FINAL

FEASIBILITY STUDY

DUPONT CHAMBERS WORKS FUSRAP SITE
DEEPWATER, NEW JERSEY

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Prepared by:

U.S. ARMY CORPS OF ENGINEERS
PHILADELPHIA DISTRICT
PHILADELPHIA, PENNSYLVANIA

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LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
AOC	Area of Concern
AOI	area of interest
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
BCG	biota concentration guideline
BNI	Bechtel National, Inc.
BRA	Baseline Risk Assessment
BTEX	benzene, toluene, ethylbenzene, xylene
°C	Celsius
CDD	Central Drainage Ditch
CEA	Classification Exception Area
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
CFR	Code of Federal Regulations
cfs	cubic feet per second
COC	Constituent of Concern
COPC	constituent of potential concern
COPEC	constituent of potential ecological concern
cpm	counts per minute
CSM	Conceptual Site Model
DCGL	Derived Concentration Guideline Levels
DE	Delaware
DOE	U. S. Department of Energy
EPC	Exposure Point Concentration
EU	exposure unit
EWDAA	Energy and Water Development Appropriations Act
ESA	Endangered Species Act
°F	Fahrenheit
FS	feasibility study
ft	feet
ft^2	square feet
FUSRAP	Formerly Utilized Sites Remedial Action Program
gpm	gallons per minute
GRA	general response action
HASP	health and safety plan
HHRA	Human Health Risk Assessment
HI	Hazard Index
HPWDS	Historic Process Water Ditch System
HSWA	Hazardous and Solid Waste Amendments
IC	institutional control
ILCR	Incremental Lifetime Cancer Risk
ISV	investigative screening value
IWS	Inceptor Well System
LNAPL	light non-aqueous phase liquid
LUC	land use control
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	maximum contaminant level

mg/L	milligrams per liter
MNA	monitored natural attenuation
mph	miles per hour
mrem/yr	millirem per year
msl	mean sea level
µg/L	micrograms per liter
µR/hr	microroentgens per hour
MED	Manhattan Engineer District
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NAVD 88	North American Vertical Datum of 1988
NJ	New Jersey
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NPDES	National Pollution Discharge Elimination System
NRC	Nuclear Regulatory Commission
O&M	operation and maintenance
OU	Operable Unit
ORNL	Oak Ridge National Laboratory
ORP	Oxidation Reduction Potential
Pa-234m	Protactinium-234m
PCB	polychlorinated biphenyl
PIC	Pressurized Ion Chamber
POTW	publicly owned treatment works
PP	Proposed Plan
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goal
pCi/g	picoCuries per gram
pCi/L	picoCuries per liter
Ra-226	Radium-226
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
ROD	Record of Decision
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity
RFI	RCRA Facility Investigation
RG	remediation goal
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
SGS	Segmented Gate System
SLERA	Screening-Level Ecological Risk Assessment
SVOC	semi-volatile organic compound
SDWA	Safe Drinking Water Act
SWMU	solid waste management unit
TAL	Target Analyte List
TBC	To Be Considered
TCL	Target Compound List
TERP	Transportation and Emergency Response Plan
Th-230	Thorium-230
Th-234	Thorium-234
U	uranium
U(4+)	tetravalent uranium
U(6+)	hexavalent uranium

UF4	green salt
UF6	uranium hexafluoride
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium-238
U_3O_8	black oxide
UO_2	brown oxide
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UCL	upper confidence limit
WWTP	wastewater treatment plant
yd^3	cubic yard

1.0 INTRODUCTION AND NEED FOR ACTION

This Feasibility Study (FS) report was prepared by the U.S. Army Corps of Engineers (USACE), Philadelphia District with technical support from Cabrera Services, Inc. (CABRERA) under contract number W912WJ-06-D-0002/CF01 for the DuPont Chambers Works Site. The Site is currently being addressed under the Formerly Utilized Sites Remedial Action Program (FUSRAP) managed by the USACE.

1.1 Authority of Action

The DuPont Chambers Works (Chambers Works) in Deepwater, New Jersey (NJ) is an active chemical manufacturing facility owned and operated by E.I. DuPont de Nemours & Company (DuPont). The U.S. Army Corps of Engineers Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC) contracted with DuPont to process uranium at Chambers Works in the 1940s. The USACE – Philadelphia District is conducting a program to investigate and clean up, if necessary, eligible residual contamination resulting from these activities. USACE is utilizing the administrative, procedural, and regulatory provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended (CERCLA) [42 U.S.C §9601 et seq.], and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 C.F.R Part 300] to guide the investigations at three operable units (OUs) within the Chambers Works property.

In 1974, the AEC (succeeded by the U.S. Department of Energy, [DOE]) established a site investigation and cleanup program that later became FUSRAP. FUSRAP was initiated to identify, investigate, and clean up or otherwise control sites where residual radioactivity remained from activities conducted under contract to the MED or the AEC during the early years of the nation's atomic energy program, or from commercial operations as directed by Congress. On October 13, 1997, Congress transferred the administration and cleanup of eligible FUSRAP sites from the DOE to USACE as part of the 1998 Energy and Water Development Appropriations Act (EWDAA). FUSRAP is a jointly managed program by both the DOE and USACE. USACE is conducting FUSRAP site cleanups under Congressional appropriations subject to the direction contained in Public Law 106-60, §611: the EWDAA for Fiscal Year

2000. This law directs USACE to conduct response actions for releases related to the nation's early atomic energy program subject to the provisions of the CERCLA and the NCP.

The DuPont Chambers Works Site is a 1,455-acre complex which includes Chambers Works chemical manufacturing area (referred to as Chambers Works) and the former Carneys Point Smokeless Powder Works (referred to as Carneys Point Works). Figure 1-1 shows the location of the Chambers Works within Pennsville and Carney Point Townships, along the southeastern shore of the Delaware River, just north of the I-295 Delaware Memorial Bridge, and adjacent to the residential community of Deepwater, NJ. MED activities were conducted only within the 700-acre Chambers Works site. No MED research, processing activities or waste disposal occurred within the Carneys Point Works, located in the northern portion of the property, and therefore, that area is not part of the FUSRAP investigation. For the purposes of this report the areas investigated under FUSRAP will be referred to collectively as the DuPont Chambers Works FUSRAP Site (the Site) in order to distinguish the FUSRAP areas and activities from DuPont's overall manufacturing complex and operations.

Based on previous DOE investigations regarding the nature of past MED activities in each area, USACE initially identified six potentially-impacted areas, referred to as areas of concern (AOCs). To facilitate further investigations and remedial decisions, the USACE organized the six AOCs into three OUs under FUSRAP. Additionally, USACE evaluated the wastes and materials used in MED operations and identified the constituents of potential concern (COPCs) that would be eligible for FUSRAP investigation and remediation (CABRERA 2011a).

USACE performed separate investigations at each of the following OUs between 2000 and 2007:

- OU 1: Former Building 845 (AOC 1) and F Corral (AOC 2) - These AOCs were production areas where uranium refinement processes occurred.
- OU 2: Central Drainage Ditch (CDD) (AOC 3) and the J-26 Area (former location of Building J-16) (AOC 5) - These AOCs include the location of a former laboratory building (J-16) and drainage ditches through which processing wastes were discharged.
- OU 3: Historical Lagoon A (AOC 4) and the East Area (AOC 6) - These AOCs were disposal areas for building rubble, discarded equipment, and process wastes.

Figure 1-2 is an aerial view of the Chambers Works property outlining the FUSRAP OUs, the six corresponding AOCs. For subsequent risk evaluation, the AOCs were grouped into five separate exposure units (EU) based on physical location within the Site (see Figure 2-17). The EUs correspond with the FUSRAP OU designations, as follows:

- EU 1 – OU 1 (AOC 1 and AOC 2)
- EU 2A, EU 2B – OU 2 (AOCs 3 and 5, respectively)
- EU 3A , EU 3B - OU 3, (AOCs 4 and 6, respectively)

Results of the FUSRAP investigations including site characteristics and nature and extent of contamination are detailed in the *Final Sitewide Remedial Investigation Report for all Operable Units, DuPont Chambers Works FUSRAP Site* (CABRERA 2011b). *The Final Baseline Risk Assessment, DuPont Chambers Works FUSRAP Site, Deepwater, New Jersey,* was completed based on RI sampling results, to evaluate actual and potential risks to human health and the environment (CABRERA 2011c). Results of the RI and baseline risk assessment (BRA) are summarized in Section 2 of this report.

1.2 Background MED-Related Operational History

MED operations involving uranium began at Chambers Works in 1942. MED contracted with DuPont to perform several uranium-processing activities. In 1946, all MED activities were transferred to the AEC, and DuPont continued research for AEC until late 1947. DuPont's contracts with MED involved the following uranium refinement processes, which were performed in OU 1:

- Brown oxide process,
- Recovery process,
- Green salt process, and
- Metal process.

Descriptions of these processes are further discussed in Section 1.5 of the Sitewide RI report. In addition to these processes, Chambers Works also converted quantities of green salt (uranium tetrafluoride) to uranium hexafluoride. This process, known as the hexafluoride process, was performed at the former Building J-16 (OU 2). Pilot-scale work on the brown oxide, green salt, and recovery processes also took place in the former Building J-16 (currently the Building J-26 Area).

DOE has estimated that more than half of the feedstock sent to Chambers Works was uranium-bearing scrap that was processed to uranium peroxide dihydrate and then used in the Brown

Oxide Process (DOE 1997). Other research involving radioactive materials was also performed onsite but there was no enriched or depleted uranium produced or used at Chambers Works.
All uranium refining processes at production scale took place in OU 1 (AOCs 1 and 2) while some small scale testing took place in AOC 5. Chambers Works converted scrap and dross (the scum that forms on the surface of molten metal) into uranium peroxide dihydrate in AOC 1, Buildings 101 and 102. These buildings adjoined each other and were later collectively called Building 845. During processing, 5,486 tons of scrap material were converted to 982 tons of black oxide. In AOC 2 uranium peroxide and other oxides were processed in Buildings 708 and 205, ultimately producing (through several steps) uranium tetrafluoride and uranium metal.

1.3 Prior Investigations and Cleanups

1.3.1 Atomic Energy Commission/Department of Energy

In 1948 and 1949, AEC conducted radiological surveys and decontamination of building surfaces at the Site. In 1949, following a radiological survey based on then-existing criteria, AEC released the buildings back to DuPont. DuPont demolished Building J-16 after it was released by AEC and in the process excavated several feet of soil from beneath the building (DOE 1996). Building J-26 was subsequently constructed over the Building J-16 footprint.

1.3.2 Oak Ridge National Laboratory 1977

Oak Ridge National Laboratory (ORNL) conducted a radiation survey of the Chambers Works site in 1977 (ORNL 1978). The results of the survey in the F Parking Corral Area (AOC 2) indicated exposure rates were consistent with background radiation levels. Two soil borings were obtained in the F Parking Corral Area, along with one water sample. Uranium-238 (U-238) results were reported, and ranged up to 6.8 picoCuries per gram (pCi/g) in the soil samples and 1.8 picoCuries per liter (pCi/L) in the water samples.

External gamma radiation levels along the CDD (AOC 3) indicated exposure rates of 3 to 23 microroentgens per hour (μR/hr), which exceeded background radiation levels. Five soil borings were taken along the drainage ditch. A water sample was collected from one of the boreholes which yielded 0.67 pCi/L for U-238.

In the East Area (AOC 6), external gamma radiation levels indicated an exposure rate of 12.2 to 15 μR/hr, which exceeded the background radiation level of 4.5 μR/hr. Ten soil borings were performed along the East Area drainage ditch. Groundwater samples collected from two soil borings yielded total uranium concentrations between 9 micrograms per liter (µg/L) and 36 µg/L.

1.3.3 Bechtel National, Inc. 1983

Bechtel National, Inc. (BNI) performed a radiation survey of the Chambers Works in 1983 (BNI 1985). Survey results available for several of the AOCs described in the RI are summarized below.

In the F Parking Corral (AOC 2), near-surface gamma radiation measurements were collected. The average background reading for this area as established by ORNL was 2,500 counts per minute (cpm). All measurement readings were below this average background level, with the exception of one, which had a maximum reading of 5,020 cpm. External gamma radiation, as measured by a pressurized ion chamber (PIC) yielded dose rates ranging from 11.6 to 13.8 µR/hr as compared to average background of 4.5 µR/hr. Nineteen boreholes were drilled in the F Parking Corral Area. Based on gamma logs, subsurface contamination was indicated in layers to a depth greater than 9 feet (ft). Results from the analysis of two soil samples, collected using a Shelby tube, indicated that U-238 was the major contaminant with concentrations ranging from 0.90 to 4,380 pCi/g. Eleven groundwater samples were also collected from the boreholes and analyzed, with results showing total uranium concentrations ranging from 1.8 to 105,105 pCi/L.

Near-surface gamma radiation measurements performed in the CDD (AOC 3) indicated surface activities that were elevated above background (i.e., a maximum of 14,532 cpm compared to a background of 2,500 cpm). External gamma radiation yielded dose rates ranging from 13 to 15 µR/hr, compared to a background reading of 4.5 µR/hr. Fifteen sediment samples were collected along the CDD. These samples were taken between 0-6 inches below the sediment surface (bgs). No samples deeper than 6 inches and no water samples were collected in this area.

1.3.4 DuPont 1988 - Present

DuPont has been conducting Resource Conservation and Recovery Act (RCRA) corrective actions at Chambers Works since 1988, completely unrelated to the ongoing FUSRAP investigations. The USEPA Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) identification number for Chambers Works is NJD002385730. The Hazardous and Solid Waste Amendments (HSWA) permit (No.

NJO02395730) was issued by U.S. Environmental Protection Agency (USEPA) to Chambers Works on November 7, 1988. As part of its RCRA investigation, DuPont has designated the areas of former MED activity as Solid Waste Management Unit (SWMU) 33. USACE is responsible for the investigation and cleanup of the areas used to support the nation's early atomic energy program. In accordance with its RCRA permit requirements, DuPont operates an extensive sitewide pump and treat system in order to control off-site migration of chemical contaminants in groundwater. These chemical contaminants resulted from manufacturing operations by DuPont and are unrelated to the FUSRAP constituents in groundwater. The pump and treat system, referred to as the Inceptor Well System (IWS), provides hydraulic containment of contaminants in groundwater, including FUSRAP-related contamination. DuPont began operation of the IWS in 1970.

DuPont submitted a RCRA Facility Investigation (RFI) Report to the New Jersey Department of Environmental Protection (NJDEP) and USEPA in 1995. The aquifers beneath Chambers Works are classified as Class IIA groundwater by the State of New Jersey. This classification indicates a designated use or potential use as a potable water source using conventional treatment (NJAC 7:9C). NJDEP has designated Chambers Works as a Classification Exception Area (CEA) where the designated uses (i.e., potable water source) are suspended for the duration of the CEA. This classification is tied to the duration of DuPont's New Jersey Pollution Discharge Elimination System (NJPDES) discharge to groundwater (DGW) permit and is re-evaluated every five years at the time of permit renewal.

1.4 Reasons for Remedial Actions

USACE is preparing this FS in accordance with CERCLA and the NCP for cleanup of contaminants resulting from work performed as part of the Nation's early atomic energy program. This document evaluates the alternatives for remedial action at the Site. It is based on historical data and the results of the Sitewide RI, which contains information on the nature and extent of contamination, and the BRA, which evaluates potential health and ecological risks which would exist if no remedial action were to be taken and no land use controls were to be implemented.

The Sitewide RI report (CABRERA 2011b) summarizes the data and analytical results from radiological and chemical characterization surveys and field investigations conducted at the Site from 2000 through 2007. These studies were undertaken to determine the nature and extent of contamination and to characterize the geologic and hydrogeologic features of the property. The results from the RI indicate that elevated uranium concentrations above the Investigative Screening Value (ISV) of 14 pCi/g (total uranium) were found in each AOC from each OU (with the exception of AOC 5); however, OU 1 (AOC 1 and AOC 2) and OU 3 (AOC 6) were the only areas with unacceptable risk, as determined in the BRA (CABRERA 2011c).

Based on the knowledge of feedstocks received at Chambers Works, MED manufacturing processes, and final products, the USACE identified the COPCs that are MED-related wastes/materials and therefore eligible for FUSRAP cleanup (CABRERA 2011a). The COPCs identified are the six initial radionuclides in the U-238 decay chain (including Radium-226 (Ra-226)), plus Uranium-235 (U-235). However, due to the short half-lives of Thorium-234 (Th-234) and Protactinium-234m (Pa-234m) (assumed to be in secular equilibrium with respect to U-238), these two radionuclides are not considered as distinct COPCs. Similarly, due to its short half-life, Thorium-231 (Th-231) is assumed to be in secular equilibrium with respect to its parent, U-235, and is not considered as a separate COPC for the Site. Therefore, five radionuclides have been identified as eligible contaminants, COPCs, for the FUSRAP investigation and cleanup: U-234, U-235, U-238, Th-230, and Ra-226.

Table 1-1: COPCS for Soil at Chambers Works FUSRAP Site

U-238 Decay Chain				
Symbol	**Element**	**Radiation**	**Half-Life**	**Decay Product**
U-238	Uranium-238	Alpha	4,460,000,000 years	Th-234
Th-234[1]	Thorium-234	Beta	24.1 days	Pa-234m
Pa-234m[1]	Protactinium-234m	Beta	1.17 minutes	U-234
U-234	Uranium-234	Alpha	247,000 years	Th-230
Th-230	Thorium-230	Alpha	80,000 years	Ra-226
Ra-226	Radium-226	Alpha	1,602 years	Rn-222
U-235 Decay Chain				
U-235	Uranium-235	Alpha	700,000,000 years	Th-231
Th-231[2]	Thorium-231	Beta	25.52 hours	

1 Due to very short half-lives (<180 days), daughter products Th-234 and Pa-234m are in secular equilibrium with respect to their parent, U-238. Therefore, those daughter products will not be considered as separate COCs in the FS.

2 Due to very short half-lives (<180 days), daughter product Th-231 is in secular equilibrium with respect to its parent, U-235. Therefore, it will not be considered as a separate COC in the FS.

The BRA report (CABRERA 2011c) evaluated the potential risks and doses for both current and hypothetical future reasonable maximum exposure (RME) receptors of the Site. Potential carcinogenic and noncarcinogenic risks to human health and the environment were quantified and compared to acceptable risk ranges under CERCLA. In addition, radiological doses for both current and hypothetical future RME receptors were calculated and compared to acceptable dose limit.

As discussed further in Section 2, the BRA results indicate that the maximum risk to industrial workers at EU 3B exceeded the CERCLA acceptable target risk range, and for EU 1, the maximum risk was at the upper end of the acceptable risk range. Furthermore, the maximum dose for construction workers and utility workers at EU 1, and the maximum dose for industrial workers and construction workers at EU 3B exceeded the acceptable dose limit.

Because the maximum risk and dose calculated for AOC 3, AOC 4, and AOC 5 did not exceed their corresponding acceptable risk and dose criteria for either current or future RME receptors, it was determined that no remedial action is required for these areas and they will not be further evaluated in this FS. Based on BRA results, remedial actions will be evaluated for OU 1 (AOCs 1 and 2) and AOC 6. The results of radiological risk and dose assessments also showed that the five radionuclides contribute to the majority of the risks and doses to various receptors present (CABRERA 2011c). Therefore, the radionuclides U-234, U-235, U-238, Thorium-230 (Th-230), and Ra-226 have been identified as the constituents of concern (COCs) for the Site and considered for evaluation in the FS.

In addition to radiological COCs, the BRA also identified two metals (antimony and nickel), three semivolatile organic compounds (SVOCs) (benzo(a)pyrene, benzo(a)anthracene, and azobenzene) and one polychlorinated biphenyl (PCB) congener, Aroclor 1254, as major chemical risk contributors for the Site. However, USACE evaluated potential chemical compounds that were utilized during the MED uranium processing and none of the above mentioned chemical constituents were identified as FUSRAP eligible contaminants (CABRERA 2011a). Since no chemical constituents were considered as COCs for the DuPont Chambers Works FUSRAP Site, only the five radionuclides (U-234, U-235, U-238, Th-230 and Ra-226) will be evaluated for possible remedial actions. In instances where non-FUSRAP chemical constituents are commingled (located) with the FUSRAP-eligible COCs, by necessity, those chemical constituents will be addressed and cleaned up. Therefore, the presence of non-FUSRAP chemical constituents will be considered in the FS from a cost perspective, as they could potentially affect health and safety measures, treatment and disposal options, and overall project costs.

The BRA did not identify any major risk contributors in surface water or sediment (CABRERA 2011c). Therefore, no COCs were identified for these two pathways.

Except for inhalation of volatiles from groundwater for the construction and utility worker scenarios, groundwater was not evaluated for four RME scenarios. Since volatile organic constituents are not FUSRAP-related constituents, and none of the FUSRAP-related radioactive COPCs are volatile, the groundwater exposure pathway is incomplete for FUSRAP-eligible constituents. In addition, current groundwater conditions preclude its use as a potential drinking water source. This is because the two uppermost aquifers exhibit high organic, metal, and salt contamination due to DuPont manufacturing operations. Accordingly, at the present time, the designated use of the Class II groundwater beneath Chambers Works as a potable water source is suspended for the duration of the CEA. This exception is re-evaluated every five years as part of DuPont's groundwater remediation plan and NJPDES DGW permit renewal for the property.

Sitewide RI results show that radioactive contamination in groundwater is encountered in areas where elevated uranium concentrations exist in soil (i.e., co-located contamination). Since there is the potential for radiological constituents present in the soil to leach into and impact groundwater at the Site, groundwater remedial alternatives will be evaluated for those areas requiring a remedial action for soils. Therefore, groundwater is evaluated for OU 1 and AOC 6 in this FS. It is expected that completed soil remedial action(s) will eliminate or minimize the radioactive contamination found in groundwater by addressing its source (i.e., soils) at the Site.

The RI, BRA, and FS comprise the primary evaluation documents. The Proposed Plan (PP) is published as a separate document and is the primary document to communicate the remedial alternatives evaluated and USACE's preferred remedial alternative to the community for consideration. The RI/FS/PP process includes review and coordination with the NJDEP, USEPA, and appropriate local agencies as well as public participation activities with affected stakeholders. The process concludes with the issuance of a Record of Decision (ROD) that selects the remedial alternative(s) for the DuPont Chambers Works FUSRAP Site.

1.5 Purpose and Scope of the FS

This FS identifies, develops, and evaluates remedial action alternatives to achieve a final remedy of eligible contaminants in soil and groundwater. The uranium isotopes (U-238, U-235, and U-234), Ra-226, and Th-230 are identified as the COCs contributing to unacceptable human health risks and doses under RME scenarios in three FUSRAP AOCs: AOCs 1, 2, and 6. AOCs 1 and 2 are in close proximity and are similar in physical characteristics and contaminant distribution, and will therefore be considered together. Candidate remedial alternatives, their evaluation, and selection will be the same for AOCs 1 and 2. AOC 6 has different physical characteristics and will be evaluated separately, possibly resulting in selection of a remedial alternative that is different from that selected for AOCs 1 and 2.

Groundwater is not addressed as a source medium within this FS but is addressed only as a potential transport mechanism for soil COCs. As mentioned previously, groundwater remedial alternatives will be evaluated for those areas (OU 1 and AOC 6) that require a remedial action for soil. Alternatives are developed on the basis of the nature and extent of contamination documented in the RI, the BRA, and related reports. Figure 1-3 shows the location of AOCs addressed by this FS.

1.6 Organization of the Report

This FS is organized consistent with available guidance from the USEPA and USACE. The general overview of the site, the need for action, and the scope of this FS are presented in Section 1. Section 2 of this report describes the DuPont Chambers Works FUSRAP Site, its history, and environmental setting. This section also summarizes the nature and extent of contamination from radiological constituents, the transport of these materials, and results of the BRA. In Section 3, remedial action objectives, applicable or relevant and appropriate requirements (ARARs) and remediation goals (RGs) are defined and remedial action technologies are identified and screened for their effectiveness in meeting those goals. The development and screening of remedial action alternatives are presented in Section 4. In Section 5, a detailed analysis of potential remedial alternatives using CERCLA guidance evaluation criteria is presented. Section 5 also provides a comparative analysis of the remedial alternatives for the DuPont Chambers Works FUSRAP Site. Section 6 lists the references used in this report. Appendix A provides the determination of the RGs for COCs present at the Site. Appendix B provides a detailed summary of the cost estimates developed for each remedial alternative. Appendix C includes uranium mass balance calculations that evaluate current uranium concentrations in groundwater and expected post remedial action residual concentrations.

1.7 Community Involvement

Scoping meetings help determine the range of issues to be addressed during the CERCLA process by identifying potential actions and significant issues to be addressed, the range of alternatives to be evaluated, the relevance of existing information, and areas where more information is needed. The USACE has conducted regular scoping and strategic planning sessions with internal team members throughout the various investigations at the Site. Community involvement has been an integral component of the remedial program and has been implemented by working closely with and meeting with various community groups. USACE has partnered with community members and held community meetings since 2000 to maintain an open dialogue about site investigations and remedial plans.

Early in the CERCLA remedial action process, USACE held regular and frequent community meetings in order to share information with interested stakeholders about FUSRAP activities at the DuPont Chambers Works FUSRAP Site consistent with community involvement requirements in CERCLA and the NCP. Additionally, USACE has established a public website for the DuPont Chambers Works Site at http://fusrap.eaest.com/. Through its community involvement program, the USACE provides opportunities for an exchange of information with the public through news releases, community and public meetings, availability sessions, mailings, newsletters, project website, and public review and comment of documents. A copy of the DuPont administrative record is maintained by the USACE at the Salem Community College Library, located at 406 Hollywood Avenue, Carneys Point, NJ.

1.8 Consultation and Coordination with Other Agencies

As previously mentioned, USACE is the lead agency for remedy selection and for conducting the FUSRAP cleanup of the Chamber Works FUSRAP site pursuant to Public Laws 105-62 and 106-60 §611. USACE coordinates with NJDEP and USEPA Region 2, the regulatory agencies with responsibilities to oversee activities at the Site. NJDEP and USEPA are responsible for overseeing the RCRA corrective action program implemented by DuPont throughout the facility. These corrective actions are separate from the FUSRAP investigations. USACE is coordinating the identification and concurrence of ARARs that may affect Site remediation with NJDEP. Through community involvement activities for the DuPont Chambers Works FUSRAP Site, the USACE also encourages Federal and State legislators, local and county officials, and the general public to participate in the decision-making process for Site remediation.

Federal and State agencies responsible for natural or cultural resources addressed in the FS have been coordinated with the U.S. Fish and Wildlife Service (USFWS) and the New Jersey Office of Natural Land Management. A request for information on the presence of federally listed endangered and threatened species in the vicinity of Chambers Works was sent to USFWS. A response regarding Section 7 of the Endangered Species Act of 1973 (ESA) was received in December 2007. This correspondence is further discussed in Section 2.4, Summary of BRA Results.

2.0 THE SITE AND AFFECTED ENVIRONMENT

2.1 Site Description and History

The Chambers Works is located in Pennsville and Carneys Point Townships, along the southeastern shore of the Delaware River, north of the I-295 Delaware Memorial Bridge, and adjacent to the residential community of Deepwater, NJ. The location of the DuPont property is shown in Figure 1-1. The complex extends 2.7 miles between Helms Cove to the north and the Salem Canal to the south. Henby Creek separates the active Chambers Works manufacturing area from the former Carneys Point manufacturing area (northern part of property). The Pennsylvania and Reading Seashore Line railroad track bounds the property to the east.

As previously mentioned, the DuPont Chambers Works FUSRAP Site is divided into three OUs. OU 1 consists of the following two AOCs: AOC 1, Former Building 845 and AOC 2, the F Corral. OU 2 consists of AOC 3 and AOC 5, which are the CDD and the J-26 Area, respectively. OU 3 consists of AOC 4, the Historical Lagoon and AOC 6, the East Area. A summary description of each of the OUs is presented below. Figure 1-2 shows the location of each OU with respect to the Chambers Works manufacturing areas. A detailed history of each OU can be reviewed in the Sitewide RI (CABRERA 2011b).

The BRA (CABRERA 2011c) results are presented later in Section 2.4 for the scenarios considered for soil exposure at the Site. The results show that the maximum radiological dose and/or risk for various RME scenarios exceeded their corresponding acceptable New Jersey dose limit of 15 millirem per year (mrem/yr) and/or CERCLA acceptable risk range (10^{-6} to 10^{-4}) at OU 1, consisting of AOCs 1 and 2, and AOC 6. Therefore, remedial actions are evaluated for these two areas (OU 1 and AOC 6) in this FS. The estimated radiological dose and risks associated with soil exposure in the remaining AOCs were within their corresponding acceptable dose and risk ranges; therefore, no remedial action is required at those locations. The locations for which remedial action are being considered (OU 1 and AOC 6) are described in the following paragraphs.

2.1.1 OU 1 - AOC 1, Former Building 845 Area

AOC 1 encompasses the site of the Former Building 845, which housed Buildings 101 and 102. Work was conducted here between 1943 and 1947 and included recovering uranium lost as scrap and dross from manufacturing activities at other MED facilities (the Recovery Process). Residual processing wastes were discharged into a wooden trough located east of the building. The wooden trough is still in existence, and currently collects storm water that discharges to the CDD. The CDD historically carried the process material to the east corner of Historical Lagoon A. Figure 2-1 shows the location of OU 1 (AOCs 1 and 2) in relation to the CDD (AOC 3).

The equipment from Building 845 was removed and either buried in the East Burial Area (AOC 6) or sent to the Niagara Falls Storage Site at the Former Lake Ontario Ordnance Works in Buffalo, NY. In 1948, the building was surveyed and decontaminated by the AEC, then released to DuPont. Subsequent building surveys occurred in 1977 by ORNL and 1983 by BNI. The building was eventually demolished in September 1999, after several surveys and decontamination efforts between 1948 and 1983. Debris and rubble were cleared for onsite disposal in the Chambers Works Sanitary Landfill, while structural steel was disposed of at a RCRA Subtitle C Landfill operated by Waste Control Specialists in Texas.

2.1.2 OU 1, AOC 2, F Corral

AOC 2 contains the F Parking Corral, located immediately west of Former Building 845. This parking lot is the former location of Building 708, which was used for the production of uranium metal. In 1945, a part of Building 708 was demolished and removed from the site. The remainder of the building was decontaminated and demolished in 1953 with building remnants and approximately 1,000 cubic yards (yd^3) of underlying soil disposed of in the Historical Lagoon A area.

2.1.3 OU 3, AOC 6, East Area

Historical reports indicated that AOC 6, originally swampland, had been backfilled with chemical refuse and used as a landfill prior to MED use. After MED activities began at Chambers Works, a 30-building complex was constructed on 21 acres and used for production of fluorinated solvents and fluorinated lubricants under contract to MED. Uranium processing did not take place in the East Area. The East Area includes the East Burial Area, which also received demolition debris and discarded equipment from MED projects. This burial area was located adjacent to, and north of, East Road.

Seven suspected disposal areas were investigated as areas of interest (AOIs) in AOC 6. Based upon results of the RI investigations, two AOIs were retained for further evaluation; AOI 4 encompasses the East Road Area, while AOI 6 is known as the Fire Fighter Training Area.

DuPont purchased the buildings of the East Area from the U.S. government in 1949. Some buildings in this area were dismantled while others were converted for industrial use. DuPont used the East Burial Area for disposal of DuPont's radioactive waste on three occasions: 1964, 1969, and 1970. DuPont was permitted by the State of New Jersey for the disposal of these wastes.

2.1.4 Environmental Setting

2.1.4.1 Regional Meteorology

Based on climatological data collected from National Weather Service Station at New Castle County Airport, Wilmington, Delaware (DE) for the period 1948 through 2000, the mean temperature in the site was 54 degrees Fahrenheit ($^{\circ}$F), ranging from a minimum monthly mean temperature of 23° F in January to a maximum monthly mean temperature of 86° F in July. The average annual precipitation for this period was 41.5 inches, with a monthly average precipitation of 3.5 inches. The highest monthly mean precipitation was in July with 4.3 inches and the lowest monthly mean precipitation was in October with 2.9 inches. The prevailing winds come from the northwest at 8 to 14 miles per hour (mph) during the spring, fall, and winter, and from the south at 9 to 10 mph during the summer.

2.1.4.2 Land Use

DuPont Chambers Works is located in the village of Deepwater. Deepwater is bordered by the town of Carneys Point and the borough of Penns Grove to the north and the town of Pennsville to the south. DuPont Chambers Works lies within both Carneys Point and Pennsville Townships. The land use directly adjacent to DuPont Chambers Works is a mix of recreational (forested/wetlands areas) and light industrial. Figure 2-2 depicts the general land use in the surrounding areas. The Chambers Works is currently zoned as industrial and the reasonable future land use is expected to remain industrial. Given current ownership and zoning designation the most likely and reasonable future use of this property is industrial or commercial.

The surrounding area is predominantly rural, with approximately 43% of the county's land used for agricultural purposes. In addition, 25% of the land is dedicated to environmental uses such as: tidal and freshwater wetlands, marshland, lakes, ponds, flyways, and natural habitats. Developed land areas make up only 13% of total land use, and accommodate all types of uses including residential, commercial, and industrial. The Salem River Watershed (117 square miles) and the Delaware River Estuary (23 square miles) cover one-third of Salem County (CABRERA 2011b).

2.1.4.3 Demographics

Among all 21 New Jersey counties Salem County ranks 10th in total area, but is the least populated. According to the 2000 US Census, the population of Salem County was 64,285; Carneys Point was 7,684; Penns Grove was 4,886; and Pennsville was 13,194. Carneys Point and Penns Grove experienced a loss in population of about 6% from 1990 to 2000. Salem County experienced a 1.5% loss in population (1,009 persons). Salem County was the only county in New Jersey to lose population from 1990 to 2000. Historically, the County has had a slow growth rate for the past 50 years.

The county median household income in 2006 was estimated to be $58,164. The median household income for Pennsville was $47,250, while Penns Grove was $26,227 with a percent change of -4.2% and -5.7% adjusted for inflation from 1989, respectively. NJ as a state had a median household income of $55,146. The median age in Salem County was 38, which is higher than the NJ median of 36.7 (U.S. Census Bureau 2006).

The racial makeup of Salem County is predominantly white (81%) with African American and Hispanic populations averaging 15% and 4%, respectively. The Salem County Labor Force estimates for 2006 show a labor force of approximately 35,000 persons with a 7.4% unemployment rate (U.S. Census Bureau 2006). The Chambers Works labor population has significantly decreased in recent years. Presently, there are approximately 900 DuPont employees and 200 subcontractor personnel working onsite with more than 60 visitors coming to the site each day to conduct a variety of business-related activities.

2.1.4.4 Topography, Drainage, and Surface Water

Topography

The DuPont Chambers Works complex is located within the Lowland Subprovince of the Atlantic Coastal Plain physiographic province (Barksdale et al., 1958). The surrounding topography is gently rolling, with elevations from 0 to 85 ft (top of landfill elevation) North American Vertical Datum of 1988 (NAVD 88). Elevations at the complex are typically approximately 10 ft above NAVD 88.

Drainage

A major drainage source at the DuPont Chambers Works FUSRAP Site is the CDD. The water flow direction of the CDD is eastward toward the B basin (discussed below). The water depth in the ditch averages 1 to 2 feet. The CDD exhibits perennial water flow.

Historically, the CDD connected Lagoon A with MED operations areas. Lagoon A was composed of three settling basins – A, B, and C. Basins A and C are no longer in use and have undergone RCRA closure. Basin A has been stabilized *in situ* and Basin C has been drained and capped. The lower half of Basin B, approximately 8 acres, is currently being used for storm-water collection. Water in Settling Basin B is treated onsite and then discharged to the Delaware River via permitted Outfall D001. Basin B is isolated by the outfall structure that prevents aquatic communities in the river from migrating into the basin. It is also a part of SWMUs 14 and 15 and has undergone remediation and received clean closure approval. However, the basin is located outside of the MED impacted area.

Surface Water Features

The Delaware River is tidal and brackish at Deepwater and is not a potable water source in the area of the Chambers Works; however, the river is a major supplier of potable water to communities north of the area. At the Reedy Point DE tide gage (station ID 8551910) located across the Delaware from Chambers Works, the yearly mean tide range is 5.34 ft and the mean tide level is -0.12 ft NAVD 88. Mean high tide is 2.87 ft NAVD 88 while mean low tide is -2.97 ft NAVD 88.

Chloride concentrations in the Delaware River at Deepwater range from 10 milligrams per liter (mg/L) during spring to 3,200 mg/L during some periods in late summer. Flow ranges from

3,000 to 100,000 cubic feet per second (cfs), averaging 11,000 cfs (DERS 1992a). The DuPont site is at river mile 70 from the mouth of the Delaware Bay. At this position, it lies within the zone of yearly fluctuation of the "salt front," which is the tongue of saline water that moves upriver from the Delaware Bay. The "salt front" is the 250 mg/L chloride concentration contour (DRBC 2004).

2.1.4.5 Regional and Local Geology and Hydrogeology

Geology

Native site soils are of alluvial and palustrine (marsh) origin, but soils have been substantially modified by landfilling and construction activities. The land along the shoreline has most likely been accreted as point-bar deposits from the Delaware River, or possibly, from over-bank deposition during periodic flooding, which has resulted in the formation of a natural levee. Topographic maps indicate that these sediments formed a strip of land approximately 200 yards wide with an average elevation of five feet msl along the river's edge. Behind these shoreline deposits, which consist of sands and silty sands, there once existed a tidal marsh consisting of silty clays, with an elevation near sea level. The Chambers Works property was gradually expanded by filling in the marsh areas. Generally, up to a distance of 200 yards from the river's edge, the soils at sea-level are the naturally occurring marsh deposits, while the soils above sea level are fill material (DERS 1993).

Hydrogeology

As detailed in the Sitewide RI (CABRERA 2011b) the sedimentary deposits beneath the Chambers Works can be divided into five major sequences: (1) the A and B Aquifers, and the A-B and B-C Aquitards; (2) the C Aquifer; (3) the C-D Aquitard; (4) the D Aquifer; and (5) the underlying D-E Aquitard through the F Aquifer unit. This nomenclature was devised by DuPont, and for clarity, was adopted for use in the FUSRAP Sitewide RI.

The A Aquifer is the uppermost water-bearing zone at the Chambers Works facility. The B Aquifer consists of sands that are interpreted to be Delaware River alluvium. The Pleistocene sand and gravel deposits that comprise the A and B Aquifers are not widely developed as a groundwater source in Salem County, although yields of up to 1,500 gallons per minute (gpm) have been reported. The deposits, which are hydraulically connected to the Delaware River, form a significant source of recharge to the underlying Potomac-Group Aquifer. The A-B

Aquitard is discontinuous and thins to zero to the east, as well as in areas where stream channels were once present.

The second sedimentary sequence is the C Aquifer, which is composed mainly of Pleistocene-age coarse-grained sands and gravels. The third sequence is the C-D Aquitard, which is composed of clays and silts of estuarine origin. The fourth sequence is the D Aquifer, consisting of coarse-grained sands and gravels. The D unit is valley-fill sediment that is incised in the underlying Potomac Group. The underlying D-E Aquitard through the F Aquifer units make up the lowest sedimentary sequence and are the Cretaceous-Age sediments of the Potomac Group. It should be noted that although the surficial aquifers are not an important source of drinking water, the Potomac aquifer is widely used as a drinking water source in southern New Jersey and Delaware.

As mentioned in Section 1.3.4, DuPont has operated and continues to operate the IWS (an extensive sitewide pump and treat system) in order to control off-site migration of chemical contaminants in groundwater (predominantly in the C and D Aquifers) since 1970, as part of an on-going RCRA corrective action program. The IWS consists of six wells and a stand-by well and constitutes over 90% of the groundwater extraction at Chambers Works in the upper four aquifers. Average monthly pumping from the interceptor wells over the last two years has ranged from 1,100 to 2,000 gpm (1.5 to 2.8 million gallons per day). It has been reported by DuPont that all the water that is pumped from the extraction/remediation wells is treated at the onsite wastewater treatment plant (WWTP) prior to discharging the water in accordance with its NJPDES DGW permit. The WWTP is not currently permitted to accept radionuclides.

2.2 Nature and Extent of FUSRAP Contamination

The RI was conducted to determine the nature and extent of eligible FUSRAP contamination at the Site. Analytical results for radiological and chemical characterization surveys are provided in detail within the Final Sitewide RI Report and appendices (CABRERA 2011b).

2.2.1 Identification of Constituents of Potential Concern (COPCs)

COPCs were identified in the RI and the BRA. As presented in the Sitewide RI, USACE is mandated to investigate and remediate only those contaminants that are eligible under FUSRAP authority and qualify for FUSRAP funding. The types of hazardous substances considered within the scope of FUSRAP cleanup activities at the DuPont Chambers Works FUSRAP site include the following:

- Radioactive contamination (primarily uranium and thorium and associated radionuclides) resulting from the Nation's early atomic energy program activities, i.e., related to MED or AEC activities, including hazardous substances associated with these activities (e.g., chemical separation, purification); and
- Other radioactive contamination or hazardous substances that are mixed or commingled with contamination from the early atomic energy program activities (USACE 2003, paragraph 6(b)(2)(b)). These contaminants are not a result of MED or early AEC activities and therefore not FUSRAP-related contaminants. However, by necessity, the commingled contaminants are to be cleaned up along with the FUSRAP contamination.

Residual radioactive contamination from MED uranium processing and any commingled hazardous substances (likely from DuPont's chemical manufacturing operations) will be addressed during the FUSRAP remediation.

The COPCs were determined by evaluating MED processes conducted at the Site and reviewing historical Site records to identify the specific compounds and feedstock materials used at Chambers Works. Additionally, general industry references that describe similar processes at other facilities were consulted to generate a list of substances and possible Site contaminants.

The five COPCs that were identified as eligible contaminants for FUSRAP investigation at the DuPont Chambers Works FUSRAP site are U-234, U-235, U-238, Th-230, and Ra-226. No chemical compounds (metals, SVOCs, VOCs) were determined to be FUSRAP eligible contaminants. Further details regarding the identification of eligible contaminants are discussed in the *Memorandum, USACE Determination of Eligible Contaminants for FUSRAP Investigation, DuPont Chambers Works FUSRAP Site, Deepwater, NJ* (CABRERA 2011a).

Soil and groundwater were sampled for other chemical constituents that may have been used or produced under MED contracts or for health and safety reasons. Target Analyte List (TAL) metals and Target Compound List (TCL) volatile and semi-volatile organic data were obtained to assist in the characterization of chemical risks as part of the draft BRA (CABRERA 2011c). Metals analysis for groundwater also provided useful information for the interpretation of geochemical conditions.

2.2.2 Soils

This summary of the nature and extent of radiologically-contaminated soil is based on the OU 1, OU 2, and OU 3 results as presented in Sections 4, 5, and 6 of the Sitewide RI report (CABRERA 2011b). During RI activities, the ISV of 14 pCi/g for total uranium was used to define the limits of possible MED-related soil contamination.

2.2.2.1 OU 1, AOC 1, Building 845 Area

The horizontal boundaries of uranium contamination for AOC 1 encompass the Uranium Oxide Area (including the area between the wooden trough and the east side of the building); potential residual contamination areas within and adjacent to the wooden trough and the CDD; and areas within the building footprint and to the west of the building. The vertical extent of contamination has been bounded by the identification of discrete depth intervals of contamination up to 4.5 ft bgs within the building footprint and the Uranium Oxide Area, and at the 5.5 ft bgs interval in the southwestern portion of the AOC. The soil contamination above the ISV has been estimated to encompass 1.1 acres of the 3.2 acres contained within AOC 1. Soil volumes of this area have been estimated at approximately 5,300 yd^3. Figure 2-3 shows the highest total uranium concentrations encountered at each sample location within AOC 1. Figure 2-4 provides an overall view of OU 1 illustrating the stratigraphy and MED-related total uranium contamination in vertical cross section across AOCs 1 and 2. The AOC 1 portion of the vertical cross section is shown separately in Figure 2-5.

With the exception of one surface soil sample from test pit (1TP018) reported to contain 27,600 pCi/g, the maximum total uranium concentration in soil collected from the Uranium Oxide Area was 677.4 pCi/g at 1.5 ft bgs. Potential soil contamination above the ISV in the northern portion of AOC 1 was located at a depth of 1.5 ft bgs and ranged from 85 to 127 pCi/g. In contrast, the deepest soil sample exceeding the ISV beneath former Building 845 was encountered at 4.5 ft bgs (579 pCi/g). In the southwestern portion of AOC 1 in the area of the CDD, contaminated soil above the ISV was reported to a depth of 2 ft bgs (149 pCi/g).

In general elevated Ra-226 and Th-230 concentrations were identified at locations within or in close proximity to uranium source areas. Ra-226 results in soil range from 0.4 to 2.3 pCi/g. Th-230 results in soil range from 0.4 pCi/g to 64 pCi/g.

2.2.2.2 OU 1, AOC 2, F Corral

The horizontal boundaries of MED-related uranium for the F Parking Corral Area encompass the potential source area of the former Building 708 and potential residual contamination areas within and adjacent to the northern drainage ditch and the northern portion of the CDD that traverses AOCs 1 and 2. The vertical extent of potential MED uranium was reported to extend to a depth of 11 ft bgs, with highest activity observed in the 2 to 4 ft depth interval. Soil contamination above the ISV has been estimated to encompass 1.7 of the 8.5 acres within AOC 2 with estimated soil volumes of approximately 8,500 yd^{3}.

For borings associated with Building 708, those located outside the building footprint exhibit soils with uranium concentrations above the ISV at depths of less than 3.5 ft bgs, with a maximum concentration of 800 pCi/g in the 1.5 ft bgs interval. Within the building footprint, potentially contaminated soils were detected at depths of up to 11 ft bgs, with the highest concentrations detected at 4 ft bgs (4,832 to 16,584 pCi/g). Between the 4.5 to 7 ft bgs interval, total uranium ranged from 23 to 2,180 pCi/g. A soil sample with a result of 1,050 pCi/g was reported at the 11 ft depth. Only two of the borings within the building footprint showed uranium concentrations above the ISV at discrete intervals; all other borings exhibited contaminated soils across all depth intervals. Depth of contaminated soil in the northeast portion of the AOC near the CDD was limited to the first 0.5 to 1.5 ft bgs (132 to 385 pCi/g). The soil sample result of 385 pCi/g was located at 2BH042. Figure 2-6 depicts the extent of MED-related total uranium contamination at AOC 2 by showing the highest uranium concentrations encountered at each sample location. Figure 2-7 provides a vertical cross section view of MED uranium contamination across the area (AOC 2). The reader is also referred back to Figure 2-4 for an overall view of OU 1 in vertical cross section.

Elevated Ra-226 and Th-230 concentrations were identified at locations within or in close proximity to uranium source areas in AOC 2. Ra-226 results in soil range from 0.37 to 2.87 pCi/g. Th-230 results in soil range from 0.19 pCi/g to 15 pCi/g.

2.2.2.3 OU 3– AOC 6, East Area

The uranium source area has been identified as the East Burial Area, currently located under and to the immediate north of East Road. MED scrap and waste were buried there with DuPont radioactive waste. The DuPont wastes included TD-nickel [thoriated nickel] and carbon-14 contained in polymer, neither of which types of waste were used by MED at Chambers Works.

Soils in AOI 4 (East Area) were contaminated above the ISV at shallow depths, less than 4 ft bgs. Most contaminated soils were detected at discrete intervals within each boring; only two borings were contaminated between the surface and 2 ft bgs depth. Total uranium concentrations that exceeded the ISV of 14 pCi/g, ranged from 15.7 pCi/g to 3,910 pCi/g (6-SB-04). The area of soils impacted above the ISV in AOC 6-AOI 4 is approximately 4800 square feet (ft^2) (0.1 acres) with estimated soil volumes of approximately 950 yd^3.

Elevated Ra-226 and Th-230 concentrations were identified at locations where elevated uranium concentrations were found. Ra-226 results in soil range from 0.3 to 14.3 pCi/g; Th-230 results in a soil range from 0.17 to 1.0 pCi/g.

Figures 2-8 and 2-9 depict the horizontal and vertical extent of MED-related total uranium contamination in AOC 6 at the DuPont Chambers Works FUSRAP Site. Figure 2-10 shows a more detailed view of the cross section under East Road.

2.2.3 Groundwater

This summary of the nature and extent of radiologically-contaminated groundwater is based on Sections 4, 5, and 6 of the RI report (CABRERA 2011b). As described in the RI, the extent of groundwater contamination was determined by comparison of total uranium concentrations to the USEPA Maximum Contaminant Level (MCL) of 30 micrograms per liter (μg/L). In addition to the total uranium results presented in this subsection, the groundwater was also analyzed for gross alpha, gross beta, Radium-226/radium-228, and thorium isotopes. The results of gross alpha and combined Ra-226/Ra-228 concentrations were compared to the USEPA MCL of 15 pCi/L and 5 pCi/L, respectively. Significant thorium contamination was not identified in soil and it also generally has a much greater distribution coefficient than uranium, so it would not be expected in groundwater. In addition, no man-made beta-emitting isotopes were identified as FUSRAP constituents in soil, so again, a comparison to a beta MCL was not considered necessary.

2.2.3.1 OU 1, AOCs 1 and 2

Aqueous-phase uranium was encountered in both the A and B Aquifers within OU 1. In the AOC 1 area of the A Aquifer, elevated total uranium is present in wells 1-MW-08A, 1-MW-10A, and 1-MW-18A, with average concentrations ranging from 109 to 26,317 µg/L. These wells are located within or adjacent to identified sources of uranium contamination (i.e., footprint of Building 845) or isolated areas of contaminated soil.

In the AOC 2 area of the A Aquifer, the area of aqueous uranium impact is centered at wells 2-MW-02A, 2-MW-12A and 2-MW-15A (Dissolved Uranium Area). Average total uranium values in these wells ranged from 168 to 14,027 µg/L. The remaining wells in both AOCs 1 and 2 were, in general, less than 5.0 µg/L for total uranium. The horizontal extent of uranium impact to groundwater in the A Aquifer remains defined by the extent of uranium impact in soil, and is presented in Figure 2-10 for OU 1 (AOCs 1 and 2). The horizontal extent of impacted groundwater is approximately 0.5 acres as compared to the 5.85 acres encompassing OU 1.

In the B Aquifer, uranium concentrations above the 30 µg/L MCL were encountered only in wells MW-03 and MW-05. These two wells are located in the Dissolved Uranium Area, and uranium concentrations averaged 29,560 and 167 µg/L, respectively. There is no evidence that uranium has been mobilized and transported any significant lateral distance within the B Aquifer. The extent of uranium impact to groundwater within the B Aquifer is limited (0.2 acres) and is largely under the footprint of the former Building 708. Figure 2-12 presents the horizontal extent of uranium impact to groundwater in the B Aquifer in OU 1 (AOCs 1 and 2). Since groundwater flow is in a northeasterly direction, the down gradient wells, 2MW01B and 2MW23B provide horizontal control in the area. The groundwater flow direction limits the occurrence of dissolved uranium in the area south of these wells (upgradient). In addition, no evidence of vertical migration was observed from B Aquifer. Vertical control is provided by the C Aquifer well (2-MW-25C), which has consistently shown no levels of uranium above the MCL. The maximum total uranium concentration at that well was 1.42 µg/L.

Gross alpha results above the USEPA MCL of 15 pCi/L were reported for both the A and B Aquifers. The maximum average concentrations were 13,739 pCi/L in the A Aquifer (1MW08A) and 11,743 pCi/L in the B Aquifer (2MW03B). The maximum gross beta concentrations were reported in the same locations. These exceedances are attributed to the elevated uranium isotopes present in the groundwater, resulting from elevated uranium concentrations in soil (source area locations). No average Radium-226/radium-228 concentration exceeded the MCL for combined Ra-226/Ra-228 of 5 pCi/L. Th-230 detections were less than 1.0 pCi/L in the A Aquifer; while the maximum concentration detected in the B Aquifer was 3.93 pCi/L.

Investigations of OU 1 groundwater have also identified the presence of benzene, toluene, ethylbenzene, and xylene (BTEX) in excess of their representative MCLs, as well as the presence of a light non-aqueous phase liquid (LNAPL). The LNAPL was determined to contain concentrations of uranium at background levels. The LNAPL appears to be coal tar or coal tar distillate with a mixture of other compounds. Neither the coal tar components nor BTEX are DuPont FUSRAP COPCs.

2.2.3.2 OU 3, AOCs 4 and 6

Uranium concentrations exceeded the MCL in one well in AOC 4 (Historical Lagoon Area), Area of Interest 1 (AOI 1) (CABRERA 2011b). In the Sitewide RI, one A Aquifer well, I17-M01A, showed an average of 145 µg/L total uranium over four quarters of monitoring. This well is located within DuPont's closed waste cell, SWMU 5 and is approximately 280 ft from the Delaware River. DuPont installed a slurry wall in the area of SWMU 5 to limit contaminant migration from the closed unit towards the river. Figure 2-13 shows AOI 1, existing well locations, slurry wall, and the area's proximity to the Delaware River. Although the groundwater flow direction in the A Aquifer is toward the river, the RI monitoring results consistently show that the uranium in groundwater is not migrating toward the river.

In AOC 6, well 6-MW-01B exhibited total uranium concentrations exceeding the MCL of 30 µg/L, with an average uranium concentration of 267 µg/L. The remaining wells in AOC 6 had uranium concentrations below the MCL. Well 6-MW-01B is located downgradient of an area of contaminated soils. Sampling methods have determined that the uranium is in the aqueous phase and not sorbed to mobile particles. Vertical delineation of potential groundwater contamination has been bounded by well MW-6-07B, which is located adjacent to 6-MW-01B and is completed at the base of the B Aquifer (50 ft bgs). In contrast, 6-MW-01B is completed to a depth of 17 ft bgs. The extent of contaminated groundwater in AOC 6 is shown in Figure 2-14.

The MCL for gross alpha was consistently exceeded in well 6-MW-01B (119 pCi/L). No Radium-226 or radium 228 concentrations exceeded the MCL for combined Radium-226/228 of 5 pCi/L and Thorium-230 was detected in one well at a concentration of less than 1.0 pCi/L.

2.2.4 Surface Water and Sediment

Surface water and sediment samples were analyzed from AOC 6. One surface water sample obtained from AOC 6 exceeded the MCL with a uranium concentration of 265 µg/L. Concentrations of total uranium values for the remaining samples were reported at less than 3.0 µg/L. One sediment sample with a reported result of 18.4 pCi/g also exceeded the ISV in AOC 6. These two sample locations are shown on Figure 2-15. MED-related uranium occurs near ground surface on the northern bank of the ditch in the vicinity where the sample was collected. As the sample was collected during a storm event, it was most likely turbid and contained surface soil particulates from the bank. However, sediment sampling results around that sample show that contaminants in the ditch have not migrated.

2.3 Contaminant Fate and Transport

The fate and transport of uranium compounds was assessed to identify the environmental media that could be potentially impacted due to contaminant migration. The primary release mechanisms or migration routes identified were:

- leaching of surface or subsurface source materials into vadose zone soils and/or shallow groundwater;
- contaminant particles dissolving into groundwater;
- contaminants migrating from the shallower A Aquifer into the deeper B Aquifer;
- contaminants moving from groundwater to surface water and sediments;
- surface water and sediments migrating downstream; and
- stormwater runoff carrying contaminants from source materials to surface soils and drainage ditches.

Potential transport mechanisms include groundwater, surface water, sediment, air, and direct contact. A generalized Conceptual Site Model (CSM) was developed for the Site to describe the complete exposure pathways based on release mechanisms and migration pathways. The generalized CSM as presented in the Sitewide RI is shown in Figure 2-16. A specific CSM for each OU and/or AOC was developed for use in the BRA.

Advection and dispersion are the primary potential transport mechanisms for dissolved uranium in onsite soil. Dissolved contaminants could potentially travel along pathways formed by soil pores between individual grains of sand, silt, and gravel. The possibility for colloid-facilitated transport was tested by comparing filtered and unfiltered aliquots of groundwater during low-flow groundwater sampling. The sampling and analytical results indicated that heavy-metal colloids were not present.

Processes that tend to attenuate the dispersion of metals include retardation resulting from their sorption to aquifer solids and precipitation. Sorption reactions are more likely to occur on clay and silt particles, with very little sorption to sand. In OU 1, the subsurface soil profile includes the presence of a silty clay layer (referred to as the AB Aquitard) located under most of AOC 1 and AOC 2. It would be expected that sorption may be a factor in retarding the migration of contaminants where these clay layers are present.

Uranium occurs in six oxidation states ranging from U(1+) to U(6+), with tetravalent uranium [U(4+)] and hexavalent uranium [U(6+)] being the most common oxidation states of uranium in nature. The tetravalent form ordinarily occurs in reducing environments while the hexavalent form is prevalent in oxidizing environments (USEPA 1999). Both low solubility uranium oxide compounds, such as pitchblende (black oxide, U_3O_8), and uraninite (brown oxide, UO_2), and the more soluble U(+6) compounds, such as metastudite and uranophane (a calcium-uranyl silicate), have been detected at OU 1. Metastudite and uranophane were encountered in the "Yellow Oxide Area," which is located in the area of the former loading dock (Building 845) (CABRERA 2011b).

The aqueous solubility of a compound is an important transport parameter in groundwater because it determines the concentration of the dissolved phase. The oxidation reduction (redox) potential of the subsurface is the primary controlling factor determining uranium solubility. In general, the higher valence state uranium compounds are more likely to be found in oxidizing environments. These soluble uranium compounds are less likely to partition, or sorb, onto soil or sediment particles, and will therefore be more mobile. Conversely, low-solubility uranium compounds, like uraninite, are more likely to be found in reducing environments, and therefore less mobile in the environment. A reducing environment is characterized by little or no free oxygen in the system. Microbial activity or specific contaminants in the environment may lead to reducing conditions by using up the available dissolved oxygen resulting in alteration of the soil chemistry.

Uranium mobility has been evaluated in Section 7.0 of the Sitewide RI. In general, geochemical conditions in OU 1 (AOCs 1 and 2) indicate groundwater with neutral pH, high sulfate concentrations, and oxidizing to slightly reducing conditions. In contrast, OU 3 conditions indicate a strongly reducing environment, which would not promote colloid formation and subsequent transport.

2.4 Summary of Baseline Risk Assessment Results

The BRA (CABRERA 2011c), including a Human Health Risk Assessment (HHRA) and a Screening Level Ecological Risk Assessment (SLERA), was performed to determine the current and potential future risks to human and ecological receptors from exposure to both radiological and non-radioactive chemicals present at the DuPont Chambers Works FUSRAP Site. The results of the BRA were used to support the identification of specific AOCs requiring remedial action and evaluation in this FS.

For evaluation in the BRA, the six FUSRAP AOCs were grouped into five separate exposure units (EUs) based on physical location within the Site and receptor exposure patterns. EUs are defined as geographic areas within which receptors may reasonably come in contact with COPCs when routinely present at the site and over a specified period of time. EUs were identified to correspond with the FUSRAP OU designations. Figure 2-17 shows the location of the five EUs for the Site and the corresponding AOC and OU designations. EU 1 consists of the two adjacent areas, AOC 1 and AOC 2, which are designated as OU 1. AOC 3 and AOC 5, which make up OU 2, were designated as EU 2A and EU 2B, respectively. For OU 3, AOC 4 and AOC 6, were designated as EU 3A and EU 3B, respectively.

2.4.1 Human Health Risk Assessment Summary

The HHRA was performed for various COPCs present at the Site by using guidelines established by the USEPA and the USACE. Four types of screening were performed to identify COPCs at the Site, including: data reduction, weight of evidence screen, background screen, and risk-based screening. Screening levels from NJDEP and USEPA Regions VI and IX guidance documents were used to screen chemicals for inclusion in the HHRA. No screening levels were available from these sources for radionuclides in soil; therefore, none were screened out of the HHRA based on risk-based criteria.

Four RME receptors were evaluated in the BRA, including: adult industrial workers, adult construction workers, maintenance workers, and utility workers. Among them, the industrial worker scenario was considered as the potential future RME scenario for the Site. The intent of the RME scenario was to focus the assessment on a conservative exposure that represents the maximum exposure reasonably expected to occur (USEPA 1989b). Radiological dose and risk assessments were also performed for a residential receptor for comparison purposes and to determine the necessity for implementing land use controls and performing five year reviews for the Site.

The CSM was utilized to determine complete exposure pathways for each RME scenario, based upon sources of contamination, contaminated media, and the pathways of migration. Only soil media was evaluated as a source of contamination for the BRA. The CSM indicated that inhalation of volatiles from groundwater was a complete exposure pathway for the utility and construction worker under the industrial scenario. Since volatile organic constituents are not FUSRAP-related, and none of the FUSRAP-related radionuclides are volatile, the groundwater exposure pathway was considered incomplete for FUSRAP-related radionuclides. The groundwater ingestion pathway was also eliminated from evaluation as no receptors are currently utilizing the groundwater beneath the Site as a potable water source; and it is not likely that groundwater will be utilized by the most likely future receptors (industrial workers). However, the groundwater ingestion and homegrown garden vegetable ingestion pathways were evaluated for the hypothetical future residential receptor for comparison purposes. Groundwater samples from the most reasonable exposure pathway (B Aquifer) were evaluated for the residential receptor in the BRA for comparison with the industrial receptor results.

In order to quantify each receptor's exposure, an exposure point concentration (EPC) was calculated for each COPC for each EU. An EPC is an upper-bound estimation of the chemical concentration a receptor is likely to come in contact with over the duration of exposure. EPCs for soil were determined by calculating the upper confidence level (UCL) of the mean chemical concentration. The UCL was used as the EPC, except in cases where the maximum detected chemical concentration was less than the EPC, in which case the maximum detected value was used. An adjusted EPC was calculated for each COPC during the radiological dose assessment by subtracting the average background concentration from the lower of its maximum detected concentration and the UCL concentration.

The residual radioactivity computer code (RESRAD) Version 6.3 was used to perform the human health dose and risk assessment for radiological COPCs (ANL 2005). The RESRAD only calculates dose and risk from groundwater, surface water, and/or sediment as a result of transport from a defined contamination source (e.g., soils). It is not capable of handling additional dose/risk contributions from existing groundwater, surface water or sediment contamination. Therefore, USEPA's Standard Risk Assessment Guidance for Superfund (RAGS) equations were utilized to perform radiological dose and risk assessment for exposure pathways involving those media (groundwater, surface water, and sediment) (USEPA 1989a).

USEPA's standard equations were utilized to quantify intake for each chemical COPC for each receptor. Exposure to chemicals via indoor air vapor migrating upward from groundwater was evaluated for residential scenarios using the Johnson & Ettinger vapor transport model (Johnson and Ettinger 1991).

The results of intake calculations were combined with chemical toxicity information for each COPC to characterize carcinogenic and noncarcinogenic risks for each of the RME receptors. With the exception of uranium, the toxicity criteria for radionuclides were limited to carcinogenic risk; uranium is evaluated as both a carcinogen and noncarcinogen. Doses and risks were calculated for each receptor at each EU. Total Site risk refers to the risks associated with all radiological and non-radiological COPCs; however, risks from these two classes of COPCs were not summed.

For carcinogens, incremental lifetime cancer risks (ILCR) were calculated. The resulting ILCRs are a probability of developing cancer and are compared to the risk range specified in the NCP of 10^{-6} to 10^{-4} (another way of saying this is one in one million to one in 10,000) (USEPA 1990). ILCRs less than 10^{-6} are considered acceptable while ILCRs greater than 10^{-4} are considered unacceptable risks. Risks between 10^{-6} and 10^{-4} are generally referred to as the "acceptable risk range".

A hazard index (HI) was calculated for all noncarcinogens for each receptor in each EU. An HI greater than 1 has been defined as the level of concern for potential adverse noncarcinogenic health effects (USEPA 1989a). In addition, RESRAD calculated the radiological dose for each radionuclide in each EU under each receptor scenario. Based on the State of New Jersey's *Soil Remediation Standards for Radioactive Materials* (NJAC 7:28-12), a dose limit criterion of 15 mrem/yr was identified as the acceptable dose criterion for the Site. The results of radiological dose assessments were compared to the State of New Jersey dose criterion (15 mrem/yr). Any resulting dose less than 15 mrem/yr is considered acceptable, while a dose greater than 15 mrem/yr is considered unacceptable.

Table 2-1 presents the summary of the results of the radiological dose and risk assessments for each receptor scenario at each EU. Highlighted values indicate the dose and risk assessment results that exceed the acceptable dose and risk criteria.

Table 2-1: Results of Radiological Dose and Risk Assessment

Receptor Scenarios	**Category**	**EU 1 (OU 1)**	**EU 2A (OU 2-AOC 3)**	**EU 2B (OU 2- AOC 5)**	**EU 3A (OU 3-AOC 4)**	**EU 3B (OU 3-AOC6)**
Industrial Worker	Dose (mrem/yr)	6.2	1	0.7	0.02	**18.5**
	Risk	1E-04	3E-05	3E-06	3E-06	**4E-04**
Construction Worker	Dose (mrem/yr)	**69.3**	1.8	1.7	7.6	**27.1**
	Risk	4E-05	5E-06	3E-06	8E-06	1E-05
Utility Worker	Dose (mrem/yr)	**25**	0.6	0.6	3	10
	Risk	1E-05	2E-06	9E-07	3E-06	5E-06
Maintenance Worker	Dose (mrem/yr)	2.5	0.1	0.1	0.15	1.1
	Risk	4E-05	7E-06	6E-07	1E-05	2E-05
Residential Receptor	Dose (mrem/yr)	**1547**	2.6	2.4	**16.2**	**75.7**
	Risk	**1E-02**	**2E-04**	2E-05	**5E-04**	**1E-03**

NOTES:

1. Bolded values exceed the acceptable dose and risk criteria for soil in each EU.
2. Residential receptor was evaluated only for comparison purposes using groundwater as a drinking water source; however, this scenario is highly unlikely because of projected future land use and groundwater conditions in the area of Chambers Works.

During the risk and dose assessment, the EPC was determined by assigning equal weight to both systematic and biased samples. Even using this very conservative assumption, the results of the radiological risk assessments for both current and future RME scenarios showed that among all RME receptors, the maximum risk to industrial workers at EU 3B exceeded the CERCLA acceptable target risk range (>1E-4), and for EU 1, the maximum risk was at the upper end of the acceptable risk range. Furthermore, the results of the radiological dose assessments showed that among all RME receptors, the maximum doses for construction workers and utility workers at EU 1, and the maximum doses for industrial workers and construction workers at EU 3B exceeded the dose limit of 15 mrem/yr. Therefore, in concert with the elevated risks (≥1E-4) and doses (>15 mrem/yr) for the industrial, construction and the utility workers, development of RAOs is warranted for EUs 1 and 3B. Remedial action may be required for EUs 1 and 3B.

The results of radiological dose and risk assessments for both current and future RME scenarios showed that the maximum dose and risk did not exceed their corresponding acceptable dose and risk criteria for EU 2A, EU 2B and EU 3A. Therefore, no further action will be required for those EUs. The results of maximum dose and risks for residential receptors show that both the doses and risks exceeded their corresponding dose and risk limit for all EUs except EU 2B. Although presented for comparison purposes only, the residential receptor results provide the USACE with information concerning the necessity for potential institutional controls and five year reviews.

The results of the chemical risk assessment are presented in detail within the Draft Final BRA report (CABRERA 2011c). The risk assessment results for non-radiological contaminants showed that except for EU 3B, the carcinogenic risks to human receptors under various RME scenarios are comparable with respect to radiological contaminants present at the Site. For EU 3B, the carcinogenic risks are either equal to or higher than that for radiological contaminants. For noncancer hazard, the hazard indices exceeded the CERCLA acceptable risk limit of 1 for both construction worker and utility worker at EU 1, EU 3A, and 3B. In addition, the chemical risk assessment identified five chemicals as major risk contributors for the Site: two metals (antimony and nickel), three SVOCs (benzo(a)pyrene, benzo(a)anthracene, and azobenzene), and one PCB congener (Aroclor 1254). Chemically-contaminated environmental media will be remediated in those instances where the non-FUSRAP chemical constituents are co-located with radiological soil contamination.

2.4.2 Screening-Level Ecological Risk Assessment Summary

Information was obtained from the U.S. Fish and Wildlife Service (USFWS) and the New Jersey Office of Natural Land Management on the presence of federally listed endangered and threatened species at or in the vicinity of Chambers Works. According to the USFWS, the federally listed (threatened) sensitive joint-vetch (*Aeschynomene virginica*) plant has been known to exist in the vicinity of the project site (USDI 2007). The plant can occur on accreting point bars and in sparsely vegetated microhabitats of freshwater tidal marsh interiors, such as low swales and areas of muskrat (*Ondatra zibethicus*) eat-out. This species is typically found in areas where plant diversity is high and annual species are prevalent. In addition, USFWS mentioned that there is a known nest site of the peregrine falcon (*Falco peregrinus*) immediately adjacent to the DuPont property (USDI 2007). While the USFWS removed the peregrine falcon from the List of Endangered and Threatened Wildlife and Plants in 1999, removing all protections provided to the species under the Endangered Species Act, the peregrine falcon continues to be protected by the Migratory Bird Treaty Act (40 Stat. 755; 16 U.S.C. 703-7I3), and under New Jersey regulations as a State-listed (endangered) species. The State-listed (endangered) plant, Chickasaw plum (*Prunus angustifulia)*, is also known to occur in the vicinity of the property.

The SLERA was developed to generate a preliminary quantitative estimate of risks posed by chemically contaminated media on and near the vicinity of the Site. Prior to initiating the SLERA, the USEPA Region VI Ecological Exclusion Worksheet and Ecological Assessment Checklist were used to determine whether or not further ecological evaluation was necessary for each EU. The assessment results showed that because of the absence of ecological habitat, no SLERA was required to be performed for EU 1, EU 2B, and EU 3B. Therefore, the scope of the SLERA included only EU 2A and EU 3A. The two types of ecological receptors evaluated in the SLERA were terrestrial and aquatic receptors.

Risk characterization for radionuclides was performed for both terrestrial and aquatic ecological receptors present at EU 2A and EU 3A. During the Level 1 SLERA, the ratio of the maximum detected concentration for each constituent of potential ecological concern (COPEC) to its corresponding biota concentration guideline (BCG) factor was determined. The resulting ratios were summed and compared to unity. The results showed that the sum of the ratios for surface soil present at both EUs are less than 1, indicating that the absorbed doses to both terrestrial and aquatic ecological receptors at both EUs are less than their corresponding acceptable dose limits. Therefore, radionuclide COPECs are not a concern for the Site.

The results of HQs for all non-radiological chemicals for ecological receptors showed that all media-specific COPECs resulted in low ecological risk to terrestrial and aquatic receptors. No further evaluation of ecological risk for the surface soil at EU 2A and EU 3A was recommended because these areas do not provide undisturbed, natural, or vegetated habitat for ecological receptors. In addition, there is low risk relative to uncertainty in risk estimates, low probability of significant ecological effect on local populations, and the lack of unique, rare and critical habitat at the Site. If the decision is made to excavate soils at the Sites to address human health risk, the residual risk to ecological receptors would also be reduced without serious impacts to ecological habitat.

3.0 IDENTIFICATION AND SCREENING OF REMEDIAL ACTION TECHNOLOGIES

This section describes the identification and screening of remedial action technologies for the DuPont Chambers Works FUSRAP Site. Identifying and screening technologies establish a range of suitable remedial action technologies to consider further in the detailed analysis.

3.1 Introduction

The purpose of this identification and screening process is to produce a range of suitable remedial action technologies that can be assembled into remedial alternatives capable of mitigating the existing contamination at the DuPont Chambers Works FUSRAP Site. USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988b) has established a structured process for identifying and screening relevant technologies for Site remediation.

Selection of a response action proceeds in a series of steps designed to reduce the number of potential alternatives to a smaller group of viable alternatives from which a final remedy may be selected. The selection of the Site remedial action alternatives involves:

- Identifying preliminary remedial action objectives (RAOs) specific to the contaminated environmental media at the site (Section 3.2);
- Identifying applicable or relevant and appropriate requirements (ARARs) (Section 3.3);
- Developing remediation goals (RGs) (Section 3.4)
- Identifying general response actions (GRAs) that may be taken to satisfy the RAOs for the site (Section 3.5);
- Identifying volumes or areas of media to which general response actions may be applied (Section 3.6);
- Identifying and screening technologies and process options applicable to GRAs to eliminate those that cannot be implemented technically at the site. (Section 3.7);
- Identifying and evaluating technology process options in terms of effectiveness, implementability, and cost to select a representative process for each technology type retained for consideration (Section 3.8).; and
- Assembling the selected technologies into alternatives representing a range of treatment and containment options, as appropriate (Section 3.9).

3.2 Development of Media-Specific Remedial Action Objectives (RAOs)

Remedial Action Objectives (RAOs) consist of media-specific goals for protecting human health and the environment. These goals take into consideration contaminants and media of interest, exposure pathways, and associated risk to human health or ecological receptors. Potential exposure pathways include:

- Direct contact with soils through ingestion and dermal contact;
- External gamma radiation from the soil. Risks are usually dominated by risks from gamma-emitting radionuclides in surface soils;
- Inhalation of fugitive dust from contaminated soils and radon gas emissions due to the radioactive decay of radium-226 (Ra-226);
- Off-site migration of contamination carried by erosion (e.g., surface-water runoff);
- Uptake by biota (i.e., animals and plants) of contamination; and
- Potential transport from contaminated soils and sediments to surface water or groundwater.

The BRA (CABRERA 2011c) results are presented in Section 2 (Table 2-1) for human RME scenarios due to soil exposure at each EU. The results show that the maximum radiological dose and/or risk for various RME scenarios exceeded their corresponding acceptable NJ dose limit and/or CERCLA risk range at OU 1, consisting of AOCs 1 and 2 (OU 1 ~ EU 1), and AOC 6 (EU 3B). Therefore, remedial actions will be evaluated for these two areas (OU 1 and AOC 6) in this FS. As discussed in Section 1, the COPCs for soils at the Chambers Works FUSRAP Site are U-234, U-235, U-238, Th-230, and Ra-226. In the BRA report, the USACE identified these five radionuclides as contributing unacceptable dose and risk to various human receptors present within the AOCs (CABRERA 2011c) and are thus considered as COCs for evaluation in this FS. The estimated radiological dose and risks associated with soil exposure in the remaining AOCs/EUs were within their corresponding acceptable dose and risk ranges; therefore, no remedial action is required at those locations (AOCs 3, 4, and 5).

Since the media-specific constituents of potential ecological concern resulted in low ecological risk to terrestrial and aquatic receptors present at the Site, no RAOs were developed for ecological receptors.

In the BRA, a CSM was developed to determine complete exposure pathways for each RME scenario, based upon sources of contamination, contaminated media and the pathways of migration. Only soil media was evaluated as a source of contamination for the BRA. The CSM indicated that inhalation of volatiles present in the groundwater was a complete exposure pathway for the utility and construction worker under the industrial use scenario. As volatile organic compounds are not FUSRAP-related, and none of the FUSRAP-related radionuclides are volatiles, the groundwater inhalation pathway was considered incomplete for purposes of the FS. The groundwater ingestion pathway was also eliminated from evaluation as there are no receptors currently utilizing the groundwater beneath the Site as a potable water source; and it is not likely that groundwater will be utilized by future receptors (industrial workers) considering the most reasonable future land use assumptions. The groundwater ingestion pathway was excluded based on current site-specific characteristics including:

- Current groundwater conditions preclude its present use as a potential drinking water source. The two uppermost aquifers beneath Chambers Works exhibit high dissolved solids as well as high organic and metal contamination due to operations associated with DuPont's long manufacturing history; and
- Chambers Works is not within the capture zone of current municipal drinking water well systems and unlikely that it would be in the future.

However, the groundwater ingestion and homegrown garden vegetable ingestion pathways were evaluated for the future residential receptor for comparison purposes. As previously mentioned, groundwater samples collected from the B Aquifer were evaluated for the risk assessment.

Even though groundwater is an incomplete exposure pathway for the four RME receptor scenarios, radiological constituents have been detected in the groundwater at concentrations exceeding the New Jersey ambient groundwater quality standards in OU 1 and AOC 6. Contaminated groundwater in the FUSRAP areas is directly related to the elevated uranium concentrations found in soil. Groundwater conditions in these areas are unique because of site-specific geochemical conditions and the nature of the FUSRAP-related uranium constituents. The presence of numerous organics and other contaminants found in groundwater from the manufacturing operations, unrelated to MED, create the existing reducing groundwater conditions at the Site.

Based upon extensive groundwater sampling and analysis in both the A and B Aquifers, it has been clearly established in the Sitewide RI that due to reducing conditions present in groundwater, the existing dissolved MED uranium in Site aquifers is not mobile, either vertically or horizontally. The OU 1 plume has migrated only a very short distance (less than 100 ft) during the past 65 years. Extremely high concentrations of uranium (up to 30,000 ug/L) exist in the source zones where the highly soluble forms of uranium are found (e.g., metastudite (U+6)). Through reactive transport mechanisms the groundwater concentrations drop off dramatically within 100 ft (below 30 ug/L) where the less soluble compound uraninite (U+4) is found. This occurs around the edges of the plume and is a function of the reducing (lack of oxygen available) conditions present at the Site.

During the course of the Sitewide RI groundwater monitoring program, the leading edge of the plume has not migrated. Existing groundwater plumes are located completely within the FUSRAP AOCs. However, there is a potential for radiological contaminants in soil to leach into the groundwater and continue to impact the A and B Aquifers, as long as elevated concentrations remain in the soil.

The uranium compound found at the Site, uranium peroxide dihydrate, is highly soluble in oxidizing conditions. If future groundwater conditions change from reducing to oxidizing, there is the possibility that aqueous uranium may become mobile, leading to potential aqueous uranium migration beyond the boundaries of OU 1 and AOC 6. Therefore, media-specific RAOs have been developed for Site groundwater. Table 3-1 presents the RAOs developed for both soil and groundwater media present at the DuPont Chambers Works FUSRAP Site.

Table 3-1: Remedial Action Objectives for Remediation of Chambers Works FUSRAP Site

Media	Remedial Action Objectives
Soil and Groundwater	Eliminate or minimize potential human exposure to soils contaminated with FUSRAP-related COCs at levels that exceed the standards established in ARARs or the site-specific remediation goals.
	Eliminate or minimize any further impact to groundwater (by minimizing the source of groundwater contamination).
	Eliminate or minimize potential human exposure to groundwater contaminated with FUSRAP-related COCs at levels that exceed the standards needed to be attained to meet ARARs or the site-specific remediation goals.

3.3 Applicable or Relevant and Appropriate Requirements (ARARs)

3.3.1 Definition of ARARs

Section 121(d)(2) of CERCLA sets requirements with respect to any hazardous substance, pollutant, or contaminant that will remain onsite. Remedial actions must, upon completion, achieve a level or standard of control that at least attains legally applicable or relevant and appropriate substantive standards, requirements, criteria, or limitations under Federal environmental law. The actions must also meet any promulgated, substantive standard, requirement, criteria or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation and is identified by a State in a timely manner.

Identifying ARARs involves determining whether a requirement is applicable, and if it is not applicable, then whether a requirement is relevant and appropriate. Individual ARARs for each site must be identified on a site-specific basis. Factors that assist in identifying ARARs include the physical circumstances of the site, contaminants present, and characteristics of the remedial action.

Applicable Requirements: Applicable requirements are defined as "those cleanup standards, standards of control, and other substantive environmental protection requirements, criterion or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site" (40 CFR 300.5). A law or rule is applicable if the jurisdictional prerequisites of the law or rule are satisfied. These jurisdictional prerequisites include:

- Who, as specified by the statute or regulation, is subject to its authority;
- The types of substances or activities listed as falling under the authority of the statute or regulation;
- The time period for which the statute or regulation is in effect; and
- The type of activities the statute or regulation requires, limits, or prohibits.

Possible applicable requirements may be only those state requirements that are (1) promulgated so that they are of general applicability and legally enforceable, (2) identified by a state in a timely manner, and (3) more stringent than federal standards.

Relevant and Appropriate Requirements: The NCP states that a relevant and appropriate requirement is a standard, requirement, criterion, or limitation under a Federal environmental law or a more stringent State environmental or facility sitting law, which is not legally applicable to the hazardous substance, pollutant or contaminant, remedial action, location, or other circumstance at a site, but which is relevant and appropriate under the circumstances. Determining whether a requirement is relevant and appropriate is a two-step process that involves determining whether the rule is relevant, and, if so, whether it is appropriate. A requirement is relevant if it addresses problems or situations sufficiently similar to the circumstances of the remedial action contemplated. It is appropriate if it is well suited to the site. In determining whether a requirement is both relevant and appropriate, the following factors may be used to evaluate a requirement:

- The purpose of the requirement and the purpose of the response action;
- The medium regulated or affected by the requirement and the medium contaminated or affected at the site;
- The substances regulated by the requirement and the substances found at the site;
- The actions or activities regulated by the requirement and the remedial action contemplated at the site;
- Any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the site;
- The type of place regulated and the type of place affected by the release or response action;

- The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the response action; and
- Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the site.

While some requirements within a regulation will be both relevant and appropriate, other requirements in that same regulation may not be.

CERCLA Section 121(e) [42 USC 9621(e)] provides that no permit is required for the portion of any removal or remedial action conducted entirely onsite. Although no permit is required, onsite actions must comply with substantive requirements of ARARs, but not with related administrative and procedural requirements. For example, remedial actions conducted onsite would not require a permit but must be conducted in a manner consistent with permitted conditions, based on promulgated requirements, as if a permit were required. Off-site activities, such as treatment of liquid waste at an off-site facility, are directly subject to both substantive and administrative requirements of the pertinent environmental regulations, including the permit requirements of those facilities. The management of CERCLA waste off-site must be in accordance with the off-site rule 58 FR 49200, Sept. 12, 1993, as codified at 40 CFR 300.440.

To Be Considered (TBC) Criteria: These criteria include non-promulgated advisories or guidance issued by Federal or State governments that are not legally binding and do not have the status of potential ARARs. However, TBCs may be used in the absence of ARARs if they are reliable and useful to the development of remedial alternatives for the site.

3.3.2 Types of ARARs

USEPA's guidance, *CERCLA Compliance with Other Laws Manual* (USEPA 1988a) classifies ARARs into three categories that address a contaminant, action, location, or other circumstance at a site. The three types of ARARs promulgated under Federal or state law are chemical-specific requirements, location-specific requirements, and action-specific requirements.

Chemical-Specific Requirements: Chemical-specific requirements are media-specific and health-based limits (criteria) developed for site-specific levels of contaminants. Chemical-specific ARARs are health- or risk-based numerical values that, when applied to site-specific conditions, can be used to formulate preliminary remediation goals (PRGs). These values reflect potentially acceptable amounts or concentrations of substances (contaminants) that may remain in affected media or be discharged to the ambient environment.

Action-Specific Requirements: Action-specific ARARs are requirements triggered by the particular remedial activities that are selected to accomplish a remedy. These requirements are those with which design, performance, and other aspects of implementation of specific remedial activities must comply.

Location-Specific Requirements: Location-specific standards are based on particular characteristics of the site or its immediate environment. Restrictions on activities may apply based on a site's location.

3.3.3 Application of ARARs to Remedial Alternatives

Remedial alternatives are evaluated in part on the basis of compliance with environmental standards that are determined to be ARARs. Through an agreement with the Nuclear Regulatory Commission (NRC), the State of New Jersey assumed NRC's regulatory authority over certain radioactive materials on September 30, 2009. Table 3-2 identifies the New Jersey ARARs related to the cleanup at the Chambers Works FUSRAP Site. Requirements identified as either applicable or relevant and appropriate are further evaluated with the identified remedial alternatives in Section 4.0. Each ARAR identified for the DuPont Chambers Works FUSRAP Site is summarized in the following sections.

Chemical Specific ARARS

New Jersey Remediation Standards for Radioactive Materials: The State of New Jersey promulgated the New Jersey Administrative Code (NJAC) 7:28-12, *Remediation Standards for Radioactive Materials* in August 2000. This regulation establishes minimum standards for the remediation of real property (including soil, groundwater, surface water and sediment) contaminated by radioactive materials at sites located within the State of New Jersey. For the Chambers Works FUSRAP soil remediation, the substantive requirement found in NJAC 7:28-12.8(a)(1) and NJAC 7:28-12.11(e) have been identified as ARARs for OU 1 (EU 1) and AOC 6 (EU3B). NJAC 7:28-12.8(a)(1) requires that a maximum dose of 15 mrem/yr above background be met for an unrestricted use remedial action, a limited restricted use remedial action, or a restricted use remedial action. Additionally, NJAC 7:28-12.11(e) is an ARAR since an alternative remediation standard is being used in lieu of standards found in NJAC 7:28-12.9 or developed in NJAC 7:28-12.10. NJAC 7:28-12.11(e) requires that the alternative remediation standard would not result in more than 100 mrem (one mSv) total annual effective dose equivalent should all institutional or engineered controls fail at the Site at some time in future.

Other regulations regarding potential RCRA material, labeling, packaging and marking requirements under the Department of Transportation, or related to shipping and disposal of materials, will be addressed in the remedial design phase and documented in the appropriate work plans.

Table 3-2: Applicable or Relevant and Appropriate Requirements (ARARs) for Chambers Works FUSRAP Site

Potential Requirement	Citation	Description of Requirement	ARAR Status	Comments
CHEMICAL-SPECIFIC ARARS (RADIOLOGICAL)				
New Jersey Remediation Standards for Radioactive Materials (Subchapter 12): Radiation Dose Standards Applicable to Remediation of Radioactive Contamination of Real Property	N.J.A.C. 7:28-12.8(a)(1)	Sites shall be remediated so that the incremental radiation dose to any person from any residual radioactive contamination at the site above that due to natural background radionuclide concentration, under either an unrestricted use remedial action, limited restricted use remedial action, or a restricted use remedial action, shall have a sum of annual external gamma radiation dose and intake dose of 15 mrem/yr or less above background.	Applicable	NJAC 7:28-12.8(a)(1) applies to soils in both OU 1 (EU 1) and AOC 6 (EU 3B) AOC 6. Only the substantive requirements of this regulation would apply.
	N.J.A.C. 7:28-12.11(e)	When using an alternative remediation standard for radioactive contamination the residual contamination remaining onsite after remediation shall not result in more than 100 mrem annual effective dose equivalent if institutional or engineered controls fail.	Relevant and Appropriate	NJAC 7:28-12.11(e) applies to soils in both OU 1 (EU 1) and AOC 6 (EU 3B); commonly referred to as the All Controls Fail (ACF) requirement.

3.4 Development of Remediation Goals (RGs)

CERCLA requires the selection of a cleanup action that is protective of human health and the environment and complies with ARARs. The requirements for cleanup actions are provided in 40 Code of Federal Regulations (CFR) 300.430. According to those requirements, the EPA defines the CERCLA acceptable target risk range as 10^{-6} to 10^{-4} for carcinogenic chemicals. The State of New Jersey's acceptable dose criterion of 15 mrem/yr was identified as an ARAR for the Site. By meeting the 15 mrem/yr dose criterion, protectiveness would be achieved for the Site. Therefore, USACE derived site-specific RGs for soil COCs based on the 15 mrem/yr dose criterion.

As previously discussed, the radionuclides U-234, U-235, U-238, Th-230, and Ra-226 have been identified as the COCs for the Site and are considered for evaluation in this FS. Due to the absence of Ra-226 and Th-230 sampling results for some samples analyzed during initial site investigations, USACE performed a surrogate evaluation to develop a RG for a surrogate radionuclide COC. Under the surrogate evaluation, it is possible to measure just one of the radionuclides instead of all five while demonstrating overall compliance for all radionuclide COCs present. During previous Site investigations U-238 was already used as a surrogate for total uranium. As Ra-226 and Th-230 are daughter products of U-238, U-238 was once again selected as the surrogate radionuclide for the Site. An alternative remediation standard was developed to meet the standard in NJAC 7:28-12 that requires sites to be remediated until the incremental radiation dose to any person from any residual radioactive contamination above that due to natural background results in an annual total effective dose equivalent of 15 mrem/yr or less. A site specific dose assessment was performed to determine the RG for the surrogate radionuclide (U-238) and is summarized in Appendix A.

As shown in Appendix A, DCGLs were determined for the industrial and construction workers at the Site. As a conservative approach, the RG for total uranium was selected to be 65 pCi/g (32 pCi/g for U-238) based on the construction worker receptor scenario. Throughout this document the RG will be referenced as 65 pCi/g total uranium to avoid confusion between the U-238 and total uranium values. This alternative remediation standard (cleanup concentration) meets the chemical-specific ARAR and will achieve the RAOs identified for soil.

The DCGL developed in Appendix A is a wide-area average (DCGLw). Therefore, the average concentrations based on confirmatory samples collected within a given survey unit will be compared to the DCGLw to demonstrate overall compliance for all COCs. In addition, an elevated measurement DCGL ($DCGL_{EMC}$ or hot spot criterion) will be developed during remedial design for use in comparing individual sampling results to determine the need for further cleanup at the Site.

In pursuing an alternative remediation standard, in accordance with NJAC 7:28-12.11, for the Critical Group (construction worker), USACE evaluated the various receptor and dose limit scenarios. Based on the ARAR evaluation, the “all controls fail (ACF) scenario” in NJAC 7:28-12.11(e) is an ARAR for the cleanup at the Site. The ACF requirement states: "Regardless of the factors used by the petitioner or licensee, the department shall not approve alternative standard petitions that include institutional and engineering controls where failure of those controls, not including the failure of a radon remediation system, would result in more than 100 mrem (one mSv) total annual effective dose equivalent.” Therefore, in order to meet the requirement and demonstrate compliance, various dose assessment evaluations were performed and are presented in Appendix A.

The dose assessments evaluated the hypothetical residential receptor using the derived DCGLs, an estimated post remediation vertical extent of contamination (4 feet), and the residential exposure pathways including the drinking water and crop ingestion pathways. As in the BRA the drinking water pathway for the residential receptor was evaluated by using a modified EPA RAGS equation. The results of the dose assessments are presented in Appendix A. The resulting peak total dose to the hypothetical residential receptor occurred within the 1000-year calculation period and was estimated to be significantly less than 100 mrem/yr (13 mrem/yr). The results for the dose assessments clearly demonstrate that the site-specific DCGL of 65 pCi/g for total uranium complies with the 100 mrem/yr dose criterion.

It is expected that the final status survey will demonstrate compliance with the “all controls fail scenario” by targeting the RG of 65 pCi/g total uranium during remediation.

At the Site, groundwater is an incomplete exposure pathway for the four RME receptor scenarios (as discussed in Section 2.4.1); therefore no risk-based RGs for groundwater have been identified. It is expected that by addressing soil contamination at the site through a remedial action the resulting groundwater conditions will be significantly improved. Therefore, RAOs for groundwater have been included in order to protect groundwater and improve groundwater conditions for some future use. The RAOs for groundwater at the Site aim to eliminate or minimize potential human exposure to groundwater contaminated with FUSRAP-related COCs at levels that exceed the 100 mrem/yr 'All Controls Fail' standard.

3.5 Identification of General Response Actions (GRAs)

This section describes the GRAs potentially applicable to the DuPont Chambers Works FUSRAP Site. GRAs for the Site were based on media of concern and were determined by defining actions that satisfy the RAOs. The GRAs involve activities that directly impact the source materials and groundwater at the Site in order to minimize the potential hazard to human health and the environment. Each GRA may include several technology options. Descriptions of the GRAs identified for the Site are provided below. The GRAs and associated potential process options are presented in Table 3-3.

3.5.1 Land Use Control

Land use controls (LUCs) are administrative, legal and/or engineering mechanisms used to protect public health and the environment from residual contamination and are designed to limit land use and onsite activities to minimize any potential future exposure. LUCs are typically used in tandem with physical or engineering measures. LUCs have been identified as a GRA for both the soil and groundwater media at the Chambers Works FUSRAP Site.

3.5.2 Monitoring

Environmental monitoring may be conducted in conjunction with all remedial alternatives to evaluate contaminant levels during ongoing remedial actions, to assess the effectiveness of remedial actions, and to ensure that off-site migration of contaminants is detected and mitigated. Environmental monitoring would be tailored to the selected remedial alternative so that monitoring objectives are realized. An adequate monitoring program considers periodic sampling of all media that would be affected by the continued presence of contaminants in environmental media.

3.5.3 Containment

Containment actions are often performed to prevent, or significantly reduce, the migration of contaminants in soils or groundwater. Containment is necessary whenever contaminated materials are to be buried or left in place at a site. In general, containment is performed when extensive subsurface contamination at a site precludes excavation and removal of wastes because of potential hazards, unrealistic cost, or lack of adequate treatment technologies.

Containment actions considered for the DuPont Chambers Works FUSRAP Site include caps for containment of the soils, vertical and horizontal barriers for groundwater, and pumping to contain the migration of contaminated groundwater.

3.5.4 Removal

Removal of contaminated soil and material effectively limits the volume and mobility of COCs at the source area and can facilitate treatment and disposal. Excavation would minimize or eliminate the potential for direct human contact with and migration of contaminated material. In addition, excavation of saturated soils results in direct or indirect (dewatering) removal of contaminated groundwater. Furthermore, the removal of contaminated soil would eliminate the source of groundwater contamination and eliminate or reduce any future impact to groundwater. Removal activities considered for groundwater typically consist of pumping systems using either vertical or horizontal extraction wells.

3.5.5 Treatment Actions

Ex situ soil treatment GRAs have been identified for the soils media at the Chambers Works Site, with the main advantage of generally requiring shorter time periods than *in situ* treatment. There is also more certainty about the uniformity of treatment because of the ability to homogenize, screen, and continuously mix the soil. *Ex situ* treatment, however, requires excavation of soils prior to implementation, which leads to increased costs and engineering for equipment, possible permitting, and material handling/worker exposure conditions.

Physical/chemical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), separate, or immobilize the contamination. Examples of each type include the following: chemical reduction/oxidation is a destruction technology; soil washing is a separation technique; and solidification/stabilization is an immobilization technique.

Bioremediation techniques are destruction or transformation techniques directed toward stimulating microorganisms to grow and use the contaminants as a food and energy source by creating a favorable environment for the microorganisms. Generally, this means providing some combination of oxygen, nutrients, and moisture, while controlling the temperature and pH. Sometimes, microorganisms adapted for degradation of the specific contaminants are applied to enhance the process.

Thermal treatments offer quick cleanup times but are typically the most costly treatment group. This difference, however, is less for *ex situ* applications compared to *in situ* applications. Cost is driven by energy and equipment requirements, resulting in considerable expenditure of both capital and operation and maintenance (O&M) resources.

GRAs for groundwater include both *ex situ* and *in situ* treatment actions. The main advantage of *ex situ* treatment is that it generally requires shorter time periods, and there is more certainty about the uniformity of treatment because of the ability to monitor and continuously mix the groundwater. *Ex situ* treatment, however, requires pumping of groundwater, leading to increased costs and engineering for equipment, possible permitting, and material handling. The main advantage of *in situ* treatment is that it allows groundwater to be treated without being brought to the surface, resulting in significant cost savings. *In situ* processes, however, generally require longer time periods, and there is less certainty about the uniformity of treatment because of the heterogeneity in aquifer characteristics.

Physical and chemical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), separate, or contain the contamination. Physical and chemical treatment is typically cost effective and can be completed in short time periods (in comparison with biological treatment). Equipment is readily available and is not engineering or energy-intensive. Treatment residuals from separation techniques will require treatment and/or disposal, which will add to the total project costs and may require permits. Physical and/or chemical treatment can be either *ex situ* or *in situ*.

In situ bioremediation techniques are destruction techniques directed toward stimulating the microorganisms to grow and use the contaminants as a food and energy source by creating a favorable environment for the microorganisms. Generally, this means providing some combination of oxygen, nutrients, and moisture, and controlling the temperature and pH. Sometimes, microorganisms adapted for degradation of the specific contaminants are applied to enhance the process.

In situ thermal treatment methods work by heating contaminated soil and groundwater. These methods are very effective for VOCs or SVOCs but not for radioactive metal; the destruction or volatilization of radioactive metal does not occur and therefore this is not a likely option. Under thermal treatment, the heat helps push chemicals through the soil toward collection wells. The heat also can destroy or evaporate certain types of chemicals. When heated, the chemicals change into gases, which then move more easily through the soil. Collection wells capture the chemicals and gases and pipe them to the ground surface for further treatment.

3.5.6 Disposal Actions

Disposal actions for the soil media involve the permanent and final placement of the waste materials in a manner that protects human health and the environment. Contaminated material is removed and transported to permitted off-site treatment and/or disposal facilities. Some pretreatment of the contaminated media usually is required in order to meet land disposal restrictions. For groundwater, disposal actions would involve surface discharge of extracted groundwater; discharges to a permitted wastewater treatment plant or POTWs, or potential deep well injection.

Table 3-3: General Response Actions and Potential Process Options for DuPont Chambers Works FUSRAP Site

GRA	Technology Types	Process Options
Soil		
Land Use Controls	Administrative and Legal Mechanisms	Governmental controls, enforcement tools, informational devices, proprietary controls
	Physical mechanisms	Physical barriers, permanent markers, security personnel
Monitoring	Environmental Monitoring	Groundwater, surface water, sediment, and air
Containment	Capping	Native soil, clay, asphalt, concrete, synthetic liner, multi-layered, concrete
Removal	Soil excavation	Soil excavation with earth moving equipment
Treatment	Physical	Encapsulation, thermoplastic solidification, solidification/stabilization, vitrification, soil washing, soil sorting,
	Chemical	Oxidation/reduction, soil washing, hydrolysis, neutralization, stabilization
	Biological	Biodegradation
	Thermal	Incineration
Disposal and Handling	Onsite disposal	Onsite engineered facility, onsite soil disposal
	Off-site disposal	Existing disposal facility or new engineered structure
	Transportation	Truck, railcar, or barge
Groundwater		
Land Use Controls	Administrative and Legal Mechanisms	Governmental controls, enforcement tools, informational devices, proprietary controls
	Physical mechanisms	Physical Barriers
Monitoring	Environmental Monitoring	Groundwater monitoring
Containment	Barriers	Sheet piles, geosynthetic membrane, slurry walls, jet grouting, soil freezing, and hydraulic barriers
Removal	Extraction Wells	Vertical wells and horizontal wells
Ex Situ Treatment	Physical	Air stripping/packed tower, evaporation ponds, crystallization, flocculation/precipitation, physical catalysis, dissolved air flotation, ultra/micro/nanofiltration, reverse osmosis, ion exchange, sedimentation
In situ Treatment	Physical	Permeable treatment walls, liquid gas extraction, vacuum extraction, air sparging, chelation, electrokinetics, MNA
	Chemical	chemical hydrolysis; geochemical immobilization
	Biological	Bioremediation
	Thermal	Incineration, distillation, steam stripping, evaporation, super critical water oxidation, and wet air oxidation.
Disposal and Handling	Onsite Disposal	Discharge to surface water, deep well injection , discharge to DuPont WWTP
	Off-site Disposal	Dispose/discharge to POTW or other disposal facility
	Transportation	Truck, railcar or barge

3.6 Volume/Area of Contaminated Media

The GRAs discussed above were identified, in part, based upon the contaminated media present at the Chambers Works FUSRAP Site. The area of contaminated soils above the RG of 65 pCi/g total uranium at OU 1 (AOC 1 and AOC 2) and AOC 6 are shown in Figures 3-1, 3-2, and 3-3, respectively. Areas of radiologically-impacted soils are estimated as *in situ* volumes and are shown in Table 3-4. Total *in-situ* soil volumes above the RG are estimated at approximately 11,600 yd^3.

Table 3-4: Estimate of *In Situ* Soil Volumes Above RG

Location	*In Situ* Volume [yd^3]
OU 1: AOC 1	3,600
OU 1: AOC 2	5,400
OU 3: AOC 6	2,600

Computer contouring software was used to draw 11 isopleth contour lines based on 11 different iterations of the uranium-concentration data set. After removing the most-outlying iteration, the software calculated the volumes based on contouring from the other 10. The average and standard deviation of these 10 iterations were used for the calculated volume and uncertainty associated with the volume calculation.

The groundwater contamination for AOCs 1 and 2 extends across both the A and B Aquifers and has been estimated at approximately 44,700 ft^2 for both AOCs, with depths ranging from 6 ft below ground surface (bgs) in AOC 1 to 18 ft bgs in AOC 2. The A Aquifer is not present in AOC 6. The extent of groundwater contamination within the B Aquifer in this AOC is limited to one well located downgradient of an area of contaminated soils. The estimated extent of impacted groundwater in AOC 6 is approximately 2,900 ft^2.

3.7 Identification and Screening of Technology Types and Process Options

This section describes the identification and initial screening of potentially applicable technology types and process options to meet the RAOs defined in Section 3.2. The term 'technology type' is used to refer to general categories of technologies, such as chemical treatment, capping, or extraction wells. The term "process options" refers to specific processes within each technology type. The initial screening results for these potentially applicable technology types and associated process options are shown in Tables 3-5 and 3-6 for soils and groundwater, respectively. Shaded entries in the tables indicate that the technology type or process option was eliminated from further consideration. In accordance with the RI/FS guidance (USEPA 1988b), these options are initially evaluated with respect to technical implementability. Those technology processes considered to be implementable are then evaluated in greater detail in Section 3.9

3.7.1 No Action (Soil and Groundwater)

No action provides a baseline for comparison with other alternatives as is required under CERCLA, i.e., no remedial actions would be taken to reduce, contain, or remove contaminated soils, and no effort would be taken to prevent or minimize human and environmental exposure to residual contaminants. Off-site migration of contaminants would not be mitigated under a No Action alternative. Under CERCLA, a review of remedial actions will be conducted for all sites where a Decision Document or Record of Decision states that hazardous substances, pollutants or contaminants may remain in place above levels that allow for unlimited use or unrestricted exposure. No remedial action will be conducted under No Action alternative, therefore, no five-year reviews would be conducted.

3.7.2 Administrative and Legal Control Mechanisms (Soil and Groundwater)

Administrative or legal mechanisms are types of LUCs that are used to protect public health and the environment from residual contamination. The four administrative and legal process options screened here are: (1) Proprietary Controls, (2) Government Controls, (3) Enforcement and Permit Tools with Land Use Control Components, and (4) Informational Devices.

Proprietary Controls: A proprietary control is a private contractual mechanism between the landowner and a third party that is contained in the deed. Proprietary controls involve placement of restrictions on land through use of easements or covenants. Proprietary controls give their holders the right to use or restrict the use of land.

Some restrictions that could be considered for the Chambers Works FUSRAP Site include the following requirements:

- groundwater would not be used for any purpose;
- gardens would not be planted on the property;

- no construction of any type would be allowed without the written approval of the government.

Easements allow the holder to use the land of another or to restrict the uses of the land. The four types of easements are: (1) appurtenant easements, which provide a specific benefit to a particular piece of land, such as allowing access to cross the property; (2) easement in gross, which benefits an individual or company, such as allowing a utility company access to land to lay a gas line; (3) affirmative easements, which allow the holder to use another's land in a way that, without the easement, would be unlawful; and (4) negative easements, which prohibit a lawful use of land such as creating a restriction on the type of development that can be conducted on the land. Of these four, the negative easement would be most applicable.

Covenants are promises that certain actions have been taken, will be taken, or will not be taken. Covenants can bind subsequent owners.

NJAC 7:26 E Subchapter 8 describes NJDEP's required deed notification process. Among other things, the regulations describe procedures for recording deed notices, documenting monitoring activities, and notification requirements for use when a person relinquishes their obligation for maintaining and inspecting the Institutional Controls (ICs).

Governmental Control: Governmental controls are restrictions that are implemented and enforced by state and local governments. They may include zoning restrictions, ordinances, statutes, building permits, or other provisions that restrict land or resource use at a site. Permit programs and planning and zoning limits are typical examples of governmental controls (USEPA 2000).

Zoning use restrictions are imposed through a local zoning authority and are intended to prohibit activities that could disturb certain aspects of a remedy or to control certain exposures not otherwise protected under a remedy. Zoning restrictions have inherent weaknesses. Zoning laws can be repealed or exceptions can be granted by the government.

Informational Tools: Informational tools provide information or notification that residual or capped contamination exists on the property. Common examples include state registries of contaminated properties, deed notices, and advisories. Due to the nature of some informational devices and their potential nonenforceability, it is important to carefully consider the objective of this category of LUCs. Informational devices are most likely to be used as a secondary "layer" to help ensure the overall reliability of other LUCs.

3.7.3 Physical Mechanisms (Soil and Groundwater)

Physical mechanisms, such as the use of fences and permanent markers (warning signs) can be used around a contaminated site to prevent unauthorized access. Security personnel can be used to deter unauthorized access to the site. All of these measures are designed to minimize the potential for direct human contact with contaminated media. Because the Site is not owned by USACE, it would be necessary to negotiate an agreement with the property owners.

3.7.4 Environmental Monitoring

Environmental monitoring would be conducted in conjunction with all remedial alternatives in order to evaluate contaminant levels during ongoing remedial actions, to assess the effectiveness of remedial actions, and to ensure that off-site migration of contaminants is detected and mitigated. Environmental monitoring is sometimes considered an LUC, but monitoring is analyzed separately for this evaluation. Environmental monitoring would be tailored to the selected remedial alternative so that monitoring objectives are realized. An adequate monitoring program considers periodic sampling of all media that would be affected by the continued presence of contaminants on the site. Periodic monitoring should be conducted for air particulates and external gamma radiation, surface water, and sediments (to measure surface runoff impacts and measure levels of contamination in CDD sediments further downgradient from AOC 1 and AOC 2), and groundwater, at representative locations.

3.7.5 Containment (Soil and Groundwater)

Containment response actions prevent contaminant migration and eliminate exposure paths by physically blocking contact with the contamination. The contaminated media are neither chemically nor physically changed, nor are the volumes of contaminated media reduced.

For the soil media, the containment technology type evaluated is that of capping. Capping would involve covering a surface area with a low-permeability material to reduce migration to the atmosphere, adjacent soils, or groundwater. Capping would reduce the infiltration of surface water through contaminated media to the groundwater, but it would not significantly reduce the migration of groundwater through contaminated sediments below the water table. Capping would not reduce the toxicity of the soil contaminants, but it would reduce mobility or migration, as well as exposure. Capping also would minimize the release of contaminated surface soil into the atmosphere as dust particles, which could potentially be inhaled or re-deposited onto another area. Depending on the thickness of the cap, gamma ray emanations to the surface would be mitigated or eliminated.

Process options for capping involve a consideration of the types of capping material to be used. Native soil, clay, asphalt, concrete, synthetic liners, or a multi-layered cap can provide containment of contaminants in soils. The availability and cost of the material required to construct the cap needs to be considered when planning the final design.

Geotechnical analyses, including permeability testing, density testing, and moisture content would be required if clay or native soil were used as the capping material. Another approach to addressing subsidence would be to use a temporary cover until the *in situ* contaminated soil is stable and the cap could be applied.

A multi-layered capping system would be designed and constructed to minimize percolation of rain and snowmelt through the contaminated soils and also would minimize the release of contaminated surface soil into the atmosphere as dust particles, which could potentially be inhaled or re-deposited onto another area.

For groundwater containment, actions involve separating the contamination source from the water and controlling migration of groundwater from the site through the installation of vertical barriers, such as sheet piling and slurry walls. Since the affected areas are within the areas of influence of DuPont's sitewide groundwater control system, the function of containment of FUSRAP-related plumes would be to prevent or minimize migration of FUSRAP-eligible contaminants (e.g., uranium) into areas of the Chambers Works currently not affected by FUSRAP contaminants.

Both sheet piling and slurry walls require a relatively impermeable soil layer at the bottom of the barrier, to avoid flow of contaminated groundwater under the barrier. These systems also are most easily constructed and function best when underground utilities are not present.

3.7.6 Soil Excavation

Contaminated soil at the Site can be partially or completely excavated with conventional earth-moving equipment including excavators, bulldozers, and front-end loaders, and manual techniques. Equipment to be used is determined by many factors, including the area to be remediated, the area available for operations, the depth of the excavation, and the capabilities of the equipment. Manual excavation techniques are used where insufficient space precludes the use of conventional equipment. Conventional construction techniques would be employed to minimize impacts to groundwater and surface water during excavation. Special consideration to occupational health requirements would be required during soil excavation activities.

Tracked excavators are the preferred equipment choice for removal of soils at various depth profiles. The smaller, wheeled ‘backhoes’ can also be utilized in smaller or shallower areas where an excavator may not have the room to operate. Bulldozers are versatile machines used on a variety of projects such as moving earth for short haul distances, spreading earth fill, backfilling trenches and pits, clearing sites of debris, and pushing debris into loading areas. Bulldozers can also remove relatively shallow, wide areas of contaminated soil by scraping the surface. Front-end loaders are used extensively in construction to load bulk material such as soil, rocks, and rubble into dump trucks and to move earth forward for short distances. Self-loading scrapers could also be utilized for wide, shallow contaminated soil areas.

For most soil removal applications, excavators (or ‘hoes’) usually work better because of their greater depth-handling capacity. The term ‘hoe’ applies to any excavating machine of the power-shovel type (e.g., excavator, backhoe, back shovel, or pull shovel). Hoes are most suited to excavating trenches and pits, and to general grading work that requires precise control of excavation depth. They are superior to drag lines for close-range work, and for loading excavated material into dump trucks.

Hoes can work from a clean area, contaminating only their buckets. Contaminated soil in certain locations, such as next to buildings or culverts, can be accessed using equipment with a smaller footprint and smaller buckets.

Dump trucks are used to haul soil, rock, aggregate, and other material. Because of their speed, they provide high earth-moving capacity at relatively low hauling cost. They also provide a high degree of flexibility because the number and types of trucks in service may easily be increased or decreased to modify the total hauling capacity of a fleet.

In some cases, it may be necessary to reroute drainage culverts to gain access to soils under them, or to use smaller equipment, possibly to the extent of using shovels to remove soil manually.

Field monitoring would be conducted during soil excavation to ensure that all contaminated soils have been removed to the specified remediation level. As required, samples would be collected from the excavation side walls and bottom for laboratory analyses to confirm the results obtained during field monitoring.

3.7.7 Removal (Groundwater)

The process options evaluated for removal of groundwater include extraction using vertical and/or horizontal wells. Vertical wells remove groundwater from aquifers or perched water zones. Systems utilizing horizontal wells generally require fewer wells than vertical well-based networks since horizontal well screens provide greater surface area contact with contaminated soils and groundwater. Horizontal wells may also be installed using directional drilling techniques, allowing wells to be installed underneath buildings and other structures. The implementability of vertical and horizontal wells is dependent on the properties of the aquifer and well construction factors. If the source contamination is not removed, continual groundwater extraction may be required to ensure long-term effectiveness. Both vertical and horizontal wells are retained for further consideration.

3.7.8 Physical Treatment (Soil)

Physical treatment considered for the soil media includes encapsulation, thermoplastic solidification, solidification/stabilization, vitrification, soil washing, and soil sorting. The *ex situ* treatment technologies evaluated for the soils media at the Chambers Works FUSRAP Site are described below.

Encapsulation: Encapsulation would coat or seal waste with an organic binder or resin. This technology is not considered technically feasible for the Site due to the large volume of fine grained soils.

Thermoplastic Solidification: Waste is sealed in asphalt, polyethylene, or thermo-setting resins to form a solid matrix. This technology is not considered technically feasible for the Site due to the likely increase of volume of contaminated material.

Solidification/Stabilization: This process produces monolithic blocks of waste with high structural integrity. The radionuclides do not necessarily interact chemically with the solidification reagents (typically cement/ash) but are mechanically locked within the solidified matrix. Materials are further stabilized by the addition of chemical binders, such as cement, silicates, or pozzolans, which limit the solubility or mobility of waste constituents even though the physical handling characteristics of the waste may not be changed or improved.

Vitrification: This process employs heat up to 1,200 degrees Celsius (°C) to melt and convert waste materials into glass or other glass and crystalline products. The high temperatures destroy any organic constituents with very few byproducts. Materials, such as heavy metals and radionuclides, are actually incorporated into the glass structure which is, generally, a relatively strong, durable material that is resistant to leaching. While this process can be carried out either *in situ* or *ex situ,* the *in situ* vitrification is not considered technically feasible as the overall effectiveness is difficult to verify. This process also limits potential reuse of the Site.

Soil Washing: Soil washing can achieve volume reduction of excavated, contaminated soils in two ways: (1) by dissolving or suspending the contaminants in the wash solution or (2) by concentrating the contaminants into a smaller volume through particle size separation. Soil washing systems that incorporate both techniques achieve the greatest success with soils contaminated with radioactive, heavy metal, and organic constituents.

Soils containing large amounts of clay and silt, such as those at the Chambers Works FUSRAP Site, are typically not effectively treated by conventional soil washing systems. However, soil washing can be enhanced by incorporating other physical and chemical processes to more effectively treat these types of soils. Following treatment, the smaller volume contaminated soil fraction could be processed through an additional treatment process (such as stabilization), or could be dewatered and disposed. The clean soils from the treatment process could be placed back on the site, or could be reused at another site. During operation the majority of the soil washing process water is filtered and recycled back into the treatment system. A small volume of this water stream would require periodic discharge.

Soil Sorting (based on radionuclide content, e.g. Segmented Gate Systems): Soil sorting involves the mechanical sorting of soils based on radionuclide concentrations to separate soils above the RGs from those below the RGs. The most prevalent soil sorting systems use gamma radiation detectors as a means for determining compliance with this criterion. Field testing of this technology would be required to ensure its effectiveness at the chosen RG of 65 pCi/g total uranium. A pilot test of this type would be performed to establish system detection levels, quantify false-alarm rates (both positive and negative), and verify/correct system throughput and quality assumptions. Pilot testing would be conducted as part of Remedial Design, if this technology were selected in the ROD. Two primary advantages of soil sorting as compared to other technologies (such as soil washing) are that this technology does not produce any secondary waste (such as process waste water) and does not require process additives. However, use of a segmented gate (or any soil sorting) system is based on the underlying assumption that soils below the RG are available for beneficial re-use on the site, e.g., as backfill soils covered with certified 'clean' cover.

3.7.9 Chemical Treatment (Soil)

The chemical treatment processes considered for soils include oxidation/reduction, chemical soil washing, hydrolysis, neutralization and chemical stabilization.

Oxidation/Reduction: Oxidation/reduction (redox) reactions chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. Redox reactions involve the transfer of electrons from one compound to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). Inorganic contaminants are the target contaminants for chemical redox reactions. Therefore this process is not considered technically feasible to address the soil COCs at the Site.

Chemical Soil Washing: This process is similar to physical soil washing but uses chemicals in the wash fluid. Chemical soil washing is not considered technically feasible for addressing the soil COCs at the Site. In addition, extraneous waste streams may be produced that would be difficult to treat.

Hydrolysis: This process involves a reaction with an organic chemical and water or hydroxide ion to break the chemical down into a less toxic form. Hydrolysis is not considered technically feasible for addressing the soil COCs at the Site.

Neutralization: In neutralization, chemicals are injected into soil strata to adjust the pH of the soil. This process is not considered technically feasible for addressing the soil COCs at the Site.

Chemical Stabilization: In chemical stabilization, the decrease in contaminant mobility is achieved by a chemical reaction between the contaminant and the stabilizing agent. Because the contaminants in soil are not very mobile at the Site, treatment by chemical stabilization would not be cost effective. Chemical stabilization was eliminated from further consideration because of the volume and cost increases associated with this technology.

3.7.10 Biological Treatment (Soil)

Biodegradation is the use of microorganisms (i.e., fungi, bacteria, and other microbes) to degrade contaminants in the soil. These techniques are used mainly for organically contaminated media and would not be technically feasible for treating the radioactive constituents at the Site.

3.7.11 Thermal Treatment (Soil)

Thermal treatment (incineration) uses high temperatures to volatilize and combust organics in waste materials. Incineration would not be technically feasible to address the COCs in Site soils.

3.7.12 Physical Treatment (Groundwater)

Physical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), or separate the contamination. Various physical treatment process options, performed both *ex situ* and *in situ*, were considered for evaluation and are described below.

Ex Situ Treatment

Air Stripping/Packed Tower: Large volumes of air are mixed with water in a packed tower to promote portioning of volatile organics into the air. This process is not technically feasible for treatment of radionuclides in groundwater.

Evaporation Ponds: Groundwater is pumped to the surface and evaporated to concentrate contaminant present in liquids. The solids are subsequently treated and disposed. This process is not technically feasible for treatment of radionuclides in groundwater.

Crystallization: In this process, certain solutes crystallize out from a saturated solution when the solvent is cooled. This process is very energy intensive, requires chemical additions, and is not technically feasible for treatment of radionuclides in groundwater.

Flocculation/Precipitation: This process transforms dissolved contaminants into an insoluble solid, facilitating the contaminant's subsequent removal from the liquid phase by sedimentation or filtration. The process usually uses pH adjustment, addition of a chemical precipitant, and flocculation. This process is technically feasible for treating radionuclides in groundwater.

Physical Catalyst: Physical processes are used to accelerate a chemical change of a contaminant. This process is not technically feasible for treatment of radionuclides in groundwater.

Dissolved Air Flotation: Minute air bubbles, introduced by pressurization/depressurization means, rise to the surface carrying low-density solids. This process is not technically feasible for treatment of radionuclides in groundwater.

Ultra/Micro/Nanofiltration: A membrane filtration process that separates high molecular weight solutes or colloids from the surrounding media. This process is not technically feasible for treatment of radionuclides in groundwater

Reverse Osmosis: In this process, pressure is applied to force flow from dilute to concentrated solutions through a membrane that is impermeable to a solute (dissolved ion). This process is technically feasible for treating radionuclides in groundwater.

Ion Exchange: Contaminated groundwater is passed through a resin bed where ions are exchanged between the resin and water. The resultant concentrated waste stream may require additional treatment. Ion exchange can remove dissolved metals and radionuclides from aqueous solutions, and has been retained as technically feasible.

Sedimentation: Suspended particles are allowed to settle in a basin or pond enclosure. Rate of settlement depends on particle diameter and specific gravity. Sedimentation is technically feasible as a post-treatment step used in conjunction with another physical process.

In SituTreatment

Permeable Treatment Walls: In this process, trenches are excavated perpendicular to groundwater flow and filled with a reactive permeable natural or synthetic medium to treat or adsorb contaminants. Permeable treatment walls are not technically feasible due to uncertain variations in flow gradient across the AOCs. Most matrices for permeable treatment walls are designed to oxidize contaminants, but aqueous uranium is mobilized by oxidizing conditions. In addition, the process is primarily used for organic compounds.

Liquid Gas Extraction: Uses gases to alter the properties of solvents, making extraction of organics more rapid and efficient. This process is not technically feasible for treatment of radionuclides in groundwater.

Vacuum Extraction: Vacuum pumps are connected via a piping system to a series of extraction wells which remove VOCs from groundwater. This process is not technically feasible for treatment of radionuclides in groundwater.

*Air Sparging: A*ir is introduced to the subsurface, causing the volatilization of organic contaminants. This process is not technically feasible for treatment of radionuclides in groundwater.

Chelation: Chelating molecules for ligands with metal ions and are used to keep metals in solution. This process is not technically feasible for treatment of radionuclides in groundwater.

Electrokinetics: Electrodes are installed and electrical power used to drive contaminants to the anode for collection in an electrolyte solution. This process is technically feasible for treating radionuclides in groundwater.

Monitored Natural Attenuation (MNA): MNA is a passive remedial measure that relies on natural processes to reduce the contaminant concentration over time. MNA is a viable remedial process option if it can reduce contamination within a reasonable time frame, given the particular circumstances of the site, and if it can result in the achievement of remediation objectives. Use of MNA as a component of a remedial alternative is appropriate along with the use of other measures, such as source control or containment measures. MNA has been retained for further consideration.

3.7.13 Chemical Treatment (Groundwater)

Chemical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), or separate the contamination. Chemical process options evaluated include chemical hydrolysis and geochemical immobilization.

Chemical Hydrolysis: The conversion of organic wastes to more benign compounds through substitution by hydroxide ions. This process is not technically feasible for the treatment of radionuclides in groundwater at the Site.

Geochemical Immobilization: In this process, a reducing agent is injected into the aquifer to chemically reduce the solubility of uranium. Although treatability studies are required to demonstrate the effectiveness of this process for site conditions, geochemical immobilization is technically feasible for treating the radioactive constituents in groundwater at Chambers Works. Generic substances (e.g. lactate, molasses) or commercial products such as HRC by Regenesis, can be injected at well points or used in a permeable reactive barrier configuration to reduce the Oxidation Reduction Potential (ORP) and, by so doing, reduce the valence of uranium from +6 to +4, and thereby reduce its solubility.

3.7.14 Biological Treatment (Groundwater)

Bioremediation is a process that attempts to accelerate the natural biodegradation process by providing nutrients, electron acceptors, and competent degrading microorganisms that may otherwise be limiting the rapid conversion of contamination organics to innocuous end products. This process would not be technically feasible for treating the radioactive constituents in groundwater at the DuPont Chambers Works FUSRAP Site.

3.7.15 Thermal Treatment (Groundwater)

Thermal treatment process options include incineration, distillation, steam stripping, evaporation, super critical water oxidation, and wet air oxidation. For most thermal process heat (or steam) is forced into an aquifer through injection wells to vaporize contaminants. Vaporized components rise to the unsaturated zone where they are removed by vacuum extraction and then treated. In the case of thermal oxidation processes, non-soluble contaminants within the superheated water can become soluble, allowing for additional treatment with dissolved oxidizers. Both type of thermal treatment processes are energy intensive and primarily applicable to organic compounds. Thus, thermal treatment has been determined to be technically infeasible for use at the Site.

3.7.16 Disposal Options (Soil and Groundwater)

Potential disposal options considered for the Chambers Works FUSRAP Site include both onsite and off-site disposal, and associated transportation options.

Onsite soil disposal would require the creation of an engineered cell on land owned or acquired by USACE. Additional acreage would be needed for monitoring wells, a buffer zone, and retention ponds. For a disposal cell occupying the same footprint as the contamination, waste soils would be excavated and set aside in a temporary storage area while an impervious base is built onsite. The disposal facility would incorporate engineered barriers into the design of the bottom clay liner and multilayer cover systems which would provide isolation of the waste from the environment. With regards to construction of onsite radioactive disposal cells, various federal and state laws may apply regarding design requirements and waste acceptance criteria. For example, many states apply for delegable authority from the USEPA to operate the RCRA hazardous waste management program. States enact laws outlining the rules for management of hazardous wastes that are no less stringent than the federal RCRA for this purpose. Onsite disposal could also include using an existing DuPont RCRA-permitted disposal cell.

Under the off-site soil disposal options, contaminated materials would be excavated and either transported to a commercially-permitted disposal facility or a newly constructed facility for permanent disposal. All of the existing commercial disposal facilities for soil and debris use shallow land burial technology (i.e., trenches). For this disposal option, the receiving facility will be responsible for conducting long-term maintenance during the lifetime of the radiological landfill cell. The receiving facility would need to have all appropriate permits or licenses. Water would be discharged to a POTW, or surface water, as permitted. For placement in a newly constructed facility, the USACE would have to purchase land and construct a disposal cell in a fashion similar to that described above.

Onsite disposal options for groundwater include potential discharge to surface water, deep well injection, or discharge to the DuPont waste water treatment plant (WWTP). Under these scenarios, extracted and treated water would be either discharged straight into surface water bodies in the vicinity of the Site or routed through the existing WWTP. For deep well injection, the water may be either treated or untreated; it is extracted from the current formation and re-injected into a geologically isolated zone. Any disposal option would require the removal of dissolved uranium, radium and thorium.

For off-site groundwater disposal, the extracted and treated water would be discharged to a POTW or other treatment and disposal facility.

Truck, railcar, or barge transportation is a feasible option for both soil and groundwater. Trucks would be more suited for short to medium distances whereas railcars and barges would be used for long distance transport. With an active rail system onsite, adjacent to OU 1, the DuPont Chambers Works FUSRAP Site is situated conveniently near major transportation routes. Waste haulers would be registered with DOT and manifesting/labeling as necessary would be performed to facilitate such off-site transport.

Table 3-5: Identification and Screening of Technologies (Soils)

GRA	Technology Type	Process Options	Description	Screening Comments
Land Use Controls	Administrative and Legal	Governmental Controls	Land use controls may be placed on the site by a government entity to control the types of land use allowed.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of residual contamination left in place.
		Informational Devices	Registries, deed notices, and/or advisories may be used to notify future land owners of residual or capped contamination	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of residual contamination left in place.
		Proprietary Controls	Contractual mechanisms based on private property law (e.g., deed covenants, easements) may be placed on the site to prevent a landowner from disturbing contaminated soil, sediment, or groundwater.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of residual contamination left in place.
	Physical Mechanisms	Physical barriers, permanent markers, and/or security personnel	Access to an area can be restricted through the use of fences, signs, or security surveillance.	Potentially applicable. Will be used in conjunction with all alternatives during implementation to prevent incidental exposure to contaminated soil.
Monitoring	Environmental Monitoring	Groundwater, surface water, sediment and air	Various types of environmental monitoring may be instituted to detect contaminant migration.	Potentially applicable. Required with remedies where waste is left in place. May be used during or after construction activities to ensure contaminants are not migrating from source area or to verify remedies are effective.
Containment	Capping	Native soil, clay, synthetic liner, multilayered, asphalt or concrete	Area of contamination covered with a layer of clean soil, clay, synthetic liner, multiple layers of different media, asphalt, or concrete.	Potentially applicable. Requires long-term maintenance and limits future use. Capping technology could be used in conjunction with other components of a remedial action to ensure compliance with ARARs.
Removal	Soil excavation	Earth moving equipment	Mechanically or hydraulically operated units such as excavators, front-end loaders, and bulldozers, and/or hand tools are used for trenching or other subsurface excavation.	Potentially applicable for excavating, loading, and moving contaminated soils.

GRA	Technology Type	Process Options	Description	Screening Comments
Treatment	Physical	Encapsulation	*Ex situ* physical encapsulation of wastes in an organic binder or resin.	Not applicable due to the large volume of fine grained soils present at the site.
		Thermoplastic Solidification	*Ex situ* process whereby waste is sealed in asphalt bitumen, paraffin, or polyethylene matrix.	Not applicable due to likely increase of volume of soil contamination present at the site.
		Stabilization/Solidification	Can be carried out *in situ* or *ex situ*. Soil solidified using various cements and silicate-based mixtures as solidifying agents. The resulting solids are resistant to leaching.	Potentially applicable. Potentially limits future reuse if done *in situ*. Typically results in increased volumes.
		Vitrification	Can be carried out *in situ* or *ex situ*. Inorganic and nonvolatile metallic constituents are immobilized in a glass matrix.	*Ex situ* vitrification is potentially applicable
				In situ vitrification limits future reuse of site and effectiveness is difficult to verify. *In situ* vitrification is eliminated from further consideration.
		Soil washing	*Ex situ* physical separation of impacted material in an aqueous base, concentrating COCs.	Potentially applicable. Typically requires other physical and chemical processes to more effectively treat soils.
		Soil sorting	Physical *ex situ* separation of impacted materials based on radionuclide concentration and/or particle size.	Potentially applicable.
	Chemical	Chemical oxidation/ reduction	Appropriate chemicals added to raise or lower the oxidation state of the reactant.	Not applicable for COCs identified at the Site. Potentially large amounts of chemical waste products will be generated and require additional waste treatment and disposal.
		Chemical soil washing	A process similar to physical soil washing; however, chemicals are used as the wash fluid.	Not applicable for COCs identified at the Site. Produces extraneous waste stream that may be difficult to treat.
		Hydrolysis	Involves a reaction with an organic chemical and water or hydroxide ion to break the chemical down to a simpler, less toxic form.	Not applicable for COCs identified at the Site.
		Neutralization	Chemicals are injected into saturated and/or unsaturated soil strata to adjust the pH of the soil and/or groundwater.	Not applicable for COCs identified at the Site.
		Stabilization	Chemicals added to bind waste into a form that is resistant to leaching of contaminants.	Not applicable for COCs identified at the Site.

GRA	Technology Type	Process Options	Description	Screening Comments
Treatment (Cont'd)	Biological	Biodegradation	Processes include slurry-phase and solid-phase biodegradation, and anaerobic biodegradation. These are destruction or transformation techniques in which a favorable environment is created for microorganisms to grow and use the contaminants as a food or energy source.	Not applicable for COCs identified at the Site.
	Thermal	Incineration	Processes use heat to volatilize contaminants. There are various forms of thermal treatment technologies as follows: incineration, infrared, retorting, pyrolysis, low temperature thermal desorption.	Not applicable for COCs identified at the Site.
Disposal and Handling	Onsite Disposal	Onsite engineered structure	Design and construct a disposal facility onsite.	Potentially applicable.
	Off-site Disposal	Existing permitted disposal facility	Transport treated and/or untreated soils meeting waste acceptance criteria to an off-site disposal facility.	Potentially applicable if contaminants are within facility's waste acceptance criteria.
		New engineered structure	Construct an engineered structure, such as a tumulus disposal trench, above ground or underground vault, underground silos, etc.	Potentially applicable.
	Transportation	Truck, railcar and/or barge	Trucks, railcars and/or barges could be used to transport soil waste to disposal facility via roadway, railway or waterway.	Trucks would be more suited for short to medium distances. Railcars would be more suited for long distance. Barges are suited for transportation over large bodies of water.

Note: Shading indicates that the technology or process option was eliminated from further consideration.

Table 3-6: Identification and Screening of Technologies (Groundwater)

GRA	Technology Type	Process Options	Description	Screening Comments
Land Use Controls	Administrative and Legal	Governmental Controls	Land use controls may be placed on the site by a government entity to control the types of land use allowed.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of contamination left in place.
		Informational Devices	Registries, deed notices, and/or advisories may be used to notify future land owners of groundwater contamination	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of contamination left in place.
		Proprietary Controls	Contractual mechanisms based on private property law (e.g., deed covenants, easements) may be placed on the site to prevent a landowner from using groundwater.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of contamination left in place.
	Physical Mechanisms	Physical barriers, permanent markers, and/or security personnel	Access to an area can be restricted through the use of fences, signs, or security surveillance.	Potentially applicable. Will be used in conjunction with all alternatives during implementation to prevent incidental exposure to contaminated groundwater.
Monitoring	Environmental Monitoring	Groundwater	Perform water quality analyses to monitor contaminant migration and assess future environmental impacts.	Potentially applicable. May be used to assist with contaminant control during soils remedial action activities and to monitor performance of the treatment alternatives.
Containment	Vertical Barriers	Sheet Piles, Geosynthetic Membrane, Slurry Walls, Jet Grouting, Soil Freezing, and Hydraulic Barriers	Vertical barriers minimize contaminant migration in groundwater by providing a physical barrier to the natural flow path of an aquifer. Although all barrier technologies have a similar application, they have widely varying designs and installation procedures.	Potentially applicable.
Removal	Extraction wells	Vertical Wells	Vertical wells remove groundwater from aquifers or perched water zones.	Potentially applicable. Dependent on properties of aquifer and well construction. May be used in conjunction with other remedial technologies.

GRA	Technology Type	Process Options	Description	Screening Comments
		Horizontal Wells	Horizontal well screens provide greater surface area in contact with the contaminated soil or groundwater; fewer wells may be required. Directionally drilled horizontal wells can be installed beneath surface structures.	Potentially applicable. Dependent on properties of aquifer and well construction. May be used in conjunction with other remedial technologies.
Ex Situ Treatment	Physical Treatment	Air Stripping/ Packed Tower	Large volumes of air are mixed with water in a packed tower to promote partitioning of VOCs to air.	Not applicable for uranium.
		Evaporation Ponds (natural)	Water is evaporated to concentrate contaminants present in liquids.	Not applicable for uranium.
		Crystallization	Process in which certain solutes crystallize out from a saturated solution when the solvent is cooled.	Not applicable for uranium. Requires chemical addition and is very energy intensive.
		Flocculation/ Precipitation	Physical process to promote flocculation of colloids. The resultant particles are too large to remain in suspension	Potentially applicable for uranium.
		Physical Catalysis	A physical process used to accelerate a chemical change of a contaminant.	Not applicable for uranium.
		Dissolved Air Flotation	Minute air bubbles, introduced by pressurization/ depressurization means, rise to the surface carrying low-density solids.	Not applicable for uranium.
		Ultra/Micro/ Nanofiltration	A membrane filtration process that separates high molecular weight solutes or colloids from their surrounding media.	Not applicable for uranium.
Ex Situ Treatment (con't)	Physical Treatment (con't)	Reverse Osmosis	Pressure is applied to force flow from dilute to concentrated solution through a membrane that is impermeable to a solute (dissolved ions).	Potentially applicable.

GRA	Technology Type	Process Options	Description	Screening Comments
		Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water.	Potentially applicable for uranium. Spent resin generates a concentrated waste stream.
		Sedimentation	Suspended particles are allowed to settle depending on the particle diameter and specific gravity in a basin or pond enclosure.	Potentially applicable as a post treatment step.
In Situ Treatment	Physical	Permeable Treatment Walls	Trenches are excavated perpendicular to groundwater flow and filled with a reactive permeable natural or synthetic medium to treat or adsorb contaminants.	Not applicable due to uncertain variations in flow gradient. Primarily used for organic compounds.
		Liquid Gas Extraction	Uses gases (CO2, propane) to alter properties of solvents to make extraction of organics more rapid and efficient.	Not applicable for uranium.
		Vacuum Extraction	Vacuum pumps are connected via a pipe system to a series of production wells to remove VOCs from groundwater.	Not applicable for uranium.
		Air Sparging	Horizontal wells are placed in saturated soil strata where air is introduced to cause the volatilization of organic contaminants.	Not applicable for uranium.
		Chelation	Chelating molecules form ligands with metal ions and are used to keep metals in solution and aid in dissolution.	Not applicable for uranium.
In Situ Treatment (con't)	Physical (con't)	Electrokinetics	Electrodes are installed and electrical power used to drive contaminants to the anode for collection in an electrolyte solution.	Potentially applicable for uranium.

GRA	Technology Type	Process Options	Description	Screening Comments
		Monitored Natural Attenuation (MNA)	Passive observation of treatment processes that occur naturally. These processes may be physical, chemical, or biological, but in this case the major process would be chemical immobilization of uranium.	Potentially applicable. MNA may be naturally occurring as uranium migrates into areas of lower ORP. MNA can be a component of a remedial alternative along with the use of other measures, such as source control.
	Chemical	Chemical Hydrolysis	Chemical decomposition by hydrolytic reactions.	Not applicable for uranium
		Geochemical Immobilization	Wells are drilled and a reducing agent is injected into the formation to chemically change the solubility of uranium.	Potentially applicable.
	Biological	Bioremediation	Groundwater is amended with oxygen (aerobic), or an electron donor (anaerobic), nutrients, and microorganisms (optional).	Not applicable. The process (even if used anaerobically) would not rely on biological activity. See Geochemical Immobilization.
	Thermal	Incineration, distillation, steam stripping, evaporation, super critical water oxidation, and wet air oxidation	Processes use the liquid/gas interface to remove contaminants and oxygen to change chemical compounds.	Not applicable. Energy intensive. More applicable to organic compounds.
Disposal and Handling	Onsite Disposal	Discharge to Surface Water	Extracted and treated water discharged to surface water in the vicinity of the site.	Potentially applicable.
		Deep Well Injection	Treated or untreated groundwater is injected into an isolated zone.	Potentially applicable.
		Discharge to DuPont WWTP	Extracted and treated water discharged to existing site WWTP.	Potentially applicable.

GRA	Technology Type	Process Options	Description	Screening Comments
	Off-site Disposal	Dispose/ Discharge to POTW or Other Disposal Facility	Discharge treated water to POTW or other treatment or disposal facility.	Potentially applicable.
	Transportation	Truck, Railcar or Barge.	Trucks, railcars and/or barges could be used to transport groundwater waste to disposal facility via roadway, railway or waterway.	Potentially applicable. Trucks would be more suited for short to medium distances. Railcars and barge would be more suited for long distance.

Note: Shading indicates that the technology or process option was eliminated from further consideration.

3.8 Evaluation of Technologies and Process Options

In this section, the technology processes considered to be implementable are evaluated in greater detail before the selection of representative technologies that are then assembled as remedial alternatives. The technologies are evaluated in terms of effectiveness, implementability and cost criteria, as described below. A summary of the evaluation of remedial technologies and process options is presented in Table 3-7 for soils and Table 3-8 for groundwater.

Effectiveness at this point will be evaluated based on a consideration of (1) the potential effectiveness in handling the estimated areas or volumes of media and meeting the RAOs; (2) the potential impacts to human health and the environment during construction and remediation; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the site.

The criterion of effectiveness measures the ability to effectively protect human health and the environment by reducing the toxicity, mobility, or volume of contaminants. Short-term protection involves reducing existing risks to the community and workers during implementation of remedial actions. The ability of a technology to meet RGs was evaluated. The time required for the technology to achieve the RGs was also considered, including the potential length of exposure to which the local public may be subjected. The criterion also includes long-term protectiveness and addresses the magnitude of residual risk and the long-term reliability. The technologies were also evaluated for their effectiveness in preventing further exposure to residual contamination.

Implementability encompasses both the technical and administrative feasibility of implementing a technology process. The assessment of short-term technical feasibility considers the ability to construct the given technology and the short-term reliability of the technology. The evaluation of long-term technical feasibility considers the following factors: the ease of undertaking additional remedial action if necessary; monitoring the effectiveness of the given remedy; O&M requirements; administrative feasibility for implementing a given technology by reviewing the ability to obtain approvals from other agencies; the likelihood of favorable community response; and the need to coordinate with other agencies.

Cost is evaluated in a comparative manner (i.e., low, moderate, or high) for technologies of similar effectiveness or implementability. The cost criterion includes capital costs and O&M costs. O&M costs are estimated for a 1,000 year period where there are hazardous substances, pollutants, or contaminants that may pose a threat to human health or the environment remaining at the site. Costs for each technology are rated qualitatively on the basis of engineering judgment as high, moderate, or low by comparison to the costs of similar technologies.

3.8.1 Administrative and Legal Mechanisms (Soil and Groundwater)

If any remedial alternative developed during the FS requires a restricted land use in order to be protective, the alternative should include components that will ensure that the remedy remains protective. As described in Section 3.5.2, LUCs are one type of control used to protect public health and the environment from residual contamination. Controls at the Site would be set in place to ensure that the property would not be used for residential purposes; that groundwater would not be used for any purpose; that gardens would not be planted on the property and that no construction of any type would be allowed without the written approval of the USACE and/or DOE as the designated federal government agency responsible for long-term operation and maintenance at the Site.

Effectiveness: LUCs increase protection of human health and the environment over baseline conditions by limiting direct access to the site using site security measures, and by limiting use of the site via deed or land-use restrictions. The Site is currently fenced with signs and other security measures and access is strictly controlled by DuPont personnel.

Although the use of LUCs would not address contaminated media, future risk would be maintained at acceptable levels as a result of access and land-use restrictions. To accomplish this, the Federal Government would need to purchase property outright, negotiate deed restrictions with property owner, or land-use restrictions would have to be imposed by appropriate state or local governmental authority.

LUCs would ensure that groundwater will not be available for future use at the site. Restrictions on groundwater use offer a means of land use control for the Site. Ground water is not presently a source of drinking water, and its potential future use could be prohibited by denying all permits to install new wells.

Implementability: Deed restrictions can be implemented, but may require negotiations and agreements with DuPont. It would be possible to secure land-use restrictions through the various zoning jurisdictions in the area, but present uses would not be affected; only future uses would be governed by new land-use regulations. Security measures can limit site access and potential exposure.

LUCs would not be difficult to implement at the Site because the Site has one private owner. Deed notices or land use restrictions can be applied to prevent, limit, or require permits for excavation, construction, or any other activity that may disturb soils. Coordination between state and local authorities would be required to enforce well permitting restrictions. Ongoing monitoring of groundwater would be used to identify any spread of contamination that would require imposing new deed restrictions. Coordination with the public health department, state, and local governments would be required to restrict the issuance of well installation permits. If the Federal Government purchases the property, it can place conditions, covenants, or restrictions in the deed as it deems appropriate, so long as the restrictions are compatible with state laws. However, currently USACE must negotiate any deed restrictions with the Site owner, DuPont. The deed restrictions would exist in perpetuity. Land-use restrictions secured from local governments could limit or bar future site development or use by rezoning the property.

Cost: The cost estimate for implementing LUCs would include low to moderate capital and low O&M costs. Although unlikely, the costs associated with imposition of LUCs must include the costs of acquiring landowner property rights. Potential legal fees and compensation for deed restrictions and property purchases could increase the costs of this alternative. Deed restrictions negotiated with property owner could generate significant legal fees, depending on the length and success of negotiations. The lower bounding cost would be only legal fees; however, the upper bounding cost would be full purchase of properties at fair market value.

Evaluation Results: Administrative and legal mechanisms, retained as representative technologies, include physical barrier signs, access restrictions, land use notices, easements, deed notices, well use advisories, well drilling prohibitions, zoning restrictions, and government ownership.

3.8.2 Environmental Monitoring

Air Monitoring: Short-term monitoring of unremediated soil areas would consist of radiation surveys to determine if contaminated particulate or gamma levels are exceeding proposed levels protective of human health.

Sediment Monitoring: As there is a potential for migration of soil contaminants into the CDD during excavation activities, periodic monitoring of sediments in the CDD would be conducted in conjunction with the excavation-based remedial alternatives. Contaminant concentrations would be monitored downstream in areas of known sediment deposition and quiescent flow conditions and would be compared with background samples. The degree of monitoring required, whether a short-term assessment or long-term monitoring of CDD sediments, would be determined by the selected remedial action.

Groundwater Monitoring: Groundwater monitoring would consist of radiological and chemical analyses of samples collected from groundwater underlying OU 1 and AOC 6. Monitoring would be implemented using upgradient and downgradient wells in order to assess potential impacts from contaminated soils.

Surface-Water Monitoring: Surface-water monitoring includes chemical and radiological monitoring of surface waters in order to determine whether dissolved contamination is present and whether it has any adverse environmental or health safety impact.

Soil Monitoring: Periodic monitoring of surface and subsurface soils would determine whether contaminants are migrating into undisturbed areas. The degree of monitoring required and the duration of continuing monitoring activities would be determined by the selected remedial action.

Effectiveness: Monitoring programs for soil and groundwater would be effective for determining the migration of radiological contaminants present at the Site.

Implementability: The monitoring programs would be easy to implement.

Cost: The estimated cost is low to moderate.

Evaluation Result: Groundwater and soil monitoring programs are retained as part of remedial alternatives.

3.8.3 Capping (Soil)

A multilayer cap is a potential containment technology that could be utilized at the Chambers Works FUSRAP Site to achieve the 15 mrem/yr dose criterion. Contaminated soils would be covered in place with a low permeability cap. The multilayer cap would reduce the potential for human exposure to underlying contaminated materials; it would also reduce both the migration of contaminants into surface water and groundwater and the generation of fugitive dust.

Effectiveness: A multilayer cap is a proven, effective technology that provides a physical barrier between receptors and contaminated soils. The cap would reduce the potential for direct contact (absorption, ingestion, or inhalation) and would minimize potential exposure to external gamma radiation. It would also minimize water infiltration and would reduce the mobilization of contaminants by leaching from soil to groundwater. Mitigation measures and proper safety procedures could control the possible short-term increased risk from fugitive dust emissions during construction. This option would require both LUCs to limit use of or access to the site and environmental monitoring to detect breaching of the cap and contaminant migration. The major disadvantage of the capping alternative is the fact that existing groundwater contamination and soil contamination located below the water table are not addressed. Radionuclides present in the saturated soil would still be capable of migrating into groundwater. Existing groundwater contamination by itself produces a dose more than 100 mrem/yr for the ACF scenario. The ARAR, NJAC 7:28-12.11(e) would not be met.

Implementability: Although no technical problems are anticipated that would limit the implementability, containment options at some FUSRAP sites have been opposed by several local stakeholders, including government officials. In addition, capping would require perpetual maintenance. Capping is a well-established technology and would be implementable at the Site. Some clearing and grubbing, rerouting of utilities and other site preparation activities would be required before the cap could be constructed. Site monitoring would be required for as long as the media under the cap represents a threat to human health and the environment.

Cost: Capping would have lower capital and O&M costs than the onsite disposal cell option. The capital costs of capping would be lower than soil excavation and off-site disposal. The capital costs include transportation of capping materials to the site, and installation of a cap. O&M costs would consist of the long-term monitoring requirements. Overall the estimated cost for capping is moderate.

Evaluation results: The capping option has been shown to be an effective means of preventing human exposure to underlying contaminated materials. However, in accordance with NJAC 7:28-12.11(e) capping, as an engineered control, could potentially fail at some time in the future and the resulting dose must not exceed 100 mrem/yr. Although capping would meet the requirements of NJAC 7:28-12.8(a)(1), it does not satisfy NJAC 7:28-12.11(e), the ACF scenario. As shown in Table 2-1 the resulting dose to an onsite resident would be 1547 mrem/yr in OU 1, primarily from the groundwater ingestion exposure pathway. For this reason, the multimedia cap is excluded from further consideration in this FS.

3.8.4 Soil Excavation (Soil)

Effectiveness: Soil excavation is protective of human health and the environment, and it achieves the RAOs for the soil. The future residual risk would be reduced and compliance with ARARs would be achieved. Exposure from fugitive dust, external gamma radiation, contaminants leaching into groundwater, and contaminated surface-water runoff would be greatly reduced. Short-term risks, including non-radiological occupational injuries and risk of fatalities as well as transportation risk, would increase as the volume of soil being handled and moved increases. During implementation, there would be possible short-term risk from fugitive dust emissions, which would be readily manageable by means of implementation of a health and safety plan and an environmental protection plan. Although air quality could be adversely affected by increases in airborne particulates, mitigation measures such as dust suppression methods and proper safety procedures could be implemented to minimize any increased risk to the community or to onsite workers during implementation. Additional measures may be needed during the remedial design to minimize or prevent contamination resulting from runoff in the areas of the excavation. There would be the potential risk of encountering non-FUSRAP chemical constituents in groundwater during the dewatering and excavation process.

Implementability: Soil excavation uses readily available resources and conventional earth-moving equipment. Some ancillary construction of temporary roads, a staging area for loading and unloading, soil erosion control, excavation dewatering, water treatment, and additional clearing and grubbing may be necessary. Transportation and disposal of wastes are technologies that are generally combined with excavation.

Cost: Costs related to soil removal are moderate to high.

Evaluation Results: Excavation using earth-moving equipment has been retained as a representative technology.

3.8.5 Stabilization/Solidification (Soil)

Effectiveness: Immobilization technologies are one of the most proven and often performed remediation technologies. It has been successfully used on radioactive and mixed waste sites to reduce the solubility and mobility of contaminants in groundwater and soils. These techniques are accomplished either in-situ, by injecting a cement based agent into the contaminated materials or ex situ, by excavating the materials, machine-mixing them with a cement-based agent, and depositing the solidified mass in a designated area. The goal of the process is to limit the spread, via leaching, of contaminated material. The end product resulting from the solidification process is a monolithic block of waste with high structural integrity. Treatment of soils by solidification would pose minimal risks to the local community and workers. Some dust may be generated during excavation; however, the amount generated would be equivalent to that generated with any alternative requiring excavation and soil handling. While most solidification processes reduce the mobility of contaminants but do not reduce the radioactivity of the waste, they are typically most effective at treating mixed waste to meet disposal facility acceptance criteria. Solidification also results in a significant increase in volume (up to double the original volume), which will further increase costs, including transportation and disposal costs.

As presented in Section 2.2.3.1, a coal-tar-like substance (LNAPL) was encountered at the top of the B Aquifer during field investigations. Therefore, some excavated soils from OU 1 may contain both radionuclides of concern and hazardous concentrations of organics (volatile and semi-volatile). As defined mixed waste contains both RCRA hazardous and AEC-regulated radionuclides (i.e., licensed source, special or byproduct material), therefore, the resultant waste material from OU 1 may not be classified as mixed waste from a regulatory standpoint. However, since the material may have the properties of mixed waste, it would be treated as such.

Implementability: Soils would require excavation and transport to a central staging area for onsite treatment. The solidified materials would be greater in volume than the original waste material. The immobilized waste would then be manifested and sent off-site for disposal at a permitted disposal facility depending on the specific waste streams. Qualified vendors and equipment are readily available to perform this treatment operation.

Cost: Capital costs would be moderate to high. The disposal costs would be significantly increased with this treatment alternative due to the increased volume of waste requiring disposal.

Evaluation Result: Due to the potential for significant increased volume, and thus increased costs associated with disposal, solidification has been eliminated from further consideration.

3.8.6 Ex Situ Vitrification (Soil)

Effectiveness: Vitrification is effective at immobilizing contaminants and thereby minimizing the migration of contaminants. Vitrification is typically used on highly concentrated mobile contaminants unlike those present at the Site. Vitrification poses a much higher risk to onsite workers as compared to the other treatment operations due to the extremely high temperatures and specialized equipment used.

Implementability: Vitrification has been used successfully to treat radioactive contaminants on other projects, but generally for much higher concentrations of contaminants and for much smaller quantities of wastes. While some volume reduction occurs during the melting, the total volume of the final waste material often increases due to the addition of glass formers. In addition, the increased volume of material would still require disposal at a permitted facility. Qualified vendors and equipment are readily available to perform this treatment operation.

Cost: High

Evaluation Result: This technology has not been retained.

3.8.7 Soil Washing

Effectiveness: Soils containing a large amount of clay and silt such as occurs in OU 1, are not typically effectively treated by soil washing alone. Soil washing enhanced with chemical extraction has been proven effective for reducing the levels of contamination at other FUSRAP sites.

The soil washing treatment system would be located onsite. The clean soils from the treatment operations could be placed back onsite or beneficially reused at another location. The smaller volume or contaminated waste stream would be sent off-site for disposal. Much of the water used for the soil washing system will be recycled back into the system. A disposal alternative will be required for any waste water removed from the system during operation and for the balance of the waste water at the completion of the treatment process. Approval would be required from DuPont to discharge any water generated from the soil washing process to the DuPont WWTP. The time required to treat the Site materials by soil washing is anticipated to be shorter than the treatment times required for soil sorting and vitrification.

Implementability: The soil washing system could be located onsite, and soils could be trucked from the surrounding areas to the treatment system for processing. Qualified vendors and equipment are readily available to perform this treatment operation.

Cost: Moderate (assuming that the treatment is conducted onsite and the cleaned soil from the treatment operation can be directly placed back onto the site as backfill).

Evaluation Result: Soil washing has been retained as a representative technology.

3.8.8 Soil Sorting

Effectiveness: Soil sorting has been used successfully to treat radioactive waste contaminated primarily with gamma emitters such as uranium. Its effectiveness relies on the assumption that sorted soils below the RG may be reused onsite as backfill. Field tests would be required to determine system sensitivity, volume reduction capability, and processing times. Due to the slower processing rate (as compared to soil washing) multiple soil sorting lines may be required. No process additives are required for the soil sorting system, and no process water would be generated.

Implementability: Adequate space exists to locate the soil sorting system. Soils would be transported to a centralized area for staging and processing. Soils that are too moist would require drying prior to processing. Rubble would require crushing or sorting to a maximum particle size of 2 inches prior to loading on any segmented gate system. It is assumed that sorted soils from the sorting operation, i.e. below RGs, would be beneficially reused onsite. The reduced volume of contaminated soil would be sent off-site for disposal. Qualified vendors and equipment are available for this treatment operation.

Cost: Moderate

Evaluation Result: Soil sorting has been retained as a representative technology.

3.8.9 Onsite Disposal (Soil)

Under this option, an encapsulated, above-ground disposal cell would be constructed at the Site. Contaminated soils at the proposed disposal site location would be excavated and replaced with fill material. At closure, wastes would be covered by a multimedia cap to control erosion and minimize generation of leachate resulting from rain-water infiltration.

Effectiveness: The engineered onsite disposal cell, if installed, operated, and maintained properly, would provide an effective and reliable means of isolating the wastes at the Site and would reduce the potential for human exposure to site contaminants. USACE and DuPont would have to discuss possible locations for construction of the disposal cell. This option would require land-use restrictions at the proposed disposal site to eliminate risks associated with direct contact with the waste in the future. Potential short-term risks to workers and the community resulting from excavation and construction activities would be considered. The risk to the public due to construction of the onsite disposal cell would not be expected to be significant because public access to the Site is currently restricted by DuPont security measures. The construction activities would cause short-term impacts to surrounding land uses (such as traffic delays and additional noise and dust) and could negatively affect some DuPont activities. The construction of the cell and the installation of the cap would also increase the potential for construction workers to be exposed to COCs in the short term. Potential exposure pathways include ingestion, inhalation of particulates, dermal absorption, and external exposure to ionizing radiation. The short-term risks to a worker resulting from excavation activities, transport of wastes, and construction of an onsite cell are not expected to exceed acceptable limits due to implementation of a site health and safety plan and the use of mitigation measures such as dust suppression methods.

Implementability: Implementation of the onsite disposal cell option is technically feasible. Construction of an onsite disposal cell is very feasible because materials for construction are commercially available and because no specialized equipment is necessary for installation. Additionally, no specialized workers are necessary for implementation of this action. Other aspects of the alternative, such as truck transport of soil, construction of temporary roads, use of staging area for loading and unloading, soil erosion control, excavation dewatering, and clearing and grubbing, are conventional activities in construction projects of this kind. Special engineering techniques involving precautions on excavation near buildings and structures would be observed during remediation.

Cost: This option would have high capital and moderate O&M costs. The cost of constructing and maintaining a new cell is high when compared to the cost of disposal at an off-site permitted disposal facility with similar features and performance.

Evaluation Result: The ability of USACE to locate an area on the Chambers Works property to site an acceptable disposal cell and the potential negative public reaction to a newly constructed unit would limit implementability of this option. In addition, the time required to coordinate acceptable locations within DuPont's property and to obtain design approval for the disposal cell could potentially cause delays in implementation of that option. Besides, the onsite radioactive disposal cells would be subjected to various Federal and state permit requirements regarding design requirements and waste acceptance criteria. Therefore, this technology has not been retained.

3.8.10 Off-Site Disposal (Soil)

The off-site disposal options under consideration include the use of an existing facility and construction of a new disposal facility. An existing facility would have appropriate State and Federal permitting requirements in place whereas construction of a new facility would need to go through the complicated and lengthy permit application process.

Effectiveness: USACE has reviewed the disposal practices used on previous cleanups and has established contracts with multiple permitted disposal facilities. Off-site disposal at existing facilities would be effective in terms of containing wastes generated at the Chambers Works FUSRAP Site remediation.

Implementability: The implementability of the disposal options would vary in terms of design, siting, and construction. A number of properly permitted facilities are available within the United States that could serve as locations for disposal of some or all Site wastes. This option therefore would be readily implemented. A number of commercial facilities have permits or licenses to receive the waste materials at this site. The material that can be accepted by the facilities varies with the terms and conditions in their license or permit. Construction of a new off-site disposal cell would be difficult to implement. Issues regarding the difficulty in locating an appropriate site and obtaining all required permits would pose significant delay in initiating remediation.

Cost: The cost of disposal at a permitted disposal facility is low to moderate.

Evaluation Result: Disposal of soils and debris at permitted facilities is retained as a remedial option. Construction of a new off-site disposal facility has not been retained.

3.8.11 Vertical Barriers (Groundwater)

Effectiveness: Vertical barriers can be effective for groundwater in the short term, but not in the long term due to potential degradation of the seal around the area of contamination.

Implementability: Vertical barrier implementability varies from easy to moderate depending on the type of barrier used.

Cost: Capital costs related to vertical barriers are moderate to high depending on the size of the area needing containment.

Evaluation Result: Not retained

3.8.12 Vertical and/or Horizontal Extraction Wells (Groundwater)

Effectiveness: Vertical wells are an effective option for groundwater extraction, but only for the short-term if the option is not accompanied by source removal. Vertical wells are retained as a potential option for use in conjunction with source removal.

Horizontal wells are effective for large areas of contamination where there is a well-defined plume. The groundwater contamination at the Site does not meet these characteristics. Contamination is found in only three or four scattered wells, making it difficult for horizontal wells to be effective. Therefore, horizontal wells were eliminated from further consideration.

Implementability: Vertical wells are easily implementable and resources are widely available commercially for installation. Horizontal wells would be hard to implement because of the lack of a well defined plume. This would lead to difficulties in correct placement of wells to achieve complete extraction.

Cost: Costs are low for both vertical and horizontal wells.

Evaluation Result: Groundwater extraction using vertical wells is retained.

3.8.13 Precipitation/Flocculation/Sedimentation (Groundwater)

Effectiveness: While all of these processes have been shown to be effective for removing metals and radionuclides from groundwater, the process options require extensive pilot studies to determine overall effectiveness. As these are *ex situ* processes, they would be implemented in conjunction with the vertical extraction wells technology described in Section 3.8.13.

Implementability: Hard

Cost: Low

Evaluation Result: None of these processes were retained for further evaluation.

3.8.14 Reverse Osmosis (Groundwater)

Effectiveness: Reverse osmosis is a general process for removing metals and other contaminants. It has been used for removal of uranium. Treatability studies would need to be performed to determine the efficiency with changes in temperature, pH, etc.

Implementability: Reverse osmosis is easily implemented, although retention time, fouling, and degradation may be issues of concern. As this is an *ex situ* process, it would be implemented in conjunction with the vertical extraction wells technology described in Section 3.8.13

Cost: Costs associated with reverse osmosis are moderate to high depending on the type of membrane necessary to remove the specific contaminants and the efficiency of the process.

Evaluation Result: Retained

3.8.15 Ion Exchange (Groundwater)

Effectiveness: Ion exchange is an effective process option for removing dilute concentrations of toxic metals and other inorganics from wastewater. The resins may be regenerated and reused.

Implementability: Ion exchange is easily implemented. As this is an *ex situ* process, it would be implemented in conjunction with the vertical extraction wells technology described in Section 3.8.13

Cost: Costs associated with ion exchange are moderate to high depending on the type of resin necessary to remove the specific contaminants.

Evaluation Result: Ion exchange is retained.

3.8.16 Electrokinetics (Groundwater)

Effectiveness: Electrokinetics is an *in situ* treatment technology used at several sites to drive metal contaminants through moist or saturated soils to an electrode where they are collected and removed from the subsurface. While it is one of the few technologies that can remove metal contaminants from soils and groundwater as opposed to immobilizing them, overall treatment time can be slow, thus requiring additional electrode installation and power supplies.

Implementability: Although electrokinetics has been implemented at comparatively few sites, the equipment and materials are proven and readily available. The electrode technology is comparable to that used in the chlor-alkali industry and the membranes are comparable to those used in reverse osmosis applications. Standard well drilling and power generation processes complete the technology.

Cost: Costs associated with electrokinetics are considered moderate, although a requirement to minimize treatment time can drive costs higher, as more electrodes and power are necessary to achieve shorter treatment times.

<u>*Evaluation Result*</u>: Not retained

3.8.17 Monitored Natural Attenuation (Groundwater)

<u>*Effectiveness:*</u> MNA would reduce contaminant concentrations below RAOs at the site. The timeframe for reduction varies as a result of lithology and contaminant characteristics. Monitoring of groundwater to date at the Site has shown that the expected immobilization of uranium occurs within a short distance of soil-contaminated areas or source zones, where the groundwater becomes reduced (low ORP). As the RI report indicates, future conversion of site groundwater to oxidizing conditions could potentially mobilize uranium in groundwater.

<u>*Implementability:*</u> MNA requires extensive site characterization and monitoring until concentrations in groundwater reach RAOs, but it can be readily implemented.

<u>*Cost:*</u> Costs associated with MNA are lower than costs associated with most active remediation measures.

<u>*Evaluation Result*</u>: Monitored natural attenuation is retained.

3.8.18 Geochemical Immobilization (Groundwater)

<u>*Effectiveness:*</u> Geochemical immobilization is an *in situ* technology that stabilizes metal contaminants without creating a solidified monolith. Although it does not remove metal contamination, geochemical processes are effective in transforming metal speciation and/or limiting the solubility of metals so that dissolved concentrations are less than concentrations of regulatory concern. One side effect of geochemical immobilization may be that, while immobilizing the target compound, other metals may be mobilized. In addition, the plumes appear to be immobilized by existing conditions (reduced groundwater), so little benefit would accrue from attempting to enhance the existing conditions.

<u>*Implementability:*</u> Standard well drilling processes would be used to create places to inject the reagents.

<u>*Cost*</u>: Costs for *in situ* geochemical immobilization are considered low.

<u>*Evaluation Result*</u>: Geochemical immobilization is not retained.

3.8.19 Onsite Discharge (Groundwater)

Under this option, any radioactive-contaminated groundwater would be treated prior to sending to the DuPont WWTP. If required further treatment of groundwater for non radioactive contamination would occur prior to discharge in accordance with DuPont's permit requirements. Since DuPont WWTP is not permitted to accept radionuclides, pretreatment of groundwater would be required. Under CERCLA, a permit is not required for discharge to a WWTP; however, some of the substantive requirements of a permit may need to be met.

Effectiveness: Good

Implementability: This feature needs DuPont concurrence and negotiations of any payment terms for USACE.

Cost: Moderate

Evaluation Result: Retained

3.8.20 Off-Site Disposal (Groundwater)

Under this option, either treated or untreated water could be sent to existing POTWs or other commercial wastewater disposal facilities, provided they are in compliance with the facility's permits and waste acceptance criteria.

Effectiveness: Off-site disposal of groundwater to a POTW or other wastewater disposal facility is considered effective. This option consists of using tanker trucks to transport either treated or untreated water to the facility for disposal.

Implementability: Off-site disposal of groundwater to a POTW or other wastewater disposal facility is an easily implemented option.

Cost: Costs for off-site disposal can be moderate to high, if treatment is required, and can vary depending on the distance to the nearest facility.

Evaluation Result: Due to the nature of contaminants present in the groundwater, it is very difficult to find POTW or wastewater disposal facilities that would accept the groundwater. Therefore, the off-site disposal option for groundwater was not retained.

3.8.21 Transportation Technologies (Soils and Groundwater)

Effectiveness: Truck and rail transportation have proven to be very effective in transporting contaminated materials for disposal during previous FUSRAP cleanup actions including the structural steel removal action conducted at Chambers Works.

Implementability: Transportation and disposal of contaminated soils and debris would use specially lined dump trucks, rail cars or intermodal containers (which can be transported by truck or rail). An active rail line, operated by DuPont, is located onsite near OU 1. Coordination and access fees would be coordinated with DuPont. If soil were moved out of state, coordination would need to be provided ahead of time to allow the waste to cross state lines. Because not all rail lines and highways can be used to transport waste material, a shipping route would need to be carefully laid out, and an emergency response procedure would need to be developed. The administrative feasibility of an out-of-state shipment would require coordination with the appropriate state and federal agencies. Barge access is not available unless truck transport is also used.

Cost: Low to moderate

Evaluation Result: Among rail, truck and barge, rails and trucks were retained for transportation of contaminated soil. There is an active rail line onsite near OU 1. For transportation of contaminated groundwater, all three options (rail, truck, and barge) are eliminated since off-site disposal is not retained as an option.

Table 3-7: Evaluation of Remedial Technologies and Process Options - Soil

GRA	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
Land Use Controls	Administrative and legal mechanisms	Government controls	Effective for mid to long term	Easy to moderate	Moderate	Retained
		Informational tools	Effective for short term	Easy to moderate	Low	Retained
		Proprietary controls	Effective for mid to long term	Easy to difficult	Moderate	Retained
	Physical mechanisms	Physical barriers, permanent signage, security patrols	Effective for short term in reducing exposure	Easy	Low to moderate	Retained
Monitoring	Environmental monitoring	Soil, groundwater, surface water, sediment, air	Does not reduce current risk but will inform future risk management decisions	Easy	Low	Retained
Containment	Capping	Clay, synthetic liner, multi-media, pavement	Effective to reduce leaching from the vadose zone and to reduce direct exposure, but failure would not meet threshold criteria	Easy to moderate	Low to moderate	Eliminated
Removal	Soil excavation	Earth moving equipment	Effective	Easy	Moderate to high (high where dewatering is required due to excavation below water table)	Retained
Treatment	Physical treatment	Stabilization/Solidification	Effective in immobilizing contaminants but likely to increase volumes and still requires disposal at permitted facility	Easy to moderate	Moderate to high (high where dewatering is required due to excavation below water table)	Eliminated
Treatment (con't)	Physical treatment (con't)	*Ex situ* vitrification	Effective in immobilizing contaminants but likely to increase volumes and	Moderate to difficult	High	Eliminated

GRA	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
			still requires disposal at permitted facility			
		Soil washing	Potentially effective, requires treatability studies. Effectiveness depends on contaminants' partitioning to fines.	Easy	Moderate to high	Retained
		Soil sorting	Potentially effective, requires treatability studies. Effectiveness does not depend on contaminants' partitioning to fines.	Moderate	Moderate to high	Retained
Disposal and Handling	Onsite disposal	New engineered structure	Effective	Difficult due to sitting/permitting requirements	Moderate to high	Eliminated
	Off-site disposal	Existing permitted disposal facility	Effective	Easy	Moderate	Retained
		New engineered structure	Effective	Difficult due to sitting/ permitting requirements	Moderate to high	Eliminated
	Transportation	Truck	Effective	Easy	Moderate (short distance) to high (long distance)	Retained
		Rail	Effective	Easy to moderate. Staging area must be established	Moderate (long distance)	Retained
		Barge	Effective	Easy to moderate. Dock loading areas must be established.	High	Eliminated

Table 3-8: Evaluation of Remedial Technologies and Process Options - Groundwater

GRA	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
Land Use Controls	Administrative and Legal Mechanisms	Government controls	Effective for mid to long term.	Easy to moderate	Moderate	Retained
		Informational Devices	Effective for short term.	Easy to moderate	Low	Retained
		Proprietary Controls	Effective for mid to long term.	Easy to difficult	Moderate	Retained
	Physical mechanisms	Physical barriers, permanent markers, security personnel	Effective for short term in reducing exposure.	Easy	Low	Retained
Monitoring	Environmental Monitoring	Groundwater monitoring	Documents site conditions. Does not reduce risk but will act as a preventative measure by providing information concerning changes in conditions.	Easy	Low	Retained
Containment	Vertical Barriers	Sheet Piles, Geosynthetic Membrane, Slurry Walls, Jet Grouting, Soil Freezing, and Hydraulic Barriers	Difficult to produce an effective seal due to nonhomogeneous strata and underground utilities. Plumes already appear contained by geochemical conditions.	Easy to moderate depending on type of barrier.	Moderate to high depending on extent and complexity of avoiding or rerouting utilities	Eliminated.
Removal	Extraction wells	Vertical Wells	Effective if accompanied by source removal	Easy	Low	Retained
		Horizontal Wells	Effective for large areas of contamination and/or under buildings	Moderate	Moderate to high	Eliminated
Ex Situ Treatment	Physical Treatment	Precipitation/flocculation/ sedimentation	Uncertain, requires treatability and perhaps pilot study	Easy	Moderate to high depending on sludge dewatering, handling and disposal	Eliminated

GRA	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
		Reverse Osmosis	Effective but subject to fouling and membrane replacement of water chemistry incompatible.	Easy	Moderate to high	Retained
		Ion Exchange	Effective for dissolved ions. May require pretreatment to remove suspended solids	Easy	Moderate to high	Retained
In Situ Treatment	Physical	Electrokinetics	Effective	Easy to moderate	Moderate to high, depending on power requirement and duration	Eliminated
		Monitored Natural Attenuation (MNA)	Effective while aquifer chemistry (pH, ORP) remains close to current values	Easy	Low	Retained
		Geochemical Immobilization	Effective for uranium but may mobilize other metals such as arsenic. Immobilization of uranium in groundwater is occurring naturally due to current geochemical conditions – this condition will be monitored as part of MNA option	Easy	Low	Eliminated
Disposal and Handling	Onsite Discharge	Discharge to surface water	Effective	Physically easy, administratively difficult	Moderate	Eliminated
		Deep well injection	Effective	Physically easy, administratively difficult	Low	Eliminated

GRA	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
		Discharge to DuPont WWTP	Effective	Physically easy, administratively moderate; requires pretreatment to remove radionuclides	Moderate to High; Depends on agreements with DuPont	Retained
	Off-site disposal	Discharge to POTW or commercial facility	Effective	Physically easy, administratively difficult	High	Eliminated
	Transportation	Truck	Effective but relies on off-site disposal which was eliminated above	Easy	Moderate to high	Eliminated
		Rail	Effective but relies on off-site disposal which was eliminated above	Easy	Moderate to high	Eliminated
		Barge	Effective but relies on off-site disposal which was eliminated above	Easy	Moderate to high	Eliminated

Note: Shading indicates that the technology or process option was eliminated from further consideration

3.9 Selection of Representative Technologies

The following technologies and process options for soil have been retained for use individually or in combination in the development of remedial alternatives:

- Land Use Controls
  - Physical Mechanisms
  - Legal and Administrative Mechanisms
    - Governmental Controls
    - Proprietary Controls
    - Informational Devices
- Environmental Monitoring
- Removal (Soil Excavation)
- Treatment (Soil Washing/Soil Sorting)
- Transportation and Disposal
  - Off-site Disposal at an Existing Facility
  - Transportation (Truck)
  - Transportation (Railcar).

The following technologies and process options for groundwater have been retained for use individually or in combination in the development of remedial alternatives:

- Land Use Controls
  - Physical Mechanisms
  - Legal and Administrative Mechanisms
    - Governmental Controls
    - Proprietary Controls
    - Informational Devices
- Environmental Monitoring (Groundwater)
- Removal (Vertical Extraction Wells)
- *Ex Situ* Treatment
  - Reverse Osmosis
  - Ion Exchange
- *In Situ* Treatment

    - Monitored Natural Attenuation
- Onsite Disposal
    - Discharge to DuPont WWTP

Remedial alternatives will be assembled from these categories and evaluated in detail, including specific itemized cost estimates for each, in Section 5.

4.0 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

4.1 Introduction

This section combines the remedial action technologies retained from preliminary screening (Section 3) to form remedial action alternatives. The alternatives cover a broad range from no action to complete removal of the contaminated materials. Emphasis was placed on developing alternatives that provide adequate protection of human health and the environment, achieve ARARs, and permanently and significantly reduce the volume, toxicity, or mobility of site-related contaminants. The development of remedial action alternatives for the Site focused on those alternatives that achieve the remedial action objectives presented in Section 3.2.

The rationale for combining response actions, technologies, and process options is briefly summarized below. The No Action response required by the NCP is the basis for identifying Alternative S1 for soils and Alternative GW1 for groundwater.

4.2 Contaminated Media and AOCs

The media of concern at the Site addressed by this FS are

- soils and debris
- groundwater

Each of the above media was evaluated independently. Appropriate alternatives for each medium were developed and analyzed separately. However, alternatives developed for each medium must be compatible with each other in remediating the contamination at the impacted areas of the Site. The discussions in Sections 4 and 5 therefore, identify any issues of compatibility. The most feasible remedial alternatives for each medium will be selected for the Proposed Plan and combined into a preferred sitewide alternative covering both soil and groundwater media.

The AOCs that are addressed by this FS are

- OU 1 (AOC 1 and AOC 2)
- AOC 6.

EPA guidance implementing CERCLA Section 104(d)(4) provides where two or more noncontiguous facilities are reasonably related on the basis of geography or threat to public health or the environment, and where wastes at these sites are compatible for a selected treatment or disposal approach, these related facilities may be treated as one site for response purposes. AOCs 1 and 2 contain similar types and degrees of FUSRAP-eligible contaminants and are contiguous and physically similar. Therefore, AOCs 1 and 2 were evaluated together, with evaluations of alternatives for soil and groundwater applying equally to both AOC 1 and AOC 2 as a single remedial unit (with some physically separate areas of remedial action). AOC 6 contains the same FUSRAP-eligible contaminants in soil and groundwater that are found in AOC 1 and AOC 2. Therefore, the same remedial alternatives were evaluated for AOC 6 as for AOC 1 and 2. However, AOC 6 differs from OU 1 in the following ways:

- Volume of contaminated soil at AOC 6 is approximately one-third of the amount of contaminated soil at OU 1; however, an active roadway and utilities are present within AOC 6 and may account for additional costs in this area. Therefore, costs related to remedial action at AOC 6 may differ significantly from costs for OU 1, based on the alternative chosen.
- Due to the presence of an important DuPont roadway and several active utility lines that cross AOC 6, re-routing of roadways and relocation of utility lines will be considered during selection of remedial action at AOC 6.
- AOC 6 is approximately 0.6 miles from AOCs 1 and 2. This distance may reduce the efficiency of using the same remedial alternatives at both locations.

Therefore, four lines of inquiry will be conducted in this FS, leading to the selection of a remedy in the Proposed Plan for the Site. These include

- OU 1 (AOC 1 and AOC 2) soils
- OU 1 (AOC 1 and AOC 2) groundwater
- AOC 6 soils
- AOC 6 groundwater

4.2.1 Soils and Debris

In AOC 1, the upper 6 to 8 feet of soil consists of backfill sand and rubble. Below 8 feet, clayey silt of the AB aquitard occurs to a depth of approximately 10 feet bgs in the northeastern portion of the AOC, but this unit thins and may not be present in the extreme southwestern portion. In AOC 2, the upper 0.5 to 11.5 feet consists of concrete, rubble, and debris. Below the fill material, the AB aquitard is present. Below the aquitard, there is a fining-upward sand unit with occasional gravel lenses. This unit extends to a depth of approximately 20 ft bgs and corresponds to the B Aquifer.

Table 4-1 presents the estimated volume of contaminated material. Figures 4-1 and 4-2 show the *in situ* volume of soil based on the assumed cutlines in OU 1 (AOCs 1 and 2) and AOC 6, respectively. Volumes are calculated, using a stacked cup approach, based on the assumed cutlines as shown in the figures and represent an over-excavation to ensure removal of the entire *in situ* volume. The *ex situ* volume is then calculated by applying a 125% swelling factor to the *in situ* soil volume removed to the assumed cutlines. The *ex situ* volume will be used for cost estimating purposes in Appendix B.

Table 4-1: Estimated Volume of Contaminated Soil

Impacted AOCs	*In Situ* Volume of Soil to Assumed Cutlines [yd^3]	*Ex Situ* Volume [yd^3] (125% Swelling Factor)
AOCs 1 and 2	13,000	16,250
AOC 6	4,300	5,375
Total	17,300	21,625

4.2.2 Groundwater

Table 4-2 presents the area and the thickness of the estimated groundwater plume in each AOC.

Table 4-2: Estimate of Area and Thickness of Plumes

Impacted AOCs	Area [ft^2]	Maximum Depth [ft]	Average Thickness [ft]
AOC 1	44,700	6	3
AOC 2		18	15
AOC 6	2,900	12	6

4.3 Description of Remedial Alternatives for Each Medium

Remedial action alternatives have been developed for each medium at the Site in accordance with NCP and USEPA guidance and on the basis of general response actions and remedial technologies identified to meet remedial action objectives (Section 3).

4.3.1 Soils

Soil remedial alternatives are presented in Table 4-3. Three soil alternatives (S1 – S3) are identified for the DuPont Chambers Works FUSRAP Site and evaluated for both areas requiring soil remediation, OU 1 and AOC 6.

Table 4-3: Soil Alternatives

Alternative #	AOC	Description of Alternatives
S1	OU 1 and AOC 6	No Action
S2		Excavation Followed by Off-site Disposal
S3		Excavation Followed by Treatment and Off-site Disposal.

Each of these soil alternatives contains the retained process options as shown in Table 4-4.

Table 4-4: Process Options Contained in Each Alternative for Soil

Response Action	Technologies	Process Options	Alternatives	
			S2	**S3**
Land Use Controls	Site security	Signs	**X**	**X**
		Physical barriers, e.g., fencing	**X**	**X**
		Deed notices		
		Well drilling prohibitions	**X**	**X**
		Commercial/industrial zoning	**X**	**X**
Removal	Excavation		Areas where concentrations of COCs exceed RGs.	
Treatment	Soil sorting	Segmented Gate System		**X**
Monitoring	Short-term monitoring (including conformity samples as part of FSS)	Air, soil, sediment, groundwater and surface water	**X**	**X**
Transportation	Rail	Covered rail cars, containers	**X**	**X**
	Truck	Covered trucks, containers	**X**	**X**
Disposal	Permitted off-site facility	Radioactive wastes, hazardous wastes, solid wastes	**X**	**X**

Technologies and Processes Common to Alternatives S2 and S3

Alternatives S2 and S3 rely on land use controls to assist in achieving effectiveness and protectiveness during the remedial action activities. LUCs will be maintained to restrict access and protect workers during Site activities and will rely on and supplement existing DuPont site access restrictions and controls. However, LUCs will not be required following completion of the remedial action. Short-term monitoring is also included as well as five-year reviews and post-remedial site inspections.

Alternatives S2 and S3 share certain features. In order to avoid duplicate discussions of the details of these features under each alternative, similar elements are discussed in the following:

- *Excavation and Confirmatory Sampling*: Alternatives S2 and S3 involve excavation of soil and debris. The excavation will be performed to achieve soil RGs. To verify removal of radiological contaminants, confirmatory sampling will be conducted following excavation as part of the final status survey.
- *Land Use Controls*: LUCs will:
    1. Utilize DuPont's existing site access restrictions and controls; and
    2. Remain in place for the duration they are needed.
- *Transportation and Waste Management*: Local transportation of contaminated materials [e.g., from excavation sites to rail spurs] would use sealed or covered trucks. Movement within areas of excavation would be performed using open trucks and conventional construction equipment. Long distance shipment would be primarily by rail from the rail spurs to off-site permitted disposal facilities. Trucking is also theoretically possible for long distance shipping. Rubble and similar materials would be crushed as appropriate for disposal. It is assumed that Site soils could be used as backfill if they meet the cleanup criteria for soils.

  Soils will be characterized at the onsite laboratory during excavation activities to determine eligibility for use as backfill, while excavated waste soil will be sampled for compliance with landfill waste-acceptance criteria prior to shipping and disposal.
- *Monitoring***:** Short-term monitoring would be continued during the remedial actions to ensure that contamination from the soils does not significantly impact air, groundwater, surface water and sediment. The results of the short-term monitoring of surface water, sediment, and groundwater would be used to assess any potential impacts to the CDD resulting from the remedial actions, and would assist in evaluating the effectiveness of the remedial actions.
- *Remedial Action Control Measures*: Water encountered during remedial actions will be characterized, treated in an onsite treatment system (if necessary), and discharged to the

DuPont sewer system, as permitted. The treatment would address chemicals and radionuclides consistent with relevant and appropriate federal and state regulations. Collection and treatment of storm water will be coordinated with the management of groundwater in excavations, for those actions that involve excavation below the water table. Supporting technologies would be used, as required during the excavation process, to prevent the spread of contamination. These actions may include re-vegetation, dust mitigation, covers, sedimentation basins, and dewatering. After excavation, backfill would be added, and the site would be graded to ensure appropriate surface water drainage. Erosion and sediment controls would be used and described in a Sedimentation Control Plan.

- *Operation and Maintenance*: USACE is responsible for surveillance, operation and maintenance at the Site for a 2-year period after Site closeout, consistent with the *Memorandum of Understanding Between the U.S. Department of Energy and the U.S. Army Corps of Engineers Regarding Program Administration and Execution of the Formerly Utilized Sites Remedial Action Program, effective March 1999.* USACE would conduct a 2-year review to document compliance with RAOs prior to transfer to DOE. Following review and pursuant to agreement between USACE and DOE, the Site would be released to DOE to fulfill the long-term surveillance, operation or maintenance responsibilities of the Federal government that are necessary for the selected remedial action(s).

The soil alternatives are numbered consecutively (S1 – S3) and briefly described in the following subsections. The soil alternatives for OU 1 and AOC 6 are then further designated with a (-1) or (-6), respectively, to identify the alternative for a specific area (e.g., Soil Alternative #2, Excavation and Off-Site Disposal, at OU 1 is designated as S2-1).

4.3.1.1 Alternatives S1-1 and S1-6 - No Action

The No Action alternative is developed to provide a baseline for comparison with other alternatives, as required under CERCLA. This alternative provides no additional protection of human health and the environment. No remedial actions would be taken to reduce, contain, or remove contaminated soils. No effort would be taken to prevent or minimize human and environmental exposure to onsite contaminants. Potential off-site migration of contaminants would not be mitigated under the No Action alternatives. No five year reviews would be conducted.

Potential effects of current site conditions on human health and the environment are presented in the BRA (CABRERA 2011c). Current doses and risks to industrial, construction, and utility workers exceed their corresponding acceptable dose and risk ranges at OU 1 (AOC 1 and 2) and

AOC 6. There would be an increase in the dose and risk to future onsite workers at AOC 6 due to radioactive decay over time, since no remedial actions would be implemented. Under the No Action alternative, there would be no reduction in the mobility, volume, or toxicity of site-related contaminants.

4.3.1.2 Alternatives S2-1 and S2-6 - Excavation Followed by Off-site Disposal

Alternative S2 consists of excavation of soils containing radionuclides above the RGs and subsequent off-site disposal. The removal of impacted soils would substantially reduce potential risks to human health and the environment. In addition, this alternative would remove the source of contaminant migration to groundwater. This alternative would require close coordination of remediation and monitoring activities with DuPont, where roadway and drainageway relocation will be required. This coordination aims to minimize health and safety risks to onsite personnel and to minimize disruption to DuPont activities consistent with a safe and effective remediation. This remedial action would require approximately 12 months for completion. Pursuant to CERCLA, a site review would be conducted every five years, as contaminants would remain onsite above levels allowing unlimited use and unrestricted exposure. It is estimated that the timeframe for OU 1 and AOC 6 will be 11 months and 2.5 months, respectively, based on soil volumes, excavation rates, and infrastructure issues in AOC 6. Components of this alternative include

- Remedial design plans
- Land use controls
- Excavation
- Transportation
- Off-site disposal
- Confirmatory sampling
- Site restoration

Remedial Design Plans: Prior to the initiation of remedial action, remedial design plans would be developed. These plans would detail at a minimum, site preparation activities, the extent of the excavations, implementation and sequence of construction activities, waste management, erosion control measures decontamination, sampling and analysis activities, and management, transportation, and disposal of various waste streams. Short term land use controls will be necessary during the active construction period to ensure a safe remediation. If Alternative S2 is

selected for both OU 1 and AOC 6, the design will include provisions to achieve efficiency and coordination, such as mobilizing only once and conducting shipping activities from one location.
Land Use Controls: LUCs would be utilized to assure protectiveness during remedial action. LUCs would include continuing the existing restrictions and installing new access restrictions; maintaining fencing and signs; and periodically inspecting the site to ensure these land use restrictions are being enforced. The controls would include measures such as governmental controls, proprietary controls and informational devices.

Excavation: Impacted soils would be excavated and immediately loaded into dump trucks and transferred to the loading and staging area present at the Site. The total disposal volume (i.e., bulk soil volume with a 15% contingency applied) is estimated to be 17,700 yd^3 (combined) from OU 1 (AOC 1 and 2), and 6,200 yd^3 from AOC 6. The bulk soil volume includes FUSRAP-related waste soil plus the cut-back soil removed during excavation. Additionally, approximately 900 yd^3 of soil from OU 1 will contain organic constituents (coal tar) that is located at the base of the excavation. This non-FUSRAP chemical waste material would require appropriate handling and health and safety measures during excavation. Standard construction equipment such as excavators, bulldozers, front-end loaders, and scrapers would be used to remove and manage contaminated material. Excavation would be guided using hand held radiation meters to detect radionuclides, onsite laboratory analysis, and confirmation with a limited quantity of samples sent for off-site laboratory analyses. Oversize debris would be crushed or otherwise processed to meet disposal facility waste acceptance criteria. Movement of impacted soils would be performed using dump trucks and conventional construction equipment. Drainage ways would either be re-routed or by-passed using pump-around systems. Overhead utility lines would be re-routed. Subsurface utilities in AOC 2 may need to be shored. Erosion control materials such as silt fences and straw bales would be installed to minimize erosion from the excavated areas.

Soils that have been excavated from below the water table will require a dewatering step using a well point dewatering system. Well points are small-diameter tubes with slots near the bottom that are inserted into the ground from which water is drawn by a vacuum generated by a dewatering pump. The groundwater and accumulated rainwater from the excavation area would be collected in aboveground storage tanks. Both groundwater and surface water would be treated and sampled prior to discharge to a permitted facility. The safety of remediation workers, onsite employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures to soil, groundwater, gamma radiation, organic vapors and dust, and the monitoring requirements to ensure protection.

Transportation: Impacted soils would be hauled to a permitted off-site disposal facility by railcar. The excavated soils would be transported via dump truck to the rail spur located adjacent to OU 1. Soil piles would be staged at a loading area where soils will be weighed and transferred into gondola rail cars lined with “burrito bags” for containment during shipping (see Figure 4-4). A “burrito bag” is a liner placed in a railcar prior to transferring soil into the railcar. Once soil has been placed, the liner (bag) is folded similar to a burrito to contain the soil and minimize potential exposure. Use of the “burrito bags” would also minimize contamination to the gondola cars and decontamination costs. The railcars would transport the contaminated materials to the disposal facility or permitted transload facility where they would be offloaded and materials placed in the appropriate waste cell. The appropriate manifest or bill-of-lading would accompany the waste shipment. Only waste transporters and vehicles that are registered with DOT would be used.

Transportation activities would be performed in accordance with a site-specific waste management and transportation plan that will be developed in the detailed design phase of the project once an alternative is selected. This plan would evaluate the types and number of rail cars to be used and appropriate emergency response procedures.

Off-site Disposal: Impacted soils would be disposed at a facility permitted to accept the characterized waste stream. The selection of an appropriate facility will consider the types of wastes, location, transportation options, and cost. Different waste streams with different constituents and/or characteristics may be generated. It may be possible to reduce disposal costs by utilizing specific disposal facilities for different waste streams.

Due to the presence of LNAPL at the top of the B Aquifer in OU 1, some excavated soils from OU 1 may contain both radionuclides of concern and non-FUSRAP hazardous constituents (volatile and semi-volatile organics). Management of these soils would likely involve treatment at the disposal site to remove hazardous organics, followed by land disposal of the treated soils still containing radionuclides. The volume of these soils is expected to be only 4.0% of the total waste volume (900 yd^3), but the cost for treatment and disposal of such wastes can be high. Therefore, treatment and disposal costs are estimated separately. Additionally, a contingency has been applied to these specific cost elements for Alternatives S2-1 and S3-1 to account for unforeseen costs related to the handling and management of non-FUSRAP hazardous constituents in soils. There is no LNAPL present at AOC 6; therefore no additional treatment costs for non-FUSRAP hazardous constituents in soil are anticipated for this AOC.

Confirmatory sampling: Sampling would be conducted during and after excavation of each area. This sampling would confirm that cleanup goals have been achieved. Areas successfully remediated would be available for activities consistent with industrial land use only. Final status surveys would then be performed using the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) statistical sampling approach to address radiological constituents. The approach will be detailed in a comprehensive sampling and analysis plan.

Site Restoration: Areas of the site where soil has been excavated will be backfilled with clean soil (off-site borrow source) and returned to present condition (paved or gravel-covered). Fill would be tested prior to placement to ensure it meets criteria as established in the design. Also a backfill strategy needs to be considered by the USACE to minimize potential future liabilities associated with removal of the AB Aquitard in OU 1. Although reconstruction of the A Aquifer, AB Aquitard, and B Aquifer is not anticipated in OU 1, it is recommended that low permeable material be considered during the remedial design. Therefore, in the cost estimate for OU 1 an additional cost element has been included to account for a lower permeable material. Confirmatory sampling and site restoration can progress area-by-area to prevent the occurrence of large denuded areas and to minimize erosion and dust generation.

4.3.1.3 Alternatives S3-1 and S3-6 – Excavation, Treatment for Volume Reduction, and Disposal

Alternative S3 consists of excavation of impacted soils above cleanup goals, soil treatment, and subsequent off-site disposal. The removal of impacted soils would reduce substantially potential risks to human health and the environment. In addition, this alternative will reduce the source of groundwater contamination. This alternative is similar to Alternative S2; however, Alternative S3 includes treatment of excavated soils to reduce the volume of contaminated material requiring disposal. This alternative would require the relocation of the roads and drainage ways and close coordination with DuPont during the remediation, treatment and monitoring activities. This will serve to minimize the health and safety risks to onsite personnel and to minimize disruption to their activities; it is consistent with safe and effective remediation.

Remedial action would take approximately 1.5 years to complete and would not require any long-term monitoring of soils at the Site. Pursuant to CERCLA, a site review would be conducted every five years, as contaminants would remain onsite above levels allowing unlimited use and unrestricted exposure. In order to determine the effectiveness of the soil treatment process, a treatability study will be performed. Components of this alternative include

- Select soil treatment technology (Treatability Study)
- Remedial design plan
- Land use controls
- Excavation
- Conduct treatment
- Transportation
- Off-site disposal of impacted soils and residual waste
- Confirmatory sampling
- Site restoration

Select Soil Treatment Technology: Soil treatment is an additional feature in Alternative S3. Soil sorting has been selected as the treatment technology and is the basis for the cost estimate for this alternative. Treatability studies would be performed to evaluate and confirm the effectiveness, implementability, and cost of soil sorting with segmented gate technology. Materials would be processed to remove contamination exceeding the RGs. The fact that soil sorting has been selected here does not preclude the addition or use of other technologies (such as soil washing), but provides a representative treatment scenario for the purpose of comparison to the other alternatives.

Remedial Design Plan: Utilizing the results of the treatability study, a remedial design plan would be developed prior to the initiation of remedial action. This plan would detail site preparation activities, the extent of the excavation, implementation and sequence of construction and soil treatment activities, decontamination, and segregation, transportation, and disposal of various waste streams. Short term land use controls will be necessary during the active construction period to ensure a safe remediation.

The safety of remediation workers, onsite employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection. Short term land use controls will be necessary during the active construction and treatment period to ensure a safe remediation.

Land Use Controls: LUCs would be utilized to assure protectiveness during remedial action. LUCs would include continuing the existing restrictions and installing new access restrictions; maintaining fencing and signs; and periodically inspecting the site to ensure these land use restrictions are being enforced. The controls would include measures such as governmental controls, proprietary controls and informational devices.

Excavation: Standard construction equipment, such as excavators, bulldozers, front end loaders, and scrapers would be used to remove contaminated material. Excavation would be guided using hand held radiation meters to detect radionuclides, onsite laboratory analysis, and confirmation with a limited quantity of off-site laboratory analyses. Oversize debris would be crushed or otherwise processed to meet disposal facility requirements. Movement of impacted soils would be performed using dump trucks and conventional construction equipment. Drainage ways would either be re-routed or by-passed using pump-around systems. Overhead utility lines would be re-routed. Subsurface utilities in AOC 2 may need to be shored. Erosion control materials, such as silt fences and straw bales, would be installed to minimize erosion in the excavated areas. Impacted soils would be kept moist or covered with tarps to minimize dust generation at the soil processing/treatment area located in AOC 1.

Conduct Treatment: The purpose of the soil sorting process is to concentrate the radiological contaminants in a smaller volume of the excavated soil. Commercial treatment equipment is available for this technology, to be either built onsite or brought to the site assembled. The specific design, throughput, and operational capability of the process must be defined and is addressed further in the detailed analysis of alternatives.

Developing physical treatment capabilities onsite would begin by establishing a specific location at which to install the treatment process. Because AOC 6 contains a relatively small amount of contaminated soil, if the alternative is chosen for both OU 1 and AOC 6, it is assumed that it would be conducted sequentially using the same equipment - first at OU 1 and concluding at AOC 6. Utilities must be available to operate the soil sorting equipment.

Soils would be transported from the area of excavation to the soil processing/treatment area. Soils that have been excavated from below the water table will require a dewatering step using well point dewatering system, because the segmented gate system (SGS) equipment requires loose and "clump-free" soil so that the soils passing under the radiation sensors are in a relatively thin layer. Well points are small-diameter tubes with slots near the bottom that are inserted into the ground from which water is drawn by a vacuum generated by a dewatering pump. The groundwater and accumulated rainwater from the excavation area would be collected in aboveground storage tanks. Both groundwater and surface water would be treated and sampled prior to discharge to a permitted facility.

Figure 4-3 shows the location of the soil processing/treatment area and the flow diagram of the overall treatment. Figure 4-4 presents the schematic of the soil sorting equipment and process. In the first treatment step, excavated soils are put through a coarse separation-sizing screen to remove any debris or large objects. The remaining soil enters the separation system. During processing, the soils are placed as a thin layer on a conveyor belt. Radiation sensors above the belt identify soils that are contaminated above criteria activity levels, and then activate "gates" that divert the contaminated soils. Soils that pass under the sensors without indicating contamination proceed to a "reuse" stockpile. It is assumed that 30% of the excavated soil would meet the soil RGs and would be available for beneficial reuse. Pilot and full-scale operations with similar equipment have been conducted elsewhere in the U.S. at capacities ranging up to 36 tons/hour.

Treatment with SGS relies on some assumptions that need to be verified. Use of this treatment option may be ineffective or not implementable until these assumptions are resolved.

- Beneficial re-use of soils below RGs: It is not known if soils with concentrations above background but lower than the RGs may be used for beneficial reuse onsite. The benefit of using SGS is to reduce the volume of soil requiring off-site disposal. Depending on NJDEP/USACE discussions regarding this issue, there may not be any advantage in using this technology.
- There can be significant re-work costs associated with false positive detections (or false negative non-detects) on a SGS. For example, alarms have to be confirmed with confirmatory surveys and sampling. This can consume time and expense if the setpoints (count rate equivalents of the RG) have a small margin above background.

After soils are processed through the SGS, the treatment residuals (soil with radionuclide concentrations above RGs) will be loaded into dump trucks and moved to the soil loading area in OU 1 (next to the rail spur). Soils will be weighed and loaded into gondolas for off-site shipment via rail.

*Transportation***:** The treatment residuals (soils with concentrations exceeding the RGs) will be hauled to a permitted off-site disposal facility by railcar. Soil piles will be staged at loading area where soils will be weighed and transferred into gondola rail cars lined with burrito bags for containment during shipping (see Figure 4-3). Use of the "burrito bags" would minimize contamination to the gondola cars. The railcars would transport the contaminated materials to the disposal facility or permitted transload facility where the railcars will be emptied and the material hauled to the appropriate waste cell. The appropriate manifest or bill-of-lading would accompany the waste shipment in accordance with DOT regulations. Only waste transporters and vehicles that are registered with DOT would be used.

Transportation activities would be performed in accordance with a site-specific waste management and transportation plan which will be developed in the detailed design phase of the project once an alternative is selected. This plan would evaluate the types and number of rail cars to be used and appropriate emergency response procedures.

Off-site Disposal: The selection of an appropriate disposal facility will consider the types of wastes, location, transportation options, and cost. Different waste streams with different constituents and/or characteristics may be generated (for example, wastes containing FUSRAP-eligible contaminants mixed with non-FUSRAP hazardous organics). It may be possible to reduce disposal costs by utilizing specific disposal facilities for different waste streams.

If the treatment technology is effective, the volume of soil requiring disposal will be reduced. The extent of the reduction will depend upon the technology chosen, its effectiveness, and implementation in the field.

Due to the presence of LNAPL at the top of the B Aquifer in OU 1, some excavated soils from OU 1 may contain both radionuclides of concern and non-FUSRAP hazardous constituents (volatile and semi-volatile organics). Management of these soils would likely involve treatment at the disposal site to remove hazardous organics, followed by land disposal of the treated soils still containing radionuclides. The volume of these soils is expected to be only 4.0% of the total waste volume (900 yd^3), but the cost for treatment and disposal of such wastes can be high. Therefore, treatment and disposal costs are estimated separately. Additionally, a contingency has been applied to these specific cost elements for Alternatives S2-1 and S3-1 in order to account for unforeseen costs related to the handling and management of non-FUSRAP hazardous constituents in soils. There is no LNAPL present at AOC 6; therefore no additional treatment costs for non-FUSRAP hazardous constituents in soil are anticipated for this AOC.

Confirmatory sampling would be conducted after excavation of each area. This sampling would confirm that cleanup goals for radiological constituents have been achieved. Areas successfully remediated would be available to resume activities consistent with industrial land use. Final status surveys would be performed using the MARSSIM statistical sampling approach to show compliance with data quality objectives outlined in the final status survey plan.

Site Restoration: Areas of the site where soil has been excavated will be backfilled with the treated soil and clean soil (off-site borrow source), compacted, and re-vegetated. Fill would be tested prior to placement to ensure it meets criteria as established in the design. Also a backfill strategy needs to be considered by the USACE to minimize potential future liabilities associated with removal of the AB Aquitard in OU 1. Although reconstruction of the A Aquifer, AB Aquitard, and B Aquifer is not anticipated in OU 1, it is recommended that low permeable material be considered during the design for backfilling. Therefore, in the cost estimate for OU 1 an additional cost element has been included to account for a lower permeable material. Confirmatory sampling and site restoration can progress area-by-area to prevent large areas of soil from being exposed at any one time and in order to minimize erosion and dust generation. Once treatment is complete, the treatment equipment will be decontaminated, dismantled, and removed and the treatment area restored.

4.3.2 Groundwater

The alternatives identified for groundwater remediation are shown below in Table 4-5. The three groundwater alternatives (GW1 – GW3) are numbered consecutively and evaluated for both areas requiring soil remediation (OU 1 and AOC 6).

Table 4-5: Groundwater Alternatives

Alternative #	AOC	Description of Alternatives
GW1	OU 1; AOC 6	No Action
GW2		*Ex Situ* Treatment
GW3		Monitored Natural Attenuation

As previously mentioned the completion of one of the soil remedial actions, either S2 or S3, is expected to remove the source of groundwater contamination as well as significant portions of the groundwater plume in OU 1 and AOC 6. In AOC 1 (OU 1), the entire groundwater plume is included within the assumed excavation cutlines as shown in Figure 4-5. The entire area estimated to have uranium concentrations greater than 30 ug/L (inside the 30 ug/L isopleth) will be excavated in AOC 1, resulting in 97% removal of the aqueous uranium in that area. Uranium mass balance calculations demonstrate the pre-excavation and post excavation concentrations of uranium in the FUSRAP areas. Appendix C includes the uranium mass balance calculations and technical evaluation. Figures 4-6 and 4-7 show the areas of impacted groundwater in relation to the assumed cutlines for AOC 2 and AOC 6, respectively. In AOC 2 (OU 1) the percent of uranium removal is estimated to be 90 % in the A Aquifer and 100% in the B Aquifer. Only the B Aquifer is present in AOC 6 and both excavation alternatives (S2 and S3) will result in 81% reduction of the aqueous uranium in groundwater. Residual groundwater concentrations in AOC 2 and AOC 6 will be significantly reduced.

The groundwater alternatives contain the retained process options as shown in Table 4-6.

Table 4-6: Process Options Contained in Each Alternative for Groundwater

Response Action	Technologies	Process Options	Alternatives	
			GW2	**GW3**
Land Use Controls	Site security	Signs	**X**	**X**
		Physical barriers, e.g., fencing	**X**	**X**
	Land use restrictions and notices	Deed notices		
		Well drilling prohibitions	**X**	**X**
		Commercial/industrial zoning	**X**	**X**
Monitoring	Long-term monitoring	Groundwater	**X**	**X**
Removal	Pumping wells	Vertical	**X**	
Treatment	Physical	Ion Exchange	**X**	
Monitoring	Short-term monitoring	Groundwater	**X**	**X**
Disposal	Discharge	DuPont WWTP	**X**	

Technologies and Processes Common to Alternatives GW2 and GW3

Alternatives GW2 and GW3 share certain features. In order to avoid duplicate discussions of the details of these features under each alternative, similar elements are discussed below.

- *Land Use Controls*: For groundwater alternatives that use LUCs (GW2 and GW3), a long-term stewardship or management plan would be developed. It would address requirements for future monitoring and maintenance of LUCs. The plan would also include provisions addressing the process by which DuPont and any future property owners can contact the designated federal government agency (USACE and/or DOE) responsible for long-term control of impacted areas and periodic reviews, maintenance, and monitoring. LUCs would be used to restrict access and protect workers during the remedial action activities at areas in which the residual groundwater contamination exceeds the concentrations as specified in groundwater RAOs. These LUCs will:
    1) Utilize DuPont's existing site access restrictions, controls, and groundwater use restrictions; and
    2) Remain in place for the duration of need.

- *Backfill Augmentation:* During backfilling of the excavation areas, the addition of mulch (or other slow release electron donor material) to the backfill material could be considered in pre-design activities. The incorporation of mulch in the unsaturated zone would help to ensure that reducing conditions are maintained in the groundwater over several years, particularly for the duration of both groundwater alternatives.

- *Short and Long Term Monitoring of Groundwater*: With the exception of the No Action Alternative, the two groundwater alternatives (GW2 and GW3) will include short and long term groundwater monitoring as a component of the remedial action.

- *AOC 4 (AOI 1) Additional Monitoring of Groundwater:* the periodic groundwater sampling of existing FUSRAP monitoring wells in AOC 4 (AOI 1) will be a common feature of each groundwater alternative. This monitoring will be in conjunction with short and long-term groundwater sampling in OU 1 and AOC 6. A limited sampling regime is proposed for the specific purpose of monitoring geochemical conditions, groundwater hydraulics, and total uranium concentrations in the area. The purpose of the sampling would be to evaluate the observed trends as documented in the Sitewide RI which showed limited movement of FUSRAP COCs towards the Delaware River. Existing FUSRAP wells will be utilized to monitor these conditions (see Figure 2-13).

- *Operation and Maintenance*: USACE is responsible for surveillance, operation and maintenance at the Site for a 2-year period after Site closeout, consistent with the *Memorandum of Understanding Between the U.S. Department of Energy and the U.S. Army Corps of Engineers Regarding Program Administration and Execution of the Formerly Utilized Sites Remedial Action Program, effective March 1999.* USACE would conduct a 2-year review to document compliance with RAOs prior to transfer to DOE. Following review and pursuant to agreement between USACE and DOE, the Site would be released to DOE to fulfill the long-term surveillance, operation or maintenance responsibilities of the Federal government that are necessary for the selected remedial action(s).

The three groundwater alternatives are numbered consecutively (GW1 – GW3) and briefly described in the following subsections. As with the soil alternatives, the groundwater alternatives for OU 1 and AOC 6 are then further designated with a (-1) or (-6), respectively, to identify the alternative for a specific area (e.g., GW2-1 is Groundwater Alternative #2, *Ex Situ* Treatment at OU 1).

4.3.2.1 Alternatives GW1-1 and GW1-6 (OU 1 and AOC 6) - No Action

Under this alternative, no remedial actions would be implemented. Existing legal and administrative mechanisms and physical measures would be left in place, but not necessarily maintained. Environmental monitoring would not be performed. In addition, restrictions on land use or access to groundwater would not be pursued. This alternative does not provide any additional protection to human health and the environment over current conditions.

This alternative would not achieve the RAOs for groundwater. No monitoring would be conducted to evaluate the potential for uranium migration or to assess potential reductions in uranium concentrations. No five-year reviews would be conducted for the site.

4.3.2.2 Alternatives GW2-1 and GW2-6 (OU 1 and AOC 6) - Ex Situ Treatment

Alternative GW2 consists of a groundwater pump and treat system and would be implemented in conjunction with Alternatives S-2 or S-3 (i.e., source removal).

Alternative GW2 relies on the installation of wells to extract impacted groundwater. The extraction wells installed in OU 1 would be screened from approximately 10 to 20 feet, in the backfilled area, placed after excavation, assuming a uniform backfill material with low permeability. It is not expected that the aquitard will be reconstructed in OU 1 as it currently exists but a lower permeability backfill is assumed. In AOC 6, the well would be screened at approximately the same interval. Once extracted, the contaminated groundwater would be piped to an onsite treatment facility, where contaminants would be removed by adsorption via solid media (ion exchange for dissolved Uranium). Because of high concentrations of organics from non-FUSRAP sources in the groundwater, pretreatment of the water would be required to protect the resin. This pretreatment would rely on use of granular activated carbon (GAC) canisters. When exhausted, these GAC canisters will have to be cleared and shipped off-site for proper disposal or regeneration.

Figure 4-8 presents a schematic of the groundwater treatment system setup and associated flow diagram for the ion exchange process to be used in OU 1. The approximate location of the pumping wells and the treatment system within OU 1 is shown in the figure. The treated water would be discharged to the DuPont stormwater drainage system for subsequent treatment in the DuPont WWTP.

The waste streams generated from the ionic exchange process would be transported to a waste processor for proper disposal since limited quantities are expected to be generated. Disposal for this material is expected to meet the waste acceptance criteria for the Energy Solutions facility in Clive, Utah. The waste brine will be solidified and sent to the same permitted disposal facility as the soil waste stream. If large quantities are generated, the brine will be put through a flocculation/precipitation process to concentrate the uranium for disposal, and the brine would be disposed of appropriately.

Figure 4-9 presents the groundwater treatment system setup, associated flow diagram and approximate location of pumping well(s) for AOC 6. The treatment process for AOC 6 groundwater differs from the process described above for OU 1. No LNAPL is present at AOC 6 so the initial pretreatment step with GAC filter is not required. If groundwater treatment using ion exchange is determined to be necessary after source removal, then it is anticipated that one pumping well will be located at the present location of 6MW01B (see also Figure 2-14).

Coordination with DuPont will be required during the installation of wells, during periodic sampling events, and for the operation of the treatment facility. Time frames for groundwater cleanup via pump and treatment could be extended if significant contamination exists in OU 1. *Ex situ* treatment would require an approximate seven to 10-year O&M period after impacted soils have been addressed; therefore, this time frame was used for cost estimating purposes. Components of this alternative include the following:

- Remedial design plan
- System design and installation
- Active pump and treat
- Confirmatory sampling
- Management plan
- Land use controls

Remedial Design Plan: Prior to the initiation of remediation, a remedial design plan would be completed. The plan would detail where the extraction and monitoring wells are to be located, what constituents are to be analyzed at each monitoring well, and what the pumping rate of each extraction well is to be. Also included would be the details of the design of the treatment system. To accomplish this, a treatability study may be needed to determine the flow rates, type of ion exchange resin, and the replacement intervals for the media. The safety of remediation workers, onsite employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

A *groundwater pump and treat system* would be designed and installed. The design would consist of the number and placement of groundwater extraction wells, as well as piping to the treatment system. Depending on the selected treatment system details, a pilot study may be completed to determine the optimal configuration. For the cost estimate it was assumed that a total number of four wells would be installed at OU 1 (2 at AOC 1 and 2 at AOC 2). Only one well would be installed at AOC 6. Additional monitoring wells may be required during the pilot study to determine accurate aquifer parameters and capture zones. Two separate water treatment systems would be installed for treating the water; one system for OU 1 and a separate system for AOC 6.

Confirmatory sampling would be conducted following the completion of active treatment. This sampling would confirm that the RAOs for radiological constituents in groundwater have been achieved.

A long-term management plan would be developed to address monitoring requirements and land use controls. The plan also would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas, as well as provide for periodic reviews. A more detailed discussion of the land use controls would be developed as part of the long-term management plan including notification requirements for changes in land use. Five-year reviews permit evaluation of the effectiveness of land use controls, as well as data obtained from ongoing monitoring to assess the presence and behavior of remaining contaminants. Continued site surveillance would ensure any land use changes or disturbances of contaminated areas are identified.

Land use controls would be used to supplement the active pump and treat remediation of groundwater as long as monitoring indicates contamination in groundwater exceeds the RAO. LUCs would include continuing the existing restrictions and installing new access restrictions; maintaining fencing and signs; establishing land use restrictions to prohibit changes in groundwater use; and periodically inspecting the site to determine if any changes in land use have occurred. Other LUCs that would be considered to supplement active pump and treat are governmental controls such as zoning, proprietary measures such as easements, and informational devices.

4.3.2.3 Alternatives GW3-1 and GW3-6 (OU 1 and AOC 6) Monitored Natural Attenuation

Alternative GW3 relies on MNA to address impacted groundwater once impacted soils are remediated. Therefore, Alternative GW3 would only be implemented in conjunction with one of the soil excavation alternatives (Alternative S2 or S3).

MNA is the protocol for determining whether natural processes can be relied on to attenuate the dissolved uranium concentrations. The dissolved uranium concentration is expected to decrease naturally over time, particularly after a source zone is removed. The key objective of MNA, which differentiates it from simply monitoring, is to collect sufficient geochemical data to describe the attenuative processes thought to be taking place. Groundwater in the OU 1 and AOC 6 source zones is oxidizing due to the presence of the U(6+) mineral metastudtite (uranium peroxide dihydrate), which creates hydrogen peroxide (and hydrogen) by alpha irradiation of water molecules. In oxidizing environments, U(6+) species are quite soluble. Hydrogen peroxide is not persistent in natural environments and the A and B aquifers surrounding the source zones are reducing. Hence, the available dissolved oxygen is consumed a short distance from the metastudtite source and the soluble, hexavalent U(6+) ions are reduced to the low-solubility tetravalent U(4+) ions. This transformation has been inferred to take place within a short distance from the source zones because dissolved uranium concentrations decrease by three orders of magnitude within a distance of 100 feet. The predominant U(4+) species in the reducing region is thought to be uranyl species such as uraninite.

Under the MNA alternative, monitoring wells would be installed to monitor concentrations of uranium in groundwater. Monitoring wells currently are proposed to be located in areas based on observed constituent trends and groundwater flow directions. Specific well locations will be determined during pre-design activities based on review of the latest groundwater monitoring data. Installation of replacement wells will be required and where possible existing wells will be used for sampling and groundwater flow direction. New well construction will be necessary to ensure viability during the potentially long time frame associated with MNA as well as the possibility of damage to or removal of wells during implementation of a soils alternative. Currently existing monitoring wells which may be removed during soil remediation include the following OU 1 wells: 1-MW-08A, 1-MW-09B, 2-MW-02A, 2-MW-03B and 2-MW-25 C. In

AOC 6 the following wells will be removed during any soil remediation: 6-MW-01B and 6-MW-07B.

Coordination with DuPont will be required both during the installation of wells and during periodic sampling events. Coordination could include obtaining the right to access properties outside the current fence in order to perform monitoring.

A number of evaluations were performed to estimate time required to achieve site-specific remediation objectives within the plume at AOC 2. Based on the mass balance evaluation, the residual groundwater concentration for total uranium at AOC 2 following excavation of soil will be 86 µg/L. Based on the attenuation rates, those evaluations estimated a range between 5 and 30 years as being required for groundwater concentrations to decrease to levels consistent with RAOs. Therefore, as a conservative approach, a 30-year O&M period was considered for MNA after impacted soils have been addressed; this time frame was used for cost estimating purposes. Components of this alternative include

- Remedial design plans
- Monitored natural attenuation
- Confirmatory sampling
- Long-term management plan
- Land use controls

Remedial Design Plans: Prior to implementing Alternative GW3, a remedial design plan will be completed. This plan will evaluate and detail the number and location of monitoring wells, the constituents to be monitored, and the criteria to determine if MNA is occurring. The safety of remediation workers, onsite employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

Monitored Natural Attenuation: Results of the fate and transport discussion presented in Section 2.3 support the conclusion that MNA would be a viable means of treating the groundwater at the Site, based upon the observed oxidation states of uranium, the documented geochemical conditions within each AOC, and an evaluation of transport and attenuation processes.

For implementation of the MNA alternative, monitoring will be conducted to demonstrate that the geochemical conditions described above are not changing, that the uranium in groundwater is being effectively attenuated, and the remedy is effective in protecting human health and the environment. A long-term monitoring program will be developed to include the following: a routine monitoring schedule, a comprehensive list of constituents to be analyzed, reporting requirements, and statistical criteria for data evaluation to determine when RAOs have been achieved. The comprehensive list of constituents will be used to verify the oxidation/reduction status of the groundwater. Typical constituents analyzed for this purpose include ferric/ferrous iron, sulfate, nitrate, nitrate and ammonia, along with measurements of dissolved oxygen and oxidation-reduction potential.

After a period of three to five years, if monitoring demonstrates changes to environmental conditions or the attenuation process is not proceeding effectively, then decisions regarding what actions are necessary will be made at that time and will be based on the data and information gathered during the monitoring program.

Confirmatory sampling would be conducted as a part of the five-year review process after MNA demonstrates a decreasing trend in contaminant concentrations in groundwater.

A long-term management plan would be developed to address monitoring requirements and land use controls. The plan also would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas as well as provide for periodic reviews. A more detailed discussion of the land use controls would be developed as part of the long-term management plan including notification requirements for changes in land use. Five-year reviews permit evaluation of the effectiveness of land use controls, as well as data obtained from ongoing monitoring to assess the presence and behavior of remaining contaminants. Continued site surveillance would ensure any land use changes or disturbances of contaminated areas are identified.

Land use controls would be used to supplement MNA as long as monitoring indicates contamination in groundwater is above the RAOs. LUCs would include periodic inspection of the site to determine if any changes in land use and land use restrictions have occurred, thereby requiring further action to restrict groundwater use. LUCs used to supplement MNA could include governmental controls, such as zoning, proprietary measures, and informational devices.

5.0 ANALYSIS OF REMEDIAL ALTERNATIVES

5.1 Introduction

This section presents a detailed analysis of the remedial alternatives that have been formulated for further evaluation. Five alternatives for soil and four alternatives for groundwater were analyzed for OU 1 (AOC 1 and 2) and AOC 6. From this set of alternatives, a combination will ultimately be chosen as the preferred remedy for the soils and groundwater at the DuPont Chambers Works FUSRAP site. Under the CERCLA remedy selection process, the preferred remedial alternative is recommended in the Proposed Plan (PP) and the selected remedial alternative is set forth in final form in the Record of Decision (ROD) after community and State review. A detailed evaluation of each alternative is performed in this section to provide the basis and rationale for identifying a preferred remedy and preparing the PP.

To ensure the FS analysis provides information of sufficient quality and quantity to justify the selection of a remedy, it must meet the requirements of the remedy selection process. This process is driven by the requirements set forth in CERCLA Section 121. In accordance with these requirements (USEPA 1988b), remedial actions must

- Be protective of human health and the environment
- Attain ARARs or provide grounds for justifying a waiver
- Be cost effective
- Use permanent solutions and alternative treatment technologies to the maximum extent practicable
- Satisfy the preference for treatment that, as a principal element, reduces volume, toxicity, or mobility

CERCLA emphasizes long-term effectiveness and related considerations for each remedial alternative. These statutory considerations include

- Long-term uncertainties associated with land disposal
- The goals, objectives, and requirements of the Solid Waste Disposal Act
- The persistence, toxicity, and mobility of hazardous substances, and their propensity to bioaccumulate
- Short- and long-term potential for adverse health effects from human exposure
- Long-term maintenance costs

- The potential for future remedial action costs if the remedial alternative in question were to fail
- The potential threat to human health and the environment associated with excavation, transportation, and re-disposal, or containment.

These statutory requirements are implemented through the use of nine evaluation criteria presented in the NCP. These nine criteria are grouped into threshold criteria, balancing criteria, and modifying criteria, as described below and as illustrated in Figure 5-1. The following description in Section 5.2 provides a detailed analysis of each alternative within each of the evaluation criteria. The analysis includes a definition of each alternative and, if necessary, more precise description of the volumes or areas of contaminated media or technologies. Following this detailed analysis is a brief description of considerations common to all alternatives (Section 5.3) and a comparative analysis (Section 5.4) among the alternatives that determines how each will perform with respect to the criteria.

5.1.1 Threshold Criteria

Two of the NCP evaluation criteria relate directly to statutory findings that must be made in the ROD. These criteria are thus considered to be threshold criteria that must be met by any remedy in order to be selected. The criteria are

- Overall protection of human health and the environment
- Compliance with ARARs

Each alternative must be evaluated to determine how it achieves and maintains protection of human health and the environment. Similarly, each remedial alternative must be assessed to determine how it complies with ARARs, or if a waiver is required, an explanation of why a waiver is justified. An alternative is considered to be protective of human health and the environment if it complies with media specific cleanup goals.

5.1.2 Balancing Criteria

The five balancing criteria represent the primary criteria upon which the detailed analysis and comparison of alternatives are based. These criteria include

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness

- Implementability
- Cost.

Long-term effectiveness and permanence is an evaluation of the magnitude of residual risk (risk remaining after implementation of the alternative) and the adequacy and reliability of controls used to manage the remaining waste (untreated waste and treatment residuals) over the long term. Alternatives that provide the highest degree of long-term effectiveness and permanence leave little or no untreated waste at the site, make long-term maintenance and monitoring unnecessary, and minimize the need for land use controls.

Reduction of toxicity, mobility, or volume through treatment emphasizes the statutory preference for alternatives that result in such reduction. The irreversibility of the treatment process and the type and quantity of residuals remaining after treatment are also assessed.

Short-term effectiveness addresses the protection of workers and the community during the remedial action, the environmental effects of implementing the action, and the time required to achieve media-specific cleanup goals.

Implementability addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during implementation. Technical feasibility assesses the ability to construct and operate a technology, the reliability of the technology, the ease in undertaking additional remedial actions, and the ability to monitor the effectiveness of the alternative. Administrative feasibility is addressed in terms of the ability to obtain approval from federal, state, and local agencies.

Cost analyses provide an estimate of the dollar cost of each alternative. The cost estimates in this report are based on estimating reference manuals, existing USACE contracts, historical costs, vendor quotes, and engineering estimates. The primary methodology used is a quantity take-off method in which costs are calculated based on a unit cost multiplied by quantity or other input parameters. Costs are reported in base year 2010 dollars, or present value (future costs are converted to year 2010 dollars using a 7% discount factor). The present value analysis is a method to evaluate expenditures, either capital or O&M, which occur over different time periods. Present value calculations allow for cost comparisons of different remedial alternatives on the basis of a single cost figure. The capital costs have not been discounted due to their relatively short implementation duration. The cost estimates are for guidance in project evaluation and implementation and are believed to be accurate within a range of -30% to +50% in accordance with USEPA guidance (USEPA 2000). Actual costs could be higher than estimated due to unexpected site conditions or potential delays. Details and assumptions used in developing cost estimates for each of the alternatives are provided in Appendix B.

5.1.3 Modifying Criteria

The two modifying criteria below will be evaluated as part of the ROD after the public has had an opportunity to comment on the PP. They are

- State acceptance
- Community acceptance

State Acceptance considers comments received from agencies of the State of New Jersey. The primary state agency supporting this investigation is the NJDEP. Comments will be accepted from state agencies on the FS and the preferred remedy as presented in the PP. This criterion will be addressed in the responsiveness summary of the ROD.

Community Acceptance considers comments made by the community, including stakeholders, on the alternatives being considered. Input has been encouraged during the ongoing community involvement program throughout the investigation to ensure the remedy selection is consistent and acceptable to the public. Community meetings have been held on a regular basis since the beginning of the investigation. Additional opportunities for public involvement are planned during the FS and PP to share results and solicit public comments and feedback. A formal public comment period will be held so community comments on the FS and the preferred remedy as presented in the PP will be accepted and part of the decision process. This criterion will be addressed in the responsiveness summary of the ROD. Because the actions above have not yet taken place, the detailed analysis of alternatives presented below cannot account for these criteria at this time. Therefore, the detailed analysis is carried out only for the first seven of the nine criteria.

5.2 Detailed Analysis of Remedial Alternatives

This section presents a detailed analysis of the retained remedial alternatives. Each alternative is described and evaluated against the criteria outlined in Section 5.1. A summary of this evaluation is presented in Tables 5-1 and 5-2.

Much of the DuPont FUSRAP site information necessary to evaluate the potential alternatives was compiled and presented in the Sitewide RI Report (CABRERA 2011b) and is summarized in Section 2 of this report. As such, it presents a summary of pertinent information regarding the environmental setting, site history, and site characterization including nature and extent of contamination, contaminant fate and transport characteristics, and BRA results.

Table 5-1: Summary of Detailed Analysis of Alternatives - Soil

Criteria	Alternatives S1-1; S1-6	Alternatives S2-1; S2-6	Alternatives S3-1; S3-6
Description	**No Action**	**Excavation and Off-site Disposal**	**Excavation, Treatment and Off-site Disposal**
Overall Protection of Human Health and the Environment			
Human Health Protection	Not Protective	Protective	Protective
Environmental Protection	Impacted soils representing a source of groundwater contamination.	Source of contamination to groundwater would be eliminated.	Source of contamination to groundwater would be eliminated.
Compliance with ARARs			
Chemical-Specific ARARs	Not compliant	Compliant	Compliant
Long-Term Effectiveness and Performance			
Magnitude of Residual Risk	High. Current and future risks exceed CERCLA risk range.	Low if LUCs are properly maintained.	Low if LUCs are properly maintained.
Reliability and Permanence of Controls	Although existing site security could provide limited control of exposures to site contaminants, this alternative does not assure controls will remain in place and does not provide any additional new controls in the future.	Excavation and off-site disposal is reliable and considered a permanent solution.	Excavation, treatment and off-site disposal are reliable, although problematic for either fine-grained or saturated soils. Considered a permanent solution.
Long Term Management	None	5-year review	5-year review
Reduction of Toxicity, Mobility, or Volume Through Treatment			
Reduction in Toxicity, Mobility, and Volume through Treatment	Not applicable	Not applicable	Volume reduction is achieved through soil sorting process.

Criteria	Alternatives S1-1; S1-6	Alternatives S2-1; S2-6	Alternatives S3-1; S3-6
Description	**No Action**	**Excavation and Off-site Disposal**	**Excavation, Treatment and Off-site Disposal**
Short-Term Effectiveness			
Protection of Community during Remedial Action	No additional health affect in the short-term due to no action taken.	Small additional short-term risk to community during excavation and transportation activities. However, risks will be minimized by using standard controls such as dust control and use of covered truck. Rail cars would be loaded onsite, so no impacts would occur on local roads off the property. There may also be short-term risks associated transportation, such as vehicle/rail exhaust and the potential for road accidents.	Small additional short-term risk to community during excavation and transportation activities. However, risks will be minimized by using standard controls such as dust control and use of covered truck. Rail cars would be loaded onsite, so no impacts would occur on local roads off the property. There may also be short-term risks associated transportation, such as vehicle/rail exhaust and the potential for road accidents.
Protection of Workers during Remedial Action	No additional health affect in the short-term due to no action taken.	Excavation of contaminated soils does pose risks to workers. Conformance with HASP should protect workers.	Excavation of contaminated soils and the operation of the treatment system does pose occupational risk to worker. Conformance with HASP should protect workers.
Environmental Impact	The existing soil contamination would continue to leach into the groundwater.	Impacts associated with excavation and handling of contaminated materials will include dust generation and the effects of rainfall and runoff. Storm water management will be critical to minimize these effects.	Impacts associated with excavation and handling of contaminated materials will include dust generation and the effects of rainfall and runoff. Storm water management will be critical to minimize these effects. The treatment system further complicates the risk of environmental impacts from the remedial action.
Implementability			
Technical Feasibility	Feasible	Feasible	Feasible
Administrative Feasibility	Not Feasible	Administratively feasible to implement	Feasible. Possible objection by state regulators to use treated soil as backfill.

Criteria	**Alternatives S1-1; S1-6**	**Alternatives S2-1; S2-6**	**Alternatives S3-1; S3-6**
Description	**No Action**	**Excavation and Off-site Disposal**	**Excavation, Treatment and Off-site Disposal**
Availability of Services, Equipment, and Technology	Not applicable	Standard services, equipment, and technology are used for this alternative and are easily available	Technologies and equipment are currently available commercially, although site-specific pilot studies will be required prior to remedial action to determine if these technologies could be cost effectively applied to this site.
Cost (in million)			
Cost ($ in millions)	**0**	**33.1**	**30.7**

Table 5-2: Summary of Detailed Analysis of Alternatives - Groundwater

Criteria	Alternative GW1-1; GW1-6	Alternative GW2-1; GW2-6	Alternative GW3-1; GW3-6
Description	**No Action**	***Ex Situ* Treatment**	**Monitored Natural Attenuation**
Overall Protection of Human Health and the Environment			
Human Health Protection	Not Protective	Protective as long as geochemical conditions remain stable, the removal of dissolved uranium through pumping and treatment will provide protection from radiological risks. Precipitated uranium could become remobilized if geochemical conditions changed.	Protective if attenuation is occurring. Higher level of protectiveness will be achieved if MNA is coupled with soil source term removal alternative.
Compliance with ARARs			
Chemical-Specific ARARs	Not Compliant	Compliant	Compliant
Long-Term Effectiveness and Performance			
Magnitude of Residual Risk	High if use as a drinking water source.	Low if geochemical conditions continue to restrict migration of uranium, plume migration will be restricted and constituents will attenuate over time to groundwater RAO levels. Potential future hydraulic changes could also impact groundwater migration.	Magnitude of residual risk will be dependent on performance of MNA. If geochemical conditions and hydrologic conditions do not change, plume migration will be restricted and constituents will attenuate over time consistent with RAO.
Reliability and Permanence of Controls	No controls provided.	The treatment system will be reliable, pending pilot testing. Permanence is uncertain because precipitated uranium could become remobilized if geochemical conditions change over time.	The reliability of MNA will be dependent on whether current geochemical conditions and hydrologic conditions continue to show minimal movement of uranium away from source areas. Routine monitoring will be conducted to evaluate geochemical conditions and document attenuation process. It is expected that MNA will provide a permanent solution in conjunction with source removal of soils.

Criteria	**Alternative GW1-1; GW1-6**	**Alternative GW2-1; GW2-6**	**Alternative GW3-1; GW3-6**
Description	**No Action**	***Ex Situ* Treatment**	**Monitored Natural Attenuation**
Long Term Management	None	5 year review	5 year review
Reduction of Toxicity, Mobility, or Volume Through Treatment			
Reduction in toxicity, mobility, and volume through treatment	None	*Ex situ* treatment would reduce toxicity, mobility and volume of contaminated groundwater by extraction, treatment and disposal.	In OU 1, natural attenuation processes will reduce the mobility of the uranium-contaminated groundwater by attenuating the more soluble U6+ to lower solubility U4+; however, volume and toxicity of groundwater will not be reduced.
Short-Term Effectiveness			
Protection of Community During Remedial Action	No additional short-term impacts to the community.	No additional short-term impacts to the community.	No additional short-term impacts to the community.
Protection of Workers During Remedial Action	No remedial actions occur.	Standard health & safety procedures and PPE will protect workers during *ex situ* treatment.	Standard health & safety procedures and PPE will protect workers during monitoring well installation and sampling.
Environmental Impact	Groundwater remains impacted.	None.	None.
Implementability			
Technical Feasibility	Not applicable.	Technical aspects are well understood and treatment should pose no difficulty.	Very easy to conduct groundwater monitoring necessary for MNA assessment.
Administrative Feasibility	Not applicable.	Administratively feasible to implement	Administratively feasible to implement.
Availability of Services, Equipment, and Technology	Not applicable.	Contractors and materials necessary to implement *ex situ* treatment are readily available.	Professional and laboratory services to evaluate MNA data are readily available.
Cost (in million)			
Cost ($ in millions)	**0**	**8.7**	**6.5**

5.2.1 Alternatives S1-1, S1-6, GW1-1, GW1-6: No Action (Soils and Groundwater)

Under this alternative, impacted soils would remain in place, no remedial action would be implemented at the Site, and potential risks to human health and the environment would not be addressed. No monitoring would be conducted for groundwater to evaluate the potential for uranium migration or to assess potential reductions in uranium concentrations. Existing LUCs and access restrictions (site security fencing) would be left in place but not necessarily maintained. Environmental monitoring would not be performed. In addition, no restrictions on future land use would be pursued. No five-year reviews would be conducted.

5.2.1.1 Overall Protection of Human Health and the Environment

These alternatives are not protective of human health and the environment. The BRA for the site indicates that current doses and risks to industrial, construction and utility workers exceeded their corresponding acceptable dose and risk criteria at OU 1 and AOC 6. There would be an increase in the dose and risk to future onsite workers at AOC 6 due to radioactive decay over time, as no remedial actions would be implemented.

These alternatives provide no additional protection to human health and the environment over baseline conditions. The risks from direct contact, ingestion, external gamma radiation, and inhalation would continue and could increase over time because current access controls, such as fencing, would not be maintained. Existing paved surfaces that deter human access to underlying soils would also undergo eventual deterioration, thereby increasing the potential for human exposure to site-related contamination. The potential for human exposure to contaminants and the potential for off-site migration could increase over time as a result of anthropogenic and natural processes and the deterioration of existing structures and paved surfaces.

There are not any risks associated with exposure to contaminated groundwater under the industrial land use scenario as evaluated in the BRA (CABRERA 2011c). The RAO for this media is to prevent migration of contaminated groundwater until the New Jersey ambient groundwater quality standards have been met. Uranium has been detected in groundwater above the New Jersey standard, and continued contact with contaminated soils will result in groundwater concentrations remaining elevated. Monitoring will not be conducted in order to evaluate contaminant migration or potential decreases in contaminant concentrations.

5.2.1.2 Compliance with ARARs

Proposed ARARs for the DuPont FUSRAP site are developed in Section 3 of this FS Report. The No Action alternatives for both soil and groundwater do not achieve the chemical-specific RAOs and do not meet associated ARARs.

5.2.1.3 Long-Term Effectiveness and Permanence

The No Action alternatives include no long-term management measures to prevent exposures to or the spread of contamination. Current and potential future risks for the soils media exceeded the CERCLA acceptable cancer risk range. Although existing site security could provide limited control of exposures to site contaminants, this alternative does not assure controls will remain in place and does not provide any additional new controls in the future. Under future land-use scenarios, there are potential unacceptable risks to human health and the environment, since the impacted soils would remain in place with no controls.

Contamination of groundwater would continue since the source of contamination, site soils, would remain in place. Leaching of contaminants from site soils would continue to impact groundwater, thus the RAO would not be achievable.

Under this alternative, no groundwater monitoring or documentation of potential reduction in contaminant levels would be conducted.

5.2.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume is achieved, because no treatment process is proposed under this alternative.

5.2.1.5 Short-Term Effectiveness

There is no significant short-term human health risks associated with these alternatives beyond baseline conditions. There would be no additional short-term health risks to the community, because no remedial actions would be implemented. There would be no transportation risks nor would workers be exposed to any additional health risks. These alternatives would not directly cause adverse impacts on soils, air quality, water resources, or biotic resources. No Action allows impacted soils to remain in place as a continued source of contamination to groundwater. The time until protection is achieved is indefinite because no action would be taken.

5.2.1.6 Implementability

No actions are proposed under this alternative.

5.2.1.7 Cost

There is no capital and operating cost under this alternative.

5.2.2 Alternatives S2-1, S2-6: Excavation and Off-Site Disposal

These alternatives include excavation and off-site disposal to remove impacted soils exceeding the RGs under industrial land use scenarios. Soils above the established cleanup goals would be excavated and shipped off-site to a permitted disposal facility. Contaminated rubble, which will be encountered in some areas of the site, would be downsized to meet requirements of the receiving disposal facility. Other technologies required during the remedial action activities include LUCs, monitoring, short-term containment technologies, and truck and rail transportation.

5.2.2.1 Overall Protection of Human Health and the Environment

In general, the alternative is protective of human health. These alternatives include removal of soil to meet the site-specific remediation goals in soils (Section 3.4). Removing soil with COCs above cleanup goals would limit risks to within the CERCLA acceptable cancer risk range. In addition, exposure would be below dose-based limits for workers and the source of groundwater contamination would be eliminated.

5.2.2.2 Compliance with ARARs

These alternatives would achieve the NJDEP's 15 mrem/yr dose criterion standard as specified in NJAC 7:28-12.8(a)(1) for radionuclides, assuming industrial land use is maintained and in the event that all controls fail, the contingency dose limit of 100 mrem/yr would still be met.

5.2.2.3 Long-Term Effectiveness and Permanence

Under these alternatives, soil COCs will not remain onsite above the media-specific cleanup goal for an expected industrial land use scenario for the construction worker (65 pCi/g total uranium). These alternatives are protective in the long term for industrial land use. Although the potential exists for existing LUCs to fail, it is reasonable to expect that, with appropriate documentation and procedures, LUCs can be successfully implemented during remedial action activities and would be effective in protecting human health and the environment.

Removal of impacted soils under this alternative would effectively remove the source of groundwater contamination and thereby reduce any long-term impact to groundwater.

5.2.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Treatment is not proposed under this alternative, except where needed for dewatering and treatment of wastewater. Therefore, a reduction in contaminant toxicity, mobility, or volume of the contaminated soils through treatment would not occur.

5.2.2.5 Short-Term Effectiveness

Short-term effectiveness is similar to the other soil alternative. The impacts are described in more detail under the evaluation of Alternative S3.

Remedial action including the design and implementation would require one year to complete and a 1000-year O&M period (Table 5.1). Following completion of excavation, backfill and restoration, the areas would be available for activities consistent with industrial land use.

5.2.2.6 Implementability

Technically, this alternative is implementable at OU 1 and AOC 6. Implementation at AOC 6 poses more of a challenge due to the presence of an active site road and utilities that will require temporary shutdown or re-routing during the remedial action. Excavation of impacted soils, construction of temporary roads, and onsite truck transport of soil are conventional activities in construction projects of this kind. Multiple disposal facilities are available that can accept the excavated wastes. Resources are readily available for removing soil and standard excavation with the use of construction equipment. Borrow sites for backfill and cover soil have not been selected, but are anticipated to be locally available.

The acceptability of this alternative would be affected by the administrative requirements for transport and disposal and the types of wastes (radioactive and hazardous substances) that are present at the Site. The DOT regulates the transport of radioactive and chemically hazardous materials. Some states also have their own additional requirements. Depending upon the types and activities of radioactivity being transported, the material may be subject to such requirements.

LUCs are implementable during the remedial action activities. No technical difficulties are anticipated. Some LUCs require the involvement of local government to implement, monitor, and maintain the controls.

Careful planning would be needed between remedial action planners and DuPont staff to minimize disruptions and/or impacts to Chambers Works operations during implementation. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to plant personnel. This type of planning will increase the difficulty of implementability, but also it will reduce the risks to personnel.

5.2.2.7 Cost

The present value cost to complete this alternative (in FY 2010 dollars) for OU 1 and AOC 6 is approximately $33.1 million. This estimated cost includes additional cost elements to account for occupational health considerations and treatment/disposal costs associated with non-FUSRAP chemical constituents that will be excavated and handled with the radioactive contaminated soil. The implementation of LUCs during remedial action is included in this cost. See Appendix B for a detailed description of costs for Alternatives S2-1 and S2-6.

5.2.3 Alternatives S3-1, S3-6: Excavation of Soils, Treatment, and Off-site Disposal

Alternatives S3-1 and S3-6 include excavation combined with treatment and off-site disposal to meet soil RGs. The SGS will be used to reduce the volume of contaminated soil by segregating it from clean soil. During the Remedial Design, another process could be selected. Consistent with USEPA guidance (OSWER Directive 9355.3-01FS3, Nov. 1989),

> "To simplify the development and evaluation of alternatives, one representative process should be selected, if possible, for each technology type remaining after the technical implementability screening procedure. During remedial design, other process options may be selected if they are found to be more advantageous."

After passing through the SGS the soils above RGs would be managed similar to Alternatives S2-1 and S2-6, described above. Contaminated rubble would be crushed or broken up to meet requirements of the SGS feed specification (particles less than 2 inches across). Treated soils meeting RGs would be used as backfill. The average total uranium concentrations in the treated soil will be approximately 13 to 20 pCi/g. However, due to larger plume size under S3, the additional uranium in the soil will not likely result in higher uranium concentration in groundwater as compared to soil alternative S2. Therefore, groundwater quality under S2 and S3 is expected to be very similar. Treated soils and residuals exceeding established ARAR-based cleanup goals would be shipped to a permitted, off-site disposal facility. During the remedial action activities LUCs, excavation, monitoring, short-term containment technologies, and truck and rail transportation are components of this alternative.

5.2.3.1 Overall Protection of Human Health and the Environment

These alternatives include excavation and treatment of soil to meet the RGs. Removing soils containing contaminants above RGs would limit risks to within the CERCLA acceptable cancer risk range. Therefore, this alternative is protective of human health and the environment.

A groundwater alternative (Sections 5.2.4 and 5.2.5) may be implemented in conjunction with this alternative to achieve a complete remediation solution.

5.2.3.2 Compliance with ARARs

ARAR-based cleanup goals selected for the DuPont Chambers Works FUSRAP site were detailed in Section 3. Under Alternatives S3-1 and S3-6, all ARAR-based cleanup goals would be satisfied. The chemical-specific ARAR for radionuclides in soil would be satisfied. Radionuclide concentrations in soils would be reduced to below the soil RGs. No location-specific and action-specific ARAR has been identified for this alternative.

5.2.3.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternatives S3-1 and S3-6 is similar to Alternatives S2-1 and S2-6. The excavation and removal of impacted soils would result in a permanent reduction in site risks.

Removal of impacted soils would effectively reduce the long-term contamination and potential for continued impact to groundwater as demonstrated in Appendix C. One of the groundwater alternatives could be selected to address the remediation of residual groundwater.

5.2.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Soil treatments, such as SGS and soil washing, concentrate the contaminants into a smaller volume. The "clean stream" still contains some low concentrations of residual contamination below soil RGs. The volume of the radioactively contaminated concentrated stream is much smaller than the original volume of impacted soils before processing, thus reducing transportation and disposal costs. Toxicity and mobility would not be affected; only volume is changed. Reduction of the contaminated fraction is estimated for cost estimating purposes to be 30 percent of the excavated volume for both OU 1 and AOC 6.

5.2.3.5 Short-Term Effectiveness

Short-term effectiveness of Alternatives S3-1 and S3-6 is similar to Alternatives S2-1 and S2-6 with the exception of the potential for worker exposure during treatment. The overall risk in implementing this alternative is increased (relative to Alternatives S2-1 and S2-6) because of the handling of wastes during treatment. When performing soil treatment, workers would follow a HASP and wear appropriate PPE to minimize exposures. Mitigation measures would be used to ensure minimization of short-term impacts, such as erosion and dust control during construction.

Remedial action would require two years to complete and would include no O&M period (Table 5-1). Following completion of excavation, treatment, and restoration, the site soils would be released for industrial use.

5.2.3.6 Implementability

Implementation concerns for this alternative include: the effectiveness of the soil treatment process to meet media-specific cleanup goals, logistical and technical problems for pilot demonstrations and scale-up to full-scale operations, potential resistance from local Stakeholders to onsite treatment, and demonstrating the achievement of acceptable dose limits when using the "clean" soils (below RGs) after treatment for beneficial reuse.

This alternative is considered to be technically implementable if certain treatment performance criteria can be met. SGS technologies and equipment are currently available commercially, although site-specific pilot studies will be required prior to remedial action to determine if these technologies could be cost effectively applied to this site. Although it is technically feasible to separate impacted soils based on their radioactivity, the volume reduction potentially achievable through SGS is uncertain. The effectiveness of SGS is impacted by soil particle size limits. Technical problems are caused by fine-grained soils, excessive rubble, and high water content, all of which can be anticipated to some degree at the Site. If pilot testing shows the volume reduction to be minimal, then Alternatives S2-1 and S2-6 will likely incur lower total costs to achieve a similar result. Therefore, technical implementability is a potential concern for this alternative.

Careful planning would be needed between remedial action planners and DuPont to minimize disruptions and/or impacts to plant operations. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to plant personnel. This type of planning will increase the difficulty of implementability, but also will reduce the risks to Site personnel.

Other aspects of this alternative, such as excavation and truck transport of soil, are conventional activities in construction projects of this kind. Standard excavation and construction equipment would be used to remove contaminated material. Resources are readily available for removing impacted soils and providing backfill over treated soils. Borrow sites, for backfill and soil cover, have not been selected, but are anticipated to be locally available.

The acceptability of these alternatives would be affected by the administrative requirements for transport and disposal. The Department of Transportation (DOT) regulates the transport of radioactive and chemically hazardous materials. Some states also have their own additional requirements. Depending upon the types and activities of radioactivity being transported, the material may be subject to such requirements.

5.2.3.7 Cost

The present value cost to complete Alternative S3-1 and S3-6 (in FY 2010 dollars) is approximately $30.7 million. Costs are based on excavation, treatment efficiency, and off-site disposal of impacted soils. This estimated cost includes additional cost elements to account for occupational health considerations and treatment/disposal costs associated with non-FUSRAP chemical constituents that will be excavated and handled with the radioactive contaminated soil. See Appendix B for a detailed description of Alternative S3-1 and S3-6 costs. The imposition and the implementation of LUCs are included in this cost.

5.2.4 Alternatives GW2-1, GW2-6: Ex Situ Treatment of Groundwater

These alternatives consist of the installation of a pump and treat system to remove contaminated groundwater from beneath the site and subsequently remove the contaminants via treatment processes. The size of the systems would vary significantly between the two sites, with the plume size and pumped flow rate considerably smaller at AOC 6 than at OU 1. These alternatives include installation of monitoring wells, extraction wells, and a treatment system. Once extracted, ion exchange would be used to remove uranium from the water. In addition, as a pretreatment step, GAC will be used to remove high concentrations of organics from non-FUSRAP sources (LNAPL) in the groundwater. Following ion exchange treatment, the treated water would be discharged to the DuPont sewer system for subsequent treatment in the DuPont WWTP. The remaining waste streams (solids/sludge/spent) generated from the ion exchange process would be characterized for disposal in accordance with Federal and state regulations.

In remedial design, another process could be selected. In accordance with USEPA guidance (OSWER Directive 9355.3-01FS3, Nov. 1989),

> "To simplify the development and evaluation of alternatives, one representative process should be selected, if possible, for each technology type remaining after the technical implementability screening procedure. During remedial design, other process options may be selected if they are found to be more advantageous."

5.2.4.1 Overall Protection of Human Health and the Environment

Remedial activities under Alternatives GW2-1 and GW2-6 would address radiological contaminants by removing groundwater from the subsurface with vertical pumping wells and treatment above ground. Until the RAO for groundwater is achieved, LUCs and land use restrictions prohibiting groundwater use will be maintained. Monitoring of groundwater would be performed while the treatment system is in operation. This alternative would be implemented in conjunction with one of the soil alternatives for a *complete* remediation solution. When combined with source removal the project duration is estimated to take less than 10 years to complete.

Possible treatment technologies such as ion exchange system would be used to remove uranium. Therefore, the alternative is protective of human health. The further release of contaminants to the groundwater above RAOs also would be eliminated through source control with one of the soil alternatives.

5.2.4.2 Compliance with ARARs

ARARs selected for the DuPont FUSRAP Chambers Works site were detailed in Section 3. Under Alternatives GW2-1 and GW2-6, RAOs established for groundwater would be satisfied.

5.2.4.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternatives GW2-1 and GW2-6 will depend on geochemical conditions in the site groundwater. Data from the RI indicate that ambient conditions at and near OU 1 and AOC 6 are minimizing transport of uranium away from the areas of soil contamination (source areas). Exceedances of groundwater criteria exist in the same locations as high soil concentrations of total uranium. Unless some event shifted the pH toward lower values and the redox conditions toward oxidizing conditions, uranium that is presently insoluble (and therefore not likely extracted via the groundwater pumping system) should remain insoluble. Therefore, combined with a soil removal alternative, Alternatives GW2-1 and GW2-6 should provide long-term effectiveness. The excavation and removal of impacted soils under one of the soil alternatives would result in a permanent reduction in the primary source of groundwater contamination. The extraction and treatment of contaminated groundwater would ensure that when LUCs were lifted, the remediation would be permanent. For the purposes of this FS, it is assumed that an environmental monitoring program would remain part of the alternative until the treatment resulted in groundwater meeting the clean-up goals. Five-year reviews would be necessary to confirm the RAOs have been met.

By removing the source material or preventing additional impacts to groundwater and by treating contaminated groundwater, the pump and treat system will reduce concentrations of contaminants to below RAOs in a shorter time frame than natural attenuation.

Dewatering, through drawdown of the relatively thin zones of groundwater contamination in the A Aquifer at OU 1, could limit the long-term effectiveness. By dewatering this shallow aquifer, contaminants would be left behind within the aquifer matrix. Re-saturation of these materials could result in the recontamination of the groundwater after pump and treat operations had ceased. Therefore, design should seek to minimize drawdown and provide for cyclic operation if necessary to re-saturate the A Aquifer, followed by pumping to remove re-dissolved uranium. This would not be an issue if the source zone soils in the A Aquifer were removed first.

5.2.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under these alternatives groundwater would be treated to remove contaminants and thus reduce their volume and mobility. Off-site migration would be reduced or eliminated through the hydraulic control (groundwater capture zones) produced by the operation of the extraction wells.

5.2.4.5 Short-Term Effectiveness

Short-term effectiveness of Alternatives GW2-1 and GW2-6 is considered very good for contaminated groundwater within the A and B Aquifers, but less effective for the A-B Aquitard (which is absent at AOC 6) due to the nature of the corresponding soils. Time frames for the remediation of sands and gravels are usually less than the time required for more silty horizons.

LUCs would be placed to restrict the use of groundwater until monitoring has shown the process to be complete. When performing groundwater sampling or servicing the equipment, workers would follow a HASP and wear appropriate PPE to minimize exposures. Mitigation measures would be used to ensure minimization of short-term impacts, such as erosion and dust control during construction and risks associated with treatment system operation (such as accidents/potential releases).

System design and installation would require two years to complete. A 10-year O&M period (Table 5-1) also is included. Following completion of monitoring well installation, and implementation of land use controls for the site property, monitoring and five-year reviews would be conducted.

5.2.4.6 Implementability

Effectiveness of this alternative will be governed by the ability to pump sufficient groundwater to reduce concentrations in the thin A Aquifer without dewatering the soil (OU 1 only). The overburden materials at OU 1 contain a thin zone of saturation. With no water moving through the materials, the constituents remain in place until becoming re-saturated. This alternative is considered to be technically implementable. Pump and treat systems are a common technology and the anticipated treatment media are available. Drilling and monitoring of groundwater wells is a well-established activity and does not pose implementation problems. Equipment and personnel are readily available. LUCs restricting groundwater use are considered technically implementable.

Careful planning would be needed between remedial action planners and DuPont to minimize disruptions and/or impacts to plant operations. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to tenant personnel. This type of planning will increase the difficulty of implementability, but also will reduce the risks to personnel.

The acceptability of Alternatives GW2-1 and GW2-6 would be affected by the administrative requirements for monitoring and the requirement to restrict groundwater use for a lengthy period of time. The acceptability also could be affected by the possible (but unlikely) need to maintain a treatment system for an extended period of time. Imposition of these controls and continuation of the treatment program would depend on the cooperation of DuPont and the State. Many durable LUCs can be placed on the property only by the owner of the property. Other durable LUCs require the involvement of local government to implement, monitor, and maintain the controls. Local government involvement occurs on a voluntary basis. All of these factors add to the administrative difficulty of implementing this alternative.

5.2.4.7 Cost

The present value cost to complete Alternatives GW2-1 and GW2-6 (in FY 2010 dollars) is approximately $8.7 million. Costs are based on assumed well locations and treatment efficiency. O&M costs are significant, especially in the short term when uranium concentrations may be high.

O&M costs (for monitoring and land use controls) are estimated for a 10-year period after source removal. The imposition and the implementation of a LUC plan are included in this cost. In addition, five-year reviews are required throughout the costing period. See Appendix B for a detailed description of costs for Alternatives GW2-1 and GW2-6.

5.2.5 Alternatives GW3-1, GW3-6: Monitored Natural Attenuation

Alternatives GW3-1 and GW3-6 consist of monitored natural attenuation, with source control. Source control would include the implementation of one of the active soil alternatives (Alternatives S2 or S3 at each site), which would eliminate further addition of mass to groundwater at concentrations above RAOs. Natural attenuation processes at the DuPont Chambers Works FUSRAP site are expected to reduce contaminant concentrations through the processes of reduction/precipitation, dispersion, and diffusion. A detailed MNA plan specifying a sampling and analysis program necessary to demonstrate reduction in groundwater concentrations will be developed. Data evaluation will occur at regular and frequent time intervals to monitor geochemical parameters and assess the effectiveness of MNA.

5.2.5.1 Overall Protection of Human Health and the Environment

Alternatives GW3-1 and GW3-6 include installation of monitoring wells to monitor attenuation and to demonstrate that the uranium is not migrating in groundwater. The further release of contaminants to the groundwater would be eliminated through source control actions. Currently, there is no unacceptable exposure to these constituents in groundwater. LUCs would restrict the use of groundwater and result in this alternative being protective to human health.

5.2.5.2 Compliance with ARARs

ARARs selected for the DuPont FUSRAP Chambers Works site were detailed in Section 3. Under Alternatives GW3-1 and GW3-6, RAOs established for groundwater would be satisfied.

5.2.5.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternatives GW3-1 and GW3-6 is very good. The excavation and removal of impacted soils under one of the soil alternatives would result in a permanent reduction in the risk of recontamination of the groundwater. Natural attenuation would ensure groundwater remediation would be permanent. By removing the source material or preventing additional impacts to groundwater, natural attenuation processes in the groundwater system will prevent migration of contaminated groundwater from beneath OU 1 and AOC 6, and eventually reduce concentrations of contaminants below RAOs. For purposes of this FS, it is assumed the current environmental monitoring program would continue until natural attenuation had resulted in attainment of groundwater goals. Five-year reviews would be necessary to confirm groundwater goals have been attained.

5.2.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under this alternative no actions would be taken to reduce the toxicity, mobility, or volume of contaminants in groundwater. Naturally occurring conditions at the site would act to reduce concentration and mobility. Mobility of the constituents is reduced through the reduction of uranium from U(6+) to the much less soluble U (4+) in response to natural, ambient geochemical conditions. Concentrations are also reduced through the processes of dispersion and diffusion, as uranium moves through the aquifer.

5.2.5.5 Short-Term Effectiveness

Short-term effectiveness of Alternatives GW3-1 and GW3-6 depends on the success of the initial soil remedial action. Because the locations of groundwater contamination at both OU 1 and AOC 6 overlap the locations of soil contamination (including below the water table), removal of the source soils and replacement with clean backfill is likely to resolve groundwater issues quickly. Monitoring, following USEPA (1999) guidance, will be used to evaluate short term effectiveness of MNA. LUCs would be placed to restrict the use of groundwater until monitoring has shown the process to be complete. When performing groundwater sampling, workers would follow a HASP and wear appropriate PPE to minimize exposures. Installation of monitoring wells would require less than 3 months to complete and then a comprehensive sampling and analysis program would be initiated. Although time frames may vary it is anticipated that this alternative will include a 30-year O&M period (Table 5-1). Following completion of monitoring well installation and implementation of land use controls, monitoring and five-year reviews would be conducted.

5.2.5.6 Implementability

This alternative is considered to be technically implementable. LUCs restricting groundwater use are considered technically implementable.

Drilling and monitoring of groundwater wells is a well known activity and generally does not pose implementation problems. Equipment and personnel are readily available. The wells would be installed to monitor observed occurrences of contaminants and geochemical conditions in the groundwater and at selected down-gradient locations from source areas to demonstrate MNA effectiveness. Post excavation monitoring well locations would be used to monitor the effectiveness of MNA. The locations are shown in Section 4, Figures 4-7 and 4-8 (OU 1 and AOC 6, respectively). A long term monitoring plan would be developed for groundwater sampling and reporting requirements.

The acceptability of Alternatives GW3-1 and GW3-6 would be affected by the administrative requirements for monitoring and the requirement to restrict groundwater use for a period of time. Imposition of these controls would depend on the cooperation of DuPont and the State. Many durable land use controls can be placed on the property only by the owner of the property. Other durable land use controls require the involvement of local government to implement, monitor, and maintain the controls. Local government involvement is outside the scope of this document. All of these factors add to the administrative difficulty of implementing this alternative.

5.2.5.7 Cost

The present value cost to complete Alternatives GW3-1 and GW3-6 (in FY 2010 dollars) is approximately $6.5 million. O&M costs (for monitoring and land use controls) are estimated for a conservative 30-year period. The implementation of an LUC plan is included in this cost. In addition, five-year reviews are required throughout the costing period. See Appendix B for a detailed description of the cost elements for Alternatives GW3-1 and GW3-6.

5.3 Considerations Common to All Alternatives

5.3.1 Monitoring and Mitigative Measures

A mitigation action plan would be developed during remedial design to specify measures that would be taken during implementation of the remedial action to minimize risk to human health and the environment (e.g., environmental controls and contingency response actions). The primary monitoring and mitigative measures that would be used at the DuPont site are described below. These measures would be effective in minimizing the potential adverse effects associated with implementation of the alternatives.

Construction Activities: Construction practices to control potential releases to the environment would include management and engineering practices. Silt fences would be used to prevent soil transport in surface water runoff. Wetting surface materials with water or dust control chemicals would mitigate fugitive dust impacts. Chemical wetting agents can increase the reduction significantly. In addition, inactive areas can be covered to reduce wind erosion. Equipment will be decontaminated before leaving the site. Re-vegetating with native trees, grasses, and wetland plants, to be compatible with future land uses, would restore the disturbed sites. Groundwater, surface water, air, and sediment monitoring would be conducted.

Transportation: Wastes would be containerized and fitted with a cover and/or liner during long distance transport via rail to the off-site disposal facility. The conveyance equipment could be fitted with a cover and/or lined with a barrier. Vehicles would be decontaminated and inspected before leaving contaminated areas.

Worker Protection: Activities would be conducted in accordance with approved health and safety plans. Personal Protective Equipment (PPE), personal monitoring devices, and decontamination procedures would be used to minimize exposure to and the spread of contamination. The potential for worker exposure is mitigated through these measures. Monitoring for external exposure and/or breathing zone air sampling would be conducted at the site to ensure workers do not receive exposures that would result in adverse health effects.

Protection of the General Public: A network of ambient air monitors would be installed to measure dust emissions during construction activities. Mitigation measures, such as wetting soil, will be implemented if emissions exceed levels that could pose a risk to human health. Access controls also would be used to restrict public access to construction areas

5.3.2 Impact of Potential Loss of LUCs

For Alternatives S1 and GW1 (No Action) at both sites, LUCs would not be maintained or monitored. Therefore, the impact of potential loss of LUCs is not relevant for the No Action alternatives. The soil and groundwater alternatives S2, S3, GW2, and GW3 at both OU 1 and AOC 6 rely on continued maintenance of LUCs (limit land and groundwater use and access to the property) to minimize exposure to soils and groundwater at the property during remediation. After completion of the remediation, existing DuPont-imposed LUCS would remain in place consistent with the industrial use of the property. USACE would not implement any additional LUCs that last longer than the remedial action. If existing DuPont LUCs should fail in the future, it is important to note that the potential for exposure above both dose-based and risk-based standards is low. In Appendix A, USACE demonstrates that the RG of 65 pCi/g total uranium is protective, complies with ARARs, and the resulting dose to an onsite resident would be less than 100 mrem/yr.

Excavation Alternatives S2-1, S2-6, S3-1 and S3-6 would remove only the soils necessary to satisfy an industrial land use scenario. If LUCs fail in these excavation alternatives, then the potential for increase for both dose and risk exposures are evaluated in the ACF scenario. These potential exposures, if LUCs fail, have been demonstrated to be less than 100 mrem/yr and comply with ARARs. If monitored natural attenuation is selected as the remedial measure for groundwater, then there is a slight potential for exposure to contaminated groundwater if LUCs fail during the remedial measure. Alternatives GW2 and GW3 for both sites rely on the use of LUCs to control groundwater use.

5.3.3 Short-term Uses and Long-term Productivity

Implementation of any set of alternatives would require the DuPont Chambers Works FUSRAP site to support cleanup activities and would involve the use of nonrenewable resources, such as construction materials, fuel, and petroleum-based products. Alternatives that include excavation and disposal would require the long-term commitment of land for waste disposal at an off-site facility or facilities.

The short-term use of the site for remedial activities could adversely affect DuPont operations. Planning will be done before implementation of any alternative to reduce risks to the current operations. Long-term effects on the plant also will be taken into account when analyzing each alternative.

The impact of the remediation on the local economy could be fairly significant. An outside contractor would be performing the work. Therefore, mostly secondary jobs would be impacted. Few local residents would be hired directly by the remediation contractors. However, the remediation workers would be spending money in the local economy for the duration of the remediation.

5.3.4 Final Status Surveys

USACE intends to use MARSSIM guidance (DOD 2000) to ensure exposure to all radiological contaminants combined will not exceed dose-based limits. MARSSIM provides a consistent and scientifically rigorous approach for demonstrating compliance with dose-based limits, such as the 15 mrem/yr ARAR for the DuPont Chambers Works FUSRAP site. The approach includes the development of surveying and sampling criteria for the final site investigation prior to release (called the "final status survey"). For this site, the surrogate COC concentration for individual sampling results will be compared with respect to the RG, developed for the Site. Areas where the surrogate concentration exceeds the RG would require further remediation. Prior to performing final status survey, a final status survey plan based on the MARSSIM methodology will be developed and implemented to ensure that current or potential future doses are acceptable. In addition, a post-remedial risk assessment will be performed to ensure that the maximum risks and doses for RME scenarios do not exceed CERCLA acceptable risk range and NJDEP's acceptable dose limit.

5.4 Comparative Analysis of Remedial Alternatives

In this section, the alternatives undergo a comparative analysis for the purpose of identifying relative advantages and disadvantages of each on the basis of the detailed analysis above. The comparative analysis provides a means by which remedial alternatives can be directly compared to one another with respect to common criteria. Overall protection and compliance with ARARs are threshold criteria that must be met by any alternative for it to be eligible for selection. The other criteria, consisting of short- and long-term effectiveness; reduction of contaminant toxicity, mobility, or volume through treatment; ease of implementation; and cost are the primary balancing criteria used to select a preferred remedy among alternatives satisfying the threshold criteria. A summary table illustrating the comparative analysis for soil is provided in Table 5-4. Community and state acceptance criteria are preliminarily assessed in Table 5-4 and will be fully addressed after the public comment period.

Additional information pertaining to the advantages and disadvantages of each groundwater alternative is included in Table 5-5. This table provides a summary of the predicted or expected timelines specific to the groundwater alternatives. The estimated time frames presented in Table 5-5 for implementation of remedial alternatives are only provided for evaluation and comparison purposes. The actual time frame for implementation will be dependent on a number of factors and will be further refined during the remedial design phase.

Table 5-3: Comparative Analysis of Alternatives – Soil

Evaluation Criteria	Alternative S1-1; S1-6 No Action	Alternative S2-1; S2-6 Excavation and Disposal	Alternative S3-1; S3-6 Excavation, Treatment and Disposal
Overall protection of human health and the environment	Alternative does not meet threshold criteria	High	High
Compliance with ARARs		High	High
Long-term effectiveness and permanence		High	High
Reduction of toxicity, mobility and volume through treatment		Medium	High
Short-term effectiveness		High	High
Implementability -Administrative - Technical		High High	High Medium
Cost	High	Low	Low

Note: *Hig*h represents a favorable rating for the specific criteria; whereas *Low* represents the least favorable rating.

Table 5-4: Comparative Analysis of Alternatives – Groundwater

Evaluation Criteria	Alternative GW1-1; GW1-6 No Action	Alternative GW2-1; GW2-6 *Ex Situ* Treatment	Alternative GW3-1; GW3-6 Monitored Natural Attenuation
Overall protection of human health and the environment	Alternative does not meet threshold criteria	Medium	High
Compliance with ARARs		High	High
Long-term effectiveness and permanence		High	High
Reduction of toxicity, mobility and volume through treatment		High	Medium
Short-term effectiveness		High	Medium
Implementability		High	High
Cost	High	Low	Medium

Note: *High* represents a favorable rating for the specific criteria; whereas *Low* represents the least favorable rating.

5.4.1 Comparison Using NCP Criteria

5.4.1.1 Overall Protection of Human Health and the Environment

Each of the alternatives, except No Action, is protective of human health and the environment. The degree of protection and the permanence of this protectiveness is a function of whether and to what extent the alternative utilizes engineering containment, removal, or institutional control (IC) strategies. Since the BRA predicted that risks above the CERCLA acceptable range of 10^{-4} to 10^{-6} are present for current RME scenarios at the site, the No Action alternative is not considered protective for the long term. The excavation and off-site disposal alternatives (Alternatives S2 and S3 for both sites), when coupled with one of the groundwater alternative, rank highest in overall protection of human health and the environment because materials above media-specific cleanup goals would be excavated and shipped off-site for disposal. For all alternatives, human health and the environment are protected as long as LUCs can be implemented and maintained.

For the soil excavation alternatives, a mitigation action plan would be developed during remedial design to specify measures that would be taken during implementation of the remedial action to minimize risk to human health and the environment (e.g., environmental controls and contingency response actions).

Alternatives GW2 and GW3, for both sites, when coupled with one of the soil remedial alternatives, are protective of human health and the environment.

5.4.1.2 Compliance with ARARs

A summary of the proposed ARARs is presented in Section 3. Alternatives S2 and S3 for both sites satisfy ARARs for soils. Alternatives GW2 and GW3 for both sites satisfy groundwater RAOs when implemented in conjunction with one of the soil remedial alternatives. However, the time frame to achieve compliance could be as long as 30 years for Alternative GW3. The No Action alternatives do not achieve media-specific cleanup goals established by the ARARs.

5.4.1.3 Long-Term Effectiveness and Permanence

Human health risks remaining after remediation give an indication of the long-term effectiveness of an alternative. Human health risks due to exposure to contaminated materials will be reduced from the existing levels of risk by varying degrees, depending on the extent of remediation provided by the alternatives.

Alternatives S2 and S3 for both sites, when coupled with one of the groundwater alternatives, provide the greatest long-term effectiveness because they would remove, for permanent off-site disposal, all soils above ARAR-based, cleanup goals. The No Action alternative would not be effective in the long term as the contaminated materials would remain at the site and would not be controlled. The groundwater alternatives (GW2 and GW3) provide long-term effectiveness when coupled with one of the soil remedial alternatives.

In accordance with CERCLA, site remedy reviews will be conducted every five years for alternatives where contaminants (i.e., soil and groundwater) would remain onsite above media-specific cleanup goals. Because concentrations of some contaminants remain onsite above the media-specific cleanup goals under all alternatives for both sites, a review would be conducted at least once every five years.

5.4.1.4 Reduction in Contaminant Volume, Toxicity, and Mobility through Treatment

Alternative S3 (both sites) is the only alternative that incorporates treatment of soils and would effect a reduction in contaminant volume. This reduction is estimated for costing purposes to be 30 percent of the throughput (Appendix B). Alternative GW2 (both sites) reduces the volume of the contaminated groundwater by using a pump and treat system. The uranium would be trapped in a solid matrix so that its mobility would be reduced.

5.4.1.5 Short-Term Effectiveness

The biggest difference in short-term effectiveness is due to the potential for accidents from the excavation and transportation of soil. Increased potential for exposure to contaminated media also increases under soil and groundwater treatment scenarios. Under the excavation alternatives, short-term risks due to accidents for workers and the public are increased because of the activities related to construction, excavation, and rail transportation involved. Under Alternative S3, there are additional short-term risks due exposure during the treatment of soil. Alternatives GW2 and GW3 involve increased risk to workers due to the activities necessary to implement the alternatives. These increased risks are due to sampling collection and handling, well drilling, installation of system piping and a treatment system, installation of power systems, and handling of ion exchange media and contaminated filter materials from pretreatment.

5.4.1.6 Implementability

This criterion addresses the ability to technically accomplish the remedy; the ability to obtain approvals and coordinate with other authorities (i.e., administrative feasibility); and the availability of materials and services required for the cleanup. Materials and services for removal of contamination and environmental monitoring activities for the various alternatives are readily available. The degree of difficulty to technically accomplish the remedy increases with the amount and type (i.e., accessible soils) of impacted soils to be excavated, the level of the design/transportation required to dispose of soils in accordance with regulations, and the time/coordination involved in completing the alternative. The probability of obtaining regulatory approvals or other stakeholder agreement decreases as the amount of soil removal decreases.

All active remedial action alternatives are considered implementable on a technical and an availability-of-services basis. Alternatives S2 and S3 rely on excavation and off-site disposal of soil and also use readily available technology and equipment. Alternative S3 is considered implementable, although it involves greater uncertainties with respect to treatment performance in the field. The proposed soil treatment process is available from commercial sources and has been effectively demonstrated in other applications. The same is true for all groundwater treatment technologies considered within Alternatives GW2 and GW3. The groundwater alternatives rely, to some extent, on LUCs, as do Alternatives S2 and S3. The implementability of these controls is proportional to the duration. Longer durations of control will be more difficult to implement.

Alternatives that include LUCs as a component of the remedial action (S2, S3, GW2, and GW3) also would be difficult, but the difficulty here would arise from implementation, maintenance and enforcement of the necessary LUCs for the required duration. Alternatives GW2 and GW3 may be difficult to implement administratively due to the extended time frames involved for residual groundwater cleanup. Although it should be noted that the time frames for residual groundwater cleanup will be re-evaluated after completion of the remedial action and two years of monitoring. The expected 10-year and 30-year time periods for GW2 and GW3, respectively, are conservative estimates.

5.4.1.7 Cost

Detailed descriptions of the costs for each alternative, itemization of individual components, and assumptions are provided in Appendix B. The estimated present value cost (in FY 2010 dollars with a seven percent discount factor) to complete each alternative is shown below in Table 5-6. The total cost reflects the combined OU 1 and AOC 6 cost estimates for each alternative.

Table 5-5: Total Cost Estimate for Each Alternative

	Alternatives	Cost ($ in million)
Soil	S1-1; S1-6	0
	S2-1; S2-6	33.1
	S3-1; S3-6	30.7
Groundwater	GW1-1; GW1-6	0
	GW2-1; GW2-6	8.7
	GW3-1; GW3-6	6.5

5.5 Potential Combinations of Media-Specific Alternatives

Table 5-7 presents a matrix of alternatives that could potentially be combined to address the contaminated media present at OU 1 and AOC 6. The alternatives were combined irrespective of potential cost efficiencies, nor do the combinations involving No Action achieve the media-specific RAOs. The matrix presents those combinations of alternatives that are logically consistent based upon the evaluation as described within Section 5.0. A combined cost is presented for each soil alternative combined with a groundwater treatment alternative.

Table 5-6: Combinations of Media Specific Alternatives

	GROUNDWATER ALTERNATIVES		
SOIL ALTERNATIVES	GW1: No Action	GW2: *Ex Situ* Treatment	GW3: Monitored Natural Attenuation
S1: No Action	A		
S2: Excavation and Disposal		B $41.8 M	B $39.6 M
S3: Excavation, Treatment, and Disposal		B $39.3 M	B $37.2 M

Notes: Alternative matrix applies to both OU1 and AOC 6 for both media
A= Logically consistent but does not necessarily achieve remedial action objectives
B = Logically consistent with combined cost presented.
Blank= Not a logical combination (No Action for one medium implies No Action for both media)

The combination of No Action alternatives would not support the attainment of RAOs for either media. Risk reduction would not be achieved through this combination of alternatives, as impacted soils would remain in place with no controls, and leaching of contaminants from site soils would continue to impact groundwater.

Alternative S2 or S3 implemented in conjunction with *ex situ* treatment or MNA for groundwater will support attainment of all RAOs. Soil RAOs would be met through either excavation alternative combined with off-site disposal. Both soil alternatives S2 and S3 would meet the soils RAOs and effectively remove the source of groundwater contamination, thus supporting the attainment of the groundwater RAO through the use of either groundwater treatment option.

Based on the comparative analysis a likely combination of alternatives that will meet RAOs is Alternative S2, soil excavation with off-site disposal combined with Alternative GW3, MNA. It has been demonstrated during the RI and discussed in Section 4.3.2.3 of this document that uranium plumes are not highly mobile due to geochemical conditions onsite. Reducing groundwater conditions at Chambers Works, due to the presence of organics, have resulted in limited movement of uranium plumes away from the source of contamination. Therefore, it is expected that source removal will significantly reduce contaminant concentrations in groundwater, after which the source will be monitored to evaluate natural attenuation of contaminants.

6.0 REFERENCES

Argonne National Laboratory (ANL) 2005. *RESRAD for Windows*, Version 6.3, Computer Code, Argonne National Laboratory, Environmental Assessment Division, August 25.

Barksdale, H.C., et al. 1958. *Groundwater Resources in the Tristate Region Adjacent to the Lower Delaware River.* New Jersey Department of Conservation and Economic Development, Division of Water Policy and Supply Special Report 13.

Bechtel National, Inc. (BNI). 1985. Radiological Survey of the E. I. DuPont De Nemours and Company, Chambers Works Plant, Deepwater, New Jersey. DOE/QR/20722-22. 143 pgs. Dames & Moore Record No. 1007.

CABRERA. 2011a. Memorandum, USACE Determination of Eligible Contaminants for FUSRAP Investigation, DuPont Chambers Works FUSRAP Site, Deepwater, NJ. June.

CABRERA. 2011b. Sitewide Remedial Investigation Report for All Operable Units, Final, DuPont Chambers Works FUSRAP Site, Deepwater, NJ. June.

CABRERA. 2011c. Baseline Risk Assessment, Final, DuPont Chambers Works FUSRAP Site, Deepwater, NJ. June.

Delaware River Basin Commission (DRBC), 2004, Delaware River Basin Commission's Web Site, *http://www.state.nj.us/drbc/data.htm.*

DuPont Environmental Remediation Services (DERS). 1992a. Perched Water Zone Assessment, Dames & Moore Record No. 1268.

DuPont Environmental Remediation Services (DERS). 1992b. Current Conditions Report, DuPont Chambers Works, Deepwater, New Jersey, Volume III, Dames & Moore Record No. 1271.

DuPont Environmental Remediation Services (DERS). 1993. Geologic Model Refinement and Well Screen Verification Program.

E.I. du Pont de Nemours Company (DuPont), 1984, Chambers Works Departmental Histories, Archived at the Hagley Museum, Wilmington, Delaware.

Johnson, P.C., and R. Ettinger. 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. Environmental Science and Technology 25, no. 8: 1445–1452.

Means, R.S. Company. 2004. Environmental Remediation Cost 2005: Unit Price

New Jersey Administrative Code (NJAC) 7:9C. Ground Water Quality Standards.

Oak Ridge National Laboratory (ORNL). 1978. U.S. Department of Energy, Formerly Utilized MED/AEC Sites Remedial Action Program, Radiological Survey of the E.I. DuPont de Nemours Company, Deepwater, New Jersey. DOE.EV-0005/8. December.

U.S. Army Corps of Engineers (USACE), Manhattan Engineer District (MED), 1946, Construction Completion Report, 98 pgs., Dames & Moore Document No. 1011.

USACE. 2003. Formerly Utilized Sites Remedial Action Program (FUSRAP) – Site Designation, Remediation Scope, and Recovering Costs. ER 200-1-4.

U.S. Census Bureau. 2006. American Community Survey. Website [http://www.census.gov/].

U.S. Department of the Interior (USDI), Fish and Wildlife Service. 2007. Reference 2008-I-0103, Response to Endangered Species Act (ESA). December 12.

U.S. Department of Defense, U.S. Department of Energy, U.S, Environmental Protection Agency, and the U.S. Nuclear Regulatory Commission (DOD, et.al.), 2000, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Revision 1, NUREG-1575, Rev.1, EPA-402-R-97-016, Rev. 1, DOE/EH-0624, Rev. 1, *http://www/epa.gov/radiation/marssim/*.

U.S. Department of Energy (DOE), 1996, Dupont Site - NHPA (Section 106) Determination, 15 pgs., Dames & Moore Record No. 1083.

U.S. Department of Energy (DOE). 1997. Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes To Their Environmental Consequences (DOE/EM-0319). Office of Environmental Management, Washington, DC. January

U.S. Environmental Protection Agency (USEPA). 1988a. CERCLA Compliance with Other Laws Manual: Interim Final. EPA/540/G-89/006. August.

USEPA. 1988b. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final. EPA/540/G-89/004. October.

USEPA. 1989a. Development and Screening of Remedial Action Alternatives. OSWER Directive 9355.3-01FS3, November.

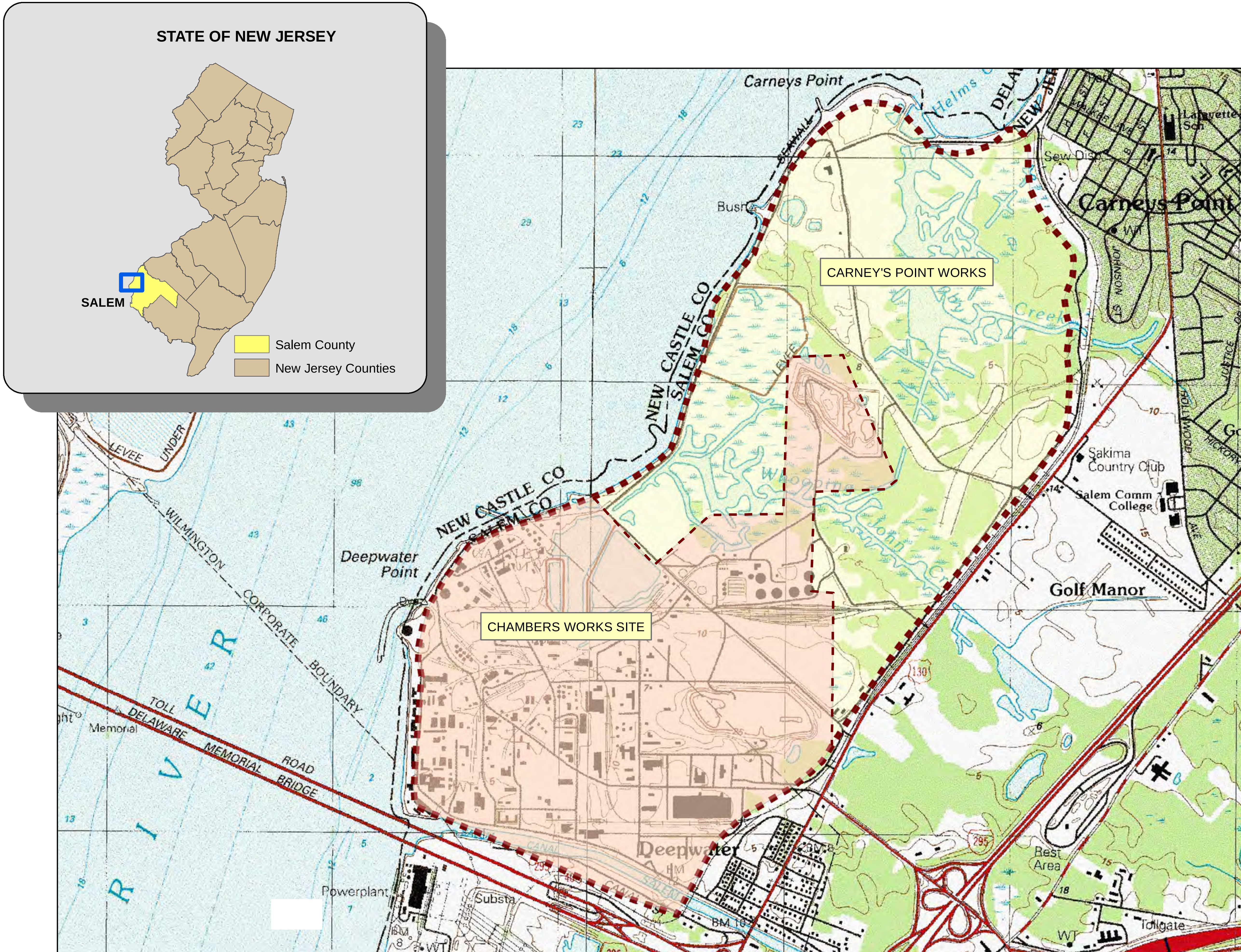
USEPA 1989b. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A). Interim Final. EPA/540/1-89/002. December.

USEPA. 1990. “National Oil and Hazardous Substances Pollution Contingency Plan,” Final Rule, FR Vol. 55, No. 46, March 8, 1990, available from U.S. Government Printing Office, Washington, D.C.

USEPA. 1999. Understanding Variation In Partition Coefficient, K_d, Values. (Volumes 1 & 2). EPA 402-R-99-004(A&B). 546 pgs.

USEPA. 2000. Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups. OSWER 9355.0-74FS-P. EPA 540-F-00-005. September.

FIGURES



Carney's Point Works

Chambers Works Site

Site Boundary

0 750 1,500 3,000 Feet

Note:
Source: USGS 7.5" Series Quads., Wimington South & Penns Grove, NJ, DEL 1967, photorevised respectively 1987 & 1988

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Location of DuPont Chambers Works

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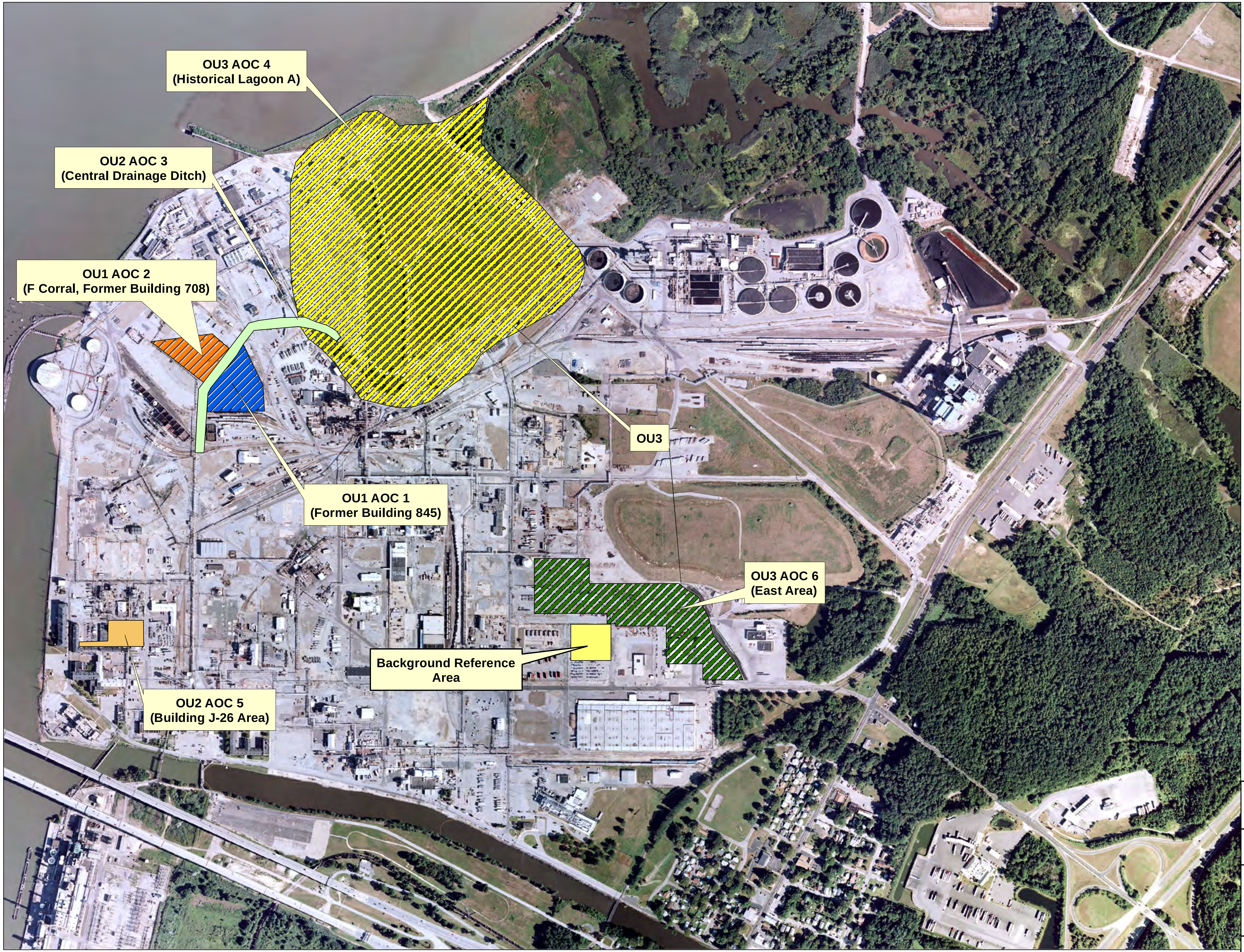
DuPont Chambers Works
Deepwater, New Jersey

Sept 2011	Figure 1-1



OU1

AOC 1

AOC 2

OU2

AOC 3

AOC 5

OU3

AOC 4

AOC 6

Background Reference Area

0 385 770 1,540 Feet

Note: Aerial Photo taken in September 2005

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Designations of Operable Units (OUs) and Areas of Concern (AOC)

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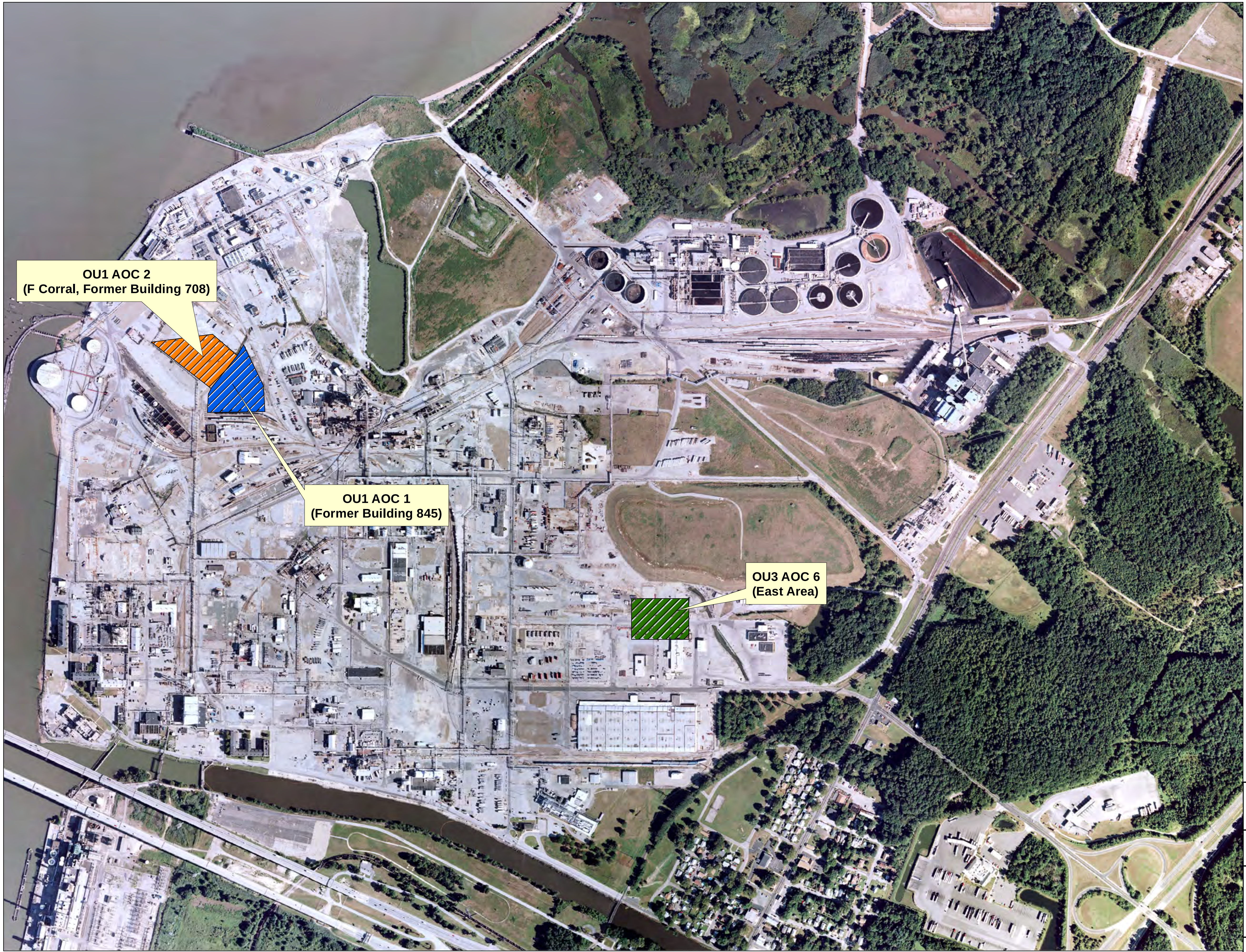
Deepwater, New Jersey

	Sept 2011	**Figure 1-2**



Note: Aerial Photo taken in September 2005

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Location of Areas Evaluated in FS

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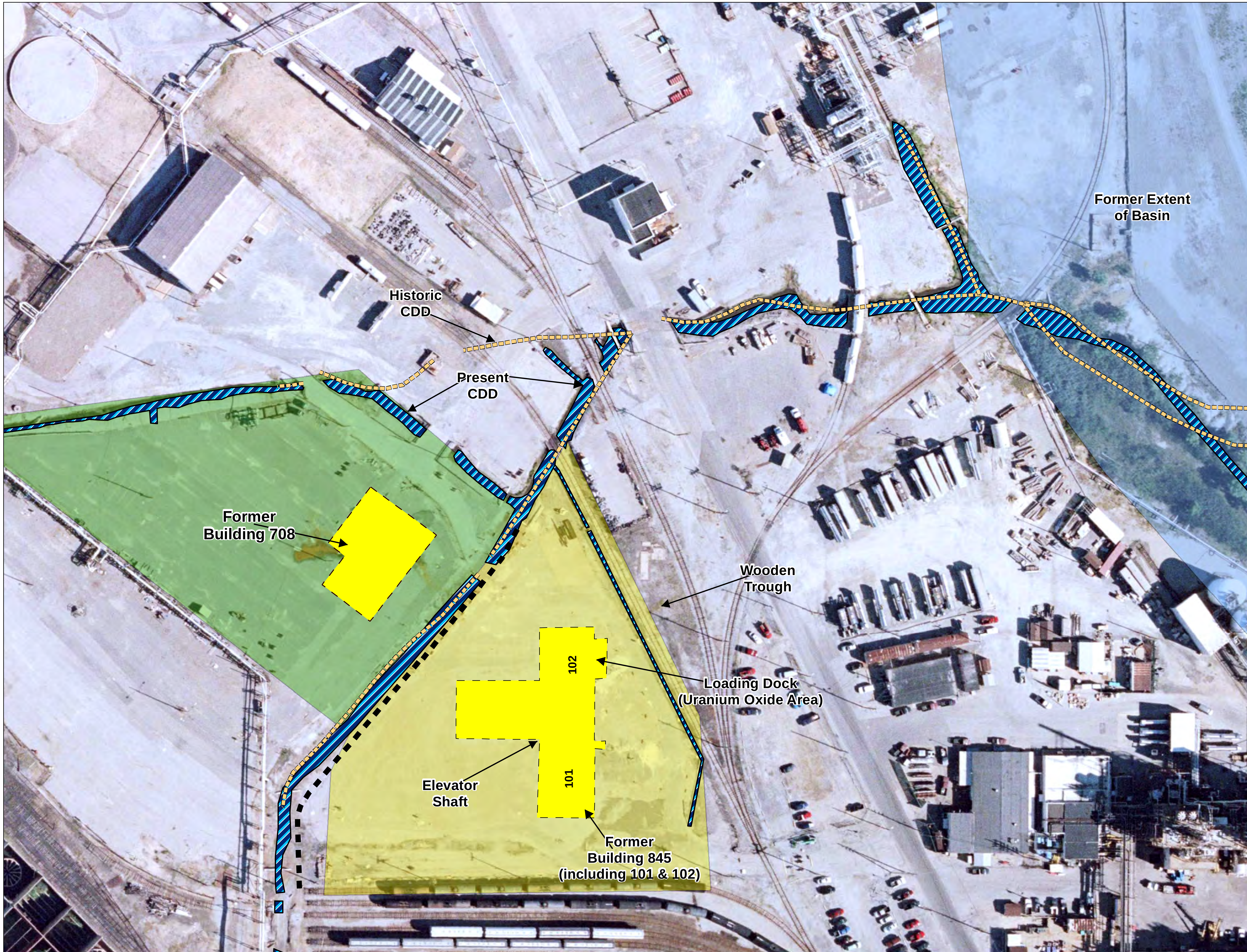
Sept 2011 | Figure 1-3



AOC Location

- AOC 1
- AOC 2
- Present Culvert
- Historic CDD
- Buildings 845 and 708
- Present CDD
- Historic Lagoon Area

0 60 120 240 Feet

Note: Aerial Photo taken in September 2005

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Location of AOCs 1 and 2, the Central Drainage Ditch, and Historical Lagoon A (Basin Complex)

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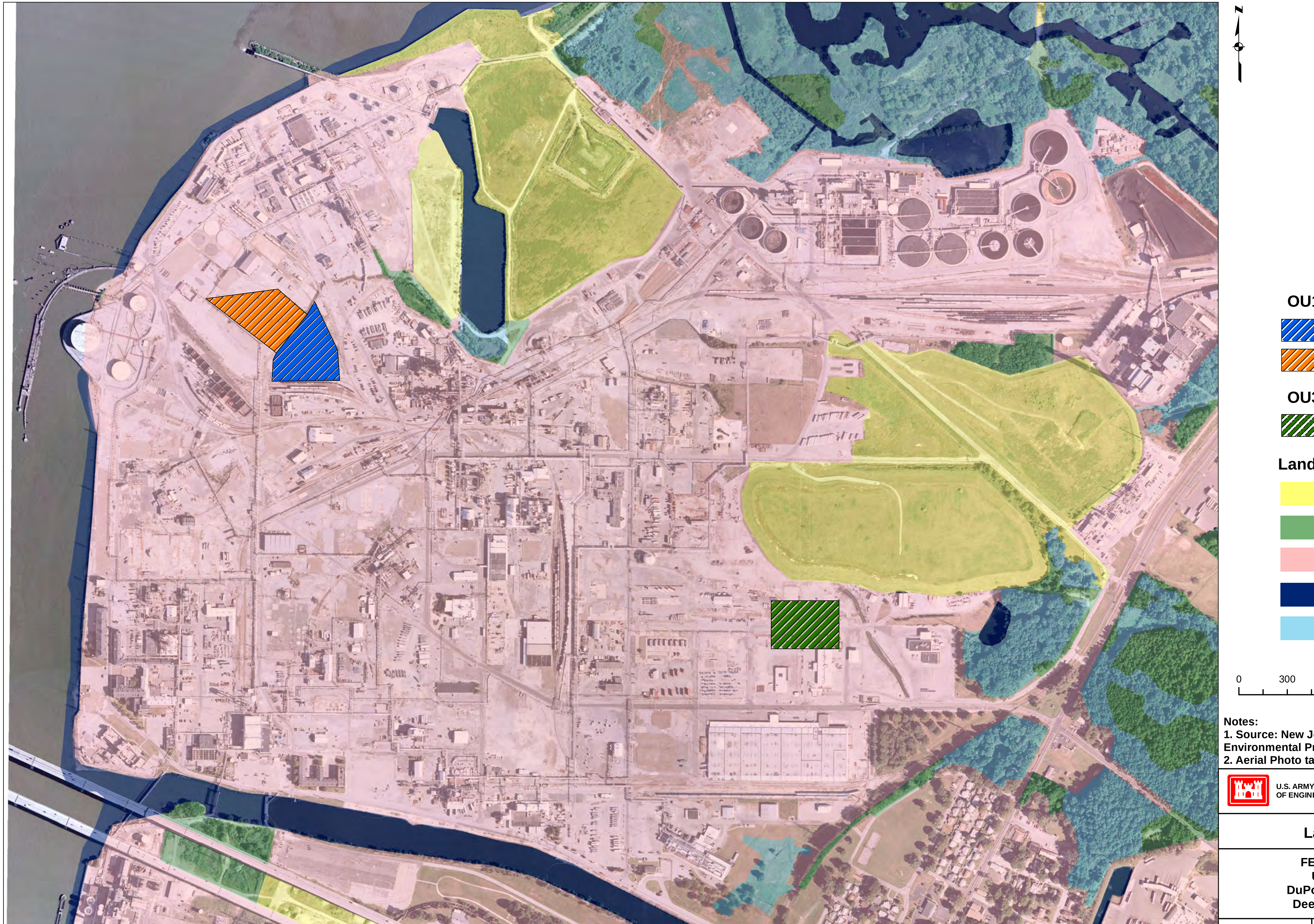
USACE-FUSRAP
DuPont Chamber Works
Deepwater, New Jersey

Sept 2011	Figure 2-1



Notes:
1. Source: New Jesery Department of Environmental Protection
2. Aerial Photo taken in September 2005

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Land Use Areas

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Total Uranium Concentrations in pCi/g and (depth in feet) below ground surface

- > 158
- 76 - 158
- 14 - 75
- 3 - 13
- < 3

1BH021 Sample Station Location and ID

Former Drainage Ditch Location

Former Building 845

Current Drainage Ditch Location

0 20 40 80 Feet

Notes:
1. The highest uranium concentration above 14 pCi/g (investigative screening value) is shown at each sample location.
2. Aerial Photo taken in September 2005

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Total Uranium Concentrations in Soil and Concrete Samples for AOC 1

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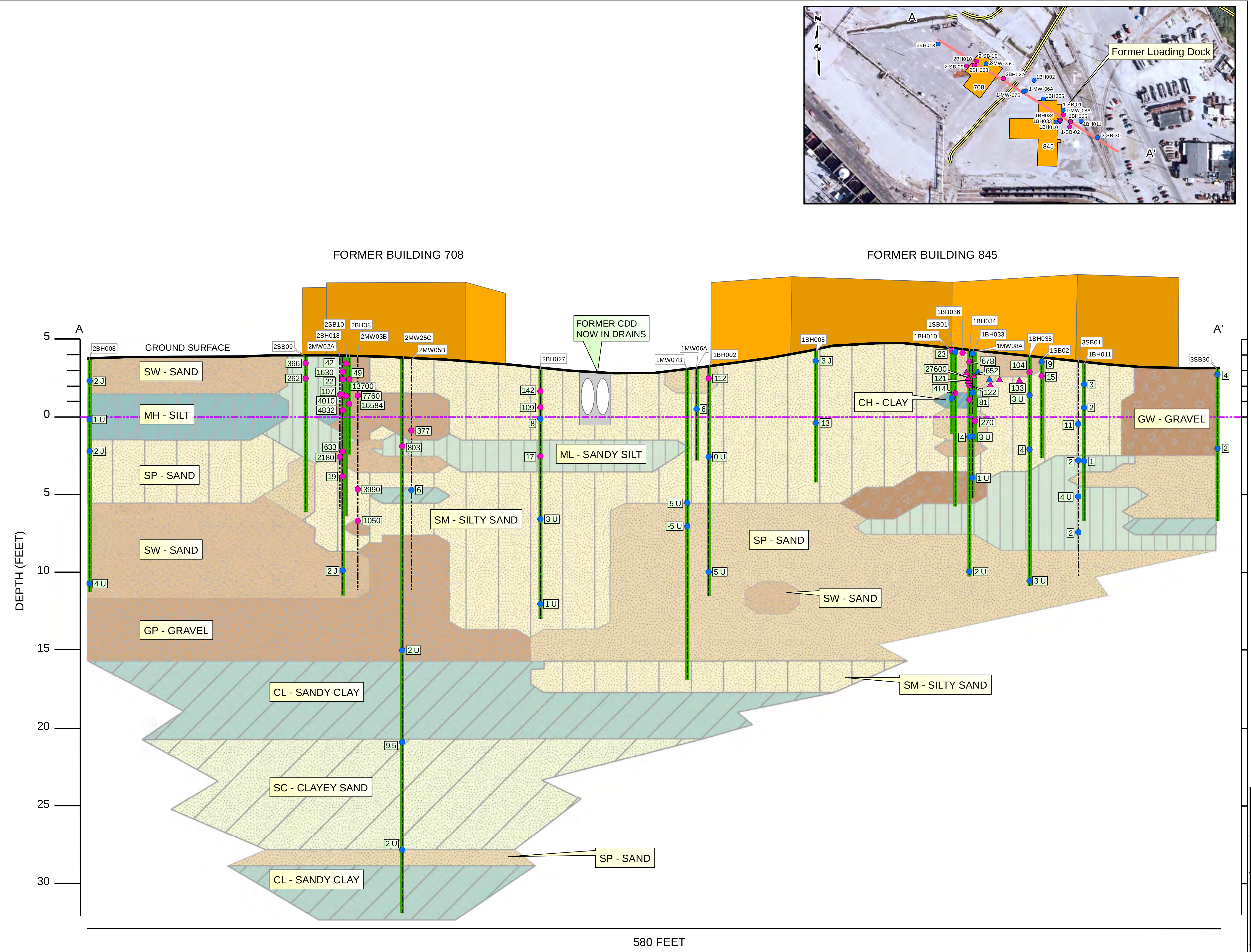
Deepwater, New Jersey

	Sept 2011	Figure 2-3



Cross Section (A - A')
Soil Boring
Boring (Not used for Lithology)
Soil Boring Sample Location
Test Pit Sample Location

Sample Results

Uranium Total > 14.0 pCi/g
Uranium Total < 14.0 pCi/g
Sample Result (pCi/g)
Drainage Ditch
Former Building

Soil Classification

GW - Gravel (Well Graded)
GP - Gravel (Poorly Graded)
SW - Sand (Well Graded)
SP - Sand (Poorly Graded)
SM - Silty Sand
SC - Clayey Sand
ML - Sandy Silt
CL - Sandy Clay
MH - Silt
CH - Clay (High Plasticity)

VERTICAL EXAGGERATION = 8X

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OU 1 Cross Section (A - A')

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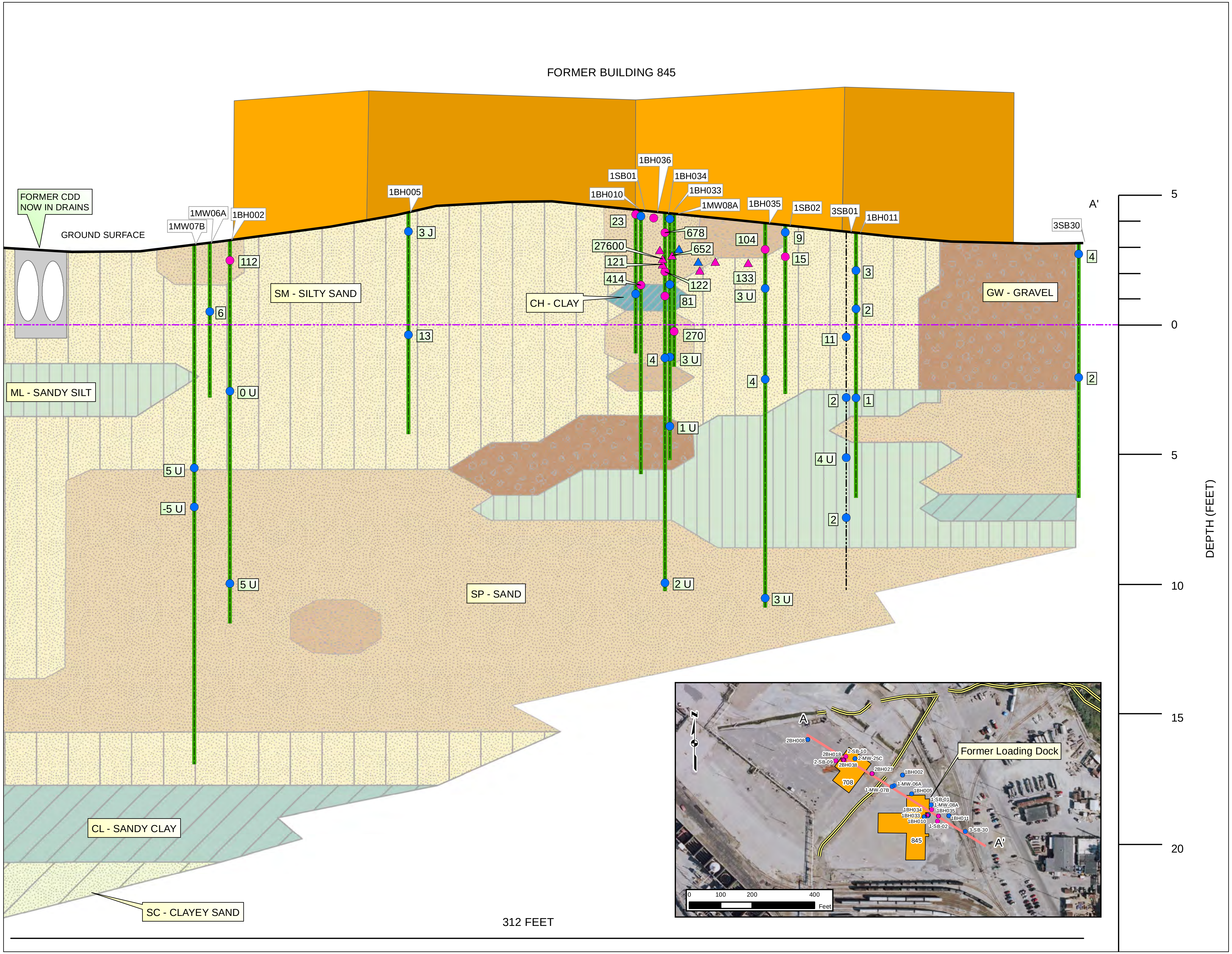
Sept 2011	Figure 2-4



Cross Section (A - A')
Soil Boring
Boring (Not used for Lithology)
Soil Boring Sample Location
Test Pit Sample Location

Sample Results

Uranium Total > 14.0 pCi/g
Uranium Total < 14.0 pCi/g
Sample Result (pCi/g)
Drainage Ditch
Former Building

Soil Classification

GW - Gravel (Well Graded)
GP - Gravel (Poorly Graded)
SW - Sand (Well Graded)
SP - Sand (Poorly Graded)
SM - Silty Sand
SC - Clayey Sand
ML - Sandy Silt
CL - Sandy Clay
MH - Silt
CH - Clay (High Plasticity)

VERTICAL EXAGGERATION = 8X

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AOC 1 View of Cross Section A - A'

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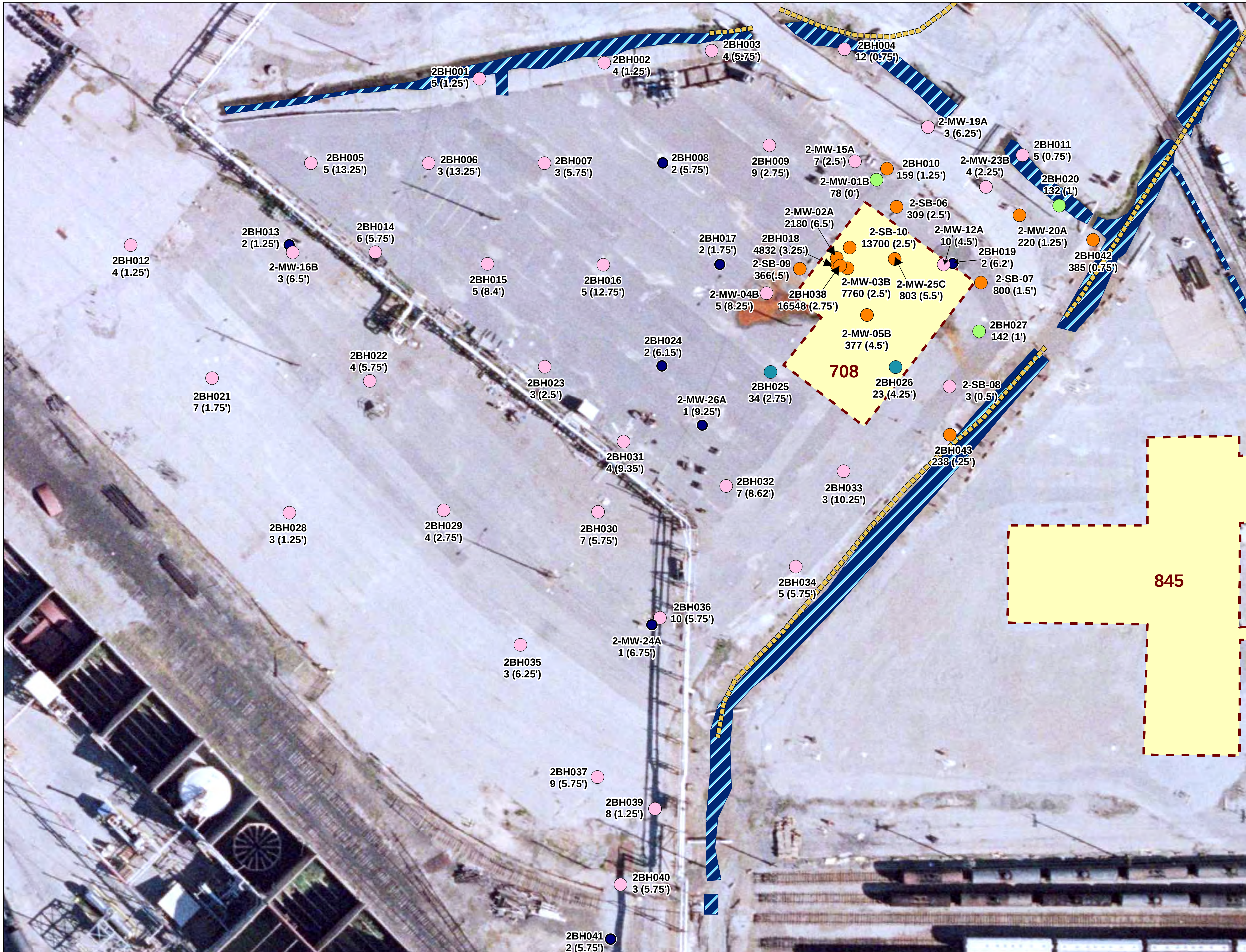
Sept 2011 | **Figure 2-5**



Total Uranium Concentrations in pCi/g and (depth in feet) below ground surface

- > 158
- 76 - 158
- 14 - 75
- 3 - 13
- < 3

2BH026 — Sample Station Location and ID

Former Drainage Ditch Location

Former Buildings 845 and 708

Current Drainage Ditch Location

0 35 70 140 Feet

Notes:
1. The highest uranium concentration above 14 pCi/g (investigative screening value) is shown at each sample location.
2. Aerial Photo taken in September 2005

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Total Uranium Concentrations in Soil Samples for AOC 2

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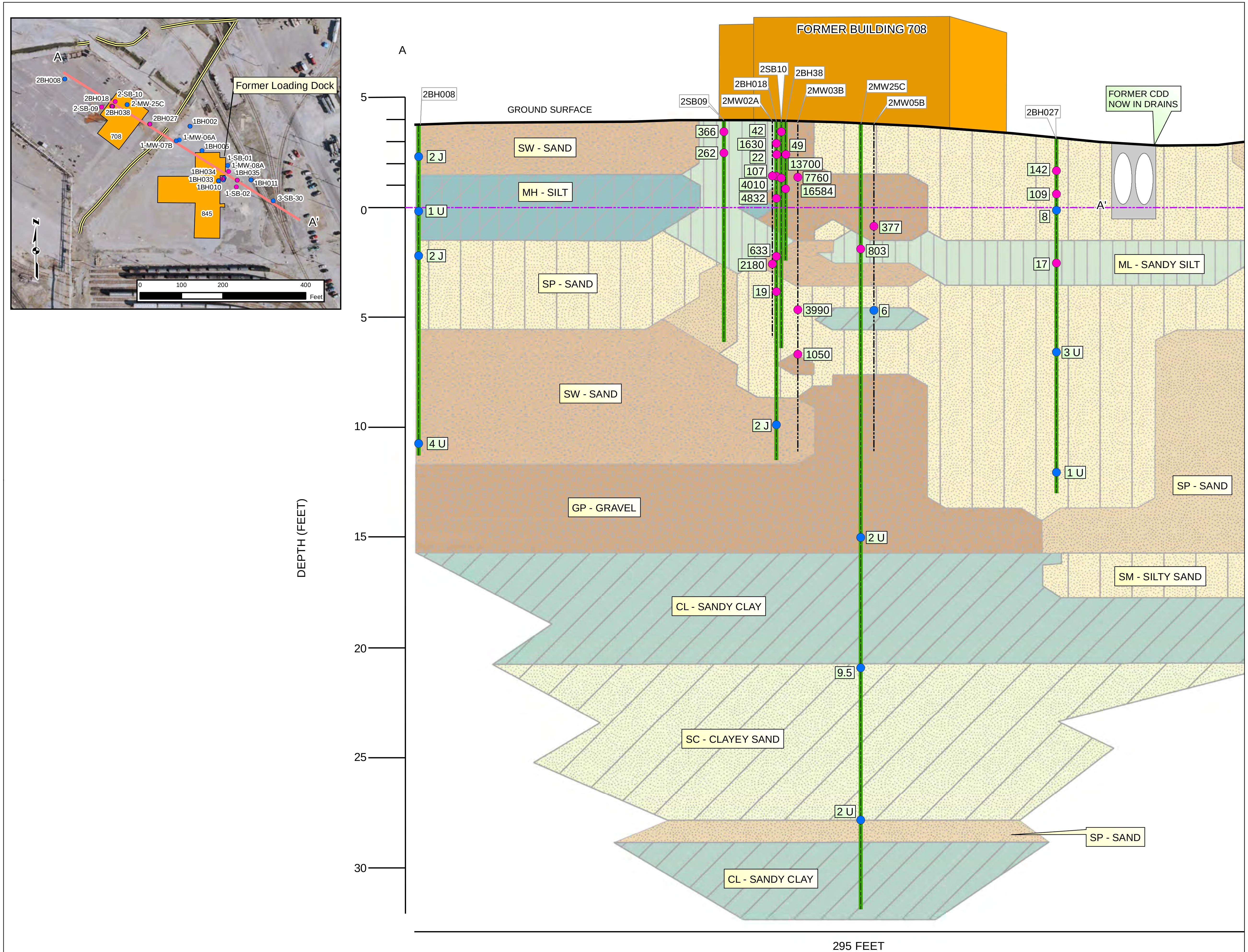
USACE- FUSRAP
DuPont Chambers Works
Deepwater, New Jersey

	Sept 2011	Figure 2-6



Cross Section (A - A')
Soil Boring
Boring (Not used for Lithology)
Soil Boring Sample Location
Test Pit Sample Location

Sample Results

Uranium Total > 14.0 pCi/g
Uranium Total < 14.0 pCi/g
Sample Result (pCi/g)
Drainage Ditch
Former Building

Soil Classification

GW - Gravel (Well Graded)
GP - Gravel (Poorly Graded)
SW - Sand (Well Graded)
SP - Sand (Poorly Graded)
SM - Silty Sand
SC - Clayey Sand
ML - Sandy Silt
CL - Sandy Clay
MH - Silt
CH - Clay (High Plasticity)

VERTICAL EXAGGERATION = 8X

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AOC 2 View of Cross Section A - A'

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Deepwater, New Jersey

	Sept 2011	**Figure 2-7**

Total Uranium Concentration in pCi/g and (depth in feet) below ground surface

- > 158
- 76 - 158
- 14 - 75
- 3 - 13
- < 3

6-CPT-37 Sample Station Location and ID

0 45 90 180 Feet

Notes:
1. The highest uranium concentration above 14 pCi/g (investigative screening value) is shown at each sample location.
2. Aerial Photo taken in September 2005

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Total Uranium Concentrations in Soil Samples for AOC 6

FEASIBILITY STUDY
USACE- FUSRAP
DuPont Chambers Works
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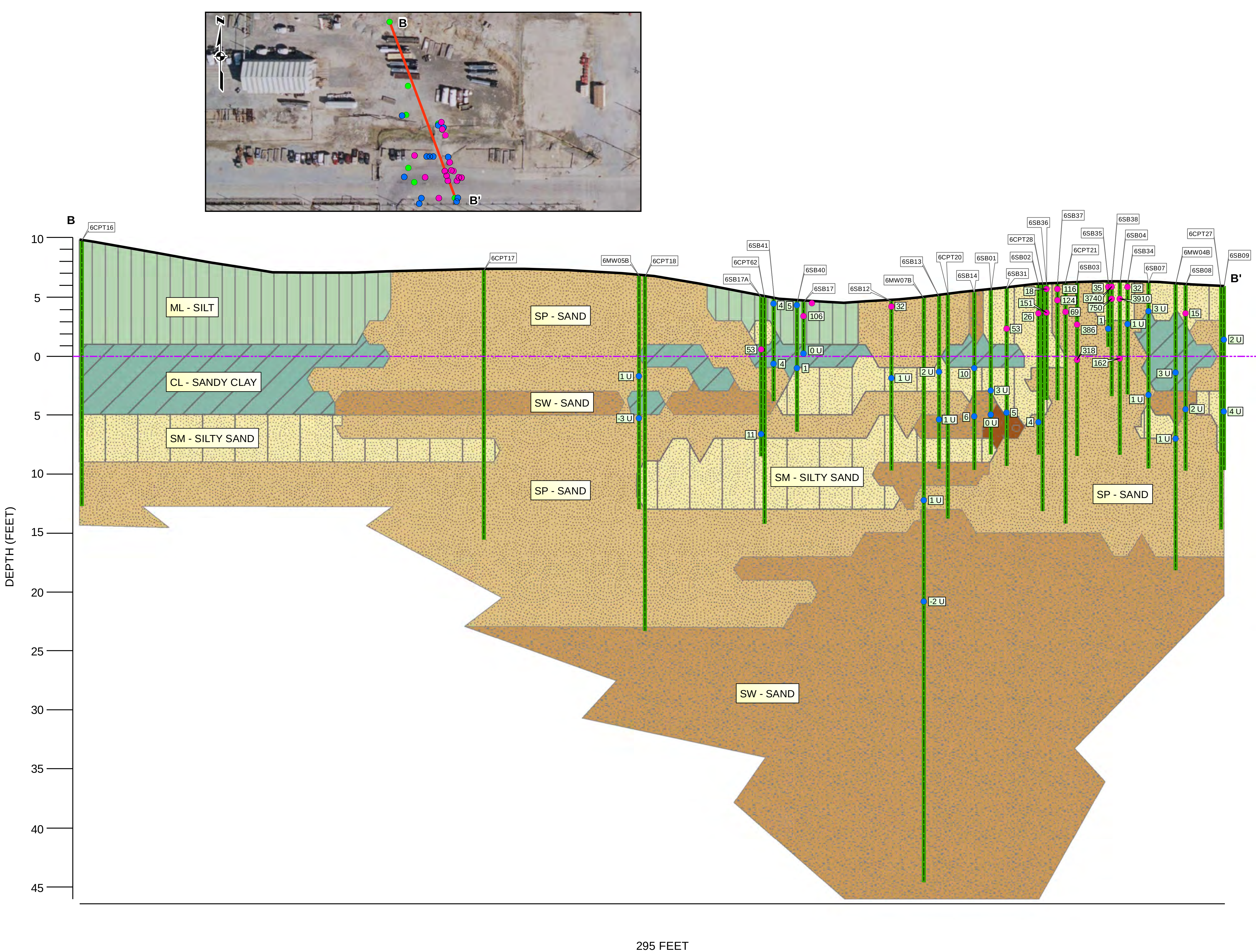
Sept 2011	Figure 2-8



Legend

- Cross Section (B - B')
- Soil Boring

Sample Results

- Uranium Total > 14 pCi/g
- Uranium Total < 14 pCi/g
- Sample Result
- CPT Location (No Sample)

Soil Classification

- GW - Gravel (Well Graded)
- GP - Gravel (Poorly Graded)
- SW - Sand (Well Graded)
- SP - Sand (Poorly Graded)
- SM - Silty Sand
- SC - Clayey Sand
- ML - Sandy Silt
- CL - Sandy Clay
- MH - Silt
- CH - Clay (High Plasticity)

VERTICAL EXAGGERATION = 3X

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AOC 6 Cross Section (B-B')

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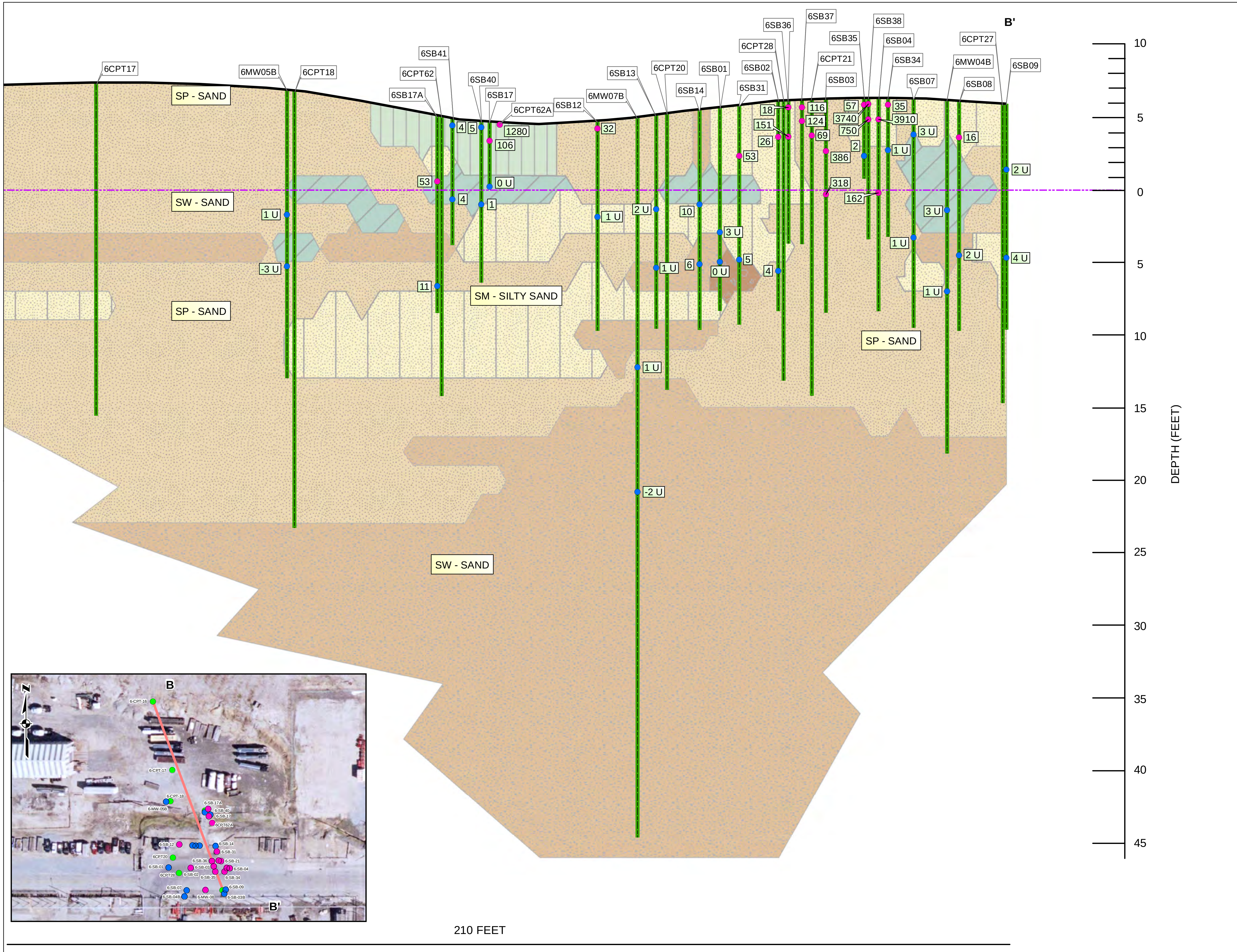

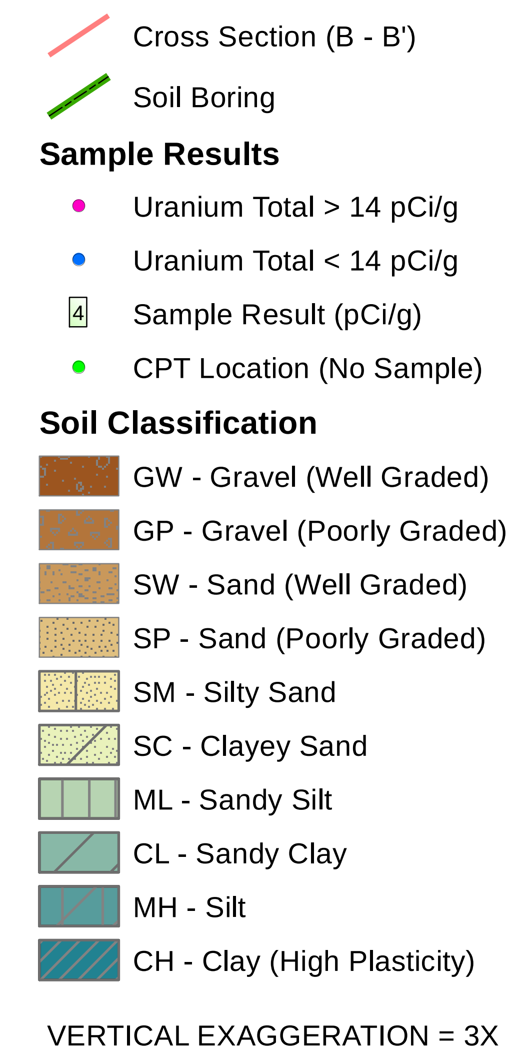

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Detailed View of Cross Section B - B' in Area of East Road

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USACE - FUSRAP
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Deepwater, New Jersey

Sept 2011	Figure 2-10

Notes:
1. Uranium Total results are reported in micrograms per liter (ug/L)
2. Aerial Photo taken in September 2005
3. Additional borings and temporary wells used to delineate groundwater contamination.
4. Drainage ditches control and capture groundwater flow in A Aquifer.

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Average Uranium Concentrations in OU 1, "A" Aquifer

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Deepwater, New Jersey

Sept 2011	Figure 2-11

Monitoring Well Location

Uranium Total results that exceed 30 micrograms per liter (ug/L)

Former Drainage Ditch Location

Former Buildings 845 and 708

Current Drainage Ditch Location

Average Groundwater Flow Direction

0 37.5 75 150 Feet

Notes:
1. Uranium Total results are reported in micrograms per liter (ug/L)
2. Well 2MW-25C is completed in the C Aquifer to evaluate vertical migration
3. Aerial Photo taken in September 2005

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Average Uranium Concentrations in OU 1, "B" Aquifer

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Sept 2011 | Figure 2-12

N

Geoprobe groundwater sample location

Well Locations

A Aquifer

B Aquifer

Area of Interest (AOI) 1

0 25 50 100 Feet

Note: Aerial Photo taken in September 2005

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Area of Interest (AOI)
Well Locations (AOC4)

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Deepwater, New Jersey

	Sept 2011	Figure 2-13

N

Monitoring Well Location

Uranium Total results that exceeds 30 micrograms per liter (ug/L)

Average Groundwater Flow Direction

0 12.5 25 50 Feet

Notes:
1. Uranium Total results are reported in micrograms per liter (ug/L)
2. Aerial Photo taken in September 2005
3. 6MW07B is completed at the base of the B Aquifer for vertical delineation

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Average Uranium Concentrations in "B" Aquifer, AOC 6

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USACE- FUSRAP
DuPont Chambers Works
Deepwater, New Jersey

	Sept 2011	**Figure 2-14**

N

Sediment (SD) and Surface Water (SW) Sample Locations

0 12.5 25 50 Feet

Notes:
1. Aerial Photo taken in September 2005
2. Bolded text represents exceedances above ISV and MCL

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Total Uranium Concentrations for Sediment and Surface Water Samples in AOC 6 (OU 3)

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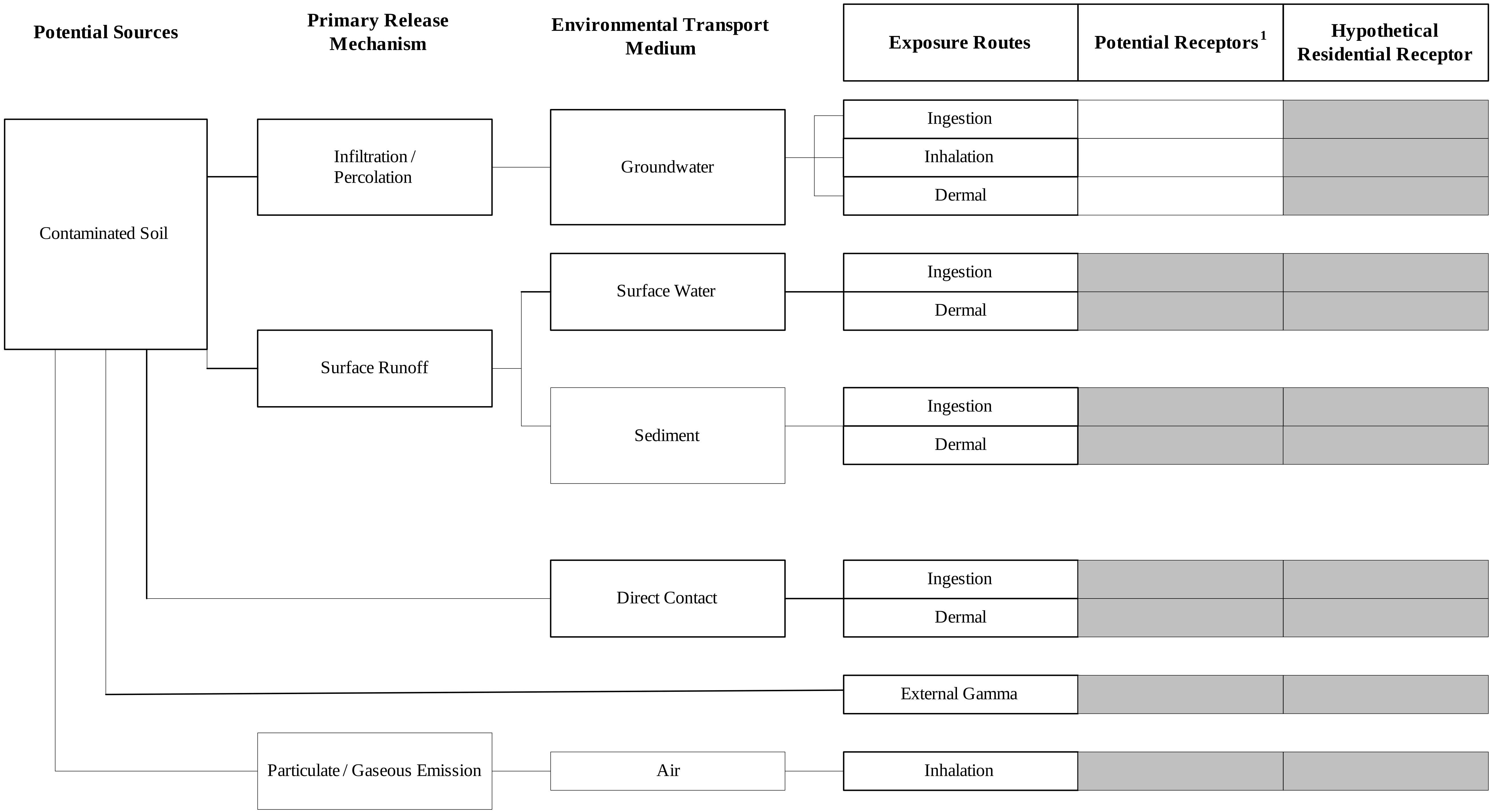
DuPont Chambers Works
Deepwater, New Jersey

Sept 2011 **Figure 2-15**



Complete Exposure Pathway

Incomplete Exposure Pathway

[1] Potential receptors include industrial, construction, utility and maintenance workers

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General Conceptual Site Model

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USACE - FUSRAP
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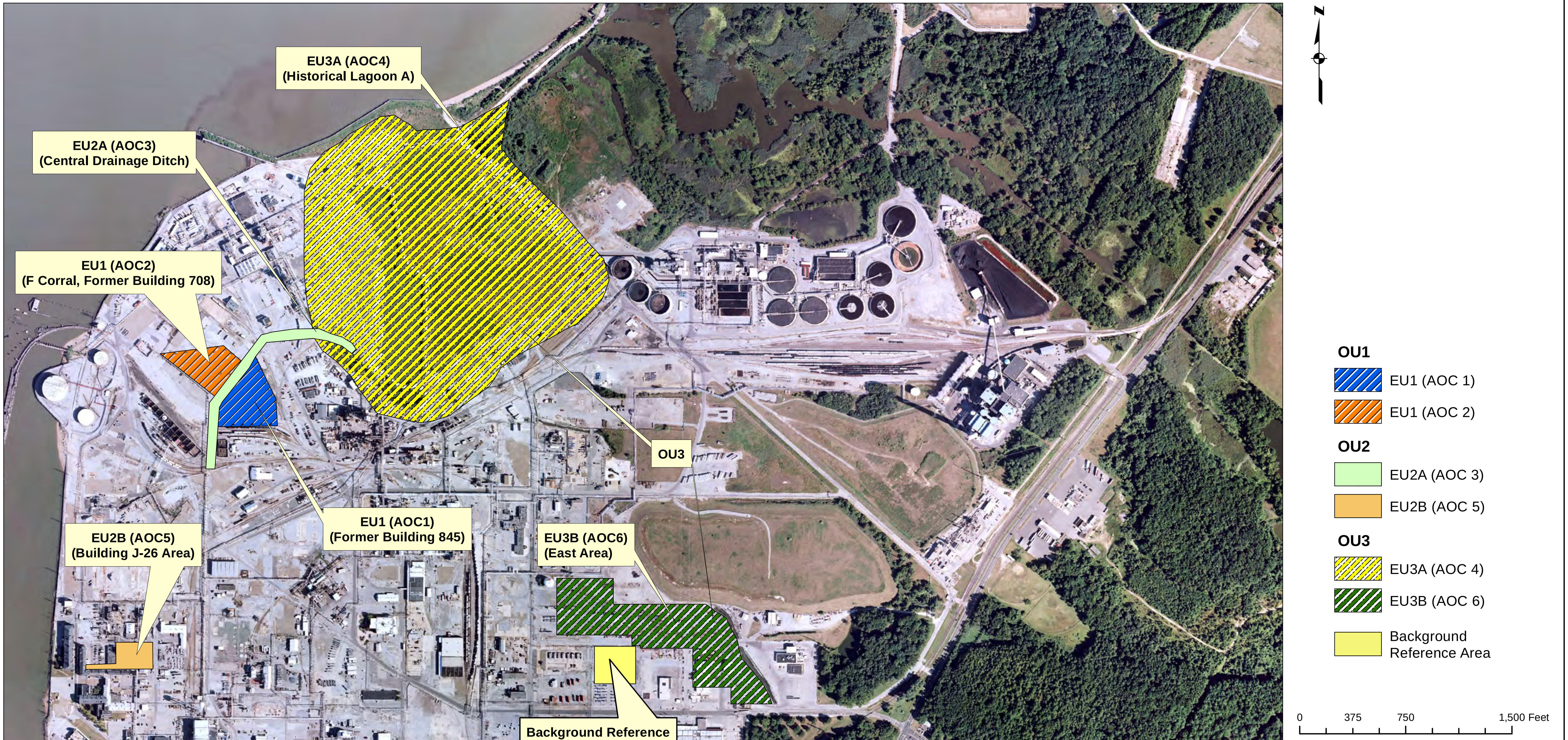
	Sept 2011	Figure 2-16



Note: Aerial Photo taken in September of 2005

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Site Layout including Exposure Units (EU)

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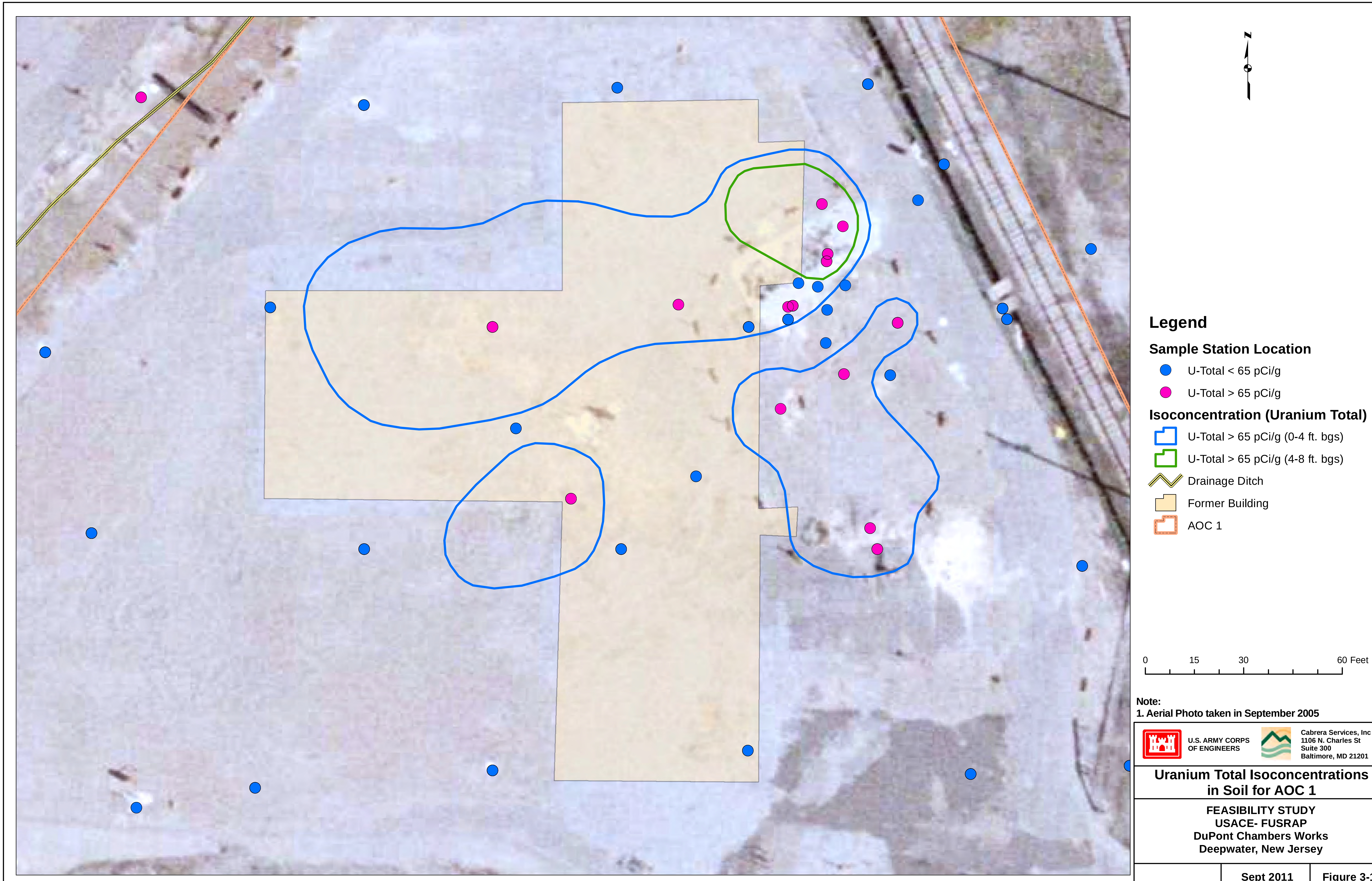

Note:
1. Aerial Photo taken in September 2005

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Uranium Total Isoconcentrations in Soil for AOC 1

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Deepwater, New Jersey

Sept 2011 | **Figure 3-1**

N

Legend

Sample Station Location

- U-Total < 65 pCi/g
- U-Total > 65 pCi/g
- Drainage Ditch

Isoconcentration (Uranium Total)

- U-Total > 65 pCi/g (0-4 ft. bgs)
- U-Total > 65 pCi/g (4-8 ft. bgs)
- U-Total > 65 pCi/g (8-12 ft. bgs)
- Former Building
- AOC 2

0 15 30 60 Feet

Note:
1. Aerial Photo taken in September 2005

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Uranium Total Isoconcentrations in Soil for AOC 2

FEASIBILITY STUDY
USACE- FUSRAP
DuPont Chambers Works
Deepwater, New Jersey

Sept 2011 | **Figure 3-2**

Legend

Sample Station Location

- U-Total < 65 pCi/g
- U-Total > 65 pCi/g

Isoconcentration (Uranium Total)

- U-Total > 65 pCi/g (0-4 ft. bgs)
- U-Total > 65 pCi/g (4-8 ft. bgs)
- CPT Sounding Locations at Background
- Drainage Ditch
- Former Building
- AOC 6

0 30 60 120 Feet

Note:
1. Aerial Photo taken in September 2005

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Uranium Total Isoconcentrations in Soil for AOC 6

FEASIBILITY STUDY
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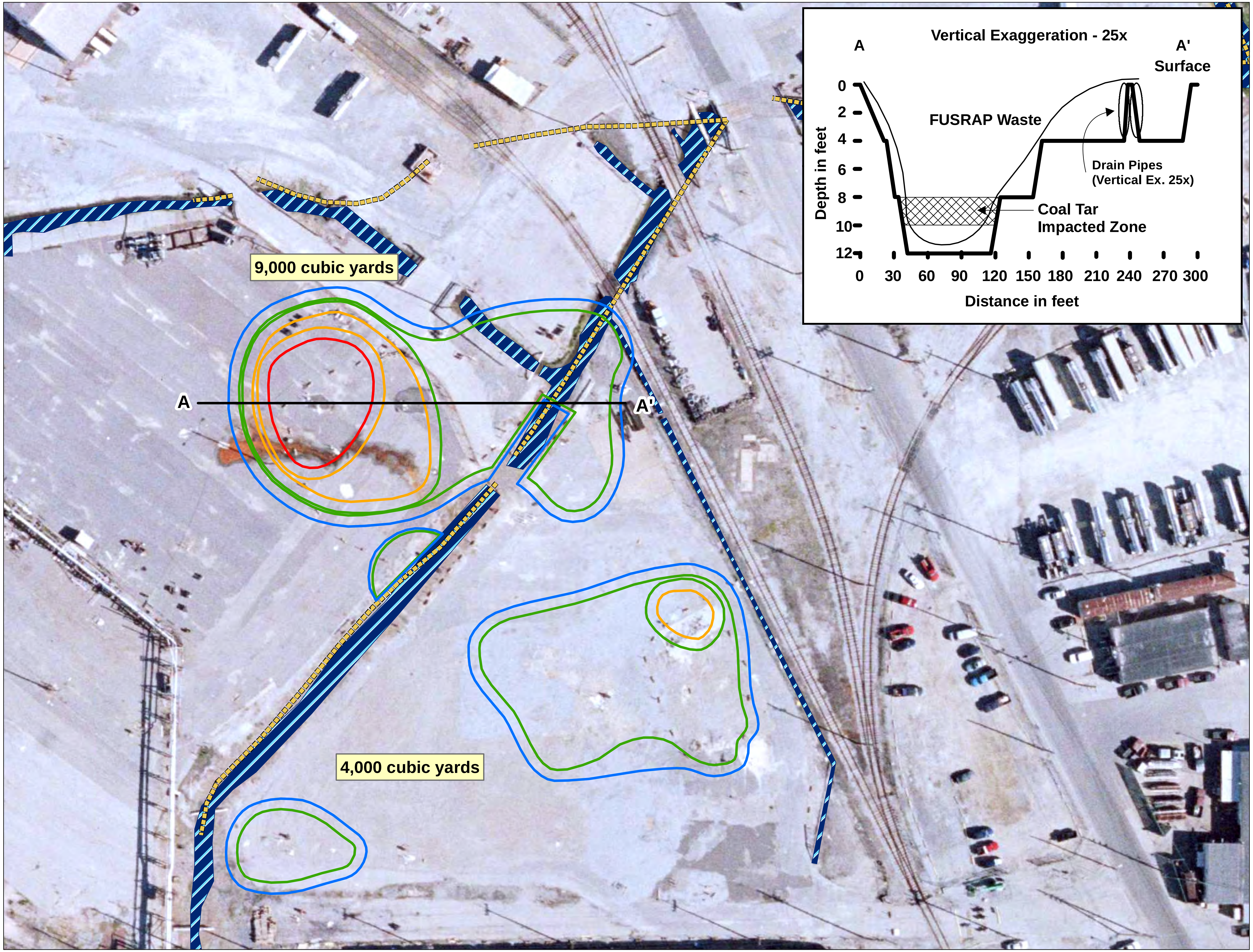
DuPont Chambers Works
Deepwater, New Jersey

	Sept 2011	Figure 3-3



Notes:
1. Aerial Photo taken in September 2005

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Assumed Excavation Cutlines for OU 1

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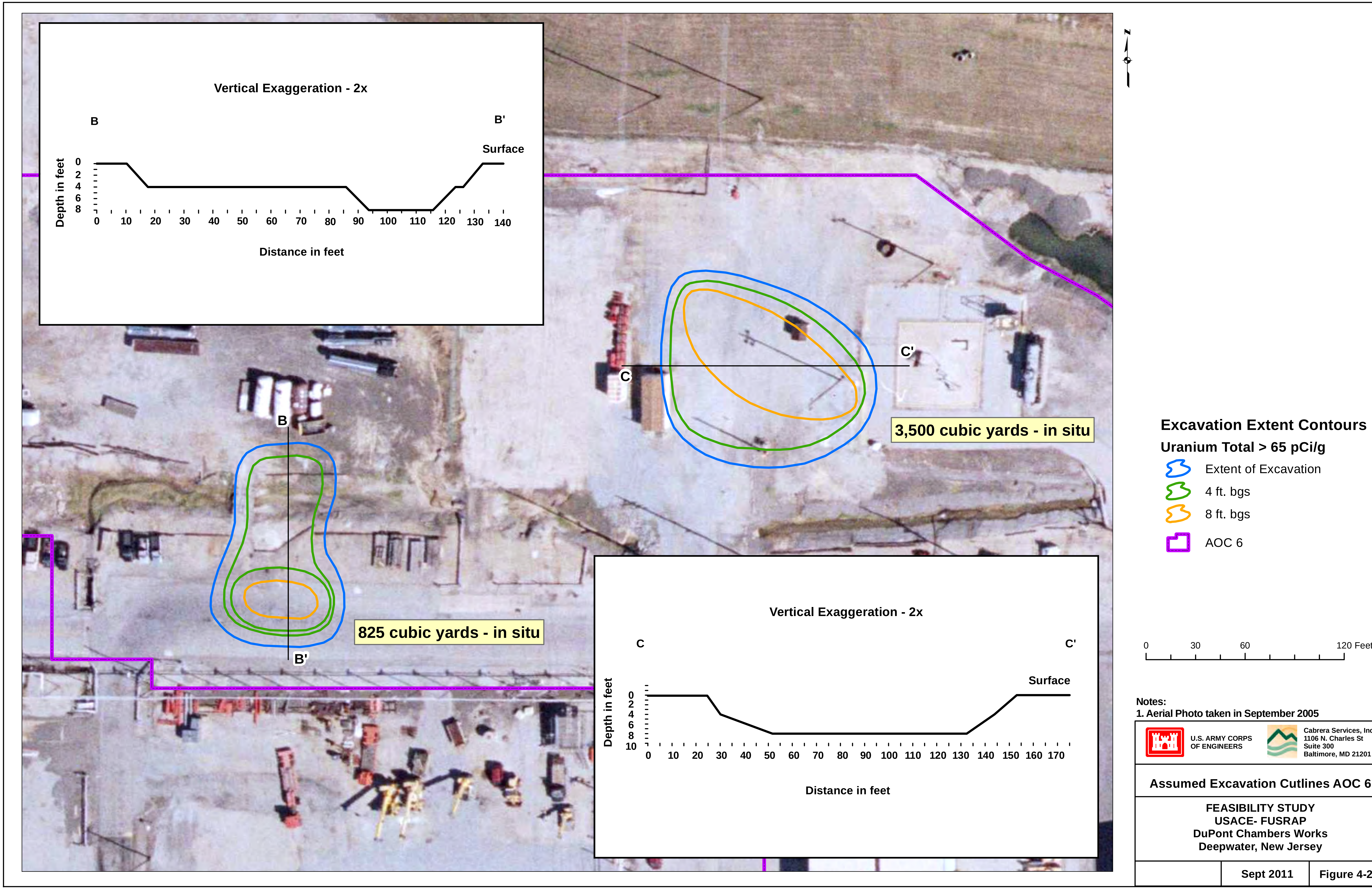
Deepwater, New Jersey

	Sept 2011	Figure 4-1



Assumed Excavation Cutlines AOC 6

Figure 4-2

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Soil Excavation Location and Treatment Diagram for OU 1

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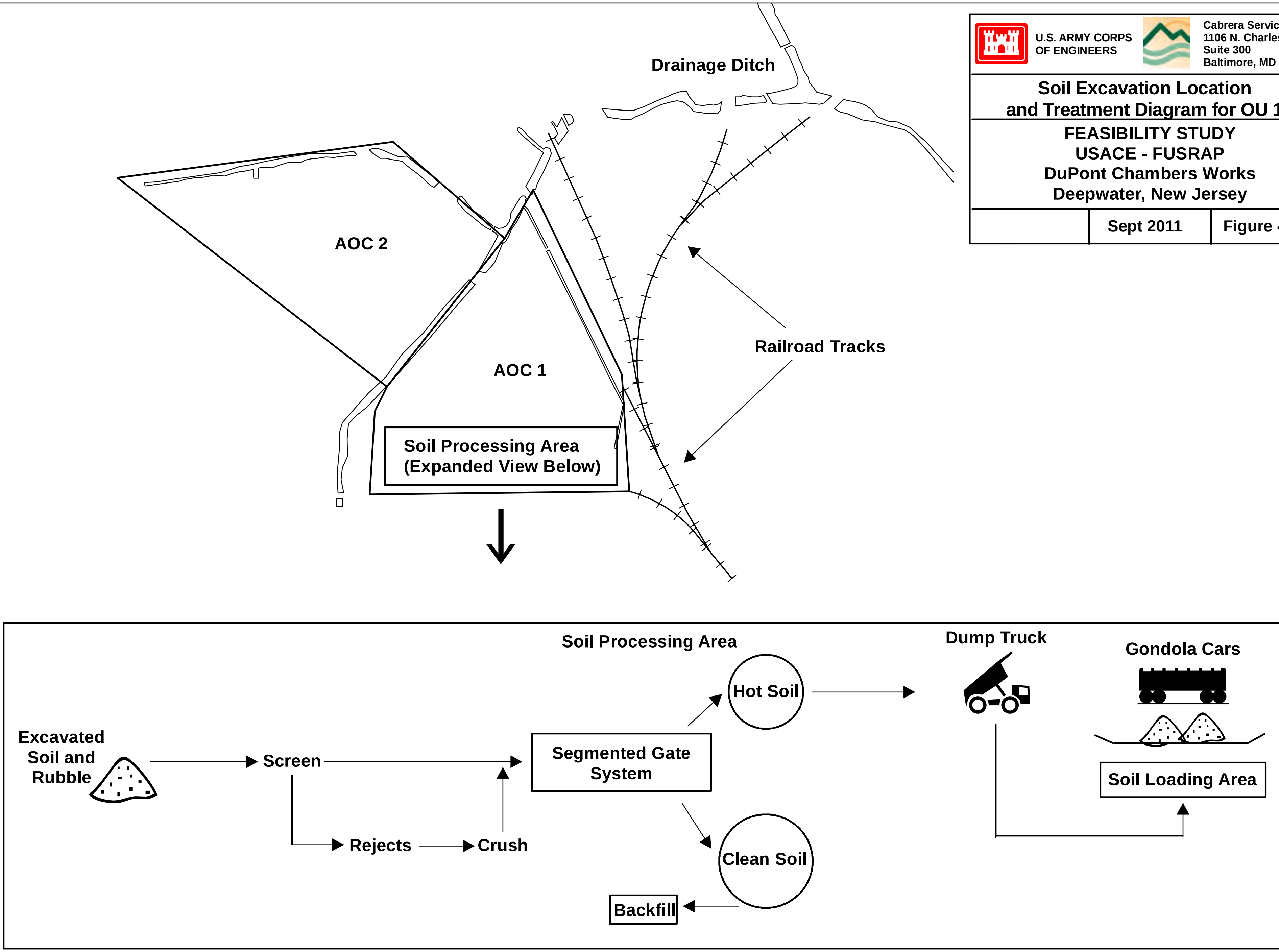
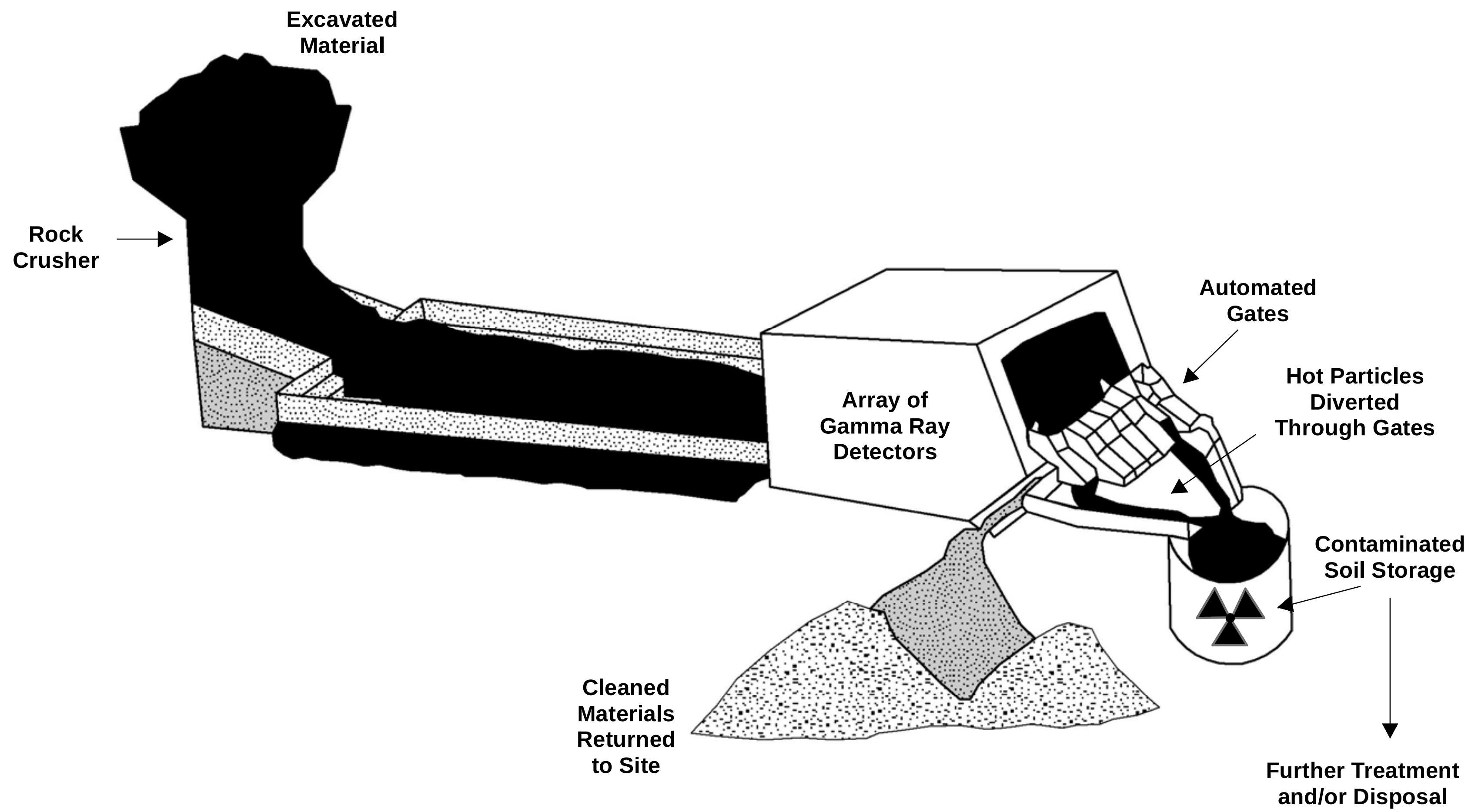
Sept 2011 | Figure 4-3





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Schematic of Soil Sorting with Segmented Gate System

FEASIBILITY STUDY
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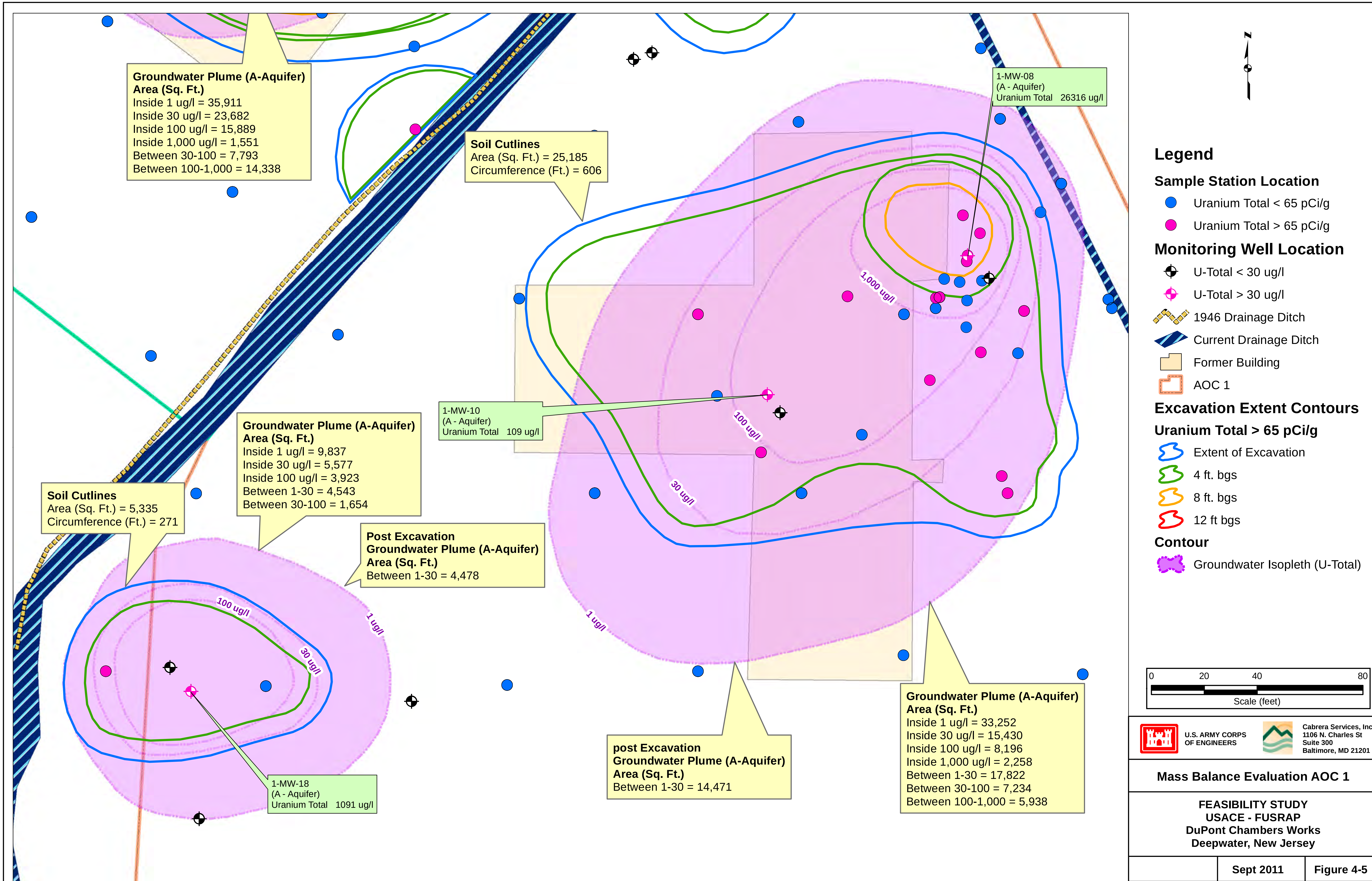
DuPont Chambers Works
Deepwater, New Jersey

	Sept 2011	Figure 4-4


Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Inside 1 ug/l = 35,911
Inside 30 ug/l = 23,682
Inside 100 ug/l = 15,889
Inside 1,000 ug/l = 1,551
Between 30-100 = 7,793
Between 100-1,000 = 14,338
Soil Cutlines
Area (Sq. Ft.) = 25,185
Circumference (Ft.) = 606
1-MW-08
(A - Aquifer)
Uranium Total 26316 ug/l
1,000 ug/l
100 ug/l
30 ug/l
1 ug/l
1-MW-10
(A - Aquifer)
Uranium Total 109 ug/l
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Inside 1 ug/l = 9,837
Inside 30 ug/l = 5,577
Inside 100 ug/l = 3,923
Between 1-30 = 4,543
Between 30-100 = 1,654
Soil Cutlines
Area (Sq. Ft.) = 5,335
Circumference (Ft.) = 271
Post Excavation
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Between 1-30 = 4,478
100 ug/l
30 ug/l
1 ug/l
1-MW-18
(A - Aquifer)
Uranium Total 1091 ug/l
post Excavation
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Between 1-30 = 14,471
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Inside 1 ug/l = 33,252
Inside 30 ug/l = 15,430
Inside 100 ug/l = 8,196
Inside 1,000 ug/l = 2,258
Between 1-30 = 17,822
Between 30-100 = 7,234
Between 100-1,000 = 5,938
N
Legend
Sample Station Location
Uranium Total < 65 pCi/g
Uranium Total > 65 pCi/g
Monitoring Well Location
U-Total < 30 ug/l
U-Total > 30 ug/l
1946 Drainage Ditch
Current Drainage Ditch
Former Building
AOC 1
Excavation Extent Contours
Uranium Total > 65 pCi/g
Extent of Excavation
4 ft. bgs
8 ft. bgs
12 ft bgs
Contour
Groundwater Isopleth (U-Total)
0
20
40
80
Scale (feet)
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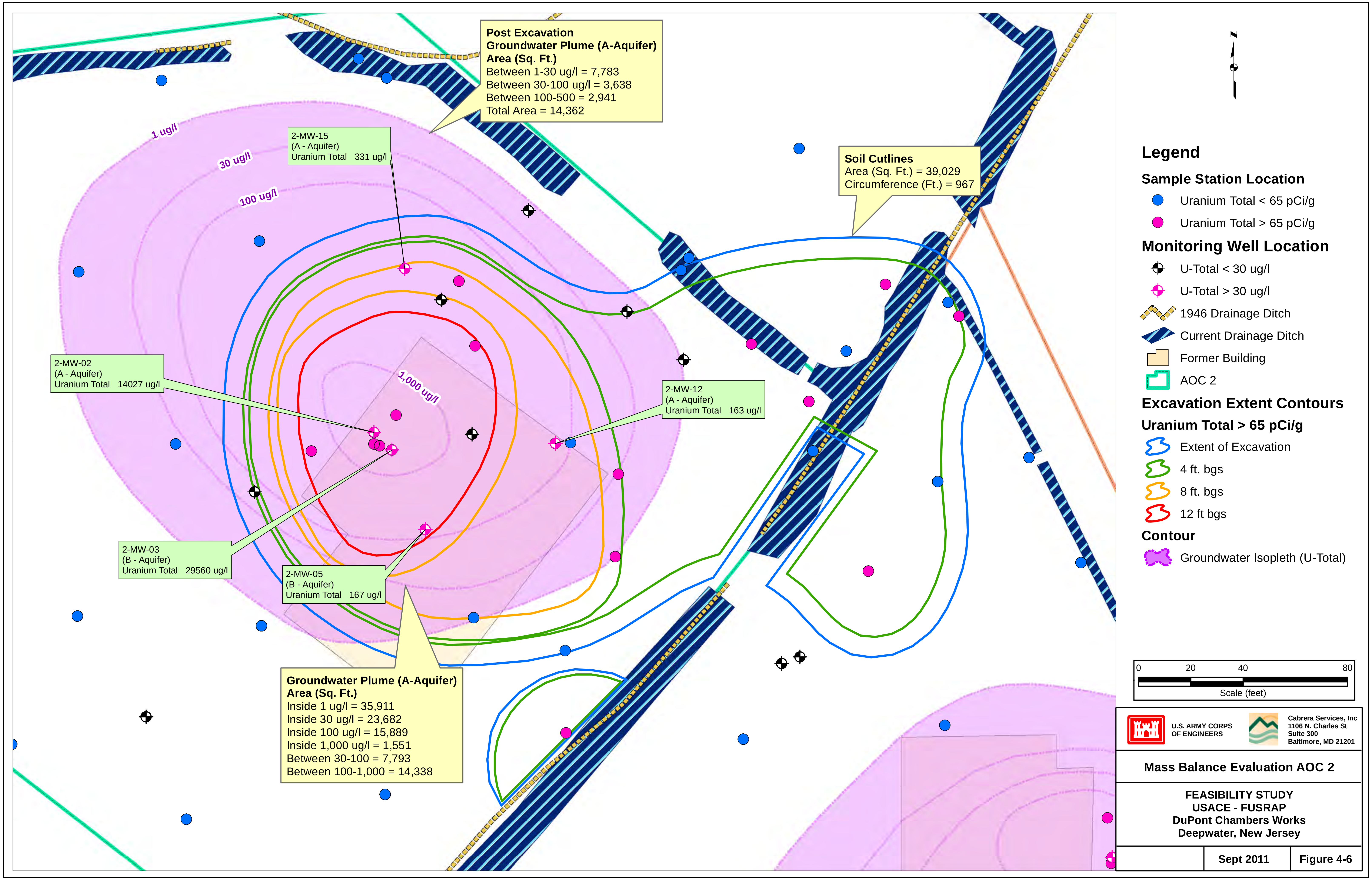
Mass Balance Evaluation AOC 1
FEASIBILITY STUDY
USACE - FUSRAP
DuPont Chambers Works
Deepwater, New Jersey
Sept 2011
Figure 4-5


Post Excavation
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Between 1-30 ug/l = 7,783
Between 30-100 ug/l = 3,638
Between 100-500 = 2,941
Total Area = 14,362
1 ug/l
30 ug/l
100 ug/l
1,000 ug/l
2-MW-15
(A - Aquifer)
Uranium Total 331 ug/l
Soil Cutlines
Area (Sq. Ft.) = 39,029
Circumference (Ft.) = 967
2-MW-02
(A - Aquifer)
Uranium Total 14027 ug/l
2-MW-12
(A - Aquifer)
Uranium Total 163 ug/l
2-MW-03
(B - Aquifer)
Uranium Total 29560 ug/l
2-MW-05
(B - Aquifer)
Uranium Total 167 ug/l
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Inside 1 ug/l = 35,911
Inside 30 ug/l = 23,682
Inside 100 ug/l = 15,889
Inside 1,000 ug/l = 1,551
Between 30-100 = 7,793
Between 100-1,000 = 14,338
N
Legend
Sample Station Location
Uranium Total < 65 pCi/g
Uranium Total > 65 pCi/g
Monitoring Well Location
U-Total < 30 ug/l
U-Total > 30 ug/l
1946 Drainage Ditch
Current Drainage Ditch
Former Building
AOC 2
Excavation Extent Contours
Uranium Total > 65 pCi/g
Extent of Excavation
4 ft. bgs
8 ft. bgs
12 ft bgs
Contour
Groundwater Isopleth (U-Total)
0
20
40
80
Scale (feet)
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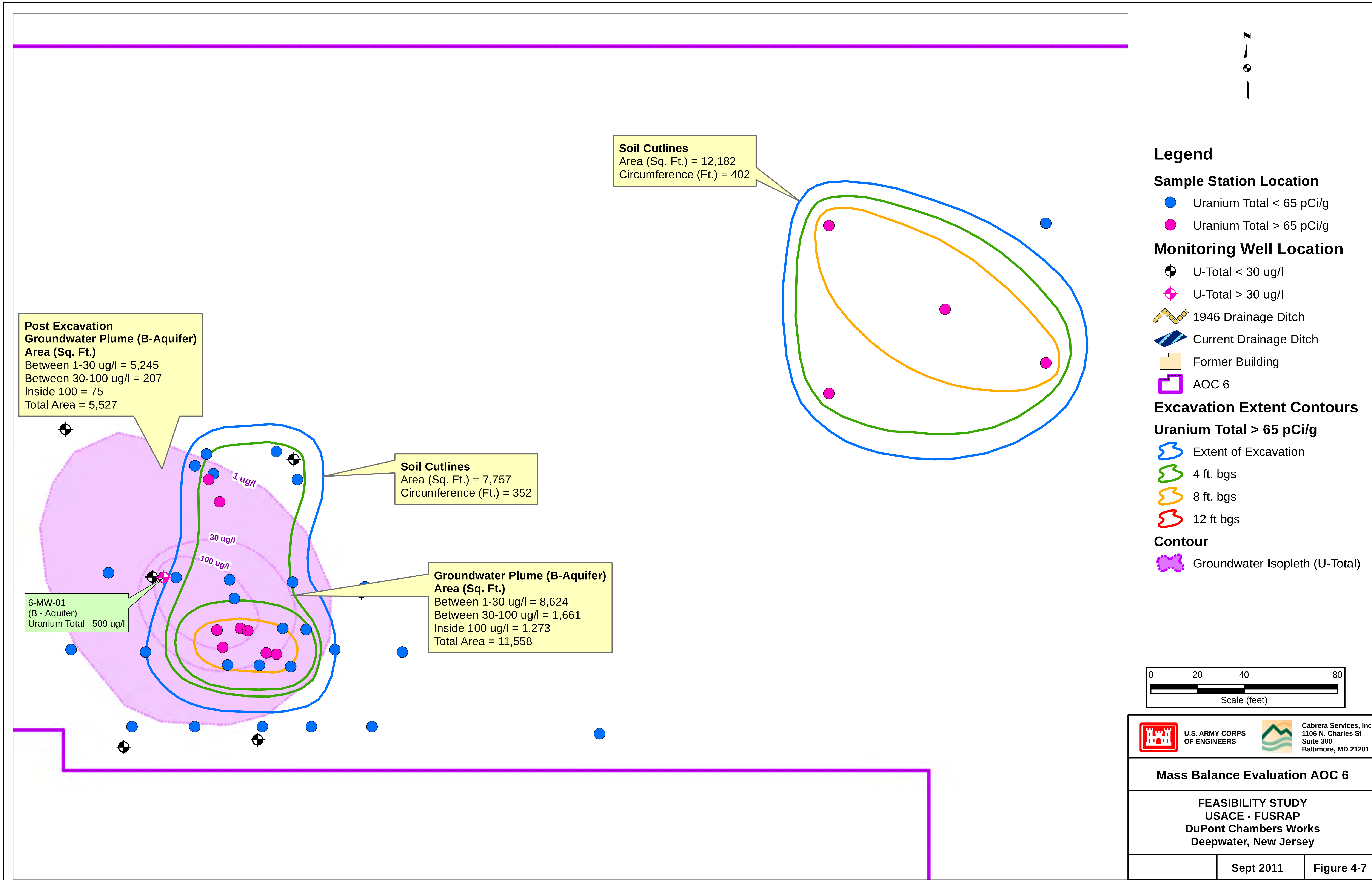
Mass Balance Evaluation AOC 2
FEASIBILITY STUDY
USACE - FUSRAP
DuPont Chambers Works
Deepwater, New Jersey
Sept 2011
Figure 4-6



N
Soil Cutlines
Area (Sq. Ft.) = 12,182
Circumference (Ft.) = 402
Post Excavation
Groundwater Plume (B-Aquifer)
Area (Sq. Ft.)
Between 1-30 ug/l = 5,245
Between 30-100 ug/l = 207
Inside 100 = 75
Total Area = 5,527
Soil Cutlines
Area (Sq. Ft.) = 7,757
Circumference (Ft.) = 352
1 ug/l
30 ug/l
100 ug/l
6-MW-01
(B - Aquifer)
Uranium Total 509 ug/l
Groundwater Plume (B-Aquifer)
Area (Sq. Ft.)
Between 1-30 ug/l = 8,624
Between 30-100 ug/l = 1,661
Inside 100 ug/l = 1,273
Total Area = 11,558
Legend
Sample Station Location
Uranium Total < 65 pCi/g
Uranium Total > 65 pCi/g
Monitoring Well Location
U-Total < 30 ug/l
U-Total > 30 ug/l
1946 Drainage Ditch
Current Drainage Ditch
Former Building
AOC 6
Excavation Extent Contours
Uranium Total > 65 pCi/g
Extent of Excavation
4 ft. bgs
8 ft. bgs
12 ft bgs
Contour
Groundwater Isopleth (U-Total)
0 20 40 80
Scale (feet)
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Mass Balance Evaluation AOC 6
FEASIBILITY STUDY
USACE - FUSRAP
DuPont Chambers Works
Deepwater, New Jersey
Sept 2011
Figure 4-7

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Conceptual Layout and Process Flow Groundwater Treatment OU 1

FEASIBILITY STUDY
USACE - FUSRAP
DuPont Chambers Works
Deepwater, New Jersey

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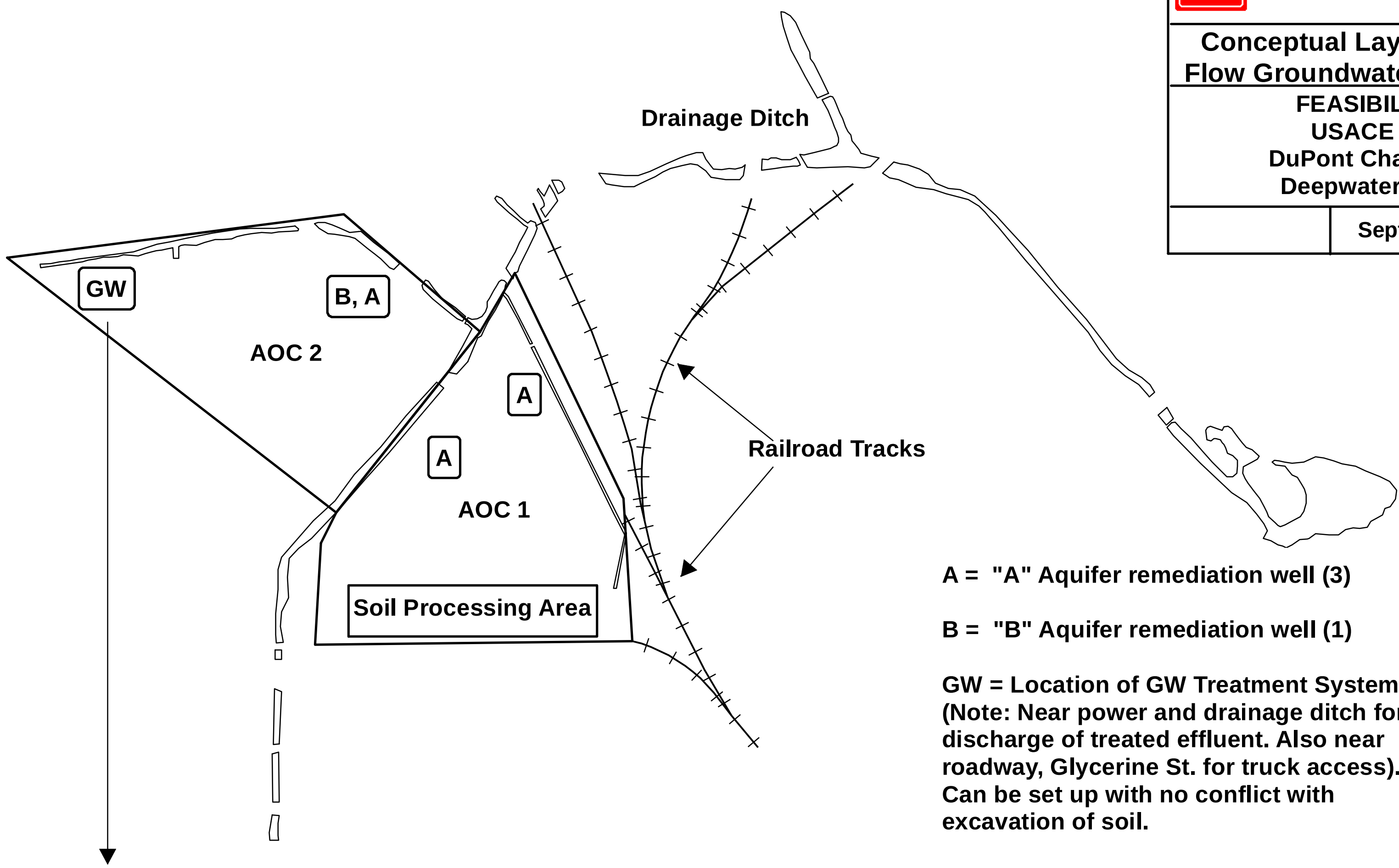
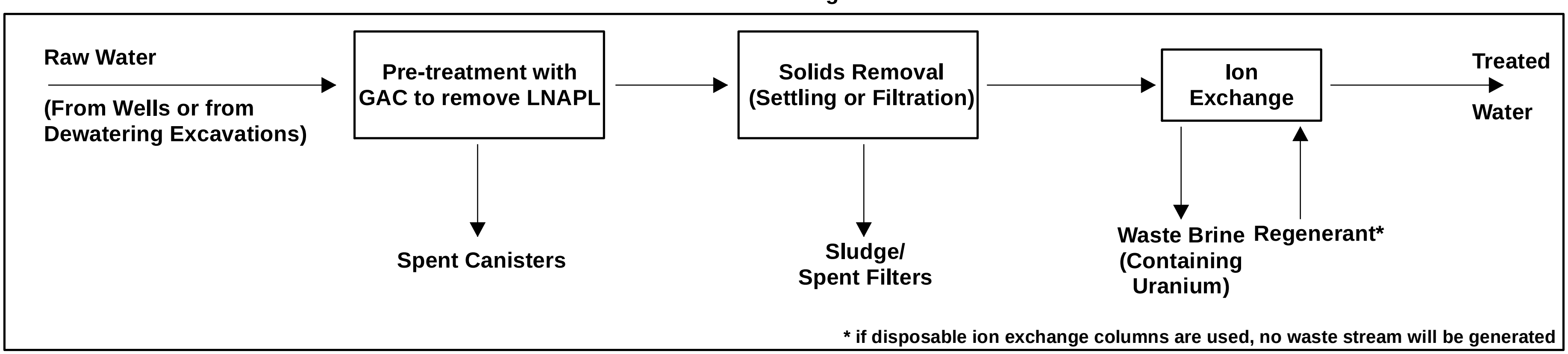
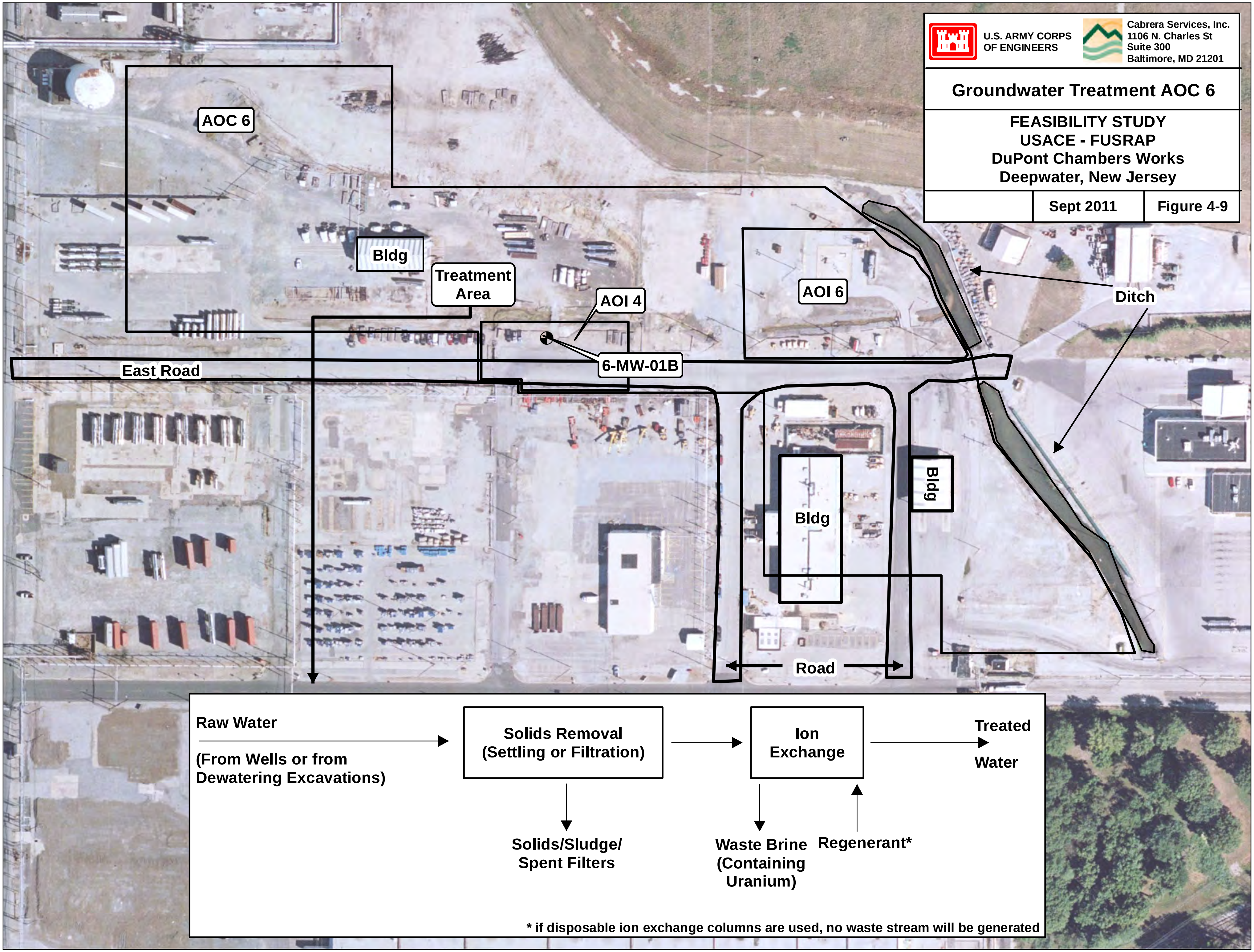


Ion Exchange





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Groundwater Treatment AOC 6
FEASIBILITY STUDY
USACE - FUSRAP
DuPont Chambers Works
Deepwater, New Jersey
Sept 2011
Figure 4-9
AOC 6
Bldg
Treatment Area
AOI 4
AOI 6
Ditch
6-MW-01B
East Road
Bldg
Bldg
Road
Raw Water
(From Wells or from Dewatering Excavations)
Solids Removal (Settling or Filtration)
Ion Exchange
Treated Water
Solids/Sludge/ Spent Filters
Waste Brine (Containing Uranium)
Regenerant*
* if disposable ion exchange columns are used, no waste stream will be generated

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

- How Alternative Provides Human Health and Environmental Protection

COMPLIANCE WITH ARARs

- Compliance with Chemical-Specific ARARs
- Compliance with Action-Specific ARARs
- Compliance with Location-Specific ARARs
- Compliance with Other Criteria, Advisories, and Guidances

LONG TERM EFFECTIVENESS AND PERMANENCE

- Magnitude of Residual Risk
- Adequacy and Reliability of Controls

REDUCTION OF TOXICITY MOBILITY, AND VOLUME THROUGH TREATMENT

- Treatment Process Used and Materials Treated
- Amount of Hazardous Materials Destroyed or Treated
- Degree of Expected Reductions in Toxicity, Mobility, and Volume
- Degree to Which Treatment is Irreversible
- Type and Quanity of Residuals Remaining After Treatment

SHORT-TERM EFFECTIVENESS

- Protection of Community During Remedial Actions
- Protection of Workers During Remedial Actions
- Environmental Impacts
- Time Until Remedial Action Objectives are Achieved

IMPLEMENTABILITY

- Ability to Construct and Operate the Technology
- Reliability of the Technology
- Ease of Undertaking Additional Remedial Actions, if Necessary
- Ability to Monitor Effectiveness of Remedy
- Ability to Obtain Approvals from Other Agencies
- Coordination with Other Agencies
- Availabilty of Offsite Treatment, Storage, and Disposal Services and Capacity
- Availability of Necessary Equipment and Specialist
- Availability of Prospective Technologies

COST

- Capital Costs
- Operating and Maintenance Costs
- Present Worth Cost

STATE* ACCEPTANCE

COMMUNITY* ACCEPTANCE

*Assessed following comment on RI/FS and PP.

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Detailed Anaysis Criteria for the Evaluation of Remedial Alternatives

Figure 5-1

APPENDICES

APPENDIX A

DETERMINATION OF REMEDIATION GOALS FOR COCS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ATTACHMENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
ACF	"All Controls Fail"
AOC	Area of Concern
ARAR	applicable or relevant and appropriate requirement
Bi-210	bismuth-210
Bi-214	bismuth-214
Bq	Becquerel
BRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COPC	Constituent of Potential Concern
d	day(s)
DCGL	Derived Concentration Guideline Level
EU	Exposure Unit
FS	Feasibility Study
FUSRAP	Formerly Utilized Sites Remedial Action Program
ICRP	International Commission on Radiological Protection
m^3	cubic meters
MED	Manhattan Engineer District
µCi	microCurie
mg	milligram
min	minute
mrem/yr	millirem per year
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
OU	operable unit
Pa-234m	protactinium-234m isomer
Pb-210	lead-210
Pb-214	lead-214
pCi/g	picoCuries per gram
Po-210	polonium-210
Po-214	polonium-214
Po-218	polonium-218
Ra-226	radium-226
RAGS	Risk Assessment Guidance for Superfund
RESRAD	RESidual RADioactivity
RG	remediation goal
RI	Remedial Investigation
Rn-222	radon-222
sec	second
Site	DuPont Chambers Works FUSRAP Site
Th-230	thorium-230
Th-231	thorium-231
Th-234	thorium-234
UCL	Upper Confidence Limit
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
yr	year

1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE) – Philadelphia District is addressing the cleanup of radiologically-contaminated areas at three operable units (OUs) within DuPont Chambers Works (referred to as Chambers Works) under the Formerly Utilized Sites Remedial Action Program (FUSRAP). A number of uranium refinement processes, performed under contracts with the Manhattan Engineer District (MED) and later the Atomic Energy Commission (AEC) in support of the nation's early atomic energy program resulted in residual radioactive contamination at specific areas on the DuPont property (for simplicity "MED" will be used hereafter to refer to MED and/or AEC). The areas investigated under FUSRAP will be referred to as the DuPont Chambers Works FUSRAP Site or the "Site" to distinguish them from manufacturing areas of Chambers Works. The U.S. Department of Energy and the USACE have conducted a number of investigations to determine the nature and the extent of FUSRAP-eligible contamination present at the Site. The results of the USACE's Sitewide Remedial Investigation (RI) identified and confirmed the presence of radioactive contamination (Cabrera 2011b). In addition, the USACE conducted a baseline risk assessment (BRA) to evaluate potential risks to both potential human and ecological receptors (Cabrera 2011c). The BRA results determined an unacceptable level of dose and risk to potential human receptors. Therefore, remedial actions are being evaluated in the Feasibility Study (FS) for the specific areas with unacceptable risk and dose. The USACE has determined appropriate remediation goals (RGs) for the radioactive constituents. This appendix summarizes the methodologies used to identify and develop the site-specific RGs for constituents of concern (COCs) at the Site and to demonstrate compliance with applicable or relevant and appropriate requirements (ARARs).

2.0 IDENTIFICATION OF CONSTITUENTS OF CONCERN

Constituents of Potential Concern (COPCs) were identified in the RI and the BRA. As presented in the Sitewide RI, USACE is mandated to investigate and remediate only those contaminants that are eligible under FUSRAP authority and qualify for expenditure of FUSRAP appropriations. The types of hazardous substances considered with the scope of the Chambers Works FUSRAP cleanup activities include the following:

- Radioactive contamination (primarily uranium and thorium and associated radionuclides) resulting from the Nation's early atomic energy program activities, i.e., related to MED or AEC activities, to include hazardous substances associated with these activities (e.g., chemical separation, purification); and
- Other radioactive contamination or hazardous substances that are mixed or commingled with MED or early AEC radioactive contamination (USACE 2003, paragraph 6(b)(2)(b)). These contaminants are not a result of MED or AEC activities and therefore not FUSRAP-related contaminants, however, by necessity; the commingled contaminants are cleaned up along with the FUSRAP contamination.

The USACE evaluated MED processes used at the Site in order to identify FUSRAP-eligible contaminants. USACE reviewed historical site records, specific compounds and feedstock materials used at Chambers Works, and general industry references describing similar processes at other facilities. Details regarding the identification of eligible contaminants are discussed in the *Memorandum, USACE Determination of Eligible Contaminants for FUSRAP Investigation, DuPont Chambers Works FUSRAP Site, Deepwater, NJ* (Cabrera 2011a).

The MED feedstock was sodium uranate, uranium oxides and uranium-bearing scrap, which was used to produce uranium tetrafluoride, uranium hexafluoride and uranium metal. The RI determined that MED-related radioactive contamination consists of natural uranium isotopes (i.e., uranium-234 (U-234), uranium-235 (U-235), and uranium-238 (U-238)) and their short-lived decay progeny. Refined natural uranium, the primary site contaminant, is in a state of secular equilibrium with its short-lived decay progeny, which consist of daughter radionuclides with half-lives short enough to allow them to decay at the same rate at which they are produced. Based on the assumption that the original uranium refinement processes were performed approximately 65 years ago, the following short-lived uranium decay progeny should be present:

- Short-lived decay progeny of U-238 expected to be present are thorium-234 (Th-234) (24-day half-life) and protactinium-234m isomer (Pa-234m) (1.17-minute half-life).
- Short-lived decay progeny of U-235 expected to be present is thorium-231 (Th-231) (25-hour half-life).
- U-234 has no short-lived decay progeny expected to be present.

Therefore, all three uranium isotopes were selected initially as the only COPCs. However, long-lived thorium isotopes (specifically thorium-230 (Th-230)) are COPCs at other FUSRAP sites where ore concentrates were used as feedstock. The sodium uranate feedstock was used and therefore, Th-230 was identified as a possible contaminant and added to the COPC list.

Radium-226 (Ra-226) was also added as a COPC as it is a daughter product in the decay chain of U-238 and is present in unrefined uranium ore. Ra-226 has been identified as a co-contaminant of uranium at other FUSRAP sites, and is also a potential contaminant in sodium uranate feedstock.

The USACE performed a data evaluation by comparing maximum site sampling results of Ra-226 and Th-230 with respect to the potential in-growth concentration of those radionuclides from their parent product, U-238 and Th-234. The data evaluation discovered that the relative concentrations of Ra-226 and Th-230 found in Area of Concern (AOC) 2 samples exceeded what would be expected from uranium-series progeny decay alone.

Table A-2-1 shows the results of theoretical in-growth for refined uranium after a 65-year decay period (WISE 2008). This example mimics what would be expected samples if in-growth was the only source of Th-230 and Ra-226.

Table A-2-1: Decay Series Activities and In-Growth of Pure Refined Uranium (U-234 and U-238)[a] After 65 years

Nuclide	Half-Life	Activity [Becquerels (Bq)]	Activity [Microcuries (µCi)]	In-growth (Compared to U-238)
U-238	4.50E+09 yr[b]	1.24E+04	3.34E-01	---
Th-234	24 d[c]	1.24E+04	3.34E-01	100%
Pa-234m	1.2 min[d]	1.24E+04	3.34E-01	100%
U-234	2.40E+05 yr	1.24E+04	3.34E-01	100%
Th-230	**7.70E+04 yr**	**7.23E+00**	**1.95E-04**	**0.0585%**
Ra-226	**1.60E+03 yr**	**1.01E-01**	**2.72E-06**	**0.0008%**
Rn-222	3.80E+00 d	1.01E-01	2.72E-06	0.0008%
Po-218	3.10E+00 min	1.01E-01	2.72E-06	0.0008%
Pb-214	2.70E+01 min	1.01E-01	2.72E-06	0.0008%
Bi-214	2.00E+01 min	1.01E-01	2.72E-06	0.0008%
Po-214	1.60E-04 sec[e]	1.01E-01	2.72E-06	0.0008%
Pb-210	2.20E+01 yr	4.40E-02	1.19E-06	0.0004%
Bi-210	5.00E+00 d	4.39E-02	1.19E-06	0.0004%
Po-210	1.40E+02 d	4.30E-02	1.16E-06	0.0003%

[a] Initial Activity (t=0) for U-234 and U-238 = 1.24E+04 Bq = 3.34E-01 µCi
[b] years
[c] days
[d] minutes
[e] seconds

Table A-2-1 shows that the in-growth of the decay series progeny below U-234 is marginal given only 65 years elapsed time. The theoretical abundance of Th-230 in the decay chain would be 0.0585% of U-238 activity while the abundance of Ra-226 only reaches 0.0008%. This is due to the relationship of the half-lives of the intermediate daughter U-234 (2.4E+05 yrs) versus the next daughter in the series Th-230 (7.7E+04 yrs). The relatively small difference in their half-lives stunts the in-growth of the remainder of the series over the short time period since the beginning of MED activities (about 65 yrs).

In the AOC 2 source zone, the maximum concentration of U-238 is 15,000 picoCuries per gram (pCi/g). Therefore, if it is assumed that the presence of Th-230 and Ra-226 was from in-growth alone, the derived concentrations (using the calculated fractions in Table A-2-1) would approach 9 pCi/g and 1.2 pCi/g, respectively. However, concentrations in AOC 2 range up to 32 pCi/g for Th-230 and 3 pCi/g for Ra-226. Since the actual concentrations are greater than the calculated values from in-growth alone, it is assumed that the excess concentrations of Th-230 and Ra-226 are due to the presence of impurities within the sodium uranate feedstock. Therefore, the following five COPCs have been identified as eligible contaminants for FUSRAP investigation at the DuPont Chambers Works FUSRAP Site: U-234, U-235, U-238, Th-230, and Ra-226 (Cabrera 2011a).

The BRA report (Cabrera 2011c) evaluated the potential risks and doses for both current and hypothetical future reasonable maximum exposure receptors of the Site. The BRA results indicate that the maximum radiological risk to industrial workers at EU (exposure unit) 3B exceeded the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) acceptable target risk range, and for EU 1, the maximum radiological risk was at the upper end of the acceptable risk range. Furthermore, the maximum radiological dose for construction workers and utility workers at EU 1, and the maximum radiological dose for industrial workers and construction workers at EU 3B exceeded the New Jersey Department of Environmental Protection (NJDEP)'s acceptable dose limit. The results of radiological risk and dose assessments also showed that the five radionuclides contribute to the majority of the risks and doses to various receptors present. Therefore, the radionuclides U-234, U-235, U-238, Th-230, and Ra-226 have been identified as the COCs for the Site and considered for evaluation in the FS.

3.0 DEVELOPMENT OF REMEDIATION GOALS FOR COCS

The CERCLA requires the selection of a cleanup action that is protective of human health and the environment and complies with ARARs. The requirements for cleanup actions are provided in 40 Code of Federal Regulations (CFR) 300.430. According to these requirements, the U.S. Environmental Protection Agency (USEPA) defines the CERCLA acceptable target risk range as 10^{-6} to 10^{-4} for carcinogenic chemicals. However, a State of New Jersey standard was identified as an ARAR and will guide the cleanup for the Site. Based on *Soil Remediation Standards for Radioactive Materials* (New Jersey Administrative Code [N.J.A.C.] 7:28-12.8(a)1), a dose limit criterion of 15 millirem per year (mrem/yr) was identified as an ARAR (NJDEP 2000). Therefore, the 15 mrem/yr dose criterion was used to derive site-specific RGs for the ROPCs.

Due to the absence of Ra-226 and Th-230 sampling results for samples analyzed during initial site investigations; USACE performed a surrogate evaluation to develop a RG for a surrogate COC. Using surrogate evaluation, it is possible to measure just one of the radionuclides, instead of all, while demonstrating overall compliance for all the COCs present. The surrogate evaluation was performed in four steps.

- Identification of the surrogate COC;
- Establishment of the relationship between the surrogate COC with respect to the other COCs;
- Determination of derived concentration guideline levels (DCGLs) for all COCs; and
- Calculation of an effective site-specific RG for the surrogate COC that accounts for all COCs at the Site.

Each of these steps is summarized in the following subsections.

3.1 Step 1: Identification of Surrogate COC

U-238 has already been used as a surrogate for total uranium at the Site. As Ra-226 and Th-230 are daughter products of U-238, U-238 was once again selected as the surrogate COC. Continued use of U-238 as the surrogate COC is supported by the following:

- It has a higher relative abundance with respect to other isotopes and
- It is the easiest COC to detect through both alpha and gamma spectrometry analysis.

3.2 Step 2: Establishment of Relationship of Surrogate COC with Respect to Other COCs

During this step, the relationships between the surrogate COC (U-238) and the other four COCs were determined. The relationships are summarized in the following.

3.2.1 Relationship Among Uranium Isotopes

The relationships between three uranium isotopes were determined by utilizing their isotopic activity ratios for natural uranium (approximately 2.2% comes from U-235, 48.8% U-238, and 48.8% U-234) (NRC 2001).

3.2.2 Relationship Among Ra-226, Th-230 and U-238

The radiological data collected at the Site were evaluated to determine the relationship between measured concentrations of U-238, Ra-226, and Th-230. At first, detected sampling results were used to calculate the ratios of Ra-226/U-238 and Th-230/U-238. The calculated ratios were then fitted against standard normal and standard log-normal distributions to evaluate which distribution would be the best input assumption in the statistical analysis using the Pro-UCL software (version 4.0) (USEPA 2007). It was determined that the data were best represented by a log-normal distribution. Therefore, log-normal ratios of Ra-226:U-238 and Th-230:U-238 were utilized to establish the relationship between these radionuclides.

Prior to establishing this relationship, the Rosner outlier test, available in Pro-UCL 4.0, was utilized to identify any potential outlier that may be present in the log-normal datasets for both ratios. The results of the Pro-UCL analysis on both ratio distributions showed no outliers to be present, meaning that all calculated ratio values appear to be part of the same log-normal distribution. Thus, the behavior of the ratios allowed all values, without exclusion, to be used in the surrogate calculations. By comparison, the results of the Rosner test on the individual nuclide distributions (also assumed normal) resulted in nine assumed outliers for U-238, 40 for Ra-226, and 21 for Th-230.

The mean values of 0.11 and 0.16 for Ra-226/U-238 and Th-230/U-238 ratio distributions, respectively, were chosen for predicting both Ra-226 and Th-230 from measured U-238 values. The mean value was chosen instead of an Upper Confidence Limit (UCL)-95 or other qualified statistical level in order to avoid potential biasing of the derived Ra-226, and Th-230 values. These values, along with the abundance values of uranium isotopes in natural uranium (0.488 U-

234, 0.022 U-235, and 0.488 U-238), were used to calculate the relationship, or the activity fraction of each COC with respect to U-238.

3.3 Step 3: Determination of DCGL for Individual COCs

RESidual RADioactivity (RESRAD) dose modeling code (version 6.3) was utilized for determining site-specific DCGLs for the COCs, including refined natural uranium, Ra-226, and Th-230 based on a dose limit criterion of 15 mrem/yr (ANL 2005). Since the Site is zoned for industrial land use and is expected to remain industrial for the foreseeable future, an industrial worker scenario, excluding active groundwater usage, was considered the most appropriate dose model for inclusion within the site conceptual model. Site specific characteristics that further support this decision include:

- Current groundwater conditions preclude its present use as a drinking water source. The two uppermost aquifers beneath Chambers Works exhibit high dissolved solids as well as high organic and metal contamination due to the long history of DuPont manufacturing operations;
- The Chambers Works is not within the capture zone of municipal drinking water well systems and it is unlikely that it will be in the future.

Based upon the RI results, it has been determined that dissolved MED uranium has not mobilized in Site aquifers, either vertically or horizontally. This is likely due to the reducing conditions encountered in both aquifers. The OU 1 plume has migrated a very short distance (less than 100 feet) during the past 65 years. Sitewide groundwater monitoring data demonstrated that the leading edge of the plume has not migrated. This behavior has been established through sampling and analysis in both the A and B aquifers.

Under the industrial worker scenario, the typical worker is modeled as one who spends most of his or her time indoors. The worker may be exposed to the residual radioactive contamination that may be present in surface soil but is not expected to have regular contact with subsurface soil. However, as a conservative approach, the industrial worker is assumed to be exposed to both surface and subsurface soil during this evaluation. The industrial worker is at the Site for 250 days per year for 25 years (USEPA 1991a). During a typical working day, the worker is assumed to spend seven hours indoors and one hour outdoors and will ingest 50 milligram (mg) of soil (USEPA 1991b). The inhalation rate for the receptor is 20 cubic meters (m^3) per day (USEPA 1991a). Exposure pathways evaluated for the industrial worker scenario include:

- External gamma radiation from radionuclides in the surface soil;
- Incidental ingestion of surface soil; and
- Inhalation of airborne contaminated dust or emissions from surface soil.

Attachment A-1 of this appendix presents the assigned values for RESRAD input parameters for the industrial worker scenario. Table A-3-1 presents the results of site-specific individual COCs DCGLs for an industrial worker without groundwater usage.

Table A-3-1: DCGLs for Individual COCs Under the Industrial Worker Scenario

Radionuclides	Dose per unit concentration		DCGL (Based on 15 mrem/yr)		Site-Specific DCGL (pCi/g)
	T=0 Years	T=1000 Years	T=0 Years	T=1000 Years	
	(mrem/yr)/(pCi/g)		pCi/g		
Ra-226	1.15E+00	2.61E-01	1.28E+01	5.75E+01	12.8
Th-230	3.19E-03	2.64E-01	4.70E+03	5.68E+01	56.8
U-234	1.23E-03	9.04E-04	1.22E+04	1.66E+04	12175.3
U-235	7.91E-02	1.01E-02	1.90E+02	1.49E+03	189.5
U-238	1.66E-02	1.95E-03	9.04E+02	7.68E+03	903.6

Additionally, a construction worker scenario, excluding active groundwater usage, was considered as an appropriate dose model for inclusion within the site conceptual model. Under the construction worker scenario, the worker is modeled as a typical worker who spends all of his or her time outdoors. The worker may be exposed to the residual radioactive contamination present in both surface soil and subsurface soil. Construction workers were assumed to be on the job eight hours per day, 250 days per year over a one-year period. During a typical working day, the construction worker is assumed to spend eight hours outdoors and will ingest 330 mg of soil (USEPA 2002a and 2002b). The inhalation rate for the receptor is 20 m^3 per day (USEPA 1989a).

Exposure pathways evaluated for the construction worker scenario include:

- External gamma radiation from radionuclides in the surface and subsurface soil;
- Incidental ingestion of surface and subsurface soil; and
- Inhalation of airborne contaminated dust or emissions from surface and subsurface soil.

Attachment A-1 of this appendix presents the assigned values for the RESRAD input parameters for the construction worker scenario. Table A-3-2 presents the results of site-specific individual COC DCGLs for a construction worker without groundwater usage.

Table A-3-2: DCGLs for Individual COCs Under the Construction Worker Scenario

Radionuclides	Dose per unit concentration		DCGL (Based on 15 mrem/yr)		Site-Specific DCGL (pCi/g)
	T=0 Years	T=1000 Years	T=0 Years	T=1000 Years	
	(mrem/yr)/(pCi/g)		pCi/g		
Ra-226	2.45E+00	2.44E+00	6.13E+00	6.16E+00	6.13
Th-230	6.05E-01	7.10E-02	2.48E+01	2.11E+02	24.8
U-234	3.01E-02	3.01E-02	4.98E+02	4.98E+02	498
U-235	1.92E-01	1.92E-01	7.80E+01	7.80E+01	78
U-238	5.99E-02	5.99E-02	2.51E+02	2.51E+02	251

3.4 Step 4: Calculation of Effective Site-specific RG

The effective DCGL for the surrogate COC was established as the Site-specific RG for use during the Site cleanup. The effective DCGL for U-238 was calculated by using the following equation (NRC 2000):

$$DCGL\,(U-238) = \frac{1}{\left(\frac{f_{Ra-226/U-238}}{DCGL_{Ra-226}} + \frac{f_{Th-230/U-238}}{DCGL_{Th-230}} + \frac{f_{U-234/U-238}}{DCGL_{U-234}} + \frac{f_{U-235/U-238}}{DCGL_{U-235}} + \frac{1}{DCGL_{U-238}}\right)} \quad \text{(Eq. 1)}$$

Where

f = activity fraction of ROPC with respect to U-238

By utilizing the relationship determined in Step 2 and the individual DCGL for each COC calculated during Step 3, the effective DCGLs for total uranium were determined to be 157 pCi/g and 65 pCi/g for the industrial and construction worker scenarios, respectively. USACE evaluated both worker scenarios, the respective DCGLs, probable future land use and site-specific conditions. USACE identified the construction worker as the critical group, defined as the most highly exposed individuals, and therefore as a conservative approach, selected the effective DCGL for total uranium (65 pCi/g) as the site-specific RG for the Site. It should be noted that the maximum risk produced by 65 pCi/g of total uranium under the construction worker scenario is within the CERCLA acceptable target risk range of 10^{-4} to 10^{-6}. Therefore, the site-specific RG of 65 pCi/g meets both CERCLA acceptable risk criteria and the NJDEP dose criterion.

The DCGL developed in this Appendix is a wide-area average (DCGLw). Therefore, the average concentrations within a given survey unit may be compared to the DCGLw to demonstrate overall compliance for all COCs present at the Site. In addition, an elevated measurement DCGL ($DCGL_{EMC}$ or hot spot criterion) will be developed during remedial design for use in comparing individual sampling results to determine the potential need for further cleanup.

4.0 COMPLIANCE WITH NJDEP ALL CONTROLS FAIL SCENARIO

Dose evaluations were performed due to the presence of residual contamination at the site under post-remediation conditions to the hypothetical residential receptor. The evaluations were performed to demonstrate compliance with the “All Controls Fail” (ACF) provision found in NJAC 7:28-12.11(e). The ACF requirement states: "The department shall not approve alternative standard petitions that include institutional and engineering controls where failure of those controls, not including the failure of a radon remediation system, would result in more than 100 mrem total annual effective dose equivalent." Evaluations to demonstrate compliance with the 100 mrem requirement used the derived DCGLs, including the crop ingestion pathway and a predicted thickness of residual contamination. The drinking water pathway was evaluated for the residential receptor using the same methodology as in the BRA. The evaluations and methodology are summarized below.

4.1 Determination of Thickness of Residual Contamination

As defined in NJAC 7:28-12, the thickness of the contaminated zone is defined as the average thickness of the post-remediation radioactive contamination over an affected area. For the development of site-specific DCGL, the assigned value for the thickness of contaminated zone was set at nine feet. This value was used for the derivation of investigative screening value for the RI and for the BRA (Cabrera 2011b). In evaluating compliance with the ACF scenario, the USACE estimated the ***post remediation*** vertical extent of contamination or predicted residual thickness assuming the selected remedial action alternative includes excavation. The evaluation process is summarized below.

Total uranium concentrations above natural background concentrations (3 pCi/g) at each boring location outside of the assumed excavation boundaries were reviewed to estimate the thickness of residual contamination. Based on these thickness measurements, contour maps were generated for AOC 1, AOC 2 and AOC 6. From each contour map, a volume was calculated for each AOC. The total volume was then divided by total area of each AOC to determine the average residual thickness for each AOC. Attachment A-2 presents the calculations of area-weighted average thickness for residual contamination at AOC 1, AOC 2 and AOC 6. The area-weighted average thickness for AOC 1, AOC 2 and AOC 6 are 3.9, 3.0, and 4.5 feet, respectively. Since the majority of the contamination is found in AOC 1 and AOC 2, the

USACE conservatively selected four feet as the thickness of the residual radioactive contamination for the FUSRAP areas.

4.2 Dose Modeling Based on Post-Remediation Site Conditions

Dose modeling was performed for the hypothetical residential receptor using the post-remediation site conditions to demonstrate compliance with the 100 mrem/yr dose criterion established under an ACF scenario. The dose assessment assumed that the hypothetical residential receptors would be exposed to both residual soil and groundwater contamination present at the site following completion of the remedial action. The dose assessment methodologies used during the BRA for an onsite residential receptor were utilized during this assessment. The methodologies and results of the dose assessments are summarized in the following sections.

4.2.1 Determination of Dose Due to Residual Soil Contamination

RESRAD (version 6.5) was utilized to determine the radiological dose resulting from residual soil contamination remaining at the site following excavation activities. Four feet was used in the dose evaluation to represent the average thickness of residual contamination (vertical extent) remaining at the site, post remediation. The residential receptor scenario as defined in the BRA was used during the dose assessment using RESRAD. Exposure pathways evaluated for the residential scenario include the following:

- external gamma radiation from radionuclides in the soil;
- incidental ingestion of soil;
- inhalation of airborne contaminated dust or volatile emissions from soil; and
- ingestion of foods from crops grown in contaminated soil.

Attachment A-1 includes the assigned values for the RESRAD input parameters under the residential receptor scenario. The exposure pathways and the assigned values were selected during the development of the BRA report. Different source terms (residual soil concentrations) were estimated for each excavation alternative and entered into the RESRAD model. The following sections summarize the derivation of the source terms for the two soil alternatives (S2 and S3).

4.2.1.1 Derivation of Source Term for Residual Soil Contamination Under Soil Alternative S2 (Excavation and Disposal)

During Alternative S2, soil excavated within the assumed excavation boundaries will be sent to an offsite disposal facility. Therefore, total uranium concentrations outside of the assumed excavation boundaries were reviewed to estimate the post-remediation residual soil contamination at the site. USEPA's approved ProUCL software, version 4.0, was used to determine the exposure point concentration (EPC) for soil by calculating the 95% upper confidence limit (UCL) of the mean based on the appropriate distribution of the sampling results. Attachment A-3 presents the results of the ProUCL runs. The results indicate that the 95%UCL for total uranium is 5.78 pCi/g. An adjusted EPC was then calculated for total uranium by subtracting the average background concentration for use during the radiological dose assessment. Specifically, the average background concentration was subtracted from either the maximum detected concentration or the 95% UCL concentration, whichever was the lower value. The adjusted EPC for total uranium was 2.78 pCi/g. The adjusted EPC of 2.78 pCi/g for total uranium and the relationship between the various COCs with respect to U-238 were used to determine the source term for each COC. Table A-4-1 presents the source term for each COC used in the modeling scenarios.

Table A-4-1: Soil Source Term (in pCi/g) for Each COC Under S2

COCs	Ratio to U-238	Concentration (pCi/g)
Ra-226[1]	0.112	0.13
Th-230	0.162	0.19
U-234	1	1.2
U-235	0.046	0.06
U-238	1	1.2
Total	**2.32**	**2.78**

[1] Source Term for Ra-226 = (2.78 pCi/g / 2.32) x 0.112 = 0.13 pCi/g

4.2.1.2 Derivation of Dose for Residual Soil Contamination under Soil Alternative S2 (Excavation and Disposal)

The source terms presented in Table A-4-1, the exposure pathways selected in Section 4.2.1, and the assigned values included in Attachment A-1 were inputted into the RESRAD model to derive the dose for the residual soil contamination under S2. Attachment A-4 presents the output summary of the dose assessment report for the residential receptor using RESRAD. The report shows that the maximum dose to the future hypothetical residential receptor is 0.8 mrem/yr and would occur at approximately year 28.

4.2.1.3 Derivation of Source Term for Residual Soil Contamination under Soil Alternative S3 (Excavation, Treatment and Disposal)

Alternative S3 consists of excavation of impacted soils above cleanup goals, soil treatment, and subsequent off-site disposal. It is assumed that 30% of the excavated soil would meet the soil RGs and would be available for beneficial reuse. Areas of the site where soil has been excavated will be backfilled with the treated soil and clean soil (off-site borrow source), compacted, and re-vegetated. However, the treated soil may result in higher residual soil radioactivity levels at the Site as compared to soil alternative, S2. Two evaluations were performed to determine the residual soil concentrations for total uranium under S3. They are summarized in the followings.

Source Term (First Evaluation): The following assumptions were considered during the first evaluation to determine residual soil contamination associated with Alternative S3 at the Site.

- 30% of the excavated soil would meet the RG of 65 pCi/g and be available for use as backfill within the OU 1 and AOC 6 excavation boundaries.
- Even though the treatment process followed by mixing with clean backfill will reduce the soil concentration well below 65 pCi/g, as a conservative approach, the areas with treated soil (2,155 m^2) were assumed to have a residual soil concentration of 65 pCi/g for total uranium.
- The residual soil concentrations for the rest of the areas (33,629 m^2) within OU 1 and AOC 6 were assumed to have a residual soil concentration of 5.78 pCi/g for total uranium. No credit was realized for the clean backfill soil at the excavation boundaries.

By utilizing the above assumptions, the area-weighted residual soil concentration for total uranium was determined to be 9.35 pCi/g. By subtracting the average background concentration, the adjusted source term for total uranium under S3 was determined to be 6.35 pCi/g. The adjusted source term of 6.35 pCi/g for total uranium and the relationship between the various COCs with respect to U-238 were used to determine the source term for each COC. Table A-4-2 presents the source term for each COC used in the modeling scenarios.

Table A-4-2: Soil Source Term for Each COC Under S3 (First Evaluation)

COCs	Ratio to U-238	Concentration (pCi/g)
Ra-226[1]	0.112	0.31
Th-230	0.162	0.44
U-234	1	2.74
U-235	0.046	0.13
U-238	1	2.74
Total	**2.32**	**6.35**

[1] Source Term for Ra-226 = (6.35 pCi/g / 2.32) x 0.112 = 0. 31 pCi/g

__Source Term (Second Evaluation)__: During Alternative S3, excavated soils with residual concentrations of less than 65 pCi/g will likely pass through the segmented gate system and be used as the backfill within the excavation boundaries. Therefore, soil sampling results with concentrations less than 65 pCi/g (total uranium) within the assumed excavation boundaries and sampling results outside of the assumed excavation boundaries were utilized to estimate the post-remediation residual soil contamination at the site. USEPA's approved ProUCL software, version 4.0, was used to determine the exposure point concentration (EPC) for soil by calculating the 95% upper confidence limit (UCL) of the mean based on the appropriate distribution of the sampling results. Attachment A-5 presents the results of the ProUCL runs. The results indicate that the 95%UCL for total uranium is 7.31 pCi/g. The adjusted EPC for total uranium after subtracting average background was 4.31 pCi/g. The adjusted EPC of 4.31 pCi/g for total uranium and the relationship between the various COCs with respect to U-238 were used to determine the source term for each COC. Table A-4-3 presents the source term for each COC used in the modeling scenarios.

Table A-4-3: Soil Source Term for Each COC Under S3 (Second Evaluation)

COCs	Ratio to U-238	Concentration (pCi/g)
Ra-226[1]	0.112	0.21
Th-230	0.162	0.30
U-234	1	1.86
U-235	0.046	0.09
U-238	1	1.86
Total	**2.32**	**4.31**

[1] Source Term for Ra-226 = (4.46 pCi/g / 2.32) x 0.112 = 0.21 pCi/g

As a conservative approach, the source terms derived under first evaluation were utilized to determine the residual dose under alternative S3.

4.2.1.4 Derivation of Dose for Residual Soil Contamination under Soil Alternative S3 (Excavation, Treatment and Disposal)

The source term presented in Table A-4-2, the exposure pathways selected in Section 4.2.1, and the assigned values included in Attachment A-1 were used in the RESRAD model to derive the dose for the residual soil contamination under S3. Attachment A-6 presents the output summary of the dose assessment report for the residential receptor using RESRAD. The report shows that the maximum dose to the future hypothetical residential receptor is 1.84 mrem/yr and would occur at approximately year 28.

4.2.2 Determination of Dose Due to Residual Groundwater Contamination (S2 and S3)

The RESRAD model determines the radiological dose due to groundwater contamination that may occur due to leaching of radiological contamination that is present in the soil. It does not calculate the radiological dose for the existing groundwater contamination. Therefore, the following modified USEPA's Risk Assessment Guidance for Superfund (RAGS) equation was used to determine the radiological dose due to the incidental ingestion of residual groundwater contamination that may be present at the site.

$$\text{Dose (mrem/yr)} = C_w \times IR \times EF \times DCF$$

where:

C_w Concentration of radionuclides in water (pCi/L) ;
IR Ingestion rate (L/day) (2 L/day);
EF exposure frequency (days/year) (350 days/year); and
DCF Dose Conversion Factor (mrem/year)

Federal Guidance Report Nos. 11 and 12 provide the DCFs for determining the radiological dose to various receptors present at the site. The DCFs are based on the International Commission on Radiological Protection (ICRP) 30 publications. Appendix C presents the uranium mass balance calculations that were performed to estimate the amount of dissolved uranium that would remain in groundwater after completion of a remedial action for soil under soil alternative S2. The results of the mass balance calculations showed that the remaining average uranium concentrations in groundwater at AOC 1, AOC 2 and AOC 6 are estimated to be 16 µg/L, 86 µg/L, and 21 µg/L, respectively. As a conservative approach, the total uranium concentration of

86 µg/L was used to determine the residual dose to the hypothetical residential receptor under soil alternative S2.

Under soil alternative S3, instead of clean backfill, sorted soil along with clean soil will be used as backfill. However, the concentration of the sorted soil is not expected to impact the future groundwater concentration at the Site. Therefore, the total uranium concentration of 86 µg/L was used to determine the residual dose to the hypothetical residential receptor under soil alternative S3.

The groundwater concentration of 86 ug/L (equivalent to 57.6 pCi/L) for total uranium and the relationship between various COCs with respect to U-238 were used to determine the source term for each COC in groundwater. Table A-4-4 presents the source term for each COC for use in the modified RAGS equation.

Table A-4-4: Groundwater Source Term for Each COC (S2 and S3)

COCs	Ratio wrt U-238	Concentration (pCi/L)
U-234[1]	1	28.2
U-235	0.046	1.3
U-238	1	28.2
Total	**2.046**	**57.6**

[1] Source Term for U-234 = (57.6 pCi/L / 2.046) x 1 = 28.2 pCi/L

As presented in Table A-4-5 the dose assessment results using the modified RAGS equation indicate that a residential receptor would receive a dose of 11 mrem/yr from the ingestion of residual groundwater at the site.

Table A-4-5: Dose Assessment Results from Residual Groundwater Contamination

Nuclide	EPC (pCi/L)	Mean BKGD Conc (pCi/L)	Adj. Conc[1] (pCi/L)	X	IR (L/day)	X	EF (days/year)	X	DCF (mrem/pCi)	=	Dose (mrem/yr)
U-234	28.2	0.17	28.03	x	2	x	350	x	2.83E-04	=	6
U-235	1.3	0.04	1.26	x	2	x	350	x	2.67E-04	=	0
U-238	28.2	0.17	28.03	x	2	x	350	x	2.69E-04	=	5
									Total Dose		**11**

4.2.3 Summary of Dose Assessments

The RESRAD model and USEPA's modified RAGS equation were used to perform the dose assessments to the hypothetical residential receptor due to residual soil and groundwater contamination at the Site. The results show that the hypothetical residential receptor would be exposed to less than 12 mrem/yr from both the residual soil and groundwater pathways under soil alternative S2. The results show that the hypothetical residential receptor would be exposed to less than 13 mrem/yr from both the residual soil and groundwater pathways under soil alternative S3. The dose assessments clearly demonstrate that remediation to the site-specific DCGL of 65 pCi/g total uranium will comply with the 100 mrem/yr dose criterion if all controls should fail after completion of the remedial action.

5.0 CONCLUSION

The USACE is conducting response actions to identify and clean up or otherwise control residual radioactive material present at the DuPont Chambers Works FUSRAP Site. The Site is contaminated with residual radioactivity due to work performed for the MED. The initial site investigations were primarily focused on refined natural uranium isotopes and their short-lived decay progenies. However, reviews of historical documents and existing documents from similar FUSRAP sites identified Ra-226 and Th-230 as potential contaminants in the sodium uranate feedstock. USACE then performed an additional evaluation by comparing Site sampling results with theoretical in-growth concentrations of Ra-226 and Th-230 from their parent radionuclide, U-238. The results of the evaluation showed that the relative concentrations of Ra-226 and Th-230 exceeded what would be expected only from uranium-progeny decay. As a result, two additional radionuclides (Ra-226 and Th-230) were added as separate COPCs. In the BRA report, the USACE identified the following five radionuclides as contributing to the unacceptable dose and risk at the site: U-234, U-235, U-238, Th-230, and Ra-226. Therefore, these radionuclides are considered the COCs in the FS.

Due to limited Ra-226 and Th-230 analytical results from initial Site investigations, the USACE performed a surrogate evaluation in order to develop an effective site-specific DCGL for all Site ROPCs. As a part of the surrogate evaluation, U-238 was first selected as the surrogate for the other four COCs present at the Site. Secondly, relationships were established for the other COCs with respect to U-238. During the third step, a RESRAD model was used to derive site-specific DCGLs for the individual COCs under an industrial worker and a construction worker scenario. Finally, the relationships for each COC with respect to U-238 and individual COC DCGL developed for each receptor scenario were then utilized to derive an effective DCGL for total uranium. As a conservative approach, the effective DCGL for total uranium of 65 pCi/g will be used as the RG for the Site during the FS evaluations; however, it may be refined if additional data is gathered during remedial design or other phases of the project.

In addition, various dose assessments were performed to demonstrate compliance with the ACF scenario as specified NJAC 7:28-12.11(e) under both soil alternatives. Using the estimated post remediation vertical extent of contamination of 4 feet and evaluating the residential receptor using both RESRAD and USEPA's modified RAGS equation the resulting total dose to a hypothetical resident from exposure to both residual soil and groundwater contamination is less than 15 mrem/yr. The dose assessment results for both residual soil and groundwater contamination clearly demonstrate that the site-specific DCGL of 65 pCi/g for total uranium complies with the 100 mrem/yr dose ACF criterion.

6.0 REFERENCES

Argonne National Laboratory (ANL) 1993. *Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil*, ANL/EAIS-8, Argonne National Laboratory, Environmental Assessment Division, Argonne, IL, April.

ANL 2005. RESRAD for Windows, Version 6.3, Computer Code, Argonne National Laboratory, Environmental Assessment Division, August.

Cabrera 2011a. Memorandum, USACE Determination of Eligible Contaminants for FUSRAP Investigation, DuPont Chambers Works FUSRAP Site, Deepwater, NJ, June.

Cabrera 2011b. Sitewide Remedial Investigation Report for all Operable Units, Final, DuPont Chambers Works FUSRAP Site, June.

Cabrera 2011c. Baseline Risk Assessment, Final, DuPont Chambers Works FUSRAP Site, June.

New Jersey Department of Environmental Protection (NJDEP) 2000. Final Rule: Soil Remediation Standards for Radioactive Materials N.J.A.C. 7:28 Subchapter 12.

U.S. Nuclear Regulatory Commission (NRC) 1994. Federal Register Notice, Volume 59, Number 161, *Comments from Workshops: Radon,* U.S. Nuclear Regulatory Commission, Washington, DC.

U.S. Nuclear Regulatory Commission (NRC) 2001. Systematic Radiological Assessment of Exemption for Source and Byproduct Materials, NUREG 1717, U.S. Nuclear Regulatory Commission, Washington, DC.

U.S. Army Corps of Engineers (USACE) 2003. Formerly Utilized Sites Remedial Action Program (FUSRAP) – Site Designation, Remediation Scope, and Recovering Costs. ER 200-1-4, August.

U.S. Environmental Protection Agency (USEPA) 1989a. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), EPA 540/1-89/002, December, 1989, PB90-155581.

USEPA 1989b. Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual. EPA/540/1-89-001. U.S. Environmental Protection Agency.

USEPA 1991a. Risk Assessment Guidance for Superfund, Vol. I: Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals, OSWER Directive 9285.7-01B, Office of Emergency and Remedial Response, Washington, D.C.

USEPA 1991b. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors, Interim Final, OSWER Directive 9285.6-03, EPA, Office of Emergency and Remedial Response, Washington, D.C.

USEPA 2002a. User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Windows® 32-bit version. EPA 540-K-01-005, OSWER 9285.7-42. Office of Solid Waste and Emergency Response, Washington, D.C.

USEPA 2002b. Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil. EPA-540-R-03-001. Washington, D.C.

USEPA 2007. ProUCL Software (version 4.00.02). A Statistical Software. National Exposure Research Laboratory, Las Vegas, April.

WISE 2008. Universal Decay Calculator. http://www.wise-uranium.org/rccu.html. Updated: 21 March.

ATTACHMENT A-1:

ASSIGNED VALUES FOR EXPOSURE PARAMETERS USED IN RESRAD MODEL

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
PATHWAY SELECTIONS						
External Gamma	N/A	Active	Active	N/A	Applicable for all Receptors	N/A
Inhalation (without radon)	N/A	Active	Active	N/A	Applicable for all Receptors	N/A
Plant Ingestion[1]	N/A	Active	**Inactive[1]**	N/A	Only applicable for Residential Receptor	N/A
Meat Ingestion[2]	N/A	Active	**Inactive**	N/A	Not applicable	N/A
Milk Ingestion[2]	N/A	Active	**Inactive**	N/A	Not applicable	N/A
Aquatic Foods[2]	N/A	Active	**Inactive**	N/A	Not applicable	N/A
Drinking Water	N/A	Active	**Inactive**	N/A	Not applicable	N/A
Soil Ingestion	N/A	Active	Active	N/A	Applicable for all Receptors	N/A
Radon	N/A	Inactive	Inactive	N/A	Not applicable per Federal Register, 1994, p. 43210	NRC 1994
CONTAMINATED ZONE PARAMETERS						
Area of contaminated zone	AREA	10,000	10,000	m^2	RESRAD defaults value was used.	
Thickness of contaminated zone	THICK0	2	**2.74**	m	A conservative approach was selected to define this parameter. The thickness of the contamination varies from 1' to 9' based on previous remediation history at portions of the facility.	ANL 1993 (Section 39)
			1.219	m	Post Remediation residual thickness; applicable for residential receptor	
Length parallel to the aquifer	LCZPAQ	100	100	m	RESRAD defaults value was used.	ANL 1993 (Section 16)
Times for calculations	TI	1, 3, 10, 30, 100, 300, 1000	1, 3, 10, 30, 100, 300, 1000	yr	RESRAD defaults for calculation times.	ANL 2005
COVER AND CONTAMINATED ZONE HYDROLOGICAL DATA						
Cover depth	COVER)	0	0	M	As a conservative approach for dose modeling, no cover depth was assumed.	ANL 1993 (Section 31)
Density of cover material	DENSCV	1.5	**N/A**	g/cm^3	Lack of cover depth precludes an assigned value for this parameter.	ANL 1993 (Section 2)
Cover erosion rate	VCV	0.001	**N/A**	m/yr	Lack of cover depth precludes an assigned value for this parameter.	ANL 1993 (Section 14)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Density of contaminated zone	DENSCZ	1.5	**1.3**	g/cm^3	Site-specific value was chosen based on the average of loam and clay loam soil. (Table 2.1)	ANL 1993 (Section 2)
Contaminated zone erosion rate	VCZ	0.001	**0.0006** **0.00006**	m/yr	Resident All others	ANL 1993
Contaminated zone total porosity	TPCZ	0.4	0.4	Unitless	RESRAD default used as an estimate of the total porosity	ANL 1993 (Section 3)
Contaminated zone field capacity	FCCZ	0.2	0.2	Unitless	RESRAD default used as an estimate of field capacity	ANL 2005
Contaminated zone hydraulic conductivity	HCCZ	10	**15.8**	m/yr	Assumed to be a factor of 10 less than the saturated zone hydraulic conductivity for clay loam from Table 5.2 of the reference.	ANL 1993 (Section 5)
Contaminated zone b parameter	BCZ	5.3	**6.6**	Unitless	The contaminated zone b parameter was selected from Table 13.1 of the reference for the average of loam and silty clay loam.	ANL 1993 (Section 13)
Humidity in air	HUMID	8	**N/A**	g/m^3	Humidity input is only required in RESRAD when tritium is a radionuclide of concern.	ANL 2005
Evapotranspiration coefficient	EVAPTR	0.5	0.5	Unitless	No site-specific data available. RESRAD default used.	ANL 1993 (Section 12)
Wind speed	WIND	2	2	m/sec	RESRAD default used.	ANL 1993 (Section 21)
Precipitation	PRECIP	1	**0.92**	m/yr	Site-specific value based on reported 36.1 inches per year	ANL 1993 (Section 9) OU 2 RI report
Irrigation	RI	0.2	0.2	m/yr	No site-specific data available. RESRAD default used.	ANL 1993 (Section 11)
Irrigation mode	IDITCH	Overhead	Overhead	Unitless	The "Overhead" and "Ditch" designations are independent of the depth of contaminated zone and have no significant impact on the RESRAD evaluation. The RESRAD default designation was selected.	ANL 2005
Runoff coefficient	RUNOFF	0.2	0.2	Unitless	The RESRAD default value was selected based on reference value for intermediate combinations of clay and loam.	ANL 1993 (Section 10)
Watershed area for nearby stream or pond	WAREA	1.00E6	1.00E6	m^2	RESRAD default used.	ANL 1993 (Section 17)
Accuracy for water/soil computations	EPS	0.001	0.001	Unitless	RESRAD default used.	ANL 2005

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
SATURATED ZONE HYDROLOGICAL DATA[3]						
Density of saturated zone	DENSAQ	1.5	**1.3**	g/cm^3	Site-specific value based on dry-bulk densities the average of loam and clay loam soil.	ANL 1993 (Section 2)
Saturated zone total porosity	TPSZ	0.4	0.4	Unitless	RESRAD default used. Equivalent to contaminated zone total porosity.	ANL 1993 (Section 3)
Saturated zone effective porosity	EPSZ	0.2	0.2	Unitless	RESRAD default used.	ANL 1993 (Section 4)
Saturated zone field capacity	FCSZ	0.2	0.2	Unitless	RESRAD default used.	ANL 2005
Saturated zone hydraulic conductivity	HCSZ	100	**158**	m/yr	Saturated zone hydraulic conductivity for clay loam taken from Table 5.2 of the reference.	Cabrera, 2005
Saturated zone hydraulic gradient	HGWT	0.02	**0.014**	Unitless	Potable water at the Site is obtained via public water supply.	Cabrera, 2005
Saturated zone b parameter	BSZ	5.3	**6.6**	Unitless	The contaminated zone b parameter was selected from Table 13.1 of the reference for the average of loam and silty clay loam.	ANL 1993 (Section 13)
Water table drop rate	VWT	0.001	0.001	m/yr	RESRAD default used.	ANL 1993 (Section 18)
Well pump intake depth (meters below water table)	DWIBWT	10	10	M	The resident will ingest groundwater as drinking water from aquifer B. However, the thickness of the aquifer varies widely across the site. RESRAD default used for this parameter.	ANL 1993 (Section 19)
Model for Water Transport Parameters [Non-dispersion (ND) or Mass-Balance (MB)]	MODEL	ND	ND	unitless	RERAD default used.	ANL 1993
Well pumping rate	UW	250	250	m^3/yr	RESRAD default used.	ANL 2005
UNCONTAMINATED UNSATURATED ZONE PARAMETERS						
Number of unsaturated zone strata	NS	1	1	unitless	RESRAD default used.	ANL 1993 (Section 25)
Unsaturated zone thickness	H(1)	4	**2**	m	Site-specific measurement.	Cabrera, 2006
Unsaturated zone soil density	DENSUZ(1)	1.5	**1.3**	g/cm^3	Soil density range from 1.3 to 1.5. The RESRAD value for the average of loam and silty loam was used based on measured site textures.	ANL 1993 (Section 2)
Unsaturated zone total porosity	TPUZ(1)	0.4	0.4	unitless	RESRAD default used (equivalent to saturated and contaminated zone total porosity inputs).	ANL 1993 (Section 3)

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Unsaturated zone effective porosity	EPSZ(1)	0.2	0.2	unitless	RESRAD default used.	ANL 1993 (Section 4)
Unsaturated zone field capacity	FCSZ(1)	0.2	0.2	unitless	RESRAD default used.	ANL 2005
Unsaturated zone hydraulic conductivity	HCSZ(1)	100	**15.8**	m/yr	Assumed to be a factor of 10 less than the [measured] saturated zone hydraulic conductivity.	ANL 1993 (Section 5)
Unsaturated zone b parameter	BSZ	5.3	**6.6**	unitless	The unsaturated zone b parameter was selected from Table 13.1 of the reference for the average of loam and silty clay loam.	ANL 1993 (Section 13)
NATURAL THORIUM						
ELEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: THORIUM						
Contaminated zone	DCNUCC(2 & 3)	60,000	60,000	cm^3/g	RESRAD default used.	ANL 1993
Unsaturated zone	DCNUCU(2 & 3,1)	60,000	60,000	cm^3/g	RESRAD default used.	ANL 1993
Saturated zone	DCNUCS(2 & 3)	60,000	60,000	cm^3/g	RESRAD default used.	ANL 1993
ELEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: RADIUM						
Contaminated zone	DCNUCC(1)	70	**100**	cm^3/g	Mean of USEPA estimates.	EPA, 2004
Unsaturated zone	DCNUCU(1,1)	70	**100**	cm^3/g	Mean of USEPA estimates.	EPA, 2004
Saturated zone	DCNUCS(1)	70	**100**	cm^3/g	Mean of USEPA estimates.	EPA, 2004
ELEMENTAL DISTRIBUTION (PARTITION) COEFFICIENTS AND LEACH RATES: URANIUM						
Contaminated zone	DCNUCC(1)	50	50	cm^3/g	RESRAD default used, which compares well with literature search.	ANL 1993
Unsaturated zone	DCNUCU(1,1)	50	50	cm^3/g	RESRAD default used, which compares well with literature search.	ANL 1993
Saturated zone	DCNUCS(1)	50	50	cm^3/g	RESRAD default used, which compares well with literature search.	ANL 1993

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
OCCUPANCY, INHALATION AND EXTERNAL GAMMA DATA						
Inhalation rate	INHALR	8,400	**7,300** **7,300** **4,990**	m^3/y	Industrial Worker Construction Worker Residential	EPA 1991b
Mass loading for inhalation	MLINH	0.0001	**7.58E-07** **6.0E-04**	g/m^3	Non-construction Construction Worker	ANL 1993 (Section 35)
Exposure duration	ED	30	**25** **1** **30**	yr	Industrial Worker Construction Worker Residential	EPA 1991b
Inhalation shielding factor	SHF3	0.4	0.4	unitless	RESRAD default used.	ANL 1993 (Section 36)
External gamma shielding factor	SHF1	0.7	**0.4**	unitless	60% shielding per EPA, SSG for all indoor receptors.	EPA 2000
Indoor time fraction	FIND	0.5	**0.200** **0.0** **0.655**	unitless	Industrial Worker (7 hrs/day for 250 days/yr) Construction Worker Residential (16.4 hours per day for 350 days/yr)	EPA 1997 EPA 1991b
Outdoor time fraction	FOTD	0.25	**0.0285** **0.228** **0.08**	unitless	Industrial Worker (1 hrs/day for 250 days/hr) Construction Worker (8 hrs/day for 250 days/hr) Residential (2 hours per day for 350 days/yr)	EPA 1991b
Shape of the contaminated zone (circular or non-circular)	FS	Circular	Circular	unitless	RESRAD default used.	ANL 1993 (Section 50)
INGESTION PATHWAY (DIETARY DATA)						
Fruits, vegetables and grain consumption	DIET(1)	160	**N/A** **464**	kg/yr	Pathway not active for other receptors Pathway active only for residential receptor (Time-weighted average)	N/A
Leafy vegetable consumption	DIET(2)	14	**N/A** **18**	kg/yr	Pathway not active Pathway active only for residential receptor (Time-weighted average)	N/A
Milk consumption	DIET(3)	92	N/A	L/yr	Pathway not active	N/A
Meat and poultry consumption	DIET(4)	63	N/A	kg/yr	Pathway not active	N/A
Fish consumption	DIET(5)	5.4	N/A	kg/yr	Pathway not active	N/A
Other seafood consumption	DIET(6)	0.9	N/A	kg/yr	Pathway not active	N/A
Soil ingestion rate	SOIL	36.5	**18.25** **120.45** **43.8**	g/yr	Industrial Worker Construction Worker Residential	EPA 1991b
Drinking water intake	DW1	510	**N/A**	L/yr	Pathway not active	N/A

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Contamination fraction of drinking water	FDW	1	**N/A**	unitless	Pathway not active	N/A
Contamination fraction of household water	FHHW	1	**NA**	unitless	Radon pathway is not selected; hence this parameter is not applicable	N/A
Contamination fraction of livestock water	FLW	1	**N/A**	unitless	Pathway not active	N/A
Contamination fraction of irrigation water	FIRW	1	**N/A**	unitless	Pathway not active	N/A
Contamination fraction of aquatic food	FR9	0.5	**N/A**	unitless	Pathway not active.	N/A
Contaminated fraction of plant food	FPLANT	-1	**0.038**	unitless	Pathway active only for residential receptor	N/A
Contaminated fraction of meat	FMEAT	-1	**N/A**	unitless	Pathway not active	N/A
Contaminated fraction of milk	FMILK	-1	**N/A**	unitless	Pathway not active	N/A
INGESTION PATHWAY (NON-DIETARY DATA)						
Livestock fodder intake for meat	LP15	68	**N/A**	kg/day	Pathway not active	N/A
Livestock fodder intake for milk	LP16	55	**N/A**	kg/day	Pathway not active	N/A
Livestock water intake for meat	LW15	50	**N/A**	L/day	Pathway not active	N/A
Livestock water intake for milk	LW15	160	**N/A**	L/day	Pathway not active	N/A
Livestock intake of soil	LS1	0.5	**N/A**	kg/day	Pathway not active	N/A
Mass loading for foliar deposition	MLFD	0.0001	**N/A**	g/m^3	Pathway not active	N/A
Depth of soil mixing layer	DM	0.15	0.15	m	RESRAD default used.	ANL 1993 (Section 35)
Depth of roots	DROOT	0.9	N/A	m	Pathway not active	N/A
Groundwater fractional usage: Drinking water	FGWDW	1	**N/A**	unitless	Pathway not active	N/A
Groundwater fractional usage: Household water	FGWHH	1	**N/A**	unitless	Pathway not active	N/A

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
Groundwater fractional usage: Livestock water	FGWLW	1	**N/A**	unitless	Pathway not active	N/A
Groundwater fractional usage: Irrigation water	FGWIR	1	**N/A**	unitless	Pathway not active	N/A
PLANT TRANSPORT FACTORS						
Wet weight crop yield: non-leafy vegetables	YV(1)	0.7	0.7	kg/m^2	RESRAD default value (Active only for residential receptor)	ANL 2005
Wet weight crop yield: leafy vegetables	YV(2)	1.5	1.5	kg/m^2	RESRAD default value (Active only for residential receptor)	ANL 2005
Wet weight crop yield: fodder	YV(3)	1.1	1.1	kg/m^2	RESRAD default value (Active only for residential receptor)	ANL 2005
Length of growing season: non-leafy vegetables	TE(1)	0.17	0.17	years	RESRAD default value (Active only for residential receptor)	ANL 2005
Length of growing season: leafy vegetables	TE(2)	0.25	0.25	years	RESRAD default value (Active only for residential receptor)	ANL 2005
Length of growing season: fodder	TE(3)	0.08	0.08	years	RESRAD default value (Active only for residential receptor)	ANL 2005
Translocation factor: non-leafy vegetables	TIV(1)	0.1	0.1	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Translocation factor: leafy vegetables	TIV(2)	1	1	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Translocation factor: fodder	TIV(3)	1	1	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Weathering removal constant	WLAM	20	20	y^{-1}	RESRAD default value (Active only for residential receptor)	ANL 2005
Wet foliar interception fraction: non-leafy vegetables	RWET(1)	0.25	0.25	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Wet foliar interception fraction: leafy vegetables	RWET(2)	0.25	0.25	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Wet foliar interception fraction: fodder	RWET(3)	0.25	0.25	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Dry foliar interception fraction: non-leafy vegetables	RDRY(1)	0.25	0.25	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Dry foliar interception fraction: leafy vegetables	RDRY(2)	0.25	0.25	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005
Dry foliar interception fraction: fodder	RDRY(3)	0.25	0.25	unitless	RESRAD default value (Active only for residential receptor)	ANL 2005

DEFAULT AND RECOMMENDED VALUES FOR RESRAD INPUT PARAMETERS

RESRAD Version 6.3/6.5					Parameter Justification	
Parameter	**Code**	**Default Value**	**User Input Value**	**Units**	**Comments**	**Reference**
STORAGE TIMES BEFORE USE						
Fruits, non-leafy vegetables and grain	STOR_T(1)	14	14	days	RESRAD default value (Active only for residential receptor)	ANL 2005
Leafy vegetables	STOR_T(2)	1	1	days	RESRAD default value (Active only for residential receptor)	ANL 2005
Milk	STOR_T(3)	1	**N/A**	days	Pathway not active.	N/A
Meat	STOR_T(4)	20	**N/A**	days	Pathway not active.	N/A
Fish	STOR_T(5)	7	**N/A**	days	Pathway not active.	N/A
Crustacea and mollusks	STOR_T(6)	7	**N/A**	days	Pathway not active.	N/A
Well water	STOR_T(7)	1	**N/A**	days	Pathway not active.	N/A
Surface water	STOR_T(8)	1	**N/A**	days	Pathway not active.	N/A
Livestock fodder	STOR_T(9)	45	**N/A**	days	Pathway not active.	N/A

Footnotes

1 These pathways were only evaluated for residential receptor scenario.

2 Due to nature of the land use scenario, these pathways were not evaluated for any RME receptor scenario. In addition, they are inactive for residential receptor as residential zoning generally prohibits keeping of livestock on site.

3 All hydrological input parameter values are presented for informational purposes only. RESRAD was not used for modeling the residual dose due to future groundwater contamination.

ATTACHMENT A-2:

DETERMINATION OF RESIDUAL THICKNESS FOR AOC 1, AOC 2 AND AOC 6

AOC 1	**Surface areas of residual thickness layers**								
Average thickness equals [(thickness1*area1)+(thickness2*area2)+…]/(sum of areas)									
Areas remediated:	7219								
	25182								
	3624								
	36025	ft^2	[not included in average thickness calculation]						
One-foot thick layers									
	6209								
	14509								
	20718	ft^2	*	1		=	20718	ft^3	
Four-foot thick layers									
	61220	ft^2	*	4		=	244880	ft^3	
Seven-foot thick layer									
	3458	ft^2	*	7		=	24206	ft^3	
Eight-foot thick layer									
	2732	ft^2	*	8		=	21856	ft^3	
Nine-foot thick layer									
	6292	ft^2	*	9		=	56628	ft^3	
sum of areas =	**94420**	ft^2	**Sum of the Volumes**			=	**368288**	ft^3	

Average residual thickness AOC 1 =	**368288**	**/**	**94420**	**=**	**3.9**	**ft**

AOC 2	**Surface areas of residual thickness layers**						
Average thickness equals [(thickness1*area1)+(thickness2*area2)+…]/(sum of areas)							
Areas remediated:	29550						
	1276						
	30826	ft^2	[not included in average thickness calculation]				
Two-foot thick layers							
	60155						
	60155						
	120310	ft^2	*	2	=	240620	ft^3
Four-foot thick layers							
	17407						
	5681						
	3075						
	2200						
	28363	ft^2	*	4	=	113452	ft^3
Six-foot thick layers							
	1718						
	1381	ft^2					
	31462	ft^2	*	6	=	188772	ft^3
Eight-foot thick layer							
	1130	ft^2	*	8	=	9040	ft^3
Sum of areas =	**181265**	ft^2	**Sum of volumes =**			**551884**	ft^3

Average residual thickness AOC 2 =	**551884**	**/**	**181265**	**=**	**3**	**ft**

AOC 6	**Surface areas of residual thickness layers**						
Average thickness equals [(thickness1*area1)+(thickness2*area2)+…]/(sum of areas)							
Areas remediated:	7757	ft^2	[not included in average thickness calculation]				
Three-foot thick layers							
	7135	ft^2	*	3	=	21405	ft^3
Five-foot thick layers							
	1180						
	865						
	2045	ft^2	*	5	=	10225	ft^3
Seven-foot thick layers							
	390						
	1203	ft^2					
	3638	ft^2	*	7	=	25466	ft^3
Sum of areas =	**12818**	ft^2	**Sum of volumes =**			**57096**	ft^3

Average residual thickness AOC 6 =	**57096**	**/**	**12818**	**=**	**4.5**	**ft**

ATTACHMENT A-3:

DETERMINATION OF RESIDUAL SOIL CONCENTRATION FOR TOTAL URANIUM UNDER SOIL ALTERNATIVE S2, POST REMEDIATION CONDITIONS, USING PRO-UCL 4.0

PRO-UCL 4.0 OUTPUT RUNS

General Statistics			
Number of Valid Observations	313	Number of Distinct Observations	234
Number of Missing Values	1		
Raw Statistics		Log-transformed Statistics	
Minimum	-4.5	Log Statistics Not Avaliable	
Maximum	72		
Mean	3.918		
Median	2.01		
SD	7.548		
Coefficient of Variation	1.927		
Skewness	4.792		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.307	Not Available	
Lilliefors Critical Value	0.0501		
Data not Normal at 5% Significance Level			
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	4.622	95% H-UCL	N/A
Assuming Normal Distribution		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	4.622	95% Adjusted-CLT UCL (Chen 1995)	4.743
		95% Modified-t UCL (Johnson-1978)	4.641
Gamma Distribution Test		Data Distribution	
Gamma Statistics Not Available		Data do not follow a Discernable Distribution (0.05)	
Potential UCL to Use			
Use 95% Chebyshev (Mean, Sd) UCL	**5.778**	95% CLT UCL	4.62
		95% Jackknife UCL	4.622
		95% Standard Bootstrap UCL	4.637
		95% Bootstrap-t UCL	4.767
		95% Hall's Bootstrap UCL	4.823
		95% Percentile Bootstrap UCL	4.649
		95% BCA Bootstrap UCL	4.741
		95% Chebyshev(Mean, Sd) UCL	5.778
		97.5% Chebyshev(Mean, Sd) UCL	6.582
		99% Chebyshev(Mean, Sd) UCL	8.163

ATTACHMENT A-4:

OUTPUT DOSE ASSESSMENT SUMMARY REPORT USING RESRAD, RESIDENTIAL RECEPTOR UNDER SOIL ALTERNATIVE S2

```
RESRAD, Version 6.5      T« Limit = 180 days        06/22/2011  12:42  Page   1
 Summary : Residual Dose Assessment Under Residential Receptor
 File    : C:\USERS\MRAHMAN\DOCUMENTS\OLD RESRAD FILES\RES- RESIDENTIALACF.RAD

                        Table of Contents
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    Part I: Mixture Sums and Single Radionuclide Guidelines
    -------------------------------------------------------
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RESRAD, Version 6.5      T« Limit = 180 days        06/22/2011  12:42  Page   2
Summary : Residual Dose Assessment Under Residential Receptor
File    : C:\USERS\MRAHMAN\DOCUMENTS\OLD RESRAD FILES\RES- RESIDENTIALACF.RAD

                          Dose Conversion Factor (and Related) Parameter Summary
                                      Dose Library: FGR 12 & FGR 11
                                                                            Current     Base      Parameter
Menu                           Parameter                                     Value#     Case*       Name
---------------------------------------------------------------------------------------------------------
A-1   DCF's for external ground radiation, (mrem/yr)/(pCi/g)
A-1   Ac-227   (Source: FGR 12)                                          4.951E-04  4.951E-04  DCF1(  1)
A-1   At-218   (Source: FGR 12)                                          5.847E-03  5.847E-03  DCF1(  2)
A-1   Bi-210   (Source: FGR 12)                                          3.606E-03  3.606E-03  DCF1(  3)
A-1   Bi-211   (Source: FGR 12)                                          2.559E-01  2.559E-01  DCF1(  4)
A-1   Bi-214   (Source: FGR 12)                                          9.808E+00  9.808E+00  DCF1(  5)
A-1   Fr-223   (Source: FGR 12)                                          1.980E-01  1.980E-01  DCF1(  6)
A-1   Pa-231   (Source: FGR 12)                                          1.906E-01  1.906E-01  DCF1(  7)
A-1   Pa-234   (Source: FGR 12)                                          1.155E+01  1.155E+01  DCF1(  8)
A-1   Pa-234m  (Source: FGR 12)                                          8.967E-02  8.967E-02  DCF1(  9)
A-1   Pb-210   (Source: FGR 12)                                          2.447E-03  2.447E-03  DCF1( 10)
A-1   Pb-211   (Source: FGR 12)                                          3.064E-01  3.064E-01  DCF1( 11)
A-1   Pb-214   (Source: FGR 12)                                          1.341E+00  1.341E+00  DCF1( 12)
A-1   Po-210   (Source: FGR 12)                                          5.231E-05  5.231E-05  DCF1( 13)
A-1   Po-211   (Source: FGR 12)                                          4.764E-02  4.764E-02  DCF1( 14)
A-1   Po-214   (Source: FGR 12)                                          5.138E-04  5.138E-04  DCF1( 15)
A-1   Po-215   (Source: FGR 12)                                          1.016E-03  1.016E-03  DCF1( 16)
A-1   Po-218   (Source: FGR 12)                                          5.642E-05  5.642E-05  DCF1( 17)
A-1   Ra-223   (Source: FGR 12)                                          6.034E-01  6.034E-01  DCF1( 18)
A-1   Ra-226   (Source: FGR 12)                                          3.176E-02  3.176E-02  DCF1( 19)
A-1   Rn-219   (Source: FGR 12)                                          3.083E-01  3.083E-01  DCF1( 20)
A-1   Rn-222   (Source: FGR 12)                                          2.354E-03  2.354E-03  DCF1( 21)
A-1   Th-227   (Source: FGR 12)                                          5.212E-01  5.212E-01  DCF1( 22)
A-1   Th-230   (Source: FGR 12)                                          1.209E-03  1.209E-03  DCF1( 23)
A-1   Th-231   (Source: FGR 12)                                          3.643E-02  3.643E-02  DCF1( 24)
A-1   Th-234   (Source: FGR 12)                                          2.410E-02  2.410E-02  DCF1( 25)
A-1   Tl-207   (Source: FGR 12)                                          1.980E-02  1.980E-02  DCF1( 26)
A-1   Tl-210   (Source: no data)                                         0.000E+00 -2.000E+00  DCF1( 27)
A-1   U-234    (Source: FGR 12)                                          4.017E-04  4.017E-04  DCF1( 28)
A-1   U-235    (Source: FGR 12)                                          7.211E-01  7.211E-01  DCF1( 29)
A-1   U-238    (Source: FGR 12)                                          1.031E-04  1.031E-04  DCF1( 30)

B-1   Dose conversion factors for inhalation, mrem/pCi:
B-1   Ac-227+D                                                           6.724E+00  6.700E+00  DCF2(  1)
B-1   Pa-231                                                             1.280E+00  1.280E+00  DCF2(  2)
B-1   Pb-210+D                                                           2.320E-02  1.360E-02  DCF2(  3)
B-1   Ra-226+D                                                           8.594E-03  8.580E-03  DCF2(  4)
B-1   Th-230                                                             3.260E-01  3.260E-01  DCF2(  5)
B-1   U-234                                                              1.320E-01  1.320E-01  DCF2(  6)
B-1   U-235+D                                                            1.230E-01  1.230E-01  DCF2(  7)
B-1   U-238                                                              1.180E-01  1.180E-01  DCF2(  8)
B-1   U-238+D                                                            1.180E-01  1.180E-01  DCF2(  9)
```

```
D-1   Dose conversion factors for ingestion, mrem/pCi:
D-1   Ac-227+D                                                     1.480E-02  1.410E-02  DCF3(  1)
D-1   Pa-231                                                       1.060E-02  1.060E-02  DCF3(  2)
D-1   Pb-210+D                                                     7.276E-03  5.370E-03  DCF3(  3)
D-1   Ra-226+D                                                     1.321E-03  1.320E-03  DCF3(  4)
D-1   Th-230                                                       5.480E-04  5.480E-04  DCF3(  5)
D-1   U-234                                                        2.830E-04  2.830E-04  DCF3(  6)
```

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                    Dose Conversion Factor (and Related) Parameter Summary (continued)
                                  Dose Library: FGR 12 & FGR 11
                                                                        Current     Base      Parameter
Menu                           Parameter                                 Value#     Case*       Name
---------------------------------------------------------------------------------------------------------
D-1   U-235+D                                                          2.673E-04  2.660E-04  DCF3(  7)
D-1   U-238                                                            2.550E-04  2.550E-04  DCF3(  8)
D-1   U-238+D                                                          2.687E-04  2.550E-04  DCF3(  9)

D-34  Food transfer factors:
D-34  Ac-227+D  , plant/soil concentration ratio, dimensionless        2.500E-03  2.500E-03  RTF(  1,1)
D-34  Ac-227+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        2.000E-05  2.000E-05  RTF(  1,2)
D-34  Ac-227+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         2.000E-05  2.000E-05  RTF(  1,3)
D-34
D-34  Pa-231    , plant/soil concentration ratio, dimensionless        1.000E-02  1.000E-02  RTF(  2,1)
D-34  Pa-231    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        5.000E-03  5.000E-03  RTF(  2,2)
D-34  Pa-231    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         5.000E-06  5.000E-06  RTF(  2,3)
D-34
D-34  Pb-210+D  , plant/soil concentration ratio, dimensionless        1.000E-02  1.000E-02  RTF(  3,1)
D-34  Pb-210+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        8.000E-04  8.000E-04  RTF(  3,2)
D-34  Pb-210+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         3.000E-04  3.000E-04  RTF(  3,3)
D-34
D-34  Ra-226+D  , plant/soil concentration ratio, dimensionless        4.000E-02  4.000E-02  RTF(  4,1)
D-34  Ra-226+D  , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        1.000E-03  1.000E-03  RTF(  4,2)
D-34  Ra-226+D  , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         1.000E-03  1.000E-03  RTF(  4,3)
D-34
D-34  Th-230    , plant/soil concentration ratio, dimensionless        1.000E-03  1.000E-03  RTF(  5,1)
D-34  Th-230    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        1.000E-04  1.000E-04  RTF(  5,2)
D-34  Th-230    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         5.000E-06  5.000E-06  RTF(  5,3)
D-34
D-34  U-234     , plant/soil concentration ratio, dimensionless        2.500E-03  2.500E-03  RTF(  6,1)
D-34  U-234     , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        3.400E-04  3.400E-04  RTF(  6,2)
D-34  U-234     , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         6.000E-04  6.000E-04  RTF(  6,3)
D-34
D-34  U-235+D   , plant/soil concentration ratio, dimensionless        2.500E-03  2.500E-03  RTF(  7,1)
D-34  U-235+D   , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        3.400E-04  3.400E-04  RTF(  7,2)
D-34  U-235+D   , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         6.000E-04  6.000E-04  RTF(  7,3)
D-34
D-34  U-238     , plant/soil concentration ratio, dimensionless        2.500E-03  2.500E-03  RTF(  8,1)
D-34  U-238     , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        3.400E-04  3.400E-04  RTF(  8,2)
D-34  U-238     , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         6.000E-04  6.000E-04  RTF(  8,3)
D-34
D-34  U-238+D   , plant/soil concentration ratio, dimensionless        2.500E-03  2.500E-03  RTF(  9,1)
D-34  U-238+D   , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)        3.400E-04  3.400E-04  RTF(  9,2)
D-34  U-238+D   , milk/livestock-intake ratio, (pCi/L)/(pCi/d)         6.000E-04  6.000E-04  RTF(  9,3)

D-5   Bioaccumulation factors, fresh water, L/kg:
```

```
D-5   Ac-227+D  , fish                                                   1.500E+01  1.500E+01  BIOFAC(  1,1)
D-5   Ac-227+D  , crustacea and mollusks                                 1.000E+03  1.000E+03  BIOFAC(  1,2)
D-5
D-5   Pa-231    , fish                                                   1.000E+01  1.000E+01  BIOFAC(  2,1)
D-5   Pa-231    , crustacea and mollusks                                 1.100E+02  1.100E+02  BIOFAC(  2,2)
D-5
D-5   Pb-210+D  , fish                                                   3.000E+02  3.000E+02  BIOFAC(  3,1)
D-5   Pb-210+D  , crustacea and mollusks                                 1.000E+02  1.000E+02  BIOFAC(  3,2)
```

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                    Dose Conversion Factor (and Related) Parameter Summary (continued)
                                  Dose Library: FGR 12 & FGR 11
                                                                    Current     Base      Parameter
Menu                           Parameter                             Value#     Case*       Name
---------------------------------------------------------------------------------------------------------
D-5   Ra-226+D  , fish                                             5.000E+01  5.000E+01  BIOFAC(  4,1)
D-5   Ra-226+D  , crustacea and mollusks                           2.500E+02  2.500E+02  BIOFAC(  4,2)
D-5
D-5   Th-230    , fish                                             1.000E+02  1.000E+02  BIOFAC(  5,1)
D-5   Th-230    , crustacea and mollusks                           5.000E+02  5.000E+02  BIOFAC(  5,2)
D-5
D-5   U-234     , fish                                             1.000E+01  1.000E+01  BIOFAC(  6,1)
D-5   U-234     , crustacea and mollusks                           6.000E+01  6.000E+01  BIOFAC(  6,2)
D-5
D-5   U-235+D   , fish                                             1.000E+01  1.000E+01  BIOFAC(  7,1)
D-5   U-235+D   , crustacea and mollusks                           6.000E+01  6.000E+01  BIOFAC(  7,2)
D-5
D-5   U-238     , fish                                             1.000E+01  1.000E+01  BIOFAC(  8,1)
D-5   U-238     , crustacea and mollusks                           6.000E+01  6.000E+01  BIOFAC(  8,2)
D-5
D-5   U-238+D   , fish                                             1.000E+01  1.000E+01  BIOFAC(  9,1)
D-5   U-238+D   , crustacea and mollusks                           6.000E+01  6.000E+01  BIOFAC(  9,2)
---------------------------------------------------------------------------------------------------------
#For DCF1(xxx) only, factors are for infinite depth & area.  See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.
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Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.219E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	1.000E+01	3.000E+00	---	T(3)
R011	Times for calculations (yr)	3.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	1.000E+02	3.000E+01	---	T(5)
R011	Times for calculations (yr)	3.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	9.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	2.000E+03	0.000E+00	---	T(9)
R011	Times for calculations (yr)	1.000E+04	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-226	1.300E-01	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Th-230	1.900E-01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): U-234	1.200E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): U-235	6.000E-02	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): U-238	1.200E+00	0.000E+00	---	S1(8)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(8)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.300E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	6.000E-04	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.580E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	6.600E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	9.200E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF

R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.300E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Saturated zone hydraulic conductivity (m/yr)	1.580E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	1.400E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	6.600E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	2.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.300E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	6.600E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	1.580E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.945E-03	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.921E-06	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R016	Distribution coefficients for U-234				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(6,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.876E-03	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for U-235				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.876E-03	ALEACH(7)

```
R016    Solubility constant                           0.000E+00  0.000E+00          not used             SOLUBK( 7)

R016  Distribution coefficients for U-238
R016    Contaminated zone (cm**3/g)                   5.000E+01  5.000E+01             ---               DCNUCC( 8)
R016    Unsaturated zone 1 (cm**3/g)                  5.000E+01  5.000E+01             ---               DCNUCU( 8,1)
R016    Saturated zone (cm**3/g)                      5.000E+01  5.000E+01             ---               DCNUCS( 8)
R016    Leach rate (/yr)                              0.000E+00  0.000E+00          5.876E-03            ALEACH( 8)
R016    Solubility constant                           0.000E+00  0.000E+00          not used             SOLUBK( 8)
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                                          Site-Specific Parameter Summary (continued)
                                                            User                      Used by RESRAD           Parameter
Menu                          Parameter                     Input      Default   (If different from user input)    Name
----------------------------------------------------------------------------------------------------------------------------------
R016  Distribution coefficients for daughter Ac-227
R016    Contaminated zone (cm**3/g)                       2.000E+01  2.000E+01             ---                DCNUCC( 1)
R016    Unsaturated zone 1 (cm**3/g)                      2.000E+01  2.000E+01             ---                DCNUCU( 1,1)
R016    Saturated zone (cm**3/g)                          2.000E+01  2.000E+01             ---                DCNUCS( 1)
R016    Leach rate (/yr)                                  0.000E+00  0.000E+00          1.458E-02             ALEACH( 1)
R016    Solubility constant                               0.000E+00  0.000E+00          not used              SOLUBK( 1)

R016  Distribution coefficients for daughter Pa-231
R016    Contaminated zone (cm**3/g)                       5.000E+01  5.000E+01             ---                DCNUCC( 2)
R016    Unsaturated zone 1 (cm**3/g)                      5.000E+01  5.000E+01             ---                DCNUCU( 2,1)
R016    Saturated zone (cm**3/g)                          5.000E+01  5.000E+01             ---                DCNUCS( 2)
R016    Leach rate (/yr)                                  0.000E+00  0.000E+00          5.876E-03             ALEACH( 2)
R016    Solubility constant                               0.000E+00  0.000E+00          not used              SOLUBK( 2)

R016  Distribution coefficients for daughter Pb-210
R016    Contaminated zone (cm**3/g)                       1.000E+02  1.000E+02             ---                DCNUCC( 3)
R016    Unsaturated zone 1 (cm**3/g)                      1.000E+02  1.000E+02             ---                DCNUCU( 3,1)
R016    Saturated zone (cm**3/g)                          1.000E+02  1.000E+02             ---                DCNUCS( 3)
R016    Leach rate (/yr)                                  0.000E+00  0.000E+00          2.945E-03             ALEACH( 3)
R016    Solubility constant                               0.000E+00  0.000E+00          not used              SOLUBK( 3)

R017  Inhalation rate (m**3/yr)                           4.990E+03  8.400E+03             ---                INHALR
R017  Mass loading for inhalation (g/m**3)                7.580E-07  1.000E-04             ---                MLINH
R017  Exposure duration                                   3.000E+01  3.000E+01             ---                ED
R017  Shielding factor, inhalation                        4.000E-01  4.000E-01             ---                SHF3
R017  Shielding factor, external gamma                    4.000E-01  7.000E-01             ---                SHF1
R017  Fraction of time spent indoors                      6.550E-01  5.000E-01             ---                FIND
R017  Fraction of time spent outdoors (on site)           8.000E-02  2.500E-01             ---                FOTD
R017  Shape factor flag, external gamma                   1.000E+00  1.000E+00     >0 shows circular AREA.    FS
R017  Radii of shape factor array (used if FS = -1):
R017    Outer annular radius (m), ring  1:                not used   5.000E+01             ---                RAD_SHAPE( 1)
R017    Outer annular radius (m), ring  2:                not used   7.071E+01             ---                RAD_SHAPE( 2)
R017    Outer annular radius (m), ring  3:                not used   0.000E+00             ---                RAD_SHAPE( 3)
R017    Outer annular radius (m), ring  4:                not used   0.000E+00             ---                RAD_SHAPE( 4)
R017    Outer annular radius (m), ring  5:                not used   0.000E+00             ---                RAD_SHAPE( 5)
R017    Outer annular radius (m), ring  6:                not used   0.000E+00             ---                RAD_SHAPE( 6)
R017    Outer annular radius (m), ring  7:                not used   0.000E+00             ---                RAD_SHAPE( 7)
R017    Outer annular radius (m), ring  8:                not used   0.000E+00             ---                RAD_SHAPE( 8)
R017    Outer annular radius (m), ring  9:                not used   0.000E+00             ---                RAD_SHAPE( 9)
R017    Outer annular radius (m), ring 10:                not used   0.000E+00             ---                RAD_SHAPE(10)
R017    Outer annular radius (m), ring 11:                not used   0.000E+00             ---                RAD_SHAPE(11)
R017    Outer annular radius (m), ring 12:                not used   0.000E+00             ---                RAD_SHAPE(12)
```

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	4.640E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.800E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	4.380E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	3.800E-02	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR

R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX

R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
TITL	Maximum number of integration points for dose	17	---	---	LYMAX
TITL	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	suppressed

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     Contaminated Zone Dimensions           Initial Soil Concentrations, pCi/g
     ----------------------------           ----------------------------------
       Area:  10000.00 square meters               Ra-226     1.300E-01
  Thickness:      1.22 meters                      Th-230     1.900E-01
Cover Depth:      0.00 meters                      U-234      1.200E+00
                                                   U-235      6.000E-02
                                                   U-238      1.200E+00

                                 Total Dose TDOSE(t), mrem/yr
                           Basic Radiation Dose Limit = 1.500E+01 mrem/yr
                Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)
                ---------------------------------------------------------------------------
   t (years):  0.000E+00  1.000E+00  1.000E+01  3.000E+01  1.000E+02  3.000E+02  9.000E+02  1.000E+03  2.000E+03  1.000E+04
    TDOSE(t):  7.336E-01  7.374E-01  7.623E-01  7.780E-01  6.832E-01  4.256E-01  2.023E-01  1.798E-01  3.453E-02  6.436E-04
        M(t):  4.890E-02  4.916E-02  5.082E-02  5.187E-02  4.555E-02  2.837E-02  1.348E-02  1.198E-02  2.302E-03  4.291E-05
Maximum TDOSE(t):  7.782E-01 mrem/yr   at t =   27.81 ñ 0.06 years
                Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                            As mrem/yr and Fraction of Total Dose At t = 2.781E+01 years
                               Water Independent Pathways (Inhalation excludes radon)
```

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	4.252E-01	0.5465	5.754E-07	0.0000	0.000E+00	0.0000	2.075E-01	0.2667	0.000E+00	0.0000	0.000E+00	0.0000	2.130E-02	0.0274
Th-230	8.070E-03	0.0104	1.357E-05	0.0000	0.000E+00	0.0000	5.047E-03	0.0065	0.000E+00	0.0000	0.000E+00	0.0000	3.618E-03	0.0046
U-234	1.409E-04	0.0002	2.939E-05	0.0000	0.000E+00	0.0000	1.318E-02	0.0169	0.000E+00	0.0000	0.000E+00	0.0000	9.262E-03	0.0119
U-235	1.254E-02	0.0161	1.391E-06	0.0000	0.000E+00	0.0000	6.880E-04	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	4.523E-04	0.0006
U-238	4.973E-02	0.0639	2.627E-05	0.0000	0.000E+00	0.0000	1.251E-02	0.0161	0.000E+00	0.0000	0.000E+00	0.0000	8.791E-03	0.0113
Total	4.957E-01	0.6370	7.120E-05	0.0001	0.000E+00	0.0000	2.390E-01	0.3071	0.000E+00	0.0000	0.000E+00	0.0000	4.342E-02	0.0558

```
                Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                            As mrem/yr and Fraction of Total Dose At t = 2.781E+01 years
                                             Water Dependent Pathways
```

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.541E-01	0.8405
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.675E-02	0.0215
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.261E-02	0.0291
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.369E-02	0.0176
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.106E-02	0.0913
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.782E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.670E-01	0.6366	2.544E-07	0.0000	0.000E+00	0.0000	1.288E-01	0.1756	0.000E+00	0.0000	0.000E+00	0.0000	5.986E-03	0.0082
Th-230	2.232E-04	0.0003	1.357E-05	0.0000	0.000E+00	0.0000	1.947E-03	0.0027	0.000E+00	0.0000	0.000E+00	0.0000	3.354E-03	0.0046
U-234	1.585E-04	0.0002	3.459E-05	0.0000	0.000E+00	0.0000	1.551E-02	0.0211	0.000E+00	0.0000	0.000E+00	0.0000	1.090E-02	0.0149
U-235	1.476E-02	0.0201	1.612E-06	0.0000	0.000E+00	0.0000	7.340E-04	0.0010	0.000E+00	0.0000	0.000E+00	0.0000	5.151E-04	0.0007
U-238	5.856E-02	0.0798	3.093E-05	0.0000	0.000E+00	0.0000	1.473E-02	0.0201	0.000E+00	0.0000	0.000E+00	0.0000	1.035E-02	0.0141
Total	5.407E-01	0.7370	8.095E-05	0.0001	0.000E+00	0.0000	1.617E-01	0.2204	0.000E+00	0.0000	0.000E+00	0.0000	3.111E-02	0.0424

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.017E-01	0.8203
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.538E-03	0.0075
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.661E-02	0.0363
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.601E-02	0.0218
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.367E-02	0.1141
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.336E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.654E-01	0.6311	2.734E-07	0.0000	0.000E+00	0.0000	1.336E-01	0.1812	0.000E+00	0.0000	0.000E+00	0.0000	6.879E-03	0.0093
Th-230	5.184E-04	0.0007	1.357E-05	0.0000	0.000E+00	0.0000	2.030E-03	0.0028	0.000E+00	0.0000	0.000E+00	0.0000	3.358E-03	0.0046
U-234	1.576E-04	0.0002	3.439E-05	0.0000	0.000E+00	0.0000	1.542E-02	0.0209	0.000E+00	0.0000	0.000E+00	0.0000	1.084E-02	0.0147
U-235	1.467E-02	0.0199	1.603E-06	0.0000	0.000E+00	0.0000	7.322E-04	0.0010	0.000E+00	0.0000	0.000E+00	0.0000	5.125E-04	0.0007
U-238	5.822E-02	0.0790	3.075E-05	0.0000	0.000E+00	0.0000	1.464E-02	0.0199	0.000E+00	0.0000	0.000E+00	0.0000	1.029E-02	0.0140
Total	5.390E-01	0.7309	8.058E-05	0.0001	0.000E+00	0.0000	1.665E-01	0.2257	0.000E+00	0.0000	0.000E+00	0.0000	3.188E-02	0.0432

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.059E-01	0.8217
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.920E-03	0.0080
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.645E-02	0.0359
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.592E-02	0.0216
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.318E-02	0.1128
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.374E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	4.515E-01	0.5923	4.140E-07	0.0000	0.000E+00	0.0000	1.687E-01	0.2213	0.000E+00	0.0000	0.000E+00	0.0000	1.354E-02	0.0178
Th-230	3.131E-03	0.0041	1.357E-05	0.0000	0.000E+00	0.0000	2.897E-03	0.0038	0.000E+00	0.0000	0.000E+00	0.0000	3.417E-03	0.0045
U-234	1.504E-04	0.0002	3.262E-05	0.0000	0.000E+00	0.0000	1.463E-02	0.0192	0.000E+00	0.0000	0.000E+00	0.0000	1.028E-02	0.0135
U-235	1.392E-02	0.0183	1.526E-06	0.0000	0.000E+00	0.0000	7.165E-04	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	4.907E-04	0.0006
U-238	5.522E-02	0.0724	2.916E-05	0.0000	0.000E+00	0.0000	1.389E-02	0.0182	0.000E+00	0.0000	0.000E+00	0.0000	9.760E-03	0.0128
Total	5.239E-01	0.6873	7.729E-05	0.0001	0.000E+00	0.0000	2.008E-01	0.2634	0.000E+00	0.0000	0.000E+00	0.0000	3.748E-02	0.0492

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.337E-01	0.8313
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.458E-03	0.0124
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.509E-02	0.0329
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.513E-02	0.0198
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.890E-02	0.1035
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.623E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	4.221E-01	0.5426	5.876E-07	0.0000	0.000E+00	0.0000	2.103E-01	0.2703	0.000E+00	0.0000	0.000E+00	0.0000	2.191E-02	0.0282
Th-230	8.658E-03	0.0111	1.357E-05	0.0000	0.000E+00	0.0000	5.338E-03	0.0069	0.000E+00	0.0000	0.000E+00	0.0000	3.648E-03	0.0047
U-234	1.401E-04	0.0002	2.902E-05	0.0000	0.000E+00	0.0000	1.301E-02	0.0167	0.000E+00	0.0000	0.000E+00	0.0000	9.144E-03	0.0118
U-235	1.238E-02	0.0159	1.376E-06	0.0000	0.000E+00	0.0000	6.846E-04	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	4.479E-04	0.0006
U-238	4.910E-02	0.0631	2.593E-05	0.0000	0.000E+00	0.0000	1.235E-02	0.0159	0.000E+00	0.0000	0.000E+00	0.0000	8.678E-03	0.0112
Total	4.924E-01	0.6329	7.048E-05	0.0001	0.000E+00	0.0000	2.417E-01	0.3107	0.000E+00	0.0000	0.000E+00	0.0000	4.382E-02	0.0563

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.543E-01	0.8411
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.766E-02	0.0227
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.232E-02	0.0287
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.352E-02	0.0174
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.015E-02	0.0902
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.780E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	3.333E-01	0.4878	6.292E-07	0.0000	0.000E+00	0.0000	2.094E-01	0.3065	0.000E+00	0.0000	0.000E+00	0.0000	2.492E-02	0.0365
Th-230	2.530E-02	0.0370	1.358E-05	0.0000	0.000E+00	0.0000	1.504E-02	0.0220	0.000E+00	0.0000	0.000E+00	0.0000	4.755E-03	0.0070
U-234	1.512E-04	0.0002	1.927E-05	0.0000	0.000E+00	0.0000	8.656E-03	0.0127	0.000E+00	0.0000	0.000E+00	0.0000	6.073E-03	0.0089
U-235	8.233E-03	0.0121	9.772E-07	0.0000	0.000E+00	0.0000	5.730E-04	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	3.302E-04	0.0005
U-238	3.254E-02	0.0476	1.719E-05	0.0000	0.000E+00	0.0000	8.188E-03	0.0120	0.000E+00	0.0000	0.000E+00	0.0000	5.753E-03	0.0084
Total	3.995E-01	0.5847	5.165E-05	0.0001	0.000E+00	0.0000	2.419E-01	0.3540	0.000E+00	0.0000	0.000E+00	0.0000	4.183E-02	0.0612

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.676E-01	0.8307
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.511E-02	0.0660
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.490E-02	0.0218
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.086E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.141E-03	0.0134
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.650E-02	0.0681
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.086E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.832E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.696E-01	0.3984	3.313E-07	0.0000	0.000E+00	0.0000	1.095E-01	0.2572	0.000E+00	0.0000	0.000E+00	0.0000	1.319E-02	0.0310
Th-230	5.586E-02	0.1313	1.361E-05	0.0000	0.000E+00	0.0000	3.466E-02	0.0814	0.000E+00	0.0000	0.000E+00	0.0000	7.106E-03	0.0167
U-234	3.487E-04	0.0008	6.037E-06	0.0000	0.000E+00	0.0000	2.857E-03	0.0067	0.000E+00	0.0000	0.000E+00	0.0000	1.916E-03	0.0045
U-235	2.567E-03	0.0060	3.637E-07	0.0000	0.000E+00	0.0000	2.840E-04	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	1.329E-04	0.0003
U-238	1.005E-02	0.0236	5.311E-06	0.0000	0.000E+00	0.0000	2.529E-03	0.0059	0.000E+00	0.0000	0.000E+00	0.0000	1.777E-03	0.0042
Total	2.384E-01	0.5601	2.565E-05	0.0001	0.000E+00	0.0000	1.498E-01	0.3520	0.000E+00	0.0000	0.000E+00	0.0000	2.412E-02	0.0567

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.922E-01	0.6866
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.765E-02	0.2294
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.465E-03	0.0152	0.000E+00	0.0000	0.000E+00	0.0000	1.159E-02	0.0272
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.543E-04	0.0015	0.000E+00	0.0000	0.000E+00	0.0000	3.638E-03	0.0085
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.147E-03	0.0144	0.000E+00	0.0000	0.000E+00	0.0000	2.050E-02	0.0482
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.327E-02	0.0312	0.000E+00	0.0000	0.000E+00	0.0000	4.256E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 9.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	2.231E-02	0.1103	4.363E-08	0.0000	0.000E+00	0.0000	1.088E-02	0.0538	0.000E+00	0.0000	0.000E+00	0.0000	1.737E-03	0.0086
Th-230	8.275E-02	0.4091	1.355E-05	0.0001	0.000E+00	0.0000	3.930E-02	0.1943	0.000E+00	0.0000	0.000E+00	0.0000	9.182E-03	0.0454
U-234	7.539E-04	0.0037	3.047E-07	0.0000	0.000E+00	0.0000	4.160E-04	0.0021	0.000E+00	0.0000	0.000E+00	0.0000	1.399E-04	0.0007
U-235	7.770E-05	0.0004	1.614E-08	0.0000	0.000E+00	0.0000	1.338E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	6.618E-06	0.0000
U-238	2.959E-04	0.0015	1.566E-07	0.0000	0.000E+00	0.0000	5.641E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	5.242E-05	0.0003
Total	1.062E-01	0.5250	1.407E-05	0.0001	0.000E+00	0.0000	5.066E-02	0.2504	0.000E+00	0.0000	0.000E+00	0.0000	1.112E-02	0.0550

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 9.000E+02 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.401E-03	0.0465	0.000E+00	0.0000	0.000E+00	0.0000	4.432E-02	0.2191
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.844E-03	0.0091	0.000E+00	0.0000	0.000E+00	0.0000	1.331E-01	0.6580
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.090E-02	0.0539	0.000E+00	0.0000	0.000E+00	0.0000	1.221E-02	0.0604
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.881E-03	0.0093	0.000E+00	0.0000	0.000E+00	0.0000	1.979E-03	0.0098
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.027E-02	0.0508	0.000E+00	0.0000	0.000E+00	0.0000	1.067E-02	0.0528
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.429E-02	0.1695	0.000E+00	0.0000	0.000E+00	0.0000	2.023E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.590E-02	0.0884	3.112E-08	0.0000	0.000E+00	0.0000	7.073E-03	0.0393	0.000E+00	0.0000	0.000E+00	0.0000	1.239E-03	0.0069
Th-230	8.376E-02	0.4660	1.353E-05	0.0001	0.000E+00	0.0000	3.631E-02	0.2020	0.000E+00	0.0000	0.000E+00	0.0000	9.262E-03	0.0515
U-234	7.765E-04	0.0043	2.274E-07	0.0000	0.000E+00	0.0000	3.659E-04	0.0020	0.000E+00	0.0000	0.000E+00	0.0000	1.174E-04	0.0007
U-235	4.337E-05	0.0002	9.470E-09	0.0000	0.000E+00	0.0000	7.370E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.926E-06	0.0000
U-238	1.645E-04	0.0009	8.709E-08	0.0000	0.000E+00	0.0000	2.865E-05	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	2.916E-05	0.0002
Total	1.006E-01	0.5599	1.388E-05	0.0001	0.000E+00	0.0000	4.378E-02	0.2436	0.000E+00	0.0000	0.000E+00	0.0000	1.065E-02	0.0593

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.495E-03	0.0528	0.000E+00	0.0000	0.000E+00	0.0000	3.371E-02	0.1875
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.243E-03	0.0125	0.000E+00	0.0000	0.000E+00	0.0000	1.316E-01	0.7320
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.129E-03	0.0341	0.000E+00	0.0000	0.000E+00	0.0000	7.389E-03	0.0411
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.121E-03	0.0062	0.000E+00	0.0000	0.000E+00	0.0000	1.176E-03	0.0065
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.673E-03	0.0316	0.000E+00	0.0000	0.000E+00	0.0000	5.895E-03	0.0328
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.466E-02	0.1372	0.000E+00	0.0000	0.000E+00	0.0000	1.798E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.000E+03 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.346E-04	0.0039	1.337E-10	0.0000	0.000E+00	0.0000	7.374E-06	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	5.323E-06	0.0002
Th-230	2.123E-02	0.6148	1.682E-06	0.0000	0.000E+00	0.0000	1.134E-03	0.0328	0.000E+00	0.0000	0.000E+00	0.0000	1.179E-03	0.0341
U-234	2.054E-04	0.0059	1.634E-08	0.0000	0.000E+00	0.0000	1.098E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	1.143E-05	0.0003
U-235	4.391E-08	0.0000	5.094E-12	0.0000	0.000E+00	0.0000	1.136E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.257E-09	0.0000
U-238	2.386E-07	0.0000	3.873E-11	0.0000	0.000E+00	0.0000	7.743E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.583E-08	0.0000
Total	2.157E-02	0.6246	1.698E-06	0.0000	0.000E+00	0.0000	1.152E-03	0.0334	0.000E+00	0.0000	0.000E+00	0.0000	1.196E-03	0.0346

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.000E+03 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.823E-03	0.1686	0.000E+00	0.0000	0.000E+00	0.0000	5.970E-03	0.1729
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.314E-03	0.1249	0.000E+00	0.0000	0.000E+00	0.0000	2.786E-02	0.8067
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.596E-04	0.0133	0.000E+00	0.0000	0.000E+00	0.0000	6.875E-04	0.0199
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.895E-06	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	3.942E-06	0.0001
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.211E-05	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.237E-05	0.0004
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.061E-02	0.3073	0.000E+00	0.0000	0.000E+00	0.0000	3.453E-02	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.997E-05	0.0466	0.000E+00	0.0000	0.000E+00	0.0000	2.997E-05	0.0466
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.122E-04	0.9511	0.000E+00	0.0000	0.000E+00	0.0000	6.122E-04	0.9511
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.476E-06	0.0023	0.000E+00	0.0000	0.000E+00	0.0000	1.476E-06	0.0023
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.436E-04	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.436E-04	1.0000

*Sum of all water independent and dependent pathways.

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Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent	Product	Thread	DSR(j,t) At Time in Years (mrem/yr)/(pCi/g)									
(i)	(j)	Fraction	0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
Ra-226+D	Ra-226+D	1.000E+00	4.601E+00	4.585E+00	4.448E+00	4.157E+00	3.282E+00	1.670E+00	2.194E-01	1.575E-01	7.914E-03	0.000E+00
Ra-226+D	Pb-210+D	1.000E+00	2.801E-02	7.565E-02	4.270E-01	8.760E-01	1.084E+00	5.782E-01	1.215E-01	1.018E-01	3.801E-02	0.000E+00
Ra-226+D	-DSR(j)		4.629E+00	4.661E+00	4.875E+00	5.033E+00	4.366E+00	2.248E+00	3.409E-01	2.593E-01	4.592E-02	0.000E+00
Th-230	Th-230	1.000E+00	2.816E-02	2.816E-02	2.815E-02	2.815E-02	2.812E-02	2.804E-02	2.537E-02	2.468E-02	2.557E-03	0.000E+00
Th-230	Ra-226+D	1.000E+00	9.842E-04	2.972E-03	2.058E-02	5.783E-02	1.700E-01	3.759E-01	5.299E-01	5.288E-01	1.181E-01	2.412E-05
Th-230	Pb-210+D	1.000E+00	4.390E-06	2.706E-05	1.046E-03	6.953E-03	3.930E-02	1.100E-01	1.452E-01	1.390E-01	2.595E-02	1.336E-04
Th-230	-DSR(j)		2.915E-02	3.116E-02	4.978E-02	9.293E-02	2.374E-01	5.139E-01	7.005E-01	6.926E-01	1.466E-01	1.577E-04
U-234	U-234	1.000E+00	2.217E-02	2.204E-02	2.091E-02	1.859E-02	1.232E-02	9.186E-03	9.059E-03	5.001E-03	9.976E-06	0.000E+00
U-234	Th-230	1.000E+00	1.308E-07	3.834E-07	2.585E-06	7.080E-06	1.922E-05	3.566E-05	3.882E-05	3.785E-05	4.016E-06	8.541E-08
U-234	Ra-226+D	1.000E+00	2.925E-09	2.066E-08	9.585E-07	7.609E-06	6.701E-05	3.427E-04	7.812E-04	7.986E-04	2.343E-04	7.948E-05
U-234	Pb-210+D	1.000E+00	1.047E-11	1.365E-10	3.384E-08	6.649E-07	1.275E-05	9.559E-05	2.978E-04	3.203E-04	3.246E-04	4.306E-04
U-234	-DSR(j)		2.217E-02	2.204E-02	2.091E-02	1.860E-02	1.242E-02	9.660E-03	1.018E-02	6.157E-03	5.729E-04	5.102E-04
U-235+D	U-235+D	1.000E+00	2.668E-01	2.653E-01	2.516E-01	2.237E-01	1.483E-01	5.086E-02	9.821E-03	5.427E-03	1.015E-05	0.000E+00
U-235+D	Pa-231	1.000E+00	2.374E-05	7.262E-05	4.887E-04	1.264E-03	2.759E-03	3.825E-03	6.544E-03	4.005E-03	1.562E-05	0.000E+00
U-235+D	Ac-227+D	1.000E+00	2.231E-07	1.451E-06	5.556E-05	3.276E-04	1.322E-03	5.947E-03	1.662E-02	1.016E-02	3.993E-05	0.000E+00
U-235+D	-DSR(j)		2.669E-01	2.653E-01	2.521E-01	2.253E-01	1.523E-01	6.064E-02	3.298E-02	1.960E-02	6.571E-05	0.000E+00
U-238	U-238	5.400E-05	1.074E-06	1.068E-06	1.013E-06	9.007E-07	5.969E-07	4.466E-07	4.419E-07	2.440E-07	4.881E-10	0.000E+00
U-238+D	U-238+D	9.999E-01	6.973E-02	6.932E-02	6.575E-02	5.846E-02	3.874E-02	1.708E-02	8.869E-03	4.898E-03	9.641E-06	0.000E+00
U-238+D	U-234	9.999E-01	3.140E-08	9.370E-08	6.223E-07	1.607E-06	3.510E-06	7.828E-06	2.315E-05	1.420E-05	5.674E-08	0.000E+00
U-238+D	Th-230	9.999E-01	1.261E-13	8.539E-13	3.818E-11	2.972E-10	2.471E-09	1.095E-08	1.837E-08	1.812E-08	2.101E-09	3.237E-10
U-238+D	Ra-226+D	9.999E-01	2.057E-15	3.121E-14	9.447E-12	2.146E-10	5.925E-09	7.833E-08	3.486E-07	3.727E-07	1.674E-07	1.935E-07
U-238+D	Pb-210+D	9.999E-01	6.231E-18	1.661E-16	2.570E-13	1.479E-11	9.565E-10	2.159E-08	1.910E-07	2.345E-07	4.409E-07	1.036E-06
U-238+D	-DSR(j)		6.973E-02	6.932E-02	6.575E-02	5.846E-02	3.875E-02	1.709E-02	8.892E-03	4.913E-03	1.031E-05	1.230E-06

The DSR includes contributions from associated (half-life ó 180 days) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.500E+01 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
Ra-226	3.241E+00	3.218E+00	3.077E+00	2.980E+00	3.436E+00	6.673E+00	4.400E+01	5.785E+01	3.266E+02	*9.885E+11
Th-230	5.147E+02	4.815E+02	3.013E+02	1.614E+02	6.318E+01	2.919E+01	2.141E+01	2.166E+01	1.023E+02	9.511E+04
U-234	6.765E+02	6.805E+02	7.173E+02	8.063E+02	1.208E+03	1.553E+03	1.474E+03	2.436E+03	2.618E+04	2.940E+04
U-235	5.621E+01	5.653E+01	5.949E+01	6.658E+01	9.846E+01	2.474E+02	4.548E+02	7.655E+02	2.283E+05	*2.161E+06
U-238	2.151E+02	2.164E+02	2.281E+02	2.566E+02	3.871E+02	8.779E+02	1.687E+03	3.053E+03	*3.361E+05	*3.361E+05

*At specific activity limit

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            Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
            and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
         at tmin = time of minimum single radionuclide soil guideline
     and at tmax = time of maximum total dose =   27.81 ñ 0.06 years
Nuclide  Initial         tmin       DSR(i,tmin) G(i,tmin) DSR(i,tmax) G(i,tmax)
  (i)    (pCi/g)       (years)                   (pCi/g)               (pCi/g)
------- ---------  ----------------  ---------  ---------  ---------  ---------
Ra-226  1.300E-01    30.47 ñ 0.06    5.033E+00  2.980E+00  5.031E+00  2.981E+00
Th-230  1.900E-01      799 ñ 2       7.035E-01  2.132E+01  8.815E-02  1.702E+02
U-234   1.200E+00     0.000E+00      2.217E-02  6.765E+02  1.884E-02  7.960E+02
U-235   6.000E-02     0.000E+00      2.669E-01  5.621E+01  2.281E-01  6.576E+01
U-238   1.200E+00     0.000E+00      6.973E-02  2.151E+02  5.922E-02  2.533E+02
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Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	t= 0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
			DOSE(j,t), mrem/yr									
Ra-226	Ra-226	1.000E+00	5.981E-01	5.961E-01	5.782E-01	5.404E-01	4.266E-01	2.171E-01	2.853E-02	2.047E-02	1.029E-03	0.000E+00
Ra-226	Th-230	1.000E+00	1.870E-04	5.646E-04	3.910E-03	1.099E-02	3.230E-02	7.142E-02	1.007E-01	1.005E-01	2.244E-02	4.583E-06
Ra-226	U-234	1.000E+00	3.510E-09	2.480E-08	1.150E-06	9.131E-06	8.041E-05	4.113E-04	9.374E-04	9.583E-04	2.811E-04	9.538E-05
Ra-226	U-238	9.999E-01	2.468E-15	3.745E-14	1.134E-11	2.576E-10	7.110E-09	9.400E-08	4.184E-07	4.472E-07	2.009E-07	2.322E-07
Ra-226	-DOSE(j)		5.983E-01	5.966E-01	5.821E-01	5.514E-01	4.590E-01	2.889E-01	1.301E-01	1.219E-01	2.375E-02	1.002E-04
Pb-210	Ra-226	1.000E+00	3.641E-03	9.834E-03	5.552E-02	1.139E-01	1.410E-01	7.516E-02	1.580E-02	1.323E-02	4.941E-03	0.000E+00
Pb-210	Th-230	1.000E+00	8.341E-07	5.141E-06	1.988E-04	1.321E-03	7.467E-03	2.090E-02	2.759E-02	2.642E-02	4.930E-03	2.538E-05
Pb-210	U-234	1.000E+00	1.256E-11	1.638E-10	4.061E-08	7.979E-07	1.530E-05	1.147E-04	3.573E-04	3.844E-04	3.896E-04	5.167E-04
Pb-210	U-238	9.999E-01	7.477E-18	1.994E-16	3.084E-13	1.774E-11	1.148E-09	2.591E-08	2.292E-07	2.814E-07	5.291E-07	1.243E-06
Pb-210	-DOSE(j)		3.642E-03	9.840E-03	5.571E-02	1.152E-01	1.485E-01	9.618E-02	4.374E-02	4.003E-02	1.026E-02	5.433E-04
Th-230	Th-230	1.000E+00	5.350E-03	5.350E-03	5.349E-03	5.348E-03	5.342E-03	5.328E-03	4.821E-03	4.689E-03	4.858E-04	0.000E+00
Th-230	U-234	1.000E+00	1.569E-07	4.601E-07	3.103E-06	8.496E-06	2.307E-05	4.279E-05	4.658E-05	4.542E-05	4.819E-06	1.025E-07
Th-230	U-238	9.999E-01	1.514E-13	1.025E-12	4.582E-11	3.566E-10	2.966E-09	1.314E-08	2.204E-08	2.174E-08	2.521E-09	3.884E-10
Th-230	-DOSE(j)		5.350E-03	5.350E-03	5.352E-03	5.356E-03	5.365E-03	5.370E-03	4.867E-03	4.734E-03	4.907E-04	1.029E-07
U-234	U-234	1.000E+00	2.661E-02	2.645E-02	2.509E-02	2.231E-02	1.478E-02	1.102E-02	1.087E-02	6.001E-03	1.197E-05	0.000E+00
U-234	U-238	9.999E-01	3.768E-08	1.124E-07	7.468E-07	1.929E-06	4.211E-06	9.394E-06	2.779E-05	1.704E-05	6.808E-08	0.000E+00
U-234	-DOSE(j)		2.661E-02	2.645E-02	2.509E-02	2.231E-02	1.478E-02	1.103E-02	1.090E-02	6.018E-03	1.204E-05	0.000E+00
U-235	U-235	1.000E+00	1.601E-02	1.592E-02	1.510E-02	1.342E-02	8.896E-03	3.052E-03	5.893E-04	3.256E-04	6.091E-07	0.000E+00
Pa-231	U-235	1.000E+00	1.425E-06	4.357E-06	2.932E-05	7.583E-05	1.656E-04	2.295E-04	3.926E-04	2.403E-04	9.374E-07	0.000E+00
Ac-227	U-235	1.000E+00	1.339E-08	8.704E-08	3.333E-06	1.965E-05	7.932E-05	3.568E-04	9.970E-04	6.098E-04	2.396E-06	0.000E+00
U-238	U-238	5.400E-05	1.289E-06	1.282E-06	1.216E-06	1.081E-06	7.163E-07	5.359E-07	5.303E-07	2.928E-07	5.858E-10	0.000E+00
U-238	U-238	9.999E-01	8.367E-02	8.318E-02	7.890E-02	7.015E-02	4.649E-02	2.049E-02	1.064E-02	5.877E-03	1.157E-05	0.000E+00
U-238	-DOSE(j)		8.367E-02	8.318E-02	7.890E-02	7.015E-02	4.649E-02	2.049E-02	1.064E-02	5.878E-03	1.157E-05	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

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Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	THF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
Ra-226	Ra-226	1.000E+00	1.300E-01	1.296E-01	1.257E-01	1.175E-01	9.273E-02	4.718E-02	6.213E-03	4.432E-03	1.511E-04	2.758E-16
Ra-226	Th-230	1.000E+00	0.000E+00	8.217E-05	8.093E-04	2.348E-03	6.980E-03	1.548E-02	2.299E-02	2.329E-02	2.376E-02	2.128E-02
Ra-226	U-234	1.000E+00	0.000E+00	2.333E-09	2.269E-07	1.921E-06	1.730E-05	8.897E-05	2.092E-04	2.158E-04	2.300E-04	2.063E-04
Ra-226	U-238	9.999E-01	0.000E+00	2.203E-15	2.129E-12	5.331E-11	1.523E-09	2.024E-08	8.977E-08	9.554E-08	1.108E-07	9.976E-08
Ra-226	-S(j):		1.300E-01	1.296E-01	1.265E-01	1.198E-01	9.972E-02	6.275E-02	2.941E-02	2.794E-02	2.414E-02	2.149E-02
Pb-210	Ra-226	1.000E+00	0.000E+00	3.966E-03	3.365E-02	7.163E-02	8.965E-02	4.784E-02	6.301E-03	4.495E-03	1.532E-04	2.797E-16
Pb-210	Th-230	1.000E+00	0.000E+00	1.263E-06	1.132E-04	8.121E-04	4.709E-03	1.326E-02	2.089E-02	2.120E-02	2.171E-02	1.945E-02
Pb-210	U-234	1.000E+00	0.000E+00	2.398E-11	2.180E-08	4.806E-07	9.595E-06	7.147E-05	1.888E-04	1.954E-04	2.101E-04	1.885E-04
Pb-210	U-238	9.999E-01	0.000E+00	1.701E-17	1.559E-13	1.047E-11	7.153E-10	1.515E-08	8.011E-08	8.580E-08	1.012E-07	9.116E-08
Pb-210	-S(j):		0.000E+00	3.967E-03	3.376E-02	7.244E-02	9.437E-02	6.117E-02	2.738E-02	2.589E-02	2.208E-02	1.964E-02
Th-230	Th-230	1.000E+00	1.900E-01	1.900E-01	1.900E-01	1.899E-01	1.897E-01	1.892E-01	1.876E-01	1.874E-01	1.848E-01	1.653E-01
Th-230	U-234	1.000E+00	0.000E+00	1.077E-05	1.049E-04	2.970E-04	8.161E-04	1.518E-03	1.810E-03	1.811E-03	1.791E-03	1.602E-03
Th-230	U-238	9.999E-01	0.000E+00	1.525E-11	1.472E-09	1.226E-08	1.044E-07	4.655E-07	8.513E-07	8.611E-07	8.660E-07	7.748E-07
Th-230	-S(j):		1.900E-01	1.900E-01	1.901E-01	1.902E-01	1.906E-01	1.907E-01	1.894E-01	1.892E-01	1.866E-01	1.669E-01
U-234	U-234	1.000E+00	1.200E+00	1.193E+00	1.131E+00	1.006E+00	6.666E-01	2.057E-01	6.042E-03	3.356E-03	9.387E-06	3.515E-26
U-234	U-238	9.999E-01	0.000E+00	3.382E-06	3.208E-05	8.555E-05	1.890E-04	1.750E-04	1.544E-05	9.528E-06	5.337E-08	1.011E-27
U-234	-S(j):		1.200E+00	1.193E+00	1.132E+00	1.006E+00	6.668E-01	2.059E-01	6.058E-03	3.366E-03	9.441E-06	3.616E-26
U-235	U-235	1.000E+00	6.000E-02	5.965E-02	5.658E-02	5.030E-02	3.334E-02	1.029E-02	3.029E-04	1.683E-04	4.720E-07	1.808E-27
Pa-231	U-235	1.000E+00	0.000E+00	1.262E-06	1.197E-05	3.192E-05	7.046E-05	6.513E-05	5.713E-06	3.523E-06	1.956E-08	3.448E-28
Ac-227	U-235	1.000E+00	0.000E+00	1.982E-08	1.672E-06	1.056E-05	4.193E-05	4.695E-05	4.364E-06	2.699E-06	1.517E-08	2.702E-28
U-238	U-238	5.400E-05	6.480E-05	6.442E-05	6.110E-05	5.433E-05	3.601E-05	1.112E-05	3.271E-07	1.818E-07	5.098E-10	1.953E-30
U-238	U-238	9.999E-01	1.200E+00	1.193E+00	1.131E+00	1.006E+00	6.667E-01	2.058E-01	6.057E-03	3.366E-03	9.440E-06	3.616E-26
U-238	-S(j):		1.200E+00	1.193E+00	1.132E+00	1.006E+00	6.668E-01	2.059E-01	6.058E-03	3.366E-03	9.441E-06	3.616E-26

THF(i) is the thread fraction of the parent nuclide.
RESCALC.EXE execution time = 1.04 seconds

ATTACHMENT A-5:

DETERMINATION OF RESIDUAL SOIL CONCENTRATION FOR TOTAL URANIUM UNDER SOIL ALTERNATIVE S3 (SECOND EVALUATION), USING PRO-UCL 4.0

PRO-UCL 4.0 OUTPUT RUNS

General Statistics

Number of Valid Samples	433	Number of Unique Samples	316
Number of Missing Values	1		
Raw Statistics		Log-transformed Statistics	
Minimum	-17.79	Log Statistics Not Avaliable	
Maximum	72		
Mean	5.252		
Median	2.28		
SD	9.837		
Coefficient of Variation	1.873		
Skewness	3.633		
Relevant UCL Statistics			
Normal Distribution Test		Lognormal Distribution Test	
Lilliefors Test Statistic	0.303	Not Available	
Lilliefors Critical Value	0.0426		
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution		Assuming Lognormal Distribution	
95% Student's-t UCL	6.031	95% H-UCL	N/A
Assuming Normal Distribution		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	6.031	95% Adjusted-CLT UCL	6.117
		95% Modified-t UCL	6.045
Gamma Distribution Test		Data Distribution	
Gamma Statistics Not Available		Data do not follow a Discernable Distribution (0.05)	
Potential UCL to Use			
Use 95% Chebyshev (Mean, Sd) UCL	**7.312**	95% CLT UCL	6.029
		95% Jackknife UCL	6.031
		95% Standard Bootstrap UCL	6.032
		95% Bootstrap-t UCL	6.16
		95% Hall's Bootstrap UCL	6.122
		95% Percentile Bootstrap UCL	6.04
		95% BCA Bootstrap UCL	6.095
		95% Chebyshev(Mean, Sd) UCL	7.312
		97.5% Chebyshev(Mean, Sd) UCL	8.204
		99% Chebyshev(Mean, Sd) UCL	9.955

ATTACHMENT A-6:

OUTPUT DOSE ASSESSMENT SUMMARY REPORT USING RESRAD, RESIDENTIAL RECEPTOR UNDER ALTERNATIVE S3

```
RESRAD Version 6.5      T« Limit = 180 days        08/17/2011  14:49  Page   1
 Summary : Residual Dose Assessment Under Residential Receptor
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Part I: Mixture Sums and Single Radionuclide Guidelines

```
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Summary : Residual Dose Assessment Under Residential Receptor
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                          Dose Conversion Factor (and Related) Parameter Summary
                                      Dose Library: FGR 12 & FGR 11
                                                                                  Current     Base      Parameter
Menu                               Parameter                                       Value#     Case*       Name
---------------------------------------------------------------------------------------------------------------------
A-1   DCF's for external ground radiation (mrem/yr)/(pCi/g)
A-1   Ac-227   (Source: FGR 12)                                                4.951E-04  4.951E-04  DCF1(  1)
A-1   At-218   (Source: FGR 12)                                                5.847E-03  5.847E-03  DCF1(  2)
A-1   Bi-210   (Source: FGR 12)                                                3.606E-03  3.606E-03  DCF1(  3)
A-1   Bi-211   (Source: FGR 12)                                                2.559E-01  2.559E-01  DCF1(  4)
A-1   Bi-214   (Source: FGR 12)                                                9.808E+00  9.808E+00  DCF1(  5)
A-1   Fr-223   (Source: FGR 12)                                                1.980E-01  1.980E-01  DCF1(  6)
A-1   Pa-231   (Source: FGR 12)                                                1.906E-01  1.906E-01  DCF1(  7)
A-1   Pa-234   (Source: FGR 12)                                                1.155E+01  1.155E+01  DCF1(  8)
A-1   Pa-234m  (Source: FGR 12)                                                8.967E-02  8.967E-02  DCF1(  9)
A-1   Pb-210   (Source: FGR 12)                                                2.447E-03  2.447E-03  DCF1( 10)
A-1   Pb-211   (Source: FGR 12)                                                3.064E-01  3.064E-01  DCF1( 11)
A-1   Pb-214   (Source: FGR 12)                                                1.341E+00  1.341E+00  DCF1( 12)
A-1   Po-210   (Source: FGR 12)                                                5.231E-05  5.231E-05  DCF1( 13)
A-1   Po-211   (Source: FGR 12)                                                4.764E-02  4.764E-02  DCF1( 14)
A-1   Po-214   (Source: FGR 12)                                                5.138E-04  5.138E-04  DCF1( 15)
A-1   Po-215   (Source: FGR 12)                                                1.016E-03  1.016E-03  DCF1( 16)
A-1   Po-218   (Source: FGR 12)                                                5.642E-05  5.642E-05  DCF1( 17)
A-1   Ra-223   (Source: FGR 12)                                                6.034E-01  6.034E-01  DCF1( 18)
A-1   Ra-226   (Source: FGR 12)                                                3.176E-02  3.176E-02  DCF1( 19)
A-1   Rn-219   (Source: FGR 12)                                                3.083E-01  3.083E-01  DCF1( 20)
A-1   Rn-222   (Source: FGR 12)                                                2.354E-03  2.354E-03  DCF1( 21)
A-1   Th-227   (Source: FGR 12)                                                5.212E-01  5.212E-01  DCF1( 22)
A-1   Th-230   (Source: FGR 12)                                                1.209E-03  1.209E-03  DCF1( 23)
A-1   Th-231   (Source: FGR 12)                                                3.643E-02  3.643E-02  DCF1( 24)
A-1   Th-234   (Source: FGR 12)                                                2.410E-02  2.410E-02  DCF1( 25)
A-1   Tl-207   (Source: FGR 12)                                                1.980E-02  1.980E-02  DCF1( 26)
A-1   Tl-210   (Source: no data)                                               0.000E+00 -2.000E+00  DCF1( 27)
A-1   U-234    (Source: FGR 12)                                                4.017E-04  4.017E-04  DCF1( 28)
A-1   U-235    (Source: FGR 12)                                                7.211E-01  7.211E-01  DCF1( 29)
A-1   U-238    (Source: FGR 12)                                                1.031E-04  1.031E-04  DCF1( 30)

B-1   Dose conversion factors for inhalation mrem/pCi:
B-1   Ac-227+D                                                                 6.724E+00  6.700E+00  DCF2(  1)
B-1   Pa-231                                                                   1.280E+00  1.280E+00  DCF2(  2)
B-1   Pb-210+D                                                                 2.320E-02  1.360E-02  DCF2(  3)
B-1   Ra-226+D                                                                 8.594E-03  8.580E-03  DCF2(  4)
B-1   Th-230                                                                   3.260E-01  3.260E-01  DCF2(  5)
B-1   U-234                                                                    1.320E-01  1.320E-01  DCF2(  6)
B-1   U-235+D                                                                  1.230E-01  1.230E-01  DCF2(  7)
B-1   U-238                                                                    1.180E-01  1.180E-01  DCF2(  8)
B-1   U-238+D                                                                  1.180E-01  1.180E-01  DCF2(  9)
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D-1   Dose conversion factors for ingestion mrem/pCi:
D-1   Ac-227+D                                                    1.480E-02  1.410E-02  DCF3(  1)
D-1   Pa-231                                                      1.060E-02  1.060E-02  DCF3(  2)
D-1   Pb-210+D                                                    7.276E-03  5.370E-03  DCF3(  3)
D-1   Ra-226+D                                                    1.321E-03  1.320E-03  DCF3(  4)
D-1   Th-230                                                      5.480E-04  5.480E-04  DCF3(  5)
D-1   U-234                                                       2.830E-04  2.830E-04  DCF3(  6)
```

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                    Dose Conversion Factor (and Related) Parameter Summary (continued)
                                      Dose Library: FGR 12 & FGR 11
                                                                        Current     Base      Parameter
Menu                           Parameter                                 Value#     Case*       Name
---------------------------------------------------------------------------------------------------------
D-1   U-235+D                                                          2.673E-04  2.660E-04  DCF3(  7)
D-1   U-238                                                            2.550E-04  2.550E-04  DCF3(  8)
D-1   U-238+D                                                          2.687E-04  2.550E-04  DCF3(  9)

D-34  Food transfer factors:
D-34  Ac-227+D   plant/soil concentration ratio dimensionless    2.500E-03  2.500E-03  RTF(  11)
D-34  Ac-227+D   beef/livestock-intake ratio (pCi/kg)/(pCi/d)    2.000E-05  2.000E-05  RTF(  12)
D-34  Ac-227+D   milk/livestock-intake ratio (pCi/L)/(pCi/d)     2.000E-05  2.000E-05  RTF(  13)
D-34
D-34  Pa-231     plant/soil concentration ratio dimensionless    1.000E-02  1.000E-02  RTF(  21)
D-34  Pa-231     beef/livestock-intake ratio (pCi/kg)/(pCi/d)    5.000E-03  5.000E-03  RTF(  22)
D-34  Pa-231     milk/livestock-intake ratio (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  23)
D-34
D-34  Pb-210+D   plant/soil concentration ratio dimensionless    1.000E-02  1.000E-02  RTF(  31)
D-34  Pb-210+D   beef/livestock-intake ratio (pCi/kg)/(pCi/d)    8.000E-04  8.000E-04  RTF(  32)
D-34  Pb-210+D   milk/livestock-intake ratio (pCi/L)/(pCi/d)     3.000E-04  3.000E-04  RTF(  33)
D-34
D-34  Ra-226+D   plant/soil concentration ratio dimensionless    4.000E-02  4.000E-02  RTF(  41)
D-34  Ra-226+D   beef/livestock-intake ratio (pCi/kg)/(pCi/d)    1.000E-03  1.000E-03  RTF(  42)
D-34  Ra-226+D   milk/livestock-intake ratio (pCi/L)/(pCi/d)     1.000E-03  1.000E-03  RTF(  43)
D-34
D-34  Th-230     plant/soil concentration ratio dimensionless    1.000E-03  1.000E-03  RTF(  51)
D-34  Th-230     beef/livestock-intake ratio (pCi/kg)/(pCi/d)    1.000E-04  1.000E-04  RTF(  52)
D-34  Th-230     milk/livestock-intake ratio (pCi/L)/(pCi/d)     5.000E-06  5.000E-06  RTF(  53)
D-34
D-34  U-234      plant/soil concentration ratio dimensionless    2.500E-03  2.500E-03  RTF(  61)
D-34  U-234      beef/livestock-intake ratio (pCi/kg)/(pCi/d)    3.400E-04  3.400E-04  RTF(  62)
D-34  U-234      milk/livestock-intake ratio (pCi/L)/(pCi/d)     6.000E-04  6.000E-04  RTF(  63)
D-34
D-34  U-235+D    plant/soil concentration ratio dimensionless    2.500E-03  2.500E-03  RTF(  71)
D-34  U-235+D    beef/livestock-intake ratio (pCi/kg)/(pCi/d)    3.400E-04  3.400E-04  RTF(  72)
D-34  U-235+D    milk/livestock-intake ratio (pCi/L)/(pCi/d)     6.000E-04  6.000E-04  RTF(  73)
D-34
D-34  U-238      plant/soil concentration ratio dimensionless    2.500E-03  2.500E-03  RTF(  81)
D-34  U-238      beef/livestock-intake ratio (pCi/kg)/(pCi/d)    3.400E-04  3.400E-04  RTF(  82)
D-34  U-238      milk/livestock-intake ratio (pCi/L)/(pCi/d)     6.000E-04  6.000E-04  RTF(  83)
D-34
D-34  U-238+D    plant/soil concentration ratio dimensionless    2.500E-03  2.500E-03  RTF(  91)
D-34  U-238+D    beef/livestock-intake ratio (pCi/kg)/(pCi/d)    3.400E-04  3.400E-04  RTF(  92)
D-34  U-238+D    milk/livestock-intake ratio (pCi/L)/(pCi/d)     6.000E-04  6.000E-04  RTF(  93)

D-5   Bioaccumulation factors fresh water L/kg:
```

```
D-5   Ac-227+D   fish                                                  1.500E+01  1.500E+01  BIOFAC(  11)
D-5   Ac-227+D   crustacea and mollusks                                1.000E+03  1.000E+03  BIOFAC(  12)
D-5
D-5   Pa-231     fish                                                  1.000E+01  1.000E+01  BIOFAC(  21)
D-5   Pa-231     crustacea and mollusks                                1.100E+02  1.100E+02  BIOFAC(  22)
D-5
D-5   Pb-210+D   fish                                                  3.000E+02  3.000E+02  BIOFAC(  31)
D-5   Pb-210+D   crustacea and mollusks                                1.000E+02  1.000E+02  BIOFAC(  32)
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                    Dose Conversion Factor (and Related) Parameter Summary (continued)
                                  Dose Library: FGR 12 & FGR 11
                                                                    Current     Base      Parameter
Menu                           Parameter                             Value#     Case*       Name
---------------------------------------------------------------------------------------------------------
D-5   Ra-226+D   fish                                              5.000E+01  5.000E+01  BIOFAC(  41)
D-5   Ra-226+D   crustacea and mollusks                            2.500E+02  2.500E+02  BIOFAC(  42)
D-5
D-5   Th-230     fish                                              1.000E+02  1.000E+02  BIOFAC(  51)
D-5   Th-230     crustacea and mollusks                            5.000E+02  5.000E+02  BIOFAC(  52)
D-5
D-5   U-234      fish                                              1.000E+01  1.000E+01  BIOFAC(  61)
D-5   U-234      crustacea and mollusks                            6.000E+01  6.000E+01  BIOFAC(  62)
D-5
D-5   U-235+D    fish                                              1.000E+01  1.000E+01  BIOFAC(  71)
D-5   U-235+D    crustacea and mollusks                            6.000E+01  6.000E+01  BIOFAC(  72)
D-5
D-5   U-238      fish                                              1.000E+01  1.000E+01  BIOFAC(  81)
D-5   U-238      crustacea and mollusks                            6.000E+01  6.000E+01  BIOFAC(  82)
D-5
D-5   U-238+D    fish                                              1.000E+01  1.000E+01  BIOFAC(  91)
D-5   U-238+D    crustacea and mollusks                            6.000E+01  6.000E+01  BIOFAC(  92)
---------------------------------------------------------------------------------------------------------
#For DCF1(xxx) only factors are for infinite depth & area.  See ETFG table in Ground Pathway of Detailed Report.
*Base Case means Default.Lib w/o Associate Nuclide contributions.
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Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.578E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.219E+00	2.000E+00	---	THICK0
R011	Fraction of contamination that is submerged	0.000E+00	0.000E+00	---	SUBMFRACT
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	1.000E+01	3.000E+00	---	T(3)
R011	Times for calculations (yr)	3.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	1.000E+02	3.000E+01	---	T(5)
R011	Times for calculations (yr)	3.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	9.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	2.000E+03	0.000E+00	---	T(9)
R011	Times for calculations (yr)	1.000E+04	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Ra-226	3.100E-01	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Th-230	4.400E-01	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): U-234	2.740E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): U-235	1.300E-01	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): U-238	2.740E+00	0.000E+00	---	S1(8)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Th-230	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(8)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.300E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	6.000E-04	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	1.580E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	6.600E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	2.000E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.000E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	9.200E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	2.000E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF

R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.300E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R014	Saturated zone hydraulic conductivity (m/yr)	1.580E+02	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	1.400E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	6.600E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	1.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1 thickness (m)	2.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1 soil density (g/cm**3)	1.300E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1 total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1 effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1 field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1 soil-specific b parameter	6.600E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1 hydraulic conductivity (m/yr)	1.580E+01	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCU(41)
R016	Saturated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.945E-03	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(51)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.921E-06	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)
R016	Distribution coefficients for U-234				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(61)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(6)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.876E-03	ALEACH(6)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(6)
R016	Distribution coefficients for U-235				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(71)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.876E-03	ALEACH(7)

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R016    Solubility constant                         0.000E+00  0.000E+00           not used              SOLUBK( 7)

R016  Distribution coefficients for U-238
R016    Contaminated zone (cm**3/g)                 5.000E+01  5.000E+01              ---                DCNUCC( 8)
R016    Unsaturated zone 1 (cm**3/g)                5.000E+01  5.000E+01              ---                DCNUCU( 81)
R016    Saturated zone (cm**3/g)                    5.000E+01  5.000E+01              ---                DCNUCS( 8)
R016    Leach rate (/yr)                            0.000E+00  0.000E+00           5.876E-03             ALEACH( 8)
R016    Solubility constant                         0.000E+00  0.000E+00           not used              SOLUBK( 8)
```

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Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Ac-227				
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCU(11)
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.458E-02	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Pa-231				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(21)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.876E-03	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(31)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.945E-03	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R017	Inhalation rate (m**3/yr)	4.990E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	7.580E-07	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor external gamma	4.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	6.550E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	8.000E-02	2.500E-01	---	FOTD
R017	Shape factor flag external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m) ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m) ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m) ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m) ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m) ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m) ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m) ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m) ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m) ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m) ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m) ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m) ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

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Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits vegetables and grain consumption (kg/yr)	4.640E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.800E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	4.380E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	3.800E-02	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	not used	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR

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R19B  Wet weight crop yield for Non-Leafy (kg/m**2)     7.000E-01  7.000E-01              ---                YV(1)
R19B  Wet weight crop yield for Leafy     (kg/m**2)     1.500E+00  1.500E+00              ---                YV(2)
R19B  Wet weight crop yield for Fodder    (kg/m**2)     not used   1.100E+00              ---                YV(3)
R19B  Growing Season for  Non-Leafy (years)             1.700E-01  1.700E-01              ---                TE(1)
R19B  Growing Season for  Leafy     (years)             2.500E-01  2.500E-01              ---                TE(2)
R19B  Growing Season for  Fodder    (years)             not used   8.000E-02              ---                TE(3)
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Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits non-leafy vegetables and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX

R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
TITL	Number of graphical time points	32	---	---	NPTS

```
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                                          Site-Specific Parameter Summary (continued)
                                                          User                      Used by RESRAD            Parameter
Menu                          Parameter                   Input     Default   (If different from user input)     Name
--------------------------------------------------------------------------------------------------------------------------------
TITL  Maximum number of integration points for dose        17        ---                 ---                LYMAX
TITL  Maximum number of integration points for risk       257        ---                 ---                KYMAX
--------------------------------------------------------------------------------------------------------------------------------


                     Summary of Pathway Selections

                    Pathway               User Selection
          ---------------------------------------------------
             1 -- external gamma              active
             2 -- inhalation (w/o radon)      active
             3 -- plant ingestion             active
             4 -- meat ingestion            suppressed
             5 -- milk ingestion            suppressed
             6 -- aquatic foods             suppressed
             7 -- drinking water            suppressed
             8 -- soil ingestion              active
             9 -- radon                     suppressed
             Find peak pathway doses        suppressed
          ---------------------------------------------------
```

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Contaminated Zone Dimensions		Initial Soil Concentrations pCi/g	
Area:	35784.00 square meters	Ra-226	3.100E-01
Thickness:	1.22 meters	Th-230	4.400E-01
Cover Depth:	0.00 meters	U-234	2.740E+00
		U-235	1.300E-01
		U-238	2.740E+00

Total Dose TDOSE(t) mrem/yr
Basic Radiation Dose Limit = 1.500E+01 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
TDOSE(t):	1.756E+00	1.765E+00	1.824E+00	1.861E+00	1.634E+00	1.014E+00	4.746E-01	4.220E-01	8.114E-02	1.471E-03
M(t):	1.171E-01	1.177E-01	1.216E-01	1.241E-01	1.089E-01	6.758E-02	3.164E-02	2.813E-02	5.410E-03	9.804E-05

Maximum TDOSE(t): 1.862E+00 mrem/yr at t = 27.71 ñ 0.06 years

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.771E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio- Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.032E+00	0.5540	1.560E-06	0.0000	0.000E+00	0.0000	4.946E-01	0.2656	0.000E+00	0.0000	0.000E+00	0.0000	5.073E-02	0.0272
Th-230	1.894E-02	0.0102	3.577E-05	0.0000	0.000E+00	0.0000	1.166E-02	0.0063	0.000E+00	0.0000	0.000E+00	0.0000	8.375E-03	0.0045
U-234	3.262E-04	0.0002	7.644E-05	0.0000	0.000E+00	0.0000	3.011E-02	0.0162	0.000E+00	0.0000	0.000E+00	0.0000	2.116E-02	0.0114
U-235	2.764E-02	0.0148	3.433E-06	0.0000	0.000E+00	0.0000	1.491E-03	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	9.803E-04	0.0005
U-238	1.156E-01	0.0621	6.832E-05	0.0000	0.000E+00	0.0000	2.859E-02	0.0154	0.000E+00	0.0000	0.000E+00	0.0000	2.008E-02	0.0108
Total	1.194E+00	0.6413	1.855E-04	0.0001	0.000E+00	0.0000	5.664E-01	0.3042	0.000E+00	0.0000	0.000E+00	0.0000	1.013E-01	0.0544

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.771E+01 years
Water Dependent Pathways

Radio- Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.577E+00	0.8469
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.901E-02	0.0210
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.168E-02	0.0278
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.011E-02	0.0162
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.643E-01	0.0883
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.862E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.132E+00	0.6449	6.906E-07	0.0000	0.000E+00	0.0000	3.071E-01	0.1749	0.000E+00	0.0000	0.000E+00	0.0000	1.427E-02	0.0081
Th-230	5.254E-04	0.0003	3.576E-05	0.0000	0.000E+00	0.0000	4.510E-03	0.0026	0.000E+00	0.0000	0.000E+00	0.0000	7.767E-03	0.0044
U-234	3.668E-04	0.0002	8.991E-05	0.0001	0.000E+00	0.0000	3.543E-02	0.0202	0.000E+00	0.0000	0.000E+00	0.0000	2.489E-02	0.0142
U-235	3.251E-02	0.0185	3.975E-06	0.0000	0.000E+00	0.0000	1.590E-03	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	1.116E-03	0.0006
U-238	1.361E-01	0.0775	8.039E-05	0.0000	0.000E+00	0.0000	3.364E-02	0.0192	0.000E+00	0.0000	0.000E+00	0.0000	2.363E-02	0.0135
Total	1.302E+00	0.7414	2.107E-04	0.0001	0.000E+00	0.0000	3.823E-01	0.2177	0.000E+00	0.0000	0.000E+00	0.0000	7.168E-02	0.0408

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.454E+00	0.8279
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.284E-02	0.0073
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.077E-02	0.0346
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.522E-02	0.0201
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.934E-01	0.1101
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.756E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.129E+00	0.6394	7.421E-07	0.0000	0.000E+00	0.0000	3.187E-01	0.1805	0.000E+00	0.0000	0.000E+00	0.0000	1.640E-02	0.0093
Th-230	1.221E-03	0.0007	3.576E-05	0.0000	0.000E+00	0.0000	4.701E-03	0.0027	0.000E+00	0.0000	0.000E+00	0.0000	7.776E-03	0.0044
U-234	3.647E-04	0.0002	8.938E-05	0.0001	0.000E+00	0.0000	3.522E-02	0.0200	0.000E+00	0.0000	0.000E+00	0.0000	2.474E-02	0.0140
U-235	3.232E-02	0.0183	3.953E-06	0.0000	0.000E+00	0.0000	1.586E-03	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	1.111E-03	0.0006
U-238	1.353E-01	0.0766	7.992E-05	0.0000	0.000E+00	0.0000	3.344E-02	0.0189	0.000E+00	0.0000	0.000E+00	0.0000	2.349E-02	0.0133
Total	1.298E+00	0.7352	2.098E-04	0.0001	0.000E+00	0.0000	3.936E-01	0.2230	0.000E+00	0.0000	0.000E+00	0.0000	7.353E-02	0.0417

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.464E+00	0.8292
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.373E-02	0.0078
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.042E-02	0.0342
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.502E-02	0.0198
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.923E-01	0.1089
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.765E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.095E+00	0.6001	1.124E-06	0.0000	0.000E+00	0.0000	4.022E-01	0.2205	0.000E+00	0.0000	0.000E+00	0.0000	3.228E-02	0.0177
Th-230	7.372E-03	0.0040	3.576E-05	0.0000	0.000E+00	0.0000	6.710E-03	0.0037	0.000E+00	0.0000	0.000E+00	0.0000	7.912E-03	0.0043
U-234	3.480E-04	0.0002	8.479E-05	0.0000	0.000E+00	0.0000	3.341E-02	0.0183	0.000E+00	0.0000	0.000E+00	0.0000	2.347E-02	0.0129
U-235	3.065E-02	0.0168	3.763E-06	0.0000	0.000E+00	0.0000	1.553E-03	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	1.063E-03	0.0006
U-238	1.283E-01	0.0703	7.581E-05	0.0000	0.000E+00	0.0000	3.172E-02	0.0174	0.000E+00	0.0000	0.000E+00	0.0000	2.228E-02	0.0122
Total	1.262E+00	0.6915	2.012E-04	0.0001	0.000E+00	0.0000	4.756E-01	0.2607	0.000E+00	0.0000	0.000E+00	0.0000	8.701E-02	0.0477

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.529E+00	0.8383
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.203E-02	0.0121
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.731E-02	0.0314
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.327E-02	0.0182
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.824E-01	0.1000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.824E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	1.024E+00	0.5499	1.595E-06	0.0000	0.000E+00	0.0000	5.015E-01	0.2694	0.000E+00	0.0000	0.000E+00	0.0000	5.224E-02	0.0281
Th-230	2.039E-02	0.0110	3.577E-05	0.0000	0.000E+00	0.0000	1.236E-02	0.0066	0.000E+00	0.0000	0.000E+00	0.0000	8.447E-03	0.0045
U-234	3.243E-04	0.0002	7.542E-05	0.0000	0.000E+00	0.0000	2.971E-02	0.0160	0.000E+00	0.0000	0.000E+00	0.0000	2.088E-02	0.0112
U-235	2.727E-02	0.0147	3.394E-06	0.0000	0.000E+00	0.0000	1.483E-03	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	9.704E-04	0.0005
U-238	1.141E-01	0.0613	6.741E-05	0.0000	0.000E+00	0.0000	2.820E-02	0.0152	0.000E+00	0.0000	0.000E+00	0.0000	1.981E-02	0.0106
Total	1.186E+00	0.6369	1.836E-04	0.0001	0.000E+00	0.0000	5.733E-01	0.3080	0.000E+00	0.0000	0.000E+00	0.0000	1.023E-01	0.0550

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.577E+00	0.8474
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.123E-02	0.0222
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.099E-02	0.0274
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.973E-02	0.0160
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.621E-01	0.0871
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.861E+00	1.0000

*Sum of all water independent and dependent pathways.

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Summary : Residual Dose Assessment Under Residential Receptor
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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	8.081E-01	0.4946	1.708E-06	0.0000	0.000E+00	0.0000	4.994E-01	0.3056	0.000E+00	0.0000	0.000E+00	0.0000	5.942E-02	0.0364
Th-230	5.959E-02	0.0365	3.581E-05	0.0000	0.000E+00	0.0000	3.482E-02	0.0213	0.000E+00	0.0000	0.000E+00	0.0000	1.101E-02	0.0067
U-234	3.503E-04	0.0002	5.009E-05	0.0000	0.000E+00	0.0000	1.977E-02	0.0121	0.000E+00	0.0000	0.000E+00	0.0000	1.387E-02	0.0085
U-235	1.813E-02	0.0111	2.410E-06	0.0000	0.000E+00	0.0000	1.242E-03	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	7.155E-04	0.0004
U-238	7.560E-02	0.0463	4.468E-05	0.0000	0.000E+00	0.0000	1.870E-02	0.0114	0.000E+00	0.0000	0.000E+00	0.0000	1.314E-02	0.0080
Total	9.618E-01	0.5886	1.347E-04	0.0001	0.000E+00	0.0000	5.739E-01	0.3512	0.000E+00	0.0000	0.000E+00	0.0000	9.815E-02	0.0601

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years
Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.367E+00	0.8366
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.055E-01	0.0645
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.403E-02	0.0208
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.687E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.010E-02	0.0123
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.075E-01	0.0658
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.687E-06	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.634E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	4.112E-01	0.4056	8.993E-07	0.0000	0.000E+00	0.0000	2.610E-01	0.2575	0.000E+00	0.0000	0.000E+00	0.0000	3.145E-02	0.0310
Th-230	1.316E-01	0.1298	3.587E-05	0.0000	0.000E+00	0.0000	8.027E-02	0.0792	0.000E+00	0.0000	0.000E+00	0.0000	1.646E-02	0.0162
U-234	8.094E-04	0.0008	1.569E-05	0.0000	0.000E+00	0.0000	6.523E-03	0.0064	0.000E+00	0.0000	0.000E+00	0.0000	4.374E-03	0.0043
U-235	5.652E-03	0.0056	8.971E-07	0.0000	0.000E+00	0.0000	6.153E-04	0.0006	0.000E+00	0.0000	0.000E+00	0.0000	2.879E-04	0.0003
U-238	2.334E-02	0.0230	1.380E-05	0.0000	0.000E+00	0.0000	5.776E-03	0.0057	0.000E+00	0.0000	0.000E+00	0.0000	4.058E-03	0.0040
Total	5.725E-01	0.5648	6.716E-05	0.0001	0.000E+00	0.0000	3.542E-01	0.3495	0.000E+00	0.0000	0.000E+00	0.0000	5.663E-02	0.0559

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years
Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.037E-01	0.6942
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.283E-01	0.2252
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.476E-02	0.0146	0.000E+00	0.0000	0.000E+00	0.0000	2.648E-02	0.0261
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.418E-03	0.0014	0.000E+00	0.0000	0.000E+00	0.0000	7.974E-03	0.0079
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.404E-02	0.0138	0.000E+00	0.0000	0.000E+00	0.0000	4.722E-02	0.0466
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.021E-02	0.0298	0.000E+00	0.0000	0.000E+00	0.0000	1.014E+00	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 9.000E+02 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	5.410E-02	0.1140	1.184E-07	0.0000	0.000E+00	0.0000	2.594E-02	0.0546	0.000E+00	0.0000	0.000E+00	0.0000	4.143E-03	0.0087
Th-230	1.949E-01	0.4106	3.571E-05	0.0001	0.000E+00	0.0000	9.100E-02	0.1917	0.000E+00	0.0000	0.000E+00	0.0000	2.126E-02	0.0448
U-234	1.751E-03	0.0037	7.920E-07	0.0000	0.000E+00	0.0000	9.500E-04	0.0020	0.000E+00	0.0000	0.000E+00	0.0000	3.195E-04	0.0007
U-235	1.711E-04	0.0004	3.982E-08	0.0000	0.000E+00	0.0000	2.899E-05	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	1.434E-05	0.0000
U-238	6.874E-04	0.0014	4.071E-07	0.0000	0.000E+00	0.0000	1.288E-04	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	1.197E-04	0.0003
Total	2.516E-01	0.5301	3.707E-05	0.0001	0.000E+00	0.0000	1.180E-01	0.2487	0.000E+00	0.0000	0.000E+00	0.0000	2.586E-02	0.0545

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 9.000E+02 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.242E-02	0.0472	0.000E+00	0.0000	0.000E+00	0.0000	1.066E-01	0.2246
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.271E-03	0.0090	0.000E+00	0.0000	0.000E+00	0.0000	3.114E-01	0.6562
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.489E-02	0.0524	0.000E+00	0.0000	0.000E+00	0.0000	2.791E-02	0.0588
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.076E-03	0.0086	0.000E+00	0.0000	0.000E+00	0.0000	4.290E-03	0.0090
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.344E-02	0.0494	0.000E+00	0.0000	0.000E+00	0.0000	2.438E-02	0.0514
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.910E-02	0.1667	0.000E+00	0.0000	0.000E+00	0.0000	4.746E-01	1.0000

*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	3.855E-02	0.0914	8.448E-08	0.0000	0.000E+00	0.0000	1.687E-02	0.0400	0.000E+00	0.0000	0.000E+00	0.0000	2.955E-03	0.0070
Th-230	1.973E-01	0.4675	3.567E-05	0.0001	0.000E+00	0.0000	8.408E-02	0.1993	0.000E+00	0.0000	0.000E+00	0.0000	2.145E-02	0.0508
U-234	1.803E-03	0.0043	5.912E-07	0.0000	0.000E+00	0.0000	8.354E-04	0.0020	0.000E+00	0.0000	0.000E+00	0.0000	2.681E-04	0.0006
U-235	9.552E-05	0.0002	2.336E-08	0.0000	0.000E+00	0.0000	1.597E-05	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.507E-06	0.0000
U-238	3.822E-04	0.0009	2.264E-07	0.0000	0.000E+00	0.0000	6.543E-05	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	6.657E-05	0.0002
Total	2.381E-01	0.5643	3.659E-05	0.0001	0.000E+00	0.0000	1.019E-01	0.2414	0.000E+00	0.0000	0.000E+00	0.0000	2.475E-02	0.0587

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years
Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.264E-02	0.0537	0.000E+00	0.0000	0.000E+00	0.0000	8.102E-02	0.1920
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.194E-03	0.0123	0.000E+00	0.0000	0.000E+00	0.0000	3.080E-01	0.7300
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.399E-02	0.0332	0.000E+00	0.0000	0.000E+00	0.0000	1.690E-02	0.0401
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.429E-03	0.0058	0.000E+00	0.0000	0.000E+00	0.0000	2.549E-03	0.0060
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.295E-02	0.0307	0.000E+00	0.0000	0.000E+00	0.0000	1.347E-02	0.0319
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.721E-02	0.1356	0.000E+00	0.0000	0.000E+00	0.0000	4.220E-01	1.0000

0*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.000E+03 years
0 Water Independent Pathways (Inhalation excludes radon)

0 Radio- Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Ra-226	3.259E-04	0.0040	3.629E-10	0.0000	0.000E+00	0.0000	1.759E-05	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	1.269E-05	0.0002
Th-230	4.994E-02	0.6154	4.434E-06	0.0001	0.000E+00	0.0000	2.626E-03	0.0324	0.000E+00	0.0000	0.000E+00	0.0000	2.730E-03	0.0336
U-234	4.765E-04	0.0059	4.246E-08	0.0000	0.000E+00	0.0000	2.506E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	2.609E-05	0.0003
U-235	9.611E-08	0.0000	1.256E-11	0.0000	0.000E+00	0.0000	2.461E-09	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.891E-09	0.0000
U-238	5.522E-07	0.0000	1.007E-10	0.0000	0.000E+00	0.0000	1.768E-08	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.614E-08	0.0000
Total	5.074E-02	0.6253	4.477E-06	0.0001	0.000E+00	0.0000	2.669E-03	0.0329	0.000E+00	0.0000	0.000E+00	0.0000	2.769E-03	0.0341

0

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 2.000E+03 years
0 Water Dependent Pathways

0 Radio- Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.389E-02	0.1711	0.000E+00	0.0000	0.000E+00	0.0000	1.424E-02	0.1755
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.990E-03	0.1231	0.000E+00	0.0000	0.000E+00	0.0000	6.529E-02	0.8046
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.049E-03	0.0129	0.000E+00	0.0000	0.000E+00	0.0000	1.577E-03	0.0194
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.439E-06	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	8.543E-06	0.0001
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.765E-05	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	2.825E-05	0.0003
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.496E-02	0.3076	0.000E+00	0.0000	0.000E+00	0.0000	8.114E-02	1.0000

0*Sum of all water independent and dependent pathways.

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Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years
0 Water Independent Pathways (Inhalation excludes radon)
0

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

0

Total Dose Contributions TDOSE(ipt) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+04 years
0 Water Dependent Pathways
0

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.940E-05	0.0472	0.000E+00	0.0000	0.000E+00	0.0000	6.940E-05	0.0472
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.398E-03	0.9505	0.000E+00	0.0000	0.000E+00	0.0000	1.398E-03	0.9505
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.369E-06	0.0023	0.000E+00	0.0000	0.000E+00	0.0000	3.369E-06	0.0023
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.471E-03	1.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.471E-03	1.0000

0*Sum of all water independent and dependent pathways.

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Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

0 Parent (i)	Product (j)	Thread Fraction	DSR(jt) At Time in Years (mrem/yr)/(pCi/g) 0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
Ra-226+D	Ra-226+D	1.000E+00	4.662E+00	4.646E+00	4.507E+00	4.212E+00	3.325E+00	1.692E+00	2.223E-01	1.596E-01	7.931E-03	0.000E+00
Ra-226+D	Pb-210+D	1.000E+00	2.801E-02	7.565E-02	4.271E-01	8.761E-01	1.084E+00	5.782E-01	1.215E-01	1.018E-01	3.801E-02	0.000E+00
Ra-226+D	-DSR(j)		4.690E+00	4.721E+00	4.934E+00	5.088E+00	4.410E+00	2.270E+00	3.439E-01	2.613E-01	4.594E-02	0.000E+00
0Th-230	Th-230	1.000E+00	2.817E-02	2.817E-02	2.817E-02	2.816E-02	2.814E-02	2.806E-02	2.539E-02	2.469E-02	2.560E-03	0.000E+00
Th-230	Ra-226+D	1.000E+00	9.974E-04	3.011E-03	2.085E-02	5.860E-02	1.722E-01	3.809E-01	5.372E-01	5.363E-01	1.199E-01	2.412E-05
Th-230	Pb-210+D	1.000E+00	4.390E-06	2.706E-05	1.046E-03	6.954E-03	3.930E-02	1.100E-01	1.452E-01	1.390E-01	2.595E-02	1.336E-04
Th-230	-DSR(j)		2.918E-02	3.121E-02	5.007E-02	9.371E-02	2.397E-01	5.189E-01	7.078E-01	7.000E-01	1.484E-01	1.577E-04
0U-234	U-234	1.000E+00	2.218E-02	2.205E-02	2.091E-02	1.859E-02	1.232E-02	9.187E-03	9.059E-03	5.001E-03	9.976E-06	0.000E+00
U-234	Th-230	1.000E+00	1.308E-07	3.837E-07	2.587E-06	7.084E-06	1.923E-05	3.568E-05	3.885E-05	3.788E-05	4.020E-06	8.541E-08
U-234	Ra-226+D	1.000E+00	2.964E-09	2.094E-08	9.711E-07	7.710E-06	6.789E-05	3.473E-04	7.918E-04	8.095E-04	2.370E-04	7.948E-05
U-234	Pb-210+D	1.000E+00	1.047E-11	1.365E-10	3.384E-08	6.649E-07	1.275E-05	9.559E-05	2.978E-04	3.203E-04	3.246E-04	4.306E-04
U-234	-DSR(j)		2.218E-02	2.205E-02	2.092E-02	1.861E-02	1.242E-02	9.666E-03	1.019E-02	6.168E-03	5.756E-04	5.102E-04
0U-235+D	U-235+D	1.000E+00	2.709E-01	2.693E-01	2.554E-01	2.271E-01	1.505E-01	5.156E-02	9.841E-03	5.439E-03	1.016E-05	0.000E+00
U-235+D	Pa-231	1.000E+00	2.376E-05	7.266E-05	4.890E-04	1.264E-03	2.761E-03	3.826E-03	6.544E-03	4.005E-03	1.562E-05	0.000E+00
U-235+D	Ac-227+D	1.000E+00	2.244E-07	1.460E-06	5.591E-05	3.296E-04	1.330E-03	5.956E-03	1.662E-02	1.016E-02	3.993E-05	0.000E+00
U-235+D	-DSR(j)		2.709E-01	2.694E-01	2.560E-01	2.287E-01	1.546E-01	6.134E-02	3.300E-02	1.961E-02	6.571E-05	0.000E+00
0U-238	U-238	5.400E-05	1.075E-06	1.068E-06	1.013E-06	9.009E-07	5.971E-07	4.466E-07	4.419E-07	2.440E-07	4.881E-10	0.000E+00
0U-238+D	U-238+D	9.999E-01	7.058E-02	7.017E-02	6.656E-02	5.918E-02	3.922E-02	1.723E-02	8.873E-03	4.900E-03	9.643E-06	0.000E+00
U-238+D	U-234	9.999E-01	3.141E-08	9.373E-08	6.225E-07	1.608E-06	3.511E-06	7.829E-06	2.315E-05	1.420E-05	5.674E-08	0.000E+00
U-238+D	Th-230	9.999E-01	1.262E-13	8.544E-13	3.820E-11	2.974E-10	2.473E-09	1.096E-08	1.838E-08	1.813E-08	2.103E-09	3.237E-10
U-238+D	Ra-226+D	9.999E-01	2.085E-15	3.163E-14	9.572E-12	2.175E-10	6.003E-09	7.936E-08	3.532E-07	3.775E-07	1.687E-07	1.935E-07
U-238+D	Pb-210+D	9.999E-01	6.231E-18	1.661E-16	2.570E-13	1.479E-11	9.565E-10	2.159E-08	1.910E-07	2.345E-07	4.409E-07	1.036E-06
U-238+D	-DSR(j)		7.058E-02	7.017E-02	6.656E-02	5.918E-02	3.922E-02	1.723E-02	8.897E-03	4.915E-03	1.031E-05	1.230E-06

The DSR includes contributions from associated (half-life ó 180 days) daughters.
0

Single Radionuclide Soil Guidelines G(it) in pCi/g
Basic Radiation Dose Limit = 1.500E+01 mrem/yr

0Nuclide (i)	t= 0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
Ra-226	3.199E+00	3.177E+00	3.040E+00	2.948E+00	3.402E+00	6.608E+00	4.362E+01	5.740E+01	3.265E+02	*9.885E+11
Th-230	5.141E+02	4.806E+02	2.996E+02	1.601E+02	6.259E+01	2.891E+01	2.119E+01	2.143E+01	1.011E+02	9.511E+04
U-234	6.763E+02	6.803E+02	7.171E+02	8.061E+02	1.208E+03	1.552E+03	1.472E+03	2.432E+03	2.606E+04	2.940E+04
U-235	5.537E+01	5.569E+01	5.860E+01	6.559E+01	9.703E+01	2.445E+02	4.545E+02	7.650E+02	2.283E+05	*2.161E+06
U-238	2.125E+02	2.138E+02	2.254E+02	2.535E+02	3.824E+02	8.704E+02	1.686E+03	3.052E+03	*3.361E+05	*3.361E+05

*At specific activity limit

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            Summed Dose/Source Ratios DSR(it) in (mrem/yr)/(pCi/g)
            and Single Radionuclide Soil Guidelines G(it) in pCi/g
         at tmin = time of minimum single radionuclide soil guideline
     and at tmax = time of maximum total dose =   27.71 ñ 0.06 years
0Nuclide  Initial        tmin       DSR(itmin) G(itmin) DSR(itmax) G(itmax)
   (i)    (pCi/g)       (years)                 (pCi/g)              (pCi/g)
 ------- ---------  ----------------  ---------  ---------  ---------  ---------
 Ra-226  3.100E-01    30.18 ñ 0.06    5.088E+00  2.948E+00  5.086E+00  2.949E+00
 Th-230  4.400E-01      801 ñ 2       7.108E-01  2.110E+01  8.867E-02  1.692E+02
 U-234   2.740E+00     0.000E+00      2.218E-02  6.763E+02  1.886E-02  7.954E+02
 U-235   1.300E-01     0.000E+00      2.709E-01  5.537E+01  2.316E-01  6.475E+01
 U-238   2.740E+00     0.000E+00      7.058E-02  2.125E+02  5.998E-02  2.501E+02
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Summary : Residual Dose Assessment Under Residential Receptor
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Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

0Nuclide (j)	Parent (i)	THF(i)	DOSE(jt) mrem/yr t= 0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
Ra-226	Ra-226	1.000E+00	1.445E+00	1.440E+00	1.397E+00	1.306E+00	1.031E+00	5.244E-01	6.892E-02	4.947E-02	2.459E-03	0.000E+00
Ra-226	Th-230	1.000E+00	4.388E-04	1.325E-03	9.174E-03	2.578E-02	7.578E-02	1.676E-01	2.364E-01	2.360E-01	5.274E-02	1.061E-05
Ra-226	U-234	1.000E+00	8.122E-09	5.737E-08	2.661E-06	2.112E-05	1.860E-04	9.515E-04	2.170E-03	2.218E-03	6.493E-04	2.178E-04
Ra-226	U-238	9.999E-01	5.712E-15	8.666E-14	2.623E-11	5.959E-10	1.645E-08	2.175E-07	9.677E-07	1.034E-06	4.622E-07	5.303E-07
Ra-226	-DOSE(j)		1.446E+00	1.442E+00	1.406E+00	1.332E+00	1.107E+00	6.929E-01	3.075E-01	2.877E-01	5.585E-02	2.289E-04
0Pb-210	Ra-226	1.000E+00	8.682E-03	2.345E-02	1.324E-01	2.716E-01	3.362E-01	1.792E-01	3.767E-02	3.155E-02	1.178E-02	0.000E+00
Pb-210	Th-230	1.000E+00	1.932E-06	1.191E-05	4.603E-04	3.060E-03	1.729E-02	4.840E-02	6.389E-02	6.118E-02	1.142E-02	5.878E-05
Pb-210	U-234	1.000E+00	2.869E-11	3.739E-10	9.272E-08	1.822E-06	3.494E-05	2.619E-04	8.160E-04	8.777E-04	8.895E-04	1.180E-03
Pb-210	U-238	9.999E-01	1.707E-17	4.552E-16	7.043E-13	4.051E-11	2.621E-09	5.916E-08	5.235E-07	6.426E-07	1.208E-06	2.838E-06
Pb-210	-DOSE(j)		8.684E-03	2.346E-02	1.328E-01	2.746E-01	3.535E-01	2.279E-01	1.024E-01	9.361E-02	2.409E-02	1.241E-03
0Th-230	Th-230	1.000E+00	1.240E-02	1.240E-02	1.240E-02	1.239E-02	1.238E-02	1.235E-02	1.117E-02	1.087E-02	1.126E-03	0.000E+00
Th-230	U-234	1.000E+00	3.585E-07	1.051E-06	7.088E-06	1.941E-05	5.270E-05	9.777E-05	1.064E-04	1.038E-04	1.101E-05	2.340E-07
Th-230	U-238	9.999E-01	3.458E-13	2.341E-12	1.047E-10	8.147E-10	6.776E-09	3.002E-08	5.036E-08	4.967E-08	5.761E-09	8.868E-10
Th-230	-DOSE(j)		1.240E-02	1.240E-02	1.240E-02	1.241E-02	1.243E-02	1.244E-02	1.128E-02	1.097E-02	1.137E-03	2.349E-07
0U-234	U-234	1.000E+00	6.077E-02	6.042E-02	5.730E-02	5.095E-02	3.376E-02	2.517E-02	2.482E-02	1.370E-02	2.733E-05	0.000E+00
U-234	U-238	9.999E-01	8.606E-08	2.568E-07	1.706E-06	4.405E-06	9.619E-06	2.145E-05	6.344E-05	3.892E-05	1.555E-07	0.000E+00
U-234	-DOSE(j)		6.077E-02	6.042E-02	5.731E-02	5.095E-02	3.377E-02	2.519E-02	2.488E-02	1.374E-02	2.749E-05	0.000E+00
0U-235	U-235	1.000E+00	3.521E-02	3.501E-02	3.320E-02	2.952E-02	1.957E-02	6.703E-03	1.279E-03	7.070E-04	1.320E-06	0.000E+00
0Pa-231	U-235	1.000E+00	3.088E-06	9.446E-06	6.356E-05	1.644E-04	3.589E-04	4.974E-04	8.507E-04	5.207E-04	2.031E-06	0.000E+00
0Ac-227	U-235	1.000E+00	2.917E-08	1.897E-07	7.268E-06	4.285E-05	1.729E-04	7.743E-04	2.160E-03	1.321E-03	5.191E-06	0.000E+00
0U-238	U-238	5.400E-05	2.944E-06	2.927E-06	2.776E-06	2.468E-06	1.636E-06	1.224E-06	1.211E-06	6.686E-07	1.338E-09	0.000E+00
U-238	U-238	9.999E-01	1.934E-01	1.923E-01	1.824E-01	1.621E-01	1.075E-01	4.720E-02	2.431E-02	1.343E-02	2.642E-05	0.000E+00
U-238	-DOSE(j)		1.934E-01	1.923E-01	1.824E-01	1.621E-01	1.075E-01	4.720E-02	2.431E-02	1.343E-02	2.642E-05	0.000E+00

THF(i) is the thread fraction of the parent nuclide.

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Summary : Residual Dose Assessment Under Residential Receptor
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Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

0Nuclide (j)	Parent (i)	THF(i)	S(jt) pCi/g t= 0.000E+00	1.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	9.000E+02	1.000E+03	2.000E+03	1.000E+04
Ra-226	Ra-226	1.000E+00	3.100E-01	3.090E-01	2.997E-01	2.801E-01	2.211E-01	1.125E-01	1.482E-02	1.057E-02	3.603E-04	6.576E-16
Ra-226	Th-230	1.000E+00	0.000E+00	1.903E-04	1.874E-03	5.437E-03	1.616E-02	3.586E-02	5.324E-02	5.394E-02	5.503E-02	4.929E-02
Ra-226	U-234	1.000E+00	0.000E+00	5.326E-09	5.180E-07	4.385E-06	3.951E-05	2.032E-04	4.777E-04	4.927E-04	5.251E-04	4.711E-04
Ra-226	U-238	9.999E-01	0.000E+00	5.029E-15	4.861E-12	1.217E-10	3.477E-09	4.622E-08	2.050E-07	2.181E-07	2.530E-07	2.278E-07
Ra-226	-S(j):		3.100E-01	3.091E-01	3.016E-01	2.856E-01	2.373E-01	1.486E-01	6.853E-02	6.500E-02	5.591E-02	4.976E-02
0Pb-210	Ra-226	1.000E+00	0.000E+00	9.458E-03	8.023E-02	1.708E-01	2.138E-01	1.141E-01	1.503E-02	1.072E-02	3.654E-04	6.669E-16
Pb-210	Th-230	1.000E+00	0.000E+00	2.926E-06	2.623E-04	1.881E-03	1.091E-02	3.070E-02	4.838E-02	4.909E-02	5.028E-02	4.504E-02
Pb-210	U-234	1.000E+00	0.000E+00	5.476E-11	4.977E-08	1.097E-06	2.191E-05	1.632E-04	4.311E-04	4.463E-04	4.797E-04	4.305E-04
Pb-210	U-238	9.999E-01	0.000E+00	3.885E-17	3.560E-13	2.391E-11	1.633E-09	3.460E-08	1.829E-07	1.959E-07	2.310E-07	2.082E-07
Pb-210	-S(j):		0.000E+00	9.460E-03	8.050E-02	1.727E-01	2.247E-01	1.449E-01	6.384E-02	6.026E-02	5.113E-02	4.547E-02
0Th-230	Th-230	1.000E+00	4.400E-01	4.400E-01	4.399E-01	4.398E-01	4.394E-01	4.382E-01	4.345E-01	4.339E-01	4.279E-01	3.828E-01
Th-230	U-234	1.000E+00	0.000E+00	2.459E-05	2.395E-04	6.782E-04	1.863E-03	3.467E-03	4.132E-03	4.135E-03	4.090E-03	3.659E-03
Th-230	U-238	9.999E-01	0.000E+00	3.482E-11	3.362E-09	2.800E-08	2.385E-07	1.063E-06	1.944E-06	1.966E-06	1.977E-06	1.769E-06
Th-230	-S(j):		4.400E-01	4.400E-01	4.402E-01	4.405E-01	4.413E-01	4.416E-01	4.387E-01	4.381E-01	4.320E-01	3.865E-01
0U-234	U-234	1.000E+00	2.740E+00	2.724E+00	2.584E+00	2.297E+00	1.522E+00	4.696E-01	1.380E-02	7.663E-03	2.143E-05	8.026E-26
U-234	U-238	9.999E-01	0.000E+00	7.722E-06	7.324E-05	1.954E-04	4.315E-04	3.996E-04	3.524E-05	2.176E-05	1.219E-07	2.308E-27
U-234	-S(j):		2.740E+00	2.724E+00	2.584E+00	2.297E+00	1.522E+00	4.700E-01	1.383E-02	7.685E-03	2.156E-05	8.257E-26
0U-235	U-235	1.000E+00	1.300E-01	1.292E-01	1.226E-01	1.090E-01	7.223E-02	2.230E-02	6.562E-04	3.646E-04	1.023E-06	3.918E-27
0Pa-231	U-235	1.000E+00	0.000E+00	2.734E-06	2.593E-05	6.916E-05	1.527E-04	1.411E-04	1.238E-05	7.634E-06	4.238E-08	7.471E-28
0Ac-227	U-235	1.000E+00	0.000E+00	4.294E-08	3.622E-06	2.289E-05	9.084E-05	1.017E-04	9.456E-06	5.848E-06	3.287E-08	5.853E-28
0U-238	U-238	5.400E-05	1.480E-04	1.471E-04	1.395E-04	1.240E-04	8.221E-05	2.538E-05	7.469E-07	4.150E-07	1.164E-09	4.459E-30
U-238	U-238	9.999E-01	2.740E+00	2.724E+00	2.583E+00	2.297E+00	1.522E+00	4.700E-01	1.383E-02	7.685E-03	2.155E-05	8.257E-26
U-238	-S(j):		2.740E+00	2.724E+00	2.584E+00	2.297E+00	1.522E+00	4.700E-01	1.383E-02	7.685E-03	2.156E-05	8.257E-26

THF(i) is the thread fraction of the parent nuclide.
0RESCALC.EXE execution time = 0.90 seconds

APPENDIX B

COST ESTIMATE ANALYSIS

TABLE OF CONTENTS

LIST OF TABLES

COST ESTIMATE WORKBOOKS

LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
BRA	Baseline Risk Assessment
ES	Energy Solutions
FS	feasibility study
FSS	final status survey
ft bgs	feet below ground surface
FUSRAP	Formerly Utilized Sites Remedial Action Program
hr(s)	hour(s)
HP	Health Physicist
HTRW	Hazardous Toxic Radioactive Waste
LS	lump sum
LUC	land use control
O&M	Operation & Maintenance
OU	operable unit
RCRA	Resource Conservation and Recovery Act
RG	remediation goal
RI	Remedial Investigation
SGS	Segmented Gate System
USEPA	U.S. Environmental Protection Agency
WAC	Waste Acceptance Criteria
yd^3	cubic yard
yd^3/hr	cubic yard per hour

1.0 INTRODUCTION

This appendix identifies the assumptions and information used in the cost estimate development for the remedial action alternatives evaluated in the Feasibility Study (FS) for the DuPont Chambers Works Formerly Utilized Sites Remedial Action Program (FUSRAP) Site in Deepwater, New Jersey. The cost estimates are intended to form a basis for comparing remedial alternatives and will be used to support remedy selection. The cost estimates provide an accuracy of -30 percent to +50 percent and are prepared using information obtained in the Sitewide Remedial Investigation (RI) and Baseline Risk Assessment (BRA) reports.

Cost estimates for each alternative were developed using Microsoft Excel©, using industry standard pricing data (labor, materials, and equipment), contractor/vendor cost quotations, previous remediation experience at other FUSRAP sites, and site-specific data and conditions (i.e., volumes, time, DuPont access and transportation).

The Excel workbooks represent a buildup of the costs associated with each remedial alternative. Each remedial alternative includes various worksheets (tables), some common to several alternatives (i.e., calculation of soil volumes, mobilization, or five-year review), while others are unique to the particular remedial alternative (i.e., soil treatment costs). All worksheets are then rolled up to provide a base price for Operable Unit (OU) 1 and for Area of Concern (AOC) 6. The base price includes all direct costs associated with labor, material, and equipment required to construct and implement the remedial alternative. Contractor markups (overhead costs and profit) and risks (contingencies) associated with unforeseen circumstances are estimated and added to the base cost in order to get a total project cost.

2.0 GENERAL COST INFORMATION

2.1 Soil and Groundwater Alternatives

Tables B-1 and B-2 present the soil and groundwater remedial alternatives selected for evaluation in the FS. Three soil alternatives (S1, S2, and S3) and three groundwater alternatives (GW1, GW2, and GW3) are identified and numbered consecutively (e.g., S1, S2 and S3 for the soil alternatives). To distinguish the remedial alternatives for OU 1 and AOC 6 the alternative is further designated with a (-1) or (-6), respectively, to identify the specific area (e.g., Soil Alternative S2, Excavation and followed by Off-site Disposal, at OU 1 is designated as S2-1).

TABLE B-1: SOIL ALTERNATIVES

Alternative #	AOC	Description of Alternatives
S1	OU 1 and AOC 6	No Action
S2		Excavation Followed by Off-Site Disposal
S3		Excavation Followed by Treatment (Sorting) and Off-Site Disposal

TABLE B-2: GROUNDWATER ALTERNATIVES

Alternative #	AOC	Description of Alternatives
GW1	OU 1 and AOC 6	No Action
GW2		*Ex Situ* Treatment
GW3		Monitored Natural Attenuation

2.2 Schedule

The remedial action alternatives are estimated to be completed within six – 18 months, depending on the selected remedial alternative. Due to the long half-lives associated with the radionuclides, costs related to O&M activities for soil alternatives were estimated for the duration of 1000 years.

To assess the net present value for each alternative a Discount Factor of seven percent (7%) was utilized (Source: USEPA 2000, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*). Working hours are based on 2,080 hours per 12 months.

2.3 Cost Elements

The remedial action alternatives include both capital and O&M costs. Both cost elements are summarized in the following subsections.

Capital Costs

Capital costs are those expenditures required to implement a remedial action and consist of both direct and indirect costs. Capital costs do not include the costs required to maintain or operate the action throughout its expected lifetime.

Direct Capital Costs

Direct capital costs include equipment, labor, and materials necessary for implementing the remedial action alternatives. These typically include costs for:

- Mobilization and demobilization
- land use controls;
- monitoring, sampling, and analysis during remedial action;
- site work;
- surface water and groundwater collection/controls;
- soil collection/containment;
- treatment;
- transportation and disposal; and
- site restoration.

Indirect Capital Costs

Indirect capital costs consist of engineering, supervision, management, administration, financial, and other services necessary to implement a remedial action. These costs are not incurred as part of actual remedial actions but are ancillary to direct or construction costs. Indirect costs typically include:

- remedial design;
- project management;
- construction management;
- program management cost; and
- prime contractor and subcontractor markups.

Operations and Maintenance (O&M) Costs

O&M costs are those post-remedial action costs necessary for monitoring and ensuring hazardous substances will not migrate into the surrounding environment. These costs typically include:

- maintaining land use controls and site database;
- monitoring, sampling and analysis after remedial action;
- five-year reviews;
- groundwater treatment system O&M; and
- site management/technical support in support of O&M activities.

For the soil alternatives, the O&M cost was calculated for a period of 1000 years. The O&M cost did not include long-term monitoring of groundwater. For groundwater alternatives GW2 and GW 3, the O&M costs were calculated based on the duration of the project.

2.4 Basis of Cost Estimate

Project Management

Project Management includes planning, reporting, and managerial support during the design, construction, and O&M phases of the project. Based on U.S. Environmental Protection Agency (USEPA) Guidance document, 540-R-00-002 (July 2000), project management has been estimated to be five percent (5%) of the total Hazardous Toxic Radioactive Waste (HTRW) construction (total remedial action) cost.

Remedial Design

Activities included within the remedial design phase are pre-design collection and analysis of field data, engineering survey for design, and the various design components such as design analysis, plans, specifications, cost estimating, and scheduling of all design phases. During this cost evaluation, the remedial design has been estimated to be eight percent (8%) of the total HTRW construction cost.

Remedial Action Contracting

Remedial action contracting activities include bid or contract administration and any legal services in addition to land use controls. These contracting activities are estimated to be one percent (1%) of the total HTRW construction cost.

Engineering during Construction

Activities include engineering survey for construction, construction observation or oversight, Health Physicists (HP) technical support, quality assurance oversight, and/or engineering during construction. Costs associated with these activities are estimated to be one percent (1%) of the total HTRW construction cost.

Construction Management

Construction Management includes services to manage construction or installation of the remedial action. Activities include review of submittals, design modification, preparation of O&M manual, documentation of quality control/quality assurance, and record drawings. These costs have been estimated to be six percent (6%) of the total HTRW construction cost.

Escalation and Contingency Cost

An escalation factor has been applied to bring the project cost from the current date of the estimates to the date when costs will be incurred. To account for the inflation of costs over time an escalation factor of seven percent (7%) has been added to the total project cost.

Project contingency is factored into the cost estimate to cover unknowns, unforeseen circumstances, or unanticipated conditions that are not possible to evaluate from available data at the time of cost estimate development. Contingency is often applied to the total cost of a remedial alternative to reduce the risk of possible cost overruns associated with construction, O&M, or other remedial activities. Design contingency was selected to be five percent (5%) for all alternatives. Based on USEPA guidance (540-R-00-002 (July 2000), the construction contingency of 25 percent (25%) was selected for alternatives S2, S3, and GW2. However, due to the proven implementation at other FUSRAP sites, the construction contingency for the groundwater alternative GW3 (MNA) was estimated to be 10 percent (10%).

HTRW Remedial Action Cost Components

Land Use Controls

Land use controls (LUCs) include both engineering controls and administrative controls to reduce or minimize exposure to contaminants left on site in Soil Alternatives S2 and S3, and Groundwater Alternatives GW2 and GW3. For soil alternatives, LUCs would be utilized to assure protectiveness during remedial action activities. LUCs would rely on DuPont's existing site restrictions and additional access restrictions, as needed (e.g., new fencing and signs and periodic inspections of the site to ensure appropriate restrictions are being enforced). The controls would include measures such as governmental controls, proprietary controls and informational devices.

LUCs are used to ensure protectiveness for groundwater alternatives at areas in which the residual groundwater contamination exceeds the concentrations as specified in RAOs. For the LUCs, a long-term stewardship plan would be developed. It would address requirements for future monitoring and maintenance of LUCs. The plan would also include provisions addressing the process by which DuPont and any future property owner(s) could contact the designated federal government agency (USACE and/or U.S. Department of Energy) responsible for the long-term control of impacted areas including periodic reviews, maintenance, and monitoring. These LUCs will remain in place for the duration of need.

Remedial Action Monitoring, Sampling, and Analysis (Soils)

Gamma walkover surveys will be performed and confirmatory soil samples collected as part of final status survey (FSS) for Alternatives S2 and S3 to verify that soil remediation goals (RGs) are met. In addition, surface water and sediment samples will be analyzed to ensure that both media are not negatively impacted by the remedial action activities. Therefore, costs associated with sample collection and analyses are included in the cost estimate(s). The cost estimate also includes the cost associated with air monitoring samples both general and breathing zone, industrial hygiene/health physics technicians and associated survey equipment required to monitor personnel and equipment, personnel protection equipment, and collection and analysis of waste profile samples. In addition, an onsite mobile laboratory will be set up to facilitate excavation, staging, and sorting of soils from the excavated areas. The cost associated with the St. Louis FUSRAP onsite laboratory was used for cost estimating purposes in this FS.

Preparatory Work

Activities to be performed as a part of site preparatory work include development of various plans and setup and installation of various temporary facilities. The plans will include environmental protection plan, sediment control plan, site safety and health plan, general site work plan and quality control plans. Installation of temporary facilities includes one operation trailer, HP trailer, break-room trailer, four toilets, two barricades and four signs. Set up and maintenance of power, water, telephone and sewer connections will be implemented for these temporary facilities.

Mobilization

Mobilization of both labor and equipment is included in this cost item. Two contracts will be implemented, one for OU 1 and one for AOC 6.

Site Work (Soils)

Activities under site work include backfilling and compaction of soils in excavated areas, removal and construction of new access roads, traffic controls and the relocation of utility lines due to the remedial activities. Due to the presence of an important DuPont roadway and several active utility lines that cross AOC 6, re-routing of roadways and relocation of utility lines will be considered during selection of remedial action at AOC 6 for alternatives S2 and S3.

Surface Water Collection/Control

Activities under sediment control system include installation of sedimentation barriers such as silt fences. Based on the type of excavation, engineering controls will be constructed to prevent surface water from leaving the site without passing through erosion control structures such as a silt fence. Additionally, pumps and above-ground holding tanks will be used to collect and treat water by using granular activation carbon and uranium recovery system. The treated water will be discharged ultimately to DuPont Wastewater Treatment plant.

Contaminated Soils Collection/Containment

Soil volumes are based on assumed excavation cut lines, using the RG of 65 picoCuries per gram (pCi/g) and are estimated to be 13,000 cubic yards (yd^3) and 4,300 yd^3 for OU 1 and AOC 6, respectively. *Ex situ* volumes are calculated by applying a 125% swelling factor to the soil volume that is excavated.

The Sitewide RI report identified limited areas of organic wastes at OU 1, specifically in AOC 2 at a depth of eight to 10 feet below ground surface. During the excavation process in AOC 2, it is expected that the different waste streams, Resource Conservation and Recovery Act (RCRA)/hazardous waste and Manhattan Engineer District (MED) radioactive waste, will be identified and handled separately before any offsite disposal. Based on the waste acceptance criteria, US Ecology will accept both waste streams. Although the volume of the RCRA hazardous soil is small, less than five percent of the total soil volume, the disposal rate for this soil is significantly higher. Disposal cost for hazardous soil is $500 per ton compared to $100 per ton for disposal of the bulk FUSRAP radioactive waste soil. Some waste may require treatment by the facility prior to disposal. The canisters used in the ionic exchange process for groundwater recovery may contain elevated radioactivity and may require special handling. Those canisters may need to be shipped to the Energy Solutions (ES) disposal facility in Clive, Utah. It is assumed that waste profiles will be developed for all waste shipments.

In Alternatives S2 and S3, the contaminated soils would be excavated using an excavator with an output of 16 cubic yard per hour (yd^3/hr) for OU1 and 18 yd^3/hr for AOC6. The output rate for OU1 is lower than AOC 6 in order to account for the expected presence of RCRA hazardous substances. The excavated material would be loaded directly into 16 ton dump trucks. This information was used to determine the total excavation time and number of trucks required to transport the contaminated soil from the impacted area to the designated loading areas.

In Alternatives S2 and S3, soils would be transported to a staging area. A front-end loader would be located at the staging area to assist with loading operations. All equipment would be decontaminated prior to leaving the site. The depth of excavation below the existing grade varies up to 20 feet below ground surface (ft bgs) in some areas. For areas of contamination below the groundwater table, dewatering will be required. Any water encountered during excavation would be collected and treated as a part of surface water treatment process, described above.

Physical Treatment (Soils)

Treatment of FUSRAP radioactive soils applies to Alternative S3 only. Because AOC 6 contains a relatively small amount of contaminated soil, if the alternative is chosen for both OU 1 and AOC 6, it is assumed that it would be conducted sequentially using the same equipment, first at OU 1 and concluding at AOC 6. For cost estimating purposes, a segmented gate system (SGS) was selected for a representative soil treatment (soil sorting) process. Utilities would be needed to operate the soil sorting equipment.

Soils would be transported from the area of excavation to the treatment site. Soils that have been excavated from below the water table will require a dewatering step, because the SGS equipment requires loose and "clump-free" soil so that a thin layer of soil is able to pass under the radiation sensors. For this cost estimate, 20 percent of the soils are assumed to be excavated from below the water table. A well-point system would be used for dewatering operation. Following dewatering operation, wet excavated soils will be dried out prior to being put through a coarse separation-sizing screen to remove any debris or large objects. The remaining soil enters the separation system. During processing, the soils are placed as a thin layer on a conveyor belt. Radiation sensors above the belt identify soils that are contaminated above criteria activity levels, and then activate "gates" that divert the contaminated soils. Soils that pass under the sensors without indicating contamination proceed to another area and stockpiled as "passing" or "clean" soils. It is assumed that 30 percent of the treated soil would be less than the soil RGs. In addition to clean offsite fill material, the "passing" or "clean" soil would also be used as backfill material.

The installation and O&M costs associated with SGS systems were obtained from vendors. However, the benefit of SGS is to reduce the overall volume of contaminated soil requiring offsite disposal. It is expected that there are considerable uncertainties associated with the successful implementation of the SGS. Additional labor and rework costs are likely in the field to ensure the proper segregation of soils (above RGs).

Transportation and Disposal (Soils)

Transportation and commercial disposal during remedial action provides for the shipment and final placement of contaminated soils at a third party commercial facility that charges a fee to accept waste depending on a variety of waste acceptance criteria.

This item would be applicable to Alternatives S2 and S3. In Alternatives S2 and S3, 24,900 yd^3 and 17,410 yd^3 of soils, respectively, would be transported to an approved and permitted disposal facility. The excavated soils would be trucked to a staging and loading area. The soils would be placed in "burrito bags" and be transported to a disposal facility such as US Ecology in Idaho by rail.

Disposal costs were estimated using the assumption that the wastes would meet US Ecology's Waste Acceptance Criteria (WAC). In order to confirm or refute this assumption, a test pit program has been included in the costs for Alternatives S2 and S3. The purpose of this program is to collect samples from excavations dug with a conventional backhoe, and analyze those samples for radionuclides and chemicals regulated by RCRA and Toxic Substance and Control Act. In this way, the amount of RCRA waste and its effects on disposal costs can be estimated prior to full-scale mobilization.

The canisters used in the ionic exchange process for water treatment as a result of dewatering and *ex situ* groundwater treatment will contain elevated radioactivity. Those canisters may require shipment to the ES facility in Clive, Utah. It is assumed that waste profiles will be developed for all shipments of waste from the site to the treatment and disposal facility. Clive typically has a minimum waste stream charge of $20,000, which was factored into the disposal costs.

During the Sitewide RI, the highest concentrations of PCBs found were lower than 50 parts per million, so PCB content should not affect disposal options. However, a small fraction of the number of samples analyzed showed concentrations of some organics and metals that may exceed standards related to Land Disposal Restrictions under RCRA. Therefore it is possible that some excavated piles may contain both radionuclides and non-radioactive chemicals constituents, requiring on-site treatment or additional costs for treatment at the disposal facility prior to disposal.

Site Restoration (Soils)

Site restoration during remedial action includes backfill, seeding, restoration of roads and fencing disturbed during site remediation. Backfill and site restoration of the excavation would commence upon verification of the survey unit and would run concurrently with excavation activities. For Alternatives S2 and S3, clean fill material would be brought from an off-site location. To enhance both groundwater remedial alternatives, the addition of mulch or other slow release electron donor material to the backfill material could be considered in remedial design activities. This addition in the unsaturated zone would help maintain reducing conditions in the groundwater for several years. Backfill would be compacted to obtain the required soil densities and areas restored to existing conditions (seeded, landscaped, or paved areas).

Monitoring, Sampling, and Analysis (Groundwater)

Monitoring, sampling, and analysis of the groundwater media apply to Alternatives GW2, and GW3. This includes the installation of seven new groundwater monitoring wells for long term monitoring, sample collection, and analysis. It was assumed that wells would be installed to a depth of 20 to 60 feet. Costs are based on the assumptions that the well installations would be permanent and that stainless steel materials would be used to ensure longevity of the wells.

2.5 Cost Estimate Summary for All Alternatives (OU 1 and AOC 6)

Table B-3 shows the total cost estimate for each remedial alternative. Tables B-4 and B-5 show the total cost estimate for the remedial action alternatives at OU 1 and AOC 6, respectively.

TABLE B-3 - COMPARISON OF TOTAL COST FOR EACH REMEDIAL ALTERNATIVE

Alternative Description	SOIL ALTERNATIVES		GROUNDWATER ALTERNATIVES	
	S2	S3	GW2	GW3
	Excavation & Disposal of Soil	Excavation, Treatment and Disposal of Soil	GW Treatment	Monitored Natural Attenuation
Total Project Duration (years)	1000	1000	10	30
Capital Costs[1]				
Real Estate Analysis/Documents	**2,380**	**2,380**	**2,380**	**2,380**
Proj Management & Pre-Rem. Action	**2,896,922**	**2,695,212**	**162,231**	**115,491**
HTRW Remedial Action (Construct)	**25,039,421**	**23,295,953**	**1,255,873**	**894,255**
Annual O&M Costs[2]				
Long Term Monitoring (B-2.1)	0	0	265,644	274,299
Site Supervision and Maintenance	79,373	65,593	82,973	71,105
Groundwater O&M Cost			588,109	
Periodic O&M Costs[3]				
Five Years Review	45,502	37,602	52,702	47,212
Present Value of O&M Costs	**1,246,345**	**1,029,966**	**6,643,913**	**5,033,910**
Engineering Design Before Construction	**250,394**	**232,960**	**14,022**	**8,943**
Construction Management	**1,502,365**	**1,397,757**	**84,134**	**53,655**
Subtotal	30,937,827	28,654,228	8,162,554	6,108,634
Escalation (7%)	2,165,648	2,005,796	571,379	427,604
TOTAL COST	**33,103,475**	**30,660,023**	**8,733,932**	**6,536,238**

Notes

[1] Capital costs are those expenditures that are required to construct a remedial action and consist of expenditures initially incurred to build, install, or execute the remedial action.

[2] Annual O&M costs are operation and maintenance costs that occur post construction and are necessary to ensure or verify the continued effectiveness of a remedial action.

[3] Periodic O&M costs are operation and maintenance costs that occur only once every few years.

[5] Bold numbers are summed into Subtotal.

TABLE B-4 - OU 1: COMPARISON OF TOTAL COST OF REMEDIAL ALTERNATIVES

Alternative Description	SOIL ALTERNATIVES		GROUNDWATER ALTERNATIVES	
	S2-1	**S3-1**	**GW2-1**	**GW3-1**
	Excavation & Disposal of Soil	**Excavation, Treatment and Disposal of Soil**	**GW Treatment**	**Monitored Natural Attenuation**
Total Project Duration (years)	1000	1000	10	30
Capital Costs[1]				
Real Estate Analysis/Documents	**1,190**	**1,190**	**1,190**	**1,190**
Proj Management & Pre-Rem. Action	**2,194,777**	**2,093,123**	**120,301**	**87,266**
HTRW Remedial Action (Construct)	**18,970,464**	**18,091,819**	**925,584**	**675,706**
Annual O&M Costs[2]				
Long Term Monitoring (B-2.1)	0	0	207,535	182,866
Site Supervision and Cap Maintenance	59,644	49,289	62,350	53,431
Groundwater O&M Cost			367,264	
Periodic O&M Costs[3]				
Five Years Review	34,192	28,256	39,602	35,477
Present Value of O&M Costs	**936,560**	**773,963**	**4,523,683**	**3,450,654**
Engineering Design Before Construction	**189,705**	**180,918**	**10,398**	**6,757**
Construction Management	**1,138,228**	**1,085,509**	**62,389**	**40,542**
Subtotal	23,430,924	22,226,522	5,643,545	4,262,114
Escalation (7%)	1,640,165	1,555,857	395,048	298,348
TOTAL COST	25,071,089	23,782,378	6,038,594	4,560,462

Notes

[1] Capital costs are those expenditures that are required to construct a remedial action and consist of expenditures initially incurred to build, install, or execute the remedial action.

[2] Annual O&M costs are operation and maintenance costs that occur post construction and are necessary to ensure or verify the continued effectiveness of a remedial action.

[3] Periodic O&M costs are operation and maintenance costs that occur only once every few years.

[4] No Action for one site assumes no action for both sites.

[5] Bold numbers are summed into Subtotal.

TABLE B-5 - AOC 6: COMPARISON OF TOTAL COST OF REMEDIAL ALTERNATIVES

Alternative Description	SOIL ALTERNATIVES		GROUNDWATER ALTERNATIVES	
	S2-6	S3-6	GW2-6	GW3-6
	Excavation & Disposal of Soil	Excavation, Treatment and Disposal of Soil	GW Treatment	Monitored Natural Attenuation
Total Project Duration (years)	1000	1000	10	30
Capital Costs[1]				
Real Estate Analysis/Documents	**1,190**	**1,190**	**1,190**	**1,190**
Proj Management & Pre-remedial Action	**702,145**	**602,089**	**41,931**	**28,225**
HTRW Remedial Action (Construct)	**6,068,957**	**5,204,134**	**330,289**	**218,550**
Annual O&M Costs[2]				
Long Term Monitoring	0	0	58,110	91,433
Site Supervision and Cap Maintenance	19,728	16,303	20,623	17,673
Groundwater O&M Cost			220,845	
Periodic O&M Costs[3]				
Five Years Review	11,310	9,346	13,099	11,735
Present Value of O&M Costs	**309,785**	**256,003**	**2,120,229**	**1,583,257**
Engineering Design Before Construction	**60,690**	**52,041**	**3,624**	**2,185**
Construction Management	**364,137**	**312,248**	**21,746**	**13,113**
Subtotal	7,506,903	6,427,706	2,519,008	1,846,520
Escalation (7%)	525,483	449,939	176,331	129,256
TOTAL COST	8,032,387	6,877,645	2,695,339	1,975,776

Notes

[1] Capital costs are those expenditures that are required to construct a remedial action and consist of expenditures initially incurred to build, install, or execute the remedial action.

[2] Annual O&M costs are operation and maintenance costs that occur post construction and are necessary to ensure or verify the continued effectiveness of a remedial action.

[3] Periodic O&M costs are operation and maintenance costs that occur only once every few years.

[4] No Action for one site assumes no action for both sites. Total cost is shown on OU1 total sheet.

[5] Bold numbers are summed into Subtotal.

AREA SPECIFIC BREAKDOWN COST COMPONENTS FOR EACH ALTERNATIVE

AND

BREAKDOWN OF COST COMPONENTS FOR EACH HTRW REMEDIAL ACTION CONSTRUCT UNDER EACH ALTERNATIVE

ALTERNATIVE S2 – SOIL

EXCAVATION AND DISPOSAL OF SOIL

TOTAL COST OF EXCAVATION AND DISPOSAL OF SOIL REMEDIAL ALTERNATIVE

Alternative Description	**S2-1** **Excavation & Disposal of Soil**	**S2-6** **Excavation & Disposal of Soil**
Total Project Duration (years)	1000	1000
Capital Costs[1]		
Real Estate Analysis/Documents	**1,190**	**1,190**
Proj Management & Pre-Rem. Action	**2,194,777**	**702,145**
HTRW Remedial Action (Construct)	**18,970,464**	**6,068,957**
Annual O&M Costs[2]		
Long Term Monitoring	0	0
Site Supervision and Maintenance	59,644	19,728
Periodic O&M Costs[3]		
Five Years Review	34,192	11,310
Present Value of O&M Costs	**936,560**	**309,785**
Engineering Design Before Construction	**189,705**	**60,690**
Construction Management	**1,138,228**	**364,137**
Subtotal	23,430,924	7,506,903
Escalation (7%)	1,640,165	525,483
TOTAL COST	**25,071,089**	**8,032,387**

Notes

[1] Capital costs are those expenditures that are required to construct a remedial action and consist of expenditures initially incurred to build, install, or execute the remedial action.

[2] Annual O&M costs are operation and maintenance costs that occur post construction and are necessary to ensure or verify the continued effectiveness of a remedial action.

[3] Periodic O&M costs are operation and maintenance costs that occur only once every few years.

Table B-2.2 - Cost Associated with Cost Components for Alternative S2 - Excavation and Disposal of Soil

This alternative involves excavating contaminated soils above the appropriate cleanup criteria and disposing those soils at an offsite commercial disposal facility.

Reference Code	Cost Components	Base Price		Contract Cost		Design Contingency		Construction Contingency		Total Cost	
		OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6
B-2.2.1	**Rights of Entry/Temporary Permit**	***1,000***	***1,000***	***140***	***140***	***50***	***50***	***0***	***0***	***1,190***	***1,190***
B-2.2.1.1	Rights of Entry Acquisition	500	500								
B-2.2.1.2	Damages	500	500								
B-2.2.2	**Proj Mang & Pre-Remedial Action**										
B-2.2.2.1	***Project Management [5% of B-2.2.3.0]***	***658,697***	***210,728***	***92,218***	***29,502***	***32,935***	***10,536***	0	0	***783,849***	***250,766***
B-2.2.2.2	***Remedial Design [8% of B-2.2.3.0]***	***1,053,915***	***337,164***	***147,548***	***47,203***	***52,696***	***16,858***	0	0	***1,254,158***	***401,225***
B-2.2.2.3	***Remedial Action Contracting [1% of B-2.2.3.0]***	***131,739***	***42,146***	***18,444***	***5,900***	***6,587***	***2,107***	0	0	***156,770***	***50,153***
B-2.2.3	**HTRW Remedial Action (Construct)**										
B-2.2.3.1	***Land Use Controls***	***125,706***	***41,580***	***17,599***	***5,821***	***6,285***	***2,079***	***31,426***	***10,395***	***181,017***	***59,875***
B-2.2.3.1.1	Preparatory Work [Table B-2.2.3]	31,046	10,269								
B-2.2.3.1.2	Land Use Control Plan [Table B-2.2.3]	45,046	14,900								
B-2.2.3.1.3	Administrative Mechanism Plan [Table B-2.2.3]	49,614	16,411								
B-2.2.3.2	***Mobilize and Preparatory Work***	***205,130***	***67,851***	***28,718***	***9,499***	***10,256***	***3,393***	***51,282***	***16,963***	***295,387***	***97,705***
B-2.2.3.2.1	Preparatory Work [Table B-2.2.4]	168,168	55,625								
B-2.2.3.2.2	Mobilization [Table B-2.2.5]	36,962	12,226								
B-2.2.3.3	***Monitoring, Sampling, Test, Analysis***	***993,930***	***437,441***	***139,150***	***61,242***	***49,697***	***21,872***	***248,483***	***109,360***	***1,431,259***	***629,915***
B-2.2.3.3.1	Environmental Monitoring [Table B-2.2.7]	61,152	49,056								
B-2.2.3.3.2	Chemical/Rad Lab Air Analysis [Table B-2.2.7]	34,787	11,766								
B-2.2.3.3.3	Additional Labor & Services [Table B-2.2.7]	605,069	119,792								
B-2.2.3.3.4	On-site Mobile Laboratory Cost [Table B-2.2.7]	30,088	169,889								
B-2.2.3.3.5	Waste Profile Sampling [Table B-2.2.7]	30,088	9,952								
B-2.2.3.3.6	Monitoring Equipment Cost [Table B-2.2.7]	161,309	53,356								
B-2.2.3.3.7	PPE Cost [Table B-2.2.7]	71,437	23,629								
B-2.2.3.4	****Site Work***	***886,577***	***431,470***	***124,121***	***60,406***	***44,329***	***21,574***	***221,644***	***107,868***	***1,276,671***	***621,317***
B-2.2.3.4.1	Install Signage [Table B-2.2.3]	2,374	986								
B-2.2.3.4.2	Install Fencing and Gates [Table B-2.2.3]	52,690	15,159								
B-2.2.3.4.3	Site Information Database [Table B-2.2.3]	9,234	3,054								
B-2.2.3.4.4	Earthwork [Table B-2.2.8]	609,517	201,610								
B-2.2.3.4.5	Compaction [Table B-2.2.8]	101,361	33,527								
B-2.2.3.4.6	Roads [Table B-2.2.8]		130,286								
B-2.2.3.4.7	Additional Labor & Services [Table B-2.2.8]	111,400	36,848								
B-2.2.3.4.8	Misc. Utility Relocations [Table B-2.2.8]		10,000								
B-2.2.3.5	***Surface Water Collect & Control***	***840,990***	***278,174***	***117,739***	***38,944***	***42,050***	***13,909***	***210,248***	***69,543***	***1,211,026***	***400,570***
B-2.2.3.5.1	Water Management [Table B-2.2.9]	277,172	91,680								
B-2.2.3.5.2	Water Treatment [Table B-2.2.9]	563,819	186,494								
B-2.2.3.6	**Sediment Control** [Table B-2.2.9]	***11,794***	***3,482***	***1,651***	***487***	***590***	***174***	***2,948***	***870***	***16,983***	***5,014***
B-2.2.3.7	***Solids Collect and Containment***	***1,263,249***	***312,937***	***176,855***	***43,811***	***63,162***	***15,647***	***315,812***	***78,234***	***1,819,079***	***450,630***
B-2.2.3.7.1	Excavation [Table B-2.2.10]	129,878	42,960								
B-2.2.3.7.2	Hauling [Table B-2.2.10]	97,175	32,143								
B-2.2.3.7.3	Additional Labor & Services [Table B-2.2.10]	719,037	237,835								
B-2.2.3.7.4	Dewatering Process [Table B-2.2.12]	317,160	0								
B-2.2.3.8	***Construction of Staging and Loading Area*** [Table B-2.2.13]	***205,754***	***12,206***	***28,806***	***1,709***	***10,288***	***610***	***51,439***	***3,051***	***296,286***	***17,576***
B-2.2.3.9	***Disposal (Commercial)***	***8,469,125***	***2,588,325***	***1,185,678***	***362,366***	***423,456***	***129,416***	***2,117,281***	***647,081***	***12,195,540***	***3,727,189***
B-2.2.3.9.1	Loading of Solids [Table B-2.2.14]	541,381	179,072								
B-2.2.3.9.2	Transportation and Emergency Response Plan [Table B-2.2.14]	7,709	2,550								
B-2.2.3.9.3	Transportation Costs [Table B-2.2.14]	4,498,132	1,474,545								
B-2.2.3.9.4	Disposal Fees and Taxes [Table B-2.2.14]	3,406,875	927,188								
B-2.2.3.9.5	Disposal Cost for Cannister Used in Ion Exchanger	15,029	4,971								

Reference Code	Cost Components	Base Price		Contract Cost		Design Contingency		Construction Contingency		Total Cost	
		OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6
B-2.2.3.10	***Site Restoration***	*14,093*	*7,588*	*1,973*	*1,062*	*705*	*379*	*3,523*	*1,897*	*20,294*	*10,927*
B-2.2.3.10.1	Earthwork [Table B-2.2.16]	3,809	2,041								
B-2.2.3.10.2	Revegetation & Planting [Table B-2.2.16]	8,041	4,345								
B-2.2.3.10.3	Site Cleanup [Table B-2.2.16]	2,243	1,202								
B-2.2.3.11	***Demobilization*** [Table B-2.2.17]	*94,844*	*31,372*	*13,278*	*4,392*	*4,742*	*1,569*	*23,711*	*7,843*	*136,576*	*45,175*
B-2.2.3.12	***Submittals*** [Table B-2.2.18]	6,434	2,128	*901*	*298*	*322*	*106*	*1,608*	*532*	*9,264*	*3,064*
B-2.2.3.13	***Test Pits (OU1 only)***	*56,307*	0	*7,883*	*0*	*2,815*	*0*	*14,077*	*0*	*81,082*	*0*
B-2.2.3.13.1	Excavation, Hauling, Backfilling & Compaction [Table B-2.2.15]	10,287									
B-2.2.3.13.2	Additional Labor & Services [Table B-2.2.15]	36,020									
B-2.2.3.13.3	Sampling Costs [Table B-2.2.15]	10,000									
B-2.2.4	**Engineering During Construction [1% of B-2.2.3.0]**	*131,739*	*42,146*	*18,444*	*5,900*	*6,587*	*2,107*	*32,935*	*10,536*	*189,705*	*60,690*
B-2.2.5	**Construction Management (S&A) [6% of B-2.2.3.0]**	*790,436*	*252,873*	*110,661*	*35,402*	*39,522*	*12,644*	*197,609*	*63,218*	*1,138,228*	*364,137*
B-2.2.6	**Post Construction**										
B-2.2.6.1	***Annual Operation, Maintenance, & Monitoring***										
B-2.2.6.1.1	Monitoring [Table B-2.2.19]	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
B-2.2.6.1.2	Post Remedial Site Supervision [Table B-2.2.19]	*41,420*	*13,700*	*5,799*	*1,918*	*2,071*	*685*	*10,355*	*3,425*	*59,644*	*19,728*
B-2.2.6.2	***Periodic Cost***										
B-2.2.6.2.1	Five Year Review [Table B-2.2.19]	*23,744*	*7,854*	*3,324*	*1,100*	*1,187*	*393*	*5,936*	*1,963*	*34,192*	*11,310*

14%	Contract Cost: includes G&A (6%) and profit (8%) for prime contractor and subcontractors, but not labor overhead.
5%	Design Contingency: includes design and planning costs for unanticipated conditions.
25%	Construction Contingency: includes construction costs for unforeseen conditions.

Table B-2.2.1: Calculation of Soil Volumes

Alternative S2

Soil Volume [CY]			
AOC	**Excavation to Cut Lines [1] [in situ] [CY]**	**Ex-Situ Vol [2] [125%] [CY]**	**Percentage of Total**
OU 1	12,300	15,375	71%
OU 1 Haz	700	875	4.0%
AOC 6	4,300	5,375	24.9%
Total	**17,300**	**21,625**	100%

Alternative S2

Off-Site Disposal			
Bulk Soil[3] [CY] [+15% contingency]	**Bulk Soil [4] [Tons]**	**Haz Soil [CY] [+15% contingency]**	**Haz Soil [4] [Tons]**
17,681	26,522		
		1,006	1509
6,181	9,272		
23,863	35,794	1,006	1509

Calculation of Soil Volume

Area	Total Excavated Volume (CY)	% Soil
OU 1	18,688	75.1%
AOC 6	6,181	24.9%
Total	24,869	

Transportation Related Issues (Rail)

Area	Volume (CY)	Volume [4] [tons]	# of Trips	# of Burritos	Assumption
Alternatives S2-1, S2-6					100% Excavated Soil
OU 1	18,688	28,031	280	280	Volume (tons) = Volume (CY) x 1.5 tons/CY; Gondola Volume = 100 tons/car;
AOC 6	6,181	9,272	93	93	
Total	24,869	37,303	373	373	

Transportation Related Issues (Truck)

Area	Volume [CY]	Volume [4] [tons]	# of Trips	Assumption
Alternatives S2-1, S2-6				
OU 1	18,688	28,031	1752	Volume (tons) = Volume (CY) x1.5 tons/CY; Truck Volume = 16 tons/car;
AOC 6	6,181	9,272	579	
Total	24,869	37,303	2331	

Footnotes

1) Mean upper bound volume estimates - mean volume [based on 10 models] plus standard deviation. Cut lines volume includes estimated using 1 : 1.5 slope from waste. In addition, the in-situ volume was rounded off during this cost estimation.

2) 125% swelling factor applicable in situ estimates

3) Bulk Soil: FUSRAP waste soil plus cut-back. Assumes both will be disposed of as same waste stream.

4) Average density of damp sand [1.7] or 110 pounds / ft^3 or 1.5 tons per cubic yard [EPA/625/12-91/002]

Table B-2.2.2: Duration of Excavation
Alternative S2

OU1 -

18,688	CY ex-situ volume to cut-lines	
16	CY/hour FUSRAP production rate	
0.95	Productivity Factor	2.56 weeks weather delays out of 50 weeks per year (USACE Guidance Document on Delays related to Severe Weather at Aberdeen Proving Ground Area)
0.9	Soil Adjustment Factor	Due to nature of material to be excavated (soils, and/or asphalt, concrete, spotty areas of contamination over large area)
0.75	Safety Factor	Additional Personal Protection Equipment due to hazardous nature of the contaminated materials below 8 ft bgs.

OU 1 Excavation Duration = (ex-situ vol /production rate) *(1/ (HTRW Productivity factor * Soil Adjustment Factor * Safety Factor)

= 168 [10] hour work days
= 42 [40] hour weeks
= 10.5 months

AOC6 -

6,181	CY in-situ volume to cut-lines	
18	CY/hour FUSRAP production rate [shallower excavation, no VOCs]	
0.95	Productivity Factor	2.56 weeks weather delays out of 50 weeks per year (USACE Guidance Document on Delays related to Severe Weather at Aberdeen Proving Ground Area)

AOC 6 Excavation Duration = (ex-situ vol /production rate) *(1/ (HTRW Productivity factor * Soil Adjustment Factor * Safety Factor)

= 36 [10] hour work days
= 9.0 40 hour Weeks

Total Work Days

= 204 [10] hour work days
= 51 [40] hour weeks
= 13 months

Production Rate Assumptions

Assume the crew will excavate 16 cy/hr. at OU1, based on experience at similar FUSRAP sites

1. Level of Personal Protective Equipment is assumed to be Level D Modified
2. Efficiency Factor (HTRW Productivity Factor) = 95%

Table B-2.2.3: Costs Associated with Land Use Controls (LUCs)

The ICs includes both land use controls (LUCs) and administrative controls (zoning, deed restrictions, and/or well construction restrictions)

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Land Use Control					167,286	
Preparatory Work[1]						
Coordination with various local, state, and Federal agencies for land use control plans and administrative mechanism plan					37,165	
Program Manager	160	hr	$128.54	20,566		See Table B-2.5.20
Project Manager	160	hr	$103.74	16,598		
Coordination with owners for land use control plans and administrative mechanism plan					4,150	
Project Manager	40	hr	$103.74	4,150		See Table B-2.5.20
Land Use Control Plan[2]					59,946	
Project Manager	80	hr	$103.74	8,299		See Table B-2.5.20
Principal Health Physicist	80	hr	$116.00	9,280		
1 Senior Scientist	160	hr	$103.74	16,598		
I Junior Engineer	240	hr	$64.76	15,542		
1 Attorney	40	hr	$151.96	6,078		
1 GIS Operator	40	hr	$61.44	2,458		
Administrative Assistant	40	hr	$42.26	1,690		
Administrative Mechanism Plan[3]					66,025	
Project Manager	80	hr	$103.74	8,299		See Table B-2.5.20
Principal Health Physicist	80	hr	$116.00	9,280		
1 Senior Scientist	160	hr	$103.74	16,598		
I Junior Engineer	240	hr	$64.76	15,542		
1 Attorney	80	hr	$151.96	12,157		
1 GIS Operator	40	hr	$61.44	2,458		
Administrative Assistance	40	hr	$42.26	1,690		
Construct - Land Use Control						
Install Signage	Fabricated stainless Steel, 18" high, 4" deep				4,776	RSMeans (10 14 19.10.2100)
Number of Signs	Install 18" Caution - "Radiological Material" Signs					
OU 1	4		$292.00	1,168		
AOC 6	2		$292.00	584		
Equipment Rental OU 1	1.5	day	$20.00	30		Assumed
Equipment Rental AOC 6	0.5	day	$20.00	10		
Union Laborer (2) OU 1	12	hrs	$49.02	1,176		See Table B-2.2.6
Union Laborer (2) AOC 6	4	hrs	$49.02	392		
Install Fencing and Gates	Install up to 1632 ft of fencing @ 165 ft/day				124,288	
Raw Materials						
Permanent Fencing	6 ga. wire, 6" high but omit barded wire, galvanized steel					RSMeans (32 31 13.20.0800)
OU 1	1260	LF	$31.00	39,060		
AOC 6	372	LF	$31.00	11,532		
Gates	6' high, 12' opening, in concrete (Double swing gates, incl. posts & hardware, in concrete)					RSMeans, 32 31 13.20 5060
OU 1	2		$1,350	2,700		
AOC 6	1		$1,350	1,350		
Labor OU 1						
Prep Work (2 laborers)	16	hrs	$49.02	1,569		See Table B-2.2.6
Installation Work (2 laborers)	80	hrs	$49.02	7,843		
Perdiem [CONUS + 15% tax]	12	days	$126.50	1,518		
Labor AOC 6						
Prep Work (2 laborers)	4	hrs	$49.02	392		See Table B-2.2.6
Installation Work (2 laborers)	16	hrs	$49.02	1,569		
Perdiem [CONUS + 15% tax]	3	days	$126.50	316		
Site Information Database [4]	200	hrs	$61.44	12,288		

Footnote

[1,2,3,4] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.4: Costs Associated with Preparatory Work

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost	Assumptions
Preparatory Work[1]						**223,793**	
Submittals/Implementation Plan						*127,178*	
Environmental Protection Plan					24,898		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineer	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Sedimentation Control Plan					29,047		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Geologist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
Site Safety and Health Plan					27,317		
Senior Health Physicist	40	hr	$116.00	4,640			20 hrs/contract; 2 contracts
Site Safety & Health Officer	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
General Site Work Plan					25,890		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Construction Manager	40	hr	$128.54	5,142			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Quality Control Plan					18,527		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Quality Control Engineers	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Permits	2		$750	1,500	1,500		$750/ permit
Setup/Construct Temp Facilities						*24,987*	
Operation Trailer	1	LS	$ 9,098	9,098			1 for both contracts
HP Trailer	1	LS	$ 7,806	7,806			1 for both contracts
Break Trailer	1	LS	$ 2,770	2,770			1 for both contracts
Toilets	2	LS	$100	200			1 for each contract
Barricades	2	LS	$1,500	3,000			1 for each contract
Signs	4	LS	$292	1,168			2 for each contract
Monthly Operating Cost						*58,168*	
Operation Trailer	16	months	$ 704.91	11,279			
HP Trailer	16	months	$ 2,266.70	36,267			
Break Trailer	16	months	$ 663.88	10,622			
Construct Temporary Utilities						*4,660*	
Power Connection/Distribution	2	LS	$500	1,000			1 for each contract
Telephone/Communication Dist.	2	LS	$100	200			1 for each contract
Water Connection/Distribution	2	LS	$1,430	2,860			1 for each contract
Sewer Connection/Distribution	2	LS	$300	600			1 for each contract
Monthly Cost -Utilities						*8,800*	
Power Distribution	16	months	$250	4,000			
Telephone/Communication Dist.	16	months	$100	1,600			
Water Distribution	16	months	$100	1,600			
Sewer Distribution	16	months	$100	1,600			

[1] Based on percentage of soil volume at OU1 and AOC6, the total preparatory cost was divided among OU1 and AOC 6.

Table B-2.2.5: Costs Associated with Mobilization

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost ($)	Assumptions
Mob Construction Equip & Fac [1]						*49,188*	
Permits	2		$500	1,000	1,000		
Construction Equipment					48,188		
Water Truck - Operation	16	hr	$61.38	982			8 hrs/contract; 2 contracts
Water Truck - Standby	64	hr	$15.28	978			32 hrs/contract; 2 contracts
Hydraulic Excavator - Operation	16	hr	$134.41	2,151			8 hrs/contract; 2 contracts
Hydraulic Excavator - Standby	64	hr	$36.79	2,355			32 hrs/contract; 2 contracts
PM Roller -Operation	16	hr	$29.67	475			8 hrs/contract; 2 contracts
PM Roller- Standby	64	hr	$6.41	410			32 hrs/contract; 2 contracts
PM Dozer, CWLR-Operation	16	hr	$49.71	795			8 hrs/contract; 2 contracts
PM Dozer, CWLR-Standby	64	hr	$10.52	673			32 hrs/contract; 2 contracts
PM Dozer, CWLR-Operation	16	hr	$60.94	975			8 hrs/contract; 2 contracts
PM Dozer, CWLR-Standby	64	hr	$15.62	1,000			32 hrs/contract; 2 contracts
PM Loader, FE - Operation	16	hr	$60.99	976			16 hrs/contract; 2 contracts
PM Loader, FE-Standby	64	hr	$15.67	1,003			64 hrs/contract; 2 contracts
Pile Hammer - Operation	8	hr	$63.45	508			4 hrs/contract; 2 contracts
Pile Hammer - Standby	16	hr	$11.95	191			8 hrs/contract; 2 contracts
TRLR, LOWBOY	80	hr	$6.88	550			40 hrs/contract; 2 contracts
2 TRK HWY-Operation	128	hr	$35.40	4,531			8 hrs/contract; 2 contracts
2 TRK HWY-Standby	128	hr	$7.97	1,020			8 hrs/contract; 2 contracts
Equipment Operator-Operation	128	hr	$49.02	6,275			8 hrs/contract; 2 contracts
Equipment Operator-Standby	128	hr	$49.02	6,275			8 hrs/contract; 2 contracts
2 Truck Drivers	128	hr	$49.02	6,275			8 hrs/contract; 2 contracts
Outside Laborers (2)	80	hr	$49.02	3,922			8 hrs/contract; 2 contracts
Perdiem [CONUS + 15% tax]	46	days	$126.50	5,870			

[1] Based on percentage of soil volume at OU1 and AOC6, the total mobilization cost was divided among OU1 and AOC 6.

Table B-2.2.6: Area, Number, and Types of SU and Number of Confirmatory Soil Samples

EU	Location	Class 1 Areas	Class 2 Areas	Total Area (m^2)	Survey Units	# of Soil Samples
3B	AOC 6	606	11472	12078	1 Class 1 and 2 Class 2	42
1	AOC 1 and AOC 2	2620	21086	23706	2 Class 1 and 2 Class 2	56

Other Samples to be Collected during Excavation
# of surface water samples for CDD = 10
# of sediment samples for CDD = 10
Total Samples = 98 Soils, 10 Sediments, 10 surface water, 6 laboratory control samples, 11 Lab Duplicates, 11 Field Duplicates, 6 MS/MSD samples and 11 Method Blanks

Air Monitoring Stations = 4 to 5 around Class 1 areas (downgradient to the air flow)
TLD Measurements for each person working at the site

High Volume Air Samplers and Personal Sample
2 high volume air samplers and 1 personal samples will be analyzed on-site per week.
Samples will be analyzed for gamma spec and gross alpha/beta.

Location	Excavation Duration		Air Sample		
	[10] hr workdays	[40] hours week	High volume	Personal	Total
OU1	168	42	84	42	**126**
AOC6	36	9.0	18	9	**27**

Table B-2.2.7: Costs Associated with Environmental Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Monitoring, Sampling, Test, Analysis					
Offsite Sample Analysis Cost					**176,577**
Environmental Monitoring					see Table B-2.5.21
OU 1	91	samples	$ 672.00	61,152	
AOC 6	73	samples	$ 672.00	49,056	
Chemical/Rad Lab Air Analysis					
OU 1					
Gamma Spec	126	samples	$119.00	14,972	
Iso U	126	samples	$157.50	19,816	
Iso Th	126	samples	$157.50	19,816	
AOC 6					
Gamma Spec	27	samples	$119.00	3,226	
Iso U	27	samples	$157.50	4,270	
Iso Th	27	samples	$157.50	4,270	
Additional Labor & Services					705,836
Includes preparation of Gamma Walkover Survey, FSS report, and collection of FSS samples.					See Table B-2.5.20
OU 1					
Project Manager	160	hrs	$103.74	16,598	
Principal Health Physicist	520	hrs	$116.00	60,320	
4 Junior HPs	4 x 168 days x 10 hrs/day	hrs	$64.76	434,541	
Perdiem [2010 CONUS rate + 15% tax]	740	days	$126.50	93,610	
AOC 6					
Project Manager	24	hrs	$103.74	2,490	
Principal Health Physicist	40	hrs	$116.00	4,640	
4 Junior HPs	4 x 36 days x 10 hrs/day	hrs	$64.76	93,637	
Perdiem [2010 CONUS rate + 15% tax]	150	days	$126.50	19,026	
Onsite Laboratory Cost[1]					**683,508**
The engineering estimate is based on installing a mobile lab similar to the St. Louis FUSRAP site					
On-site Mobile Laboratory Setup Cost	1	LS	$187,000	187,000	
On-site Mobile Laboratory Operating Cost	13.0	months	$5,430.75	70,600	See Table B-2.5.22
Environmental Monitoring					
OU 1	182	samples	$336.00	61,152	
AOC 6	146	samples	$336.00	49,056	
On-Site Laboratory Labor & Services					
Lead Technician	204 days x 10 hrs/day	hrs	$64.76	132,044	
Lab Technician	204 days x 10 hrs/day	hrs	$64.76	132,044	
Perdiem [2010 CONUS rate + 15% tax]	408	days	$126.50	51,612	
Waste Profile Cost[2] (Assume 20 samples)					
Chemical Parameters					**26,600**
TCLP VOCs	20	samples	$ 148.75	2,975	See Table B-2.5.21
TCLP SVOCs	20	samples	$ 271.25	5,425	
TCLP Pesticides/Herbicides	20	samples	$ 420.00	8,400	
TCLP (8 RCRA Metals+Zinc)	20	samples	$ 148.75	2,975	
Ignitability	20	samples	$ 35.00	700	
Corrosivity	20	samples	$ 17.50	350	
Toxicity	20	samples	$ 70.00	1,400	
Reactive Cyanide& Sulfide	20	samples	$ 105.00	2,100	
PCBs	20	samples	$ 113.75	2,275	
Radionuclides					**13,440**
Gamma Spec	20	samples	$ 119.00	2,380	See Table B-2.5.21
Ra-226	20	samples	$ 119.00	2,380	
Ra-228	20	samples	$ 119.00	2,380	
Iso-U	20	samples	$ 157.50	3,150	
Iso-Th	20	samples	$ 157.50	3,150	
Monitoring Equipment Cost[3]					**214,665**

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Bioassays (14 months for 20 peoples)	20	people	$168.77	3,375	Previous Experiences at Other FUSRAP Sites
Fiskers (2 for Excavated Areas, 2 for loading Areas and 1 at Onsite Lab)	5 x 13 months	month	$145	9,239	
Radiological Detectors					
FIDLER w/scaler	1x 13 months	month	$548	6,984	
Alpha/beta detectors (e.g., Ludlum Models 43-93)	2 x 13 months	month	$96	2,447	
Radiological Meters					
A smear counter (Ludlum Model 2929)	2 x 13 months	month	$211	5,378	
Dosimetry					
TLDs	20 x 13 months	month	$100	25,487	
Radiological Air Samplers					
Personal Air Sampling Pumps	3 x 13 months	month	$83	3,173	
Air Sampling Pump Chargers	2 x 13 months	month	$52	1,325	
High Volume Air Samples	10 x 13 months	month	$130	16,567	
Field Sampling Equipments					
GPS- Trimble XR-Pro	13	month	$1,104	140,690	
PPE Cost[4]					**95,067**
Number of People using PPE	20 persons x 204 workdays		$ 23.31	95,067	See Table B-2.5.23

[1,2,3,4] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.8: Costs Associated with Site Work

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
****Site Work***					***1,234,549***	
Earthwork[1]					811,127	
Backfill (Dozer, Backfilling, no compaction, up to 300')	24,869	CY	$1.54	38,298		31 23 23.13 1300
Borrow (Fill , load, 1 mile haul, spread with dozer)	24,869	CY	$11.30	281,017		31 23 23.16 0020
Hauling (15 MPH ave., 0.5 mile, 25 min wait/Ld./Uld)	24,869	CY	$5.20	129,318		31 23 23.20 0314
Compaction[2]					134,888	
Riding Compaction (sheepsfoot roller, 8" lifts, common fill)	24,869	CY	$1.50	37,303		31 23 23.24 0300
Water Compaction	24,869	CY	$1.50	37,303		Assumed
*** Roads*					130,286	
Bituminous Surfacing						
Asphaltic Conc (3" Thick -Binder Course)	157	SY	$11.75	1,845		32 12 16.13 0160
Asphaltic Conc (3" thick Wearing Course)	157	SY	$11.44	1,796		32 12 16.13 0460
Prime Coat (Surface Treatment)	1,406	CSF	$3.68	5,174		32 11 26.19 0800
Base Course (Crushed Stone)	157	SY	$15.40	2,418		32 11 26.19 1100
Geotextile Fabric	157	SY	$2.13	334		
Striping	78	MLF	$194.72	15,188		Road = 51' x 27'
Pavement Removal (Bituminous roads, 4" to 6" thick)	157	SY	$7.90	1,240		02 41 13.17 5010
Hauling of Pavement for Disposal						
Hwy Haulers (15 MPH ave, cycle 0.5 mile, 25 min. wait)	157	CY	$5.20	816		31 23 23.20 0314
Landfill Tipping Fee for Con	157	CY	$263.50	41,370		02 81 20.10 1100
Traffic Control	175	hr	$10.74	1,880		
Additional Labor & Services (Backfilling)					148,248	
Engineering Manager	255	hr	$103.74	26,440		See Table B-2.5.20
Lead Engineer	255	hr	$103.74	26,440		
Engineer	1,019	hr	$64.76	66,022		
Perdiem [CONUS + 15% tax]	153	days	$126.50	19,345		
Surveying Services	1	ls	$5,000	5,000		Assumption
Compaction Testing	1	ls	$5,000	5,000		Assumption
Misc. Utility Relocations	1	ls	$10,000	10,000	10,000	Assumption

[1,2] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.9: Costs Associated with Storm Water and Erosion Control

Surface Water and Groundwater Collection during Dewatering and Control

Assumptions
Average monthly surface water accumulation = 2 inches.
Infiltration Rate = 20%

Total Area of Excavation = 312,955 ft^2.
Total Volume of surface water to be collected = (312,955 ft^2 x (2/12) ft x 0.8 x 7.48 gal/ft^3) = 312,120 gallons
Total Volume of Groundwater Produced during Dewatering Process

OU 1 =	857	gal/day x	168	days =	143,762	gallons
AOC 2 B Aquifer =	36000	gal/ day x	5	days =	180,000	gallons
AOC 6 =	8735	gal/ day x	36	days =	315,750	gallons
		Total Volume Produced Groundwater =			**639,512**	gallons

Design of SW Treatment System
Use 10 each, 18000 gallons above-ground storage tanks during the duration of excavation activities (13 months).
A complete Z-92 Uranium removal portable exchange system will be used to treat the surface water.

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Cost ($)	Sources for Unit Cost
Surface Water and Sediment Control					**1,146,782**	
Surface Water and Groundwater Collect & Control					***1,119,164***	
Water Management [1]					368,852	
Engineering Manager	510	hr	$103.74	52,881		See Table B-2.5.20
Construction Engineer	1019	hr	$128.54	131,045		
Senior Engineer	510	hr	$103.74	52,881		
Junior Engineer	2039	hr	$64.76	132,044		
Water Treatment [2]					750,312	
Renting of Aboveground Storage Tank	13.0	months	$1,500	$195,000		Quote from Sub Contractor
Granular Activation Carbon						
Capital Cost	1	LS	$10,000	10,000		
O & M Cost	1	yr	$25,000	25,000		
Equipment Cost (U Removal System)	1	LS	$103,020	103020		
Additional Piping Cost	1	LS	$5,000	5000		
Consulting Services	1	yr	$2,000	2,000		
Testing & Analysis	204	days	2 samples/day x $50/sample	20,390		
HP Tech	13.0	months	$5,000	65,000		
Permit Coordinator	510	hr	$95.60	48,732		
Chemical Engineer	2039	hr	$103.74	211,524		
Perdiem [CONUS + 15% tax]	511	days	$126.50	64,647		
Sediment Control					***27,618***	
Sediment Barriers					27,618	
s, Polypropylene. 3' High (Adverse Condition)						
OU 1	1260	LF	$1.26	1,588		31 25 13.10 1100
AOC 6	372	LF	$1.26	469		32 25 13.10 1100
Hay Bales, Staked						
OU 1	1260	LF	$8.10	10,206		31 25 13.10 1250
AOC 6	372	LF	$8.10	3,013		31 25 13.10 1250

[1,2] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.10: Costs Associated with Soil Excavation

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Solids Collect and Containment					***1,503,169***	
Contaminated Soil Collection					*1,503,169*	
Excavation						
Hydraulic Excavator[1]	24,869	CY	$6.95	172,838	172,838	31 23 16.13 0500
Hauling (15 MPH ave,cycle 0.5 mile, 25 min wait)[2]	24,869	CY	$5.20	129,318	129,318	31 23 23.20 0314
Additional Labor & Services[3]					956,872	
Site Manager	510	hr	$103.74	52,881		See Table B-2.5.20
Senior Engineer	1019	hr	$103.74	105,762		
Field Engineer	2039	hr	$64.76	132,044		
Principal Health Physicist	510	hr	$116.00	59,130		
Environmental Scientist	2039	hr	$64.76	132,044		
Field Supervisor	2039	hr	$54.12	110,350		
Operators(s)	4078	hr	$49.02	199,902		
Perdiem [CONUS + 15% tax]	1223	days	$126.50	154,759		
Surveying Services	1	ls	$5,000	5,000		Assumption
Geotech Services	1	ls	$5,000	5,000		Assumption

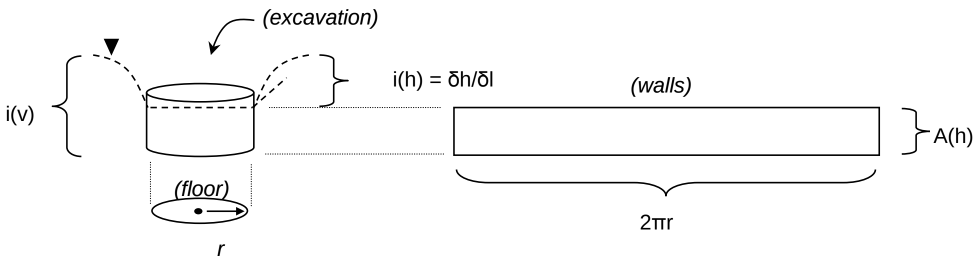
[1,2,3] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.11: Steady-State Flow to an Excavation using Darcy's Law

Author: Carl Young, P.G.
Date: 2/15/2010
Project: OU 1

Darcy's Law : Q = kiA

Where: Q=flow, k=hydraulic conductivity, i=gradient, A=cross sectional area perpendicular to flow



r =	15.0 m	i(h) =	20%	k(h) =	1.0E-05	m/s [avg. sand]
2πr	94.2 m	i(v) =	100%	k(v) =	5.0E-06	m/s [50% of k(h)]
A(h) =	2 m					

Flow through excavation walls [Qh]: Qh = k(h) * i(h) * [2πr*A(h)]

horizontal hydraulic conductivity [k(h)] =	1.0E-05	m/s		
hydraulic gradient [i(h)] =	20%	[-]		
flow cross sectional area (walls) [Aw] =	188.4	m^2		
Qh =	3.8E-04	m^3/s =	6.0	gpm

Flow through excavation floor [Qv]: Qv = k(v) * i(v) * [π*r^2]

vertical hydraulic conductivity [k(v)] =	5.0E-06	m/s		
hydraulic gradient [i(v)] =	100%	[-]		
flow cross sectional area (floor) [Af] =	706.5	m^2		
Qv =	3.5E-03	m^3/s =	56.0	gpm

Total groundwater flow into excavation [Q]: Q = Qh + Qv

Q = 3.9E-03 m^3/s = 62.0 gpm

Basis of Estimates:

A(h): est. 6 ft excavation into B Aquifer
i(h): estimated gradient drawdown [Introduction to Geotechnical Processes, John Woodward, 2005, Sec. 3]
i(v): vertical gradient is equal to depth of penetration into aquifer
k(h): average hydraulic conductivity for silty sand [Groundwater, Freeze & Cherry, 1979, Table 2.2]
k(v): vertical (k) is estimated at 50% of k(h) [Groundwater, Freeze & Cherry, 1979, Sec. 2.4, pg.32]

Table B-2.2.12: Costs Associated with Soil Dewatering Process

Soils that have been excavated from below the water table will require a dewatering step, because the segmented gate system (SGS) equipment requires loose and "clump-free" soil so that the soil passing under the radiation sensors is in a relatively thin layer.

Estimated time for excavation: 168 work days [OU1]
Time for dewatering OU1 [below water table] = work days x 20%
34 work days

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Dewatering					**317,160**	
Premoblization & Mobilization	1	LS	$7,500	7,500		
6" centrifugal pump (10 gpm)	1	LS	$1,050	1,050		31 23 19.20 1100
20' Deep wells	20	LF	$67.50	1,350		31 23 19.30 0020
Installation and Removal of Single stage System	500	LF	$36.50	18,250		31 23 19.40 0110
Pump Operation	2	months	$47,000	94,000		31 23 19.40 0500
500' long header, 8" diameter	2	months	$238	476		31 23 19.40 1300
Demobilization	1	LS	$15,000	15,000		Assumed
Technical Support Options						
Site Activities	336	hr	$100	33,550		Assumed
Per Diem	34	days	$126.50	4,244		Assumed

Table B-2.2.13: Costs Associated with Staging and Loading Area

The total concrete slab area calculated for soil staging (5000 CY), soil loading, and truck staging (2 each) was 11,000 SF.

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Staging and Loading Area[1]					**217,960**
Pad Subgrade Preparation	980	CY	$5.85	5733	
Cat 215, 1.0 CY, Soil, Shallow, Trenching	3.47	CY	$1.62	6	
Compact Subgrade, 2 Lifts	980	CY	$0.61	598	
Dry Roll Gravel, Steel Roller	1468	SY	$1.05	1541	
Gravel, Delivered and Dumped	407	CY	$27.67	11262	
Gravel (90%) & Sand Base (10%), with Calcium Chloride (1 lb/CY)	407	CY	$28.07	11424	
Concrete Curb (6" x 6")	859	LF	$2.68	2302	
26"x 26", 5' Deep Area Drain with Grate	1	EA	$3,370.74	3371	
6" Structural Slab on Grade	11000	Sf	$6.40	70400	
Reinforced Concrete Sump	1	EACH	$4,048.88	4049	
CIP Concrete In-Ground Trench Drain with Metal Grate	39	LF	$118.12	4607	
Erosion Control/Drainage Filter Fabric (80 Mil)	1468	SY	$1.54	2261	
Pump and Controls	1	LS	$2,000	2,000	
Discharge Piping	1	LS	$1,000	1,000	

[1] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.14: - Costs Associated with Disposal

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Disposal (Commercial)					
Transportation to Storage/Disposal Facility					
Loading of Solids[1]					**720,453**
1 FE Loader	2039	Hr	$54.12	110,350	
Outside Equip. Operators (2)	4078	Hr	$49.02	199,902	
Outside Laborer Foreman	2039	Hr	$54.12	110,350	
Outside Laborers (3)	6117	Hr	$49.02	299,852	
Transportation and Emergency Response Plan[2]					**10,258**
Project Manager	8	hr	$116.00	928	
Senior Engineer	40	hr	$103.74	4,150	
Junior Engineer	80	hr	$64.76	5,181	
Transportation Costs (Rail)					
OU 1					**4,498,132**
OU 1 (Rail)					
Burrito	280	trip	$1,000	280,313	
Transportation cost by Rail to US Ecology	280	trip	$14,000	3,924,375	
DuPont RR Bumping Fee	561	trip	$150	84,094	
Absorbent Material	841	each	$20	16,819	
Demurrage Charge	374	hr	$65	24,310	
OU 1 (Truck)					
Dump Truck (2 each)	1752	trip	$72.74	127,437	
Truck Drivers (2)	832	hrs	$49.02	40,785	
AOC 6					**1,474,545**
AOC 6 (Rail)					
Burrito	93	trip	$1,000	92,719	
Transportation cost by Rail to US Ecology	93	trip	$14,000	1,298,063	
DuPont RR Bumping Fee	185	trip	$150	27,816	
Absorbent Material	278	each	$20	5,563	
Demurrage Charge	93	hr	$65	6,027	
AOC 6 (Truck)					
Dump Truck (2 each)	579	trip	$72.74	42,152	
Truck Drivers (2)	45	hrs	$49.02	2,206	
Disposal Fees and Taxes					**4,334,063**
Landfill					
OU 1					
US Ecology-Bulk Soil	26,522	tons	$100	2,652,188	
US Ecology-HazWaste	1,509	tons	$500	754,688	
AOC 6					
US Ecology-Bulk Soil	9,272	tons	$100	927,188	

[1,2] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.15: - Costs Associated with Excavation of Test Pits

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost ($)	Assumptions
# of Test Pits	6					64,619	Each pit = 27 yd3
Loader-backhoe, Heavy soil	162	CY	$63.50	10,287	10,287		02 32 19.10 0130
Additional Labor & Services					36,020		
Site Manager	40	hr	$103.74	4,150			See Table B-2.5.20
Principal Health Physicist	80	hr	$116.00	9,280			
Environmental Scientist	80	hr	$64.76	5,181			
Geotech Services	1	ls	$5,000	5,000			
2 laborers	160	hr	$49.02	7,843			
Perdiem [CONUS + 15% tax]	36	days	$126.50	4,567			
Sampling Costs	1	LS	$10,000	10,000	10,000		Assumption

Table B-2.2.16: Costs Associated with Site Restoration

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Site Restoration					***22,229***	
Earthwork	It includes rough grading with dozer, followed by fine grading				*5,850*	
Grading					5,850	
OU 1	5.86	acres	$650	3,809		Previous Experiences at Other FUSRAP Sites
AOC 6	3.14	acres	$650	2,041		
Revegetation & Planting	It includes watering, mechanical seeding and spray fertilizer				*12,934*	
Hydroseeding, 67% Level & 33% Sloped					5,951	
OU 1	5.86	acres	$661.17	3,874		
AOC 6	3.14	acres	$661.17	2,076		
Fertilizer, Hydro Spread					1,778	
OU 1	5.86	acres	$197.59	1,158		
AOC 6	3.14	acres	$197.59	620		
Watering with 3000-gallon Tank Truck					705	
OU 1	5.86	acres	$78.35	459		
AOC 6	3.14	acres	$78.35	246		
Miscellaneous Landscaping					4,500	
OU 1	5.86	acres	$500	2,930		
AOC 6	3.14	acres	$500	1,570		
Site Cleanup					*3,445*	
Site Debris Cleanup and Removal Cost					3,445	
OU 1	5.86	acres	$382.81	2,243		
AOC 6	3.14	acres	$382.81	1,202		

Table B-2.2.17: Costs Associated with Demobilization

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Demobilization [1]					***126,216***	
Removal of Temporary Facilities					21,850	Previous Experiences at Other FUSRAP Sites
Office Trailers (Contractor) only	1	LS	$750	750		
Storage Facilities	1	LS	$2,500	2,500		
Decon. Fac. For Const. Equip	1	LS	$15,000	15,000		
Toilets	2	LS	$100	200		
Barricades	2	LS	$1,500	3,000		
Signs	4	LS	$100	400		
Removal of Temporary Utilities					2,710	
Power Connection/Distribution	2	LS	$500	1,000		
Telephone/Communication Dist.	2	LS	$55	110		
Water Connection/Distribution	2	LS	$500	1,000		
Sewer Connection/Distribution	2	LS	$300	600		
Demob of Construction Equip/Fac						
Permits	1	LS	$500	500	500	
Demob. Of Construction Equipment					44,439	
Water Truck - Operation	16	hr	$61.38	982		
Water Truck - Standby	64	hr	$15.28	978		
Hydraulic Excavator - Operation	8	hr	$134.41	1,075		
Hydraulic Excavator - Standby	64	hr	$36.79	2,355		
PM Roller -Operation	16	hr	$29.67	475		
PM Roller- Standby	64	hr	$6.41	410		
PM Dozer, CWLR-Operation	16	hr	$49.71	795		
PM Dozer, CWLR-Standby	64	hr	$10.52	673		
PM Dozer, CWLR-Operation	16	hr	$60.94	975		
PM Dozer, CWLR-Standby	64	hr	$15.62	1,000		
2 PM Loader, FE - Operation	32	hr	$60.99	1,952		
2 PM Loader, FE-Standby	128	hr	$15.67	2,006		
CR, ME, CWLR, Lifting - Operation	8	hr	$91.24	730		
CR, ME, CWLR, Lifting - Standby	16	hr	$30.43	487		
Pile Hammer - Operation	8	hr	$83.45	668		
Pile Hammer - Standby	16	hr	$11.95	191		
TRLR, LOWBOY	80	hr	$6.88	550		
TRK HWY - Operation	80	hr	$35.40	2,832		
TRK HWY - standby	80	hr	$7.97	638		
Equip, Operators-Standby	80	hr	$49.02	3,922		
Equip, Operators-Operation	80	hr	$49.02	3,922		
Outside Truck Driver	80	hr	$49.02	3,922		
2 Outdoor Laborers	160	hr	$49.02	7,843		
Perdiem [CONUS + 15% tax]	40	days	$126.50	5,060		
Decon. Of Construction Equipment					56,717	
Mechanics Truck	224	hr	$7.97	1,785		
Equipment Operators	224	hr	$49.02	10,980		
2 Outdoor Laborers	448	hr	$49.02	21,961		
Perdiem [CONUS + 15% tax]	89.6	days	$126.50	11,334		
Small Tools	224	hr	$37.52	8,404		
Power Washer	224	hr	$1.57	352		
Compressor	224	hr	$8.48	1,900		

[1] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.18: Costs Associated with Submittals

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Submittals					***8,562***	
Project Acceptance					8,562	
Cost Accountant	80	hr	$64.76	5,181		See Table B-2.5.20
Administrative Assistance	80	hr	$42.26	3,381		

[1] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.19: Costs Associated with Annual Operation, Maintenance & Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Assumptions
Annual Operation, Maintenance, & Monitoring						
Monitoring [1]	1	yr	$0	0	0	Monitoring of Groundwater
Five Year Review (Per Event) [2]					31,598	
1 Project Manager	40	hr	$103.74	4,150		40 hrs per review
Principal Health Physicist	40	hr	$116.00	4,640		40 hrs per review
1 Senior Scientist	80	hr	$103.74	8,299		40 hrs/review
I Junior Engineer	160	hr	$64.76	10,362		160 hrs/review
1 GIS Operator	40	hr	$61.44	2,458		
Administrative Assistance	40	hr	$42.26	1,690		
Post Remedial Site Supervision (per Year) [3]					55,120	
1 Site Supervisor	1000	hr/yr	$54.12	54,120		4 hr/day for 250 days/yr
Miscellaneous Equipment Cost	1	yr	$1,000	1,000		

[1,2,3] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.2.20: Labor Rates

DISCIPLINES	Code	Base Labor Rates	Burdened Labor Rates [1]
Principal	PRI	$75.98	$151.96
Program Manager	PGM	$64.27	$128.54
Senior Project Manager	SPM	$51.87	$103.74
Regulatory Specialist	RSP	$47.80	$95.60
Industrial Hygienist (Certified)	CIH	$51.87	$103.74
Sr. Environmental Scientist	SES	$51.87	$103.74
Sr Health Physicist	SHP	$58.00	$116.00
Senior Scientist	SSC	$51.87	$103.74
Senior Engineer	SEN	$51.87	$103.74
Senior Geologist	SGE	$51.87	$103.74
Construction Manager	CM	$64.27	$128.54
Quality Control Specialist	QC	$44.93	$89.86
Site Safety & Health Officer	SHO	$44.93	$89.86
Jr Health Physicist	JHP	$32.38	$64.76
Cost Accountant	AC	$32.38	$64.76
Junior Engineer	JEN	$32.38	$64.76
Illustrator/draftsperson	GIS	$30.72	$61.44
Senior Hydrologist	SHY	$58.00	$116.00
Jr. Environmental Scientist	JES	$32.38	$64.76
Junior Scientist	JSC	$32.38	$64.76
Field Supervisor	FS	$27.06	$54.12
Chemist	CH	$32.38	$64.76
Administrative Assistant	AA	$21.13	$42.26
Truck Driver	TD	$24.51	$49.02
Laborer	LAB	$24.51	$49.02

[1] Burdened labor rates include labor overhead multiplier but not profit
Labor Overhead Multiplier (LOH) = 2.0

Table B-2.2.21: Analytical Cost ($)

Radionuclides	***Unit Cost***	**Total Cost**
Soil Sample Analysis		
Gamma Spec	119.00	
Ra-226	119.00	
Ra-228	119.00	
Iso-U	157.50	
Iso-Th	157.50	
		672.00
TCLP VOCs	148.75	
TCLP SVOCs	271.25	
TCLP Pesticides/Herbicides	420.00	
TCLP (8 RCRA Metals+Zinc)	148.75	
Ignitability	35.00	
Corrosivity	17.50	
Toxicity	70.00	
Reactive Cyanide& Sulfide	105.00	
PCBs	113.75	
		1,330.00
Air Filter Sample Analysis		
Gamma Spec	119	
Iso U	157.5	
Iso Th	157.5	
		434.00
Groundwater Sample Analysis		
Gross Alpha/Beta	$ 50.00	
Ra-226/Ra-228	$ 65.00	
Iso Thorium	$ 80.00	
Iso Uranium	$ 80.00	
		275.00

Table B-2.2.22: PPE Costs

	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity Needed Per Person Per Day	Extended	Comments/Assumptions
Level D Modified (cost per person-day)							
Cotton Liner Gloves (6 pair)	Pack	$ 5.47	$ 0.33	$ 5.80	0.6667	$ 3.87	4 pair per person per day
Duct Tape (2 rolls)	Pack	$ 7.96	$ 0.48	$ 8.44	0.0333	$ 0.28	2 yd per person per day
Face Shield (clear visor)	Each	$ 7.48	$ 0.45	$ 7.93	0.0042	$ 0.03	1 per person per year
Face Shield (ratchet head gear)	Each	$ 15.50	$ 0.93	$ 16.43	0.0042	$ 0.07	1 per person per year
Hard hat	Each	$ 8.00	$ 0.48	$ 8.48	0.0042	$ 0.04	1 per person per year
Hearing Protection (200 pair)	Case	$ 31.60	$ 1.90	$ 33.50	0.0150	$ 0.50	3 pair per person per day
Nitrile Gloves (lab grade) (box 50 pair)	Box	$ 11.95	$ 0.72	$ 12.67	0.0800	$ 1.01	4 pair per person per day
Rain gear	Each	$ 115.70	$ 6.94	$ 122.64	0.0042	$ 0.51	1 set per person per year
Reflective Vest	Each	$ 10.99	$ 0.66	$ 11.65	0.0500	$ 0.58	1 per person per month
Rubber Overboots	Pair	$ 29.80	$ 1.79	$ 31.59	0.0083	$ 0.26	2 per person per year
Safety Glasses	Pair	$ 3.16	$ 0.19	$ 3.35	0.0167	$ 0.06	4 per person per year
Safety Shoes	Each	$ 100.00	$ -	$ 100.00	0.0042	$ 0.42	1 pair per person per year - $100 limit
Tyvek Suits - Medium Weight w/ hood and shoe covers (case 25)	Case	$ 123.30	$ 7.40	$ 130.70	0.1200	$ 15.68	3 per person per day
Work Gloves (leather/cotton insulated)	Pair	$ -	$ -	$ -	0.2000	$ -	1 per person per week
Work Gloves (leather/cotton)	Pair	$ 2.64	$ 0.16	$ 2.80	0.2000	$ 0.56	1 per person per week
	COST PER PERSON-DAY FOR MODIFIED LEVEL D					**$ 23.31**	

Table B-2.2.23: Trailer Costs - Initial Setup

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Operations Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	2	$ 295.93
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	1	$ 104.93
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	3	$ 572.37
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	2	$ 275.58
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	3	$ 2,594.72
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	6	$ 64.81
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	3	$ 111.27
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	6	$ 12.66
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	3	$ 158.97
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	3	$ 83.89
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (24 person)	Each	$ 51.20	$ 3.07	$ 54.27	1	$ 54.27
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	4	$ 27.69
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
		TOTAL COST FOR OUTFITTING OPERATIONS TRAILER				**$ 9,098.47**
HP Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	3	$ 443.90
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	3	$ 314.79
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	1	$ 190.79
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	1	$ 137.79
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	2	$ 1,729.81
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	2	$ 21.60
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	1	$ 37.09
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	1	$ 2.11
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	2	$ 105.98
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	1	$ 27.96
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	2	$ 13.84
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
		TOTAL COST FOR OUTFITTING HP TRAILER				**$ 7,806.12**
Break Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	1	$ 147.97
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	5	$ 524.65
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	5	$ 264.95
Microwave	Each	$ 269.00	$ 16.14	$ 285.14	3	$ 855.42
Refrigerator	Each	$ 629.10	$ 37.75	$ 666.85	1	$ 666.85
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
Large Trash Can	Each	$ 29.97	$ 1.80	$ 31.77	3	$ 95.30
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
`		**TOTAL COST FOR OUTFITTING BREAK TRAILER**				**$ 2,770.18**
		TOTAL COST FOR OUTFITTING SITE TRAILERS				**$ 19,674.77**

Trailer Costs - Monthly

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Laboratory Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	2	$ 110.22
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	2	$ 10.58
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	3	$ 19.05
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	1	$ 16.95
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	1	$ 24.37
Staples (pack 6000)	Each	$ 1.79	$ 0.11	$ 1.90	0.5	$ 0.95
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	0.5	$ 2.96
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Radiological Waste Bags (18" × 24" - roll 250 bags)	Roll	$ 55.25	$ 3.32	$ 58.57	1	$ 58.57
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	0.5	$ 3.44
Printer Ink Cartridges	Set	$ 139.99	$ 8.40	$ 148.39	2	$ 296.78
Smears with folders (box 500)	Box	$ 28.00	$ 1.68	$ 29.68	20	$ 593.60
Replacement mylar window (Ludlum Model 43-37)	Each	$ 80.00	$ 4.80	$ 84.80	1.67	$ 141.33
Replacement mylar window (Ludlum Model 43-93)	Each	$ 28.00	$ 1.68	$ 29.68	1.67	$ 49.47
Replacement Detector Cables (5-ft)	Each	$ 59.00	$ 3.54	$ 62.54	4	$ 250.16
D Batteries (pack 8)	Each	$ 14.99	$ 0.90	$ 15.89	1	$ 15.89
Marinelli Beakers (case 12)	Each	$ 236.00	$ 14.16	$ 250.16	11.11	$ 2,779.56
HEPA flexible duct (12" of 25 ft duct)	Each	$ 16.96	$ 1.02	$ 17.98	0.17	$ 3.00
P-10 Gas (300 cf tank)	Each	$ 78.60	$ 4.72	$ 83.32	2	$ 166.63
Liquid Nitrogen (180 Liter dewar with 22 psi)	Each	$ 110.50	$ 6.63	$ 117.13	4	$ 468.52
HEPA Air Filter Unit 2000 CFM	Each	$ 104.00	$ 6.24	$ 110.24	1	$ 110.24
Plastic Sheeting	Each	$ 94.00	$ 5.64	$ 99.64	0.17	$ 16.61
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	1	$ 8.47
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	1	$ 11.97
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	1	$ 15.15
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	1	$ 18.54
Ice Machine	LS	$ 195.00	$ -	$ 195.00	1	$ 195.00
		TOTAL MONTHLY COST FOR LABORATORY TRAILER				**$ 5,430.75**
Operations Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	3	$ 165.33
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	2	$ 10.58
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	2	$ 33.90
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	2	$ 48.74
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	1	$ 5.93
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	2	$ 16.94
Binder (1 1/2 inch)	Each	$ 9.29	$ 0.56	$ 9.85	2	$ 19.69
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	2	$ 23.93
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	2	$ 30.29
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	2	$ 37.08
		TOTAL MONTHLY COST FOR OPERATIONS TRAILER				**$ 704.91**
HP Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	1	$ 55.11
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	3	$ 15.87
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	3	$ 19.05
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	1	$ 16.95
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	1	$ 24.37
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	0.5	$ 2.96
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98
Air Sample Filters (Low Vol - 47 mm cellulose - 100 filters)	Box	$ 14.00	$ 0.84	$ 14.84	2	$ 29.68
Air Sample Filters (BZA - 47 mm mixed cellulose - 100 filters)	Box	$ 87.02	$ 5.22	$ 92.24	2	$ 184.48
Air Sample Filters (High Vol - 4 in cellulose - 100 filters)	Box	$ 18.00	$ 1.08	$ 19.08	2	$ 38.16
Smears with folders (box 500)	Box	$ 28.00	$ 1.68	$ 29.68	3	$ 89.04
MASSLINN Decontamination Wipes (18" × 24" - case 500 wipes)	Case	$ 80.50	$ 4.83	$ 85.33	1	$ 85.33
MASSLINN Decontamination Wipes (24" × 24" - case 500 wipes)	Case	$ 94.25	$ 5.66	$ 99.91	1	$ 99.91
Radiological Waste Bags (18" × 24" - roll 250 bags)	Roll	$ 55.25	$ 3.32	$ 58.57	1	$ 58.57
Radiological Waste Bags (36" × 48" - roll 100 bags)	Roll	$ 100.00	$ 6.00	$ 106.00	1	$ 106.00
Step off Pad/ Sticky Mat (4 mats, 30 sheets each mat)	Case	$ 78.80	$ 4.73	$ 83.53	1	$ 83.53

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Step off Pad/ Sticky Mat - printed message (4 mats, 30 sheets/mat)	Case	$ 130.70	$ 7.84	$ 138.54	1	$ 138.54
Radiological Stickers (pack 25)	Pack	$ 21.03	$ 1.26	$ 22.29	1	$ 22.29
Radiological Boundary Ribbon (roll 200 ft)	Roll	$ 16.08	$ 0.96	$ 17.04	1	$ 17.04
Radiological Boundary Plastic Tape (roll 1,000 ft)	Roll	$ 11.00	$ 0.66	$ 11.66	1	$ 11.66
Radiological Boundary Rope (roll 600 ft)	Roll	$ 26.00	$ 1.56	$ 27.56	1	$ 27.56
Radiological Warning Sign	Each	$ 20.00	$ 1.20	$ 21.20	1	$ 21.20
Radiological Boundary Adhesive Tape (roll 36 yds)	Roll	$ 17.65	$ 1.06	$ 18.71	1	$ 18.71
Right in the Rain Notebook	Each	$ 16.95	$ 1.02	$ 17.97	2	$ 35.93
Alconox - 4 pound Box	Each	$ 28.95	$ 1.74	$ 30.69	1	$ 30.69
Alconox - 50 1/2 oz packets	Each	$ 39.95	$ 2.40	$ 42.35	1	$ 42.35
Steel Bowl	Each	$ 12.50	$ 0.75	$ 13.25	0.5	$ 6.63
Steel Spoon	Each	$ 5.95	$ 0.36	$ 6.31	1	$ 6.31
5-gallon bucket	Each	$ 2.34	$ 0.14	$ 2.48	4	$ 9.92
Ziploc 10-gallon bags (pack 30)	Each	$ 3.29	$ 0.20	$ 3.49	20	$ 69.75
Cooler	Each	$ 43.10	$ 2.59	$ 45.69	4	$ 182.74
Red Marking Paint	Each	$ 5.27	$ 0.32	$ 5.59	3	$ 16.76
Orange Marking Paint (pack 12)	Each	$ 44.88	$ 2.69	$ 47.57	1	$ 47.57
Pin Flags (pack 100)	Each	$ 7.98	$ 0.48	$ 8.46	2	$ 16.92
Safety Fence	Each	$ 36.98	$ 2.22	$ 39.20	3	$ 117.60
Utility Post	Each	$ 5.39	$ 0.32	$ 5.71	10	$ 57.13
Nylon Cable Ties (pack 100)	Each	$ 6.94	$ 0.42	$ 7.36	3	$ 22.07
Cable Ties (8 in pack 1000)	Each	$ 19.97	$ 1.20	$ 21.17	0.5	$ 10.58
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	2	$ 16.94
Binder (1 1/2 inch)	Each	$ 9.29	$ 0.56	$ 9.85	2	$ 19.69
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	2	$ 23.93
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	2	$ 30.29
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	2	$ 37.08
		TOTAL MONTHLY COST FOR HP TRAILER				**$ 2,266.70**
Break Trailer						
Water (case 28, 24 oz)	Case	$ 12.49	$ 0.75	$ 13.24	20	$ 264.79
Gatorade (case 6, 20 oz)	Case	$ 6.99	$ 0.42	$ 7.41	20	$ 148.19
Hand Wipes (40 wipes)	Pack	$ 2.99	$ 0.18	$ 3.17	6	$ 19.02
Paper Towels (6 rolls)	Pack	$ 10.49	$ 0.63	$ 11.12	6	$ 66.72
Sun Block	Each	$ 10.99	$ 0.66	$ 11.65	6	$ 69.90
Insect Repellent	Each	$ 6.49	$ 0.39	$ 6.88	6	$ 41.28
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	6	$ 54.00
		TOTAL MONTHLY COST FOR BREAK TRAILER				**$ 663.88**
		TOTAL MONTHLY COST FOR SITE TRAILERS				**$ 9,066.24**

Table B-2.2.24: Groundwater Sampling Costs per Event

ITEM DESCRIPTION	NO. UNITS	UNIT OF MEASURE	COST / UNIT	TOTAL COST
LABOR				
Lead Technician - sampling event	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
Hydrogeologist - report preparation	40	hours	$ 103.74	$ 4,150
GIS/CAD specialist - report preparation	8	hours	$ 61.44	$ 492
project assistant - report preparation	16	hours	$ 42.26	$ 676
project manager - QA/review	8	hours	$ 103.74	$ 830
ODCs				
CONSUMABLES				
consumables - FedEx coolers	32	shipments	$ 100.00	$ 3,200
consumables - Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
consumables - Misc Field Supplies	1	each	$ 2,000.00	$ 2,000
consumables - X-Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
EQUIPMENT				
equipment - 1/4" OD LDPE Tubing	820	feet	$ 0.65	$ 533
equipment - 2929	2	week(s)	$ 150.00	$ 300
equipment - GM detector	2	week(s)	$ 135.00	$ 270
equipment - In-Situ Troll multiparameter meter 9500 (4 units)	8	weeks	$ 200.00	$ 1,600
equipment - Silicone Tubing - Size 15	50	feet	$ 2.10	$ 105
equipment - tubing Pumps (4 units)	8	weeks	$ 150.00	$ 1,200
equipment - water level meter [2]	4	week(s)	$ 80.00	$ 320
SUB				
sub - analysis - 32 water suites + 6 field duplicates + 6 MS/MSD	44	each	$ 275.00	$ 12,100
sub - trailer, rent	1	months	$ 350.00	$ 350
TRAVEL				
travel - fuel 2 vehicles, 10 gallons/day	200	gallon	$ 3.00	$ 600
travel - per diem (for 4 people, 2 weeks at $140 (est))	40	days	$ 140.00	$ 5,600
travel - rental SUV [2]	20	days	$ 65.00	$ 1,300
travel - tolls	4	day	$ 12.00	$ 48
Assumptions:				
Monitoring, sampling, reporting for 32 wells in one event				
			GRAND TOTAL:	$ 46,118.80

ALTERNATIVE S3

EXCAVATION, TREATMENT AND DISPOSAL OF SOIL

TOTAL COST FOR SOIL EXCAVATION, TREATMENT AND DISPOSAL OF SOIL ALTERNATIVE

Alternative Description	S3-1 Excavation, Treatment and Disposal of Soil	S3-6 Excavation, Treatment and Disposal of Soil
Total Project Duration (years)	1000	1000
Capital Costs[1]		
Real Estate Analysis/Documents	**1,190**	**1,190**
Proj Management & Pre-Rem. Action	**2,093,123**	**602,089**
HTRW Remedial Action (Construct)	**18,091,819**	**5,204,134**
Annual O&M Costs[2]		
Long Term Monitoring	0	0
Site Supervision and Maintenance	49,289	16,303
Periodic O&M Costs[3]		
Five Years Review	28,256	9,346
Present Value of O&M Costs	**773,963**	**256,003**
Engineering Design Before Construction	**180,918**	**52,041**
Construction Management	**1,085,509**	**312,248**
Subtotal	22,226,522	6,427,706
Escalation (7%)	1,555,857	449,939
Total Cost	**23,782,378**	**6,877,645**

Notes

[1] Capital costs are those expenditures that are required to construct a remedial action and consist of expenditures initially incurred to build, install, or execute the remedial action.

[2] Annual O&M costs are operation and maintenance costs that occur post construction and are necessary to ensure or verify the continued effectiveness of a remedial action.

[3] Periodic O&M costs are operation and maintenance costs that occur only once every few years.

Table B-2.3 - Cost Associated with Cost Components for Alternative S3: Excavation, Treatment and Disposal of Soil
1,000 Year Cost

This alternative involves excavating contaminated soils above the appropriate cleanup criteria and treating the radioactive and hazardous waste using a soil sorting technology. Following treatment, the soil that meets or is below the cleanup criterion would be used as backfill for the site. The contaminated radioactive soil would be disposed at an offsite commercial disposal facility.

TABLE CITED	ITEM	Base Price		Contract Cost		Design Contingency		Construction Contingency		Total Cost	
		OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6
B-2.3.1	***Rights of Entry/Temporary Permit***	1,000	1,000	140	140	50	50	0	0	1,190	1,190
B-2.3.1.1	Rights of Entry Acquisition	500	500								
B-2.3.1.2	Damages	500	500								
B-2.3.2	**Proj Mang & Pre-Remedial Action**										
B-2.3.2.1	***Project Management [5% of B-2.6.3.0]***	628,188	180,699	87,946	25,298	31,409	9,035	0	0	747,544	215,032
B-2.3.2.2	***Remedial Design [8% of B-2.6.3.0]***	1,005,101	289,119	140,714	40,477	50,255	14,456	0	0	1,196,070	344,051
B-2.3.2.3	***Remedial Action Contracting [1% of B-2.6.3.0]***	125,638	36,140	17,589	5,060	6,282	1,807	0	0	149,509	43,006
B-2.3.3	**HTRW Remedial Action (Construct)**										
B-2.3.3.1	***Land Use Controls***	125,706	41,580	17,599	5,821	6,285	2,079	31,426	10,395	181,017	59,875
B-2.3.3.1.1	Preparatory Work [Table B-2.3.3]	31,046	10,269								
B-2.3.3.1.2	Land Use Control Plan [Table B-2.3.3]	45,046	14,900								
B-2.3.3.1.3	Administrative Mechanism Plan [Table B-2.3.3]	49,614	16,411								
B-2.3.3.2	***Mobilize and Preparatory Work***	205,130	54,025	28,718	7,563	10,256	2,701	51,282	13,506	295,387	77,796
B-2.3.3.2.1	Preparatory Work [Table B-2.3.4]	168,168	41,799								
B-2.3.3.2.2	Mobilization [Table B-2.3.5]	36,962	12,226								
B-2.3.3.3	***Monitoring, Sampling, Test & Analysis***	1,176,184	264,537	164,666	37,035	58,809	13,227	294,046	66,134	1,693,704	380,933
B-2.3.3.3.1	Environmental Monitoring [Table B-2.3.7]	61,152	49,056								
B-2.3.3.3.2	Chemical/Rad Lab Air Analysis [Table B-2.3.7]	54,603	11,766								
B-2.3.3.3.3	Additional Labor & Services [Table B-2.3.7]	605,069	53,096								
B-2.3.3.3.4	On-site Mobile Laboratory Cost [Table B-2.3.7]	192,526	63,682								
B-2.3.3.3.5	Waste Profile Sampling [Table B-2.3.7]	30,088	9,952								
B-2.3.3.3.6	Monitoring Equipment Cost [Table B-2.3.7]	161,309	53,356								
B-2.3.3.3.7	PPE Cost [Table B-2.3.7]	71,437	23,629								
B-2.3.3.4	***Site Work***	761,179	389,992	106,565	54,599	38,059	19,500	190,295	97,498	1,096,098	561,589
B-2.3.3.4.1	Install Signage [Table B-2.3.3]	2,374	986								
B-2.3.3.4.2	Install Fencing and Gates [Table B-2.3.3]	52,690	15,159								
B-2.3.3.4.3	Site Information Database [Table B-2.3.3]	9,234	3,054								
B-2.3.3.4.4	Earthwork [Table B-2.3.8]	479,370	158,561								
B-2.3.3.4.5	Compaction [Table B-2.3.8]	101,361	33,527								
B-2.3.3.4.6	Roads (AOC 6) [Table B-2.3.8]		130,286								
B-2.3.3.4.7	Additional Labor & Services (Backfilling) [Table B-2.3.8]	116,150	38419								
B-2.3.3.4.8	Misc. Utility Relocations [Table B-2.3.8]		10,000								
B-2.3.3.5	***Surface Water Collect & Control***	779,557	257,853	109,138	36,099	38,978	12,893	194,889	64,463	1,122,562	371,309
B-2.3.3.5.1	Water Management [Table B-2.3.9]	277,172	91,680								
B-2.3.3.5.2	Water Treatment [Table B-2.3.9]	502,385	166,174								
B-2.3.3.6	***Sediment Control*** [Table B-2.3.9]	11,794	3,482	1,651	487	590	174	2,948	870	16,983	5,014
B-2.3.3.7	***Solids Collect and Containment***	995,369	329,237	139,352	46,093	49,768	16,462	248,842	82,309	1,433,331	474,102
B-2.3.3.7.1	Excavation [Table B-2.3.10]	129,878	42,960								
B-2.3.3.7.2	Hauling [Table B-2.3.10]	97,175	32,143								
B-2.3.3.7.3	Additional Labor & Services [Table B-2.3.10]	768,315	254,135								
B-2.3.3.8	***Pilot Test Program***	472,000	28,000	66,080	3,920	23,600	1,400	118,000	7,000	679,680	40,320
B-2.3.3.9	***Pretreatment***	431,875	7,120	60,462	997	21,594	356	107,969	1,780	621,899	10,253
B-2.3.3.9.1	Dewatering Process [Table B-2.3.12]	317,160	0								
B-2.3.3.9.2	Screen (19,119 lb for OU1 and 1,186 lb for AOC6)	95,595	5,930								
B-2.3.3.9.3	Crush Concrete rubble (1,912 lbs = OU1 and 119 lbs =AOC6)	19,120	1,190								
B-2.3.3.10	***Physical Treatment***										

TABLE CITED	ITEM	Base Price		Contract Cost		Design Contingency		Construction Contingency		Total Cost	
		OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6
B-2.3.3.10.1	Soil Sorting [Table B-2.3.13]	***935,557***	***309,453***	***130,978***	***43,323***	***46,778***	***15,473***	***233,889***	***77,363***	***1,347,202***	***445,613***
B-2.3.3.11	***Construction of Staging and Loading Area*** [Table B-2.3.14]	***90,589***	***29,964***	***12,682***	***4,195***	***4,529***	***1,498***	***22,647***	***7,491***	***130,448***	***43,148***
B-2.3.3.12	***Disposal (Commercial)***	***6,414,754***	***1,860,722***	***898,066***	***260,501***	***320,738***	***93,036***	***1,603,688***	***465,180***	***9,237,245***	***2,679,440***
B-2.3.3.12.1	Loading of Solids [Table B-2.3.15]	551,452	182,403								
B-2.3.3.12.2	Transportation Costs[Table B-2.3.15]	3,146,427	1,029,287								
B-2.3.3.12.3	Disposal Fees and Taxes [Table B-2.3.15]	2,716,875	649,031								
B-2.3.3.12.4	Disposal Cost for Cannister Used in Ion Exchanger	15,029	4,971								
B-2.3.3.13	***Site Restoration***	***11,544***	***6,186***	***1,616***	***866***	***577***	***309***	***2,886***	***1,546***	***16,623***	***8,907***
B-2.3.3.13.1	Earthwork [Table B-2.3.16]	3,809	2,041								
B-2.3.3.13.2	Revegetation & Planting [Table B-2.3.16]	5,491	2,943								
B-2.3.3.13.3	Site Cleanup [Table B-2.3.16]	2,243	1,202								
B-2.3.3.14	***Demobilization*** [Table B-2.3.17]	***89,800***	***29,703***	***12,572***	***4,158***	***4,490***	***1,485***	***22,450***	***7,426***	***129,312***	***42,772***
B-2.3.3.14.1	Submittals [Table B-2.3.18]	***6,434***	***2,128***	***901***	***298***	***322***	***106***	***1,608***	***532***	***9,264***	***3,064***
B-2.3.3.15	***Test Pits (OU1 only)***	***56,295***		***7,881***	***0***	***2,815***	***0***	***14,074***	***0***	***81,064***	***0***
B-2.3.3.15.1	Excavation, Hauling, Backfilling & Compaction [Table B-2.3.19]	10,287									
B-2.3.3.15.2	Additional Labor & Services [Table B-2.3.19]	36,008									
B-2.3.3.15.3	Sampling Costs [Table B-2.3.19]	10,000									
B-2.3.4	**Engineering During Construction [1% of B-2.3.3.0]**	***125,638***	***36,140***	***17,589***	***5,060***	***6,282***	***1,807***	***31,409***	***9,035***	***180,918***	***52,041***
B-2.3.5	**Construction Management (S&A) [6% of B-2.3.3.0]**	***753,826***	***216,839***	***105,536***	***30,357***	***37,691***	***10,842***	***188,456***	***54,210***	***1,085,509***	***312,248***
B-2.3.6	**Post Construction**										
B-2.3.6.1	***Annual Operation, Maintenance, & Monitoring***										
B-2.3.6.1.1	Monitoring [Table B-2.3.20]	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***
B-2.3.6.1.2	Post Remedial Site Supervision [Table B-2.3.20]	***41,420***	***13,700***	***5,799***	***1,918***	***2,071***	***685***	***10,355***	***3,425***	***49,289***	***16,303***
B-2.3.6.2	***Periodic Cost***										
B-2.3.6.2.1	Five Year Review [Table B-2.3.20]	***23,744***	***7,854***	***3,324***	***1,100***	***1,187***	***393***	***5,936***	***1,963***	***28,256***	***9,346***

14%	Contract Cost: includes G&A (6%) and profit (8%) for prime contractor and subcontractors, but not labor overhead.
5%	Design Contingency: includes design and planning costs for unanticipated conditions.
25%	Construction Contingency: includes construction costs for unforeseen conditions.

Table B-2.3.1: Calculation of Soil Volumes

Alternatives S3

Soil Volume [CY]			
AOC	Excavation to Cut Lines [2] [in situ] [CY]	Ex-Situ Vol [3] [125%] [CY]	Percentage of Total
OU 1	12,300	15,375	71%
OU 1 Haz	700	875	4.0%
AOC 6	4,300	5,375	24.9%
Total	**17,300**	**21,625**	100%

Soil Volume with 15% Contingency			
Off-Site Disposal			
Bulk Soil[4] [CY] [+15% contingency]	Bulk Soil [5] [Tons]	Haz Soil [CY] [+15% contingency]	Haz Soil [5] [Tons]
17,681	26522		
		1,006	1509
6,181	9272		
23,863	35,794	1,006	1509

Calculation of Treated Soil Volume (Alternatives S3-1, S3-6)

Area	Total Excavated Volume (CY)	% Treated	Treated Soil Volume (CY)	Disposal Volume (CY)	Disposal Volume (tons)	% Soil Volume
OU 1	18,688	30%	5,606	13,081	19,622	75.1%
AOC 6	6,181		1,854	4,327	6,490	24.9%
Total	24,869		7,461	17,408	26,112	

Transportation Related Issues (Rail)

Area	Volume (CY)	Volume (tons)	# of Trips	# of Burritos	Assumption
Alternatives S3-1, S3-6					30% of Excavated Soil
OU 1	13,081	19,622	196	196	Volume (tons) = Volume (CY) x 1.5 tons/CY; Gondola Volume = 100 tons/car;
AOC 6	4,327	6,490	65	65	
Total	17,408	26,112	261	261	

Transportation Related Issues (Truck)

Area	Volume [CY]	Volume [4] [tons]	# of Trips	Assumption
Alternatives S3-1, S3-6				
OU 1	13,081	19,622	1226	Volume (tons) = Volume (CY) x 1.5 tons/CY; Truck Volume = 16 tons/car;
AOC 6	4,327	6,490	406	
Total	17,408	26,112	1632	

Footnotes

1) Mean upper bound volume estimates - mean volume [based on 10 models] plus standard deviation. Cut lines volume includes estimated using 1 : 1.5 slope from waste. In addition, the in-situ volume was rounded off during this cost estimation.

2) 125% swelling factor applicable in situ estimates

3) Bulk Soil: FUSRAP waste soil plus cut-back. Assumes both will be disposed of as same waste stream.

4) Average density of damp sand [1.7] or 110 pounds / ft^3 or 1.5 tons per cubic yard [EPA/625/12-91/002]

Table B-2.3.2: Duration of Excavation
Alternative S3

OU1 -

18,688	CY ex-situ volume to cut-lines	
16	CY/hour production rate	
0.95	HTRW Productivity Factor	2.56 weeks weather delays out of 50 weeks per year (USACE Guidance Document on Delays related to Severe Weather at Aberdeen Proving Ground Area)
0.9	Soil Adjustment Factor	Due to nature of material to be excavated (soils, and/or asphalt, concrete, spotty areas of contamination over large area)
0.75	Safety Factor	Additional Personal Protection Equipments due to hazardous nature of the contaminated materials below 8 ft bgs.

Total Excavation Duration = (ex-situ vol /production rate) *(1/ (HTRW Productivity factor * Soil Adjustment Factor * Safety Factor)

= 168 [10] hour work days
= 42 [40] hour weeks
= 10.5 months

AOC6 -

6,181	CY in-situ volume to cut-lines	
18	CY/hour production rate [shallower excavation, no VOCs]	
0.95	HTRW Productivity Factor	2.56 weeks weather delays out of 50 weeks per year (USACE Guidance Document on Delays related to Severe Weather at Aberdeen Proving Ground Area)
1	Soil Adjustment Factor	No presence of asphalt and/or concrete
1	Safety Factor	Due to absence of hazardous substances at the Site

Total Excavation Duration = (ex-situ vol /production rate) *(1/ (HTRW Productivity factor * Soil Adjustment Factor * Safety Factor)

= 36 [10] hour work days
= 9.0 40 hour Weeks
= 2.3 months

Total Work Days

= 204 [10] hour work days
= 51 [40] hour weeks
= 12.7 months

Production Rate Assumptions

Assume the crew will excavate 16 cy/hr. at OU1, based on experience at similar FUSRAP sites

1. Level of Personal Protective Equipment is assumed to be Level D Modified

Table B-2.3.3: Costs Associated with Land Use Controls (LUCs)

The ICs includes both land use controls (LUCs) and administrative controls (zoning, deed restrictions, and/or well construction restrictions)

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Land Use Control					167,286	
Preparatory Work[1]						
Coordination with various local, state, and Federal agencies for land use control plans and administrative mechanism plan					37,165	
Program Manager	160	hr	$128.54	20,566		See Table B-2.6.21
Project Manager	160	hr	$103.74	16,598		
Coordination with owners for land use control plans and administrative mechanism plan					4,150	
Project Manager	40	hr	$103.74	4,150		See Table B-2.6.21
Land Use Control Plan[2]					59,946	
Project Manager	80	hr	$103.74	8,299		See Table B-2.6.21
Principal Health Physicist	80	hr	$116.00	9,280		
1 Senior Scientist	160	hr	$103.74	16,598		
I Junior Engineer	240	hr	$64.76	15,542		
1 Attorney	40	hr	$151.96	6,078		
1 GIS Operators	40	hr	$61.44	2,458		
Administrative Assistant	40	hr	$42.26	1,690		
Administrative Mechanism Plan[3]					66,025	
Project Manager	80	hr	$103.74	8,299		See Table B-2.6.21
Principal Health Physicist	80	hr	$116.00	9,280		
1 Senior Scientist	160	hr	$103.74	16,598		
I Junior Engineer	240	hr	$64.76	15,542		
1 Attorney	80	hr	$151.96	12,157		
1 GIS Operators	40	hr	$61.44	2,458		
Administrative Assistance	40	hr	$42.26	1,690		
Construct - Land Use Control						
Install Signage	Fabricated stainless Steel, 18" high, 4" deep				4,776	RSMeans (10 14 19.10.2100)
Number of Signs	Install 18" Caution - "Radiological Material" Signs					
OU 1	4		$292.00	1,168		
AOC 6	2		$292.00	584		
Equipment Rental OU 1	1.5	day	$20.00	30		Assumed
Equipment Rental AOC 6	0.5	day	$20.00	10		
Union Laborer (2) OU 1	12	hrs	$49.02	1,176		See Table B-2.2.6
Union Laborer (2) AOC 6	4	hrs	$49.02	392		
Install Fencing and Gates	Install up to 1632 ft of fencing @ 165 ft/day				124,288	
Raw Materials						
Permanent Fencing	ga. wire, 6" high but omit barded wire, galvanized ste					RSMeans (32 31 13.20.0800)
OU 1	1260	LF	$31.00	39,060		
AOC 6	372	LF	$31.00	11,532		
Gates	6' high, 12' opening, in concrete (Double swing					RSMeans, 32 31 13.20 5060
OU 1	2		$1,350	2,700		
AOC 6	1		$1,350	1,350		
Labor OU 1						
Prep Work (2 laborers)	16	hrs	$49.02	1,569		See Table B-2.2.6
Installation Work (2 laborers)	80	hrs	$49.02	7,843		
Perdiem [CONUS + 15% tax]	12	days	$126.50	1,518		
Labor AOC 6						
Prep Work (2 laborers)	4	hrs	$49.02	392		See Table B-2.2.6
Installation Work (2 laborers)	16	hrs	$49.02	1,569		
Perdiem [CONUS + 15% tax]	3	days	$126.50	316		
Site Information Database [4]	200	hrs	$61.44	12,288		

Footnote

[1,2,3,4] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.4: Costs Associated with Preparatory Works

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost ($)	Assumptions
Preparatory Work[1]						**223,793**	
Submittals/Implementation Plan						*127,178*	
Environmental Protection Plan					24,898		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineer	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Sedimentation Control Plan					29,047		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Geologist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
Site Safety and Health Plan					27,317		
Senior Health Physicist	40	hr	$116.00	4,640			20 hrs/contract; 2 contracts
Site Safety & Health Officer	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
General Site Work Plan					25,890		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Construction Manager	40	hr	$128.54	5,142			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Quality Control Plan					18,527		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Quality Control Engineers	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Permits	2		$750	1,500	1,500		$750/ permit
Setup/Construct Temp Facilities						*24,987*	
Operation Trailer	1	LS	$ 9,098	9,098			1 for both contracts
HP Trailer	1	LS	$ 7,806	7,806			1 for both contracts
Break Trailer	1	LS	$ 2,770	2,770			
Toilets	2	LS	$100	200			1 for each contract
Barricades	2	LS	$1,500	3,000			1 for each contract
Signs	4	LS	$292	1,168			2 for each contract
Monthly Operating Cost						*58,168*	
Operation Trailer	16	months	$ 704.91	11,279			
HP Trailer	16	months	$ 2,267	36,267			
Break Trailer	16	months	$ 664	10,622			
Construct Temporary Utilities						*4,660*	
Power Connection/Distribution	2	LS	$500	1,000			1 for each contract
Telephone/Communication Dist.	2	LS	$100	200			1 for each contract
Water Connection/Distribution	2	LS	$1,430	2,860			1 for each contract
Sewer Connection/Distribution	2	LS	$300	600			1 for each contract
Monthly Cost -Utilities						*8,800*	
Power Distribution	16	months	$250	4,000			
Telephone/Communication Dist.	16	months	$100	1,600			
Water Distribution	16	months	$100	1,600			
Sewer Distribution	16	months	$100	1,600			

[1] Based on percentage of soil volume at OU1 and AOC6, the total preparatory cost was divided among OU1 and AOC 6.

Table B-2.3.5: Costs Associated with Mobilization

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost ($)	Assumptions
Mob Construction Equip & Fac[1]						*49,188*	
Permits	2		$500		1,000		
Construction Equipment					48,188		
Water Truck - Operation	16	hr	$61.38	982			8 hrs/contract; 2 contracts
Water Truck - Standby	64	hr	$15.28	978			32 hrs/contract; 2 contracts
Hydraulic Excavator - Operation	16	hr	$134.41	2,151			8 hrs/contract; 2 contracts
Hydraulic Excavator - Standby	64	hr	$36.79	2,355			32 hrs/contract; 2 contracts
PM Roller -Operation	16	hr	$29.67	475			8 hrs/contract; 2 contracts
PM Roller- Standby	64	hr	$6.41	410			32 hrs/contract; 2 contracts
PM Dozer, CWLR-Operation	16	hr	$49.71	795			8 hrs/contract; 2 contracts
PM Dozer, CWLR-Standby	64	hr	$10.52	673			32 hrs/contract; 2 contracts
PM Dozer, CWLR-Operation	16	hr	$60.94	975			8 hrs/contract; 2 contracts
PM Dozer, CWLR-Standby	64	hr	$15.62	1,000			32 hrs/contract; 2 contracts
PM Loader, FE - Operation	16	hr	$60.99	976			16 hrs/contract; 2 contracts
PM Loader, FE-Standby	64	hr	$15.67	1,003			64 hrs/contract; 2 contracts
Pile Hammer - Operation	8	hr	$63.45	508			4 hrs/contract; 2 contracts
Pile Hammer - Standby	16	hr	$11.95	191			8 hrs/contract; 2 contracts
TRLR, LOWBOY	80	hr	$6.88	550			40 hrs/contract; 2 contracts
2 TRK HWY-Operation	128	hr	$35.40	4,531			8 hrs/contract; 2 contracts
2 TRK HWY-Standby	128	hr	$7.97	1,020			8 hrs/contract; 2 contracts
Equipment Operator-Operation	128	hr	$49.02	6,275			8 hrs/contract; 2 contracts
Equipment Operator-Standby	128	hr	$49.02	6,275			8 hrs/contract; 2 contracts
2 Truck Drivers	128	hr	$49.02	6,275			8 hrs/contract; 2 contracts
Outside Laborers (2)	80	hr	$49.02	3,922			8 hrs/contract; 2 contracts
Perdiem [2010 CONUS rate]	46	days	$126.50	5,870			hotel +15% tax +M&IE

[1] Based on percentage of soil volume at OU1 and AOC6, the total mobilization cost was divided among OU1 and AOC 6.

Table B-2.3.6: Area, Number and Types of SU and Number of Confirmation Soil Samples

EU	Location	Class 1 Areas	Class 2 Areas	Total Area	Survey Units	# of Soil Samples
3B	AOC 6	606	11472	12078	1 Class 1 and 2 Class 2	42
1	AOC 1 and AOC 2	2620	21086	23706	2 Class 1 and 2 Class 2	56

<u>Other Samples to be Collected during Excavation</u>
# of surface water samples for CDD = 10
# of sediment samples for CDD = 10

Total Samples = 98 Soils, 10 Sediments, 10 surface water, 6 laboratory control samples, 11 Lab Duplicates, 11 Field Duplicates, 6 MS/MSD samples and 11 Method Blanks

Air Monitoring Stations = 4 to 5 around Class 1 areas (downgradient to the air flow)
TLD Measurements for each person working at the site

<u>High Volume Air Samplers and Personal Sample</u>

2 high volume air samplers and 1 personal samples will be analyzed on-site per week.
Samples will be analyzed for gamma spec and gross alpha/beta.

	Excavation Duration		Air Sample		
Area	**[10] hr workdays**	**[40] hours week**	**High volume**	**Personal**	**Total**
OU1	168	42	84	42	**126**
AOC6	36	9.0	18	9	**27**

Table B-2.3.7: Costs Associated with Environmental Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Monitoring, Sampling, Test, Analysis					
Offsite Sample Analysis Cost					**176,577**
Environmental Monitoring					see Table B-2.6.22
OU 1	91	samples	672.00	61,152	
AOC 6	73	samples	672.00	49,056	
Chemical/Rad Lab Air Analysis					
OU 1					
Gamma Spec	126	samples	$119.00	14,972	
Iso U	126	samples	$157.50	19,816	
Iso Th	126	samples	$157.50	19,816	
AOC 6					
Gamma Spec	27	samples	$119.00	3,226	
Iso U	27	samples	$157.50	4,270	
Iso Th	27	samples	$157.50	4,270	
Additional Labor & Services					**658,164**
It includes preparation of Gamma Walkover Survey, FSS report, and collection of FSS samples.					
OU 1					
Project Manager	160	hrs	$103.74	16,598	
Principal Health Physicist	520	hrs	$116.00	60,320	
4 Junior HPs	4 x 168 days x 10 hrs/day	hrs	$64.76	434,541	
Perdiem [2010 CONUS rate + 15% tax]	740	days	$126.50	93,610	
AOC 6					
Project Manager	24	hrs	$103.74	2,490	
Principal Health Physicist	40	hrs	$116.00	4,640	
4 Junior HPs	4 x 36 days x 10 hrs/day	hrs	$64.76	26,940	
Perdiem [2010 CONUS rate + 15% tax]	150	days	$126.50	19,026	
Onsite Laboratory Cost[1]					**682,116**
e is based on installing a mobile lab similar to the St. Louis FUSRAP site					
On-site Mobile Laboratory Setup Cost	1	LS	$187,000	187,000	
On-site Mobile Laboratory Operating Cost	12.7	months	$ 5,431	69,207	
Environmental Monitoring					
OU 1	182	samples	$336.00	61,152	
AOC 6	146	samples	$336.00	49,056	
On-Site Laboratory Labor & Services					
Lead Technician	204 days x 10 hrs/day	hrs	$64.76	132,044	
Lab Technician	204 days x 10 hrs/day	hrs	$64.76	132,044	
Perdiem [2010 CONUS rate + 15% tax]	408	days	$126.50	51,612	
Waste Profile Cost[2] (Assume 20 samples)					
Chemical Parameters					**26,600**
TCLP VOCs	20	samples	$ 148.75	2,975	See Table B-2.5.21
TCLP SVOCs	20	samples	$ 271.25	5,425	
TCLP Pesticides/Herbicides	20	samples	$ 420.00	8,400	
TCLP (8 RCRA Metals+Zinc)	20	samples	$ 148.75	2,975	
Ignitability	20	samples	$ 35.00	700	
Corrosivity	20	samples	$ 17.50	350	
Toxicity	20	samples	$ 70.00	1,400	
Reactive Cyanide& Sulfide	20	samples	$ 105.00	2,100	
PCBs	20	samples	$ 113.75	2,275	
Radionuclides					**13,440**
Gamma Spec	20	samples	$ 119.00	2,380	See Table B-2.5.21
Ra-226	20	samples	$ 119.00	2,380	
Ra-228	20	samples	$ 119.00	2,380	
Iso-U	20	samples	$ 157.50	3,150	
Iso-Th	20	samples	$ 157.50	3,150	

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Monitoring Equipment Cost[2]					**214,665**
Bioassays (10 months for 20 peoples)	20	people	$168.77	3,375	
Fiskers (2 for Excavated Areas, 2 for loading Areas and 1 at Onsite Lab)	5 x 11.7 months	month	$145	9,239	
Radiological Detectors					
FIDLER w/scaler	1x 13 months	month	$548	6,984	
Alpha/beta detectors (e.g., Ludlum Models 43-93)	2 x 13 months	month	$96	2,447	
Radiological Meters					
A smear counter (Ludlum Model 2929)	2 x 13 months	month	$211	5,378	
Dosimetry					
TLDs	20 x 13 months	month	$100	25,487	
Radiological Air Samplers					
Personal Air Sampling Pumps	3 x 13 months	month	$83	3,173	
Air Sampling Pump Chargers	2 x 13 months	month	$52	1,325	
High Volume Air Samples	10 x 13 months	month	$130	16,567	
Field Sampling Equipments					
GPS- Trimble XR-Pro	13	month	$1,104	140,690	
PPE Cost[4]					**95,067**
Number of People using PPE	20 persons x 204 workdays		$ 23.31	95,067	See Table B-2.6.24

[1,2] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.8: Costs Associated with Site Work

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
***Site Work**					***1,067,674***	
Earthwork[1]					637,931	wrt 2010 Dollars
Backfill (Dozer, Backfilling, no compaction, up to 300')	17,408	CY	$1.54	26,809		31 23 23.13 1300
Borrow (Fill by borrow, load, 1 mile haul, spread with dozer)	17,408	CY	$11.30	196,712		31 23 23.16 0020
Hauling (15 MPH ave., 0.5 mile, 25 min wait/Ld./Uld)	24,869	CY	$5.20	129,318		31 23 23.20 0314
Compaction[2]					134,888	wrt 2010 Dollars
Riding Compaction (sheepsfoot roller, 8" lifts, common fill)	24,869	CY	$1.50	37,303		31 23 23.24 0300
Water Compaction	24,869	CY	$1.50	37,303		
** Roads (AOC 6)					130,286	wrt 2010 Dollars
Bituminous Surfacing						
Asphaltic Conc (3" Thick -Binder Course)	157	SY	$11.75	1,845		32 12 16.13 0160
Asphaltic Conc (3" thick Wearing Course)	157	SY	$11.44	1,796		32 12 16.13 0460
Prime Coat (Surface Treatment)	1406	CSF	$3.68	5,174		32 11 26.19 0800
Base Course (Crushed Stone)	157	SY	$15.40	2,418		32 11 26.19 1100
Geotextile Fabric	157	SY	$2.13	334		
Striping	78	MLF	$194.72	15,188		
Pavement Removal (Bituminous roads, 4" to 6" thick)	157	SY	$7.90	1,240		02 41 13.17 5010
Hauling of Pavement for Disposal						
Hwy Haulers (15 MPH ave, cycle 0.5 mile, 25 min.	157	CY	$5.20	816		31 23 23.20 0314
Landfill Tipping Fee for Con	157	CY	$263.50	41,370		02 81 20.10 1100
Traffic Control	175	hr	$10.74	1,880		
Additional Labor & Services (Backfilling)					154,569	
Engineering Manager	255	hr	$128.54	32,761		See Table B-2.6.21
Lead Engineer	255	hr	$103.74	26,440		
Engineer	1,019	hr	$64.76	66,022		
Perdiem [2010 CONUS rate+tax]	153	days	$126.50	19,345		
Surveying Services	1	ls	$5,000	5,000		Assumption
Compaction Testing	1	ls	$5,000	5,000		
Misc. Utility Relocations (AOC 6)	1	ls	$10,000	10,000	10,000	

[1,2] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.9: Costs Associated with Storm Water and Erosion Control

Surface Water and Groundwater Collection during Dewatering and Control

Assumptions

Average monthly surface water accumulation = 3 inches.
Infiltration Rate = 20%

Total Area of Excavation = 100,400 ft^2.

Total Volume of surface water to be collected = (10400 ft^2 x (3/12) ft x 0.8 x 7.48 gal/ft^3) = 15587 gallons

Total Volume of Groundwater Produced during Dewatering Process

OU 1 =	857	gal/day x	168	days =	143,762	gallons
AOC 2 B Aquifer =	36000	gal/ day x	5	days =	180,000	gallons
AOC 6 =	8735	gal/ day x	36	days =	315,750	gallons
		Total Volume Produced Groundwater =			**639,512**	gallons

Design of SW Treatment System

Use 6 each, 18000 gallons above-ground storage tanks during the excavation activities (16 month duration).
A complete Z-92 Uranium removal portable exchange system will be used to treat surface water.

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Surface Water and Sediment Control					**1,065,028**	
Surface Water and Groundwater Collect & Control					***1,037,410***	
Water Management [1]					368,852	
Engineering Manager	510	hr	$103.74	52,881		See Table B-2.6.21
Construction Engineer	1019	hr	$128.54	131,045		
Senior Engineer	510	hr	$103.74	52,881		
Junior Engineer	2039	hr	$64.76	132,044		
Water Treatment [2]					668,559	
Renting of Aboveground Storage Tank	12.7	months	1500	114,693		Quote from Sub-Contractors
Granular Activation Carbon						
Capital Cost	1	LS	$10,000	10,000		
O & M Cost	1	yr	$25,000	25,000		
Equipment Cost (U Removal System)	1	LS	$103,020	103020		
Additional Piping Cost	1	LS	$5,000	5000		
Consulting Services	1	yr	$2,000	2,000		
Testing & Analysis	204	days	2 samples/day x $50/sample	20,390		
HP Tech	13	months	$5,000	63,718		
Permit Coordinator	510	hr	$95.60	48,732		
Chemical Engineer	2039	hr	$103.74	211,524		
Perdiem [2010 CONUS rate + 15% tax]	510	days	$126.50	64,483		
Sediment Control					***27,618***	wrt 2010 Dollars
Sediment Barriers					27,618	
Silt Fences, Polypropylene. 3' High (Adverse Condition)						
OU 1	1260	LF	$1.26	1,588		31 25 13.10 1100
AOC 6	372	LF	$1.26	469		32 25 13.10 1100
Hay Bales, Staked						
OU 1	1260	LF	$8.10	10,206		31 25 13.10 1250
AOC 6	372	LF	$8.10	3,013		31 25 13.10 1250

[1,2] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.10: Costs Associated with Soil Excavation

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Solids Collect and Containment					***1,568,747***	wrt 2010 Dollars
Contaminated Soil Collection					*1,568,747*	
Excavation						
Hydraulic Excavator[1]	24,869	CY	$6.95	172,838	172,838	31 23 16.13 0500
Hauling (15 MPH ave,cycle 0.5 mile, 25 min wait)[2]	24,869	CY	$5.20	129,318	129,318	31 23 23.20 0314
Additional Labor & Services[3]					1,022,451	
Site Manager	510	hr	$103.74	52,881		See Table B-2.6.21
Senior Engineer	1019	hr	$103.74	105,762		
Field Engineer	2039	hr	$64.76	132,044		
Principal Health Physicist	1019	hr	$116.00	118,261		
Environmental Scientist	2039	hr	$64.76	132,044		
Field Supervisor	2039	hr	$54.12	110,350		
Operators)	4078	hr	$49.02	199,902		
Perdiem (CONUS + 15% tax)	1274	days	$126.50	161,207		
Surveying Services	1	yr	$5,000	5,000		Assumption
Geotech Services	1	yr	$5,000	5,000		

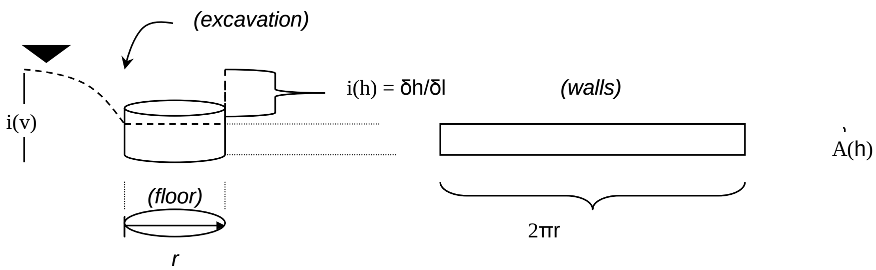
[1,2,3] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.11: Steady-State Flow to an Excavation using Darcy's Law

Author: Carl Young, P.G.
Date: 2/15/2010
Project: OU 1

Darcy's Law : Q = kiA

Where: Q=flow, k=hydraulic conductivity, i=gradient, A=cross sectional area perpendicular to flow



r =	15.0	m	i(h) =	20%	k(h) =	1.0E-05	m/s [avg. sand]
2πr	94.2	m	i(v) =	100%	k(v) =	5.0E-06	m/s [50% of k(h)]
A(h) =	2	m					

Flow through excavation walls [Qh]: Qh = k(h) * i(h) * [2πr*A(h)]

horizontal hydraulic conductivity [k(h)] =	1.0E-05	m/s		
hydraulic gradient [i(h)] =	20%	[-]		
flow cross sectional area (walls) [Aw] =	188.4	m^2		
Qh =	3.8E-04	m^3/s =	6.0	gpm

Flow through excavation floor [Qv]: Qv = k(v) * i(v) * [π*r^2]

vertical hydraulic conductivity [k(v)] =	5.0E-06	m/s		
hydraulic gradient [i(v)] =	100%	[-]		
flow cross sectional area (floor) [Af] =	706.5	m^2		
Qv =	3.5E-03	m^3/s =	56.0	gpm

Total groundwater flow into excavation [Q]: Q = Qh + Qv

Q = 3.9E-03 m^3/s = 62.0 gpm

Basis of Estimates:

A(h): est. 6 ft excavation into B Aquifer
i(h): estimated gradient drawdown [Introduction to Geotechnical Processes, John Woodward, 2005, Sec. 3]
i(v): vertical gradient is equal to depth of penetration into aquifer
k(h): average hydraulic conductivity for silty sand [Groundwater, Freeze & Cherry, 1979, Table 2.2]
k(v): vertical (k) is estimated at 50% of k(h) [Groundwater, Freeze & Cherry, 1979, Sec. 2.4, pg.32]

Table B-2.3.12: Costs Associated with Soil Dewatering Process

Soils that have been excavated from below the water table will require a dewatering step, because the segmented gate system (SGS) equipment requires loose and "clump-free" soil so that the soil passing under the radiation sensors is in a relatively thin layer.

Estimated time for excavation: 168 work days [OU1]
Time for dewatering OU1 [below water table] = work days x 20%
34 work days

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources Sources for Unit Cost
Dewatering					**317,160**	wrt 2010 Dollars
Premoblization & Mobilization	1	LS	$7,500	7,500		
6" centrifugal pump (10 gpm)	1	LS	$1,050	1,050		31 23 19.20 1100
20' Deep wells	20	LF	$68	1,350		31 23 19.30 0020
Installation and Removal of Single stage System	500	LF	$36.50	18,250		31 23 19.40 0110
Pump Operation	2	months	$47,000	94,000		31 23 19.40 0500
500' long header, 8" diameter	2	months	$238	476		31 23 19.40 1300
Demobilization	1	LS	$15,000	15,000		Assumed
Technical Support Options						
Site Activities	336	hr	$100	33,550		Assumed
Per Diem	34	days	$126.50	4,244		Assumed

Table B-2.3.13: Costs Associated with Soil Treatment

Four tasks included in Soil Segmented Gate System (Soil Sorting System) are as follows:

1. Pre-mobilization & Mobilization Activities
   - 1.1 Prepare a safety and health plan
   - 1.2 Conduct training
   - 1.3 Prepare SOP
   - 1.4 Conduct mobilization
2. SGS Operational Activities (includes all labor, materials, and equipments)
   - 2.1 Provides all labors, materials, and equipments
   - 2.2 Loading and unloading of soils
   - 2.3 Provides radiological controls for all activities
   - 2.4 Provides radiological surveys of equipment and personnel entering and exiting the SGS processing area
   - 2.5 Conduct Final Status Survey
   - 2.6 Perform decontamination of equipment
3. Demobilization of all laborers, materials, and equipment related to SGS system
4. Technical Services Options

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
					1,245,010
Soil Sorting System[1]					1,245,010
Premoblization & Mobilizatio	1	LS	$80,000	80,000	
Operational Activities	30.6	weeks	$32,000	978,375	
Demobilization	1	LS	$45,000	45,000	
Technical Support Options					
Site Activities	1223	hr	$100	122,297	
Per Diem	153	days	$126.50	19,338	

SGS estimated rate per week but not a production rate. Assumed excavation rates of 16 cy/hr for OU1 and 18 cy/hr for AOC6 in situ volume)

Letter from SGS said "generally" 24 cu m per hour so used the following excavation rate estimates

OU1	18,688	CY	1168	hours	29	weeks
AOC6	6,181	CY	55	hours	1.4	weeks
Total	24,869	CY	1223	hours	30.6	weeks

[1] Based on percentage of soil volume at OU1 and AOC6, the total soil sorting cost was divided among OU1 and AOC 6.

Table B-2.3.14: Costs Associated with Staging and Loading Area

The total concrete slab area calculated for soil staging (5000 CY), soil loading, and truck staging (2 each) was 11,000 SF.

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Staging and Loading Area[1]					**217,960**
Pad Subgrade Preparation	980	CY	$5.85	5733	
Cat 215, 1.0 CY, Soil, Shallow, Trenching	3.47	CY	$1.62	6	
Compact Subgrade, 2 Lifts	980	CY	$0.61	598	
Dry Roll Gravel, Steel Roller	1468	SY	$1.05	1541	
Gravel, Delivered and Dumped	407	CY	$27.67	11262	
(10%), with Calcium Chloride (1 lb/CY)	407	CY	$28.07	11424	
Concrete Curb (6" x 6")	859	LF	$2.68	2302	
26"x 26", 5' Deep Area Drain with Grate	1	EA	$3,370.74	3371	
6" Structural Slab on Grade	11000	Sf	$6.40	70400	
Reinforced Concrete Sump	1	EACH	$4,048.88	4049	
CIP Concrete In-Ground Trench Drain with Metal Grate	39	LF	$118.12	4607	
Erosion Control/Drainage Filter Fabric (80 Mil)	1468	SY	$1.54	2261	
Pump and Controls	1	LS	$2,000	2,000	
Discharge Piping	1	LS	$1,000	1,000	

[1] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.15: Costs Associated with Disposal

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Disposal (Commercial)					
Loading of Solids[1]					**723,695**
1 FE Loader	2039	hr	$55.71	113,592	
Outside Equip. Operators (2)	4078	hr	$49.02	199,902	
Outside Laborer Foreman	2039	hr	$54.12	110,350	
Outside Laborers (3)	6117	hr	$49.02	299,852	
Transportation and Emergency Response Plan[2]					**10,160**
Project Manager	8	hr	$103.74	830	
Senior Engineer	40	hr	$103.74	4,150	
Junior Engineer	80	hr	$64.76	5,181	
Transportation Costs					
OU 1					**3,146,427**
OU 1 (Rail)					
Burrito Bag	196	trip	$1,000	196,219	
Transportation cost by Rail to US Ecology	196	trip	$14,000	2,747,063	
DuPont RR Bumping Fee	392	trip	$150	58,866	
Absorbent Material	589	Each	$20	11,773	
Demurrage Charge	228	hrs	$65	14,820	
OU 1 (Truck)					
Dump Truck (2 each)	1226	trips	$72.74	89,206	
Truck Drivers (2)	581	hrs	$49.02	28,481	
AOC 6					**1,029,287**
AOC 6 (Rail)					
Burrito	65	trip	$1,000	64,903	
Transportation cost by Rail to US Ecology	65	trip	$14,000	908,644	
DuPont RR Bumping Fee	130	trip	$150	19,471	
Absorbent Material	195	Each	$20	3,894	
Demurrage Charge	20	hrs	$65	1,300	
AOC 6 (Truck)					
Dump Truck (2 each)	406	trips	$72.74	29,507	
Truck Drivers (2)	32	hrs	$49.02	1,569	
Disposal Fees and Taxes					**3,365,906**
Landfill					
OU 1					
US Ecology-Bulk Soil	19,622	tons	$100	1,962,188	
US Ecology-Hazardous FUSRAP waste	1,509	tons	$500	754,688	
AOC 6					
US Ecology-Bulk Soil	6,490	tons	$100	649,031	

[1,2] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC

Table B-2.3.16: Costs Associated with Site Restoration

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Site Restoration					***22,229***	
Earthwork	It includes rough grading with dozer, followed by fine grading				*5,850*	Previous Experiences at Other FUSRAP Sites
Grading					5,850	
OU 1	5.86	acres	$650	3,809		
AOC 6	3.14	acres	$650	2,041		
Revegetation & Planting	It includes watering, mechanical seeding and spray fertilizer				*12,934*	
Hydroseeding, 67% Level & 33% Sloped					5,951	
OU 1	5.86	acres	$661.17	3,874		
AOC 6	3.14	acres	$661.17	2,076		
Fertilizer, Hydro Spread					1,778	
OU 1	5.86	acres	$197.59	1,158		
AOC 6	3.14	acres	$197.59	620		
Watering with 3000-gallon Tank Truck					705	
OU 1	5.86	acres	$78.35	459		
AOC 6	3.14	acres	$78.35	246		
Miscellaneous Landscaping					4,500	
OU 1	5.86	acres	$500.00	2,930		
AOC 6	3.14	acres	$500.00	1,570		
Site Cleanup					*3,445*	
Site Debris Cleanup and Removal Cost					3,445	
OU 1	5.86	acres	$382.81	2,243		
AOC 6	3.14	acres	$382.81	1,202		

Table B-2.3.17: Costs Associated with Demobilization

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Demobilization [1]					***119,503***	
Removal of Temporary Facilities					21,850	Previous Experiences at Other FUSRAP Sites
Office Trailers (Contractor) only	1	LS	$750	750		
Storage Facilities	1	LS	$2,500	2,500		
Decon. Fac. For Const. Equip	1	LS	$15,000	15,000		
Toilets	2	LS	$100	200		
Barricades	2	LS	$1,500	3,000		
Signs	4	LS	$100	400		
Removal of Temporary Utilities					2,710	
Power Connection/Distribution	2	LS	$500	1,000		
Telephone/Communication Dist.	2	LS	$55	110		
Water Connection/Distribution	2	LS	$500	1,000		
Sewer Connection/Distribution	2	LS	$300	600		
Demob of Construction Equip/Fac						
Permits	1	LS	$500	500	500	
Demob. Of Construction Equipment					44,439	
Water Truck - Operation	16	hr	$61.38	982		
Water Truck - Standby	64	hr	$15.28	978		
Hydraulic Excavator - Operation	8	hr	$134.41	1,075		
Hydraulic Excavator - Standby	64	hr	$36.79	2,355		
PM Roller -Operation	16	hr	$29.67	475		
PM Roller- Standby	64	hr	$6.41	410		
PM Dozer, CWLR-Operation	16	hr	$49.71	795		
PM Dozer, CWLR-Standby	64	hr	$10.52	673		
PM Dozer, CWLR-Operation	16	hr	$60.94	975		
PM Dozer, CWLR-Standby	64	hr	$15.62	1,000		
2 PM Loader, FE - Operation	32	hr	$60.99	1,952		
2 PM Loader, FE-Standby	128	hr	$15.67	2,006		
CR, ME, CWLR, Lifting - Operation	8	hr	$91.24	730		
CR, ME, CWLR, Lifting - Standby	16	hr	$30.43	487		
Pile Hammer - Operation	8	hr	$83.45	668		
Pile Hammer - Standby	16	hr	$11.95	191		
TRLR, LOWBOY	80	hr	$6.88	550		
TRK HWY - Operation	80	hr	$35.40	2,832		
TRK HWY - standby	80	hr	$7.97	638		
Equip, Operators-Standby	80	hr	$49.02	3,922		
Equip, Operators-Operation	80	hr	$49.02	3,922		
Outside Truck Driver	80	hr	$49.02	3,922		
2 Outdoor Laborers	160	hr	$49.02	7,843		
Perdiem [CONUS + 15% tax]	40	days	$126.50	5,060		
Decon. Of Construction Equipment					50,004	
Mechanics Truck	224	hr	$7.97	1,785		
Equipment Operators	224	hr	$49.02	10,980		
2 Outdoor Laborers	448	hr	$49.02	21,961		
Perdiem [CONUS + 15% tax]	89.6	days	$126.50	11,334		
Small Tools	224	hr	$1.57	352		
Power Washer	224	hr	$8.48	1,900		
Compressor	224	hr	$7.55	1,691		

[1] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.18: Costs Associated with Submittals

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Submittals [1]					***8,562***	See Table B-2.6.21
Project Acceptance					8,562	
Cost Accountant	80	hr	$64.76	5,181		
Administrative Assistance	80	hr	$42.26	3,381		

[1] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.19: - Costs Associated with Excavation of Test Pits

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost ($)	Assumptions
# of Test Pits	6					64,606	Each pit = 27 yd3
Loader-backhoe, Heavy soil	162	CY	$63.50	10,287	10,287		02 32 19.10 0130
Additional Labor & Services					36,008		
Site Manager	40	hr	$103.74	4,150			See Table B-2.6.21
Principal Health Physicist	80	hr	$116.00	9,280			
Environmental Scientist	80	hr	$64.76	5,181			
Geotech Services	1	yr	$5,000	5,000			
2 laborers	160	hr	$49.02	7,843			
Perdiem [CONUS + 15% tax]	36	days	$126.50	4,554			
Sampling Costs	1	LS	$10,000	10,000	10,000		Assumptions

Table B-2.3.20: Costs Associated with Annual Operation, Maintenance & Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Assumptions
Post Construction						
Annual Operation, Maintenance, & Monitoring						
Monitoring [1]	1	yr	$ -	0	0	No Monitoring of Groundwater
Five Year Review (Per Event) [2]					31,598	
1 Project Manager	40	hr	$103.74	4,150		40 hrs per review
Principal Health Physicist	40	hr	$116.00	4,640		40 hrs per review
1 Senior Scientist	80	hr	$103.74	8,299		40 hrs/review
I Junior Engineer	160	hr	$64.76	10,362		160 hrs/review
1 GIS Operators	40	hr	$61.44	2,458		
Administrative Assistance	40	hr	$42.26	1,690		
Post Remedial Site Supervision (per Year) [3]					55,120	
1 Site Supervisor	1000	hr/yr	$54.12	54,120		4 hr/day for 250 days/yr
Miscellaneous Equipment Cost	1	yr	$1,000	1,000		

[1,2, 3] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.3.21: Labor Rates

DISCIPLINES	Code	Burdened Labor Rates [1]	Base Labor Rates
Principal	PRI	$151.96	$75.98
Program Manager	PGM	$128.54	$64.27
Senior Project Manager	SPM	$103.74	$51.87
Regulatory Specialist	RSP	$95.60	$47.80
Industrial Hygienist (Certified)	CIH	$103.74	$51.87
Sr. Environmental Scientist	SES	$103.74	$51.87
Sr Health Physicist	SHP	$116.00	$58.00
Senior Scientist	SSC	$103.74	$51.87
Senior Engineer	SEN	$103.74	$51.87
Senior Geologist	SGE	$103.74	$51.87
Construction Manager	CM	$128.54	$64.27
Quality Control Specialist	QC	$89.86	$44.93
Site Safety & Health Officer	SHO	$89.86	$44.93
Jr Health Physicist	JHP	$64.76	$32.38
Cost Accountant	AC	$64.76	$32.38
Junior Engineer	JEN	$64.76	$32.38
Illustrator/draftsperson	GIS	$61.44	$30.72
Senior Hydrologist	SHY	$116.00	$58.00
Jr. Environmental Scientist	JES	$64.76	$32.38
Junior Scientist	JSC	$64.76	$32.38
Field Supervisor	FS	$54.12	$27.06
Chemist	CH	$64.76	$32.38
Administrative Assistant	AA	$42.26	$21.13
Truck Driver	TD	$49.02	$24.51
Laborer	LAB	$49.02	$24.51

[1] Burdened labor rates include labor overhead multiplier but not profit

Labor Overhead Multiplier (LOH) = 2.0

Table B-2.3.22: Analytical Costs

Radionuclides	*Unit Cost*	**Total Cost**
Soil Sample Analysis		
Gamma Spec	119.00	
Ra-226	119.00	
Ra-228	119.00	
Iso-U	157.50	
Iso-Th	157.50	
		672.00
Waste Profile Analysis		
TCLP VOCs	148.75	
TCLP SVOCs	271.25	
TCLP Pesticides/Herbicides	420.00	
TCLP (8 RCRA Metals+Zinc)	148.75	
Ignitability	35.00	
Corrosivity	17.50	
Toxicity	70.00	
Reactive Cyanide& Sulfide	105.00	
PCBs	113.75	
		1,330.00
Air Filter Sample Analysis		
Gamma Spec	119	
Iso U	157.5	
Iso Th	157.5	
		434.00
Groundwater Sample Analysis		
Gross Alpha/Beta	$ 50.00	
Ra-226/Ra-228	$ 65.00	
Iso Thorium	$ 80.00	
Iso Uranium	$ 80.00	
		275.00

Table B-2.3.23: PPE Costs

Items	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity Needed Per Person Per Day	Extended	Comments/Assumptions
PPE - Level D Modified (cost per person-day)							
Cotton Liner Gloves (6 pair)	Pack	$ 5.47	$ 0.33	$ 5.80	0.6667	$ 3.87	4 pair per person per day
Duct Tape (2 rolls)	Pack	$ 7.96	$ 0.48	$ 8.44	0.0333	$ 0.28	2 yd per person per day
Face Shield (clear visor)	Each	$ 7.48	$ 0.45	$ 7.93	0.0042	$ 0.03	1 per person per year
Face Shield (ratchet head gear)	Each	$ 15.50	$ 0.93	$ 16.43	0.0042	$ 0.07	1 per person per year
Hard hat	Each	$ 8.00	$ 0.48	$ 8.48	0.0042	$ 0.04	1 per person per year
Hearing Protection (200 pair)	Case	$ 31.60	$ 1.90	$ 33.50	0.0150	$ 0.50	3 pair per person per day
Nitrile Gloves (lab grade) (box 50 pair)	Box	$ 11.95	$ 0.72	$ 12.67	0.0800	$ 1.01	4 pair per person per day
Rain gear	Each	$ 115.70	$ 6.94	$ 122.64	0.0042	$ 0.51	1 set per person per year
Reflective Vest	Each	$ 10.99	$ 0.66	$ 11.65	0.0500	$ 0.58	1 per person per month
Rubber Overboots	Pair	$ 29.80	$ 1.79	$ 31.59	0.0083	$ 0.26	2 per person per year
Safety Glasses	Pair	$ 3.16	$ 0.19	$ 3.35	0.0167	$ 0.06	4 per person per year
Safety Shoes	Each	$ 100.00	$ -	$ 100.00	0.0042	$ 0.42	1 pair per person per year - $100 limit
Tyvek Suits - Medium Weight w/ hood and shoe covers (case 25)	Case	$ 123.30	$ 7.40	$ 130.70	0.1200	$ 15.68	3 per person per day
Work Gloves (leather/cotton insulated)	Pair	$ -	$ -	$ -	0.2000	$ -	1 per person per week
Work Gloves (leather/cotton)	Pair	$ 2.64	$ 0.16	$ 2.80	0.2000	$ 0.56	1 per person per week
COST PER PERSON-DAY FOR MODIFIED LEVEL D						**$ 23.31**	

Table B-2.3.24: Trailer Costs - Initial Setup

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Operations Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	2	$ 295.93
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	1	$ 104.93
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	3	$ 572.37
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	2	$ 275.58
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	3	$ 2,594.72
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	6	$ 64.81
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	3	$ 111.27
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	6	$ 12.66
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	3	$ 158.97
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	3	$ 83.89
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (24 person)	Each	$ 51.20	$ 3.07	$ 54.27	1	$ 54.27
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	4	$ 27.69
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
		TOTAL COST FOR OUTFITTING OPERATIONS TRAILER				**$ 9,098.47**
HP Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	3	$ 443.90
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	3	$ 314.79
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	1	$ 190.79
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	1	$ 137.79
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	2	$ 1,729.81
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	2	$ 21.60
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	1	$ 37.09
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	1	$ 2.11
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	2	$ 105.98
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	1	$ 27.96
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	2	$ 13.84
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
		TOTAL COST FOR OUTFITTING HP TRAILER				**$ 7,806.12**
Break Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	1	$ 147.97
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	5	$ 524.65
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	5	$ 264.95
Microwave	Each	$ 269.00	$ 16.14	$ 285.14	3	$ 855.42
Refrigerator	Each	$ 629.10	$ 37.75	$ 666.85	1	$ 666.85
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
Large Trash Can	Each	$ 29.97	$ 1.80	$ 31.77	3	$ 95.30
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
`		**TOTAL COST FOR OUTFITTING BREAK TRAILER**				**$ 2,770.18**
		TOTAL COST FOR OUTFITTING SITE TRAILERS				**$ 19,674.77**

Trailer Costs - Monthly

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Laboratory Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	2	$ 110.22
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	2	$ 10.58

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	3	$ 19.05
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	1	$ 16.95
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	1	$ 24.37
Staples (pack 6000)	Each	$ 1.79	$ 0.11	$ 1.90	0.5	$ 0.95
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	0.5	$ 2.96
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Radiological Waste Bags (18" × 24" - roll 250 bags)	Roll	$ 55.25	$ 3.32	$ 58.57	1	$ 58.57
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	0.5	$ 3.44
Printer Ink Cartridges	Set	$ 139.99	$ 8.40	$ 148.39	2	$ 296.78
Smears with folders (box 500)	Box	$ 28.00	$ 1.68	$ 29.68	20	$ 593.60
Replacement mylar window (Ludlum Model 43-37)	Each	$ 80.00	$ 4.80	$ 84.80	1.67	$ 141.33
Replacement mylar window (Ludlum Model 43-93)	Each	$ 28.00	$ 1.68	$ 29.68	1.67	$ 49.47
Replacement Detector Cables (5-ft)	Each	$ 59.00	$ 3.54	$ 62.54	4	$ 250.16
D Batteries (pack 8)	Each	$ 14.99	$ 0.90	$ 15.89	1	$ 15.89
Marinelli Beakers (case 12)	Each	$ 236.00	$ 14.16	$ 250.16	11.11	$ 2,779.56
HEPA flexible duct (12" of 25 ft duct)	Each	$ 16.96	$ 1.02	$ 17.98	0.17	$ 3.00
P-10 Gas (300 cf tank)	Each	$ 78.60	$ 4.72	$ 83.32	2	$ 166.63
Liquid Nitrogen (180 Liter dewar with 22 psi)	Each	$ 110.50	$ 6.63	$ 117.13	4	$ 468.52
HEPA Air Filter Unit 2000 CFM	Each	$ 104.00	$ 6.24	$ 110.24	1	$ 110.24
Plastic Sheeting	Each	$ 94.00	$ 5.64	$ 99.64	0.17	$ 16.61
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	1	$ 8.47
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	1	$ 11.97
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	1	$ 15.15
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	1	$ 18.54
Ice Machine	LS	$ 195.00	$ -	$ 195.00	1	$ 195.00
		TOTAL MONTHLY COST FOR LABORATORY TRAILER				**$ 5,430.75**
Operations Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	3	$ 165.33
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	2	$ 10.58
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	2	$ 33.90
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	2	$ 48.74
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	1	$ 5.93
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	2	$ 16.94
Binder (1 1/2 inch)	Each	$ 9.29	$ 0.56	$ 9.85	2	$ 19.69
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	2	$ 23.93
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	2	$ 30.29
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	2	$ 37.08
		TOTAL MONTHLY COST FOR OPERATIONS TRAILER				**$ 704.91**
HP Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	1	$ 55.11
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	3	$ 15.87
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	3	$ 19.05
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	1	$ 16.95
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	1	$ 24.37
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	0.5	$ 2.96
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Air Sample Filters (Low Vol - 47 mm cellulose - 100 filters)	Box	$ 14.00	$ 0.84	$ 14.84	2	$ 29.68
Air Sample Filters (BZA - 47 mm mixed cellulose - 100 filters)	Box	$ 87.02	$ 5.22	$ 92.24	2	$ 184.48
Air Sample Filters (High Vol - 4 in cellulose - 100 filters)	Box	$ 18.00	$ 1.08	$ 19.08	2	$ 38.16
Smears with folders (box 500)	Box	$ 28.00	$ 1.68	$ 29.68	3	$ 89.04
MASSLINN Decontamination Wipes (18" × 24" - case 500 wipes)	Case	$ 80.50	$ 4.83	$ 85.33	1	$ 85.33
MASSLINN Decontamination Wipes (24" × 24" - case 500 wipes)	Case	$ 94.25	$ 5.66	$ 99.91	1	$ 99.91
Radiological Waste Bags (18" × 24" - roll 250 bags)	Roll	$ 55.25	$ 3.32	$ 58.57	1	$ 58.57
Radiological Waste Bags (36" × 48" - roll 100 bags)	Roll	$ 100.00	$ 6.00	$ 106.00	1	$ 106.00
Step off Pad/ Sticky Mat (4 mats, 30 sheets each mat)	Case	$ 78.80	$ 4.73	$ 83.53	1	$ 83.53
Step off Pad/ Sticky Mat - printed message (4 mats, 30 sheets/mat)	Case	$ 130.70	$ 7.84	$ 138.54	1	$ 138.54
Radiological Stickers (pack 25)	Pack	$ 21.03	$ 1.26	$ 22.29	1	$ 22.29
Radiological Boundary Ribbon (roll 200 ft)	Roll	$ 16.08	$ 0.96	$ 17.04	1	$ 17.04
Radiological Boundary Plastic Tape (roll 1,000 ft)	Roll	$ 11.00	$ 0.66	$ 11.66	1	$ 11.66
Radiological Boundary Rope (roll 600 ft)	Roll	$ 26.00	$ 1.56	$ 27.56	1	$ 27.56
Radiological Warning Sign	Each	$ 20.00	$ 1.20	$ 21.20	1	$ 21.20
Radiological Boundary Adhesive Tape (roll 36 yds)	Roll	$ 17.65	$ 1.06	$ 18.71	1	$ 18.71
Right in the Rain Notebook	Each	$ 16.95	$ 1.02	$ 17.97	2	$ 35.93
Alconox - 4 pound Box	Each	$ 28.95	$ 1.74	$ 30.69	1	$ 30.69
Alconox - 50 1/2 oz packets	Each	$ 39.95	$ 2.40	$ 42.35	1	$ 42.35
Steel Bowl	Each	$ 12.50	$ 0.75	$ 13.25	0.5	$ 6.63
Steel Spoon	Each	$ 5.95	$ 0.36	$ 6.31	1	$ 6.31
5-gallon bucket	Each	$ 2.34	$ 0.14	$ 2.48	4	$ 9.92
Ziploc 10-gallon bags (pack 30)	Each	$ 3.29	$ 0.20	$ 3.49	20	$ 69.75
Cooler	Each	$ 43.10	$ 2.59	$ 45.69	4	$ 182.74
Red Marking Paint	Each	$ 5.27	$ 0.32	$ 5.59	3	$ 16.76
Orange Marking Paint (pack 12)	Each	$ 44.88	$ 2.69	$ 47.57	1	$ 47.57
Pin Flags (pack 100)	Each	$ 7.98	$ 0.48	$ 8.46	2	$ 16.92
Safety Fence	Each	$ 36.98	$ 2.22	$ 39.20	3	$ 117.60
Utility Post	Each	$ 5.39	$ 0.32	$ 5.71	10	$ 57.13
Nylon Cable Ties (pack 100)	Each	$ 6.94	$ 0.42	$ 7.36	3	$ 22.07
Cable Ties (8 in pack 1000)	Each	$ 19.97	$ 1.20	$ 21.17	0.5	$ 10.58
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	2	$ 16.94
Binder (1 1/2 inch)	Each	$ 9.29	$ 0.56	$ 9.85	2	$ 19.69
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	2	$ 23.93
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	2	$ 30.29
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	2	$ 37.08
		TOTAL MONTHLY COST FOR HP TRAILER				**$ 2,266.70**
Break Trailer						
Water (case 28, 24 oz)	Case	$ 12.49	$ 0.75	$ 13.24	20	$ 264.79
Gatorade (case 6, 20 oz)	Case	$ 6.99	$ 0.42	$ 7.41	20	$ 148.19
Hand Wipes (40 wipes)	Pack	$ 2.99	$ 0.18	$ 3.17	6	$ 19.02
Paper Towels (6 rolls)	Pack	$ 10.49	$ 0.63	$ 11.12	6	$ 66.72
Sun Block	Each	$ 10.99	$ 0.66	$ 11.65	6	$ 69.90
Insect Repellent	Each	$ 6.49	$ 0.39	$ 6.88	6	$ 41.28
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	6	$ 54.00
		TOTAL MONTHLY COST FOR BREAK TRAILER				**$ 663.88**
		TOTAL MONTHLY COST FOR SITE TRAILERS				**$ 9,066.24**

Table B-2.3.25: Groundwater Sampling Costs per Event

ITEM DESCRIPTION	NO. UNITS	UNIT OF MEASURE	COST / UNIT	TOTAL COST
LABOR				
Lead Technician - sampling event	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
Hydrogeologist - report preparation	40	hours	$ 103.74	$ 4,150
GIS/CAD specialist - report preparation	8	hours	$ 61.44	$ 492
project assistant - report preparation	16	hours	$ 42.26	$ 676
project manager - QA/review	8	hours	$ 103.74	$ 830
ODCs				
CONSUMABLES				
consumables - FedEx coolers	32	shipments	$ 100.00	$ 3,200
consumables - Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
consumables - Misc Field Supplies	1	each	$ 2,000.00	$ 2,000
consumables - X-Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
EQUIPMENT				
equipment - 1/4" OD LDPE Tubing	820	feet	$ 0.65	$ 533
equipment - 2929	2	week(s)	$ 150.00	$ 300
equipment - GM detector	2	week(s)	$ 135.00	$ 270
equipment - In-Situ Troll multiparameter meter 9500 (4 units)	8	weeks	$ 200.00	$ 1,600
equipment - Silicone Tubing - Size 15	50	feet	$ 2.10	$ 105
equipment - tubing Pumps (4 units)	8	weeks	$ 150.00	$ 1,200
equipment - water level meter [2]	4	week(s)	$ 80.00	$ 320
SUB				
sub - analysis - 32 water suites + 6 field duplicates + 6 MS/MSD	44	each	$ 275.00	$ 12,100
sub - trailer, rent	1	months	$ 350.00	$ 350
TRAVEL				
travel - fuel 2 vehicles, 10 gallons/day	200	gallon	$ 3.00	$ 600
travel - per diem (for 4 people, 2 weeks at $140 (est))	40	days	$ 140.00	$ 5,600
travel - rental SUV [2]	20	days	$ 65.00	$ 1,300
travel - tolls	4	day	$ 12.00	$ 48
Assumptions:				
Monitoring, sampling, reporting for 32 wells in one event				
			GRAND TOTAL:	$ 46,118.80

ALTERNATIVE GW2

GROUNDWATER TREATMENT

TOTAL COST FOR GROUNDWATER TREATMENT ALTERNATIVE

Alternative Description	GW2-1	GW2-6
	GW Treatment	GW Treatment
Total Project Duration (years)	10	10
Capital Costs[1]		
Real Estate Analysis/Documents	**1,190**	**1,190**
Proj Management & Pre-Rem. Action	**120,301**	**41,931**
HTRW Remedial Action (Construct)	**925,584**	**330,289**
Annual O & M Costs[2]		
Long Term Monitoring	207,535	58,110
Site Supervision and Maintenance	62,350	20,623
Groundwater O &M Cost	367,264	220,845
Periodic O & M Costs[3]		
Five Years Review	39,602	13,099
Present Value of O&M Costs	**4,523,683**	**2,120,229**
Engineering Design Before Construction	**10,398**	**3,624**
Construction Management	**62,389**	**21,746**
Subtotal	5,643,545	2,519,008
Escalation (7%)	395,048	176,331
TOTAL COST	**6,038,594**	**2,695,339**

Notes

[1] Capital costs are those expenditures that are required to construct a remedial action and consist of expenditures initially incurred to build, install, or execute the remedial action.

[2] Annual O&M costs are operation and maintenance costs that occur post construction and are necessary to ensure or verify the continued effectiveness of a remedial action.

[3] Periodic O&M costs are operation and maintenance costs that occur only once every few years.

Table B-2.4 - Cost Associated with Cost Components for Alternatives GW2-1, GW2-6: Treatment of GW

This alternative involves ex situ treatment of contaminated groundwater. An uranium removal ion exchange system will be used to remove uranium and gross alpha.

Reference Table	ITEM	Base Price		Contract Cost		Design Contingency		Construction Contingency		Total Cost	
		OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6
B-2.4.1	**Rights of Entry/Temporary Permit**	1,000	1,000	140	140	50	50	0	0	1,190	1,190
B-2.4.1.1	Rights of Entry Acquisition	500	500								
B-2.4.1.2	Damages	500	500								
B-2.4.2	**Proj Manag. & Pre-Remedial Action**										
B-2.4.2.1	***Project Management [5% of B-2.4.3.0]***	36,105	12,584	5,055	1,762	1,805	629	0	0	42,965	14,975
B-2.4.2.2	***Remedial Design [8% of B-2.4.3.0]***	57,767	20,135	8,087	2,819	2,888	1,007	0	0	68,743	23,960
B-2.4.2.3	***Remedial Action Contracting [1% of B-2.4.3.0]***	7,221	2,517	1,011	352	361	126	0	0	8,593	2,995
B-2.4.3	**HTRW Remedial Action (Construct)**										
B-2.4.3.1	***Land Use Controls***	83,778	27,711	11,729	3,880	4,189	1,386	20,944	6,928	120,640	39,904
B-2.4.3.1.1	Preparatory Work [Table B-2.4.2]	34,164	11300								
B-2.4.3.1.2	Administrative Mechanism Plan [Table B-2.4.2]	49,614	16,411								
B-2.4.3.2	***Mobilize and Preparatory Work***	191,768	57,025	26,848	7,983	9,588	2,851	47,942	14,256	276,146	82,116
B-2.4.3.2.1	Preparatory Work [Table B-2.4.3]	168,168	55,625								
B-2.4.3.2.2	Mobilization[1]	23,600	1400				0				
B-2.4.3.3	***Site Work***	64,298	17,346	9,002	2,428	3,215	867	16,075	4,336	92,589	24,978
B-2.4.3.3.1	Install Signage [Table B-2.4.2]	2,374	986								
B-2.4.3.3.2	Install Fencing and Gates [Table B-2.4.2]	52,690	15,159								
B-2.4.3.3.3	Site Information Database [Table B-2.4.2]	9234	1,201								
B-2.4.3.4	***Monitoring, Sampling, Test & Analysis***	219,828	61,675	30,776	8,634	10,991	3,084	54,957	15,419	316,552	88,811
B-2.4.3.4.1	Environmental Monitoring [Table B-2.4.4]	9,092	3,008								
B-2.4.3.4.2	Additional Labor & Services [Table B-2.4.4]	161,626	42,423								
B-2.4.3.4.3	Waste Profile Sampling [Table B-2.4.4]	15,044	4,976								
B-2.4.3.4.4	Monitoring Equipment Cost [Table B-2.4.4]	16,548	5,473								
B-2.4.3.4.5	PPE Cost [Table B-2.4.4]	17,518	5,794								
B-2.4.3.5	***Groundwater Treatment and Management***										
B-2.4.3.5.1	Groundwater Treatment Cost (Capital) [Table B-2.4.5]	124,850	75,500	17,479	10,570	6,243	3,775	31,213	18,875	179,784	108,720
B-2.4.3.6	***Solids Collect and Containment***	0	0								
B-2.4.3.7	***Disposal (Commercial)***	15,029	4,971								
B-2.4.3.8	***Site Restoration***	0	0								
B-2.4.3.9	***Demobilization***[2]	22543	7,457	3,156	1,044	1,127	373	5,636	1,864	32,462	10,738
B-2.4.4	**Engineering During Construction [1% of B-2.4.3.0]**	7,221	2,517	1,011	352	361	126	1,805	629	10,398	3,624
B-2.4.5	**Construction Management (S&A) [6% of B-2.4.3.0]**	43,326	15,101	6,066	2,114	2,166	755	10,831	3,775	62,389	21,746
B-2.4.6	**Post Construction**										
B-2.4.6.1	***Annual Operation, Maint. & Monitoring***										
B-2.4.6.1.1	Monitoring [Table B-2.4.6]	144,121	40353.95	20,177	5,650	7,206	2,018	36,030	10,088	207,535	58,110
B-2.4.6.1.2	Post Remedial Site Supervision [Table B-2.4.6]	43,298	14321.73	6,062	2,005	2,165	716	10,825	3,580	62,350	20,623
B-2.4.6.1.3	Annual Groundwater Management Cost [Table B-2.4.5]	255,045	153,365	35,706	21,471	12,752	7,668	63,761	38,341	367,264	220,845
B-2.4.6.2	***Periodic Cost***										
B-2.4.6.2.1	Five Year Review [Table B-2.4.6]	27,502	9,097	3,850	1,274	1,375	455	6,875	2,274	39,602	13,099

14%	Contract Cost: includes G&A (6%) and profit (8%) for prime contractor and subcontractors, but not labor overhead. [See Table B-3.4 for overhead]
5%	Design Contingency: includes costs fro design and planning for unanticipated conditions.
25%	Construction Contingency: includes construction costs for unforeseen conditions.

[1,2] Total mobilization and demobilization costs are 25,000 and 30,000 respectively. The total cost was divided with respect to % of soil volume for OU1 and AOC 6.

Table B-2.4.1: Calculation of Soil Volumes

AOC	Soil Volume [CY] Excavation to Cut Lines [1] [in situ] [CY]	Ex-Situ Vol [2] [125%] [CY]	Percentage of Total
OU 1	12,300	15,375	71%
OU 1 Haz	700	875	4.0%
AOC 6	4,300	5,375	24.9%
Total	**17,300**	**21,625**	100%

Off-Site Disposal			
Bulk Soil[3] [CY] [+15% contingency]	Bulk Soil [4] [Tons]	Haz Soil [CY] [+15% contingency]	Haz Soil [4] [Tons]
17,681	26522		
		1,006	1509
6,181	9272		
23,863	35,794	1,006	1509

Calculation of Percentage Soil Volume

Area	Total Excavated Volume (CY)	% Soil
OU 1	18,688	75.1%
AOC 6	6,181	24.9%
Total	24,869	

Footnotes

1) Mean upper bound volume estimates - mean volume [based on 10 models] plus standard deviation. Cut line volume estimated using 1 : 1.5 slope from waste. The in situ volume was rounded off during cost estimation.

2) 125% swelling factor applied to in situ estimates.

3) Bulk Soil: FUSRAP waste soil plus cut-back. Assumes both will be disposed of as same waste stream.

4) Average density of damp sand [1.7] or 110 pounds / ft^3 or 1.5 tons per cubic yard [EPA/625/12-91/002].

Table B-2.4.2: Costs Associated with Land Use Controls (LUCs)

The ICs include both land use controls (LUCs) and administrative controls (zoning, deed restrictions, and/or well construction restrictions).

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Land Use Control					176,062	
Preparatory Work[1]						
Coordination with various local, state, and Federal agencies for land use control plans and administrative mechanism plan					37,165	
Program Manager	160	hr	$128.54	20,566		See Table B-2.7.7
Project Manager	160	hr	$103.74	16,598		
Coordination with owners for land use control plans and administrative mechanism plan					8,299	
Project Manager	80	hr	$103.74	8,299		See Table B-2.7.7
Land Use Control Plan[2]					64,574	
Project Manager	80	hr	$103.74	8,299		See Table B-2.2.6
Principal Health Physicist	160	hr	$116.00	18,560		
1 Senior Scientist	240	hr	$103.74	24,898		
I Junior Engineer	40	hr	$64.76	2,590		
1 Attorney	40	hr	$151.96	6,078		
1 GIS Operator	40	hr	$61.44	2,458		
Administrative Assistant	40	hr	$42.26	1,690		
Administrative Mechanism Plan[3]					66,025	
Project Manager	80	hr	$103.74	8,299		See Table B-2.7.7
Principal Health Physicist	80	hr	$116.00	9,280		
1 Senior Scientist	160	hr	$103.74	16,598		
I Junior Engineer	240	hr	$64.76	15,542		
1 Attorney	80	hr	$151.96	12,157		
1 GIS Operator	40	hr	$61.44	2,458		
Administrative Assistance	40	hr	$42.26	1,690		
Construct - Land Use Control						
Install Signage	Fabricated stainless Steel, 18" high, 4" deep				4,776	RSMeans (10 14 19.10.2100)
Number of Signs	Install 18" Caution - "Radiological Material" Signs					
OU 1	4		$292.00	1,168		
AOC 6	2		$292.00	584		
Equipment Rental OU 1	1.5	day	$20.00	30		Assumed
Equipment Rental AOC 6	0.5	day	$20.00	10		
Union Laborer (2) OU 1	12	hrs	$49.02	1,176		See Table B-2.2.6
Union Laborer (2) AOC 6	4	hrs	$49.02	392		
Install Fencing and Gates	Install up to 1632 ft of fencing @ 165 ft/day				124,288	
Raw Materials						
Permanent Fencing	6 ga. wire, 6" high but omit barded wire, galvanized steel					RSMeans (32 31 13.20.0800)
OU 1	1260	LF	$31.00	39,060		
AOC 6	372	LF	$31.00	11,532		
Gates	6' high, 12' opening, in concrete (Double swing gates, incl. posts & hardware, in concrete)					RSMeans, 32 31 13.20 5060
OU 1	2		$1,350	2,700		
AOC 6	1		$1,350	1,350		
Labor OU 1						
Prep Work (2 laborers)	16	hrs	$49.02	1,569		See Table B-2.2.6
Installation Work (2 laborers)	80	hrs	$49.02	7,843		
Perdiem [CONUS + 15% tax]	12	days	$126.50	1,518		
Labor AOC 6						
Prep Work (2 laborers)	4	hrs	$49.02	392		See Table B-2.2.6
Installation Work (2 laborers)	16	hrs	$49.02	1,569		
Perdiem [CONUS + 15% tax]	3	days	$126.50	316		
Site Information Database [4]	200	hrs	$61.44	12,288		

Footnote

[1,2,3,4] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.4.3: Costs Associated with Preparatory Work

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost ($)	Assumptions
Preparatory Work[1]						**223,793**	
Submittals/Implementation Plan						*127,178*	
Environmental Protection Plan					24,898		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineer	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Sedimentation Control Plan					29,047		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Geologist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
Site Safety and Health Plan					27,317		
Senior Health Physicist	40	hr	$116.00	4,640			20 hrs/contract; 2 contracts
Site Safety & Health Officer	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
General Site Work Plan					25,890		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Construction Manager	40	hr	$128.54	$5,142			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Quality Control Plan					18,527		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Quality Control Engineers	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Permits	2		$750.00	1,500	1,500		$750/ permit
Setup/Construct Temp Facilities + Monthly Cost						*83,154*	
Operation Trailer	1	LS	$ 9,098	9,098			1 for both contracts
HP Trailer	1	LS	$ 7,806	7,806			1 for both contracts
Break Trailer	1	LS	$ 2,770	2,770			1 for both contracts
Toilets	2	LS	$100	200			1 for each contract
Barricades	2	LS	$1,500	3,000			1 for each contract
Signs	4	LS	$292	1,168			2 for each contract
Monthly Operating Cost							
Operation Trailer	16	months	$ 704.91	11,279			See Table 2.4.10
HP Trailer	16	months	$ 2,266.7	36,267			
Break Trailer	16	months	$ 663.88	10,622			
Construct Temporary Utilities +Monthly Cost						*13,460*	
Power Connection/Distribution	2	LS	$500	1,000			1 for each contract
Telephone/Communication Dist.	2	LS	$100	200			1 for each contract
Water Connection/Distribution	2	LS	$1,430	2,860			1 for each contract
Sewer Connection/Distribution	2	LS	$300	600			1 for each contract
Monthly Cost -Utilities							
Power Distribution	16	months	$250	4,000			Assumed
Telephone/Communication Dist.	16	months	$100	1,600			
Water Distribution	16	months	$100	1,600			
Sewer Distribution	16	months	$100	1,600			

[1] Based on percentage of soil volume at OU1 and AOC6, the total preparatory cost was divided among OU1 and AOC 6.

Table B-2.4.4: Costs Associated with Environmental Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Monitoring, Sampling, Test, Analysis					
Offsite Sample Analysis Cost					**12,100**
Environmental Monitoring [32 water suites + 6 field duplicates + 6 MS/MSD]					
OU 1 and AOC 6	44	samples	275.00	12,100	
Additional Labor & Services					
OU 1					161,626
Project Manager	16	hrs	$103.74	1,660	
Principal Health Physicist	40	hrs	$116.00	4,640	
2 Junior HPs	2 x 100 days x 10 hrs/day	hrs	$64.76	129,520	
Perdiem [CONUS + 15% tax]	204	days	$126.50	25,806	
AOC 6					42,423
Project Manager	16	hrs	$103.74	1,660	
Principal Health Physicist	16	hrs	$116.00	1,856	
2 Junior HPs	2 x 25 days x 10 hrs/day	hrs	$64.76	32,380	
Perdiem [CONUS + 15% tax]	52	days	$126.50	6,527	
[1] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided between OU1 and AOC 6.					
Waste Profile Cost[1] (Assume 10 samples)					**20,020**
Chemical Parameters					
TCLP VOCs	10	samples	$ 148.75	1,488	See Table B-2.5.21
TCLP SVOCs	10	samples	$ 271.25	2,713	
TCLP Pesticides/Herbicides	10	samples	$ 420.00	4,200	
TCLP (8 RCRA Metals+Zinc)	10	samples	$ 148.75	1,488	
Ignitability	10	samples	$ 35.00	350	
Corrosivity	10	samples	$ 17.50	175	
Toxicity	10	samples	$ 70.00	700	
Reactive Cyanide& Sulfide	10	samples	$ 105.00	1,050	
PCBs	10	samples	$ 113.75	1,138	
Radionuclides					
Gamma Spec	10	samples	$ 119.00	1,190	See Table B-2.5.21
Ra-226	10	samples	$ 119.00	1,190	
Ra-228	10	samples	$ 119.00	1,190	
Iso-U	10	samples	$ 157.50	1,575	
Iso-Th	10	samples	$ 157.50	1,575	
Monitoring Equipment Cost[2]					**22,021**
Bioassays (6 months for 10 people)	10	people	$148.75	1,488	Previous Experiences at Other FUSRAP Sites
Fiskers (1 for OU1, 1 for AOC 6, and 1 at Trailer)	3 x 6 months	month	$271	8,138	
Radiological Detectors					
FIDLER w/scaler	1x 6 months	month	$548	3,288	
Alpha/beta detectors (e.g., Ludlum Models 43-93)	1 x 6 months	month	$96	576	
Radiological Meters					
A smear counter (Ludlum Model 2929)	2 x 6 months	month	$211	2,532	
Dosimetry					
TLDs	10 x 6 months	month	$100	6,000	
PPE Cost[3]					**23,312**
Number of People using PPE	10 persons x 100 workdays		$ 23.31	23,312	See Table B-2.5.23

[1,2,3,4] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.4.5: Costs Associated with Groundwater Treatment

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Groundwater Treatment					
Capital Cost					
OU 1					124,850
Installation of Extraction Wells	4	wells	$5,000	20,000	
Process and Control Building	200	sq ft	$250	50,000	
Granular Activation Carbon	1	LS	$10,000	10,000	
Uranium Removal Ion Exchange System	1	LS	$37,850	37,850	
Transportation to Site	1	LS	$2,000	2,000	
Additional Piping	1	LS	$5,000	5,000	
AOC 6					75,500
Installation of Extraction Wells	1	wells	$5,000	5,000	
Process and Control Building	100	sq ft	$250	25,000	
Granular Activation Carbon	1	LS	$2,000	2,000	
Uranium Removal Ion Exchange System	1	LS	$36,500	36,500	
Transportation to Site	1	LS	$2,000	2,000	
Additional Piping	1	LS	$5,000	5,000	
Annual O&M Cost					
OU1					
Management and Operation					255,045
Engineering Manager	250	hr	$103.74	25,935	
Construction Engineer	250	hr	$128.54	32,135	
Senior Engineer	250	hr	$103.74	25,935	
Junior Engineer	500	hr	$64.76	32,380	
Field Technician	100	hr	$49.02	4,902	
Perdiem [CONUS + 15% tax]	135	days	$126.50	17,078	
Granular Activation Carbon	1	LS	$25,000	25,000	
Uranium Removal Ion Exchange System					
Replacement of ion exch media tanks	4	LS	$21,670	86,680	
Misc. O&M (power, chemicals, etc)	1	LS	$5,000	5,000	
AOC6					
Management and Operation					$153,365
Engineering Manager	250	hr	$103.74	25,935	
Construction Engineer	250	hr	$128.54	32,135	
Senior Engineer	250	hr	$103.74	25,935	
Junior Engineer	500	hr	$64.76	32,380	
Field Technician	100	hr	$49.02	4,902	
Perdiem [CONUS + 15% tax]	135	days	$126.50	17,078	
Granular Activation Carbon	1	LS	$5,000	5,000	
Uranium Removal Portable Exchange System					
Replacement of ion exch media tanks	1	LS	$7,000	7,000	
Misc. O&M (power, chemicals, etc)	1	LS	$3,000	3,000	

Table B-2.4.6: Costs Associated with Annual Operation, Maintenance & Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Assumptions
Post Construction						
Annual Operation, Maintenance, & Monitoring						
Monitoring [1]	1	yr	$ 184,475	184,475	184,475	Monitoring of Groundwater
Five Year Review (Every 5 year) [2]					36,598	
1 Project Manager	40	hr	$103.74	4,150		40 hrs per review
Principal Health Physicist	40	hr	$116.00	4,640		40 hrs per review
1 Senior Scientist	80	hr	$103.74	8,299		80 hrs per review
I Junior Engineer	160	hr	$64.76	10,362		160 hrs per review
1 GIS Operator	40	hr	$61.44	2,458		
Administrative Assistance	40	hr	$42.26	1,690		1 month (40 hrs/review)
Additional Labor and Services	1	LS	$5,000	5,000		Assumed
Post Remedial Site Supervision (per Yr) [3]					57,620	
1 Site Supervisor	1000	hr	$54.12	54,120		4 hr/day for 250 days/yr
Miscellaneous Equipment Cost	1	LS	$1,000	1,000		Assumed
Additional Labor and Services	1	LS	$2,500	2,500		Assumed

[1,2,3] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.4.7: LABOR RATES

DISCIPLINES	Code	Base Labor Rates	Burdened Labor Rates [1]
Principal	PRI	$75.98	$151.96
Program Manager	PGM	$64.27	$128.54
Senior Project Manager	SPM	$51.87	$103.74
Regulatory Specialist	RSP	$47.80	$95.60
Industrial Hygienist (Certified)	CIH	$51.87	$103.74
Sr. Environmental Scientist	SES	$51.87	$103.74
Sr Health Physicist	SHP	$58.00	$116.00
Senior Scientist	SSC	$51.87	$103.74
Senior Engineer	SEN	$51.87	$103.74
Senior Geologist	SGE	$51.87	$103.74
Construction Manager	CM	$64.27	$128.54
Quality Control Specialist	QC	$44.93	$89.86
Site Safety & Health Officer	SHO	$44.93	$89.86
Jr Health Physicist	JHP	$32.38	$64.76
Cost Accountant	AC	$32.38	$64.76
Junior Engineer	JEN	$32.38	$64.76
Illustrator/draftsperson	GIS	$30.72	$61.44
Senior Hydrologist	SHY	$58.00	$116.00
Jr. Environmental Scientist	JES	$32.38	$64.76
Junior Scientist	JSC	$32.38	$64.76
Field Supervisor	FS	$27.06	$54.12
Chemist	CH	$32.38	$64.76
Administrative Assistant	AA	$21.13	$42.26
Truck Driver	TD	$24.51	$49.02
Laborer	LAB	$24.51	$49.02

[1] Burdened labor rates include labor overhead multiplier but not profit
Labor Overhead Multiplier (LOH) = 2.0

Table B-2.4.8: Laboratory Analysis Cost ($)

Radionuclides	*Unit Cost*	Total Cost
Soil Sample Analysis		
Gamma Spec	119.00	
Ra-226	119.00	
Ra-228	119.00	
Iso-U	157.50	
Iso-Th	157.50	
		672.00
TCLP VOCs	148.75	
TCLP SVOCs	271.25	
TCLP Pesticides/Herbicides	420.00	
TCLP (8 RCRA Metals+Zinc)	148.75	
Ignitability	35.00	
Corrosivity	17.50	
Toxicity	70.00	
Reactive Cyanide& Sulfide	105.00	
PCBs	113.75	
		1,330.00
Air Filter Sample Analysis		
Gamma Spec	119	
Iso U	157.5	
Iso Th	157.5	
		434.00
Groundwater Sample Analysis		
Gross Alpha/Beta	$ 50.00	
Ra-226/Ra-228	$ 65.00	
Iso Thorium	$ 80.00	
Iso Uranium	$ 80.00	
		275.00

Table B-2.4.9: PPE Costs

	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity Needed Per Person Per Day	Extended	Comments/Assumptions
PPE - Level D Modified (cost per person-day)							
Cotton Liner Gloves (6 pair)	Pack	$ 5.47	$ 0.33	$ 5.80	0.6667	$ 3.87	4 pair per person per day
Duct Tape (2 rolls)	Pack	$ 7.96	$ 0.48	$ 8.44	0.0333	$ 0.28	2 yd per person per day
Face Shield (clear visor)	Each	$ 7.48	$ 0.45	$ 7.93	0.0042	$ 0.03	1 per person per year
Face Shield (ratchet head gear)	Each	$ 15.50	$ 0.93	$ 16.43	0.0042	$ 0.07	1 per person per year
Hard hat	Each	$ 8.00	$ 0.48	$ 8.48	0.0042	$ 0.04	1 per person per year
Hearing Protection (200 pair)	Case	$ 31.60	$ 1.90	$ 33.50	0.0150	$ 0.50	3 pair per person per day
Nitrile Gloves (lab grade) (box 50 pair)	Box	$ 11.95	$ 0.72	$ 12.67	0.0800	$ 1.01	4 pair per person per day
Rain gear	Each	$ 115.70	$ 6.94	$ 122.64	0.0042	$ 0.51	1 set per person per year
Reflective Vest	Each	$ 10.99	$ 0.66	$ 11.65	0.0500	$ 0.58	1 per person per month
Rubber Overboots	Pair	$ 29.80	$ 1.79	$ 31.59	0.0083	$ 0.26	2 per person per year
Safety Glasses	Pair	$ 3.16	$ 0.19	$ 3.35	0.0167	$ 0.06	4 per person per year
Safety Shoes	Each	$ 100.00	$ -	$ 100.00	0.0042	$ 0.42	1 pair per person per year - $100 limit
Tyvek Suits - Medium Weight w/ hood and shoe covers (case 25)	Case	$ 123.30	$ 7.40	$ 130.70	0.1200	$ 15.68	3 per person per day
Work Gloves (leather/cotton insulated)	Pair	$ -	$ -	$ -	0.2000	$ -	1 per person per week
Work Gloves (leather/cotton)	Pair	$ 2.64	$ 0.16	$ 2.80	0.2000	$ 0.56	1 per person per week
COST PER PERSON-DAY FOR MODIFIED LEVEL D						**$ 23.31**	

Table B-2.4.10: Trailer Costs - Initial Setup

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Operations Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	2	$ 295.93
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	1	$ 104.93
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	3	$ 572.37
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	2	$ 275.58
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	3	$ 2,594.72
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	6	$ 64.81
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	3	$ 111.27
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	6	$ 12.66
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	3	$ 158.97
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	3	$ 83.89
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (24 person)	Each	$ 51.20	$ 3.07	$ 54.27	1	$ 54.27
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	4	$ 27.69
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
	TOTAL COST FOR OUTFITTING OPERATIONS TRAILER					**$ 9,098.47**
HP Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	3	$ 443.90
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	3	$ 314.79
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	1	$ 190.79
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	1	$ 137.79
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	2	$ 1,729.81
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	2	$ 21.60
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	1	$ 37.09
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	1	$ 2.11
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	2	$ 105.98
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	1	$ 27.96
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	2	$ 13.84
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
	TOTAL COST FOR OUTFITTING HP TRAILER					**$ 7,806.12**
Break Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	1	$ 147.97
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	5	$ 524.65
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	5	$ 264.95
Microwave	Each	$ 269.00	$ 16.14	$ 285.14	3	$ 855.42
Refrigerator	Each	$ 629.10	$ 37.75	$ 666.85	1	$ 666.85
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
Large Trash Can	Each	$ 29.97	$ 1.80	$ 31.77	3	$ 95.30
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
`	**TOTAL COST FOR OUTFITTING BREAK TRAILER**					**$ 2,770.18**
	TOTAL COST FOR OUTFITTING SITE TRAILERS					**$ 19,674.77**

Table B-2.4.10: Trailer Costs - Initial Setup CONT.
Trailer Costs - Monthly

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Laboratory Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	2	$ 110.22
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	2	$ 10.58
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	3	$ 19.05
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	1	$ 16.95
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	1	$ 24.37
Staples (pack 6000)	Each	$ 1.79	$ 0.11	$ 1.90	0.5	$ 0.95
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	0.5	$ 2.96
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Radiological Waste Bags (18" × 24" - roll 250 bags)	Roll	$ 55.25	$ 3.32	$ 58.57	1	$ 58.57
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	0.5	$ 3.44
Printer Ink Cartridges	Set	$ 139.99	$ 8.40	$ 148.39	2	$ 296.78
Smears with folders (box 500)	Box	$ 28.00	$ 1.68	$ 29.68	20	$ 593.60
Replacement mylar window (Ludlum Model 43-37)	Each	$ 80.00	$ 4.80	$ 84.80	1.67	$ 141.33
Replacement mylar window (Ludlum Model 43-93)	Each	$ 28.00	$ 1.68	$ 29.68	1.67	$ 49.47
Replacement Detector Cables (5-ft)	Each	$ 59.00	$ 3.54	$ 62.54	4	$ 250.16
D Batteries (pack 8)	Each	$ 14.99	$ 0.90	$ 15.89	1	$ 15.89
Marinelli Beakers (case 12)	Each	$ 236.00	$ 14.16	$ 250.16	11.11	$ 2,779.56
HEPA flexible duct (12" of 25 ft duct)	Each	$ 16.96	$ 1.02	$ 17.98	0.17	$ 3.00
P-10 Gas (300 cf tank)	Each	$ 78.60	$ 4.72	$ 83.32	2	$ 166.63
Liquid Nitrogen (180 Liter dewar with 22 psi)	Each	$ 110.50	$ 6.63	$ 117.13	4	$ 468.52
HEPA Air Filter Unit 2000 CFM	Each	$ 104.00	$ 6.24	$ 110.24	1	$ 110.24
Plastic Sheeting	Each	$ 94.00	$ 5.64	$ 99.64	0.17	$ 16.61
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	1	$ 8.47
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	1	$ 11.97
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	1	$ 15.15
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	1	$ 18.54
Ice Machine	LS	$ 195.00	$ -	$ 195.00	1	$ 195.00
	TOTAL MONTHLY COST FOR LABORATORY TRAILER					**$ 5,430.75**
Operations Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	3	$ 165.33
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	2	$ 10.58
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	2	$ 33.90
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	2	$ 48.74
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	1	$ 5.93
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	2	$ 16.94
Binder (1 1/2 inch)	Each	$ 9.29	$ 0.56	$ 9.85	2	$ 19.69
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	2	$ 23.93
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	2	$ 30.29
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	2	$ 37.08
	TOTAL MONTHLY COST FOR OPERATIONS TRAILER					**$ 704.91**

Table B-2.4.10: Trailer Costs - Initial Setup CONT.

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
HP Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	1	$ 55.11
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	3	$ 15.87
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	3	$ 19.05
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	1	$ 16.95
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	1	$ 24.37
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	0.5	$ 2.96
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98
Air Sample Filters (Low Vol - 47 mm cellulose - 100 filters)	Box	$ 14.00	$ 0.84	$ 14.84	2	$ 29.68
Air Sample Filters (BZA - 47 mm mixed cellulose - 100 filters)	Box	$ 87.02	$ 5.22	$ 92.24	2	$ 184.48
Air Sample Filters (High Vol - 4 in cellulose - 100 filters)	Box	$ 18.00	$ 1.08	$ 19.08	2	$ 38.16
Smears with folders (box 500)	Box	$ 28.00	$ 1.68	$ 29.68	3	$ 89.04
MASSLINN Decontamination Wipes (18" × 24" - case 500 wipes)	Case	$ 80.50	$ 4.83	$ 85.33	1	$ 85.33
MASSLINN Decontamination Wipes (24" × 24" - case 500 wipes)	Case	$ 94.25	$ 5.66	$ 99.91	1	$ 99.91
Radiological Waste Bags (18" × 24" - roll 250 bags)	Roll	$ 55.25	$ 3.32	$ 58.57	1	$ 58.57
Radiological Waste Bags (36" × 48" - roll 100 bags)	Roll	$ 100.00	$ 6.00	$ 106.00	1	$ 106.00
Step off Pad/ Sticky Mat (4 mats, 30 sheets each mat)	Case	$ 78.80	$ 4.73	$ 83.53	1	$ 83.53
Step off Pad/ Sticky Mat - printed message (4 mats, 30 sheets/mat)	Case	$ 130.70	$ 7.84	$ 138.54	1	$ 138.54
Radiological Stickers (pack 25)	Pack	$ 21.03	$ 1.26	$ 22.29	1	$ 22.29
Radiological Boundary Ribbon (roll 200 ft)	Roll	$ 16.08	$ 0.96	$ 17.04	1	$ 17.04
Radiological Boundary Plastic Tape (roll 1,000 ft)	Roll	$ 11.00	$ 0.66	$ 11.66	1	$ 11.66
Radiological Boundary Rope (roll 600 ft)	Roll	$ 26.00	$ 1.56	$ 27.56	1	$ 27.56
Radiological Warning Sign	Each	$ 20.00	$ 1.20	$ 21.20	1	$ 21.20
Radiological Boundary Adhesive Tape (roll 36 yds)	Roll	$ 17.65	$ 1.06	$ 18.71	1	$ 18.71
Right in the Rain Notebook	Each	$ 16.95	$ 1.02	$ 17.97	2	$ 35.93
Alconox - 4 pound Box	Each	$ 28.95	$ 1.74	$ 30.69	1	$ 30.69
Alconox - 50 1/2 oz packets	Each	$ 39.95	$ 2.40	$ 42.35	1	$ 42.35
Steel Bowl	Each	$ 12.50	$ 0.75	$ 13.25	0.5	$ 6.63
Steel Spoon	Each	$ 5.95	$ 0.36	$ 6.31	1	$ 6.31
5-gallon bucket	Each	$ 2.34	$ 0.14	$ 2.48	4	$ 9.92
Ziploc 10-gallon bags (pack 30)	Each	$ 3.29	$ 0.20	$ 3.49	20	$ 69.75
Cooler	Each	$ 43.10	$ 2.59	$ 45.69	4	$ 182.74
Red Marking Paint	Each	$ 5.27	$ 0.32	$ 5.59	3	$ 16.76
Orange Marking Paint (pack 12)	Each	$ 44.88	$ 2.69	$ 47.57	1	$ 47.57
Pin Flags (pack 100)	Each	$ 7.98	$ 0.48	$ 8.46	2	$ 16.92
Safety Fence	Each	$ 36.98	$ 2.22	$ 39.20	3	$ 117.60
Utility Post	Each	$ 5.39	$ 0.32	$ 5.71	10	$ 57.13
Nylon Cable Ties (pack 100)	Each	$ 6.94	$ 0.42	$ 7.36	3	$ 22.07
Cable Ties (8 in pack 1000)	Each	$ 19.97	$ 1.20	$ 21.17	0.5	$ 10.58
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	2	$ 16.94
Binder (1 1/2 inch)	Each	$ 9.29	$ 0.56	$ 9.85	2	$ 19.69

Table B-2.4.10: Trailer Costs - Initial Setup CONT.

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	2	$ 23.93
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	2	$ 30.29
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	2	$ 37.08
	TOTAL MONTHLY COST FOR HP TRAILER					**$ 2,266.70**
Break Trailer						
Water (case 28, 24 oz)	Case	$ 12.49	$ 0.75	$ 13.24	20	$ 264.79
Gatorade (case 6, 20 oz)	Case	$ 6.99	$ 0.42	$ 7.41	20	$ 148.19
Hand Wipes (40 wipes)	Pack	$ 2.99	$ 0.18	$ 3.17	6	$ 19.02
Paper Towels (6 rolls)	Pack	$ 10.49	$ 0.63	$ 11.12	6	$ 66.72
Sun Block	Each	$ 10.99	$ 0.66	$ 11.65	6	$ 69.90
Insect Repellent	Each	$ 6.49	$ 0.39	$ 6.88	6	$ 41.28
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	6	$ 54.00
	TOTAL MONTHLY COST FOR BREAK TRAILER					**$ 663.88**
	TOTAL MONTHLY COST FOR SITE TRAILERS					**$ 9,066.24**

Table B-2.4.11: Groundwater Sampling Costs Per Event

ITEM DESCRIPTION	NO. UNITS	UNIT OF MEASURE	COST / UNIT	TOTAL COST
LABOR				
Lead Technician - sampling event	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
Hydrogeologist - report preparation	40	hours	$ 103.74	$ 4,150
GIS/CAD specialist - report preparation	8	hours	$ 61.44	$ 492
project assistant - report preparation	16	hours	$ 42.26	$ 676
project manager - QA/review	8	hours	$ 103.74	$ 830
ODCs				
CONSUMABLES				
consumables - FedEx coolers	32	shipments	$ 100.00	$ 3,200
consumables - Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
consumables - Misc Field Supplies	1	each	$ 2,000.00	$ 2,000
consumables - X-Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
EQUIPMENT				
equipment - 1/4" OD LDPE Tubing	820	feet	$ 0.65	$ 533
equipment - 2929	2	week(s)	$ 150.00	$ 300
equipment - GM detector	2	week(s)	$ 135.00	$ 270
equipment - In-Situ Troll multiparameter meter 9500 (4 units)	8	weeks	$ 200.00	$ 1,600
equipment - Silicone Tubing - Size 15	50	feet	$ 2.10	$ 105
equipment - tubing Pumps (4 units)	8	weeks	$ 150.00	$ 1,200
equipment - water level meter [2]	4	week(s)	$ 80.00	$ 320
SUB				
sub - analysis - 32 water suites + 6 field duplicates + 6 MS/MSD	44	each	$ 275.00	$ 12,100
sub - trailer, rent	1	months	$ 350.00	$ 350
TRAVEL				
travel - fuel 2 vehicles, 10 gallons/day	200	gallon	$ 3.00	$ 600
travel - per diem (for 4 people, 2 weeks at $140 (est))	40	days	$ 140.00	$ 5,600
travel - rental SUV [2]	20	days	$ 65.00	$ 1,300
travel - tolls	4	day	$ 12.00	$ 48
Assumptions:				
Monitoring, sampling, reporting for 32 wells in one event				
			GRAND TOTAL:	$ 46,118.80

ALTERNATIVE GW3

MONITORED NATURAL ATTENUATION

TOTAL COST FOR GROUNDWATER MONITORED NATURAL ATTENUATION ALTERNATIVE

Alternative Description	GW3-1 Monitored Natural Attenuation	GW3-6 Monitored Natural Attenuation
Total Project Duration (years)	30	30
Capital Costs[1]		
Real Estate Analysis/Documents	**1,190**	**1,190**
Proj Management & Pre-Rem. Action	**87,266**	**28,225**
HTRW Remedial Action (Construct)	**675,706**	**218,550**
Annual O&M Costs[2]		
Long Term Monitoring	182,866	91,433
Site Supervision and Maintenance	53,431	17,673
Periodic O&M Costs[3]		
Five Years Review	35,477	11,735
Present Value of O&M Costs	**3,450,654**	**1,583,257**
Engineering Design Before Construction	**6,757**	**2,185**
Construction Management	**40,542**	**13,113**
Subtotal	4,262,114	1,846,520
Escalation (7%)	298,348	129,256
TOTAL COST	**4,560,462**	**1,975,776**

Notes

[1] Capital costs are those expenditures that are required to construct a remedial action and consist of expenditures initially incurred to build, install, or execute the remedial action.

[2] Annual O&M costs are operation and maintenance costs that occur post construction and are necessary to ensure or verify the continued effectiveness of a remedial action.

[3] Periodic O&M costs are operation and maintenance costs that occur only once every few years.

Table B-2.5 - Cost Associated with Cost Components for Alternative GW3: Monitored Natural Attenuation
30 Year Cost

This alternative involves quarterly monitoring of groundwater. Sampling results of newly installed wells and selected existing wells will be used to monitor geochemical conditions and quality of groundwater. A total of seven monitoring wells are estimated to be installed in the excavation areas in OU 1 and AOC 6.

Reference Table	ITEM	Base Price		Contract Cost (8%)		Design Contingency		Construction Contingency		Total Cost	
		OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6	OU 1	AOC 6
B-2.5.1	**Rights of Entry/Temporary Permit**	1000	1000	*140*	*140*	*50*	*50*	*0*	*0*	*1,190*	*1,190*
B-2.5.1.1	Rights of Entry Acquisition	500	500								
B-2.5.1.2	Damages	500	500								
B-2.5.2	**Proj Mang & Pre-Remedial Action**										
B-2.5.2.1	***Project Management [5% of B-2.5.3.0]***	*26,190*	*8,471*	*3,667*	*1,186*	*1,310*	*424*	0	0	*31,166*	*10,080*
B-2.5.2.2	***Remedial Design [8% of B-2.5.3.0]***	*41,904*	*13,553*	*5,867*	*1,897*	*2,095*	*678*	0	0	*49,866*	*16,129*
B-2.5.2.3	***Remedial Action Contracting [1% of B-2.5.3.0]***	*5,238*	*1,694*	*733*	*237*	*262*	*85*	0	0	*6,233*	*2,016*
B-2.5.3	**HTRW Remedial Action (Construct)**										
B-2.5.3.1	***Land Use Controls***	*125,706*	*41,580*	*17,599*	*5,821*	*6,285*	*2,079*	*12,571*	*4,158*	*162,161*	*53,638*
B-2.5.3.1.1	Preparatory Work [Table B-2.5.2]	31,046	10,269								
B-2.5.3.1.2	Land Use Control Plan [Table B-2.5.2]	45,046	14,900								
B-2.5.3.1.3	Administrative Mechanism Plan [Table B-2.5.2]	49,614	16,411								
B-2.5.3.2	***Mobilize and Preparatory Work***	*172,472*	*57,049*	*24,146*	*7,987*	*8,624*	*2,852*	*17,247*	*5,705*	*222,489*	*73,593*
B-2.5.3.2.1	Preparatory Work [Table B-2.5.3]	153,686	50,835								
B-2.5.3.2.2	Mobilization[1]	18,786	6214								
B-2.5.3.3	***Monitoring, Sampling, Test & Analysis***	*138,783*	*44,134*	*19,430*	*6,179*	*6,939*	*2,207*	*13,878*	*4,413*	*179,030*	*56,933*
B-2.5.3.3.1	Environmental Monitoring [Table B-2.5.4]	14,383	4,757								
B-2.5.3.3.2	Additional Labor & Services [Table B-2.5.4]	81,949	22,297								
B-2.5.3.3.3	Monitoring Equipment Cost [Table B-2.5.4]	11,046	3,654								
B-2.5.3.3.4	PPE Cost [Table B-2.5.4]	16,405	5,426								
B-2.5.3.3.5	Replacement Cost for Monitoring Wells[3]	15,000	8,000								
B-2.5.3.4	***Site Work***	*64,298*	*19,199*	*9,002*	*2,688*	*3,215*	*960*	*6,430*	*1,920*	*82,945*	*24,767*
B-2.5.3.4.1	Install Signage [Table B-2.5.2]	1,168	584								
B-2.5.3.4.2	Equipment Rental plus Labor Cost [Table B-2.5.2]	1,206	402								
B-2.5.3.4.3	Install Fencing and Gates [Table B-2.5.2]	41,760	12,882								
B-2.5.3.4.4	Laborer Cost [Table B-2.5.2]	10,930	2,277								
B-2.5.3.4.5	Site Information Database [Table B-2.5.2]	9,234	3,054								
B-2.5.3.5	***Surface Water Collect & Control***										
B-2.5.3.6	***Solids Collect and Containment***										
B-2.5.3.7	***Disposal (Commercial)***										
B-2.5.3.8	***Site Restoration***										
B-2.5.3.9	***Demobilization***[2]	*22543.4*	*7457*	*3,156*	*1,044*	*1,127*	*373*	*2,254*	*746*	*29,081*	*9,619*
B-2.5.4	**Engineering During Construction [1% of B-2.5.3.0]**	*5,238*	*1,694*	*733*	*237*	*262*	*85*	*524*	*169*	*6,757*	*2,185*
B-2.5.5	**Construction Management (S&A) [6% of B-2.5.3.0]**	*31,428*	*10,165*	*4,400*	*1,423*	*1,571*	*508*	*3,143*	*1,017*	*40,542*	*13,113*
B-2.5.6	**Post Construction**										
B-2.5.6.1	***Annual Operation, Maint. & Monitoring***										
B-2.5.6.1.1	Monitoring [Table B-2.5.5]	*141,757*	*70,878*	*19,846*	*9,923*	*7,088*	*3,544*	*14,176*	*7,088*	*182,866*	*91,433*
B-2.5.6.1.2	Post Remedial Site Supervision [Table B-2.5.5]	*41,420*	*13700*	*5,799*	*1,918*	*2,071*	*685*	*4,142*	*1,370*	*53,431*	*17,673*
B-2.5.6.2	***Periodic Cost***										
B-2.5.6.2.1	Five Year Review [Table B-2.5.5]	*27,502*	*9,097*	*3,850*	*1,274*	*1,375*	*455*	*2,750*	*910*	*35,477*	*11,735*

14%	Contract Cost: includes G&A (6%) and profit (8%) for prime contractor and subcontractors, but not labor overhead.
5%	Design Contingency: includes costs fro design and planning for unanticipated conditions.
10%	Construction Contingency: includes construction costs for unforeseen conditions.

[1,2] Total mobilization and demobilization costs are 25,000 and 30,000 respectively. The total cost was divided with respect to % of soil volume for OU1 and AOC 6.

[3] Replacement costs for monitoring wells are based on replacing 5 and 2 monitoring wells at OU1 and AOC 6, respectively.

Table B-2.5.1: Calculation of Soil Volumes

AOC	Soil Volume [CY]		
	Excavation to Cut Lines [1] [in situ] [CY]	Ex-Situ Vol [2] [125%] [CY]	Percentage of Total
OU 1	12,300	15,375	71%
OU 1 Haz	700	875	4.0%
AOC 6	4,300	5,375	24.9%
Total	**17,300**	**21,625**	100%

Off-Site Disposal			
Bulk Soil[3] [CY] [+15% contingency]	Bulk Soil [4] [Tons]	Haz Soil [CY] [+15% contingency]	Haz Soil [4] [Tons]
17,681	26522		
		1,006	1509
6,181	9272		
23,863	35,794	1,006	1509

Calculation of Percentage Soil Volume

Area	Total Excavated Volume (CY)	% Soil
OU 1	18,688	75.1%
AOC 6	6,181	24.9%
Total	24,869	

Footnotes

1) Mean upper bound volume estimates - mean volume [based on 10 models] plus standard deviation. Cut lines volume estimated using 1 : 1.5 slope from waste. In addition, the in situ volume was rounded off during this cost estimation.

2) 125% swelling factor applied to in situ soil estimates.

3) Bulk Soil: FUSRAP waste soil plus cut-back. Assumes both will be disposed of as same waste stream.

4) Average density of damp sand [1.7] or 110 pounds / ft^3 or 1.5 tons per cubic yard [EPA/625/12-91/002]

Table B-2.5.2: Costs Associated with Land Use Controls (ICs)

The ICs include both land use controls (LUCs) and administrative controls (zoning, deed restrictions, and/or well construction restrictions).

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Land Use Control					298,169	
Preparatory Work						
Coordination with various local, state, and Federal agencies for land use control plans and administrative mechanism plan					$37,165	
Program Manager	160	hr	$128.54	20,566		
Project Manager	160	hr	$103.74	16,598		See Table B-2.8.6
Coordination with owners for land use control plans and administrative mechanism plan					$4,150	
Project Manager	40	hr	$103.74	4,150		See Table B-2.8.6
Land Use Control Plan					$59,946	
Project Manager	80	hr	$103.74	8,299		
Principal Health Physicist	80	hr	$116.00	9,280		
1 Senior Scientist	160	hr	$103.74	16,598		
I Junior Engineer	240	hr	$64.76	15,542		
1 Attorney	40	hr	$151.96	6,078		
1 GIS Operators	40	hr	$61.44	2,458		
Administrative Assistant	40	hr	$42.26	1,690		See Table B-2.8.6
Administrative Mechanism Plan					$66,025	
Project Manager	80	hr	$103.74	8,299		
Principal Health Physicist	80	hr	$116.00	9,280		
1 Senior Scientist	160	hr	$103.74	16,598		
I Junior Engineer	240	hr	$64.76	15,542		
1 Attorney	80	hr	$151.96	12,157		
1 GIS Operators	40	hr	$61.44	2,458		
Administrative Assistance	40	hr	$42.26	1,690		See Table B-2.8.6
Monitoring, Sampling, Test, Analysis	Equipments/materials for 4 air monitoring stations				$1,820	
IH Supplies - Air Monitoring (4)	41	days	$20	820		
IH Supplies - PPE, other misc.	10	days	$100	1,000		

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Sources for Unit Cost
Site Work						
Construct - Land Use Control						
Install Signage	Fabricated stainless Steel, 18" high, 4" deep				$4,776	RSMeans (10 14 19.10.2100)
Number of Signs	Install 18" Caution - "Radiological Material" Signs					
OU 1	4		$292	1,168		
AOC 6	2		$292	584		
Equipment Rental OU 1	1.5	day	$20	30		
Equipment Rental AOC 6	0.5	day	$20	10		
Union Laborer (2) OU 1	12	hrs	$49.02	1,176		See Table B-2.8.6
Union Laborer (2) AOC 6	4	hrs	$49.02	392		
Install Fencing and Gates	Install up to 1632 ft of fencing @ 165 ft/day				$112,000	
Raw Materials						
Permanent Fencing	ga. wire, 6" high but omit barded wire, galvanized stee					RSMeans (32 31 13.20.0800)
OU 1	1260	LF	$31	39,060		
AOC 6	372	LF	$31	11,532		
Gates	6' high, 12' opening, in concrete (Double swing gates, incl. posts & hardware, in concrete)					RSMeans, 32 31 13.20 5060
OU 1	2		$1,350	2,700		
AOC 6	1		$1,350	1,350		
Labor OU 1						
Prep Work (2 laborers)	16	hrs	$49.02	1,569		See Table B-2.8.6
Installation Work (2 laborers)	80	hrs	$49.02	7,843		
Perdiem [CONUS + 15% tax]	12	days	$126.50	1,518		
Labor AOC 6						
Prep Work (2 laborers)	4	hrs	$49.02	392		See Table B-2.8.6
Installation Work (2 laborers)	16	hrs	$49.02	1,569		
Perdiem [CONUS + 15% tax]	3	days	$126.50	316		
Site Information Database [1]	200	hrs	$61.44	12,288	$12,288	

[1] Based on percentage of soil volume at OU1 and AOC6, the total preparatory cost was divided among OU1 and AOC 6.

Table B-2.5.3: Costs Associated with Preparatory Work

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Major Cost ($)	Assumptions
Preparatory Work[1]						**204,521**	
Submittals/Implementation Plan						*127,178*	
Environmental Protection Plan					24,898		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineer	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Sedimentation Control Plan					29,047		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Geologist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
Site Safety and Health Plan					27,317		
Senior Health Physicist	40	hr	$116.00	4,640			20 hrs/contract; 2 contracts
Site Safety & Health Officer	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Certified Industrial Hygienist	80	hr	$103.74	8,299			40 hrs/contract; 2 contracts
General Site Work Plan					25,890		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Construction Manager	40	hr	$128.54	5,142			20 hrs/contract; 2 contracts
Civil Engineers	160	hr	$103.74	16,598			80 hrs/contract; 2 contracts
Quality Control Plan					18,527		
Project Manager	40	hr	$103.74	4,150			20 hrs/contract; 2 contracts
Quality Control Engineers	160	hr	$89.86	14,378			80 hrs/contract; 2 contracts
Permits	2		$750	1,500	1,500		$750/ permit
Setup/Construct Temp Facilities						*24,787*	
Operation Trailer	1	LS	$ 9,098	9,098			1 for both contracts
HP Trailer	1	LS	$ 7,806	7,806			1 for both contracts
Break Trailer	1	LS	$ 2,770	2,770			1 for both contracts
Toilets	2	LS	$1,500	3,000			1 for each contract
Barricades	2	LS	$292	584			1 for each contract
Signs	2	LS	$292	584			2 for each contract
Monthly Operating Cost						*43,626*	
Operation Trailer	12	months	$ 704.91	8,459			See Table 2.5.10
HP Trailer	12	months	$ 2,266.70	27,200			
Break Trailer	12	months	$ 663.88	7,967			
Construct Temporary Utilities						*2,330*	
Power Connection/Distribution	1	LS	$500	500			1 for both contracts
Telephone/Communication Dist.	1	LS	$100	100			1 for both contracts
Water Connection/Distribution	1	LS	$1,430	1,430			1 for both contracts
Sewer Connection/Distribution	1	LS	$300	300			1 for both contracts
Monthly Cost -Utilities						*6,600*	Assumed
Power Distribution	12	months	$250	3,000			
Telephone/Communication Dist.	12	months	$100	1,200			
Water Distribution	12	months	$100	1,200			
Sewer Distribution	12	months	$100	1,200			

[1] Based on percentage of soil volume at OU1 and AOC6, the total preparatory cost was divided among OU1 and AOC 6.

Table B-2.5.4: Costs Associated with Environmental Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)
Monitoring, Sampling, Test, Analysis					
Offsite Sample Analysis Cost					
Environmental Monitoring [32 water suites + 6 field duplicates + 6 MS/MSD] [1]					**19,140**
OU1, AOC 4 and AOC 6	44	samples	435.00	19,140	
Additional Labor & Services					
OU 1					
Project Manager	24	hrs	$103.74	2,490	
Principal Health Physicist	40	hrs	$116.00	4,640	
2 Junior HPs	2 x 48 days x 10 hrs/day	hrs	$64.76	62,170	
Perdiem [CONUS + 15% tax]	100	days	$126.50	12,650	
AOC 6					
Project Manager	16	hrs	$103.74	1,660	
Principal Health Physicist	16	hrs	$116.00	1,856	
2 Junior HPs	2 x 12 days x 10 hrs/day	hrs	$64.76	15,542	
Perdiem [CONUS + 15% tax]	26	days	$126.50	3,238	
Monitoring Equipment Cost [2]					**14,700**
Bioassays (1 year for 15 peoples)	15	people	$168.77	2,532	Previous Experiences at Other FUSRAP Sites
Fiskers (1 for OU1, 1 for AOC 6, and 1 at Trailer)	3 x 4 months	month	$145	1,740	
Radiological Detectors					
FIDLER w/scaler	1x 4 months	month	$800	3,200	
Alpha/beta detectors (e.g., Ludlum Models 43-93)	1 x 4 months	month	$96	384	
Radiological Meters					
A smear counter (Ludlum Model 2929)	1 x 4 months	month	$211	844	
Dosimetry					
TLDs	15 x 4 months	month	$100	6,000	
PPE Cost [3]					**21,832**
Number of People using PPE	15 persons x 64 workdays		$ 22.74	21,832	See Table B-2.5.23

[1,2,3] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.5.5: Costs Associated with Annual Operation, Maintenance & Monitoring

Cost Components	Quantity	Unit	Unit Cost	Cost ($)	Sub Total ($)	Assumptions
Post Construction						
Annual Operation, Maintenance, & Monitoring						
Monitoring [1]	1	yr	$212,635	212,635	212,635	Monitoring of Groundwater
Five Year Review (Every 5 year) [2]					36,598	
1 Project Manager	40	hr	$103.74	4,150		40 hrs per review
Principal Health Physicist	40	hr	$116.00	4,640		40 hrs per review
1 Senior Scientist	80	hr	$103.74	8,299		80 hrs per review
I Junior Engineer	160	hr	$64.76	10,362		160 hrs per review
1 GIS Operator	40	hr	$61.44	2,458		40 hrs per review
Administrative Assistance	40	hr	$42.26	1,690		Assumptions
Additional Labor and Services	1	LS	$5,000	5,000		
Post Remedial Site Supervision (Per year) [3]					55,120	
1 Site Supervisor	1000	hr	$54.12	54,120		4 hr/day for 250 days/yr
Miscellaneous Equipment Cost	1	LS	$1,000	1,000		$1000 /year

[1,2,3] Based on percentage of soil volume at OU1 and AOC6, the total cost was divided among OU1 and AOC 6.

Table B-2.5.6: LABOR RATES

DISCIPLINES	Code	Base Labor Rates	Burdened Labor Rates [1]
Principal	PRI	$75.98	$151.96
Program Manager	PGM	$64.27	$128.54
Senior Project Manager	SPM	$51.87	$103.74
Regulatory Specialist	RSP	$47.80	$95.60
Industrial Hygienist (Certified)	CIH	$51.87	$103.74
Sr. Environmental Scientist	SES	$51.87	$103.74
Sr Health Physicist	SHP	$58.00	$116.00
Senior Scientist	SSC	$51.87	$103.74
Senior Engineer	SEN	$51.87	$103.74
Senior Geologist	SGE	$51.87	$103.74
Construction Manager	CM	$64.27	$128.54
Quality Control Specialist	QC	$44.93	$89.86
Site Safety & Health Officer	SHO	$44.93	$89.86
Jr Health Physicist	JHP	$32.38	$64.76
Cost Accountant	AC	$32.38	$64.76
Junior Engineer	JEN	$32.38	$64.76
Illustrator/draftsperson	GIS	$30.72	$61.44
Senior Hydrologist	SHY	$58.00	$116.00
Jr. Environmental Scientist	JES	$32.38	$64.76
Junior Scientist	JSC	$32.38	$64.76
Field Supervisor	FS	$27.06	$54.12
Chemist	CH	$32.38	$64.76
Administrative Assistant	AA	$21.13	$42.26
Truck Driver	TD	$24.51	$49.02
Laborer	LAB	$24.51	$49.02

[1] Burdened labor rates include labor overhead multiplier but not profit

Labor Overhead Multiplier (LOH) = 2.0

Table B-2.5.7: Laboratory Analysis Cost ($)

Radionuclides	*Unit Cost*		Total Cost
Soil Sample Analysis			
Gamma Spec		119.00	
Ra-226		119.00	
Ra-228		119.00	
Iso-U		157.50	
Iso-Th		157.50	
			672.00
Waste Profile Analysis			
TCLP VOCs		148.75	
TCLP SVOCs		271.25	
TCLP Pesticides/Herbicides		420.00	
TCLP (8 RCRA Metals+Zinc)		148.75	
Ignitability		35.00	
Corrosivity		17.50	
Toxicity		70.00	
Reactive Cyanide& Sulfide		105.00	
PCBs		113.75	
			1,330.00
Air Filter Sample Analysis			
Gamma Spec	119		
Iso U	157.5		
Iso Th	157.5		
			434.00
Groundwater Sample Analysis			
Gross Alpha/Beta	$	50.00	
Ra-226/Ra-228	$	65.00	
Iso Thorium	$	80.00	
Iso Uranium	$	80.00	
Alkalinity as $CaCO_3$	$	10.00	
Chloride	$	10.00	
Fluoride	$	10.00	
Nitrate	$	20.00	
Total Phosphates	$	20.00	
Sulfate	$	10.00	
Nitrite	$	10.00	
Sulfide	$	10.00	
Oxid. Reduc. Potential	$	10.00	
Oxygen, dissolved	$	10.00	
pH	$	10.00	
Specific Conductance	$	10.00	
Temperature	$	10.00	
Turbidity	$	10.00	
			435.00

Table B-2.5.8: PPE Costs

Item Description	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity Needed Per Person Per Day	Extended	Comments/Assumptions
PPE - Level D Modified (cost per person-day)							
Cotton Liner Gloves (6 pair)	Pack	$ 5.47	$ 0.33	$ 5.80	0.6667	$ 3.87	4 pair per person per day
Duct Tape (2 rolls)	Pack	$ 7.96	$ 0.48	$ 8.44	0.0333	$ 0.28	2 yd per person per day
Face Shield (clear visor)	Each	$ 7.48	$ 0.45	$ 7.93	0.0042	$ 0.03	1 per person per year
Hard hat	Each	$ 8.00	$ 0.48	$ 8.48	0.0042	$ 0.04	1 per person per year
Nitrile Gloves (lab grade) (box 50 pair)	Box	$ 11.95	$ 0.72	$ 12.67	0.0800	$ 1.01	4 pair per person per day
Rain gear	Each	$ 115.70	$ 6.94	$ 122.64	0.0042	$ 0.51	1 set per person per year
Reflective Vest	Each	$ 10.99	$ 0.66	$ 11.65	0.0500	$ 0.58	1 per person per month
Rubber Overboots	Pair	$ 29.80	$ 1.79	$ 31.59	0.0083	$ 0.26	2 per person per year
Safety Glasses	Pair	$ 3.16	$ 0.19	$ 3.35	0.0167	$ 0.06	4 per person per year
Safety Shoes	Each	$ 100.00	$ -	$ 100.00	0.0042	$ 0.42	1 pair per person per year - $100 limit
Tyvek Suits - Medium Weight w/ hood and shoe covers (case 25)	Case	$ 123.30	$ 7.40	$ 130.70	0.1200	$ 15.68	3 per person per day
Work Gloves (leather/cotton insulated)	Pair	$ -	$ -	$ -	0.2000	$ -	1 per person per week
Work Gloves (leather/cotton)	Pair	$ 2.64	$ 0.16	$ 2.80	0.2000	$ 0.56	1 per person per week
COST PER PERSON-DAY FOR MODIFIED LEVEL D						**$ 22.74**	

Table B-2.5.9: Trailer Costs - Initial Setup

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Operations Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	2	$ 295.93
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	1	$ 104.93
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	3	$ 572.37
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	2	$ 275.58
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	3	$ 2,594.72
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	6	$ 64.81
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	3	$ 111.27
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	6	$ 12.66
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	3	$ 158.97
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	3	$ 83.89
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (24 person)	Each	$ 51.20	$ 3.07	$ 54.27	1	$ 54.27
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	4	$ 27.69
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
	TOTAL COST FOR OUTFITTING OPERATIONS TRAILER					**$ 9,098.47**
HP Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	3	$ 443.90
Desk	Each	$ 539.00	$ 32.34	$ 571.34	6	$ 3,428.04
Office Chair	Each	$ 99.00	$ 5.94	$ 104.94	6	$ 629.64
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	3	$ 314.79
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	1	$ 52.99
Filing Cabinet (4 drawer)	Each	$ 179.99	$ 10.80	$ 190.79	1	$ 190.79
Filing Cabinet (2 drawer)	Each	$ 129.99	$ 7.80	$ 137.79	1	$ 137.79
Desktop Computer	Each	$ 815.95	$ 48.96	$ 864.91	2	$ 1,729.81
Stapler	Each	$ 10.19	$ 0.61	$ 10.80	2	$ 21.60
Hole Punch	Each	$ 34.99	$ 2.10	$ 37.09	1	$ 37.09
Staple Remover	Each	$ 1.99	$ 0.12	$ 2.11	1	$ 2.11
USB Flash Drive - 8 GB	Each	$ 49.99	$ 3.00	$ 52.99	2	$ 105.98
Scotch Tape (pack 10)/Tape Dispenser	Each	$ 26.38	$ 1.58	$ 27.96	1	$ 27.96
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 221.00	$ 13.26	$ 234.26	1	$ 234.26
Uninterrupted Power Source	Each	$ 207.99	$ 12.48	$ 220.47	1	$ 220.47
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Wastebasket 7 gallon	Each	$ 6.53	$ 0.39	$ 6.92	2	$ 13.84
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
	TOTAL COST FOR OUTFITTING HP TRAILER					**$ 7,806.12**
Break Trailer						
Shelving Unit (2 x 4 x 6)	Each	$ 139.59	$ 8.38	$ 147.97	1	$ 147.97
Folding Table	Each	$ 98.99	$ 5.94	$ 104.93	5	$ 524.65
Folding Chair (4 chairs)	Pack	$ 49.99	$ 3.00	$ 52.99	5	$ 264.95
Microwave	Each	$ 269.00	$ 16.14	$ 285.14	3	$ 855.42
Refrigerator	Each	$ 629.10	$ 37.75	$ 666.85	1	$ 666.85
First Aid Kit (16 person)	Each	$ 36.85	$ 2.21	$ 39.06	1	$ 39.06
Surge Protector	Each	$ 39.99	$ 2.40	$ 42.39	2	$ 84.78
Large Trash Can	Each	$ 29.97	$ 1.80	$ 31.77	3	$ 95.30
Fire Extinguisher (ABC - 10 lb)	Each	$ 86.05	$ 5.16	$ 91.21	1	$ 91.21
`	**TOTAL COST FOR OUTFITTING BREAK TRAILER**					**$ 2,770.18**
	TOTAL COST FOR OUTFITTING SITE TRAILERS					**$ 19,674.77**

Trailer Costs - Monthly

Item	Unit	Unit Cost	Tax or Shipping 6%	Unit Total Cost	Quantity	Extended
Operations Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	3	$ 165.33
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	2	$ 10.58
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	2	$ 33.90
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	2	$ 48.74
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	1	$ 5.93
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98
Binder (1 inch)	Each	$ 7.99	$ 0.48	$ 8.47	2	$ 16.94
Binder (1 1/2 inch)	Each	$ 9.29	$ 0.56	$ 9.85	2	$ 19.69
Binder (2 inch)	Each	$ 11.29	$ 0.68	$ 11.97	2	$ 23.93
Binder (3 inch)	Each	$ 14.29	$ 0.86	$ 15.15	2	$ 30.29
Binder (4 inch)	Each	$ 17.49	$ 1.05	$ 18.54	2	$ 37.08
	TOTAL MONTHLY COST FOR OPERATIONS TRAILER					**$ 704.91**
HP Trailer						
Paper (Case 5000 sheets)	Case	$ 51.99	$ 3.12	$ 55.11	1	$ 55.11
Magic Markers (box 4)	Each	$ 5.79	$ 0.35	$ 6.14	1	$ 6.14
Sharpie (box 5)	Pack	$ 4.99	$ 0.30	$ 5.29	3	$ 15.87
Pens (box 12)	Pack	$ 5.99	$ 0.36	$ 6.35	2	$ 12.70
Highlighters	Pack	$ 5.99	$ 0.36	$ 6.35	3	$ 19.05
Folder (pack 100)	Each	$ 15.99	$ 0.96	$ 16.95	1	$ 16.95
Hanging File Folders (pack 25)	Each	$ 22.99	$ 1.38	$ 24.37	1	$ 24.37
Staples (pack 6000)	Each	$ 11.98	$ 0.72	$ 12.70	0.25	$ 3.17
Trash Bags	Box	$ 8.49	$ 0.51	$ 9.00	2	$ 18.00
Scotch Tape (pack 10)	Each	$ 22.39	$ 1.34	$ 23.73	0.25	$ 5.93
Paperclips (pack 1000)	Each	$ 5.59	$ 0.34	$ 5.93	0.5	$ 2.96
Binder clips (pack 144)	Each	$ 6.49	$ 0.39	$ 6.88	1	$ 6.88
Konica Minolta Bizhum C253 w/scanning feature	Each	$ 233.00	$ 13.98	$ 246.98	1	$ 246.98
Air Sample Filters (Low Vol - 47 mm cellulose - 100 filters)	Box	$ 14.00	$ 0.84	$ 14.84	2	$ 29.68
Air Sample Filters (BZA - 47 mm mixed cellulose - 100 filters)	Box	$ 87.02	$ 5.22	$ 92.24	2	$ 184.48
Air Sample Filters (High Vol - 4 in cellulose - 100 filters)	Box	$ 18.00	$ 1.08	$ 19.08	2	$ 38.16
Smears with folders (box 500)	Box	$ 28.00	$ 1.68	$ 29.68	3	$ 89.04
MASSLINN Decontamination Wipes (18" × 24" - case 500 wipes)	Case	$ 80.50	$ 4.83	$ 85.33	1	$ 85.33
MASSLINN Decontamination Wipes (24" × 24" - case 500 wipes)	Case	$ 94.25	$ 5.66	$ 99.91	1	$ 99.91
Radiological Waste Bags (18" × 24" - roll 250 bags)	Roll	$ 55.25	$ 3.32	$ 58.57	1	$ 58.57
Radiological Waste Bags (36" × 48" - roll 100 bags)	Roll	$ 100.00	$ 6.00	$ 106.00	1	$ 106.00
Step off Pad/ Sticky Mat (4 mats, 30 sheets each mat)	Case	$ 78.80	$ 4.73	$ 83.53	1	$ 83.53
Step off Pad/ Sticky Mat - printed message (4 mats, 30 sheets/mat)	Case	$ 130.70	$ 7.84	$ 138.54	1	$ 138.54
Radiological Stickers (pack 25)	Pack	$ 21.03	$ 1.26	$ 22.29	1	$ 22.29
Radiological Boundary Ribbon (roll 200 ft)	Roll	$ 16.08	$ 0.96	$ 17.04	1	$ 17.04
Radiological Boundary Plastic Tape (roll 1,000 ft)	Roll	$ 11.00	$ 0.66	$ 11.66	1	$ 11.66

Radiological Boundary Rope (roll 600 ft)	Roll	$	26.00	$	1.56	$	27.56	1	$	27.56
Radiological Warning Sign	Each	$	20.00	$	1.20	$	21.20	1	$	21.20
Radiological Boundary Adhesive Tape (roll 36 yds)	Roll	$	17.65	$	1.06	$	18.71	1	$	18.71
Right in the Rain Notebook	Each	$	16.95	$	1.02	$	17.97	2	$	35.93
Alconox - 4 pound Box	Each	$	28.95	$	1.74	$	30.69	1	$	30.69
Alconox - 50 1/2 oz packets	Each	$	39.95	$	2.40	$	42.35	1	$	42.35
Steel Bowl	Each	$	12.50	$	0.75	$	13.25	0.5	$	6.63
Steel Spoon	Each	$	5.95	$	0.36	$	6.31	1	$	6.31
5-gallon bucket	Each	$	2.34	$	0.14	$	2.48	4	$	9.92
Ziploc 10-gallon bags (pack 30)	Each	$	3.29	$	0.20	$	3.49	20	$	69.75
Cooler	Each	$	43.10	$	2.59	$	45.69	4	$	182.74
Red Marking Paint	Each	$	5.27	$	0.32	$	5.59	3	$	16.76
Orange Marking Paint (pack 12)	Each	$	44.88	$	2.69	$	47.57	1	$	47.57
Pin Flags (pack 100)	Each	$	7.98	$	0.48	$	8.46	2	$	16.92
Safety Fence	Each	$	36.98	$	2.22	$	39.20	3	$	117.60
Utility Post	Each	$	5.39	$	0.32	$	5.71	10	$	57.13
Nylon Cable Ties (pack 100)	Each	$	6.94	$	0.42	$	7.36	3	$	22.07
Cable Ties (8 in pack 1000)	Each	$	19.97	$	1.20	$	21.17	0.5	$	10.58
Binder (1 inch)	Each	$	7.99	$	0.48	$	8.47	2	$	16.94
Binder (1 1/2 inch)	Each	$	9.29	$	0.56	$	9.85	2	$	19.69
Binder (2 inch)	Each	$	11.29	$	0.68	$	11.97	2	$	23.93
Binder (3 inch)	Each	$	14.29	$	0.86	$	15.15	2	$	30.29
Binder (4 inch)	Each	$	17.49	$	1.05	$	18.54	2	$	37.08
		TOTAL MONTHLY COST FOR HP TRAILER							**$**	**2,266.70**
Break Trailer										
Water (case 28, 24 oz)	Case	$	12.49	$	0.75	$	13.24	20	$	264.79
Gatorade (case 6, 20 oz)	Case	$	6.99	$	0.42	$	7.41	20	$	148.19
Hand Wipes (40 wipes)	Pack	$	2.99	$	0.18	$	3.17	6	$	19.02
Paper Towels (6 rolls)	Pack	$	10.49	$	0.63	$	11.12	6	$	66.72
Sun Block	Each	$	10.99	$	0.66	$	11.65	6	$	69.90
Insect Repellent	Each	$	6.49	$	0.39	$	6.88	6	$	41.28
Trash Bags	Box	$	8.49	$	0.51	$	9.00	6	$	54.00
		TOTAL MONTHLY COST FOR BREAK TRAILER							**$**	**663.88**
		TOTAL MONTHLY COST FOR SITE TRAILERS							**$**	**3,635.49**

Table B-2.5.10: Cost Estimate - Groundwater Sampling per Event

ITEM DESCRIPTION	NO. UNITS	UNIT OF MEASURE	COST / UNIT	TOTAL COST
LABOR				
Lead Technician - sampling event	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
geotechnician - sampling	40	hours	$ 64.76	$ 2,590
Hydrogeologist - report preparation	40	hours	$ 103.74	$ 4,150
GIS/CAD specialist - report preparation	8	hours	$ 61.44	$ 492
project assistant - report preparation	16	hours	$ 42.26	$ 676
project manager - QA/review	8	hours	$ 103.74	$ 830
ODCs				
CONSUMABLES				
consumables - FedEx coolers	32	shipments	$ 100.00	$ 3,200
consumables - Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
consumables - Misc Field Supplies	1	each	$ 2,000.00	$ 2,000
consumables - X-Large Nitrile Gloves	4	boxes	$ 10.50	$ 42
EQUIPMENT				
equipment - 1/4" OD LDPE Tubing	820	feet	$ 0.65	$ 533
equipment - 2929	2	week(s)	$ 150.00	$ 300
equipment - GM detector	2	week(s)	$ 135.00	$ 270
equipment - In-Situ Troll multiparameter meter 9500 (4 units)	8	weeks	$ 200.00	$ 1,600
equipment - Silicone Tubing - Size 15	50	feet	$ 2.10	$ 105
equipment - tubing Pumps (4 units)	8	weeks	$ 150.00	$ 1,200
equipment - water level meter [2]	4	week(s)	$ 80.00	$ 320
SUB				
sub - analysis - 32 water suites + 6 field duplicates + 6 MS/MSD	44	each	$ 435.00	$ 19,140
sub - trailer, rent	1	months	$ 350.00	$ 350
TRAVEL				
travel - fuel 2 vehicles, 10 gallons/day	200	gallon	$ 3.00	$ 600
travel - per diem (for 4 people, 2 weeks at $140 (est))	40	days	$ 140.00	$ 5,600
travel - rental SUV [2]	20	days	$ 65.00	$ 1,300
travel - tolls	4	day	$ 12.00	$ 48
Assumptions:				
Monitoring, sampling, reporting for 32 wells in one event				
			GRAND TOTAL:	$ 53,158.80

APPENDIX C

TECHNICAL EVALUATIONS
URANIUM MASS BALANCE CALCULATIONS

Technical Evaluation
Feasibility Study
DuPont Chambers Works FUSRAP Site

Uranium Mass Balance

Purpose: Mass balance calculations were performed during development of the Feasibility Study (FS). The purpose was to estimate the amount of dissolved uranium that would remain in groundwater after completion of a remedial action for soil, specifically an excavation alternative. Results will help to develop a qualitative understanding of the distribution of uranium in media both before and after excavation. Additionally, further understanding will be gained about the potential for post-excavation dissolved uranium to become a completed exposure pathway to potential receptors.

Approach: Soil contamination in Area of Concern (AOC) 1, AOC 2, and AOC 6 is the source of groundwater contamination. Highest concentrations of uranium in groundwater are found in areas where elevated concentrations of uranium exist in soil (source areas). If selected, one of the excavation alternatives (S2 or S3) for contaminated soil is expected to remove the source of groundwater contamination as well as significant portions of the groundwater plume. Cabrera evaluated the uranium mass balance in these areas by:

- Calculating post excavation groundwater concentrations
- Determining the percentage of the groundwater plume removed during excavation
- Evaluating the percentage of the groundwater plume removed during dewatering of excavation

Calculations are included in the attached Excel workbook. Attachments A, B, and C show the results for the AOC 1, AOC 2, and AOC 6 calculations, respectively. Attachment D includes the accompanying figures for each AOC.

Conclusions: An evaluation of the pre-excavation and post-excavation average groundwater concentrations and the areas of impacted groundwater between the one (1), 30, 100, and 1000 micrograms per liter (ug/L) isopleths resulted in an estimate of percent removal of the dissolved uranium in groundwater. Site-specific and standard literature values were used in the evaluation. Area estimates of groundwater plumes and excavation cutlines were measured using GIS mapping tools (see Attachment D). Results show that by excavating to the remediation goal (65 pCi/g) as shown by the assumed excavation cutlines:

- In AOC 1, 97% of the aqueous uranium in the A Aquifer would be removed by excavation alone. Pre-excavation uranium in groundwater is calculated to be 646 grams. After excavation approximately 17 grams of aqueous uranium would remain in the A Aquifer, resulting in a 97% reduction. Dewatering would not result in removal of aqueous uranium from the A Aquifer (0% removal). Aqueous uranium is not elevated in the B Aquifer in AOC 1.

- In AOC 2, 90% of the uranium in the A Aquifer and 100% of the uranium in the B Aquifer would be removed by excavation alone. Pre-excavation aqueous uranium mass is estimated to be 1,094 grams in the A Aquifer and 4,114 grams in the B Aquifer. After excavation approximately 112 grams of aqueous uranium would remain in the A Aquifer, resulting in a 90% reduction. Dewatering removes only 0.3% of the aqueous uranium in the A Aquifer. The entire uranium plume in the B Aquifer (4,114 grams) would be removed (100% reduction).

- In AOC 6, the A Aquifer is not present so uranium only impacts the B Aquifer. Approximately 81% of the aqueous uranium would be removed by excavation alone. Dewatering would not result in removal of aqueous uranium in the B Aquifer (0% removal). Pre-excavation aqueous uranium mass is estimated to be 71 grams. After excavation approximately 13 grams of aqueous uranium would remain, resulting in the 81% reduction.

In conclusion, excavation of impacted soil (source areas) will greatly reduce the impacted groundwater at the FUSRAP AOCs. The evaluation demonstrates that excavation of contaminated soil will result in residual groundwater concentrations in the A Aquifer of 16 ug/L (AOC 1) and 86 ug/L (AOC 2). The residual groundwater concentrations in the B Aquifer of AOC 6 will average 21 ug/L.

Calculation of Groundwater Concentrations after Soil Excavation - AOC 1

Aquifer Characteristics	Value	Unit	SI Unit	
Saturated thickness -Aquifer A	5.0	ft	1.5	m
Saturated thickness -Aquitard A/B	1.0	ft	0.3	[-]
Total porosity A	0.4	[-]		

Determination of Average Groundwater Concentration for Pre-Excavation Aquifer A Plume Area

Plume Areas	Area	Unit	SI Unit	
Inside 1 ug/L	42,274	ft^2	3,927	m^2
Inside 30 ug/L	21,007	ft^2	1,952	m^2
Inside 100 ug/L	12,119	ft^2	1,126	m^2
Inside 1000 ug/L	2,258	ft^2	210	m^2
Between (1-30) ug/L	21,267	ft^2	1,976	m^2
Between (30-100) ug/L	8,888	ft^2	826	m^2
Between (100-1000) ug/L	9,861	ft^2	916	m^2

Plume Areas	Avg Conc (ug/L)	Area [ft^2]	Conc x Area [(ug/L)*ft^2]
Between (1-30) ug/L	16	21,267	329,639
Between (30-100) ug/L	65	8,888	577,720
Between (100-1000) ug/L	550	9,861	5,423,550
Inside 1000 ug/L	2,250	2,258	5,080,500
	Total	**42,274**	**11,411,409**
	Average U Concentration		**270 ug/L**

Determination of Average Groundwater Concentration for Post Excavation Aquifer A Plume Area

Plume Areas	Area	Unit	Area	Unit
Between (1-30) ug/L	14,417	ft^2	1339	m^2
Between (30-100) ug/L	0	ft^2	0	m^2
Between (100-1000) ug/L	0	ft^2	0	m^2
Area of plume	14,417	ft^2	1339	m^2

Plume Areas	Conc (ug/L)	Area [ft^2]	Conc x Area [(ug/L)*ft2]
Between (1-30) ug/L	16	14,417	223,464
Between (30-100) ug/L	65	0	0
Between (100-1000) ug/L	550	0	0
	Total	14,417	223,464
	Average U concentration		**16 ug/L**

Determination of Percentage of Plume Removed During Excavation

Pre-Excavation Aqueous Uranium Mass in Aquifer A	Value	Unit
Area	3,927	m^2
Thickness	2	m
Porosity	0.4	[-]
Volume impacted GW	2,394	m^3
Volume impacted GW	2,394,133	L
Avg. conc.	270	ug/L
Mass U in GW	646,270,208	ug
Mass U in GW	646	g
Pre-excavation Uranium mass in groundwater	**0.6**	**kg**

Assumptions:

Post-Excavation Uranium Mass in Aquifer A	Value	Unit
Area	1,339	m^2
Thickness	2	m
Porosity	0.4	[-]
Volume of impacted GW	1,072	m^3
Mass of impacted GW	1,071,507	L
Average concentration	16	ug/L
Mass U in groundwater	16,608,351	ug
Mass U in groundwater	17	g
Post-excavation Uranium mass in groundwater	**0.02**	**kg**
% of plume to be removed by excavation alone from Aquifer A:	**97%**	

All of the plume will be excavated

Determination of Percentage of Plume Removed During Dewatering Process

Water production during dewatering of A:		
Q=KA dh/dl	**Value**	**Unit**
K	1.00E-03	cm/s
	1.00E-05	m/s
	0.86	m/d
L [plume width]	46	m
H [aquifer thickness]	1.5	m
A [=H*L]	70	m^2
dh/dl [gradient]	1%	[-]
Q [water production]	0.60	m^3/d
	602	L/d
	159	gal/d

Excavation period	30	Days est
Mass 'A' produced groundwater	18.1	m^3
	18,060	L
Avg U concentration in 'A'	16	ug/L
Mass 'A' produced groundwater	279,935	ug
	0.28	grams

% of U removed by dewatering in Aquifer A during excavation:	**0%**

Conclusion:

Aquifer A

Pre-excavation:	**Value**	**Unit**
Volume of A-aquifer plume:	2394	m^3
Average U concentration	270	ug/L
Mass of U in A-aquifer groundwater:	0.6	kg

Post-excavation:	**Value**	**Unit**
Volume of A-aquifer plume:	1072	m^3
Average U concentration	16	ug/L
Mass of U in A-aquifer groundwater:	0.02	kg
Percent removal of A-Aquifer dissolved U:		**97%**

Calculation of Groundwater Concentrations after Soil Excavation - AOC 2

Aquifer Characteristics	Value	Unit	SI Unit		Assumptions:
Saturated thickness -Aquifer A	8.0	ft	2.4	m	measurement from contour map
Saturated thickness - Aquifer B	8.0	ft	2.4	m	measurement from contour map
Saturated thickness -Aquitard A/B	1.0	ft	0.3	[-]	measurement from contour map
Total porosity A	0.4	[-]			standard literature value
Total porosity B	0.4	[-]			standard literature value

Determination of Average Groundwater Concentration for Pre-Excavation Plume Area

Plume Areas	Area	Unit	SI Unit		
Inside 1 ug/L	35,911	ft^2	3,336	m^2	measurement from contour map
Inside 30 ug/L	23,682	ft^2	2,200	m^2	measurement from contour map
Inside 100 ug/L	15,889	ft^2	1,476	m^2	measurement from contour map
Inside 1000 ug/L	1,551	ft^2	144	m^2	measurement from contour map
Between (1-30) ug/L	12,229	ft^2	1,136	m^2	measurement from contour map
Between (30-100) ug/L	7,793	ft^2	724	m^2	measurement from contour map
Between (100-1000) ug/L	14,338	ft^2	1,332	m^2	measurement from contour map

Plume Areas	Avg Conc (ug/L)	Area [m^2]	Conc x Area [(ug/L)*m^2]	
Between (1-30) ug/L	16	1,136	17,610	average concentration between contours
Between (30-100) ug/L	65	724	47,060	average concentration between contours
Between (100-1000) ug/L	550	1,332	732,624	average concentration between contours
Inside 1000 ug/L	2,250	144	324,208	average concentration between contours
	Total	**3,336**	**1,121,502**	
	Average U Concentration		**336 ug/L**	

Determination of Average Groundwater Concentration for Post Excavation Plume Area

Plume Areas	Area	Unit	Area	Unit
Between (1-30) ug/L	7,783	ft^2	723	m^2
Between (30-100) ug/L	3,638	ft^2	338	m^2
Between (100-500) ug/L	2,941	ft^2	273	m^2
Area of plume	14,362	ft^2	1334	m^2

Plume Areas	Conc (ug/L)	Area [ft^2]	Conc x Area [(ug/L)*ft2]
Between (1-30) ug/L	16	7,783	120,637
Between (30-100) ug/L	65	3,638	236,470
Between (100-500) ug/L	300	2,941	882,300
	Total	14,362	1,239,407
	Average U concentration		**86 ug/L**

Determination of Percentage of Plume Removed During Excavation

Pre-Excavation Uranium Mass in Aquifer A	Value	Unit
Area	3,336	m^2
Thickness	2	m
Porosity	0.4	[-]
Volume impacted GW	3,254	m^3
Volume impacted GW	3,254,036	L
Avg. conc.	336	ug/L
Mass U in GW	1,093,867,959	ug
Mass U in GW	1,094	g
Pre-excavation Uranium mass in groundwater	**1.1**	**kg**

Post-Excavation Uranium Mass in Aquifer A groundwater	Value	Unit
Area	1,334	m^2
Thickness	2	m
Porosity	0.4	[-]
Volume of impacted GW	1,301	m^3
Mass of impacted GW	1,301,397	L
Average concentration	86	ug/L
Mass U in groundwater	112,307,468	ug
Mass U in groundwater	112	g
Post-excavation Uranium mass in groundwater	**0.11**	**kg**
% of plume to be removed by excavation alone from Aquifer A:	**90%**	

Determination of Percentage of Plume Removed During Dewatering Process

Water production during dewatering of A:		
Q=KA dh/dl	**Value**	**Unit**
K	1.00E-03	cm/s
	1.00E-05	m/s
	0.86	m/d
L [plume width]	64	m
H [plume height]	2.4	m
A	156	m^2
dh/dl	1%	[-]
Q	**1.35**	**m^3/d**
	1349	**L/d**
	356	**gal/d**

Excavation period	30	Days est
Mass 'A' produced groundwater	40.5	m^3
	40,455	L
Conc. 'A' water	86	ug/L
Mass 'A' produced groundwater	3,491,187	ug
	3.49	grams

% of aq. U removed by dewatering in Aquifer A during excavation:	**0.3%**

Determination of Percentage of Plume Removed During Excavation - B Aquifer

Pre-Excavation U Mass in B Aquifer:	Value	Unit
Area of 'B' plume	3024	ft^2
	281	m^2
Thickness of B	8	ft
	2.4	m
Total porosity B	0.4	[-]
Volume GW in 'B' plume	274	m^3
	274,016	L
Avg conc in 'B' plume	30,000	max
	30	min
	15,015	avg ug/L
Pre-Excavation Mass U in B plume	**4.1.E+09**	**ug**
	4,114	**g**
	4	**kg**

Conclusion:

Aquifer A

Pre-excavation:	**Value**	**Unit**
Volume of A-aquifer plume:	3254	m^3
Average U concentration	336	ug/L
Mass of U in A-aquifer groundwater:	1.1	kg

Post-excavation:	**Value**	**Unit**
Volume of A-aquifer plume:	1301	m^3
Average U concentration	86	ug/L
Mass of U in A-aquifer groundwater:	0.1	kg
Percent removal of A-Aquifer dissolved U:		**90%**

Aquifer B

Pre-excavation:	**Value**	**Unit**
Volume of B-aquifer plume:	274	m^3
Average U concentration	15015	ug/L
Mass of U in B-aquifer groundwater:	4.1	kg

Post-excavation:
Percent removal of B-Aquifer dissolved U: 100%

Calculation of Groundwater Concentrations after Soil Excavation - AOC 6

Aquifer Characteristics	Value	Unit	SI Unit		Assumptions
Sat. thickness -Aquifer A	[-]	ft	[-]	m	'A' not present
Sat. thickness - Aquifer B	10	ft	3.0	m	plume thickness in this case
Sat. thickness -Aquitard A/B	[-]	ft	[-]	m	'A/B' not present
Length cut through plume	38	ft	11.6	m	from map of plume
Area of impacted soils	7777	ft^2	723	m^2	from map of excavation area
Circumference of excavation	352	ft	107	m	from map of plume
Total porosity B	0.4	[-]			standard literature value

Determination of Average Groundwater Concentration for Pre-Excavation Plume Area

Assumptions: Concentrations are averaged within the mapped contour lines.

Contour	Area	Unit	SI Unit		
Inside 1 ug/L	11,558	ft^2	1074	m^2	from map of plume
Inside 30 ug/L	2,934	ft^2	273	m^2	from map of plume
Inside 100 ug/L	1,273	ft^2	118	m^2	from map of plume
Between (1-30) ug/L	8,624	ft^2	801	m^2	from map of plume
Between (30-100) ug/L	1,661	ft^2	154	m^2	from map of plume

Contour	Av Conc (ug/L)	Area [m^2]	Conc x Area (ug/L)*(m^2)	
Between (1-30) ug/L	16	**801**	12,419	calculated from areas above
Between (30-100) ug/L	65	154	10,030	calculated from areas above
Greater than 100 ug/L	300	118	35,480	calculated from areas above
	Total		**57,928**	
	Average U Concentration		**54 ug/L**	

Determination of Average Groundwater Concentration for Post Excavation Plume Area

Contour	Area	Unit	SI Unit	
Between (1-30) ug/L	5,245	ft^2	487	m^2
Between (30-100) ug/L	207	ft^2	19	m^2
Between (100-500) ug/L	75	ft^2	7	m^2
Area of plume	5,527	ft^2	513	m^2

Contour	Av. Conc. (ug/L)	Area [m^2]	Conc x Area (ug/L)*(m^2)
Between (1-30) ug/L	16	487	7,553
Between (30-100) ug/L	65	19	1,250
Greater than 100 ug/L	300	7	2,090
	Total	**513**	**10,893**
	Average U Concentration		**21 ug/L**

Determination of Percentage of Plume Removed During Excavation

Pre-Excavation Uranium Mass in Aquifer B	Value	Unit
Area	1074	m^2
Thickness	3.0	m
Porosity	0.4	[-]
Mass impacted GW	1309	m^3
Mass impacted GW	1,309,144	L
Avg. conc.	54	ug/L
Mass U in GW	70,626,406	ug
Mass U in GW	71	g
Mass U in GW	**0.071**	**kg**

Post-Excavation Uranium Mass in Aquifer B	Value	Unit	
Area	513	m^2	area residual plume
Thickness	3.0	m	plume thickness
Porosity	0.4	[-]	standard literature value
Volume of impacted GW	626	m^3	
Volume of impacted GW	626,029	L	
Avg. conc.	21	ug/L	
Mass U in GW	13,280,884	ug	
Mass U in GW	13	g	
Mass U in GW	**0.013**	**kg**	
% of plume to be removed by excavation alone	**81%**		

Determination of Percentage of Plume Removed During Dewatering Process

Assumptions: Aqueous U will flow into the side of the excavation from the residual portion of the plume during dewatering. Flow is estimated the Darcy equation assuming steady-state flow (Q=KA dh/dl). Flux is assumed steady-state also.

Water production during Dewatering of B			
Sides	**Value**	**Unit**	
Kh	1.00E-03	cm/s	vertical hydraulic conductivity
	1.00E-05	m/s	
	0.86	m/d	
L	107	m	circumference of excavation
H	1.5	m	saturated thickness
A (=L*H)	163.5	m^2	
dh/dl	1%	[-]	gradient while pumping
Q	1.41	m^3/d	GW production rate
	1413	L/d	
	373	gal/d	
Excavation period	4	days	estimated in FS
Mass 'A' GW made	5.7	m^3	
	5,651	L	
Conc. A water	2	ug/L	10% of avg. conc. because 10% of sidewalls plume
Mass U made	11,988	ug U	
	0.0	g U	

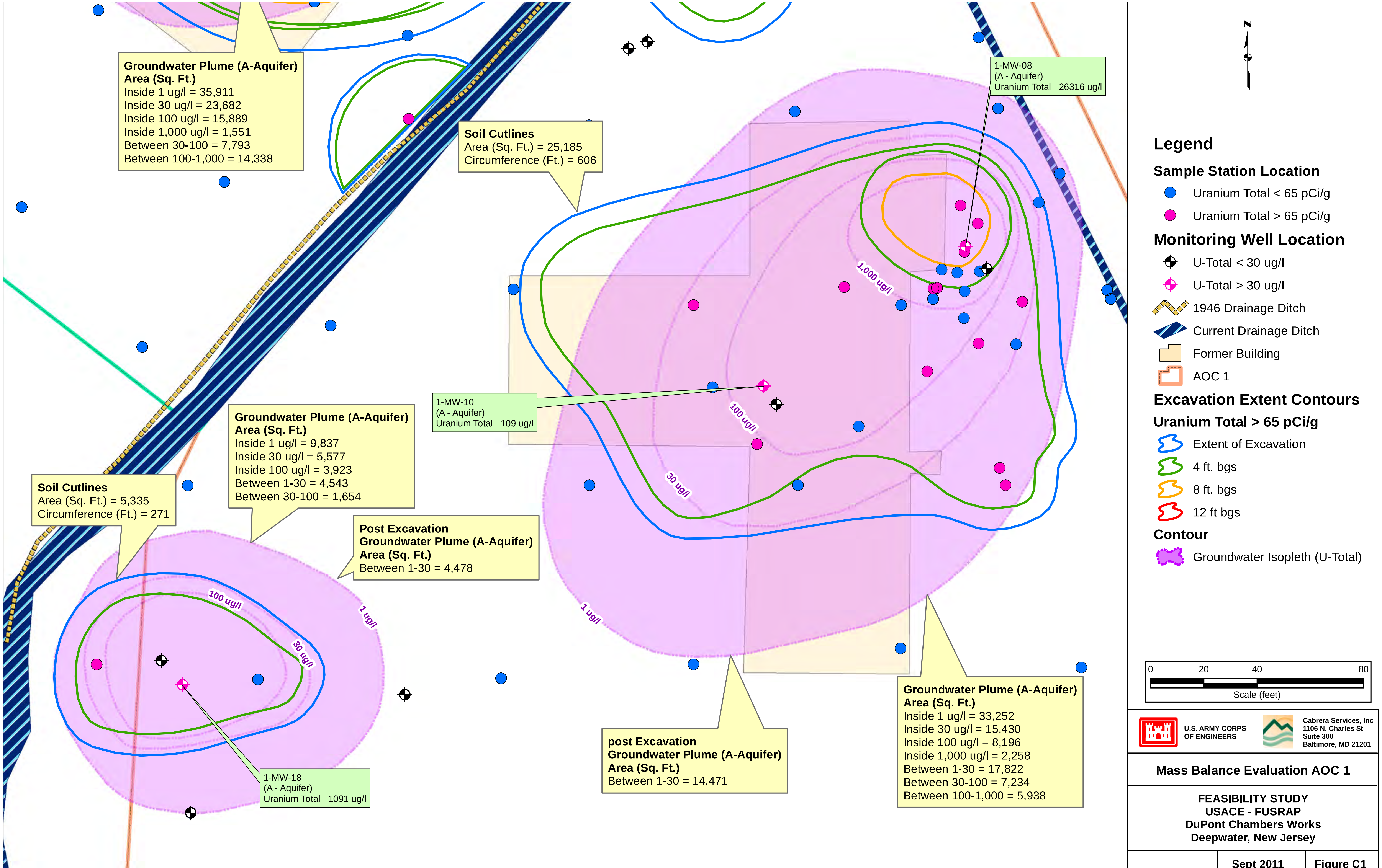
% of U removed by dewatering during Excavation	0%

Conclusion:

Pre-excavation:	**Value**	**Unit**
Volume of plume:	1309	m^3
Average U concentration:	54	ug/L
Mass of U in groundwater:	0.071	kg

Post-excavation:	**Value**	**Unit**
Volume of plume:	626	m^3
Average U concentration:	21	ug/L
Mass of U in groundwater:	0.013	kg

% U (aq) removed by excavation:	**81%**
% U (aq) removed by dewatering during excavation:	**0%**



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Cabrera Services, Inc
1106 N. Charles St
Suite 300
Baltimore, MD 21201

Mass Balance Evaluation AOC 1

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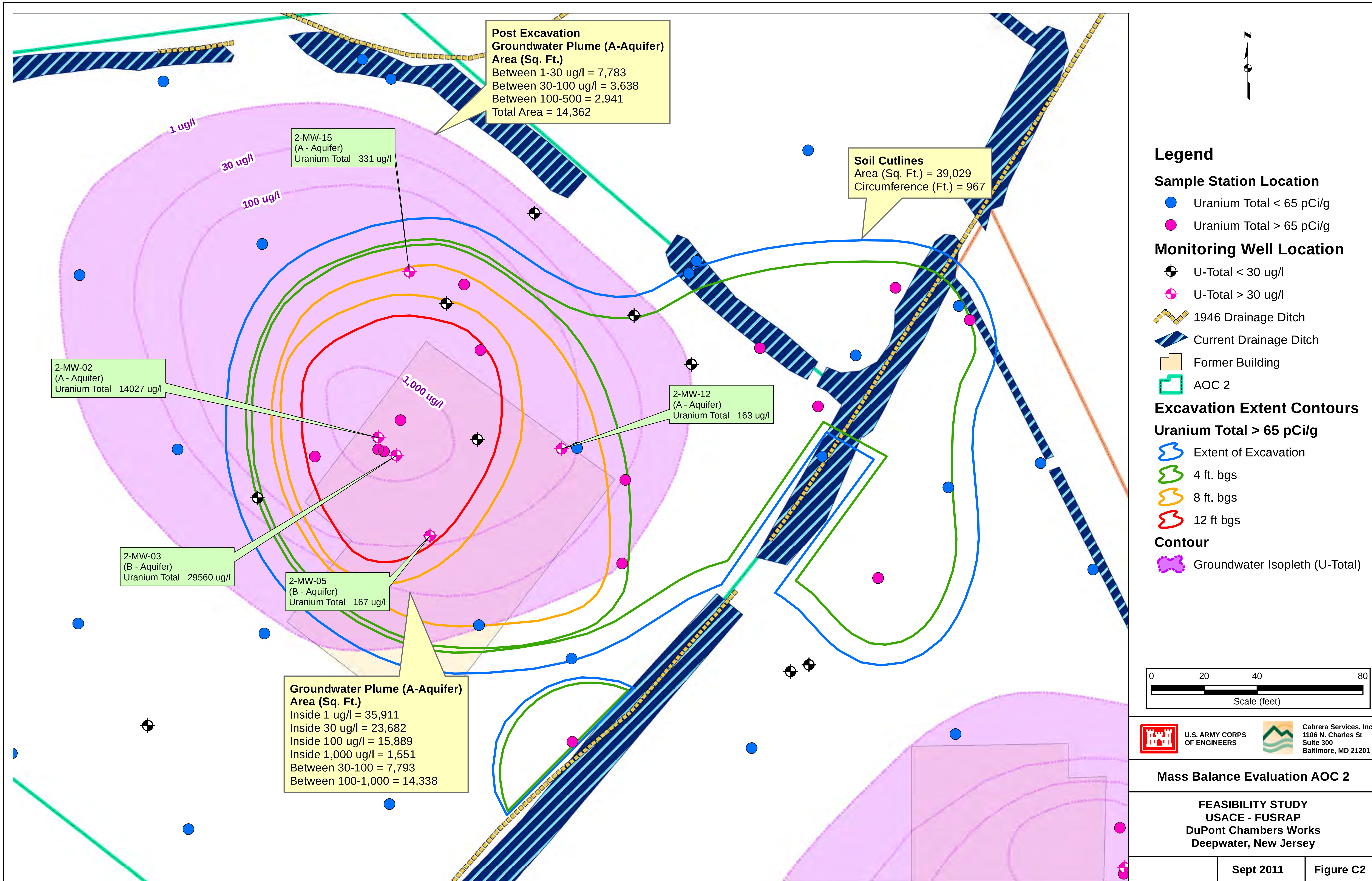
Sept 2011	Figure C1


Post Excavation
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Between 1-30 ug/l = 7,783
Between 30-100 ug/l = 3,638
Between 100-500 = 2,941
Total Area = 14,362
1 ug/l
30 ug/l
100 ug/l
1,000 ug/l
2-MW-15
(A - Aquifer)
Uranium Total 331 ug/l
Soil Cutlines
Area (Sq. Ft.) = 39,029
Circumference (Ft.) = 967
2-MW-02
(A - Aquifer)
Uranium Total 14027 ug/l
2-MW-12
(A - Aquifer)
Uranium Total 163 ug/l
2-MW-03
(B - Aquifer)
Uranium Total 29560 ug/l
2-MW-05
(B - Aquifer)
Uranium Total 167 ug/l
Groundwater Plume (A-Aquifer)
Area (Sq. Ft.)
Inside 1 ug/l = 35,911
Inside 30 ug/l = 23,682
Inside 100 ug/l = 15,889
Inside 1,000 ug/l = 1,551
Between 30-100 = 7,793
Between 100-1,000 = 14,338
N
Legend
Sample Station Location
Uranium Total < 65 pCi/g
Uranium Total > 65 pCi/g
Monitoring Well Location
U-Total < 30 ug/l
U-Total > 30 ug/l
1946 Drainage Ditch
Current Drainage Ditch
Former Building
AOC 2
Excavation Extent Contours
Uranium Total > 65 pCi/g
Extent of Excavation
4 ft. bgs
8 ft. bgs
12 ft bgs
Contour
Groundwater Isopleth (U-Total)
0 20 40 80
Scale (feet)
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Suite 300
Baltimore, MD 21201
Mass Balance Evaluation AOC 2
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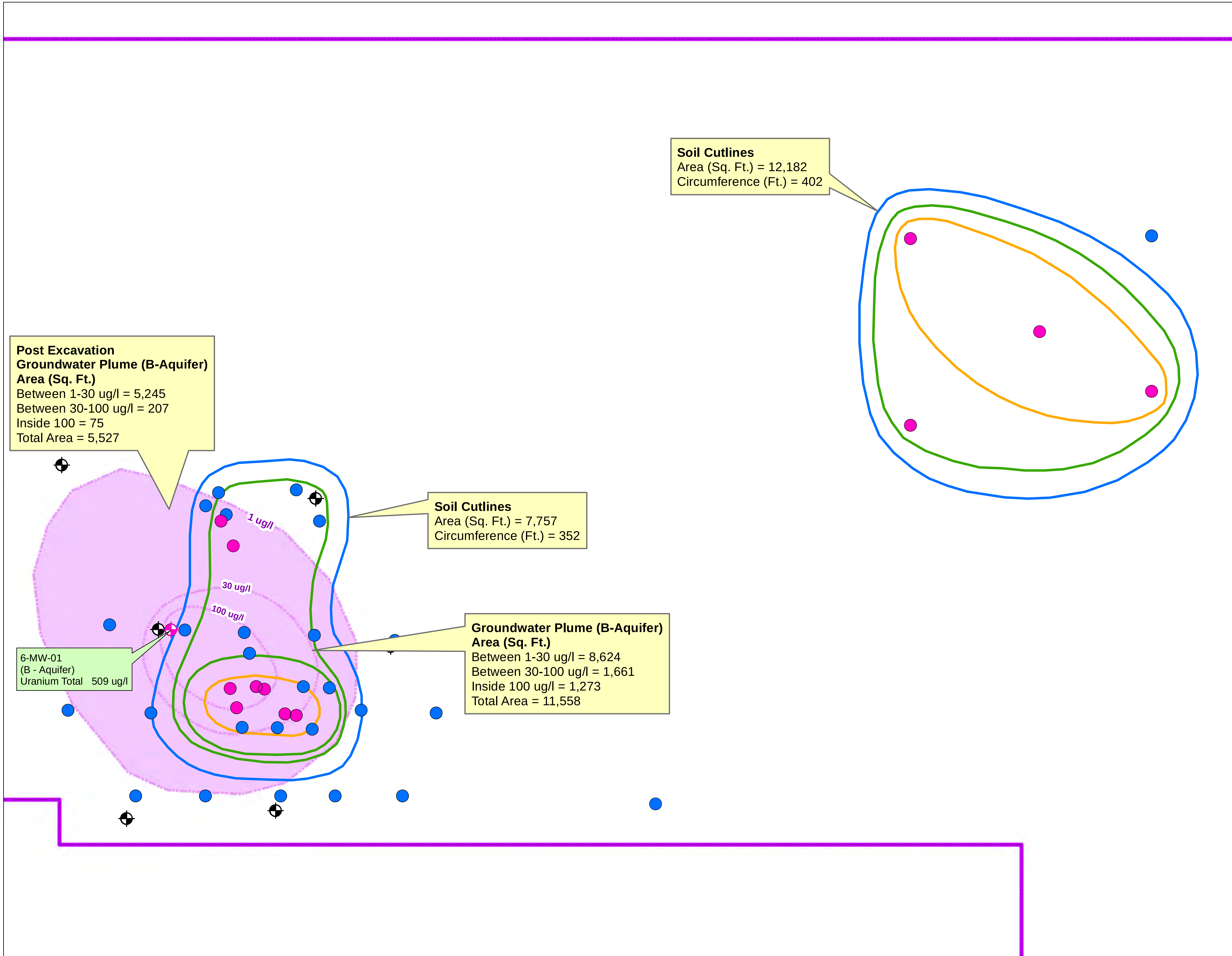

Legend

Sample Station Location

- Uranium Total < 65 pCi/g
- Uranium Total > 65 pCi/g

Monitoring Well Location

- U-Total < 30 ug/l
- U-Total > 30 ug/l
- 1946 Drainage Ditch
- Current Drainage Ditch
- Former Building
- AOC 6

Excavation Extent Contours

Uranium Total > 65 pCi/g

- Extent of Excavation
- 4 ft. bgs
- 8 ft. bgs
- 12 ft bgs

Contour

- Groundwater Isopleth (U-Total)

0 20 40 80
Scale (feet)

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Cabrera Services, Inc
1106 N. Charles St
Suite 300
Baltimore, MD 21201

Mass Balance Evaluation AOC 6

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