NOTICE

All drawings located at the end of the document.

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March 4, 1994

94-RF-02669

F. R. Lockhart
Environmental Restoration Division
DOE/RFO

SUBMISSION OF PARTS IV AND V OF THE OPERABLE UNIT 4 (OU 4) INTERIM MEASURE/INTERIM REMEDIAL ACTION DECISION DOCUMENT (IM/IRA DD) - SRK-043-94

In accordance with OU 4 Phase IM/IRA "Roundtable Review" schedule, EG&G Rocky Flats, Inc., is hearby transmitting Parts IV and V (Conceptual Design and Post Closure Monitoring Plan, respectively) of the IM/IRA DD to the Department of Energy, Rocky Flats Office (DOE/RFO) for review and comment. These parts of the IM/IRA DD are the final components of the document for review and comment under the roundtable review cycle prior to finalizing the document for the first Interagency Agreement (IAG) milestone on April 14, 1994.

If you have any questions or concerns regarding these documents, please contact me at extension 8541 or R. T. Ogg at extension 8608.

S R Keith

S. R. Keith
Director
Solar Pond Projects

RTO:bep

Enclosures:
As Stated

Orig. and 1 cc - F. R. Lockhart

cc:
S. Howard - w/o encl.
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NOTICE:

UNNUMBERED PAGES

The following document contains pages that were not numbered. The microform copy is representative of the paper copy. If replacement pages are distributed, they will be microfilmed and included in the Administrative Record file.

The Adminstrative Record Staff

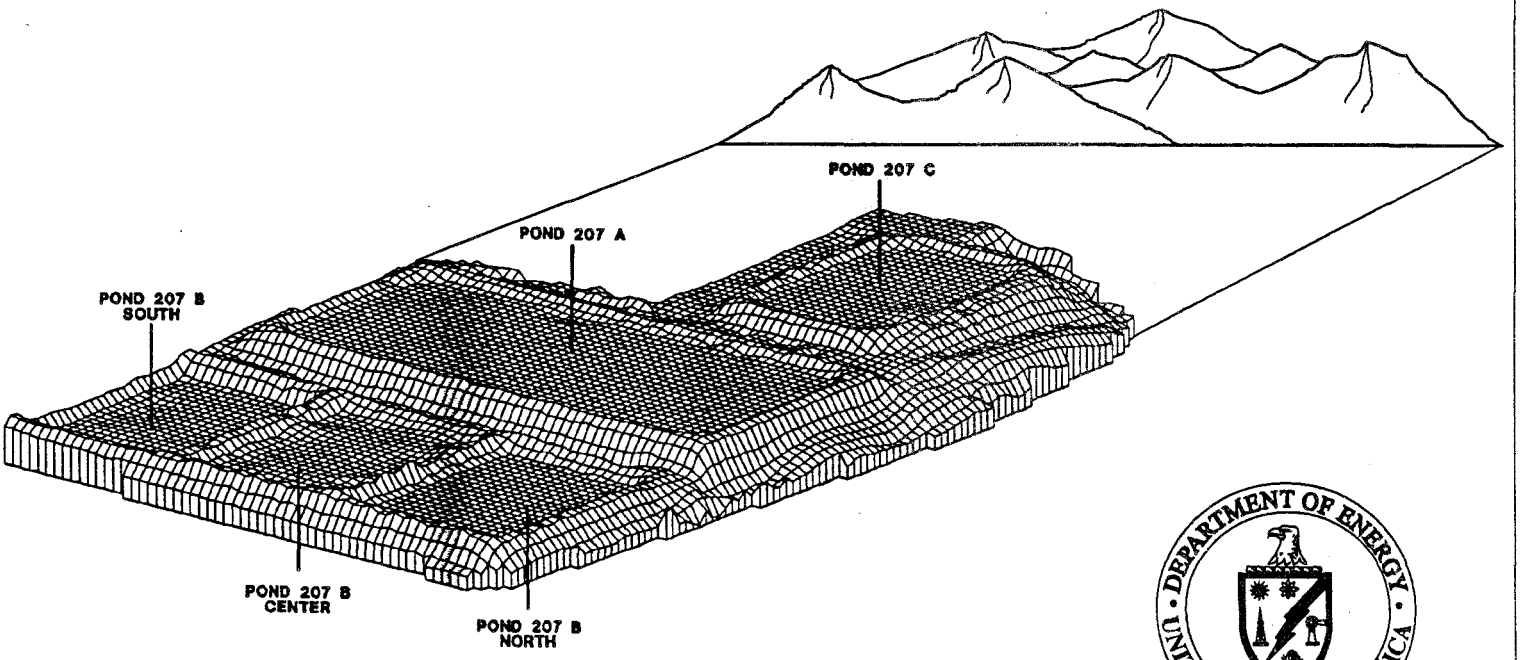
OU4 Solar Evaporation Pond Interim Measures/Interim Remedial Action Environmental Assessment Decision Document

U.S. Department of Energy
Rocky Flats Plant
Golden, Colorado

February 1994

Revision: Roundtable Review Draft

Parts IV and V, Appendices



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PART IV RECOMMENDED IM/IRA ALTERNATIVE

Part IV provides the conceptual design of the proposed general response action (GRA) to close/remediate the Solar Evaporation Ponds (SEPs), also known as Operable Unit 4 (OU4), at the U.S. Department of Energy's (DOE's) Rocky Flats Plant (RFP) in Colorado. Section IV.1 contains a general programmatic summary of the project activities that will be performed. Section IV.2 provides the functional design requirements and the specific design criteria that must be complied with in order for the SEP closure/remediation system to achieve the established goals and objectives. Section IV.3 presents the conceptual design for the closure/remediation system summarized in Section IV.1. Section IV.4 provides a waste management plan identifying the wastes that will be generated as the project is implemented. A list of the specifications that will be prepared during the detailed design period is presented in Section IV.5. Section IV.6 provides work plans for engineering optimization studies that will be implemented during the detailed design period to provide information required for design completion. This section also contains a conceptual-level construction schedule to implement the design. Section IV.7 presents a conceptual-level construction cost estimate. A construction quality assurance plan is presented in Section IV.8. Section IV.9 discusses health and safety considerations for the construction activities. Section IV.10 assesses the risks associated with the proposed GRA, identifies any environmental impact, and compares the environmental impact from the proposed GRA to the no-action GRA. Section IV.11 presents how the design will comply with the identified appropriate or relevant and applicable requirements (ARARs) and proposes to establish an OU4 Corrective Action Management Unit (CAMU).

IV.1 GENERAL PROJECT DESCRIPTION

The following section provides a general description of the activities that will be performed as part of the OU4 IM/IRA closure/remediation plan. A detailed engineering description of the closure/remediation design is presented in Section IV.3.

IV.1.1 Description of the Selected Alternative

DOE will utilize a combination of the various alternatives that were proposed and described under General Response Action II to close/remediate the OU4 SEPs. Contaminated media will be consolidated within an established CAMU to minimize the areal extent of the engineered cover. Section IV.11.2 presents a request for a CAMU designation. All SEP liners, contaminated subgrade vadose zone material, and associated berms will be excavated to a depth where the soil contaminant concentrations are less than or equal to the vadose zone preliminary remediation goals (PRGs) or to the elevation of the mean of the seasonal high water table elevation, and will be consolidated within SEP-207-A and the western two-thirds of the 207-B Series SEPs. The liners from the 207-B Series SEPs will be excavated because the mean of the seasonal high water table elevation in the 207-B Series SEPs exceeds the elevation of the base of the 207-B Series SEP liners. Contaminated media from within the OU4 boundaries will be used as fill material to raise the elevation of the vadose zone within the western two-thirds of the 207-B Series SEPs to the base elevation of the existing SEP 207-A liner. This will raise the

base grade of the closure in the B-Series SEPs to an elevation above the mean of the seasonal high water table elevation. The liners in SEP 207-A will be excavated and crushed with the liners from the 207-B Series SEPs. A subsurface drainage system consisting of a sand and gravel layer will be installed above the SEP 207-A base grade and above the new vadose zone in the western two-thirds of the 207-B Series SEPs. The crushed liners will be mixed with contaminated soil media and placed above the subsurface drainage layer. The subsurface drainage layer will provide an additional measure of protection to prevent the future water table from rising and contacting the liners. A final engineered cover will be constructed over the consolidated liners and contaminated media. The berms from the eastern side of SEP 207-A and the western-most sides of the 207-B Series SEPs will be pushed into the area of the consolidated material as required to establish a final grade for the construction of the engineered cover. The northern portions of SEPs 207-A and 207-B North will be excavated and consolidated beneath the engineered cover to reduce the impact that the final engineered cover will have on the northern hillside slope stability. Engineered Cover Alternative 6, as described in Section III.3.2.1 (Figure III.3-8), will be constructed over the consolidated materials. The excavated areas of SEP 207-A (northern and western portions), and the 207-B Series SEPs (eastern one-third) that will not be under the full thickness of the final engineered cover will be closed with clean backfill.

The liners and contaminated media from SEP 207-C will be excavated, crushed, and consolidated beneath the final engineered cover. The soils beneath Building 788 between SEP 207-C and SEP 207-A also will be excavated and consolidated beneath the final engineered cover. The depth of excavation will extend no deeper than the vertical extent of contamination or the mean of the seasonal high water table elevations. Samples will be collected and analyzed to determine the optimum extent of soil removal. Excavation may be terminated when contaminants of concern (COC) concentrations are less than the vadose zone PRGs, or when the elevation of the mean of the seasonal high water table elevations is encountered. The SEP 207-C liners will be consolidated above the subsurface drainage system. Any uncharacterized soils from SEP 207-C (top few feet) will also be consolidated above the subsurface drainage system. Characterized soils that are determined to be protective of human health and the environment may be used as backfill material to raise the elevation of the vadose zone within the western two-thirds of the 207-B Series SEPs.

Engineered Cover Alternative 6 was selected for the final engineered cover because it has the highest potential to prevent precipitation infiltration into the consolidated liners and contaminated media during the specified 1,000 year period. The engineered cover system, in conjunction with the physical site characteristics must protect human health and the environment from the contaminants in the liners for 1,000 years as required by the State of Colorado hazardous waste landfill siting criteria (CCR Title 6 Chapter 1007 Article 2). Engineered Cover Alternative 6 is best suited to meet the 1,000-year design criteria because it utilizes all earthen materials and is expected to maintain the highest long-term integrity.

Engineered Cover Alternative 1, as described in Section III.3.2.1 (Land Reclamation) (Figure III.3-3), will be constructed over SEP 207-C and over the portions of the SEPs not

covered by the full extent of the final engineered cover. A more substantial engineered cover will not be required because all of the SEP materials and contaminated media with COC concentrations exceeding PRGs will be removed. Engineered Cover Alternative 1 will also be constructed over other areas in OU4 where contaminated soil media are excavated for consolidation under the final engineered cover. Engineered Cover Alternative 1 essentially will be used to re-establish grade and prevent erosion over areas where all contamination has been removed. Figure IV.1-1 depicts the areal extent of the two engineered covers. The locations of the engineered covers have been configured to address the different types of contaminated media and the physical constraints of the site (i.e., the hillside to the north, other RFP facilities, and the potential for a high water table elevation in the southeastern area of the site).

Surface soils immediately south of SEP 207-A with COC concentrations exceeding the PRGs will be either excavated and consolidated under the engineered cover or will remain in place beneath the engineered cover. Engineered Cover Alternative 1 will be constructed over areas where soils have been excavated for remediation. This process will establish a final grade and a grass cover to help minimize erosion.

Hillside soils from the area between the SEP berms and the downhill seepline (Figure IV.1-2) with COC concentrations exceeding the surface soil PRGs will be excavated and consolidated beneath the final engineered cover. The soils downgradient from the seep areas will not be excavated for remediation since the source of the contamination is likely to be the ground water that seeps to the surface. The closure of the SEPs does not address the ground water and the seep areas. The ground water seeps and downgradient soil media will be addressed during future hydrogeologic investigations. Remediation of these areas (as required) will be conducted as a separate project. In addition, the areas surrounding RFP buildings 783, 780, 780B, and 786 will not be remediated because of existing operations in this area. Remediation of this industrial area, including soil and ground water, will be addressed when these facilities are closed. The OU4 area between the security fences also will not be remediated as part of the IM/IRA. This area will be addressed in the future when the security area is closed.

Surface soils north of the perimeter security fence (buffer zone) and within the OU4 boundary with COC concentrations exceeding the surface soil PRGs will be excavated and consolidated beneath the final engineered cover or beneath the clean-closed SEP 207-C (if the COC concentrations are less than the vadose zone PRGs). Contamination of surface soils within this region of OU4 is not likely to be from ground water seeps. Once the contaminated soils are removed, the clean backfill is not likely to become contaminated from ground water seeps. DOE may collect additional surface soil samples to confirm that this area requires remediation. The samples would be analyzed for the following COCs (contaminants detected at concentrations exceeding the PRGs during the RFI/RI program):

- Beryllium,
- Mercury,
- Benzo(a)anthracene,

- Benzo(b)fluoranthene,
- Benzo(k)fluoranthene,
- 1,4-Dichlorobenzene,
- Benzo(a)fluoranthene,
- Benzo(a)pyrene, and
- Bis(2 ethylhexyl)Phthalate.

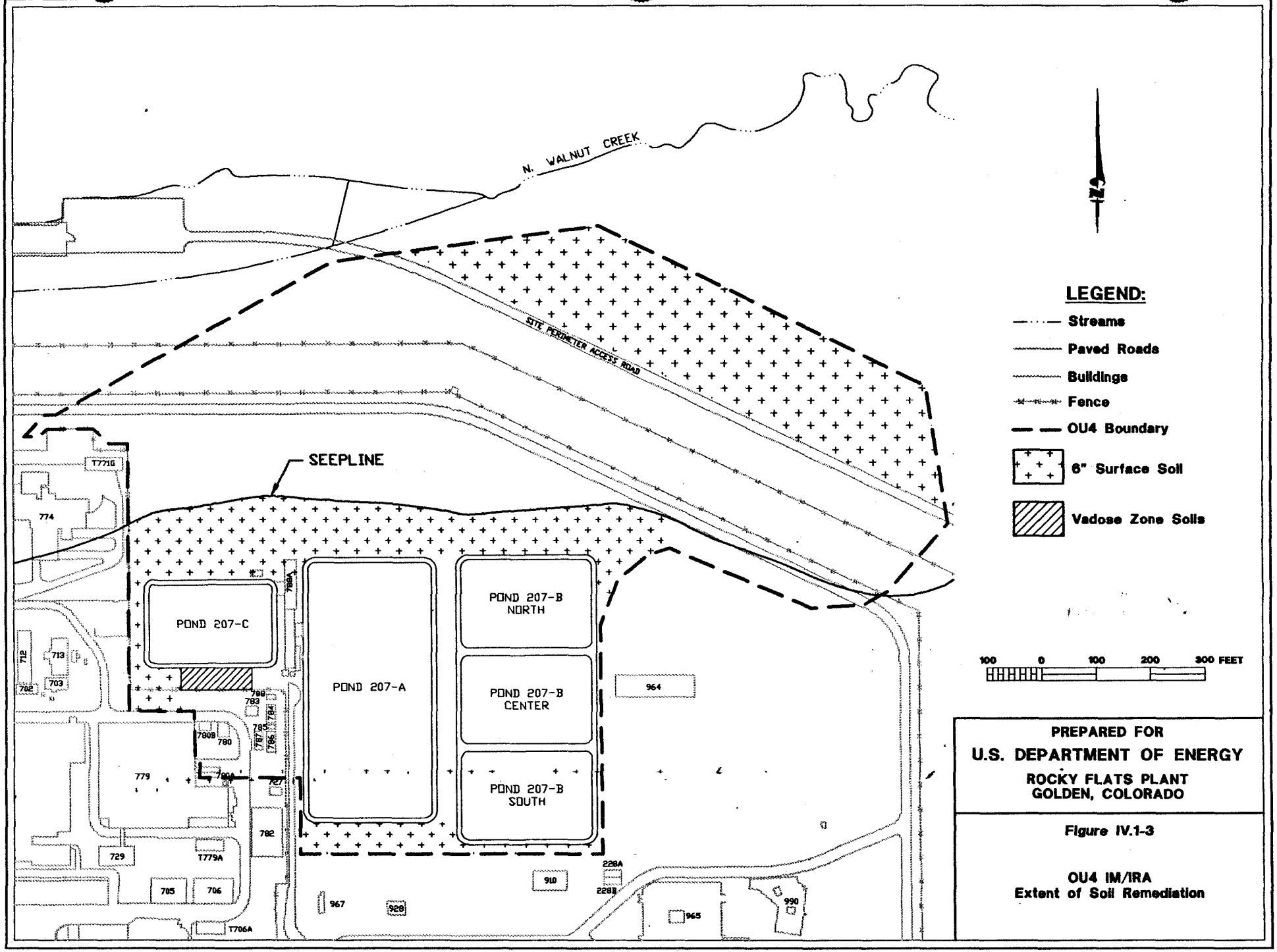
Figure IV.1-3 illustrates the regions where contaminated surficial and vadose zone soils will be remediated. The RFI/RI results indicate that there are only two areas where vadose zone soils adjacent to the SEPs have COC concentrations which exceed the vadose zone PRGs. The vadose zone soil in the area immediately south of SEP 207-C is contaminated, but will not undergo complete remediation because it is adjacent to buildings 783, 784, 786, and 787 where ongoing RFP operations will restrict access. However, any contaminated vadose zone soils in this region that will be beneath the toe of the final engineered cover will be excavated and consolidated beneath the engineered cover. Therefore, vadose zone soils will be excavated from the area south of SEP 207-C to approximately 15 feet from the existing industrial area fence line. The 15-foot area will allow room for excavation without impacting the fence line or the RFP industrial operations. There is also vadose zone soil contamination just south of the SEP 207-A adjacent to the berm. This material will be excavated and consolidated beneath the final engineered cover. Primarily surficial soils require remediation in the vicinity of the SEPs. The top 6 inches of surficial soil will be excavated.

Samples will be collected for COC analysis to verify that all the contaminated soils have been removed from the areas being remediated. Section IV.8 provides a methodology for conducting the confirmational sampling and identifies the COCs for analysis. Excavated areas will be regraded with clean topsoil (as required) and seeded (Engineered Cover Alternative 1).

DOE will consolidate the OU4 investigation-derived material, which consists of drill cuttings from the OU4 borings, beneath the final engineered cover to help establish the grade for the construction of the engineered cover. There are approximately 200 drums (30-gallon capacity) of drill-cutting soils resulting from the OU4 RFI/RI program. The soils will be consolidated beneath the final engineered cover, and the drums will be decontaminated (if necessary) and returned to the waste management program for re-use.

The rubble/debris from excavated and removed utilities will be size-reduced and deposited beneath the final engineered cover. These materials will consist of segments of excavated piping, excess soils from the excavation of the utilities, and rubble/debris from the foundation of Building 788 and other OU4 subgrade structures adjacent to the SEPs (i.e., concrete caissons, foundations, and footers). These materials will be size-reduced and positioned as necessary to ensure that they will not contribute to subsidence of the final engineered cover.

DOE may have to stabilize the northern hillside to prevent landsliding that might occur as a result of natural slope stability problems or the additional load of the engineered cover. A geotechnical investigation of the hillside, in conjunction with slope stability modeling, will be


N. WALNUT CREEK
SITE PERIMETER ACCESS ROAD
SEEPLINE
POND 207-C
POND 207-A
POND 207-B NORTH
POND 207-B CENTER
POND 207-B SOUTH
T771G
774
712
713
702
703
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780B
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967
928
910
228A
228B
964
965
990
LEGEND:
Streams
Paved Roads
Buildings
Fence
OU4 Boundary
6" Surface Soil
Vadose Zone Soils
100 0 100 200 300 FEET
PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO
Figure IV.1-3
OU4 IM/IRA
Extent of Soil Remediation

performed to determine the extent of hillside stabilization required. Section IV.6.1 presents details concerning the stability of the hillside area and provides a geotechnical investigation work plan to obtain data to be used during the analysis and design.

The remaining sections of Part IV present the conceptual design details and a description of the design. In addition, modeling results are presented demonstrating that the closure system will be protective of human health and the environment for 1,000 years.

IV.1.2 Classification of the Selected Alternative

Per DOE Order 6430.1A and 5430.19, United States Department of Energy General Design Criteria, a nuclear facility (special facility) is defined as, "A facility whose operations involve radioactive materials in such form and quantity that a significant nuclear hazard potentially exists to the employees or the general public. Included are facilities that: (1) produce, process, or store radioactive liquid or solid waste, fissionable materials, or tritium; (2) conduct separation operations; (3) conduct irradiated materials inspection, fuel fabrication, decontamination, or recovery operations; or, (4) conduct fuel enrichment operations..." The remediated SEPs will be classified as a nuclear facility because they will ultimately store solid radioactive waste materials. As discussed in Division 13, 1300-1.2 of the General Design Criteria, 20 different types of special facilities have been designated. The most appropriate designation for the SEPs is that of a Radioactive Solid Waste Facility. A more detailed discussion of the special facility applicability and its effects on the design of the remedial alternative for the SEPs is provided in Appendix IV.A.

The Rocky Flats Plant Conduct of Engineering Manual (COEM), 2-DOS-COEM-6.3.6, "Classification of Systems, Components, and Parts," provides a method and criteria for the classification of systems, components, and parts to provide a level of design, procurement, and quality assurance commensurate with the safety function of the system. The classification of systems, components, and parts at the RFP supports the graded approach of ensuring that all phases of design, construction, and repair work are subject to levels of review and control commensurate with the safety function of the system, component, or part. Four system categories have been designated at the RFP. System Category 1 is composed of those systems, components, or structures, including portions of systems, whose failure could adversely affect the environment or the safety and health of the public. System Category 2 is defined as systems, components, or structures, including portions of systems, whose failure could reasonably be expected to inhibit or prevent a Category 1 system, component, or structure from performing its intended vital function. System Category 3 includes those systems, components, or structures, including portions of systems, which provide a margin of protection for personnel or the environment, but which do not perform vital safety functions as defined in the basis for Category 1 and Category 2 items. Lastly, System Category 4 is defined as those systems, components, or structures, including portions of systems, that do not meet any of the criteria for classification in Category 1, 2, or 3.

An example of a System Category 3 is, "Systems providing containment for radioactive contamination or material as defined in HSP 18.02." Based on this example, the remediated SEPs have been designated as a System Category 3. Systems, components, and parts that have been designated as System Category 3 and 4 are, by definition, classified as Non-Safety Class (NSC). NSC is defined as any system, component or part which is not required to ensure a System Category 1 or 2 system performs its vital safety function(s). All NSC items may be purchased as commercially available without procurement specifications. The DOE cognizant engineer (CE) may specify additional inspection and/or testing requirements for NSC items and impose select additional inspection and/or testing requirements through the use of procurement specifications, in accordance with COEM 6.5.14, "Engineering Standards for the Procurement, Receipt, and Control of Safety Related Items." The additional inspection and/or testing requirements may be imposed to ensure a particular level of quality commensurate with engineering design, DOE, or other regulatory requirements.

IV.2 DESIGN BASIS

The following section addresses the functional objectives of the proposed alternatives and presents the detailed design requirements which the engineered cover systems must meet or exceed. The design codes, standards, and DOE orders that must be adhered to are identified. In addition, assumptions and constraints or limitations that may have an impact on the design are specified. The design basis will be used to guide the detailed design of the SEP closure/remediation IM/IRA.

IV.2.1 Functional Objectives

IV.2.1.1 The overall OU4 closure/remediation design shall mitigate contaminants in the subsurface such that established PRGs are met.

IV.2.1.2 The SEP facility shall be closed such that it will control, minimize, or eliminate, to the extent necessary to protect human health and the environment, the escape of hazardous waste, hazardous constituents, leachate, or contaminated runoff to the ground water, surface waters, or the atmosphere.

IV.2.1.3 Contaminated media that can be remediated by this IM/IRA should be consolidated within the CAMU to the maximum extent practicable.

IV.2.1.4 The construction of the OU4 closure/remediation IM/IRA shall be conducted in a manner which minimizes exposure to environmental hazards.

IV.2.1.5 The OU4 facility shall be closed with a cover system designed to:

- Provide long-term minimization of the migration of liquids through the cover and/or the underlying material;

- Function with minimal short-term maintenance and no long-term maintenance;
- Promote drainage of precipitation away from the landfill;
- Minimize damage to the cover from erosion or abrasion;
- Accommodate settling and subsidence so that the integrity of the cover and the subsurface drain is maintained; and
- Have a permeability less than or equal to the permeability of existing natural subsoils.

IV.2.1.6 Any wastes (liners) in the SEP facility must be kept isolated from the ground water to be protective of human health and the environment for 1,000 years. Constructed hydraulic barriers or subsurface drains should be considered in addition to the cover system for control of shallow ground water migration through the SEP facility area where the liners are consolidated to prevent a rising water table from contacting the consolidated liners.

IV.2.1.7 The overall SEP facility closure/remediation design shall be demonstrated via modeling and qualitative assessment to be protective of human health and the environment from contaminated media for 1,000 years.

IV.2.2 Design Requirements

IV.2.2.1 The SEP facility cover system shall:

- Minimize the migration of liquids through the cover and/or the subsurface with a system of evaporation, transpiration, lateral drainage pathways, and hydraulic barriers that will resist infiltration through the cover system and divert any external or infiltrated liquids away from the closed SEPs;
- Function with minimal maintenance by providing the following:
  - An optimal slope to the cover system that will promote drainage while minimizing erosion. The cover system maximum erosion rate shall not exceed 2 tons/acre/year, in accordance with U.S. Environmental Protection Agency (EPA) guidance (EPA, 1989);
  - A biotic barrier to deter human and animal intrusion into the underlying contaminated media; and
  - A final vegetated surface of native species that are drought resistant, do not require frequent mowing, and provide a dense, uniform cover;

- Provide a stormwater management system that will accommodate a 25-year, 6-hour storm event;

- Promote drainage of precipitation by providing side slopes of 20 percent and top slopes of 5 percent. (Side slopes may be steeper where the cover construction area is constrained, but additional erosion control and slope stability measures will be considered.)

- Accommodate settling and subsidence such that the top slope shall remain between 3 and 5 percent after subsidence;

- Have a hydraulic barrier with a hydraulic conductivity that does not exceed the average subsurface soil hydraulic conductivity; and

- Meet all applicable requirements of the State of Colorado hazardous waste regulations.

IV.2.2.2 Contaminated surface soils may be used as backfill material during cover system construction to artificially increase the thickness of the vadose zone under the cover system if the COC concentrations are protective of ground water as demonstrated by the leaching model.

IV.2.2.3 All contaminated media from SEP 207-C shall be excavated and consolidated beneath the final engineered cover.

IV.2.2.4 The overall SEP facility closure/remediation design shall:

- Be demonstrated to be protective of human health and the environment for 1,000 years using qualitative assessment and results from computer models such as:

  - HELP, Version 2.0 (EPA code for infiltration assessment)
  - VLEACH, Version 1.02 (EPA code for vadose zone transport)
  - MYGRT, Version 2.0 (Electric Power Research Institute (EPRI) code for ground water impact)
  - XSTABL, Version 4.10 (Proprietary code for slope stability modeling)

- Meet all applicable requirements of the:

  - Federal Facility Compliance Agreement and Consent Order for the RFP;
  - Federal regulations;
  - State of Colorado hazardous waste regulations;
  - DOE orders and directives; and
  - RFP standards and design criteria.

IV.2.2.5 The SEP facility may be closed with the existing pond liners in place or relocated and consolidated under the cover system. The SEP liners shall be crushed to a minimum appropriate size and mixed with soil to provide a layer in the cover system of uniform composition and thickness.

IV.2.2.6 Contaminated OU4 soils from the hillsides north and east of the SEP facility between the berms and the seepline and from the buffer zone shall be excavated to remove all soils with COCs above PRGs. These soils will be mixed and compacted beneath the engineered cover system boundary to adequately support the cover system. Contaminated soils from the OU4 buffer zone shall also be excavated and consolidated beneath the final engineered cover, or beneath the SEP 207-C cover if the COC concentrations are less than the vadose zone PRGs.

IV.2.2.7 The hillsides north and east of the SEP facility shall be evaluated with regard to landsliding and surface erosion. If necessary, the hillsides will be stabilized to reduce the potential for degradation of the structural integrity of the cover system.

IV.2.2.8 Underground utilities, aboveground utilities, and structures within the boundary of the SEP facility cover system shall be either abandoned and closed in place, removed, or relocated. Locations of utilities and structures will be verified, as necessary. Any removed utilities or structures will be treated as debris and consolidated under the cover system. Underground utilities and other structures within the boundary of the SEP facility cover system will be managed as follows:

- The underground utilities and structures will be abandoned and closed in place if the utility or structure will no longer be required after the cover system has been installed and will not impede construction or implementation of the cover system. Abandonment will include the following actions:

- The soils around the utilities or structures will be excavated as necessary to provide access for in-place closure equipment and materials.

- Utilities, structures, and/or excavated soils will be monitored for radioactive contamination, and dispositioned and handled in accordance with appropriate DOE and RFP directives and procedures. Excavated areas will be sampled and analyzed to ensure that all contaminated soils have been removed.

- Grout may be pumped into underground utility lines and structures to minimize the void spaces or open areas.

- Excavation areas around the grouted utilities or structures will be backfilled with grout to a level that will provide a permanent barrier between the utilities trench and other backfill materials, if the utility being closed in place is beneath the engineered cover and there is a concern that ground water may

flow along the utility line beneath the engineered cover. The remainder of the excavation areas will be backfilled with clean materials.

- Grouting of utilities, structures, and excavations shall not extend outside the cover system footprint.

- The underground utilities and structures will be removed if the utility or structure will no longer be required after the cover system has been installed and causes an impediment to construction or implementation of the cover system. Removal will include the following actions:

  - The soils around the utilities or structures will be excavated as necessary to allow their removal.

  - Utilities, structures, and/or excavated soils will be monitored for radioactive contamination and dispositioned and handled in accordance with appropriate DOE and RFP directives and procedures.

  - Utilities and other structures will be removed and size-reduced and placed under the cover system. Asbestos or asbestos-containing materials will not be placed under the cover system.

  - Excavation areas will be backfilled with clean materials.

- The underground utilities and structures will be relocated if the utilities or structures will be required to be in service after the cover system has been installed. Relocation will include the following actions:

  - Utilities, structures, and/or excavated soils will be monitored for radioactive contamination and dispositioned and handled in accordance with appropriate DOE and RFP directives and procedures. If closed portions of relocated lines will be left in place, then procedures outlined in Section IV.2.2.8.1 will apply. If closed portions of relocated lines will be excavated, then the procedures outlined in Section IV.2.2.8.2 will be applied.

  - Excavation areas shall be backfilled with clean materials.

  - Construction for relocated utilities shall be performed in accordance with applicable federal, state, and RFP requirements.

IV.2.2.9 Monitoring wells required for the SEP facility post-closure plan will be installed prior to completion of the closure/remediation. Some wells may be required

prior to completion of the engineered cover. Other wells may be required after the engineered covers are installed.

IV.2.2.10 The SEP facility post-closure monitoring system design will be integrated with the SEP facility closure/remediation design. The post-closure monitoring system will be installed prior to completion of closure/remediation.

IV.2.2.11 The feasibility of modifying the RFP security system in the area of the SEP facility will be investigated for the purpose of providing temporary ease-of-access to the construction area for equipment, personnel, and materials during remediation construction.

IV.2.2.12 The closed SEP facility will be provided with access roads to allow maintenance vehicles and equipment access to the facility to perform required maintenance. The roads shall be designed in accordance with appropriate DOE and RFP procedures, standards, and directives.

IV.2.2.13 The closed SEP facility will have chain-link fence installed around the overall perimeter of the ponds and cover system with appropriate gated accessways for future inspections of the facility. The fence shall be designed in accordance with appropriate DOE and RFP procedures, standards, and directives.

IV.2.2.14 The closed SEP facility will be provided with protective security illumination in accordance with appropriate DOE and RFP procedures, standards, and directives.

IV.2.2.15 The design for the closure/remediation of the SEPs will include specification of procedures to prevent the spread of contaminants to soil, water, or air during construction. The design will include the following:

- Approved mitigation techniques to prevent airborne dust contamination during earthmoving and other activities;
- Drainage control, stockpile coverage, and other measures, including collection and treatment of stormwater if required, to prevent surface water contamination; and
- Careful planning of stockpile management and earthmoving techniques to prevent soil contamination.

IV.2.2.16 The SEP facility new and/or relocated utilities shall be designed in accordance with appropriate federal, state, DOE, and RFP procedures, standards, and directives.

IV.2.3 Applicable Codes, Standards, and References

The following is a list of the national codes and standards, DOE orders, RFP procedures, and reference documents to be considered during the design of the SEP closure/remediation.

Code of Federal Regulations Title 40, Part 265 (40 CFR 265) - Interim Status Standard for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities, July 1990.

COEM - DES - 5, Rev. 4; "Specification for Procurement and Construction," 6/17/91.

COEM - DES - 12, Rev. 3; "Power Distribution Systems Management," 6/17/91.

COEM - DES - 13, Rev. 1; "Illumination Engineering Design and Review Procedure," 6/17/91.

COEM - DES - 19, Rev. 2; "Drafting Practices," 6/17/91.

COEM - DES - 25, Rev. 2; "Facility CADD System," 6/17/91.

COEM - DES - 27, Rev. 3; "Operational Requirements Document," 6/17/91.

COEM - 6.1.5, Rev. 0; "Title I Design Summary/Review," 4/30/92.

COEM - 6.3.6, Rev. 0; "Classification of Systems Components and Parts," 7/30/93.

COEM - 6.4, Rev. 0; "Design Calculations," 3/31/92.

COEM - 6.6.2, Rev. 0; "Engineering Drawing Control," 1/31/92.

DOE/EH - 0256T, Radiological Control Manual, 6/92.

DOE Order 4010.1A; "Value Engineering," 5/14/92.

DOE Order 4700.1, Change 001; "Project Management System," 6/2/92.

DOE Order 5400.1, Change 001; "General Environmental Protection Program," 6/29/90.

DOE Order 5400.3; "Hazardous and Radioactive Mixed Waste Program," 2/22/89.

DOE Order 5400.4; "Comprehensive Environmental Response, Compensation, and Liability Act Requirements," 10/6/89.

DOE Order 5400.5, Change 002; "Radiation Protection of the Public and the Environment," 2/8/90.

DOE Order 5480.4, Change 004; "Environmental Protection Safety and Health Protection Standards," 1/7/93.

DOE Order 5480.11, Change 003; "Radiation Protection for Occupational Workers," 6/17/92.

DOE Order 5700.6C; "Quality Assurance," 8/21/91.

DOE Order 5700.2D; "Cost Estimating, Analysis, and Standardization," 6/12/92.

DOE Order 5820.2A; "Radioactive Waste Management," 9/26/88.

DOE Order 6430.1A; Change 001 "General Design Criteria," 4/6/89.

DOE, Rocky Flats Plant, *Draft Integration of NEPA, CERCLA and RCRA for Activities Under the Interagency Agreement at Rocky Flats Plant,* June 1992.

DOE, *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards,* UCRL-15910, June 1990.

EG&G Rocky Flats, Inc., Annual Report: *Sitewide Treatability Studies,* March 1992.

EG&G Rocky Flats, Inc., *Background Geochemical Characterization Report,* September 1992.

EG&G Rocky Flats, Inc., *Design Criteria for Engineering and Architectural Services.*

EG&G Rocky Flats, Inc., *Draft Environmental Evaluation Working Document for Phase I RFI/RI Work Plan, OU4*, January 1993.

EG&G Rocky Flats, Inc., Environmental Restoration Technical Support Document: *A NEPA Support Document for the Rocky Flats Plant,* June 1992.

EG&G Rocky Flats, Inc., *Final Phase I RFI/RI Work Plan for OU4, Solar Evaporation Ponds,* Vol. I and II, January 1992.

EG&G Rocky Flats, Inc., *Historical Release Report for the Rocky Flats Plant,* June 1992.

EG&G Rocky Flats, Inc., *Proposed Interim Measure/Interim Remedial Action Decision Document for the Solar Evaporation Ponds Operable Unit No. 4.*,April 1992.

EG&G Rocky Flats, Inc., *Technical Memorandum No 1 to Final Phase I RFI/RI Work Plan, Vadose Zone Investigation, OU4,* December 1992.

EPA, *Data Quality Objectives for Remedial Response Activities, Development Process,* EPA/540/G-87/003, March 1987.

EPA, *Data Quality Objectives for Remedial Response Activities, Example Scenario,* March 1987.

EPA, *Ecological Assessments of Hazardous Waste Sites: A Field and Laboratory Reference,* EPA/600/3-89/013, March 1989.

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

EPA, *Guidance for Data Usability in Risk Assessment,* October 1990.

EPA, *Guideline for Conducting Remedial Investigations and Feasibility Studies Under CERCLA,* EPA/540/2-058, December 1989.

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

EPA, *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual, Interim Final,* EPA/540/1-89-001, March 1989.

EPA, *Technical Guidance Document; Final Covers on Hazardous Waste Landfills and Surface Impoundments,* EPA/530-FW-89-047, July 1989.

Facilities & Engineering Manual 009; *Architect-Engineer's Guide to Construction Cost Estimating for Rocky Flats Plant,* July 1992.

Federal Facility Agreement and Consent Order, USEPA Region VIII and The State of Colorado in the Matter of US DOE Rocky Flats (Colorado) Site, January 1991.

National Electric Code 1993, NFPA 70.

State of Colorado Department of Health, *Draft Interim Final Policy and Guidance on Risk Assessment for Corrective Action at RCRA Facilities*, October 25, 1993.

State of Colorado Hazardous Waste Regulations, 6CCR1007-6, Part 265.

Uniform Building Code, 1988.

IV.2.4 Constraints and Limitations

Closure/remediation of the OU4 SEPs will be designed and implemented within the following constraints and limitations.

IV.2.4.1 Other RFP facilities are located in the vicinity of the SEPs and cannot be impacted by the engineered cover system. These facilities include:

- Building 910 south of SEP 207-B South,
- Holding tanks south of SEP 207-A,
- Cooling towers south of SEP 207-C,
- Storage Shed 964 east of SEP 207-B Center.

IV.2.4.2 The OU4 SEP closure will not adversely impact ongoing or planned activities in other operable units.

IV.2.4.3 Use of some areas for construction-related activities may be constrained by the presence of the protected area (PA) security systems.

IV.2.4.4 The vadose zone is defined as the unsaturated region from the ground surface to the mean of the seasonal high water table elevations.

IV.2.5 Design Basis Assumptions

Closure/remediation of the OU4 SEPs is based on the following assumptions.

IV.2.5.1 The SEP liners are considered hazardous waste by the Colorado Department of Health (CDH).

IV.2.5.2 The SEP 207-B Series liners must be elevated at a minimum to the level of the base of the 207-A liner to prevent contact of the SEP 207-B Series liners with the mean seasonal high ground water elevation.

IV.2.5.3 The SEP facility waste liquids, sludges, and residues will be removed prior to the commencement of the closure/remediation project.

IV.2.5.4 Building 788 (RCRA Unit No. 48) will be removed as required by the SEP facility closure activity. The removal of this building will be conducted as a separate project.

IV.2.5.5 Equipment associated with draining the SEPs and producing pondcrete will be removed prior to closure/remediation activities. This activity will be addressed through a separate project.

IV.2.5.6 The CDH will adopt the federally promulgated CAMU concept which will allow the consolidation of contaminated media beneath the engineered cover.

IV.2.5.7 Field- or bench-scale testing will not be required to demonstrate that the SEP facility cover system will meet the Colorado hazardous waste regulations.

IV.2.5.8 Contamination under SEP 207-C may be identified at greater depths than in the other SEPs because the original SEPs were constructed in this area. All of the contaminated media beneath SEP 207-C will be excavated and consolidated beneath the final engineered cover. Any uncharacterized soils will be consolidated above the subsurface drainage layer. Characterized soils that are determined to be protective of human health and the environment may be used as backfill material to raise the elevation of the vadose zone within the western two-thirds of the 207-B Series SEPs.

IV.2.5.9 The SEP facility closure is classified as System Category 3 NSC in accordance with COEM 6.3.6.

IV.2.5.10 Adequate stabilization of the hillside north and east of the SEPs can be accomplished by compaction and regrading of the surface soils. Following an analysis of slope stability, it may be determined that ground water controls are required for slope stabilization.

IV.2.5.11 The SEP facility design basis wind speed is 109 miles per hour.

IV.2.5.12 The SEP facility is located within Seismic Zone 1. A Peak Ground Acceleration (PGA) equivalent to 0.1 g will be used for slope stability modeling.

IV.2.5.13 The SEP facility design frost depth is 36 inches.

IV.2.5.14 The minimum culvert diameter is 15 inches.

IV.3 CONCEPTUAL DESIGN

This section provides an engineering description of the closure/remediation system proposed for the OU4 SEPs. The section is divided into two components. The first component addresses closure of the SEPs and soil remediation. The second component addresses closure or relocation of utilities in the vicinity of the SEPs. Appendix IV.B contains a set of conceptual design drawings.

IV.3.1 Site Layout and Engineered Cover

Drawing 51045-100 depicts an overall site layout of OU4. Drawing 51045-120 presents the topographic area/extent of the engineered covers. Drawing 51045-121 provides cross-section details of the engineered covers. Drawing 51045-130 presents the drainage plan for surface water runoff.

IV.3.1.1 Site Layout

Location of the Final Engineered Cover

A final engineered cover will be built over SEP 207-A and the western portion of the 207-B Series SEPs. This cover is described in Section III.2.2.1 and identified as Engineered Cover Alternative 6. An illustration of the engineered cover and backfilled area site layout is presented as Figure IV.3-1.

Site layout will be impacted by the consolidation of materials from several areas. The excavated soil and materials will be transferred to SEP 207-A and the western portion of the B-Series SEPs prior to the construction of the engineered cover. The liners in all the SEPs will be crushed in place to achieve material uniformity to ensure adequate compaction. These crushed liner materials will be placed above contaminated surface soil media from several locations as discussed below and will be used to form a specified grade for construction of the final engineered cover. The liner and soil material may require size-screening prior to placement beneath the engineered cover to ensure that the materials have the ability to be adequately compacted.

A subsurface drainage system will be constructed beneath the final engineered cover because there is a significant seasonal fluctuation in the water table elevation. Historical records from 1986 to 1993 indicate that a seasonally high water table has contacted the SEP 207-B Series liners. The records also indicate that the water table has risen above the liners in the 207-B Series SEPs. Given the historically high water table, an artificial vadose zone, in conjunction with a subsurface drainage system, was designed to decrease the possibility for ground water to contact the liners beneath the engineered cover. The subsurface drainage layer will prevent a future rising ground water table from contacting the consolidated liners.

To facilitate the construction of the subsurface drainage layer, SEP 207-A and the B-Series SEP liners will be excavated. Clean backfill will be placed in the eastern portion of the B-Series SEPs not under the final engineered cover. The thickness of this backfill will depend on the final site grade. An 8-foot artificial vadose zone consisting of contaminated soil media will be placed in the western two-thirds of the B-Series SEPs to raise the grade to that of SEP 207-A. This material will be beneath the final engineered cover. The subsurface drainage layer will be placed above the newly constructed vadose zone soils and above the SEP 207-A area at the same grade. This subsurface drainage layer will consist of a layer of gravel under a layer of sand. The crushed liners from SEP 207-A, SEP 207-C, and the 207-B Series SEPs will be excavated and placed above the contaminated soil media. These soil and liner layers will be placed above the subsurface drainage layers.

At the completion of construction, the entire region beneath the engineered cover will have a subsurface drainage system. The subsurface drainage system will connect with the ITS system via a subsurface drainage trench. The system will drain ground water away from the

consolidated liners if the water table rises in the future, thereby reducing the potential for ground water contamination due to contact with the consolidated liners.

Soils will be excavated from SEP 207-C and the berms between SEP 207-C and SEP 207-A. It is anticipated that this excavation will include an area totaling approximately 83,100 square feet and extend to a depth of approximately 7 feet below existing ground surface. Clean backfill will be used to fill SEP 207-C. This area will be graded to enhance the stability of the north slope and reduce erosion potential. This area is identified as Zone "A" in Figure IV.3-1.

Soils under the western side of SEP 207-A (including the berm) will be excavated and consolidated within the artificial vadose zone beneath the final engineered cover. The areal extent is approximately 46,900 square feet and the depth of excavation will range from 2 to 4 feet below the bases of the existing liners. This area is identified as Zone "B" on Figure IV.3-1.

Soils under the eastern one-third side of the 207-B Series SEPs (including the berm) will be excavated and consolidated within the artificial vadose zone beneath the engineered cover. The areal extent of this region is approximately 45,600 square feet and the depth of excavation will be 2 feet. The depth of excavation in this area is dictated primarily by the mean of the seasonal high water table elevations. This area is designated as Zone "C" on Figure IV.3-1.

Soils exceeding PRG concentrations will be excavated from the northern portion of SEP 207-A and SEP 207-B North. This area will be backfilled with clean soils and graded to reduce the potential problems associated with the hillside stability, to reduce erosion and to provide a proper base for the engineered cover. Clean backfill will be used to fill the northern portion of SEP 207-A and SEP 207-B North that will not be beneath the final engineered cover. The thickness of this backfilled area will depend on the overall final grade. This excavation will have an area of approximately 37,700 square feet and extend to a depth of approximately 2 to 4 feet below existing ground surface. This area is identified as Zone "D" on Figure IV.3-1.

Soil with COC concentrations exceeding PRGs will be excavated from the surface of the hillside north of the SEPs to the downhill seepline. It is anticipated that this excavation will include a vegetated area totaling approximately 121,600 square feet and will extend to a depth of approximately 6 inches below existing ground surface. This material will be consolidated with the liners above the subsurface drainage layer beneath the final engineered cover. This area is identified as Zone "E" on Figure IV.3-1.

OU4 surface soils with COC concentrations exceeding PRGs will be excavated north of the perimeter security fence (buffer zone). The vegetated excavation area will total approximately 290,600 square feet and extend to a depth of approximately 6 inches bgs. This material will be consolidated above the subsurface drain under the engineered cover or will be deposited in the deepest excavation of SEP 207-C since its COC concentrations are less than vadose zone PRGs. This area is identified as Zone "F" on Figure IV.3-1.

Soils from the southern end of the SEP 207-A and SEP 207-B South (including the berms) will be excavated and consolidated within the artificial vadose zone beneath the final engineered cover. The areal extent is approximately 63,000 square feet and the depth of excavation will be 3 feet. This area is identified as Zone "G" on Figure IV.3-1.

Table IV.3-1 presents the excavation depth, location of deposition, and approximate quantity of material for each remediation zone. The depth of excavation is based on Figure IV.3-2, which shows the location of the soil borings with COC concentrations that exceed vadose zone PRGs, and Figure IV. 3-3 which shows the vadose zone thickness based on the mean of the seasonal high water table elevations. An average excavation depth of 7 feet was assumed for SEP 207-C (Zone A) because boring data do not yet exist and this depth reflects an average of the seasonal ground water elevations. Contaminants are not expected to migrate deeper than 7 feet based on the boring data from the other SEPs.

Location of Backfilled Area

Backfilled areas will be constructed over SEP 207-C (Zone A), the western edge of SEP 207-A (Zone B), the hillside north of the SEPs to the downhill seepline and north of the security fence (buffer zone) (Zone F), northern portions of SEPs 207-A and 207-B (Zone D), the eastern one-third of the 207-B Series SEPs (Zone C) and the southern portions of SEPs 207-A and 207-B (Zone G). The chosen cover design is described in Section III.2.2.1 and identified as Alternative 1. A drawing of the reclaimed areas and the final engineered cover site layout is presented as Figure IV.3-1.

Rationale for Site Layout

Several benefits exist for the excavation and transfer of materials from SEP 207-C, the hillside north of the SEPs to the downhill seepline, north of the site security fence and the northern portions of SEPs 207-B North and 207-A the western edge of SEP 207-A, and the eastern one-third of the B-Series SEPs as described in the "location of the final engineered cover" section above.

The excavation and transfer of materials allow consolidation of the waste materials existing in the SEPs location. Consolidation of waste materials balances the wastes and reduces the contaminant area, thereby reducing construction and materials costs and operation and maintenance requirements. The area reduction also facilitates a decrease in control and monitoring requirements.

The mean of the seasonally high ground water table that exists under the 207-B Series SEPs has precluded the option of leaving liners, berms, and contaminated soils in that location. Raising the 207-B Series SEPs to an elevation consistent with SEP 207-A reduces the potential of ground water contacting the waste zone. A subsurface drainage layer will be installed as an additional preventive measure. This system will be installed at the same level as the 207-A SEP liner with clean fill below and contaminated material above the drainage layer. This system will

Table IV.3-1

ZONES OF EXCAVATION			
Zone	**Average Depth of Excavation**	**Location of Deposition**	**Quantity**
Zone A	7 feet	Above subsurface drain	
Zone B	2-12 feet	Artificial vadose zone	
Zone C	2 feet	Artificial vadose zone	
Zone D	2-4 feet	Artificial vadose zone	
Zone E	6 inches	Above subsurface drain	
Zone F	6 inches	C Pond vadose zone	
Zone G	3 feet	Artificial vadose zone	
Zone H (IDM) 30yd^3		Artificial vadose zone	
Contingency along west side of A Pond	7 feet	Above subsurface drain	

prevent a future rise in the water table elevation from contacting the hazardous waste materials. This subsurface drain will consist of a layer of gravel under a layer of sand. The position of this system is depicted on Drawing 51045-121.

Control of the backfill materials, vegetation, gravel, mulch, grading, and slope will manage surface water and wind erosion, and promote runoff away from the engineered cover. Construction of the engineered covers away from the crest of the north hillside and backfilling and regrading the hillside materials will reduce the potential for slope instability.

IV.3.1.2 Closure System Details

The chosen design for the final engineered cover was generated from research underway at the DOE's Hanford Site in eastern Washington State and the Los Alamos National Laboratory in Los Alamos, New Mexico. This research provides engineering cover design criteria for semi-arid to subhumid climates as at the RFP. The design uses natural earthen materials with proven long-term durability. The materials chosen for the engineered cover design are best suited to protect human health and the environment for a period of 1,000 years.

The goals of the engineered cover include the isolation of consolidated wastes from transport pathways by controlling water infiltration, plant and animal intrusion, and wind and water erosion. The final engineered cover has the ability to provide long-term passive performance. The engineered cover system will also provide an aesthetically pleasing appearance. The design criteria meet state and federal regulations as presented in Section III.5.2.

The goals of the backfilled areas identified as Zones A,B,C,D,E,F, and G on Figure IV.3-1 and the perimeter runoff swales, include removing contaminated materials from the areas and creating a final grade with a consistent slope for positive drainage and erosion control. The backfilled areas will be designed to direct runoff away from the engineered cover.

Final Engineered Cover

The engineered cover will be constructed of several layers placed above the contaminated material to form an abovegrade mound. The layers will be constructed of different materials, each with its own function. All the materials used in the engineered cover design can be obtained locally. The layers used to construct the final engineered cover include the following:

- Vegetation,
- Pea Gravel,
- Topsoil,
- General backfill,
- Sand,
- Gravel,
- Angular riprap,
- Sand,

- Asphalt,
- Asphaltic concrete, and
- Gravel base course.

Figure IV.3-4 illustrates the cross-section of the proposed engineered cover. Drawing 51045-122 provides a drawing of the cross-section specifying the thickness of each layer.

The layers of the engineered cover have been chosen based on the DOE Hanford Site research performed by Dr. Hakonson at Los Alamos National Laboratory.

The first soil layer will be composed of a topsoil/gravel mixture. This layer will control erosion, facilitate evaporation, and support vegetation. Characteristics examined to determine the most effective transpiration rate include plant size, soil type, availability of water, rooting characteristics, and atmospheric factors.

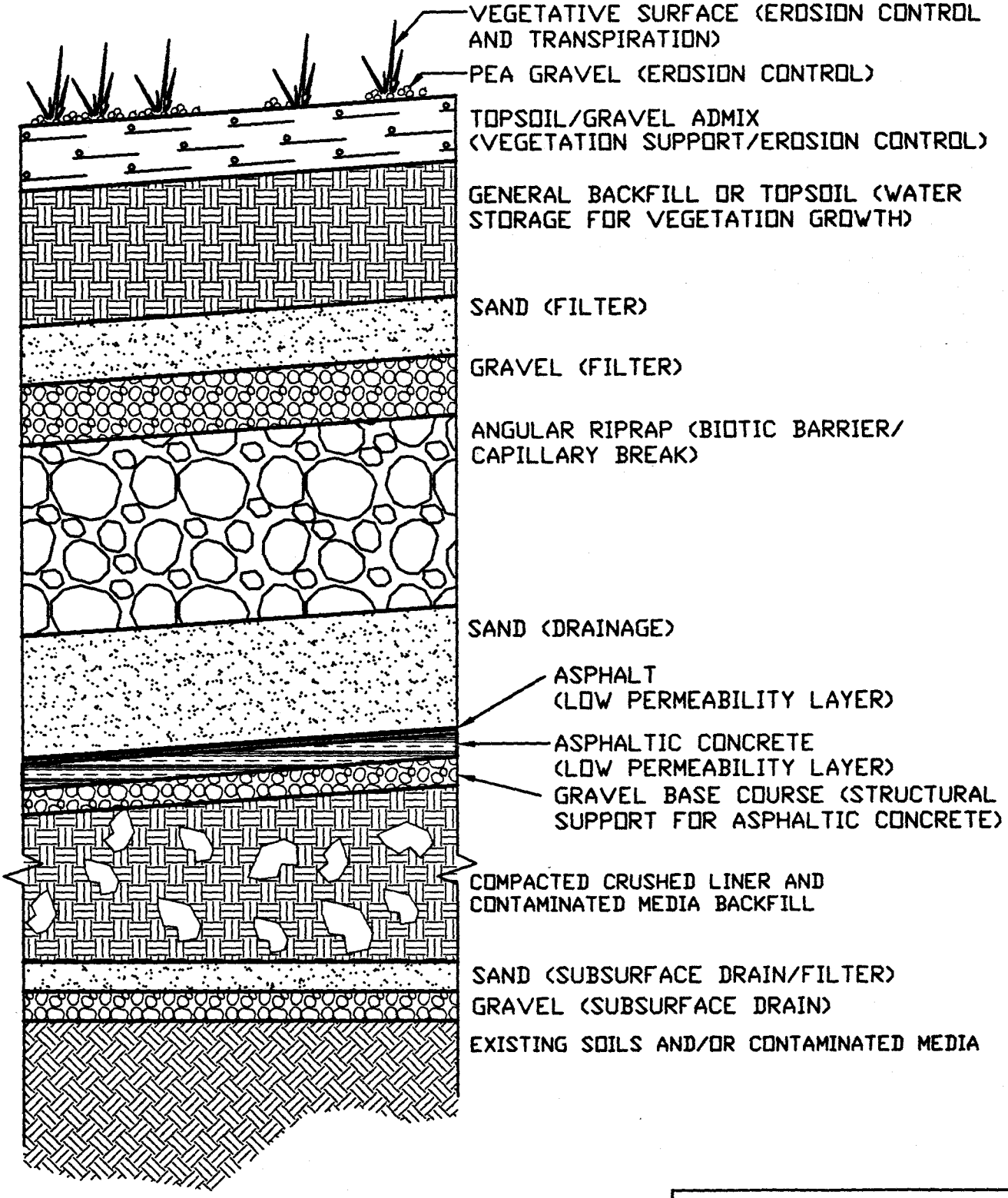
The incorporation of gravel into the surface of the topsoil is intended to mimic conditions that led to the formation of desert pavements that have remained stable for thousands of years. (Waugh, 1990). Pea gravel has a higher surface area-to-volume ratio than larger gravel or cobble and thus may provide greater soil protection with less impact on soil hydraulic properties.

The use of pea gravel to prevent wind erosion has been researched for the Hanford Site engineered cover (Ligotke, et al, 1990). Results of these studies indicated that the addition of 0.28 to 0.67 centimeter gravels as admixtures to the silt-loam soil at the Hanford Site provided 54 to 32 times less surface deflation respectively, than soil only. Inclusion of the fine-grained gravels reduced erosion rates to 2.3 - 1.5 percent of those rates occurring from unprotected soil-only surfaces. Wind tunnel tests have produced results indicating that the best gravel choice for protective barriers exposed to extreme eolian stresses, for either admixture or surface layers, would be a river or crushed gravel containing particles ranging in size from 0.2 to 0.95 centimeters.

The general backfill layer will function as a water storage layer to promote vegetative growth. Local soils (e.g., sandy loams) will be used as the layer material. This layer will not be compacted to allow for adequate root penetration.

The sand and gravel layers will act as filter media to prevent the overlying soils from migrating into the biotic barrier. Compaction of these layers will be required to fill voids, decrease shifting, and provide a stable base for overlying layers.

The angular riprap layer is composed of high quartzite-granite material. This material is locally available and is more durable than the basalt materials specified in the Hanford Site design. The riprap layer provides a biotic barrier to prevent burrowing animals from entering the contaminated media and opening a direct channel for precipitation to reach the waste zone. The layer will also restrict deep-rooted plants from extending to deeper zones by providing a capillary break. This capillary break concept has been researched for several years for the



NOTE:

1. THE DEPTH OF THE GENERAL BACKFILL WILL VARY WITH RESPECT TO THE DEPTH OF THE EXCAVATION AND DESIRED FINAL GRADE.

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Figure IV.3-4

OU4 IM/IRA
Final Engineered Cover

engineered cover design at the Hanford Site (Wing, 1993). Results of the tests have indicated that the capillary break has functioned as designed. Compaction of this layer may be required to fill voids, decrease shifting, and provide a stable base for overlying layers.

The lower sand layer beneath the riprap will promote lateral drainage of water that passes through the capillary zone. This layer will also act as a cushion to prevent the angular riprap from damaging the asphalt layers below. Compaction of this layer will be required to fill voids, decrease shifting, and provide a stable base for overlying layers.

An asphalt layer will act as a low permeability zone to mitigate the infiltration of any liquid that migrates through the upper layers. Rubberized asphalt exhibits dramatic elastic properties that allow the material to stretch up to 13 times its original length without rupturing or exhibiting significant plastic deformation . As early as 3000 B.C., asphalt was used as a water stop between the brick walls of a water reservoir. It was used by early humans as a paving material, wood preservative, sealant, adhesive, and mortar. Many artifacts dated 4,900 to 5,500 years old have been recovered in the Middle East in good condition, attesting to the long-term stability of asphalt under anaerobic conditions (Freeman, 1989).

The asphalt concrete layer will work in conjunction with the asphalt layer to minimize infiltration. Ultraviolet light and frost are known to decrease the integrity of asphalt concrete. Therefore, this layer will be shielded from ultraviolet light and placed below the frost depth of 36 inches.

Asphalt materials have been tested by Pacific Northwest Laboratory (PNL) as a cover system at a uranium mill tailings site in Grand Junction, Colorado. Results of these tests have indicated that asphalt has an extremely low permeability to both radon and water and penetration by plants and animals (Freeman, 1989).

The Hanford research team organized lysimeter tests to measure the efficiency of asphalt materials (Freeman, 1989). In fiscal year 1989, these studies indicated that the asphalt barriers did not leak during the first 12 months of lysimeter monitoring. The 20- and 22-weight percentage specimens of cationic asphalt emulsion from the Akzo Chemicals America resulted in a hydraulic conductivity of 3×10^{-7} centimeters per second (cm/s), well above the target of 1×10^{-9} cm/s. Research and testing have been performed on ancient asphalts in the La Brea' Tar Pits and naturally occurring asphaltic pavements. This research has revealed that asphalt is a natural material with long-term durability. The Hanford research team has determined that the asphalt layers can achieve a permeability of 1.0×10^{-11} centimeters per second.

The gravel base layer will act as a structured base to increase stability of overlying asphalt layers. Compaction to decrease voids, decrease shifting, and provide a stable base for overlying layers will be required for this layer.

Compacted backfill will include crushed liners from all SEPs and the materials excavated from the hillside north of the SEPs to the downhill seepline, north of the perimeter security

fence (buffer zone), northern portions of SEPs 207-B North and 207-A, the eastern portion of the B-Series SEPs, the western edge of SEP 207-A and 207-B, the western portion of 207-A, and soils from SEPs 207-C. Compaction is critical for the backfill material to provide stability and reduce settlement.

A gravel and sand filter layer will be placed beneath the soils and consolidated liners. These layers will provide adequate drainage of ground water away from the consolidated liners if the water table elevation rises above the historical high elevation.

Barrier Overhang

The full thickness of the engineered cover surface will extend approximately 10 feet beyond the perimeter of the waste zone in each direction. The barrier overhang will prevent the lateral flow of water from the toe of the cover from migrating back to the waste zone. Drawing 51045-123 includes a detail of the toe of the engineered cover.

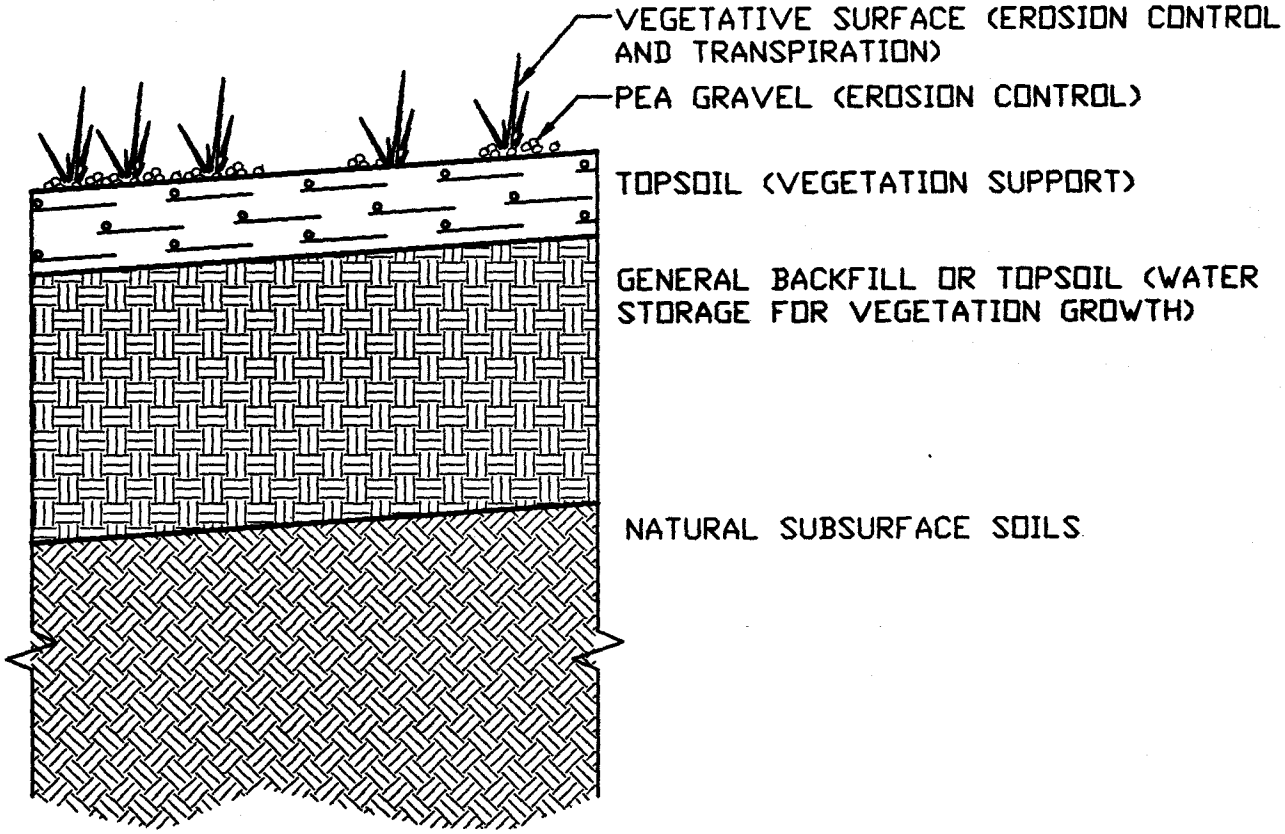
A wedge of clean backfill will be placed between the compacted backfill contaminated media and the engineered cover. The clean fill wedge will be 10 feet thick at the toe and taper to tie in to the crest of the transition slopes (tops sides) of the underlying backfill.

Backfilled Areas

The backfilled areas will be composed of several layers placed in the excavated areas to form a consistent slope. The excavated areas include SEP 207-C (Zone A), the hillside north of the SEPs to the downhill seepline (Zone E), north of the perimeter security fence (buffer zone) (Zone F), a western portion of SEP 207-A (Zone B), a northern portion of SEP 207-A and SEP 207-B North (Zone D), the eastern portion of the 207-B Series SEPs (Zone C) and the southern portion of SEPs 207-A and 207-B (Zone G). The backfilled areas will reduce human and animal contact and provide consistent drainage pathways to minimize damage from erosion. The layers will be constructed of several materials, each with its own function. Local soil backfill, topsoil, pea gravel and vegetation will be included in the backfill area design. All of the materials used in the backfill area design can be obtained locally and are consistent with the materials imported for the engineered cover. Contaminated materials from the backfill areas will have been removed and transferred to the SEPs. After excavation of the contaminated media and the use of clean backfill material in these areas, they will be considered protective of human health and the environment. Figure IV.3-5 and Drawing 51045-122 illustrate the cross-section of the proposed backfilled areas.

The surface layer will be composed of topsoil and pea gravel at thicknesses required to establish an appropriate grade. This layer will control erosion and support vegetation. To encourage root growth, this layer will not be compacted.

The general backfill layer will store water for vegetative growth. The soils will be composed of clean backfill hauled in from offsite.



NOTE:

1. THE DEPTH OF THE GENERAL BACKFILL WILL VARY WITH RESPECT TO THE DEPTH OF THE EXCAVATION AND DESIRED FINAL GRADE.

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Figure IV.3-5

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Backfill Cover

IV.3.1.3 Engineered Cover Performance Modeling

The primary purpose of an engineered cover is to minimize infiltration of precipitation and to limit percolation of water through contaminated soils and liner materials. In determining the most effective engineered cover design, calculation of the amount of infiltration percolating through the engineered cover system is necessary to select the most viable cover components. Infiltration is also important in predicting the potential for contaminant leaching and migration through the underlying vadose zone soils. The Hydrologic Evaluation of Landfill Performance (HELP), computer model Version 2.05, was chosen to estimate the amount of infiltration and percolation that would percolate through the final engineered cover design. The predicted infiltration rate was then used to evaluate the effectiveness of the engineered cover design and in providing input for the VLEACH Model to predict the potential for contaminants to leach from the underlying vadose zone soils (Section 10.4). The HELP model will also be used throughout the detailed design process to optimize the engineered cover design.

HELP is a quasi-two-dimensional computer code that models landfill performance with respect to the hydrologic cycle. Figure IV.3-6 presents a conceptual model of the hydrologic input and output data. The model accepts climatologic, soil characteristics, and design data, and utilizes a solution technique that accounts for the daily effects of surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage. Landfill systems including various combinations of vegetation, cover soils, waste cells, special drainage layers and relatively impermeable barrier soils, as well as synthetic membrane covers and liners may be modelled (Schroeder, et al. 1988). HELP does not account for capillary flow in the variably saturated cover components and as a consequence provides a conservative estimate of percolation through the engineered cover (Nichols, 1991).

Two engineered cover scenarios were modelled with HELP. The first is the proposed engineered cover design alternative which is shown in Figure IV.3-4. The second engineered cover is the selected cover design but without the asphalt barrier system. This second engineered cover is shown in Figure III.3-4. This second cover was modelled for comparison purposes to demonstrate the necessity of the asphalt barrier layer.

The two engineered cover designs were modelled using five different scenarios:

1) normal climatological and vegetation data,
2) double annual yearly precipitation,
3) triple annual yearly precipitation,
4) normal precipitation with no vegetation, and
5) projected future climate changes.

Normal climatological and vegetation data were modeled to establish a baseline for comparison. The normal, average, annual precipitation was doubled and tripled to evaluate the cover performance under extreme precipitation conditions. There is a possibility that fire, drought, or disease could destroy the vegetated cover layer. Therefore, the model was run

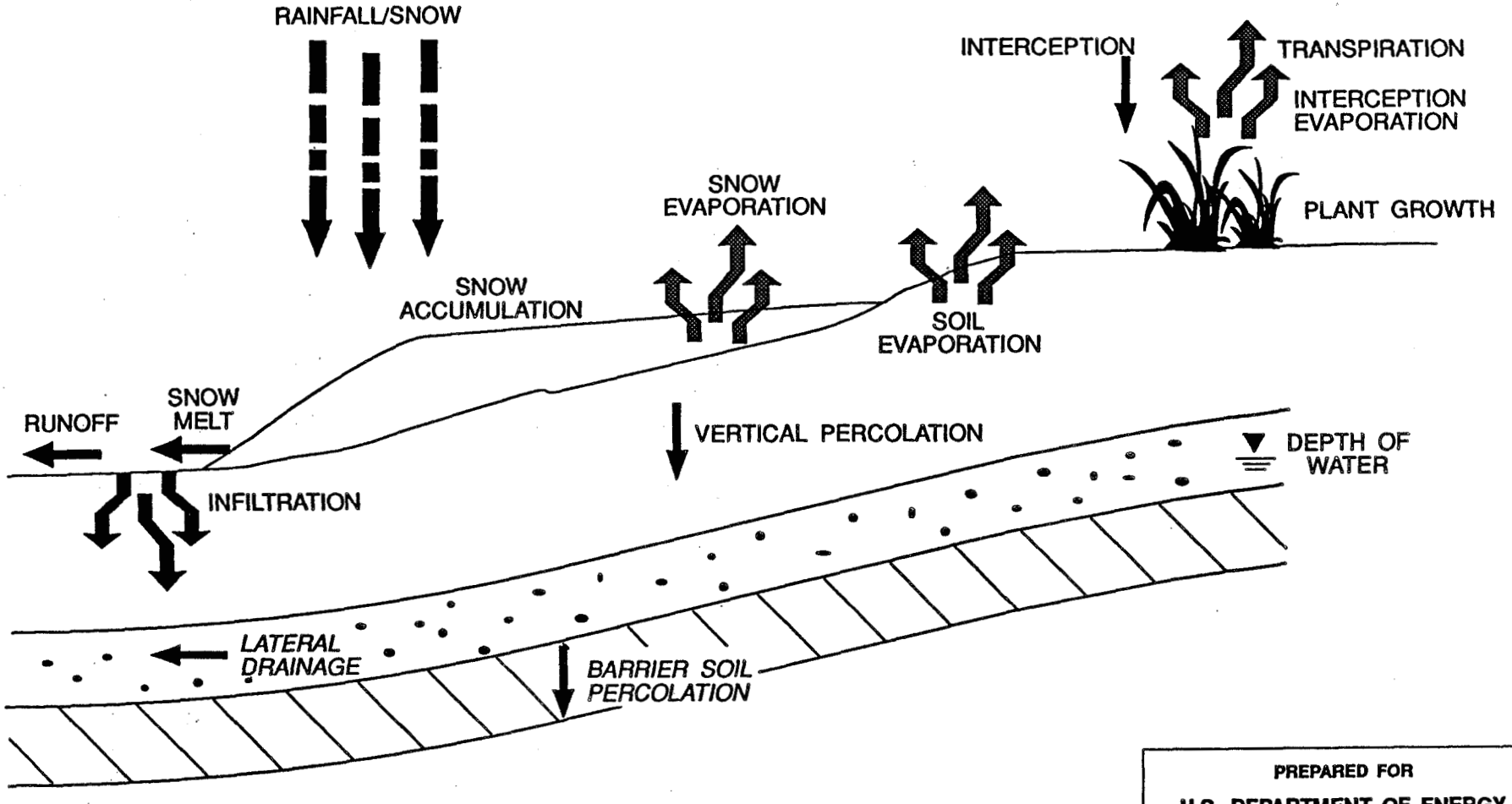

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Figure IV.3-6

OU4 IM/IRA
Simulation Processes in the HELP Model

DE30722b-IM/IRA-EA

without vegetation to determine the affect that vegetation had on cover performance. Lastly, the model was run with parameters to reflect projected climate changes such as an increase in precipitation and temperature, and a reduction in solar radiation due to an increase in "greenhouse" gasses.

IV.3.1.3.1 Soil Input

<u>Soil Input Options</u>

HELP allows the user to enter soil characteristics to a layer by either the default option or the manual option. Table IV.3.1 shows the characteristics for the 18 default soil types and the soil texture classification assigned using the United Soil Classification System (USCS) available in HELP.

Under the default option, the user selects soil textures for each layer. HELP calculates the initial soil water concentrations for each layer and the Soil Conservation Service (SCS) runoff curve number for the top layer. The manual input option allows the user to enter values for porosity, wilting point, field capacity, initial soil water content, and saturated hydraulic conductivity. These properties are defined below.

<u>Porosity</u> - the soil water content at saturation.

<u>Field Capacity</u> - the soil water content after a prolonged period of gravity drainage.

<u>Wilting Point</u> - the lowest soil water content that can be achieved by plant transpiration.

<u>Hydraulic Conductivity</u> - the rate at which water drains vertically through a saturated soil with no pressure gradient.

<u>Soil Water Content</u> - the ratio of the volume of water in soil to the total soil volume.

<u>SCS Runoff-Curve Number</u> - the concept of runoff-curve numbers was developed by the SCS to permit estimation of the relative amount of surface water runoff that would result from a rainfall event. Runoff curve numbers are a function of soil permeability, the antecedent moisture condition and the amount of rainfall intercepted by vegetation or structures (ASI, 1991). Runoff curve numbers can theoretically range from zero (an infinite retention and infiltration capacity) to 100 (no retention and infiltration capacity). Typical values range from 40 or 50 percent for well-drained soils, up to 98 percent for developed areas (pavement etc.) (ASI, 1991). Curve numbers have been developed for each soil type for various land characteristics and land-use designations at RFP by ASI (1991).

Table IV.3-1 HELP Default Soil Characteristics

Soil Texture Class		Total Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)
HELP	USCS				
1	GS	0.417	0.045	0.018	1.0E-02
2	SW	0.437	0.062	0.024	5.8E-03
3	SM	0.457	0.083	0.033	3.1E-03
4	SM	0.437	0.105	0.047	1.7E-03
5	SM	0.457	0.131	0.058	1.0E-02
6	SM	0.453	0.190	0.085	7.2E-04
7	SM	0.473	0.222	0.104	5.2E-04
8	ML	0.463	0.232	0.116	3.7E-04
9	ML	0.501	0.284	0.135	1.9E-04
10	SC	0.398	0.244	0.136	1.2E-04
11	CL	0.464	0.310	0.187	6.4E-05
12	CL	0.471	0.342	0.210	4.2E-05
13	CH	0.430	0.321	0.221	3.3E-05
14	CH	0.479	0.371	0.251	2.5E-05
15	CH	0.475	0.378	0.265	1.7E-05
16	Barrier Soil	0.430	0.366	0.280	1.0E-07
17	Barrier Soil	0.400	0.356	0.290	1.0E-08
18	Municipal Waste	0.520	0.294	0.140	2.0E-04
19	User-defined soil characteristics				
20	User-defined soil characteristics				

Site Specific Soil Characteristics

The input soil data for the specific layers of the engineered covers are summarized below in the following paragraphs and in Table IV.3-2.

Topsoil and Backfill

It was assumed that local soils could be procured for the topsoil and backfill. Soil properties for the topsoil/gravel admix and backfill were estimated from soil tests performed on OU4 soils by Daniel B. Stephens & Associates, Inc (1993). It was assumed that the soil properties of the topsoil and backfill layers were the same. The topsoil and backfill layers were not compacted to allow for vegetative growth.

Sand, Gravel and Riprap

HELP default soil data were used for the porosity, wilting point, and field capacity for the sand and gravel layers. Hydraulic conductivity values for sand and gravel were obtained from Freeze and Cherry (1979). User-defined data was used to model the riprap layer to account for the low porosity and high saturated hydraulic conductivity of the riprap material. The sand, gravel, and riprap layers were not modeled as compacted layers.

Asphalt Barrier

The asphalt barrier was modelled as two separate layers. The top layer consists of approximately 1" of asphalt coating. This layer was modeled as a barrier layer. Research performed at Hanford indicates a saturated hydraulic conductivity of 6×10^{-11} cm/s for liquid asphalt (Freeman and Gee, 1988). This value was used as input for the HELP model. HELP does not use porosity, wilting point, and field capacity for barrier layers. However, information on these parameters, must be included to run the model. Data was not available for these parameters so HELP default values for a compacted clay layer were used.

The bottom layer is an asphaltic concrete layer approximately 6" thick. Hanford research has determined hydraulic conductivities of 3×10^{-7} to 7.2×10^{-7} cm/s for asphalt concrete mixtures of 20 to 22 wt.% and 24 wt.% asphalt content respectively (Freeman and Gee, 1988 and 1989). A hydraulic conductivity value of 7.2×10^{-7} cm/s was used as input. This layer was modelled as a vertical percolation layer because HELP will not allow a barrier layer directly below another barrier layer. Actual data were used for saturated hydraulic conductivity when the soil properties were available. HELP default barrier data, representing a clay barrier layer were used in the absence of material specific data.

Initial Soil Water Content

HELP was initially run for 20 years to establish an equilibrium for the initial soil water content. Subsequent HELP simulations were run using these initial soil moisture content values.

Table IV.3-2 Input Values for Soil and Barrier Characteristics

Layer	Thickness (inches)	Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Initial Soil Water Content (vol/vol)	Saturated Hydraulic Conduct. (cm/sec)
Gravel[(1),(3)]	2	0.4178	0.0454	0.0200	0.0958	1×10^{-1}
Topsoil/Gravel Admix[(2)]	18	0.3705	0.3458	0.2649	0.2708	1.5×10^{-4}
Backfill[(2)]	30	0.3705	0.3458	0.2649	0.2708	1.5×10^{-4}
Sand[(1),(3)]	12	0.4370	0.0629	0.0245	0.1295	1×10^{-2}
Gravel[(1),(3)]	12	0.4178	0.0454	0.0200	0.0958	1×10^{-1}
Riprap[(5)]	24	0.3000	0.0400	0.0200	0.0622	10
Sand[(1),(3)]	12	0.4370	0.0624	0.0245	0.1295	1×10^{-2}
Liquid Asphalt[(1),(4)]	1	0.4000	0.3560	0.2900	0.4000	6×10^{-11}
Asphaltic Concrete[(1),(4)]	6	0.4300	0.3660	0.2800	0.3887	7.2×10^{-7}
Gravel[(1),(3)]	6	0.4178	0.0454	0.0200	0.0297	1×10^{-1}
Contaminated Backfill	6	0.3705	0.3458	0.2649	0.2708	1.5×10^{-4}

(1) Soil and barrier data from HELP default soil data.
(2) Soil data from Daniel B. Stephens and Associates (1993).
(3) Hydraulic Conductivity of sand and gravel taken from Freeze and Cherry (1979).
(4) Hydraulic Conductivity for barriers taken from Freeman and Gee (1988 and 1989).
(5) Riprap data defined by user.

SCS Runoff-curve Number

The HELP model was set to calculate the SCS runoff-curve number.

IV.3.1.3.2 Cover Design Input Data

An illustration of the layout and area of the proposed OU4 engineered covers is shown in Figure IV.1-1. Input parameters for the engineered cover, surface area, slope, and lateral drainage distance are shown below.

Engineered cover surface area = 338,100 ft^2

Slope of top layer*

Top of cover	=	5%
Edge of cover	=	5:1

* An overall 5% slope was used as a conservative measure.

Maximum lateral drainage distance along slope (feet) = 310 ft

IV.3.1.3.3 Climate-Related Input Parameters

Climate data used as input into HELP are divided into two categories;

- normal conditions, and
- predicted climate change conditions.

The differences are discussed below. Default climatologic data is available for Denver, Colorado. However, where possible, site-specific data for Rocky Flats were used.

Climatic change may occur as a result of emissions from human activities in the past century and may also result from natural activities such as volcanism. Potential emissions released by these processes may increase the atmospheric concentrations of "greenhouse" gases: carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide (IPCC, 1992). Due to the increase in "greenhouse" gases some researchers predict an increase in average atmospheric temperature, precipitation and cloud cover (IPCC, 1990 and IPCC, 1992). Changes in these parameters will impact the local climatic conditions potentially resulting in increased precipitation, decreased evapotranspiration, and increased infiltration. Cloud cover absorbs and reflects solar radiation, thus reducing the amount of solar radiation received at the earths surface. As a consequence, reducing the evaporative demand at the surface (Waugh, 1989).

Temperature

Temperature data from Rocky Flats Plant Site Environmental Report for 1992 was used as temperature input for "normal climate conditions" and are shown in Table IV.3-3.

As mentioned above temperature is may increase during potential climatic change due to an increase in "greenhouse" gasses. Two different models predict an increase in average annual temperature in North America by 3.6°F (2°C) over the next 75-100 years or as the present concentration of carbon dioxide doubles (IPCC, 1990). In order to simulate temperature changes for the HELP model, normal mean RFP temperature was adjusted by adding 3.6° F. The adjusted normal mean monthly temperatures at Rocky Flats Plant (°F) are shown below in Table IV.3-3.

Table IV.3-3 Monthly Temperatures at Rocky Flats Plant (°F)*

	Normal (Mean) Monthly Temperatures	Adjusted Normal (Mean) Monthly Temperatures
January	31.0	34.6
February	33.0	36.6
March	37.0	40.6
April	45.5	49.1
May	55.5	59.1
June	64.5	68.1
July	71.5	75.1
August	70.5	74.1
September	61.5	65.1
October	52.5	56.1
November	40.0	43.6
December	33.5	37.1

* Data taken from EG&G (1992).

Precipitation Input

Three options are available to generate climatologic data: a default precipitation option, a manual precipitation option and a synthetic precipitation option. For the purpose of this

performance assessment the synthetic precipitation option was used with precipitation data for RFP.

Under the synthetic precipitation option the user has the option of entering normal mean monthly precipitation values to adjust for specific locations. The first column in Table IV.3-4 shows the normal (mean) monthly precipitation values for Rocky Flats. The second column shows the average, monthly precipitation values used as input for the HELP model to adjust the data for Rocky Flats. The third column shows the average, monthly, precipitation values generated by HELP. By entering the user-defined precipitation values, HELP can generate precipitation values that replicate the exact averages for Rocky Flats precipitation.

TABLE IV.3-4 Precipitation Data

	Normal (mean) Monthly Precipitation at Rocky Flats Plant (inches)*	Average Monthly Precipitation Input into HELP Model (inches)	Average (20 year) Monthly Precipitation Output of HELP Model (inches)
January	0.46	0.51	0.46
February	0.48	0.53	0.48
March	1.22	1.26	1.22
April	1.73	2.40	1.73
May	2.74	3.18	2.75
June	1.85	1.55	1.85
July	1.49	1.38	1.49
August	1.52	1.67	1.52
September	1.49	1.50	1.49
October	0.92	1.08	0.92
November	0.79	0.62	0.79
December	0.64	0.64	0.64
Total Annual Precipitation	15.33	16.32	15.34

* Data taken from EG&G (1992).

The precipitation data was doubled (total annual precipitation of 30.65) and tripled (total

annual precipitation of 46.03) to compare the amount of infiltration under extreme precipitation conditions.

Precipitation is may increase during potential climatic change. Several models predict an increase in average annual precipitation by as much as 15% in the Northern Hemisphere due to potential climatic change over the next 75 to 100 years or when the current carbon dioxide level doubles (IPCC, 1990). To simulate potential precipitation increases an annual precipitation of 30.65 inches was used, double the current annual precipitation.

Growing Season

Rocky Flats is located at an elevation of approximately 6000 feet above mean sea level. The average growing season in this area is 126 to 142 days feet (SCS, 1980). The growing season used for this model was assumed to be 135 days and is shown below in the Julian Date model input format. Although the length of the growing season will probably change during climatic change, no realistic estimate of the change is available so 135 days was used for the climatic change scenario.

Start of growing season (Julian Date)	=	139
End of growing season (Julian Date)	=	274*

Evapotranspiration

Evapotranspiration is the most significant factor affecting infiltration through the engineered cover. HELP overestimates the amount of evapotranspiration in arid and semi-arid environments. To counter overestimation of evapotranspiration, conservative values were used for the parameters that affect evapotranspiration the most in the HELP model: evaporative zone depth, and maximum leaf area index (vegetative cover).

Evaporative Zone Depth

Evaporative zone depth is the maximum depth from which water may be removed by evapotranspiration. Where vegetation is present the evaporative depth should at least equal the expected average depth of root penetration. The actual evaporative zone depth is slightly greater than this due to capillary action (Schroeder, 1988). An increase in evaporative zone depth produces an increase in evapotranspiration and generally a decrease in lateral drainage and percolation (EPA, 1991). Loamy or clayey soils in the Rocky Flats area with slopes less than 3:1, have an effective root depth of up to 60 inches (SCS, 1980). The main plant species on these soils consist of tall-prairie grasses: western wheatgrass, blue gramma, green needlegrass, and little bluestem (SCS, 1993). HELP designates a value of 28 inches as a typical root depth value for a fair stand of grass in Denver, Colorado. For the purpose of this evaluation a conservative evaporative zone depth value of 18 and 14 inches was used to simulate poor vegetation and no vegetation, respectively.

Evapotranspiration would likely decrease under the projected climate changes due to a decrease in solar radiation from increased cloud cover. To simulate this effect the evaporative zone depth was decreased to a value of 12 inches.

Maximum Leaf Area Index

Maximum leaf area index is the dimensionless ratio of the leaf area of actively transpiring vegetation to the nominal surface area of the land on which the vegetation is growing.

Typical values used in the HELP model (Schroeder, 1988) are:

0.0 for bare grass,
1.0 for poor grass,
2.0 for fair grass,
3.3 for good grass, and
5.0 for excellent grass.

As the leaf area index increases, the amount of evapotranspiration increases. Given the precipitation values and the length of the growing season, the maximum leaf area index for Denver, Colorado is 2.5, without irrigation. A value of 2.0 is a typical value for a fair stand of grass. A value of 1.0 was used as the maximum leaf area index for the poor grass scenario. A value of 0.0 was used for no vegetation. These are conservative estimates considering the maximum leaf area index value for Denver is about 2.5.

A wetter climate would increase the abundance and diversity of plants capable of growing in the RFP area. Under the increased precipitation conditions a maximum leaf area index of 2.5 was selected. This value is equivalent to the estimated leaf area index for Denver under present-day climatic conditions and therefore is conservative for simulating potential climatic change.

Latitude

The latitude used for solar radiation data generation for normal conditions is 39.77° North, the latitude of Denver, Colorado. Solar radiation is expected to decrease as a result of increased "greenhouse" gasses. The latitude used for solar radiation data generation was increased to reflect this change. A latitude of 46.00° North(an increase of approximately 15%) was used instead of 39.77° North.

A summary of the climate input parameters used in HELP are shown below in Table IV.3-5.

Table IV.3-5 Summary of Climate Input Parameters

	Normal Conditions		Climate Change Conditions
	Vegetation	No Vegetation	
Evaporative Zone Depth	18 inches	14 inches	12 inches
Maximum Leaf Area Index	1.0	0.0	2.5
Latitude	39.77° North	39.77° North	46.00° North

IV.3.1.3.4 Results of the HELP Model

The HELP model results are shown in Table IV.3-6 and graphically in Figure IV.3-7. These results show that inclusion of the capillary break, drainage layer, and asphalt barrier in the engineered cover significantly decreases the amount of percolation through the engineered cover. Even when the precipitation is doubled and tripled the asphalt barrier minimizes the amount of percolation through the engineered cover compared to the cover with the asphalt barrier.

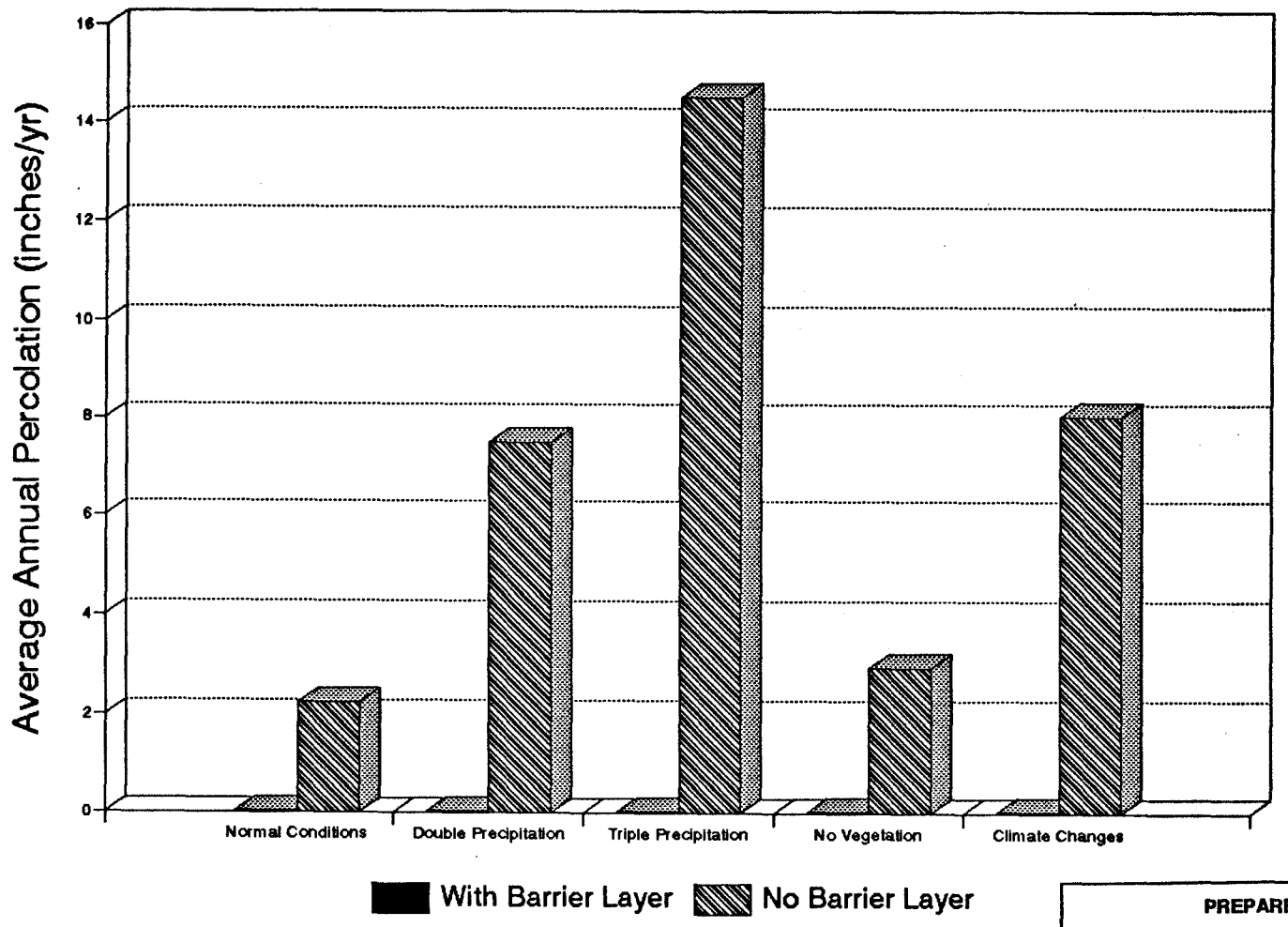
In general, vegetation decreases surface runoff and increases evapotranspiration but tends to have little effect on the overall water balance (EPA, 1991). The results of the model runs support this finding. As the results indicate, vegetation does not appear to significantly affect percolation in either engineered cover design. However, percolation through the engineered cover without the asphalt liner is approximately three orders of magnitude greater. The asphalt liner promotes lateral drainage because it is essentially impermeable. These findings suggest that if an asphalt barrier system is not used, then maintenance of the vegetative cover will be required over the duration of the engineered cover life.

The results of the HELP model indicate that the engineered cover design with an asphalt barrier will significantly reduce the amount of infiltration that percolates through the engineered cover. The modeling results demonstrate that the proposed final engineered cover will be effective at minimizing the amount of precipitation that infiltrates into the consolidated contaminated materials. These results were used in the VLEACH model (Section 10.4) to assess whether the expected quantity of infiltration will result in a quantity of leachate that will be protective of human health and the environment.

Table IV.3-6 HELP Model Results

	Percolation through 1000-year cover (with asphalt layer) (inches/year) and (ft^3/year)	Percolation through 1000-year cover (without asphalt layer) (inches/year) and (ft^3/year)
Normal Conditions	0.0008 21	2.2346 62,960
Double Annual Precipitation	0.0015 42	7.4744 210,590
Triple Annual Precipitation	0.021 59	14.5046 408,666
No Vegetation/ Normal Precipitation	0.0008 23	2.9377 82,769
Climate Changes	0.0014 39	8.0144 225,806

Note: Volumetric infiltration rate (ft^3/yr) is dependent on the engineered cover area.



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GOLDEN, COLORADO

Figure IV.3-7

OU4 IM/IRA
Percolation Through Engineered Covers

rf85x11h

IV.3.2 Utilities Dispositioning

There are numerous utility lines throughout the OU4 area. Some of the utilities will be needed in service after closure of the SEPs. If these utilities will be impacted by the SEP closure/remediation, they will be relocated. Utilities that will be impacted by the engineered cover that can be removed from service will be removed or closed in place. Figure IV.3-8 provides a flow diagram that will be used to assess the removal or rerouting of all the utilities in the vicinity of the OU4 SEPs. Drawing 51045-430 identifies and locates the utilities in the vicinity of the SEPs. The following sections address how the utilities will be removed, rerouted, or closed in place.

IV.3.2.1 Utilities Requiring Removal or Rerouting

There are several utilities that will remain in operation after closure of the OU4 SEPs. Domestic cold water, raw water, storm drains, and telephone and electrical power will remain in service in and around the OU4 area, and will require relocation. The following steps will be required to accomplish removal and rerouting:

- Excavation of the buried utilities from the connection to the plantwide system to the farthest service point will be required. Health and safety personnel will be present during excavation to provide radiological screening. All excavated materials will be laid in piles parallel to the excavation trench. Excavation procedures will be specified in the project-specific health and safety plan.

- Backfill materials from the existing trench will be removed along with the other excavated materials for consolidation under the engineered cover.

- If COC concentrations in excavated material (i.e., outside the engineered cover) are above PRGs, then excavation will continue until the soil concentrations are less than the vadose zone PRGs. Contaminated soils will be contained and removed from the excavation area and dispositioned as contaminated media for consolidation beneath the engineered cover.

- Removal of each utility from the excavated area will require that appropriate methods be used for the specific conditions. The type of material will dictate which dismantling method(s) are used. Removal of existing utilities that require relocation would accomplish the following:

  - No residual contaminants,
  - Require no provisions in cover design, and
  - Provide complete clean-site remediation of utilities materials.

The following is a list of the construction material of the specific utilities and the appropriate dismantling procedure for each.

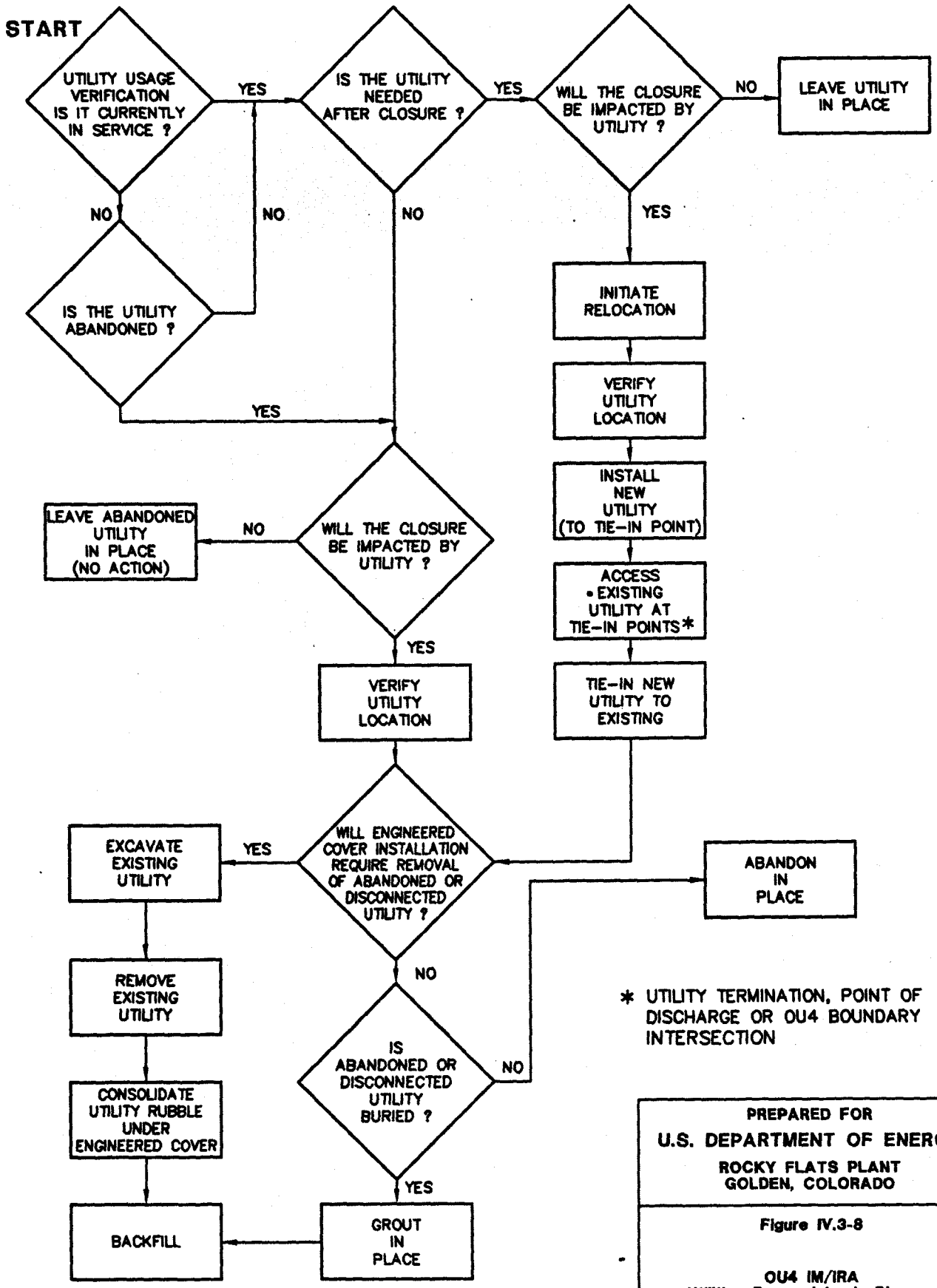

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Figure IV.3-8

OU4 IM/IRA
Utilities Removal Logic Diagram

Cement Asbestos Pipe

Cement asbestos pipe (CAP) is best removed in sections by dismantling at the bell and spigot joints. Where this type of dismantling is not practical, wet-saw cutting would be the best approach. Saw-cutting CAP will require that asbestos abatement procedures be used to contain the airborne materials resulting from removal of the CAP from the trench. Workers will also have to follow the appropriate health and safety procedures for asbestos abatement.

Vitrified Clay Pipe

As with CAP, vitrified clay pipe (VCP) is best removed in complete sections by dismantling at the bell and spigot joints. However, in some cases, this may prove impractical. One example would be if the excavated VCP is damaged. In this case, the pieces should be removed. Large pieces can be broken into manageable sizes for containerization or transport. The weight of VCP may require that rigging and overhead machinery be used to remove the pipe from the trenches.

Cast Iron, Steel, and Stainless Steel Piping

Cast iron (CI), steel (STL), and stainless steel (SS) piping could be dismantled by sawing or mechanical cutting. Where access is available, piping cutters can be used on pipe up to 4 inches in diameter (nominal). Those pipes that do not permit ample access for a pipe cutter or have diameters greater than 4 inches will require saw-cutting. The cutting area should be lined with plastic sheeting to collect the metal fines and prevent any mixing with the surrounding excavated materials.

Polyvinyl Chloride Pipe

Polyvinyl chloride (PVC) pipe will be saw-cut into manageable lengths as required. The sawing can be accomplished in the excavations as the piping is exposed. Plastic sheeting should be placed in the excavation to contain the saw cuttings.

Corrugated Metal Pipe

Corrugated metal pipe (CMP) will be removed by means of saw-cutting. However, care should be taken to determine the presence of sediments in the bottom of the CMP. An inspection hole should be cut in the top prior to the complete cutting of each section. A health and safety survey of any sedimentary materials will be made prior to exposure of those materials when the pipe is opened. Since dismantling at the original joints of the CMP could be difficult, the sections should be cut to manageable lengths for handling and containerization. A tarpaulin should be placed in the excavation to contain saw cuttings.

VI.3.2.2 Utilities Suitable for Closure In-Place

In-place closure will leave the piping in the OU4 area intact. The only isolation technique available would be permanent closure of existing valves that feed the pipe lines below the cover. Existing valves will be permanently disabled by removing the handles and welding the shafts in the closed position. Access to these valves may also be eliminated by filling the open valve box with grout. The engineered cover may then be installed above the grouted valve box or disabled valves and piping.

Capping the piping at the OU4 boundaries would effectively isolate all of the piping within the OU4 boundary from the rest of the RFP operations. Each pipe closed in-place would be excavated at the OU4 boundary and the point of termination in the OU4 area. The exposed pipe would be cut and a section removed to allow for installation of a permanent pipe cap. The pipe caps would be made of the same material as the pipe being capped. All pipe caps would be permanently installed for each piping material type as follows:

- STL and SS - Butt-welded or socket-welded pipe cap fittings,
- CI - Material-transition to PVC and install a solvent-glued and back-welded PVC pipe cap or a fabricated flat-end plate welded in place,
- PVC - Solvent-glued and back-welded pipe cap,
- VCP - Bell and spigot - VCP fitting with end plugs installed and grouted in place or transition to PVC with a solvent-glued and back-welded pipe cap, and
- CMP - Fabricated end-plate welded in place or transition to fiberglass and installation of fiberglass reinforced plastic (FRP) end cap with catalyzed resin and woven fiberglass wrapping.

Grouting the piping at the OU4 boundaries and the points of termination is an alternative method to capping. An inert nonshrinking Portland cement-based grout would be used. Each end of the pipe section to be grouted would be excavated and exposed. A standpipe would be installed at each end for filling. The grout could then be pumped into the pipe from one of the exposed ends until flow was seen rising in the opposite standpipe. Grout spill control/containment should be provided for grout that may have contacted hazardous materials in the piping. The standpipes would then be cut to below grade and the excavations at both ends filled with grout to encapsulate the standpipes and provide a barrier at each end of the pipe. Drawing 51045-431 provides a detail for the grouting design. Grouting underground utilities is desirable for because it would:

- Completely isolate the utility and backfilled trenches,
- Provide long-term structural integrity without appreciable degradation, and
- Prevent any future exposure or tampering.

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IV.3.3 Power Modification Request and Power Usage Survey

A power modification request (PMR) will be required to identify both the electrical services which will be disconnected and no longer needed and those services requiring relocation for continued service or new service requirements associated with the closure/remedy. Prior to processing the PMR, a power usage survey will be conducted. This survey will be performed as a component of the utility location verification work plan discussed in Section IV.5.2. The PMR will include provisions for electrical requirements associated with post-closure monitoring systems. However, this conceptual design does not include details of the post-closure monitoring systems.

IV.4 WASTE MANAGEMENT PLAN

The implementation of the OU4 IM/IRA will follow the DOE mandate to minimize the generation of new wastes. Waste generation will be minimized by the consolidation of soil and rubble/debris beneath the final engineered cover. The CAMU concept provided in 40 CFR 264.552 and 40 CFR 264.553, along with the debris rule, provides the regulatory framework by which waste generation will be minimized. Figure IV.4-1 presents a waste management flow diagram that specifies the wastes that will be generated and those that will not be consolidated beneath the engineered cover. The primary wastes that will require additional handling or treatment for disposal include:

- Cement asbestos piping waste,
- Removed electrical equipment and wire,
- Personal protective equipment,
- Building 788 ancillary equipment (potential),
- Vegetation (potential), and
- Decontamination wastes.

Figure IV.4-1 also identifies potential methods for managing the generated wastes. Offsite disposal will be minimized. The following subsections describe how each waste stream will be dispositioned.

IV.4.1 Excavated Soil

Soil will be generated from the areas within OU4 that are being remediated as part of the OU4 IM/IRA and from the removal/relocation of buried utilities. Section IV.3.1 presents the plan for disposition of soils that are being remediated. Soils that are generated during the removal or relocation of buried utilities both within and outside of OU4 will be dispositioned based on the location of the excavation and the type/level of contamination.

Soils excavated from within the area of the final engineered cover will be consolidated beneath the final engineered cover. Contaminated soils excavated in areas of OU4 will be consolidated beneath the engineered cover and clean soil will be used as backfill with the

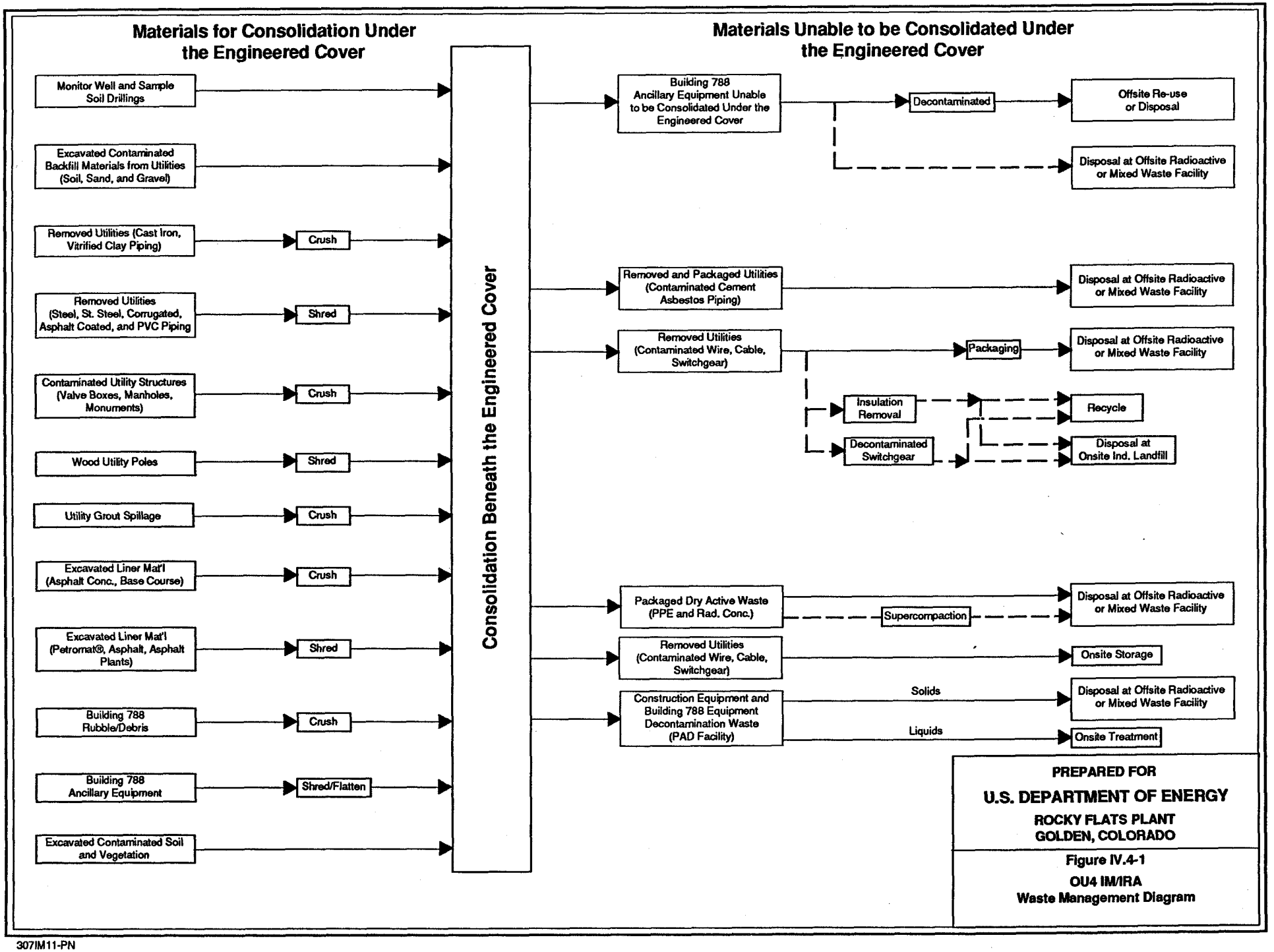

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Figure IV.4-1

OU4 IM/IRA
Waste Management Diagram

307IM11-PN

excavation. Soils excavated in areas of OU4 that do not require remediation, based on the OU4 RFI/RI results, will be returned to the excavation as backfill. Uncontaminated excess soil that cannot be used as backfill in the utility excavation will be used as backfill to create the artificial vadose zone beneath the B-Series SEPs.

Excess soil generated during utilities work in other OUs will be consolidated under the OU4 final engineered cover if possible. Contaminated soil from another OU may be dispositioned back into the excavation. Returning excavated soil to the excavation will reduce the amount of clean backfill that is brought onsite and mixed with potentially contaminated soils that may require future remediation. Excess soils that cannot be returned to the excavation may be dispositioned by their OU-of-origin according to the current RFP waste management procedures. Alternatively, the excess soils from another OU may be consolidated within the OU4 CAMU beneath the final engineered cover. Disposition of these soils beneath the OU4 engineered cover would depend on historical process knowledge indicating that the contaminants are the same as those in OU4, or waste characterization results indicating that the contaminants within the excess soil are at concentrations that would be protective of human health and the environment if they were consolidated beneath the final engineered cover. Section IV.10.4 provides a methodology for making the determination that contaminated soils consolidated beneath the final engineered cover will be protective of human health and the environment.

Investigation-derived material from the OU4 RFI/RI program will be consolidated beneath the engineered cover. The empty 30-gallon drums will be returned to the waste management program for potential re-use. The drums may be decontaminated prior to being returned (if necessary).

IV.4.2 Debris

Debris will be generated during implementation of the OU4 IM/IRA. The debris materials will include:

- Utilities piping,
- Electrical cable/switchgear,
- Grout spillage,
- Concrete foundations/foots, and
- Equipment associated with Building 788.

Figure IV.4-2 presents a detailed flow diagram for the disposition of the various types of materials that were used for utilities piping. It should be noted that the wooden utility poles will be chipped and disposed of in a thin layer above the subsurface drainage layer.

Cement-asbestos material was used at the RFP for piping wastewater. This material will not be consolidated beneath the final engineered cover. Excavated cement-asbestos pipe will be packaged and disposed of in accordance with asbestos disposal regulations.

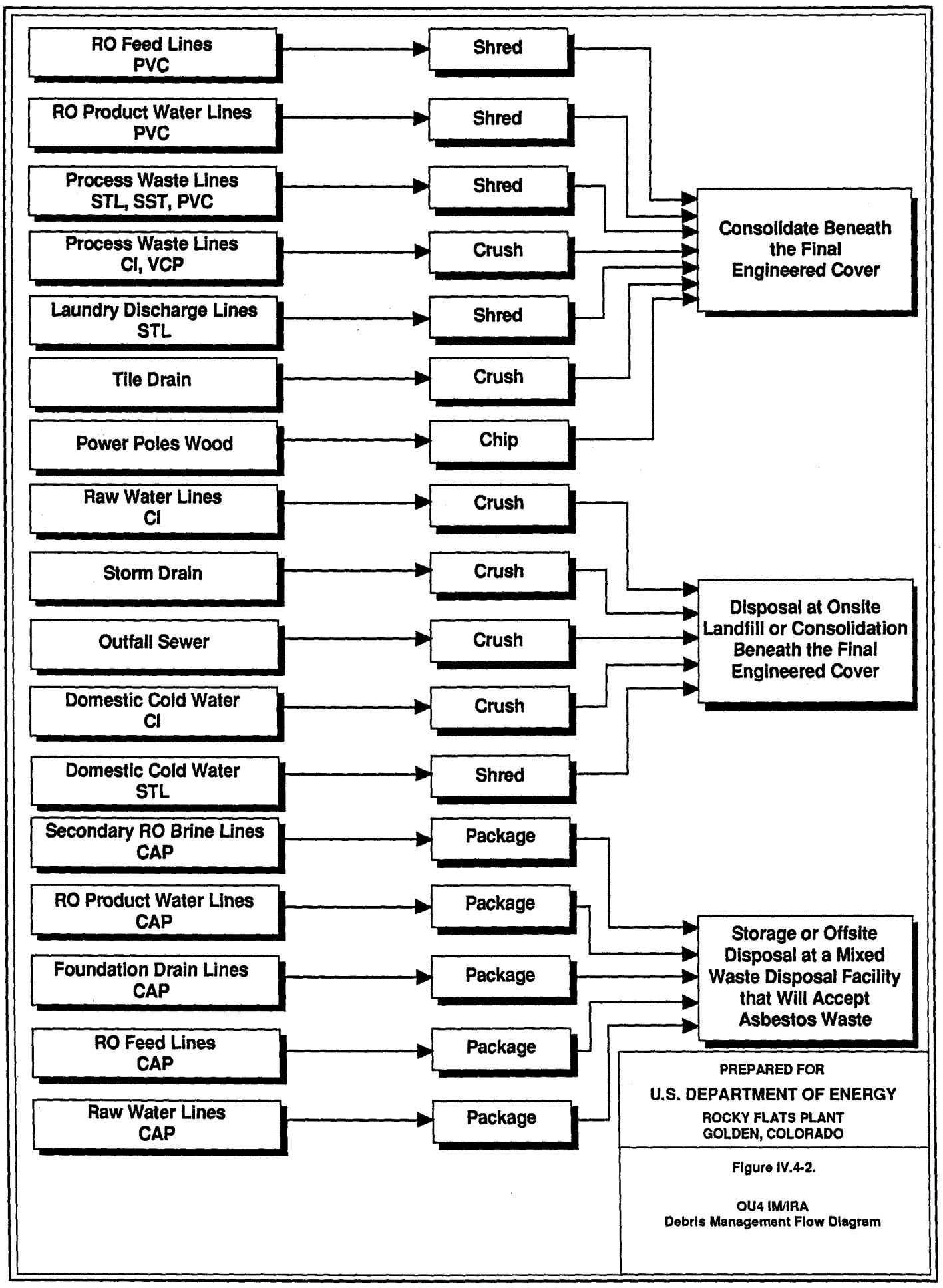

Figure IV.4-2.

OU4 IM/IRA
Debris Management Flow Diagram

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Electrical cable and switchgear will be packaged in standard waste crates for onsite storage, recycling, or disposal. If this material is contaminated, then it may require disposal at an offsite low-level radioactive or mixed-waste disposal facility.

Concrete debris from the vicinity of the SEPs will be crushed and consolidated above the subsurface drainage layer. Any grout spilled during utility abandonment will also be crushed and consolidated beneath the engineered cover.

Equipment associated with Building 788 may be crushed, flattened, or shredded and spread in a thin layer above the consolidated liners, provided that the material will not cause subsidence problems with respect to the final engineered cover.

IV.4.3 Vegetation

Vegetation growing within the project areas consists primarily of grasses and weeds. There are no trees or shrubs in these areas. The vegetation will be mixed with the excavated soils and dispositioned with the soil materials. It is important to note that the excavation of these areas will be performed in the winter when the vegetation has died back so that the organic material volume will be minimized.

IV.4.4 Decontamination Wastes

Wastewaters will be generated from decontaminating equipment and machinery and will be collected for onsite treatment at a wastewater treatment facility. Solid decontamination wastes will be packaged for storage/disposal according to current site procedures.

IV.4.5 Personal Protective Equipment

Personal protective equipment wastes will be generated during construction activities. These wastes will be disposed of according to the standard RFP practices and procedures.

IV.5 REQUIRED SPECIFICATIONS

This section identifies the construction specifications that will be prepared during the title design phase of the project. A construction specification will be prepared for each of the applicable major section numbers from the Construction Specification Institute's (CSI) specification program. The Division I specification provides the general project requirements, and the Division 2-16 specifications present detailed project requirements per specific applicable discipline. A typical outline for the Division 1 specification is as follows:

DIVISION 1
GENERAL REQUIREMENTS

1.0 SUMMARY OF WORK

1.1 Work Included in this Subcontract

1.1.1 General
1.1.2 Description of Work Elements
1.1.3 Definitions

1.2 Related Work to be Performed by Others
1.3 Work Sequence and Scheduling

1.4 Occupancy and Use of Premises

1.4.1 Joint Occupancy
1.4.2 Access and Support Services
1) Personnel Access
2) Material and Equipment Access
3) Office Space and Utilities

1.5 Meetings and Reporting

1.5.1 Weekly Status Meetings
1.5.2 Daily Activity Plans
1.5.3 Weekly Schedule Updates

2.0 SUBMITTALS

3.0 HEALTH AND SAFETY REQUIREMENTS

4.0 QUALITY

4.1 INSPECTION

4.1.1 Receipt Inspection
4.1.2 Verification of Construction
4.1.3 Nonconforming Items
4.1.4 Inspection Records

4.2 TESTING

4.2.1 Testing Requirements

4.2.2 Nonconforming Items
4.2.3 Test Records

4.3 PROCEDURES AND QUALIFICATIONS

4.4 INSPECTION AND TEST EQUIPMENT

5.0 TEMPORARY FACILITIES

6.0 SPECIAL CONTROLS

6.1 MATERIAL TRANSPORTATION

6.2 ENVIRONMENTAL PROTECTIONS

6.3 WASTE MANAGEMENT

7.0 PROJECT COMPLETION

7.1 PROJECT RECORDS

7.2 FINAL ACCEPTANCE

A typical outline for the Division 2-16 specifications is as follows:

TYPICAL DIVISIONS 2 THRU 16

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included
1.1.2 Related Work Specified Elsewhere
1.1.3 Work to be Performed by Others

1.2 REFERENCE DOCUMENTS

1.3 SUBMITTALS

PART 2 PRODUCTS

2.1 MATERIAL REQUIREMENTS

2.2 PRODUCT DELIVERY, STORAGE, AND HANDLING

PART 3 EXECUTION

3.1. PERFORMANCE REQUIREMENTS

3.2 INSPECTION REQUIREMENTS

3.3 TESTING REQUIREMENTS

IV.5.1 Engineered Cover Specifications

The construction specifications associated with the final engineered cover will address each layer of the engineered cover system as well as the general site improvements. At a minimum, the following specifications have been identified for the construction activities. It should be noted that all the layers of the engineered cover will be addressed under Specification Section 02200 entitled "Earthwork." Additional specifications may be required as further definition of the design is obtained.

DIVISION 1 - GENERAL REQUIREMENTS

1010	-	Summary of Work
1027	-	Application and Measurement for Payment
1030	-	Geotechnical Data
1040	-	Project Coordination
1045	-	Cutting and Patching
1095	-	Reference Standards and Definitions
1200	-	Project Meetings
1300	-	Submittals
1370	-	Schedule of Values
1380	-	Construction Photographs
1400	-	Quality Control Services
1500	-	Temporary Facilities
1600	-	Materials and Equipment
1700	-	Contract Closeout
1720	-	Project Records Documents
1730	-	Operating and Maintenance Data

CSI Section No.	**Title**
	Division 2 - Civil
02020	Land Use and Subsurface Conditions
02102	Clearing and Regrading
02140	Diversion and Control of Water During Construction
02200	Earthwork
02272	Permanent Diversion Ditches and Swales
02950	Reclamation Seeding, Mulching, and Reutilizing

IV.5.2 Utilities Specifications

Construction specifications will be provided for grouting and abandonment of piping systems formerly used for transferring aqueous solutions between the SEPs and Building 910. Also included with these types of piping systems are those which were used to transfer SEP water between the ponds to allow for routine maintenance of the SEPs.

Specifications will also be provided for the installation and/or the rerouting of required electrical services. At a minimum, the following specifications have been identified for the construction activity. Additional specifications may be required as further definition for the design is obtained.

CSI Section No.	Title
	Division 15 - Mechanical
15060	Piping and Appurtenances
15099	Process Valves, Regulators, and Miscellaneous Components
15180	Pipe Insulation
	Division 16 - Electrical
16010	Electrical
16050	Basic Materials and Methods
16401	Overhead Electrical Service Systems
16402	Underground Electrical Service

IV.6 IMPLEMENTATION PLAN AND PROPOSED SCHEDULE

This section provides work plans for conducting engineering implementation studies that will be performed during the title design phase of the project. The results of these studies will be used to finalize the design. This section also provides a preliminary construction schedule.

IV.6.1 Geotechnical Investigation

The stability of the hillside north of the proposed location of the engineered covers will be investigated due to recent field observations and results of previous studies (Woodward-Clyde, 1970; CTL/Thompson, 1979). Results of field investigations show the presence of ground water seepage, surface soil sloughing, and potential bedrock slump blocks in the north hillside. Because of the critical nature of the subgrade stability with respect to the stability of the engineered cover, a geotechnical investigation is required to collect data on slope stability and settlement. Previous investigations have collected analytical and physical data on the soils and bedrock in the area of the SEPs, but data specific to slope stability and settlement analyses are lacking.

The purpose of this work plan is to provide a field sampling plan (FSP) and a geotechnical testing plan outlining field and laboratory activities. The plan is designed to generate data required for analysis of the stability of the hillside north of the SEPs and for an estimate of settlement below the proposed engineered cover. Site conditions relevant to slope stability and settlement are summarized in Section IV.6.1.1. A discussion of the specific objectives of the geotechnical investigation is presented in Section IV.6.1.2. The FSP, which includes subsections on sampling rationale, borehole drilling and sampling, sample handling, standard operating procedures (SOPs), and air monitoring surveillance activities, is presented in Section IV.6.1.3. The geotechnical testing program, outlining laboratory testing of soil and bedrock samples, is presented in Section IV.6.1.4.

IV.6.1.1 Site Conditions

The study area is located immediately north of the SEPs and south of North Walnut Creek, as shown on Figure IV.6-1. The perimeter plant road and security fence lines run east to west on a bench in the hillside. The remaining hillside is vacant and covered with vegetation. As shown on Figure IV.6-1, the SEPs sit on top of the hill which slopes downward to the north, having a maximum elevation change of approximately 70 feet. Bedrock on the site consists primarily of firm-to-hard claystone. A sandstone unit subcrops on the north side of SEP 207-C (see Figure IV.6-2). Borehole logs from the area show a zone of fractured or weathered bedrock varying in thickness from 5 to 40 feet. The bedrock is overlain by clayey gravels and sands of the Rocky Flats Alluvium varying in thickness from approximately 3.5 to 10 feet.

Relatively high ground water elevations are assumed to cause surface seepage on the hillside just below the SEPs. The upper boundary of known seepage is shown on Figure IV.6-1.

Previous studies (Woodward-Clyde, 1970) indicate that the bedrock dips to the north about 3 degrees and strikes generally east-west. There are small slumps of various ages along the breakpoint between the pediment on which the SEPs are located and the hillside down to North Walnut Creek. The RI/RFI program for OU4 has delineated potential bedrock slump blocks, on the hillside below the SEPs. These potential slump blocks and sloughing apparent on the hillside surface give an indication of the type of slope failure that may be expected if no stability control measures are implemented.

IV.6.1.2 Objectives

The primary objective of the geotechnical investigation is to obtain information required for slope stability analysis of the hillside north of the SEPs. In addition, data are required for an evaluation of potential settlement below the proposed cover system.

The stability analysis requires determination of shear strength and density characteristics of the soil and bedrock and also requires information regarding locations of fracture zones, slickensides, and other potential failure surfaces. Other information (e.g., ground water elevations) needed for the analysis is available from previous studies. Sample collection and

geotechnical testing will allow for analysis of the stability of the hillside for the proposed cover configuration and provide information needed for evaluation of slope stabilization remedies.

The settlement analysis requires determination of consolidation characteristics of the soil and fill below the proposed cover. Physical properties of the materials such as moisture content, density, and specific gravity also need to be determined for the analysis.

IV.6.1.3 Field Sampling Plan

The FSP describes field activities associated with the generation of data required for slope stability and settlement analyses. This section is divided into subsections addressing sampling rationale, borehole drilling and sampling, sample handling, SOPs, and air monitoring surveillance activities.

Sampling Rationale

Surficial soils and bedrock will be sampled to allow for geotechnical testing and determination of parameters required for slope stability analysis. Boreholes will be drilled in suspected slide areas, as determined by surface topography and bedrock surface maps from the RFI/RI program. Samples will be collected of the Rocky Flats Alluvium and from assumed failure zones in the bedrock. Efforts will be made to collect relatively undisturbed samples for shear-strength testing. The first borehole drilled will be advanced deep enough into competent bedrock to be reasonably sure that the deepest potential failure zone has been encountered.

Samples will also be collected from the soils and fill below Pond 207-A for use in determination of consolidation characteristics. These samples will be taken from an area that will undergo loading due to the proposed engineered cover.

Borehole Drilling and Sampling

Boreholes will be drilled at the five locations shown on Figure IV.6-1. Three of the boreholes are located in suspected hillside slump areas and one is located in the Arapahoe Sandstone Formation. The fifth borehole is located in SEP 207-A, where the proposed engineered cover is to be installed. These locations may be adjusted as new information from the RFI/RI program is evaluated. Engineering judgement will be used in the field for siting exact locations prior to drilling.

The first boring drilled (GB-3) will be advanced a minimum of 50 feet into competent bedrock to investigate potential deep failure zones. The other boreholes in the hillside will be advanced a minimum of 6 feet into competent bedrock. The drilling depths of all the hillside boreholes will be determined based on preliminary slope stability modeling and engineering judgement in the field. The borehole drilled into SEP 207-A will be advanced to below the interface of the alluvial materials with the fractured bedrock.

Soil samples from below Pond 207-A and from the boreholes on the hillside will be collected using a hollow-stem auger method for drilling and sampling, as presented in SOP GT.2. Standard penetration test (SPT) values will be noted during sampling.

Bedrock drilling will be performed using a continuous-coring technique to allow for visual inspection and detailed logging. Attention will be given to determination of fracture orientation and rock quality designation index (RQD) values. The rotary drilling and rock coring methods to be used are described in SOP GT.4. Special care will be taken to collect relatively undisturbed samples from potential failure zones, as indicated by fractures, slickensides, and material changes.

Samples for geotechnical testing will be chosen in the field by qualified personnel who are familiar with sample requirements for triaxial testing and the other methods presented in Section IV.6.1.4. For the triaxial and direct shear testing, efforts will be made to obtain failure zone samples.

Sample Handling

Due to the fragile nature of soil and fractured rock samples, special care must be taken to ensure minimal disturbance during transport of samples to the geotechnical laboratory. Once chosen for testing, samples will be immediately wrapped in plastic and coated with wax to minimize loss of moisture. Samples will be wrapped in styrofoam or other materials and placed in secure containers for transport to the laboratory. Sample transport and geotechnical testing will be completed as soon as possible after drilling and sampling.

Prior to shipping offsite, all samples will be screened for radioactivity. The geotechnical testing laboratory will be informed of the radioactivity screening plan and other potential contaminants before initiation of the testing program.

Standard Operating Procedures

SOPs to be used during the field sampling activities are included in the RFI/RI Work Plan for OU4. The following SOPs are relevant to the geotechnical investigation:

FO.1	Windblown Contaminant Dispersion Control
FO.2	Field Document Control
FO.3	General Equipment Decontamination
FO.4	Heavy Equipment Decontamination
FO.6	Handling of Personal Protective Equipment
FO.7	Handling of Decontamination Water and Wash Water
FO.8	Handling of Drilling Fluids and Cuttings
FO.9	Handling of Residual Samples
FO.10	Receiving, Labeling, and Handling of Waste Containers
FO.11	Field Communications

FO.12	Decontamination Facility Operations	
FO.13	Containerizing, Preserving, Handling, and Shipping Soil and Water Samples	
FO.14	Field Data Management	
FO.15	Use of Photoionization and Flame Ionization Detectors	
FO.16	Field Radiological Measurements	
FO.18	Environmental Sample Radioactivity Content Screening	
GT.1	Logging Alluvial and Bedrock Material	
GT.2	Drilling and Sampling Using Hollow-Stem Auger Techniques	
GT.4	Rotary Drilling and Rock Coring	
GT.10	Borehole Clearing	

<u>Air Monitoring Surveillance Activities</u>

Air monitoring will be performed during field activities to ensure that all sampling activities comply with the Interim Plan for Prevention of Contaminant Dispersion (IPPCD) (EG&G, 1991). Air quality monitoring will be performed in accordance with SOPs presently being developed by EG&G.

Air quality monitoring requirements for activities such as borehole drilling where there is a significant potential for producing appreciable quantities of suspended particulates include the following:

- Site perimeter and community Radiological Ambient Air Monitoring Program (RAAMP) data for radiological parameters will be available.
- Local monitoring of Respirable Suspended Particulates (RSP) at individual activity work sites shall be conducted using a TSI "Piezobalance"® Model 3500 Respirable Aerosol Mass Monitor, a real-time instrument. Local RSP measurements will be used to guide the project manager's evaluation of the potential hazards associated with activity-related emissions. The threshold RSP concentration for curtailing intrusive activities will be 6.0 milligrams per cubic meter (mg/m^3).
- Additional worker health and safety monitoring as required by the Site-Specific Health and Safety Plan (SSH&SP).

IV.6.1.4 Geotechnical Testing Program

Samples collected during the field activities will be tested to determine geotechnical parameters required for the slope stability and settlement analyses. The following subsections describe the testing methods to be used on the various samples collected from the hillside and below SEP 207-A. Table IV.6-1 summarizes the type and number of samples to be tested using each method.

TABLE IV.6-1

SUMMARY OF GEOTECHNICAL TESTING

		Number of Samples Tested for Given Soil/Rock Type			
Testing Method	Designation	Claystone	Sandstone	Surface Soils	Pond Soils
Triaxial	ASTM D2850	6	4	4	0
Direct Shear	ASTM D3080	6[a]	4[a]	4[a]	0
Unconfined Compression	ASTM 2166	0[b]	0	0	0
Consolidation	ASTM D2435	0	0	0	3
Specific Gravity	ASTM D854	0	0	0	3
Moisture Content	ASTM D2216	6	4	4	3
Gradation	ASTM D422	0	0	4	3
Atterberg Limits	ASTM 4318	0	0	4	3
Unit Weight	ASTM D2937	6	4	4	4

a/ Maximum number of samples to be tested. Direct shear tests to be performed on samples for which triaxial testing is not feasible.

b/ To be performed on samples from competent bedrock.

Triaxial Testing

Six samples of claystone bedrock and four samples of sandstone bedrock will be tested to determine shear strength parameters using triaxial testing methods [American Society for Testing and Materials (ASTM) D2850]. If the surficial soils are cohesive enough to collect relatively competent samples, triaxial testing will be performed on four of these samples. Consolidated-Undrained (CU) methods with pore pressure measurements or consolidated-drained (CD) methods will be used for testing all samples.

Direct Shear Testing

For surficial soil samples with little cohesion and for highly fractured or weathered bedrock samples for which triaxial testing is not feasible, direct shear testing (ASTM 3080) will be performed. To investigate residual shear strengths, fractured bedrock samples may be sheared multiple times along the same failure surface. A maximum of four surficial soil samples, four sandstone samples, and six claystone samples will be tested.

Consolidation Testing

Consolidation tests (ASTM D2435) will be performed on three soil samples collected from below SEP 207-A. The results from these tests will be used to facilitate a settlement analysis that considers loading due to construction of the engineered cover.

Physical Properties Testing

To aid in the settlement analysis, physical properties testing will be performed on the three soil samples collected from below SEP 207-A. Testing on these samples will include determination of specific gravity (ASTM D854), moisture content (ASTM D2216), gradation (ASTM D422), Atterberg Limits (ASTM 4318), and unit weight (ASTM D2937). Four surficial soil samples collected from the hillside will be tested for moisture content, unit weight, gradation, and Atterberg limits. In addition, for use in slope stability analysis, six claystone and four sandstone samples will be tested for unit weight and moisture content.

IV.6.1.5 Quality Assurance Plan

The geotechnical sampling and analysis program will be performed using OU4 RFI/RI field procedures and will be covered by the quality assurance plan (QAP) specified in the RFI/RI work plan.

IV.6.2 Utilities Verification Plan

The utilities verification plan will be implemented to obtain accurate information regarding the identification, service, origin, location, and status of the utilities in the vicinity of the OU4 SEPs which might be affected by the closure/remediation activities. Drawing 51045-

provides a table from which initial physical information may be obtained. This information was obtained from RFP Utility Drawings and includes the location, size, service, and material of construction for the piping, and electrical and telephone services in the 207-SEPs area and adjacent areas that may be disturbed during OU4 SEPs closure. Due to the uncertainty of the accuracy of the utilities drawings, a utilities survey will be performed. This survey is intended to accurately complete and verify the physical information presented on Drawings 50145-440 and 51045-441. This survey will enable the selected construction contractor to accurately locate the utilities during closure/remediation.

IV.6.2.1 Verification Plan Tasks

The following onsite preliminary investigative tasks should be accomplished to provide detailed information for closure of the SEPs area:

- Verification
  - This task includes verification of "service status" (abandoned or active) for each pipe line, electrical power line, and telephone cable listed.
  - Those utility systems that are deemed inactive or abandoned would be categorized for removal or permanent abandonment in-place as required by the remediation alternative selected. Currently active utility systems would require a determination as to whether or not they would be required in the future after remediation of the OU4 area. Active utilities that need to remain in-service after closure will require rerouting. Coordination of temporary service interruption may be required.
- Location
  - The physical location of each item, as shown on the existing utilities documents, should be verified using surface landmark/site survey, ground-penetrating radar (GPR), and/or exploratory excavation.
  - Several of the services listed on Drawings 51045-440 and 51045-441 are routed adjacent to the SEP areas and in some cases parallel the fence and perimeter road. Although these services may not require alteration to accomplish pond closure, verification of their exact location is necessary. This verification will ensure that any excavation and earthwork can be accomplished without interruption of these utilities and other site operations.

IV.6.2.2 Implementation

Each item listed on Drawings 51045-440 and 51045-441 should be taken through the following steps:

- Verification

  - Review the location as shown on the existing RFP utilities drawings identifying routing and connections;

  - Interview RFP engineering, operations, and maintenance personnel to determine present utility use; and

  - Field-verify utility user locations. Compile a list of buildings, equipment, and systems using service.

- Location

  - Review the utility location given on the existing RFP utilities drawings as listed on Drawings 51045-440 and 51045-441. Identify any noted landmarks (e.g., ground penetrations, valve boxes, building intrusions, etc.).

  - Interview RFP engineering, operations, and maintenance personnel to determine if any recent activities (e.g., surveys, maintenance, construction) may have involved the utility being investigated.

  - Field-verify the location of any landmarks that have been identified during the drawing review or personnel interviews. Assuming that the RFP coordinate system has been established in the OU4 area, measure to the nearest landmarks and mark the utilities drawings with those measured points.

  - GPR can be used at this point in the location activities to determine approximate depth and location of the utility. If the utility being traced is in close proximity to other buried utilities and piping, GPR should verify the area to initiate exploratory excavation.

  - Exploratory excavation should be used to verify any utility location that cannot be verified by surface landmark, certified prior survey documents, or other documents that EG&G will certify as providing accurate location of the utility being traced.

IV.6.2.3 Service Requirements

Determine users of domestic cold water, raw water, process waste to ponds, electrical power, and telephone services.

- Interview operations, engineering, and maintenance personnel to determine the impact of interruption of services in the OU4 area.

- Locate shut-off/isolation valves and show the locations on the utilities drawings.

- Locate electrical disconnects and update the utilities drawings to show locations.

- Prepare a utilities shut-down schedule to coordinate construction activities with utility users' requirements.

IV.6.3 Project Schedule

Figure IV.6-2 provides a summary-level conceptual project construction schedule. Construction activities are planned to start in June of 1995. The construction should be completed in June of 1997. A detailed time-phased logic diagram is presented as Plate IV.6-1. The following are project milestone activities and estimated dates (month and year) for their occurrence. The estimated project milestones are based upon receipt of CDH/EPA approval by February 1995.

Project Milestones

Milestone Activity	Estimated Date
Complete Title Design	November 1994
Project Approval	February 1995
Utility Verification Completion	March 1995
Removal of Building 788	March 1995
Award Contract	May 1995
Mobilize Construction	June 1995
Utilities Completion	March 1996
Final Engineered Cover Completion	May 1997
Demobilization	June 1997
Post Closure System Start-up	July 1997

The schedule is based on the following assumptions:

- Materials will be delivered 6 days per week over a 12-hour working day.

- The construction contractor will work five 10-hour days because extended work hours over a long period of time has been too inefficient and unsafe.

- Materials will be brought in as needed for specific layers of the engineered cover because there is limited laydown area available for early material stockpiling.

- Building 788 will be removed prior to the start of construction.

- The start of construction date is based on the DOE IAG milestone schedule.

IV.6.4 Implementation of Site Preparation Activities

DOE will commence construction of site preparation activities prior to formal approval of the IM/IRA in an effort to expedite the construction schedule. These activities will not be components of the OU4 closure/remediation. However, completion of certain activities will be required prior to the start of the closure/remediation activities. The activities for early construction include:

- Upgrading the site security system so construction equipment can access the Protected Area (PA) efficiently;
- Relocation of utility lines that will be impacted by construction and are required for ongoing RFP activities;
- Removal of excess utilities and equipment located aboveground; and
- General site improvements such as pulling electrical power and a sewer line to the locations where construction trailers will be located. Site lighting will also be installed for security purposes as well as performing construction activities at night.

It is important that the vegetated areas requiring remediation be excavated during the winter months when plants are essentially dormant and have died back. This will reduce the volume of plant material consolidated beneath the final engineered cover. DOE may have to excavate these areas early in order to perform the work during the appropriate season. In the event of early excavation, DOE will move the excavated materials into piles located within the excavation zone. The piles will be covered with tarpaulins for future disposition when remediated activities formally commence. The excavated areas will be tested for verification that all the contamination was removed, and backfilled upon the completion of dispositioning the contaminated piles.

IV.6.5 IM/IRA Construction Implementation Sequence

Construction of the engineered cover will include several well-planned phases of work. The tasks that must be completed prior to the construction of the engineered cover include installation of a security fence and accessways, removal and rerouting of utilities, excavation of soils and vegetation from the hillside north of the existing security fence (buffer zone) shown as Zone F on Figure IV.3-1, and the hillside north of the SEPs shown as Zone E on Figure IV.3-1, and are discussed in the above Section IV.6.4.

Initially, the site must be prepared for construction activities. A stockpile area must be created to temporarily store soils brought in from offsite. A trailer area must also be sited to place mobile laboratories, office, break, and decontamination trailers. For the preparation of the stockpile area, as shown on Drawing 51045-110, the rubbish and intermodal containers currently located adjacent to SEP 207B-North, on the eastern side, must be relocated to the

eastern side of the newly installed security fence, south of their current location. This stockpile area must be cleared and graded, to achieve a consistent slope. If required, this area will also be covered with gravel to establish a clean zone. The trailer area, as shown on Drawing 51045-110, must also be cleared and graded to a consistent slope. Water, sewer, electrical, and telephone utility lines must be connected to the trailers to make them operational as discussed above in Section IV.6.4. The roads inside the newly installed security fence, as shown on Drawing 51045-110, must be upgraded to support large construction equipment entering and exiting the job site.

All soils required for backfilling activities and engineered cover construction will arrive on the site and may be stockpiled east of SEP 207B-North in the designated stockpile area. These materials will be delivered to the site throughout the project to keep ahead of construction needs. All materials arriving on the job site will be quality-control tested in accordance with engineering specifications.

There may be existing excavations on the area north of the perimeter fence and on the hillside north of the SEPs due to tasks completed prior to the commencement of engineered cover construction activities as discussed in Section IV.6.4. Approximately 5,400 cubic yards of topsoil and 900 cubic yards of pea gravel will be placed in the area north of the perimeter security fence (buffer zone). Approximately 5,000 cubic yards of topsoil and 800 cubic yards of pea gravel will be placed on the hillside north of the SEPs. These reclamation activities are described as Alternative 1 in Section IV.3.1.1.

The liners in SEPs 207-A, 207-C, and the B-series liners, totaling approximately 11,800 cubic yards, will be excavated, crushed, and placed on the southern portion of SEP 207-A.

Approximately 17,100 cubic yards of contaminated soil with concentrations below vadose zone PRGs will be excavated from Zones B, C, D, and G as shown in Figure IV.3-1. Approximately 15,400 cubic yards of berm soils from B, C, D, and the southern half of SEPs 207-A and 207B-South will be excavated. Soils and berms excavated from Zones B, C, D, and the southern end of SEPs 207-A and 207B-South will be placed in the B-Series SEPs with approximately 26,700 cubic-yard capacity to form the artificial vadose zone as necessary to achieve the appropriate slope. Excavations in zones B, C, D, and E will be backfilled with approximately 20,200 cubic yards of general backfill described as Alternative 1 in Section IV.3.1.1. The installation of the vadose zone monitoring equipment will begin upon completing placement of the artificial vadose zone soils; ERM/G&M will install the horizontal piping, wiring and electric cable conduit as soon as the artificial vadose zone is completed. Monitoring sensors will be placed on a vertical post and protected by a solid casing. The post and casing will be affixed in the soil during back-filling. Compaction around the casing will be pulled from around the vertical post. Backfilling the borehole will be performed manually while pulling the casing.

During construction of the artificial vadose zone, ground water monitoring wells will be installed as a portion of post-closure. Wastes generated from the installation of these wells can

be stockpiled for future placement above the subsurface drains for inclusion beneath the engineered cover. The top of the monitoring wells will be placed at least 6 inches below the surface. Protective vaults will be installed to minimize the potential for damage to the wells as a result of on-going construction activities.

A subsurface drain will be constructed under the entire engineered cover at the completion of installing the vadose zone monitoring equipment. The drain will consist of approximately 3,500 cubic yards of gravel overlain by approximately 3,500 cubic yards of sand. Approximately 200 cubic yards of gravel will be used to construct the drain trench for the engineered cover. Geotextile filter fabric will be installed above the gravel layer and above the sand layer to keep the materials from mixing during construction activities. Since the southern portion of SEP 207-A will be used as a temporary stockpile for liners excavated from SEPs 207-A, 207-C, and the B-Series SEPS, the subsurface drain will be constructed in the northern portion of SEP 207-A and the B-Series SEPs first.

During construction of the subsurface drain in the northern portion of SEP 207-A and the B-Series SEPs, 27,800 cubic yards of contaminated soils from SEP 207-C and in the vicinity of SEP 207-C, shown as Zone A on Figure IV.3-1, will be excavated. Upon completing the construction of the subsurface drain in the northern portion of SEP 207-A and the B-Series SEPs, the soils excavated from SEP 207-C, soils from the vicinity of SEP 207-C, IDM, and soils from utility excavations will be placed above the completed portion of the subsurface drain, as necessary, and graded to achieve the appropriate slope. A volume of soil necessary for placement above the subsurface drain in the southern portion of SEP 207-A will be stockpiled on the northern portion of SEP 207-A. Sized-reduced utility piping and potential debris from Building 788 will be placed, graded, and compacted above the soil layer in the northern portion of SEP 207-A and the B-Series SEPs. A volume of debris necessary to place above the soil on the southern portion of SEP 207-A will be stockpiled on the northern portion of SEP 207-A.

The liners located in the temporary stockpile on the southern portion of SEP 207-A will be placed on the northern portion of SEP 207-A and the B-Series SEPs above the soils placed on top of the subsurface drain. A volume of crushed liners necessary to place in the southern portion of SEP 207-A will be stockpiled on the northern portion of SEP 207-A for future placement. The subsurface drain will be constructed in the southern portion of SEP 207-A once the stockpiled liners are relocated to the northern portion of SEP 207-A or the B-Series SEPs.

Upon the completion of the subsurface drain on the southern portion of SEP 207-A, the soils stockpiled on the northern portion of SEP 207-A can be placed above the subsurface drain on the southern portion of SEP 207-A. The soils will be graded and compacted to achieve appropriate grade. The utility piping stockpiled on the northern portion of SEP 207-A will be placed, graded, and compacted above the soils. The liners stockpiled on the northern portion of SEP 207-A will be placed above the soils and debris on the southern portion of SEP 207-A. The crushed liners will also undergo grading and compaction to achieve the appropriate slope.

Approximately 2,300 cubic yards of soil from the hillside north of the SEPs will be stockpiled on the northern portion of SEP 207-A. Excavation activities associated with this area have been discussed in Section IV.6.4.

Soil from the hillside north of the SEPs stockpiled on the northern portion of SEP 207-A will be graded and compacted on SEP 207-A and the B-Series SEPs to the appropriate slope for the construction of the engineered cover. At this point in construction, the artificial vadose zone and the subsurface drains will have been completed, and soils and liners will have been placed above the drains and graded to the appropriate slope.

The excavation in SEP 207-C will be backfilled with approximately 6,100 cubic yards of soil and vegetation excavated from the area north of the perimeter fence (buffer zone). Excavation activities associated with this area have been discussed in Section IV.6.4. Approximately 4,600 cubic yards of general backfill, 1,500 cubic yards of topsoil and 250 cubic yards of pea gravel described as Alternative 1 in Section IV.3.1.1 will be placed in SEP 207-C above the soil and vegetation from the area north of the perimeter fence (buffer zone) and graded to achieve the appropriate slope.

After compaction of the liners, the SEP 207-A and B-Series SEPs will be ready to receive clean imported components of the engineered cover. The components include the gravel base course, asphalt concrete, asphalt, lower sand layer, angular riprap, gravel, upper sand layer, general backfill, topsoil/gravel admix, pea gravel, and vegetation. Instrumentation for monitoring moisture in the 1,000-year cover will have to be installed concurrently with the construction of the cover to avoid drilling through the cover. Sensors will be located at four locations in the cover. These locations are at the bottom of the sand (drainage/cushion) layer, the top of the sand (filter) layer, and the bottom and the top of the general backfill layer.

A clean fill wedge totaling approximately 4,000 cubic yards of material will be constructed around the perimeter of the waste extending approximately 10 feet in each direction for redundancy purposes. This clean fill wedge will be constructed prior to the placement of the components of the engineered cover.

The first layer installed for the engineered cover includes approximately 5,300 cubic yards of gravel base course. This material will be transferred from the stockpile area east of SEP 207B-North to SEP 207-A and the B-Series SEPs. The gravel base course will be graded and compacted to the appropriate slope.

The volume of asphaltic concrete and asphalt layer total approximately 5,300 cubic yards (combined). The asphaltic concrete and asphalt will arrive onsite at the time it is needed. The asphaltic concrete will be placed, graded, and compacted to achieve the appropriate grade. The asphalt layer will be applied as a liquid in a thin layer over the asphaltic concrete. The layers will be allowed adequate time for the asphalt materials to cure prior to placement of the next layer. Quality-control testing will be performed before and after the materials are placed in the engineered cover.

Approximately 10,700 cubic yards of sand will be placed above the asphalt layer. This material will be transferred from the stockpile area east of SEP 207B-North to the engineered cover location. The sand will be graded and compacted to the appropriate grade.

Angular riprap will be placed above the lower sand layer totaling approximately 21,300 cubic yards. The angular riprap will be transferred from the stockpile area to the engineered cover location. Grading and compaction will be required to complete the construction of the angular riprap layer. Geotextile filter fabric will be installed above the angular riprap layer to keep upper components of the cover during construction.

Approximately 10,700 cubic yards of gravel will be placed above the angular riprap layer. This material will also be transferred from the stockpile area. The gravel will require grading and compaction to achieve the appropriate slope. Geotextile filter fabric will be installed above the gravel layer to keep components of the cover separated during construction.

The upper sand layer will total approximately 10,700 cubic yards of material which will be transferred from the stockpile area. Grading and compaction will be required for this layer. Geotextile filter fabric will be installed above the upper sand layer to keep components of the cover separated during construction.

Approximately 26,700 cubic yards of general backfill will be placed above the upper sand layer. This material will be transferred from the stockpile area and graded to achieve the appropriate grade. This layer will not be compacted to allow for adequate rock penetration.

Approximately 18,800 cubic yards of topsoil/gravel admix will be transferred from the stockpile area for placement above the local soil backfill layer. The topsoil will be graded to the appropriate grade. The topsoil/gravel admix layer will not be compacted to allow for adequate rock penetration. Pea gravel totaling approximately 2,100 cubic yards will be placed above the topsoil/gravel admix layer and graded to the appropriate grade.

A perimeter toe drain will be constructed to direct clean runoff away from the engineered cover. Approximately 300 cubic yards of gravel will be required to install the perimeter toe drain. The perimeter runoff swales will also be constructed to direct runoff away from the engineered cover. Approximately 80 cubic yards of topsoil and approximately 30 cubic yards of pea gravel will be needed to construct the perimeter runoff swales.

The backfilled areas including the area north of the security fence (buffer zone), shown as Zone F in Figure IV.3-1, the hillside north of the SEPs, shown as Zone E in Figure IV.3-1, Zones B, C, and D shown on Figure IV.3-1, SEP 207-C, perimeter runoff swales and the engineered cover will require 27 acres of seeding for the promotion of vegetative growth.

The final construction activities will include the installation of a fence surrounding the final engineered cover to prevent intruder access, and finalizing a construction of the ground water monitoring wells that were protected during activities.

IV.7 COST ESTIMATE

This section presents the estimated costs for implementing the OU4 SEP IM/IRA. This includes a summary estimate, a funding strategy, and a project contingency analysis. The cost information used to prepare the estimate was obtained through Means Man-Hour Standards for construction and interviews with local contractors/vendors.

IV.7.1 Summary Estimate

Table IV.7-1 presents a summary of the capital cost estimate. The detailed backup sheets are included as Appendix IV.C. The estimated cost of the project is approximately $33 million. The estimate is based on 1994 dollars escalated at 9.7 percent of the construction costs to reflect 1997 dollars.

IV.7.2 Funding Strategy

The OU4 SEP IM/IRA will be funded in fiscal year (FY) 94, 95, 96, and 97 based on the conceptual schedule. Table IV.7-2 presents an anticipated funding schedule per fiscal year.

Table IV.7-2
Fiscal Year Funding Strategy
(in thousands of dollars)

	Fiscal Year				
	1994	**1995**	**1996**	**1997**	**1998**
Estimated Funding ($)	2,000	5,820	13,188	10,377	1,652

IV.7.3 Contingency Analysis

The contingency analysis for the project is based on the specific level of confidence with respect to the major components of the closure/remediation. The contingency considers the risk of the following:

1) Variations and unknowns in scope definition.
2) Technical uncertainties (lack of SEP 207-C boring data, north hillside stability, utility location uncertainty, and lack of detailed construction specifications).
3) Estimating methodologies used to develop the estimate and associated expenditures.
4) Cost impacts from the technical complexity of the closure/remediation (primarily due to excavation and utilities removal).

The overall contingency for the project is estimated to be approximately 30 percent. The total contingency cost is approximately $7.5 million. The major factors contributing to the

TABLE IV.7-1

DOE ESTIMATED COST SUMMARY

A. ENGINEERING, DESIGN AND INSPECTION	$2,500,000
B. LAND AND LAND RIGHTS	
C. CONSTRUCTION COSTS	$16,628,000
(1) IMPROVEMENTS TO LAND	
(2) BUILDINGS	
(A) NEW	
(B) MODIFICATIONS	
(3) OTHER STRUCTURES	
(4) SPECIAL FACILITIES	
(A) EQUIPMENT	
(B) INSTALLATION	
(5) UTILITIES	$95,000
(6) PROJECT & CONSTRUCTION MGMT	$5,809,000
D. STANDARD EQUIPMENT	
E. REMOVAL COST LESS SALVAGE	$491,000
F. CONTINGENCY	$7,514,000
G. TOTAL ESTIMATED COST (ROUNDED TEC)	$33,037,000

contingency are variations and uncertainty with respect to the project scope and technical uncertainties.

IV.8 CONSTRUCTION QUALITY ASSURANCE/QUALITY CONTROL PLAN

A construction QA/QC Plan will be prepared to describe the QA and QC procedures that will be followed during construction of the final engineered cover at OU4. Its purpose will be to ensure, with a reasonable degree of certainty, that the completed engineered cover meets or exceeds all requirements of the design criteria and the accepted final design.

For clarification purposes, QA is defined as the activities performed by the construction oversight contractor for ensuring that the construction contractors have constructed the engineered covers in accordance with the accepted construction drawings and specifications, and that the contractor(s) have adequately followed and are in compliance with the approved construction QC procedures. QC is defined as the activities performed by the construction contractors in monitoring construction activities such that all constructed engineered cover components comply with the construction drawings and specifications.

Appendix IV.D provides a construction QC plan outline and an attached outline for a QA plan.

Appendix IV.E provides a sampling and analysis workplan/stragety that will be implemented to verify that all the contaminated soils have been excavated from areas undergoing remediation.

The QC requirements and forms applicable to each construction contractor will be included in the specifications for the general contractor and the electrical, piping, and drilling contractors. These contractors are envisioned to be responsible for all construction activities on this project.

The Project Quality Assurance Program Plan (PQAP) will establish the quality requirements for the work performed, and shall be in conformance with the requirements of DOE Order 5700.6C, Quality Assurance. A quality assurance standards which meets the majority of the requirements of the order for the development and implementation of quality assurance programs is ANSI/ASME NQA-1, Quality Assurance Program Requirements for Nuclear Facilities.

IV.9 HEALTH AND SAFETY CONSIDERATIONS

DOE Order 4700.1 requires that a comprehensive health and safety program be established and utilized for all projects to be conducted at DOE facilities. The goals of this Environmental Safety and Health (ES&H) Program are to protect DOE employees, contractor employees, and the general public from hazards; to protect property from damage; and to

prevent delay or interruptions that can be caused by accidents and fires in connection with the construction activities.

A Project Health and Safety Plan was utilized for the RFI/RI sampling activities. Prior to the start of construction of the remedial alternative for the SEPs, a Health and Safety Plan specific to the construction activities will be provided to EG&G for review and approval. It will provide specific information related to the Environmental Safety and Health Work Survey, safety and health hazard analysis, personnel training requirements, monitoring requirements, and medical surveillance information pertinent to the scope of work. Activities that will be discussed in detail include construction safety, radiation, contamination, and the transportation (both onsite and offsite) of materials. Construction of the remedial alternative will not begin until the project-specific Health and Safety Plan has been approved.

IV.10 IM/IRA RISK ANALYSIS AND POTENTIAL IMPACT DETERMINATION

The following sections describe the expected impacts the proposed IM/IRA action would have on OU4 and the surrounding area compared to the impacts resulting from implementation of no action. Issues addressed include human health and ecological risks, potential effects to air and water quality, impacts to natural resources, transportation, cultural/archeological resources, and other potential impacts. Both the proposed IM/IRA alternative and the no action alternative were evaluated quantitatively and qualitatively through modeling and reasonable estimations based on available information. It should be noted that the risk-based impacts focus primarily on human health because the OU4 site has been highly disturbed by RFP industrial activities. Therefore, the ecosystem surrounding the SEPs is not considered to support a normal association of vegetation and wildlife. Quantitative estimates of potential ecological effects will be addressed in the baseline risk assessment that will be prepared at the conclusion of the additional hydrogeological studies.

IV.10.1 Human Health Risks

The proposed IM/IRA action should be protective of and result in no unacceptable risks to human health and the environment. The proposed action would eliminate exposure to surface soil and airborne contaminants. In addition, exposure to contaminants in surface water runoff would be eliminated. While a potential for contaminant leaching into the ground water exists with the proposed action, results of the VLEACH and MYGRT modeling (Section IV.10.4) demonstrate that this potential is negligible. Results of the atmospheric distribution calculations (Section IV.10.3) indicate there is negligible risk to the community outside of the Rocky Flats Plant boundary from the proposed action.

The ability of the proposed IM/IRA to meet ARARs and other regulatory requirements was also evaluated. An ARAR evaluation of the five GRAs is included in Part III of this Decision Document. Only action- and location-specific ARARs were considered in the IM/IRA evaluation. No chemical-specific ARARs were identified for the media evaluated as part of the IM/IRA. Because surface and subsurface soils are the only media that were considered during

IM/IRA. Because surface and subsurface soils are the only media that were considered during the IM/IRA, and because there are no promulgated, chemical-specific ARARs for soil, consideration of only action- and location-specific ARARs was considered sufficient. Other regulatory requirements generally include DOE directives and executive orders. The proposed action is, therefore, adequately protective of human health and the environment.

A detailed ARAR/TBC evaluation is shown in Table III.5.2. This table lists all the proposed action- and location-specific ARARs and denotes which ones are applicable, relevant and appropriate, to be considered, and not ARARs for each of the five GRAs. Because General Response Action II is the proposed IM/IRA, the column associated with General Response Action II lists the results of the ARAR evaluation for the proposed IM/IRA. The requirements that do not apply include those for generating, storing, and transporting hazardous waste. This table presents all the ARARs that the proposed IM/IRA (as well as the other four GRAs) must meet in order to be protective of human health and the environment.

Section IV.11.2 (Table 11.1) shows regulatory requirements and the implementation strategy for the proposed IM/IRA. In this evaluation, the regulatory requirements are separated by category and an implementation strategy for each of the requirements is presented. This table is designed to provide a listing of all the appropriate regulatory actions that must be completed to implement the proposed IM/IRA. As described in the table, each of the requirements should be met using the proposed implementation strategy. In this way, the proposed IM/IRA will be protective of human health and the environment by meeting all the regulatory requirements pertaining thereto.

IV.10.2 Ecological Risk

A detailed, quantitative environmental evaluation of the potential threats to the natural environment associated with contaminants or the proposed action under the IM/IRA program has not yet been conducted at the site. OU4 has been characterized as a highly disturbed industrial area which can support only the most hardy species of plants and animals. The natural environment at and adjacent to OU4 has been significantly altered by construction and operation of the SEPs and other industrial facilities (DOE, 1993a). A complete description of the environmental characteristics of OU4 is presented in Section I.4 of this document. Briefly, no vulnerable or sensitive populations, habitats, or natural resources (such as wetlands or floodplains) have been identified at OU4. No threatened or endangered species has been observed within the OU4 area (DOE, 1989). Vegetation within OU4 boundaries is attributed to previous reseeding programs at the site and natural colonization by some hardy plant species (DOE, 1993a). Wildlife species observed within the OU4 boundaries include small mammals such as deer mice, medium-sized mammals (such as desert cottontails and feral cats), and possibly small birds of ground nesting species (DOE, 1992).

A quantitative and qualitative environmental evaluation is a large component of the baseline risk assessment that will be completed for OU4 as part of the additional hydrogeological investigation and focused risk assessment activities for the site. Previous environmental

and contaminant fate and transport mechanisms governing ecological exposure. No attempt has yet been made to define ecological endpoints to be used to measure adverse effects or "risks" associated with OU4 contamination (e.g., reduction in population size due to increased mortality or decreased births or increased emigration or decreased immigration, and changes in community structure due to direct or indirect contaminant influences). The proposed environmental evaluation for OU4 is outlined in Section VI.7.2.

Given the current environmental characteristics of OU4, the objectives of the OU4 IM/IRA program, and DOE's plans to qualitatively and quantitatively assess potential, remaining threats to ecological receptors at OU4 in forthcoming characterization efforts, EPA and CDH determined not to require quantitative characterization of the adverse environmental effects associated with contaminants in surficial and vadose zone soils. In support of this approach, however, a potential list of contaminant concentration levels that may provide some level of protection for specific ecological receptors (i.e., vegetation, rat, mouse, and rabbit) was developed from available guidance materials and the technical literature. Contaminant concentration levels presented on this preliminary list included concentration limits where: no observed effect (NOEL) was measured; lowest observed effect (LOEL) was measured; chronic dose that was lethal to 50 percent of the target population (chronic LD_{50}); and the acute dose that was lethal to 50 percent of the target population (acute LD_{50}). This preliminary list is analogous to the risk-based human health PRGs discussed in Sections III.2.2 and IV.10.1 because specific ecological contaminant concentration "goals" were identified for a variety of measurable adverse assessment endpoints or "risks" to target ecological receptors. Comparison of these potential ecological concentration limits to the risk-based human health PRGs developed under the OU4 IM/IRA program demonstrated that the risk-based human health PRGs for surficial soils and vadose zone soils were generally more conservative than the potential ecological concentration limits. Quantitative estimates of potential effects due to exposure to remaining OU4 contamination will be addressed in the forthcoming baseline risk assessment once ecological receptors, potential exposure pathways, and target assessment endpoints have been defined.

It is possible, however, to qualitatively assess potential physical changes to the OU4 environment as a result of implementing the proposed IM/IRA alternative. Approximately 27 acres (1,176,120 ft square feet) within the boundaries of OU4 will be affected by construction of the engineered cover. Relocation of contaminanted soils, placement of clean borrow soils, and construction of the engineered cover will extensively alter the existing topography of the site. Current conceptual engineering plans call for the excavation, relocation, and consolidation of 67,409 cubic yards (1.8×10^6 cubic feet) of contaminated soil material within the OU4 engineered cover. Interim storage of construction material and clean fill within OU4 will also be required during cover construction. Sections of OU4 that potentially may be used as material staging areas are included in the total affected acreage estimate. It is highly probable that these construction activities will interfere with any existing vegetation and animal use of the OU4 site. However, installation of the engineered cover and revegetation of other affected areas within OU4 marks the end of disruptive industrial activity at the site. Additionally, implementation of the proposed IM/IRA alternative will likely diminish the nature and extent of additional

remediation activities required at the site by isolating potential sources of contamination, which will minimize potential receptor exposure and prevent further environmental migration.

Section IV.10.3 Impacts to Air Quality

Historically, the SEPs at the RFP have been used to store chemical, radiological, and mixed wastes. As a result of this, the pond liners and some soils underlying and adjacent to the SEPs have become contaminated. As part of the OU-4 remediation effort, some of these soils and liners are to be excavated. As the excavation progresses, dusts will be released into the air that has the potential to be inhaled by workers performing the excavation, onsite personnel, and the offsite public. Adult receptors are utilized with one newborn child being included as an additional offsite receptor. To ensure that these receptors will suffer no ill effects as a result of the excavation, computerized air dispersion models were used to conservatively estimate the amount of chemical and radiological contaminants that the receptors might inhale. Note that models such as these have been determined to be conservative as they are based on empirical data and must cover a wide range of situations. The purpose of this conservative calculation was to produce an estimate of the dose (chemical and radiological) that receptors might receive if they are not using personal protection equipment and are exposed for the full duration of the excavation, the entire time that the excavation is occurring. Also, since some of the chemicals and the radionuclides are potential carcinogens the increase to the receptor's overall cancer risk was determined. Cancer risk refers to the chances that an individual will incur a latent cancer later in life due to a given exposure. The 95% upper confidence level (UCL) concentrations were used as the source term for the emissions and it has been assumed, with the exception of two chemicals, that the soils are homogeneously contaminated even though this realistically is not the case. Using the 95% UCLs adds conservatism to the final result as those concentrations will provide an upper bound for the wide range of actual soil concentrations.

Contaminants of concern (COC) are given in Table III.2-4 The total particulate emissions from the excavation were estimated using modeling techniques found in the Air/Superfund National Technical Guidance Series (NTGS) Volume 3 "Estimation of Air Emissions from Clean-up Activities at Superfund Sites" (NTGS 1992). Output from the models was in the form of average emission rates. These rates were then converted to expected doses. This is readily done given an average breathing rate, a dispersion coefficient, and the estimated time for completion.

Various assumptions were used in the models including:

- Mass of a reference of adult 70 kilograms (kg) (RAD 1984),
- Mass of a newborn female infant is 3.4 kg (RAD 1984),
- Downwind exposure height of 2 meters (m),
- Width of the contaminated area of 3600 m,
- Average breathing rates of 1.2 m^3/hour (light activity) for the adult and 0.09 m^3/hour for the child (RAD 1984),
- Respirable particles are less than 15 microns in diameter (NTGS 1992).

- Workday of 24 hours (three 8 hour shifts).
- Receptors include a worker (among the excavation equipment), on-site personnel 100m from the excavation, and an off-site person at the nearest fenceline (2000 m).
- Receptors remain in the plume 24 hours/day (maximum dose from the removal activities).
- A scraper weight of 30-50 tons and speeds of 10-20 miles per hour, and
- 2 scrapers used on other soils and 4 backhoes used for pond soils.

Of these assumptions, numbers 5, 7, and 9 are additional sources of conservatism. The breathing rate that is normally used for DOE purposes is less than that being used here (DOE 5400.5). By using the increased breathing rate the receptors will receive a higher dose. Item 7 adds conservatism as there is no worker that will work for an entire 24-hour shift. Item 9 is a source of conservatism as the plume will not be directed toward the receptors for the entire 24 hour period due to almost hourly changes in wind speed and wind direction.

The soil removal process will encompass several steps including excavation, transport, storage, processing, and dumping of the soils. Most of the emissions are expected from the excavation phase of the removal action. The modeling equations used are from Table 24 of the NTGS. They are:

$$\text{Backhoe Excavation Emission Rate}\,(kg/hr) = 0.45\,(s)^{1.5}\,(M)^{-1.4}$$

$$\text{Dumping Emission Rate}\,(kg/mg) = k\,(0.0016)\,\left(\frac{U}{2.2}\right)^{1.3}\left(\frac{M}{2}\right)^{1.4}$$

$$\text{Scraper Excavation Emission Rate}\,(kg/hr) = 2.2x10^{-6}\,(s^{1.4})\,(W^{2.5})\,Sp$$

Where:

s is the silt content of the soil (wt. %) (Chap. II)
M is the moisture content of the soil (wt. %) (Chap.II)
k is the particle size multiplier from Table 23 of NTGS for 15 microns or less, value is 0.48 dimensionless,
U is the mean wind speed (m/sec) from Table 1.1 of the Air Quality Management Plan Rocky Flats Plant (EG&G),
W is the mean weight of the scraper, and
Sp is the mean speed of the scraper.

The end result of the air emission models are emission rates of: backhoe 1.9 kg/hr, scraper 56.1 kg/hr, and dump truck $1.3x10^{-4}$ kg/hr. The dumping rate is seen to be four orders

of magnitude lower than the backhoe and as such is deemed inconsequential. Therefore no total emissions estimates are determined from the dumping of the soils. The models were developed using worst case empirical data and are therefore intrinsically conservative. The emission rates are mean values but are conservative due to the conservative nature of the models.

To determine the final dose, the completion time estimates and dispersion coefficients need to be quantified. Typical removal rates for the backhoe and scraper can be found from NTGS Table 32. To be conservative, the smallest size bucket is used for the backhoe, as this will yield the longest removal time, and therefore, the most emissions. It is also assumed that each bucket load will be half full. This assumption adds an additional source of conservatism to the overall result. This excavation rate for the backhoe is 300 m^3/ day. The total number of days for the excavation of the soil by the backhoe was calculated from the volume of soil and the excavation rate. The removal rate for the scraper is 235 m^3/day as calculated by the same method used for the backhoe. The contaminants were assumed to be spread homogeneously in the soils to calculate a total removal time for the hillside and SEP soils. The equation used to calculate the removal times is:

$$Removal\ Time\,(hr) = \frac{Volume\,(m^3)}{Equipment\ Removal\ Rate\,(\frac{m^3}{day})} * Workday\,(\frac{hr}{day})$$

Use of the total soil excavation volumes, as discussed within Chapter 4 of this document, will add conservatism to the emission estimates due to the heterogeneous nature of the contamination in the soils. The excavation times and the estimated volumes of the surficial soils are the same for all contaminants with the exception of chromium VI. To determine the volumes for both chromium VI and barium, the RFI/RI data were utilized. These results indicated the location and the depth of each of the COCs. It was then assumed that for each location that was to be excavated in which the chromium VI and/or barium concentrations exceeded the PRGs, that a 10 m^2 area was contaminated. The depth of the COCs in the soils that have been designated for excavation throughout OU4 are as discussed within Chapter 4 of this document. For chromium VI the estimated surficial volume is 1.1 m^3 for both the SEP and other soils (hillside and soils around the road to the north). The removal times for chromium VI are then calculated to be 1.5 minutes for the backhoe and 3.5 minutes for the scraper. Removal times for the rest of the chemicals in the surficial soils are then found to be 40 hours for the backhoe and 138 hours for the scraper. Estimated volumes and removal times are the same for each contaminant in the vadose soils with the exceptions of chromium VI and barium. Volumes for chromium VI and barium are estimated as 27 m^3 for both the SEPs and the other soils. The removal times for both chromium VI and barium are then determined to be one hour for both the scraper and the backhoe. Removal times for the rest of the chemicals in the vadose soils were calculated to be 19 days for the backhoe and 5 days for the scraper. Different removal times were calculated for the scraper and backhoe based on both the depth and the volume of soil each can excavate in one pass. Scrapers will be used to remove the other soils while backhoes will

remove the pond soils. Both chromium VI and barium are highly toxic and with the conservatism used with the other chemicals the final results would be an extreme overestimation of the actual cancer and toxicological risks involved in the cleanup effort. Chromium VI has the highest slope factor of any chemical evaluated and barium has a very high reference dose. Therefore a somewhat less conservative soil volume contaminated with these two chemicals was estimated using the borehole sampling information, as explained above. Also note that cancer slope factors and reference doses for the COCs were taken from HEAST 1992 and MEPAS 1989.

To determine the dispersion coefficients, a separate computer code was used: CAP88-PC. This program is an EPA air modeling program that provides dispersion coefficients (χ/Q) for user input distances. Onsite and offsite distances were chosen as 100 m and 2000 m respectfully. 2000 m was chosen as the closest fenceline. A ground release and a contaminated area with a width of 3600 m was assumed. As previously stated, the exposure height was 2 m above the ground. The code also took into account the actual atmospheric conditions at RFP (prevailing wind patterns, average wind speeds, etc.). The χ/Q values used for 100 m and 2000 m are 2.14E-4 sec/m^3 and 7.26E-7 sec/m^3, respectfully.

With the dispersion coefficients calculated, the dose to the onsite and offsite receptors are determined by the following formula:

$$Dose\ (mg(pCi)) = \frac{\chi}{Q}\left(\frac{sec}{m^3}\right) * BR\left(\frac{m^3}{sec}\right) * RT(hr) * Emission\ Rate\left(\frac{mg(pCi)}{hr}\right)$$

Doses were calculated for each COC for both the surface and vadose soils, as appropriate. Doses are either in mg or pCi, depending upon whether the emission rate is in mg/hr for chemicals or pCi/hr for radionuclides. Note that BR is the breathing rate (m^3/sec) and RT is the removal time (hours).

Worker doses were calculated using a Nearfield Box Model (FEMP 1992). This model is capable of determining the air concentrations close to the release point. The equation to be utilized is as follows:

$$C_a = Q / (H_b W_b U_m)$$

Where:

Q is the contaminant emission rate (mg/sec) or (pCi/sec),
H_b is the downwind exposure height (m),
W_b is the width of contaminated area (m),
U_m is the mean wind speed (m/sec), and

C_a is the contaminant air concentration (mg/m^3) or (pCi/m^3).

Once the air concentrations have been determined, the dose can be calculated using the following equation (FEMP 1992):

$$Dose = C_a * BR * RT$$

Tables IV.10-1 and IV.10-2 provides the final dose estimates and cancer risks for the excavation of the SEPs and the other soils. Table 1 presents information for the adult worker, onsite, and off-site receptors, Table IV.10-2 presents information for the newborn child offsite receptor. The estimates were completed assuming 4 backhoes and 2 scrapers were utilized for the excavation activities. Tables IV.10-1 and IV.10-2 also presents the non-cancer hazard quotients for each chemical (RAGS 1989). These individual hazard quotients were then summed to yield the overall hazard index. The hazard index indicates the possibility for the estimated dose to result in health effects other than cancer. The number does not represent a risk, however it indicates the possibility for the existence of a health effect. When the hazard index exceeds unity, there may be concern for the potential health effects. The last line in Table IV.10-1 gives the total chemical hazard index and the overall cancer risks. The overall cancer risks are just the summation of the individual cancer risks for each chemical.

The quantification of the actual radiation dose from the internal deposition of the various radionuclides was done by multiplying the dose conversion factor (DCF) of the radionuclide by the quantity of material inhaled (pCi) that was calculated earlier. The use of the DCFs provides a manner in which the dose in mrem can be calculated for those quantities of radioactive material which might be inhaled (Argonne 1989). Table IV.10-3 presents the result of the radiation dose calculation. This table indicates that none of the receptors will receive more than 10 mrem/yr. The highest receptor was calculated to be the on-site receptor (8 mrem), followed by the worker (5.5 mrem), the off-site adult receptor (3e-2 mrem) and the off-site child receptor (1.7e-3 mrem).

In conclusion the atmospheric dispersion associated with the removal of the asphalt liners and the soils under and around the SEPs presents no significant increase in the overall cancer risk to the workers, on-site personnel, or the off-site public. Also there is no indication that the atmospheric dispersion from the removal action will cause other toxic effects in the receptors. The increase in the cancer risk is less than $1x10^{-6}$ for the worker and on-site population, and less than $1x10^{-8}$ for the off-site public. The hazard index is less than $1x10^{-2}$ for the worker and on-site population, and less than $1x10^{-4}$ for the off-site public. The yearly radiation dose to the receptors is less than 10 mrem.

Table IV.10-1 - Total Dose from 2 Scrapers and 4 Backhoes									
Contaminant of Concern	On-Site Dose (mg)	On-Site Hazard Quotient	Off-Site Dose (mg)	Off-Site Hazard Quotient	Worker Dose (mg)	Worker Hazard Quotient	On-Site Cancer Risk	Off-Site Cancer Risk	Worker Cancer Risk
Barium	1.65e-03	9.28e-04	5.61e-06	3.15e-06	4.30e-03	2.41e-03	0	0	0
Beryllium	6.63e-04	NA	2.25e-06	NA	8.60e-05	NA	3.18e-09	1.08e-11	4.13e-10
Cadmium	3.12e-02	NA	1.06e-04	NA	3.54e-02	NA	1.09e-07	3.70e-10	1.23e-07
Chromium (VI)	5.10e-04	NA	1.73e-06	NA	1.27e-03	NA	1.19e-08	4.05e-11	2.97e-08
Mercury	8.10e-04	1.25e-03	2.75e-06	4.23e-06	1.44e-03	2.21e-03	0	0	0
Nickel	6.34e-03	NA	2.15e-05	NA	8.24e-04	NA	3.05e-09	1.03e-11	3.95e-10
Nitrate	1.40e-03	1.10e-07	4.74e-06	3.72e-10	1.92e-04	1.51e-08	0	0	0
Strontium	1.16e-01	5.36e-05	3.94e-04	1.82e-07	2.07e-01	9.56e-05	0	0	0
Cyanide	2.28e-02	8.94e-05	7.73e-05	3.03e-07	5.92e-02	2.32e-04	0	0	0
Chromium (III)	9.19e-02	1.44e-03	3.12e-04	4.89e-06	1.26e-01	1.98e-03	0	0	0
1,4-dichloro-benzene	1.89e-04	1.49e-07	6.42e-07	5.04e-10	2.46e-05	1.93e-08	0	0	0
2,6-dinitrotoluene	1.75e-04	NA	5.93e-07	NA	4.54e-04	NA	0	0	0
Benzo(a)anthracene	2.64e-04	NA	8.95e-07	NA	4.66e-04	NA	9.19e-10	3.12e-12	1.62e-09

Table IV.10-1 - Total Dose from 2 Scrapers and 4 Backhoes									
Contaminant of Concern	On-Site Dose (mg)	On-Site Hazard Quotient	Off-Site Dose (mg)	Off-Site Hazard Quotient	Worker Dose (mg)	Worker Hazard Quotient	On-Site Cancer Risk	Off-Site Cancer Risk	Worker Cancer Risk
Benzo(a)pyrene	2.76e-04	NA	9.35e-07	NA	4.67e-04	NA	9.61e-10	3.26e-12	1.63e-09
Benzo(b)fluor-anthene	3.19e-04	NA	1.08e-06	NA	4.73e-04	NA	0	0	0
Benzo(k)flour-anthene	3.41e-04	NA	1.16e-06	NA	4.76e-04	NA	0	0	0
Bis(2-ethylhexyl)-phthalate	4.48e-04	1.76e-06	1.52e-06	5.96e-09	3.91e-04	1.53e-06	1.74e-13	5.90e-16	1.52e-13
Chrysene	2.76e-04	NA	9.35e-07	NA	4.67e-04	NA	9.61e-10	3.26e-12	1.63e-09
Hexachloro-benzene	1.75e-04	1.72e-05	5.93e-07	5.82e-08	4.54e-04	4.45e-05	1.70e-10	5.76e-13	4.41e-10
Indeno(1,2,3-cd)-pyrene	1.75e-04	NA	5.93e-07	NA	4.54e-04	NA	6.10e-10	2.07e-12	1.58e-09
N-nitrosodi-propylamine	1.75e-04	NA	5.93e-07	NA	4.54e-04	NA	2.60e-09	8.82e-12	6.75e-09
Pentachlorophenol	8.48e-04	2.22e-06	2.88e-06	7.53e-09	2.20e-03	5.76e-06	0	0	0
1,1,2,2-tetrachloro-ethane	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	1.76e-12	5.96e-15	4.56e-12
1,1,2-trichloro-ethane	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	5.01e-13	1.70e-15	1.30e-12
Benzene	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	2.55e-13	8.64e-16	6.61e-13
Trichloroethene	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	1.14e-13	3.87e-16	2.96e-13
Vinyl Chloride	3.07e-05	NA	1.04e-07	NA	7.98e-05	NA	4.04e-11	1.37e-13	1.05e-10

Table IV.10-1 - Total Dose from 2 Scrapers and 4 Backhoes									
Contaminant of Concern	On-Site Dose (mg)	On-Site Hazard Quotient	Off-Site Dose (mg)	Off-Site Hazard Quotient	Worker Dose (mg)	Worker Hazard Quotient	On-Site Cancer Risk	Off-Site Cancer Risk	Worker Cancer Risk
1,2-dichloroethane	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	7.99e-13	2.71e-15	2.07e-12
1,1-dichloroethene	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	1.05e-11	3.58e-14	2.74e-11
1,2-dichloro-propane	1.54e-05	8.62e-08	5.21e-08	2.92e-10	3.99e-05	2.24e-07	5.53e-13	1.88e-15	1.44e-12
Bromodichloro-methane	1.54e-05	2.01e-06	5.21e-08	6.82e-09	3.99e-05	5.22e-06	0	0	0
Bromoform	1.54e-05	6.03e-08	5.21e-08	2.05e-10	3.99e-05	1.57e-07	0	0	0
Carbon Tetrachloride	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	1.14e-12	3.87e-15	2.96e-12
Chloroform	1.54e-05	1.21e-07	5.21e-08	4.09e-10	3.99e-05	3.13e-07	7.11e-13	2.41e-15	1.85e-12
Chloromethane	3.07e-05	NA	1.04e-07	NA	7.98e-05	NA	3.16e-12	1.07e-14	8.21e-12
Cis-1,3-dichloro-propene	1.54e-05	4.02e-06	5.21e-08	1.36e-08	3.99e-05	1.04e-05	0	0	0
Dibromochloro-methane	1.54e-05	2.41e-06	5.21e-08	8.19e-09	3.99e-05	6.26e-06	0	0	0
Methylene Chloride	5.30e-03	NA	1.80e-05	NA	1.38e-02	NA	4.24e-11	1.44e-13	1.10e-10
Trans-1,3-dichloro -propene	1.54e-05	4.02e-06	5.21e-08	1.36e-08	3.99e-05	1.04e-05	0	0	0
3,3-dichloro-benzidine	3.50e-04	NA	1.19e-06	NA	9.08e-04	NA	1.30e-11	4.41e-14	3.37e-11
N-nitrosodi-diphenylamine	8.48e-04	NA	2.88e-06	NA	2.20e-03	NA	2.37e-12	8.06e-15	6.16e-12

Table IV.10-1 - Total Dose from 2 Scrapers and 4 Backhoes									
Contaminant of Concern	On-Site Dose (mg)	On-Site Hazard Quotient	Off-Site Dose (mg)	Off-Site Hazard Quotient	Worker Dose (mg)	Worker Hazard Quotient	On-Site Cancer Risk	Off-Site Cancer Risk	Worker Cancer Risk
1,1-dichloroethane	1.54e-05	8.62e-09	5.21e-08	2.92e-11	3.99e-05	2.24e-08	0	0	0
2-butanone	4.66e-05	7.32e-08	1.58e-07	2.48e-10	1.21e-04	1.90e-07	0	0	0
4-methyl-2-pentanone	3.07e-05	4.83e-08	1.04e-07	1.64e-10	7.98e-05	1.25e-07	0	0	0
Acetone	2.60e-02	6.79e-07	8.81e-05	2.31e-09	6.74e-02	1.76e-06	0	0	0
Bromomethane	3.07e-05	6.03e-06	1.04e-07	2.05e-08	7.98e-05	1.57e-05	0	0	0
Carbon Disulfide	1.54e-05	1.21e-08	5.21e-08	4.09e-11	3.99e-05	3.13e-08	0	0	0
Chlorobenzene	1.54e-05	2.12e-07	5.21e-08	7.18e-10	3.99e-05	5.49e-07	0	0	0
Chloroethane	3.07e-05	1.34e-10	1.04e-07	4.55e-13	7.98e-05	3.48e-10	0	0	0
Ethylbenzene	2.23e-02	1.75e-05	7.55e-05	5.93e-08	5.78e-02	4.54e-05	0	0	0
Styrene	1.54e-05	6.03e-09	5.21e-08	2.05e-11	3.99e-05	1.57e-08	0	0	0
Tetrachloroethene	1.54e-05	NA	5.21e-08	NA	3.99e-05	NA	1.76e-12	5.96e-15	4.56e-12
Toluene	1.03e-04	5.39e-09	3.50e-07	1.83e-11	2.67e-04	1.40e-08	0	0	0
Total Xylenes	1.54e-05	6.03e-10	5.21e-08	2.05e-12	3.99e-05	1.57e-09	0	0	0
Vinyl Acetate	3.07e-05	1.15e-08	1.04e-07	3.90e-11	7.98e-05	2.98e-08	0	0	0

Table IV.10-1 - Total Dose from 2 Scrapers and 4 Backhoes									
Contaminant of Concern	On-Site Dose (mg)	On-Site Hazard Quotient	Off-Site Dose (mg)	Off-Site Hazard Quotient	Worker Dose (mg)	Worker Hazard Quotient	On-Site Cancer Risk	Off-Site Cancer Risk	Worker Cancer Risk
Fluoranthene	3.57e-04	4.59e-05	1.21e-06	1.56e-07	4.78e-04	6.15e-05	7.13e-11	2.42e-13	9.55e-11
Pyrene	1.94e-04	7.62e-06	6.58e-07	2.58e-08	2.52e-05	9.89e-07	0	0	0
Archlor-1254	5.63e-03	NA	1.91e-05	NA	7.31e-04	NA	1.38e-08	4.70e-11	1.80e-09
Americum 241	5.57e+00	NA	1.89e-02	NA	1.86e+00	NA	1.78e-07	6.05e-10	5.95e-08
Plutonium 239/240	6.01e+00	NA	2.04e-02	NA	5.02e+00	NA	2.28e-07	7.75e-10	1.91e-07
Uranium 235	1.91e-01	NA	6.49e-04	NA	2.86e-01	NA	4.78e-09	1.62e-11	7.16e-09
Uranium 233	2.39e+00	NA	8.10e-03	NA	3.28e+00	NA	5.97e-08	2.02e-10	8.19e-08
Uranium 234	2.39e+00	NA	8.10e-03	NA	3.28e+00	NA	5.97e-08	2.02e-10	8.19e-08
Uranium 238	1.72e+00	NA	5.83e-03	NA	2.30e+00	NA	4.30e-08	1.46e-10	5.75e-08
Totals		3.9e-03		1.3e-05		7.1e-03	5.6e-07	1.9e-09	4.3e-07

Table IV.10-2 - Total Child Dose from 2 Scrapers and 4 Backhoes			
Contaminant of Concern	Off-Site Child Dose (mg)	Off-Site Child Hazard Quotient	Off-Site Child Cancer Risk
Barium	4.2e-07	4.9e-06	0
Beryllium	1.7e-07	NA	9.3e-13
Cadmium	8.0e-06	NA	2.5e-10
Chromium (VI)	1.3e-07	NA	6.0e-11
Mercury	2.1e-07	4.5e-06	0
Nickel	1.6e-06	NA	8.9e-13
Nitrate	3.6e-07	3.4e-11	0
Strontium	3.0e-05	1.9e-07	0
Cyanide	5.8e-06	4.7e-07	0
Chromium (III)	2.3e-05	4.0e-06	0
1,4-dichlorobenzene	4.8e-08	4.4e-11	0
2,6-dinitrotoluene	4.5e-08	NA	0
Benzo(a)anthracene	6.7e-08	NA	3.3e-12
Benzo(a)pyrene	7.0e-08	NA	3.3e-12
Benzo(b)fluoranthene	8.1e-08	NA	0
Benzo(k)flouranthene	8.7e-08	NA	0
Bis(2-ethylhexyl)phthalate	1.1e-07	3.1e-09	3.1e-16
Chrysene	7.0e-08	NA	3.3e-12
Hexachlorobenzene	4.5e-08	9.0e-08	8.9e-13
Indeno(1,2,3-cd)pyrene	4.5e-08	NA	3.2e-12
N-nitrosodipropylamine	4.5e-08	NA	1.4e-11
Pentachlorophenol	2.2e-07	1.2e-08	0

Table IV.10-2 - Total Child Dose from 2 Scrapers and 4 Backhoes			
Contaminant of Concern	Off-Site Child Dose (mg)	Off-Site Child Hazard Quotient	Off-Site Child Cancer Risk
1,1,2,2-tetrachloroethane	3.9e-09	NA	9.2e-15
1,1,2-trichloroethane	3.9e-09	NA	2.6e-15
Benzene	3.9e-09	NA	1.3e-15
Trichloroethene	3.9e-09	NA	6.0e-16
Vinyl Chloride	7.8e-09	NA	2.1e-13
1,2-dichloroethane	3.9e-09	NA	4.2e-15
1,1-dichloroethene	3.9e-09	NA	5.5e-14
1,2-dichloropropane	3.9e-09	4.5e-10	2.9e-15
Bromodichloromethane	3.9e-09	1.1e-08	0
Bromoform	3.9e-09	3.2e-10	0
Carbon Tetrachloride	3.9e-09	NA	6.0e-15
Chloroform	3.9e-09	6.3e-10	3.7e-15
Chloromethane	7.8e-09	NA	1.7e-14
Cis-1,3-dichloropropene	3.9e-09	2.1e-08	0
Dibromochloromethane	3.9e-09	1.3e-08	0
Methylene Chloride	1.3e-06	NA	2.2e-13
Trans-1,3-dichloropropene	3.9e-09	2.1e-08	0
3,3-dichlorobenzidine	8.9e-08	NA	6.8e-14
N-nitrosodidiphenylamine	2.2e-07	NA	1.2e-14
1,1-dichloroethane	3.9e-09	4.5e-11	0
2-butanone	1.2e-08	3.8e-10	0

Table IV.10-2 - Total Child Dose from 2 Scrapers and 4 Backhoes				
Contaminant of Concern	Off-Site Child Dose (mg)	Off-Site Child Hazard Quotient	Off-Site Child Cancer Risk	
4-methyl-2-pentanone	7.8e-09	2.5e-10	0	1
Acetone	6.6e-06	3.6e-09	0	2
Bromomethane	7.8e-09	3.2e-08	0	3
Carbon Disulfide	3.9e-09	6.3e-11	0	4
Chlorobenzene	3.9e-09	1.1e-09	0	5
Chloroethane	7.8e-09	7.0e-13	0	6
Ethylbenzene	5.7e-06	9.2e-08	0	7
Styrene	3.9e-09	3.2e-11	0	8
Tetrachloroethene	3.9e-09	NA	9.2e-15	9
Toluene	2.6e-08	2.8e-11	0	10
Total Xylenes	3.9e-09	3.2e-12	0	11
Vinyl Acetate	7.8e-09	6.0e-11	0	12
Fluoranthene	9.1e-08	1.2e-07	1.9e-13	13
Pyrene	4.9e-08	2.2e-09	0	14
Archlor-1254	1.4e-06	NA	4.1e-12	15
Americum 241	1.4e-03	NA	4.5e-11	16
Plutonium 239/240	1.5e-03	NA	5.8e-11	17
Uranium 235	4.9e-05	NA	1.2e-12	18
Uranium 233	6.1e-04	NA	1.5e-11	19
Uranium 234	6.1e-04	NA	1.5e-11	20
Uranium 238	4.4e-04	NA	1.1e-11	21
		1.4e-05	4.5e-10	22
				23

Table IV.10-3 - Radiation Dose

Radionuclide	DCF (mrem/pCi)	On-site Dose (mrem)	Off-site Dose (mrem)	Worker Dose (mrem)	Off-site Child Dose (mrem)
Americum 241	0.52	3.41	0.01	1.14	7.4e-04
Plutonium 239/240	0.51	3.61	0.01	3.02	7.8e-04
Uranium 235	0.12	0.03	9.0e-05	0.04	5.8e-06
Uranium 233	0.13	0.37	1.0e-03	0.50	7.9e-05
Uranium 234	0.13	0.37	1.0e-03	0.50	7.9e-05
Uranium 238	0.12	0.24	8.0e-04	0.33	5.2e-05
Totals		8.02	0.03	5.54	1.7e-03

IV.10.4 Impact to Water Quality

Potential adverse impacts to both ground water and surface water resulting from both existing OU4 site conditions and the implementation of the preferred IM/IRA were evaluated using quantitative fate and transport models. The purpose of these analyses was to demonstrate that the implementation of the preferred IM/IRA would provide long-term protection for ground water and surface water. Adverse effects anticipated if no action were taken at OU4 are also described for comparative purposes.

Two separate scenarios were used to investigate hypothetical potential future effects on ground water quality. First, the migration of currently immobile contaminants through the unsaturated vadose zone soils under the influence of downward advective (leaching) processes was quantitatively explored by coupling the one-dimensional finite difference vadose zone leaching model, VLEACH, developed for the USEPA, with the two-dimensional porous flow model MYGRT, which was developed for the Electric Power Research Institute (EPRI). VLEACH was used to simulate the downward leaching of several analytes through unsaturated vadose zone soils underlying OU4. Data results from this leaching model were then used as the initial source concentration in the saturated solute transport model MYGRT to conservatively estimate the quantity and quality of potential ground water impacts at the northeastern toe of the engineered cover. This location was selected as the point of compliance (POC) for the preferred

IM/IRA as it is the closest, downgradient spot where a well could be installed following construction of the engineered cover.

The second scenario investigated in support of the preferred IM/IRA focused on quantifying any potential adverse impacts to ground water should the potentiometric surface rise to or above the historic high piezometric surface to contact contaminated, unsaturated soils beneath the subsurface drainage layer under the engineered cover. A conservative catastrophic model was used to calculate the total mass of contaminants that could be instantaneously introduced into the ground water should the vadose zone soils be saturated. Data from this catastrophic model were then used as the initial source concentration in the saturated solute transport model MYGRT to conservatively estimate the quantity and quality of potential ground water impacts at the POC. A 1,000-year simulation time period was selected for both analyses.

Although no surface water bodies exist within the boundaries of OU4, the potential adverse effects to adjacent surface water bodies were evaluated quantitatively using fate and transport calculations and qualitatively based on existing local surface water hydrology information and existing surface water control structures.

IV.10.4.1 Downward Leaching Potential

The purpose of modeling downward contaminant migration through the OU4 vadose zone soil was to determine the type and magnitude of plausible impacts to ground water quality resulting from the downward leaching of contaminants. Data from the engineered cover performance assessment using the HELP model (described in Section IV.3.1.1) were incorporated into the leaching model to evaluate the expected effectiveness of the proposed cover in minimizing infiltration and further contaminant migration.

Selected Vadose Zone Leaching Model

A simple, one-dimensional vadose zone leaching model was selected to provide conservative estimates of the potential for downward migration of contaminants through unsaturated soils over time. The use of a one-dimensional model is defensible because lateral dispersion effects are likely to be insignificant under unsaturated conditions. Given the aforementioned considerations, VLEACH Version 1.02 (IGWMC, 1991) was chosen to model downward contaminant migration through the OU4 vadose zone soils.

VLEACH is a one-dimensional finite difference model which simulates contaminant leaching through the vadose zone by simultaneously solving several mass balance equations. The model is capable of simulating four main processes typically governing fate and transport in the vadose zone:

- Liquid-phase downward advection,
- Solid phase adsorption,

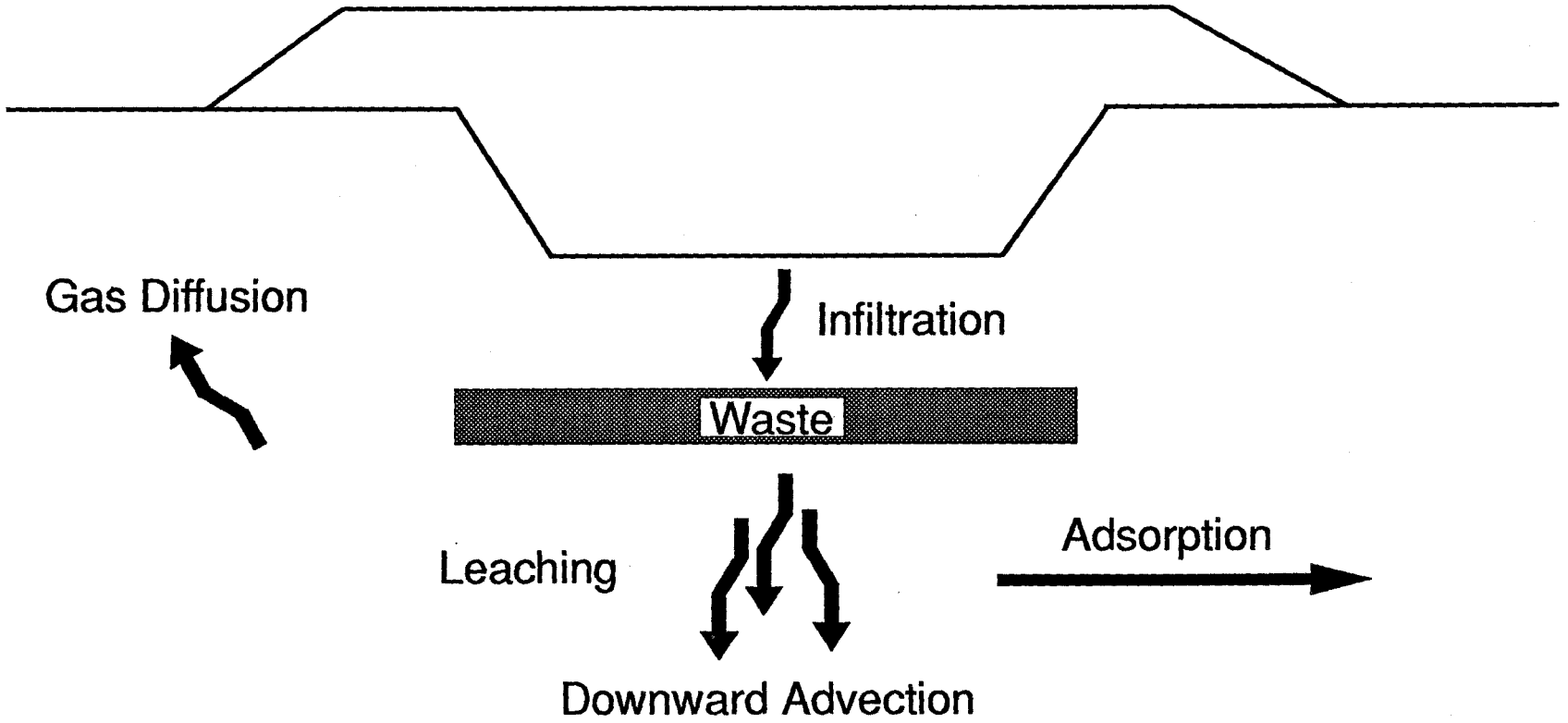
- Vapor-phase equilibrium, and
- 3-phase equilibrium.

Figure IV.10-1 presents a generalized schematic of the natural processes included in the VLEACH model.

VLEACH couples existing site conditions (both physical and chemical properties) with analyte-specific properties to simulate contaminant behavior under unsaturated conditions over the user-defined period of time. The VLEACH model requires several analyte-specific input parameters (e.g., K_{oc}, K_H, D_{air}) as well as site-specific characteristics that may influence the behavior of contaminants within unsaturated soils. In general, the data requirements for VLEACH fall into four categories: chemical parameters, soil properties, site properties, and model parameters. Chemical parameters are analyte-specific and depend upon the assumptions governing the nature of site contamination which are incorporated into model simulations. For example, assumptions made regarding the chemical speciation of each contaminant to be modeled must be developed. Thus, all chemical-specific parameters used in the VLEACH model must then be related to the assumed chemical species. The remaining site-specific parameters focus on the extent of site contamination and the physical vadose conditions at OU4 that may influence the behavior of the modeled contaminants.

The VLEACH model can be constructed to subdivide a specific site into separate units or "polygons" with distinct chemical and/or physical characteristics. Each polygon is then represented by a stack of vertical cells that extend from the ground surface to the piezometric surface. In this way, the model may be developed to adequately describe heterogeneous site conditions, assuming instantaneous equilibrium (i.e., the model does not include potential kinetic considerations). However, it is important to note that the VLEACH model is subject to several major assumptions that should be considered during model development and result interpretation. The VLEACH model assumes that the vadose zone soil within a particular model polygon is completely homogeneous and behaves as a uniform porous medium, with a constant moisture content profile and no preferential flow pathways. Further, the model does not support *in situ* production or degradation of contaminants. The model also assumes that contaminant partitioning between soil gas, vadose zone pore water, and solid media can be described by simple linear relationships. These are extremely limiting assumptions designed to simplify computations. However, if conservative input parameters and assumptions about site conditions are used, the model should produce reasonable estimates of how contaminants might behave under the influence of simple leaching processes at the site.

VLEACH calculates the contaminant present in each cell assuming instantaneous equilibrium between the three model phases, soil gas, vadose zone pore water, and solid soil matrix. The model output, a series of mass balance calculations and cumulative mass fluxes across the liquid phase into ground water, provides valuable information about the potential effectiveness of the no action alternative and the preferred IM/IRA.



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

Figure IV.10-1

OU4 IM/IRA
Vadose Zone Model Schematic

rf85x11h

Governing Transport Equations

The VLEACH model incorporates three major processes into contaminant fate and transport calculations. Contaminants in the liquid phase are subject to downward advection via leaching vadose zone pore water; contaminants in the soil gas are subject to gas diffusion; and the mass of contaminants present in each phase (including the solid soil matrix) is re-equilibrated between each phase based on the given distribution coefficients, assuming instantaneous equilibrium. All of these processes are affected by both the physical and chemical characteristics of the OU4 site as well as the modeled contaminants themselves. The following is a summary of the key equations included in the VLEACH model code to approximate changing contaminant concentrations under the influence of leaching processes over time. Table IV.10-3 summarizes the variables used in the following equations.

Downward Advection

Downward advection of contaminants through vadose zone soil is driven by the flux of recharging ground water. Mass flux due to downward advection of recharging ground water can be described by the following partial differential equation:

$$\frac{\partial C}{\partial t} = -\left(\frac{q}{\theta}\right)\frac{\partial C}{\partial z}$$

Within the numerical VLEACH model code, however, this partial differential equation is approximated by the following finite difference equation, which considers the asymmetric nature of advection:

$$\frac{C_i^{t+\Delta t} - C_i^t}{\Delta t} = \frac{-q}{2\theta\Delta t}\left[\left(C_i^{t+\Delta t} - C_{i-1}^{t+\Delta t}\right) + \left(C_i^t - C_{i-1}^t\right)\right]$$

The concentration of a contaminant within each individual cell which comprises a defined polygon is calculated using this equation. These equations are then solved simultaneously using the Thomas algorithm. The mass flux from ground surface to ground water is then computed:

$$J_T = qC_{firstcell}$$

$$J_{BOTTOM} = qC_{lastcell}$$

Table IV.10-3.		Definitions of Variables Used in Leaching Equations
M_T	=	Total mass of contamination in a model cell [M]
ΔZ	=	Thickness of cells in VLEACH calculations [L]
n	=	Total porosity of soil [dimensionless]
θ	=	Water-filled porosity of soil [dimensionless]
ρ_b	=	Bulk density of soil [M/L^3]
K_D	=	Distribution coefficient for soil-water partitioning [L^3/M]
K_H	=	Henry's constant for air-water partitioning [dimensionless]
C_s	=	Contaminant concentration in sorbed phase [M/L^3]
C_l	=	Contaminant concentration in liquid phase [M/L^3]
C_g	=	Contaminant concentration in gas phase [M/L^3]
C_{INF}	=	Contaminant concentration in infiltrating water [M/L^3]
C_{NCELL}	=	Contaminant concentration in water in bottom cell [M/L^3]
C_{ATM}	=	Contaminant concentration in atmospheric air above soil surface [M/L^3]
C_{gw}	=	Contaminant concentration in groundwater (with respect to gas phase exchange between water table and vadose zone) [M/L^3]
f_{oc}	=	Fraction organic carbon in soil [dimensionless]
K_{oc}	=	Organic carbon partition coefficient [L/M^3]
D	=	Effective diffusion coefficient [L^2/T]
D_{AIR}	=	Free air diffusion coefficient [L^2/T]
q	=	Darcian flux of percolating water [L/T]
In finite difference equations:		
$C_{i-1}^{t+\Delta t}$		
C	=	Refers to concentration of gas or liquid, depending on the equation [M/L^3]
$t+\Delta t$	=	Refers to the time step at which the concentration is calculated
i-1	=	Refers to the cell number in which the concentration is calculated

Gas Diffusion

Diffusion of contaminants into the soil gas phase is given by the following partial differential equation (Fick's Second Law):

$$\frac{\partial C}{\partial t}=D\frac{\partial^2 C}{\partial z^2}$$

As with the downward advection equation, the VLEACH model code approximates this partial differential equation using the following finite difference equation:

$$\frac{C_i^{t+\Delta t}-C_i^t}{\Delta t}=\frac{D}{(\Delta z)^2}\left(C_{i-1}^{t+\Delta t}-2C_i^{t+\Delta t}+C_{i+1}^{t+\Delta t}\right)$$

The mass flux due to gas diffusion from ground surface to ground water is then computed using the following flux equations:

$$J_T=(n-\Theta)\,D\frac{(C_{ATM}-C_i)}{\Delta z}$$

$$J_{BOTTOM}=(n-\Theta)\,DK_H\frac{(C_{lastcell}-C_{groundwater})}{\Delta z}$$

Equilibration Amongst Phases

The VLEACH model estimates the concentration within each phase by solving several mass partitioning equations simultaneously. These equations couple chemical-specific characteristics with site-specific conditions to estimate the mass and concentration of contaminant within each phase at each discrete time step. The following equations are solved concurrently to estimate the concentration of each modeled contaminant within the soil gas phase, the pore water phase, and the solid soil phase, respectively:

$$M_T=\Delta z\,(\Theta C_i+C_g(n-\Theta)+\rho_b C_s)$$

$$C_{gas} = \frac{M_T}{\Delta z\left[\frac{\Theta}{K_H} + (n-\Theta) + \rho_b\left(\frac{K_D}{K_H}\right)\right]}$$

$$C_{liquid} = \frac{M_T}{\Delta z\left[\Theta + K_H(n-\Theta) + \rho_b K_D\right]}$$

$$C_{soil} = \frac{M_T}{\Delta z\left[\frac{\Theta}{K_D} + (n-\Theta)\left(\frac{K_H}{K_D}\right) + \rho_b\right]}$$

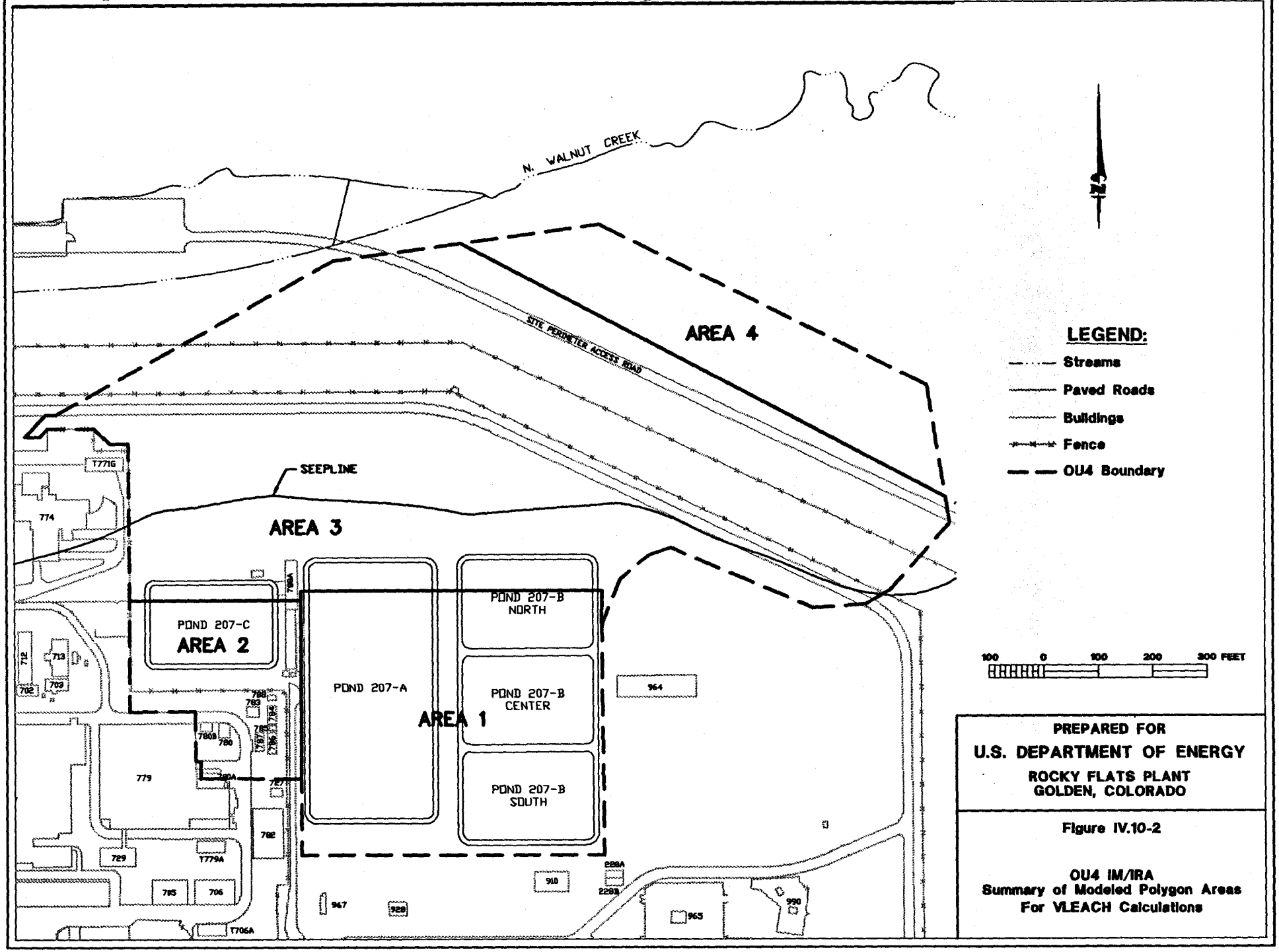
The VLEACH model output reports the change in mass within the defined vadose zone profile and the cumulative mass flux to the ground water due to downward advection and gas diffusion.

Physical Input Parameters for VLEACH

The following discussions briefly describe the soil properties, site properties, and other model parameters used to simulate downward migration of contaminants in unsaturated soils using the VLEACH model. Input parameters used in the VLEACH modeling effort, which are related to site-specific properties that define the extent of site contamination and the physical vadose conditions at OU4 that may influence the behavior of the modeled contaminants, are presented. Note that most site-specific model input parameters are based on available data from the OU4 RFI/RI program. Additional site-specific characteristics that were incorporated into the MYGRT model to characterize the quantity and quality of ground water impact from contaminants leaching from unsaturated soils are discussed shortly.

The VLEACH model was configured to simulate leaching from four separate "polygons" within the boundaries of OU4. Each polygon was represented by a vertical stack of leaching cells that extend from ground surface to the piezometric surface. Four separate polygons were necessary to adequately describe site conditions as depth to the piezometric surface and initial contaminant concentration varies across the OU4 site. Figure IV.10-2 schematically illustrates how OU4 was subdivided into four model polygons.

The first polygon (hereafter called Area 1) includes the general site of the preferred IM/IRA engineered cover. Area 1 has an overall surface area of approximately 300,000 ft^2. The second polygon (hereafter called Area 2) covers the remaining southwestern portion of OU4, including Pond 207C. Area 2 is approximately 93,000 ft^2 in areal extent, and is characterized by a lower piezometric surface and variable contaminant concentrations. The third polygon (hereafter Area 3) covers the remaining land surface to be addressed under the IM/IRA from Areas 1 and 2 to the seep area along the hillside north of the SEPs. Area 3 is estimated to be about 320,000 ft^2 in areal extent, and is characterized by a higher piezometric surface and


N. WALNUT CREEK
SITE PERIMETER ACCESS ROAD
AREA 4
SEEPLINE
AREA 3
POND 207-C
AREA 2
POND 207-A
AREA 1
POND 207-B
NORTH
POND 207-B
CENTER
POND 207-B
SOUTH
T771G
774
712
713
702
703
779
780B
780
780A
727
782
729
T779A
785
706
T706A
947
928
910
228A
228B
965
990
964
LEGEND:
Streams
Paved Roads
Buildings
Fence
OU4 Boundary
100 0 100 200 300 FEET
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ROCKY FLATS PLANT
GOLDEN, COLORADO
Figure IV.10-2
OU4 IM/IRA
Summary of Modeled Polygon Areas
For VLEACH Calculations

contaminant concentrations different from those within either Areas 1 or 2. The fourth and final polygon (hereafter Area 4) covers the northeastern portion of the hillside north of the Protected Area (PA) and the SEPs. Area 4 is approximately 290,000 ft^2 in areal extent, and is characterized predominately by shallow source contamination (i.e., existing contamination is limited to surficial soil).

The VLEACH model code used to assess potential adverse impacts to ground water quality due to leaching of contaminants from unsaturated soils was built to account for differing soil properties, recharge rate, depth to piezometric surface, or contaminant concentrations across the four defined model areas. However, many of the site-specific properties, such as recharge rate, total porosity, and volumetric water content, cannot be justifiably delineated by area for use in the simple, one-dimensional VLEACH model. Contaminant concentrations and depth to ground water, however, are defining characteristics of each of the polygons used in the VLEACH model simulation runs. These characteristics define the number and nature of the vertical stack of cells within each polygon. By definition, the number of cells within each polygon multiplied by the height of each individual cell is the depth to the piezometric surface within that specified polygon. The depths to ground water for VLEACH modeling purposes in Areas 1 through 4 was conservatively defined as 2 feet below ground surface (bgs), 6 feet bgs, 2 feet bgs, and 10 feet bgs, respectively. Each polygon was then defined by a stack of vertical cells of height 0.25 feet so that the total combined height of the cells equaled the estimated depth to the piezometric surface for that specified polygon.

Initial model conditions were selected to ensure conservative model results. The fraction organic carbon content (f_{OC}) of the OU4 soils was estimated from total organic carbon (TOC) data from the OU4 RFI/RI program. Note that f_{OC}, which can be used to describe adsorption for a specific analyte, was not included in the model code when a specific K_D value (which mathematically describes the extent to which an analyte sorbs to some other material, usually the solid soil matrix) was available for the modeled contaminant. Recharge rates under the no action alternative and for areas not affected by the preferred IM/IRA were conservatively based upon hydraulic conductivity estimates under saturated conditions at OU4. The range of these hydraulic conductivity values are consistent with recharge rates expected for poorly to moderately sorted, poorly stratified gravel, sand, cobbles, silt, and clay characteristic of unconsolidated geologic materials underlying OU4 (see Section I.4). As indicated earlier, output from the HELP model described in Section IV.3.1.1 was used to simulate expected recharge rates within Area 1 under the preferred IM/IRA analysis. Table IV.10-4 summarizes these and other important site conditions incorporated into the model.

Modeled Contaminants

Several analytes have been measured in surficial soil and vadose zone soil in concentrations in excess of their respective target long-term concentration limits that are protective of public health (see Section III.3.3). To identify those contaminants to be included in the modeling efforts, each of the identified COCs were screened on the basis of its physical and chemical properties that may enhance or inhibit downward migration through unsaturated

Table IV.10-4. Summary of Site-Specific VLEACH Input Parameters

Parameters	Area 1	Area 2	Area 3	Area 4
Area (sq. ft)	300000	93000	320000	290000
Cell depth (ft)	0.25	0.25	0.25	0.25
Recharge rate (ft/yr)	0.103 – 1034.7	0.103 – 1034.7	0.103 – 1034.7	0.103 – 1034.7
Density of soil (g/cc)	1.7	1.7	1.7	1.7
Total effective porosity	0.361	0.361	0.361	0.361
Volumetric water content	0.134	0.134	0.134	0.134
Fraction organic content	0.003	0.003	0.003	0.003
Depth to GW (ft)	2	6	2	10

soil. Mobility, source concentration, and toxicity were generally the three factors used to determine whether a specific analyte should be included in the VLEACH model to conservatively estimate downward mass flux into ground water over time. This analysis indicated that 19 of the 25 defined COCs for OU4 were characterized by physical and/or chemical properties which should significantly hinder downward migration. These 19 contaminants were eliminated from the model in the interest of providing the most conservative estimates of the potential effects of leaching. The contaminants selected for inclusion in the modeling effort were generally not retarded significantly by soils, thus providing a conservative estimate of potential impacts to ground water quality. Table IV.10-5 summarizes the rationale used for selecting the six contaminants that were modeled to investigate downward leaching potential.

Briefly, the six contaminants that were modeled were the radionuclides americium-241 and uranium-235, the semi volatile organics 2,6-dinitrotoluene and pentachlorophenol, and the metals barium and beryllium. All major contaminant groups at OU4 which may pose a risk to public health were included in the VLEACH model. The following discussion explains why each of these contaminants was selected for inclusion.

Radionuclides

Americium-241 was included in this quantitative analysis in support of the preferred IM/IRA because it will likely migrate downward through the vadose zone over time. Additionally, this contaminant was found in soils within OU4 at concentrations up to 110 pCi/g. As with other radionuclides and metals, the speciation of americium in the OU4 soils will be defined by the pH and whether complexing ligands (i.e., chemicals such as oxygen, carbon dioxide, nitrate, and chloride that bind to a target analyte to create a unique chemical compound with unique chemical and physical properties) are present. No soil pH data for OU4 are available. However, background pH values for vadose zone soils similar to OU4 soils are slightly alkaline, with an average pH value of 7.97 (USDOE, 1993; see Section III.3.1). The range of these background soil pH data (pH values from 4 to 10) suggest that americium may actually be present as several cationic species (PNL, 1978; USEPA, 1978). In the absence of complete chemical speciation data for OU4 and in the interest of simplifying the vadose zone leaching model input data, the most mobile americium species were assumed. Assuming limited oxygen is available within the unsaturated soils at OU4 (i.e., reducing conditions prevail), the americium hydroxide species AmO_2 and the americium chloride species $AmCl_4$ were assumed to be the dominant chemical species (PNL, 1978; USEPA, 1978; Micromedix, 1994). Note that assumed chemical speciation is used only to define chemical-specific parameters that may influence downward migration. Most conservative parameters were employed in the model simulations.

Uranium-235 was selected to be modeled because it can be mobile in a soil medium and is a known human carcinogen. The uranium peroxide species $[UO_2(OH)_2]$ and the various uranyl carbonato species were assumed to be the most common chemical species at the OU4 site due to its speciation characteristics under the presumed pH and other chemical conditions at the site (PNL, 1978; USEPA, 1978; Hsi, 1981). Although uranium-235 adsorption onto soil/rock

Table IV.10-5. Rationale for Selecting Contaminants to Include in VLEACH

Contaminant of Concern	Use in Model	Rationale	Reference
Americium−241	Y	More soluble than Pu and migrates faster	EPA 520/6−78−007B
Plutonium−239	N	Less soluble than Am and migrates slower	EPA 520/6−78−007B
Uranium−235	Y	Can be mobile in soil; highly carcinogenic	EPA 520/6−78−007B
1,4−dichlorobenzene	N	Only a potential hot spot contaminant	OU4 IM/IRA, 1994
2,6−dinitrotoluene	Y	Migrates effectively via soil−water pathway	Micromedix Inc., 1994
Benzo(a)anthracene	N	Sorbs strongly to soils	Micromedix Inc., 1994
Benzo(a)pyrene	N	Sorbs strongly to soils; not likely to leach	Micromedix Inc., 1994
Benzo(b)fluoranthene	N	Sorbs strongly to soils	Micromedix Inc., 1994
Benzo(k)fluoranthene	N	Sorbs strongly to soils	Micromedix Inc., 1994
Bis(2−ethylhexyl)phthlate	N	Highly volatile (e.g., see Henry's constant)	McKay, 1991
Chrysene	N	Sorbs strongly to soils	Micromedix Inc., 1994
Hexachlorobenzene	N	Highly volatile (e.g., see Henry's constant)	McKay, 1991
Indeno(1,2,3−cd)pyrene	N	Sorbs strongly to soil	Micromedix Inc., 1994
N−nitrosodipropylamine	N	Highly volatile (e.g., see Henry's constant)	Micromedix Inc., 1994
Pentachlorophenol	Y	Only sorbs well under acidic conditions	Micromedix Inc., 1994
Arochlor−1254	N	Sorbs strongly to soils	Micromedix Inc., 1994
Barium	Y	Widespread contamination	OU4 IM/IRA, 1994
Beryllium	Y	Known carcinogen; widespread at site	Micromedix Inc., 1994
Cadmium	N	Tends to sorb to soil	Micromedix Inc., 1994
Chromium	N	Tends to sorb to soil	Micromedix Inc., 1994
Mercury	N	Highly volatile, especially from soils	Micromedix Inc., 1994
Nickel	N	Only a potential hot spot contaminant	OU4 IM/IRA, 1994

material is poor at pH values greater than 6 (USEPA, 1978), this contaminant emits significant alpha radiation, which may pose a threat to public health.

In contrast to americium-241 and uranium-235, plutonium-239/240 was eliminated from the modeling effort because it has been demonstrated to migrate more slowly through the soil medium than either of the other radionuclide species and is less soluble at alkaline pH values.

Semi Volatile Organics

The organic analytes 2,6-dinitrotoluene and pentachlorophenol were included in the VLEACH modeling completed in support of the preferred IM/IRA. The analyte 2,6-dinitrotoluene was selected because it migrates effectively through unsaturated soils with characteristics similar to those found at OU4 and does not adsorb readily to saturated, deep soils (Micromedix, 1994). Pentachlorophenol was also selected for similar reasons. Pentachlorophenol has been shown to only adsorb to soil medium similar to those found at OU4 under acidic conditions. Under the presumed prevailing alkaline conditions at OU4, pentachlorophenol should be relatively mobile. Using both of these contaminants in the leaching and saturated solute transport models should conservatively estimate the likelihood of adverse impacts to ground water quality due to leaching of semi volatile organics. Note that the presence of both of these analytes is based on historical (pre-RFI/RI) data only.

Although 1,4-dichlorobenzene is also relatively mobile under the presumed prevailing site conditions at OU4, this contaminant was not included in the VLEACH simulations because it has been characterized as a potential "hot spot" contaminant (i.e., measured only at discrete locations at concentrations in excess of the target, long-term concentration). Detailed fate and transport estimates were determined to be unnecessary given the limited source area of this type of contamination.

Metals

Barium and beryllium were selected as representative metal contaminants that may pose a threat to ground water quality. Barium was selected to be modeled because it is present in high concentrations in surficial and vadose zone soils at OU4. The most soluble and mobile barium species [e.g., $Ba(Cl)_2$] was assumed to be the chemical form of all measured barium in source soils. This assumption is not unrealistic given the presumed subsurface conditions at OU4 (e.g., alkaline, limited oxygen, limited carbon dioxide, presence of chloride ions). Beryllium was also selected to be modeled because it is classified as a human carcinogen. Although beryllium is relatively insoluble in most forms, the potential for health risks caused by potential human exposure to beryllium leaching from soils into ground water was investigated. The beryllium hydroxide species was assumed to be the most common chemical species in OU4 surficial and vadose zone soils. Note that these chemical speciation determinations are based on reasonable yet simplistic assumptions about the site conditions. Complex, variable environmental conditions cannot be simulated easily. Thus, most

conservative parameters and assumptions appropriate for the site have been employed during model simulations.

Cadmium and chromium were not included in the modeling effort because these metals adsorb readily to soils. Both metals are not likely to leach significantly from unsaturated soils unless soil conditions are generally acidic (PNL, 1978; USEPA, 1978).

Chemical Input Parameters for VLEACH

Once the contaminants to be included in the models were identified, several chemical-specific characteristics which define the analyte's ability to partition amongst phases were defined based either on empirical data in the literature and some site-specific calculations. Each of these characteristics describes the behavior of the assumed chemical species in question. The free air diffusion coefficient (D_{air}) and Henry's Constant (K_H) govern how readily the contaminant species partitions into soil gas. The distribution coefficient for soil-water partitioning (K_D) or the fraction organic carbon in soil (f_{OC}) and organic carbon partition coefficient (K_{OC}) define how the contaminant partitions into the solid soil medium (e.g., governs adsorption). If a specific K_D was identified from the literature or developed from available site-specific data, the model input parameters for VLEACH were adjusted to eliminate computation of a K_D term using f_{OC} and K_{OC}, as discussed previously.

Table IV.10-6 summarizes the chemical-specific characteristics used in the VLEACH model for each of the modeled contaminants. Source information for each of these values are also indicated on the table. The K_D values presented in this table represent a range of values found in the technical literature and/or developed by comparing OU4 borehole/ground water well sample pairs. Calculation of site-specific K_D values was based on the premise that the soil/water pairs were in equilibrium. This simple screening exercise was only intended to clarify whether the literature range of K_D values may be a reasonable approximation for OU4 conditions. Uncertainties associated with these and other single-point values are addressed following presentation of model results. Note that the air diffusion partition coefficients for the semi volatile organics were calculated using the FSG Method (Fuller et al., 1991).

The distribution of modeled contaminants within each vertical cell of each Area was also incorporated into the VLEACH model. Data from both historical and RFI/RI characterization activities (see Section III.2.1) were used to develop conservative, vertical contaminant concentrations for each model area. Again, assuming a homogeneous and completely uniform soil medium, the contaminant concentration within any one cell was conservatively defined as the maximum measured concentration within that area for that particular cell (by depth). If a particular modeled analyte was not detected within any one area or within any one cell in an area, then the initial contaminant concentration was set equal to zero prior to simulating the effects of leaching. Table VI.10-7 presents the contaminant distributions used for each of the six analytes and four areas included in this VLEACH modeling effort.

Table IV.10-6. Chemical-Specific Characteristics for Each Contaminant Included in the VLEACH Model

Contaminant of Concern	Assumed* Chemical Speciation	References	Da cm2/sec	Log Koc ml/g	Kd ml/g	Henry's Constant atm*m3/mol	Solubility mg/l
Americium−241	hydroxide and chloride	EPA 520/6−78−007B Micromedix, Inc., 1994	0		115.8 − 8700	0	0.0024
Uranium−235	hydroxide and carbonato	Hsi, 1981 Micromedix, Inc., 1994	0		20 − 270	0	329
2,6−dinitrotoluene	2,6−dinitrotoluene	EPA 520/6−78−007B Micromedix, Inc., 1994	0.0682	1.79		0.0000079	300
Pentachlorophenol	Pentachlorophenol	EPA 520/6−78−007B Micromedix, Inc., 1994	0.0592	2.96		0.0000034	25
Barium	hydroxide and chloride	EPA 520/6−78−007B Micromedix, Inc., 1994	0		150 − 300	0	310000
Beryllium	hydroxide and chloride	EPA 520/6−78−007B Micromedix, Inc., 1994	0		175 − 250	0	200

* Selected most common chemical species for each contaminant of concern based on site conditions and available literature.

Table IV.10-7. Conservative Contaminant Distributions, by Area, by Cell

Area 1												
Cell Depth	Barium (mg/kg)	Reporting Location	Beryllium (mg/kg)	Reporting Location	Am-241 (pCi/g)	Reporting Location	U-235 (pCi/g)	Reporting Location	2,6-DNT (ug/kg)	Reporting Location	Pentachlorophenol (ug/kg)	Reporting Location
0 – 3" bgs	238	SS400793	3.6	43793	110	43793	0.53	43793	0		0	
3" – 1' bgs	270	42493	5.6	P210289	6.1	43793	0.54	43793	330	3887	1600	3887
1' – 2' bgs	270	42493	5.6	P210289	6.1	43793	0.54	43793	330	3887	1600	3887

Area 2												
Cell Depth	Barium (mg/kg)	Reporting Location	Beryllium (mg/kg)	Reporting Location	Am-241 (pCi/g)	Reporting Location	U-235 (pCi/g)	Reporting Location	2,6-DNT (ug/kg)	Reporting Location	Pentachlorophenol (ug/kg)	Reporting Location
0 – 3" bgs	80.7	42393	1.1	42993	2.132	SS401693	0.17	42393	0		0	
3" – 1' bgs	228	P210189	4	P209189	4	43593	0.1	43593	0		0	
1' – 2' bgs	228	P210189	4	P209189	4	43593	0.1	43593	0		0	
2' – 3' bgs	228	P210189	4	P209189	4	43593	0.1	43593	0		0	
3' – 4' bgs	109	43593	4.5	P209189	4	43593	0.3	P210189	0		0	
4' – 5' bgs	109	43593	4.5	P209189	4	43593	0.3	P210189	0		0	
5' – 6' bgs	113.99	SP0187	4.5	P209189	4	43593	0.3	P210189	0		0	

Area 3												
Cell Depth	Barium (mg/kg)	Reporting Location	Beryllium (mg/kg)	Reporting Location	Am-241 (pCi/g)	Reporting Location	U-235 (pCi/g)	Reporting Location	2,6-DNT (ug/kg)	Reporting Location	Pentachlorophenol (ug/kg)	Reporting Location
0 – 3" bgs	393	41693	9.6	SS402893	12	41693	0.25	40993	400	40893	1900	40893
3" – 1' bgs	761	P208989	3.5	P209589	2.7	41693	0.87	42193	0		1600	3987
1' – 2' bgs	160	40793	3.5	P209589	2.7	41693	0.87	42193	0		1600	3987

Area 4												
Cell Depth	Barium (mg/kg)	Reporting Location	Beryllium (mg/kg)	Reporting Location	Am-241 (pCi/g)	Reporting Location	U-235 (pCi/g)	Reporting Location	2,6-DNT (ug/kg)	Reporting Location	Pentachlorophenol (ug/kg)	Reporting Location
0 – 3" bgs	156	SS402593	1.4	SS401193	0.0363	SS402593	0.0643	SS401193	0		0	
3" – 1' bgs	0		0		0		0		0		0	
1' – 2' bgs	0		0		0		0		0		0	
2' – 3' bgs	0		0		0		0		0		0	
3' – 4' bgs	0		0		0		0		0		0	
4' – 5' bgs	0		0		0		0		0		0	
5' – 6' bgs	0		0		0		0		0		0	
6' – 7' bgs	0		0		0		0		0		0	
7' – 8' bgs	0		0		0		0		0		0	
8' – 9' bgs	0		0		0		0		0		0	
9' – 10' bgs	0		0		0		0		0		0	

Selected Saturated Solute Transport Model

Results from VLEACH simulation runs demonstrate whether significant concentrations of modeled contaminants are capable of leaching from contaminated, unsaturated soils and to what degree natural attenuation processes effectively preclude downward migration into the ground water. If any one modeled contaminant reaches the ground water in measurable concentrations, however, the governing transport equations used to mathematically describe the fate and transport of an analyte must be modified for use in fully saturated environments. MYGRT (version 2.0) simulates two-dimensional ground water and solute transport under the influence of advective, dispersive, and attenuation (i.e., retardation and decay) processes within a steady-state flow field. Ground water was assumed to flow under porous conditions; the potential effects of fracture flow were not considered.

This numerical model was configured to estimate the concentration of each contaminant at the POC by using the model leachate output from VLEACH as the initial source concentration for MYGRT. Conservative values and assumptions were used to model a potential leachate release from overlying unsaturated soils and transport via groundwater to the POC. Concentration values for each modeled contaminant were also calculated at various times for two other locations: 70 feet north of the SEPs at the downhill seep line and 650 feet north of the SEPs to the closest point at North Walnut Creek. These additional points were evaluated as they likely represent the first locations where potentially contaminanted ground water may come into contact with another media (surface water) and/or be accessible for future receptor contact. Note, however, that potential risks due to exposure to contamination at these areas is not included in the scope of the IM/IRA. Such information is presented to quantitatively and qualitatively investigate foreseeable impacts to surrounding environmental resources only.

Governing Transport Equations

MYGRT was designed to simulate the fate and transport of organic or inorganic solutes in ground water downgradient of a source based on the partial differential equation describing two-dimensional advection-dispersion-decay-adsorption equation:

$$D_{xx}\frac{\partial^2 C}{\partial x^2}+D_{yy}\frac{\partial^2 C}{\partial y^2}-\bar{v}\frac{\partial C}{\partial x}-\lambda RC=R\frac{\partial C}{\partial x}$$

This partial differential equation has been numerically approximated by the MYGRT code. Readers interested in the numerical solution and associated boundary conditions are encouraged to consult the MYGRT user manual. In brief, however, the transport equations in the MYGRT code are built upon the assumptions that the ground water flow velocity remains constant over the modeled area and that dispersion is adequately represented by Fick's Law. As with VLEACH, MYGRT models adsorption as a linear equilibrium partitioning relationship

between aqueous and solid phases. Retardation (R) is used as a measure of the partitioning between liquid and solid phases. Retardation is incorporated into the numerical solution using the following expression:

$$R = (1 + \frac{1-\theta}{\theta} \rho_b K_D)$$

where all variables are as defined previously.

The behavior of the contaminants in the ground water was modeled as a continuous leachate source the size of the model area under investigation. MYGRT was used to calculate the contaminant concentration in the aquifer by mixing the upgradient ground water with the leachate simulated using VLEACH based on its flux and composition.

Physical Input Parameters for MYGRT

To investigate potential impacts of contaminants leaching from surficial and vadose soil on ground water quality, a simple conceptual site model describing ground water flow was developed. The parameters used in the MYGRT model simulations are summarized in Table IV.10-8. The mean saturated ground water velocity of 21.8 ft/yr (6.64 m/yr) as reported in the RCRA Groundwater Monitoring Report for OU4 was used in solute transport simulations. The direction of ground water flow across the entire modeled area was assumed to be in the northeastern direction toward the North Walnut Creek. Although this is likely an oversimplification of the hydrogeology at the site, it should yield conservative results. Horizontal and transverse dispersion values were conservatively estimated.

Chemical Input Parameters for MYGRT

The only chemical-specific parameters required by MYGRT are initial source concentration and the chemical-specific retardation coefficient (R). The initial source concentrations for each contaminant are presented as the results of the VLEACH model. A retardation coefficient was not included in the MYGRT code for this analysis as a worst-case, upper bound estimate of potential impact on ground water quality at the POC.

<u>VLEACH/MYGRT Model Results</u>

Tables IV.10-9 and IV.10-10 summarize the predicted concentration of leachate generated both cumulatively and by individual Area as water infiltrates unsaturated soils and mobilizes soil contaminants under both the preferred IM/IRA and no action alternative. Tables IV.10-9 and IV.10-10 also present the expected cumulative and Area-specific maximum concentration of each contaminant at the POC, respectively, as computed using MYGRT. As expected, the radionuclides and metals are generally immobile and do not migrate readily through the

Table IV.10-8. Summary of Site-Specific MYGRT Input Parameters

Parameter	Value
Groundwater velocity (m/yr)	6.64
Horixontal dispersion (m/yr)	0.996
Transverse dispersion (m/yr)	0.329
Source width (m)	129.5
Source area (sq. m)	27400
Infiltration rate (m/yr)	0.3
Effective porosity	0.361
Depth of mixed water (m)	5.18 – 6.71
Time leachate starts (yr)	0
Time leachate ends (yr)	0.25
Average distance to POC (m)	211.6
Average distance to seep (m)	232.9
Average distance to creek (m)	409.7

Table IV.10-9. VLEACH/MYGRT Model Results: Site Wide

Contaminant	Initial Annual Leachate Concentration		Comparison Criteria
	No Action	Engineered Cover	
Barium (mg/l)	0.15 – 0.18	0.06 – 0.14	1
Beryllium (mg/l)	0.0022 – 0.0027	0.00098 – 0.0012	0.004
2,6–dinitrotoluene (ug/l)*	9.53 – 9.67	0.947 – 1.19	0.125(a)
Pentachlorophenol (ug/l)*	20 – 22.7	4.65 – 5.36	1
Americium–241 (pCi/l)	4.05E–10 – 5.11E–10	5.79E–11 – 7.38E–11	0.05
Uranium–235 (pCi/l)	8.43E–10 – 9.78E–10	2.39E–10 – 2.9E–10	10

(a) = risk–based preliminary remediation goal (PRG) for residential ingestion of water calculated from carcinogenic slope factors.

* = maximum contaminant concentrations based almost exclusively on pre–Phase I RFI/RI characterization data.

*NOTE: A range of leachate concentrations is provided based upon the modeled hydraulic conductivity of the unsaturated soils. The minimum value shown is attributed to a hydraulic conductivity (K) of 0.103 ft/yr, and the maximum value results from a K of 1034.7 ft/yr. K for Area 1 under the Hakonson Liner and the Asphalt Layer Liner was defined by the HELP model sensitivity results.

Table IV.10-10. VLEACH/MYGRT Model Results: By Model Area

Contaminant	Comparison Criteria	Area 1 Annual Leachate Concentration No Action	Area 1 Annual Leachate Concentration Engineered Cover	Area 2 Annual Leachate Concentration No Action	Area 2 Annual Leachate Concentration Engineered Cover
Barium (mg/l)	1	0.19 – 0.22	0.0009 – 0.0026	0.26 – 0.39	0.26 – 0.4
Beryllium (mg/l)	0.004	0.0039 – 0.0045	0.00002 – 0.000055	0.0073 – 0.0104	0.0072 – 0.01
2,6–dinitrotoluene (ug/l)*	0.125(a)	37.9 – 38.3	0.525 – 1.5	0 – 0	0 – 0
Pentachlorophenol (ug/l)*	1	42.6 – 47.7	0.243 – 0.72	0 – 0	0 – 0
Americium–241 (pCi/l)	0.05	1.37E–9 – 1.71E–9	2.17E–12 – 6.42E–12	7.26E–10 – 1.05E–9	3.7E–10 – 5.32E–10
Uranium–235 (pCi/l)	10	1.31E–9 – 1.5E–9	9.77E–12 – 2.89E–11	1.32E–9 – 1.77E–9	1.25E–9 – 1.66E–9

Contaminant	Comparison Criteria	Area 3 Annual Leachate Concentration No Action	Area 3 Annual Leachate Concentration Engineered Cover	Area 4 Annual Leachate Concentration No Action	Area 4 Annual Leachate Concentration Engineered Cover
Barium (mg/l)	1	0.29 – 0.34	0.29 – 0.34	0.06 – 0.065	0.06 – 0.065
Beryllium (mg/l)	0.004	0.003 – 0.0036	0.002 – 0.0026	0.0005 – 0.00059	0.000006 – 0.0000062
2,6–dinitrotoluene (ug/l)*	0.125(a)	6.46 – 6.65	3.7 – 3.8	0 – 0	0 – 0
Pentachlorophenol (ug/l)*	1	49 – 55.8	20 – 23.2	0 – 0	0 – 0
Americium–241 (pCi/l)	0.05	3.0E–10 – 3.45E–10	1.45E–10 – 1.64E–10	1.5E–12 – 1.63E–12	1.50E–12 – 1.63E–12
Uranium–235 (pCi/l)	10	1.94E–9 – 2.2E–9	6.25E–10 – 7.09E–10	8.29E–11 – 8.96E–11	3.16E–11 – 3.44E–11

(a) = risk–based preliminary remediation goal (PRG) for residential ingestion of water calculated from carcinogenic slope factors.

* = maximum contaminant concentrations based almost exclusively on pre–Phase I RFI/RI characterization data.

*NOTE: A range of leachate concentrations is provided based upon the modeled hydraulic conductivity of the unsaturated soils.

The minimum value shown is attributed to a hydraulic conductivity (K) of 0.103 ft/yr, and the maximum value results from a K of 1034.7 ft/yr.

K for Area 1 under the Hakonson Liner and the Asphalt Layer Liner was defined by the HELP model sensitivity results.

unsaturated soils at OU4. Metals and radionuclides are usually strongly adsorbed by soil material, unless the chemistry of the pore water significantly alters migration behavior (e.g., significant concentrations of complexing chemicals which bind to the radionuclides and/or metals to form a compound that is much more mobile). A range of leachate concentration was computed using the range of K_D values found in the technical literature and the range of potential infiltration rates expected under both the no action alternative and the preferred IM/IRA. For metals and radionuclides, even the most concentrated leachate estimate is orders of magnitude lower than potential ground water protection standards. Potential ground water protection standards are presented for comparison purposes only. No attempt has yet been made to define appropriate ground water protection standards for OU4.

Note, however, that the organic contaminants migrate more readily through the unsaturated soils than the radionuclide and metal contaminants. Such behavior is consistent with the chemical characteristics of these contaminants. Organic contaminants are likely to be more mobile than metals and radionuclides, especially in soils with characteristically low fractional organic carbon content. These analytes were included in the modeling effort to provide an extremely conservative estimate of potential ground water impacts. Although these contaminants were only measured in OU4 soil samples during pre-RFI/RI sampling programs, they were included in the risk analysis efforts described in Section III.2.2 to ensure the development of conservative risk-based PRGs for surficial soil and vadose zone soil. It is not clear whether these organic contaminants actually represent measurable site contamination since they were not detected under the recent RFI/RI program or whether their presence is the result of early analytical and data management problems. In any event, several organic contaminants were included in both risk analysis and modeling activities to provide a conservative, upper-bound estimate of potential risks due to exposure to site contamination and further contaminant migration.

In conclusion, results from this quantitative evaluation demonstrate that there is little potential for significant leaching of contaminants from unsaturated soils into the ground water under both the preferred IM/IRA and the no action alternative. Comparison of the simulated concentrations at the POC with potential ground water protection standards show that both the no action alternative and the IM/IRA will not likely cause an incremental, significant impact on ground water quality due to downward leaching. Further, contaminant concentrations decrease significantly at distance from the source. Thus, these analyses also suggest that downward leaching of contaminants also pose negligible risk to downgradient surface water bodies, such as the seep line and North Walnut Creek. Uncertainties inherent in using single-point values to describe physical site conditions and chemical characteristics are discussed following results from the catastrophic dissolution/MYGRT model.

Catastrophic Dissolution Potential

The purpose of modeling potential catastrophic dissolution of immobile contaminants was to determine whether contaminated soils left in place under the subsurface drainage layer beneath the engineered cover could present a threat to ground water quality should the ground water rise

to contact these currently unsaturated soils. Data from the engineered cover performance assessment using the HELP model (described in Section IV.3.1.1) were incorporated into the leaching model to evaluate the expected effectiveness of the proposed cover in minimizing infiltration and further contaminant migration.

Catastrophic Dissolution Calculation

The conceptual design for the preferred IM/IRA includes using contaminated soil material to construct an artifical vadose zone beneath the subsurface drainage layer to stabilize the area for the engineered cover. Although these contaminated soils will be isolated from direct contact and significant infiltration (as shown by the HELP/VLEACH models) by the engineered cover, these deeper soils could foreseeably become saturated should the ground water rise above the historic high piezometric surface. Further, the risk-based PRGs were developed as target long-term concentration goals that should minimize risks due to exposure to site contamination via several upward routes (i.e., direct contact, inhalation of contaminated particulates, and incidental ingestion of contaminated soil material). These PRGs were not originally developed to be protective of ground water quality under hypothetical potential future scenarios, such as a rise in ground water elevation. Thus, a very conservative method was developed to test whether contaminanted soils left in place would contribute significantly to the degradation of ground water quality if immobilized contaminants were instantaneously released from the solid soil matrix.

Potential "worst case" leachate concentrations were computed by assuming that all contaminant mass to be left in place beneath the subsurface drainage layer of the engineered cover dissolved instantaneously into the pore water of the newly saturated soil zone. Contaminant mass estimates were developed using available site characterization data (see Section III.2.1) and preliminary engineering excavation and relocation estimates (see Section IV.1.1). Actual contaminant concentrations by area and depth were used to compute the total mass of contaminants in the soils beneath the subsurface drainage layer. Note that only seven radionuclide and metal contaminants were measured above detection limits in these soil materials. Two different soil zones were identified during this calculation: (1) deep soils that are not currently saturated and are not included in the preliminary excavation plans, and (2) shallow soils that include the soil materials used to construct the artificial vadose zone beneath the subsurface drainage layer. An estimate of the pore water volume was based on an effective, saturated porosity of 0.361 (as reported by the RFI/RI program). Table IV.10-11 presents the contaminant mass estimates available for dissolution for both shallow and deeper soils.

Leachate concentrations were computed by instantaneously dissolving the entire mass of contaminants into the available pore water. These concentrations are compared with maximum solubility limits for each analyte for illustrative purposes. Although none of the calculated leachate concentrations exceed maximum solubility limits, it is important to recognize that these leachate concentrations likely represent an upper-bound estimate. Instantaneous dissolution of all available contaminant mass is an extremely conservative assumption. Table IV.10-11 summarizes these leachate concentration results.

Table IV.10-11. Summary of Contaminant Mass and Leachate Concentration Estimates Used in Catastrophic Dissolution Calculation

Contaminant of Concern (COC)	Mass in Lower Undisturbed Soil (pCi/ft or mg/ft)	Mass in Upper Undisturbed Soil (pCi/ft or mg/ft)	Mass in Artificial Vadose Zone Soil (pCi/ft or mg/ft)	Leachate Conc from Deeper Soils (pCi/L or mg/L)	Leachate Conc from Upper Soils (pCi/L or mg/L)	Maximum Solubility (pCi/L or mg/L)
Radionuclides						
Americium−241	8.77E+08	8.77E+09	2.98E+10	290.9	12807.7	8.27E+06
Plutonium−239/240	1.08E+09	1.46E+10	2.47E+10	359.4	13028.4	3.57E+05
Uranium−235	1.08E+09	4.52E+08	5.05E+09	357.1	1826.0	5.07E+05
Metals						
Barium	1.34E+09	5.64E+08	7.79E+08	445.6	445.6	3.10E+05
Cadmium	3.15E+08	1.32E+08	1.19E+09	104.4	439.3	3.26E+06
Chromium	3.18E+08	1.34E+08	1.85E+08	105.5	105.5	1.50E+05
Mercury	5.85E+06	2.45E+06	6.30E+07	1.9	21.7	4.80E+05

Selected Saturated Solute Transport Model

Once catastrophic leachate concentrations were computed for each contaminant, the two-dimensional fate and transport model MYGRT was used to simulate the effects of advection, dispersion, and adsorption on the contaminant mass as it travels to the POC. The physical input parameters presented in Table IV.10-8 were used to estimate contaminant concentrations at the three locations described earlier (i.e., POC, seep line, and North Walnut Creek). Because of the uncertainty associated with K_D values, the catastrophic fate and transport model employed very conservative chemical-specific retardation coefficients (R). Retardation was estimated by assuming a K_D that was 10 percent of the smallest K_D in the identified range. For example, the most conservative K_D value identified for uranium-235 was 20 L/Kg. The calculated R value using this K_D value would be 73.92, which means that uranium-235 would migrate relatively slowly in the ground water toward the POC. However, in the interest of developing a "worst case" estimate of potential contaminant concentrations at the POC as a result of dissolving currently immobile contaminants into the ground water, the R value used for uranium-235 was decreased to 7.35 (an order of magnitude less than suggested by available K_D values). A smaller R value would limit the influence of adsorption processes on the fate and transport estimates.

Although these conservative values should preclude discussions regarding the appropriateness of any one specific and larger K_D value, it is possible that these conservative retardation estimates may still overestimate the influence of adsorption on contaminant migration. Efforts are currently underway to determine whether these values are representative of site conditions using historic data on liquid wastes stored in the SEPs and ground water monitoring data. These efforts and other uncertainties associated with these fate and transport calculations are discussed at the end of this section.

Catastrophic Dissolution/MYGRT Results

Table IV.10-12 summarizes the contaminant concentrations expected at and the travel time following saturation of these soils to the POC. In many instances, no contamination migrates to the POC after 1,000 years from the time of release even using conservative model input parameters. Contaminant concentrations at the POC are compared to potential ground water protection standards for illustrative purposes only. In brief, all contaminants introduced by catastrophic dissolution are expected to be present at concentration levels less than potential comparison criteria. These simulated results are not unexpected given the hydrogeology and properties of the soil and soil contaminants at OU4. The contaminants measured in surficial soil and vadose zone soil that are the focus of this IM/IRA program have been naturally attenuated by soils at OU4 during the years that the SEPs were in use. The model suggests that remobilization of these contaminants, even under saturated conditions, is not likely to contribute significantly to the degradation of ground water quality. Although uranium-235 appears to slightly exceed the potential ground water comparison criteria, this result is directly attributable to the extremely conservative assumptions built into the catastrophic dissolution approach. Instantaneous dissolution of all uranium-235 contained in shallow soils and extremely limited adsorption are very conservative (even unrealistic) scenarios.

Table IV.10-12. Catastrophic Dissolution/MYGRT Model Results

Contaminant of Concern (COC)	Max. Conc. at POC: Deeper Soils (pCi/L or mg/L)	Max. Conc. at POC: Deeper Soils Time (years)	Max. Conc. at POC: Shallow Soils (pCi/L or mg/L)	Max. Conc. at POC: Shallow Soils Time (years)	Comparison Criteria
Radionuclides					
Americium−241	0.002	1000	6.55E−06	989	0.05 pCi/L
Plutonium−239/240	0.345	1000	6.52E−06	1000	15 pCi/L
Uranium−235	3.180	161	1.17E+01	242	10 pCi/L
Metals					
Barium	0.000	1000	0.000	1000	1 mg/L
Cadmium	0.000	1000	0.000	1000	0.005 mg/L
Chromium	0.000	1000	0.000	1000	0.1 mg/L
Mercury	0.000	1000	0.000	1000	0.002 mg/L

Uncertainties Analysis

All fate and transport calculations require simplifying assumptions about site characteristics and chemical properties. It is impossible to exactly simulate actual fate and transport mechanisms, which are characteristically complex at most sites. A rudimentary sensitivity analyses on the MYGRT code using both OU4 leachate sources described above demonstrated that the model results are affected by the chemical-specific retardation value. In the absence of site-specific K_D values, the technical literature and historic site characterization data were reviewed to identify a range of potential retardation values for each contaminant. Although the model results presented herein were developed using extremely conservative assumptions and estimates, efforts are currently underway to verify that natural attenuation of metal and radionuclide species has and is occurring at OU4. Liquid pond waste data is currently being compared to downgradient well data to determine the source and nature of contamination migration at the site. Geochemical analyses of these two solutions can be used to empirically show that metal- and radionuclide-containing waste from the SEPs have been effectively retarded, even under saturated conditions. Once these data are available, these model results will be reviewed to determine whether appropriate assumptions were used. Fate and transport model results will be revised accordingly, as appropriate.

IV.10.5 Impact from the Commitment of Irreversible and Irretrievable Resources

Pursuant to the DOE NEPA regulations regulations (10 CFR 1021) requiring discussion of irreversible and irretrievable commitments of resources, the preferred IM/IRA would not be expected to result in substantial loss of valuable resources. However, all of the materials for the construction of the engineered cover will be irrevocably and irretrievably committed to the implementation of the remedial action. Energy resources consumed during the construction period would also be irretrievable but small compared to consumption due to daily activities at the RFP.

There appear to be no commercially exploitable metallic mineral resources in the RFP security zone (FEIS RFP, 1980). Unmined uranium reserves (from the Schwartzwalder uranium mine) are located 4 miles southwest of the RFP but future mining operations would not be impacted by RFP remedial activities.

Other resources that have been developed in the vicinity of the RFP, such as sand, gravel, crushed rock, and coal, would not be expected to be impacted by the preferred IM/IRA action due to the small area involved (less than 30 acres). Quarrying operations (sand, gravel, and crushed rock) do exist locally, some even in the RFP buffer zone; but, with the estimated millions of cubic yards of unmined sand and gravel available in the Golden quadrangle there is little potential for the OU4 IM/IRA action negatively impacting the industry (FEIS RFP, 1980). Although coal was mined historically in the area between Golden and Boulder, no mining has occurred since 1950. For the same reasons as discussed previously, it is likely coal mining would not be impacted by the IM/IRA.

Implementation of the preferred IM/IRA will however limit potential future land use options. Due to the constructed cover and monitoring well requirements, commercial, industrial, and residential land use will be permanently prohibited on the engineered cover. It is assumed that grading and reseeding of the OU4 area will result in an acceptable appearance of the remediated site, consistent with adjacent lands. Reseeding may promote normal ecological succession in the vicinity of the SEPs.

The no action alternative would not be expected to negatively impact energy or mineral resources. Under the no action alternative it is reasonable to assume SEP land would continue to have no substantial ecological, economical, or recreational use. Land within OU4 but outside the SEPs IHHS is currently undeveloped and will remain so for the foreseeable future as part of the RFP. The ecosystem in the SEPs area has been greatly disturbed over the past several decades and would remain inaccessible to most regional indigenous plant and wildlife species. In addition to the plant species being disturbed by physical stressors, the vegetation at the RFP has been historically suppressed via routine herbicide treatments. Generally, only first-succession plant species are present in the SEPs area.

IV.10.6 Transportation Impacts

Implementation of the preferred IM/IRA action would be expected to cause minor direct and indirect impacts to the transportation system, both in and around the RFP. Shipments of construction materials are anticipated to be made entirely by trucks. Therefore, it is reasonable to assume that traffic on the state, county, and RFP roads may experience relatively minor delays due to this increase in construction materials, supplies, workers, and equipment entering and exiting the facility. These off-site transportation impacts would be less severe under the preferred IM/IRA alternative in comparison to other potentially reasonable alternatives as there is no required removal of contaminated materials to areas outside the RFP for disposal.

IV.10.6.1 Offsite Impacts

Impact on the highways surrounding the RFP is anticipated to be minimal. State Highway 93 will be the thoroughfare used by construction delivery trucks. The vehicles will enter and exit at the west gate of the RFP located off Highway 93. The Colorado Department of Transportation (CDOT) 1992 traffic data shows that between State Highway 128 to the north of the RFP and Cheyenne Street in Golden to the south of the RFP, an average of 215 combined unit trucks (i.e., tractor/trailer vehicles, etc.) were counted on Highway 93 per day (1993, CDOT). Total vehicle traffic for this section of Highway 93 averaged 13,700 ADT, therefore combined unit (c.u.) trucks accounted for 1.6% of total traffic. Based on a conservative estimate, the IM/IRA would result in a maximum increase of 60 c.u. trucks per day for this highway (120 c.u. counts) translating to c.u. trucks accounting for 2.4% of total traffic. Assuming 1992 traffic statistics are adequate estimates for the IM/IRA startup, the conservative number of 60 vehicles spread over 10 hours (avoiding delivery during peak rush-hours) would not be expected to have a noticeable impact on local transportation infrastructure. Informal discussions with CDOT resulted in the same conclusion (CDOT, 1994). In addition, the traffic

lights at the west gate and the state highway 93/72 intersection and the left and right turn lanes into the RFP will further mitigate potential adverse impacts to traffic (1994, DRCOG).

IV.10.6.2 On-site impacts

It is expected that the impact of the increased traffic at the RFP would be small. The approximately 10,000 truck loads (at 18 cubic yard payloads) of material required for cover construction and backfill activities will be delivered over a 12 to 18 month period. During the most intense delivery periods, a maximum of 6 trucks per hour (ten hours per day) will unload at an area adjacent to OU4. These deliveries would occur ahead of construction needs for each cover layer; logistical issues will be addressed as appropriate. Such issues include coordination of activities and deliveries of materials with other RFP projects to minimize delays and traffic congestion on site. Deliveries would not be expected to be allowed during peak rush-hours in the mornings and evenings thereby avoiding disruption to traffic flow during heaviest volumes.

The security gates and the RFP roads within or adjacent to OU4 would receive the greatest direct impacts from the preferred IM/IRA. The relatively concentrated area of truck operations and the time required to clear security procedures account for the expected site congestion and delays. The time required for a single truck to enter the RFP, deliver its load, and exit the facility will be greatly reduced by a proposed modification to the site security system that will allow for easier access than currently exists. A proposed separate construction vehicle access point will reduce impacts to on site traffic flow in that construction vehicles will stay off main site roadways to access the proposed construction gate. The most dramatic increase in usage may occur on the dirt road west of SEP 207-C, the access road east and northeast of the SEPs, and the paved road south of the SEPs.

Human health impacts normally incident to transportation include possible traumatic injuries and fatalities resulting from vehicular operations in addition to vehicle emissions (DOE, 1991, OU4 dewatering E.A.). Rao et al. (1982) estimated risks resulting from truck transportation based on nationwide Department of Transportation (DOT) statistics. The accident-related risk estimates were average values that accounted for traffic differences between urban, suburban, and rural areas (DOE, 1991). Using the risk estimate for trucking accidents (4.83E-8 per mile) (Rao, 1982) approximately 210,000 truck shipments (one-way distance of 50 miles) would be required to result in one additional traumatic fatality. This value provides a reasonable reference point to assess IM/IRA transportation impacts since it is anticipated that the materials for the engineered cover construction will be obtained from quarries within a 50-mile radius of the RFP, and will be delivered by trucks. Comparing this value to the projected 10,000 or fewer truckloads of construction material required to implement the preferred IM/IRA, human health impacts due to traffic accidents would not be expected.

Dust resuspension due to the increased traffic on OU4 roads, especially the dirt road to the east of Pond 207-C, could also result in the potential for short-term adverse health effects to the workers. These temporary impacts to human health could result from the inhalation or ingestion of the dust particulates (i.e., respiratory distress). These potential negative impacts

could be mitigated through dust suppression techniques (frequent watering of the roads, etc.), erosion protection, air monitoring, and personnel protection measures. Long-term health impacts resulting from inhalation of contaminated particulates have been indirectly assessed in the PRG calculations for OU4 (see Section IV.10.1). As previously mentioned, the engineered cover would result in long-term beneficial impacts to human health by eliminating significant exposure pathways. The no action alternative would not require shipments of construction materials and so would result in no noticeable increase in traffic.

IV.10.7 Short-Term Versus Long-Term Impacts

The environmental restoration of the OU4 area could result in short-term degradation of habitats of topsoil borrow sites. Required removal of clean fill is expected to be less than 60,000 cubic yards. This potential can be mitigated as it is expected that clean fill material will be procured from commercial mining/quarrying sites that hold the proper permits. It is anticipated that the material would be removed in a manner that would minimize long-term impacts by such procedures as:

- Excavating only above the ground water table to avoid affecting ground water;
- Grading and revegetating borrow areas to be consistent in appearance with adjacent lands;
- Avoiding excavation in sensitive areas such as wetlands, flood plains, and areas that potentially provide habitat to threatened or endangered or other species of concern; and
- Locating stockpiles of construction materials and clean fill in areas void of vegetation and wildlife. These areas will include the SEPs themselves and disturbed vacant lots to the east of the SEPs.

SEP habitat is essentially nonexistent due to the extensive industrial activity in the area over the last 20 years.

In the long-term, the preferred IM/IRA action for the OU4 area would be expected to have a positive impact on the local hydrology, vegetation, and wildlife by eliminating industrial disturbance.

As discussed in the previous media quality impact sections, the no action alternative will not remove or isolate the contamination source and consequently will not limit the potential for adverse human health or environmental risks. It is reasonable to assume that in the short and long-term, degradation of the environment will continue and acceptable cleanup levels will be more difficult to achieve in the future.

IV.10.8 Impact to Cultural/Historical and Archeological Resources

The proposed actions would have no impact on archaeological and/or historic resources. Recent resource cultural surveys have revealed that no sites found on the 5,900-acre RFP are eligible for National Register of Historic Places designation (Burney and Associates, 1988 & EG&G 1992). The State Office of Archaeology and Historic Preservation has concluded that the areas within the 384-acre security-fenced zone of the RFP are so highly disturbed that little cultural resource information would be available (DOE, 1991, Dewar. EA).

IV.10.9 Cumulative Impacts

Cumulative impacts are the result of the accumulation of incremental effects of past, present, and reasonably foreseeable future actions. These impacts must be considered because minor impacts from specific projects may, when collectively considered, result in substantial effects to the environment.

At present, there are no other activities scheduled for the OU4 area that would be expected to cause significant impacts to the area. Ongoing and anticipated hydrogeological characterization activities will be limited to short term sampling events. It is assumed that construction activities at various OUs in the RFP will continue in the future. However, these actions are not all likely to overlap due to the lengthy process of project design, approval, and implementation. Therefore, short-term future cumulative effects would not be substantial. Long-term cumulative impacts, i.e., IM/IRA action in conjunction with other site restoration activities, will facilitate future beneficial use of the RFP land and fulfill mandated cleanup objectives.

Regarding past and present actions, the IM/IRA alternative would result in cumulative impacts to ground water, surface water, air quality, vegetation, wildlife, land use, and transportation in and immediately around the OU4 area. However, these impacts would be small or immeasurable, and in many cases favorable to the current OU4 situation when viewed over the long term.

It is anticipated that the no action alternative would result in continued risk of adverse impacts to the environment; contaminated soils would remain exposed to the elements. These soils may then contribute to contamination of the ground water, air, and surface water.

IV.10.10 Comparison of the Preferred IM/IRA to the No Action Alternative

The potential adverse and beneficial impacts of the two alternatives are expected to be significantly different in both the magnitude and degree to which they affect the quality of the human environment. Implementation of the preferred IM/IRA is not expected to have any substantial adverse impacts to human health or the environment and is consistent with long-term remediation goals for the RFP. In the instances where potentially small impacts may occur, appropriate mitigation measures may be employed.

The no action alternative could have potentially adverse impacts to both human health and the environment by allowing media concentrations of contaminants to exceed protective, risk-based levels. Contaminants would remain available to migrate (via air, groundwater, surface water, or possibly biota) and thus potentially allow for direct or indirect receptor exposure and intake. A comparison of how the two alternatives could impact human health and the environment is presented below in Table IV.10.13.

IV.11 Regulatory Requirements

According to Part 18 of the IAG, portions of the response actions called for and conducted entirely within the boundaries of the RFP are exempt from the procedural requirement to obtain federal, state, or local permits. This permit exemption is intended to avoid delay of the onsite response actions due to procedural requirements of the permit process. Although this provision exempts the need for new permits to execute the IM/IRA, Part 11 of the IAG and Section XV of the IAG Scope of Work require that all units used to treat, store, or dispose of hazardous and/or mixed waste are subject to the substantive and procedural requirements of the CHWA including permitting requirements. In addition to the CHWA permit/closure requirements, the DOE must identify the permits which would otherwise be required, identify the associated permitting requirements, and explain how the IM/IRA will comply with these identified requirements.

This section is intended to identify the regulatory requirements associated with the IM/IRA in accordance with the above IAG provisions and to demonstrate compliance with these regulatory requirements. Subsection IV.11.1 provides a list of the permits that would be required of implementation of the preferred IM/IRA. Subsection IV.11.2 describes how the preferred IM/IRA will comply with the ARARs, including the substantive permitting requirements, identified in Part III.5.2. Subsections IV.11.3 and IV.11.4 provide additional details describing ARAR compliance for the State of Colorado Requirements for Siting Hazardous Waste Disposal Sites (6 CCR 1007-2, Part 2) and the proposed regulations for Corrective Action Management Unit (CAMU) designations (6 CCR 1007-3, 264.552), respectively. Subsection IV.11.5 presents a discussion of the consistency of the proposed remedial action with potential final remedies.

TABLE IV.10.13

SUMMARY OF POTENTIAL IMPACTS: PREFERRED IM/IRA VERSUS NO ACTION

Impact	Preferred IM/IRA	No Action
Human Health	Minimize or eliminate existing risks due to long-term potential exposure to surficial soil and vadose zone soil contamination Short-term risks due to worker exposure to soil materials that exceed PRGs during remediation Potential adverse effects to workers as a result of encountering unknown utilities or uncharacterized areas of high contamination Risks to workers associated with soil excavation, relocation, and construction activities (e.g., increased fugitive dust generation, increased transportation requirements)	Failure to achieve PRGs that are protective of human health Short-term risks due to exposure to site contamination during grading and reseeding activities Potential adverse effects to workers as a result of encountering unknown utilities or uncharacterized areas of high contamination Risks to workers associated with grading (e.g., increased fugitive dust generation, increased vehicular use)
Environment	Temporary physical disruption of industrial area during construction of engineered barrier; more than 27 acres affected by soil excavation, material staging, and construction activities Temporary physical disruption of borrow area used for clean fill material Increase in local traffic requirements, increased dust generation during construction, and increased potential for erosion due to changes in surface topography at both OU4 and borrow area No wetlands, floodplains, critical habitats, or threatened and endangered species will be affected	Physical disruption of industrial area during regrading activities Remaining uncontrolled contaminants could negatively affect colonizing vegetation and wildlife and impact receiving surface water and ground water No wetlands, floodplains, critical habitats, or threatened and endangered species will be affected

TABLE IV.10.13

SUMMARY OF POTENTIAL IMPACTS: PREFERRED IM/IRA VERSUS NO ACTION

Air Quality	Atmospheric dispersion calculations demonstrate no risk due to exposure to site contaminants to remediation workers, on-site workers, or the public during soil excavation and construction activities Potential increase in PM_{10} emissions at both OU4 and borrow areas during construction	Failure to achieve PRGs which include inhalation of contaminanted particulates Potential increase in PM_{10} emissions at industrial area during regrading activities
Groundwater Quality	Negligible downward migration of site contaminants consolidated under engineered cover (VLEACH/MYGRT calculations) Little potential for significant re-mobilization of contaminants consolidated under engineered cover, even under complete saturation (catastrophic dissolution/MYGRT) Potential effects on local hydrogeology by reducing percolation and changing topography in a potential recharge area	Limited downward migration of site contaminants (VLEACH/MYGRT calculations) Minimal effects on local hydrogeology due to changes in drainage patterns from grading in a potential recharge area
Surface Water Quality	No surface water bodies exist within the boundaries of OU4 Fate and transport calculations demonstrate no risk to adjacent surface water bodies via the groundwater pathway Consolidation of soil contamination under engineered cover will minimize or eliminate precipitation run-off	No surface water bodies exist within the OU4 area Protection of adjacent surface water bodies from contaminanted run-off from OU4 limited to ITS system
Cultural, Historical and Archaelogical Resources	No resources present	No resources present

TABLE IV.10.13

SUMMARY OF POTENTIAL IMPACTS: PREFERRED IM/IRA VERSUS NO ACTION

Transportation	Minor increase in traffic volume and patterns during construction activities; negligible impact on surrounding transportation infrastructure	Slight increase in traffic volume and patterns, although less than those expected under the preferred IM/IRA
Short-term v. Long-term uses	Short-term disruption of industrial area and borrow area required to minimize potential risks associated with exposure to site contamination Construction of engineered cover will preclude unrestricted use of area underlying and adjacent to engineered cover	Short-term disruption of industrial area and borrow area required during regrading activities Need for long-term institutional controls to minimize risks associated with exposure to remaining, available site contamination
Irreversible & Irretrievable Commitments	Clean fill from borrow areas, construction materials, and area underneath and adjacent to engineered cover	Clean fill from borrow areas used in grading activities
Direct/Indirect Effects	As described above Short-term direct increase in remediation jobs; indirect job loss due to eliminating production functions at RFP	As described above Short-term direct increase in remediation jobs; indirect job loss due to eliminating production functions at RFP
Cumulative Impacts	Implementation of the preferred IM/IRA is consistent with the long-term mission of remediating the RFP Implementation may interfere slightly with other activities in progress at the RFP	Implementation of no action would impede or at least delay site-wide goals to remediate the RFP

TABLE IV.10.13

SUMMARY OF POTENTIAL IMPACTS: PREFERRED IM/IRA VERSUS NO ACTION

Mitigation Measures	Implementation may require short-term changes in access points at OU4 to expedite construction activites Delivery of construction materials would not occur during the peak morning or evening rush hour Dust suppression during construction activities Erosion protection measures	Implementation may require short-term changes in access points at OU4 to expedite grading activities Dust suppression during grading activities Erosion protection measures

IV.11.1 Permit Identification

Based on the scope of the preferred IM/IRA, the following permitting requirements would need to be addressed:

- Modification of the existing CHWA/RCRA Part B Permit to incorporate provisions for the closure of the SEPs and corrective actions required to remediate the OU4 sources and soils,
- Issuance of a Certificate of Designation for developing a hazardous waste disposal site (i.e., in-place closure of hazardous waste), and
- Modification of the existing storm water permit application under the NPDES program, if required, to address proposed changes to the drainage system as a result of installing the engineered cover.

As stated in Section IV.11, DOE must comply with both the procedural and substantive CHWA/RCRA permitting aspects for the closure of the SEPs. This Decision Document constitutes the closure and post-closure plans required to be submitted for the SEPs to modify the existing Part B permit. To fulfill CHWA/RCRA permitting requirements, the State shall open a public comment period for this proposed OU4 IM/IRA Decision Document to satisfy the public comment requirements for draft closure plans. The implementation strategy to achieve compliance with the provisions of the CHWA/RCRA Part B permit and the hazardous waste closure/post-closure requirements are addressed in Section IV.11.2.

In addition to modification of the existing Part B permit, the closure of the SEPs with hazardous waste in-place has been determined to constitute the development a hazardous waste disposal site. As such, the closure activities are required to comply with the siting and design provisions for obtaining a Certificate of Designation under 6 CCR 1007-2, Part 2. Pursuant to Part 18 of the IAG, the DOE does not have to comply with the procedural requirements to obtain a Certificate of Designation for the onsite response action; however, the preferred IM/IRA must comply with the substantive requirements of this regulation. The implementation strategy to achieve compliance with these design provisions is addressed in Section IV.11.3.

Per 40 CFR 122.26, DOE submitted a NPDES Storm Water Discharge Permit Application. This permit application addresses the sitewide monitoring program for all storm water discharges. Although the requirements of this permit application are not specific to OU4, the changes to the drainage will be evaluated to determine if the surface water monitoring program needs to be modified. If required, the permit application will be amended to reflect the drainage changes.

IV.11.2 Implementation/Compliance Strategy

The regulatory requirements to be satisfied during the implementation of the preferred IM/IRA were identified in Section III.5.2. This section identifies what actions will be taken to

ensure compliance with these ARARs/TBCs. For each identified ARAR/TBC, an overview of the requirement and the implementation strategy to ensure compliance is presented in Table IV.11-1. Similar regulatory requirements were combined together if a common implementation strategy assures compliance with the combined requirements. The implementation strategy may also provide a reference to the section in the decision document that demonstrates compliance with the ARAR/TBC.

IV.11.3 Siting Requirements

As stated above, DOE does not have to comply with the procedural requirements to obtain a Certificate of Designation but must comply with the substantive requirements of 6 CCR 1007-2, Part 2. The substantive requirements are being invoked to ensure that the hazardous wastes (i.e., liners) are effectively isolated from natural environmental pathways to ensure the long-term protection of public health. Table IV.11-2 identifies the Part 2 criteria and provides cross-references to the appropriate sections of this decision document that demonstrate compliance with the criteria. The Part 2 criteria were paraphrased for the purpose of Table IV.11-2 to better reflect the applicability to the preferred IM/IRA.

IV.11.4 Request for CAMU Designation

On February 16, 1993, EPA promulgated a final rule for CAMUs to promote more expeditious cleanups at many sites. The CAMU designation is allowed for the purpose of implementing corrective actions as necessary to address releases of hazardous waste or constituents from any solid waste management unit at the facility. The CAMU rule requires that cleanup operations be protective of human health and the environment, but allows these operations to be tailored to the actual site conditions. The State of Colorado is in the process of adopting a CAMU rule (6 CCR 1007-3, 264.552) similar to that promulgated by the EPA.

The preferred IM/IRA involves the installation of an engineered cover to isolate contaminated media and soils to prevent exposures to human health and the environment. The preferred IM/IRA has been determined to be protective of human health and the environment and be the most cost-effective remedy considering the nature and extent of contamination. It is proposed that contaminated media and soils, some of which may be classified as a listed waste by strict application of the "mixture" rule (6 CCR 1007-3, 261.3(a)(2)(iv)) and "contained-in" policy, be consolidated within the current location of SEP 207A and the 207B-Series SEPs to limit the areal extent of the engineered cover. The CAMU concept is a sound approach because it will prevent the further spread of contamination through consolidation and containment while protecting human health and the environment via the engineered cover.

To effectively implement consolidation of contaminated media and soils under the preferred IM/IRA, DOE is requesting that a portion of OU4 be designated as a CAMU as identified in Figure IV.11-1. This CAMU designation is requested based on the expectation that the Colorado Hazardous Waste Commission will act favorably to promulgate the proposed CAMU rule (6 CCR 1007-3, 264.552) which will support the planned closure/remediation activities.

TABLE IV.11-1
ARAR/TBC COMPLIANCE DEMONSTRATION

ARAR/TBC Category	Regulatory Requirement	Implementation/Compliance Strategy
Location - Floodplain and Wetland Impacts	Federal agencies are to avoid construction within a floodplain or wetland unless there are no practical alternatives. If it is necessary to locate any of the remediation facilities within a floodplain or wetland, all practicable measures are to be taken to minimize any impacts to the floodplain or wetland. Actions must minimize destruction, loss, or degradation of wetlands, as defined by Executive Order 11990, Section 7. A floodplain or wetland assessment must be published in the Federal Register prior to taking any action within the floodplain/wetland to allow time for public review and comment. 10 CFR 1022 {CRS 25-12-101 to 25-12-108} [Applicable] Executive Orders 11988 & 11990 [To Be Considered]	Per Section IV.10.4, implementing the preferred IM/IRA will not result in significant impact to wetlands. Likewise, the preferred IM/IRA construction activities will avoid any floodplain areas. Therefore, a wetland or floodplain assessment does not need to be prepared and special precautions do not need to be established.
Location - Historic and Archeological Preservation	The Secretary of the Interior must be notified in writing whenever DOE finds or is notified in writing by an appropriate historical or archaeological authority that the activities in connection with a project may cause irreparable loss or destruction of significant scientific, prehistorical, historical, or archaeological data. Any data that may be lost or destroyed must be preserved by the DOE or the Department of Interior. 36 CFR 65 & 800 {CRS 20-80-401} [Applicable] DOE Environmental Compliance Guide (DOE/EP-0098) [To Be Considered]	Per Section IV.10.8, historic or archeological sites will not be impacted as a result of implementing the preferred IM/IRA. Therefore, notifications and provisions to preserve artifacts are not required.
Location - Endangered Species Act	Practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife. Taking is defined to include harassment, harm, pursuit, hunting, wounding, trapping, death, capture, or collection. Threatened or endangered species indigenous to Colorado should be protected to maintain and enhance their numbers. 50 CFR 402 {CRS 33-2-101 to 33-2-107} [Applicable]	Per Section IV.10.2, neither threatened or endangered species, nor criteria habitats will be impacted as a result of implementing the preferred IM/IRA. The results indicated no significant findings. Therefore, special provisions are not required.

TABLE IV.11-1 (continued)
ARAR/TBC COMPLIANCE DEMONSTRATION

ARAR/TBC Category	Regulatory Requirement	Implementation/Compliance Strategy
Location - Hazardous Waste Disposal Facilities	Part 2 requirements described in Sections 2.1 through 2.9 provide performance criteria for the siting, design, construction, and operation for a hazardous waste disposal site. 6 CCR 1007-2, Part 2 [Applicable]	Section IV.11.3 provides the details to demonstrate compliance with the Part 2 requirements.
Action, General - Public Health and the Environment	DOE activities are to be conducted so that radiation exposures to members of the public are maintained below acceptable limits. This proposed regulation also addresses the management of real and personal property to control exposures to residual radioactive materials. DOE facilities have the capability, consistent with the types of operations conducted, to monitor routine and non-routine releases and assess doses. 10 CFR 834 (Proposed) [To Be Considered] DOE Order 5400.5 [To Be Considered]	As demonstrated in Section IV.10.3, the calculated lifetime offsite exposure to an individual of the public resulting from potential fugitive emissions during excavation activities was determined to be less than 0.03 mrem.
Action, General - Worker Protection	At DOE facilities, the radiation protection standards contained in DOE Order 5480.11 for occupational workers, unborn children, minors, and onsite members of the public shall not be exceeded. 10 CFR 835 (Proposed) [To Be Considered] DOE Order 5480.11, Section 9 [To Be Considered]	Occupational workers and onsite members of the public are required to wear dosimeters and personal protective equipment when entering a radiologically controlled area. Radiation monitoring is also required for all individuals exiting a radiologically controlled area. The personal protective equipment and monitoring will be used to ensure that occupational exposure limits are not exceeded; no additional controls are anticipated at this time. If monitoring during implementation of the preferred IM/IRA indicates a potential concern, additional work practices and engineering controls will be implemented. Details regarding the personal protective equipment and radiation monitoring requirements will be identified in the task-specific health and safety plan.

TABLE IV.11-1 (continued)
ARAR/TBC COMPLIANCE DEMONSTRATION

ARAR/TBC Category	Regulatory Requirement	Implementation/Compliance Strategy
Action, General - Worker Protection	The health and safety requirements provided in 29 CFR 1910.120 apply specifically to workers engaged in the handling of hazardous waste/materials at uncontrolled hazardous waste sites. Implementation of remedial activities is required to be conducted by OSHA-trained personnel and under OSHA requirements. All remediation employers are required to develop and implement a written safety and health program for their employees involved in hazardous waste operations. 29 USC §§ 657 and 667 [Applicable] 29 CFR 1910, Subpart Z [Applicable]	The preferred IM/IRA will be conducted in accordance with the provisions of this regulation. As required by 29 CFR 1910.120(b)(4), a task-specific health and safety plan will be prepared prior to the initiation of construction activities.
Action, General - Worker Protection	Federal agencies are required to establish and maintain an effective and comprehensive occupational safety and health program which is consistent with the standards promulgated under the Occupational Safety and Health Act. Specifically, 29 CFR 1926 Subpart P provides guidelines (including requirements for egress, safety, and protective systems) for workers engaged in activities related to excavations. 29 USC § 668 [Applicable] 29 CFR 1926 [Applicable] DOE Order 5483.1A [To Be Considered]	A project-specific health and safety program will be developed to implement the preferred IM/IRA.
Action, Operational - Interim Status Hazardous Waste Facilities	General requirements of this section apply to all owners and operators of hazardous waste facilities, except as Section 265.1 provides otherwise. Security, training, and inspection programs will need to be maintained and revised, if necessary, to ensure that public health and the environment are adequately protected during the closure activities. The location (40 CFR 265.18) and construction quality assurance (40 CFR 265.19) standards do not apply to the closure of the SEPs. 40 CFR 265, Subpart B {6 CCR 1007-3, 265, Subpart B} [Applicable]	Existing site procedures will be reviewed and revised accordingly to ensure that the preferred IM/IRA is implemented to comply with these provisions. Security fencing will be maintained around the SEPs until they are certified as being closed.

TABLE IV.11-1 (continued)
ARAR/TBC COMPLIANCE DEMONSTRATION

ARAR/TBC Category	Regulatory Requirement	Implementation/Compliance Strategy
Action, Closure - Surface Impoundment	The owner or operator must close the facility in a manner that (1) minimizes the need for further maintenance and (2) controls, minimizes, or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste decomposition products to the ground or surface waters, or to the atmosphere. 40 CFR 265.111 {6 CCR 1007-3, 265.111} [Applicable] At closure, the owner or operator must (1) remove or decontaminate all waste residues, contaminated containment system components (liners, etc.) contaminated subsoils, structures, and equipment contaminated with waste and leachate, and manage them as required; or (2) close the impoundment and provide post-closure care for a landfill under Subpart G and Section 265.310. 40 CFR 265.228 {6 CCR 1007-3, 265.228} [Applicable]	As provided in 40 CFR 265.228, the SEPs will be closed by installing an engineered cover. The engineered cover is designed to minimize the need for further maintenance and to preclude the escape of hazardous waste constituents that may have an adverse impact on human health and the environment. The minimization of maintenance will be accomplished by (1) minimizing subsidence through consolidation, size reduction, and compaction of materials beneath the cover; (2) implementing a construction quality control program to ensure that the engineered cover is constructed in accordance with approved specifications; (3) limiting the slope of the cover and establishing uniformed vegetation to minimize the potential for erosion due to runoff; and (4) consolidating the contaminated media thus minimizing the area requiring maintenance. As presented in Section III.5.1, the preferred IM/IRA reduces current risks associated with OU4 to protect human health and the environment.
Action, - Disposal or Decontamination	During the closure, all contaminated equipment, structures, and soils must be properly disposed of or decontaminated. These materials shall be managed based on the results of characterization. 40 CFR 265.114 {6 CCR 1007-3, 265.114} [Applicable]	Section IV.4 details the waste management plan for the materials and equipment expected to be generated as a result of the preferred IM/IRA.

TABLE IV.11-1 (continued)
ARAR/TBC COMPLIANCE DEMONSTRATION

ARAR/TBC Category	Regulatory Requirement	Implementation/Compliance Strategy
Action, - Establishment of a CAMU	The CAMU/TU rule facilitates the implementation of reliable, effective, protective, and cost- effective remedies while not creating unacceptable risks to humans or to the environment. This regulation identifies the requirements for the designation of a CAMU by the State of Colorado. Although the State of Colorado has not adopted the CAMU/TU rule, the implementation of the preferred IM/IRA is based on the expectation that the Colorado Hazardous Waste Commission will act favorably to promulgate a CAMU/TU rule which will support the planned closure/remediation activities. 40 CFR 264.552 {6 CCR 1007-3, 264.552, proposed} [Relevant and Appropriate]	Section IV.11.4 identifies the CAMU requirements.
Action, - LDR Treatment Standards	Hazardous waste with concentrations in excess of the land disposal restrictions (LDRs) cannot be placed into a land disposal unit unless the waste is treated, a variance is provided in accordance with the provisions of 40 CFR 268, or the CAMU designation is approved by CDH/EPA. 40 CFR 268, Subpart A to D {6 CCR 1007-3, 268, Subpart A to D} [Applicable]	As discussed in Section III.5.2, there is a remote possibility that some of the contaminated soil and/or media may exceed LDR treatment standards; however, adequate characterization information (i.e., TCLP results) is not currently available to definitively demonstrate that LDRs would not apply. Compliance with the LDR standards is based on CDH/EPA approving the CAMU designation. If a CAMU designation is not obtained, additional characterization information will be obtained in an attempt to demonstrate LDR compliance.
Action, General - Waste Determination	A person who generates a solid waste must determine if that waste is a hazardous waste using the procedures identified in 40 CFR 262.11. An overview of the hazardous waste determination procedures is presented in 40 CFR 260, Appendix I. 40 CFR 262.11 {6 CCR 1007-3, 262.11} [Applicable]	Any waste streams generated during the IM/IRA for storage and/or disposal will be assessed for hazardous wastes by review of the OU4 RFI/RI data base, review of process/historical records, and sampling and analysis (as required). Hazardous waste determinations will not be conducted for contaminated media (including contaminated soils, rubble and debris, investigation-derived materials, and other remediation waste) which is consolidated within the confines of the designated CAMU (if approved by CDH/EPA).

TABLE IV.11-1 (continued)
ARAR/TBC COMPLIANCE DEMONSTRATION

ARAR/TBC Category	Regulatory Requirement	Implementation/Compliance Strategy
Action, General - Air Discharges	Any owner or operator of land that has been cleared of greater than one acre in non-attainment areas from which fugitive emissions will be emitted shall be required to use all available and practical methods which are technologically feasible and economically reasonable to minimize such emissions in accordance with the requirements of Section III.D. The RFP is located in a non-attainment area for particulates. 5 CCR 1001 - Regulation 1, III.D [Applicable]	Dust suppression measurements (i.e., water sprays, restriction of work during periods of high winds, etc.) will be employed to minimize fugitive particulate emissions.
Action, General - Air Discharges (Radionuclides)	Emissions of radionuclides to the ambient air from DOE facilities shall not cause any member of the public to receive an effective dose equivalent in excess of 10 mrem per year above background. This limit is based on an effective dose equivalent as calculated per the International Commission on Radiological Protection's Publication No. 26. 40 CFR 61, Subpart H [Applicable] DOE Order 5400.5 [To Be Considered] DOE Order 5820.2A Chapter III [To Be Considered]	As demonstrated in Section IV.10.3, public exposure resulting from potential fugitive emissions was determined to be less than 1.0×10^{-6}. In addition dust suppression measurements (i.e., water sprays, restriction of work during periods of high winds, etc.) will be employed to minimize fugitive particulate emissions.
Action, General - Storm Water Management	Industrial facilities (as defined in 40 CFR 122.26) are required to submit an NPDES Stormwater Discharge Permit Application to US EPA by October 2, 1992. This permit application is to identify the sitewide monitoring program (including monitoring parameters and locations) for all storm water discharges. 40 CFR 122.26 {5 CCR 1002-3} [Applicable]	Section IV.11.1 discusses permitting requirements.
Action, Closure - Time Allowed for Closure	The owner or operator must complete closure activities within 180 days after approval of the closure plan or per CDH-approved extension. 40 CFR 265.113 {6 CCR 1007-3, 265.113} [Applicable]	The time required to complete the closure activities associated with the preferred IM/IRA is approximately 29 months after approval of the Decision Document which is anticipated to be February 1995. The justification for this schedule is provided in Section IV.6.3.

TABLE IV.11-1 (continued)
ARAR/TBC COMPLIANCE DEMONSTRATION

ARAR/TBC Category	Regulatory Requirement	Implementation/Compliance Strategy
Action, Closure - Certification	Within 60 days after completion of closure, the owner or operator must submit to CDH by registered mail a certification that the SEPs have been closed in accordance with the specifications in the approved closure plan. 40 CFR 265.115 {6 CCR 1007-3, 265.115} [Applicable]	A professional engineer will be responsible for overseeing the closure activities to ensure that they comply with the CDH/EPA approved decision document. A field log will be maintained to document the professional engineer's observations. The field observations, along with the engineered cover construction quality control results and the verification sample results, will be summarized in a closure report. The closure report will be certified by the professional engineer and submitted to CDH/EPA within 60 days after completion of closure.
Action, Closure - Survey Plat	No later than the submission of closure certification, the owner or operator must submit to the authority with jurisdiction over local land use and to CDH a survey plat indicating the location and dimensions of the hazardous waste disposal unit. 40 CFR 265.116 {6 CCR 1007-3, 265.116} [Applicable]	A survey plat showing the boundaries of the engineered cover will be submitted along with the closure report. The survey plat will also be submitted to the authority with jurisdiction over local land use. Arrangements for restricting use of the property will be providing as part of the deed filed with the local land use authority.
Action, Post-Closure	Post-closure care of the hazardous waste management unit is subject to the requirements of Sections 264.117 to .120 and must begin after completion of closure and continue for 30 years after that date. The 30 year monitoring and maintenance period can be extended or shortened based on CDH's review. Likewise post-closure use of the property must never be allowed to disturb the integrity of the final cover or any other components associated with the final cover with out prior approval from CDH. 40 CFR 264.117 to .120 {6 CCR 1007-3, 264.117 to .120} [Applicable] Requirements for ground water monitoring listed in 40 CFR 264 Subpart F are required for land disposal facilities where hazardous wastes remain in place after closure. 40 CFR 264, Subpart F {6 CCR 1007-3, 264, Subpart F} [Applicable]	Section V identifies the ground water monitoring, engineered cover performance assessment, and maintenance programs.

TABLE IV.11-2
COMPLIANCE WITH DESIGN AND SITING REQUIREMENTS

6 CCR 1007-2, Part 2 Requirement	Implementation/Compliance Strategy
2.4.1 Design performance will assure long-term protection of human health and the environment.	As discussed in Sections III.5.1 and III.5.3, the preferred IM/IRA will provide long-term protection of human health and the environment by isolating the hazardous waste from the air, direct contact, ingestion, and surface water exposure pathways. The residual risks associated with the preferred IM/IRA are presented in Section IV.10. The VLEACH modeling results indicate that long-term protection of the ground water will be achieved.
2.4.2 Designed to prevent adverse effects on ground water quality.	The VLEACH modeling results indicate that long-term protection of the ground water will be achieved. In addition, a drainage layer will be installed between the hazardous waste and ground water to preclude contact of ground water with the hazardous waste in the event that the ground water elevation should rise.
2.4.3 Designed to prevent adverse effects on surface water quality.	The engineered cover will effectively provide long-term isolation of the hazardous waste to prevent any adverse effects on surface water quality. In the short-term, the ITS will continue to be operated to preclude the migration of ground water contaminants from seeping into surface waters. The need for the continued operation of the ITS will be addressed during the additional hydrogeological investigation described in Part VI.
2.4.4 Designed to prevent adverse effects on air quality.	The engineered cover will effectively provide long-term isolation of the hazardous waste to prevent any adverse effects on air quality. The short-term impacts as a result of excavation activities were determined to have an insignificant impact to offsite air quality (see Section IV.10.3).
2.4.5 Designed to prevent long-term adverse effects on public health and the environment due to migration of waste constituents in the surface and subsurface environment.	See criteria 2.4.1.
2.4.6 Any liner system installed to accomplish the design performance objectives shall be protected.	As demonstrated by the VLEACH modeling results (see Section IV.10.4), a liner system does not need to be installed to accomplish the design performance objectives. Therefore, protection of the liner is not required.

TABLE IV.11-2 (continued)
COMPLIANCE WITH DESIGN AND SITING REQUIREMENTS

6 CCR 1007-2, Part 2 Requirement	Implementation/Compliance Strategy
2.4.7 Any leachate and runoff control system shall be designed with sufficient capacity such that the design performance objectives will be met.	As demonstrated by the VLEACH modeling results (see Section IV.10.4), a leachate collection is not required to be installed to accomplish the design performance objectives. Once the SEPs are closed, runoff controls are not required since the engineered cover will effectively preclude the potential contact of precipitation with the hazardous waste.
2.4.8 The closure design will provide reasonable assurance that the long-term performance objectives are met.	Section IV.10 provides information to quantify the residual risks. Residual risks associated with air, direct contact, ingestion, and surface water pathways will be eliminated. Slight potential exists for contaminant migration to ground water; however, modeling to determine the potential for leaching of contaminants from the untreated contaminated media demonstrates that the risk to human health is insignificant.
2.4.9 The design shall include ground water and surface water monitoring systems. Quality controls shall be implemented to ensure proper construction materials are used.	The post-closure ground water monitoring program is described in Section V.4.3. This section includes a description of the well construction procedures. Surface water monitoring is currently conducted on a site-wide basis. Additional surface monitoring for OU4 is not proposed.
2.4.10 The design shall include procedures to be followed during construction, including supervision and certification by a professional geologist or professional engineer, to demonstrate that the facility is constructed in accordance with the approved design.	The construction quality control program is described in Section IV.8 and includes provisions for oversight by a professional engineer. A field log will be maintained to document the professional engineer's observations. The field observations, along with the engineered cover construction quality control results and the verification sample results, will be summarized in a closure report. The closure report will be certified by the professional engineer and submitted to CDH/EPA within 60 days after completion of closure.
2.5.1 Demonstrate that the minimum design performance criteria (Section 2.4) will be satisfied after construction.	As indicated above, the minimum performance criteria will be satisfied by installation of the engineered cover. The construction quality control program and professional engineer certification will ensure that the design specifications are met.
2.5.2(a) The odor-threshold concentrations established in the State air pollution regulations shall not be exceeded under normal climatic conditions.	Given the nature of the hazardous waste and the odor-threshold criteria provided in 5 CCR 1001, Regulation 2 - Odor Emissions, it is unlikely that an odor violation would occur when implementing the preferred IM/IRA.

TABLE IV.11-2 (continued)
COMPLIANCE WITH DESIGN AND SITING REQUIREMENTS

6 CCR 1007-2, Part 2 Requirement	Implementation/Compliance Strategy
2.5.2(b) Access routes shall be reasonably safe based on minimizing public exposure to transportation incidents.	This criterion does not apply to the preferred IM/IRA; public roadways will not be used to transport hazardous waste to OU4. Traffic impacts resulting from transporting construction materials for the engineered cover to OU4 are described in Section IV.10.6.
2.5.2(c) Provide adequate fire protection on a 24-hour basis.	Given the nature of the hazardous waste, fire protection is not required. Equipment fires are considered the only creditable incident. RFP has adequate fire protection equipment and trained personnel to respond to this type of incident.
2.5.2(d) Provide adequate security on a 24-hour basis.	OU4 is within the RFP perimeter security. The security is adequate to restrict access to the SEPs and will be maintained, at a minimum, until closure of the SEPs is certified.
2.5.2(e) Ensure availability of proper materials for constructing the engineered cover.	Construction material suppliers will be identified prior to initiating cover installation. Staging areas will be provided to ensure material availability during construction. The quality control tests will ensure that the material conforms to design specifications.
2.5.2(f) Ensure availability of adequate professional competence and resources for the design, construction, and post-closure care.	Professional personnel and resources will be made available to the extent required to comply with applicable laws and regulations.
2.5.3 The geological and hydrological conditions of the site shall provide reasonable assurance to isolate the hazardous waste away from the natural environmental pathways that could expose the public for 1,000 years, or some demonstrated shorter period in which the wastes are transformed to an innocuous condition.	The VLEACH modeling results indicate that long-term protection of the ground water will be achieved under the existing geological and hydrological conditions with the installation of the engineered cover. In addition, the engineered cover will isolate the hazardous waste from the air, direct contact, ingestion, and surface water exposure pathways. The engineered cover is designed to provide long-term protection of the public on the order of 1,000 years.
2.5.4 A liner shall be provided unless it is demonstrated to be unnecessary.	As demonstrated by the VLEACH modeling results (see Section IV.10.4), a liner system does not need to be installed to accomplish the design performance objectives.
2.5.5 A leachate collection and runoff control system shall be provided.	As demonstrated by the VLEACH modeling results (see Section IV.10.4), a leachate collection is not required to be installed to accomplish the design performance objectives. Once the SEPs are closed, runoff controls are not required since the engineered cover will effectively preclude the potential contact of precipitation with the hazardous waste.

TABLE IV.11-2 (continued)
COMPLIANCE WITH DESIGN AND SITING REQUIREMENTS

6 CCR 1007-2, Part 2 Requirement	Implementation/Compliance Strategy
2.5.6 The facility shall be located to provide a buffer zone to prevent adverse effects on public health should unexpected discharges of hazardous waste occur.	OU4 is centrally located within the large buffer zone of the RFP. Air dispersion modeling (see Section IV.10.3) indicates that creditable emissions during excavation activities are insignificant.

This section provides the justification for the proposed CAMU and identifies how the proposed CAMU will be implemented to achieve compliance with the proposed Colorado rule.

IV.11.4.1 Justification

As stated in 6 CCR 1007-3, 264.552(c), the CDH shall designate a CAMU in accordance with the following:

1) The CAMU shall facilitate the implementation of reliable, effective, protective, and cost-effective remedies.

2) Waste management activities associated with CAMU shall not create unacceptable risks to humans or the environment resulting from exposure to hazardous waste or hazardous constituents.

3) The CAMU shall include uncontaminated areas of the facility only if including such areas for the purpose of managing remediation waste is more protective than management of such wastes at contaminated areas of the facility.

4) Areas within the CAMU, where remediation wastes remain in place after closure of the CAMU, shall be managed and contained to minimize future releases.

5) The CAMU shall expedite the timing of remedial activity implementation, when appropriate.

6) The CAMU shall enable the use, when appropriate, of treatment technologies (including innovative technologies) to enhance the long-term effectiveness of remedial actions by reducing the toxicity, mobility, or volume of remediation wastes that will remain in-place after closure of the CAMU.

7) The CAMU shall minimize the land area of the facility upon which remediation wastes will remain in place after closure of the CAMU.

Each designation criteria is addressed below and provides the justification for designating a CAMU at OU4 to facilitate implementation of the preferred IM/IRA.

1) The CAMU shall facilitate the implementation of reliable, effective, protective, and cost-effective remedies.

If the proposed CAMU designation is not approved by the CDH/EPA, one of the following alternate approaches would need to be implemented to comply with regulatory constraints.

- Installation of Minimum Technology Requirements (i.e., liner and leachate collection systems);

- Removal and offsite disposal of contaminated soils and debris;

- Provision of an engineered cover for the entire contaminated area; or

- Full characterization of the contaminated soils and debris to make a hazardous waste determination and/or petition to delist these materials if they are determined to contain a listed hazardous waste.

Of the above options, the proposed CAMU will provide the most cost-effective means of waste management through consolidation of the contaminated media and soils while still ensuring protection of human health and the environment. The consolidation efforts will also minimize areal extent of contamination.

Under the first option, a liner/leachate collection system would need to be constructed if the proposed CAMU designation was not approved. However, the VLEACH modeling results demonstrate that these systems are not necessary to ensure the long-term protection of human health. In addition, from a regulatory perspective, the liner/leachate collection system could be installed over the contaminated soils if they are not excavated since placement would not occur. It is neither practical nor warranted to excavated these contaminated soils just for the sake of installing a liner/leachate collection system since the VLEACH model demonstrates that contaminant migration is not a concern. Nor is it logical to install the liner/leachate collection system if contaminated soils are allowed to remain below the system. Therefore, installation of the liner/leachate collection system would only inflate the cost of the preferred IM/IRA without providing additional components to protect human health.

Under the second option, all designated hazardous waste (i.e., the SEP liners) would be excavated for offsite shipment. This option is similar to GRA IV which was eliminated due to excessive cost. These unnecessary costs (i.e., waste packaging, labeling, sampling for waste acceptance criteria, completing the shipping manifest, establishing a new storage facility to house the containers, and transportation/disposal) could be eliminated by establishing the proposed CAMU.

Under the third option, the construction of an engineered cover for the entire area is not technically feasible due to the stability concerns associated with the northern hillside. This option is also inconsistent with the seventh criterion for designating a CAMU which states that the areal extent shall be minimized after closure.

Under the final option, additional samples would be collected in order to make a hazardous waste determination. The collection and analysis of these additional samples would unnecessarily delay the closure and remediation of OU4. Given the fact that the SEPs contain listed hazardous waste, the contaminated soils and media could be classified as listed hazardous waste by strict application of the "mixture" rule and "contained-in" policy. As such, these designated listed hazardous waste would need to be delisted prior to their consolidation in the

event that the proposed CAMU designation is not approved. The delisting process could be very lengthy.

Of the above options, the proposed CAMU is the most effective in implementing the preferred IM/IRA and will provide adequate protection to human health and the environment as demonstrated by the risk analysis (Section IV.10). The project cost savings realized as a result of the proposed CAMU can be utilized in the implementation other RFP remediation projects.

2) **Waste management activities associated with the CAMU shall not create unacceptable risks to humans or the environment resulting from exposure to hazardous wastes or hazardous constituents.**

The waste management activities (consolidation and isolation of contaminants) associated with the proposed CAMU will not create an unacceptable risk to humans or the environment. The excavation and consolidation of the liners and contaminated soils could generate fugitive particulate emissions. However, air modeling results (see Section IV.10.3) indicate that the potential exposure to workers, onsite personnel, and offsite public is insignificant. The use of personal protective equipment and emission controls are therefore not required for further risk reduction. However, dust suppression will be implemented as required during these activities to mitigate airborne particulates. In addition, ambient air monitoring may be performed around the proposed CAMU to provide surveillance of the emission controls. If monitoring indicates that particulate levels exceed predetermined levels, additional engineering controls can be implemented to reduce airborne contaminant levels. Potential controls include dust inhibitors and wind screens.

3) **The CAMU shall include uncontaminated areas of the facility, only if including such areas for the purpose of managing remediation waste is more protective than management of such wastes at contaminated areas of the facility.**

The entire proposed CAMU area requires some remedial action to achieve compliance with the PRGs. All remedial activities can be completed within the confines of the proposed CAMU without utilizing any uncontaminated area.

4) **Areas within the CAMU, where remediation wastes remain in place after closure of the CAMU, shall be managed and contained to minimize future releases.**

The contaminated soils and media at concentrations exceeding PRGs will be consolidated beneath a conservatively designed engineered cover. The engineered cover will be constructed from natural materials with known durability. A low permeability layer will have a hydraulic conductivity that is less than or equal to the hydraulic conductivity of the natural subsurface soils. This will minimize the potential for precipitation to infiltrate into the consolidated materials. Section IV.3 provides a detailed discussion of the final engineered cover.

A post-closure monitoring program will be implemented to provide an early warning system designed to identify when the potential exists for contaminant migration to enter the ground water. The monitoring program is designed to detect infiltration of precipitation through the cover and the presence of contaminants in the vadose zone. Monitoring wells will also be provided as an early warning to determine if contaminants may be migrating into the ground water. An in-depth overview of the monitoring program is detailed in Part V.

In addition to these monitoring systems, the engineered cover will be periodically inspected to ensure that erosion control measures are intact as part of the maintenance program outlined in Part V.

5) The CAMU shall expedite the timing of remedial activity implementation, when appropriate.

Without the proposed CAMU, the IM/IRA schedule may need to be extended to accommodate the below listed activities.

- Sample collection and analysis for hazardous waste determination and to determine if LDRs apply to the excavated soils and debris. [The proposed CAMU would provide the capacity to accommodate the untreated soils and debris while still providing adequate protection as demonstrated by the VLEACH modeling program.]

- Excavation activities may be sluggish if contaminated soil must be segregated to accommodate the management of classified listed waste from other materials. [The proposed CAMU will allow for the continuous excavation of soils and debris.]

- If the SEP materials were excavated and prepared for offsite shipment, additional time may be needed to construct a storage facility to house the containers, since storage space is not currently available.

- If the contaminated soils are not consolidated, additional time would be required to construct an engineered cover over the entire contaminated area.

6) The CAMU shall enable the use, when appropriate, of treatment technologies (including innovative technologies) to enhance the long-term effectiveness of remedial actions by reducing the toxicity, mobility, or volume of remediation wastes that will remain in-place after closure of the CAMU.

The long-term effectiveness and performance of the engineered cover is demonstrated by VLEACH modeling results (Section IV.10.4). The results show that the residual risk associated with leaving untreated contaminated media under the final engineered cover is protective to human health and the environment. However, the potential for contaminant migration is not likely to significantly impact ground water quality because most of the COCs are not relatively

mobile in the unsaturated soils due to their low hydraulic conductivity and high ion exchange capacity.

The engineered cover would meet the IM/IRA performance objectives by effectively isolating the contaminated soil and debris from the air, direct contact, ingestion, and surface water exposure pathways. As such, treatment of the remediation waste to enhance the long-term effectiveness by reducing the toxicity, mobility, or volume is not required for the preferred IM/IRA.

7) The CAMU shall, to the extent practicable, minimize the land area of the facility upon which remediation wastes will remain in place after closure of the CAMU.

With the proposed CAMU, consolidation of the contaminated soils and media can occur and would significantly minimize the areal extent of OU4 upon which remediation wastes will remain in place after closure. The unconsolidated area for the SEPs and the contaminated soils present within the northern hillside represent approximately 1,176,120 ft^2. However, with the consolidation of the contaminated soils the final engineered cover only requires approximately 338,100 ft^2. Of this total area for the cover, remediation waste would represent 218,600 ft^2. The consolidation of the OU4 contamination represents an 81% reduction of the original remediation zone.

IV.11.4.2 CAMU Implementation

To obtain a CAMU designation, the existing RCRA Part B permit is required to be modified or an order is required to be issued by CDH. The purpose of this section is to demonstrate compliance with the requirements required to be specified in the permit modification or order. It is intended that this demonstration will fulfill CDH's obligations to modify the existing RCRA permit in accordance with the process specified in the IAG. Table IV.11-3 provides information demonstrating compliance with the CAMU designation requirements.

The proposed CAMU is not intended of change CDH's existing authority to address clean-up levels. These clean-up levels are established and approved through the PRG process.

IV.11.5 Consistency With Final Remedies

The Comprehensive List of Technologies (CLT) data base, developed for EG&G as Task 3 of the CMS/FS (ES, 1994), was utilized to identify process options that could potentially be employed to remediate soils and ground water at OU4. The process options were selected based on chemical contaminants identified during the RFI/RI work (Part II of this IM/IRA) and historical research examined while preparing the follow-up hydrogeological studies (Part VI of this IM/IRA). The impacted media data were utilized in combination with the chemical contaminants information to generate a list of potential remedial options.

TABLE IV.11-3
COMPLIANCE WITH CAMU DESIGNATION REQUIREMENTS

CAMU Permit Requirements		IM/IRA-EA Decision Document Section Reference
(1)	The areal configuration of the CAMU.	Figure IV.11-1 identifies the boundary of the proposed CAMU.
(2)	Requirements for remediation waste management to include the specification of applicable design, operation and closure requirements.	Section III details the engineered cover, Section IV.4 details the waste management plan, Section V identifies the monitoring and maintenance programs.
(3)	Requirements for ground water monitoring that are sufficient to:	Section V identifies the monitoring and assessment programs.
(i)	Continue to detect and to characterize the nature, extent, concentration, direction, and movement of existing releases of hazardous constituents in ground water from sources located within the CAMU; and	
(ii)	Detect and subsequently characterize releases of hazardous constituents to ground water that may occur from areas of the CAMU in which remediation wastes will remain in place after closure of the CAMU.	
(4)	Closure and post-closure requirements.	Section IV.3.1 identifies design details to minimize maintenance requirements and Section V details post-closure requirements.
(i)	Closure of corrective action management units shall:	
(A)	Minimize the need for further maintenance;	
(B)	Control, minimize, or eliminate, to the extent necessary to protect human health and the environment, for areas where remediation wastes remain in place, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground, to ground water, to surface waters, or to the atmosphere.	
(ii)	Requirements for closure of any CAMUs shall include the following, as appropriate and as deemed necessary by the CDH to protect human health and the environment:	Section IV.1 details the excavation of the contaminated media and soil and subsequent consolidation of these materials beneath the engineered cover.
(A)	Requirements for excavation, removal, treatment or containment of remediation wastes;	
(B)	For areas in which remediation wastes will remain after closure of the CAMU requirements for lining and/or capping of such areas;	Section IV.3.1 details the selected engineered cover.

TABLE IV.11-3 (continued)
COMPLIANCE WITH CAMU DESIGNATION REQUIREMENTS

CAMU Permit Requirements		IM/IRA-EA Decision Document Section Reference
(C)	Requirements for removal and decontamination of equipment, devices, and structures used in remediation waste management activities within the CAMU.	Section IV.4 details the waste management plan.
(iii)	In establishing specific closure requirements for CAMUs under 264.552(e), the CDH shall consider the following factors:	Section IV.11.4 identifies CAMU designation request.
(A)	CAMU characteristics;	
(B)	Volume of remediation wastes which remain in place after closure;	Section IV.3.1.1 identifies anticipated volumes.
(C)	Potential for releases from the CAMU;	Section IV.10.4 identifies VLEACH modeling results.
(D)	Physical and chemical characteristics of the remediation waste;	The physical and chemical characteristics of the remediation waste are provides in Section III.2 which identifies the COCs and PRGs.
(E)	Hydrological and other relevant environmental conditions at the facility which may influence the migration of any potential or actual releases; and	Sections II.4 and II.5 provides geology information. Section IV.10 considers the potential for releases.
(F)	Potential for exposure of humans and environmental receptors if releases were to occur from the CAMU.	Section IV.10 identifies risk analysis and potential impact determination.
(iv)	Post-closure requirements as necessary to protect human health and the environment, shall include, for areas where remediation wastes will remain in place, monitoring and maintenance activities, and the frequency with which such activities shall be performed to ensure the integrity of any cap, final cover, bottom liner(s), or other containment system, and, in all instances, a notation to the deed to the facility property that will in perpetuity notify any potential purchaser of the property that the land has been used to manage hazardous wastes.	Section V details monitoring systems program. The DOE will be responsible for providing the appropriate notation to the property deed.
(f)	The CDH shall document the rationale for designating CAMUs and shall make such documentation available to the public.	The rationale of the proposed CAMU is provided as Section IV.11.4.1.

TABLE IV.11-3 (continued)
COMPLIANCE WITH CAMU DESIGNATION REQUIREMENTS

CAMU Permit Requirements		IM/IRA-EA Decision Document Section Reference
(g)	Incorporation of a CAMU into an existing permit must be approved by the CDH according to the procedures for CDH-initiated permit modifications under § 100.61 of these regulations, or according to the permit modification procedures of § 100.63 of these regulations.	It is intended that this demonstration will fulfill CDH's obligations to modify the existing RCRA permit in accordance with the process specified in the IAG.
(h)	The designation of a CAMU does not change CDH's existing authority to address cleanup levels, media-specific points of compliance to be applied to remediation at a facility, or other remedy selection decisions.	The proposed CAMU is not intended of change CDH's existing authority to address cleanup levels. These cleanup levels are established and approved through the PRG process.

It has not been determined if the chemical contaminants in ground water at OU4 exist at concentrations that pose a threat to human health and the environment. These chemicals cannot be considered COCs at this time. However, the COCs for the soils at OU4 have been determined (Part III of this IM/IRA). Historical information concerning chemical contaminants present in the soils at OU4 has not been reconfirmed and its accuracy is questionable. A conservative approach was taken in identifying chemical contaminant groups present in OU4 soils. Several of the chemical contaminants identified in this scope of work may be eliminated in future projects.

The chemical contaminant groups identified for each medium are summarized below.

Ground Water -	Metals
	Radionuclides
	PCBs/pesticides
	Semivolatile Organic compounds
	Volatile Organic Compounds
	Other (Inorganics)
Soils and Sediments -	Metals
	Radionuclides
	PCBs/Pesticides
	Semivolatile Organic Compounds

A search of the CLT for the above-noted contaminant groups resulted in numerous process options for treatment of both ground water and soils. Only process options which are capable of treating all of the chemical contaminants were considered for this discussion.

Ex situ treatment of the contaminated soils north of the seepline should not have an impact on the engineered covers. *In-situ* treatment of these contaminated soils should also be possible without impacting the engineered covers.

Interception and removal of ground water downgradient of the engineered cover via pumping or french drains should not compromise the structural integrity of the covers. Therefore, aboveground treatment of the ground water beneath the engineered cover should not pose a problem. *In situ* treatment options should also be possible from perimeters of the cover.

Numerous process options were identified that had the ability to treat the ground water at OU4. *Ex situ* treatment options include incineration, sedimentation, centrifugation, and filtration/microfiltration/ultrafiltration techniques. Oxidation/reduction processes, slurry walls, or grout curtains could be utilized for *in situ* treatment or containment of ground water.

Containment options were also identified for the treatment of soils at OU4. These containment options included capping, diversion ditches, etc. *Ex situ* treatment options include incineration, sedimentation/separation, and centrifugation. It should be noted, however, that

excavation of the soil in the vicinity of the engineered cover may cause stabilization problems for the cover. *In situ* chemical fixation, stabilization, or vitrification could be accomplished for the soils at OU4. These processes would be more likely not to disturb the stability of the engineered cover in comparison to excavation options.

Process options were identified that could potentially be employed to remediate ground water and soils at OU4. Review of these options indicated that construction of the engineered covers should not limit future remediation efforts for those which do not include excavation of soils.

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APPENDIX IV.A

ROCKY FLATS, OU-4
SOLAR EVAPORATION PONDS
NUCLEAR FACILITY DESIGNATION

ROCKY FLATS, OU-4
SOLAR EVAPORATION PONDS
NUCLEAR FACILITY DESIGNATION

Per DOE Order 6430.1A, United States Department of Energy General Design Criteria, a nuclear facility (special facility) is defined as:

> "A facility whose operations involve radioactive materials in such form and quantity that a significant nuclear hazard potentially exists to the employees or the general public. Included are facilities that: (1) produce, process, or store radioactive liquid or solid waste, fissionable materials, or tritium; (2) conduct separation operations; (3) conduct irradiated materials inspection, fuel fabrication, decontamination, or recovery operations; or, (4) conduct fuel enrichment operations..."

The remediated Solar Evaporation Ponds (SEPs) will be classified as a nuclear facility as they will ultimately store solid radioactive waste materials. As discussed within Division 13, 1300-1.2 of the General Design Criteria, twenty different types of special facilities have been designated. The most appropriate designation for the SEPs is that of Radioactive Solid Waste Facility (RSWF).

Radioactive solid waste facilities store, treat, and dispose of the range of solid waste generated by DOE nuclear facilities and reactor facilities. This waste contains high-level, low-level, and transuranic-contaminated solid waste including radioactive mixed waste. These radioactive solid waste facilities may be separate facilities of they may be adjunct to another type of nuclear facility (e.g., a high-level solid waste storage facilities associated with a reprocessing facility). The environmental, safety, and health concerns to be addressed to fulfill the design requirements for these facilities vary significantly according to the nature of the waste, the waste management techniques that are implemented, and the characteristics of the facility site.

DOE Order 6450.1A, "General Design Criteria", specifically addresses the requirements associate with the design of a Radioactive Solid Waste Facility. The Solar Evaporation Ponds (SEPs) are considered to fit into this category as some of the contaminated soils, liners and debris that exceed the calculated PRGs will be placed under the final engineered cover once the facility is remediated. There is no intent to actually turn this site into an active (operational) disposal facility. Because of this, some aspects of the regulations pertaining to the Radioactive Solid Waste Facilities are not applicable to the particular OU4 situation. The requirements designated within 6430.1A as specifically pertaining to Radioactive Solid Waste Facilities and their applicability to the OU4 remediation activities are discussed within the sections.

1324 RADIOACTIVE SOLID WASTE FACILITIES

1324-1 COVERAGE

"Section 1300, General Requirements, shall apply. These requirements are *in addition* to the requirements of the section and other applicable sections of these criteria, particularly those sections numbered -99.0, Nonreactor Nuclear Facilities-General."

RESPONSE

DOE is in concurrence with this statement.

1324-2 OBJECTIVES

1324-2.1 General

"The design objective shall be to ensure that conservatively estimated consequences of normal operations and credible accidents are limited in accordance with the guidelines contained in Section 1300-1.4 Guidance on Limiting Exposure of the Public."

RESPONSE

The objective of the SEP remediation design is to ensure that conservatively estimated consequences of normal operations and credible accidents are limited in accordance with the guidelines contained in Section 1300-1.4, Guidance on Limiting Exposure of the Public. It should be noted however, that the normal operations for the SEPs is the remediation of the facility, not the operation of a Radioactive Solid Waste Facility. Accident and exposure estimates are based upon those scenarios appropriate for the remediation of the SEPs.

1324-2.2 Siting Design Dose Objectives for Normal Operations and Anticipated Operational Occurrences

1324-2.2.1 Disposal (Permanent Isolation) Facilities

"For those DOE facilities not regulated by the Nuclear Regulatory Commission (NRC), the combined annual dose equivalent to any member of the public in the general environment resulting from discharge of radioactive material and direct radiation shall not exceed 25 mrem (0.25 mSv) to the whole body and 75 mrem (0.75 mSv) to any organ [40 CFR 191.03(b)]...Section 1300-1.4.3, Routine Releases, provides references for additional limits that are applicable to these facilities."

"For those DOE facilities regulated by the NRC, the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation shall not exceed 25 mrem (0.25 mSv) to the whole body, 75 mrem (0.75 mSv) to the thyroid, and 25 mrem (0.25 mSv) to any other organ [40 CFR 191.03(a)]. Additional requirements specific to these facilities are provided in 10 CFR 60 and 10 CFR 61."

RESPONSE

The combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation shall not exceed 25 mrem (0.25 mSv) to the whole body, 75 mrem (0.75 mSv) to the thyroid, and 25 mrem (0.25 mSv) to any other organ.

1324-2.2.2 Waste Management and Storage Facilities (Not to Include Disposal)

"The references specified in Section 1300-1.4.3, Routine Releases, provide the appropriate dose limits for members of the public for these facilities."

RESPONSE

DOE is in concurrence with this statement.

1324-3 NUCLEAR CRITICALITY SAFETY

"Nuclear criticality safety at RSWFs is applicable to those facilities that store or process enriched uranium, uranium-233, or transuranic contaminated solid waste. For other radioactive solid waste facilities, nuclear criticality safety is not a design or operational consideration."

"Nuclear criticality control provisions for a RSWF shall consider the following:

- Design of radioactive solid waste storage and/or process systems to prevent the carry-over of fissile material and other material capable of sustaining a chain reaction from geometrically favorable portions of the facility to other areas of the facility (e.g., from a compaction area to a storage area).

- A system of positive control and backflow preventors, such as air gaps (siphon breakers), to prevent inadvertent transfer of fissile materials and other material capable of sustaining a chain reaction from geometrically favorable or poisoned containers to unsafe containers.

- Inclusion of heating or cooling jackets in the favorable dimension of geometrically favorable vessels to preclude a leak in the jacket from causing an unacceptable reduction of the margin of subcriticality.

- The design of sumps for nuclear criticality safety if a credible mechanism exists for accumulating fissile material and other material capable of sustaining a chain reaction (e.t., due to leakage from or failure of the primary confinement boundary and/or cooling water system)"

RESPONSE

Nuclear criticality safety is not a concern for the remediation of the SEPs. The major isotopes, and their 95% UCL values, that will be placed under the final engineered cover are those stipulated in Table III.2-3, *OU4 Characterization, Background, and PRG Information for Potential Contaminants of Concern.*

1324-4 RADIATION PROTECTION

"For those DOE facilities regulated by the NRC, the occupational radiation protection requirements specified in 10 CFR 20 and DOE 5480.11, both apply (the most conservative limits taking precedent)."

RESPONSE

The Rocky Flats Plant is not regulated by the NRC. DOE does understand however, that the radiation protection criteria specified in DOE 5480.11 does apply to the remediation of the SEPs.

1324-5 SPECIAL DESIGN FEATURES

1324-5.1 General

"Process equipment off-gas treatment systems shall be designed to ensure their integrity for normal operations, anticipated operational occurrences, and for the DBAs they are required to withstand."

"Cooling water systems or cooling air systems shall be provided, where required, for facilities and equipment associated with the interim storage or treatment of high-level radioactive solid waste, and to ensure the long-term integrity of the primary confinement boundary. As a minimum, cooling water systems shall comply with Section 1540-99, Special Facilities. To the extent practicable, passive cooling means shall be used for air cooling systems. If a cooling air system is provided to ensure an acceptable temperature of the stored material, it shall be designed as a safety class system."

"Instrumentation and control systems shall be required at a RSWF to provide monitoring and control capabilities associated with confinement, nuclear criticality safety, and radiation protection."

RESPONSE

The normal operations for this facility will be simply to remediate the SEPs. Due to the types, quantities and form of the materials that are involved with this remediation effort, these special design features are not applicable, and are therefore not required.

1324-5.2 High-Level Waste Disposal Facility Confinement

"During the short-term period following emplacement when short-lived nuclides dominate the hazard associated with a disposal facility, the engineered system of barrier shall remain effective and shall contain the emplaced wastes. This time period is considered to include at least 300 years, but not more than 1,000 years following permanent closure. Technical criteria associated with the engineered system of barriers shall address the following:

- Establishment of a high-integrity confinement system during establishment (limit the rate of release of radionuclides from the system)
- *In situ* stresses affecting the engineered system of barriers
- Corrosion affecting the engineered system of barriers
- Radiological effects on barrier integrity
- Contact with groundwater"

"During the long-term period, reliance shall not be placed on the engineered system of barriers to contain emplaced waste. Confinement during the long-term period shall be accomplished by the geologic setting. Technical criteria associated with the geologic setting shall address the following:

- Leaching characteristics of waste and waste binders
- Site and soil characteristics, including fractures, porosity, hydraulic conductivity, sorption, hydraulic gradient, and thermal gradient
- Long-term geologic stability
- Groundwater travel time
- Absence of resources that would be an incentive for human intrusion
- Stability of rock mass"

"The facility shall be designed to allow retrieval of wastes during the 50-year period following emplacement and before permanent closure of the facility."

RESPONSE

No high level radioactive waste will be consolidated within the Solar Evaporation Ponds, and therefore, this requirement is not applicable.

1324-5.3 Low-Level Waste Disposal Facility Confinement

"Low-level solid waste that is disposed to the ground shall be confined by a site-specific system of barriers that may include, but not necessarily be limited to, waste form, waste packaging, and the geologic setting."

"When site permeability characteristics do not provide the required confinement capabilities, the confinement system shall be augmented by the following:

- Constructing low permeability walls around the low-level waste
- Lining the walls and bottom of the excavated area with low permeability material
- Other suitable methods for reducing permeability"

"Means shall be provided to minimize contact of emplaced low-level waste with water. Active water control measures shall not be required following permanent closure. Typical requirements for water control are as follows:

- Placing a layer of highly permeable material (e.g., sand, gravel) beneath the low-level waste to channel any percolating water to a sump
- Mounding the soil surface to facilitate surface water runoff
- Use of a suitable low-permeability cover material (e.t., clay) over the disposal area to prevent contact of the waste by infiltrating rainwater. This cover material shall be protected by a layer of overburden (e.g., sand, gravel, top soil).
- A site diversion system for surface water runoff during operation of the facility. (This system shall not be required following site permanent closure.)
- Temporary protective covers (e.t., tarpaulin) before the completion of the natural in-place soil barrier over the low-level waste
- Revegatation of the overburden layer
- Other suitable and reliable means for minimizing water contact with low-level waste"

RESPONSE

The remediated site permeability characteristics and the design of the final engineered cover meet these requirements as they are related to both confinement and the minimization of contact with waste materials and water.

1324-6 CONFINEMENT SYSTEMS

1324-6.1 General

"The following provisions are typical for a RSWF confinement system. The actual confinement system requirements for a specific RSWF shall be determined on a case-by-case basis."

"The degree of confinement required in a radioactive solid waste facility is both storage-specific and process-specific, but in either case shall suit the most restrictive case anticipated."

"In general, the primary contamination confinement shall be the radioactive solid waste process systems equipment and associated off-gas or vent systems during the treatment stage of processing. In special cases, such as radioactive solid waste facilities where the process or storage include corrosive or noxious materials, the radioactive solid waste process or storage system shall be totally enclosed and provided with its own ventilation system and off-gas cleanup system. In such cases, the radioactive solid waste process or storage system shall be treated as the primary confinement system. however, depending on the waste being processed and stored, the primary confinement and secondary confinement shall consists of a site-specific engineered system of barriers (e.g., drums, liners, concrete casks) when the primary confinement described above is not required."

"Secondary confinement for radioactive solid waste during treatment shall be a process cell or building its ventilation system, while for such waste during interim storage, a storage building or structure shall be used."

"Tertiary confinements are not required in most cases for radioactive solid waste during the treatment or interim storage phase of the radioactive solid waste management process. however, the final repository for all such solid wastes shall be tertiary confinement by the natural geologic setting that has been selected as a site and for the specific solid wastes processed at the facility."

"In addition to these principal confinement systems, features such as change rooms and special access ways shall be used to minimize the spread of radioactive contamination within the facility."

RESPONSE

The remediation of the SEPs will not include the treatment or processing of radioactive materials as discussed within this portion of DOE Order 6430.1A, 1324-6.1. The only materials to be consolidated within this facility are soils, liners and debris associated with the SEPs. An exception is taken to this requirements as the concentrations and form of the contaminates do not necessitate this type of confinement system.

1324-6.2 **Primary Confinement System**

"The primary confinement system consists of process systems equipment and its associated ventilation and off-gas system, storage containers, or other waste and site-specific engineered barriers."

"Systems components, and structures that compose the process system and/or storage containers shall be designed to ensure their integrity for normal operations, anticipated operational occurrences, and for the DBAs they are required to withstand."

"As a minimum, portions of the process system and/or storage containers whose failure would result in an unacceptable risk and whose functions are necessary to facilitate a safe shutdown conduction shall be designed to remain functional following a DBA. High-level enriched uranium, uranium-233, and transuranic solid waste processes and/or storage containers shall meet these requirements. The need to meet these requirements for other solid waste shall be determined on a case-by-case basis and shall be commensurate with the potential hazards associated with the waste."

RESPONSE

The remediation of the SEPs will not include the treatment or processing of radioactive materials as discussed within this portion of DOE Order 6430.1A, 1324-6.1. The only materials to be consolidated within this facility are soils, liners and debris associated with the SEPs. An exception is taken to this requirements as the concentrations and form of the contaminants do not necessitate this type of confinement system.

1324-6.3 **Secondary Confinement System**

"The secondary confinement system consists of the process cell barriers and the ventilation systems associated with the cells or building, or a storage building or structure. In some cases, a drum, cask, or other waste and site-specific engineered barrier shall provide secondary confinement."

"The process cell and/or building confinement barriers and associated ventilation systems shall be capable of performing their necessary functions following a DBE. Other secondary confinements shall be considered to determine the need to meet these

requirements commensurate with the hazards associated with the radioactive solid waste to be confined."

"The secondary confinement shall be designed to ensure that it can withstand the effect of server natural phenomena and man-made events, include the DBAs and the DBF initiated by these events, and remain functional to the extent that the guidelines in Section 1300-1.4.2, Accidental Releases, are not violated.

"All penetrations of the secondary confinement shall have positive seals to prevent the migration of contamination out of the secondary confinement area."

"Process cells shall be supplied with ventilation air from the building ventilation system, and shall be provided exhaust ventilation with sufficient capacity to ensure an adequate controlled ventilation flow as required in the event of a credible breach in the secondary confinement barrier. Pressure in the compartments shall be negative with respect to the building ventilation system. Special features (e.t., air locks or enclosed vestibules) shall be considered for access through secondary and tertiary confinement barriers."

RESPONSE

The remediation of the SEPs will not include the treatment or processing of radioactive materials as discussed within this portion of DOE Order 6430.1A, 1324-6.1. The only materials to be consolidated within this facility are soils, liners and debris associated with the SEPs. An exception is taken to this requirements as the concentrations and form of the contaminants do not necessitate this type of confinement system.

1324-6.4 Tertiary Confinement System

"The natural geologic setting composes the tertiary confinement system."

"The tertiary confinement system shall function during normal operations, anticipated operational occurrences, and the DBAs it is required to withstand. It shall be capable of performing its necessary functions following a DBE."

"The tertiary confinement system shall remain functional following DBAs, and the severe natural phenomena postulated for the facility site. In addition, the tertiary confinement system shall meet the following performance objectives:

- Following permanent closure, ongoing site maintenance shall not be needed.
- In the absence of unplanned natural processes or human contact with a low-level waste disposal facility, calculated contaminant levels in groundwater at the site boundary shall not exceed the maximum contaminant levels established in 40 CFR 141.

- In the event of human-induced activities following permanent closure, or reasonably foreseeable but unplanned natural processes, the guidelines of Section 1300-1.42., Accidental Releases, shall not be violated. Institutional controls may be relied on for a limited time following closure to preclude reclamation activities at a low-level waste disposal site. For the purposes of calculation, these controls shall not be relied on for more than 100 years following permanent closure."

RESPONSE

The remediation of the SEPs will not include the treatment or processing of radioactive materials as discussed within this portion of DOE Order 6430.1A, 1324-6.1. The only materials to be consolidated within this facility are soils, liners and debris associated with the SEPs. An exception is taken to this requirements as the concentrations and form of the contaminants do not necessitate a tertiary confinement system. It should be noted, however, that the design for the remediated SEPs does meet the objectives of the tertiary confinement system.

1324-7 EFFLUENT CONTROL AND MONITORING

1324-1.1 Radioactive Solid Waste

"The fundamental radioactive solid waste treatment concepts include volume reduction, immobilization of, change of composition, and removal of radioactive material from the waste. The waste treatment concept(s) for a particular application shall be selected on an individual case basis. To the extent practicable, however, features shall be included to allow volume reduction and/or immobilization."

"The solid radioactive wastes typically associated with RSWFs that shall be considered during the design include, but are not limited to, fuel cladding hulls, spent fuel elements intended for disposal, solidified high-level liquid waste, nontransuranic waste (e.t., waste dryer solids, nonfuel tearing components), and general trash (e.g., paper, rags, gloves). Nuclear criticality safety shall be considered in the design of the solid radioactive solid waste processing facility."

RESPONSE

The materials to be consolidated under the final engineered cover will be volume reduced as much as possible in order to provide a stable base for the cover. The only wastes that will be consolidated under the final engineered cover will be soils, liners and debris associated with the SEPs. Nuclear criticality safety is not a concern for the remediation of the SEPs. The major isotopes, and their 95%UCL values, that will be placed under the final engineered cover are those stipulated in Table III.2-3, *OU4 Characterization, Background, and PRG Information for Potential Contaminants of Concern.*

1324-7.2 Radioactive Liquid Waste

1324-7.2.1 Process Wastes

"The liquid radioactive wastes typically associated with RSWFs that are to be considered during the design include, but are not limited to, decontamination solutions, washdown solutions, water collection systems, and contaminated laundry waste. Nuclear criticality safety shall be considered in the design of the radioactive liquid waste processing facility."

RESPONSE

No liquid wastes will be disposed within the remediated SEPs.

1324-7.3 Effluents

"The airborne radioactive wastes typically associated with radioactive solid waste facilities that shall be considered during the design include, but are not limited to, the airborne effluents from process system vents and fission product gases. Effluent system designs shall preclude the holdup or collection of fissile material and other material capable of sustaining a chain reaction in portions of the system not geometrically favorable. Nuclear criticality safety shall be considered in the design of airborne effluent systems."

"Exhaust outlets that may contain transuranics or fission products shall be provided with tow monitoring systems. These monitoring systems shall comply with Section 1589.99.0.1., Radioactive Airborne Effluents."

RESPONSE

No effluent systems will be included in the design of the final engineered cover; however, effluent emission calculations have been performed to assess the airborne and surface water routes. Groundwater effluents will be evaluated in the Phase II portion of the RFI/RI for the SEPs. Nuclear criticality safety is not a concern for the remediation of the SEPs. The major isotopes, and their 95% UCL values, that will be consolidated under the final engineered cover are those stipulated in Table III.2-3, *OU4 Characterization, Background, and PRG Information for Potential Contaminants of Concern.*

APPENDIX IV.B

DESIGN DRAWINGS

See the binder labeled Part IV and V, Drawings

APPENDIX IV.C

COST ESTIMATE DETAILS

CLIENT: [redacted]
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes/Lux

OU[redacted]RA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH NOVEMBER 1997

DATE: 25-Feb-94
TIME: 10:07:17 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
0100	**Baseline radiological/hazardous survey**									
	Initial survey									
	Set up material staging area	80	MH		0	65.00	5,200		0	5,200
	Set up exclusion zone	160	MH		0	65.00	10,400		0	10,400
	Set up step-off/survey area	80	MH		0	65.00	5,200		0	5,200
	Develop radiation worker permit for zone entry	80	MH		0	65.00	5,200		0	5,200
	Baseline survey by HPT	80	MH		0	65.00	5,200		0	5,200
	Obtain excavation permit	40	MH		0	65.00	2,600		0	2,600
	Conduct pre-job training on sampling grid	60	MH		0	65.00	3,900		0	3,900
	Phase II activities									
	Modify radiation worker permit for excavation	40	MH		0	65.00	2,600		0	2,600
	Write health and safety plan	640	MH		0	65.00	41,600		0	41,600
	Phase III activities				0					
	Daily initial surveys, surveys of equipment leaving exclusion zone and daily end of day surveys of ground and equipment	4000	MH		0	65.00	260,000		0	260,000
	Covering any "surface contamination" during operations and overnight if discovered in end-of-day survey	2800	MH		0	65.00	182,000		0	182,000
0200	**Monitor job site remediation/entry security**									
	Rad technicians - 4 for 9 months of project	4,536	MH		0	34.53	156,628		0	156,628
	Construction personnel enter/exit job site	20,180	MH		0	40.00	807,200		0	807,200
5000	**Indirect field costs**									
5010	Obtain building permits	80	MH		0	40.00	3,200		0	3,200
	Cost of Permit	1	LS	500.00	500					500
5020	Mobilization - set up construction staging area and perform decon and smear tests on equipment entering the job site	1,000	MH		0	40.00	40,000		0	40,000
5040	Sanitary (portable toilets) - 8	26	MONTH		0		0	584.00	15,184	15,184

CLIENT: [redacted]
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes/Lux

O[redacted]RA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH NOVEMBER 1997

DATE: [redacted]25-Feb-94
TIME: 10:07:17 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
5045	Handwash unit – 4	26	MONTH					340.00	8,840	8,840
	Eyewash Unit – 4	26	MONTH					116.62	3,032	3,032
5050	Temporary utils (phone, water, 220V elec)	26	MONTH	500.00	13,000		0		0	13,000
	Temporary security fence and lighting installation									
5060	Security fence	2,090	LF	4.00	8,360	6.00	12,540		0	20,900
	Terminal posts	8	EA	70.00	560	105.00	840		0	1,400
	Security gates	4	EA	404.00	1,616	606.00	2,424		0	4,040
	Lights north of seepline	26	MONTH					4100	106,600	106,600
	Lights south of seepline	26	MONTH					4100	106,600	106,600
5100	Trucks									
	Water tanker (631ww) and operator	572	DAY		0	320.00	183,040	1,235.00	706,420	889,460
	Off highway truck (777C) and operator	572	DAY		0	320.00	183,040	1,910.00	1,092,520	1,275,560
	Wheel loader (992C) and operator	572	DAY		0	320.00	183,040	2,995.00	1,713,140	1,896,180
5110	Mobile lab for geotechnical soil testing	26	MONTH		0		0	700.00	18,200	18,200
	Geotechnical Technician	1500	MH			80.00	120,000		0	120,000
	Field Technician	3000	MH			80.00	240,000		0	240,000
5120	Mobile analytical lab for environmental testing				0					
	Staffed lab	120	DAY		0	3,000.00	360,000		0	360,000
	Standby lab	120	DAY		0	800.00	96,000		0	96,000
5121	Site prep. trailer area									
	Road base (6") and grading	740	SY	7.54	5,580	0.06	44	0.04	30	5,654
5125	Office trailer	26	MONTH					375.00	9,750	9,750
5126	Break trailer	26	MONTH					260.00	6,760	6,760
5130	Trailer with lockers	26	MONTH		0		0	375.00	9,750	9,750
5150	Personnel decon trailer with showers	26	MONTH		0		0	550.00	14,300	14,300
5155	Lab/trailer:set-up/remove	6	LS		0		0	505	3,030	3,030
5170	Prepare backfill stockpile area	200,000	SY		0	0.10	20,000	0.07	14,000	34,000
5185	Geotextile material (construction purpose only)	143,500	SY	0.45	64,575	0.75	107,625			172,200
5200	Health and Safety equipment	1	LS		0		0	605,700.00	605,700	605,700
5210	Demobilization/project site final clean up	1	LS		0	120,000.00	120,000		0	120,000
	Decontamination of equipment inside the PA	800	MH			17.84	14,272			14,272
	Decontamination of equipment – buffer zone	400	MH			17.84	7,136			7,136
	Waste crates									
5220	Purchase waste crates	100	EA	260.00	26,000		0		0	26,000
	Install lids on waste crates	100	EA		0	12.00	1,200		0	1,200
	Offload waste crates	100	EA		0	7.00	700		0	700
5230	Assay waste crates	200	MH		0	80.00	16,000		0	16,000

CLIENT: [redacted]
ADDRESS: Rocky Flats Plant
ESTIMATOR: Edmonson/Montes/Lux

OU[redacted]RA PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH NOVEMBER 1997

DATE: 25-Feb-94
TIME: 10:07:17 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
6000	**Relocate power lines from between Ponds 207A and 207B-series**									
6001	Lock out/tag out	64	MH			81.8	5,235			5,235
6010	Install power poles	563	MH		12,386	33.17	18,675		0	31,061
6020	Install conductors	2,600	LF	2.10	5,460	3.14	8,164		0	13,624
6030	Tie in relocated power lines	121	MH		0	33.17	4,014		0	4,014
6040	Perform hi-pot test on new power lines	241	MH		0	33.17	7,994		0	7,994
6050	Remove obsolete power lines and poles	392	MH		0	33.17	13,003		0	13,003
6060	Transport and Store Power Lines	181	MH		0	33.17	6,004		0	6,004
6070	Shred obsolete poles & dispose in 207A	120	MH		0	33.17	3,980		0	3,980
7000	**Vegetation removal**									
	Zones E and F									
7030	Lie Down Liner (double thickness)	24	MH		0	40.00	960		0	960
	Bottom Liner	9,000	SF	1.50	13,500		0		0	13,500
7040	Excavate veg. and soils from remediation areas	2,251	CY		0	1.26	2,836	0.84	1,891	4,727
7050	Cover Piles W/Heavy Tarp	24	MH			40.00	960		0	960
	Top Liner	9,000	SF	1.00	9,000		0		0	9,000
8000	**Pond preparation for cover**									
8110	Grind 207A, 207C and 207B-series liners (grinder, 3000 SY/day)	11,800	CY		0	0.24	2,832	0.08	944	3,776
8115	Move and stockpile liners	5900	CY			1.51	8,909	1.01	5,959	14,868
8120	Excavate berms and Zones B, C, D & G	21,737	CY		0	1.26	27,389	0.84	18,259	45,648
8121	Move & place backfill for Zones B,C,D & E	20,200	CY	6.27	126,654	1.51	30,502	1.01	20,402	177,558
8130	Dispose berms and Zones B, C, D & G into B pond (Vadose Zone) (scraper, 500 CY/day)	21,737	CY		0	1.51	32,823	1.01	21,954	54,777
8140	Subsurface drain									
	Delivery of Gravel (drain trench)	3667	CY	15.07	55,262		0		0	55,262
	Move gravel	3667	CY		0	1.51	5,537	1.01	3,704	9,241
	Grade gravel	3667	CY		0	0.06	220	0.04	147	367
					0					
	Delivery of sand	3519	CY	8.28	29,137		0		0	29,137
	Move sand	3519	CY		0	1.51	5,314	1.01	3,554	8,868
	Grade sand	3519	CY		0	0.06	211	0.04	141	352

CLIENT: E[redacted]
ADDRESS: [redacted]ky Flats Plant
ESTIMATOR: Edmonson/Montes/Lux

OU[redacted]A PROJECT COST ESTIMATE
CONS[redacted]UCTION SCHEDULE: JUNE 1995 THROUGH NOVEMBER 1997

DATE: [redacted]-Feb-94
TIME: 10:07:17 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
8150	Excavate C Pond Soils	27,796	CY		0	1.26	35,023	0.84	23,349	58,372
8160	Move C Pond Soils on top of Drainage	27,796	CY		0	1.51	41,972	1.01	28,074	70,046
8170	Move balance of berms on top of drainage	1,238	CY		0	1.51	1,869	1.01	1,250	3,120
8180	Spread liner material	11,800	CY		0	1.51	17,818	1.01	11,918	29,736
8190	Grade soil, liner and berm material in 207-A	37,024	CY		0	0.06	2,221	0.04	1,481	3,702
8200	Compact 207-A, and B-series ponds (Vibratory sheepsfoot, 5-ton roller, 4 passes)	128,000	SY		0	0.04	5,120	0.03	3,840	8,960
8260	Construct Equipment decon wash area	1	LS		0		0	60,000.00	60,000	60,000
8280	Move and distribute soils & veg. from the hillside north of the seepline in SEP 207-C	2,251	CY		0	1.51	3,399	1.01	2,274	5,673
8290	Grade soils in SEP 207-C	9225	SY		0	0.06	554	0.04	369	923
8300	Compact 207-C pond (Vibratory sheepsfoot, 5-ton roller, 2 passes)	18450	SY		0	0.04	738	0.03	554	1,292
8400	Reclaim Pond C area									
	Delivery of general backfill	4613	CY	6.27	28,924					28,924
	Move general backfill	4613	CY			1.51	6,966	1.01	4,659	11,625
	Grade general backfill	4613	CY			0.06	277	0.04	185	461
	Delivery of topsoil	1538	CY	19.03	29,268					29,268
	Move topsoil	1538	CY			1.51	2,322	1.01	1,553	3,876
	Grade topsoil	1538	CY			0.06	92	0.04	62	154
	Delivery of pea gravel	246	CY	15.5	3,813	0	0	0	0	3,813
	Move pea gravel	246	CY			1.51	371	1.01	248	620
	Grade pea gravel	246	CY			0.06	15	0.04	10	25
	Seed Pond C	1.9	AC					2500	4,750	4,750
9000	**Stabilize hillside**									
9060	Deliver topsoil	10389	CY	19.03	197,703		0		0	197,703
9070	Move topsoil	10,389	CY		0	1.51	15,687	1.01	10,493	26,180
9080	Grade topsoil	10,389	SY		0	0.06	623	0.04	416	1,039
9085	Hydroseed	13.5	AC		0		0	2,500.00	33,750	33,750
9090	Deliver pea gravel	1662	CY	15.5	25,761		0		0	25,761
9100	Move pea gravel	1,662	CY		0	1.51	2,510	1.01	1,679	4,188
9110	Grade pea gravel	30,000	SY		0	0.06	1,800	0.04	1,200	3,000
10000	**Utilities**									
10001	Design/review shoring activities	200	MH			90.00	18,000			18,000

CLIENT: E[illegible]
ADDRESS: [illegible]ocky Flats Plant
ESTIMATOR: Edmonson/Montes/Lux

QU[illegible]A PROJECT COST ESTIMATE
CONSTRUCTION SCHEDULE: JUNE 1995 THROUGH NOVEMBER 1997

DATE: [illegible]25-Feb-94
TIME: 10:07:17 AM

COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
10005	Shoring (excavation/removal)	5580	LF			40.40	225,432			225,432
10006	Shoring (excavation/grouting)	1150	LF			8.08	9,292			9,292
10020	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10030	Remove 3"-LD-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10040	Remove 3"-PW-STL	60	LF		0	27.24	1,634	1.33	80	1,714
10090	Remove and grout 3"-PW-SST, Remove and grout 3"-PW-STL	570	LF		0	27.24	15,527	1.33	758	16,285
10100	Remove & Relocate 6"-RW-CI	550	LF		0	27.24	14,982	1.33	732	15,714
10110	Remove 3"SROB-CAP	310	LF		0	27.24	8,444	1.33	412	8,857
10120	Remove 8"PWF-CI	40	LF		0	27.24	1,090	1.33	53	1,143
10130	Remove 8"PW-CI	30	LF		0	27.24	817	1.33	40	857
10140	Remove 440V-E	130 50	LF A/G LF U/G		0 0	27.24 27.24	3,541 1,362	1.33 1.33	173 67	3,714 1,429
10150	Remove 440-V-E	620	LF		0	27.24	16,889	1.33	825	17,713
10160	Remove 15"-SD-CMP	520	LF		0	27.24	14,165	1.33	692	14,856
10200	Remove/relocate 440V-E	320	LF		0	27.24	8,717	1.33	426	9,142
10210	Remove/relocate telephone	350	LF		0	27.24	9,534	1.33	466	10,000
10220	Remove @ 10"PW-PVC (VCP) 6"-PW-VCP	290	LF		0	27.24	7,900	1.33	386	8,285
10260	Remove 3"-SROB-CAP	90	LF		0	27.24	2,452	1.33	120	2,571
10270	Remove 3/4" E-PVC	90	LF		0	27.24	2,452	1.33	120	2,571
10280	Grout 8"-RW-CAP	760	LF		0	46.98	35,705	11.08	8,421	44,126
10290	Grout 8"-RW-CAP	390	LF		0	46.98	18,322	11.08	4,321	22,643
10300	Remove 12"-OS-CMP	50	LF		0	27.24	1,362	1.33	67	1,429
10310	Remove 1-1/2"DCW-STL	320	LF		0	27.24	8,717	1.33	426	9,142
10320	Remove 3"-SROB-CAP, Remove 3"-ROPW-CAP, Remove 3"-SROP-CAP, Remove 6"-SE-CAP	140	LF		0	27.24	3,814	1.33	186	4,000
10350	Remove 8"-PW-CI	20	LF		0	27.24	545	1.33	27	571
10360	Remove 8"-PW-CI (8"-PCWF-CI)	50	LF		0	27.24	1,362	1.33	67	1,429

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OU[illegible]A PROJECT COST ESTIMATE
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10390	Dispose of utilities in 207-A	6,730	LF		0	1.51	10,162	1.01	6,797	16,960
10410	Cut, Transport and store piping (Includes PPE)	6,730	LF		0	3.00	20,190		0	20,190
11000	**Install Final Engineered cover over Pond 207-A and western portion of B-series ponds**									
11010	Delivery of Gravel Base	5,326	CY	15.07	80,263					80,263
11010	Move gravel base course to Pond 207-A	5,326	CY		0	1.51	8,042	1.01	5,379	13,422
11020	Grade gravel base course in Pond 207-A	5,326	CY		0	0.06	320	0.04	213	533
11030	Compact lower base course (1 pass)	32,000	SY		0	0.04	1,280	0.03	960	2,240
11100	Delivery of asphalt concrete and asphalt layer	32,000	SY	12.02	384,640		0		0	384,640
11120	Unload & distribute asphalt concrete and asphlalt layer	32,000	SY		0	1.51	48,320	1.01	32,320	80,640
11200	Delivery of Sand (drainage)	10,652	CY	8.28	88,199		0		0	88,199
11205	Move sand for lower sand layer	10,652	CY		0	1.51	16,085	1.01	10,759	26,843
11210	Grade lower sand layer	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11220	Compact lower sand layer (2 passes)	64,000	SY		0	0.04	2,560	0.03	1,920	4,480
11300	Delivery of angular riprap (4"-8" dia.)	21,304	CY	18.28	389,437		0		0	389,437
11305	Move angular riprap	21,304	CY		0	1.51	32,169	1.01	21,517	53,686
11310	Grade angular riprap layer	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11320	Compact angular riprap layer (4 passes)	128,000	SY		0	0.04	5,120	0.03	3,840	8,960
11400	Delivery of gravel (filter)	10,652	CY	15.07	160,526					160,526
11405	Move gravel	10,652	CY		0	1.51	16,085	1.01	10,759	26,843
11410	Grade gravel layer	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11420	Compact gravel layer (2 passes)	64,000	SY		0	0.04	2,560	0.03	1,920	4,480
11500	Delivery of sand (filter)	10,652	CY	8.28	88,199		0		0	88,199
11505	Move sand for upper sand layer	10,652	CY		0	1.51	16,085	1.01	10,759	26,843
11510	Grade upper sand layer	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11520	Compact upper sand layer (2 passes)	64,000	SY		0	0.04	2,560	0.03	1,920	4,480
11600	Delivery of general backfill	26,630	CY	6.27	166,970		0		0	166,970
11605	Move general backfill	26,630	CY		0	1.51	40,211	1.01	26,896	67,108
11620	Grade general backfill	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11700	Delivery of topsoil/gravel admix (20%)	18,783	CY	19.03	357,440		0		0	357,440
11705	Move topsoil	18,783	CY		0	1.51	28,362	1.01	18,971	47,333
11710	Grade topsoil	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11800	Delivery of pea gravel	2129	CY	15.5	33,000		0		0	33,000
11805	Move pea gravel	2,129	CY		0	1.51	3,215	1.01	2,150	5,365
11810	Grade pea gravel	32,000	SY		0	0.06	1,920	0.04	1,280	3,200
11820	Perimeter runoff swales									
	Delivery of Topsoil	74	CY	19.03	1,408		0		0	1,408
	Move Topsoil	74	CY			1.51	112	1.01	75	186
	Grade Topsoil	74	CY			0.06	4	0.04	3	7

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COST CODE	DESCRIPTION	QTY	UNIT	MATERIAL UNIT COST	MATERIAL TOTAL COST	LABOR UNIT COST	LABOR TOTAL COST	CONSTR. EQUIP UNIT COST	CONSTR. EQUIP TOTAL COST	TOTAL
	Delivery of Pea gravel	25	CY	15.5	388	0	0		0	388
	Move Pea Gravel	25	CY			1.51	38	1.01	25	63
	Grade Pea Gravel	25	CY			0.06	2	0.04	1	3
11830	Delivery of Gravel (Toe Drain)	296	CY	15.07	4,461		0		0	4,461
	Move Gravel	296	CY			1.51	447	1.01	299	746
11840	Clean fill wedge									
	Delivery of general Backfill	4,000	CY	6.27	25,080		0		0	25,080
	Move general Backfill	4,000	CY			1.51	6,040	1.01	4,040	10,080
	Grade general Backfill	4,000	CY			0.06	240	0.04	160	400
11850	Reclaim Traffic areas and Misc.									
	Delivery of Pea Gravel	645	CY	15.50	9,998		0		0	9,998
	Move Pea Gravel	645	CY			1.51	974	1.01	651	1,625
	Grade Pea Gravel	645	CY			0.06	39	0.04	26	65
11855	Seed Traffic Area	5	AC		0		0	2,500.00	12,500	12,500
11860	Seed Cover	7.8	AC					2,500.00	19,500	19,500
13000	Remove Equipment Decon Wash Area	1	LS		0	15,000.00	15,000		0	15,000
14000	**Off-site disposal**									
	Transportation by railcar	2	EA		0		0	2,210.00	4,420	4,420
	Envirocare	100	EA		0		0	1,792.00	179,200	179,200
15000	**Final site survey by HPT**	160	MH		0	80.00	12,800		0	12,800
18000	**Training**	2,400	HR		0	50.00	120,000		0	120,000
19000	**Postclosure (monitoring system)**	1	LS		0	254,296.00	254,296	341,040.00	341,040	595,336
20000	**Construction subtotal**				2,447,065		4,635,848		5,449,922	12,532,835
21000	**Building Factor (33.5%)**									1,553,009
22000	**Construction subtotal**									14,085,844
23000	**Engineering Costs**									2,500,000
24000	**Purchase small tools and consumables (5%)**									78,000
25000	**Project Management (6%)**									751,970
26000	**Contractor Construction Management**									3,000,000
27000	**Construction Management (15%)**									2,112,877
28000	**Contractor G&A (10.75% Total Const. Cost)**									1,514,228
29000	**Subtotal**									24,042,919
30000	**Escalation (9.73% Const. Cost)**									1,370,553
31000	**Escalated Subtotal**									25,413,471
32000	**Contingency (30%)**									7,624,041
33000	**Total estimated cost**									33,037,513

COST ESTIMATE FOR ROCKY FLATS OPERABLE UNIT 4
POST CLOSURE VADOSE ZONE
MONITORING SYSTEM

CAPITAL COSTS

Direct Capital Cost

Item	Units	Quantity	Cost per Unit	Total
SITE IMPROVEMENT				
Vadose Zone Monitoring Installation	l.s.	1	$118,000	$118,000
SUBTOTAL				$118,000
CAPITAL EQUIPMENT				
VADOSE ZONE MONITORING				
Neutron Probe System	l.s.	1	$36,000	$36,000
Pressure Vacuum Lysimeter	l.s.	1	$4,200	$4,200
FDC Sensor	l.s.	1	$11,000	$11,000
SUBTOTAL				$51,200
SUBTOTAL OF CAPITAL EQUIPMENT COST				$51,200
SUBTOTAL DIRECT CAPITAL COST				**$169,200**

Indirect Capital Cost

Testwork (capital equipment)	2%	$1,024
Permitting and Deed Changes (site improvement)	5%	$5,900
Equipment Replacement (capital equipment)	5%	$1,024
Construction Oversight (To be included in cost estimate rollup)		
Engineering and Design (To be included in cost estimate rollup)		
Contingency (To be included in cost estimate rollup)		
Building Factor (To be included in cost estimate rollup)		
SUBTOTAL INDIRECT CAPITAL COST		**$7,948**
TOTAL CAPITAL COST		**$177,148**

OPERATING AND MAINTENANCE COSTS

Direct Operations and Maintenance Cost

Item	Units	Quantity	Cost per Unit	Annual Cost	Years Incurred
Vadose Zone Monitoring	hour	570	$85	$48,450	1–30
Pore Liquid Analysis	each	21	$3,850	$80,850	1–30
Vadose Zone Monitoring Maintenance	hour	40	$85	$3,400	1–30
Compliance Reporting	each	4	$2,000	$8,000	1–30
Meetings	each	4	$1,200	$4,800	1–30
Engineering Review & Evaluation	l.s.	1	$3,000	$3,000	1–30
Data Processing and Evaluation	hour	128	$85	$10,880	1–30
SUBTOTAL				$159,380	
SUBTOTAL ANNUAL COST				**$159,380**	

Indirect Operations and Maintenance Cost

Contingency (To be included in cost estimate rollup)	
Project Management (To be included in cost estimate rollup)	
Building Factor (To be included in cost estimate rollup)	
Escalation Factor over 30 Years (To be included in cost estimate rollup)	
SUBTOTAL INDIRECT CAPITAL COST	**$0**
TOTAL ANNUAL OPERATIONS AND MAINTENANCE COST	**$159,380**

This is a preliminary estimate based on 1992 Means Site Work and Landscape Data, vendor quotes, and engineering judgment.

APPENDIX IV.D

CONSTRUCTION QUALITY CONTROL

PLAN

QUALITY CONTROL PROCEDURES

U.S. Department of Energy (DOE)

The DOE will be responsible for implementation of construction activities and control of the project. The DOE will conduct audits of the QA/QC testing activities and has the ultimate authority to approve QA/QC tests.

Construction Manager (CM)

The CM will be responsible for overseeing and supervising construction activities. The CM will also provide verification and acceptance to the contractor regarding QA/QC tests and procedures. The QA/QC tests will be submitted to the DOE by the CM.

Contractors

The contractor will be responsible for performing the construction activities in accordance with engineering specifications. The construction contractors are directly responsible for performance of QC activities, as required in their contracts, and report to the CM. A third party contractor will perform the QC activities. Therefore, the QC testing will not be performed by either the CM's organization or the construction contractor's organization. The QC contractor will provide reports to the construction contractor. The construction contractors will forward copies of inspection reports to the CM for each category of work performed (earthwork, drilling, sampling, etc.) and a summary of all corrective actions and deviations to ensure the adequacy of the QC effort.

Quality Control Inspection Methods and Testing Procedures

QC inspection methods and testing procedures associated with the OU4 remediation activities are described in the following paragraphs by construction activity. The construction activities are as follows:

- Site preparation,
- Excavation of contaminated soil media,
- Backfilling of excavations,
- Crushing of liners from SEPs,
- Placement of engineered cover components,
- Closure of existing underground utilities,
- Rerouting of existing underground utilities,
- Borehole advancement,
- Recordkeeping during well development, and
- Closure certification.

Site Preparation

The site initially shall be cleared of vegetation, rocks, rubbish, and all other perishable and detrimental matter. Adequacy of the site preparation procedures will be determined by visual inspection. After the SEPS are closed and areas with surface elevations higher than the grade shown on the construction drawings as determined by surveying are identified, the areas shall be graded and excavated as necessary to the required grade.

The contractor shall have full responsibility for the direction of the work and arranging for inspection of the work in progress and coordination of any inspection agency or surveillance to ensure conformance with standards and specifications.

Excavation of Contaminated Soil Media

Excavation activities will be performed to consolidate the OU4 liners and contaminated media beneath the engineered cover.

Excavation shall meet alignments, grades, dimensions, and shapes shown on the construction drawings.

A sufficient number of monuments and benchmarks will be established for overall horizontal and vertical control. The surveyors shall provide initial layout, concurrent inspection, and final checkout to ensure that all work performed conforms to lines, grades, cross-sections and details indicated on construction drawings.

Approval of the contaminated soil media from the excavation areas and from the SEPs is the responsibility of the contractor and will be documented in a written report.

The contractor shall have full responsibility for the direction of the work, for arranging for inspection of the work in progress, and for coordination with any inspection agency or surveillance to ensure conformance with standards and specifications.

Backfilling Excavations

Excavated areas that will not be beneath an engineered cover will be backfilled with clean native soils. The backfilled areas will be regraded and seeded.

Prior to field activities, all soils to be used as backfill will be tested to determine maximum dry density and optimum moisture content. Testing services shall be provided by an independent testing laboratory. Compaction of backfill will be verified by in-place density testing. Nuclear-gauge density testing and sand-core testing will be used for verification of conformance to specifications. The frequency of in-place density tests shall not be less than one test per lift per 10,000 square feet of compacted material.

Further compaction or excavation and recompaction will be ordered should verification testing show nonconformance to specifications. Comparison of results from one-point proctor testing with established proctor curves to verify material type will be performed if the specified density requirements cannot be met without unusually extensive compactive effort.

The laboratory protector tests, in-place nuclear-gauge testing, and sand-core testing shall be documented by a third party laboratory with certified independent laboratory test reports and submitted to the contractor, who will in turn submit them to the CM for verification and acceptance.

The contractor shall have full responsibility for the direction of the work, for arranging for inspection of the work in progress, and for coordination of any inspection agency or surveillance to ensure conformance to standards and specifications.

Crushing and Excavation of Liners from SEPs

The liners from SEPs 207-A, 207-C, and the B Series SEPs will be crushed and excavated prior to placement beneath the SEP 207-A engineered cover.

Visual observations shall be made to ensure that the material that is placed in the engineered cover as backfill has passed the crushing criteria in accordance with engineering specifications.

Approval of activities to crush the liners from the SEPs is the responsibility of the contractor and will be documented in a written report.

The contractor shall have full responsibility for the direction of the work, for arranging for inspection of the work in progress, and for coordination of any surveying services, inspection agency, or surveillance to ensure conformance to standards and specifications.

Placement of Materials for the Engineered Cover

Offsite materials will be procured for construction of the engineered cover.

The following in-process tests may be required:

Material	Requirements
Topsoil	surveying visual inspection
General backfill	surveying in-place density
Sand (filter)	surveying visual inspection gradation in-place density
Gravel (filter)	surveying visual inspection gradation in-place density
Angular Riprap	surveying visual inspection
Sand (drainage)	surveying visual inspection in-place density
Asphalt	surveying sampling compressive strength
Asphalt Concrete	surveying sampling compressive strength
Gravel Base Course	surveying visual inspection in-place density
Compacted Backfill	surveying visual inspection
Subgrade	surveying visual inspection in-place density

A sufficient number of monuments and benchmarks will be established for overall horizontal and vertical control. The surveyors shall provide initial layout, concurrent inspection, and final checkout to ensure that all work performed conforms to lines, grades, cross-sections and details indicated on construction drawings.

The in-process tests shall be documented with certified independent third-party laboratory test reports and submitted to the contractor, who in turn shall submit them to the CM for verification and acceptance. All tests shall be dated and signed by the person performing the tests. Daily reports, including a record of all in-process inspections and tests performed, should be maintained.

The contractor shall have full responsibility for the direction of the work, for arranging for surveying and other services, including inspection of work in progress and coordination of any inspection agency to ensure conformance to project requirements.

Closure of Existing Underground Utilities

Some of the underground utilities in and around the OU4 SEPs that are not necessary for future activities at the RFP will be closed in-place. These utilities may be excavated and removed or filled with a Portland cement-type grout for permanent closure. Another alternative for permanent closure includes capping the ends of the pipe with a material consistent with the pipe material.

The capping requirements include visual observation of capping activities to ensure that specifications are met. The valve boxes should be visually inspected to ensure that the control handles have been removed and that the shafts have been welded in the closed position. The valve boxes should be filled with grout according to specifications.

The underground utilities requiring grouting should also be visually inspected. The volume of grout required to fill the piping system should be closely monitored. The volume should not exceed 20 percent of the volume expected to fill the pipe. Any exceedence may indicate that the pipe is broken or cracked.

QC testing for grout will be performed according to design specifications. The in-process tests shall be documented with certified independent third-party laboratory test reports and submitted to the contractor, who in turn shall submit them to the CM for verification and acceptance. All tests shall be dated and signed by the person performing the tests. Daily reports of all in-process inspections and tests performed should be maintained. Tests and inspections will be documented.

The contractor shall have full responsibility for the direction of the work, for arranging for surveying and other services, including inspection of work in progress and coordination of any inspection agency to ensure conformance to project requirements.

Rerouting of Existing Underground Utilities

Some of the underground utilities in and around the OU4 SEPs are necessary for future activities at the RFP. These utilities include domestic cold-water, raw-water, storm drains, telephone service, and electrical power. The utilities will be rerouted around the perimeter of the engineered covers. Utility piping requiring rerouting will be excavated in sections or cut for easier removal.

All new piping shall be inspected by the contractor for obvious defects upon delivery to the site. Piping shall then be assembled by the contractor in accordance with the design specifications. All installed domestic cold-water and-raw water piping shall be hydrostatically and/or pneumatically pressure-tested by the contractor according to design specifications.

Borehole Advancement

A log of each borehole shall be prepared by the contractor's onsite geologist which notes lithologies encountered and other pertinent information. The geologic boring log completed by the geologist shall include the following information, at a minimum:

- Depth,
- Profile,
- Unified Soil Classification Systems (USCS) soil classification,
- Geologic description (including color, grain size, moisture, plasticity, fractures, joints, and local formation name, if known),
- Drill pressure/blow counts,
- Remarks (includes photoionization detector measures, water table information, weather, and any pertinent comments regarding drilling),
- Drilling machinery, and
- Equipment decontamination procedures.

After a day of drilling is completed, the contractor's geologist will review his/her logs for completeness and consistency, and will revise them as necessary. Changes will be made by crossing out the error with one line and writing in the correction along with the author's initials and the date. Field logs shall be typed for readability in reports, and shall accompany the typed geologic log, without exception. A contractor-oversight geologist will ensure that these procedures are followed.

Monitoring well/piezometer construction will be observed by the contractor's geologist to ensure adherence to the QA/QC plan and the project design specifications. In addition to the data recorded on the geologic boring log for completion of soil borings, the following information will be recorded on the boring log:

- Well material decontamination procedures,
- Total depth of completed well, and

- Depth to water table after sufficient time has elapsed to allow for water table stabilization.

Recordkeeping During Well Development

The following information shall be recorded by the contractor in a bound, sequentially paginated fieldbook during development of each monitoring well:

- Date;
- Time;
- Well number and location;
- Depth of well;
- Depth to water table before development begins;
- Depth to top of screen;
- Development method, rate of water removal, and total volume removed;
- Temperature, pH, and specific conductance measured for the initial ground water sample and for subsequent sampling;
- Documentation of field instrument calibrations;
- Physical appearance of the water removed during development and photograph identification; and
- Signatures of those performing this work.

Proper recordkeeping shall document the effectiveness of the well construction and the adequacy of development. The contractor will check the contractor's logs for completeness. The recorded information will be turned over to the CM upon completion.

Closure Certification

Within 60 days after the completion of closure, the owner of operator must submit a certification that the SEPs have been closed in accordance with the specifications in the approved closure plan.

A professional engineer (P.E.) will be responsible for overseeing the closure activities to ensure that they comply with the approved decision docoument. The P.E. shall have full responsibility for maintaining a field log documenting observations. These field observations will be summerized in a closure report.

Quality Assurance

Attachment 1 provides a quality assurance outline which specifies the 18 required aspects of the RFP quality assurance program.

ATTACHMENT 1 TO APPENDIX D

QUALITY ASSURANCE PROCEDURES

1.0 Organization and Responsibilities

- Purpose

  This procedure will define the functional and administrative organizations, associated responsibilities, and lines of communication required for the control of activities affecting quality.

- Scope

  This procedure will apply to all programs, project activities, and operations.

- Requirements

  The quality assurance (QA) organizational structure, functional responsibilities, levels of authority, and lines of control will be documented and controlled.

2.0 Quality Assurance Program

- Purpose

  This procedure will define the actions and responsibilities necessary for implementation and maintenance of the QA program.

- Scope

  This procedure will apply to all activities affecting quality, and to all participants in programs or projects.

- Requirements

  A documented QA program will be planned, implemented, and maintained in accordance with RFP procedures.

3.0 Construction Control

- Purpose

  This procedure will establish the responsibilities and actions required to assure the implementation of QA requirements and controls on construction activities.

- Scope

  This procedure will apply to all construction activities conducted in support of operations.

- Requirements

  The responsible design organization shall ensure that construction activities are defined, controlled, and verified, and that:

  (a) Applicable design inputs are appropriately specified on a timely basis and correctly translated into design documents;
  (b) Design interfaces are identified and controlled;
  (c) Design adequacy is verified by persons other than those who designed the item; and
  (d) Design changes, including field changes, are governed by control measures equal to those applied to the original design.

4.0 Control of Procurement Documentation

- Purpose

  This procedure will define the actions and responsibilities for preparing and controlling documents implemented for the procurement of items and services purchased for activities.

- Scope

  This procedure will apply to the procurement of all items and services used in the performance of activities.

- Requirements

  Requirements necessary to ensure the required quality shall be included or invoked on documents (purchase requisitions, Statement of Work, purchase orders, and specifications) developed for the purchase of items or services. In addition,

measures shall be established to ensure that purchased items or services conform to procurement document requirements.

5.0 Instructions, Procedures, and Drawings

- Purpose

  This procedure will define the actions necessary for ensuring that design, procurement, environment investigation, construction, maintenance, operation, and other activities are performed in accordance with approved instructions, procedures, and drawings.

- Scope

  This procedure will apply to activities requiring a high degree of confidence that the item or service meets requirements and is satisfactory to the customer, and where thoroughness, accuracy, and precision are essential for performance.

- Requirements

  Instructions, procedures, and drawings shall be prepared, approved, and controlled to ensure that all operations and services are performed and controlled within specific guidelines and in accordance with appropriate regulatory requirements.

6.0 Document Control

- Purpose

  This procedure will define the actions and responsibilities required to control documents that specify quality requirements, document the achievement of quality, or prescribe activities affecting quality, and to ensure that applicable documents are available at locations where they are to be used.

- Scope

  This procedure will apply to organizations responsible for the control of the identification, classification, preparation, review and approval, revision, maintenance, and distribution of documents and records that furnish evidence of quality. Document control includes the actions necessary to ensure that accurate and current documents are available at the worksite and used by those performing activities affecting quality.

- Requirements

  Documents that specify quality requirements or prescribe activities affecting quality shall be controlled to ensure that correct documents are being employed. Control includes identification, preparation, issue, change, maintenance, review, approval by authorized personnel, and release for use.

7.0 Control of Purchased Items and Services

- Purpose

  This procedure will define the QA actions and responsibilities necessary for procuring items and services through the procurement system, and also will define interfacing technical activities.

- Scope

  This procedure will apply to the procurement of standard and special items and services used in the performance of activities.

- Requirements

  Requirements necessary to control the procurement of items or services shall be invoked to ensure conformance to specified requirements. At a minimum, procurement of items and services affecting quality shall be controlled. Control shall provide for source evaluation and selection, evaluation of objective evidence of quality furnished by the supplier, and examination of items or services upon delivery or completion.

8.0 Identification and Control of Items

- Purpose

  This procedure will define the actions and responsibilities required to ensure that only correct and accepted items are used, analyzed, installed, transferred, stored, or placed into service.

- Scope

  This procedure will apply to all items acquired, provided, or generated in support of operations and activities.

- Requirements

  Controls shall be established and implemented to ensure that only correct and accepted items are analyzed, used, or installed at any stage from initial collection or receipt through final stage.

9.0 Special Process Control

- Purpose

  This procedure will define the actions and responsibilities required to ensure that special processes are identified and that they are performed by qualified personnel in accordance with specified requirements.

- Scope

  This procedure will apply to all special processes (e.g., welding, environmental sampling, well drilling, and construction, laboratory analysis, and nondestructive examination).

- Requirements

  Processes that affect quality shall be controlled. The level of control shall be commensurate with the nature of the process and its relationship to the whole of the activity. Performance shall be by qualified personnel using controlled procedures, and control shall be in accordance with specified requirements.

10.0 Inspections

- Purpose

  This procedure will define the requirements and actions necessary for planning, executing, and reporting inspections conducted to verify that items, services, or activities conform to specified requirements.

- Scope

  This procedure will apply to all activities where a high degree of confidence is required to ensure that the item, activity, or service will meet specified requirements.

- Requirements

  Inspection activities required to verify conformance of an item or activity to specified requirements shall be planned, executed, and documented.

11.0 Test Control

- Purpose

  This procedure will define the actions and responsibilities required to plan, accomplish, and evaluate tests that verify conformance of items, services, and operations to specified requirements.

- Scope

  This procedure will apply to all test activities performed on items, services, materials, and analyses used in the conduct of design, construction, environmental investigation, environmental remediation, and waste management activities.

- Requirements

  Tests required to verify conformance of an item or service to specified requirements and to demonstrate that items will perform satisfactorily in service shall be planned and executed. Characteristics to be tested and test methods to be employed shall be specified. Test results shall be documented and their conformance with acceptance criteria shall be evaluated. Tests required to collect data shall be planned, executed, documented, and evaluated.

12.0 Control of Measuring and Testing Equipment

- Purpose

  This procedure will define the requirements for control and calibration of Measuring and Testing Equipment (M&TE).

- Scope

  This procedure will apply to M&TE used in activities where quality must be assured (e.g., field sampling, laboratory analysis, fabrication, construction, installation, testing, inspection, and operation and maintenance of activities and facilities). M&TE includes working (installed and portable) devices or systems and standards used for calibration of devices or systems.

Calibration and control measures are not required for rulers, tape measures, levels, and other such devices if normal commercial equipment provides adequate accuracy.

- Requirements

M&TE used to measure controlled characteristics of items affecting quality, safety, or processes shall be of the proper type, range, accuracy, and tolerance. M&TE shall be identified or maintained in a documented usage/calibration program.

13.0 Handling, Storage, and Shipping

- Purpose

This procedure will describe the actions and responsibilities necessary for controlling the handling, storage, and shipping of items or materials to prevent damage or loss and to prevent the release of hazardous materials to the environment.

- Scope

This procedure applies to all activities that require assurance that an item or material being handled, stored, or shipped is protected from damage or loss and from accidental release of contaminants into the environment.

- Requirements

Measures shall be established for the control of samples, waste, materials, and equipment to ensure protection from loss, deterioration, and physical damage and to ensure containment integrity during handling, storage, and shipping. Activities associated with handling, storage, and shipping shall be conducted in accordance with approved instructions, procedures, and drawings.

14.0 Inspection, Test, and Operating Status

- Purpose

This procedure will define the actions and responsibilities for determining and identifying the operational status of items or systems and for ensuring that they are not inadvertently installed, used, or operated.

- Scope

  This procedure will apply to all activities where knowledge of the operating status of equipment or systems is required to prevent the inadvertent use of those items or systems.

- Requirements

  The status or results of inspection and test activities shall be identified either on items or in documents traceable to the items to ensure that required inspections and tests are performed and that items that have not passed the necessary inspections or tests are not inadvertently installed, used, or operated.

15.0 Nonconformance Control

- Purpose

  This procedure will define the actions and responsibilities necessary to identify and control (i.e., segregate, dispose, and report) nonconforming items, activities, or services performed, fabricated, or purchased.

- Scope

  This procedure will apply to all items, services, or activities performed, used, fabricated, or purchased that do not conform to specifications.

- Requirements

  Procedures shall be developed and implemented to control items, services, or activities that do not conform to requirements and specifications to prevent their inadvertent installation and use. These measures shall include appropriate requirements and controls for the identification, documentation, segregation, and disposition of nonconforming items and notification to affected organizations.

16.0 Corrective Action

- Purpose

  This procedure will define the actions necessary to initiate, evaluate, track, and verify completion of corrective actions implemented to prevent recurrence of conditions adverse to quality.

- Scope

  This procedure will apply to all corrective actions initiated for nonconformance which occur during the conduct of activities and projects.

- Requirements

  Corrective actions shall be taken to prevent recurrence of conditions adverse to quality. The corrective action shall be documented and reported to appropriate levels of management and follow-up action shall be taken to verify implementation of the corrective action(s). When necessary, investigations will be undertaken to determine the root cause(s), to evaluate QA measures taken to mitigate causes, and to define appropriate technical and corrective actions and follow-up.

17.0 Quality Assurance and Project Records

- Purpose

  The purpose of the procedure will be to describe the actions and responsibilities necessary for the identification, control, storage, disposition, and retrieval of quality-related records and documents.

- Scope

  This procedure will apply to the management of quality-related records generated, acquired, or used by personnel, subsidiaries, or subcontractors in the performance of their job activities. For the purpose of this procedure, the term "Record" refers to documents, instructions, procedures, drawings, and project record files.

- Requirements

  Records furnishing documentary evidence of quality shall be maintained and the requirements for record transmittal, distribution, storage, retention, maintenance, and disposition shall be established and documented.

18.0 Conduct of Audits

- Purpose

  This procedure will define the requirements and actions necessary for planning, conducting, and reporting QA Audits.

- Scope

  This procedure will apply to internal and external audit activities conducted to verify and evaluate the adequacy of the application of QA requirements and controls to projects, operations, or other activities performed.

- Requirements

  Planned and scheduled audits shall be performed to verify compliance with all aspects of the QA program and to determine its effectiveness. These audits shall be performed in accordance with written procedures or checklists by qualified personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented to responsible management. Follow-up action shall be taken when indicated to provide the necessary corrective action required to eliminate the cause of the problem area and to verify the corrective action adequacy.

APPENDIX IV.E

SAMPLING AND ANALYSIS WORKPLAN FOR VERIFICATION OF RECLAIMED AREA

SECTION 1

INTRODUCTION

1.1 Purpose

The following methodology represents the proposed approach for the sampling and analysis plan. Issues such as QA/QC will be addressed as this methodology evolves into the sampling plan.

The preferred remedial alternative for Operable Unit 4 is the consolidation of SEP soils and liners. Following the excavation of contaminated soils, samples will be collected and analyzed for the prevalent COCs within in the immediate area based on the information derived from the RI/RFI sampling program. Once analytical results have confirmed that the specified COCs have been removed, a composite sample will be collected from six points from within the area of excavation. This composite sample will be used to demonstrate that no further excavation is required. The composite sample will be tested for the entire list of COCs.

The purpose of this sample and analysis plan is to identify the analytical procedures and defining an approach for confirming excavation efforts have captured the specific COCs within that area. This plan is divided into an excavation sampling program and a verification sampling program since the two programs have different objectives and will occur in sequential phases.

Section 2 of this plan presents the sample collection and analysis procedures associated with the excavation activities. In summary, the objective of the excavation sampling program is to provide an inexpensive and quick screening method to control the excavation of potentially contaminated soils. The basic approach to achieve this objective is to select a limited number of indicator parameters which are the most representative of the extent of contamination within the designated area. Ideally, when the clean-up level for the indicator parameter is met, all other contaminants will be below their respective clean-up limits.

Section 3 provides a description of the verification sample collection and analysis procedures. Since the results of these analyses will be used to demonstrate that the soils have been excavated to levels below their respective PRGs, the data will require a high quality level while being statistically defensible. To the extent practicable, the analytical results obtained during the excavation sampling program will be used to verify that the PRGs have been attained. The sampling results will be supplemented by applying a composite sampling approach to verify that the remaining Contaminants of Concern (COCs) are below their respective PRGs. The results of the verification sampling program will be statistically evaluated to ensure that an adequate number of samples were collected to support initiation of backfill operations.

1.2 Existing OU4 Soil Data

Soil samples have been collected around the SEP area as identified in Figures III.2-2 and III.2-3. These samples were screened for the presence of semi-volatile organics, metals, radionuclides, and pesticides. This sampling information then was used to establish the levels

of contamination, determine PRGs, and identify the COCs.

SECTION 2

EXCAVATION SAMPLE AND ANALYSIS PLAN

2.1 Excavation Sampling Program

The objective of the excavation sampling program is to provide timely analytical information to efficiently control the excavation of potentially contaminated soils at a reasonable cost. The sampling program must have a quick turn-around time for analytical results since any delays in receiving the results could inflate excavation costs. To minimize analytical cost, the COCs with the highest contaminant concentration levels will be selected as the indicator parameter(s). Sample screening for these parameters will determine if additional excavation is required.

The utilization of existing sample information will minimize the amount samples required for determining soil excavation depths as well as minimize the amount of clean soils excavated. A secondary objective of the excavation sampling program is to use the COC concentration results as part of the verification program to demonstrate that the OU4 soils have been remediated to the levels specified by the PRGs. To achieve the verification and waste minimization goals, the analytical methodology prescribed for the excavation sampling program must be sensitive enough to determine, with a high degree of confidence, whether the soil is above or below the remediation limit. Although a higher level of QA will be required to obtain defensible results, the dual use of the results will minimize the need to duplicate the results during the verification sampling phase. Guidelines for decommissioning NRC-licensed sites state that the detection sensitivity of the analytical methods used during the final survey should be capable of measuring levels which are 10 to 25 percent of the established clean-up limits (NRC 1992a). In the absence of other regulatory guidance documents, this detection limit goal was adopted for the selection of the analytical and sampling methods.

2.2 Initial Equipment Decontamination

All sampling equipment, whether existing or newly purchased, will be decontaminated at a designated central on-site staging area prior to use. This decontamination requirement is designed to prevent the introduction of contaminants from other sources and to ensure worker protection. A sample of the final decontamination rinseate will verify that none of the COCs identified in Table III.2-4 are being introduced from outside sources. The rinseate sample will be collected and preserved in accordance with site requirements. If sample results indicate the presence of contamination, the decontamination procedure will be repeated or the piece of equipment will not be used.

2.3 Sample Locations

A grid over OU4 will be established to facilitate the systematic selection of sample locations, to provide a reference to coordinate excavation, and to allow relocation of the sample point in the event that the analytical results need to be confirmed. A systematic 10-meter by 10-

meter grid was selected as the basis for determining the sample locations. The 10-meter interval was used to be consistent with the remediation requirements identified in 40 CFR 192.12 for uranium mill tailing sites. Although the standards specified in this regulation are for radium contamination, this grid size has been adopted by the NRC for site decommissioning projects (NRC 1992a).

The x-axis of the grid has a west-east orientation, and the y-axis runs south-north. The 10-meter intervals are lettered along the x-axis and numbered along the y-axis. The combination of letters and numbers were used to eliminate the potential for transposing the x and y coordinates. The grid will be tied to the site coordinate system with the origin (A,0). A figure will be developed detailing the grid.

Although the grid system is divided into 10-meter intervals, it may not be necessary to collect and analyze soil samples at every node point. The selection of sampling locations will be based on COC levels derived from RI/RFI sampling results.

2.4 Sample Collection

The sample teams will meet prior to initiating field work to review the work plan and address health and safety requirements. The required supplies, including portable radios, will be obtained from the support trailer. Once the proper notifications have been made, the sample teams will begin field work.

The sample locations will be determined by measuring distances between the surveyed stakes and markers. Sampling equipment will not be placed directly on the ground or on other potentially contaminated surfaces prior to sample collection. A polyethylene sheet will be spread out by the sample location to provide a clean working surface; only one side of the polyethylene sheet be allowed to come in contact with the ground.

The sampler will identify the sample location, label the sample containers, and record the location information in the field log. This information will be derived from the grid. The "x" axis will be lettered and the "y" will be numbered. An unique alphanumeric identifier shall be assigned to each sample collected as follows:

1) The first three places of the sample identifier will be "EX4" to signify that the sample was collected as part of the excavation sampling program for OU4

2) The next two places will identify the x-axis (east-west) coordinate; a minus sign will be used, if needed, depending on the location of the origin

3) The next two places will identify the y-axis (north-south) coordinate; a minus sign will be used, if needed, depending on the location of the origin

4) The final place will be a letter to identify the depth of the sample; "A" represents the 0- to 6-inch interval, "B" represents the 6- to 12-inch interval, "C" represents the 12- to 18-inch interval, etc. If sampling is required below the 5-foot soil column collected, the

lettering system shall be continued based on the surface elevation prior to soil excavation.

For example, the 12- to 18-inch sample collected at sample location (K, 22) would be assigned "EX4K22C" for tracking purposes.

Disposable latex gloves shall be worn while collecting and handling the soil samples. The samplers shall wear a new pair of gloves for each sample location as well as decontaminating the sampling tool (stainless trowel, scoop, coring device, or shovel) prior to collecting each soil samples. This action will avoid the potential for cross-contaminating samples collected at different intervals at the same location. To minimize down-time due to the decontamination process, multiple sets of sampling equipment will be used. The used sampling equipment will be wrapped in plastic for transport to the decontamination area. However, a rinseate sample will be collected once for each 20 batches of sampling equipment decontaminated. The sampler will attach the sample identification tag to the sample equipment to allow the source of the rinseate sample to be tracked. If contamination is detected in the rinseate samples, this frequency may be increased.

The sampler shall close the sample containers and seal them with custody tape. The soil samples will be placed into a cardboard box for transport to the laboratory facilities. The cardboard box will be closed and sealed with custody tape. The appropriate labels, with sample identifier, shall be affixed to the outside of the cardboard box.

Sampling equipment will be decontaminated between sample locations to avoid the potential for cross-contamination. The equipment will be wrapped in plastic for transport to the decontamination area. The sampling equipment will be decontaminated in accordance with site procedures. A rinseate sample will be collected once for every 20 batches of sampling equipment decontaminated. The sampler will attach the sample identification tag to the sample equipment to allow the source of the rinseate sample to be tracked. If contamination is detected in the rinseate samples, this frequency may be increased.

Used gloves and other debris will be discarded into a plastic bag for disposal in accordance with site procedures. Excess soils collected during sampling will be returned to the excavation site. This is an acceptable action since if analytical results indicate that further samples and additional soil excavation is required then the soils will be collected at that time.

At the end of the day, the sampler will complete the Daily Field Activity Log for submission to the Project Manager. The samplers will place the sampling equipment in proper storage areas and make arrangements to acquire supplies for the next day's sampling.

SECTION 3

VERIFICATION SAMPLE AND ANALYSIS PLAN

3.1 Verification Sampling Program

The objective of the verification sampling program is to demonstrate that soil excavation is complete and to provide certification for closure. The final ground surface elevations will be surveyed to verify that all the contaminated soil identified through the excavation sampling program was removed. After verification of the survey elevations, soil samples will be collected and analyzed to verify that the COCs are statistically below the PRGs. If the results demonstrate that the remediation is complete, final backfilling, grading, and vegetating will commence. If the results indicate the presence of contaminants, additional samples may be collected to determine if further soil excavation is warranted.

Since all analytical results will need to be defensible, a high quality level will need to be maintained throughout program implementation. As such, all samples are considered critical and analyses will be conducted at either QA level 4 or QA level 5 for radiological. Table 1 identifies the COCs, PRGs, the analytical procedure, and approximate sample preparation and analysis time.

In order to verify that the analytical results are less than the PRGs, the detection limit shall be a minimum of 25 percent of the PRG. For the purpose of this plan, the minimum detection limits are based on the PRGs. Lower detection limits will be used to the extent practicable since lower detection limits provide more flexibility to average and statistically evaluate the results to verify that the PRGs have been achieved.

Some of the listed PRGs may be unattainable due to current analytical laboratory technologies and/or practical economic constraints. The dollar amounts listed below in Table 2 reflect only the costs associated with sample preparation and analysis time. These estimates do not include any costs associated with the actual sample collection. Analytical costs vary greatly and in a competitive industry it would be difficult to pinpoint a dollar amount without a formal laboratory bid proposal. The actual sample cost can be influenced by several factors to include: number of samples, sample matrix, quality control levels, and current amount of work within the local laboratory industry. Another major cost factor to consider is the required turn-around time for the analytical results. With short duration turn-around times, it could result in developing custom analytical methods which can increase costs by 200 to 300 percent. The analytical unit costs listed below in Table 2 are based on standard laboratory turnaround times of 30 working days.

TABLE 1
ANALYTICAL METHODS FOR VERIFICATION SAMPLES

Contaminant of Concern	PRG Surface Soils (0" - 3") (a)	PRG Vadose Soils (3" - 12') (a)	GRASP CRQL/CRDL (b)	MDL (Other Methods) (c)	MDL (Other Methods) (d)	MDL (Other Methods) (c)	Sample Preparation Time (e)	Sample Analysis Time (e)
			SW846-8270	SW846-8310	SW846-8270M SIM Mode	SW846-8260		
1,4-Dichlorobenzene (μg/kg)	117	(f)	330		2.0	5	1 Hour	45 Min
2,6-Dinotrotoluene (μg/kg)	(g)	230	330		2.0			
Benzo(a)anthracene (μg/kg)	0.577	20.6	330	13	2.0			
Benzo(a)pyrene (μg/kg)	0.183	6.43	330	23	2.0			
Benzo(b)fluoranthene (μg/kg)	0.833	29.2	330	20	2.0			
Benzo(k)fluoranthene (μg/kg)	8.33	292	330	20	2.0			
Bis(2-ethylhexyl)phthalate (μg/kg)	105	3420	330		2.0			
Chrysene (μg/kg)	57.2	(f)	330	150	2.0			
Hexachlorobenzene (μg/kg)	(g)	13.3	330		2.0	10		
Indeno(1,2,3-cd)pyrene (μg/kg)	(g)	214	330	43	2.0			
N-nitrosodipropylamine (μg/kg)	(g)	3.05	330		2.0			
Pentachlorophenol (μg/kg)	(g)	682	1600 (h)		2.0			
Phenathrene (μg/kg)	(i)	(i)	330	640	2.0			
			SW846-8080					
Arochlor (1254) (μg/kg)	0.173	(f)	160 (h)				1 Hour	45 Mins

TABLE 1 (continued)
ANALYTICAL METHODS FOR VERIFICATION SAMPLES

Contaminant of Concern	PRG Surface Soils (0" - 3") (a)	PRG Vadose Soils (3" - 12') (a)	GRASP CRQL/CRDL (b)	MDL (Other Methods) (c)	MDL (Other Methods) (d)	MDL (Other Methods) (c)	Sample Preparation Time (e)	Sample Analysis Time (e)
			SW846-6010	SW846-7090				
Barium (mg/kg)	(g)	4190	40				15 Mins	5 Mins
Beryllium (mg/kg)	0.0148	(f)	1.0	0.1				
Cadmium (mg/kg)	4.77	150	1.0					
Chromium (mg/kg)	23.8	752	2.0					
Nickel (mg/kg)	59.5	(f)	8.0					
			SW846-7470					
Mercury (mg/kg)	0.106	8	0.2				20 Mins	15 Mins
			SW846-8240					
1,1,1-Trichloroethane (μg/kg)	(i)	(i)	5			5	10 Mins	30 Mins
2-Hexanone (μg/kg)	(i)	(i)	10			10		
Chloroethane (μg/kg)	(i)	(i)	10			10		
1,2-Dichloropropane (μg/kg)	(i)	(i)	5			5		

TABLE 1 (continued)
ANALYTICAL METHODS FOR VERIFICATION SAMPLES

Contaminant of Concern	PRG Surface Soils (0" - 3") (a)	PRG Vadose Soils (3" - 12') (a)	GRASP CRQL/CRDL (b)	MDL (Other Methods) (c)	MDL (Other Methods) (d)	MDL (Other Methods) (c)	Sample Preparation Time (e)	Sample Analysis Time (e)
			907-OEPA 600/480-32					
Americium-241 (pCi/g)	0.34	2.06	0.02				7 Days[k]	4 Hours[k]
Plutonium-239/240 (pCi/g)	0.492	2.51	0.03					
Uranium-235 (pCi/g)	0.0247	0.278	0.3	(j)				
			906-OEPA 600/480-32					
Tritium (pCi/L)	(i)	(i)	400				7 Days[k]	4 Hours[k]

NOTES:

(a) Calculated risk-based preliminary remediation goal (PRG) for the future resident exposure scenario (comparison criteria) from OU4 RFI/RI.

(b) Method reporting limit - CLP CRDL/CRQL (Contract Laboratory Program Contract Required Detection Limit/Contract Required Quantitation Limit) as per statement of work in the July 2, 1991, Version 2.1, GRRASP (General Radiochemistry and Routine Analytical Services Protocol EG&G Rocky Flats Statement of Work).

(c) Instrument method detection limits must be laboratory established in order to meet the PRG concentrations. All MDL's listed are estimates.

(d) SW846-8270 analyses via SIM Mode are uncommon and do not have published MDL's. Listed MDL's are based on past history experience and are highly variable.

(e) Time estimates are approximations per sample based on a fixed laboratory. However, samples are generally analyzed in "batch groups" containing associated QC samples. Sample batch preparation time depends on size and generally takes 4 to 6 hours. Sample analysis batches generally run in 12 hour shifts.

(f) Not a contaminant of concern for vadose soils (3"-12').

(g) Not a contaminant of concern for surface soils (0"-3").

(h) Latest revision of the CLP statement of work dated August 1991 OLM01.8 lowers the CRQL for pentachlorophenol to 800 μg/kg and PCB 1254 to 33 μg/kg.

(i) PRG values are not provided for these analyses as no toxicity data was available from IRIS or HEAST.

(j) Analytical counting time can be extended to lower method detection activity (MDA).

(k) Preparation is based on a series of column separation techniques and is time consuming. Analytical counting time is variable, dependent upon sample weight and detector efficiencies.

TABLE 2
PROJECTED ANALYTICAL COST

Semi-Volatiles:	
SW846 Test Method	Cost Per Sample
8270	$300 - $600
8270M SIM Mode	$400 - $800
8310	$150 - $250
Volatiles:	
8240	$150 - $300
8260	$150 - $300
Metals:	
6010	$10 - $20 Each metal
7000	$20 - $30 Each metal
7470	$20 - $40 Each metal
Polycholorinated biphenyls:	
8080	$150 - $250
Radionuclides:	
Isotope	Cost Per Sample
Americium-241	$100 - $200
Plutonium-239/240	$100 - $200
Uranium 235	$100 - $200

3.2 Initial Equipment Decontamination

All sampling equipment, whether existing or newly purchased, will be decontaminated at a designated central on-site staging area prior to use. This decontamination requirement is designed to prevent the introduction of contaminants from other sources and to ensure worker protection. A sample of the final decontamination rinseate will verify that none of the COCs identified in Table III.2-4 are being introduced from outside sources. The rinseate sample will be collected and preserved in accordance with site requirements. If sample results indicate the presence of contamination, the decontamination procedure will be repeated or the piece of equipment will not be used.

3.3 Sample Locations

The grid established for the excavation sampling program will be used as the basis for locating the verification samples. Composite samples will be collected from 6 points within the excavation area and will be analyzed for all of the COCs listed in Table III.2-4.

3.4 Sample Collection

The sample teams will meet prior to initiating new field work to review the work plan and to address health and safety requirements. The required supplies, including portable radios, will be obtained from the support trailer. Once the proper notifications have been made, the sample teams will begin field work. In accordance with buddy system principals, the sample teams will consist of two members.

Sampling equipment will not be placed directly on the ground or on other potentially contaminated surfaces prior to sample collection. A polyethylene sheet will be spread out by the sample location to provide a clean working surface; only one side of the polyethylene sheet be allowed to come in contact with the ground. The removal of grass and other vegetation should not be a consideration for this sampling effort since samples will be collected shortly after soil excavation.

The team members will identify the sample location, label the sample containers, and record the location information in the field log. An unique alphanumeric identifier shall be assigned to each sample collected as follows:

1) The first three places of the sample identifier will be "VS4" to signify that the sample was collected as part of the verification sampling program for OU4;

2) The next two places will identify the x-axis (east-west) coordinate; a minus sign will be used, if needed, depending on the location of the origin;

3) The next two places will identify the y-axis (north-south) coordinate; a minus sign will be used, if needed, depending on the location of the origin

Disposable latex gloves shall be worn while collecting and handling the soil samples.

The samplers shall wear a new pair of gloves for each sample location as well as decontaminating the sampling tool (stainless trowel, scoop, coring device, or shovel) prior to collecting each soil samples. This action will avoid the potential for cross-contaminating samples collected at different intervals at the same location. To minimize down-time due to the decontamination process, multiple sets of sampling equipment will be used. The used sampling equipment will be wrapped in plastic for transport to the decontamination area. However, a rinseate sample will be collected once for each 20 batches of sampling equipment decontaminated. The sampler will attach the sample identification tag to the sample equipment to allow the source of the rinseate sample to be tracked. If contamination is detected in the rinseate samples, this frequency may be increased.

The sampler shall close the sample containers and seal them with custody tape. The soil samples will be placed into a cardboard box for transport to the laboratory facilities. The cardboard box will be closed and sealed with custody tape. The appropriate labels, with sample identifier, shall be affixed to the outside of the cardboard box.

Used gloves and other debris will be discarded into a plastic bag for disposal in accordance with site procedures. Excess soil will be returned to fill in any depressions resulting from the sampling activity. Returning the excess soil to fill in depressions is deemed appropriate since additional actions will occur if the samples indicate the presence of contamination.

At the end of the day, the sampler will complete a the Daily Field Activity Log for submission to the Project Manager. The samplers will also place the sampling equipment in proper storage areas and make arrangements to acquire supplies for the next day's sampling.

SECTION 4

INVESTIGATIVE DERIVED WASTE HANDLING AND DISPOSITION

Used gloves and other debris from both the excavation and verification sampling programs will be discarded into a plastic bag for disposal in accordance with site procedures.

Excess soil from the sampling verification program will be returned to fill in any depressions resulting from the sampling activity.

Spent decontamination fluids will be collected for treatment prior to discharge.

OU4 IM/IRA DECISION DOCUMENT
PART V - PROPOSED CONCEPTUAL POST-CLOSURE MONITORING AND ASSESSMENT PLAN

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PROPOSED CONCEPTUAL POST-CLOSURE MONITORING AND ASSESSMENT PLAN SOLAR EVAPORATION PONDS, OPERABLE UNIT 4 ROCKY FLATS PLANT, GOLDEN, COLORADO

V.1 INTRODUCTION

V.1.1 Purpose and Objectives

This plan is the proposed conceptual post-closure monitoring and assessment plan for the engineered horizontal barrier at the Solar Evaporation Ponds (SEP), Operable Unit 4 (OU4) at the Rocky Flats Plant (RFP) in Golden, Colorado. The engineered barrier is a hybrid design with a design life of 1,000 years. The purpose of this conceptual post-closure monitoring and assessment plan is to provide the basis for the detailed design of an integrated set of monitoring systems capable of providing the types of data required to assess the performance of the engineered barrier. Specifically, this plan provides the methods by which these data will be acquired, compiled, manipulated, interpreted, and utilized for the purpose of assessing the characteristics and dynamics of the engineered barrier, the vadose zone, and the upper hydrostratigraphic unit groundwater system. This plan also provides the general basis for routine barrier inspection and care procedures, once the system is in place. This plan complies with applicable state and federal regulations (40 CFR 264 Subpart G) and follows applicable guidance documents (Cullen and Everett, 1993).

V.1.2 Description of Post-Closure Monitoring Systems and Programs

Three primary monitoring systems and programs are selected, conceptually designed, and described in this plan. They include the following:

- Engineered barrier/cover monitoring system and program
- Vadose zone monitoring system and program
- Groundwater monitoring system and program

All three post-closure monitoring programs will be implemented concurrently with the express objective of identifying potential releases from beneath the engineered barrier and assessing the performance of the engineered barrier. Each program is designed to provide early warning of a release to a potential medium or receptor. The engineered barrier/cover monitoring system and program are designed to measure a loss of integrity of the cover and provide early warning of the potential for water movement into the waste pile. The vadose zone monitoring system and program are designed to monitor for movement of liquids through the vadose zone and provide early warning of the potential for contaminant migration to the groundwater system. The groundwater monitoring system and program are designed to detect

releases from beneath the cover and the vadose zone to the groundwater. The groundwater monitoring system and program will function as an early warning system to downgradient potential receptors. The groundwater monitoring system includes an upper hydrostratigraphic unit groundwater monitoring network.

V.1.3 Organization of Plan

The plan is organized into ten major sections. Section V.2, Design Basis, includes an overview of the regulatory framework under which this post-closure monitoring plan was developed. It also identifies the performance criteria that were established to facilitate appropriate selection of the three post-closure monitoring systems. The section explains how the design of the engineered barrier is integrated with the post-closure monitoring systems.

Section V.3, Technology Evaluation and Selection, explains how the various vadose zone monitoring technologies were selected based on the criteria of effectiveness, implementability, and relative cost; and how the optimum set of monitoring technologies were assembled in a manner that fulfills the applicable performance criteria identified in Section V.2.

Section V.4, Conceptual Design of Monitoring System, develops the monitoring alternatives assembled in Section V.3 to the conceptual level. At this point in the design process, the systems are portrayed schematically in plan view and profile (when applicable) and in the context of the engineered barrier design. It is important to design the monitoring system in the context of the engineered barrier design at this conceptual level because the engineered barrier and the monitoring systems are so closely integrated. The integration of the two designs will continue in all subsequent phases of design and construction.

Section V.5, Monitoring System Detailed Design, is included as an indication of what is to be expected in the 60%, 90%, and Title II designs. In this conceptual design document, Section V.5 will merely outline the contents of this section. This section will be developed further in subsequent versions of this document.

Section V.6, Sampling and Analysis Plan, will identify the types of samples that will be collected and the types of analyses that will be performed for all three components of the post-closure monitoring system. Some level of detail is provided in this conceptual document, including the proposed sampling/measurement frequencies and proposed analyses (when applicable).

Section V.7, Annual Monitoring System Assessment Program, discusses what data will be required and provided in the Annual Monitoring Assessment Reports. The major components of these annual reports will be outlined in this section.

Section V.8, Post-Closure Care Activities, will identify the required components of the Engineered Barrier Inspection and Care Program. The applicable record keeping and reporting practices that are currently accepted by EG&G during monitoring activities at the RFP are also described. These same practices will be utilized during post-closure monitoring system

construction and monitoring. Where applicable, RFP Standard Operating Procedures (SOPs) will be cited. A brief description and the intent of each of these components is provided in this section.

Section V.9, Post-Closure Performance and Assessment, will describe the required types and frequency of reporting that will occur to document the performance of the engineered barrier. The types of data and methods by which they will be presented in these Performance and Assessment reports will be outlined in this section. These reports will also serve as a mechanism to assess the status of the post-closure monitoring systems and the reports may also serve as the basis for proposals regarding modifications to the sampling program or frequency. Such modifications may include recommendations for the upgrade and/or abandonment of certain portions of the system through time.

Section V.10, Monitoring System Abandonment, will describe the methods that will be used to abandon specific components of the post-closure monitoring system. Where applicable, RFP SOPs will be cited.

Section V.11, References, is a comprehensive list of the references that were utilized during the preparation of this conceptual design document.

Cost, Schedule, and an Implementation Plan (Construction Narrative) are specifically not included in this document. Because the cost, schedule, and implementation plan for the post-closure monitoring system are so intimately integrated with those for the engineered barrier, the cost, schedule, and implementation plans for the post-closure monitoring system were integrated into the "Master Cost Section, the Master Schedule Section, and the Master Implementation Plan Section" of the IM/IRA/DD.

V.1.4 Integration with Future RFI/RI Activities

Planned future RFI/RI activities in OU4 will investigate potential impacts to groundwater in the area. An opportunity exists to combine and integrate the groundwater monitoring system of the future RFI/RI activities with the monitoring system for the OU4 post-closure activities. This is especially true since the planned future RFI/RI activities are scheduled to occur before construction of the engineered barrier and post-closure monitoring system. This plan will be integrated to the greatest extent possible and practical with the future RFI/RI activities such that the data collected for each program complement but do not duplicate or compromise the other. Commonality between the two activities will most likely occur in the groundwater monitoring aspects of the two activities, including well locations.

V.2
DESIGN BASIS

V.2.1 Regulatory Framework

Remediation of OU4 is part of a comprehensive, phased program of characterization, remedial investigations, feasibility studies, interim measures/remedial actions, and remedial/corrective actions currently in progress at RFP. These investigations are pursuant to an Interagency Agreement (IAG) among the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Health (CDH) dated January 22, 1991. The IAG addresses general and specific regulatory requirements identified in the following environmental acts as administered by the EPA:

- Resource Conservation and Recovery Act (RCRA);
- Hazardous and Solid Waste Amendments [to RCRA] of 1984 (HSWA);
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and
- Superfund Amendments and Reauthorization Act of 1986 (SARA).

In addition to and consistent with the IAG, the remedial activities at the RFP are conducted under the requirements stated in the HSWA permit issued to DOE by the CDH. Under both the IAG and the HSWA permit, the IAG addresses general and specific regulatory requirements identified in the Colorado Hazardous Waste Act (CHWA) as administered by the CDH. State regulations governing the management of hazardous wastes are contained in 6 CCR 1007-3.

The IAG outlines the regulatory process which satisfies the requirements of these environmental acts (Table 6 in the IAG). Remediation of OU4 is a two-phased approach in which Phase I addresses contaminant source(s) and Phase II addresses contaminated ground water. The OU4 Phase I activities conducted pursuant to the IAG, are presented in the following documents:

- Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI) work plans and reports;
- Phase I Interim Measure/Interim Remedial Action (IM/IRA) proposed and final Decision Documents and Responsiveness Summaries; and
- Phase I IM/IRA implementation documents.

The Phase I RFI/RI (EG&G, 1992) characterizes the contaminant sources within OU4 and provides the information necessary to develop the IM/IRA Decision Document. The IM/IRA will be conducted as an expedited response action of OU4 contaminant sources to

minimize the risks to human health and the environment by eliminating potential exposure pathways and preventing migration of contaminants. The IM/IRA remedial alternative selected should be consistent with the final OU4 remedy and shall be consistent with the Colorado closure and post-closure requirements. The final remedy and State closure and post-closure care plans will address both source and groundwater remediation.

The final remedy and State closure and post-closure plans for OU4 will be determined as part of the Phase II activities which are to be conducted and presented in the following required documents:

- Phase II RFI/RI work plans and reports;
- Phase II Corrective Measures Study/Feasibility Study (CMS/FS) reports;
- Phase II Corrective and Remedial Action Proposed Plans and Responsiveness Summaries;
- Phase II Corrective Action/Final Action Decision (CAD/FAD); and
- Phase II CAD/FAD implementation documents.

The Post Closure Monitoring and Assessment Plan for the SEP is presented as part of the IM/IRA Decision Document. In effect, this monitoring and assessment plan is consistent with monitoring activities associated with post-closure activities required under 6 CCR 1007-3, Part 264, Subpart G. Therefore, this plan would be reiterated in a subsequent post closure plan.

As stated in previous sections, the monitoring and assessment program is divided into three components: 1) engineered barrier/cover system; 2) vadose zone system and; 3) groundwater system. Each component was designed to be in conformance with applicable RCRA regulations, as well as other applicable or relevant and appropriate requirements (ARARs). Where applicable, the technical rationale and detail of each monitoring system and associated data assessment programs was designed with the aid of relevant technical guidance documents.

Note that other monitoring and maintenance activities will be required as part of post-closure care, specifically monitoring, inspection, and maintenance of the engineered barrier/cover system (264.118(b); 264.310 (b)). The general scope and requirements of these activities are presented in section V.8 of this document for informational purposes. Specific requirements of these activities will become evident once the 60% design document has been developed. At that point specific details regarding inspection activities, monitoring and inspection frequencies, performance assessment and performance criteria will be developed. This information will be presented in the post-closure plan.

V.2.1.1 Engineered Barrier/Cover Monitoring System

Specific regulations prescribing monitoring requirements for cover systems are not promulgated to date. Instead, technical guidance for both cover design (USEPA, 1991) and vadose zone monitoring system (Durant et al., 1993) was used to design a monitoring system that emphasizes the early detection of moisture migration within the cover.

V.2.1.2 Vadose Zone Monitoring System

Specific regulations prescribing monitoring requirements for the vadose zone beneath closed surface impoundments, such as the SEP, have not been promulgated to date. Technical guidance for such a program, however, is based on vadose zone monitoring requirements for land treatment units (CCR 264.278). Under this regulation, the owner or operator must monitor the soil and soil-pore liquid to determine whether hazardous constituents migrate out of the treatment zone. In this case, the treatment zone is considered to be analogous to the base of the closed unit (USEPA, 1988).

Specific requirements of the vadose zone monitoring program hazardous waste landfarms include the installation of a sufficient number of sampling points at appropriate locations and depths to yield samples to represent background concentrations not affected by the unit (CCR 264.278 (b)) and to detect statistically significant changes in concentrations for any hazardous constituent (CCR 264.278 (f)). In the case of the SEP closure, background concentrations represent soil-pore water quality conditions in the engineered barrier beneath the subsurface drainage layer. This program is presented in Section V.4 of this document.

Vadose zone monitoring requirements under CCR 264.278 also include the development and use of consistent sampling and analysis procedures to ensure results that provide a reliable indication of soil-pore liquid quality. These procedures include sample collection, preservation and shipment, analytical procedures, and chain of custody control. These procedures are discussed in Section V.6.2 of this document.

To aid in the design of a vadose zone monitoring program and the assessment of data collected under such a program, the USEPA has developed technical guidance document including EPA's approach to vadose zone monitoring (Durant et al., 1993) and the "Draft Permit Writer's Guidance Manual for Monitoring Unsaturated Regions of the Vadose Zone at RCRA, Subtitle C Facilities" (Cullen, 1993). These documents were used to develop the vadose zone monitoring system for the Solar Evaporations Pond's closure.

V.2.1.3 Groundwater Monitoring System

Post closure monitoring of groundwater is required under 6 CCR 1007-3, 264 Subpart G. This monitoring program is subject to regulations governing releases from applicable units (264 Subpart F) including determination of point of compliance (264.95), compliance period (264.96) and general groundwater monitoring requirements (264.97). Applicable units include those that received hazardous waste after July 26, 1992 and closed after January 1, 1983.

The general groundwater monitoring requirements include the design of a sufficient number of wells to 1) represent background water quality, 2) represent water quality at the point of compliance; and 3) allow for detection of contamination emanating from the regulated unit. This program is described in Section V.4.3 of this document.

The general monitoring requirements also provide requirements for the adequate construction of monitoring wells (264.97 (c)), the collection of groundwater samples (264.97 (d)), and the analysis of samples (264.97 (e)). These procedures are described in Section V.6 of this document.

Finally, the general groundwater monitoring requirements include procedures to be used in evaluating groundwater monitoring data (264.97 (h)) and assessment of data. These procedures are presented in Section V.7 of this document.

To aid in the development of the groundwater monitoring program, the USEPA has developed numerous technical guidance documents including "Groundwater Monitoring: Draft Technical Guidance" (USEPA, 1992) and "The Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities" (USEPA, 1992). These guidance documents were used to develop the groundwater monitoring program for the SEP.

V.2.2 Performance Criteria

Performance criteria have been developed to evaluate technologies that may potentially be used in the monitoring system for the remedial action at OU4. Technologies that do not meet these performance criteria will not be considered for use. The criteria were developed to establish the minimum level of performance for the post-closure monitoring and assessment system.

Because the engineered cover/barrier, vadose zone, and groundwater components of the monitoring system will differ in design and methods, the performance criteria for each system are, for the most part, unique. However, the primary goal of each monitoring system is to verify that the selected remedial alternative is providing the intended containment and isolation of potential groundwater contaminants.

V.2.2.1 Engineered Cover/Barrier System

The performance criteria for the engineered cover/barrier component of the monitoring system at OU4 are listed below. In order for the engineered cover/barrier monitoring system to be selected for implementation, it must:

1) **Be feasible to install, operate and sample with respect to the site hydrogeology and the selected engineered remedial alternative.**

It must be physically possible to install the proposed sampling and measurement instrumentation and equipment. Sampling and measurement instrumentation and

equipment to be installed as a part of the post closure cover/vadose zone monitoring system should be capable of operating under the site conditions as dictated by the hydrogeology and engineered design of the site.

2) **Provide data that can be used to identify and provide early warning of conditions conducive to penetration of water through the engineered barrier/cover.**

The engineered barrier/cover is designed to prevent movement of infiltrating precipitation waters into the waste pile. The monitoring system must provide data that will indicate when conditions are such that infiltrating water can potentially move through the overlying barrier/cover system and into the underlying waste pile. Such conditions might be indicated by a combination of analysis of climatic (precipitation) data and soil moisture data in the cover material. Monitoring by use of climatic data alone is not considered sufficient because of the potential concentration of runoff waters at the surface (it is assumed that a surface drainage system will be incorporated into the barrier design), and the consequences of unusually heavy and/or sustained periods of precipitation.

3) **Provide adequate spatial coverage.**

The monitoring system should provide spatial coverage such that it is reasonably certain that the development of conditions potentially conducive to infiltration into the waste pile will be detected.

4) **Provide adequate temporal coverage.**

The monitoring system should provide temporal coverage such that early warning of conditions conducive to infiltration and potential contaminant migration from the waste pile can be achieved before potential impacts to groundwater occur. The monitoring system should also be capable of collecting sufficient data to identify seasonal trends in the monitoring parameters and allow analysis of the correlation between hydrologic events that occur outside of the cover with those that occur within.

5) **Provide data upon which to base a release response action.**

Measurement of a change in the subsurface soil moisture conditions within the engineered barrier/cover may indicate that the potential for subsurface migration exists. It does not provide diagnostic evidence that contaminants have migrated from the waste pile. The monitoring system must provide data of sufficient sensitivity necessary to make decisions regarding an appropriate response. Threshold values of change that would trigger initiation of an appropriate response should be identifiable. Appropriate release responses are varied and site-specific, but they may include actions such as an unscheduled maintenance inspection of the engineered barrier/cover system.

6) **Provide for remote and automatic monitoring of data.**

It is assumed that monitoring will be conducted for a period of at least 30 years after implementation of the remedial alternative. Regular manual monitoring over an extended period of time will require a significant annual expenditure of resources in terms of the labor and equipment required to obtain the data. The monitoring system should be capable of automatic acquisition and logging of data. It should also be possible to remotely access data generated by the monitoring system via telemetry or telephone hookup.

7) **Be integrated into the design and construction of the selected remedial alternative.**

The cost of installation of monitoring points is generally greater when implemented after construction of the remedial alternative. In order to maximize efficiency of construction and the effectiveness of the monitoring system in terms of placement of the monitoring points, the monitoring system should be integrated into the design and construction of the selected remedial alternative. The monitoring system should also be integrated into the design of the selected remedial alternative such that it does not substantially or unnecessarily interfere or compromise the integrity of the selected remedial alternative.

8) **Incorporate monitoring techniques that are precise.**

Precision of the instrumentation speaks to the repeatability of the measurement techniques. Variability that is measured/sampled with the monitoring system must be attributable to the media being monitored and should not represent variability resulting from the monitoring system itself. The monitoring system must provide measurements and or samples that have a high degree of precision. Standards of precision will vary with the particular kind of instrumentation selected for use in the project. Measurement precision standards will be identified, in subsequent documentation, that address evaluation of alternative parameter measurement techniques and equipment.

9) **Incorporate planned redundancy.**

Failure of one monitoring point should not result in failure of the entire monitoring system. When a monitoring instrument breaks down, another identical or equivalent unit should provide equivalent data until the original instrument is repaired or replaced. Because of the complexities of flow in the vadose zone, it is also prudent to have sampling and measurement systems in place that are not only redundant, in case of failure, but also act in a confirmatory capacity in terms of acquisition and interpretation of monitoring data.

10) **Be cost effective to install and operate.**

The financial resources for remediation and post-closure monitoring are finite. The design of the post closure monitoring system should be fiscally efficient as well as protective of human health and the environment by providing early warning of conditions conducive to contaminant migration to the water table.

11) **Incorporate proven technologies that have a record of performance for measuring, sampling, and analyzing soil and vadose zone monitoring parameters.**

Implementation of a monitoring system for the engineered barrier/cover does not represent a research effort and should not be considered primarily as the applicable site for development and testing of innovative monitoring techniques. The primary monitoring system will consist of equipment and techniques that have been previously tested.

V.2.2.2 Vadose Zone System

The performance criteria for the vadose zone component of the monitoring system at OU4 are listed below. In order for the vadose zone monitoring system to be selected for implementation, it must:

1) **Be feasible to install, operate and sample with respect to the site hydrogeology and the selected engineered remedial alternative.**

It must be physically possible to install the proposed sampling and measurement instrumentation and equipment. Sampling and measurement instrumentation and equipment to be installed as a part of the post-closure vadose zone monitoring system should be capable of operating under the site conditions as dictated by the hydrogeology and engineered design of the site.

2) **Provide data that can be used to identify the production and migration of leachate within the waste pile.**

Production of leachate within the waste pile (whether as the result of vertically infiltrating waters or laterally intruding waters) will be prevented by the engineered barrier/cover and by maintenance of soil moisture conditions in the waste pile dry enough to maintain low unsaturated hydraulic conductivity of the water. The monitoring system should be capable of identifying moisture conditions within the waste pile that are indicative of the production of leachate or of significant migration of leachate from the waste pile. Detection of water movement into, within, or out of the waste pile will be considered an indicator of conditions conducive to potential leachate migration.

3) **Provide data that can be used to identify the movement of water into the waste pile.**

Water movement into the waste pile is undesirable as it may be a precursor to production and subsequent migration of leachate. Monitoring points will be identified and installed such that conditions can be identified that would indicate that water is moving into the waste pile from sources other than surface infiltration, including: 1) lateral sources, as in the case of perched water moving along horizontal preferential flow pathways; and 2) below, as in the case of a rising water table. Detection of water movement into, within, or out of the waste pile will be considered an indicator of conditions conducive to potential leachate migration.

4) **Provide data that can be used to identify movement of leachate out of the waste pile.**

Monitoring points will be identified and installed such that conditions can be identified that indicate water movement out of the waste pile. Detection of water movement into, within, or out of the waste pile will be considered an indicator of conditions conducive to potential leachate migration.

5) **Provide adequate spatial coverage.**

The OU4 subsurface was characterized in Part II of this IM/IRA/DD. Part of the purpose of that characterization was to identify vadose zone contaminant transport pathways. The monitoring system should be designed to monitor the vadose zone contaminant transport pathways as identified in Part II.

6) **Provide adequate temporal coverage.**

The monitoring system should provide temporal coverage such that early warning of conditions conducive to potential contaminant migration from the waste pile can be achieved in the underlying vadose zone before potential impacts to groundwater occur. The monitoring system should also be capable of collecting sufficient data to identify seasonal trends in the monitoring parameters and allow analysis of the correlation between hydrologic events that occur outside of the waste pile with those that occur within.

7) **Provide data upon which to base a release response action.**

Measurement of a change in the vadose zone soil moisture conditions may indicate that the potential for subsurface migration exists. It does not provide diagnostic evidence that contaminants have migrated from the waste pile. The monitoring system must provide data of sufficient sensitivity to make decisions regarding an appropriate release response. Threshold values of change in the measured parameters, that will trigger initiation of an appropriate release response, should be identifiable. Appropriate release responses are varied and site-specific but may include actions such as: an unscheduled maintenance inspection of the engineered barrier/cover,

direct sampling and laboratory analysis of vadose zone pore liquids using suction lysimetry, or dewatering of perched water layers.

8) **Provide for remote and automatic monitoring of data.**

It is assumed that monitoring will be conducted for a period of at least 30 years after implementation of the remedial alternative. Regular manual monitoring over an extended period of time will require a significant annual expenditure of resources in terms of the labor and equipment required to obtain the data. The monitoring system should be capable of automatic acquisition and logging of data. It should also be possible to remotely access data generated by the monitoring system via telemetry or telephone hookup.

9) **Be integrated into the design and construction of the selected remedial alternative.**

The cost of installation of monitoring points is generally greater when implemented after construction of the remedial alternative. In order to maximize efficiency of construction and the effectiveness of the monitoring system in terms of placement of the monitoring points, the monitoring system should be integrated into the design and construction of the selected remedial alternative. The monitoring system should also be integrated into the design of the selected remedial alternative such that it does not substantially or unnecessarily interfere or compromise the integrity of the selected remedial alternative.

10) **Incorporate monitoring techniques that are precise.**

Precision of the instrumentation speaks to the repeatability of the measurement techniques. Variability that is measured/sampled with the monitoring system must be attributable to the media being monitored and should not represent significant variability resulting from the monitoring system itself. The monitoring system must provide measurements and or samples that have a high degree of precision. Standards of precision will vary with the particular kind of instrumentation selected for use in the project. Measurement precision standards will be identified, in subsequent documentation, that address evaluation of alternative parameter measurement techniques and equipment.

11) **Incorporate planned redundancy.**

Failure of one monitoring point should not result in failure of the entire monitoring system. When a monitoring instrument breaks down, another identical or equivalent unit should provide equivalent data until the original instrument is repaired or replaced. Because of the complexities of flow in the vadose zone, it is also prudent to have sampling and measurement systems in place that are not only redundant, in case of failure, but also act in a confirmatory capacity in terms of acquisition and interpretation of monitoring data.

12) **Be cost effective to install and operate.**

The financial resources for remediation and post-closure monitoring are finite. The design of the post closure monitoring system should be fiscally efficient as well as protective of human health and the environment by providing early warning of contaminant migration to the water table.

13) **Incorporate proven technologies that have a record of performance for measuring, sampling, and analyzing soil and vadose zone monitoring parameters.**

Implementation of a vadose zone monitoring system at OU4 does not represent a research effort and should not be considered primarily as the applicable site for development and testing of innovative monitoring techniques. The primary monitoring system at the SEP will consist of equipment and techniques that have been previously tested as a part of a vadose zone monitoring system.

V.2.2.3 Groundwater System

The performance criteria for the groundwater component of the monitoring system at OU4 are listed below. In order for the groundwater monitoring system to be selected for implementation, it must:

1) **Comply with appropriate regulations.**

Groundwater monitoring programs for interim status land units such as OU4 are regulated under 40 CFR (Resource Conservation and Recovery Act) Part 265 - Interim Status Standards for Owners and Operators of Hazardous Waste TSD Facilities. Statistical analysis of groundwater-quality data is governed by the EPA guidance document "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities" (USEPA, 1989).

2) **Be feasible to install, operate, and sample with respect to the site hydrogeology and selected engineered remedial alternative.**

It must be physically possible to install and access the wells included in the monitoring system. Individual components of the groundwater monitoring system must be compatible and appropriate for site hydrogeology and the selected remedial alternative.

3) **Be integrated into the design and construction of the selected remedial alternative.**

The monitoring system must be integrated into the design of the selected remedial alternative, to the extent required, such that it does not substantially and unnecessarily interfere or compromise the integrity of the selected remedial alternative. Wells may

be located within the perimeter of the site remedial alternative. These wells must be installed during construction of the alternative. Access to the wells must also be ensured. Sufficient room to perform well sampling also needs to be provided.

4) **Be consistent with the "RCRA Groundwater Monitoring: Technical Guidance" (USEPA, 1992).**

Well casing must be screened and the annulus filled with properly sized sand across the aquifer section(s) of concern. The annulus shall be filled with cement grout or bentonite slurry above the aquifer. The wells will require replacement and maintenance over time due to problems such as biological and sediment fouling of the screen. Well maintenance must be consistent to ensure that the groundwater-quality data are comparable over time. Well replacement and/or maintenance activities should not compromise the accuracy or precision of the groundwater quality data.

5) **Be capable of yielding groundwater in sufficient quantity to provide groundwater samples for the required analyses (RCRA).**

The wells must be of a large enough diameter and be correctly screened to allow purging and sample collection in sufficient quantity to complete the required analyses. There may be limitations in groundwater yield due to the aquifer characteristics. To the extent possible, monitoring wells will be installed in locations that yield a sufficient flow and recovery rate.

6) **Provide groundwater-quality data from wells both hydraulically upgradient and downgradient of OU4.**

There shall be an appropriate number of upgradient wells that are constructed in the upper hydrostratigraphic unit and are not affected by OU4. There shall be an appropriate number of wells downgradient at the limit of OU4. The downgradient wells may be located either within OU4 or further downgradient than the limit of OU4 if sufficient justification can be provided. The downgradient wells shall be constructed in the appropriate aquifer and provide timely detection of constituents of concern that may have potentially migrated from OU4 to the aquifer. The location and number of wells shall be sufficient to provide groundwater-quality data representative of the entire upgradient and downgradient flow across OU4.

V.2.3. Integration of the Monitoring Systems with the Engineered Barrier Design

Installation of the monitoring equipment for each of the proposed monitoring systems requires integration with the design of the engineered barrier to ensure compatibility of materials as well as feasibility of placement. The ground water monitoring system may be constructed after completion of the engineered barrier; however, integration of existing wells and new wells constructed as part of future RI/RFI activities may require planning to prevent damage to wells during construction of the engineered barrier.

The engineered barrier/cover and vadose zone monitoring systems must be placed in concert with the construction schedule for the engineered barrier. Much of the vadose zone monitoring equipment will be placed directly following removal of the liners, but installation must occur prior to the placement of the gravel underdrain. The installation of monitoring equipment in the engineered barrier itself must be closely coordinated with the placement plans for the engineered barrier.

The majority of the coordination between the engineered barrier design and the monitoring systems design will occur during detailed design. Additional details on the integration of the construction schedules are provided in the Master Implementation Plan (Construction Narrative) (see Part IV).

V.3
VADOSE ZONE MONITORING TECHNOLOGY EVALUATION AND SELECTION

V.3.1 Technology Evaluation and Selection Methodology

This section presents the evaluation and selection methodology used to select the preferred monitoring alternative for the engineered barrier and the vadose zone monitoring systems. This process consists of two parts. Monitoring technologies that are generally applicable to the monitoring objectives described in Section V.1.1 are first identified. The technologies are screened to eliminate those that are limited with respect to meeting the technical feasibility of the monitoring objectives. Once technically feasible technologies are identified, they are evaluated with respect to the performance criteria described in Section V.2.2. Screening of the monitoring options will result in a preferred post-closure monitoring system which best satisfies the performance criteria and represents the most appropriate monitoring system for the site.

An evaluation and selection of groundwater monitoring technologies is not performed because groundwater monitoring wells are considered the standard technology for monitoring groundwater quality. No other technologies are available which consistently produce reliable, high quality data and are capable of meeting the groundwater monitoring system performance objectives described in Section V.2.2.3. The conceptual design and layout of the groundwater monitoring system is presented in Section V.4.

V.3.1.1 Technology Screening Criteria

The screening criteria used to eliminate those technologies and process options that are limited with respect to meeting the technical feasibility of the monitoring objectives are described for each technology and process option in Tables V.3-1 and V.3-2. The screening criteria include the following, listed in order of importance:

- Effectiveness
- Implementability
- Relative Cost

Effectiveness is defined as the ability of a given technology to monitor the performance of the cover systems, to collect sufficient spatial and temporal data within the engineered barrier and the vadose zone beneath the engineered barrier to provide early warning of conditions conducive to migration of precipitation and/or leachate through the engineered barrier and the waste layer, to have a proven record of providing precise and reliable data with respect to the soil moisture conditions of the unsaturated zone, and to protect human health and the environment during construction phases of the monitoring systems. In addition, the technology should be reliable and proven with respect to monitoring under local conditions at the site. However, innovative technologies should also be given equal consideration.

Table V.3-1 Initial Screening and Evaluation of Technologies for the Engineered Barrier/Cover Monitoring System, OU4 Rocky Flats Plant, Golden, Colorado.

Technology Type	Monitoring Option	Effectiveness	Implementability	Relative Cost	Retained
Indirect Pore-Liquid Monitoring	Tensiometer	Effective range of tensiometers is reduced by the altitude of the site and depth of placement.	Requires penetration of the engineered barrier to collect samples from the vadose zone beneath the barrier.	High	No
	Thermocouple Psychrometer	Precision of instruments is affected by a variety of environmental factors. Not effective in long-term, permanent installations	Implementable.	Medium	No
	Heat Dissipation Sensors	Calibration of probes to specific soil types is required.	Implementable	High	No
	Neutron Probe	Effective.	Horizontal access tubes not implementable. Vertical access tubes require penetration of cap.	High	No
	Time Domain Reflectometry	Effective. Probes may require replacement prior to the end on the post-closure monitoring period	Implementable. Probe leads are limited to 100' in length.	High	Yes
	Frequency Domain Capacitance	Effective. Probes may require replacement prior to the end of the post-closure monitoring period.	Implementable. Probe leads may be up to 700' in length.	High	Yes
	Soil Water Hydrographs	Effective as a reporting technique, but not as a standalone monitoring option.	Implementable. Would require construction of lysimeters external to OU4 to monitor infiltration and evapotranspiration.	Medium	No

Table V.3-1 Initial Screening and Evaluation of Technologies for the Engineered Barrier/Cover Monitoring System, OU4 Rocky Flats Plant, Golden, Colorado.

Technology Type	Monitoring Option	Effectiveness	Implementability	Relative Cost	Retained
	Gypsum Blocks	Not effective in long term. Block life is insufficient for a long-term monitoring program.	Not implementable. Probe replacement may compromise the integrity of the engineered barrier.	Low	No
Vadose Zone Direct Pore-Liquid Monitoring	Suction Lysimeter	Not applicable. Soil water in engineered barrier will consist of infiltrated precipitation, not leachate.	Implementable	Medium	No
	Absorption Sampler	Effectiveness is questionable due to anticipated low moisture content of soils.	Implementable	Medium	No

Table V.3-2 Initial Screening and Evaluation of Technologies for the Vadose Zone Monitoring System, OU4 Rocky Flats Plant, Golden, Colorado.

Technology Type	Monitoring Option	Effectiveness	Implementability	Relative Cost	Retained
Vadose Zone Indirect Pore-Liquid Monitoring	Tensiometer	Effective range of tensiometers is reduced by the altitude of the site and depth of placement.	Requires penetration of the engineered barrier to collect samples from the vadose zone beneath the barrier.	High	No
	Thermocouple Psychrometer	Precision of instruments is affected by a variety of environmental factors. Not effective in long-term, permanent installations	Implementable.	Medium	No
	Heat Dissipation Sensors	Calibration of probes to specific soil types is required.	Implementable	Medium	No
	Neutron Probe	Effective.	Vertical access tubes may require penetration of the engineered barrier. Horizontal access tubes are implementable.	High	Yes
	Time Domain Reflectometry	Effective. Probes may require replacement prior to the end of the post-closure monitoring period.	Probe leads are limited to 100' in length, limiting placement to perimeter of cap.	High	No
	Frequency Domain Capacitance	Effective. Probes may require replacement prior to the end of the post-closure monitoring period.	Implementable. Probe leads may be up to 700' in length.	High	Yes

Table V.3-2 Initial Screening and Evaluation of Technologies for the Vadose Zone Monitoring System, OU4 Rocky Flats Plant, Golden, Colorado.

Technology Type	Monitoring Option	Effectiveness	Implementability	Relative Cost	Retained
	Soil Water Hydrographs	Effective as a reporting technique, but not as a standalone monitoring option.	Implementable. Would require construction of lysimeters external to OU4 to monitor infiltration and evapotranspiration.	Medium	No
	Gypsum Blocks	Not effective in long term. Block life is insufficient for a long-term monitoring program.	Not implementable. Block replacement may compromise the integrity of the engineered barrier.	Low	No
Vadose Zone Direct Pore-Liquid Monitoring	Suction Lysimeter	Deep sampling pressure-vacuum samplers are effective for all sample depths.	Requires penetration of the engineered barrier to collect samples from the vadose zone beneath the barrier.	Medium	Yes
	Absorption Sampler	Effectiveness is questionable due to anticipated low moisture content of soils.	Implementable	Medium	No

Implementability is defined as the ability of a given monitoring technology to obtain necessary approval from government agencies and to comply with regulatory requirements and the degree to which a monitoring options is feasible to install, operate, and sample with respect to site hydrogeology and the design of the engineered barrier. Although implementability primarily considers institutional factors, technical implementability is also considered. The definition of implementability also includes consideration of the availability of required equipment and personnel, and integration with the cover system and the Phase 2 RFI/RI. Monitoring options which may compromise the integrity of the engineered barrier when installed are determined to not be implementable at OU4.

The cost evaluation criterion for this preliminary screening is defined as the relative capital, operation, and maintenance costs associated with a given monitoring technology. Costs are estimated using best engineering judgement and are presented as low, medium, or high. Cost comparisons are only performed between technologies that are comparable with respect to the type of remedial technology. Cost is considered the least important criterion in evaluation of the technologies, but is used to eliminate options that are substantially more expensive than other technologies that provide that same degree of effectiveness and implementability.

The following subsections discuss the various monitoring technologies considered in this initial screening process. Tables V.3-1 and V.3-2 summarize the screening of technologies. More detailed descriptions of each process option and its effectiveness, implementability, and relative cost are presented in the following subsections.

V.3.2 Description of Monitoring Technologies and Process Options

Two major vadose zone monitoring technologies are available to monitor the unsaturated zone. The following sections provide brief descriptions of direct and indirect pore-liquid monitoring techniques which are potentially applicable to development of monitoring systems for the engineered barrier and the vadose zone beneath the engineered barrier. Indirect pore-liquid monitoring refers to vadose zone monitoring techniques which do not directly measure the pore-liquids by physically collecting a sample of them. Instead, indirect pore-liquid monitoring techniques rely on indirectly measuring the state of the unsaturated zone by correlating the soil moisture with other physical properties of the soil and pore-liquids. Direct pore-liquid monitoring techniques are those monitoring methods which are able to collect samples of the pore-liquids directly from the vadose zone.

V.3.2.1 Technology Type: Indirect Pore-Liquid Monitoring

V.3.2.1.1 Vadose Zone Indirect Pore-Liquid Monitoring Option: Tensiometers

Tensiometers can be used to measure soil water tension, also known as soil suction, in unsaturated portions of the vadose zone (ASTM, 1992). A tensiometer consists of a sealed body tube with a porous ceramic cup on one end and a vacuum measuring device, such as a gauge or transducer, on the other end. Water in the pores of the ceramic cup are placed in intimate contact with water films in the pores and void spaces of unsaturated soils. The pores of the ceramic cup are sufficiently small (less than 2.5 micrometers [μm] in diameter) such that

water will be retained against a gradient of at least 100 centibar (cbar) across the cup by capillary forces. When placed in a soil with a soil suction greater than zero, water will move out of the body of the tube, through the porous ceramic, and into the surrounding soil. As the water moves out of the tube, a vacuum or negative pressure, is created. Water will cease to move out of the body of the tube when the vacuum exactly opposes the soil suction drawing the water out of the instrument. As soil water is depleted by evaporation or transpiration, or replenished by precipitation, corresponding changes in soil suction can be measured using the tensiometer.

Since tensiometers are vacuum based, the theoretical range of operation is 0 to 1 atmospheres (atm [1 atmosphere is approximately equal to 1 bar]). Because of small leaks, dissolved oxygen in water, and other inefficiencies, the practical range of measurement is approximately 0 to 0.8 bars at sea level. Increasing altitude decreases the range of measurement by approximately 3.4 cbar per 1000 feet of elevation. Measurements made with a tensiometer must be corrected for the vertical length of the water column between the ceramic cup and the vacuum measuring device. Even when the soil surrounding the porous cup of a tensiometer is saturated, the uncorrected tension at the readout position will measure 0.1 cbar per centimeter (cm) (0.25 cbar per inch) of vertical length between the ceramic cup and the readout. Furthermore, the range of measurement of the tensiometer is reduced by that length.

For example, at the RFP (elevation approximately 6,000 feet above sea level) with a tensiometer cup placed 2 meters below the gauge and ground surface, the range of measurement would be as follows:

$$80\,cbars - \left(6{,}000\,ft \times \frac{3.4\,cbar}{1{,}000\,ft}\right) - \left(200\,cm \times \frac{0.1\,cbar}{cm}\right) = 39.6\,cbar$$

The above calculation illustrates the fundamental constraints that are inherent to the use of tensiometers for subsurface measurement of soil suction. Tensiometers are typically best suited for applications where the soil suction readings are made within three meters of the surface installation point or where soil samples can be brought to the surface so that a tensiometer can be subsequently inserted for measurement.

Tensiometers can be successfully used to determine hydraulic head gradients in the unsaturated zone and to observe spatial and temporal variations in the soil water status of the unsaturated zone. When used in combination with a soil water characteristic curve, tensiometers can be used to measure unsaturated water content.

V.3.2.1.2 Vadose Zone Indirect Pore-Liquid Monitoring Option: Thermocouple Psychrometers

Psychrometers measure soil-water pressure under very dry conditions where a tensiometer unit is ineffective because of air entry problems. Basically, the soil-water psychrometer measures the relative humidity of the subsurface atmosphere in the unsaturated

zone and infers the soil suction based on the relationship between negative soil-water potential and the relative humidity of soil water (Everett et al., 1984).

Psychrometers consist of a porous bulb chamber to sample relative humidity of a soil, a sensitive thermocouple, heat sink, reference electrode, and associated electronic circuitry. Such units use the principle of Peltier cooling to lower the temperature of one junction of the thermocouple below the dew point, thereby allowing an evaluation of the relative humidity.

Two types of thermocouple psychrometers (TCP) are available. One unit, installed in access tubes, consists of positioning psychrometers in porous cups at the base of the tubing. This unit may be withdrawn for re-calibration at regular intervals. The second type of unit, called the "sealed cup" psychrometer, has the thermocouple unit permanently sealed into a porous enclosure.

Each psychrometer must be calibrated before field installation. Calibration stability of the units is variable depending on the type of psychrometer used. Sealed cup psychrometers are generally more reliable than the access tube type. Improved data accuracy can be achieved by taking multiple readings using automatic techniques and computer processing instead of manually operating the data collection system.

Psychrometers have been employed at depths varying from a few inches to over 300 feet and in a wide variety of hydrogeologic settings. They have been found to be most useful in measuring water potential in dry soils. A primary assumption in their operation is that the ceramic material in which the thermocouple is embedded is in equilibrium with the native soil water. The degree to which this assumption is met directly affects the accuracy of the measurements. This assumption is most valid when the pore size distribution of the ceramic closely matches that of the surrounding soil. When installing the psychrometer in coarse material, care must be taken to establish good contact between the cup and the surrounding formation. In tight, well-indurated material or at great depths, this is difficult, and non-representative measurements may occur.

Fluctuations in temperature affect the reading of thermocouple psychrometers and can cause errors. Psychrometer readings are subject to hysteresis in their characteristic curves. Determining whether the test area is drying or wetting during the measurements is important to accurately interpret the readings. Field studies indicate that psychrometers perform very poorly in wet media (water pressures greater than 1 atm). Thermocouple psychrometers are poorly suited for use in acidic environments due to the potential for corrosion of thermocouple wires. Contaminants can cause errors if allowed to enter the sample chamber or thermocouple junction.

Thermocouple psychrometers are designed to measure negative soil water pressure from relative humidity versus output voltage relationships. In relating water potential to water content, characteristic curves must be developed for each soil type in which the units are to be installed. This is a time consuming process and may not be economically feasible for small projects. Most units are fragile and require great care during installation. Response times are generally slow; however, this problem is not severe in dry media.

V.3.2.1.3 Vadose Zone Indirect Pore-Liquid Monitoring Option: Heat Dissipation Sensors

Heat dissipation sensors are based on the concept that heat dissipation in a soil is sensitive to water content (Phene et al., 1971). In soils, air is a good thermal insulator with respect to water. When a soil is wet, the path length for thermal conduction is short and through the water. When the soil dries, the water films become thinner and the path length for thermal conduction becomes much longer. The result is that dry soils require a larger temperature gradient to dissipate a given amount of heat than wet soils. Conversely, the water content can be measured by supplying a known quantity of heat with a sensor and measuring the resulting rise in temperature at that point.

Measurement is made using a diode bridge which is connected to a sensor (Campbell and Gee, 1986). A change in the diode temperature generated as a heater current is applied causes electromotive force (emf) which is measured with the bridge. Calibration curves are used to relate emf data to matrix potential. Because of the time required for heat to dissipate between readings, measurements typically cannot be made more frequently than hourly.

Heat dissipation sensors are subject to some of the same sources of errors as gypsum electrical resistance blocks including hysteresis, use of calibration curves which are not suited to the measurement range of interest, and differences in the pore size distribution between the sensor matrix and the measured soil matrix.

Heat dissipation sensors have the advantage, however, of more easily lending themselves to automatic data acquisition than tensiometers. Measurement precision is estimated to be about $\pm$ 0.1 bar when the optimum calibration curve is used.

V.3.2.1.4 Vadose Zone Indirect Pore-Liquid Monitoring Option: Neutron Probe

The term neutron probe describes two basic types of instruments. Neutron-porosity loggers are used primarily in liquid filled boreholes. Neutron moisture probes are used in dry access tubes. Both types use a fast neutron source and thermal neutron detectors. Neutron porosity loggers are well established in the oil industry where they are used to infer the porosity in saturated sediments. They employ strong sources (250 millicurie [mCi] to 5,000 mCi) to enhance sampling volume and dual detectors to isolate borehole effects. These probes utilize long tool lengths (4-21 feet) and sophisticated and expensive logging vehicles. Neutron moisture probes are designed for precise measurement of soil moisture in small diameter (2-inch) access tubes, but also have been employed in larger access tubes (Tyler, 1985, 1988; Keller et al., 1990; Kramer et al., 1990). These probes employ a low strength source (10-50 Mci) and a single, near-source detector. Similar to nuclear density gauges used by many geotechnical firms, they require minimal operator training (8-hour radiation safety course) and are subject to less regulatory oversight than neutron porosity loggers. Neutron moisture probes are the method of choice for vadose zone monitoring tasks, especially where frequent sequential data are required.

The radius of influence for neutron moderation probes varies with source strength, hydrogen density, solids density, and chemistry. Practical limits are from 6 to 24 inches from the point between the source and the detector (Kramer et al., 1990; Silvestri et al., 1991). The

cloud of thermalized neutrons is compact in wet and/or dense soils, and expanded in dry and/or loose soils. Strong neutron absorbers, including boron and chlorine, will diminish the radius of influence.

Sensitivity of the neutron probe to wetting fronts depends on the magnitude of the possible moisture change and the masking effects of grout and casing. The neutron probe is most sensitive in ungrouted access tubes with minimal distance between the tube and soils (Teasdale and Johnson, 1970). Small diameter (2-inch) metal casings are best. Steel, aluminum, stainless steel, and PVC in diameters up to 4-inches have been successfully used.

The neutron moisture probe cannot distinguish chemical species (e.g. leachate from groundwater) and is sensitive only to changes in hydrogen density or neutron absorbing solutes and liquids. Neutron data cannot be used to distinguish between gasoline and water, which have similar hydrogen densities (Kramer et al., 1990), nor to detect a steady state flow situation which has no changing hydrogen content. In high background moisture environments or in the presence of high boron or chlorine concentrations, detection of wetting fronts with a neutron probe would be difficult to impossible.

V.3.2.1.5 Vadose Zone Indirect Pore-Liquid Monitoring Option: Time Domain Reflectometry

Field measurement of infiltration can be accomplished through the use of recently developed dielectric methods which include Time Domain Reflectometry (TDR). This method provides a means for determining volumetric water content in the subsurface virtually instantaneously at a level of accuracy as high as $\pm$ 1%.

TDR measures the velocity of a microwave pulse propagated down a parallel transmission line. The velocity of propagation is dependent on the dielectric constant of the material in contact with and surrounding the transmission line. The higher the dielectric constant, the slower the velocity of propagation.

Soil is composed, in general, of air, mineral and organic particles, and water. The dielectric constant for these materials is:

- Air 1
- Mineral Particles 2-3
- Water 80

Since the dielectric constant for water is almost two orders of magnitude greater than the other constituents of soils and sediments, the velocity of propagation of a microwave pulse is highly dependent on the water content. Although soils and sediments have a wide range of particle size distributions, the relationship between the dielectric constant and the water content remains essentially constant. In addition, the bulk density, temperature, and/or salt content does

not significantly interfere with the dielectric-water content relationship. The precision of the water content measurement by TDR has been reported as $\pm$ 2% by volume (Topp, et al., 1983).

While soil salt content does not interfere with the dielectric-water content relationship, highly conductive soils present problems when making TDR measurements. Above a given conductivity, the electromagnetic pulse can be completely attenuated, resulting in no measurement.

Using sophisticated electronic instrumentation, it is possible to measure the time required for a microwave pulse to travel down a known length of parallel transmission line, or wave guides, buried in the soil. The apparent dielectric constant is then readily calculated and related to the water content of the soil. TDR wave guides can be buried in the soil and used to monitor water content changes over short infiltration episodes, diurnal fluctuations in water content, or long-term seasonal soil water content variations.

Many of the first applications of TDR to soil hydrologic applications were carried out using equipment originally designed for locating breaks in coaxial transmission cables. Simple soil probes used in TDR consist of two parallel rods (called wave guides) inserted into the soil. The wave guides are attached directly to twin lead cables. A balance signal can then be provided to the wave guides. An alternative to the twin lead setup uses coaxial cable connected to the wave guides. Because coaxial cable carries an unbalanced signal, an impedance balancing transformer (also called a balun) is required. In this configuration, a balun is required for each wave guide inserted in the soil. Application of this configuration is generally limited to uses where the wave guide can be temporarily inserted and retrieved after a measurement is completed due the high cost of the balun.

Recently, unbalanced TDR soil probes have become available which obviate the need for the expensive balun. The wave guide emulates the coaxial configuration by using three or more rods. In this configuration, the central rod of the wave guide is connected to the signal lead of the coaxial cable and the other rods are connected to the shield of the cable. Since the cost of the wave guides is reduced in this configuration, unbalanced probes have found greater use in applications which require the wave guides to be buried at depth for long periods of time.

Manual measurement and interpretation of the time travel of the microwave pulse can be made using traditional cable testing equipment. The results can be converted to volumetric water content through a series of straight-forward calculations. Software is available for use with cable testers to automatically process the signal return and calculate moisture content. TDR instrumentation has also been developed commercially for specific application to soil hydrology. Current TDR probe designs allow burying the wave guides up to 100 feet away from the signal processing unit. Multiplexing is available which facilitates placement and measurement of hundreds of wave guides arranged in various three dimensional arrays.

V.3.2.1.6 Vadose Zone Indirect Pore-Liquid Monitoring Option: Frequency Domain Capacitance Probe

The dielectric constant of soil, and thus the volumetric water content, can also be measured in the frequency domain by use of the capacitance method (Thomas, 1966; Dean et al., 1987; Bell et al., 1987). A capacitance probe measures the capacitance of an electrode system based on the dielectric constant of the in situ soil surrounding the probe. A capacitor forms the part of the feedback loop of a high frequency oscillator. Currently, techniques for direct in situ measurement of non-aqueous pore liquids from the unsaturated zone remains a research topic.

Once the dielectric constant is determined using the capacitance probe, the relationship between the capacitance and the volumetric water content of the soil can be used to directly calculate the volumetric water content. Alternatively, the capacitance probe can be used directly by calibrating the probe frequency response against soil materials of known water content. As with the TDR probe, one calibration curve works well with a wide variety of soil types.

Capacitance probes are less than 2-inches in diameter and about 8-inches long. Probes can be buried with leads brought back to a central measurement point. Signal processing units are available for automatic data retrieval, acquisition, and storage. Capacitance probes also have the advantage that they can be lowered down standard 2-inch well casing for monitoring water content with depth. Accuracy of capacitance probes is equivalent to that of TDR instruments and should conservatively be considered to be about $\pm$ 2% volumetric water content.

V.3.2.1.7 Vadose Zone Indirect Pore-Liquid Monitoring Option: Soil Water Hydrographs

The water budget in an identifiable closed system in the unsaturated zone can be estimated by evaluating and accounting for precipitation, runoff, evapotranspiration, soil water storage, and infiltration. Precipitation data may be acquired from local meteorological stations. If local information is not accessible or appropriate for use, an on-site meteorological station should be established.

Soil water hydrographs are useful for hydrologic accounting of inputs and outputs from facilities where conditions approximate a closed system and all uncontrolled hydrologic variables can be measured or otherwise accounted for. Taking evaporation and precipitation into account, soil water hydrographs can be used to determine the quantity of infiltration and volume of liquid leached into the unsaturated zone beneath the engineered barrier.

V.3.2.1.8 Vadose Zone Indirect Pore-Liquid Monitoring Option: Gypsum Blocks

Gypsum blocks are a specific example of what are more generally known as electrical resistance blocks. Electrical resistance blocks measure the electrical potential between two wires spaced a known distance apart. This distance is typically on the order of centimeters. Some designs utilize concentric stainless steel coils which are carefully spaced during manufacture. The wires or coils are embedded in a porous matrix which soil pore liquids can freely enter and

exit. As the soil water potential changes, the water in the porous matrix of the block achieves an equilibrium with the surrounding soil. When soils (and thus the electrical resistance block) are dry, the resistance to electrical current flow is high and can be read on a resistance meter. Conversely, when the soil and block become wet, a low resistance is measured on the meter.

Native salts can affect the electrolytic concentration of pore water and consequently the electrical resistance of the pore-liquid solution. While the water condition in the soil may be dry, an increase in salt concentration of the pore-liquids could reduce the resistance measured across the resistance blocks and result in an incorrect reading. To avoid this problem, the most effective electrical resistance blocks are constructed of gypsum (calcium sulfate), one of the most soluble of naturally occurring soil salts.

Because of its high solubility, the gypsum in gypsum blocks is continuously dissolving into the soil solution and creating a background condition of electrolytes which buffers the effect of native soil salts on the measurement. However, the constant dissolution of the gypsum blocks limits the life and accuracy of the blocks. Experience in irrigation management and agriculture indicates that gypsum blocks typically have a life span of about three years. This life span would be increased in an arid environment.

The accuracy of gypsum blocks is generally considered to be approximately $\pm$ 15%. Experience in agricultural applications indicates that they are most effectively used in fine-textured soils (silts to silty clays) in relatively arid environments. Gypsum blocks provide a straight forward, inexpensive means of detecting wetting front movement in arid soil environments over limited time periods. Gypsum blocks are recommended only as part of a short-term unsaturated zone monitoring program. They can be effectively used in the short term to provide an inexpensive means of quality assurance.

V.3.2.2 Technology Type: Vadose Zone Direct Pore-Liquid Monitoring

The term "pore-liquid" is applicable to any liquid residing in soil (ASTM, 1992). The sampling techniques described in the following sections are designed for sampling aqueous pore-liquids only (as opposed to non-aqueous liquids such as oil or other contaminants which may be present in the vadose zone). The performance of the described sampling techniques with other than aqueous liquids may be quite different than that described here.

Most samplers designed for sampling liquid from unsaturated pores may also be used to sample liquid from saturated pores. This may be useful in areas where the water table fluctuates, so that both saturated and unsaturated conditions occur at different times. However, samplers designed specifically for sampling from saturated pores cannot generally be used in unsaturated conditions. This is because the liquid held in unsaturated pores is held at less than atmospheric pressures and will not drain readily into cavities at atmospheric pressures. Wells and open cavities cannot be used to collect liquids flowing in the vadose zone under negative pore pressures (soil suction).

Pore-liquid sampling devices for unsaturated media are categorized into three types:

- Suction samplers
- Experimental suction samplers
- Absorption samplers

Pore-liquid sampling devices applicable to saturated media within the vadose zone are called perched groundwater samplers. Since experimental suction samplers are usually limited to research applications by their fragility and untested performance, they are not recommended for general use.

V.3.2.2.1 Vadose Zone Direct Pore-Liquid Monitoring Option: Suction Lysimeters

The term lysimeter has two definitions. Originally, the term applied to a soil column placed in a field environment in which the inputs and outputs are carefully measured and accounted for such that mass balance calculations are possible. More recently the term lysimeter has been used to describe devices utilized for collecting percolating subsurface water for analysis. Devices which induce flow along a hydraulic gradient under unsaturated conditions are termed suction lysimeters.

The selection of an appropriate porous membrane for sampling in the unsaturated zone is perhaps the most critical aspect of selecting a suction lysimeter. The porous membrane must be hydrophilic and have a maximum pore size small enough to prevent air entry and vacuum failure upon application of a vacuum to collect aqueous pore-liquids. Two porous membrane materials are recommended for use is sampling: ceramic and stainless steel. For most applications, the ceramic membranes are appropriate because of their ability to sustain an applied vacuum of up to 1 bar. Stainless steel, while having a lower air entry value of 0.25 bar, is appropriate for specifically sampling many biological agents. The use of ceramic porous membranes for sampling biological agents is problematic because certain biological agents have dimensions greater than the pore size of the ceramic material.

Suction lysimeters may be subdivided into the following four categories:

- Shallow sampling suction lysimeters
- Pressure-vacuum lysimeters
- Deep sampling pressure-vacuum samplers
- Filter tip

Vacuum-operated lysimeters typically consist of a porous cup mounted on the end of a small diameter PVC body tube, similar to a tensiometer. The upper end of the body tube projects above the soil surface. A rubber stopper and outlet tubing are inserted into the upper end of the body tube. Vacuum is applied to the system and soil water moves within films of water in the soil sediment through the water-saturated pores of the ceramic cup and collects in

the body tube. To extract a sample, a small diameter tube is inserted within the outlet tubing and extended to the base of the porous cup. The small diameter tubing is connected to a sample collection flask. A vacuum is applied and the sample is sucked into the collection flask. These units are generally used to sample to depths up to 6 feet below the ground surface. Consequently, they are used primarily to monitor the near surface.

To extract samples from depths greater than the vacuum lift of water (approximately 25 feet), a pressure-vacuum lysimeter can be used. The body tube of the unit is typically about 2-feet long, holding a maximum of 850-900 milliliters (ml) of sample. Two access tubes are forced through a 2-hole rubber stopper sealed into the body tube. One access tube extends to the base of the porous cup and the other terminates a short distance below the rubber stopper. The longer line connects to a sample bottle and the shorter line connects to a vacuum/pressure pump. All lines and connections are sealed.

In operation, a vacuum is applied to the system while the longer tube to the sample bottle is clamped closed. When sufficient time has passed for the porous cup to fill with liquid, the vacuum is released and the clamp on the outlet line is released. Air pressure is then applied to the system, forcing the sample into the collection flask. A basic problem with this type of system is that when sufficient air pressure is applied to drive the sample solution to the ground surface for recovery, some of the solution in the cup may be forced back through the cup into the surrounding soil, or, in the worst case, the porous cup can be ruptured. This type of pressure-vacuum system is therefore recommended for depths up to about 50 feet below ground surface.

Deep sampling pressure-vacuum lysimeters overcome the main problem of the simple pressure-vacuum system (Wood, 1973). Solution is forced out of the engineered barrier/cover during application of pressure. Two chambers in the assembly are isolated with the exception of a connecting check valve. A sample delivery tube extends from the base of the upper chamber to the surface. This tube also contains a check valve. A second, shorter tube terminating at the top of the sampler is used to deliver vacuum or pressure. When a vacuum is applied to the system, it opens the lower, one-way check valve and causes the upper check valve in the delivery tube to close. The sample is delivered in the upper chamber, which typically has a capacity of 850-900 ml. The vacuum is released and pressure is applied to the shorter tube to deliver the sample to the surface. The lower one-way valve is forced to close by the air pressure and the upper one-way valve is opened. The sample is then forced to the surface. High pressures can be applied without danger of damaging the porous cup. Consequently, the sampler can be used to depths in excess of 300 feet below ground surface (Cullen et al., 1991).

Filter tip samplers also utilize a porous membrane as the sampling interface to the unsaturated subsurface. They consist of a permanently installed filter tip and mechanically retrievable sample vial, a porous section, a nozzle, and a septum. The filter tip includes a pointed end to assist installation. The samplers can be installed in pre-drilled access holes or driven with cone penetration-style equipment. The tip is threaded onto riser pipes which terminated at the surface and act as the conduit to deliver and retrieve the sampling vial. When sampling, a pre-evacuated sample vial fitted with a septum port at one end is mechanically

lowered down the riser pipe to the filter tip which is also fitted with a septum port. A disposable, double-ended hypodermic needle pierces both septa and pore liquids flow into the sample vial under the gradient created across the porous membrane by the vacuum in the sample vial.

Filter tip samples are advantageous when use of a driven sampler is desirable. While expensive, the filter tips are retrievable and the porous membrane can be fitted with materials of different porosity and construction for use in other sampling tasks (e.g. driven piezometers). The depth of sampling is only limited by the operator's ability to drive or drill access holes.

V.3.2.2.2 Vadose Zone Direct Pore-Liquid Monitoring Option: Absorption Samplers

Absorption samplers are used to collect a sample by absorbing the pore-liquids in the matrix of the sampler. The liquid is allowed to absorb into the sampler material over time and is later extracted for analysis. Absorbent samplers are simple to use but are physically limited to soils close to saturation (Dorrance, et al., 1991). The ability of porous materials to absorb liquids is inversely related to the size of the pores in that material, assuming that the material is hydrophilic. Potential problems with absorption samplers include chemical absorption, desorption, precipitation, cation exchange, and screening of various pore-liquid components as a function of sampler material. For these reasons, absorbent samplers have largely been considered an experimental approach.

V.3.3 Initial Screening of Technologies

Vadose zone monitoring technologies were described in Section V.3.2. These technologies represent the range of currently available methodologies for monitoring pore-liquids in the vadose zone. In order to select monitoring systems which are most appropriate for monitoring the engineered barrier/cover and the vadose zone beneath the engineered barrier at OU4, all of the monitoring options described above are initially screened against the broad criteria of effectiveness, implementability, and relative cost as described in Section V.3.1.1. This initial screening process retains only those monitoring options which may reasonably be expected to meet the performance criteria established for the engineered barrier and vadose zone monitoring systems in Section V.2.2.

Initial screening of the monitoring options is performed separately for the engineered barrier monitoring system and the vadose zone monitoring system. The results of the initial screening are presented in the following sections.

V.3.3.1 Initial Screening of Monitoring Options for the Engineered Barrier/Cover Monitoring System

The initial screening and evaluation of monitoring options for the engineered barrier monitoring system is presented in Table V.3-1. Each monitoring option is screened with respect to the broad criteria of effectiveness, implementability, and relative cost as described above. Those monitoring options that are able to meet these criteria, as they specifically pertain to the engineered barrier/cover monitoring system, are retained for further evaluation.

As shown in Table V.3-1, TDR (time domain reflectometry) and frequency domain capacitance probes (FDC) were the only monitoring technologies which were retained for the engineered barrier. TDR is a proven and effective monitoring option. TDR is implementable at OU4 and will not compromise the integrity of the engineered barrier if correctly installed. The relative capital cost of TDR is high compared to the other screened monitoring options. However, TDR is compatible with automated data collection and storage systems, significantly reducing the operations and maintenance costs associated with TDR.

FDC is also a proven and effective monitoring option. FDC systems closely resemble TDR monitoring systems in form, and are therefore implementable and will not compromise the integrity of the engineered barrier if correctly installed. The relative capital cost of FDC is high compared to the other screened monitoring options. However, as with TDR, FDC is compatible with automated data collection and storage systems, significantly reducing the costs associated with FDC operations and maintenance.

V.3.3.2 Initial Screening of Monitoring Options for Vadose Zone Monitoring System

The initial screening and evaluation of monitoring options for the vadose zone monitoring system is shown in Table V.3-2. Each monitoring option is screened with respect to the broad criteria of effectiveness, implementability, and relative cost as described above. Those monitoring options that are able to meet these criteria as they specifically pertain to the vadose zone monitoring system are retained for further evaluation.

As shown in Table V.3-2, the monitoring options retained for further evaluation include neutron probes, FDC, and suction lysimeters. Neutron probes are an effective and proven monitoring option. They are implementable in the vadose zone monitoring system if installed in horizontal access tubes that do not penetrate the overlying engineered barrier. The capital cost of neutron probes is high relative to other monitoring options. The operations and maintenance costs associated with neutron probes are also high if the monitoring system must be operated manually. If the neutron probes are left in place in between monitoring events, automated data collection and storage systems may be installed to significantly reduce the operations and maintenance costs. At this time, however, it is assumed that the probes can not be left in place.

FDC is also a proven and effective monitoring option. FDC systems are implementable at OU4 and will not compromise the integrity of the engineered barrier if appropriately installed. The relative capital cost of FDC is high compared to the other screened monitoring options. However, FDC is compatible with automated data collection and storage systems, significantly reducing the operations and maintenance cost associated with the use of FDC instrumentation.

Suction lysimeters are an effective direct pore-liquid monitoring option. Suction lysimeters are the only retained monitoring option capable of collecting a direct vadose zone pore-liquid sample that may be analyzed to determine the chemical quality of pore liquids which may be present in the vadose zone beneath the waste layer, indicative of leachate migrating out of the waste layer. Suction lysimeters are technically implementable and will not compromise

the integrity of the engineered barrier if correctly installed. The relative capital cost of suction lysimeters is low with respect to other monitoring options. The relative operations and maintenance cost of suction lysimeters is high because sample collection, data acquisition, and storage from suction lysimeters cannot be automated with currently available technology.

V.3.4 Evaluation of Monitoring Options with Respect to Performance Criteria

Performance criteria for the engineered barrier monitoring system and the vadose zone monitoring system were developed in Section V.2.2.1 and V.2.2.2, respectively. The following sections present an evaluation of the monitoring options selected in Section V.3.3 for the engineered barrier and vadose zone monitoring systems with respect to the performance criteria developed in Section V.2.2 for these monitoring systems.

V.3.4.1 Evaluation of the Engineered Barrier Monitoring System

TDR and FDC are the two monitoring options retained for the engineered barrier/cover monitoring system. These monitoring options will be combined to form the engineered barrier monitoring system. These monitoring options are evaluated against the engineered barrier performance criteria. The engineered barrier performance criteria are summarized below.

1) Be feasible to install, operate and sample with respect to the site hydrogeology and the selected engineered remedial alternative.

2) Provide data that can be used to identify and provide early warning of conditions conducive to penetration of water through the engineered barrier/cover.

3) Provide adequate spatial coverage.

4) Provide adequate temporal coverage.

5) Provide data upon which to base a release response action.

6) Provide for remote and automatic monitoring of data.

7) Be integrated into the design and construction of the selected remedial alternative.

8) Incorporate monitoring techniques that are precise.

9) Incorporate planned redundancy.

10) Be cost effective to install and operate.

11) Incorporate proven technologies that have a record of performance for measuring, sampling, and analyzing soil and vadose zone monitoring parameters.

An evaluation of the retained engineered barrier monitoring options is presented in Table V.3-3. All of the engineered barrier performance criteria are individually satisfied by TDR or FDC monitoring options with the exception of performance criteria number 9 which requires that the monitoring system incorporate planned redundancy. Individually, TDR and FDC are not able to satisfy this performance requirement. However, when these monitoring options are combined, the redundancy requirement is fulfilled. The conceptual design of the engineered barrier monitoring system will therefore incorporate both TDR and FDC into the overall monitoring system. The conceptual design of the engineered barrier is presented in Section V.4.1.

V.3.4.2 Evaluation of the Vadose Zone Monitoring System

Neutron probes, FDC, and suction lysimeters are the vadose zone monitoring options which have been retained for the vadose zone monitoring system. All of the other monitoring options were screened out based on the broad evaluation criteria of effectiveness, implementability, and relative cost in Section V.3.3. The retained monitoring options must satisfy the vadose zone monitoring system performance requirements that were developed in Section V.2.2. The vadose zone performance requirements are summarized below.

1) Be feasible to install, operate and sample with respect to the site hydrogeology and the selected engineered remedial alternative.

2) Provide data that can be used to identify the production and migration of leachate within the waste pile.

3) Provide data that can be used to identify the movement of water into the waste pile.

4) Provide data that can be used to identify movement of leachate out of the waste pile.

5) Provide adequate spatial coverage.

6) Provide adequate temporal coverage.

7) Provide data upon which to base a release response action.

8) Provide for remote and automatic monitoring of data.

9) Be integrated into the design and construction of the selected remedial alternative.

10) Incorporate monitoring techniques that are precise.

11) Incorporate planned redundancy.

12) Be cost effective to install and operate.

Table V.3-3 Evaluation of the Engineered Barrier/Cover Monitoring Options with respect to the Engineered Barrier Performance Criteria

	Performance Criteria Number*										
Monitoring Option	1	2	3	4	5	6	7	8	9	10	11
Frequency Domain Capacitance	Feasible with respect to the site hydrogeology and engineered barrier	Capable of collecting data that may be used to provide early warning.	May provide adequate spatial coverage if correctly designed.	May provide adequate temporal coverage if correctly designed.	Capable of providing data upon which to base a response action.	May be sampled remotely.	Can be integrated into the design of the engineered barrier.	Provide precise monitoring data.	Is redundant when used with TDR system.	Cost effective relative to other available monitoring techniques.	Proven technology
Time Domain Reflectometry	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Is redundant when used with FDC. system.	Same as above.	Same as above.

*See Section V.3.4.1

NOTE: A meteorological station will be installed in OU4 as part of the engineered barrier/cover monitoring system to account for climatological factors affecting infiltration, evapotranspiration and runoff.

13) Incorporate proven technologies that have a record of performance for measuring, sampling, and analyzing soil and vadose zone monitoring parameters.

An evaluation of the retained vadose zone monitoring options with respect to the vadose zone performance criteria is presented in Table V.3-4. All three of the retained monitoring options meet the performance criteria with the exception of criteria numbers 8 and 11. Vadose zone performance criteria number 8 is not satisfied because suction lysimeters cannot be sampled remotely using currently available technology. However, no direct vadose zone monitoring options are available which can be operated remotely. A direct pore-liquid monitoring option is necessary for the vadose zone monitoring system to provide redundant data to confirm the quality of the soil moisture present in the vadose zone. If elevated soil moisture conditions are detected by the vadose zone monitoring system, pore-liquid samples collected from the suction lysimeters can be used to help determine if leachate is being released from the waste layer.

Neutron probes may not satisfy performance criteria number 8 if the probes are not permanently stored in the neutron probe access tubes. Because the neutron probes contain low-level radioactive sources, it is currently unknown whether permanent storage of the neutron probes in the access tubes in the vadose zone will be feasible at the RFP.

Performance criteria number 11 is not satisfied by the vadose zone monitoring options when they are considered individually. However, when the monitoring options are evaluated together as pieces of a complete system comprised of all three of the retained vadose zone monitoring options, this performance criterion is satisfied. The redundancy requirement is satisfied by incorporating all three options into the vadose zone monitoring system. The selected vadose zone monitoring system will therefore consist of three components: neutron probes, FDC, and suction lysimeters. The conceptual design of the vadose zone monitoring system is presented in Section V.4.2.

Table V.3-4 Evaluation of the Vadose Zone Monitoring Options with respect to the Vadose Zone Performance Criteria

	Performance Criteria Number*												
Monitoring Option	1	2	3	4	5	6	7	8	9	10	11	12	13
Frequency Domain Capacitance	Feasible with respect to the site hydrogeology and engineered barrier	Capable of collecting data that may be used to identify the production of leachate within the waste layer.	Capable of collecting data that may be used to identify the production of leachate into the waste layer.	Capable of collecting data that may be used to identify the movement of leachate out of the waste layer.	May provide adequate spatial coverage if correctly designed.	May provide adequate temporal coverage if correctly designed.	Capable of providing data upon which to base a response action.	May be sampled remotely.	Can be integrated into the design of the engineered barrier.	Provide precise monitoring data.	Is redundant when used with TDR system.	Cost effective relative to other available monitoring techniques.	Proven technology
Neutron Probe	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	May be sampled remotely if neutron probes are stored in place	Same as above.	Same as above.	Same as above.	Is redundant when used with FDC and suction lysimeters	Same as above.
Suction Lysimeter	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Same as above.	Can't be sampled remotely	Same as above.	Same as above.	Same as above.	Is redundant when used with neutron probes and suction lysimeters	Same as above.

*See Section V.3.4.2.

V.4
CONCEPTUAL DESIGN OF THE MONITORING SYSTEM

The post-closure monitoring system is designed to provide information that will allow the identification of the following conditions:

- Penetration of water through the engineered barrier/cover.
- Production and/or migration of leachate within the waste pile.
- Migration of contaminants from the waste pile into the underlying shallow aquifer.

This information will support the evaluation of the performance of the remedial design. Data from the post-closure monitoring system will be generated in a timely fashion to facilitate early warning of conditions favoring contaminant migration, thereby providing protection against any potential threats to human health and the environment.

The monitoring system will consist of three subsystems. These are the:

- engineered barrier/cover monitoring system (including a geotechnical stability monitoring system)
- vadose zone monitoring system
- groundwater monitoring system

The barrier/cover monitoring system is designed to identify and provide early warning of infiltrating waters that could potentially move through the overlying cover/barrier and into the underlying waste pile. The vadose zone monitoring system (the vadose zone is defined for the purpose of this application as the backfilled contaminated soil materials beneath the barrier/cover and the native colluvium/alluvium above the historical mean annual high water table) is designed to identify moisture conditions within the waste pile beneath the barrier that are indicative of the production of leachate and to identify significant leachate migration from the waste pile. Additionally, the vadose zone monitoring system is designed to identify and provide early warning of the movement of subsurface waters into the waste pile from lateral sources, or from below as in the case of a rising water table. The groundwater monitoring system will monitor the quality of the underlying groundwater at the point of compliance boundary in the groundwater underlying the site, and provide early warning of the potential migration of released COC's to potential downgradient receptors.

V.4.1 Engineered Barrier/Cover Monitoring System

Conceptually, the engineered barrier/cover is a multi-layer, composite barrier designed to prevent contaminant migration away from the confines of the waste pile. The top layer of the cover/barrier consists of gravelly topsoil materials that will support vegetative growth and provide armoring to control erosion. This top layer overlies a capillary barrier consisting sequentially of a sand filter and a gravel filter over angular riprap. The purpose of these poorly sorted, coarse textured materials is to act as a capillary break against unsaturated flow from above and as a biotic barrier to plant root and rodent penetration. Beneath the riprap, a sand drainage layer will be emplaced over a composite asphaltic low-permeability barrier. The cross sectional design of the engineered barrier/cover is shown in Figure V.4-1.

The engineered barrier/cover monitoring system is designed to provide monitoring data necessary to assess the performance of the cover/barrier in impeding percolation of precipitation water into the underlying waste pile. In the event that the engineered barrier/cover does not limit downward movement of infiltration water to above the capillary break, the monitoring system will provide data that can be used to identify and provide early warning of conditions conducive to movement of infiltrating waters through the engineered barrier/cover system and into the underlying waste pile. Specifically, the cover/barrier monitoring system is designed to:

- Provide data regarding site weather conditions sufficient to establish a correlation between hydrologic events occurring at the surface and hydrologic conditions measured within the cover/barrier.

- Provide sufficient measurements of volumetric soil moisture content in the cover materials in order to determine if the water holding capacity of the topsoil materials is being exceeded such that percolation of water through the capillary barrier and into the underlying drainage materials can occur.

- Provide sufficient measurements of volumetric soil moisture content in the sand drainage layer above the asphaltic low permeability layer such that saturated or near-saturated conditions can be identified. Such conditions would exist before significant movement of percolating waters through the low permeability asphaltic layer could occur. A distribution of sensors in the drainage layer down the slope will be used to determine if the drainage layer is functioning as designed.

- Provide sufficient subsurface temperature measurements of the cover materials in order to identify the progression of winter freezing fronts and spring thawing fronts. Temperature measurements are necessary to assess the impact of frozen soil layers on the distribution of soil moisture within the cover profile and to assess the potential for a slug of water moving through the cover profile at spring thaw.

- Provide sufficient surface and subsurface data to facilitate evaluation of the approximate water balance in the cover/barrier. Determination of the approximate water balance in the cover will provide a backup means of identifying conditions conducive to the buildup of positive pore pressures and saturation above the low permeability asphaltic layer.

V.4.1.1 Description of the Engineered Barrier/Cover Monitoring System

The engineered barrier monitoring system will consist of TDR (time domain reflectometry) soil moisture sensors at the interface between the ground surface and the engineered barrier/cover, FDC (frequency domain capacitance) probes installed in vertically distributed arrays, and a meteorological station installed in OU4 to record climatic factors that affect the water balance in the cover/barrier. Conceptual installation locations of the monitoring instrumentation are discussed in the following sections and shown in cross section and plan view, respectively, in Figures V.4-2 and V.4-3.

V.4.1.2 Location and Spatial Distribution of TDR Wave Guides in the Engineered Barrier

TDR sensors, more commonly known as wave guides, will be located in the cover/barrier above the low permeability asphaltic layer and at the interface of the ground surface and the engineered barrier. In order to avoid unnecessarily compromising the integrity of the barrier, no TDR wave guides will be installed in or through the low permeability asphaltic layer. Two clusters of TDR wave guide arrays will be installed in the cover/barrier.

Cluster locations were selected to simultaneously provide monitoring data on representative slope conditions that are to be included in the design of the engineered barrier, and to provide measurements from representative vadose zone areas at the ground surface/engineered barrier interface. Interface areas represent potentially vulnerable areas that may provide flow pathways for entry of surface and/or rising groundwater into the waste pile. One cluster is located in the northwestern corner of the cover/barrier and another is located in the southeastern corner of the barrier/cover. Figure V.4-3 illustrates the conceptual location of the wave guide clusters and associated waveform interpretation modules in plan view. The selected locations will specifically provide:

- Soil moisture measurements representative of the two different slope conditions anticipated as a part of the remedial design. Conceptual location of the TDR arrays are illustrated in the cross sectional drawing Figure V.4-2.

- Soil moisture measurements representative of differing slope conditions that may affect soil and surface temperatures and thus the propagation of freezing and thawing fronts in the soil. Slope conditions can also affect evapotranspiration and consequently storage of soil moisture in the cover. The selected locations illustrated in plan view (Figure V.4-3) will yield soil moisture measurements beneath slopes that are oriented north, east, south and west.

- Access to acquire soil moisture measurements from the interface area between the ground surface and the engineered barrier.

In addition to their use in monitoring the cover/barrier, TDR wave guides will also be used in monitoring beneath the ground surface/engineered barrier interface. Wave guides placed in both locations will be simultaneously serviced by a common waveform interpretation module.

Each wave guide cluster will consist of arrays installed radially out from a centrally located waveform interpretation module. In the cover/barrier monitoring system, an array will consist of two or more wave guides vertically distributed within the cover profile, more or less in line, at any radial distance from the waveform interpretation module. Conceptual locations of the wave guide clusters, arrays, and associated waveform interpretation modules are also shown in cross section in Figure V.4-2.

Wave guides will be vertically distributed in the cover portion of the cover/barrier in order to monitor the performance of the cover in absorbing precipitation water and allowing escape of this precipitation to the atmosphere via evapotranspiration at the vegetative cover. Additionally, TDR measurements used in combination with soil and surface temperature measurements will be used to evaluate the propagation of freezing and thawing fronts and the potential consequential impounding of water in the cover soil until final spring thaw allows a slug of water to pass through the soil material and onto the underlying low permeability layer.

V.4.1.3 Location and Spatial Distribution of Frequency Domain Capacitance Probes for Monitoring the Engineered Barrier/Cover System Performance

FDC probes will be installed in vertical arrays just below the interface of the waste pile and the engineered barrier. Although the FDC arrays are installed in the waste layer (technically part of the vadose zone), they are included as a component of the engineered barrier monitoring system because their principal purpose is to monitor and identify vertically propagating wetting fronts within the waste pile. In addition, data from the FDC probes will be used to measure soil water content distribution within the waste pile and assess the performance of the engineered barrier in maintaining waste pile soil water contents low enough to prevent significant flow of percolating waters within the waste pile, thereby preventing vertical migration of soluble COC's. Areal locations of the FDC arrays are shown in the plan view drawing Figure V.4-3. Vertical distribution of the FDC sensors is shown in the cross sectional drawing Figure V.4-2.

Data from the FDC probes will also be used to assess the performance of the subsurface drainage layer. By design of the subsurface drainage layer, a rising water table should have no impact on the water content of the soil materials in the waste pile. In the event of a rising water table, an increase in the water content of the soil materials in the waste pile would indicate a potential failure in the subsurface drainage layer. Data on the water content distribution within the waste pile will be collected using a vertical and areal distribution of FDC probes and will be used to identify the location of any such problems that might arise.

Data regarding identification of vertically propagating wetting fronts are partially redundant to the data provided by the neutron probe access tubes. As with neutron probe access tube data described in Section V.4.2.2, data collected using the FDC probes will be used to identify the location of vertically propagating wetting fronts and discriminate between a facility-wide design failure and the development of a localized preferential flow pathway that would indicate the need for repair of the engineered barrier/cover. When used in combination with data from the TDR waveguides and the neutron probe access tube, data from the FDC arrays can be used to identify the location of, and discriminate between, downward propagating wetting fronts and upward moving water caused by a rising water table.

V.4.1.4 Meteorological Monitoring of the Engineered Barrier/Cover

A meteorological station will be installed as a part of the engineered barrier/cover system to monitor climatological factors affecting infiltration, evapotranspiration, and runoff. These factors in turn affect the storage of water in the cover soils of the engineered barrier. Monitoring of weather conditions will provide a baseline of data that will document the range of environmental conditions to which the remedial design is exposed over time. In addition, a record of site-specific environmental data will provide the basis for developing a correlation between meteorological events at the surface and the hydrologic status of the subsurface of the engineered barrier/cover.

The meteorological monitoring station will consist of an array of sensors integrated into an automated system that will facilitate data acquisition for the interpretation of weather-related influences on the engineered barrier on a daily or weekly basis. The meteorological monitoring station will be based on designs that have been traditionally used for site-specific agricultural and irrigation scheduling applications. The station will be specifically designed to measure weather factors that affect the cover soil water storage and plant water consumption using calculations based on a modified Penman-Monteith equation (Penman, 1948). The weather station data acquisition system will be supported by a personal computer and associated software for data retrieval and analysis.

Continuous measurements of meteorological conditions will be made by the monitoring station at intervals that will allow data interpretation and analysis on a daily, weekly, or monthly basis. Meteorological variables that will be measured by the weather station include:

- temperature
- relative humidity
- wind speed
- wind direction
- solar radiation
- precipitation (rainfall and snow)

- soil temperature

Measurement height for all sensors, except for the soil temperature sensors, is anticipated to be approximately 3 meters above ground surface. All measurement electronics and communication peripherals will be protected in an environmentally-rugged housing. Data will be electronically retrieved, processed, and transferred between the weather station and a base station computer via a telecommunication link. The telecommunication link will consist of a Hayes-compatible modem at a personal computer connected by phone line to a modem at the weather station. Conceptual location of the meteorological monitoring station is shown in plan view and cross section, respectively, on Figures V.4-3 and V.4-2.

V.4.1.5 Engineered Barrier/Cover System and Slope Geotechnical Stability Monitoring Systems

The geotechnical stability of the engineered barrier/cover system must be monitored to determine if a local or general failure has occurred. Stability monitoring efforts would be focused on evaluating the slope stability of the caped area against lateral movement and against horizontal movement of the cover structure. It is important, however, to note that until the soil engineering parameters are properly defined and dimensions of the cap are known, the following proposed stability monitoring instrumentation and techniques may change and therefore, cost estimates for the monitoring activities may change.

V.4.1.5.1 Slope Lateral Stability

To monitor the slope stability of the caped area, instrumentations are proposed to be installed at the critical areas of the slope. The critical areas may be defined as the portion of the slope with the least factor of safety or increased potential of failure due to external forces. Currently, no information is available regarding the slope dimensions and soil engineering parameters such as internal friction angle and shear strengths. Therefore, the critical portion of the slope cannot be determined at this time. It is assumed most of the slopes of the capped area will be monitored.

The only monitoring instrumentation that requires limited installation effort has been selected to minimize the need for instrusive activities which may result in breaching the integrity of the cap. The instrumentation currently being considered for the slope stability monitoring includes a combination of stable points for precise surface survey and stable monuments with tape extensometers. When the survey is performed regularly in reference to a stable bench mark located off the cap (on a nearby building or power pole), it will indicate movements of the surveyed points on the cap which in turn will determine movement of the slope. A reference point on the slope to be surveyed can be the tip of a rod in a 6 inch by 6 inch concrete block.

The tape extensometers can be connected between these points and assembled where a reading of any movement can be taken at any time. These delicate extensometers are recommended for precise measurements of slope movements.

V.4.1.5.2 Cap Horizontal Stability

The stability of the cap against horizontal short and long-term settlements can be monitored by several means. Only options that contain limited or no intrusion into the cap structure have been considered. As proposed for the slope stability monitoring, stable points to assist a frequent surface survey are proposed to be installed on a grid based on the top of the cap structure. These points are to be located approximately 50 feet apart. The points would be surveyed in reference to a stable bench mark to determine if any movement has occurred.

In addition to the surface survey, tiltmeters with tiltplates are also proposed. Tiltmeters would be used to measure changes in the inclination of the cap as a result of soil compactions. Tiltmeters are particularly beneficial in determining the rotation rates that normally accompany settlement.

As in the case of the soil lateral stability, instrumentation to monitor the cap horizontal stability are easy to install and will require limited operation and maintenance efforts.

V.4.2 Vadose Zone Monitoring System

The vadose zone represents a buffer zone between subsurface groundwater and surface-generated anthropogenic COC's. The vadose zone also represents the most logical location for the early detection of migrating COC's that could degrade groundwater quality.

Traditionally, the vadose zone is defined as that portion of the geologic profile from ground surface to the top of the water table. The term vadose zone typically includes not only unsaturated soils and sediments, but also perched zones that are isolated zones of saturation or only periodically saturated. At the OU4 remedial action site, the term vadose zone takes on a slightly modified meaning because of the substantial earth moving and reconfiguration of the subsurface that is planned as part of the selected remedial alternative.

There will actually be two separate components of the vadose zone at SEP as the result of the remedial action. From uppermost to lowermost, the upper portion consists of soil cover material, a sand and gravel filter, a riprap biotic barrier, a sandy drainage layer, and a low-permeability composite asphaltic layer (Figure V.4-1). As engineered, this upper portion will be hydraulically isolated from the contaminated soil material placed in the waste pile underneath the barrier. No contaminated soils will be placed in this upper component. While according to the traditional definition the upper component is part of the vadose zone, it is treated separately for the purposes of this application. The upper portion is referred to in this report as the engineered barrier/cover and will be monitored by a separate system as described in Section V.4.1.

As applied to the SEP at OU4, the vadose zone consists of the unsaturated soil materials and in-situ soils located just under the engineered barrier/cover down to the historic mean high water table as interpreted from the groundwater hydrographs from groundwater wells in OU4 presented in the "1994 Report of RCRA Facility Investigation/Remedial Investigation,

OU4, SEP" (in preparation). The interpreted six-year high water table is illustrated in the context of the proposed remedial design in cross-sectional drawing Figure V.4-2.

The primary region of concern with respect to contaminant mobility is the volume of soil in the waste pile that is located above the subsurface drain as show in Figure V.4-2. In order to impact groundwater, potentially mobile COC's would have to travel from the top of the waste pile vertically down to the water table. The subsurface drain will act as a barrier to a rising water table and facilitate drainage into the interceptor trench system. The subsurface drain, on the other hand, will not impede a vertically propagating wetting front that is at or near saturation. The critical region of contaminant migration detection is then the range of distances that exist under OU4 from the top of the subsurface drain to the water table.

Based on the cross-sectional drawing of the proposed facility as illustrated in Figure V.4-2, the depth of vadose zone at the OU4 proposed facility ranges from about 8 feet at the southeastern corner to more than 22 feet under the peak in the engineered barrier/cover at the center of the facility. This range of depths provides a more than adequate cross-section over which to monitor changes in vadose zone moisture conditions.

V.4.2.1 Description of the Vadose Monitoring System

The vadose zone monitoring system will consist of horizontal neutron probe access tubes (NPAT) placed beneath the subsurface drain layer at the bottom of the waste pile, and five paired installations of FDC probes and pressure/vacuum suction lysimeters placed beneath the subsurface drain layer. Conceptual installation locations of the monitoring instrumentation are discussed in the following sections and shown in cross section and plan view, respectively, in Figures V.4-2 and V.4-3.

The vadose zone monitoring system is designed to identify moisture conditions within the waste pile beneath the barrier that are indicative of the production of leachate, and to identify significant leachate migration from the waste pile. Additionally, the vadose zone monitoring system is designed to identify and provide early warning of the movement of subsurface waters into the waste pile from lateral sources, or from below as in the case of a rising water table. Specifically, the vadose zone monitoring system will:

- Provide sufficient spatially distributed neutron moderation logs as a relative measure of soil water content in the vadose zone beneath the SEP. The neutron logs will be taken from just beneath the subsurface drainage layer beneath the waste pile. When used in conjunction with piezometers and groundwater monitoring wells, the neutron moderation logs can be interpreted to indicate the presence of a capillary fringe as the result of a rising water table and to provide early warning of the downward propagation of a wetting front.

- Collect pore liquid samples from the vadose zone beneath the waste pile in OU4. Collection of pore liquid samples will allow monitoring of pore liquid quality over time. In either the case of a rising water table or in the case of downward leachate migration from the waste pile, pore liquid sampling will

enable data regarding the quality of pore liquids to be collected for interpretation as to the source of contaminant migration. This will prove to be especially significant in an area known to contain upgradient sources of groundwater contamination. FDC proves will be installed adjacent to each pore liquid sampler to identify and confirm whether soil moisture conditions appropriate for pore liquid sampling are present.

V.4.2.2 Location and Spatial Distribution of Neutron Probe Access Tubes in the Vadose Zone

Three NPAT (neutron probe access tubes) will be installed just beneath the subsurface drainage layer as shown in the cross sectional drawing Figure V.4-2. Because the NPATs represent monitoring lines, as opposed to monitoring points, they will be used to increase the spatial coverage of vadose zone monitoring beneath OU4 for the purpose of detecting vertically propagating wetting fronts that would be indicative of the potential for leaching of COC's from the waste pile. The NPAT lines will be oriented in a north-south direction and be will be equally spaced from west to east in order to maximize spatial coverage and provide data from representative areas beneath the facility.

Vertically propagating wetting fronts moving downward through the waste pile would be intercepted by the subsurface drainage layer and conducted laterally away from groundwater only when near-saturated conditions develop in the overlying waste pile. In this case, some of the leachate would have the potential for percolating into the subsurface beneath the drainage layer and potentially impacting groundwater. NPATs will indicate the spatial extent of these potential wetting fronts.

Data collected using the NPATs will be used to identify the location of vertically propagating wetting fronts, and to discriminate between a facility-wide design failure and the development of a localized preferential flow pathway that would indicate the need for repair of the engineered barrier/cover. When used in combination with data from the TDR waveguides and FDC arrays, data from the NPATs can be used to identify the location of, and discriminate between, downward propagating wetting fronts and upward moving water caused by a rising water table.

Data from the NPATs will also be used to assess the performance of the subsurface drainage layer. Identification of the spatial extent of a rising water table can be used to indicate the relative quantity of water that would be expected in the outflow of water at the discharge point of the subsurface drain.

Measurements taken with the NPATs, will also be used as indicators of the need to implement unscheduled pore liquid sampling in the vadose zone using the pressure/vacuum lysimeters as discussed in section V.4.2.3. Detection of a wetting front by the NPATs, whether from downward propagating wetting fronts or from a rising water table, will be used as an indicator to implement pore liquid sampling to monitor the chemical quality of the wetting front pore liquids.

The purpose of the subsurface drain is to act as a barrier to a rising water table intersecting the waste pile. In the unlikely event that the water table rises into the drainage layer, water will be drained out through the gravel layer and discharged into the interceptor trench system. NPAT data will be used in combination with the FDC, TDR, and groundwater elevation data as an indicator of a rising water table that will result in drainage from the subsurface drain layer. When drainage occurs, a grab sample will be collected from the discharge, upstream of the interceptor trench system.

Lastly, NPATs will provide the planned redundancy in the vadose zone monitoring system specified in the performance criteria.

The current conceptual design of the NPATs provides for manual operation of a neutron probe during each sampling event. A significant cost savings will be realized from an operations and maintenance perspective, if automated neutron probe systems are installed. Automated monitoring using neutron probes is technically feasible and implementable. However, automated systems would require storage of the neutron probe, which contains a low-level radioactive source, in each NPAT on a permanent basis. Specific security issues related to permanent storage of the neutron probes in the NPATs at the RFP are currently unknown.

V.4.2.3 Location and Spatial Distribution of Pressure/Vacuum Lysimeters in the Vadose Zone

Pore liquid sampling devices, known as pressure/vacuum lysimeters, will be placed in the vadose zone beneath the subsurface drain for the purpose of sampling potentially migrating pore liquids in the vadose zone. Lysimeters will be installed at five locations areally distributed beneath the waste pile. The distribution of the lysimeter locations is shown in plan view in Figure V.4-3.

Propagating wetting fronts moving downward out of the waste pile, laterally from the interface between ground surface and the engineered barrier/cover, or upward because of a rising water table will cause an increase in saturation and a decrease in the negative pore pressures of the soil materials beneath the subsurface drain. When these negative pore pressures are reduced to a level where significant flow (and the resulting potential for COC migration) can occur, lysimeters will be utilized to determine the chemical quality of the migrating pore liquids. Vertical position of the lysimeters relative to the subsurface drain is shown in Figure V.4-2. FDC probes will be installed adjacent to each pore liquid sampler to identify and confirm whether soil moisture conditions appropriate for pore liquid sampling are present.

The lysimeters will be located beneath the subsurface drain in order to sample potentially migrating liquids that are produced by leachate in the case that infiltration occurs through the engineered barrier/cover. Samples recovered from the lysimeters will indicate the composition of the pore liquids and the presence of migrating COC's.

In accordance with the design of the engineered barrier/cover, saturation levels in the vadose zone beneath the facility will be low and negative pore pressures high. Data from IM/IRA Part II confirm this and indicate that the observed negative pore pressures currently

exceed the range in which lysimeters are capable of collecting a pore liquid sample. Lysimeters are capable of collecting pore liquid samples in the negative pore pressure range of 0 to approximately 65 centibars. It is anticipated that pore liquid samples will not be recoverable from the lysimeters on a regular basis. However, installation of the lysimeters is critical to the monitoring plan so that they are available and in place to collect pore liquid samples if and when intrusion of a wetting front is detected by the other indirect techniques such as the TDR waveguides, NPAT, or FDC probes.

Data from lysimeter samples will be used to identify migrating COC's in the vadose zone and to determine the chemical quality of downward moving wetting fronts or of wetting fronts caused by a rising water table. Used in combination with the other indirect monitoring technologies at the facility, lysimeter data will be used to assess the performance of the engineered barrier/cover even in the unlikely event that leachate is produced within the waste pile and begins to vertically migrate. Vertical migration of pore fluids alone is not diagnostic confirmation that a release to groundwater will occur from the facility. Lysimeters will be used to confirm the chemical quality of any detected migrating pore liquids that may impact groundwater.

V.4.3 Groundwater System

The purpose of the groundwater monitoring system for the OU4 is to detect the introduction of waste constituents into groundwater from the waste piles. The system will be used to monitor groundwater quality and flow in the upper hydrostratigraphic unit. The upper hydrostratigraphic unit consists of several distinct lithostratigraphic units. These units are the Quaternary alluvium, colluvium, valley-fill alluvium, landslide deposits, weathered bedrock of the Arapahoe/Laramie Formation, and all sandstones within the Arapahoe/Laramie Formation that are in hydraulic connection with overlying unconsolidated deposits, or that crop out at the surface. Specifically, the groundwater monitoring system is designed to:

- Provide sufficient coverage of hydraulically downgradient locations to detect the potential migration of waste constituents from the OU4 at the point-of-compliance boundary.

- Provide sufficient coverage of hydraulically upgradient locations to characterize groundwater quality, and detect the potential migration of groundwater contaminants beneath the OU4 from potential upgradient sources.

- Allow the collection of quantitative and defensible groundwater flow and quality data through the application of monitoring well construction specifications that are consistent with existing and accepted SOPs at the RFP.

The data collected from the groundwater monitoring system for the OU4 will be suitable for appropriate statistical evaluations designed to facilitate comparison of upgradient and downgradient groundwater quality conditions, and identify trends at individual monitoring locations.

V.4.3.1 Well Location

The location of groundwater monitoring wells is based on an evaluation of observed groundwater flow conditions at OU4, as reported in the "1992 Annual RCRA Groundwater Monitoring Report for Regulated Units at the Rocky Flats Plant" (EG&G, 1993). Four quarters of groundwater flow data were evaluated to determine adequate coverage of both upgradient and downgradient locations. EG&G, in the 1992 RCRA report, separated their discussions of groundwater flow in the upper hydrostratigraphic unit into flow in the "surficial materials" (alluvium, colluvium, fill, etc.) and flow in the weathered bedrock.

Groundwater flow conditions in the alluvium/colluvium, for four quarters of 1992, are illustrated in Figure V.4-4. Generalized groundwater flow lines originate at the four corners of the engineered barrier/cover system waste pile. The flow lines were developed manually by extending flow paths from the waste pile corners in directions perpendicular to equipotential lines. The illustration of groundwater flow potential with equipotential lines is representative of site-specific hydrologic conditions; however, the use of groundwater flow lines is based on the assumption that the alluvium/colluvium is homogeneous and isotropic. Although this assumption might not be entirely accurate, any variation from homogeneous and isotropic conditions is expected to be localized and on a limited scale. Therefore, over the areal extent of the SEP, flow conditions as depicted in Figure V.4-4 are expected to be reasonably representative.

The predominant direction of groundwater flow in the alluvium/colluvium is to the north and northeast. There is also a localized southeasterly component of flow at the eastern end of the southern boundary of the SEP. This divergence of flow results from an apparent east-west trending groundwater divide, near the southeast corner of the SEP, that may be related to the topography of the bedrock surface. Because this groundwater divide occurs near the southern point-of-compliance boundary, it does not affect flow beneath the waste material. Therefore, the southern point-of-compliance boundary, south of former Ponds 207-A and 207-B, is considered to be upgradient.

Groundwater flow conditions in the weathered bedrock, for four quarters of 1992, are illustrated in Figure V.4-5. Generalized groundwater flow lines were developed in the same fashion, and based on the same assumptions, as described above for the alluvium/colluvium. Groundwater flow in the weathered bedrock is, for the most part, similar to flow in the alluvium/colluvium. The predominant direction of groundwater flow in the weathered bedrock is to the north and northeast. However, the southeasterly component of flow identified in the alluvium/colluvium, at the eastern end of the southern boundary of the SEP, is more pronounced in the weathered bedrock. The apparent east-west trending groundwater divide in the weathered bedrock is located in the center of the SEP. Similar to the alluvium/colluvium, groundwater flowing toward the SEP within the weathered bedrock originates primarily in the area to the southwest. However, a portion of the southern boundary of the SEP unit that was determined to be upgradient for the alluvium/colluvium may be downgradient in the weathered bedrock.

For the purpose of monitoring groundwater in the upper hydrostratigraphic unit at the SEP, new wells will be screened across the uppermost saturated intervals, regardless of which

lithostratigraphic unit (i.e., alluvium, weathered bedrock, or hydraulically connected sandstone) the water table is encountered in. As presented above, flow conditions are quite similar in both the alluvium/colluvium and the weathered bedrock. The only appreciable difference is along the southern point-of-compliance boundary, where flow may vary slightly between the two lithologies.

Locations for monitoring wells screened in the upper hydrostratigraphic unit are illustrated in Figure V.4-6. Where appropriate, existing wells will be incorporated into the monitoring system. New and existing wells that are located on the point-of-compliance boundary will be used for compliance monitoring. In addition, existing wells located away from the point-of-compliance boundary will be used for compliance and performance monitoring.

Alluvial/colluvial wells 2686, 3887, and P207689 are located along the southern point of compliance boundary for the SEP and will be included in the groundwater monitoring system for compliance monitoring. Weathered bedrock wells 2586, P207589, P207789, P208989, 3186, 3286, and P209489 are located along the southern and northern portions of the compliance boundary for the SEP, and will also be included in the groundwater monitoring system for compliance monitoring.

Groundwater flowing toward the point of compliance boundary originates primarily in the plant area west of the SEP, where several potential groundwater contaminant sources are present. Historic data from existing alluvial/colluvial wells 2286, 5687, 2486, and P207489, and weathered bedrock wells P209189, P210189, 2386, and P207389 indicate significant variations in groundwater quality between these upgradient locations. In the case of wells 2286 and 5687, water-quality conditions provided in the 1993 RCRA Groundwater Report (EG&G, 1993) show significant disparity over a relatively short lateral distance (Figure V.4-6). These data point to the potential for various discreet and discontinuous upgradient plumes. Therefore, it is important that a sufficient number of data collection points be established to allow a reasonably complete characterization of upgradient groundwater quality, and a statistically significant distinction between upgradient and downgradient groundwater quality conditions. Alluvial/colluvial wells 2286, 5687, 2486, and P207489, and weathered bedrock wells P209189, P210189, 2386, and P207389 will be incorporated into the groundwater monitoring system for compliance and performance monitoring.

Three additional weathered bedrock wells (3987, P208889, and P209589) are located approximately 100 feet to the northeast of the northeast corner of the compliance boundary, and one alluvial/colluvial well (P207889) and one weathered bedrock well (P207989) are located approximately 100 feet east of the eastern point-of-compliance boundary. These five wells will be included in the post-closure monitoring system for compliance and performance monitoring.

Where existing wells are not present along the point-of-compliance boundary, new wells will be installed at approximate 200-foot intervals. The distribution of downgradient and upgradient wells depicted in Figure V.4-6 is sufficient to allow the detection of waste constituents that would potentially migrate from the SEP should conditions arise that would cause leaching of the waste piles, and to allow a statistically significant distinction between upgradient and downgradient groundwater quality conditions. In all, seven existing weathered bedrock

wells, three existing alluvial/colluvial wells, and seven new wells to be completed in the upper hydrostratigraphic unit are proposed to be used for post-closure compliance monitoring in OU4. An additional eight existing wells screened in the weathered bedrock, and five existing wells screened in the alluvium/colluvium, will be included in the post-closure monitoring system for the purposes of compliance and performance monitoring. Based on available data (Figures V.4-4 and V.4-5), it was assumed that the west point of compliance boundary for the upper hydrostratigraphic unit represents the upgradient point of compliance boundary (Figure V.4-6). It was also assumed that the south, east, and north boundaries are downgradient point of compliance boundaries (Figure V.4-6). These assumed upgradient and downgradient boundaries must be confirmed through water level measurements once the network is established. Moreover, it seems likely that quarterly water level measurements conducted concurrently with water quality sampling would be prudent to ensure a clear understanding of the upper hydrostratigraphic unit flow regime in OU4 over time.

V.4.3.2 Well Construction

Monitoring well construction specifications are consistent with existing and accepted SOPs at the RFP. Both bedrock and alluvial wells will be installed to monitor upgradient and downgradient groundwater flow and quality conditions at the SEP. Wells will be installed in accordance with RFP EMD Operating Procedure No. GT.06, "Monitoring Wells and Piezometer Installation" and No. GT.03, "Isolating Bedrock from Alluvium with Grouted Surface Casing."

V.5
MONITORING SYSTEM DETAILED DESIGN

V.5.1 Engineered Barrier/Cover Monitoring System

A detailed description of the engineered barrier/cover monitoring system design will be completed for the 60 percent design report; however, this section is included here as an indication that this description is forthcoming. The detailed description of the engineered barrier/cover monitoring system will include the following information.

- Precise placement locations for all monitoring equipment within the engineered barrier/cover system, including the layers in which the equipment will be placed and the horizontal location of each device.
- Placement specifications, including details on the integration of the placement of engineered barrier/cover layer materials and the placement of the monitoring equipment, placement vaults, access ports, wiring, and other peripherals such as data collection stations.
- Equipment specifications and drawings for all monitoring equipment and data collection equipment.
- Wiring diagrams and control schematics.
- Telimetered data transmittal specifications and details of the archiving and storage mechanisms.
- Equipment shakedown procedures.
- Surveying (horizontal and vertical positioning) requirements.

Where practicable , the design specifications of the engineered barrier/cover monitoring system (including below and above ground components) will be consistent with applicable, existing SOPs for similar equipment at the RFP.

V.5.2 Vadose Zone Monitoring System

A detailed description of the vadose zone monitoring system design will be completed for the 60 percent design report; however, this section is included here as an indication that this description is forthcoming. The detailed description of the vadose zone monitoring system will include information similar to that presented in Section V.5.1 for the engineered barrier/cover monitoring system.

V.5.3 Groundwater System

A detailed description of the groundwater monitoring system design will be completed for the 60 percent design report; however, this section is included here as an indication that this description is forthcoming. The detailed description of the groundwater monitoring system design will include the following information.

- Precise well locations.
- Well installation specifications (drilling methods, etc.).
- Well construction specifications (well and borehole diameters, well materials, screen size, filter pack design, etc.).
- Casing and screen intervals.
- Measuring point descriptions and surveying requirements.
- Well development techniques and development water handling procedures.
- Well identification.

Where practicable, the design specifications of the groundwater monitoring system will be consistent with applicable, existing SOPs for monitoring well installation and construction at the RFP.

V.6
SAMPLING AND ANALYSIS PLAN

V.6.1 Engineered Barrier/Cover Monitoring System

This engineered barrier/cover monitoring system sampling and analysis plan description presents data quality and quality assurance/quality control objectives for the engineered barrier/cover monitoring program at the SEP. In most cases, detailed descriptions of field and laboratory procedures are not included here; however, a detailed engineered barrier/cover monitoring sampling and analysis plan will be developed and kept at the facility for post-closure monitoring.

V.6.1.1 Data Quality Objectives

The overall DQO (data quality objective) for the engineered barrier/cover monitoring program is to ensure that data of known and acceptable quality are produced. Specifically, data produced through the post-closure engineered barrier/cover monitoring program must be suitable for appropriate evaluations designed to facilitate the positive and timely identification of conditions conducive to, or indicative of, infiltration of surface waters and/or precipitation into the engineered barrier/cover. Proper execution of each sampling and analysis task will yield consistent results that are representative of actual conditions within the engineered barrier/cover, and are useful for meeting the intended project objectives.

V.6.1.2 Quality Assurance/Quality (QA/QC) Control Objectives

QA/QC objectives are established to ensure that all data collected during post-closure monitoring are of acceptable quality to support response action decisions and the DQOs. The implementation of appropriate QA/QC procedures allows development of meaningful technical conclusions. Components of the QA/QC program include evaluations of the following characteristics of measured data.

- Precision
- Accuracy
- Representativeness
- Completeness
- Comparability

Data from the engineered barrier/cover monitoring system can vary in quality due to measuring protocol, data logging protocols, data processing techniques, instrumentation, and available documentation. QA programs include all of the activities necessary to provide

measurement data at a requisite precision and accuracy (ASTM, 1993, Vol. 11.03, Practice 1357-82).

The precision of a measurement process is a generic concept related to the closeness of agreement between test results obtained under prescribed like conditions from the measurement process being evaluated. Accuracy is a generic concept of exactness related to the closeness of agreement between the average of one or more test results and an accepted reference value (ASTM, 1993, Vol. 14.02, Practice E 177-86). Overall precision and accuracy targets for soil moisture content and neutron probe measurements can be set at 2 percent allowable deviation with 90 percent confidence limits.

Representativeness is a measure of the degree to which analytical results reflect true field conditions. Field errors in data logging and sampling intensity are two factors affecting representativeness. The comparability of the data collected refers to the ability to interpret the results in light of previous data collection efforts and data collection efforts published as the result of other similar investigations. Completeness refers to the number of samples collected and analyzed compared to the planned number of samples.

In all of these quality assurance activities it should be noted that factors including geophysical conditions and definition of sampling volume in the vadose zone often have higher variability than the instrumentation and equipment calibration procedures. Table V.6-1 provides preliminary quantitative limits for QA/QC objectives.

V.6.1.3 Measurement Procedures

The quality of the data collected from the vadose zone depends on the quality of the measurement procedures and sampling activities. Therefore, field operations will be carefully planned and implemented. Procedures and protocols for monitoring and sampling of the vadose zone in the engineered barrier will be in accordance with applicable existing SOPs for vadose zone monitoring and sampling at the RFP. As described in Section V.4.1, the conceptual design of the engineered barrier monitoring system includes indirect pore-liquid monitoring techniques using time domain reflectometry and frequency domain capacitance. Specific procedures for installing and monitoring this equipment are provided in existing Vadose Zone SOP VZ.4, "Procedures for Dielectric Water Content Measurement," included in Technical Memorandum No. 1 for OU4.

V.6.1.4 Frequency of Measurement

The sampling and analysis plan is designed such that the intervals between measurement and sampling event are shortest at the beginning of the remedial action and become greater as time elapses and the performance of the remedial design is assessed and verified. Data collected during the initial 3-year period will be used to develop an understanding of the effect of seasonal weather changes on the monitoring data, identify gaps in the data, further characterize the completed remedial design, identify any additionally required monitoring locations, and evaluate sources of uncertainty such as sampling, analysis, and site conditions.

Table V.6-1 Conceptual Quantitative Limits for the Quality Assurance/Quality Control Objectives in the Engineered Barrier/Cover and Vadose Zone Monitoring Systems for Instruments Used.

Data Quality Objective	Parameter	Instruments	Quantitation Limit
Accuracy	Volumetric Water Content	TDR FDC	2% 2%
	Standard Count	NPAT	2%
	NBS Standards	MET Station	1%
	Lab Standard Recovery	Lysimeter Sampling	+/-10%
Precision	Replicate Measurement	TDR FDC NPAT MET Station	2% 2% 2% 1%
	Lab Replicate	Lysimeter Sampling	<20%
Representativeness	Duplicate Field Measurement	TDR FDC NPAT MET Station	2% 2% 2% 1%
	Laboratory Blank	Lysimeter Sampling	<10%
Completeness	Completion (%)	TDR FDC NPAT MET Station Lysimeter Sampling	>90% >90% >90% >90% >90%*
Comparability	Professional Judgement	TDR FDC NPAT MET Station Lysimeter Sampling	N/A** N/A N/A N/A N/A

* when soil water tension is less than 60 centibars
** N/A = not applicable

The recommended long-term frequency for measurement and sampling depends in part on the effectiveness of the remedial action as determined through the ongoing monitoring program. If the monitoring data demonstrates that a steady, predictable stabilization of the pore liquids in the waste pile has occurred, then reducing the sampling frequency will be a reasonable course of action. Frequency of monitoring is also dependent upon the labor intensity of the measurement process as it effects the cost of acquiring data. For example, there is little cost differential between weekly and daily monitoring of weather parameters when data from the sensors are electronically logged, acquired and presented in report format.

Frequency is also dependent upon the status of other sensors in the overall system. Measurement redundancy is built into the system in anticipation of the contingency that sensors may become disabled in the future. For example, if the FDC sensors (which are part of the engineered barrier monitoring system) become disabled at some point in the future, the NPAT can also perform the function of detecting downward migration of leachate. The frequency of NPAT data acquisition would be increased in the event that FDC probes become disabled. Likewise, once it can be shown that the engineered barrier/cover and vadose zone monitoring system data are reliably and consistently being used to demonstrate no leachate migration from the waste pile, the frequency of monitoring at all or some of the proposed groundwater monitoring wells could be reduced or even eliminated.

The monitoring data will provide the basis for determining that the remedial action objectives have been met and that the source control action, which is the goal of the remedial action, prevents further degradation of groundwater.

Monitoring data from MET and TDR sensors in the engineered barrier/cover system will be electronically acquired on a daily basis throughout the period of monitoring. During the initial 3 years of data acquisition, the data will be used to assess the performance of the cover system and to develop a baseline of meteorological data that will be used to define the site-specific environmental conditions affecting the remedial action. The meteorological data may also be used to develop the statistical basis for de-seasonalizing the soil moisture data if required.

At the end of the initial 3-year monitoring period, MET and TDR data will be used in conjunction with the water elevations from the groundwater monitoring wells to determine the appropriate time of the year to collect pore liquid samples (PLS) from the pressure vacuum lysimeters. A statistical correlation between the MET data, groundwater elevation data, and TDR data will be developed for the purpose of defining the time of year when development of leachate within the pile is most likely, when a rising water table is most likely, and when the concentration of COC's is likely to be highest because of the concentrating effect of soil desaturation.

Statistical correlation will be developed during the initial monitoring phase (0 to 3 years) and in the secondary phase (3 to 10 years) between the MET data and TDR data for the purpose of developing a tool to predict the performance of the engineered barrier/cover system design based on weather data. For example, precipitation events will be identified that are most likely to saturate the cover soils and penetrate the capillary barrier portion of the engineered

barrier. Likewise, additional climatic data will be examined in order to assess the effect of weather patterns and intensity on the performance of the engineered barrier/cover. For example, soil temperature sensing data will be collected and evaluated to determine the effect of freezing and thawing fronts on saturation of the engineered barrier/cover system.

Assuming that the remedial design performs as intended, MET and TDR sensors in the engineered barrier/cover system will be the primary means of monitoring performance of the remedial action 10 years after installation of these systems. FDC monitoring of the engineered barrier/cover and vadose zone monitoring will be reduced in frequency as described in section V.6.2.3.

Thirty years after installation of the facility, all of the sensors will remain in place. However, it is anticipated that only the MET and TDR sensors will be used for data collection thereafter, as part of a normal operating weather station. Based on the statistical correlations established during the 30-year monitoring period, weather events or climatic trends will be identified that could trigger additional monitoring of the unsaturated zone beneath the engineered barrier/cover.

Table V.6-2 summarizes the frequency of measurement of the monitoring instrumentation planned as a part of the design of the monitoring system.

V.6.2 Vadose Zone Monitoring System

This vadose zone monitoring system sampling and analysis plan description presents data quality and quality assurance/quality control objectives for the vadose zone monitoring program at the SEP. In most cases, detailed descriptions of field and laboratory procedures are not included here; however, a detailed vadose zone monitoring sampling and analysis plan will be developed and kept at the facility for post-closure monitoring.

V.6.2.1 Data Quality Objectives

The overall DQO for the vadose zone monitoring program is to ensure that data of known and acceptable quality are produced. Specifically, data produced through the post-closure vadose zone monitoring program must be suitable for appropriate evaluations designed to facilitate the positive and timely identification of conditions conducive to, or indicative of, the production of leachate, the movement of fluids through the waste pile, and/or the infiltration of fluids into the waste pile from the engineered barrier/cover or from rising water-table conditions. Proper execution of each sampling and analysis task will yield consistent results that are representative of actual conditions within the vadose zone, and are useful for meeting the intended project objectives.

V.6.2.2 Quality Assurance/Quality (QA/QC) Control Objectives

QA/QC objectives for monitoring the vadose zone are similar to those for the engineered barrier/cover monitoring system. However, the vadose zone monitoring system must also address data that will result from collection of pore liquid samples using the

Table V.6-2 Frequency of Sampling for Instrumentation which makes up the Conceptual Design of the Engineered Barrier/Cover and Vadose Zone Monitoring Systems.

Monitoring Technology	Frequency of measurement (years after facility installation)			
	0-3	3-10	10-30	30+
MET	**Daily**	**Daily**	**Daily**	**Daily**
TDR	**Daily**	**Daily**	**Daily**	**Daily**
FDC	**Weekly**; unless triggered by TDR rise then daily	**Monthly**; unless triggered by FDC rise then daily	**Monthly**; unless triggered by FDC rise then daily	**No measurement** unless triggered by MET/TDR
NPAT	**Monthly**	**Quarterly**; unless triggered by a rise in NPAT or FDC then monthly	**Semiannually** unless triggered by a rise in NPAT or FDC then monthly	**No measurement** unless triggered sequentially by MET/TDR and FDC
PLS	**Quarterly** or when triggered by water table rise or rise in NPAT or adjacent FDC	**4 times per year** based on previous 3-year MET and well data; or only when triggered by NPAT or adjacent FDC if pore liquid samples are NS	**No measurement** unless trig-gered by rise in NPAT, adja-cent FDC or water table rise	**No measurement** unless triggered sequentially by MET/TDR, FDC, and NPAT, or water table rise

MET = meteorological instrumentation; TDR = time domain reflectometry: NPAT = neutron probe access tube; FDC = frequency domain capacitance probes; PLS = pore liquid samplers; NS = no sample obtainable due to high negative pore pressures.

pressure/vacuum lysimeters and data generated using the neutron probe. In addition to the factors affecting data quality from the measuring techniques as described in Section V.6.2.3, pore liquid sampling data can vary in quality due to measurement protocol, sampling methodology, sample preparation, analytical procedures, laboratory quality control, and available documentation.

The vadose zone monitoring system sampling and analysis plan includes activities necessary to provide measurement data at a requisite precision and accuracy (ASTM, 1993, Vol. 11.03, Practice 1357-82). The overall quality assurance objective for measurement data is to ensure that data of known and acceptable quality are provided. In order to meet these objectives, QA/QC objectives are defined for data measurements in support of the vadose zone monitoring data interpretation. These data characteristics include precision, accuracy, representativeness, completeness, and comparability.

The precision of a measurement process is a generic concept related to the closeness of agreement between test results obtained under prescribed like conditions from the measurement process being evaluated. Accuracy is a generic concept of exactness related to the closeness of agreement between the average of one or more test results and an accepted reference value (ASTM, 1993, Vol. 14.02, Practice E 177-86). Overall precision and accuracy targets for chemical constituent measurements can be set at 10 percent allowable deviation with 90 percent confidence limits. General precision and accuracy targets for soil moisture content and neutron probe measurements can be set at 2 percent allowable deviation with 90 percent confidence limits.

Representativeness is a measure of the degree to which analytical results reflect true field conditions. Field contamination of pore liquid samples, field measurement data logging errors, and sampling intensity are two factors affecting representativeness. Completeness refers to the number of samples collected and analyzed compared to the planned number of samples. The comparability of the data collected refers to the ability to interpret the results in light of previous data collection efforts.

In all of these quality assurance activities it should be recognized that factors including geophysical conditions and definition of sampling volume in the vadose zone often have higher variability than analytical equipment calibration procedures. Table V.6-1 provides preliminary quantitative limits for QA/QC objectives.

V.6.2.3 Measurement Procedures

The quality of the data collected from the vadose zone depends on the quality of the measurement procedures and sampling activities. Therefore, field operations will be carefully planned and implemented. Procedures and protocols for monitoring and sampling of the vadose zone beneath the engineered barrier and the waste layer will be in accordance with applicable existing SOPs for vadose zone monitoring and sampling at the RFP (included in Technical Memorandum No. 1 for OU4). As described in Section V.4.2, the conceptual design of the vadose zone monitoring system includes both direct and indirect pore-liquid monitoring techniques using suction lysimeters, neutron probes, time domain reflectometry and frequency

domain capacitance. Specific procedures for installing and monitoring this equipment are listed in existing SOPs as follows:

- Vadose Zone SOP VZ.4, "Procedures for Dielectric Water Content Measurement"
- Vadose Zone SOP VZ.7, "Procedure for Neutron Moisture Logging"
- Vadose Zone SOP VZ.10, "Procedure for Lysimeter Installation and Sampling"

SOP VZ.7 is specifically applicable to neutron moisture logging in vertical neutron probe access tubes. The conceptual design of the vadose zone monitoring system includes horizontal access tubes. As required, SOP VZ.7 will be modified to include procedures specific to neutron moisture logging from horizontal access tubes.

V.6.2.4 Frequency of Measurement

General comments that relate to the development of the monitoring schedule are similar to those presented in Section V.6.1.4 and summarized in Table V.6-2. The sampling and analysis plan is designed such that the intervals between measurement and sampling events are shortest at the beginning of the remedial action and become greater after a period of time within which the performance of the remedial design is assessed and verified.

The proposed long-term plan for the frequency of measurement and sampling depends, in part, on the effectiveness of the remedial action as determined through the ongoing monitoring program. If the monitoring data demonstrate that a steady, predictable stabilization of the pore liquids is maintained in the waste pile, then reducing the sampling frequency will be a reasonable course of action. Frequency of monitoring is also dependent upon the labor intensity of the measurement process as it affects the cost of acquiring data. Scheduling and costing of the NPAT monitoring data acquisition is based on the assumption that substantial field labor will be required to acquire the data. An evaluation of the cost/benefit of designing and constructing an automatic data acquisition system for collecting and analyzing NPAT data will be conducted before the monitoring system design is finalized. Results of that evaluation will be presented with the final monitoring system design.

Monitoring of the vadose zone with the NPAT will be conducted on a monthly schedule for the initial 3 years after installation of the facility. Data collected during the initial 3-year period will be used to develop an understanding of the effect of seasonal weather changes on the monitoring data, assess gaps in the data, further characterize the completed remedial design, identify any additionally required monitoring locations, and evaluate sources of uncertainty such as sampling, analysis, and site conditions.

In the second phase of monitoring the remedial facility, NPAT data will be collected quarterly. If a significant rise in neutron counts is detected at any measuring event, the measurement will be immediately repeated to verify the data. Once the count rise is verified, NPAT data collection frequency will be increased to monthly until an appropriate response is

initiated or until, in the judgement of the interpreting hydrologist, the event has stabilized and is shown to not represent migrating COC's. NPAT monitoring will also be conducted at monthly intervals whenever a significant rise is detected in the FDC probes of the engineered barrier/cover monitoring system. The same criteria as above will apply in determining when and if a return to quarterly monitoring intervals is appropriate.

Ten years after installation of the facility, the NPAT monitoring interval will be reduced to semiannual. Unscheduled monitoring during this interval would be triggered by a rising water table that is anticipated to intersect the subsurface drain or by a significant increase in normally scheduled NPAT or FDC measurements. NPAT data collection frequency will be increased to monthly until an appropriate response is initiated or until, in the judgement of the interpreting hydrologist, the event has stabilized and is shown to not represent migrating COC's.

Assuming the remedial design performs as intended, no monitoring of the NPAT is anticipated beyond 30 years unless triggered by data that would indicate a rise in the water table into the subsurface drain, or sequential detections by the MET/TDR, FDC, and NPAT that would indicate an increase in soil water content.

V.6.2.5 Pore Liquid Sampling Procedures

Field operations will be carefully planned and implemented to ensure high quality of the sampling data collected. Procedures and protocols for pore liquid sampling will be in accordance with applicable existing SOPs for pore liquid sampling at the RFP. Specifically, SOP VZ.10, "Procedure for Lysimeter Installation and Sampling" (in Technical Memorandum No. 1 for OU4), will be closely adhered to when sampling pore liquids.

Initially, pore liquid samples will be collected from the pressure/vacuum lysimeters on pre-determined quarterly intervals based on conformance to the protocols for groundwater sampling. After the initial 3-year period, PLS data will be collected four times a year. However, the exact times of the year will be determined by examining the previous 3 years of MET, TDR, NPAT, and groundwater monitoring well elevation data. Based on groundwater hydrographs, soil water hydrographs, and their correlation with cyclic weather patterns, sampling dates will be selected that will optimize characterization of pore liquids with respect to seasonal cycling of hydrologic parameters.

No pore liquid sampling is planned after 10 years of monitoring unless data from the NPAT, TDR, FDC or groundwater elevations indicate the presence of a downward propagating wetting front or a rising water table.

It should be noted that it is likely that the lysimeters will not be capable of collecting samples when the design of the remedial action is performing as intended. This is because the range of negative pore pressures within which lysimeters are capable of collecting samples is approximately 0 to 60 centibars. Preliminary data interpreted from Part II of the IM/IRA indicate that these sampling pressures have only been observed in the capillary fringe above a rising water table. The design of the remedial action is intended to block movement of soil water into the waste pile vadose zone and into the underlying native vadose zone. By design, it

is intended that the soil water content will be maintained at low levels which would relate to negative pore pressures well above 60 centibars. If the initial 3 years of attempting to collect pore liquid samples indicate that the pore pressures are not sufficient to allow collection of pore liquid samples, all attempts at pore liquid sampling will be discontinued until data from the NPAT or FDC indicate the presence of a wetting front or of a rising water table.

V.6.2.6 Sample Preservation and Shipment

Procedures and protocols for sample preservation and shipment of pore liquid samples will be in accordance with applicable existing SOPs for groundwater sample preservation and shipment at the RFP as per Procedure No. GW.06, "Groundwater Sampling," and FO.13, "Containerization, Preserving, Handling, and Shipping of Soil and Water Samples."

V.6.2.7 Analytic Parameters and Procedures for Lysimeter Pore Liquids

The SEP are currently undergoing groundwater monitoring as specified in 6 CCR 1007-3 Section 265.93 (d) (40 CFR 265.93(d)), because it has been determined that groundwater quality has been affected by the ponds, which are regulated as interim-status units. Once interim-status is terminated and final administrative disposition of the post-closure permit is made, monitoring will be pursuant to 40 CFR Part 264. In accordance with the IAG, analytical parameters for post-closure monitoring will consist of the RCRA Appendix IX Groundwater Monitoring List (40 CFR Part 264, Appendix IX) and any contaminants of concern identified for the OU4 IM/IRA. Only four IM/IRA contaminants of concern are not listed in Appendix IX; these are Americium 241, Plutonium 239/240, Uranium 235, and Tritium.

The complete list of analytical parameters for post-closure groundwater monitoring at the SEP is provided in Table V.6-2. The same analyses that have been specific for groundwater monitoring will make up the analyze list for pore liquid sampling. Also listed in Table V.6-2 are suggested analytical methods and practical quantitation limits (PQLs) for Appendix IX analyses. Analytical methods and PQLs for Americium 241, Plutonium 239/240, Uranium 235, and Tritium are consistent with established analytical SOPs for the RFP. In some cases, individual Appendix IX compounds are listed with more than one suggested analytical method and corresponding PQL. In these cases, the analytical method and PQL that are consistent with current RFP SOPs will be selected. Efforts will be made to reduce the number of analytical methods by selecting those methods that encompass the greatest number of individual analyses. Field parameters will include pH, specific conductance, and groundwater temperature.

V.6.2.8 Chain-of-Custody Control

Sample custody is widely recognized as vitally important in achieving the goals of quality data collection and reporting. Samples must be traceable from the time of sample collection until the analyses are performed and reported. Procedures and protocols for chain-of-custody control of pore liquid samples will be in accordance with applicable existing SOPs for groundwater sampling at the RFP. Specific SOPs that will be implemented as a part the pore

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Acenaphthene		X	8100 8270	200 10
Acenaphthylene		X	8100 8270	200 10
Acetone		X	8240	100
Acetophenone		X	8270	10
Acetonitrile; Methyl cyanide		X	8015	100
2-Acetylaminofluorene; 2-AAF		X	8270	10
Acrolein		X	8030 8240	5 5
Acrylonitrile		X	8030 8240	5 5
Aldrin		X	8080 8270	0.05 10
Allyl chloride		X	8010 8240	5 100
4-Aminobiphenyl		X	8270	10
Aniline		X	8270	10
Anthracene		X	8100 8270	200 10
Antimony		X	6010 7040 7041	300 2,000 30
Aramite		X	8270	10
Arsenic		X	6010 7060 7061	500 10 20
Barium	X	X	7080 6010	1,000 20
Benzene		X	8020 8240	2 5
Benzo[a]anthracene; Benzanthracene	X	X	8100 8270	200 10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Benzo[b]fluoranthene	X	X	8100 8270	200 10
Benzo[k]fluoranthene	X	X	8100 8270	200 10
Benzo[ghi]perylene		X	8100 8270	200 10
Benzo[a]pyrene	X	X	8100 8270	200 10
Benzyl alcohol		X	8270	20
Beryllium	X	X	6010 7090 7091	3 50 2
alpha-BHC		X	8080 8250	0.05 10
beta-BHC		X	8080 8250	0.05 40
delta-BHC		X	8080 8250	0.1 30
gamma-BHC; Lindane		X	8080 8250	0.05 10
Bis(2-chloroethoxy)methane		X	8270	10
Bis(2-chloroethyl)ether		X	8270	10
Bis(2-chloro-1-methylethyl) ether; 2,2-Dichlorodiisopropyl ether		X	8010 8270	100 10
Bis(2-ethylhexyl) phthalate	X	X	8060 8270	20 10
Bromodichloromethane		X	8010 8240	1 5
Bromoform; Tribromomethane		X	8010 8240	2 5
4-Bromophenyl phenyl ether		X	8270	10
Butyl benzyl phthalate; Benzyl butyl phthalate		X	8060 8270	5 10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Cadmium	X	X	6010	40
			7130	50
			7131	1
Carbon disulfide		X	8240	5
Carbon tetrachloride		X	8010	1
			8240	5
Chlordane		X	8080	0.1
			8250	10
p-Chloroaniline		X	8270	20
Chlorobenzene		X	8010	2
			8020	2
			8240	5
Chlorobenzilate		X	8270	10
p-Chloro-m-cresol		X	8040	5
			8270	20
Chloroethane; Ethyl chloride	X	X	8010	5
			8240	10
Chloroform		X	8010	0.5
			8240	5
2-Chloronaphthalene		X	8120	10
			8270	10
2-Chlorophenol		X	8040	5
			8270	10
4-Chlorophenyl phenyl ether		X	8270	10
Chloroprene		X	8010	50
			8240	5
Chromium	X	X	6010	70
			7190	500
			7191	10
Chrysene	X	X	8100	200
			8270	10
Cobalt		X	6010	70
			7200	500
			7201	10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Copper		X	6010	60
			7210	200
m-Cresol		X	8270	10
o-Cresol		X	8270	10
p-Cresol		X	8270	10
Cyanide		X	9010	40
2,4-D; 2,4-Dichlorophenoxyacetic acid		X	8150	10
4,4'DDD		X	8080	0.1
			8270	10
4,4' DDE		X	8080	0.05
			8270	10
4,4' DDT		X	8080	0.1
			8270	10
Diallate		X	8270	10
Dibenz[a,h]anthracene		X	8100	200
			8270	10
Dibenzofuran		X	8270	10
Dibromochloromethane; Chlorodibromomethane		X	8010	1
			8240	5
1,2-Dibromo-3-chloropropane; DBCP		X	8010	100
			8240	5
			8270	10
1,2-Dibromoethane; Ethylene dibromide		X	8010	10
			8240	5
Di-n-butyl phthalate		X	8060	5
			8270	10
o-Dichlorobenzene		X	8010	2
			8020	5
			8120	10
			8270	10
m-Dichlorobenzene		X	8010	5
			8020	5
			8120	10
			8270	10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
p-Dichlorobenzene; 1,4-Dichlorobenzene	X	X	8010	2
			8020	5
			8120	15
			8270	10
3,3'-Dichlorobenzidine		X	8270	20
trans-1,4-Dichloro-2-butene		X	8240	5
Dichlorodifluoromethane		X	8010	10
			8240	5
1,1-Dichloroethane		X	8010	1
			8240	5
1,2-Dichloroethane; Ethylene dichloride		X	8010	0.5
			8240	5
1,1-Dichloroethylene; Vinylidene chloride		X	8010	1
			8240	5
trans-1,2-Dichloroethylene		X	8010	1
			8240	5
2,4-Dichlorophenol		X	8040	5
			8270	10
2,6-Dichlorophenol		X	8270	10
1,2-Dichloropropane	X	X	8010	0.5
			8240	5
cis-1,3-Dichloropropene		X	8010	20
			8240	5
trans-1,3-Dichloropropene		X	8010	5
			8240	5
Dieldrin		X	8080	0.05
			8270	10
Diethyl phthalate		X	8060	5
			8270	10
O,O-Diethyl O-2-pyrazinyl phosphorothioate; Thionazin		X	8270	10
Dimethoate		X	8270	10
p-(Dimethylamino)azobenzene		X	8270	10
7,12-Dimethylbenz[a]anthracene		X	8270	10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
3,3'-Dimethylbenzidine		X	8270	10
alpha, alpha-Dimethylphenethylamine		X	8270	10
2,4-Dimethylphenol		X	8040 8270	5 10
Dimethyl phthalate		X	8060 8270	5 10
m-Dinitrobenzene		X	8270	10
4,6-Dinitro-o-cresol		X	8040 8270	150 50
2,4-Dinitrophenol		X	8040 8270	150 50
2,4-Dinitrotoluene		X	8090 8270	0.2 10
2,6-Dinitrotoluene	X	X	8090 8270	0.1 10
Dinoseb; DNBP; 2-sec-Butyl-4,6-dinitrophenol		X	8150 8270	1 10
Di-n-octyl phthalate		X	8060 8270	30 10
1,4-Dioxane		X	8015	150
Diphenylamine		X	8270	10
Disulfoton		X	8140 8270	2 10
Endosulfan I		X	8080 8250	0.1 10
Endosulfan II		X	8080	0.05
Endosulfan sulfate		X	8080 8270	0.5 10
Endrin		X	8080 8250	0.1 10
Endrin aldehyde		X	8080 8270	0.2 10
Ethylbenzene		X	8020 8240	2 5

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Ethyl methacrylate		X	8015 8240 8270	10 5 10
Ethyl methanesulfonate		X	8270	10
Famphur		X	8270	10
Fluoranthene		X	8100 8270	200 10
Fluorene		X	8100 8270	200 10
Heptachlor		X	8080 8270	0.05 10
Heptachlor epoxide		X	8080 8270	1 10
Hexachlorobenzene	X	X	8120 8270	0.5 10
Hexachlorobutadiene		X	8120 8270	5 10
Hexachlorocyclopentadiene		X	8120 8270	5 10
Hexachloroethane		X	8120 8270	0.5 10
Hexachlorophene		X	8270	10
Hexachloropropene		X	8270	10
2-Hexanone	X	X	8240	50
Indeno(1,2,3-cd)pyrene	X	X	8100 8270	200 10
Isobutyl alcohol		X	8015	50
Isodrin		X	8270	10
Isophorone		X	8090 8270	60 10
Isosafrole		X	8270	10
Kepone		X	8270	10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Lead		X	6010	40
			7420	1,000
			7421	10
Mercury	X	X	7470	2
Methacrylonitrile		X	8015	5
			8240	5
Methapyrilene		X	8270	10
Methoxychlor		X	8080	2
			8270	10
Methyl bromide; Bromomethane		X	8010	20
			8240	10
Methyl chloride; Chloromethane		X	8010	1
			8240	10
3-Methylcholanthrene		X	8270	10
Methylene bromide; Dibromomethane		X	8010	15
			8240	5
Methylene chloride; Dichloromethane		X	8010	5
			8240	5
Methyl ethyl ketone; MEK		X	8015	10
			8240	100
Methyl iodide; Iodomethane		X	8010	40
			8240	5
Methyl methacrylate		X	8015	2
			8240	5
Methyl methanesulfonate		X	8270	10
2-Methylnaphthalene		X	8270	10
Methyl parathion; Parathion methyl		X	8140	0.5
			8270	10
4-Methyl-2-pentanone; Methyl isobutyl ketone		X	8015	5
			8240	50
Naphthalene		X	8100	200
			8270	10
1,4-Naphthoquinone		X	8270	10
1-Naphthylamine		X	8270	10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
2-Naphthylamine		X	8270	10
Nickel	X	X	6010 7520	50 400
o-Nitroaniline		X	8270	50
m-Nitroaniline		X	8270	50
p-Nitroaniline		X	8270	50
Nitrobenzene		X	8090 8270	40 10
o-Nitrophenol		X	8040 8270	5 10
p-Nitrophenol		X	8040 8270	10 50
4-Nitroquinoline 1-oxide		X	8270	10
N-Nitrosodi-n-butylamine		X	8270	10
N-Nitrosodiethylamine		X	8270	10
N-Nitrosodimethylamine		X	8270	10
N-Nitrosodiphenylamine		X	8270	10
N-Nitrosodipropylamine; Di-n-propylnitrosamine	X	X	8270	10
N-Nitrosomethylethylamine		X	8270	10
N-Nitrosomorpholine		X	8270	10
N-Nitrosopiperidine		X	8270	10
N-Nitrosopyrrolidine		X	8270	10
5-Nitro-o-toluidine		X	8270	10
Parathion		X	8270	10
Polychlorinated biphenyls; PCBs	X[4]	X	8080 8250	50 100
Polychlorinated dibenzo-p-dioxins; PCDDs		X	8280	0.01
Polychlorinated dibenzofurans; PCDFs		X	8280	0.01
Pentachlorobenzene		X	8270	10
Pentachloroethane		X	8240 8270	5 10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Pentachloronitrobenzene		X	8270	10
Pentachlorophenol	X	X	8040 8270	5 50
Phenacetin		X	8270	10
Phenanthrene	X	X	8100 8270	200 10
Phenol		X	8040 8270	1 10
p-Phenylenediamine		X	8270	10
Phorate		X	8140 8270	2 10
2-Picoline		X	8240 8270	5 10
Pronamide		X	8270	10
Propionitrile; Ethyl cyanide		X	8015 8240	60 5
Pyrene		X	8100 8270	200 10
Pyridine		X	8240 8270	5 10
Safrole		X	8270	10
Selenium		X	6010 7740 7741	750 20 20
Silver		X	6010 7760	70 100
Silvex; 2,4,5-TP		X	8150	2
Styrene		X	8020 8240	1 5
Sulfide		X	9030	10,000
2,4,5-T; 2,4,5-Trichlorophenoxyacetic acid		X	8150	2
2,3,7,8-TCDD; 2,3,7,8-Tetrachlorodibenzo-p-dioxin		X	8280	0.005

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
1,2,4,5-Tetrachlorobenzene		X	8270	10
1,1,1,2-Tetrachloroethane		X	8010 8240	5 5
1,1,2,2-Tetrachloroethane		X	8010 8240	0.5 5
Tetrachloroethylene; Perchloroethylene; Tetrachloroethene		X	8010 8240	0.5 5
2,3,4,6-Tetrachlorophenol		X	8270	10
Tetraethyl dithiopyrophosphate; Sulfotepp		X	8270	10
Thallium		X	6010 7840 7841	400 1,000 10
Tin		X	7870	8,000
Toluene		X	8020 8240	2 5
o-Toluidine		X	8270	10
Toxaphene		X	8080 8250	2 10
1,2,4-Trichlorobenzene		X	8270	10
1,1,1-Trichloroethane; Methylchloroform	X	X	8240	5
1,1,2-Trichloroethane		X	8010 8240	0.2 5
Trichloroethylene; Trichloroethene		X	8010 8240	1 5
Trichlorofluoromethane		X	8010 8240	10 5
2,4,5-Trichlorophenol		X	8270	10
2,4,6-Trichlorophenol		X	8040 8270	5 10
1,2,3-Trichloropropane		X	8010 8240	10 5
O,O,O-Triethyl phosphorothioate		X	8270	10
sym-Trinitrobenzene		X	8270	10

Table V.6-3 Analytical Parameters for Post-Closure Groundwater Monitoring and Pore Liquid Monitoring, OU4 Solar Evaporation Ponds, Rocky Flats Plan, Golden, Colorado.

Compound	Contaminants of[1] Concern	Part 264[2] App. IX	Suggested Analytical Methods	PQL[3] (ug/L)
Vanadium		X	6010	80
			7910	2,000
			7911	40
Vinyl acetate		X	8240	5
Vinyl chloride		X	8010	2
			8240	10
Xylene (total)		X	8020	5
			8240	5
Zinc		X	6010	20
			7950	50
Americium-241	X			
Plutonium-239/240	X			
Tritium	X			
Uranium-235	X			

1. Contaminant of concern for OU4 soils. Data collected July 1987 to May 1993.
2. Groundwater monitoring list, Appendix IX, RCRA Part 264.
3. Practical quantitation limits for groundwater samples in micrograms per liter.
4. Arochlor-1254 is the only PCB compound listed as a contaminant of concern.

liquid sample chain-of-custody control are FO.13, "Containerization, Preserving, Handling, and Shipping of Soil and Water Samples," and FO.14, "Field Data Management."

V.6.3 Groundwater Monitoring System

This groundwater monitoring system sampling and analysis plan description presents the data quality and quality assurance/quality control objectives for the groundwater monitoring program at the Solar Evaporation Ponds, and for the field and laboratory procedures that will be followed to ensure that these objectives are met. In most cases, detailed descriptions of field and laboratory procedures are not included here. Instead, the reader is referred to established SOPs for the RFP. In accordance with 40 CFR 265.92 Subpart F, a detailed groundwater sampling analysis plan will be developed and maintained at the facility for post-closure monitoring.

V.6.3.1 Data Quality Objectives

The overall data quality objective (DQO) for the groundwater monitoring program at the Solar Evaporation Ponds is to ensure that data of known and acceptable quality are produced. Specifically, data produced through the post-closure groundwater monitoring program must be suitable for appropriate statistical evaluations designed to facilitate comparison of upgradient and downgradient groundwater quality conditions, and to identify trends at individual monitoring locations. In addition, data must be of sufficient quantity to support statistical evaluations. The comparison of upgradient and downgradient groundwater quality must take into consideration sources of contamination located upgradient from the ponds. Proper execution of each sampling and analysis task will yield consistent results that are representative of actual groundwater quality conditions, and are useful for meeting the intended project objectives. Data will be reported in units consistent with those of other agencies and organizations to allow comparability of databases.

In addition, analytical results must support an evaluation of potential threats to human health and the environment for those compounds that are being monitored. That is, groundwater contaminants must be detectable at concentrations that are at or below applicable or relevant and appropriate requirements (ARARs) for the OU4. ARARs may include, but may not be limited to, federal and/or state drinking water standards, Colorado groundwater standards, and published and unpublished risk-based standards. For the conceptual design, it is assumed that currently published practical quantitation limits (PQLs) (40 CFR Part 264, Appendix IX) will satisfy the DQOs. If it is determined through the RI/RFI process at OU4 that PQLs will not support the detection of groundwater contaminants at concentrations at or below ARARs, analytical methodologies will be reevaluated prior to the development of a detailed groundwater sampling and analysis plan. PQLs for non-Appendix IX contaminants of concern (americium 241, plutonium 239/240, uranium 235, and tritium) will be consistent with established SOPs for the RFP.

V.6.3.1.1 Background Groundwater Quality

Groundwater flowing towards the Solar Evaporation Ponds originates primarily in the plant area, southwest of the ponds. Several potential groundwater contaminant sources are present in the plant area. The comparison of upgradient and downgradient groundwater quality must take into consideration sources of contamination located upgradient from the ponds. Four existing alluvial/colluvial wells and four existing weathered bedrock wells located south and west (upgradient) of the Solar Evaporation Ponds will be included in the post-closure groundwater monitoring system to help achieve this DQO.

V.6.3.2 Quality Assurance/Quality Control Objectives

QA/QC objectives are established to ensure that all data collected during post-closure monitoring are of acceptable quality to support response action decisions and the DQOs. The implementation of appropriate QA/QC procedures allows development of meaningful technical conclusions. Components of the QA/QC program include evaluations of the following characteristics of measured data:

- Precision
- Accuracy
- Representativeness
- Completeness
- Comparability

V.6.3.2.1 Precision

Precision is a measure of the reproducibility of measurements under a given set of conditions. Precision is assessed through a comparison of duplicate measurements, and is usually quantified in terms of a relative percent difference between primary and replicate samples. In the analysis of groundwater, duplicate analyses are performed on replicates of the primary sample. Replicates prepared in the field are submitted blind to the laboratory. The relative percent difference (RPD) test will be used to assess the laboratory's ability to reproduce test results from replicate or split samples. The RPD is defined as:

$$(X-Y)/[(X+Y)/2)] \; x \; 100$$

where

X = primary sample concentration

Y = replicate/split/laboratory duplicate sample concentration

V.6.3.2.2 Accuracy

Accuracy is a measure of the bias that exists in a measurement system. That is, it is a measure of the trueness of a particular measurement, where the actual measurement is compared to the known value of a true standard. Sources of bias in the sampling and analysis of groundwater include field contamination and improper sampling, preservation techniques, sample handling, and/or analytical procedures.

The accuracy of analytical procedures is assessed by analyzing known standards, or spiking an unknown sample with a known quantity of standard, and analyzing the resultant mixture. The first approach quantifies measured values as a percentage of true values. The latter technique quantifies accuracy in terms of percent recoveries of the added spike, and takes into account matrix effects specific to a particular sample. USEPA Contract Laboratory Program Statement of Work (SOW) (USEPA, 1990) stipulates those constituents appropriate for spiking and subsequent measurement, and defines the percent recovery required for proper QA/QC. The acceptable percent recoveries vary from constituent to constituent. Laboratories performing analyses as part of the Solar Evaporation Pond post-closure sampling effort will employ one or both of these methods as part of their project-specific QA/QC measures. Evaluation of the significance of laboratory percent recovery data, with respect to accuracy, will be performed as part of the data validation process. Percent recovery measurements must fall within the ranges defined by the SOW (USEPA, 1990) for each particular constituent. Acceptable percent recoveries will be taken as evidence of accuracy in laboratory data measurement.

V.6.3.2.3 Representativeness

Representativeness is the extent to which sample data accurately and precisely represent selected characteristics of the sampled population. The assessment of representativeness is qualitative and addresses the overall design of a sampling program. Considerations in evaluating the representativeness of the data include, but are not necessarily limited to, the proper selection of sample locations, the methods used to obtain environmental samples at the site, and the appropriateness of the analytical method for the type of sample obtained. The following factors will be considered as part of the implementation and subsequent evaluation of sampling and analysis programs to ensure that representative data are obtained during the performance of this program.

Sample locations will be carefully selected to characterize groundwater quality both upgradient an downgradient of the waste material. Efforts will be made to minimize or reduce the effects of environmental conditions on sampling efforts. For example, field instrumentation will be isolated from field conditions so that data accurately reflect site conditions. The parameters selected for analysis will be based on the analytical requirements as specified in 40 CFR part 265 and will include the list of contaminants of concern for the OU4.

V.6.3.2.4 Completeness

Completeness is a measure of the amount of valid data obtained from a measurement system or program compared to the amount that was expected to be obtained under ideal conditions. It can be expressed as a percentage, as follows:

$$\frac{ValidData}{TotalData} X\ 100 = Percent\ Completeness$$

Completeness will be routinely assessed using this equation. Based on information presented by USEPA (1987), and the QA/QC procedures that will be implemented as part of this sampling and analysis plan, completeness ratings of 80 to 85 percent should be expected. The completeness data quality objective for this project is 85 percent. Data that do not meet the completeness data quality objective will be cause for re-sampling of the analytes determined to be deficient.

V.6.3.2.5 Comparability

Comparability expresses the confidence with which one data set can be compared to another. Data comparability is assessed in a qualitative manner, and only after accuracy and precision of each data set are known. The comparability of data sets is determined by identifying the difference, if any, between data sets in terms of sampling methods, handling, preservation, holding times, location, analytical methods, and quantifiable accuracy and precision.

Given that post-closure monitoring can extend over a considerable time period, and can involve different contractors, subcontractors, personnel, and laboratories, and often include new and currently evolving analytical techniques, the QA/QC standards necessary to ensure data comparability are a critical element. For data collected in the field during this investigation, sample collection and handling procedures are specified in the sampling and analysis plan. The consistent use of these procedures throughout the remedial actions will ensure that data sets are comparable on the basis of these field variables.

Laboratory QA/QC techniques for the analysis of environmental samples have become standardized, and many of the currently accepted techniques are outlined in the USEPA SOW (1990). For non-USEPA methodologies, ASTM methods (or their equivalents) provide standardization. These methods, together with the specific QA plans and data validation procedures for sample analysis, will help ensure that laboratory procedures are comparable between data sets obtained by parties to the remedial action.

V.6.3.2.6 Field Quality Assurance and Quality Control Samples

During implementation of the field sampling program described in the SAP, field QA/QC samples will be collected to assess the reproducibility of the field collection techniques,

the quality of preservation reagents and sample bottles, and the effectiveness of field decontamination procedures.

QA/QC samples will be collected and shipped to the Contract Laboratory for analysis. These samples, which are described below, consist of trip blanks, field replicates, and equipment blanks.

- Trip Blanks (volatile organic compounds (VOCs) only): A trip (travel) blank is a sample container filled with organic-free water in the laboratory that travels unopened with the sample bottles. It is returned to the laboratory with the field samples, opened in the laboratory and analyzed along with the field samples for VOCs.

- Field Replicate: A field replicate is a sample prepared at the sampling location from equal portions of all sample aliquots combined to make the field sample. Both the field replicate and the field sample are collected at the same time, in the same container type, preserved in the same way, and analyzed by the same laboratory as a measure of sampling and analytical precision.

- Equipment Blank: An equipment blank (also called an equipment rinsate blank) is made by pouring organic-free water into or through the field sampling equipment (bailer, pump tubing, soil sampling equipment) that conceivably could be a source of contamination. The water is then collected and sealed in the same type of sample container as the other field samples, preserved in the same manner (using the same preservative) transported to the laboratory with the field samples, and analyzed for the same parameters as the associated soil or water samples. Equipment blanks will be collected before the associated field sample is collected.

Field replicate and equipment blank samples will be collected at the site at a minimum frequency of one per 20 samples per matrix. Trip blank samples will be supplied by the laboratory and one set of trip blanks will be returned to the laboratory in each cooler containing samples for VOCs analysis. These samples will be collected, preserved, and handled in the same manner as the field samples. Each field QA/QC sample will be packed and shipped along with the field samples to the laboratory for analysis of the same constituents using the same analytical procedures as the field samples.

V.6.3.3 Sampling Procedures

The quality of the data collected in an environmental study depends on the quality of the sampling activities. Therefore, field operations will be carefully planned and implemented. Procedures and protocols for groundwater sampling will be in accordance with applicable existing SOPs for groundwater sampling at the RFP. Specific groundwater sampling activities are as follows.

- GW.01 Water Level Measurements in Wells and Piezometers

- GW.02 Well Development
- GW.05 Field Measurement of Groundwater Field Parameters
- GW.06 Groundwater Sampling
- FO.03 General Equipment Decontamination
- FO.13 Containerization, Preserving, Handling, and Shipping of Soil and Water Samples

V.6.3.4 Sample Preservation and Shipment

Procedures and protocols for sample preservation and shipment will be in accordance with applicable existing SOPs for groundwater sampling at the RFP (SOP FO.13).

V.6.3.5 Analytical Parameters and Procedures

The Solar Evaporation Ponds are currently undergoing groundwater monitoring as specified in 6 CCR 1007-3 Section 265.93 (d) (40 CFR 265.93 (d)), because it has been determined that groundwater quality has been affected by the ponds, which are regulated as interim-status units. Once interim-status is terminated and final administrative disposition of the post-closure permit is made, monitoring will be pursuant to 40 CFR Part 264. In accordance with the IAG, analytical parameters for post-closure monitoring will consist of the RCRA Appendix IX Groundwater Monitoring List (40 CFR Part 264, Appendix IX) and any contaminants of concern identified for the OU4 IM/IRA. Only four IM/IRA contaminants of concern are not listed in Appendix IX; these are americium 241, plutonium 239/240, uranium 235, and tritium.

The complete list of analytical parameters for post-closure groundwater monitoring at the Solar Evaporation Ponds is provided in Table V.6-3. Also listed in Table V.6-3 are suggested analytical methods and practical quantitation limits (PQLs) for Appendix IX analytes. Analytical methods and PQLs for americium 241, plutonium 239/240, uranium 235, and tritium are consistent with established analytical SOPs for the RFP. In some cases, individual Appendix IX compounds are listed with more than one suggested analytical method and corresponding PQL. In these cases, the analytical methods and PQLs that are consistent with current RFP SOPs will be selected. Efforts will be made to reduce the number of analytical methods by selecting those methods that encompass the greatest number of individual analytes. Field parameters will include Ph, specific conductance, and groundwater temperature.

V.6.3.5.1 Sampling Frequency

Groundwater sampling will be conducted quarterly. Samples will be collected annually for analyses encompassing the contaminants of concern and Appendix IX analytes. Sample parameters for the remaining three quarters will consist of the contaminants of concern. Field parameters will be measured during each sampling event. Water levels will be measured

at the beginning of each quarterly sampling event, and groundwater elevation/flow maps will be generated.

V.6.3.6 Chain-of-Custody Control

Sample custody is a vital aspect of collecting quantifiable and legally-defensible analytical data. The samples must be traceable from the time of sample collection until the analyses are performed. Procedures and protocols for chain-of-custody control will be in accordance with applicable existing SOPs for groundwater sampling at the RFP. Specific elements of chain-of-custody control SOPs that will be implemented are FO.13, "Containerization, Preserving, Handling, and Shipping of Soil and Water Samples," and FO.14, "Field Data Management."

V.7
MONITORING SYSTEM ASSESSMENT PROGRAM

V.7.1 Engineered Barrier/Cover Monitoring System Assessment

The purpose of the engineered barrier/cover monitoring system is to detect moisture entering the waste material via vertical infiltration through the engineered barrier/cover. Instruments will be placed at various locations within the engineered barrier/cover to detect changes in moisture content which may be indicative of the potential for water movement. The following sections specify the approach to be used in evaluating the data collected from the engineering barrier/cover monitoring system (statistical evaluation), determining what results constitute grounds for further action (threshold values), and the steps to be taken when action is warranted (response actions).

V.7.1.1 Statistical Evaluation

Statistical tests will be performed on data from the engineering barrier/cover monitoring systems to satisfy general performance standards for statistical analysis of data from RCRA facilities according to EPA guidance. Initial testing will be performed on a baseline suite of data collected in a short time period immediately after the instrumentation becomes operational to determine if an assumption of normally distributed data is appropriate for the instrumentation installed at the site. This will also permit the definition of precision for each type of monitoring data at each monitoring point. It is anticipated that normal theory tests will be appropriate for the treatment of TDR and FDC data. Meteorological instruments will be tested and calibrated according to manufacturer specifications and a precision for field-installed instruments will be measured if possible.

A time series data analysis is required to detect trends from measurements of interrelated processes. Control charts of selected parameters will be maintained using a Shewhart-Cusum control chart methodology (Starks, 1991). Calculated evapotranspiration will be plotted alongside soil water contents, runoff, and soil temperature at all monitored points. The number of consecutive measurements used for each measurement type in the Cusum running average will be evaluated after one year of data acquisition.

For detection of moisture increases, an out-of-control level will be set to signal significant changes in data. Initially, the Type I error level of 0.01 (approximately three standard deviations) above or below the mean determined from the initial baseline data at each position will be set as the out-of-control level. If the standard deviation of the original baseline data is too small to measure, a measured volumetric moisture content change of 2 percent will be considered significant. After one year of data acquisition this will be reevaluated and reset, if appropriate (e.g. if it is deemed likely that construction-water redistribution has elevated the background moisture at any positions).

V.7.1.2 Threshold Values

Threshold values for soil moisture content measurements will be set for each type of material monitored; the natural materials at the ground surface/engineered barrier interface, the upper soil of the engineered barrier/cover and the compacted waste. Threshold values will be selected based on laboratory characterization of the natural soils, the cover soil and the compacted waste material. The unsaturated hydraulic conductivity as a function of water content for each material will be measured directly or calculated from soil moisture characteristics using the van Genuchten or other well-accepted technique (van Genuchten, 1980, 1991). For each material type, the moisture content at which flow is considered significant will be selected as a threshold. The threshold value for the sand layer beneath the angular riprap layer will be set at the statistically determined out-of-control level, regardless of the hydraulic conductivity implications of the increase. This is done as an early warning measure to trigger evaluation of the adequacy of the overlying soil layer and possible appropriate response as early as possible.

V.7.1.3 Response Actions

An exceedance event occurs if threshold values at any monitored point are exceeded. The initial response action to an exceedance event will be to intensify monitoring efforts by immediately (within days) re-sampling or remeasuring the point of the exceedance event and adjacent points in the monitoring network. If the threshold is not exceeded again, hydrological events prior to the initial exceedance event will be examined to determine the likelihood that a slug of water moved rapidly through the system, and monitoring schedules may be adjusted to capture subsequent similar events. If the threshold is exceeded again a variety of response actions are triggered. All monitoring systems involved will be checked and tested to identify any malfunctions that could cause false-positives. If any are identified, they will be corrected. Re-sampling must be performed and all measurements must be below threshold values to return to standard monitoring schedules. Otherwise, the monitoring schedule will be intensified at the discretion of the project manager in order to characterize the hydrologic event under observation. Visual inspection of the engineered barrier/cover system, guided by monitoring data and all monitoring systems, will be performed. An evaluation of an exceedance event will be made in writing with recommendations for alteration of the engineered barrier/cover design, repairs, and/or increase of threshold values at any monitoring points as necessary.

V.7.2 Vadose Zone Monitoring System Assessment

The purpose of the vadose zone monitoring system is to detect moisture either entering the waste material via upward movement (i.e., capillary action or rising water table) through the vadose zone. Instruments will be placed at various locations within the vadose zone to detect changes in moisture content which may be indicative of the potential for water movement. The following sections specify the approach to be used in evaluating the data collected from the vadose zone monitoring system (statistical evaluation), determining what results constitute grounds for further action (threshold values), and the steps to be taken when action is warranted (response actions).

V.7.2.1 Statistical Evaluation

Statistical evaluation of FDC data from beneath the subsurface drain layer will be the same as for FDC measurements related to the engineered barrier/cover monitoring system described above.

Neutron probe data from the access tubes beneath the gravel drain will consist of position/count data pairs from either neutron counts taken at set positions or from counts integrated across known distances from digitized continuous logs. A set of baseline logs (subject to budgetary constraints, but ideally greater than 20) will be run to determine the precision at each position using parametric statistical tests. The total error at each position will consist of a relocation error component and an instrumental error component related to the counting statistics of the neutron probe used.

It is useful to separate the two error types when evaluating numerous neutron probe logs. The repositioning error can be estimated by observing the reported location of a known sharp interface where neutron counts increase or decrease sharply. It is appropriate to adjust morphologically similar logs to reduce obvious offsets in data before precision is calculated. The instrumental error can be calculated from the original baseline data set using parametric statistical tests, including the Student T test for samples smaller than 20, or it can be estimated by assuming the standard deviation is equal to the square root of the mean of the counts at any position. For the purposes of this analysis, a significance level of 95 percent will be used to define meaningful increases in neutron counts.

Lysimeter data will consists of chemical concentrations of the COC's present in pore fluids (not necessarily readily mobile depending on the tensions at which they are extracted). Current information on subsurface conditions at RFP indicate that it may frequently be impossible to collect a pore liquid sample. The unknown availability of future samples from all lysimeters at the site make determination of statistical tests inappropriate at this stage of the design effort. Availability of pre-existing lysimeters that could serve as background samplers, and the quantity and chemistry of past and future pore liquid samples taken at the site, will ultimately determine the appropriate method. For example if most values are below detection, a test of proportions is suggested. After a sufficient number of independent samples (minimum 4) has been taken, three approaches will be considered.

- Comparison to background at each time
- Comparison with a constant limit
- Intrasampler comparisons

It is anticipated that after the first 3-year period there will be sufficient data to define a relevant procedure.

In the interim, comparison with chemistry of soil samples taken during installation of the lysimeters, groundwater chemistry and appropriate PRG's will be used to identify upward trends or conditions that would signal leachate releases.

Statistical tests will be reviewed in the event that groundwater rises to flood the pore liquid sampling (PLS) positions. Groundwater is already contaminated and the potential for residual liquids from ground water influencing future detection tests must be evaluated.

V.7.2.2 Threshold Values

Two threshold values for the FDC samplers placed below the gravel sub-drain layer are appropriate. The first will be at a moisture content in equilibrium with 60 cbars of pore water tension as defined by laboratory characterization of soils at the site. This threshold will signal the possibility for collecting a pore liquid sample (at this tension, a small gradient can be generated into the sampler at the elevation of RFP). The second threshold will be at a moisture content that corresponds to the "field capacity" of the site soils. This threshold will indicate mobility of pore liquids is highly probable.

Threshold values for the neutron probe will be established as neutron counts at each position that signal a significant increase in moisture content. A reasonable expectation, based on other sites, is that neutron counts corresponding to a five percent volumetric water content increase can be detected at the 95 percent level.

Threshold values for PLS will initially consist of MCL's or other appropriate constant limits. PLS threshold values are subject to reevaluation after data from the initial 3-year monitoring period is available (assuming no release has occurred).

V.7.2.3 Vadose Zone System Response Actions

An exceedance event occurs if threshold values at any monitored point are exceeded. Exceedance events involving the first (lowest) FDC threshold value at positions with a record of moisture contents below the threshold will trigger PLS sampling and intensified neutron logging. In cases where FDC indicate conditions conducive to sampling are ever-present, PLS sampling will occur on pre-scheduled intervals.

The initial response action to any other exceedance events will be to intensify monitoring efforts by immediately (within days) re-sampling or remeasuring the point of the exceedance event and adjacent points in the monitoring network. If the threshold is not exceeded again, hydrological events prior to the initial exceedance event will be examined to determine the likelihood that a slug of water moved rapidly through the system, and monitoring schedules may be adjusted to capture subsequent similar events. If the threshold is exceeded again a variety of response actions are triggered. All monitoring systems involved will be checked and tested to identify any malfunctions that could cause false-positives. If any are identified they will be corrected. Re-sampling must be performed and all measurements must be below threshold values to return to standard monitoring schedules. Otherwise, the monitoring schedule shall be intensified at the discretion of the project manager in order to characterize the

hydrologic event under observation. Visual inspection of the engineered barrier/cover system, guided by monitoring data and all monitoring systems shall be performed. Evaluation of an exceedance event will be made in writing with recommendations for alteration of the engineered barrier/cover design, repairs, and/or increase of threshold values at any monitoring points.

V.7.3 Groundwater Monitoring System

The purpose of the groundwater monitoring system is to detect releases of hazardous constituents from the closed unit to groundwater. Groundwater monitoring wells will be placed at various locations upgradient and downgradient of the units to detect changes in groundwater quality which may be indicative of a release. The following sections specify the approach to be used in evaluating the data collected from the groundwater monitoring system (statistical evaluation), determining what results constitute grounds for further action (threshold values), and the steps to be taken when action is warranted (response actions).

V.7.3.1 Statistical Evaluation

The purpose of the groundwater monitoring system surrounding the SEP is to detect a release from the SEP to groundwater. A release is defined as an exceedence of applicable groundwater quality standards for one or more constituents which is directly attributable to migration of those constituents from the waste material in the closed unit. Due to the presence of other sources of OU4 constituents of concern upgradient of OU4, as well as existing contamination in groundwater, the identification of a release from the SEP requires careful evaluation of upgradient groundwater quality as it relates to concentrations of constituents detected in downgradient wells. A statistical evaluation will be performed in compliance with the Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities (USEPA, 1992). This guidance document provides guidance on using several different types of statistical tests in comparing upgradient and downgradient groundwater monitoring data and in comparing downgradient groundwater monitoring data against applicable standards to determine if a release has occurred.

The amount and nature of the data collected from the groundwater monitoring system will influence the choice of statistical test employed. There are six types of statistical tests for significance discussed the RCRA guidance for analysis of detection monitoring data:

- Test of Proportions
- Nonparametric One-Way ANOVA
- Parametric One-Way ANOVA
- Tolerance Limits
- Prediction Intervals
- Control Charts

Once an adequate groundwater quality baseline has been established for the OU4 area, other appropriate statistical analysis methods will be considered in lieu of the recommended methods; however, if another method is submitted, it must meet certain requirements regarding statistical accuracy and confidence (Type I and Type II error rates). The general process for selecting a statistical test is documented in the RCRA guidance document. In addition to standard statistical tests for determining significant differences between upgradient and downgradient groundwater quality, Shewhart-Cusum Control Charts will be maintained for each groundwater quality parameter to identify time-varying trends in the data.

During the first several years of operation of the groundwater monitoring system, other factors will likely complicate the analysis of the groundwater monitoring system data, such as active remediation of groundwater or remedial actions taking place upgradient of the OU4 area. These factors will be taken into account in any evaluation of the groundwater monitoring system data. Since the engineering barrier/cover and vadose zone monitoring systems will act as an early warning system, identifying any potential releases prior to their impacting groundwater, it is suggested that the first several years of groundwater monitoring data serve as a baseline for evaluation, particularly while other remedial actions (either groundwater remediation or other upgradient surface remediations) are taking place.

V.7.3.2 Threshold Values

Threshold values for identifying a release to ground water will be established in two parts. This first threshold value is expressed as a statistically significant difference between upgradient and downgradient groundwater quality for one or more of the constituents monitored. This type of threshold indicates that constituents may have migrated from the closed unit, and will be established following the RCRA guidance described in Section V.7.3.1. In addition, a threshold value identifying an exceedence of applicable groundwater quality standards will be established for each constituent regulated under the RCRA program and monitored in the groundwater sampling and analysis program described in Section V.6.3.5. Threshold values will be established using promulgated groundwater quality regulations at the time of submittal of the Post Closure Permit application.

V.7.3.3 Response Actions

In the event a condition is detected in groundwater exceeding applicable threshold values, an immediate re-sampling event will be initiated. The re-sampling will include the well(s) where the exceedence was detected, and may include other wells for the purpose of identifying potential upgradient sources. If the re-sampling event confirms the exceedence of the threshold value(s) with no identifiable upgradient sources, the monitoring schedule will be intensified at the discretion of the project manager to characterize the nature and extent of the release. Visual inspections of the engineered barrier/cover system and evaluation of the current and historical engineered barrier/cover and vadose zone monitoring data will also be initiated. An evaluation of the exceedence event will be submitted in writing with recommendations for any necessary remedial actions such as alteration or repair of the engineered barrier/cover system, and/or increasing the monitoring frequency and network scope to identify any potential impacts to human health or the environment.

V.8
POST-CLOSURE CARE ACTIVITIES

Pursuant to CCR 264.112, the SEP will be subject to post-closure care requirements including unit-specific monitoring, operations, maintenance, inspections, and associated record keeping. These activities will be presented in a Post-Closure Plan. Groundwater and Vadose Zone monitoring objectives and procedures have been developed and are presented in Section V.4 of this document. Upon review and acceptance by the regulatory agencies, this monitoring program will be reiterated in the Post-Closure Plan. The remaining post-closure operating, maintenance, and inspection objectives and procedures are conceptually outlined below, and will be presented in detail in the Post-Closure Plan. Specifically, the proposed post-closure activities include:

- Inspection and monitoring of the cover system and surface-water control system, including mitigation procedures.
- Maintenance of the cover system, including erosion prevention;
- Inspection and maintenance activities associated with security;
- Monitoring for settlement and lateral displacement;
- Inspection and monitoring activities associated with the groundwater and vadose zone monitoring systems;
- Record keeping and reporting.

V.8.1 Cover System Inspection and Monitoring

Throughout the post-closure care period at the SEP, regular inspections of the cover system and associated structures will occur. The cover will be inspected for signs of erosion, cracking, differential subsidence, lack of vegetation, and accumulation of standing water. The surface-water control system will be inspected for breaches, erosion, damage, silting and other obstructions to flow. An inspection schedule for each of these elements will be presented in the Post-Closure Plan. In addition to regular inspection schedule, inspection will occur after significant precipitation events, defined as greater than 1 inch magnitude over a 24-hour period.

As part of the inspection program, physical indicators may be placed in the part of the cover so that the extent and severity of any erosion or cracking can be readily detected. These indicator layers may consist of a geomembrane fabric or a layers of distinctively colored gravel, and would be placed at depths below which a loss of soil material may cause saturated flow to reach the underlying capillary break layer leading to infiltration of the cap.

For each inspection, pre-printed forms will be used to record inspection findings, unusual conditions and corrective actions taken. These forms will be presented in the Post-Closure Plan along with associated record keeping procedures.

If a problem is discovered during inspection, the severity of the situation will be assessed to determine whether the integrity of the cover system has been compromised. A standard set of mitigation procedures and implementation schedule will be developed in the Post-Closure Plan. These measures will generally include erosion and cracking repairs, replacement of compatible fill material, repairs to runoff controls system, and revegetation. In addition, if the assessment indicates that the integrity of the cover has been compromised, relevant regulatory agencies will be notified.

V.8.2 Cover Maintenance

The cover system maintenance program will include components for the prevention of erosion damage, revegetation care, surface-water conveyance care and repair, and leachate collection system care and maintenance. This program is conceptually outlined below and will be presented in detail in the Post-Closure Plan.

Inspection for erosion control will be performed on a regular basis plus after significant rainfall events. Steps will be taken to ensure that drainage pathways and cover thickness established during closure are maintained.

Drainage ditches and cover-system pipe outlets will also be inspected on regular basis and after significant rainfall events. At the time of inspection, standard maintenance activities will be undertaken such as removal of accumulated sediment.

Vegetation will be inspected on a regular basis plus after significant rainfall events. A regular schedule of mowing, subject to seasonal climatic conditions, will be followed to establish the vegatative cover, promote root growth and to allow cover inspection. Maintenance activities will also include removal of undesirable foreign vegetation and revegetation of bare areas.

The leachate collection and piping systems will be inspected for leaks and operational integrity. Cleaning and repair activities will follow based on inspection findings. Replacement parts (e.g. pumps, pipes) will conform to those originally used to maintain consistency with the specifications of the original design.

V.8.3 Security

The existing security measures at the Rocky Flats plant include:

- Three-strand barbed wire cattle fence surrounding the facility posted to identify the land as a government reservation/restricted area,

- A fence surrounding and armed guards posted 24 hours per day at two gates to the controlled area of the facility,

- 6-foot high chain link fence topped by 2 feet of three-strand barbed wire surrounding and guards posted 24 hours per day at gates to the perimeter security zone (PSZ),

- Guards patrolling the controlled area and the PSZ 24 hours per day, and

- Surveillance by security cameras 24 hours per day.

The existing security measures are sufficient to meet the requirements of CCR, Section 264.14.

The existing fences and gates are operated and maintained by the U.S. Department of Energy. Maintenance requirements will be performed by the U.S. Department of Energy, regardless of the activities at the solar evaporation ponds.

During the post-closure period, the SEP will be secured by a 8-foot chain link perimeter fence and a locking gate to prevent unauthorized entry. Signs will be placed around the fenced area to indicate that unauthorized access is prohibited.

V.8.4 Monitoring for Settlement and Subsidence

As described in Section V.8.1, inspection for excessive settlement will be performed on a regular basis, with inspection frequency to be established in the Post-Closure Plan. In addition to these inspections, a long-term monitoring and assessment program will be established to detect longer-term, more subtle changes in vertical elevations and slope angles that may be indicative of cover system failure. The monitoring program will begin with the installation and surveying of benchmarks, settlement markers and slope indicators (Section V.4.1.5). The locations of these markers will be presented in the subsequent 60% Design Document. Monitoring procedures,measurement frequency, and performance criteria will be presented in the Post-Closure Plan. If the vertical, horizontal or slope angle movements exceed performance criteria established in the Post-Closure Plan, then an assessment and mitigation plan will be submitted within a specified period. Note that all settlement/subsidence markers and measurement instruments will be inspected for damage and functionality during the regular inspection program.

V.8.5 Groundwater and Vadose Zone Monitoring System Maintenance

The groundwater and vadose zone monitoring systems have been conceptually designed and are presented in Section V.4 of this document, including associated maintenance of these systems. These activities will be reiterated in the Post-Closure Plan.

V.8.6 Record Keeping and Reporting

The monitoring system to be used for this project will consist of data collection, storage, transmission, and analysis/archival subsystems, to allow for remote site monitoring. The subsystems will provide the means to collect data from strategically placed sensors which will monitor soil moisture, soil temperature, air data, rainfall, and snowfall. The system will be able to integrate additional sensors if found necessary.

The data collection subsystem (DCS) will interrogate sensors at programmable intervals, store raw data for up to one week, and download to an off-site data management system. The DCS will be connected to commercial power, but will have a back-up power system to assure continuous operation in the event of a commercial power outage.

The data analysis/archival subsystem will accomplish the following:

- Automatically interrogate the DCS via landlines at periodic intervals, and download all raw data collected since the previous interrogation;
- Convert the raw data into standard engineering units;
- Analyze and display the data in forms that are suitable to allow for adequate management decisions with regard to the site;
- Store the raw data and any analysis in suitable archival form;
- Alert the site management of any rapid changes in the data from the site sensors.

This system will be used to meet the record keeping requirements stated in the IAG (Interagency Agreement), and those applicable requirements provided under the Colorado Hazardous Waste Act regulations, 6CCR 1007.3.

The IAG states that DOE shall preserve, for a minimum of ten (10) years after termination of the IAG, all of its records and documents in its possession which relate in any way to the presence of hazardous substances, pollutants, and contaminants at the site. After this ten-year period, DOE shall notify EPA and the State at least 45 days prior to destruction or disposal of any such documents or records. Upon request by EPA or the State, DOE shall make available such records or documents to either party.

DOE will also be required to establish and maintain an Administrative Record at or near the site in accordance with section 113(k) of CERCLA. The Administrative Record will be established in accordance with EPA policy and guidelines and will be updated on at least a quarterly basis. A master copy will be maintained by DOE at the RFP in the Environmental Restoration Department currently located in Building T130B. Four additional locations will satisfy the requirement of public access. These four repositories are as follows:

Rocky Flats Reading Room
Front Range Community College
3645 W. 112th Avenue
Library
Westminster, Colorado 80030
(303) 469-4435

Colorado Department of Health
4210 East 11th Avenue
Room 351
Denver, Colorado 80220
(303) 331-4830

Rocky Flats Environmental
Monitoring Council
1536 Cole Blvd., Suite 150
Golden, Colorado 80401
(303) 232-1966

U.S. Environmental Protection
Agency (EPA)
Superfund Documents Room
5th Floor
999 18th Street
Denver, Colorado 80202
(303) 293-1444

The EPA will make the final determination of whether a document should be included in the Administrative Record. The State will take part in this determination if found necessary. The EPA or the State may also submit documents to DOE that are to be included in the Administrative Record.

As a part of post-closure care, compliance monitoring reports will be submitted to the EPA and the State regarding results collected from four separate modes of monitoring the integrity of the cover system. These methods include cover system monitoring, vadose zone monitoring, groundwater monitoring, and cover system inspections. Each of these are addressed below.

Cover System Monitoring

Reporting results of the cover system monitoring program will be completed at the same frequency as determined necessary for the vadose zone.

Vadose Zone Monitoring

Monitoring of the vadose zone will follow the methods described in section V.6, Sampling and Analysis Plan. The frequency that the reports will be generated and distributed will be determined during the final monitoring system design. This frequency, at a minimum, will be on a quarterly basis.

Groundwater Monitoring

The purpose of the groundwater monitoring report is to present monitoring data as required under Colorado Hazardous Waste Act regulations, 6 CCR 1007-3, Subpart F, Section 265.90 for RCRA interim status waste management units at the RFP. These regulations require that a groundwater monitoring program be implemented that will determine the facility's impact on the uppermost hydrostratigraphic unit beneath the facility. Records are to be maintained throughout the post-closure care period of the analyses required in Sections 265.92(c) and (d),

the associated groundwater surface elevations required in Section 265.92(e), and the evaluations required in Section 265.93(b).

Information should be reported during the first year when initial background concentrations are being established for the facility: concentrations or values of the parameters listed in Section 265.92(b) for each groundwater monitoring well within 15 days after completing each quarterly analysis. Another report should be generated annually, identifying concentrations or values of the parameters listed in Section 265.92(b)3 for each groundwater monitoring well, along with the required evaluations for these parameters under Section 265.93(b). The owner or operator must separately identify any significant differences from initial background found in the upgradient wells, in accordance with Sec. 265.93(c)(1). Results from the evaluation of groundwater surface elevations performed under Section 265.93(f) should be submitted no later than March 1 following each calendar year.

V.8.6.1 Cover System Inspections

Physical inspections of the engineered barrier will be completed as described in section V.8.1. Results from these inspections will be recorded on pre-printed forms. These forms will then be included in the groundwater monitoring reports. If a problem is detected which may effect the integrity of the cover system, the extent of the problem will be assessed and when necessary, a corrective action plan submitted. Appropriate regulatory agencies will be notified.

Five year and thirty year assessments will also be completed to evaluate the integrity of the cap. These assessments will be discussed in Section V.9 under Post Closure Performance and Assessment.

V.9
POST CLOSURE PERFORMANCE AND ASSESSMENT

V.9.1 Five Year Assessment

At five year intervals following approval of the Post Closure Permit for OU4, a Five Year Assessment report will be submitted describing the performance of the engineered barrier/cover as measured by the engineered barrier/cover, vadose zone, and groundwater monitoring systems. The purpose of the five year assessment report is to provide a detailed assessment of the monitoring data collected and visual inspections performed over the five year period and to determine if the data indicate that either remedial actions or modifications to the monitoring program are warranted. The Five Year Assessment reports will contain similar analyses to the annual reports, and will follow the procedures outlined in Section V.7, Monitoring System Assessment Program.

Additional details on the content and format of the Five Year Assessment reports will be provided in the 60 percent design report and in the Post-Closure Permit Application for OU4.

V.9.2 Thirty Year Assessment

The RCRA regulations currently specify a thirty-year monitoring period for post closure care of regulated units. A Thirty Year Assessment report will be submitted thirty years after approval of the Post Closure Permit for OU4. The purpose of the Thirty Year Assessment report is to document the performance of the engineered barrier/cover system for OU4 over the thirty year period, and to determine if post-closure care may be discontinued.

Additional details on the content and format of the Thirty Year Assessment report will be provided in the 60 percent design report and in the Post Closure Permit Application for OU4.

V.9.3 Reduction in Monitoring

The sampling and analysis plan is designed such that the intervals between measurement and sampling event are shortest at the beginning of the remedial action and become greater as time elapses and the performance of the remedial design is assessed and verified. Data collected during the initial 3-year period will be used to develop an understanding of the effect of seasonal weather changes on the monitoring data, identify gaps in the data, further characterize the completed remedial design, identify any additionally required monitoring locations, and evaluate sources of uncertainty such as sampling, analysis, and site conditions.

The costs associated with initiating the engineered barrier/cover monitoring system and vadose zone monitoring activities will be relatively high during the first few years of operation. Therefore, the effort expended and associated costs will decrease substantially through time.

The recommended long-term frequency for measurement and sampling depends in part on the effectiveness of the remedial action as determined through the ongoing monitoring program. If the monitoring data demonstrates that a steady, predictable stabilization of the pore liquids in the waste pile has occurred, then reducing the sampling frequency will be a reasonable course of action. Frequency of monitoring is also dependent upon the labor intensity of the measurement process as it effects the cost of acquiring data. For example, there is little cost differential between weekly and daily monitoring of weather parameters when data from the sensors are electronically logged, acquired and presented in report format.

Frequency is also dependent upon the status of other sensors in the overall system. Measurement redundancy is built into the system in anticipation of the contingency that sensors may become disabled in the future. For example, if the FDC sensors (which are part of the engineered barrier monitoring system) become disabled at some point in the future, the NPAT can also perform the function of detecting downward migration of leachate. The frequency of NPAT data acquisition would be increased in the event that FDC probes become disabled. Likewise, once it can be shown that the engineered barrier/cover and vadose zone monitoring system data are reliably and consistently being used to demonstrate no leachate migration from the waste pile, the frequency of monitoring at all or some of the proposed groundwater monitoring wells could be reduced or even eliminated.

The monitoring data will provide the basis for determining that the remedial action objectives have been met and that the source control action, which is the goal of the remedial action, prevents further degradation of groundwater.

Statistical correlation will be developed during the initial monitoring phase (0 to 3 years) and in the secondary phase (3 to 10 years) between the MET data and TDR data for the purpose of developing a tool to predict the performance of the engineered barrier/cover system design based on weather data. For example, precipitation events will be identified that are most likely to saturated the cover soils and penetrate the capillary barrier portion of the engineered barrier. Likewise, additional climatic data will be examined in order to assess the effect of weather patterns and intensity on the performance of the engineered barrier/cover. For example, soil temperature sensing data will be collected and evaluated to determine the effect of freezing and thawing fronts on saturation of the engineered barrier/cover system.

Assuming that the remedial design performs as intended, MET and TDR sensors in the engineered barrier/cover system will be the primary means of monitoring performance of the remedial action 10 years after installation of the facility. FDC monitoring of the engineered barrier/cover and vadose zone monitoring will be reduced in frequency as described in section V.6.2.3.

Thirty years after installation of the facility, all of the sensors will remain in place. Only the MET and TDR sensors will be used for data collection thereafter, as part of a normal operating weather station. Based on the statistical correlations established during the 30-year monitoring period, weather events or climatic trends will be identified that could trigger additional monitoring of the unsaturated zone beneath the engineered barrier/cover.

The proposed long-term plan for the frequency of measurement and sampling depends, in part, on the effectiveness of the remedial action as determined through the ongoing monitoring program. If the monitoring data demonstrates that a steady, predictable stabilization of the pore liquids is maintained in the waste pile, then reducing the sampling frequency will be a reasonable course of action. Frequency of monitoring is also dependent upon the labor intensity of the measurement process as it affects the cost of acquiring data. Scheduling and costing of the NPAT monitoring data acquisition is based on the assumption that substantial field labor will be required to acquire the data. An evaluation of the cost benefit of designing and constructing an automatic data acquisition system for collecting and analyzing NPAT data will be conducted before the monitoring system design is finalized. Results of that evaluation will be presented with the final monitoring system design.

Assuming the remedial design performs as intended, no monitoring of the NPAT is anticipated beyond 30 years unless triggered by data that would indicate a rise in the water table into the subsurface drain, or sequential detections that would indicate an increase in soil water content by the MET/TDR, FDC, and NPAT. Sampling intervals and collection procedures for the PLS (pore liquid sampling) devices are discussed in Section V.6.2.

V.10
MONITORING SYSTEM ABANDONMENT

V.10.1 Access Casing and Sensor Abandonment Procedures

The abandonment procedures for the Rocky Flats OU4 engineered barrier/cover monitoring system and vadose zone monitoring system will follow the ASTM designation: D5299-92 entitled "Standard Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Bore Holes, and Other Devices for Environmental Activities" (unless superseded by existing RFP SOPs) (ASTM, 1993). This standard was published formally in January 1993 and has been unanimously approved by the membership of ASTM. The guide was established to cover procedures that are specifically related to permanent closure of environmental activities. The guide was intended for use where solid or hazardous materials or waste are found.

Abandonment is necessary to:

- Eliminate the possibility that the sensor or access holes are used for purposes other than intended,
- Prevent migration of contaminants into the subsurface aquifer
- Prevent migration of contaminants through the vadose zone
- Reduce the potential for vertical or horizontal migration of fluids in the access hole or adjacent to the access hole, and
- Remove the sensor or access casing from active use when the device is no longer capable of rehabilitation, or has failed structurally; no longer required for monitoring; no longer capable of providing representative samples or is providing unreliable samples; or, required to be abandoned; or, to meet regulatory requirements.

V.10.1.1 Abandonment Procedure

The abandonment procedure will proceed in order of the following steps:

V.10.1.1.1 Planning:

1. <u>Records Review:</u> All available records and information relating to use of the monitoring device, casing, etc. will be carefully reviewed. This review may include the following information:

1a. Review applicable Federal, state, and local regulations contacting the applicable Federal, state or local agency having jurisdiction and preparation of the necessary documentation to start.

1b. Collection of drillers' logs, geophysical logs, access well construction, or geologic logs, including stratigraphy, structural geology, subsurface information, construction materials, depth, hydraulic gradients (if water levels are available from other wells for its determination), legal location, date of installation, and photographs of the site.

1c. Review of analytical chemical data for soil pore-water and groundwater over the life of the site and variations in water levels over time.

1d. Review of records of the repairs, modifications, or other changes made to the site during the lifetime of the site.

1e. Evaluation of historic, current, and planned land use.

1f. While not directly part of the decommissioning activity, proper disposal of displaced fluids and other materials (such as pulled or drilled out casing and cement seals) should be considered. Some of these materials may be classified as a hazardous waste under Federal, state, or local regulations. Conduct a review of these regulations and appropriate analytical documentation prior to classifying a material as a hazardous waste.

2. Verification of Field Data: The variety and quality of field practices and reporting require that the site be inspected to verify the actual field situation prior to decommissioning. The following list of procedures is recommended so that the actual condition of the site is know.

2a. Inspection of casing head installation for integrity

2b. Current length measurement of the casing

2c. Water Quality Sampling and Analysis: A final sample collected from the devices may be required for regulatory purposes.

2d. Down-hole Inspections: Including caliper logs to measure inside diameter; television logs to determine in-well conditions such as casing breaks, etc.; gamma logs to verify geologic information, if not already available; cement bond logs (sonic) to determine if the casing is firmly attached to grout (presently available for holes 2 1/2-inch (6.35-cm) or larger in diameter); flow logs (flow meter or spinners) to determine if flow occurs within the casing; and hydraulic integrity test to determine if the neutron access is intact.

2e. Verification of field data is an ongoing responsibility. Use verified information to modify plans in order that the decommissioning activity is correctly conducted. Continue this activity during the field phase and change specifications as needed.

3. Review of Decommissioning Options: After the records have been thoroughly reviewed and verified in the field, select an appropriate decommissioning procedure. Evaluate each possible option to determine the most appropriate method for the selection. The following list of evaluation criteria is recommended:

3a. The potential for fluid movement should be eliminated.

3b. Materials to be used in plugging must be compatible with well casing and screen (if left in place), and with subsurface formation and ground water, etc. over the period of time hazardous materials are found at these sites.

3c. Future land use (as is known at the time of decommissioning) should be compatible with decommissioning plans.

3d. Closure options should be compatible with applicable Federal, state, and local requirements.

V.10.1.1.2 Implementation

1. All work performed on the site should be completed by competently trained drillers, equipped with appropriate tools, under the direction of a geological or engineering professional who is qualified to certify that the decommissioning is completed according to the planned procedures and is consistent with applicable regulations.

1a. Approve any modifications to the proposed work plan and record in writing by the on-site geologist or engineer (or their representatives) prior to implementation.

1b. The geologist or engineer should be on-site during the field activities to verify that the activities are completed as planned. Maintain documentation of decommissioning activities for the post-closure period or period required by regulations (if specified). While regulations may require documentation for a period of 30 years, it is advisable to continue this activity for a period lasting as long as hazardous materials occur at the site.

V.10.1.1.3 Decommissioning of Neutron Probe Access Tubes, Lysimeter Installations, and Time Domain Reflectometry Devices.

1a. It is desirable to remove all existing well construction materials such as casing, filter pack, seal, and grout from the hole to reduce the potential for the formation of a conduit to occur at the contact between casing and annular seal;

reduce the potential of these materials interfering with the decommissioning operation; decrease the potential of a reaction between the materials used; or to minimize the reaction with the native materials or ground water. In situations where casing materials are removed and borehole collapse occurs, redrill the borehole following the guidance provided in 7.3.6 of ASTM D5299 (ASTM, 1993).

1b. Steel casing may be removed using jacks to free casing from the hole followed by lifting the casing out using a drill rig, backhoe, cranes, etc. of sufficient capacity. If the annular space has been cemented over a long distance, this method may not be readily used unless a poor contact occurs between the casing and borehole. Small lengths of cement (typically less that 10 ft. (3cm) can be removed along with the casing if the drill rig has sufficient lifting or pulling capacity. When the casing cannot be removed, perforate the casing and screen using a suitable tool. This is necessary as encrustation or corrosion may have occurred. A wide variety of commercial equipment is available for perforating casings and screens. Due to the diversity of application, consult an experienced contractor prior to selection of the technique. A minimum of four rows of perforations several inches (millimeters)long and a minimum of five perforations per linear foot (meter) of casing or screen is recommended.

Remove steel casing by over-drilling (over-reaming) the casing. Over-reaming can be done using an over-reaming tool. Select a pilot bit that is nearly the same size as the inside diameter of the casing. The reaming bit should be slightly larger than the borehole diameter to remove all well construction materials and a small amount of native material. As drilling proceeds, the casing, grout, bentonite seal, filter pack, and other well materials are destroyed and returned to the surface. In situations when the grout in the annular space can be verified to be in good condition, it may be very difficult to remove casing and grout and grout can be left in place by pressure grouting the slotted interval and casing. Verifying the integrity of the grout can be difficult.

PVC and other low tensile strength materials generally cannot be removed by pulling if they have been properly cemented into place. Over-drilling is necessary to remove these casing and screen materials.

A hollow stem auger equipped with outward facing carbide cutting teeth with a diameter 2 to 4-inch (50.8 to 101.6-cm) larger than the casing may be used for over-drilling. Place the lead auger over the casing and rotate. The casing guides the cutting head and remains inside the auger. When the full diameter and length of the well has been penetrated, the casing can be retrieved from the center of the auger. It is important to use outward facing cutting teeth in order that the cutting tool does not sever the casing and drift off center. An alternative is to install a steel guide pipe inside the well casing so that the augers can be centered. Firmly attach this temporary working pipe to the inside of the casing by use of a packer, or other type of expansion or friction device.

When the auger reaches full length and the casing materials have been removed, pump plugging materials through the hollow stem as the augers are withdrawn.

After removal of the casing, decommissioning can be completed in accordance with 7.3.6 ASTM D5299. Note that a complete discussion of plugging materials, cement additives, extenders (bentonite), accelerators, retarders, and density improvers is found in D5299. A detailed discussion of the required plugging material volume, grout water, cement and bentonite mixing is provided in D5299.

V.10.2 Groundwater Monitoring Well Abandonment Procedures

The compliance monitoring wells for the SEP do not penetrate the waste piles; therefore, abandonment procedures for the groundwater monitoring system are less rigorous than the abandonment procedures for the engineered barrier/cover monitoring system and vadose zone monitoring system. Unless superseded by existing (and more stringent) RFP SOPs, groundwater monitoring wells will be abandoned in accordance with the abandonment standards of the State of Colorado Division of Water Resources (CDWR).

Prior to abandonment, all well construction logs/information will be assembled and reviewed to determine the construction specifications of each well to be abandoned. All monitoring wells at the SEP are to be completed into unconfined aquifers. For abandonment, each well will be backfilled with clean sand to approximately 2 feet above the top of the screened interval. Well casing will be cut off at a depth of 5 feet below land surface, and the remaining solid casing will be filled with grout. A permanent cap will be affixed to the top of the casing and sealed with cement. The remaining hole will then be backfilled with materials that are compatible with the surrounding soils.

V.11
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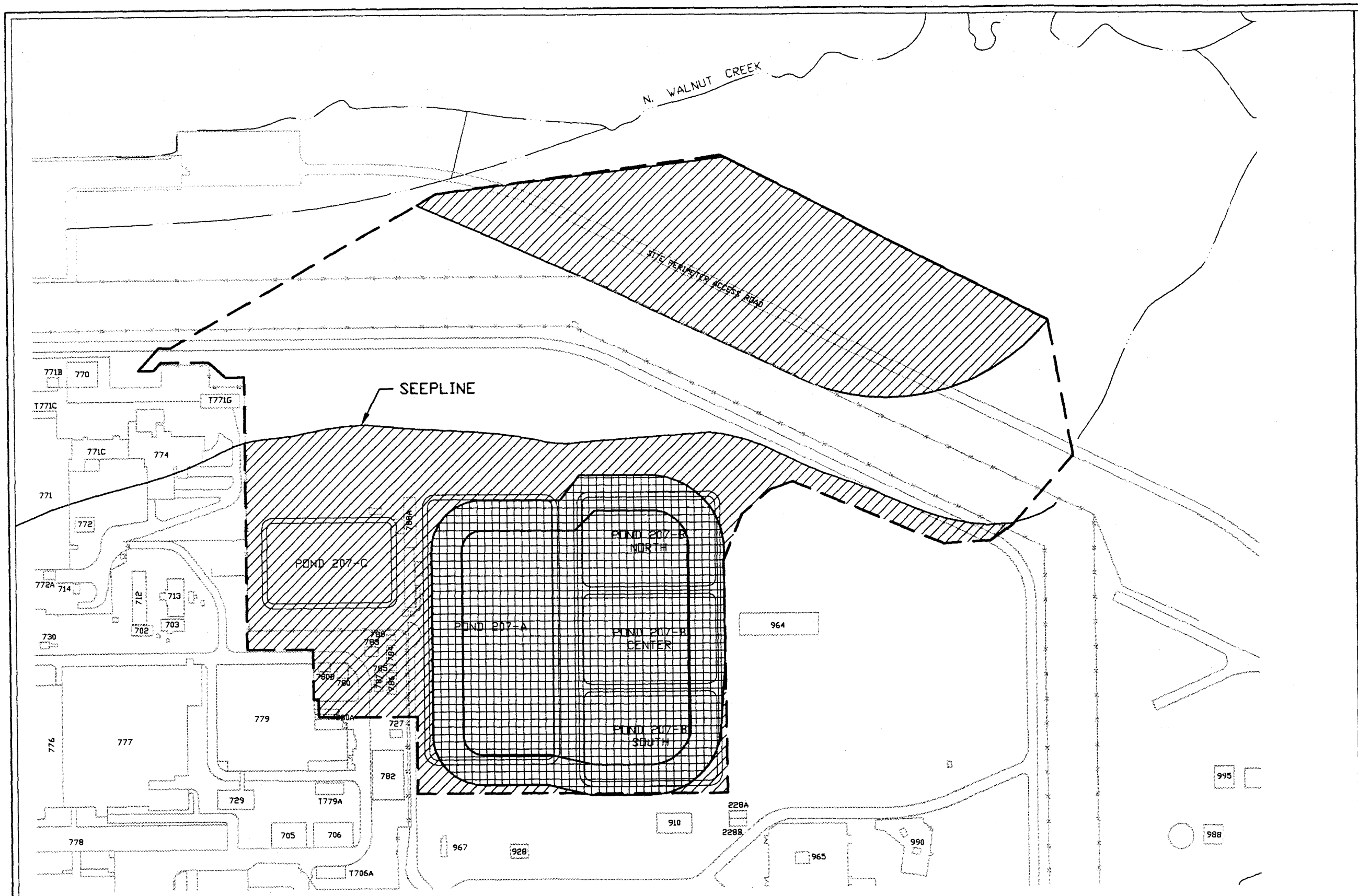

LEGEND:

- Streams
- Paved Roads
- Buildings
- OU4 Boundary
- Final Engineered Cover
- Reclaimed Areas

100 0 100 200 300 FEET

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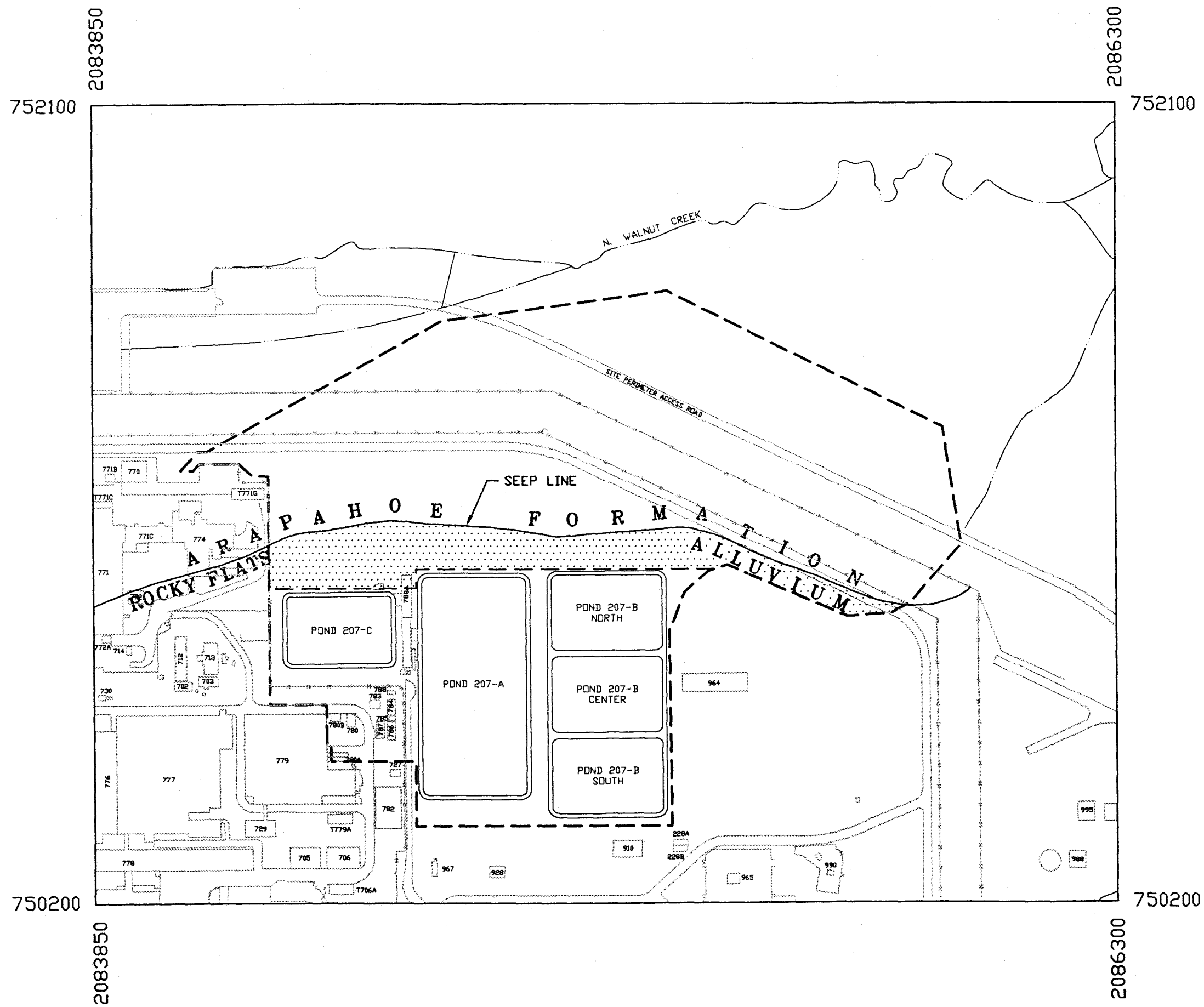
Figure IV.1-1

OU4 IM/IRA
Location of the Final Engineered Cover and Reclaimed Areas



LEGEND:

- Streams
- Paved Roads
- Buildings
- OU4 Boundary
- Formation Boundary
- Seep Line Impact Area

Source:
Geologic Map of Rocky Flats Plant and Vicinity, Jefferson and Boulder Counties, Colorado.
Prepared for
E.G.&G. Rocky Flats, Inc.
March, 1992.

100 0 100 200 300 FEET

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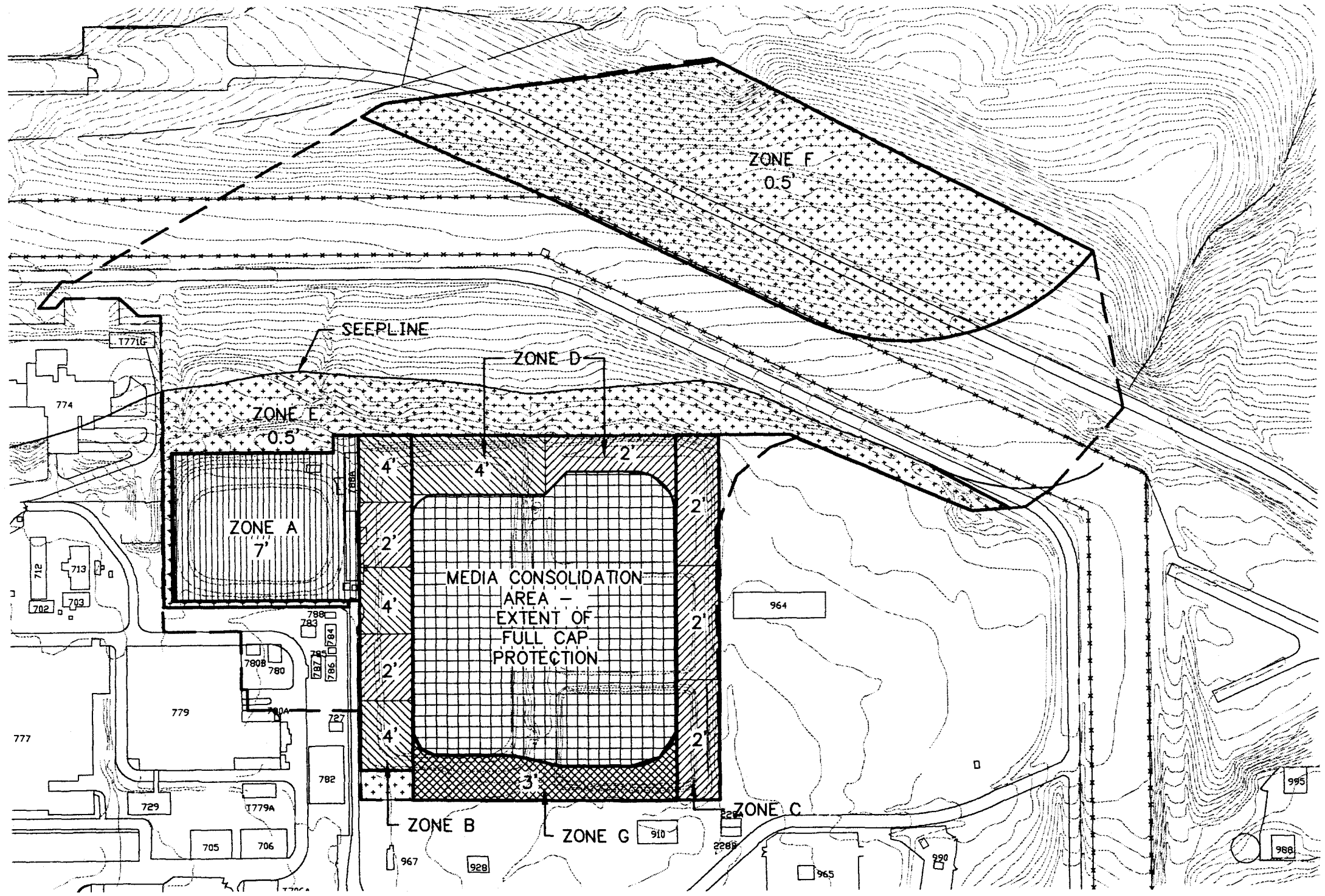
Figure IV.1-2

OU4 IM/IRA
Contaminated Hillside Soil Perimeter



LEGEND:

- Streams
- Paved Roads
- Buildings
- Fence
- OU4 Boundary
- Surface Soils (6 in.)
- 2 Ft. Excavation
- 4 Ft. Excavation
- 3 Ft. Excavation
- 7 Ft. Excavation
- Extent of Media Consolidation

100 0 100 200 300 FEET

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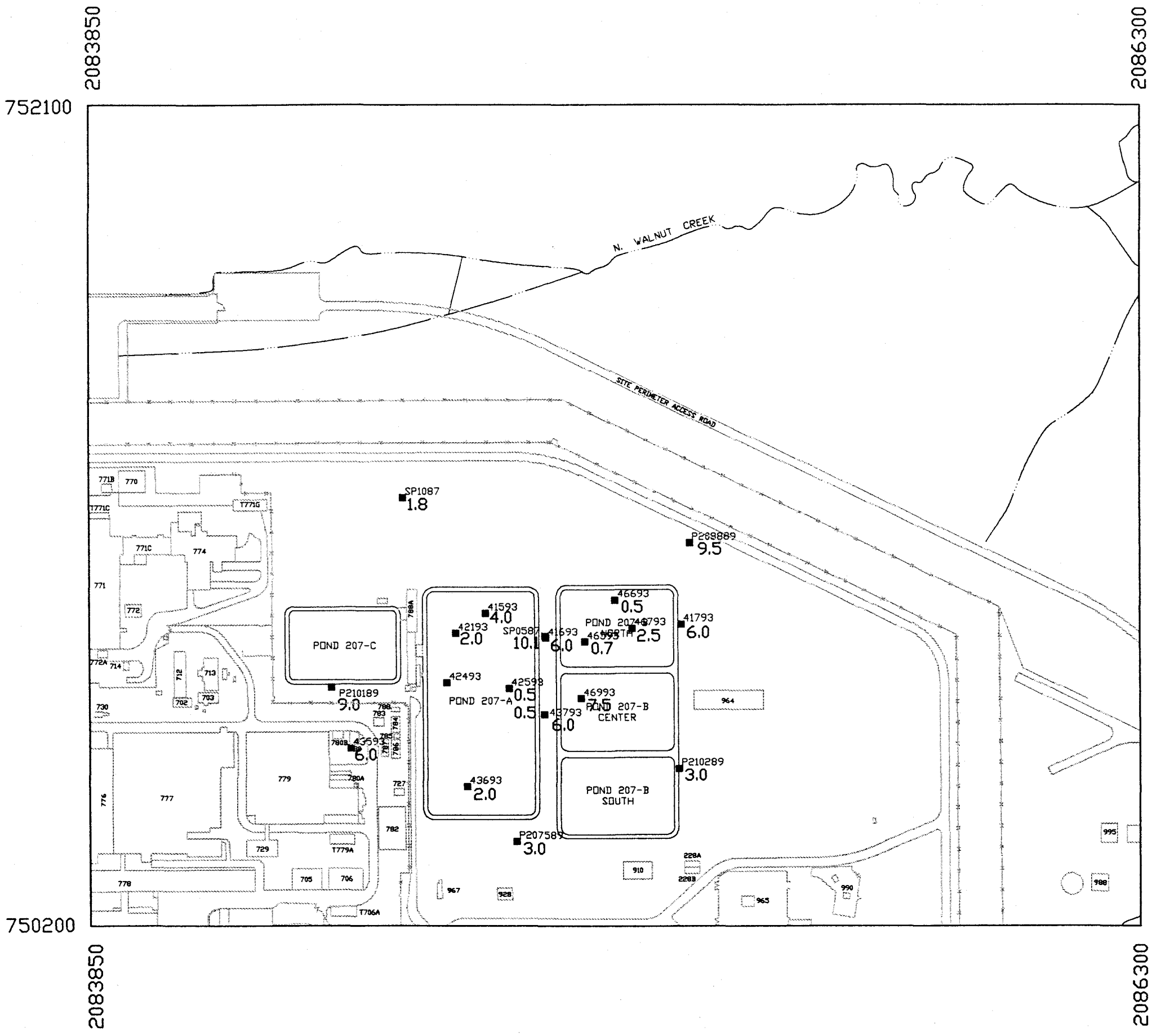
Figure IV.3-1

OU4 IM/IRA
Zones of Soil Excavation



LOCATION	DEPTH	CHEMICAL	RESULT	UNITS
SP0587	9.5-10.1'	Chromium	780.50	mg/kg
SP1087	0-1.8'	Plutonium-239/240	3.50	pCi/g
P207589	0-3'	Mercury	10.80	mg/kg
P208889	3.5-9.5'	Barium	11600.00	mg/kg
P210189	3-9'	Uranium-235	0.30	pCi/g
P210289	0-3'	Plutonium-239/240	2.50	pCi/g
41593	0.4-0.5'	Americium-241	3.30	pCi/g
	0.4-0.5'	Plutonium-239/240	14.00	pCi/g
	0.4-0.5'	Uranium-235	0.29	pCi/g
	0.5-2'	Uranium-235	0.59	pCi/g
	2-4'	Uranium-235	0.30	pCi/g
41693	0-6'	Americium-241	2.70	pCi/g
	0-6'	Plutonium-239/240	3.00	pCi/g
	0-6'	Uranium-235	0.39	pCi/g
41793	0-6'	Americium-241	2.10	pCi/g
	0-6'	Plutonium-239/240	2.90	pCi/g
42193	0-2'	Uranium-235	0.87	pCi/g
42493	0.5-0.6'	Americium-241	4.90	pCi/g
	0.6-2'	Uranium-235	0.29	pCi/g
	0.6-2'	Cadmium	360.00	mg/kg
	2-4'	Cadmium	550.00	mg/kg
42593	0.4-0.5'	Plutonium-239/240	2.55	pCi/g
43593	1-6'	Americium-241	4.00	pCi/g
	1-6'	Plutonium-239/240	25.00	pCi/g
43693	0.4-0.5'	Americium-241	2.17	pCi/g
	0.4-0.5'	Plutonium-239/240	4.55	pCi/g
	0.5-2'	Americium-241	2.48	pCi/g
43793	0-6'	Americium-241	6.10	pCi/g
	0-6'	Plutonium-239/240	4.10	pCi/g
	0-6'	Uranium-235	0.54	pCi/g
46593	0.6-0.7'	Americium-241	2.78	pCi/g
	0.6-0.7'	Plutonium-239/240	19.80	pCi/g
	0.6-0.7'	Uranium-235	0.483	pCi/g
46693	0.33-0.5'	Americium-235	44.70	pCi/g
	0.33-0.5'	Plutonium-239/240	8.54	pCi/g
	0.33-0.5'	Uranium-235	1.69	pCi/g
46793	0.33-0.5'	Americium-241	11.70	pCi/g
	0.33-0.5'	Plutonium-239/240	12.90	pCi/g
	0.33-0.5'	Uranium-235	0.383	pCi/g
	0.5-2.5'	Uranium-235	0.3064	pCi/g
46993	0.9-1.3'	Uranium-235	0.399	pCi/g
	1.3-3.3'	Uranium-235	0.5193	pCi/g
	5.5-7.5'	Uranium-235	0.3832	pCi/g

Streams
Paved Roads
Buildings
Fence

46993 Borehole Location and Identification Number

7.5 Maximum Depth to Contamination (in feet)

100 0 100 200 300 FEET

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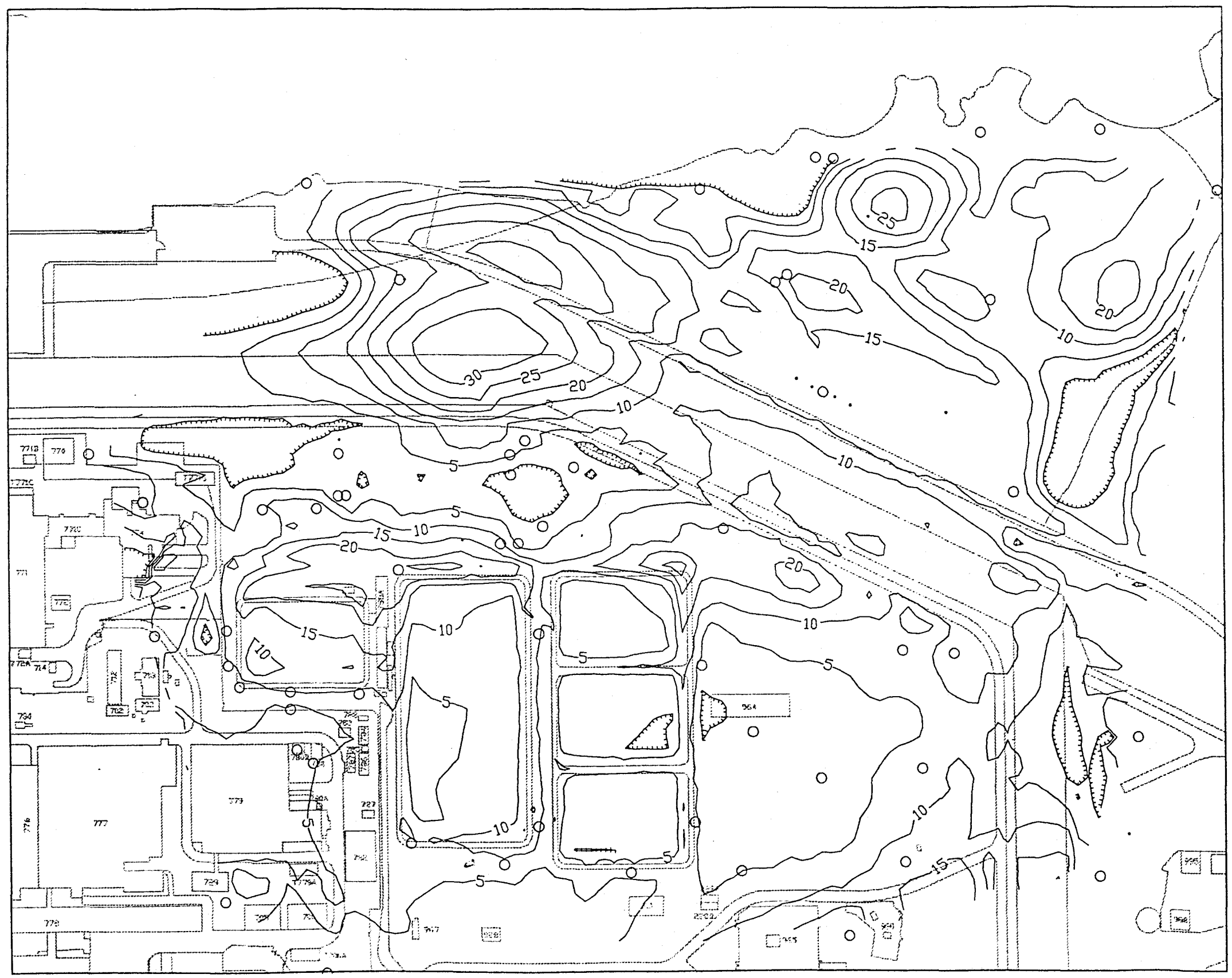
Figure IV.3-2

OU4 IM/IRA
Extent of Contaminants of Concern in Subsurface Soils at Levels Greater Than Vadose Zone PRGs



Note: This map represents the thickness of the Vadose Zone from the surface elevation to the mean of the seasonal high ground water elevation.

100 0 100 200 300 FEET

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Figure IV.3-3

OU4 IM/IRA
Minimum Vadose Zone Thickness
Based on the Mean of the Seasonal
High Water Table Elevations

LEGEND:

- Streams
- Paved Roads
- Buildings
- ⊗ Proposed Boring Location

100 0 100 200 300 FEET

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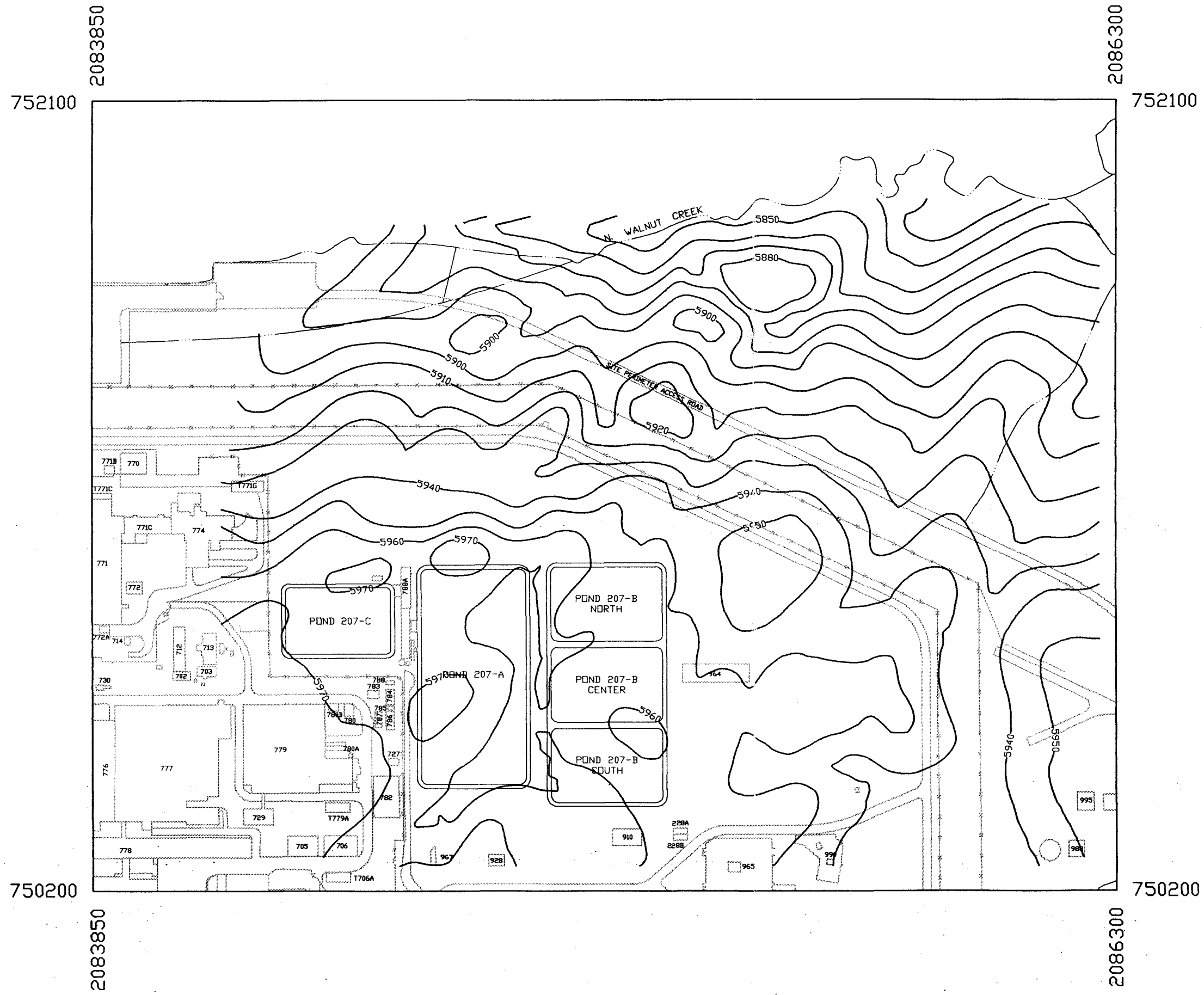
Figure IV.6-1

OU4 IM/IRA
Proposed Geotechnical Sampling Locations



LEGEND:

- Streams
- Paved Roads
- Buildings
- Fence

100 0 100 200 300 FEET

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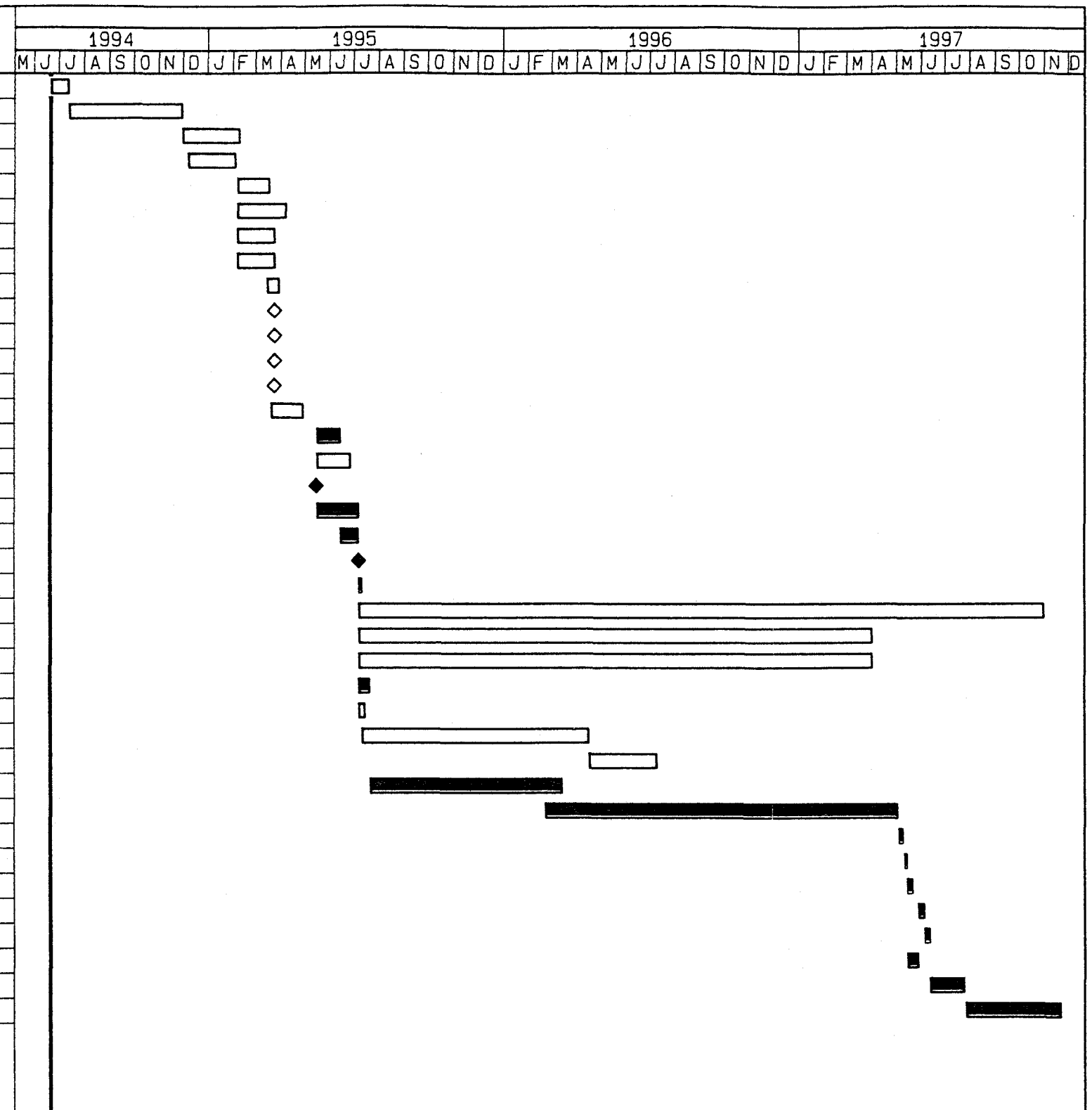
GOLDEN, COLORADO

Figure IV.6-2

OU4 IM/IRA
Bedrock Surface Topography

ACTIVITY ID	ACTIVITY DESCRIPTION	EARLY START	EARLY FINISH	ORIG DUR
000	GEOTECHNICAL ANALYSES	21JUN94	12JUL94	15
005	90 % TITLE II DESIGN	13JUL94	29NOV94	97
010	FINAL TITLE II	30NOV94	8FEB95	50
015	PROPOSAL	7DEC94	3FEB95	42
020	EVALUATION	6FEB95	17MAR95	30
025	WASTE DISPOSAL PLAN	6FEB95	7APR95	45
030	EXCAVATION PERMIT	6FEB95	24MAR95	35
035	SECURITY PLAN	6FEB95	24MAR95	35
036	EXCAVATE VEG & SOILS N & S OF SEEPLINE	15MAR95	29MAR95	11
040	U/G UTILITY VERIFICATION	24MAR95		0
045	D & D BLDG. 788	24MAR95		0
046	RELOCATE POWER LINES	24MAR95		0
047	SECURITY FENCE	24MAR95		0
048	NEGOTIATIONS	20MAR95	28APR95	30
050	TRAINING	16MAY95	13JUN95	20
055	JOB SAFETY ANALYSIS	16MAY95	26JUN95	29
060	AWARD CONTRACT	15MAY95		0
065	SITE SPECIFIC H & S PLAN	16MAY95	6JUL95	36
070	MOBILIZATION	14JUN95	6JUL95	16
075	START CONSTRUCTION	7JUL95		0
100	BASELINE RADIOLOGICAL/HAZARDOUS SURVEY	7JUL95	10JUL95	2
140	PROJECT & CONSTRUCTION MANAGEMENT	7JUL95	31OCT97	592
150	CLEAN-UP & LABOR SUPPORT	7JUL95	1APR97	442
400	MONITOR JOBSITE (HEALTH & SAFETY)	7JUL95	1APR97	442
5000	INDIRECT FIELD COSTS	7JUL95	20JUL95	10
6000	REMOVE & SHRED OBSOLETE POLES	7JUL95	14JUL95	6
8000	POND LINER PREPARATION	11JUL95	15APR96	196
9000	STABILIZE HILLSIDE	16APR96	9JUL96	59
10000	UTILITIES	21JUL95	13MAR96	165
11000	INSTALL FINAL ENGINEERED COVER	22FEB96	2MAY97	305
13000	REMOVE & DECONTAMINATE STAGING AREA	5MAY97	9MAY97	5
15000	FINAL SITE SURVEY	12MAY97	14MAY97	3
15500	SEED	15MAY97	21MAY97	5
16000	FINAL SITE PREPARATION	29MAY97	5JUN97	5
16500	DEMOBILIZATION	6JUN97	12JUN97	5
A100	SLOPE STABILITY	15MAY97	28MAY97	10
A150	SETTLEMENT MONUMENT INSTALLATION	13JUN97	25JUL97	30
A200	POST CLOSURE AND SYSTEM START-UP	28JUL97	21NOV97	84



Plot Date 24FEB94
Data Date 21JUN94
Project Start 7JUN94
Project Finish 21NOV97

(c) Primavera Systems, Inc.

Activity Bar/Early Dates
Critical Activity
Progress Bar
Milestone/Flag Activity

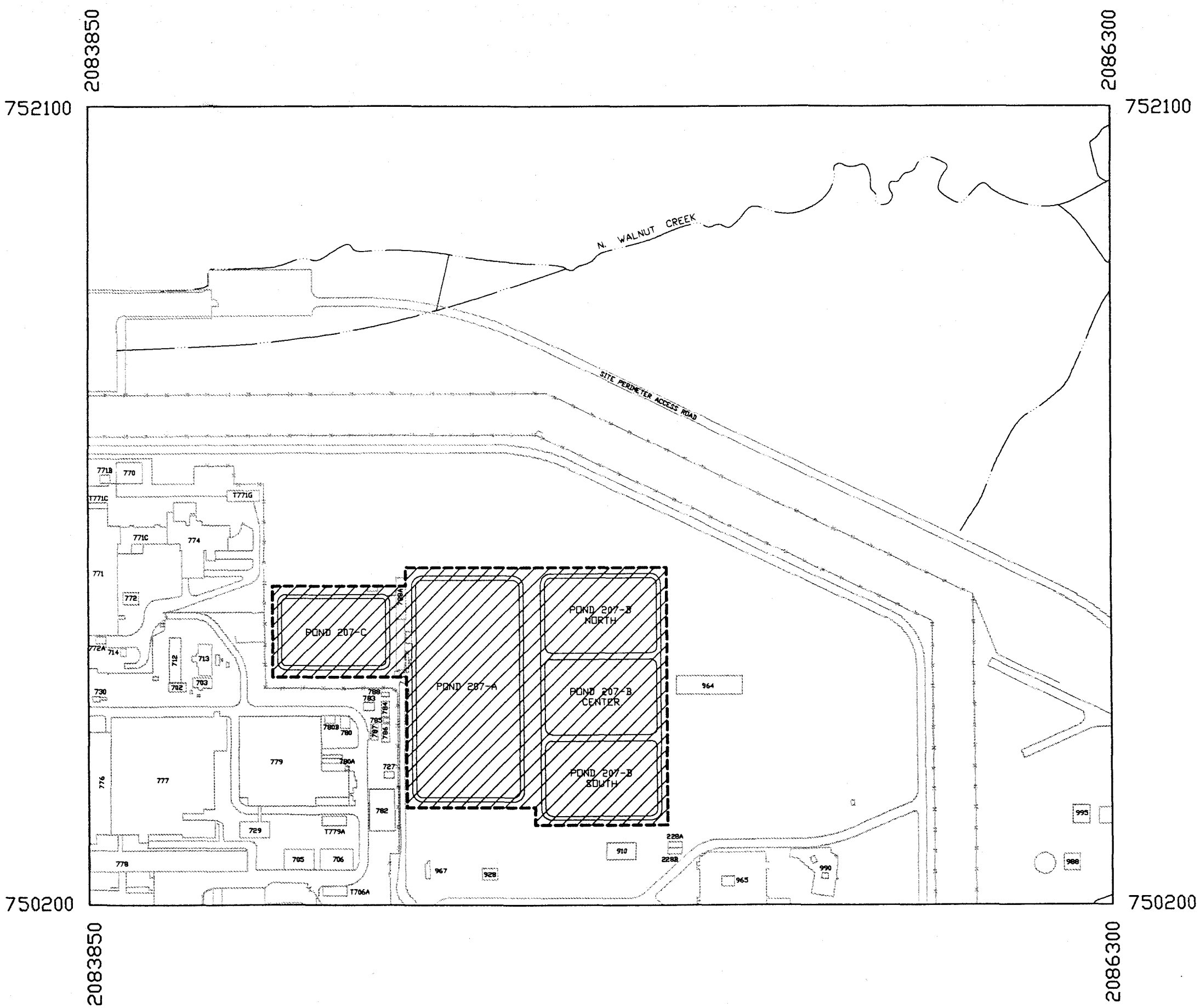
0100

Sheet 1 of 1

FIGURE IV 6-2 OU4 IM/IRA
SUMMARY LEVEL
CONCEPTUAL SCHEDULE

-----PROJECT SCHEDULE-----

Date	Revision	Checked	Approved



LEGEND:

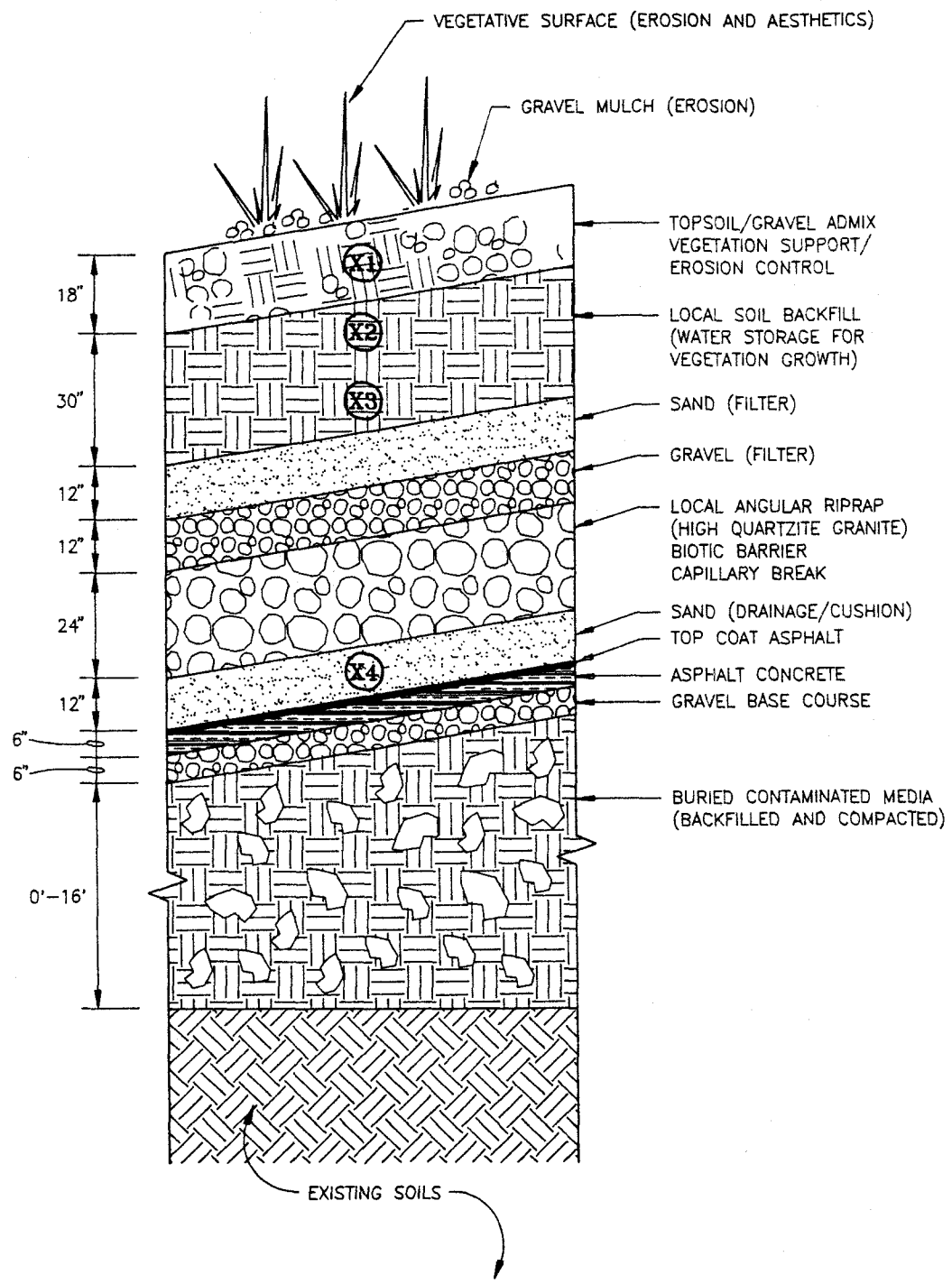
- Streams
- Paved Roads
- Buildings
- Fence
- Corrective Action Management Unit (CAMU) Boundary

100 0 100 200 300 FEET

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

Figure IV.11-1

OU4 IM/IRA
CAMU Boundary



1,000 YEAR CAP SECTION

SCALE: 1"=3'

CONCEPTUAL DESIGN

PART	QUAN.	DESCRIPTION	MATERIAL

NOTES:

1) SENSORS AND NAPT'S NOT SHOWN TO SCALE.

LEGEND:

X1 X2 X3 X4 INDIVIDUAL TDR WAVEGUIDES

Prepared by:

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GERAGHTY & MILLER, INC.
Environmental Services

ENGINEERING-SCIENCE, INC.

KEYWORDS	A	ORIGINAL ISSUE
1.	ISSUE	DESCRIPTION
2.		
3.		
4.		
5.		
BLDG./FACILITY		
ROOM/AREA		
GRID COOR./COL NO.		
MASTER YES ☐ NO ☒	SCALE: AS NOTED	

DATE		RFP	DOE	CLASS	JOB NO.
DESIGNED					
DRAWN	LEMME				
CHECKED					
APPROVED					
SUBMITTED					
APPROVED RFP					
APPROVED DOE					

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS AREA OFFICE GOLDEN, COLORADO

ROCKY FLATS
ROCKY FLATS PLANT
GOLDEN, CO

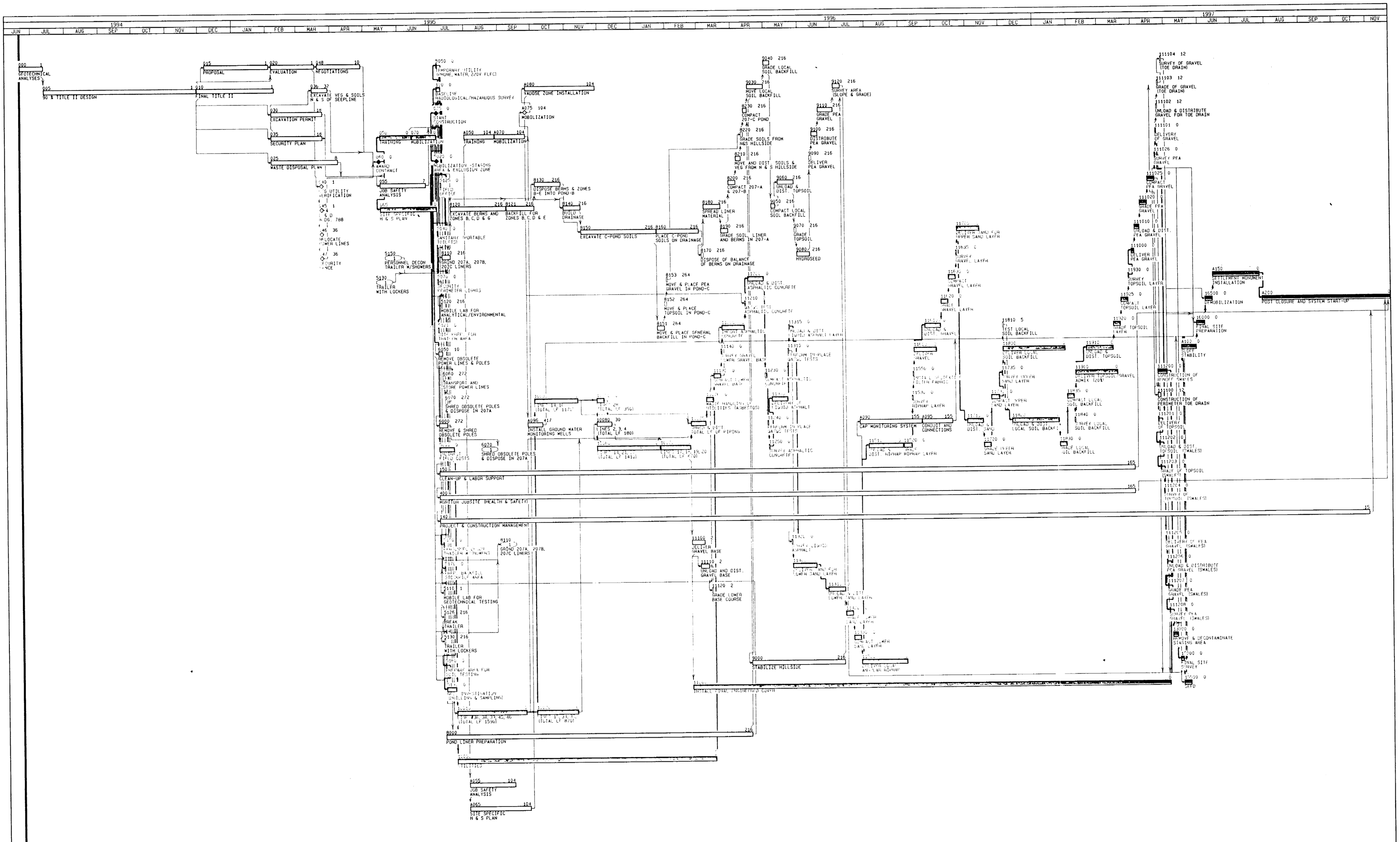
SOLAR EVAP PONDS OU4AG PHASE I IM

CROSS–SECTIONAL DETAIL OF ENGINEERED BARRIER COVER SHOWING POSITION OF TDR WAVEGUIDES SOLAR EVAPORATION PONDS, OPERABLE UNIT 4, ROCKY FLATS PLANT, GOLDEN, COLORADO

SIZE	DRAWING NUMBER	ISSUE	SHEET
B	FIGURE V.4–1	A	OF

FILENAME = FIGV4–1.DWG PLOT SCALE 1 = 100

"COMPUTER–GENERATED: NO MANUAL CHANGES ALLOWED"



Plot Date 24FEB94
Data Date 01JAN94
Project Start 01JAN94
Project Finish 01MAR97

Activity Bar/Total Float
Critical Activity
Progress Bar
Milestone/Key Activity
Connecting Activity on Sheet 2

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PLATE IV.6-1 OU4 IM/IRA
CONCEPTUAL SCHEDULE
TIME SCALED LOGIC DIAGRAM

Sheet 1 of 1

PROJECT SCHEDULE

Date	Revision	Checked	Approved