identified prior to locating off-site sources of material to minimize transport distances and the impact on the local communities. All fill and topsoil considered for use on the project would be subjected to geotechnical, chemical, and agronomic testing as appropriate prior to acceptance. Cool and warm season native grasses would be established on the landfill surface to control erosion.

Potential sources of suitable fill and topsoil within FTBL would be identified prior to locating off-site sources of material to minimize transport distances and the impact on the local communities. All fill and topsoil considered for use on the project would be subjected to geotechnical, chemical, and agronomic testing as appropriate prior to acceptance.

Prior to site restoration, final grade elevations would be obtained and compared to the pre-construction topography to verify that a nominal soil cover thickness of 24 inches is in place within the limits of fill placement.

In conjunction with the RCRA cap construction, an LFG venting system would be designed and installed at both landfill areas.

Upon completion of the cap system installation, all disturbed areas would be restored in full compliance with the approved site restoration plan. Required tree mitigation would be accomplished in accordance with the approved mitigation plan. Soil erosion and sediment controls would be removed only after the site has been re-vegetated and all required approvals have been obtained in writing from FTBL and designated regulators.

A Corrective Measures Implementation (CMI) Report would be prepared and submitted for review and approval in draft, draft final, and final versions. The contents of the CMI Report would be defined in the CMIWP prior to the start of construction.

The LTM program would include, semi-annual inspections of the landfill cover systems during the first five years of O&M with typically one inspection during the spring and a second inspection during the fall. Additional inspections would typically be conducted following severe weather events. Annual inspections would be conducted each fall after Year 5. The inspections would include an assessment of the vegetative cover and identification of any evidence of erosion or standing water on or adjacent to the landfill cover. The location and extent of any critical observation would be documented in a written field inspection report. Photodocumentation would be obtained showing representative landfill cover conditions at the time of each inspection as well as photos of any critical observations. As part of the

LTM program, monitoring of methane controls would be conducted on a semi-annual basis at the landfill boundaries to verify that methane levels do not exceed the methane LEL. The LTM Plan would include a process for prompt notification of the Army and other stakeholders in the event that methane levels exceed the LEL. The results of the landfill cover inspections and methane monitoring would be evaluated and incorporated in an annual CMI Monitoring Report.

The LTM program would also include groundwater sampling events for monitoring wells screened in the shallow aquifer to evaluate MNA. **Table 5-1** lists the monitoring locations to be included in the LTM program and the number of samples collected in each event. Groundwater samples would be analyzed for VOCs using US EPA Method 8260D and natural attenuation parameters. A total of 14 monitoring wells are proposed for inclusion in the MNA LTM program, as shown on **Figure 5-9**. Groundwater sampling would occur semi-annually for the first 5 years, and thereafter annually. Results from the sampling events would provide data on spatial and temporal changes in the extent of groundwater contamination. The duration of the LTM program is conservatively projected to be 30 years.

An Land Use Control Implementation Plan (LUCIP) would be prepared for this alternative that would address periodic inspections, certifications, and regulatory notifications necessary enacted to prevent future disturbance of the landfill cover systems. The LUCs would prohibit future construction, development, or use of groundwater within the designated LUC limits. The LUCIP would describe the implementation, monitoring, and maintenance of the LUCs. LUCs implemented under the LUCIP would be recorded in the Installation Master Plan.

5.2.2 Control of Source Releases

Alternative 2 would provide greater long-term control of source releases by installing an engineered low permeability cap over the entire landfill footprints at CC-A11 and CC-A12. In the long term, the caps should minimize infiltration of precipitation through the existing landfill cover into the underlying waste and thereby reduce the quantity of resulting landfill leachate.

The removal of the existing well-established forest cover may result in a temporary increase in percolation of surface water into the underlying waste during construction which may or may not result in an increase in groundwater contamination.

5.2.3 Protection of Human Health and the Environment

Alternative 2 complies with the US EPA Presumptive Remedy guidance and would be protective of human health and the environment. LUCs would be protective of human health by restricting unauthorized use of groundwater and ground disturbance that might result in human exposure to the landfill contents. As part of an approved LTM program, regular inspections would be conducted at both landfill areas to identify necessary repairs including landfill cover erosion and any exposed waste. In addition, LTM would include monitoring of methane levels and testing of groundwater and surface water to verify that COI concentrations in groundwater are decreasing.

5.2.4 Compliance with Applicable Standards for Management of Wastes

This alternative fully complies with CMOs and all applicable federal, state, and local regulations. In particular, this alternative is consistent with the US EPA's Presumptive Remedy for Municipal and Military Landfills as well as RCRA landfill closure requirements.

5.2.5 Long-Term Reliability and Effectiveness

The long-term reliability, stability, and effectiveness of the existing landfills would be improved by the proposed RCRA cap installation. The existing landfill covers are generally, well vegetated, and stable; however, areas exist on both landfills where soil cover and vegetative cover are limited and therefore less likely to provide adequate containment as compared to the installation of a low permeability cover over the entire landfill surface at both sites.

Once the RCRA caps are in place and vegetative cover established on both landfills, it is anticipated there will be an improvement in the overall performance and integrity of the landfill cover systems. The caps will divert stormwater to perimeter drainage swales. Semi-annual LTM during Years 2 through 5 and annual LTM during Years 6 through 30 will serve to identify necessary maintenance and repairs that, when implemented, will serve to ensure the long-term reliability and effectiveness of the landfill cover system.

LTM and MNA sampling would verify that COI concentrations in groundwater are decreasing over the long term.

5.2.6 Short-Term Effectiveness

The footprint of construction for Alternative 2 is the largest of all alternatives considered; therefore, it will greatly impact the environment in the short term as follows:

- It requires clearing and grubbing of approximately 70 acres of well-established forest and meadows;
- It will increase air and noise emissions generated by heavy earthmoving equipment, diesel operated equipment;
- It will increase site traffic due to timber removal and soil importation;
- It will require construction in close proximity to sensitive environmental areas, potentially impacting Accotink Creek and wetlands; and,
- It will require considerable material consumption (e.g., equipment fuel and oil, soils imported from off-site sources, new trees and shrubs from off-site sources, water, etc.) and larger waste generation (e.g., clearing/grubbing debris, field supplies, spent water, etc.).

The temporary impacts to wildlife due to the removal of forested habitat and construction activities in wetlands and other sensitive environments would be mitigated as much as possible through surveys, permits, and proper work procedures. Additional perimeter monitoring would be conducted and documented during construction as necessary to verify that construction traffic was not affecting methane concentrations.

Removal of established vegetation will also temporarily destabilize the cover within the limits of the targeted ET cover system zones. A temporary increase in the volume of surface water that infiltrates/percolates into the underlying waste mass is anticipated during the construction phase and for a period of time following construction. Once vegetative cover has been restored and fully established, percolation volumes will decrease. However, in the short term, the increased rate of percolation will most likely cause more leachate to be generated within the landfill — which may or may not result in an increase in groundwater contaminant concentrations. Since the landfills closed in the 1970s, it is assumed that the existing forests are over 30 years old. Therefore, it is expected that forest recovery in the areas affected by Alternative 2 may take decades to attain similar canopy features. The removal of vegetation may also impact sensitive habitats (wetlands) and/or habitat utilized by the small whorled pagonia (federally listed threatened), wood turtle (state-listed threatened species), bald eagle (state-listed threatened species), or peregrine falcon (state-listed endangered species). A biological survey of the area would need to be conducted prior to removal activities to assess the presence of sensitive habitats and/or the listed species identified above.

5.2.7 Feasibility

This alternative is readily implementable because the required improvements are understood and executable in the field.

Administrative feasibility would require significant coordination with FTBL and sensitive environment surveying and permitting. Prior to construction, a survey would be conducted to identify any sensitive wildlife or habitat receptors within or adjacent to the construction areas. If the small whorled pogonia, wood turtle, and the bald eagle are found in or near targeted areas, the proposed construction may not be possible.

Advance notification would be provided to the Army prior to specific construction activities, such as mobilization, demobilization, and when hauling fill and topsoil, to minimize any disruption to the adjoining Base community. Roadways would be inspected and maintained as necessary, particularly during periods of increased truck traffic or following periods of precipitation. Additional perimeter monitoring would be conducted and documented during construction as necessary to verify that construction traffic was not affecting methane concentrations.

5.2.8 Cost

The costs with implementing this alternative are broken down into capital costs, O&M costs for 30 years, and the present value cost which represents in today's dollars the capital costs and O&M costs after an annual discount factor of 5 percent. More detailed breakdown of these costs is provided in **Appendix A**.

	Alternative 2
Capital Cost	$13,713,671
O&M Cost	$1,406,384
30-Year Present Value	$14,789,413

This alternative is characterized by high capital costs relative to O&M cost. The O&M cost is due to semi-annual sampling for MNA assumed to continue for 5 years and annual MNA sampling for another 25 years. If concentrations in groundwater decline to acceptable levels earlier, or if a less frequent sampling approach can be agreed upon, the O&M costs can be significantly reduced.

5.2.9 State, US EPA, and Community Acceptance

State, US EPA, and community acceptance will be determined after completion of the Statement of Basis and Public Comment Period. At this time, the Army knows of no State or Community concerns regarding the acceptability of the alternative.

5.3 ALTERNATIVE 3 – ENGINEERED ET COVER SYSTEM, LTM, MNA, AND LUCS

5.3.1 Description

Alternative 3 proposes the installation of an engineered ET cover system to address presumptive remedy guidance regarding landfill containment and inadequate landfill soil cover thickness. The engineered ET cover system would require removal of all vegetation in areas with less than 24 inches of landfill soil cover and where necessary for access and erosion controls, the addition of fill and topsoil to provide 24 inches of cover, and the replacement/mitigation of cleared vegetation. Approximately 18 acres of established forest and meadow would be cleared for soil addition, access roads, and erosion controls. The targeted zones for Alternative 3 are illustrated on **Figures 5-5 and 5-6**.

The proposed cover system would either be a monolithic or capillary break type ET system and would function as a containment measure to do the following:

- Minimize infiltration of precipitation/surface waters into the underlying waste mass, thereby minimizing leachate production and percolation of leachate from the waste to the groundwater;
- Isolate the wastes from receptors (i.e., humans, animals, environment) and control movement by wind or water;
- Control LFG and potential odor emissions; and
- Promote surface water runoff, and minimize erosion.

The engineering and design of Alternative 3 would require limited modeling using published data, determination of appropriate soils, vegetative species, and any necessary modifications to the existing site grading and surface water drainage; a short-term monitoring and maintenance plan to be utilized until vegetation has been fully established; and, a long-term monitoring and maintenance plan. Potential wetlands would need to be identified and delineated with permits obtained prior to any clearing or ground disturbance.

A pre-design survey and reconnaissance would be performed to identify areas requiring the ET cover system; specifically, identifying the areas with less than 2 ft of soil cover, and areas with 2 ft of soil cover and poor vegetation. A CMIWP would be developed describing in detail the areas that would receive the engineered ET cover system. The CMIWP would identify the extent of inadequate soil cover thickness as well as limits and/or location of poor vegetative cover, exposed waste, eroded or unstable soil cover, inadequate drainage, and unsuitable slopes. The CMIWP would present the engineering, design, and operational approach for the proposed ET cover system and would, at a minimum, address the following:

- Landfill cover system deficiencies and corrective measures;
- Existing topography and proposed grading;
- Anticipated limits of disturbance and tree removal inventory;
- Access routes and traffic control plan;
- Soil erosion and sediment control design;
- Sensitive receptor inventory to include wetlands, bodies of water, critical habitat;
- Any construction restrictions such as Virginia's Bald Eagle Protection Guidelines;
- Anticipated sources of construction materials such as select fill and topsoil;
- LFG control and monitoring;
- LTM;
- Site restoration plan to include a construction mitigation plan; and,
- LUCs.

This alternative would require clearing and grubbing of trees and other vegetation to the limits of the proposed ET cover system installation and in areas where needed to provide construction access and erosion controls. To increase the thickness of the soil cover, it is anticipated that 18 acres of trees and other vegetation would require removal. An additional 1 to 2 acres would be cleared to provide for vehicle and equipment access as well as installation of erosion controls. The extent of clearing would be clearly demarcated in the field to limit unnecessary clearing and to minimize disturbance of the landfill surface beyond the extent of the proposed ET cover system installation. An inventory of impacted vegetation would be prepared prior to site disturbance for use in planning site restoration and any subsequent mitigation. Trees greater than 4 inches in diameter that are removed would require replacement with two trees either within the limits of disturbance or elsewhere within FTBL. Soil erosion and sediment control measures would be installed, inspected, and approved in conjunction with site clearing in accordance with the approved plan. All cleared materials would be logged or chipped on site with final disposition determined by FTBL.

Waste materials and debris observed on the landfill surface would be handled and removed in accordance with applicable standards, with final disposition to be recycling or disposal as determined by FTBL.

Potential sources of suitable fill and topsoil within FTBL would be identified prior to locating off-site sources of material to minimize transport distances and the impact on the local communities. All fill and topsoil considered for use on the project would be subjected to geotechnical, chemical, and agronomic testing as appropriate prior to acceptance.

Prior to site restoration, final grade elevations would be obtained and compared to the pre-construction topography to verify that a nominal soil cover thickness of 24 inches is in place within the limits of fill placement.

In conjunction with the ET cover system installations, any additions or improvements to the LFG venting system will be implemented in accordance with the approved design.

Upon completion of the ET cover system installation, all disturbed areas would be restored in full compliance with the approved site restoration plan. Required tree mitigation would be accomplished in accordance with the approved mitigation plan. Soil erosion and sediment controls would be removed only after the site has been re-vegetated and all required approvals have been obtained in writing from FTBL and designated regulators.

A CMI Report would be prepared and submitted for review and approval in draft, draft final, and final versions. The contents of the CMI Report would be defined in the CMIWP prior to the start of construction.

The LTM program would include, semi-annual inspections of the landfill cover systems during the first 2 years of O&M with typically one inspection during the spring and a second inspection during the fall. The semi-annual inspections are to verify that new vegetation, which is potentially vulnerable, is flourishing and appropriately controlling erosion. Additional inspections would typically be conducted following severe weather events. Annual inspections would be conducted each fall after Year 2. The inspections would include an assessment of the vegetative cover and identification of any evidence of erosion or standing water on or adjacent to the landfill cover. The location and extent of any critical observation would be documented in a written field inspection report. Photodocumentation would be obtained showing representative landfill cover conditions at the time of each inspection as well as photos of any critical observations. As part of the LTM program, monitoring of methane controls would be conducted on a semi-annual basis at the landfill boundaries to verify that methane levels do not exceed the methane LEL. The LTM Plan would include a process for prompt notification of the Army and other stakeholders in the event that methane levels exceed the LEL. The results of the landfill cover inspections and methane monitoring would be evaluated and incorporated in an annual CMI Monitoring Report.

The LTM program would also include groundwater sampling events for monitoring wells screened in the shallow aquifer to evaluate MNA. **Table 5-1** lists the monitoring locations to be included in the LTM program and the number of samples collected in each event. Groundwater samples would be analyzed for VOCs using US EPA Method 8260D and natural attenuation parameters. A total of 14 monitoring wells are proposed for inclusion in the MNA LTM program, as shown on **Figure 5-9**. Groundwater sampling would occur semi-annually for the first 5 years, and thereafter annually. Results from the sampling events would provide data on spatial and temporal changes in the extent of groundwater contamination. The duration of the LTM program is conservatively projected to be 30 years.

An LUCIP would be prepared for this alternative that would address periodic inspections, certifications, and regulatory notifications necessary enacted to prevent future disturbance of the landfill cover systems. The LUCs would prohibit future construction, development, or use of groundwater within the designated LUC limits. The LUCIP would describe the implementation, monitoring, and maintenance of the LUCs. LUCs implemented under the LUCIP would be recorded in the Installation Master Plan.

5.3.2 Control of Source Releases

Alternative 3 will provide greater control of source releases by increasing the soil cover thickness to 24 inches in all areas currently measuring less than 24 inches. The increase in soil cover thickness should reduce the quantity of precipitation that may infiltrate through the landfill cover into the underlying waste and thereby reduce the quantity of resulting landfill leachate. However, replacement of well-established forest cover with small trees and ground cover may cause a temporary reduction in vegetative transpiration until vegetation fully matures. The temporary decrease in transpiration and subsequent increase in surface water infiltration may result in an increase in landfill leachate which could cause an increase in groundwater contamination. Additionally, the residual root mass from removed trees would decay in the future and could create ponding and preferential pathways for infiltration, partially negating the benefits of the added soil cover.

5.3.3 Protection of Human Health and the Environment

Alternative 3 would be protective of human health and the environment. The cover would prevent exposure to waste and minimize surface water infiltration.

LUCs would be protective of human health by restricting unauthorized access or any ground disturbance that might result in human exposure to the landfill contents. As part of an approved LTM program, regular inspections would be conducted at both landfill areas to identify necessary repairs including landfill cover erosion and any exposed waste. In addition, LTM would include monitoring of methane levels and testing of groundwater to verify that COI concentrations in groundwater are decreasing.

5.3.4 Compliance with Applicable Standards for Management of Wastes

This alternative fully complies with CMOs and all applicable federal, state, and local regulations. In particular, this alternative is consistent with the US EPA's Presumptive Remedy for Municipal and Military Landfills.

5.3.5 Long-Term Reliability and Effectiveness

The long-term reliability, stability, and effectiveness of the landfill cover systems will be greatly improved by the proposed ET cover system installation at each landfill. The existing landfill covers are generally, well vegetated, and stable; however, areas exist on both landfills where soil cover and vegetative cover are limited and therefore less likely to provide adequate containment as compared to the greater portions of the landfills where soil cover thickness is at least 2 ft and vegetative cover is dense and well established.

Once the vegetative cover on each landfill surface has been established, it is anticipated there will be an improvement in the overall performance and integrity of the landfill cover systems. The established vegetative cover system will minimize the amount of liquid that percolates into the waste mass; and their associated root systems will stabilize the cover and minimize the potential for erosion and sedimentation. The engineered ET cover would be designed and modeled to ensure a balanced water budget. However, the residual root mass from removed trees would decay in the future and could create ponding and preferential pathways for infiltration, partially negating the benefits of the added soil cover.

Semi-annual LTM during Years 2 through 5 and annual LTM during Years 6 through 30 will serve to identify necessary maintenance and repairs that, when implemented, will serve to ensure the long-term reliability and effectiveness of the landfill cover system. The long-term reliability and effectiveness of LUCs and LTM is expected to be excellent, as the U.S. Government owns and controls the property and the site falls under RCRA permit.

LTM and MNA sampling would verify that COI concentrations in groundwater are decreasing over the long term.

5.3.6 Short-Term Effectiveness

It is anticipated that there would be temporary impacts to wildlife due to construction in or near wildlife habitat and wetlands. Appropriate surveys and permits will be needed to work in these areas. Short-term impacts to the surrounding environment will include heavy equipment usage and truck traffic to import gravel, fill, and topsoil, and to remove timber. Impacts will include truck traffic in the community, air and dust emissions, noise, and potential disturbance and mobilization of pockets of methane. Additional perimeter monitoring would be conducted and documented during construction as necessary to verify that construction traffic was not affecting methane concentrations.

Removal of established vegetation will also temporarily destabilize the cover within the targeted ET cover system zones. In the short term, the increased rate of percolation will most likely cause more leachate to be generated within the landfill, which could result in an increase in groundwater contaminant concentrations. The removal of vegetation may also impact sensitive habitats (wetlands) and/or habitat utilized by the small whorled pagonia (federally listed threatened), wood turtle (state-listed threatened species), bald eagle (state-listed threatened species), or peregrine falcon (state-listed endangered species). A biological survey of the area will be conducted prior to removal activities to assess for the presence of sensitive habitats and/or the listed species identified above.

Impacts to areas outside of the targeted improvement zones will also occur to create roads and install erosion controls. As part of the CMIWP, a set of protocol will be developed to minimize disturbance to the existing stands of healthy trees and their respective understory.

5.3.7 Feasibility

This alternative is technically feasible because the required improvements are understood and implementable in the field.

This alternative should be administratively feasible because it complies with Presumptive Remedy guidance and would be consistent with the 24-inch soil cover standard used at other landfills at FTBL. However, it will require a significant amount of surveying and permitting in a protected wildlife and wetland area to protect from the impacts of construction of landfills, access roads, and erosion controls. Prior to construction, a survey would be conducted to identify any sensitive wildlife or habitat receptors within or adjacent to the construction areas. If the small whorled pogonia, wood turtle, and the bald eagle are found in or near targeted areas, the proposed construction may not be possible. If permits can be obtained to perform the construction, activities would be scheduled between July 16th and December 14th to comply with Virginia's bald eagle protection guidelines.

Advance notification would be provided to the Army prior to specific construction activities, such as mobilization, demobilization, and when hauling fill and topsoil, to minimize any disruption to the adjoining Base community. Roadways and sidewalks would be inspected and maintained as necessary, particularly during periods of increased truck traffic or following periods of precipitation. Additional perimeter monitoring would be conducted and documented during construction as necessary to verify that construction traffic was not affecting methane concentrations.

5.3.8 Cost

The costs with implementing this alternative are broken down into capital costs, O&M costs for 30 years, and the present value cost which represents in today's dollars the capital costs and O&M costs after an annual discount factor of 5 percent. More detailed breakdown of these costs is provided in **Appendix A**.

	Alternative 3
Capital Cost	$1,912,669
O&M Cost	$1,394,309
30-Year Present Value	$2,979,058

This alternative is characterized by similar capital and O&M costs, with the O&M due to semi-annual sampling for MNA assumed to continue for 5 years and annual MNA sampling for another 25 years. If concentrations in groundwater decline to acceptable levels earlier, or if a less frequent sampling approach can be agreed upon, the O&M costs can be significantly reduced.

5.3.9 State, US EPA, and Community Acceptance

State, US EPA, and community acceptance will be determined after completion of the Statement of Basis and public comment period. At this time, the Army knows of no State or Community concerns regarding the acceptability of the alternative.

5.4 ALTERNATIVE 4 – ENGINEERED VEGETATIVE COVER ENHANCEMENT, LTM, MNA, AND LUCS

5.4.1 Description

Alternative 4 proposes the installation of an engineered vegetative cover system to address presumptive remedy guidance regarding landfill containment and inadequate landfill vegetative cover, defined as not present, sparse, stressed, diseased, or dead, regardless of soil cover thickness. The objective of Alternative 4 is to enhance the existing vegetative cover system without clearing well-established forest acreage, destroying existing wildlife habitat, threatening adjoining wetlands and water bodies, and increasing truck traffic by hauling logs off site and importing fill and topsoil on site. In landfill areas where vegetation is inadequate, Alternative 4 would provide for soil addition or amendments to sustain healthy vegetative cover and incorporate new vegetation consistent with the engineered vegetative cover design. Soil cover would be increased to 24 inches, where attainable, within the areas of vegetative cover enhancement subject to site conditions. There would be no soil cover increases in areas of well-established vegetation so as to preserve established habitat whenever possible. Landfill areas potentially benefiting from soil addition/amendment and planting of new vegetation are identified on **Figures 5-7 and 5-8**. These areas, which are based on inspection of aerial photographs, would be revised as necessary based on field inspections by qualified personnel.

The physical conditions of the CC-A11 and CC-A12 cover systems were inspected during the 2005 VSIs and the 2011 Final Phase II RFI to be overall, generally good with typically 2 ft of soil cover and healthy, long-established mixed stands of vegetation across most portions of the units. Some limited areas of the units were reported to have less than 2 ft of cover soil (specifically between 1 ft and <2 ft); and some smaller isolated areas were observed on recent aerial images (ESRI aerial map dated January 2009, and a Google Earth aerial map dated August 2010) to have sparse to no vegetation or stressed vegetation.

The existing cover systems appear to function as a monolithic type ET cover system, supporting healthy, thriving stands of mixed vegetation across most portions of both landfill units, with dense stands of mixed pine, poplar, and successional hardwood trees located along the western portions. Alternative 4 proposes enhancements to the existing cover system in areas exhibiting the following features:

- Less than 2 ft of cover soil with poor vegetative cover including:
  - Areas with ground cover and/or shrubs but few or no trees;
  - Areas with sparse vegetative cover;
  - Areas with no vegetative cover; and,
  - Areas with stressed, diseased and/or dead trees or other vegetation.
- Greater than 2 ft of cover soil with any of the following conditions:
  - Sparse vegetation;
  - Stressed, diseased and/or dead vegetation; and,
  - No vegetation.
- Visible signs of stressed, diseased, or unhealthy trees may include the following:
  - Excessive dieback of the canopy or branches;
  - Off-colored foliage (e.g., yellow, brown, etc.);
  - Loss of foliage early in the season;
  - Unrelated species in general area of trees that exhibit similar signs; and,
  - Unhealthy ratio of tree canopy vs. trunk (i.e., an unhealthy tree has $\leq$ 40% canopy to $\geq$ 60% trunk vs. a healthy tree which has 60% canopy to 40% trunk).

Areas identified for improvement (**Figures 5-7 and 5-8**) will receive supplemental soil cover where needed, soil amendments for enhanced vegetative growth, and final vegetative cover by seeding and/or plantings. Supplemental soil cover would include native type soils including sandy to silty-clayey loams. The existing soil surface cover would be regraded/recontoured as needed for improved stormwater drainage and control. A total of approximately 10 acres are expected to be disturbed for vegetative enhancement, access roads, and erosion control. Native vegetative species (similar to what has already been established on site) would be planted after placement of the supplemental soil cover and any soil amendments were added. Removal and disposal of any surface debris/litter would also be done at this time.

Prior to construction, a pre-design survey and reconnaissance would be performed to identify areas requiring improvement. A CMIWP would be developed describing in detail any necessary improvements to the existing landfill cover systems. The CMIWP would identify the extent of inadequate vegetation as well as limits and/or location of exposed waste, eroded or unstable soil cover, inadequate drainage, and unsuitable slopes. The CMIWP would present the design and operational approach for all landfill improvements and would, at a minimum, address the following:

- Existing landfill cover system deficiencies and corrective measures;
- Existing topography and proposed grading;
- Anticipated limits of disturbance and tree removal inventory;
- Access routes and traffic control plan;
- Soil erosion and sediment control design;
- Sensitive receptor inventory to include wetlands, bodies of water, critical habitat;
- Any construction restrictions such as Virginia's Bald Eagle Protection Guidelines;
- Anticipated sources of construction materials such as soil amendments, select fill and topsoil;
- Methane control and monitoring;
- LTM;
- Site restoration plan to include a construction mitigation plan; and,
- LUCs.

This alternative would require very limited clearing of trees and other vegetation to the limits of the targeted enhancement zones and where needed to provide construction access. The extent of any clearing would be clearly demarcated in the field to limit unnecessary clearing and to minimize disturbance of the landfill surface beyond the extent of landfill cover enhancement and vegetative addition. An inventory of any impacted vegetation would be prepared prior to site disturbance for use in site restoration and any subsequent mitigation. Trees greater than 4 inches in diameter that are removed would require replacement with two trees either within the limits of disturbance or elsewhere within FTBL. Soil erosion and sediment control measures would be installed, inspected, and approved in conjunction with site clearing and prior to ground disturbance in accordance with the approved plan. All cleared materials would be logged or chipped with final disposition determined by FTBL. Waste materials and debris observed on the landfill surface would be handled and removed in accordance with applicable standards, with final disposition to be recycling or disposal as determined by FTBL. Handling and segregation of the materials would be dependent on final disposition such as recycling or disposal in a landfill.

Potential sources of suitable select fill and topsoil within FTBL would be identified prior to locating off-site sources of material to minimize transport distances and the impact on the local communities. All select fill and topsoil considered for use on the project would be subjected to geotechnical, chemical, and agronomic testing as appropriate prior to acceptance.

This alternative would be initiated only after establishment of approved site access and approval of installed soil erosion and sediment control devices. Coordination of all activities would be closely coordinated with FTBL to minimize impact on the surrounding community. This will require a mandatory survey for the small whorled pogonia between June 1 and July 15, the bald eagle (nests and mated pairs have been documented in the area) and wetlands (a 4-month process). Controlled clearing and grubbing would be conducted within the limits of vegetative addition to remove or relocate any vegetative debris that interferes with new planting. Any imported amendments, topsoil or fill would be transported in tri-axle dump trucks to the landfill construction staging areas and then transferred to the work areas in a manner to minimize impact to landfill vegetation. To avoid excessive compaction, any placement of select fill or topsoil would be conducted using low ground pressure equipment; and, subsequent equipment, vehicle, and/or foot traffic would be limited.

In conjunction with landfill cover improvements, installation of the LFG passive vent system will be implemented in accordance with the approved design, to reduce the risk of buildup and/or migration of LFG.

Upon completion of landfill cover improvements, all disturbed areas would be restored in full compliance with the approved site restoration plan. Any required tree mitigation would be accomplished in accordance with the approved mitigation plan. Soil erosion and sediment controls would be removed only after the site has been re-vegetated and all required approvals have been obtained in writing from FTBL and designated regulators.

A CMI Report would be prepared and submitted for review and approval in draft, draft final, and final versions. The contents of the CMI Report would be defined in the CMIWP prior to the start of construction.

The LTM program would include semi-annual inspections of the landfill cover systems during the first 5 years of O&M with typically one inspection during the spring and a second inspection during the fall. The purpose of semi-annual inspections would be to verify that new vegetation, which would potentially be vulnerable, is flourishing and appropriately controlling erosion. Additional inspections would typically be conducted following severe weather events. Annual inspections would be conducted each fall after Year 3. The inspections would include an assessment of the vegetative cover and identification of any evidence of erosion or standing water on or adjacent to the landfill cover. The location and extent of any critical observation would be documented in a written field inspection report. Photodocumentation would be obtained showing representative landfill cover conditions at the time of each inspection as well as photos of any critical observations. As part of the LTM program, monitoring of methane controls would be conducted on a semi-annual basis at the landfill boundaries to verify that methane levels do not exceed the methane LEL. The LTM Plan would include a process for prompt notification of the Army and other stakeholders in the event that methane levels exceed the LEL. The results of the landfill cover inspections and methane monitoring would be evaluated and incorporated in an annual CMI Monitoring Report.

The LTM program would also include groundwater sampling events for monitoring wells screened in the shallow aquifer to evaluate MNA. **Table 5-1** lists the monitoring locations to be included in the LTM program and the number of samples collected in each event. Groundwater samples would be analyzed for VOCs using US EPA Method 8260D and natural attenuation parameters. A total of 14 monitoring wells are proposed for inclusion in the MNA LTM program, as shown on **Figure 5-9**. Groundwater sampling would occur semi-annually for the first 5 years, and thereafter annually. Results from the sampling events would provide data on spatial and temporal changes in the extent of groundwater contamination. The duration of the LTM program is conservatively projected to be 30 years.

An LUCIP would be prepared for this alternative that would address periodic inspections, certifications, and regulatory notifications necessary enacted to prevent future disturbance of the landfill cover systems. The LUCs would prohibit future construction, development, or use of groundwater within the designated LUC limits. The LUCIP would describe the implementation, monitoring, and maintenance of the LUCs. LUCs implemented under the LUCIP would be recorded in the Installation Master Plan.

5.4.2 Control of Source Releases

Alternative 4 would provide greater control of source releases from waste in place by improving the soil and vegetative cover in targeted enhancement zones where existing ground cover and other vegetation are inadequate. Once the vegetation has been fully established in these areas, percolation volumes will decrease.

Enhancements to the landfill cover would, over the long term, minimize infiltration of surface waters into the waste, thereby minimizing leachate production potential and the potential for further migration of contaminants into the groundwater system. Methane levels would be monitored as part of the LTM program to detect any releases above the LEL.

5.4.3 Protection of Human Health and the Environment

Vegetative addition and soil cover enhancement would improve the performance of the existing landfill cover and would be protective of human health. The cover would prevent exposure to waste and minimize surface water infiltration.

LUCs would be protective of human health by restricting unauthorized access or any ground disturbance that might result in human exposure to the landfill contents. As part of an approved LTM program, regular inspections would be conducted at both landfills to identify any areas requiring repairs and/or maintenance including landfill cover erosion and any exposed waste. In addition, LTM would include monitoring of methane levels and testing of groundwater to verify that COI concentrations in groundwater are decreasing.

5.4.4 Compliance with Applicable Standards for Management of Wastes

This alternative fully complies with all applicable federal, state, and local regulations. In particular, this alternative is consistent with the US EPA's Presumptive Remedy for Municipal and Military Landfills. However, this alternative is not fully consistent with the relevant standard of a minimum 2-ft soil cover thickness at legacy landfills. The soil cover is only being amended in areas where vegetation is being added. Both the CC-A11 and CC-A12 landfills stopped operating well before RCRA was passed into law. Attempting to accomplish the 24-inch cover guidance may adversely impact human health and the environment by disturbing functional and stable landfill cap systems. Maintaining and enhancing the existing landfill cover, although less than the 24-inch standard for cover thickness in some areas, may qualify for consideration as an alternative landfill design in that it appears to be functioning as an effective vegetative landfill cover. One objective of the cover system is to reduce infiltration to minimize leachate. Further, drainage features are in place to redirect surface water around the landfill caps and minimize stormwater run-on. The combination of well-established vegetation and effective stormwater run-on controls serve to minimize infiltration through the landfill cover systems at CC-A11 and CC-A12. As such, the proposed improvements to the existing landfill covers meet the intent of RCRA performance standards for landfill closure, including being protective of human health and the environment, when applied to municipal landfills that were closed prior to RCRA.

5.4.5 Long-Term Reliability and Effectiveness

The long-term reliability, stability, and effectiveness of the landfill cover will be enhanced by the proposed improvements at each landfill. The existing landfill covers are well vegetated, stable, and generally intact; however, areas exist where limited vegetative cover may not provide adequate capture of rainfall. The vegetative improvements would improve a balanced water budget and reduce infiltration through waste.

Once the vegetative cover on each landfill surface has been established, it is anticipated there will be an improvement in the overall performance and integrity of the landfill cover. The established vegetative cover system will minimize the amount of liquid that percolates into the waste mass; and their associated root systems will stabilize the cover and minimize the potential for erosion and sedimentation. LTM will serve to identify necessary maintenance and repairs that, when implemented, will serve to ensure the long-term reliability and effectiveness of the landfill cover system. The long-term reliability and effectiveness of LUCs and LTM is expected to be excellent, as the U.S. Government owns and controls the property and the site falls under RCRA permit.

LTM and MNA sampling would verify that COI concentrations in groundwater are decreasing over the long term.

5.4.6 Short-Term Effectiveness

It is anticipated that there would be temporary impacts to wildlife due to construction in or near wildlife habitat and wetlands. Appropriate surveys and permits will be needed to work in these areas. Short-term impacts to the surrounding environment will include heavy equipment usage and truck traffic to import gravel, fill, and topsoil, and to remove timber. Impacts will include truck traffic in the community, air and dust emissions, noise, and potential disturbance and mobilization of pockets of methane. Additional perimeter monitoring would be conducted and documented during construction as necessary to verify that construction traffic was not affecting methane concentrations.

The removal of vegetation may also impact sensitive habitats (wetlands) and/or habitat utilized by the small whorled pagonia (federally listed threatened), wood turtle (state-listed threatened species), bald eagle (state-listed threatened species), or peregrine falcon (state-listed endangered species). A biological survey of the area will be conducted prior to removal activities to assess for the presence of sensitive habitats and/or the aforementioned listed species. Removal of established vegetation will also temporarily destabilize the cover within the targeted enhancement area. However, since this alternative only targets areas of poor vegetation, the temporary destabilization will be minimized and improved vegetation will soon be established.

Impacts to areas outside of the targeted improvement zones will also occur to create roads and install erosion controls. As part of the CMIWP, a set of protocol will be developed to minimize disturbance to the existing stands of healthy trees and their respective understory.

5.4.7 Feasibility

This alternative is technically feasible because the required improvements are understood and executable in the field.

The alternative should be administratively feasible because it complies with Presumptive Remedy guidance. However, it will require a survey to identify any sensitive wildlife or habitat within or adjacent to the construction areas. If the small whorled pogonia, wood turtle, and the bald eagle are found in or near targeted areas, the proposed construction may not be possible. If permits can be obtained to perform the construction, activities would be scheduled between July 16th and December 14th to comply with Virginia's bald eagle protection guidelines.

US EPA has indicated that alternatives to Subtitle D landfill closure requirements may be considered if the alternative design achieves landfill closure objectives and would meet the intent of RCRA performance standards for landfill closure. The proximity of sensitive habitats associated with nearby wetlands and the Potomac River may justify consideration of alternatives to clearing and ground disturbance which may impact human health and the environment.

5.4.7.1 Cost

The costs with implementing this alternative are broken down into capital costs, O&M costs for 30 years, and the present value cost which represents in today's dollars the capital costs and O&M costs after an annual discount factor of 5 percent. More detailed breakdown of these costs is provided in **Appendix A**.

	Alternative 4
Capital Cost	$1,122,298
O&M Cost	$1,394,309
30-Year Present Value	$2,188,688

This alternative is characterized by low capital costs relative to O&M cost. The O&M cost is due to semi-annual sampling for MNA assumed to continue for 5 years and annual MNA sampling for another 25 years. If concentrations in groundwater decline to acceptable levels earlier, or if a less frequent sampling approach can be agreed upon, the O&M costs can be significantly reduced.

5.4.8 State, US EPA, and Community Acceptance

State, US EPA, and community acceptance will be determined after completion of the Statement of Basis and public comment period. At this time, the Army knows of no State or Community concerns regarding the acceptability of the alternative.

5.5 SUMMARY AND COMPARISON OF ALTERNATIVES FOR LANDFILL CONTAINMENT

The alternatives evaluated in this section are summarized as follows:

- Alternative 1 – No Action includes no proposed measures be employed at CC-A11 and CC-A12. It is included as a baseline for comparison purposes only.
- Alternative 2 – Engineered RCRA Cap System, LTM, MNA, and LUCs includes:
  - Removal of all vegetation within the entire landfill limits (see **Figures 5-3 and 5-4**);

- Addition of select fill and re-grading of landfill surface to attain required sloping for surface water runoff;
- Placement of low permeability soil and topsoil to achieve the minimum 24-inch thickness;
- Restoration of vegetation;
- LFG venting;
- LUCs to protect the cover system and contained waste;
- Groundwater monitoring for MNA; and,
- LTM to verify cover and LUC effectiveness.

- Alternative 3 – Engineered ET Cover System, LTM, MNA, and LUCs includes:
  - Removal of all vegetation within the delineated limits of landfill soil cover thickness measuring less than 24 inches (see **Figures 5-5 and 5-6**);
  - Placement of select fill, as required, and topsoil to achieve the minimum 24-inch soil cover thickness;
  - Restoration of native vegetation in disturbed areas to achieve a modeled water budget to minimize infiltration of rainfall into waste;
  - LFG venting;
  - LUCs to protect the cover system and contained waste;
  - Groundwater monitoring for MNA; and,
  - LTM to verify cover and LUC effectiveness.
- Alternative 4 – Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs includes:
  - Delineation of areas within landfill limits with no vegetation or insufficient vegetation (see **Figures 5-7 and 5-8**) for preliminary determination);
  - Removal or relocation of existing vegetative debris in vegetative enhancement areas;
  - Enhancement of existing soils in vegetative enhancement areas either by addition or amendment;
  - Planting of native trees and groundcover;
  - LFG venting;
  - LUCs to protect the cover system and contained waste;
  - Groundwater monitoring for MNA; and,
  - LTM to verify cover and LUC effectiveness.

Alternative 2 is the most protective alternative in the long term, as it includes completely replacing the entire 40 acres (CC-A11 and CC-A12 combined) of existing cover system to meet current RCRA closure requirements. Consequently, it is the most intrusive and expensive alternative and disturbs the current wildlife habitat to the greatest degree.

The primary difference between Alternatives 3 and 4 is the area targeted for improvement. Alternative 3 targets approximately 18 acres where soil cover is less than 24 inches, adding soil and re-vegetating in a manner that exploits ET. Alternative 4 targets approximately 10 acres where vegetation is inadequate, adding or amending soil cover as needed and re-vegetating. In Alternative 4, areas with less than 24 inches of soil cover that have adequate vegetative cover will remain undisturbed to preserve the established vegetation and habitat.

In regards to controlling sources of releases, protection of human health and the environment, compliance with standards, long-term reliability and effectiveness, and feasibility, both Alternatives 3 and

4 provide similar improvement compared to the No Action alternative, by improving the cover to reduce infiltration, controlling LFG buildup, implementing LUCs, and performing LTM. However, Alternative 3 includes removal of significantly more trees, leaving root systems in the ground that would decay and potentially create LFG, subsidence, standing water, and preferential flow paths.

The short-term impacts to wildlife habitat and the community associated with Alternatives 3 and 4 are greater compared to No Action, as they include removal of vegetation and construction activities. Alternative 3 will result in more short-term impacts compared to Alternative 4 because it includes clearing of approximately 18 acres of primarily well-established forest, where trees of significant size will be removed. By comparison, Alternative 4 targets 10 acres of poorly vegetated area. The smaller and less vegetated footprint of construction for Alternative 4 will:

- Reduce disturbance to site soils, vegetation, and ecosystems/habitats;
- Reduce the footprint of existing cover temporarily destabilized, thereby reducing the volume of surface water infiltration that would occur until re-vegetation matures;
- Reduce potential disturbance of landfill waste;
- Reduce noise and air emissions generated by heavy earthmoving equipment, and site traffic volumes;
- Reduce potential impacts to nearby water bodies including sedimentation, nutrient loading, and overall water quality;
- Require less material consumption (e.g., equipment fuel and oil, soils and soil amendments imported from off-site sources, new trees and shrubs from off-site sources, water, etc.); and,
- Reduce waste generation (e.g., clearing/grubbing debris, field supplies, etc.).

The smaller footprint of construction associated with Alternative 4 supports many BMPs outlined in US EPA's *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (US EPA, 2008), including:

- Use minimally invasive technologies;
- Minimize soil and habitat disturbance;
- Reduce noise and lighting disturbance;
- Minimize use of heavy equipment to reduce fuel consumption, and particulate and dust emissions;
- Minimize land disturbance and excavations to reduce overall dust emissions;
- Reduce atmospheric release of toxic or priority pollutants (ozone, particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide, and lead);
- Minimize dust export of contaminants;
- Avoid disturbance to existing vegetation and use native vegetation where needed to reduce need for irrigation;
- Prevent impacts such as nutrient loading on water quality in nearby water bodies;
- Use technologies designed to minimize waste generation;
- Minimize natural resource extraction and disposal; and,
- Reduce emission of CO2, N2O, CH4, and other greenhouse gases contributing to climate change.

The capital, O&M, and 30-year present value costs for the four alternatives are shown below. Alternative 2 is the most expensive, followed by 3 and 4. O&M costs for Alternatives 2 through 4 are the same.

	1	2	3	4
CC-A11 and CC-A12	**No Action**	**Engineered RCRA Cap System, LTM, MNA, and LUCs**	**Engineered ET Cover System, LTM MNA, and LUCs**	**Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs**
Capital Cost	$0	$13,713,671	$1,912,669	$1,122,298
O&M Costs	$0	$1,406,384	$1,394,309	$1,394,309
Total Present Worth	$0	$14,789,413	$2,979,058	$2,188,688

Table 5-1
Analytical Schedule LTM Sampling Program for MNA

Proposed Samples	Frequency[1]	TCL VOCs	MNA Indicator Parameters[2]	Water Quality Parameters[3]
Groundwater				
A11-MW01	Semi-Annual	X	X	X
A11-MW02	Semi-Annual	X	X	X
A11-MW03	Semi-Annual	X	X	X
A11-MW10	Semi-Annual	X	X	X
A11-MW11	Semi-Annual	X	X	X
A12-MW01	Semi-Annual	X	X	X
A12-MW02	Semi-Annual	X	X	X
A12-MW03	Semi-Annual	X	X	X
A12-MW04	Semi-Annual	X	X	X
A12-MW05	Semi-Annual	X	X	X
A12-MW08	Semi-Annual	X	X	X
A12-MW09	Semi-Annual	X	X	X
A12FTBL-MW01	Semi-Annual	X	X	X
A12FTBL-MW02	Semi-Annual	X	X	X
QC Samples				
Field Duplicate[4]	10%	X	X	--
Rinse Blank[5]	5%	X	X	--
Trip Blank[6]	1/cooler	X	--	--

[1] Wells to be samples semi-annually for first 15 years, switching to annually for years 16 – 30.
[2] MNA indicator parameters include nitrate, chloride, sulfate, TOC, methane, ethane, ethene, and ferrous iron. Ferrous iron is to be performed in the field with Hach kit. For wells where it is seen to exhibit good degradation, *Dehalococcoides ethenogenes* analysis will also be performed on select samples.
[3] Water quality parameters include pH, specific conductance, DO, temperature, turbidity, and ORP.
[4] Field duplicates will be collected on a 10% frequency for each matrix (groundwater, surface water, sediment).
[5] Rinse blanks will be collected on a 5% frequency for groundwater and sediment only. Surface water samples will be collected directly from the sample jars.
[6] Trip blanks will accompany each cooler containing aqueous VOC samples.

6.0 JUSTIFICATION AND RECOMMENDATION OF THE PREFERRED ALTERNATIVES

This section provides justification and recommendations for the preferred CMA for CC-A11 and CC-A12. CMAs were evaluated to address landfill waste and groundwater.

6.1 JUSTIFICATION AND RECOMMENDATION FOR CC-A11 AND CC-A12

The CMOs to address landfill waste and groundwater at CC-A11 and CC-A12 were developed in Sections 3.1 and 3.2, respectively, and included containment of the underlying waste mass with the following objectives:

- Reduce infiltration of surface waters into the waste, thereby reducing leachate production;
- Isolate the wastes from receptors (i.e., humans, animals, environment) and control movement by wind or water;
- Control LFG and odor emissions;
- Promote surface water runoff, and minimize erosion;
- Remain effective for at least 30 years;
- Be protective of endangered, threatened, and sensitive species and habitat;
- Utilize BMPs of US EPA's defined core elements of green remediation;
- Prevent use of groundwater containing PCE, TCE, or VC in concentrations exceeding MCLs; and,
- Contain the PCE, TCE, and VC solute plume to below MCLs at the Point of Compliance (defined as Accotink Creek) within 30 years. It should be noted that this CMO appears to have already been met based on RFI sampling.

Technologies for containment of waste and groundwater were identified and screened in Section 4.0, and alternative actions were identified and evaluated in Section 5.0. Four alternatives were evaluated:

- <u>Alternative 1 – No Action</u> includes no proposed measures to be employed at CC-A11 and CC-A12. It is included as a baseline for comparison purposes only.
- <u>Alternative 2 – Engineered RCRA Cap System, LTM, MNA, and LUCs</u> includes:
    - Removal of all vegetation within the entire landfill limits (see **Figures 5-3 and 5-4**);
    - Addition of select fill and re-grading of landfill surface to attain required sloping for surface water runoff;
    - Placement of low permeability soil and topsoil to achieve the minimum 24-inch thickness;
    - Restoration of vegetation;
    - LFG venting;
    - LUCs to protect the cover system and contained waste;
    - Groundwater monitoring for MNA; and,
    - LTM to verify cover and LUC effectiveness.
- <u>Alternative 3 – Engineered ET Cover System, LTM, MNA, and LUCs</u> includes:
    - Removal of all vegetation within the delineated limits of landfill soil cover thickness measuring less than 24 inches (see **Figures 5-5 and 5-6**);
    - Placement of select fill, as required, and topsoil to achieve the minimum 24-inch soil cover thickness;

  - Restoration of native vegetation in disturbed areas to achieve a modeled water budget to minimize infiltration of rainfall into waste;
  - LFG venting;
  - LUCs to protect the cover system and contained waste;
  - Groundwater monitoring for MNA; and,
  - LTM to verify cover and LUC effectiveness.

- <u>Alternative 4 – Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs</u> includes:
  - Delineation of areas within landfill limits with no vegetation or insufficient vegetation (see **Figures 5-7 and 5-8**) for preliminary determination);
  - Removal or relocation of existing vegetative debris in vegetative enhancement areas;
  - Enhancement of existing soils in vegetative enhancement areas either by addition or amendment;
  - Planting of native trees and groundcover;
  - LFG venting;
  - LUCs to protect the cover system and contained waste;
  - Groundwater monitoring for MNA; and,
  - LTM to verify cover and LUC effectiveness.

As summarized in **Table 6-1**, all alternatives (other than No Action) utilize MNA to achieve CMOs for groundwater. Samples collected for MNA will be evaluated to determine if natural attenuation through reductive dechlorination, phytoremediation, dispersion, dilution, volatilization, and sorption is occurring at a sufficient rate. There currently is limited data available for MNA, but the anaerobic conditions and presence of breakdown products suggest that natural attenuation processes are occurring. The CMO of containing the plume to below MCLs at Accotink Creek within 30 years appears to have already been met based on RFI sampling. Therefore, MNA is the only groundwater technology included with the alternatives.

As summarized in **Table 6-1**, Alternatives 2, 3 and 4 all control source releases, comply with standards and criteria, provide long-term effectiveness, and are feasible to implement. However, the removal of mature forested areas in Alternative 3 poses a concern regarding the root systems of the trees. Removal of the root systems is not recommended due to the potential for disturbing and exposing buried waste. Leaving them in place poses a concern regarding decomposition of the roots, subsidence of the cover, ponding of water, and preferential infiltration pathways.

Alternatives 2, 3, and 4 all contribute some short-term impacts to the environment associated with removal of vegetation and associated disruption of wildlife habitat and impacts to traffic. However, the extent of disturbance varies greatly, with Alternative 2 disturbing approximately 70 acres, Alternative 3 disturbing 20 partly forested acres, to Alternative 4 disturbing only 10 poorly vegetated acres. The smaller and less vegetated footprint of construction for Alternative 4 will:

- Reduce disturbance to site soils, vegetation, and ecosystems/habitats;
- Reduce the footprint of existing cover temporarily destabilized, thereby reducing the volume of surface water infiltration that would occur until re-vegetation matures;
- Reduce potential disturbance of landfill waste;
- Reduce noise and air emissions generated by heavy earthmoving equipment, and site traffic volumes;
- Reduce potential impacts to nearby water bodies including sedimentation, nutrient loading, and overall water quality;

- Require less material consumption (e.g., equipment fuel and oil, soils and soil amendments imported from off-site sources, new trees and shrubs from off-site sources, water, etc.); and,
- Reduce waste generation (e.g., clearing/grubbing debris, field supplies, etc.).

The smaller footprint of construction associated with Alternative 4 supports many BMPs outlined in the US EPA's *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (US EPA, 2008). Alternative 4 will also be more feasible to implement in regards to obtaining permits to perform construction in wetlands and sensitive environmental habitats.

The capital and 30-year present value costs to implement Alternative 4 are also lower than Alternatives 2 and 3, as shown in **Table 6-1**.

In consideration of these criteria, Alternative 4 Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs is the preferred alternative to address landfill waste and groundwater at CC-A11 and CC-A12. Compared to Alternatives 2 and 3, this alternative provides the best combination of control of source releases, protection of human health and the environment, long-term reliability, and short-term effectiveness. It meets CMOs, complies with applicable standards, is the most feasible to implement and has the lowest cost.

Table 6-1
Summary of Alternative Evaluation for CC-A11 and CC-A12

Criteria	Alternative 1 No Action	Alternative 2 Engineered RCRA Cap System, LTM, MNA, and LUCs	Alternative 3 Engineered ET Cover System, LTM, MNA, and LUCs	Alternative 4 Engineered Vegetative Cover Enhancement, LTM, MNA, and LUCs
1. CONTROL OF SOURCE RELEASES				
Containment of waste and control of migration through groundwater.	No added control beyond existing cover, which is functioning to some extent as an evapotranspiration (ET) cover. No added control of migration of contaminants beyond natural attenuation, which appears to be occurring, but at an unknown rate.	Yes, provides a low permeability cap over the entire landfill footprints thus minimizing and reducing infiltration. Monitoring of contaminants in groundwater is provided, including quantification of natural attenuation to verify CMOs are achieved.	Yes, improves the existing cover thickness where less than 24 inches, adds vegetation for ET, thus reducing infiltration. Monitoring of contaminants in groundwater is provided, including quantification of natural attenuation to verify CMOs are achieved.	Yes, improves the existing vegetative cover for ET, thus reducing infiltration. Monitoring of contaminants in groundwater is provided, including quantification of natural attenuation to verify CMOs are achieved.
2. PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT				
Protection of Human Health	No controls to monitor quality of existing cover and LFG in the future, and prevent unauthorized disturbance of waste. No controls to restrict human consumption of groundwater and no monitoring to ensure exposure assumptions do not change.	Yes, provides and monitors protection to human health from exposure to waste and LFG, with some impacts to site workers and community during construction. Provides controls to restrict future ingestion of contaminated groundwater.	Yes, provides and monitors protection to human health from exposure to waste and LFG, with some impacts to site workers and community during construction. Provides controls to restrict future ingestion of contaminated groundwater.	Yes, provides and monitors protection to human health from exposure to waste and LFG, with limited impacts to site workers and community during construction. Provides controls to restrict future ingestion of contaminated groundwater.
Protection of the Environment	No protection is included, but ecosystem appears to be thriving. No monitoring to ensure that there are no unacceptable impacts to surface water in the future.	Yes, provides protection of the environment with heavy short-term impacts associated with disturbance of wildlife and wetland areas. Protective of the environment through monitoring to ensure that there are no unacceptable impacts to surface water in the future.	Yes, provides protection of the environment with moderate short-term impacts associated with disturbance of wildlife and wetland areas. Protective of the environment through monitoring to ensure that there are no unacceptable impacts to surface water in the future.	Yes, provides best protection of the environment by improving poorly vegetated areas. Minor short-term impacts associated with disturbance of wildlife and wetland areas. Protective of the environment through monitoring to ensure that there are no unacceptable impacts to surface water in the future.
3. COMPLIANCE WITH STANDARDS AND CRITERIA				
Compliance with CMOs	No	Yes	Yes	Yes
Compliance with Laws and Permits	No	Yes	Yes	Yes, although some areas of landfill will have less than 2-ft of soil cover, which has been a relevant requirement.
4. LONG-TERM RELIABILITY AND EFFECTIVENESS				
Magnitude of Residual Risk	Low but unmonitored.	Low and monitored to ensure acceptability.	Low and monitored to ensure acceptability.	Low and monitored to ensure acceptability.
Adequacy and Reliability of Controls	No controls.	Yes, government-owned property under RCRA provides reliable control.	Yes, government-owned property under RCRA provides reliable control.	Yes, government-owned property under RCRA provides reliable control.
Reduction of Toxicity, Mobility, and Volume	None	Some reduction of mobility from landfill is likely. No reduction in groundwater beyond what is naturally occurring, but monitoring allows quantification.	Some reduction of mobility from landfill is likely. No reduction in groundwater beyond what is naturally occurring, but monitoring allows quantification.	Some reduction of mobility from landfill is likely. No reduction in groundwater beyond what is naturally occurring, but monitoring allows quantification.
5. SHORT-TERM EFFECTIVENESS				
Community Protection	No action, so no short-term impacts.	Minor air quality impacts during construction due to dust emissions from earthmoving activities; particulates and toxic air pollutant emissions due to diesel / gasoline operated equipment and vehicles; and noise. Impacts greater than Alternatives 3 and 4 due to larger footprint of construction. Restrictions on use of contaminated groundwater until CMOs are met is included.	Minor air quality impacts during construction due to dust emissions from earthmoving activities; particulates and toxic air pollutant emissions due to diesel / gasoline operated equipment and vehicles; and noise. Impacts are greater than Alternative 4 due to larger footprint of construction. Restrictions on use of contaminated groundwater until CMOs are met is included.	Minor air quality impacts during construction due to dust emissions from earthmoving activities; particulates and toxic air pollutant emissions due to diesel / gasoline operated equipment and vehicles; and noise. Impacts are less than Alternatives 2 and 3 due to smaller footprint of construction. Restrictions on use of contaminated groundwater until CMOs are met is included.
Worker Protection	No action, so no short-term impacts.	Personal protective equipment and safe operating procedures utilized by site workers to minimize any potential impacts during construction.	Personal protective equipment and safe operating procedures utilized by site workers to minimize any potential impacts during construction.	Personal protective equipment and safe operating procedures utilized by site workers to minimize any potential impacts during construction.
Environmental Impacts	No action, so no short-term impacts.	Approximately 70 acres disturbed to cap 100% of the landfill and construct access roads, erosion controls, and sedimentation basins. Disturbance requires removal of all trees and vegetation. Impacts to wildlife may include destruction of habitat, air emissions, and noise. Affected ecosystem and protected wildlife to be determined after survey for wetlands, wood turtle, and small whorled pogonia. Minor impact and disturbance to surface water possible, minimized through the use of erosion and sedimentation controls.	Approximately 20 acres disturbed to increase soil cover and construct access roads, erosion controls, and sedimentation basins. Disturbance requires removal of trees and portions of tree stands in low soil cover areas. Impacts to wildlife may include destruction of habitat, air emissions, and noise. Affected ecosystem and protected wildlife to be determined after survey for wetlands, wood turtle, and small whorled pogonia. Minor impact and disturbance to surface water possible, minimized through the use of erosion and sedimentation controls.	Approximately 10 acres disturbed to improve poorly vegetated areas and construct access roads, erosion controls, and potentially sedimentation basins. Disturbance requires removal of individual trees in areas where vegetation is poor. Impacts to wildlife may include destruction of habitat, air emissions, and noise. Affected ecosystem and protected wildlife to be determined after survey for wetlands, wood turtle, and small whorled pogonia. Minor impact and disturbance to surface water possible, minimized through the use of erosion and sedimentation controls.
Sustainability During Remediation	Not Applicable	Does not utilize Best Management Practices (BMPs) of Green Remediation because the area disturbed is extensive and significant resources are utilized.	Utilizes the same BMPs of Green Remediation as Alternative 4, but to a lesser degree because the footprint of construction is greater and the vegetation disturbed includes tree stands.	Utilizes BMPs of Green Remediation: • Uses minimally invasive technologies • Minimizes soil and habitat disturbance • Reduces noise and lighting disturbance • Minimizes use of heavy equipment • Minimizes land disturbance • Reduces atmospheric emissions • Minimizes dust export of contaminants • Avoids disturbance to existing vegetation • Prevents impacts to water bodies • Uses technologies to minimize waste • Minimizes resource extraction/disposal • Reduces greenhouse gas emmissions
Time until Action is Complete	None	1 1/2 years for capping (8 months planning, 10 months construction) 10 to 30 years estimated for groundwater	1 year for cover system (8 months planning, 2 months construction) 10 to 30 years estimated for groundwater	1 year for cover system (8 months planning, 2 months construction) 10 to 30 years estimated for groundwater
6. FEASIBILTY				
Technical Feasibility	Technically feasible	Technically feasible	Technically feasible	Technically feasible
Administrative Feasibility	Not likely to be acceptable under RCRA program.	Least feasible, due to potential impacts to wetland and wildlife. If protected wildlife is found during survey, construction may not be administratively feasibile.	Potentially feasible, but requires wetland and wildlife surveys and permitting. If protected wildlife is found during survey, construction may not be administratively feasibile.	Most feasibile, since the footprint of construction reduces the potential for impacts to protected habitat. Requires wetland and wildlife surveys and permitting.
7. COST				
Capital	$0	$13.7M	$1.9M	$1.1M
30-Year O&M	$0	$1.4M	$1.4M	$1.4M
Present Value	$0	$14.8M	$3.0M	$2.2M
8. STATE, US EPA, AND COMMUNITY ACCEPTANCE				
	To be determined after completion of the Statement of Basis and Public Comment Period			

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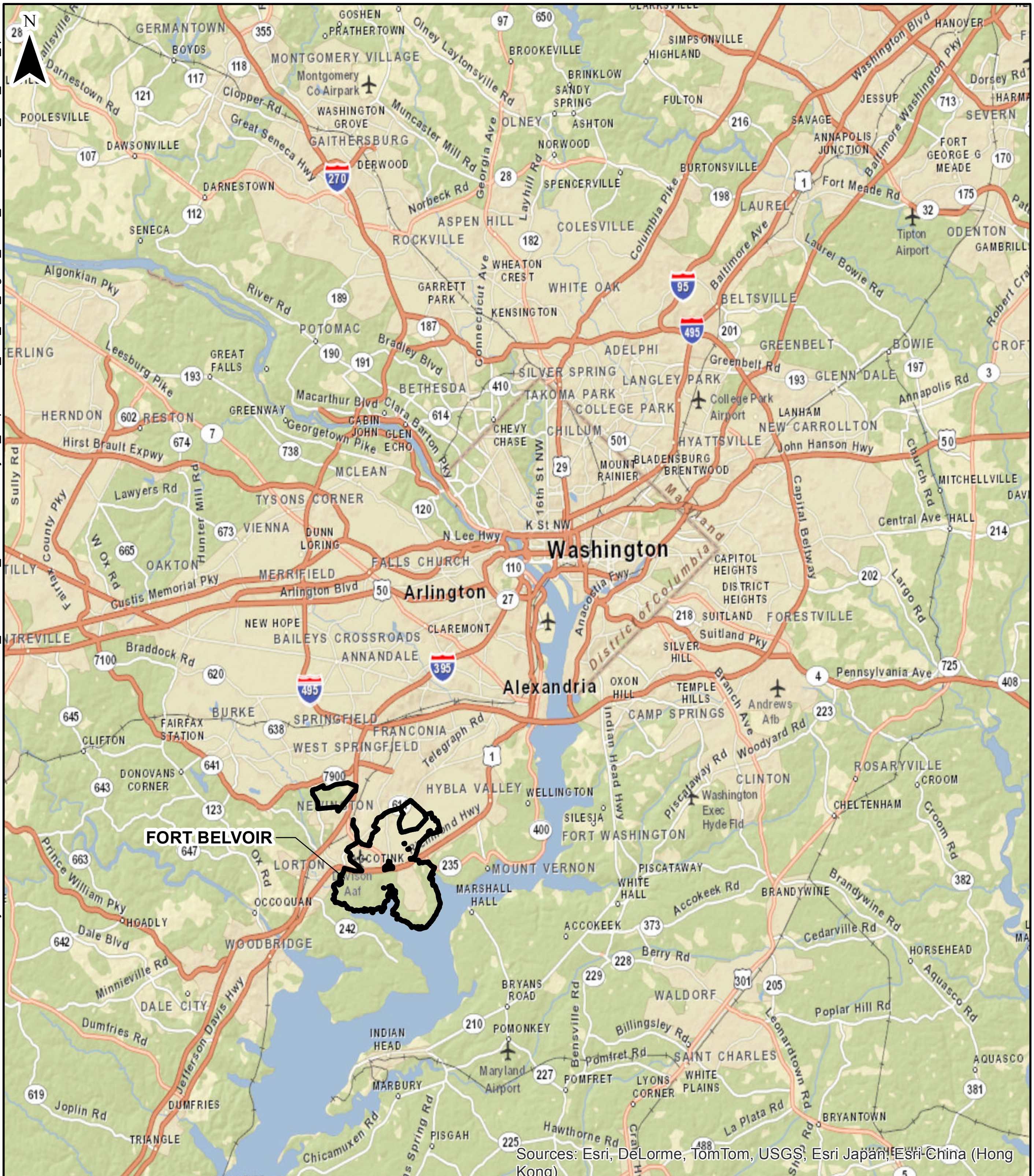

Fort Belvoir Installation Boundary

0 5 10 Miles

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 1-1	FORT BELVOIR LOCATION CORRECTIVE MEASURES STUDY REPORT FORT BELVOIR, VIRGINIA

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IRP Site Boundary
Surface Water Body
Fort Belvoir Installation Boundary

0 4,000 8,000 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

Project Number: 146324

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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 2-1	CC-A11 AND CC-A12 SITE LOCATION MAP CORRECTIVE MEASURES STUDY REPORT FORT BELVOIR, VIRGINIA

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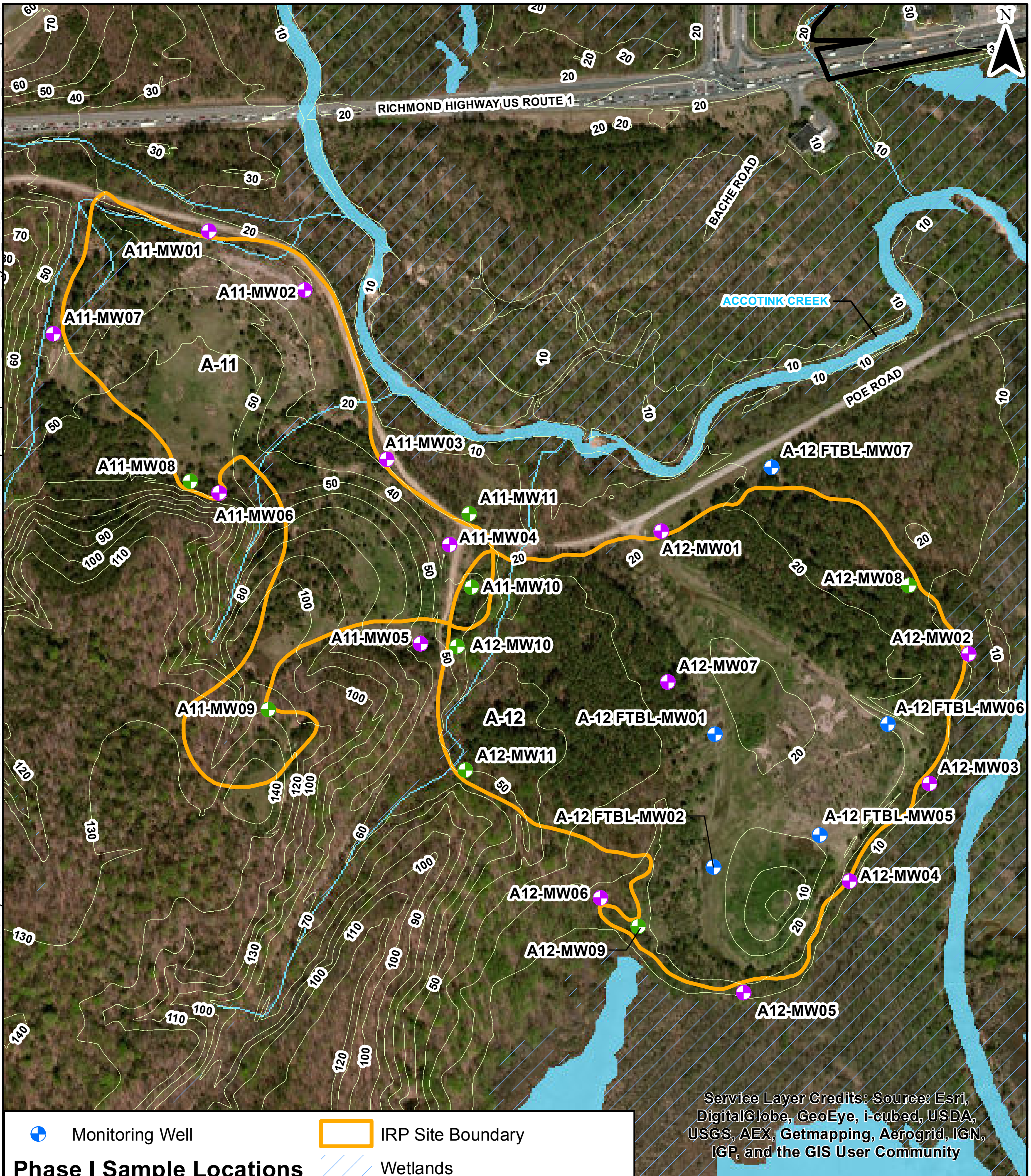

Monitoring Well

Phase I Sample Locations

Monitoring Well

Phase II Sample Locations

Monitoring Well

Ground Surface Contour (10 ft Interval)

Surface Water Feature

IRP Site Boundary

Wetlands

Fort Belvoir Installation Boundary

Surface Water Body

0 450 900 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 2-2

CC-A11 AND CC-A12
SITE FEATURES MAP
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

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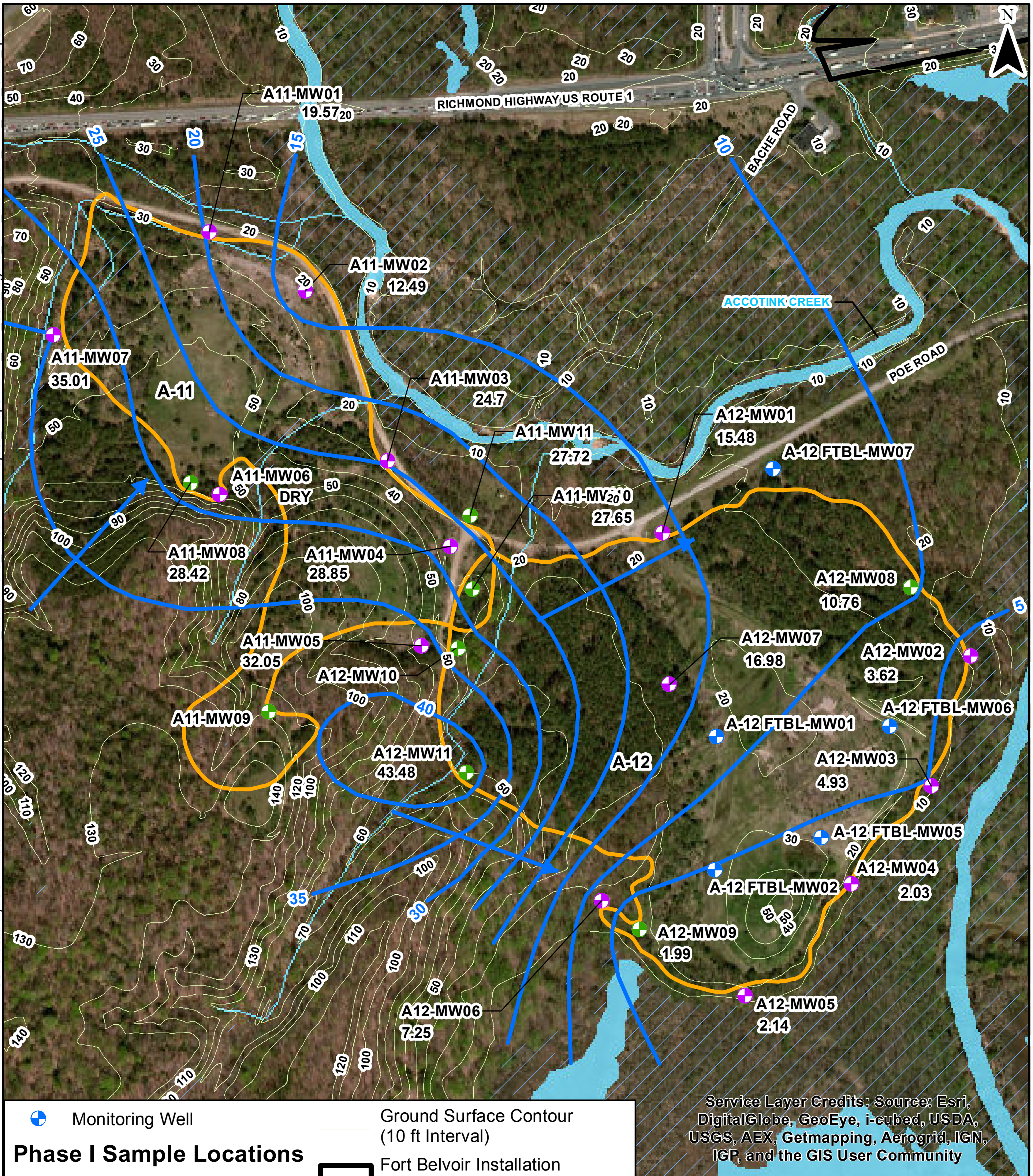
Project Number: 146324



Monitoring Well

Phase I Sample Locations

Monitoring Well

Phase II Sample Locations

Monitoring Well

Groundwater Contour Line (ft)

Groundwater Flow Direction

Surface Water Feature

Ground Surface Contour (10 ft Interval)

Fort Belvoir Installation Boundary

Surface Water Body

IRP Site Boundary

Wetlands

Notes:
1) Groundwater contours are approximate.

0 450 900 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 2-3

CC-A11 AND CCA-12 GROUNDWATER ELEVATION MAP
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

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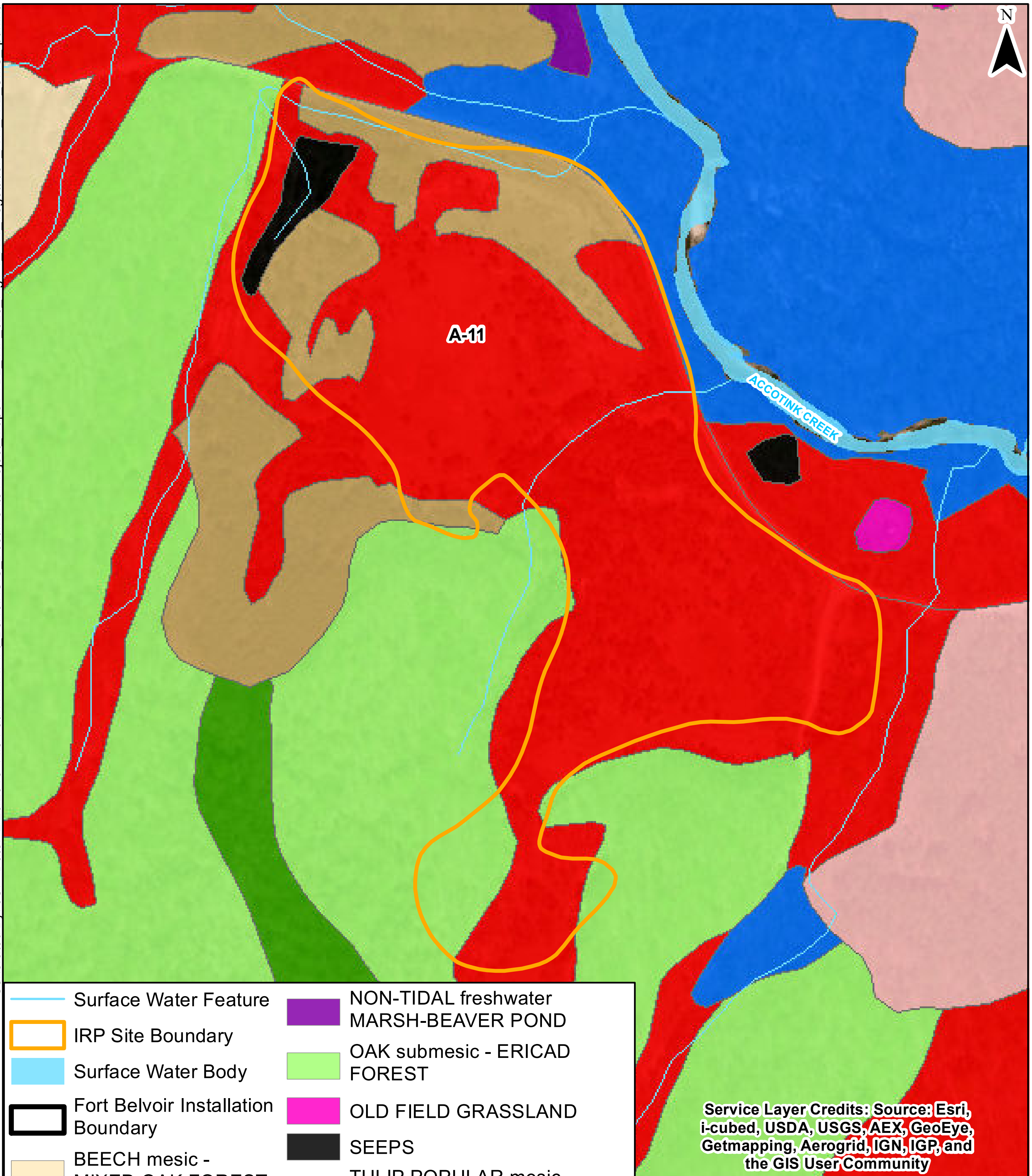

Surface Water Feature
IRP Site Boundary
Surface Water Body
Fort Belvoir Installation Boundary
BEECH mesic - MIXED OAK FOREST
FLOODPLAIN HARDWOOD FOREST
LOBLOLLY PINE FOREST
MIXED PINE-HARDWOOD FOREST
NON-TIDAL freshwater MARSH-BEAVER POND
OAK submesic - ERICAD FOREST
OLD FIELD GRASSLAND
SEEPS
TULIP POPULAR mesic - MIXED HARDWOOD FOREST
VIRGINIA PINE FOREST

0 300 600 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 4-1

CC-A11
VEGETATION
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

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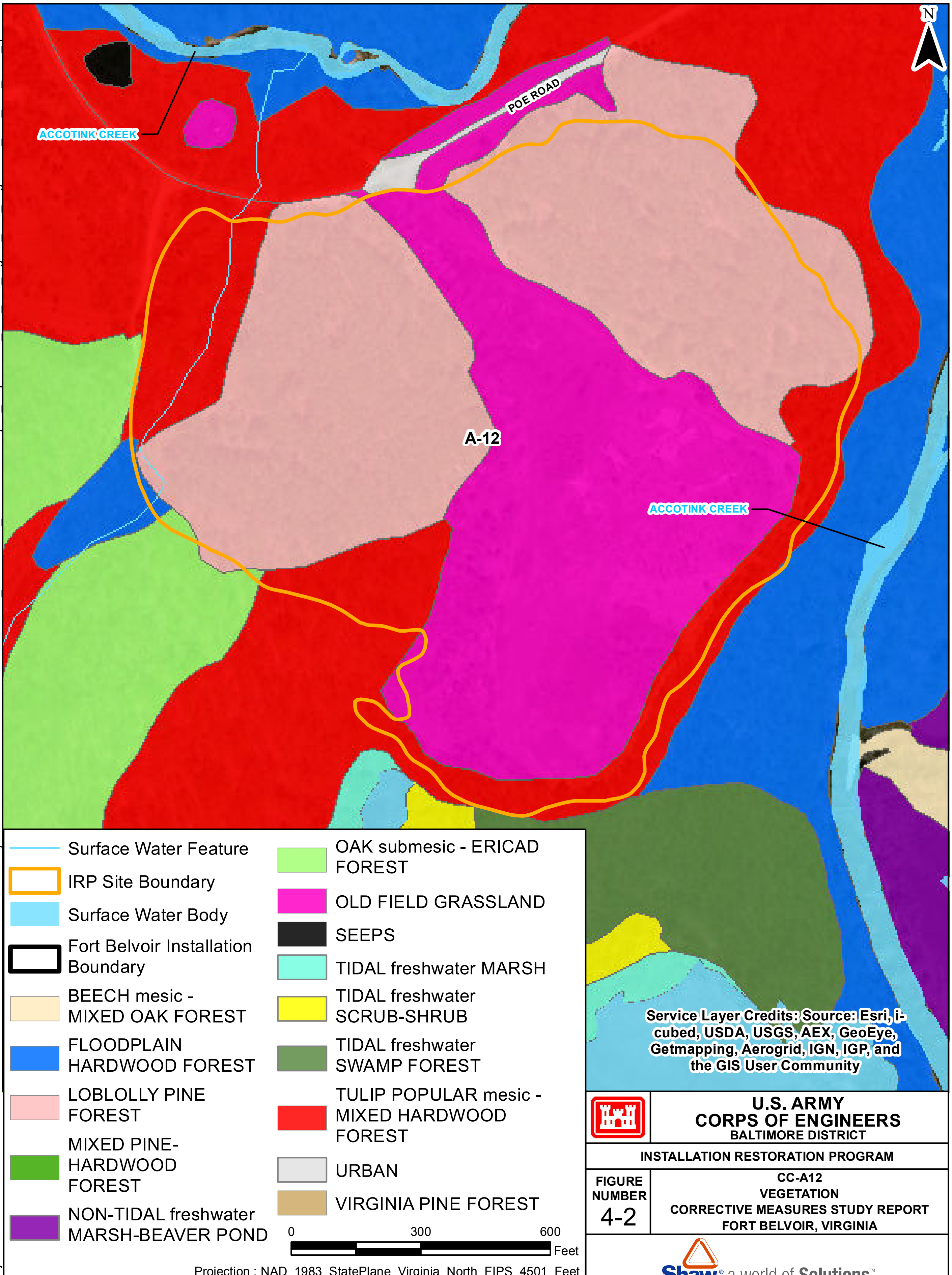
Project Number: 146324



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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 4-2

CC-A12
VEGETATION
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

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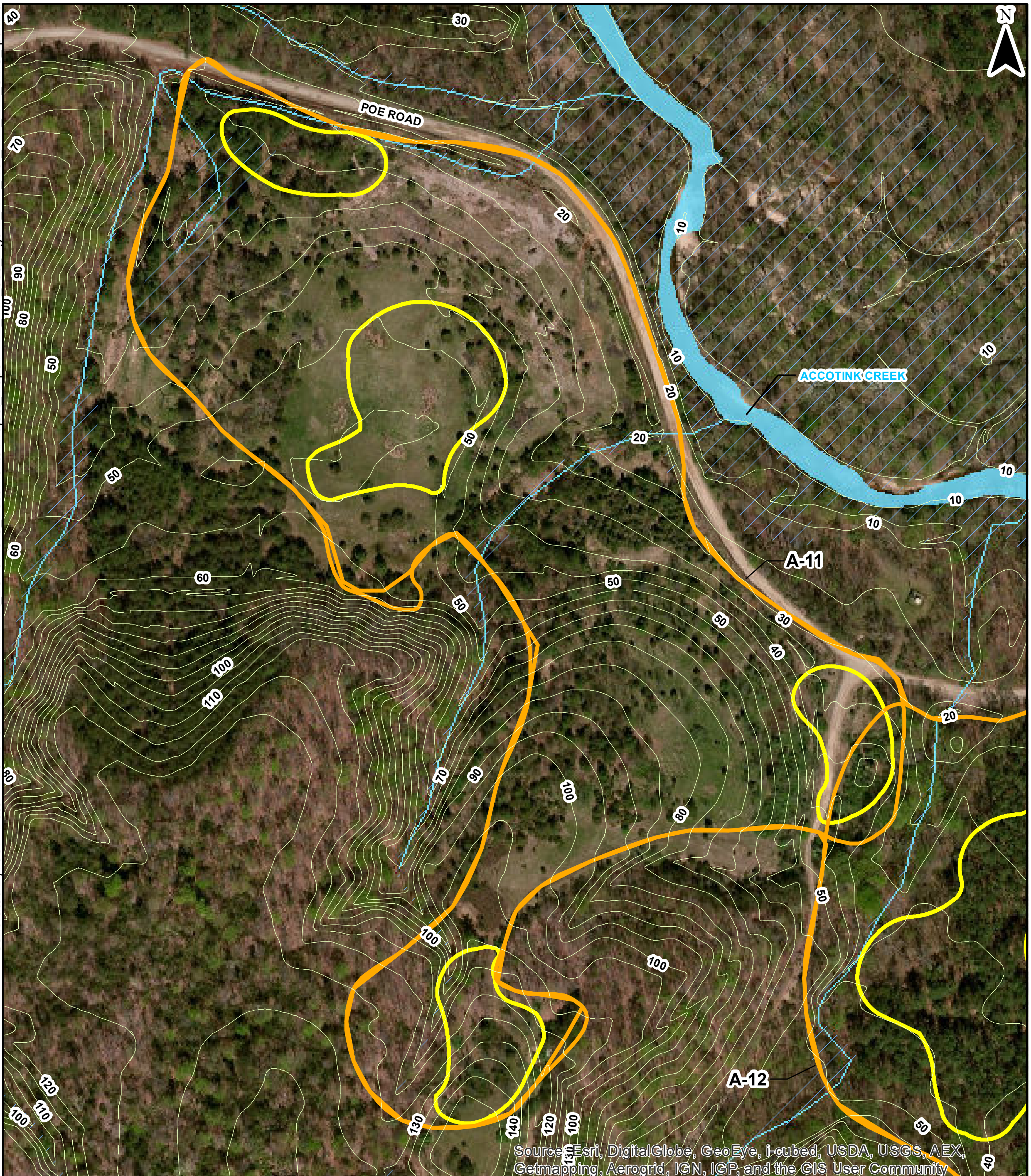

Ground Surface Contour (5 ft Interval)
Surface Water Feature
IRP Site Boundary
Fort Belvoir Installation Boundary
Wetlands
Surface Water Body
Area of Landfill Cover Less Than 2 Feet Thick

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER	
5-1	CC-A11 ALTERNATIVE 1: NO ACTION CORRECTIVE MEASURES STUDY REPORT FORT BELVOIR, VIRGINIA

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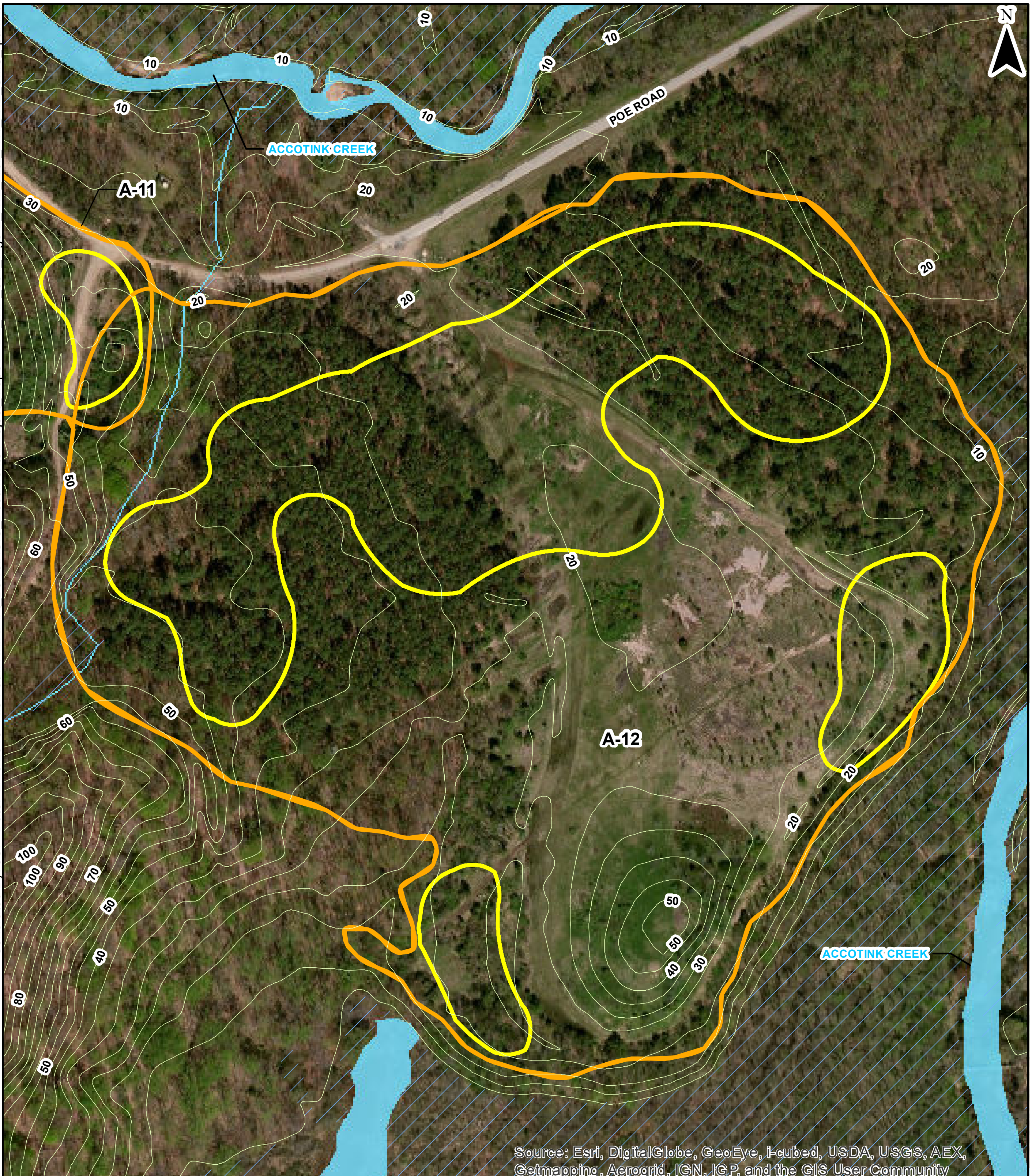
Project Number: 146324



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Project Number: 146324

Ground Surface Contour (5 ft Interval)

Surface Water Feature

IRP Site Boundary

Fort Belvoir Installation Boundary

Wetlands

Surface Water Body

Area of Landfill Cover Less Than 2 Feet Thick

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

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INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER	
5-2	CC-A12 ALTERNATIVE 1: NO ACTION CORRECTIVE MEASURES STUDY REPORT FORT BELVOIR, VIRGINIA

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Project Number: 146324

Surface Water Feature

Fort Belvoir Installation Boundary

Surface Water Body

Wetlands

IRP Site / Proposed RCRA Cap Area

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 5-3

CC-A11
ALTERNATIVE 2: ENGINEERED RCRA CAP SYSTEM
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

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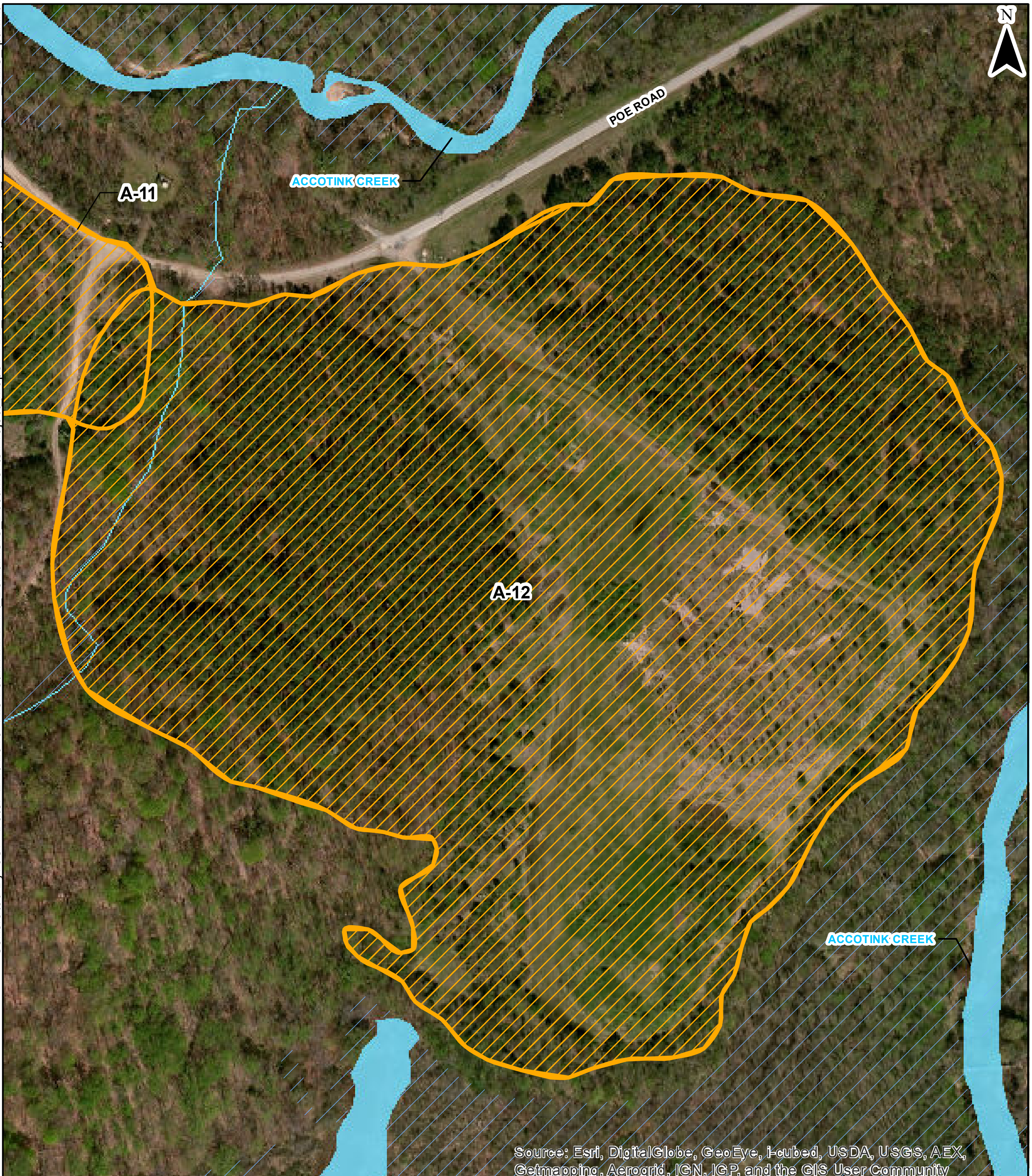


Surface Water Feature
Fort Belvoir Installation Boundary
Surface Water Body
Wetlands
IRP Site / Proposed RCRA Cap Area

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

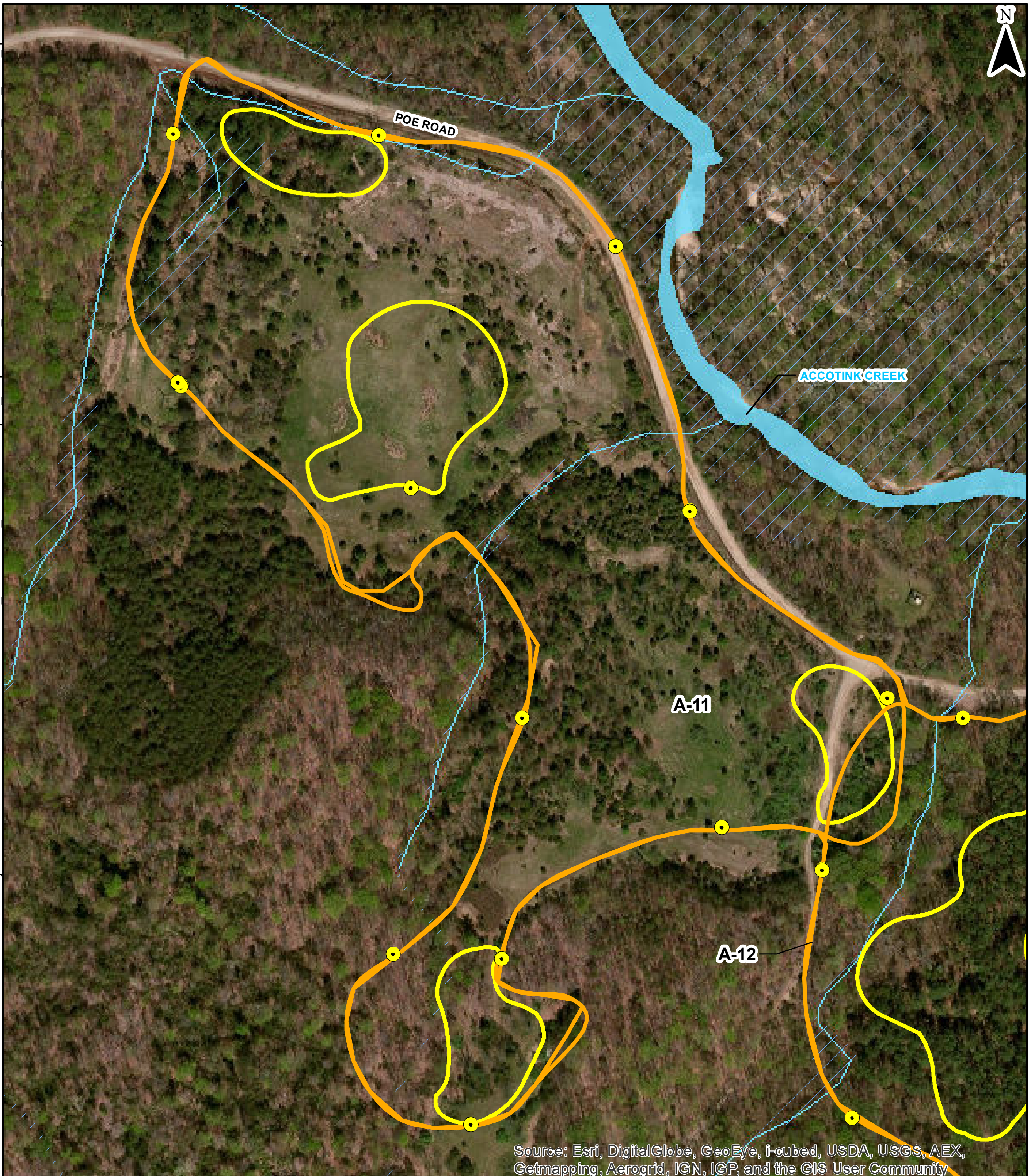
U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 5-4

CC-A12
ALTERNATIVE 2: ENGINEERED RCRA CAP SYSTEM
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

Shaw® a world of Solutions™



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Proposed LF Gas Vent Location

Surface Water Feature

IRP Site Boundary

Fort Belvoir Installation Boundary

Wetlands

Surface Water Body

Limits of ET Cover System (Areas With Less Than 24-inch Existing Cover)

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

Project Number: 146324

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER	CC-A11
5-5	ALTERNATIVE 3: ENGINEERED ET COVER SYSTEM CORRECTIVE MEASURES STUDY REPORT FORT BELVOIR, VIRGINIA

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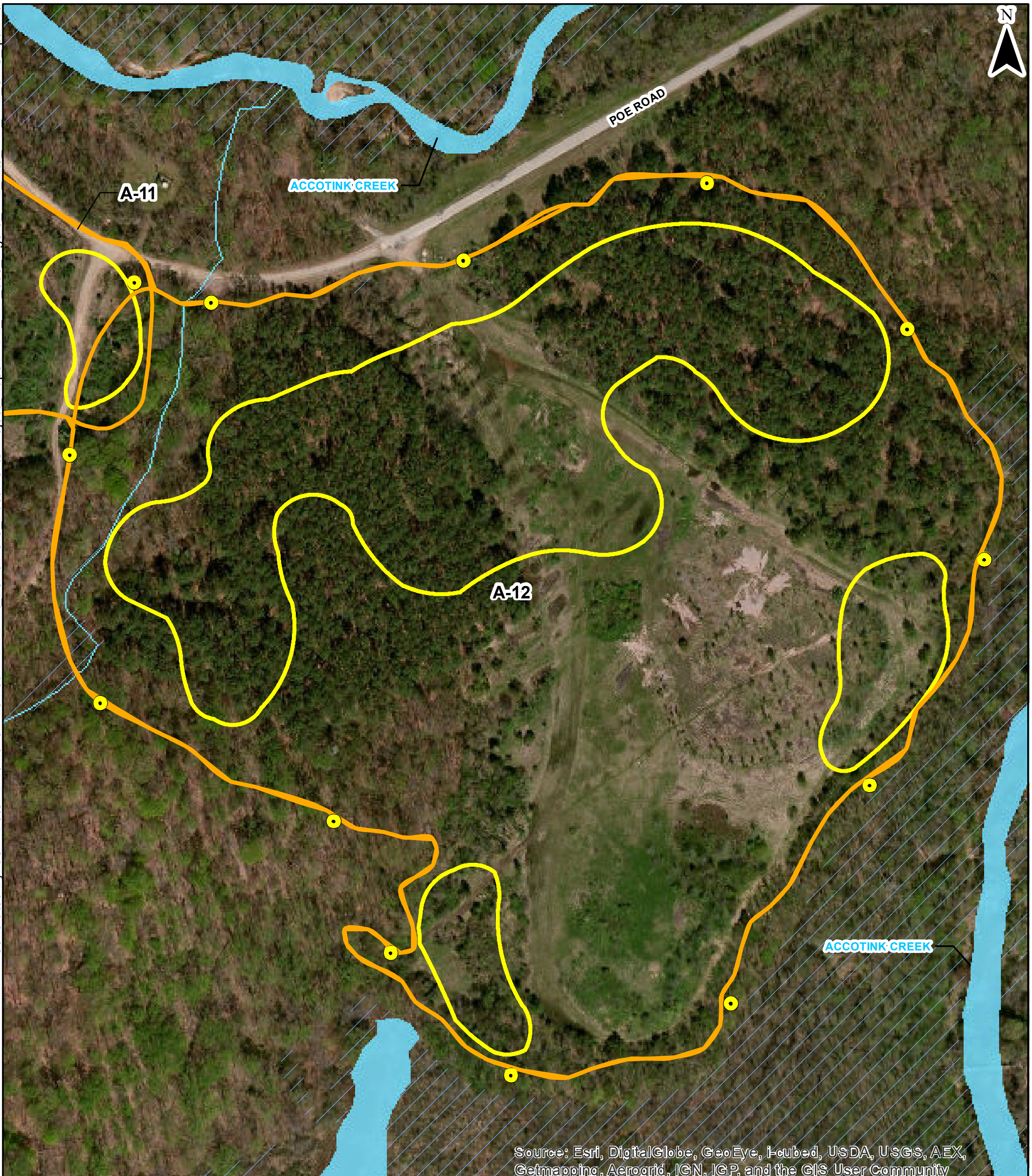
Generated By: JCP Date: 2/26/2013 File Path: H:\IRP\Ft Belvoir\GIS Documents\Project Maps\FTBL IRP 065 Fig5-6 A12 Alt3 A11 A12 CMS rpt.mxd



Proposed LF Gas Vent Location

Surface Water Feature

IRP Site Boundary

Fort Belvoir Installation Boundary

Wetlands

Surface Water Body

Limits of ET Cover System (Areas With Less Than 24-inch Existing Cover)

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

Project Number: 146324

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 5-6

CCA-12
ALTERNATIVE 3: ENGINEERED ET COVER SYSTEM
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

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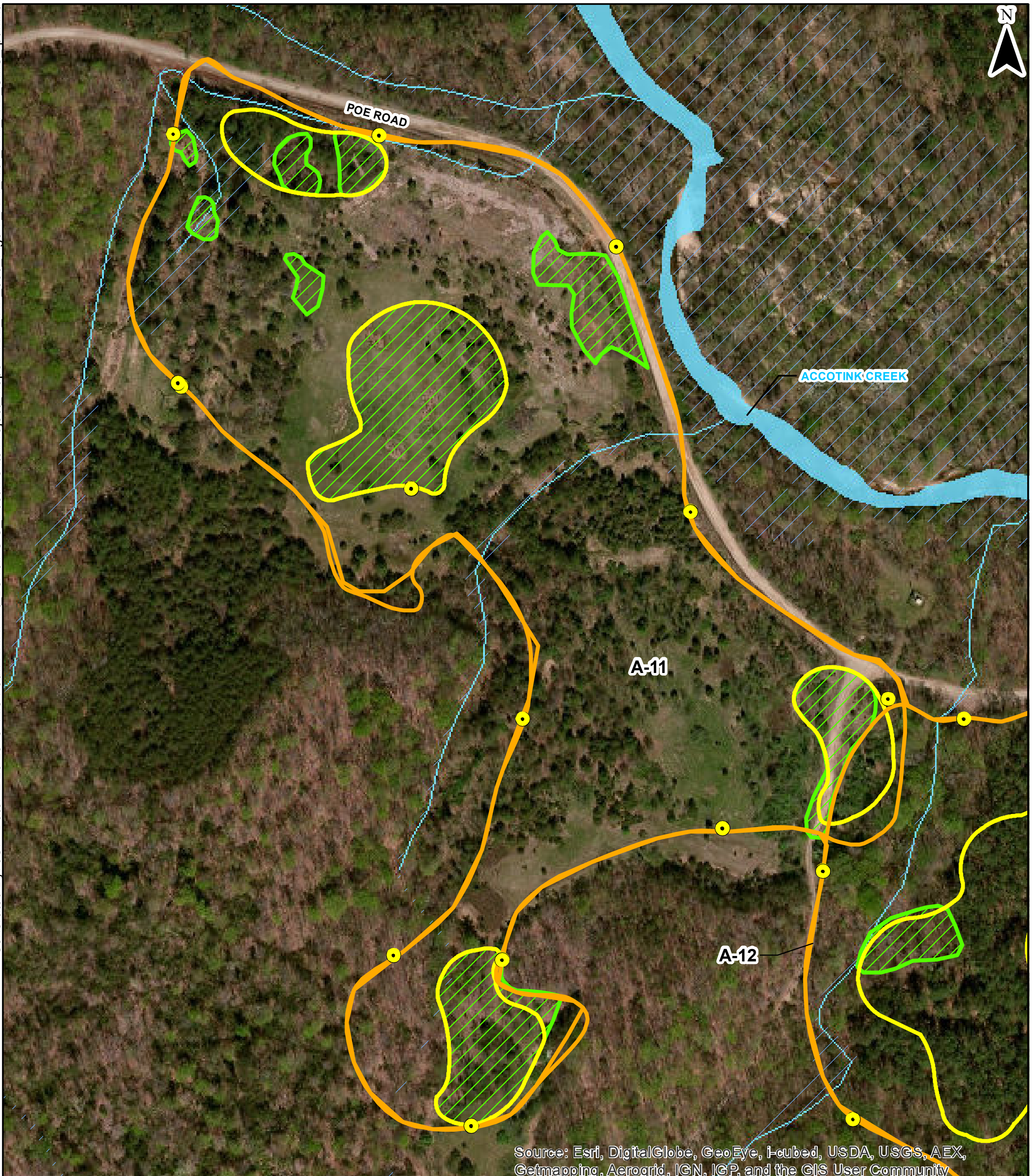
Generated By: JCP Date: 2/26/2013 File Path: H:\IRP\Ft_Belvoir\GIS_Documents\Project_Maps\FTBL_IRP_066_Fig5-7_A11_Alt4_A11_A12_CMS_rpt.mxd



- Proposed LF Gas Vent Location
- Surface Water Feature
- IRP Site Boundary
- Fort Belvoir Installation Boundary
- Wetlands
- Surface Water Body
- Soil Amendment and Vegetative Addition Area
- Area With Less Than 24-inch Existing Cover

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER 5-7

CC-A11 ALTERNATIVE 4:
ENGINEERED VEGETATIVE COVER ENHANCEMENT
CORRECTIVE MEASURES STUDY REPORT
FORT BELVOIR, VIRGINIA

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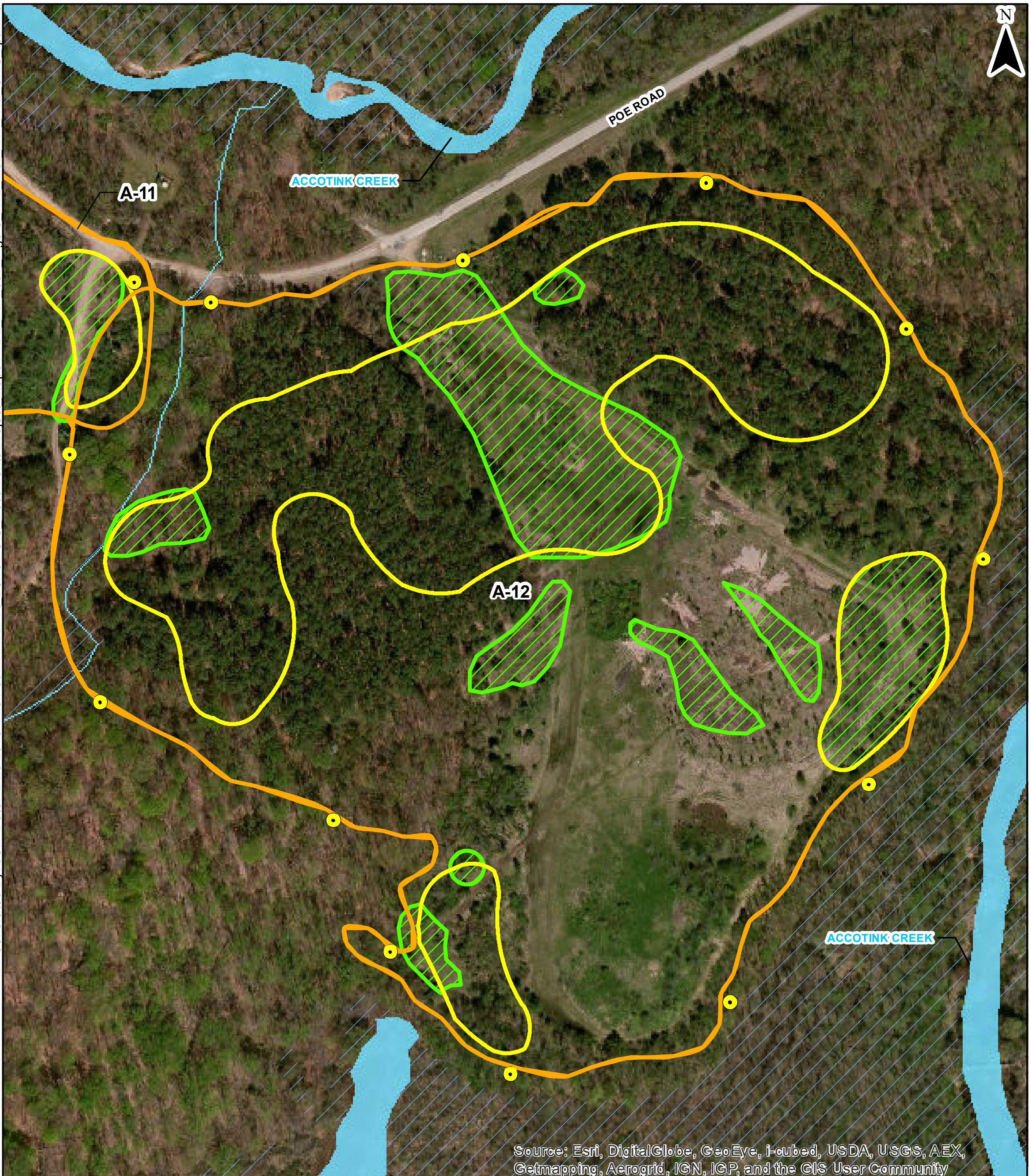
Project Number: 146324



Proposed LF Gas Vent Location

Surface Water Feature

IRP Site Boundary

Fort Belvoir Installation Boundary

Wetlands

Surface Water Body

Soil Amendment and Vegetative Addition Area

Area With Less Than 24-inch Existing Cover

0 250 500 Feet

Projection : NAD_1983_StatePlane_Virginia_North_FIPS_4501_Feet

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

INSTALLATION RESTORATION PROGRAM

FIGURE NUMBER	CC-A12 ALTERNATIVE 4: ENGINEERED VEGETATIVE COVER ENHANCEMENT CORRECTIVE MEASURES STUDY REPORT FORT BELVOIR, VIRGINIA
5-8	

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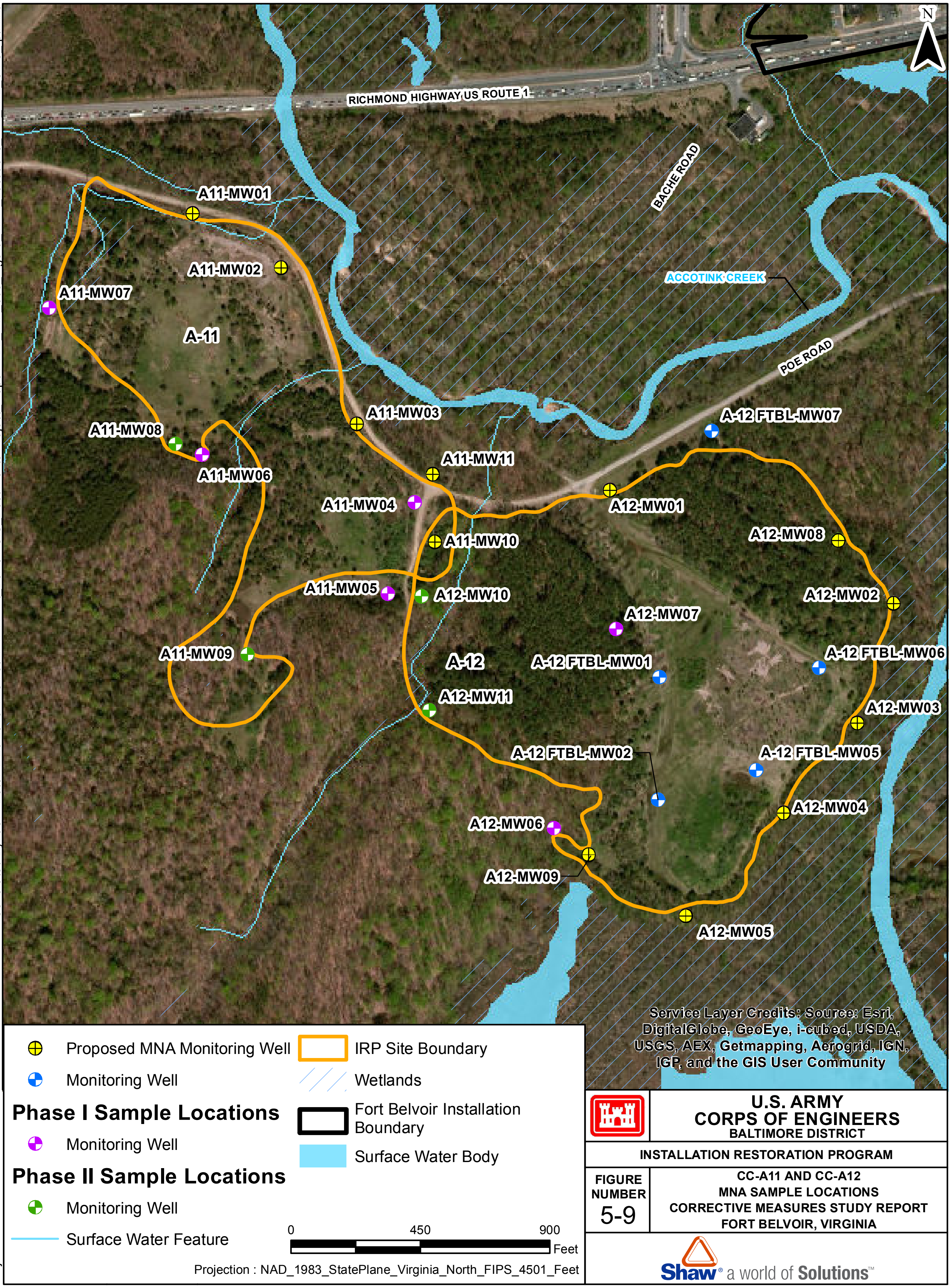
Generated By: JCP Date: 2/26/2013 File Path: H:\IRP\Ft Belvoir\GIS Documents\Project Maps\FTBL IRP 067 Fig5-8 A12 Alt4 A11 A12 CMS rpt.mxd

Project Number: 146324



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Project Number: 146324

Appendix A
Detailed Cost Estimates for CC-A11 and CC-A12 Remedial Alternatives

Cost Summary

	Soil Cover Alternatives			
	1	2	3	4
	No Action	**ENGINEERED RCRA CAP SYSTEM, LTM, MNA, and LUCs**	**ENGINEERED ET COVER SYSTEM, LTM, MNA, and LUC**	**ENGINEERED VEGETATIVE COVER ENHANCEMENT, LTM, MNA, and LUCs**
CC-A11 and CC-A12 Combined				
Capital Cost	$0	$13,713,671	$1,912,669	$1,122,298
O&M Costs	$0	$1,406,384	$1,394,309	$1,394,309
Total Present Worth	$0	$14,789,413	$2,979,058	$2,188,688

Estimated Cost for Alternative 1
No Action
CC-A11 and CC-A12
Fort Belvoir, Virginia

Capital Cost

None		$0
	Total	**$0**

Total Estimated Cost for Alternative S-1

Total Capital Cost	$0
Total present worth cost	**$0**

ALTERNATIVE 2
ENGINEERED RCRA CAP SYSTEM, LTM, MNA, and LUCs

Alternative 2 consists of the installation of an engineered RCRA Subtitle D landfill cap system over the entire landfill surface at CC-A11 and CC-A12. This alternative entails all elements of design and construction including CMIWP, erosion controls, removal of existing vegetation, importation of clay fill and topsoil, and 2 for 1 tree replacement outside the existing landfill limits to mitigate removal of trees > 4" in diameter for cap construction. This alternative would also include land use controls and long-term monitoring of the entire final cover system at both sites. Also includes MNA of groundwater.

GENERAL ASSUMPTIONS

The costs are adopted from previous work conducted by Shaw Environmental at Fort Belvoir and other facilities in Virginia and Maryland, and professional judgment. Assume total cap area of 65 acres, 5 acres for support areas, roads, erosion controls, and assume 50% mature trees and 50% meadow vegetation.

Assumed dimensions of the Areas of Concern:

Areas to Receive Subtitle D Cap	Area (SF)	Area (AC)	Thickness (ft)	Volume (CY)
A-11	1,013,941	23.28	2.0	75,107
A-12	1,801,941	41.37	3.0	200,216
Total	**2,815,882**	**64.64**		**275,322**

1.0 Permits, Design and Plan/Report Writing

The costs in this section consist of initial stakeouts of landfill limits; landfill reconnaissance; endangered plant & animal surveys; delineations; tree inventory ≥ 4"; permit acquisition; preparation of draft, draft final, and final versions of the CMIWP and design; preparation of draft, draft final, and final LUCIP and LTM plan; preparation of draft, draft final, and final versions of construction plans (HASP, VESCP, SWPPP, and CQCP/CQAP); and, preparation of draft, draft final, and final versions of a first post-construction CMI report. This item assumes that existing data for landfill limits and topography is sufficient as a basis for design and construction.

Item		Unit Rate	Quantity	Cost
Site Reconnaissance, Surveys, Delineation, Inventory		$30,000	1	$30,000
Corrective Measures Implementation Work Plan (CMIWP)		$20,000	1	$20,000
Land Use Control Implementation Plan (LUCIP)		$5,000	1	$5,000
LTM Plan		$5,000	1	$5,000
CMIWP Design		$20,000	1	$20,000
Permits (e.g., Wetlands, Stream Encroachment)		$20,000	1	$20,000
Health and Safety Plan (HASP)		$5,000	1	$5,000
Virginia Erosion & Sediment Control Plan (VESCP)		$10,000	1	$10,000
Stormwater Pollution Prevention Plan (SWPPP)		$10,000	1	$10,000
CQCP/CQAP		$5,000	1	$5,000
CMI Report after Construction Phase		$15,000	1	$15,000
			SUBTOTAL	**$145,000**
			Contingency (10%)	$14,500
			Management (5%)	$7,250
			TOTAL	**$166,750**

2.0 RCRA Subtitle D Cap System - Construction Phase

The costs in this section are based on a duration of 300 construction days at CC-A11 and CC-A12 and include the following activities: initial construction stakeouts of design elements, establishment of support areas and access routes (concurrent with clearing), vegetative clearing and removal (or grinding in place) of stumps to limits and installation of erosion and sediment controls (30 days), grade control, testing of fill and topsoil, importation and placement of grading fill, low permeability fill, and topsoil with any required debris removal and erosion repair, and gas vent installation performed concurrently (250 days), site restoration consisting of native ground cover and tree planting based on 2:1 tree replacement (70 days), removal of erosion and sediment controls and restoration of areas formerly containing erosion and sediment controls (15 days), and as-built survey. Costs are based on 65 acres of capping and 5 acres for erosion controls, access, etc. Assume minimum 5% slope required at CC-A12 and that 12" x 42 acres necessary to achieve this. Existing slopes at CC-A11 appear acceptable.

Item	Unit	Unit Rate	Quantity	Cost
Mob / Demob / Rotations of Personnel and Equipment	Lump Sum	$75,000	1	$75,000
Clear Heavy Trees / Veg and Grind Stumps	Acre	$12,000	32	$384,000
Construction Site Mgr (10-hr day)	Day	$918	300	$275,400
Sr. Field Engineer (10-hr day)	Day	$885	300	$265,500
Safety/Quality Specialist (10-hr day)	Day	$885	300	$265,500
Foreman #1 (10-hr day)	Day	$487	300	$146,100

Foreman #2 (10-hr day)	Day	$487	300	$146,100
Equipment Operator (EO3) #1 (10-hr day)	Day	$432	300	$129,600
Equipment Operator (EO3) #2 (10-hr day)	Day	$432	300	$129,600
Equipment Operator (EO3) #3 (10-hr day)	Day	$432	300	$129,600
Equipment Operator (EO3) #4 (10-hr day)	Day	$432	300	$129,600
Equipment Operator (EO3) #5 (10-hr day)	Day	$432	300	$129,600
Equipment Operator (EO3) #6 (10-hr day)	Day	$432	300	$129,600
Laborer (L3) #1 (10-hr day)	Day	$331	300	$99,300
Laborer (L3) #2 (10-hr day)	Day	$331	300	$99,300
Laborer (L3) #3 (10-hr day)	Day	$331	300	$99,300
Laborer (L3) #4 (10-hr day)	Day	$331	300	$99,300
Laborer (L3) #5 (10-hr day)	Day	$331	300	$99,300
Laborer (L3) #6 (10-hr day)	Day	$331	300	$99,300
Laborer (L3) #7 (10-hr day)	Day	$331	300	$99,300
Laborer (L3) #8 (10-hr day)	Day	$331	300	$99,300
UXO Supervisor (until site is graded / covered)	Day	$700	88	$61,600
Per Diem (18 mo x 27 d/mo x 19 FT personnel + UXO)	Day	$240	9,354	$2,244,960
Trailer, Telcomm, Toilets, Dumpster, etc.	Month	$1,500	18	$27,000
Quiet Generator w/ FOG	Month	$1,000	18	$18,000
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #1	Month	$1,277	18	$22,986
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #2	Month	$1,277	18	$22,986
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #3	Month	$1,277	18	$22,986
Rental Small SUV w/ FOG #1	Month	$2,070	18	$37,260
Rental Small SUV w/ FOG #2	Month	$2,070	18	$37,260
Dozer D6 or equiv / GPS / wide track w/ FOG (4 x 15 mos)	Month	$4,200	60	$252,000
Excavator / 19 to 21 Ton (1 x 24 mos)	Month	$5,254	24	$126,096
Compactor - 5 Ton Smooth / Padfoot (2 x 15 mos)	Month	$2,205	30	$66,150
Rubber Tire Loader / 4 CY (2 x 15 mos)	Month	$6,000	30	$180,000
Off-Road End Dump (4 x 12 mos)	Month	$6,000	48	$288,000
Surveying - 3 Man Crew for site control / initial stakeouts	Hours	$175	40	$7,000
Surveying - 2 Man Crew for grade control and as-builts	Hours	$150	240	$36,000
Surveying - Office CAD / Support	Hours	$80	120	$9,600
Erosion Control Dikes (Screened Topsoil)	CY	$28.00	2500	$70,000
Erosion Mat for Dikes, Swales, etc.	Rolls	$50.00	400	$20,000
Truck / Equipment Wash Station	Lump Sum	$3,000	2	$6,000
Aggregate (miscellaneous sizes)	Ton	$30	500	$15,000
Miscellaneous Construction Materials	LS	$20,000	1	$20,000
Chemical, physical and agronomic testing (fill / topsoil)	Lump Sum	$25,000	1	$25,000
Low Permeability Borrow	Ton	$12	234,659	$2,815,912
Screened Topsoil	LCY	$28	62,575	$1,752,104
Seeding/Fertilizer/Straw/Tackifier (native seed) cap + E&SC	Acre	$2,500	70	$175,000
Tree Mitigation (50% currently forested at 2:1 = 70 acres)	Acre	$3,500	70	$245,000
			SUBTOTAL	**$11,733,500**
			Contingency (10%)	$1,173,350
			Management (5%)	$586,675
			TOTAL	**$13,493,525**

3.0 Baseline Sampling and Analysis for MNA

Groundwater monitoring for VOCs and NAPs
Data interpretation and reporting
Two events, collect groundwater samples from 14 wells, plus 10% QC

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$3,000	2	$6,000
Chemist III	Day	$637	3	$1,911
Scientist II (10-hr day)	Day	$620	7	$4,340
Scientist II (10-hr day)	Day	$620	7	$4,340
Per Diem	Day	$240	14	$3,360
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	2	$600
Sampling Equipment	Each	$500	2	$1,000
Document Reproduction	Each	$500	2	$1,000
Analytical for MNA	Each	$465	32	$14,880
Analytical for VOCs	Each	$100	36	$3,600

Daily Sample Shipping	Each	$40	10	$400
RDW Containment and Disposal	Each	$2,500	2	$5,000
			SUBTOTAL	**$46,431**
			Contingency (10%)	$4,643
			Management (5%)	$2,322
			TOTAL	**$53,396**

TOTAL CAPITAL: $13,713,671

4.0 Years 2 to 5 Semi-Annual RA(O): LUCs, LTM including GW & Methane Monitoring and Annual Reporting

Annual costs for Year 2 thru 5 semi-annual landfill inspections, gas vent monitoring, photos & documentation [middle of growing season (May) and end of growing season (Oct)] for Years 2 through 5. Two days per visit x 2/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$1,000	2	$2,000
Scientist II (10-hr day)	Day	$620	4	$2,480
Scientist II (10-hr day)	Day	$620	4	$2,480
Per Diem	Day	$240	8	$1,920
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	1	$300
Methane Monitoring Instrument	Each	$50	4	$200
Annual CMI Report (draft, draft final & final)	Each	$1,500	1	$1,500
Document Reproduction	Each	$500	2	$1,000
Semi-annual GW Monitoring for MNA (from 3.0 above)	Lump Sum	$46,431	1	$46,431
			SUBTOTAL	**$58,311**
			Contingency (10%)	$5,831
			Management (5%)	$2,916
			TOTAL	**$67,058**

5.0 Years 6 to 30 Annual RA(O): LUCs, LTM including GW & Methane Monitoring and Annual Reporting

Annual costs for Year 6 thru 30 annual landfill inspections, gas vent monitoring, photos & documentation at end of growing season (Oct). Two days per visit x 1/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$1,000	1	$1,000
Scientist II (10-hr day)	Day	$620	2	$1,240
Scientist II (10-hr day)	Day	$620	2	$1,240
Per Diem	Day	$240	4	$960
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	1	$300
Methane Monitoring Instrument	Each	$50	2	$100
Annual CMI Report (draft, draft final & final)	Each	$1,500	1	$1,500
Document Reproduction	Each	$500	1	$500
Annual GW Monitoring for MNA (from 3.0 above)	Lump Sum	$46,431	0.5	$23,216
			SUBTOTAL	**$30,056**
			Contingency (10%)	$3,006
			Management (5%)	$1,503
			TOTAL	**$34,564**

6.0 Five-Year Review

Annual costs for Year 6 thru 30 annual landfill inspections, gas vent monitoring, photos & documentation at end of growing season (Oct). Two days per visit x 1/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Five-Year Review	LS	$30,000	1	$30,000
			SUBTOTAL	**$30,000**
			Contingency (10%)	$3,000
			Management (5%)	$1,500
			TOTAL	**$34,500**

PRESENT WORTH CALCULATION:

Using a discount rate of: **2%**

Description of Cost Details	Year	Capital	O&M	Present Worth Value
Summary of Capital Costs	0	$13,713,671		
LTM/MNA (Semi-Annual)	1		$67,058	$65,743
LTM/MNA (Semi-Annual)	2		$67,058	$64,454
LTM/MNA (Semi-Annual)	3		$67,058	$63,190
LTM/MNA (Semi-Annual)	4		$67,058	$61,951
5-Year Review, Semi-Annual LTM/MNA	5		$101,558	$91,984
LTM/MNA (Annual)	6		$34,564	$30,692
LTM/MNA (Annual)	7		$34,564	$30,090
LTM/MNA (Annual)	8		$34,564	$29,500
LTM/MNA (Annual)	9		$34,564	$28,921
5-Year Review & Annual LTM/MNA	10		$69,064	$56,656
LTM/MNA (Annual)	11		$34,564	$27,798
LTM/MNA (Annual)	12		$34,564	$27,253
LTM/MNA (Annual)	13		$34,564	$26,719
LTM/MNA (Annual)	14		$34,564	$26,195
5-Year Review & Annual LTM/MNA	15		$69,064	$51,315
LTM/MNA (Annual)	16		$34,564	$25,178
LTM/MNA (Annual)	17		$34,564	$24,684
LTM/MNA (Annual)	18		$34,564	$24,200
LTM/MNA (Annual)	19		$34,564	$23,726
5-Year Review & Annual LTM/MNA	20		$69,064	$46,478
LTM/MNA (Annual)	21		$34,564	$22,804
LTM/MNA (Annual)	22		$34,564	$22,357
LTM/MNA (Annual)	23		$34,564	$21,919
LTM/MNA (Annual)	24		$34,564	$21,489
5-Year Review & Annual LTM/MNA	25		$69,064	$42,097
LTM/MNA (Annual)	26		$34,564	$20,655
LTM/MNA (Annual)	27		$34,564	$20,250
LTM/MNA (Annual)	28		$34,564	$19,853
LTM/MNA (Annual)	29		$34,564	$19,463
5-Year Review & Annual LTM/MNA	30		$69,064	$38,128
	TOTAL:	**$13,713,671**	**$1,406,384**	**$1,075,742**

TOTAL PRESENT WORTH: $14,789,413

ALTERNATIVE 3
ENGINEERED ET COVER SYSTEM, LTM, MNA, and LUC

Alternative 3 consists of the installation of an engineered ET landfill cover system at CC-A11 and CC-A12 wherever the soil cover system is less than the required final cover thickness. This alternative entails all elements of design and construction including CMIWP, erosion controls, removal of existing vegetation, importation of fill and topsoil, and 2 for 1 tree mitigation as part of site restoration. This alternative would also include land-use controls and long-term monitoring of the entire final cover system at both sites. Also includes MNA of groundwater.

GENERAL ASSUMPTIONS

The costs are adopted from previous work conducted by Shaw Environmental at Fort Belvoir and other facilities in Virginia and Maryland, and professional judgment. Assume A-11 is 50% mature trees and 50% meadow within limits of disturbance; and, A-12 is 75% mature trees and 25% meadow within limits of disturbance. Assumes placing 6" fill and 6" topsoil within areas currently having less than 24" of cover within the landfill limits at CC-A11 and CC-A12.

Assumed dimensions of the Areas of Concern:

Areas Requiring Soil Addition & ET Vegetation	Area (SF)	Area (AC)	Depth (ft)	Volume (CY)
A-11	181,837	4.2	1.0	6,735
A-12	597,403	13.7	1.0	22,126
Total	**779,240**	**17.9**		**28,861**

Areas Requiring Soil Addition & ET Vegetation	Trees (AC)	Meadow (AC)	Total Area (SF)	Total Area (AC)
A-11	2.1	2.1	181,837	4.2
A-12	10.3	3.4	597,403	13.7
Total	**12.4**	**5.5**	**779,240**	**17.9**

1.0 Permits, Design and Plan/Report Writing

The costs in this section consist of initial stakeouts of landfill limits and limits of insufficient soil cover; landfill reconnaissance; delineations; tree inventory ≥ 4"; permit acquisition; preparation of draft, draft final, and final versions of the CMIWP and design; preparation of draft, draft final, and final LUCIP and LTM plan; preparation of draft, draft final, and final versions of construction plans (HASP, VESCP, SWPPP, and CQCP/CQAP); and, preparation of draft, draft final, and final versions of a first post-construction CMI report. This item assumes that existing data for landfill limits, topography, and soil cover thickness is sufficient as a basis for demarcation and design of ET cover system improvements.

Item		Unit Rate	Quantity	Cost
Site Reconnaissance, Surveys, Delineation, Inventory		$25,000	1	$25,000
Corrective Measures Implementation Work Plan (CMIWP)		$10,000	1	$10,000
Land Use Control Implementation Plan (LUCIP)		$5,000	1	$5,000
LTM Plan		$5,000	1	$5,000
CMIWP Design		$10,000	1	$10,000
Permits (e.g., Wetlands, Stream Encroachment)		$10,000	1	$10,000
Health and Safety Plan (HASP)		$5,000	1	$5,000
Virginia Erosion & Sediment Control Plan (VESCP)		$5,000	1	$5,000
Stormwater Pollution Prevention Plan (SWPPP)		$5,000	1	$5,000
CQCP/CQAP		$5,000	1	$5,000
CMI Report after Construction Phase		$10,000	1	$10,000
			SUBTOTAL	**$95,000**
			Contingency (10%)	$9,500
			Management (5%)	$4,750
			TOTAL	**$109,250**

2.0 ET Cover System Improvements - Construction Phase

The costs in this section consist of initial construction stakeouts of design elements, establishment of support areas and access routes (concurrent with clearing), vegetative clearing, stump grinding, and installation of erosion and sediment controls (20 days), grade control, testing of fill and topsoil, importation and placement of fill and topsoil with debris removal, any erosion repair and slope re-grading, and gas vent installation, and 25 acres of site restoration consisting of native ground cover and tree planting, including 17.9 acres for ET cover on the landfill and 7.1 acres to complete 2:1 tree mitigation (30 days), removal of erosion and sediment controls and restoration of areas formerly containing erosion and sediment controls (10 days), and as-built survey.

Item	Unit	Unit Rate	Quantity	Cost
Mob / Demob / Rotations of Personnel and Equipment	Lump Sum	$20,000	1	$20,000
Clear Lower Density Wooded Areas and Grind Stumps	Acre	$10,000	13.0	$130,000
Construction Site Mgr (10-hr day)	Day	$918	40	$36,720

Sr. Field Engineer (10-hr day)	Day	$885	40	$35,400
Safety/Quality Specialist (10-hr day)	Day	$885	40	$35,400
Foreman (10-hr day)	Day	$487	40	$19,480
Equipment Operator (EO3) #1 (10-hr day)	Day	$432	40	$17,280
Equipment Operator (EO3) #2 (10-hr day)	Day	$432	40	$17,280
Equipment Operator (EO3) #3 (10-hr day)	Day	$432	40	$17,280
Laborer (L3) #1 (10-hr day)	Day	$331	40	$13,240
Laborer (L3) #2 (10-hr day)	Day	$331	40	$13,240
Laborer (L3) #3 (10-hr day)	Day	$331	40	$13,240
Laborer (L3) #4 (10-hr day)	Day	$331	40	$13,240
UXO Supervisor	Day	$700	40	$28,000
Per Diem (2 mo x 27 d/mo x 12 FT personnel)	Day	$240	648	$155,520
Trailer, Telcomm, Toilets, Dumpster, etc.	Month	$1,500	2	$3,000
Quiet Generator plus Fuel	Month	$1,000	2	$2,000
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #1	Month	$1,277	2	$2,554
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #2	Month	$1,277	2	$2,554
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #3	Month	$1,277	2	$2,554
Rental Small SUV w/ FOG #1	Month	$2,070	2	$4,140
Rental Small SUV w/ FOG #2	Month	$2,070	2	$4,140
Dozer D6 or equiv / GPS / wide track w/ FOG (2 x 2 mos)	Month	$4,200	4	$16,800
Rubber Tire Loader / 4 CY (2 x 2 mos)	Month	$6,000	4	$24,000
Off-Road End Dump (4 x 1.5 mos)	Month	$6,000	6	$36,000
Surveying - 3 Man Crew for site control / initial stakeouts	Hours	$175	40	$7,000
Surveying - 2 Man Crew for grade control and as-builts	Hours	$150	40	$6,000
Surveying - Office CAD / Support	Hours	$80	40	$3,200
Erosion Control Dikes (Unscreened Topsoil) (or Silt Fence)	CY	$23.00	800	$18,400
Erosion Mat for Dikes, Swales, etc.	Rolls	$50.00	200	$10,000
Truck / Equipment Wash Station	Lump Sum	$3,000	1	$3,000
Aggregate (miscellaneous sizes)	Ton	$25	200	$5,000
Miscellaneous Construction Materials for Gas Vents etc.	LS	$10,000	1	$10,000
Chemical, physical and agronomic testing (fill / topsoil)	Lump Sum	$4,000	1	$4,000
Low Permeability Borrow	Tons	$12	21,646	$259,747
Unscreened Topsoil	CY	$23	17,316	$398,278
Seeding/Fertilizer/Straw/Tackifier (native seed) cap + E&SC	Acre	$2,500	19	$47,500
Tree Mitigation (2:1 replacement of existing wooded areas)	Acre	$3,500	25	$86,573
			SUBTOTAL	**$1,521,759**
			Contingency (10%)	$152,176
			Management (5%)	$76,088
			TOTAL	**$1,750,023**

3.0 Baseline Sampling and Analysis for MNA

Groundwater monitoring for VOCs and NAPs
Data interpretation and reporting
Two events, collect groundwater samples from 14 wells, plus 10% QC

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$3,000	2	$6,000
Chemist III	Day	$637	3	$1,911
Scientist II (10-hr day)	Day	$620	7	$4,340
Scientist II (10-hr day)	Day	$620	7	$4,340
Per Diem	Day	$240	14	$3,360
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	2	$600
Sampling Equipment	Each	$500	2	$1,000
Document Reproduction	Each	$500	2	$1,000
Analytical for MNA	Each	$465	32	$14,880
Analtyical for VOCs	Each	$100	36	$3,600
Daily Sample Shipping	Each	$40	10	$400
RDW Containment and Disposal	Each	$2,500	2	$5,000
			SUBTOTAL	**$46,431**
			Contingency (10%)	$4,643
			Management (5%)	$2,322
			TOTAL	**$53,396**

TOTAL CAPITAL: $1,912,669

4.0 Years 2 to 5 Semi-Annual RA(O): LUCs, LTM including GW & Methane Monitoring and Annual Reporting

Annual costs for Year 2 thru 5 semi-annual landfill inspections, gas vent monitoring, photos & documentation [middle of growing season (May) and end of growing season (Oct)] for Years 2 through 5. Two days per visit x 2/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$1,000	2	$2,000
Scientist II (10-hr day)	Day	$620	4	$2,480
Scientist II (10-hr day)	Day	$620	4	$2,480
Per Diem	Day	$240	8	$1,920
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	1	$300
Methane Monitoring Instrument	Each	$50	4	$200
Annual CMI Report (draft, draft final & final)	Each	$1,500	1	$1,500
Document Reproduction	Each	$200	2	$400
Semi-annual GW Monitoring for MNA (from 3.0 above)	Lump Sum	$46,431	1	$46,431
			SUBTOTAL	**$57,711**
			Contingency (10%)	$5,771
			Management (5%)	$2,886
			TOTAL	**$66,368**

5.0 Years 6 to 30 Annual RA(O): LUCs, LTM including GW & Methane Monitoring and Annual Reporting

Annual costs for Year 6 thru 30 annual landfill inspections, gas vent monitoring, photos & documentation at end of growing season (Oct). Two days per visit x 1/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$1,000	1	$1,000
Scientist II (10-hr day)	Day	$620	2	$1,240
Scientist II (10-hr day)	Day	$620	2	$1,240
Per Diem	Day	$240	4	$960
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	1	$300
Methane Monitoring Instrument	Each	$50	2	$100
Annual CMI Report (draft, draft final & final)	Each	$1,500	1	$1,500
Document Reproduction	Each	$200	1	$200
Annual GW Monitoring for MNA (from 3.0 above)	Lump Sum	$46,431	0.5	$23,216
			SUBTOTAL	**$29,756**
			Contingency (10%)	$2,976
			Management (5%)	$1,488
			TOTAL	**$34,219**

6.0 Five-Year Review

Annual costs for Year 6 thru 30 annual landfill inspections, gas vent monitoring, photos & documentation at end of growing season (Oct). Two days per visit x 1/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Five-Year Review	LS	$30,000	1	$30,000
			SUBTOTAL	**$30,000**
			Contingency (10%)	$3,000
			Management (5%)	$1,500
			TOTAL	**$34,500**

PRESENT WORTH CALCULATION:

Using a discount rate of: 2%

Description of Cost Details	Year	Capital	O&M	Present Worth Value
Summary of Capital Costs	0	$1,912,669		
LTM/MNA (Semi-Annual)	1		$66,368	$65,066
LTM/MNA (Semi-Annual)	2		$66,368	$63,791
LTM/MNA (Semi-Annual)	3		$66,368	$62,540
LTM/MNA (Semi-Annual)	4		$66,368	$61,313

5-Year Review, Semi-Annual LTM/MNA	5		$100,868	$91,359
LTM/MNA (Annual)	6		$34,219	$30,385
LTM/MNA (Annual)	7		$34,219	$29,790
LTM/MNA (Annual)	8		$34,219	$29,205
LTM/MNA (Annual)	9		$34,219	$28,633
5-Year Review & Annual LTM/MNA	10		$68,719	$56,373
LTM/MNA (Annual)	11		$34,219	$27,521
LTM/MNA (Annual)	12		$34,219	$26,981
LTM/MNA (Annual)	13		$34,219	$26,452
LTM/MNA (Annual)	14		$34,219	$25,934
5-Year Review & Annual LTM/MNA	15		$68,719	$51,059
LTM/MNA (Annual)	16		$34,219	$24,927
LTM/MNA (Annual)	17		$34,219	$24,438
LTM/MNA (Annual)	18		$34,219	$23,959
LTM/MNA (Annual)	19		$34,219	$23,489
5-Year Review & Annual LTM/MNA	20		$68,719	$46,246
LTM/MNA (Annual)	21		$34,219	$22,577
LTM/MNA (Annual)	22		$34,219	$22,134
LTM/MNA (Annual)	23		$34,219	$21,700
LTM/MNA (Annual)	24		$34,219	$21,275
5-Year Review & Annual LTM/MNA	25		$68,719	$41,886
LTM/MNA (Annual)	26		$34,219	$20,448
LTM/MNA (Annual)	27		$34,219	$20,048
LTM/MNA (Annual)	28		$34,219	$19,654
LTM/MNA (Annual)	29		$34,219	$19,269
5-Year Review & Annual LTM/MNA	30		$68,719	$37,938
	TOTAL:	**$1,912,669**	**$1,394,309**	**$1,066,389**

TOTAL PRESENT WORTH: $2,979,058

ALTERNATIVE 4
ENGINEERED VEGETATIVE COVER ENHANCEMENT, LTM, MNA, and LUCs

Alternative 4 consists of enhancements to the landfill cover system at CC-A11 and CC-A12 only where vegetation is essentially not present or inadequate within the landfill limits. This alternative entails all elements of design and construction including CMIWP, erosion controls, removal of dead or inadequate vegetation, importation of topsoil and/or soil amendments, and 2 for 1 tree mitigation, as necessary, as part of site restoration combined with land-use controls and long-term monitoring of the soil cover. Also includes MNA of groundwater.

GENERAL ASSUMPTIONS

The costs are adopted from previous work conducted by Shaw Environmental at Fort Belvoir and other facilities in Virginia and Maryland, and professional judgment.

Assumed dimensions of the Areas of Concern:

Areas Requiring Soil / Amendment & New Vegetation	Area (SF)	Area (AC)	Depth (ft)	Volume (CY)
A-11	188,701	4.3	1.0	6,989
A-12	266,284	6.1	1.0	9,862
Total	**454,985**	**10.4**		**16,851**

Areas Requiring Soil / Amendment & New Vegetation	Trees (AC)	Meadow (AC)	Total Area (SF)	Total Area (AC)
A-11	0.4	3.9	188,701	4.3
A-12	0.6	5.5	266,284	6.1
Total	**1.0**	**9.4**	**454,985**	**10.4**

1.0 Permits, Design and Plan/Report Writing

The costs in this section consist of initial stakeouts of landfill limits and limits of insufficient vegetative cover; landfill reconnaissance; delineations; tree inventory ≥ 4"; permit acquisition; preparation of draft, draft final, and final versions of the CMIWP and design; preparation of draft, draft final, and final LUCIP and LTM plan; preparation of draft, draft final, and final versions of construction plans (HASP, VESCP, SWPPP, and CQCP/CQAP); and, preparation of draft, draft final, and final versions of the initial post-construction CMI report. This item assumes that existing data for landfill limits, topography, and soil cover thickness is sufficient as a basis for demarcation and design of vegetative cover system improvements.

Item		Unit Rate	Quantity	Cost
Site Reconnaissance, Surveys, Delineation, Inventory		$20,000	1	$20,000
Corrective Measures Implementation Work Plan (CMIWP)		$10,000	1	$10,000
Land Use Control Implementation Plan (LUCIP)		$5,000	1	$5,000
LTM Plan		$5,000	1	$5,000
CMIWP Design		$10,000	1	$10,000
Permits (e.g., Wetlands, Stream Encroachment)		$10,000	1	$10,000
Health and Safety Plan (HASP)		$5,000	1	$5,000
Virginia Erosion & Sediment Control Plan (VESCP)		$5,000	1	$5,000
Stormwater Pollution Prevention Plan (SWPPP)		$5,000	1	$5,000
CQCP/CQAP		$5,000	1	$5,000
CMI Report after Construction Phase		$10,000	1	$10,000
			SUBTOTAL	**$90,000**
			Contingency (10%)	$9,000
			Management (5%)	$4,500
			TOTAL	**$103,500**

2.0 Vegetative Cover System Enhancements - Construction Phase

The costs in this section consist of initial construction stakeouts of design elements, establishment of support areas and access routes (concurrent with clearing activities), clearing and removal of inadequate vegetation and installation of erosion controls (15 days), chemical and agronomic testing of existing cover soil and imported soil amendment, importation of topsoil or soil amendment and mixing with cover soil, debris removal, and gas vent installation, site restoration consisting of 11.4 acres to include 9.4 acres of native trees and ground cover and 2.0 acres of tree planting based on 2:1 tree replacement (15 days), removal of erosion and sediment controls and restoration of areas formerly containing erosion and sediment controls (5 days), and as-built survey.

Item	Unit	Unit Rate	Quantity	Cost
Mob / Demob / Rotations of Personnel and Equipment	Lump Sum	$15,000	1	$15,000
Clear Dead or Insufficient Vegetation	Acre	$10,000	1.3	$12,500
Construction Site Mgr (10-hr day)	Day	$918	30	$27,540
Sr. Field Engineer (10-hr day)	Day	$885	10	$8,850
Safety/Quality Specialist (10-hr day)	Day	$885	30	$26,550

Foreman (10-hr day)	Day	$487	30	$14,610
Equipment Operator (EO3) #1 (10-hr day)	Day	$432	30	$12,960
Equipment Operator (EO3) #2 (10-hr day)	Day	$432	30	$12,960
Laborer (L3) #1 (10-hr day)	Day	$331	30	$9,930
Laborer (L3) #2 (10-hr day)	Day	$331	30	$9,930
Laborer (L3) #3 (10-hr day)	Day	$331	30	$9,930
Laborer (L3) #4 (10-hr day)	Day	$331	30	$9,930
UXO Supervisor	Day	$700	30	$21,000
Per Diem (1.5 mo x 27 d/mo x 9 FT personnel + Sr Eng)	Day	$240	375	$90,000
Trailer, Telcomm, Cell, Toilets, Dumpster, etc.	Month	$1,500	2	$2,250
Quiet Generator plus Fuel	Month	$1,000	2	$1,500
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #1	Month	$1,277	1.5	$1,916
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #2	Month	$1,277	1.5	$1,916
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG #3	Month	$1,277	1.5	$1,916
Rental Small SUV w/ FOG #1	Month	$2,070	1.5	$3,105
Rental Small SUV w/ FOG #2	Month	$2,070	0.5	$1,035
Dozer D4 or equiv / GPS / wide track w/ FOG (2 x 1.5 mos)	Month	$3,042	3.0	$9,126
Rubber Tire Loader / 4 CY w/ FOG (1 x 1.5 mos)	Month	$6,000	1.5	$9,000
Backhoe or Skid Steer / Attachments / FOG (1 x 1.5 mos)	Month	$1,106	1.5	$1,659
Off-Road End Dump (2 x 1 mos)	Month	$6,000	2	$12,000
Surveying - 3 Man Crew for site control / initial stakeout	Hours	$175	24	$4,200
Surveying - 2 Man Crew for grade control and as-builts	Hours	$150	16	$2,400
Surveying - Office CAD / Support	Hours	$80	12	$960
Erosion Control Dikes (Unscreened Topsoil) (or Silt Fence)	CY	$23.00	400	$9,200
Erosion Mat for Dikes, Swales, etc.	Rolls	$50.00	200	$10,000
Truck / Equipment Wash Station	Lump Sum	$3,000	1	$3,000
Aggregate (miscellaneous sizes)	Ton	$25	100	$2,500
Miscellaneous Construction Materials for Gas Vents etc.	LS	$5,000	1	$5,000
Chemical, physical and agronomic testing (fill / topsoil)	Lump Sum	$2,500	1	$2,500
Soil Amendment (LeafGro or equivalent)	CY	$50	400	$20,000
Low Permeability Borrow	Tons	$12	12,638	$151,662
Unscreened Topsoil	CY	$23	10,111	$232,548
Seeding/Fertilizer/Straw/Tackifier (native seed) cap + E&SC	Acre	$2,500	11.4	$28,500
Tree Planting (includes 2:1 replacement of existing trees)	Acre	$3,500	11.4	$39,900
			SUBTOTAL	**$839,481**
			Contingency (10%)	$83,948
			Management (5%)	$41,974
			TOTAL	**$965,403**

3.0 Baseline Sampling and Analysis for MNA

Groundwater monitoring for VOCs and NAPs

Data interpretation and reporting

Two events, collect groundwater samples from 14 wells, plus 10% QC

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$3,000	2	$6,000
Chemist III	Day	$637	3	$1,911
Scientist II (10-hr day)	Day	$620	7	$4,340
Scientist II (10-hr day)	Day	$620	7	$4,340
Per Diem	Day	$240	14	$3,360
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	2	$600
Sampling Equipment	Each	$500	2	$1,000
Document Reproduction	Each	$500	2	$1,000
Analytical for MNA	Each	$465	32	$14,880
Analtyical for VOCs	Each	$100	36	$3,600
Daily Sample Shipping	Each	$40	10	$400
RDW Containment and Disposal	Each	$2,500	2	$5,000
			SUBTOTAL	**$46,431**
			Contingency (10%)	$4,643
			Management (5%)	$2,322
			TOTAL	**$53,396**

TOTAL CAPITAL: $1,122,298

4.0 Years 2 to 5 Semi-Annual RA(O): LUCs, LTM including GW and Methane Monitoring and Annual Reporting

Annual costs for Year 2 thru 5 semi-annual landfill inspections, gas vent monitoring, photos & documentation [middle of growing season (May) and end of growing season (Oct)] for Years 2 through 5. Two days per visit x 2/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$1,000	2	$2,000
Scientist II (10-hr day)	Day	$620	4	$2,480
Scientist II (10-hr day)	Day	$620	4	$2,480
Per Diem	Day	$240	8	$1,920
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	1	$300
Methane Monitoring Instrument	Each	$50	4	$200
Annual CMI Report (draft, draft final & final)	Each	$1,500	1	$1,500
Document Reproduction	Each	$200	2	$400
Semi-annual GW Monitoring for MNA (from 3.0 above)	Lump Sum	$46,431	1	$46,431
			SUBTOTAL	**$57,711**
			Contingency (10%)	$5,771
			Management (5%)	$2,886
			TOTAL	**$66,368**

5.0 Years 6 to 30 Annual RA(O): LUCs, LTM including Methane amd GW Monitoring and Annual Reporting

Annual costs for Year 6 thru 30 annual landfill inspections, gas vent monitoring, photos & documentation at end of growing season (Oct). Two days per visit x 1/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Mobilization of Personnel and Equipment	Lump Sum	$1,000	1	$1,000
Scientist II (10-hr day)	Day	$620	2	$1,240
Scientist II (10-hr day)	Day	$620	2	$1,240
Per Diem	Day	$240	4	$960
Rental Pickup/Crew Cab/F150 Class/Gas/4WD/FOG	Week	$300	1	$300
Methane Monitoring Instrument	Each	$50	2	$100
Annual CMI Report (draft, draft final & final)	Each	$1,500	1	$1,500
Document Reproduction	Each	$200	1	$200
Annual GW Monitoring for MNA (from 3.0 above)	Lump Sum	$46,431	0.5	$23,216
			SUBTOTAL	**$29,756**
			Contingency (10%)	$2,976
			Management (5%)	$1,488
			TOTAL	**$34,219**

6.0 Five-Year Review

Annual costs for Year 6 thru 30 annual landfill inspections, gas vent monitoring, photos & documentation at end of growing season (Oct). Two days per visit x 1/year
Preparation of an annual CMI report with cost identified in Item 1.0 above.

Item	Unit	Unit Rate	Quantity	Cost
Five-Year Review	LS	$30,000	1	$30,000
			SUBTOTAL	**$30,000**
			Contingency (10%)	$3,000
			Management (5%)	$1,500
			TOTAL	**$34,500**

PRESENT WORTH CALCULATION:

Using a discount rate of: **2%**

Description of Cost Details	Year	Capital	O&M	Present Worth Value
Summary of Capital Costs	0	$1,122,298		
LTM/MNA (Semi-Annual)	1		$66,368	$65,066
LTM/MNA (Semi-Annual)	2		$66,368	$63,791
LTM/MNA (Semi-Annual)	3		$66,368	$62,540
LTM/MNA (Semi-Annual)	4		$66,368	$61,313

5-Year Review, Semi-Annual LTM/MNA	5		$100,868	$91,359
LTM/MNA (Annual)	6		$34,219	$30,385
LTM/MNA (Annual)	7		$34,219	$29,790
LTM/MNA (Annual)	8		$34,219	$29,205
LTM/MNA (Annual)	9		$34,219	$28,633
5-Year Review & Annual LTM/MNA	10		$68,719	$56,373
LTM/MNA (Annual)	11		$34,219	$27,521
LTM/MNA (Annual)	12		$34,219	$26,981
LTM/MNA (Annual)	13		$34,219	$26,452
LTM/MNA (Annual)	14		$34,219	$25,934
5-Year Review & Annual LTM/MNA	15		$68,719	$51,059
LTM/MNA (Annual)	16		$34,219	$24,927
LTM/MNA (Annual)	17		$34,219	$24,438
LTM/MNA (Annual)	18		$34,219	$23,959
LTM/MNA (Annual)	19		$34,219	$23,489
5-Year Review & Annual LTM/MNA	20		$68,719	$46,246
LTM/MNA (Annual)	21		$34,219	$22,577
LTM/MNA (Annual)	22		$34,219	$22,134
LTM/MNA (Annual)	23		$34,219	$21,700
LTM/MNA (Annual)	24		$34,219	$21,275
5-Year Review & Annual LTM/MNA	25		$68,719	$41,886
LTM/MNA (Annual)	26		$34,219	$20,448
LTM/MNA (Annual)	27		$34,219	$20,048
LTM/MNA (Annual)	28		$34,219	$19,654
LTM/MNA (Annual)	29		$34,219	$19,269
5-Year Review & Annual LTM/MNA	30		$68,719	$37,938
	TOTAL:	**$1,122,298**	**$1,394,309**	**$1,066,389**

TOTAL PRESENT WORTH: $2,188,688

Appendix B

Summary of Studied Landfill Sites with Engineered Vegetative Soil Cover Systems (a.k.a., Monolithic ET Covers) Compared to Fort Belvoir SWMU Site Vegetative Soil Cover Conditions

Summary of Studied Landfill Sites with Engineered Vegetative Soil Cover Systems (a.k.a., Monolithic ET Covers) Compared to Fort Belvoir SWMU Site Vegetative Soil Cover Conditions												
									Climate Conditions			
Site Name and Location	Type of Site	Regulatory Status	Vegetation	Tree Density	Cap Area (acres)	Cap Thick-ness (feet)	Soil Type / Description	Install. Yr.	Overall	Avg. Annual Precip. (inches)	Avg. Annual Snow	Notes
Studied Landfill Sites:												
Elmendorf Air Force Base, Anchorage, AK	MSW	Superfund Site - USEPA approved	Cottonwood, poplar, aspen, and willow trees	n/a	56	2 + 4	2-ft forest soils (sandy loam) w/ underlying 4-ft drainage layer	2004-2005	Cold region	22.5	70.0	Demonstration project performed followed by full scale implementation.
Marine Corps Logistics Base, Albany, GA	MSW w/ some old fill - Haz. Waste	ACAP Program / Superfund Site - USEPA approved	Mix of hardwood and pine trees	n/a	32	2.5	30-inch cover comprised of blended materials	2010	Wet seasons, hot summers, and cool winters	50.4	0.7	Demonstration project performed followed by full scale implementation.
Bluestem LF Site No. 1, Marion, IA	MSW	ACAP Program	Hybrid poplar trees	5,600 trees per 3 acres of land	3	2	24 inches of cover soil	1994	precip. throughout year, hot humid summers, cold winters	34.0	34.9	Demonstration project performed by Ecolotree Inc.
College Park Landfill, College Park, MD	MSW	Superfund Site - USEPA approved	Variety of deciduous and evergreen trees, shrubs, grasses, and ground cover	n/a	n/a	3.5-5	n/a	n/a	wet seasons, hot humid summers, cold winters	40.8	17.0	Demonstration project performed; full scale implementation pending.
Casting Sand Landfill, Detroit, MI	RCRA - Utility Waste (flyash)	n/a	Hybrid poplar trees	7,500 trees per 5 acres of land	5	2	1 foot of soil amendment overlying 1 foot of silty clay loam cover	1998	precip. throughout year, hot humid summers, cold winters	31.0	42.7	Demonstration project performed by Ecolotree Inc.
Electrical Power Plant – Ash Landfill, Saint Louis, MO	RCRA - Utility Waste (flyash)	n/a	Hybrid poplar trees	7,500 trees per 5 acres of land	5	2	Sandy loam soils	1995	wet seasons, hot humid summers, cold winters	38.0	17.7	Demonstration project performed by Ecolotree Inc.
GE Main Plant, Schenectady, NY	RCRA Haz. Waste	USEPA approved	Hybrid poplar and willow trees, and native plants	n/a	120	n/a	n/a	2001	wet seasons, hot humid summers, cold winters	36.8	59.1	
Welsh Road Landfill, Honeybrook, PA	MSW	Superfund Site - USEPA approved	Hybrid poplar trees with understory vegetation	770 trees per acre	5.2	3 - 4	Minimum of 4 ft cover soil except 3 ft on slopes greater than 10%	2006	wet seasons, hot humid summers, cold winters	43.0	27.0	Ecolotree Inc. project
Clearview Landfill, Darby Twp / Darby Co., PA	MSW w/ some old fill - Haz. Waste	Superfund Site - CMS alternative cover options evaluated	Healthy stand of trees with other vegetation	LAI modeled as a "2" and a "5"	n/a	n/a	n/a	not installed	wet seasons, hot humid summers, cold winters	29.6 - 49.2	28.2	ET cover option modeled using the VADOSE/W Model. Results show an infiltration reduction ranging from 83% to 99% (varies w/LAI).
Fort Belvoir Site - SWMUs with Vegetative Soil Cover System:												
Fort Belvoir SWMUs, Fort Belvoir, VA	MSW w/ some old fill		Areas with dense healthy stands of loblolly pines, pines, mixed oak, mixed hardwoods, and various types of groundcover	varies from approx. 1,000 to >1,500 trees per 1-acre of land (must be field verified)	varies from approx. 8 to 41 acres	2	silty, sandy, clay loams	>30 yrs ago	wet seasons, hot humid summers, cold winters	44.3	10.3	

Source:

Information obtained from the USEPA CLU-IN website (http://clu-in.org/products/altcovers/usersearch/lf_search.cfm), communications with Steve Rock with the USEPA Office of Research & Development (ORD), current 5-Year Reports and status update information for various sites obtained from USEPA's Superfund website / database, and weather data for some sites obtained from the NOAA - National Climatic Data Center website (http://www.ncdc.noaa.gov/cdo-web/).

Notes:

"ACAP" is alternative cap assessment program.

"LAI" is leaf area index. An LAI of 2 equals a fair stand, versus a 5 which stands for an excellent stand.

"n/a" is not available.