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Preliminary Design for an Engineered Surface Barrier at the Subsurface Disposal Area

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ABSTRACT

This report presents a preliminary design for an engineered surface barrier at the Subsurface Disposal Area, a radioactive waste landfill that is part of the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory. Contaminants in the landfill include hazardous chemicals, remote-handled fission and activation products, and transuranic radionuclides.

EXECUTIVE SUMMARY

This report presents a preliminary design for an engineered surface barrier at the Subsurface Disposal Area, a radioactive waste landfill that is part of the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory (INEEL). A surface barrier is an element of all remedial alternatives being evaluated for the landfill. Contaminants in the landfill include hazardous chemicals, remote-handled fission and activation products, and transuranic radionuclides.

To identify appropriate site-specific design features, the effects of waste types, distribution, characteristics, and transport properties on long-term performance of engineered surface barriers are analyzed. Considered in this analysis are hydrogeologic and climate conditions, as well as an examination of INEEL landfill barriers and test bed studies of barriers conducted at the INEEL. The objective of an engineered barrier is to prevent migration of contaminants from the landfill. Four preliminary performance criteria are identified to meet this objective: (1) minimize infiltration into and through the waste, (2) prevent gas buildup in the waste, (3) inhibit plant and animal intrusion, and (4) maintain performance for a 1,000-year period. Using these preliminary performance criteria, a number of existing alternative designs for engineered surface barriers are evaluated, and design features appropriate for the Subsurface Disposal Area are identified. A detailed cost estimate for three barrier alternatives is included in this report.

The conclusion from this evaluation is that an evapotranspiration barrier with a biobarrier most effectively meets the preliminary performance criteria and should be evaluated in the detailed analysis of remedial alternatives in the comprehensive remedial investigation/feasibility study for Operable Unit 7-13/14. Operable Unit 7-13/14 comprises the comprehensive remedial investigation and feasibility study for the Radioactive Waste Management Complex (Waste Area Group 7) at the INEEL.

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ACRONYMS

ABRA	Ancillary Basis for Risk Analysis
ACAP	Alternative Cover Assessment Project
ANL-W	Argonne National Laboratory-West
BORAX-1	Boiling Water Reactor Experiment-1
CA	Composite Analysis
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFA	Central Facilities Area
COC	contaminant of concern
CQA	construction quality assurance
CTB	Centennial Tectonic Belts
DEQ	(Idaho) Department of Environmental Quality
DOE	Department of Energy
EA	Environmental Assessment
EBTF	Engineered Barrier Test Facility
EPA	U.S. Environmental Protection Agency
ESRP	Eastern Snake River Plain
ET	evapotranspiration
FFA/CO	Federal Facility Agreement and Consent Order
HELP	Hydrologic Evaluation of Landfill Performance
IBC	International Building Code
ICDF	INEEL CERCLA Disposal Facility
INEEL	Idaho National Engineering and Environmental Laboratory
ISB	Intermountain Seismic Belt
NADP	National Atmospheric Deposition Program
NRF	Naval Reactors Facility

OU	operable unit
PC	performance category
PC/BE	Protective Cap/Biobarrier Experiment
PERA	Preliminary Evaluation of Remedial Alternatives
RCRA	Resource Conservation and Recovery Act
RFP	Rocky Flats Plant
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RWMC	Radioactive Waste Management Complex
SCS	Soil Conservation Service
SDA	Subsurface Disposal Area
SL-1	Stationary Low-Power Reactor-1
SVE	soil vapor extraction
TDR	time domain reflectrometry
TRU	transuranic
TSA	Transuranic Storage Area
TSCA	Toxic Substances Control Act
USGS	United States Geological Survey
VOC	volatile organic compound
WAG	Waste Area Group
WCF	Waste Calcining Facility
WRRTF	Water Reactor Research Test Facility

Preliminary Design for an Engineered Surface Barrier at the Subsurface Disposal Area

1. INTRODUCTION

This report presents a preliminary design for an engineered surface barrier at the Subsurface Disposal Area (SDA), a radioactive waste landfill that is part of the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL) (see Figure 1 for a map of the INEEL). Contaminants in the landfill include hazardous chemicals, remote-handled fission and activation products, and transuranic (TRU) radionuclides.

Examining barrier design as affected by waste types, distribution, characteristics, and transport properties in the SDA identified preliminary site-specific requirements for performance of the engineered surface barrier. Considered in this analysis are hydrogeologic and climate conditions, as well as barrier construction and previous test bed studies of barriers at the INEEL. Four preliminary performance criteria are identified to prevent contaminant migration from the landfill: (1) minimize water infiltration into and through the waste, (2) prevent gas buildup in the waste, (3) inhibit plant and animal intrusion, and (4) maintain performance for a 1,000-year period. Using these site-specific requirements for performance, a number of existing alternative designs for engineered surface barriers were evaluated.

The conclusion from this evaluation is that an evapotranspiration (ET) barrier with a built-in biobarrier most effectively satisfies preliminary performance criteria and should be evaluated in the detailed analysis of remedial alternatives in the comprehensive remedial investigation/feasibility study (RI/FS) for Operable Unit (OU) 7-13/14. Detailed cost estimates for the ET barrier and two other previous barriers have been included in this report.

This evaluation was made in support of OU 7-13/14, which comprises the comprehensive RI/FS for Waste Area Group (WAG) 7[a] at the INEEL. The RI/FS is being conducted under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 USC 9601 et seq.), as implemented by the Federal Facility Agreement and Consent Order (FFA/CO) (DOE-ID 1991). Except for the no action alternative, all alternatives being evaluated for the SDA include an engineered surface barrier (Holdren and Broomfield 2003, 2004).

1.1 Purpose

Initially, a draft version of this report was prepared to support roundtable discussions with Idaho Department of Environmental Quality (DEQ) personnel held on March 11, 2004, immediately after an Environmental Protection Agency (EPA)-sponsored Evapotranspiration Cover Workshop in Denver, Colorado. These discussions centered on alternatives for an engineered surface barrier for the SDA. The objective of this report is to develop a preliminary design for a surface barrier for the SDA that would meet performance criteria and address any additional issues based on site-specific features.

a. The FFA/CO lists 10 WAGs for the INEEL. Each WAG is subdivided into OUs. The RWMC is identified as WAG 7 and originally contained 14 OUs. Operable Unit 7-13 (transuranic pits and trenches RI/FS) and OU 7-14 (WAG 7 comprehensive RI/FS) were ultimately combined into the OU 7-13/14 comprehensive RI/FS for WAG 7.

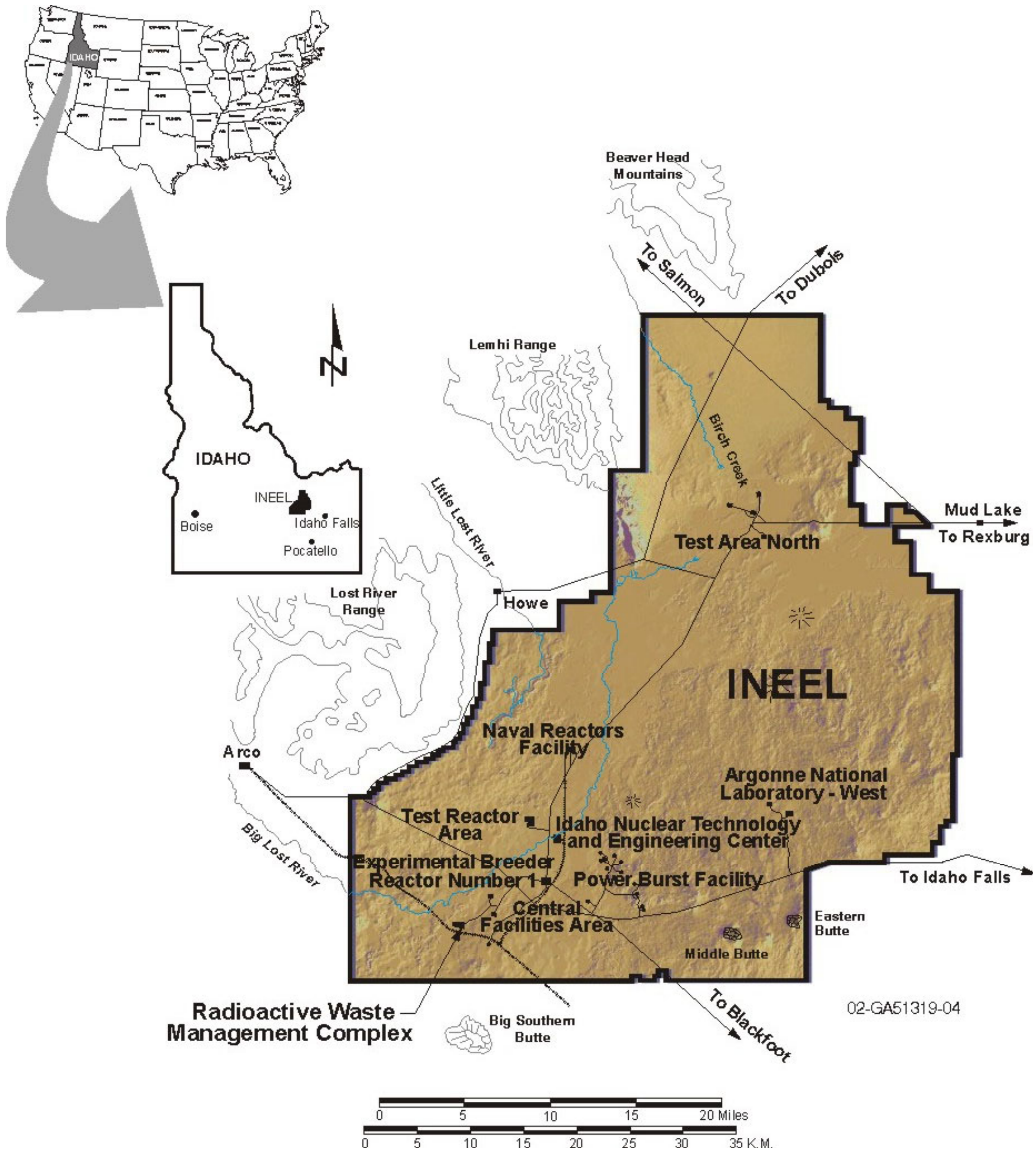

Figure 1. Map showing the locations of the Radioactive Waste Management Complex and other major facilities at the Idaho National Engineering and Environmental Laboratory.

A fundamental assumption for OU 7-13/14 is that the selected remedy will include a surface barrier and institutional controls in perpetuity (Holdren and Broomfield 2003). Therefore, all remedial alternatives being considered in the OU 7-13/14 feasibility study include an engineered surface barrier over the SDA (Holdren and Broomfield 2004). This report supports the comprehensive RI/FS for RWMC, which will be developed within the framework of CERCLA as implemented in the FFA/CO between the U.S. Department of Energy (DOE), DEQ, and EPA.

1.2 Scope

This report presents data in support of the development and recommendation of a preconceptual design for a barrier to be used in the feasibility study for OU 7-13/14. This report: (1) identifies preliminary performance criteria for a surface barrier for the SDA, (2) evaluates alternative designs for barriers, and (3) proposes a preferred design for the surface barrier. In addition, this report addresses DEQ questions posed at the roundtable discussions.

1.3 Brief History of the Subsurface Disposal Area

The SDA is a radioactive waste landfill located at the RWMC within the INEEL in southeastern Idaho (Figure 1). Contaminants in the landfill include hazardous chemicals, remote-handled fission and activation products, and TRU radionuclides. Located in the southwestern quadrant of the INEEL, RWMC's 71 ha (177 acres) is divided into three separate areas by function: the SDA, the Transuranic Storage Area (TSA), and the administration and operations area.

The original landfill, established in 1952, was called the National Reactor Testing Station Burial Ground. Now part of the SDA, the original landfill covered 5 ha (13 acres) and was used for shallow land disposal of radioactive waste. In 1958, the SDA was expanded to 36 ha (88 acres). Relocating the security fence in 1988 outside the dike surrounding the SDA established its current size of 39 ha (97 acres). The TSA was added to the RWMC in 1970. Located next to the east side of the SDA, the TSA's 23 ha (58 acres) is used to store, prepare, and ship retrievable TRU waste to the Waste Isolation Pilot Plant near Carlsbad, New Mexico. The 9-ha (22-acre) administration and operations area at RWMC includes administrative offices, maintenance buildings, equipment storage, and miscellaneous support facilities. For a map of RWMC disposal locations and facilities see Figure 2.

1.4 Regulatory Setting

The INEEL was added to the EPA's National Priorities List of Superfund sites (54 FR 48184 1989) under CERCLA (42 USC § 9601 et seq. 1980). The FFA/CO (DOE-ID 1991) established the procedural framework for evaluating and identifying appropriate actions that must be implemented to protect human health and the environment at the INEEL in accordance with the following:

- National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300 2003)
- CERCLA
- Resource Conservation and Recovery Act (RCRA) (42 USC § 6901 et seq. 1976)
- Idaho Hazardous Waste Management Act (Idaho Code § 39-4401 et seq. 1983).

The action plan attached to the FFA/CO includes the original schedule for developing, prioritizing, implementing, and monitoring response actions. The action plan provides for remediation of RWMC under the designation of WAG 7. The overall remediation of WAG 7 is currently being evaluated through a comprehensive CERCLA RI/FS under OU 7-13/14. The primary focus of the RI/FS is the SDA. Ultimately the RI/FS will lead to risk management decisions and selection of a final comprehensive remedial approach through development of a CERCLA record of decision (ROD) (DOE-ID 1999a). This evaluation of a landfill surface barrier for the SDA supports the RI/FS

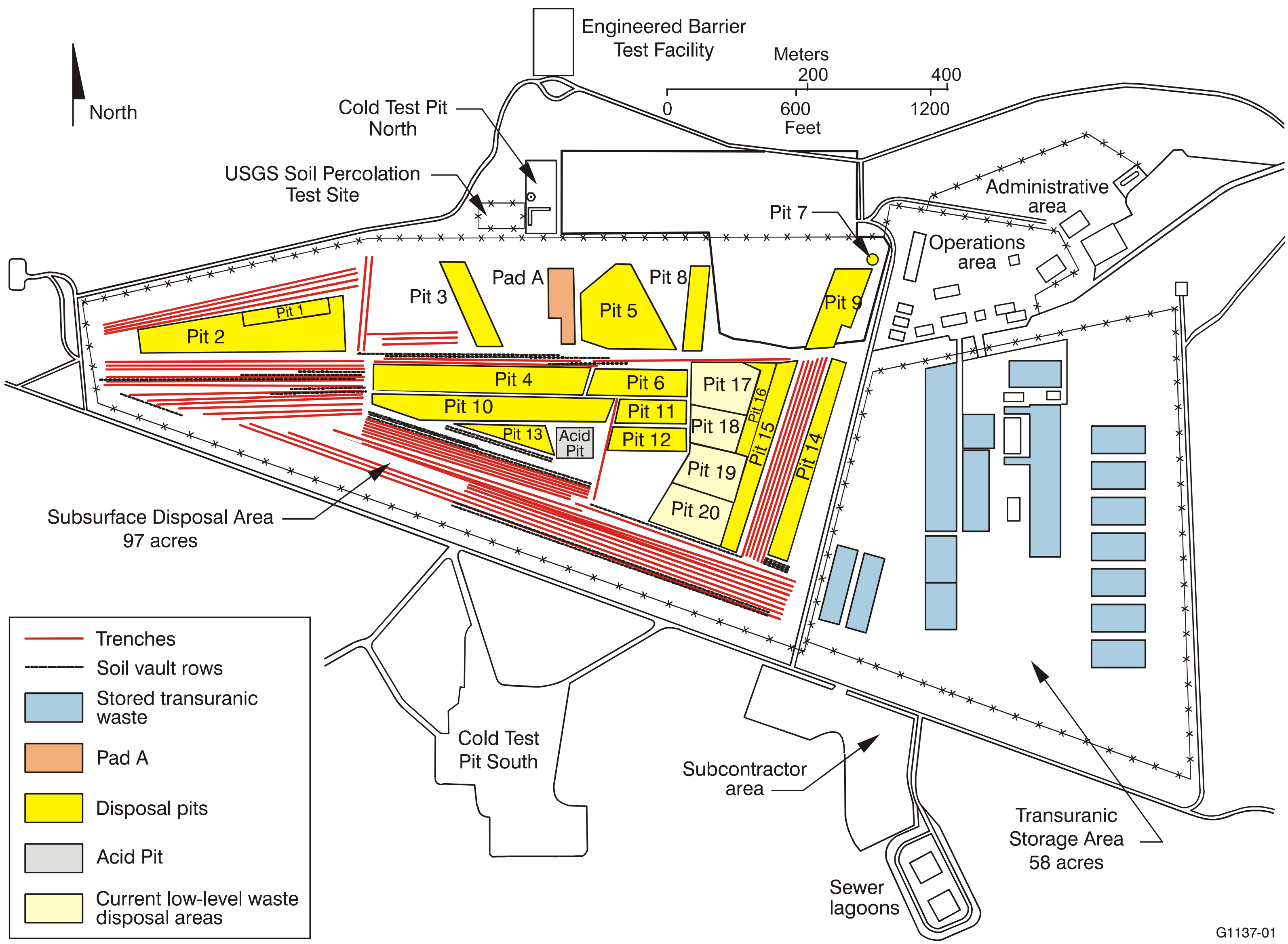

Figure 2. Map of the Radioactive Waste Management Complex showing the location of the Subsurface Disposal Area and the various disposal areas.

1.5 Document Organization

The remainder of this report is organized as follows:

- Section 2 provides a brief background of the SDA, including physical characteristics, waste types and their locations in the SDA, landfill surface barriers now in use at the INEEL, and regulatory considerations
- Section 3 discusses site-specific requirements for surface barrier performance and possible pretreatments before constructing the barrier at the SDA
- Section 4 describes the recommended design for the surface barrier
- Section 5 discusses monitoring of the installed surface barrier's performance
- Section 6 gives the cost estimates of three surface barrier designs
- Section 7 summarizes the report and discusses remaining uncertainties
- Section 8 lists the references cited in this report
- Appendix A provides the geophysical and hydrological characteristics of the site
- Appendix B gives the waste types and locations in the SDA
- Appendix C describes the landfill barriers in use at the INEEL
- Appendix D discusses the requirements for municipal solid waste landfills
- Appendix E provides characteristics specific to the SDA
- Appendix F discusses potential SDA remedial action alternatives
- Appendix G reviews conventional barrier designs
- Appendix H describes alternative landfill barrier designs
- Appendix I gives estimations of the performance of alternative barriers
- Appendix J discusses preliminary modeling of the hydraulic performance of surface barriers at the INEEL
- Appendix K reviews soil availability at the INEEL
- Appendix L describes performance monitoring
- Appendix M provides details of the construction cost estimate.

2. BACKGROUND

The following subsections contain a brief description of:

- Physical characteristics of the SDA that affect performance of a surface barrier (for a more detailed description see Appendix A, Detailed Geological and Hydrological Characteristics of the Site)
- Waste types and locations in the SDA (for a more detailed description see Appendix B, Waste Types and Locations in the Subsurface Disposal Area)
- Landfill surface barriers now in use at the INEEL (for a detailed description of the barriers, see Appendix C, Detailed Description of Landfill Barriers in Use at the Idaho National Engineering and Environmental Laboratory)
- Regulatory considerations that affect barrier design.

2.1 Site Physical Characteristics

A portion of the Snake River Plain Aquifer underlies RWMC at an approximate depth of 177 m (580 ft), and flows generally from the northeast to the southwest. The aquifer is bounded on the north and south by the edge of the Snake River Plain, on the west by surface discharge into the Snake River near Twin Falls, Idaho, and on the northeast by the Yellowstone basin. The aquifer consists of a series of water-saturated basalt layers and sediment.

The regional subsurface below a shallow (approximately 10 m [32 ft]) soil horizon is characterized by alternating layers of fractured basalt and sedimentary deposits called interbeds. The interbeds tend to retard infiltration to the aquifer (McElroy and Hubbell 2004) and are important in determining the rate of transport of contaminants toward the aquifer. In the 177-m (580-ft) interval from the surface to the aquifer, three major interbeds are of particular importance. Using nomenclature established by the United States Geological Survey (Anderson and Lewis 1989), these sedimentary layers are referred to as the A-B, B-C, and C-D interbeds. Surficial sediments resulting from fluvial, lacustrine, and aeolian deposition are similar to the sedimentary interbeds, though surface sediments are less mature and little stratigraphic layering remains in the soil used to bury waste.

The Snake River Plain is an arid environment with an average annual precipitation of 23 cm/year (9 in./year). Infiltration of water occurs episodically from rain and snowmelt. The soil horizon at the SDA is unsaturated most of the year and underlying formations are characterized as a vadose zone.

2.2 Brief Description of Waste Types, Locations, and Disposal Practices

The SDA is a radioactive waste landfill with shallow subsurface disposal units consisting of pits, trenches, and soil vaults. Contaminants in the landfill include hazardous chemicals, remote-handled fission and activation products, and TRU radionuclides. Waste acceptance criteria and record-keeping protocols for the facility have changed over time in keeping with waste management technology and legal requirements. When the SDA was created, requirements for disposals were much less stringent than today’s requirements, which have been developed from knowledge gained over the past several decades about potential environmental impacts of waste management techniques. In the past, however, shallow landfill disposal of radioactive and hazardous waste was the technology of choice. The general layout of the SDA, showing relative locations of individual disposal units, is shown in Figure 2.

At the SDA, disposals of TRU waste—mostly from Rocky Flats Plant (RFP) in Colorado—were allowed through 1970. Buried RFP TRU waste is located primarily in Pits 1 through 6 and 9 through 12, and Trenches 1 through 10. Disposal of mixed waste containing hazardous chemical and radioactive contaminants was allowed through 1983. Since 1984, waste disposals in the SDA have been limited to low-level radioactive waste generated at the INEEL. Construction, operation, and decommissioning of the INEEL nuclear reactor testing programs have resulted in large volumes of waste. See Appendix B for a detailed listing of waste types and locations, including maps showing locations of specific contaminants.

Disposal practices have varied widely across the SDA over time because of more stringent regulations, varying types of waste disposed of, and increasing concern for worker exposure to hazardous and radioactive wastes. Originally, waste containers were stacked, but concern for workers' health resulted in dumping containers instead. Larger individual items—such as tanks, furniture, process and laboratory equipment, engines, and vehicles—were placed separately as loose trash. Various containers were used for shipping and disposing of waste, including steel drums (i.e., 30-, 40-, and 55-gal), cardboard cartons, and wooden boxes (as large as 267 × 267 × 544 cm [105 × 105 × 214 in.]). Some disposals received limited compaction from steel plates being dropped on the disposal location. These practices have resulted in widely varying potential across the SDA for large and small void spaces in the buried waste. Possible subsidences in the SDA caused by collapse of these void spaces may affect the performance of a surface barrier.

2.3 Landfill Barriers in Use at the Idaho National Engineering and Environmental Laboratory

The following subsections describe briefly the surface barriers now in use at the INEEL, their expected duration, and available performance results. For a detailed description of each of the barriers, see Appendix C. Figure 3 shows the location of the landfills, barrier test beds, and potential borrow sources for an SDA barrier. Table 1 briefly summarizes a comparison of all these barriers.

2.3.1 Central Facilities

A remedial action under CERCLA placed final barriers over each of the Central Facilities Area (CFA) Landfills I, II, and III in 1996. Each surface barrier consisted of: (1) a general backfill layer that brought the existing grade up to the design slope (rough grade), (2) a compacted low-permeability soil layer, and (3) a topsoil layer that created the final grade and allowed for growth of a vegetative cover. The general background material is composed of clay with sand. The final topsoil layer was not compacted. In addition, for Landfill II, a riprap layer was installed at the extreme northeast face of the landfill, rather than revegetating the area, to prevent erosion because of the steepness of the slope. A detailed description of the remedial action, including the installation of the landfill barriers, is provided in the *Remedial Action Report for CFA Landfills I, II, and III Native Soil Cover Project Operable Unit 4*-12 (DOE-ID 1997).

The monitoring plan for the CFA Landfills provides data for evaluating whether the remedial action is meeting the remedial action objectives stated in the ROD (DOE-ID 1995). In particular, the monitoring data will be used to evaluate the remedial action objectives to minimize infiltration and ensure that drinking water standards are not exceeded in the Snake River Plain Aquifer because of contaminant migration from the landfills. The monitoring plan for the CFA Landfills includes monitoring groundwater, vadose zone, and infiltration at all three landfills to:

- Monitor the flux of moisture through the landfill's surface barriers on a monthly basis

- Monitor the soil gas volatile organic compounds (VOCs) and methane concentrations in the vadose zone near each landfill annually in the fall

- Monitor the concentrations of contaminants in the groundwater near the landfills annually in the fall

- Establish a baseline of potential contaminant concentrations in the aquifer against which future data could be compared

- Monitor the groundwater flow direction in the aquifer near the landfills annually in the fall.

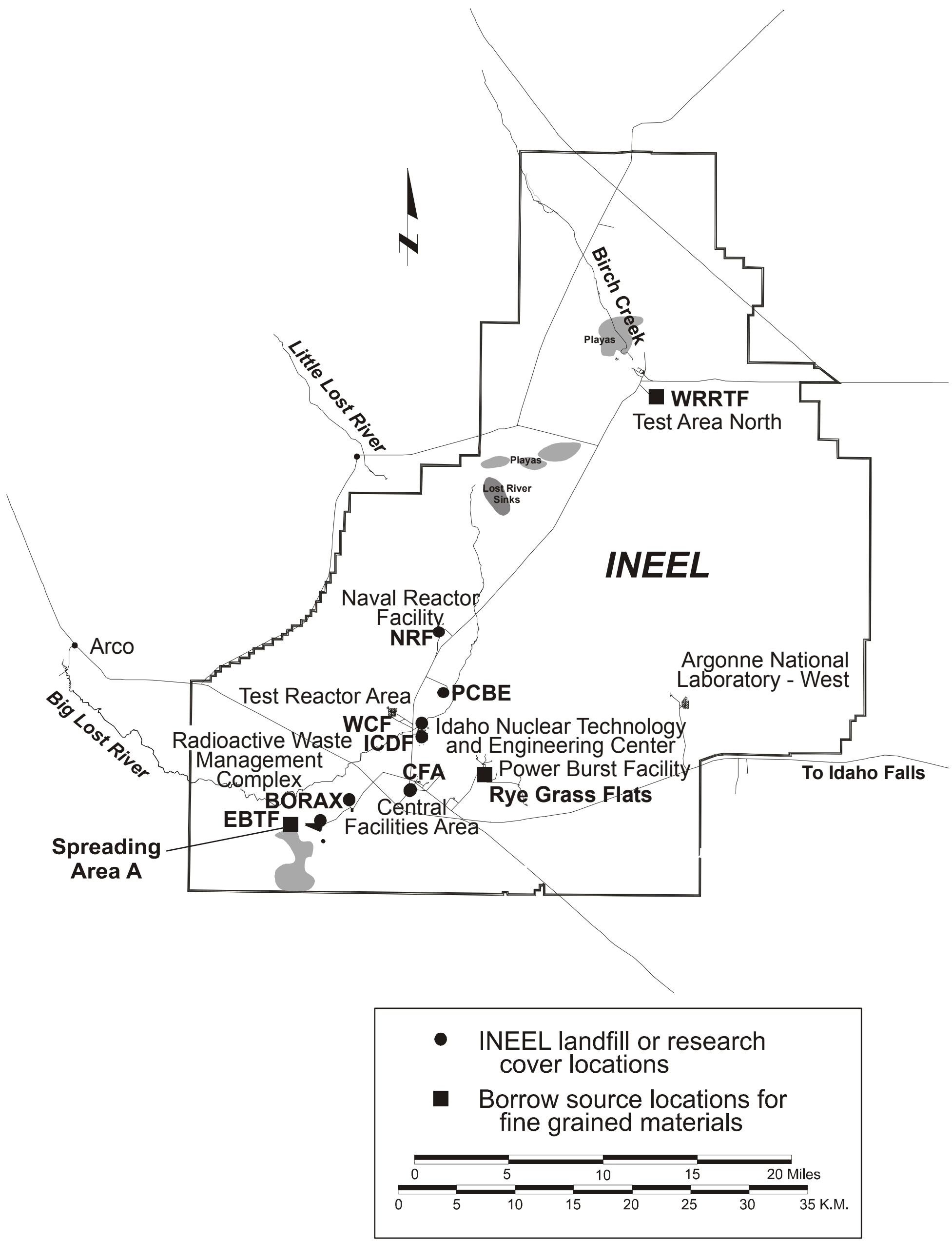

Figure 3. Location of Idaho National Engineering and Environmental Laboratory landfills, barrier test beds, and potential borrow sources.

Table 1. Summary of Idaho National Engineering and Environmental Laboratory landfills and their barriers.

LANDFILL					BARRIER							
Name	Type	Installed (yr)	Waste Disposal Method	Contents	Type (date installed)	Total Thickness m (ft)	Vegetative Cover Thickness m (ft)	Biobarrier Thickness m (ft)	Geomembrane	Surface Slope (%)	Gas Venting	Monitoring System
Central Facilities Area Landfill I	Municipal	Early 1950s	Trenches	Construction debris, paper, cafeteria garbage, wood, paper, and flammable materials	Native soil ET (~1984 and 1996)		Yes	NA	None		None	Cap—TDR and neutron probe Vadose—soil gas Aquifer—monitoring wells
Central Facilities Area Landfill II	Municipal	1972	Direct disposal	Trash sweepings, cafeteria garbage, wood and scrap lumber, masonry/concrete, metals, and liquid waste	Native soil ET (~1984 and 1996)		Yes, with riprap over northeast face	NA	None		None	Cap—TDR and neutron probe Vadose—soil gas Aquifer—monitoring wells
Central Facilities Area Landfill III	Municipal	1982	Trenches	Trash sweepings, cafeteria garbage, wood and scrap lumber, masonry and concrete, waste asphalt, and paint	Native soil ET (~1984 and 1996)		Yes	NA	None		None	Cap—TDR and neutron probe Vadose—soil gas Aquifer—monitoring wells
Stationary Low-Power Reactor-1 landfill	Radiological	1961	Trenches and pits	Entire reactor building contaminated by critical nuclear reaction	RCRA biobarrier (1997)	0.56 (1.8)	None	0.56 (1.83)	None		None	Surface—radioactivity sampling Cap—TDR and neutron probe Vadose—soil gas Aquifer—monitoring wells
Boiling-Water Reactor Experiment-1 landfill	Radiological	1954	Buried	Radioactive debris and fuel fragments from destructed nuclear reactor	RCRA biobarrier (1997)	1.5 (4.9)	None	1.5 (4.9)	None	Mounded	None	Surface—radioactivity sampling
Naval Reactors Facility landfills	Municipal				ET (1996)	1 (3.3)	Wheatgrass and Lewis flax	NA	None	3%	None	Vadose—soil gas Aquifer—monitoring wells
Naval Reactors Facility landfills	Radiological	2004	Leach fields	Soil	ET with biobarrier (2004)	1.75 (5.7)	Grasses and forbs	0.45 (1.5)	None		None	Surface—radioactivity sampling Cap—neutron probe Aquifer—monitoring wells
Waste Calcining Facility	Radiological	1963	Collapsed structure—in situ grouted	Radioactive and hazardous constituents	Reinforced concrete slab (1996)		NA		None	1%	None	Cap—visual inspection for cracks Aquifer—monitoring wells
INEEL CERCLA Disposal Facility	RCRA	2000	Direct disposal	CERCLA (radioactive and hazardous constituents)	Modified Hanford (in design only)	5.35 + (17.6)	0.31 (1.0)	1.38 (4.5)	Yes	3%	Yes	Aquifer—monitoring wells
Protective Cap/Biobarrier Experiment	8 × 8 m test plots	1993	NA	NA	ET (1993)	2 (6.6)	1) Wheatgrass, 2) 12 native plants	0	None	0	None	Cap—soil moisture, changes vegetation, and plant rooting depths
Protective Cap/Biobarrier Experiment	8 × 8 m test plots	1993	NA	NA	ET with shallow biobarrier (1993)	2.5 (8.2)	1) Wheatgrass, 2) 12 native plants	0.5 (1.6)	None	0	None	Cap—soil moisture, changes vegetation, and plant rooting depths
Protective Cap/Biobarrier Experiment	8 × 8 m test plots	1993	NA	NA	ET with deep biobarrier (1993)	2.5 (8.2)	1) Wheatgrass, 2) 12 native plants	0.5 (1.6)	None	0	None	Cap—soil moisture, changes vegetation, and plant rooting depths
Protective Cap/Biobarrier Experiment	8 × 8 m test plots	1993	NA	NA	RCRA (1993)	1.6 (5.3)	1) Wheatgrass, 2) 12 native plants	0	Yes	0	None	Cap—soil moisture, changes vegetation, and plant rooting depths

LANDFILL					BARRIER							
Name	Type	Installed (yr)	Waste Disposal Method	Contents	Type (date installed)	Total Thickness m (ft)	Vegetative Cover Thickness m (ft)	Biobarrier Thickness m (ft)	Geomembrane	Surface Slope (%)	Gas Venting	Monitoring System
Engineered Barrier Test Facility	4 – 3 × 3 m cells	1996	NA	NA	ET (1996)		None	0	None	0	None	Cap—tensiometers, TDRs, heat dissipation sensors, thermocouples, and neutron probe
Engineered Barrier Test Facility	4 – 3 × 3 m cells	1996	NA	NA	Capillary barrier (1996)	2.51 (8.2)	None	0.76 (2.5)	Yes	0	None	Cap—tensiometers, TDRs, heat dissipation sensors, thermocouples, and neutron probe

CERCLA—Comprehensive Environmental Response, Compensation, and Liability Act
ET—evapotranspiration
INEEL—Idaho National Engineering and Environmental Laboratory
TDR— time domain reflectometry

2.3.2 Stationary Low-Power Reactor-1 and Boiling-Water Reactor Experiment-1

The design life of the surface barriers on the Stationary Low-Power Reactor-1 and Boiling-Water Reactor Experiment (BORAX)-1 landfills was based on reducing total excess cancer risk for all contaminants to less than 1 in 10,000 for 400 years and 320 years, respectively (INEL 1995). The objective of these surface barriers is to protect against surface exposures. Groundwater pathways were not identified as risk drivers for these landfills. Therefore, the barriers were designed to endure erosive effects of wind and water, allowing them to maintain an acceptable depth of cover over the course of their expected life based on the soil types and addition of a riprap layer. Avoiding water infiltration through the waste was not an objective. Areas adjacent to both barriers were graded to encourage drainage around and away from the capped landfill site to diminish erosion of the surface soils and barrier materials. The surrounding area also was planted in native grass species to slow surface water flow velocities and provide additional erosion protection.

Although the surface barrier is operating as expected, rodent activity has been noted during annual landfill inspections; specifically, "extensive evidence of rabbit activity around the barrier at SL-1" (INEEL 2003). Rabbits are probably using the boulder field for shelter. The annual inspection also noted that new spring growth of grass was well established.

2.3.3 Naval Reactors Facility

The Naval Reactors Facility (NRF) has surface barriers on both municipal and radiological landfills (installed in 1996 and the summer of 2004, respectively). The barriers consist of a soil layer that permits ET and improves surface drainage away from the waste. The barriers have a slope of 3%, include a topsoil layer to support vegetation, and a subsurface soil layer for moisture control. The 1997 annual inspection of the municipal barriers indicated that vegetation was sparse; the vegetation was reseeded (NRF 2001). The 5-year annual report (NRF 2001) states that the barriers are performing as designed with the exception of the problems with establishing the vegetation on the surface and minor erosion on one landfill.

Because it was constructed this year, no performance results are available for the radiological landfill. However, post-closure monitoring of the radiological barrier includes radioactive surveys over the barrier and collecting soil and vegetation samples to assess the effectiveness of the barrier in reducing contaminant release. Infiltration of moisture through the barrier will be monitored using neutron probes in vertical access tubes. In addition, groundwater will be monitored to assess effectiveness (NRF 2002).

2.3.4 Waste Calcining Facility

The Waste Calcining Facility (WCF) was closed with radioactive and hazardous constituents in place and met the closure requirements applicable to landfills by the construction of an engineered concrete barrier over the facility (WCF96a). Belowground voids created by vessels and cells were filled with grout to prevent subsidence and maintain the integrity of the barrier (Piet et al. 2003). The barrier extends about 1.5 m (5 ft) past the ground level footprint of the WCF building. Water stops were installed in the joints in the barrier. The concrete barrier functions with a minimum of maintenance, reduces erosion, and promotes drainage away from the landfill because of the graded surface.

Post-closure monitoring includes groundwater monitoring. The concrete barrier is being monitored at least annually for cracks in each section of the barrier and joints will be inspected for loss or degradation of the joint between sections. Construction is too recent to evaluate effectiveness of this barrier.

2.3.5 INEEL CERCLA Disposal Facility

The surface barrier for the INEEL CERCLA Disposal Facility (ICDF) landfill is designed to minimize infiltration, maximize run-off, and protect against inadvertent intrusion for more than 1,000 years. It meets the requirements of RCRA Subtitle C, and the requirements for landfill design and construction for polychlorinated biphenyls from the Toxic Substances Control Act (TSCA). The ICDF landfill accepts radioactive low-level, mixed low-level, hazardous, and TSCA waste generated from INEEL CERCLA activities. Although not yet built, to be protective of the Snake River Plain Aquifer the surface barrier's preliminary design has three layers:

- Upper layer—stores water (top 2.7 m [9 ft]) during wet periods for later release during dry periods. The upper section will be seeded with native vegetation that will include wheatgrass, bluegrass, bottlebrush squirreltail, and green rabbitbrush.

- Middle layer—protects against biointrusion from burrowing animals and provides a capillary break; approximately 1.4-m (4.5-ft) thick.

- Lower layer—a composite liner system that complies with the Idaho Administrative Procedures Act 58.01.05.008 (40 CFR 264.310); minimum of 1.2-m (4-ft) thick and 4 m (13 ft) below the surface of the barrier.

2.3.6 Protective Cap/Biobarrier Experiment

The Protective Cap/Biobarrier Experiment (PC/BE) started in 1993 at the Experimental Field Station to compare four different ET barrier designs. These studies provide data for design of an "effective, economical surface barrier for the INEEL and climatically similar repositories, a surface barrier constructed of natural materials that will function with minimal maintenance over the long term as a natural ecosystem" (Anderson and Forman 2003). Four different landfill barrier configurations were constructed in a series of heavily instrumented 8 × 8-m (26 × 26-ft) plots to assess the effect of differences in vegetation community and climate. All barrier configurations, vegetation types, and combinations of precipitation and irrigation were replicated three times. Results of the first 7 years of the PC/BE are available in Anderson and Forman (2003).

Water balance monitoring indicates that all four barriers effectively eliminate water flux into underlying material, even when testing the effect of increased summer rainfall. Under increased winter precipitation, however, only the soil-only barrier and biobarrier were able to prevent moisture infiltration through the barrier. Monitoring data indicate that results would be the same even under much larger increases in precipitation. Because regional precipitation occurs primarily in the winter at the INEEL, increased precipitation rates would be most likely to occur during spring snowmelt.

Field studies of plant species suggest that design of an ET barrier should include consideration of the plant species. The growth of some deep-rooted species resulted in intrusion through shallow biobarriers and could present a mechanism for contaminant transport to the surface; however, extraction of water from below the barrier near these roots was generally high (i.e., greater than 25% by volume).

2.3.7 Engineered Barrier Test Facility

The Engineered Barrier Test Facility (EBTF) is a concrete structure consisting of five cells (i.e., plots) on each side of an enclosed access trench, ten cells in total. Each cell has four walls and a floor, and measures 3.0 m wide × 3.0 m long × 3.0 m deep (10 × 10 × 10 ft). The top of each cell is open to the atmosphere. Each cell has two floor drains that empty into separate sumps in the access trench. This trench is also a protected area for housing the data acquisition system and those instruments (e.g., tensiometers) that penetrate the cell walls. Test barriers are designed to exploit the transpiration capabilities of plants to extract water that infiltrates into the surface barriers. However, during the present testing period, all test plots have been kept free of vegetation to allow evaluation of the behavior of the barriers under the most extreme hydrologic conditions that are likely to occur. Each test plot is heavily instrumented to continuously measure soil moisture, soil moisture tension, soil temperature, and drainage.

Relatively rapid melting of accumulated snowfall produced the most significant infiltration events each year during the study. Capillary barriers yielded less total drainage than thick soil barriers. By limiting drainage, capillary barriers increased water storage in the upper portions of the test plots, which led to increased evaporation from the capillary barrier plots compared with thick soil plots. Increased evaporation in the capillary barrier plots allowed more water to infiltrate in the second season following the wetting tests, but without triggering drainage. All thick soil plots again yielded drainage in the second season. Within two years of intentionally induced breakthrough, evaporation alone (without transpiration) restored the capability of the capillary barriers to function as intended, although water storage in these barriers remained high (Porro 2001).

2.4 Regulatory Considerations Affecting Design of Surface Barriers

Regulations for sanitary landfills (40 CFR 258) and hazardous and mixed waste landfills (40 CFR 264, 40 CFR 265, EPA/625/4-89/022) generally require landfill barriers to minimize infiltration of moisture into the underlying waste while also minimizing surface erosion. With traditional barriers, applicable regulations and EPA design guidance documents give specific requirements for a barrier profile in meeting these criteria (see Appendix D, Requirements for Municipal Solid Waste Landfills, for specific requirements of both municipal and hazardous and mixed waste landfills).

The EPA's guidance for the design and construction of final barriers under RCRA and CERCLA (EPA 1991) emphasizes that proper closure is essential to complete a waste landfill. The EPA's general approach to barrier design has been to prescribe general design criteria for a final barrier that meet the stringent closure regulations specified under RCRA. However, the EPA does allow for final barrier designs that consider site conditions and encourages alternative designs that are innovative and use site-specific information.

The minimum requirements specified by RCRA require that—to protect public health and the environment—a barrier must:

- Minimize liquid migration
- Promote drainage while controlling erosion
- Minimize maintenance
- Have permeability equal to or less than the permeability of the natural subsoil
- Account for freeze/thaw effects
- Accommodate settling and subsidence so that the barrier's integrity is maintained.

3. SITE-SPECIFIC REQUIREMENTS FOR BARRIER PERFORMANCE

The 1989 EPA guidelines (EPA 1989b) focus design criteria on minimizing water infiltration through the surface barrier, although contaminant transport through liquid advection is not the only potential transport mechanism that could endanger human health and the environment. In addition to general regulatory considerations, requirements specific to the SDA are based on contaminant types, their dominant transport mechanisms, and their locations. Four preliminary performance criteria for the SDA design are specified:

- Minimizing liquid migration is qualitative, making performance monitoring of the surface barrier problematic. Because of climatic conditions at the INEEL, quantitative performance-based criteria of water infiltration through the SDA surface barrier are suggested as a goal to meet the requirement of minimizing liquid migration beneath the barrier.

- Waste characteristics and transport properties will require additional performance criteria to protect human health and the environment. Gas transport of chlorinated solvents and radionuclides must also be evaluated to their potential of impacting the environment.

- Potential for both animal and plant biotic intrusion to bring SDA waste material to the barrier surface must be addressed.

- A 1,000-year surface barrier performance period has been adopted as a design criterion because of the long half-lives of radioactive contaminants buried at the SDA.

The following subsections summarize discussion of site-specific requirements for barrier performance (see Appendix E, Characteristics Specific to the Subsurface Disposal Area, for more detailed discussion of these requirements).

3.1 Moisture Infiltration

An infiltration flux-based performance criterion for the SDA barrier of 1 cm (0.4 in.) per year is proposed. This water flux value is consistent with the Composite Analysis for the SDA (McCarthy et al. 2000) and the Performance Assessment for the SDA (Case et al. 2000), is within the range of the expected performance of natural materials, and is a reasonable value to achieve for the SDA surface barrier.

Modeling of moisture transport—Attempts to calibrate the SDA dissolved-phase transport model have been hampered by several factors, primarily lack of adequate calibration targets. To compensate for the lack of calibration targets, the model was implemented using conservative parameters, and therefore, over-predicts contaminant concentrations compared to monitoring results. Although the SDA transport model is not calibrated sufficiently, the modeling results using these conservative assumptions can provide an upper limit of allowable percolation through an SDA surface barrier.

Modeling will be updated for the RI/FS. Until then, this preliminary conceptual design will assume a performance criterion of 1 cm/yr (0.4 in./yr) (3×10^{-8} cm/sec) as an acceptable infiltration flux. This flux value was chosen based on the results of the RWMC Performance Assessment (Case et al. 2000) and Composite Analysis (McCarthy et al. 2000). The 1-cm/yr (0.4 in./yr) flux was originally obtained from the barrier modeling study for the SDA by Magnuson (1993) and is consistent with water flux rates calculated by Cecil et al. (1992). In addition, the 1-cm/yr (0.4 in./yr) water flux rate through the surface barrier should be achievable according to chloride mass balance results presented in this report (see Appendix A).

Surface barrier less permeable than underlying sediments—A second potential infiltration performance issue for the SDA is the requirement for the surface barrier to be less permeable than the underlying sediments. Few measured hydraulic properties have been made of undisturbed soils beneath the SDA. Inverse modeling results indicate that the surface barrier should be designed with a saturated hydraulic conductivity less than 1×10^{-5} cm/sec to minimize the development of perched water within the SDA waste.

Construction materials most likely to be used in building the SDA barrier are sufficiently fine to meet requirements for permeability of the surface barrier. A study conducted by Smith et al. (1994) includes the results of physical properties analysis of soil samples taken from two areas that will probably be used to obtain additional soil materials. The hydraulic properties of both areas of fine-grained borrow soil show lower permeability than the undisturbed soil beneath the SDA.

3.2 Gas Transport and Heat

Release and transport of vapors is affected by temperature and barometric pressure. Gaseous transport to the atmosphere is significant at the SDA because the buried waste is near the land surface. Design of a surface barrier for the SDA must accommodate or minimize gas transport within the barrier. For this preliminary analysis, the assumption is that the SDA barrier will require a venting system to remove VOCs and C-14. Installation of a surface barrier over the SDA without a venting system would reduce the fraction of gas that is presently vented to the atmosphere through the soil surface. The barrier soil would reduce the surface flux and result in a higher gaseous concentration in the waste zone. These gaseous contaminants would be vented around the barrier to the surface and transported deeper into the subsurface. However, the transport of gas is a complex process that includes distance from the source to the boundary of interest, soil moisture content, gas-aqueous partitioning, water flux, solid-aqueous partitioning, soil-gas diffusion coefficients, and barometric pressure variations. The potential increase of risk to the groundwater from installing an impermeable barrier has not been evaluated in the current SDA risk models. Before the final design of the barrier can be completed, effects on gas transport from the SDA should be carefully analyzed.

Heat generated by biological degradation of organics and radioactive decay of the waste has been preliminarily evaluated to determine whether the soil is sufficiently heated near the waste to effect contaminant transport. This preliminary evaluation indicates that the heat generated by radionuclide decay of radioactive wastes or biological decay of organic wastes will not be a significant variable in the landfill barrier design.

3.3 Biological Intrusion

Based on ecological contaminants of concern (COCs) discussed in the Ancillary Basis for Risk Analysis (ABRA), a biotic intrusion layer is necessary to inhibit animal and plant intrusion into the wastes (Holdren et al. 2002). Biological intrusion is generally controlled through the incorporation of barriers that are designed to prevent or limit the contact of plant roots or burrowing animals with buried waste. The ABRA identified seven ecological COCs where the primary pathways of ecological concern were associated with burrowing animals and insects and plant uptake (Holdren et al. 2002). Therefore, a biobarrier layer to protect the SDA waste from biotic intrusion will be a required element of the future surface barrier (DOE-ID 1998; Holdren and Broomfield 2003). See Appendix E for a more detailed discussion of biotic intrusion.

3.4 Subsidence

Waste subsidence in the SDA is well documented and has been occurring for more than 20 years (Keck and Seitz 2002). Subsidence events with areal extents of yards and depths of feet have been observed with regularity, but appear to be more common in certain locations (e.g., Pad A) (Keck and Seitz 2002). Dimensions, depths, and specific locations for some individual occurrences were recorded during routine inspections (Keck and Seitz 2002).

In general, landfills that rely on a drainage layer and are expected to experience large amounts of differential settlement—such as the SDA—should not be closed with barriers including a geomembrane or thin multiple layers. Geomembranes can tear because of the high tensile stresses caused by differential settlement and serve as a funnel for surface water into the landfill. Multiple layers used for drainage, such as those found in a traditional RCRA Subtitle C landfill barrier or the ICDF barrier, could be severely damaged by discontinuities formed through continued differential settling. Because of the variability of the waste types and disposal methods (i.e., pits, trenches, and soil vaults), avoiding the use of geomembrane material and other synthetic layers is recommended.

For this report, the assumption is that some differential subsidence will occur after the barrier is installed. Therefore, the preliminary barrier design does not include geomembrane layers, asphalt layers, or a series of thin multiple layers. Before final design, additional analyses of the SDA waste types, location, and subsidence history should be used in evaluating critical areas of probable future subsidence. This analysis can then be used to examine deformation of the biointrusion layer resulting from these potential subsidences.

3.5 Longevity

Longevity of the SDA barrier was evaluated in relation to erosion, plant species, and hydraulic property evolution. Preliminary design criteria used to develop the conceptual design described in this document include the DOE-specified 1,000-year performance period specified in DOE Order 435.1. Longevity issues affecting the SDA surface barrier design not described elsewhere in this report include effects of water and wind erosion of the surface and wild fires killing the vegetation on the surface barrier.

A gravel admixture generally protects a barrier from long-term wind erosion. The protection from water erosion will depend on the depth, velocity, and duration of water flowing across the landfill barrier. Potential surface water flow at the SDA is limited to precipitation and runoff. These flow values can be established from the physical properties of the surface barrier (e.g. slope, convex or concave grading, slope uniformity, and length of flow paths) and the intensity of the precipitation water (e.g., precipitation rates, infiltration versus runoff relationships, snowmelt, and offsite flows).

Based on the above, a gravel admixture for a landfill surface barrier must be focused on maintaining long-term ecological stability and protection of the soil barrier from runoff generated by a major storm event. The degree of the barrier slope must be examined to find a balance between surface runoff and allowable infiltration into the ET barrier. Anderson and Forman (2003) recommend a very shallow slope to ensure sufficient moisture in the barrier for the survival of vegetation.

Other barrier longevity issues were examined using infiltration flux calculations from a borehole near the SDA. Using chloride data collected by Cecil et al. (1992) (see Appendix A), preliminary calculations indicate that the soil moisture at a depth of 5.5 m (18 ft) is approximately 20,000 years old, indicating a flux rate of 0.1 mm/yr (0.004 in./yr). These results suggest that percolation rates beneath the root zone of the plants is very small and has been very small over the last 20,000 years in soils near the

SDA. These results possibly represent effective percolation rates that also incorporate thousand of years of plant evolution, fires, and potential changes in soil evolution. However, these results are from a single borehole near the SDA and may not be completely representative of how an ET barrier may perform.

3.6 Prebarrier Treatment Options and Effects on Barrier Design

Except for the no action alternative, all alternatives being evaluated for the SDA include an engineered surface barrier (Holdren and Broomfield 2003). Remedial decisions for the SDA ultimately will be determined in a CERCLA ROD. The feasibility study being prepared to support the ROD will examine several remedial action alternatives, including in situ grouting to reduce migration of contaminants, retrieval for selected waste streams, and containment with a surface barrier. The Preliminary Evaluation of Remedial Alternatives (Zitnik et al. 2002) contains a complete description of these alternatives. Potential pre-barrier treatment options consistent with alternatives identified in the *Second Addendum to the Work Plan for the OU 7-13/14 Waste Area Group 7 Comprehensive Remedial Investigation/Feasibility Study* (Holdren and Broomfield 2004) were examined in relation to their effect on the design of a surface barrier at the SDA and are summarized in the following (see Appendix F, Subsurface Disposal Area Potential Remedial Action Alternatives, for more detailed discussions of these pre-barrier treatment options):

- **In situ grouting**—A technique developed in the construction industry and adapted for environmental use. The process entails injecting a slurry-like mixture of grouts (including cements, chemical polymers, or petroleum-based waxes) into contaminated soil or a waste landfill. The process employs nondisplacement jet grouting, mixing soil and waste debris with grout-forming materials in the subsurface to create a large grout monolith (DOE-ID 1999b; Loomis, Zdinak and Bishop 1997) or a series of columns. Overall volume of the waste site remains constant, but density of the site is substantially increased as grout fills void spaces between discrete waste components.

- **Retrieval, treatment, and disposal**—Waste removed from a site can be treated to reduce toxicity and mobility of many chemicals. Removed and treated material can then be disposed of in an approved engineered facility. Retrieval removes or greatly reduces risk associated with the site if the retrieved waste is disposed of offsite or is isolated from the environment. Typically, removing waste and reducing the contaminant source can reduce long-term site monitoring and maintenance requirements. For some sites, complete removal of waste can satisfy requirements for unrestricted land use. However, for the SDA it is assumed that long-term institutional controls will be required in perpetuity (Holdren and Broomfield 2003).

- **Soil vapor extraction (SVE)**—Also known as soil venting or vacuum extraction, a vacuum is applied through wells near or within the contamination source to extract volatile constituents. Extracted vapor is treated and released to the atmosphere. Extraction and injection wells may be installed either vertically or horizontally. Soil vapor extraction would accelerate the removal of VOCs from the waste and increase the void volume of the waste in those areas. If the areas are small and are surrounded by well-compacted soil or waste, or if in situ grouting has been used to create pillars within the area, then the barrier should not be affected.

  A second option is to apply SVE after the barrier is in place. The SVE system would draw vapor from the gas permeable layer of the barrier; this process might also accelerate the removal of other vapor-phase contaminants, such as tritium and C-14. However, in situ grouting or other techniques (e.g., dynamic compaction) can enhance the physical stability of the waste before building the barrier; thus removal of VOCs would not threaten the physical stability of the surface barrier.

- **Pad A removal**—More than 20,000 waste containers, including 55-gal drums and plywood boxes, are now stacked on the asphalt pad. The waste consists primarily of nitrate salt, depleted uranium, and sludge. The containers are not full and significant subsidence is expected to continue. The covered waste area reaches an average height of 9 m (29.5 ft).

  Leaving Pad A on the surface of the SDA would hamper construction of a low profile surface barrier; this evaluation assumes that Pad A waste would be retrieved. This assumption is consistent with most remedial alternatives identified in the Second Addendum (Holdren and Broomfield 2004).

- **Dynamic compaction—**The method is to systematically drop a heavy weight—10 to 40,000 kg (22 to 88,185 lb)—from a height of 5 to 25 m (16.4 to 82 ft) in a pattern designed to improve the underlying density of soils. In soft ground areas, dynamic compaction has proved to be an effective and economical alternative to preloading, foundation piling, deep vibratory compaction, and soil undercutting and replacement. In coarser soil, the shock waves create liquefaction that leads to compaction. In finer textured soil, shock waves create positive pore water pressures and are followed by soil consolidation.

  Dynamic compaction would be best used in waste areas that have poor structural waste containers, such as plywood boxes that contain poorly consolidated wastes. Pretreatment of the waste would not be cost effective if minimal subsidence over time were expected. However, the variety of wastes, fragility of some containers, and configurations present in the waste make subsidence highly probable. Subsidences have been regularly recorded at the SDA for more than 20 years (Keck and Seitz 2002).

- **No pretreatment**—One option under no pretreatment is to address subsidence through the barrier design. This approach, however, would probably significantly increase the complexity and cost of the barrier.

  A second option under no pretreatment is to deal with zones of major subsidence and retrieval issues after the surface barrier has been built. In situ grouting or SVE are viable alternatives after barrier placement. Minimum damage to the surface barrier would occur through the drill access holes to employ these treatments. Any holes created for venting or grouting purposes can be adequately decommissioned at the end of their useful life. Waste retrieval and dynamic compaction treatment would be more difficult to implement after the final barrier placement, but not impossible.

4. RECOMMENDED SURFACE BARRIER DESIGN

The SDA barrier design to be considered for the RI/FS must satisfy, in the most effective way, RCRA hazardous waste considerations and site-specific requirements imposed by the wastes buried in the SDA, by soil conditions, and by the semi-arid environment of the INEEL. Four preliminary performance criteria that drive barrier design at the SDA are:

- Limit moisture infiltration into underlying waste
- Prevent build-up of gases beneath the barrier
- Minimize intrusion of animals and plants
- Sustain barrier effectiveness for 1,000 years.

Several conventional barrier designs have been investigated and determined to be unsuitable because they do not satisfy site-specific requirements for performance of a surface barrier at the SDA. A review of these conventional barrier designs and discussion of the individual reasons for their unsuitability is in Appendix G, Review of Conventional Barrier Designs. Alternative landfill barriers have several advantages over conventional regulatory barriers while being equally protective of human health and the environment. Some of the advantages include more readily available construction materials, ease of construction, less complex quality assurance/quality control programs, greater cost-effectiveness, and increased long-term sustainability with decreased maintenance (ITRC 2003). See Appendix H, Alternative Landfill Barrier Designs, for details of the alternative designs for landfill barriers. Two alternative design concepts presented in this report that satisfy the first performance criteria above are an ET barrier and a capillary barrier.

ET barrier concept—Evapotranspiration is defined as water removal by a combination of evaporation and transpiration through vegetation. The ET barrier is a single, vegetated soil layer constructed as an optimal mix of soil texture, soil thickness, and vegetation that retains infiltrated water until is removed by ET (Dwyer 1997) (see Figure 4). The soil acts as a sponge (i.e., infiltrated water is held in the soil until it can be removed through ET). Previous research has shown that a simple soil barrier can be very effective at minimizing infiltration and erosion, particularly in dry environments (Nyhan et al. 1990; Dwyer 2001; Dwyer 2003).

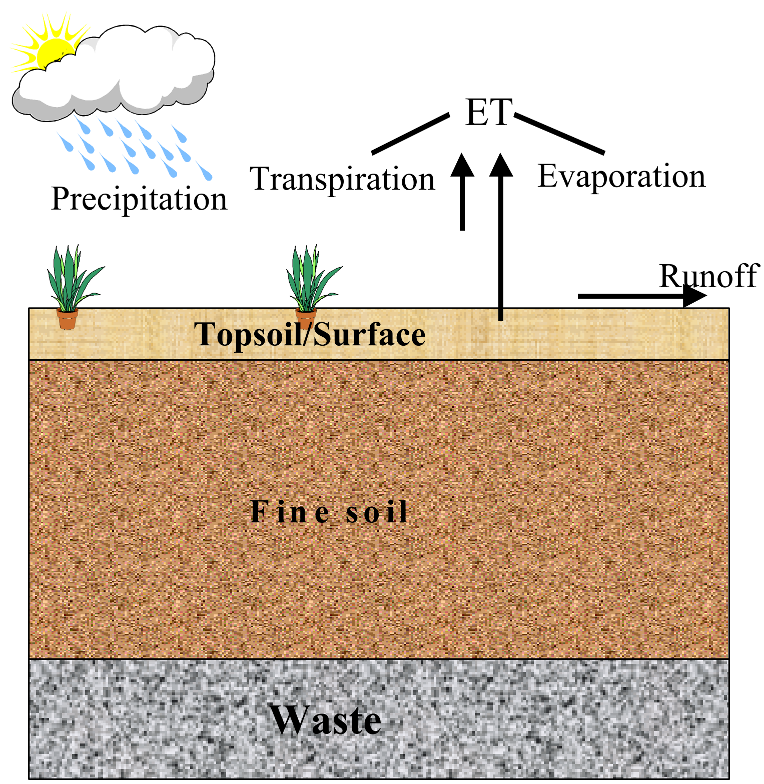

Figure 4. Typical evapotranspiration barrier profile.

Capillary barrier concept—A capillary barrier physically operates identically to an ET barrier in terms of relying on evaporation and plants to remove precipitation that has infiltrated the barrier. The additional aspect of the capillary barrier is that under the upper fine layer that stores the water, a coarse layer is included (see Figure 5). Differences in pore size distribution between the two soil layers cause infiltrated water to be retained in the upper soil layer under unsaturated flow conditions (Dwyer 1997). The capillary barrier is another alternative barrier system suggested for use in final landfill closures in dry climates.

Both kinds of barriers capitalize on the naturally occurring high ET rate coupled with a low precipitation rate. The recommended surface barrier combines these two design concepts and meets RCRA requirements. In addition to these two concepts, to minimize intrusion of animals and plants into the SDA, a biobarrier layer will be included in the design. The recommended barrier is built of natural materials to promote longevity of the surface barrier, to minimize deterioration from freeze-and-thaw cycles, and to allow for waste subsidence.

The following subsections provide a detailed description of the recommendations for the SDA surface barrier.

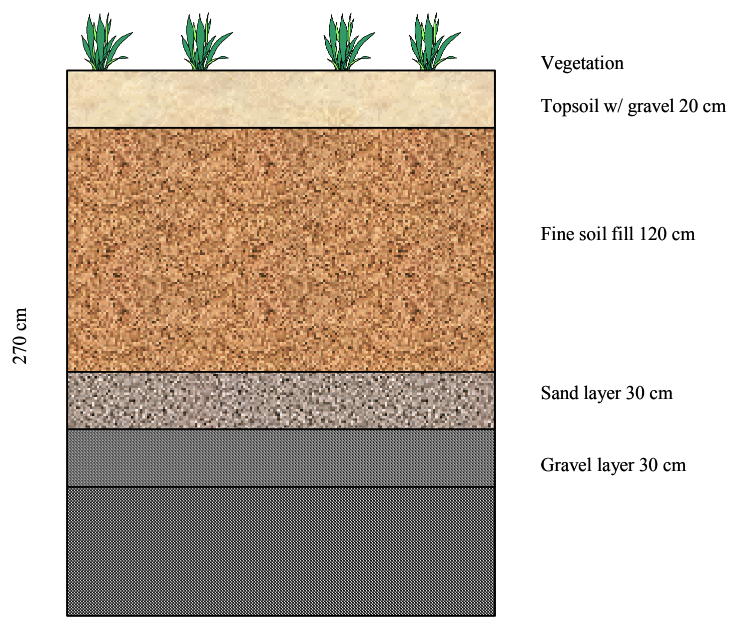

Figure 5. Profile of capillary barrier.

4.1 General Design Elements of the Evapotranspiration Barrier for the Subsurface Disposal Area

The design should include surface vegetation whose roots match the depth of the barrier's water storage layer, a barrier with a minimal number of layers that conforms to differential subsidence, and the combination of biointrusion and gas venting in a single layer to reduce the overall height of the barrier. The barrier and vegetation should mimic the surrounding natural environment in an attempt to work with nature rather than against it. The barrier must have a sloped surface to promote surface drainage, but the least slope possible to minimize erosion.

Of the barriers now in use at the INEEL (described in Section 2.3), the closest to meeting these requirements are the NRF radioactive landfills. This barrier design must be modified for gas removal and to account for subsidence. The barrier should not be constructed of concrete because of deterioration caused by freezing and thawing cycles. Figure 6 illustrates the cross section of a proposed ET/biobarrier design for the SDA to be used in the detailed analysis of assembled remedial alternatives for the OU 7-13/14 feasibility study.

The NRF radioactive landfill barrier design is based on the PC/BE field test and Hydrologic Evaluation of Landfill Performance (HELP) modeling results (NRF 2002) (see Appendix I, Estimating the Performance of Alternative Barriers). This design had a topsoil and gravel admixture layer on the surface, a 1.2-m (3.9-ft) thick water storage layer, and a 30-cm (11.8-in.) biobarrier consisting of gravel and cobbles. Although the upper water storage layer of the NRF radioactive landfill design appears to be appropriate to control percolation through the barrier, the NRF radioactive landfill barrier will not meet all the SDA preliminary performance criteria identified in this document. Subsidence and gas venting were not major barrier design issues at NRF. Unlike the SDA that has a variety of waste types disposed of in numerous pits, trenches, and soil vaults, the NRF radiological barriers are placed over leaching pits and beds and sewage basin areas where little subsidence is expected. In addition, gas transport of contaminants at NRF was not an issue and a gas-venting layer was not required.

The barrier design recommended for the SDA in this report has a dual purpose for the biobarrier layer: minimizing biointrusion and venting subsurface gas (see Figure 6). While the ICDF includes both a biobarrier layer and a gas-venting layer as two separate units—and there is nothing technically wrong with this approach—one could increase cost savings (i.e., material costs) of the barrier by combining these two functions into a single layer. Some additional improvement could be gained by drying the biobarrier through the venting process. Gas extracted from the subsurface is typically near 100% saturation with respect to water. If air with low humidity were used as "input" air, the biobarrier would have a higher negative matric potential than the surrounding soil and would dry adjacent material. Reduced root penetration in this dry zone also provides an additional benefit.

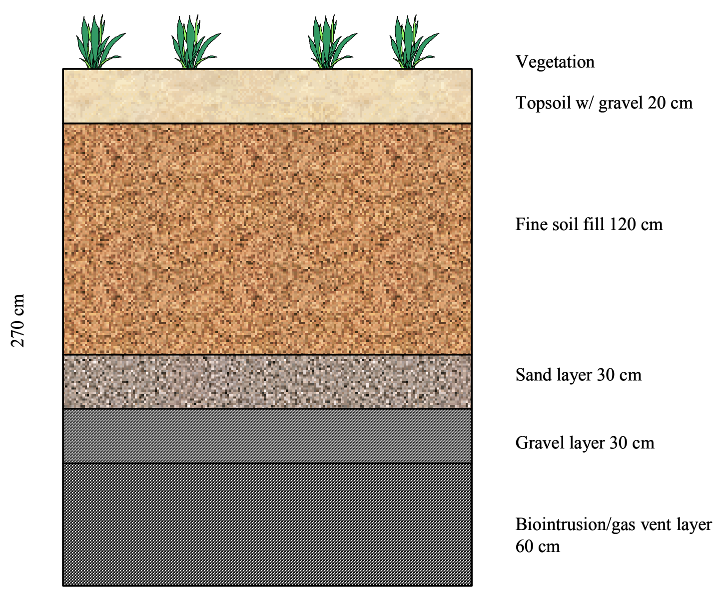

Figure 6. Cross section of the evapotranpiration/biobarrier design recommended for the Subsurface Disposal Area.

Before final design of a barrier for the SDA, additional analysis is needed for more detail about performance requirements for the biointrusion layer. Anderson and Forman (2003) concluded that a 1-m depth is more effective than a biointrusion layer placed at 0.5 m. Their conclusion was based on field results of examining root penetration at the PC/BE field site, and on field observations of burrowing depths. The PC/BE biobarrier design consisted of a total thickness of 0.5 to 30-cm (0.2 to 11.8 in.) (0.1- to 0.2-m [0.3- to 0.7-ft] diameter) river cobbles sandwiched between two 0.1-m (0.3-in.) thick layers of crushed gravel (5- to 15-mm [0.2- to 0.6-in.] diameter) (Anderson and Forman 2003). However, the anticipated subsidence and gas release at the SDA may make this design insufficient. This preliminary analysis indicates that the biobarrier would have to be designed more in accordance with that of the ICDF to prevent biotic intrusion, but unlike the proposed ICDF design, it would also serve as a gas-venting layer.

The upper water storage layer should be designed more in accordance with that at the NRF radioactive landfill barrier than that of the ICDF barrier. Field observation indicates a thickness of 1.2 m (3.9 ft) is effective in controlling water flux through the PC/BE barriers. HELP modeling results of NRF also support these field observations. For this preliminary design, a water storage layer of 1.2 m (3.9 ft) is assumed sufficiently thick to control infiltration through the ET/biobarrier. Preliminary modeling results of the performance of the ET/biobarrier design indicate that the design is sufficient to control water flux through the barrier. A 55-year meteorological dataset for the INEEL was used to define the daily precipitation and ET potential and was used as the upper boundary constraint to evaluate the barrier design. These modeling results are not meant to simulate exactly the ET/biobarrier, but to allow some confidence that the water storage layer is designed within a reasonable thickness. Appendix J, Preliminary Modeling of the Hydraulic Performance of Surface Barriers at the Idaho National Engineering and Environmental Laboratory, provides a detailed description of the model used and the modeling results.

A water storage layer that is too thick (i.e., thicker than the root distribution of the vegetation on the barrier surface) will not add additional performance to the water storage layer. The ET/biobarrier relies on plants to remove water from the water storage layer. Water that infiltrates below the root zone has little chance of removal through ET and can eventually infiltrate through the barrier. The water storage layer has to be thick enough to accommodate storage of water while the plants are dormant, yet thin enough to be compatible with the expected root dynamics of the vegetative community.

The proposed ET/biobarrier design incorporates a gravel admixture in the topsoil layer for erosion control, an approximately 1.2-m (3.9-ft) thick water storage layer, and a biobarrier similar to that of the ICDF at approximately 1 m (3.3 ft) (Figure 6). A diverse plant community is recommended to be tailored to the water storage thickness. The proposed ET/biobarrier design will satisfy the requirements specific to the SDA discussed in Section 3.

4.2 Specific Design Elements of the Evapotranspiration/Biobarrier for the Subsurface Disposal Area

The proposed SDA barrier would be constructed as an ET barrier composed of two major layers: an upper fine grain soil layer for infiltration control, and a lower coarse grain layer for biointrusion control and gas venting. Secondary design considerations discussed below will affect compositional details of both major layers.

4.2.1 Upper Fine Layer

ET landfill barriers typically have a flux-based performance criterion. The typical values permitted are in the range of 1 cm/yr (0.4 in./yr). This is also the value used for landfill barrier performance standard at the American Ecology RCRA Subtitle C site near Mountain Home, ID (0.3 cm/yr [.01 in./yr]). Risk modeling presented in the ABRA (Holdren et al. 2002) shows groundwater risk is relatively insensitive to variations in percolation rates through the SDA. Based on typical performance standards applied elsewhere and little risk reduction to be gained from a more stringent criterion, this study uses a percolation value of 1 cm/yr (0.4 in./yr) for design evaluations.

Primary design elements—The fine layer will be a minimum of 1.2-m (3.9-ft) thick. Results of the PC/BE discussed in Section 2 empirically show that 1.2 m (3.9 ft) of soil over a biobarrier provides adequate water storage to meet a 1 cm/yr (0.4 in./yr) flux criterion. Natural analog studies by the United States Geological Survey (Cecil et al. 1992) suggest natural water flux rates of approximately 1 cm/yr (0.4 in./yr). NRF (2002) HELP modeling of a similar barrier profile discussed in Section 2 showed minimal water flux. Numerical modeling studies using more sophisticated models have shown similarly low flux rates through similar barrier cross sections (Porro 2001).

Secondary design elements—Erosion considerations may warrant increasing the thickness of the fine layer. Wind and water erosion damage must be mitigated for the design life of the facility. Erosion calculations may result in increased barrier thickness, particularly if the facility has steep slopes. Reduced slopes (0% to 3%) should be evaluated for improved long-term barrier performance because steeper slopes are more susceptible to erosion. Runoff also increases with slope angle resulting in ponding and increased percolation at slope toes.

A diverse native seed mixture is likely to be specified. Using diverse native vegetation can minimize long-term erosion and percolation. Diversity provides a more stable ground barrier through perturbations such as fire, selective grazing, or plant disease. Establishing the barrier vegetation will ensure successful long-term transpiration of water.

4.2.2 Coarse Layer

Primary design element: biobarrier—A specific barrier to minimize bio-intrusion into the underlying waste is needed below the topsoil and above the waste. The biobarrier in the NRF design is a gravel and cobble layer between the waste and the evapotranspirative soil barrier and may not maintain integrity during subsidence events. Thus, a more detailed review of the NRF and ICDF foundation specifications will be needed to evaluate the suitability of these designs for the SDA.

Secondary design element: minimize moisture infiltration—Ideally, the coarse layer should work in concert with the fine layer to minimize infiltration. In the proposed cross section, the biobarrier will tend to act as a capillary barrier and reduce downward movement of water from the overlying fine layer. While this effect is likely to improve barrier performance, a significant improvement in barrier performance caused by the presence of the coarse layer would suggest the fine layer is too thin. Infiltration can also be limited by using venting at the base of the landfill barrier to dry soil in and near the waste. Drying creates inward water potential gradients that prevent outward movement of contaminants in liquid phase. Drying the biobarrier will also help inhibit plant root intrusion through the barrier.

Secondary design element: gas venting—Gas venting may be a desirable secondary design feature for parts of the SDA. C-14 flux in gas phase to the aquifer is a significant risk factor. Methane can be generated by volatilizing chlorinated solvents and degrading waste, and create oxygen-depleted zones leading to potential undesirable chemical reactions in the waste and the surrounding soil. Gas generation results in a local increase in gas pressure in the waste. An unvented barrier will also increase downward movement of these gases. Barrier designs that reduce upward gas flux will increase downward fluxes of C-14 and carbon tetrachloride. To date, no formal risk analysis has quantified the increase in risk created by a barrier with lower air permeability than the current temporary barrier.

4.2.3 General Secondary Design Elements

Secondary design element: annual inspection—An annual inspection is a standard component of a landfill closure plan. The typical annual inspection plan envisioned for the SDA surface barrier will include maintenance requirements, such as regular inspection and planned reactions to expected subsidence, cracking, ponding, burrowing, vegetative cover, and other observed or potential problems. These are performance criteria in the sense that appropriate maintenance and observation, especially in early years, are needed to ensure meeting primary performance criteria.

In addition to qualitative visual inspections, a quantitative monitoring system is recommended. The primary performance criterion of moisture infiltration can be monitored using heat dissipation sensors or other devices. The primary performance criterion of preventing biointrusion can be monitored qualitatively with colored soil or rock below the biobarrier. Biointrusion can also be monitored by geophysical methods. Because the basic intention of proposed primary performance standards is containment of radioactive waste, radiation scanning as a component of annual monitoring is also appropriate. In addition to monitoring barrier performance, continued monitoring of the aquifer and vadose zone in and beneath the SDA waste is recommended.

Secondary design element: ecological effects—Water flux calculations performed by Cecil et al. (1992) and by scientists at the INEEL (see Appendix A) suggest that tighter estimates of background water flux rates near the SDA could provide a lower limit to water flux rates and risk estimates. In particular, further evaluation of the effects of slope steepness and length are likely to bear upon the important design criterion of infiltration and practical minimization of system infiltration. Surface runoff-runon will increase the local infiltration at the top of the surface barrier. This increase in infiltration will subsequently affect the type, density, and rooting patterns of the plant community. It is uncertain whether deep-water flux will increase at these locations or the plant community will be able to remove this increased infiltration through transpiration.

Secondary design element: subsidence—Subsidence will clearly continue to occur in the SDA. In order to evaluate the effectiveness of pretreatment options, developing a subsidence map of the facility is recommended to guide choosing the locations of pretreatment options. Otherwise, the biobarrier must be designed to maintain its integrity and accommodate these expected subsidences. Such a map also can be used in developing the monitoring plan. The annual maintenance plan also will address repair of subsidences on the final surface barrier.

4.3 Additional Considerations

In addition to the considerations discussed above, the following paragraphs address the ET/biobarrier in terms of construction, maintenance, possible later retrievals of waste, and soil availability at the INEEL.

4.3.1 Construction, Maintenance, and Possible Retrieval

A phased construction approach to the SDA surface barrier may be necessary to accommodate ongoing landfill operations and remediation. In this approach, sections of the SDA may have the surface barrier constructed to near final design at one period of time while other areas would be covered at a later date, allowing completion of other remedial activities and closure of the active low-level waste pit to be completed.

A more complicated landfill barrier profile causes a more difficult phased construction of a landfill closure in coordinating the various phases. For example, a multi-layered landfill barrier with an internal lateral drainage layer must be able to drain this layer freely to its designated collection area. Any subsequent construction must continue to allow for this while allowing any new construction to drain as well. Furthermore, if a barrier contains a geomembrane or other geosynthetic within its profile, it may be difficult to tie these materials together during phased construction. An ET barrier with a biobarrier layer is much more conducive to phased construction approaches than the ICDF barrier.

Besides being simpler to construct, either as a single unit or in a phased approach, the ET/biobarrier also would allow for easier potential removal of SDA waste after the barrier is constructed. The ET/biobarrier is thinner than the ICDF and would require less sideslope engineering if a selected area of the SDA waste were to be removed. After waste removal, the ET/biobarrier design is readily rebuilt, similar to the phased construction paragraphs above.

4.3.2 Soil Availability at the Idaho National Engineering and Environmental Laboratory

A preliminary assessment of borrow sources on the INEEL evaluated the potential amounts of the two least available soils—topsoil and silty loam material—necessary to construct a surface barrier for the SDA. Additional analysis of potential borrow sources will be necessary to evaluate engineering options and to estimate barrier construction costs. See Figure 3 in Section 2.3 for a map showing the locations of borrow sources at the INEEL; see also Appendix K, Soil Availability at the Idaho National Engineering and Environmental Laboratory, for more details on soil availability at the INEEL.

The INEEL contains eight permitted gravel and borrow sources that support onsite maintenance operations, new construction, and environmental restoration and waste management activities (Minkin et al. 1994). The CFA landlord has developed a permitting process to regulate excavations within all active INEEL gravel and borrow pits to facilitate scheduling and compliance with necessary environmental, safety, and permitting requirements. Archived information provides a history of past demand and provides a basis for future planning. Presently, approvals for the use of gravel and borrow materials are provided to projects on a first-come, first-served basis.

According to the preliminary borrow source assessment, a sufficient amount of soil is available to complete construction of a barrier over the SDA. The potential total amount of silt and clay available for INEEL use from the three approved INEEL sources is in excess of 13 million yd^3 (DOE 1997). However, under the current approved regulations, only 9.7 ha (24 acres [116,159 yd^2]) can be excavated each year (DOE 1997) and this amount is insufficient to supply the amount of silt and clay material needed to complete barrier construction in a single year. Either multiple years of excavation or modifications to the current permits will be necessary for an SDA barrier. Obtaining sufficient amounts of silt and clay from the INEEL may be problematic.

Although not examined in detail for this preliminary evaluation, material for sand and gravel layers should not be problematic for construction of a barrier, as both materials are common onsite. Processed sand and gravel would be needed for constructing the transition from the water storage layer to the biointrusion layer. These materials could be obtained from the BORAX Gravel Pit located about 4,023 m (2.5 miles) from the SDA (Zitnik et al. 2002).

Biointrusion materials also were not evaluated in detail, but may be obtained from several potential sources, including an offsite vendor (for cobble), onsite stockpiles of basalt rubble, or through blasting of in-place volcanic rock. Blasting of basalt rock near the SDA was assumed the best option for obtaining coarse materials. Coarse-fractured basalt will be needed for constructing biotic barriers, and probably for riprap erosion control. A basalt outcrop about 8,046 m (5 miles) from the SDA may be available for mining to supply these materials (Zitnik et al. 2002). Though cobbles also could be used for the biotic barriers, the nearest apparent source for cobbles is approximately 72,420 m (45 miles) from the SDA in

Idaho Falls, making river cobbles expensive. Evaluations, therefore, assume that the basalt outcrop will be mined and the rock will be processed to provide coarse-fractured basalt and riprap for constructing surface barriers.

5. MONITORING PERFORMANCE OF INSTALLED SURFACE BARRIER

A comprehensive monitoring plan will be developed and integrated into all phases of the remedial action life cycle including the design, installation, and stewardship of the SDA surface barrier. Monitoring is required by law to ensure long-term protection of human health and the environment (EPA 1989a). At the front end of the design process, monitoring data will be used to support development of goals for surface barrier performance. Monitoring and modeling may be needed to compare and project the performance of prototype barrier designs for a range of environmental scenarios for current conditions and possible future conditions. During the barrier installation phase, monitoring will be required to verify the quality of materials and construction practices. After installation of the barrier (post-closure), monitoring will be essential for long-term stewardship to demonstrate the near-term effectiveness of the completed barrier, to detect precursors of failure in an effort to limit costly maintenance and retrofitting, and to reassess periodically the long-term performance projections, sustainability, and risks.

Three types of evaluations probably will be required for the SDA surface barrier. First is the collection and use of data to design and evaluate the performance of the surface barrier. Prototype barriers, including the PC/BE and the EBTF, have been built and evaluated for their performance under INEEL meteorological conditions. Long-term performance of these barriers can then be predicted using numerical models and these results can be compared to data collected from natural analog studies.

The second evaluation takes place during the construction of the barrier. First, the monitoring during this phase will ensure that material properties and installation are within limits of design specification and procedures. In addition to the geotechnical evaluation, attention should be paid to establishment of vegetation on the barrier.

The final evaluation of the barrier includes post-closure monitoring and care to ensure that it is performing to expectations. Monitoring for both contaminant release and parameters that could indicate potential contaminant release should be included. The post-closure monitoring issues for the SDA barrier are associated with leachate and groundwater contamination, barrier water balance and percolation flux, release of gas contamination to the atmosphere, barrier integrity and subsidence, soil erosion and deposition, vegetation establishment and growth, animal intrusion, and radiological monitoring of surface soil and ecology.

A more extensive review of these evaluations is contained in Appendix L, Performance Monitoring; however, detailed descriptions of these evaluation processes are outside the scope of this document and will be developed during final design.

6. COST ESTIMATES

The ET/biobarrier design was the lowest of the estimates at approximately $46.7M. In addition to the ET/biobarrier option, two additional preliminary cost estimations were prepared for comparison purposes: a modified RCRA C design estimated to cost $58.1M and an ICDF design—highest of the estimates—at $101.5M. These estimates include a 25% contingency cost and a 24.61% escalation cost that add about a 50% multiplier to the estimated construction cost. Details of the estimates can be found in Appendix M, Details of Construction Cost Estimate.

A significant amount of soil and rock material is required to construct a landfill barrier over the SDA. Appendix M contains an estimate of the amount of materials needed for three surface barriers: RCRA modified C, ICDF, and the ET/biobarrier. These three barriers were chosen to enable examination of relative differences in material volumes and verification of availability of a sufficient amount of materials on the INEEL for construction. The cost estimates also are calculated to construct these barriers using the estimated volumes of construction materials and are suitable for comparison of these alternatives.

7. SUMMARY

All closure options for the SDA will require a surface barrier (Holdren and Broomfield 2003). In support of the future comprehensive RI/FS for RWMC, potential SDA barrier designs were evaluated for their potential performance to protect human health and the environment. A draft version of this report was prepared to support roundtable discussions held on March 11, 2004, immediately after an EPA-sponsored Evapotranspiration Cover Workshop in Denver, Colorado, centering on alternative barriers for the SDA. Those present at the discussions included DEQ personnel who would eventually be responsible for acceptance of the barrier design. Responses to DEQ comments and general discussion from this meeting have been addressed in this final document.

Numerous field evaluations have concluded that ET barriers have several advantages over conventional regulatory barriers while being equally protective of human health and the environment (ITRC 2003). Some of the advantages include locally available construction materials, ease of construction, less complex quality assurance and quality control programs, greater cost-effectiveness, and increased long-term sustainability with decreased maintenance (ITRC 2003). In addition, performance of ET barriers is not detrimentally affected by freeze and thaw cycles.

7.1 Summary of Site-Specific Factors that Affect Barrier Design

SDA climate, topology, waste characteristics, disposal history, and location were examined to assess their effects on barrier design. These factors included:

- **Local surface water runoff**—On three previous occasions, the SDA was flooded by local runoff. A dike was constructed around the SDA, which has been effective in eliminating flooding within the landfill. For the final design, local topology and surface runoff must be evaluated to design removal of excess surface water.

- **River flooding—**Although the Big Lost River is 9 to 12 m (29.5 to 39.3 ft) higher than the SDA, the river is topographically isolated from the SDA. A study of potential effects of a failure of Mackay Dam upstream concluded that the resulting flood would not inundate the SDA (Koslow and Van Haaften 1986).

- **Long-term erosion**—Geological evaluation of the surrounding soil materials indicate that the surface material has been stable, supporting the assumption that an ET barrier can be expected to perform for a long period of time.

- **Low natural water flux rates**—Previous studies indicate that an ET barrier can minimize water flux to the SDA waste for thousands of years under natural conditions that would be likely to include episodic events such as fire. A surface barrier performance-based flux standard of 1 cm/yr (0.4 in./yr) should be achievable.

7.2 Other Factors Contributing to Barrier Design

- **Groundwater and surface pathways of COCs—**For the majority of the COCs exhibiting the highest degree of risk, the pathway was through groundwater ingestion; however, some surface pathways and ecological COCs were also identified. These COCs are transported as solutes, gas, and potentially through biota. A barrier will have to account for all three transport mechanisms.

- **Single barrier design**—The distribution of the waste types and the requirements to protect the environment from the COC exposure pathways precludes making specialized barrier designs for parts of the SDA. A single barrier design for the entire SDA is appropriate.

- **Risk modeling—**Until better confidence can be obtained in risk modeling results, a performance criterion of 1 cm/yr (0.4 in./yr) (3×10^{-8} cm/s) is assumed as an acceptable percolation flux.

- **Risk from gas transport—**Although some COCs are known to be transported in the gas phase in the vadose zone, the potential increased risk to the groundwater because of the installation of an impermeable barrier has not been evaluated in the current SDA risk models.

- **Heat generation—**Results of a preliminary analysis indicate that the amount of heat released appears to be insignificant, at least when averaged over the entire SDA. However, a more complete analysis of heat production in the SDA is recommended and these results should be compared to the natural geothermal flux.

- **Differential subsidences—**Differential subsidences are likely to occur at the SDA. For this reason, the preliminary barrier design will not include geomembrane layers, asphalt layers, or a series of thin multiple layers.

- **Biobarrier—**A biobarrier is needed for the SDA surface barrier, but additional issues concerning the size of the cobbles and layering should be further evaluated before final design.

- **Barrier slope—**Evaluation of optimal slope for the barrier is needed. The slope should be balanced between surface runoff, allowable infiltration into the surface ET barrier, and vegetation needs.

- **Pretreatment—**Pretreatment remedial alternatives would be best used to create a stable foundation for the barrier.

7.3 Construction Considerations for Barrier Design

- **Pad A—**Pad A is 9 m (29.5 ft) tall and would hamper the construction of a low-profile barrier. The assumption used in this report is that Pad A waste would be retrieved.

- **Fine-grained soil—**Sufficient fine-grained soil to build an SDA barrier is available on the INEEL. However, volume of topsoil to establish the vegetative materials at the INEEL is limited. Amendments to Spreading Area A soil should be investigated and be consistent with a barrier revegetation plan.

- **Borrow source regulations—**Under the current approved regulations, only 9.7 ha (24 acres [116,159 yd^2] can be excavated each year and this amount is insufficient to supply the amount of silt and clay material to complete the barrier construction in a single year. These regulations may have to be modified.

- **Coarse grain material—**Biointrusion materials were not evaluated in this report but may be obtained from several potential sources, including an offsite vendor (for cobble), onsite stockpiles of basalt rubble, through blasting of in-place volcanic rock, or use of onsite demolition waste. Additional analysis of source for coarse grain material is needed.

- **SDA vegetation plan—**Establish a plan for vegetation to determine whether irrigation of the SDA soil barrier is needed (and when), amount and type of soil amendments needed (e.g., fertilizers and organics), weed control on the barrier surface, planting technique, topsoil preparation, and other requirements.

7.4 Remaining Modeling Uncertainties

A preliminary one-dimensional modeling study was conducted to ensure the preferred ET design proposed in this document was adequate. This modeling study incorporated a number of assumptions that should be investigated further to ensure that the proposed design will meet performance objectives over the life span of the barrier. Additional sensitivity studies should include:

- Studies to define a minimal slope for the SDA landfill barrier. These studies would be evaluated for potential effects of runoff and runon that could increase local infiltration, and a cost analysis to examine the benefit of minimizing the amount of grade fill material required to construct the barrier.

- Refinement of the limited chloride mass balance work near the SDA could be used to provide natural analog support for a natural flux consistent with barrier performance requirements. Both modeling and field data are needed. A lack of sufficient datasets to evaluate long-term modeling results prevents evaluation of the modeling results. Only two water flux datasets exist in undisturbed soils that would be representative of an ET surface barrier. Both chloride mass balance datasets agree that water flux is low at the INEEL; however, these datasets may not be representative of water flux everywhere at the INEEL.

- A worst-case scenario of precipitation has not been evaluated or defined. As seen in the modeling simulations in this document, most of the water flux through the barrier occurs during a fairly short period of time around 1965 (see Appendix J). Additional modeling simulations would refine understanding of the processes and ways to identify a priori indicators of potential infiltration through the barrier.

- A better snow melt algorithm. The current HYDRUS model does not include an algorithm for snow accumulation and subsequent melt during the spring.

- A better grass and shrub simulation model. Little information exists for plant diseases that can affect the local semi-arid plant community. Such data would achieve better reliability of the numerical predictions.

- Effects of fire on the transpiration rate have not been evaluated.

- Gas venting has not been included in simulations to date. Venting and drying of the biobarrier may or may not be needed to meet the barrier performance standards.

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Appendix A

Detailed Geophysical and Hydrological Characteristics at the Site

Detailed Geophysical and Hydrological Characteristics at the Site

A-1. SITE CHARACTERISTICS

The following subsections offer detailed descriptions of site characteristics that are important considerations in performance of a surface barrier.

A-1.1 Surface and Subsurface Geology

The Eastern Snake River Plain (ESRP) is a topographic depression trending east-northeast, is 600-km long and 100-km wide, and extends from Twin Falls to Ashton, Idaho. The Idaho National Engineering and Environmental Laboratory (INEEL) covers 2,315 km^2 of the ESRP. The terrain is semiarid steppe. Mountains and valleys associated with the Basin-and-Range province bound the ESRP on the north and south. These mountains trend perpendicular to the axis of the Snake River Plain.

Several major late Tertiary geologic events are important to the formation of the ESRP. These include: (1) volcanism associated with the track of the Yellowstone hotspot, (2) crustal extension which produced the Basin-and-Range province, (3) basaltic lavas and construction of coalescent shield volcanoes, and (4) glaciation and associated sedimentation and catastrophic flooding (Hughes et al. 1999).

Near-surface basalt flows erupted from several volcanic vents in the southwestern part of the INEEL. Anderson and Lewis (1989) defined ten basalt flow groups and seven major sedimentary interbeds in the area. Interbeds may act to slow percolation to the aquifer and are thus important features in assessing the fate and transport of contaminants. In the 177-m (580-ft) interval from the ground surface to the aquifer, three major interbeds are of particular importance. These three uppermost sedimentary deposits in the Subsurface Disposal Area (SDA) vicinity are commonly referred to as the A-B, B-C, and C-D interbeds.

If climate fluctuations are within historical limits, no major soil erosion should occur at the SDA for the next 10,000 years. The past 10,000 years (i.e., the Holocene period, which followed the last glacial period) was a period of soil formation and limited erosion in the small valley in which the Radioactive Waste Management Complex (RWMC) is located. The limited erosion probably will continue at least until the next glacial period (Hackett et al. 1995). Regional tributary flooding caused water to enter the RWMC basin on a number of occasions in the Holocene period through the wind gaps in the adjacent Quaking Aspen Butte basalt flow and has left a thin scattering of small (less than 2 mm [0.08 in.]) alluvial sand just inside the basin near the wind gaps. Evidence indicates that alluvial deposits in the SDA were possibly left during the Pleistocene period and evidence of glacial outburst flooding of the Big Lost River is also from the same geologic period (Rathburn 1989, 1991). Glacial outburst flooding inundated the area that RWMC presently covers during the late Pinedale glacial period (about 20,000 years ago) eroding sediments from higher convex positions around the basin and depositing large basalt boulders within the basin. Nevertheless, substantial soil layers with ages ranging from about 20,000 to 120,000 years remain apparently undisturbed, which indicates that significant erosion of older soil did not occur (Hackett et al. 1995). Climate changes during the approximate 10,000 years after the last glacial period have had little effect on the soil landscape within the RWMC basin.

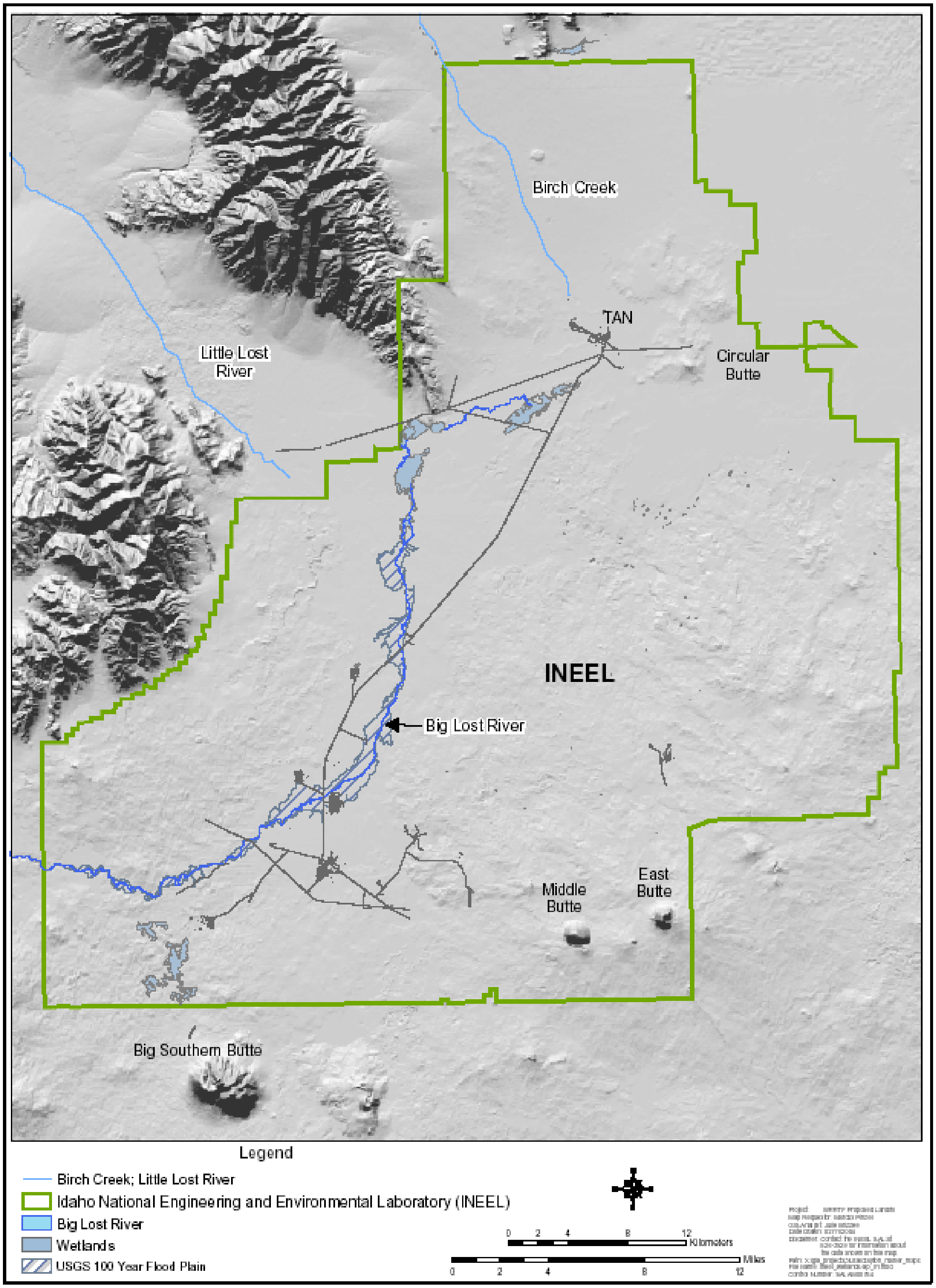

Figure A-1. Flood plain for the Idaho National Engineering and Environmental Laboratory with a flood magnitude of 7,200 cfs.

A-1.2 Surface Hydrology

The INEEL is located in a small, closed, sedimentary basin called the Big Lost Trough (Geslin et al. 2002), which has no outlet; therefore, water flowing onto the INEEL either evaporates or infiltrates into the ground. Three streams drain into the Big Lost Trough: (1) the Big Lost River, (2) the Little Lost River, and (3) Birch Creek. These streams receive water from mountain watersheds located to the north and northwest of the INEEL. Stream flows often are depleted before reaching the facility by irrigation diversions and infiltration losses along stream channels. The Big Lost River is located approximately 3 km north of the SDA (Figure A-1). Although the Big Lost River is 9 to 12 m higher than the SDA, the river is topographically isolated from the SDA and a study examining the potential effects of the upstream Mackay Dam failure concluded that the resulting flood would not inundate the SDA (Koslow and Van Haaften 1986). Big Lost River flows have not entered the SDA since operations began in 1952. A mineralogical correlation of surficial sediment from area drainages with sedimentary interbeds suggests that the present day drainage patterns of the streams at RWMC may be similar to historical patterns (Bartholomay 1990). A plot of the average percentages of total clay minerals plus mica, total feldspar, and carbonates of the sedimentary interbeds indicates that the interbeds at RWMC are similar to the Big Lost River channel, overbank, and spreading area deposits (Koslow and Van Haaften 1986). Similarities indicate that most of the sedimentary interbeds analyzed at RWMC may be flood plain deposits of an early river containing sediments similar to the present day Big Lost River deposits. The correlations suggest that the sedimentary interbeds probably were deposited in a depositional basin similar to the present day basin. Discharge of water from septic system, water mains, and irrigation is small and has no effect on surface infiltration within the SDA (Holdren et al. 2002).

Several studies have presented estimates of the potential magnitude of the 100-yr flood for the Big Lost River, some of which are discussed below. The 100-yr flood for the Big Lost River near Arco, a station 14 miles upstream from the INEEL diversion dam, has an estimated magnitude of approximately 3,700 to 4,400 cfs based on analyses of historical stream gauging records (Tullis and Koslow 1983; U.S. Army Corps of Engineers 1991; Stone et al. 1992; Hortness and Rousseau 2002). Another study concluded a higher flood magnitude but for a station upstream of the Mackay Reservoir, and estimated a peak flow of 7,200 cfs for the 100-yr flood for the Big Lost River at the Arco station (Kjelstrom and Berenbrock 1996). This estimate is considered to be conservatively high. Perhaps the most complete study (Ostenaa et al. 1999) used paleohydrologic data collected from several stream reaches along the Big Lost River below the Arco station in combination with historical stream gage data from the Arco station and a Bayesian flood-frequency analysis and estimated a magnitude of 3,300 cfs for the 100-yr flood for the Big Lost River at the Arco station. Although the earlier studies indicated higher flood magnitudes, this latest study combining historical streamflow data with paleohydrologic field study sites along the Big Lost River likely provides the best estimate of the 100-yr flood to date at 3,300 cfs, a value greater than the highest recorded flow at the Arco station (i.e., 1,890 cfs in July of 1967).

The INEEL diversion dam, which controls flow onto the INEEL, will add additional protection of the downstream facilities. Gates placed on two large, corrugated steel culverts control flow onto the Site; less than 900 cfs of flow is released through the diversion dam, downstream onto the INEEL (Lamke 1969). The INEEL diversion channel is capable of handling flows in excess of 7,200 cfs (Bennett 1986). However, a recent field investigation pertaining to the structural integrity of the INEEL diversion dam by the Army Corps of Engineers indicates sustained flows of 7,200 cfs (diversion dam capacity with no freeboard) could damage or overtop the dam (Berger 1997). The report indicates dam failure is possible at flows in excess of 6,000 cfs. The safe holding capacity of the diversion dam with a minimum freeboard of 3 ft is now determined to be about 5,000 cfs. The controlled flow of the Big Lost River downstream of the INEEL and the lack of additional contributing flows to the river on the INEEL indicate the 100-year flood (3,300 cfs) on the Big Lost River would be contained within the natural channel and diversion channel, posing no flood threat to INEEL facilities.

Ostenna et al. (1999) performed a Bayesian flood-frequency analysis that indicates peak flows on the Big Lost River with return periods of 500, 1,000, and 10,000 years are 4,000, 4,400, and 5,300 cfs, respectively. These results suggest that exceedance of the estimated maximum capacity of the INEEL diversion dam of 9,300 cfs (Bennett 1986) has an extrapolated annual exceedance probability smaller than 0.00001 (or greater than 100,000-year return period). Assuming a safeholding capacity of 5,000 cfs for the INEEL diversion dam, the annual exceedance probability is 0.0002 (or a 5,000-year return period).

Using Ostenna et al. (1999) data for the 100-, 500-, and 1000-year flood magnitudes, even a 1000-year flood would not inundate the SDA (Figure A-1). A study by Kjelstrom and Berenbrock (1996) concluded that the SDA would not be flooded with a 7,200 cfs flooding event. Berenbrock and Kjelstrom's 1998 stream flow magnitude is much larger than those proposed by Ostenna et al. and suggest that the 1000-year flood magnitude predicted by Osternna and others would not impact the SDA.

Soils in the RWMC area are polygenetic, meaning they were formed from several types of soil genesis cycles, including loess deposition, leaching of calcium carbonate, accumulation of clay, and erosion. The RWMC area is topographically associated with the Big Lost River and Big Southern Butte fluvial systems and contains pebble lag within the area of boulder trains, indicating at least one Holocene-age flood from the Big Lost River. However, evidence of erosion by these systems during the last 10,000 years following the end of the Pinedale glaciation period is not evident (Holdren et al. 2002).

Physical, chemical, and mineralogical characteristics of the RWMC area soil are detailed in Dechert, McDaniel, and Falen (1994) and McDaniel (1991). Generally, the soil mantling the landscape surrounding RWMC was deposited as loess during the Pinedale glaciation period and mixed with eolian sand and slope wash in lower areas of the basin. Soil from RWMC typically has high clay (i.e., approximately 36%) and high silt content (i.e., approximately 56%) (Chatwin et al. 1992). Generally, the soil has moderate water-holding capacity though some areas of RWMC have shallow soil with low water-holding capacity (Bowman et al. 1984). Some RWMC soil also may be derived from historic stream deposits from the Big Lost River.

Undisturbed surficial deposits within the RWMC area range in thickness from 0.6 to 7.0 m (2 to 23 ft) (Anderson, Liszewski, and Ackerman 1996). Irregularities in soil thickness generally reflect the undulating surface of underlying basalt flows. Many physical features are common within the soil stratigraphy of the RWMC area, such as pebble layers, freeze-thaw textures, glacial loess deposits, and platy caliche horizons. Surface soil in RWMC has been significantly disturbed and recontoured with additional backfill added for subsidence and runoff control.

Precipitation is a highly variable source of water at the INEEL. Based on a 38-year historical record analyzed by Clawson et al. (1989), the average annual precipitation was approximately 22 cm/yr (6.0×10^{-4} m/d) with a maximum of 36 cm/yr (9.9×10^{-4} m/d) and a minimum of 11 cm/yr (3.0×10^{-4} m/d). Heaviest precipitation usually occurs in the spring and early summer and most of the precipitation events are less than 0.25 cm/d (2.5×10^{-3} m/d). However, thundershowers can produce a significant amount of precipitation in a short period of time. The historic record of precipitation from the Central Facilities Area (CFA) weather station, approximately 8 km northeast of the SDA, indicates precipitation intensities greater than 2.5 cm/hr (6.0×10^{-1} m/d) in 8 of the 38 years at CFA. The long CFA precipitation record is likely representative of conditions at the southern portion of the INEEL (Magnuson 1993), including the SDA.

Snowfall history at the CFA weather station indicates that average snowfall is 70.1 cm, and ranges from 17.3 to 151.6 cm. A typical winter has snow cover from mid-November to mid-April (Clawson et al. 1989). Moderate to strong surface winds cross the plains at the INEEL, resulting in spatially and temporally variable snowdrifts exceeding 1 m in depth. These drifting events contribute to localized enhanced percolation (Martin and Magnuson 1994) as the snow melts. Most of the episodic infiltration events are attributed to the rapid melting of the snow and overland land flow because of frozen soil creating localized ponding.

The RWMC is located within a natural topographic depression with no permanent surface water features. However, the local depression tends to hold precipitation and to collect additional runoff from the surrounding slopes. Surface water either eventually evaporates or infiltrates into the vadose zone (i.e., the unsaturated subsurface) and underlying aquifer. Historically, the SDA has been flooded by local runoff at least three times. Dikes and drainage channels were constructed around the perimeter of the SDA in 1962 in response to the first flooding event. The height of the dike was increased and the drainage channel was enlarged following a second flood in 1969. The dike was breached by accumulated snowmelt in 1982, resulting in a third inundation of the SDA. Significant flood-control improvements were subsequently implemented, including increasing the height and width of the dike, deepening and widening the drainage channel, and surface contouring to reduce formation of surface ponds within the SDA.

As presently contoured, intense summer thunderstorms and melting snow create surface water ponds within the SDA. The SDA land surface has been severely altered by the creation of excavated pits and trenches for waste disposal. These excavation activities destroyed much of the native plant communities and recontoured surface topography by mounding soil on top of waste pits, building roads, covering trenches, and constructing soil vaults. As a result, local surface ponding after heavy summer thunderstorms or early spring snowmelt is common. During the winter months, melt-water runoff atop frozen soil creates localized surface ponds and has enhanced percolation (Martian and Magnuson 1994; Bishop 1998). Much of this surface water infiltrates into the ground, although a portion is diverted off-site through a series of unlined ditches. It is likely that these episodic high intensity precipitation events and melting snow contribute to the bulk of water flux through the SDA.

A-1.3 Near Surface Hydrology

Published estimates of water flux rates in undisturbed natural sediments adjacent to the SDA are small and suggest that approximately 5% of the annual precipitation infiltrates to the base of the root zone. These flux rates would likely be representative of the expected performance of a vegetative surface cover that relies on evapotranspiration. Cecil et al. (1992) measured the water flux rate using three separate methods in undisturbed soil immediately north of the SDA. Chlorine-36 and tritium profiles were determined to approximately 5.5 m in depth. These measurements indicated water flux rates of 0.71 and 1.1 cm/yr (1.9×10^{-5} and 3.0×10^{-5} m/d). A water flux rate using the tritium mass balance method gave a rate of 0.89 cm/yr (2.4×10^{-5} m/d). The Darcian flux beneath the root zone (below 3.7 m in this case) for a 4-year period averaged 0.36 cm/yr (9.9×10^{-6} m/d). These low flux rates are considered to represent the background flux rate and are often used as such in the SDA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) performance assessment numerical transport models as 1 cm/yr (2.7×10^{-5} m/d) (Magnuson and Sondrup 1998).

Martian (1995) calculated water flux estimates for CERCLA modeling activities through the SDA and suggested that the flux rate may be almost an order of magnitude greater inside the SDA compared to those reported by Cecil et al. (1992). At the SDA, McElroy (1993; McElroy and Hubbell 1993) and Bishop (1996) measured a wide variety of water flux rates using neutron moisture measurements from the neutron access tubes. This monitoring network was enhanced in the early-1990s to a total of 27 measuring locations located throughout the SDA. Net water flux was calculated from changes in the measured moisture content profile below a depth of approximately 1 m (3 ft), assuming changes from land surface to 1 m were because of evapotranspiration. During five years, (i.e., 1989, 1993 through 1996), sufficient data were available to estimate the net flux. These estimates ranged from 0.3 to 55.9 cm/yr (8.2×10^{-6} to 1.5×10^{-3} m/d) depending on the year and location of measurement. They attributed these highly variable estimates to snow drifting and plowing, presence or absence of frozen soil, soil disturbance, topographic variations, and local drainage patterns.

Reevaluation of the Cecil et al. (1992) data, and the results of recently collected borehole samples near the Vadose Zone Research Park, suggest that the diffuse water flux beneath the rooting zone is much less than 1 cm/yr. The most commonly quoted value describing the long-term average water flux rate through the vadose zone at the INEEL is 1 cm/yr determined by Cecil et al. (1992) from analysis of Cl-36 and tritium in soil from a test trench adjacent to RWMC. This value may actually be biased because the observed Cl-36 peak is still completely contained in the root zone where percolation is still being extracted. A more thorough analysis of data from the test trench study, and analysis of Cl-36 profiles from other undisturbed sites on the INEEL, indicates that the actual long-term average flux past the root zone is less than 1 mm per year, approximately an order of magnitude lower than the oft-quoted figure from Cecil et al. (1992).

The flux rate reported by Cecil et al. (1992) was based on the position of the highest Cl-36/Cl^- ratio in a soil profile obtained by hand augering through relatively undisturbed soil in the United States Geological Survey (USGS) test trench area. Chlorine-36 is an isotope that is continually produced at a relatively low rate in the atmosphere by interaction of cosmic rays with gaseous argon. In the mid 1950's however, neutron activation of Cl-35 in seawater during nuclear weapons testing in the Pacific introduced dramatically higher concentrations of Cl-36 to the atmosphere across the globe. Chlorine-36 in the atmosphere behaves as other forms of chloride; it is washed out of the atmosphere by precipitation within a couple of years, so the amount of Cl-36 that began infiltrating the Earth's surface approximately 45 years ago was several orders of magnitude higher than the background ratio attributable to cosmic ray production. The position of that peak in the subsurface is thus an indication of the water flux rate averaged over approximately 50 years. In arid regions, however, it typically takes much longer for soil moisture to penetrate below the root zone. Recent studies at several sites in the arid southwestern United States, for example, indicate that water flux has not penetrated past the root zone for many thousands of years (Walvoord et al. 2003; Scanlon et al. 2003). The Cl-36 peak, as a result of atmospheric testing in such profiles, is effectively stuck in the root zone biasing long-term flux rate analyses.

Because water is continually extracted from the root zone, but not below it, salt concentrations typically increase with depth to the bottom of the root zone and then reach a relatively constant value that represents the average salt-concentrating ability of the root zone. The chloride concentration of soil in the root zone, as mass of chloride per unit mass of soil, is thus inversely related to the net water flux rate. At the USGS test trench, the Cl^- concentration profile indicates that the bottom of the root zone is approximately 1.5 m deep (Figure A-2a), a depth typical for sagebrush-dominated ecosystems. Examining the atmospheric testing tracer peaks (C-36l/Cl^- and tritium) in Figure A-2b indicates that both peaks are clearly still within the root zone. The fact that Cl^- concentrations increase by approximately two orders of magnitude below the depth of maximum Cl-36/Cl^- ratio demonstrates that much of the downward moisture flux at that depth is ultimately returned to the atmosphere through root water uptake and transpiration.

Because the atmospheric testing tracer peaks are still within the root zone for the USGS test trench data, this data likely overestimate the calculated estimates of the percolation rate. Because of this bias for the SDA data, a more reliable estimate of the long-term average water flux rate can be obtained using chloride concentrations and the mass balance approach. The mass balance approach considers the rate of chloride influx to the surface and the amount of chloride contained in a given depth of soil to estimate the age of the soil moisture at that depth. The age provides an indication of the velocity at which Cl^- is transported into the deep subsurface from which a soil moisture flux can be calculated if the average water content of the soil is known.

The chloride mass balance approach to estimating water flux rates rests on several assumptions: (1) water movement is essentially downward, (2) chloride is conservative and transport occurs primarily by advection, (3) soil minerals are not a significant source of chloride, (4) chloride input to the land surface through precipitation and dry fallout is relatively constant over time, and (5) the surface input at the USGS trench site was not effected by the MgCl applied to the SDA roads. These assumptions imply that Cl^-deposited at the surface migrates downward with infiltrating precipitation and, while most of the water may be removed through plant transpiration, virtually all of the infiltrating Cl^- remains in the soil. The amount of Cl^- in the soil above a certain depth, divided by the rate of Cl^- loading to the surface, is thus indicative of the age of the infiltrating water at that depth.

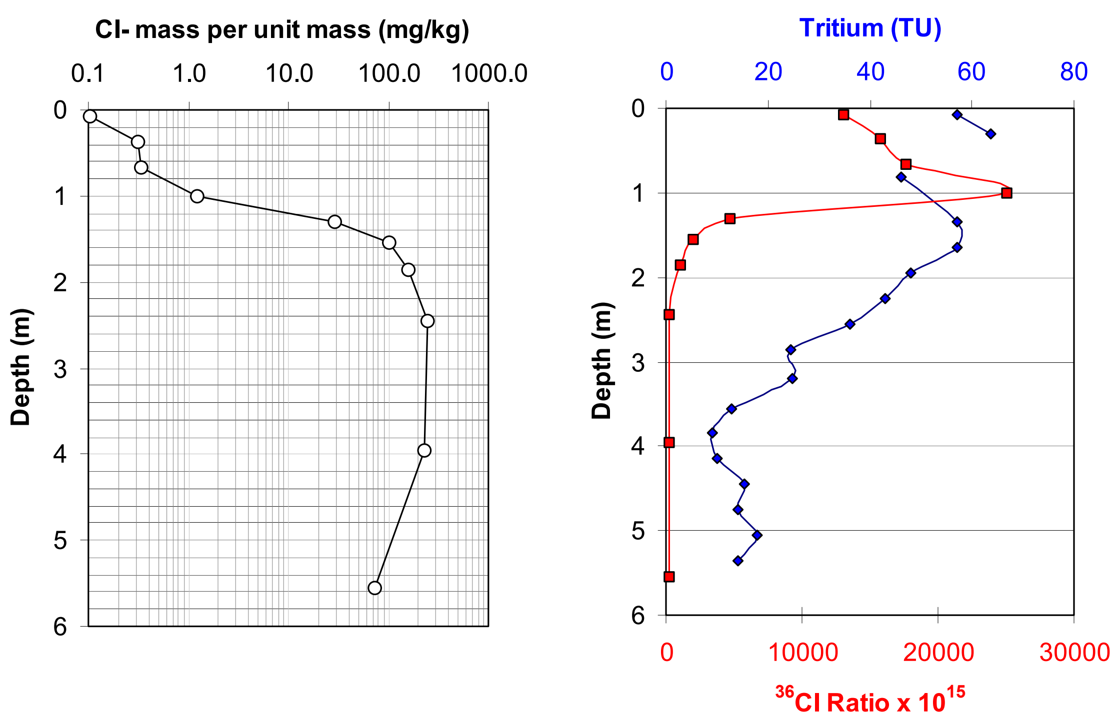

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Figure A-2. Data from the United States Geological Survey test trench soil conducted just outside the Radioactive Waste Management Complex. Figure A-2a illustrates the concentration profile of Cl^-. Figure A-2b illustrates the Cl-36 (red squares) and tritium (blue diamonds) concentration profiles.

The long-term average chloride-loading rate may be calculated in a number of ways. Based on long-term monitoring of precipitation and precipitation chemistry at the National Atmospheric Deposition Program (NADP) station, Craters of the Moon, ID, the long-term average Cl^- loading to the land surface via precipitation is approximately 46 mg/m^2 per year. Assuming that about a third of the total Cl^-deposition is dry fallout (Phillips 1994), the total average Cl^- loading to the ground surface at the INEEL would be approximately 69 mg/m^2 per year. While the USGS test trench Cl-36 data should not be used to directly infer a groundwater recharge rate, those data do provide another means of estimating the Cl^- loading rate. The peak Cl-36/Cl^- ratio is located at a depth of 1 m in the USGS test trench profile and the cumulative Cl^- mass per unit area at that depth, assuming an average bulk density of 1600 kg/m^3, is approximately 3.1 g/m^2. Divided by the assumed age of approximately 45 years, that yields an estimated Cl^- flux of 69 mg/m^2 per year, remarkably close to the value obtained from the NADP data.

With the estimated Cl^- flux to the surface, soil moisture age as a function of depth from the cumulative mass of Cl^- above each point can be estimated. Interpreted in this way, the Cl^- mass balance age versus depth profile (Figure A-3) indicates that soil moisture age increases rapidly with depth below 1.5 m to an age of approximately 20,000 years at the sediment-basalt interface (approximately 5.5 m). The average rate of increase in Cl^- mass balance age with depth below the root zone indicates that the average vertical velocity of the migrating Cl^- is approximately 0.2 mm/yr. Because the soil moisture carrying that Cl^- is transported only though the water-filled pore space, the flux density of soil moisture through that region equals that velocity multiplied by the soil moisture content, which is assumed to be essentially constant:

$$q = \upsilon \cdot \theta$$

where ν is the average transport velocity, q is the water flux rate and θ is the volumetric water content. The average volumetric water content (Cecil et al. 1992), θ is approximately 24%, implying a virtually insignificant water flux rate of approximately 0.05 mm/yr below the root zone. Although this value is significantly less than the value reported by Cecil et al. (1991), it is consistent with our current understanding of water percolation processes in undisturbed sediments.

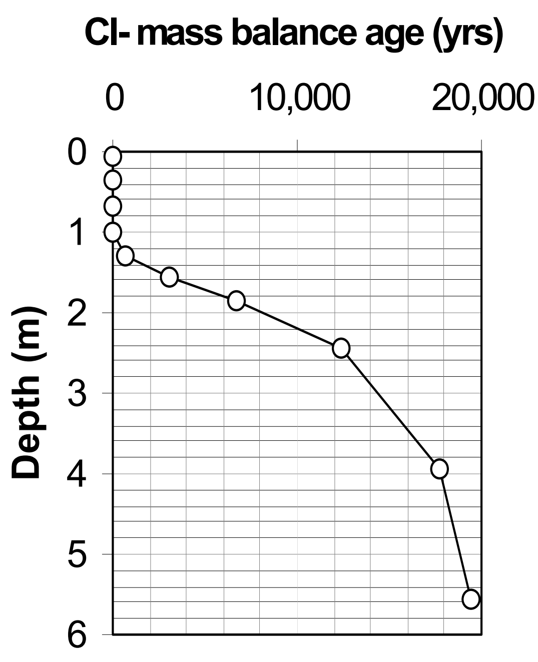

Figure A-3. Chloride mass balance age plot for the United States Geological Survey test trench profile.

Until recently, the USGS test trench profile has been the only place where environmental tracers have been used to estimate background water flux rates in undisturbed areas of the INEEL. As part of a 2003 INEEL Laboratory-Directed Research and Development project, another location was sampled to provide a Cl^- profile for chloride mass balance analysis. These soil samples were obtained from a test boring in undisturbed sagebrush steppe ecosystem on the INEEL. This boring, ICPP-1906, was located approximately 500 m southwest of the INEEL Vadose Zone Park infiltration ponds. It penetrated approximately 14 m of coarse alluvium typical of Big Lost River trough sediments before terminating at the sediment-basalt interface. Chloride concentrations in samples from the boring were measured at the INEEL using a Dionex through ion chromatograph.

As in the USGS test trench profile, the mass of Cl^- per gram of soil increases steeply in the upper two meters of soil, but compared to the test trench profile the magnitude of that change is less. Chloride concentrations are fairly uniform at approximately 1.5 mg/kg in the upper 1.5 m of soil, then increase to approximately 7 mg/kg by 2 m and remain at that level to the bottom of the borehole. Using the same Cl^- loading rate applied to the test trench data, this indicates a cumulative age-versus-depth profile is essentially a straight line, with a slope of approximately 7 mm/yr. The age of soil moisture at the bottom of the profile is thus approximately 1,800 years. Based on the average water content in that profile, approximately 7%, the Cl^- data suggest that the soil moisture flux is on the order of 0.5 mm/yr.

A-1.4 Deep Subsurface Hydrology

The crescent-shaped Snake River Plain Aquifer underlies the eastern part of the ESRP. The aquifer is bounded on the north and south by the edge of the Snake River Plain and on the northeast by the Yellowstone highlands. The unsaturated zone and aquifer are composed of a 500-m thick sequence of discontinuous volcanic and sedimentary deposits. Large zones of irregular fractures and voids—creating internal variations that may be highly transmissive—characterize the basaltic lava flows of the ESRP aquifer (Barraclough et al. 1976). These fractures and void within and between the basalt flows control the hydraulic conductivity on scales ranging from a few centimeters to several meters, and the directional variances they cause are probably random throughout a lava flow. The saturated basalt layers and sediment interbeds that underlie RWMC are approximately 177 m (580 ft) deep with hydraulic gradient (flow direction) generally from the northeast to the southwest.

Conditions of subsurface hydrology at the INEEL that affect spread of contamination and therefore must be considered for remediation purposes include:

- Vadose zone—the unsaturated zone between land surface and water table. Vadose zone thickness near RWMC is approximately 180 to 186 m (590 to 610 ft). Rates of moisture movement in sediment and basalt under varying moisture conditions have been quantified near RWMC and vary widely depending on the location, material type, and timing of infiltration at the surface.

- Perched water—unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone (Driscoll 1987) and usually formed beneath the SDA where a layer of dense basalt or fine sedimentary interbeds occurs with a hydraulic conductivity that is low enough that downward movement of infiltrating water is restricted. Perched water is transitory beneath RWMC, but has been detected in 11 boreholes (monitoring wells) at various times. Typically, the perched water wells are dry or contain so little water that the volume collected for analysis is limited. Perched water bodies have been identified in association with interbeds at two depth intervals of approximately 24 to 27 m (80 to 90 ft) and 61 to 67 m (200 to 210 ft).

- The Snake River Plain Aquifer—the saturated part of a series of basalt flows and intercalated pyroclastic and sedimentary deposits that underlie the ESRP. The aquifer arcs approximately 354 km (220 mi) through the eastern Idaho subsurface and varies from approximately 80 to 113 km (50 to 70 mi) wide terminating at Thousand Springs near Twin Falls, Idaho. Total area of the aquifer is estimated at 24,862 km^2 (9,600 mi^2). The ESRP aquifer is recharged primarily by infiltration from rain and snowfall within the drainage basins surrounding the ESRP and from deep percolation of irrigation water.

Aquifer wells completed in the ESRP aquifer beneath the INEEL are routinely monitored to characterize groundwater quality, to study potential for contaminant migration, and to provide input for the design of remedial activities. Knowledge of the surface of the aquifer, or water table, is used to infer general groundwater flow direction and magnitude. Although regional groundwater flow (the hydraulic gradient) is generally to the south-southwest, the flow direction can vary through recharge from rivers, surface water spreading areas, and physical geologic heterogeneities in the aquifer. Flow velocities, or magnitudes, within the ESRP aquifer beneath the INEEL range from between 1.5 to 6.1 m/day (5 to 20 ft/day) (Irving 1993) with an average gradient of 4 ft/mi (Anderson, Kuntz, and Davis 1999).

A-1.5 Seismic and Volcanic Summary

The SDA is located within the ESRP, a broad low-relief basin floored with basaltic lava flows and sediments. The ESRP is commonly recognized as representing the track of the Yellowstone hotspot, a region marked by time-progressive rhyolitic volcanism followed by diachronous basalt volcanism (Morgan 1972; Armstrong et al. 1975; Pierce and Morgan 1992). In the region of the INEEL, northwest-trending mountain ranges abruptly end along the northwest margin of the ESRP. The mountain ranges are bounded by normal faults along the southwest sides resulting in half-graben basins and block-tilted ranges. The southernmost segments of the Lost River and Lemhi faults are within 20 km of RWMC.

Two seismically active areas, the Intermountain Seismic Belt (ISB) and Centennial Tectonic Belts (CTB), surround the ESRP (Smith and Arabasz 1991; Stickney and Bartholomew 1987). Seismic monitoring by the INEEL indicates the ESRP has little seismic activity relative to the surrounding ISB and CTB (Figure A-4). The INEEL has compiled earthquake data from 1972 to 2002. During this period, only 29 small magnitude microearthquakes ($M < 1.5$) have been detected within or near the boundary of the ESRP, indicating that infrequent, small-magnitude earthquakes ($M < 1.5$) are characteristic of ESRP seismicity. In contrast, historic moderate-to-large earthquakes have occurred along normal fault segments in the ISB and CTB, including the 1983 M_s 7.3 Borah Peak, Idaho and 1959 M_s 7.5 Hebgen Lake, Montana earthquakes (Doser 1985).

A probabilistic seismic hazard assessment was completed in 1996 for all facility areas at the INEEL, including RWMC (Woodward Clyde Federal Services et al. 1996). This assessment evaluated ground motion levels from all potential earthquakes sources (e.g., normal faults, background seismicity, and volcanic rift zones) using regional and site-specific attenuation relationships. Probabilistic seismic hazard evaluations were developed for seismic hazard annual probabilities of exceedance of 500, 1,000, 2,500, and 10,000 years corresponding to Performance Categories (PC) 1, 2, 3, and 4, respectively, per the Department of Energy (DOE)-STD-1020-02 and DOE—STD-1023-95.

The resulting ground motion levels for rock conditions were developed into design criteria for moderate- (PC-3) and high-hazard (PC-4) facilities (DOE-ID 2002). The input data used in the 1996 INEEL seismic hazard assessment were also incorporated into the USGS seismic hazards evaluation that produced the National Seismic Hazards maps (FEMA 1998; USGS 2002). For low-hazard (PC-1 and 2) facilities at the INEEL, the International Building Code (IBC) is used for seismic design considerations (DOE-ID 2002). The IBC refers to the National Seismic Hazard maps for the rock ground motion levels (IBC 2000). Soil ground motion levels are calculated using the procedure in the IBC and the soil site classification listed in DOE-Idaho Architectural and Engineering Standards (DOE-ID 2002).

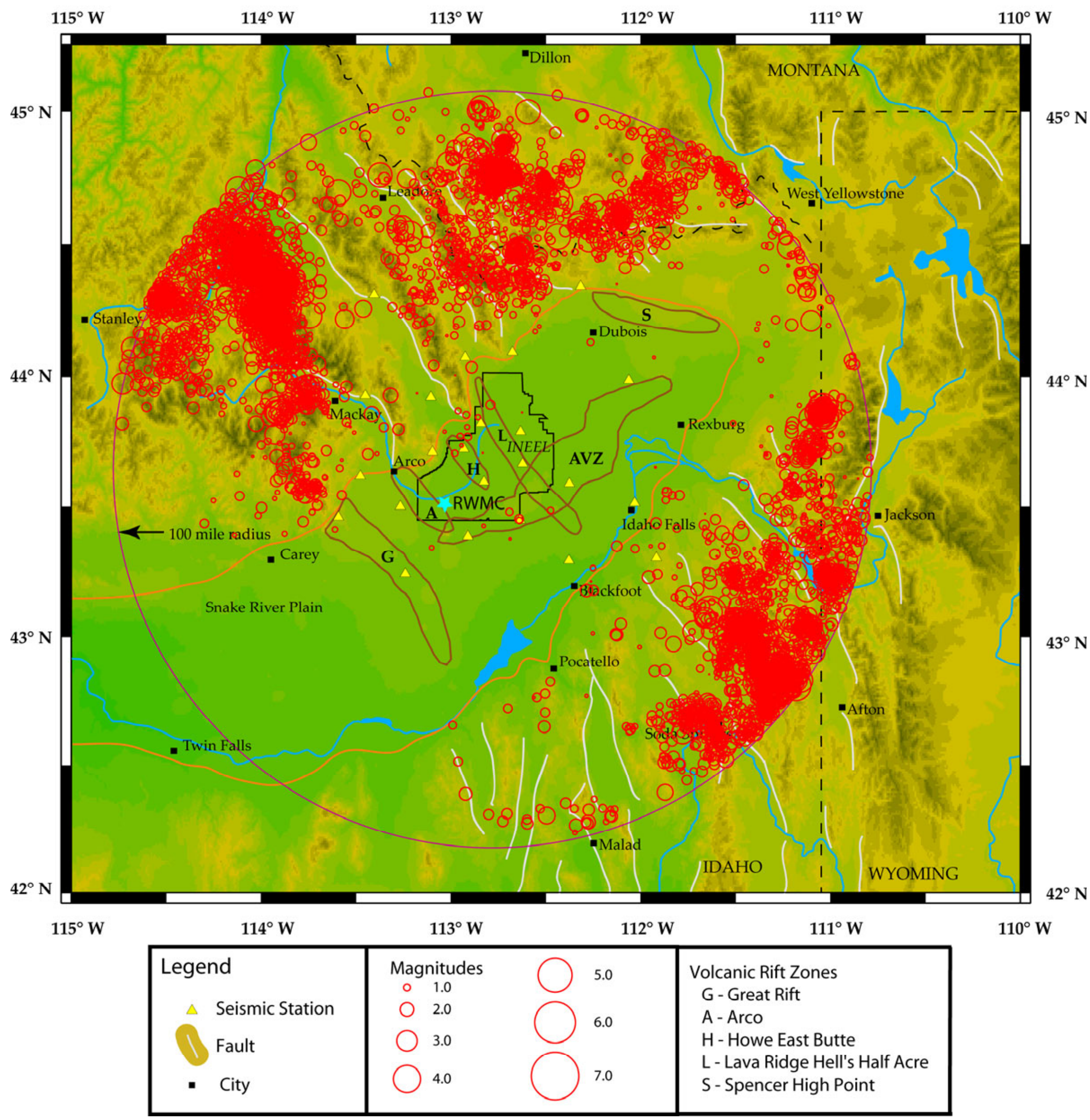

Figure A-4. Map showing the locations of earthquakes from 1972 to 2002 within a 160-km (100-mile) radius of the Idaho National Engineering and Environmental Laboratory.

From a volcanic perspective, the INEEL resides in the region of the ESRP that experienced explosive silicic volcanism from 7 to 4.3 Ma associated with the Yellowstone hotspot (Pierce and Morgan 1992). The Yellowstone hotspot is presently located beneath the Yellowstone caldera approximately 120 mi (200 km) northwest of the INEEL. Since the passage of the hotspot, volcanism for the past 4 My has been dominated by the eruption of basaltic lava flows. No eruptions have occurred on the ESRP during recorded history, but basaltic lava flows in the Hell's Half Acre lava field erupted near the southern INEEL boundary as recently as 5.4 Ka, and eruptions occurred as recently as 2.1 Ka along the Great Rift, 18 mi (30 km) southwest of the INEEL (Kuntz et al. 1986; Hackett and Smith 1994).

Volcanic vents are not randomly distributed on the ESRP, but occur within several recognized volcanic zones. RWMC is located near the northern boundary of the Arco volcanic rift zone. ESRP volcanic rift zones are marked by linear arrays of fissure-fed basaltic lava flows, small-shield volcanoes, pyroclastic cones, and collapse craters. ESRP basaltic eruptions typically involve localized ground deformation, mild effusions of fluid, gas-poor, pahoehoe lava flows from fissures and small-shield volcanoes (Kuntz et al. 1988, 1992, 1994).

Hackett (1993) evaluated potential impacts of three magmatic processes associated with basalt volcanism at RWMC:

1. The nature, probability, and potential impact of basaltic lava-flow inundation

2. The nature, probability and potential consequences of basaltic-dike emplacement

3. The composition of volcanic gases that may be associated with future ESRP basaltic-dike intrusion or lava effusion.

The results of the evaluation indicated RWMC could be inundated by lava flows or impacted by intrusion of feeder dikes along the Arco volcanic rift zone or from the axial volcanic zone. The general probabilities of basaltic-lava eruptions or dike-intrusion events near RWMC are 6.2 × 10-5 per year (recurrence interval of approximately 16,000 years) for the Axial volcanic zone and 5.9 × 10-5 per year (approximately 17,000 years) for the Arco volcanic rift zone (Hackett and Smith 1994). The conditional probability of inundation or physical disruption of RWMC because of these processes is estimated to be less than the general probabilities since not all lava flows would reach RWMC, and RWMC lies several kilometers from known areas of dike-induced faulting and fissuring within the Arco volcanic rift zone and the axial volcanic zone (Hackett 1993). Hackett (1993) suggested the earthen dike around the SDA has a geometry and composition (compacted soil and rock) that may be adequate to impede the flow of relatively thin basaltic-lava flows of up to about 3-m thick.

A-2. REFERENCES

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Appendix B

Waste Types and Locations in the Subsurface Disposal Area

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Waste Types and Locations in the Subsurface Disposal Area

B-1. SUBSURFACE DISPOSAL AREA WASTE TYPES AND LOCATIONS

Because of the Ancillary Basis for Risk Analysis (ABRA) and the distribution of the contaminants of concern (COCs) in the Subsurface Disposal Area (SDA), a surface barrier would have to minimize the percolation through the barrier, mitigate surface exposure pathways, and inhibit intrusion into the waste by plants, burrowing animals, and insects. The ABRA (Holdren et al. 2002) identified human health and ecological COCs for buried waste within the SDA. Nineteen human health COCs were identified. The majority of the COCs exhibiting the highest degree of risk was through groundwater ingestion; however, some surface pathways were also identified, as well as some ecological COCs. The Preliminary Evaluation of Remedial Alternatives divided the SDA waste into four major waste types: actinides, activation and fission products, volatile organic compounds (VOCs), and nitrates.

Actinide COCs include Am-241, U-233, U-234, U-235, U-236, U-238, Pu-238, Pu-239, Pu-240, and Np-237. The majority of the long-lived, relatively immobile actinides are contained within the Rocky Flats Plant (RFP) sludge deposited in drums within the pits, Pad A, and Trenches 1 through 10. Distribution of actinide waste in the SDA is depicted in Figure B-1.

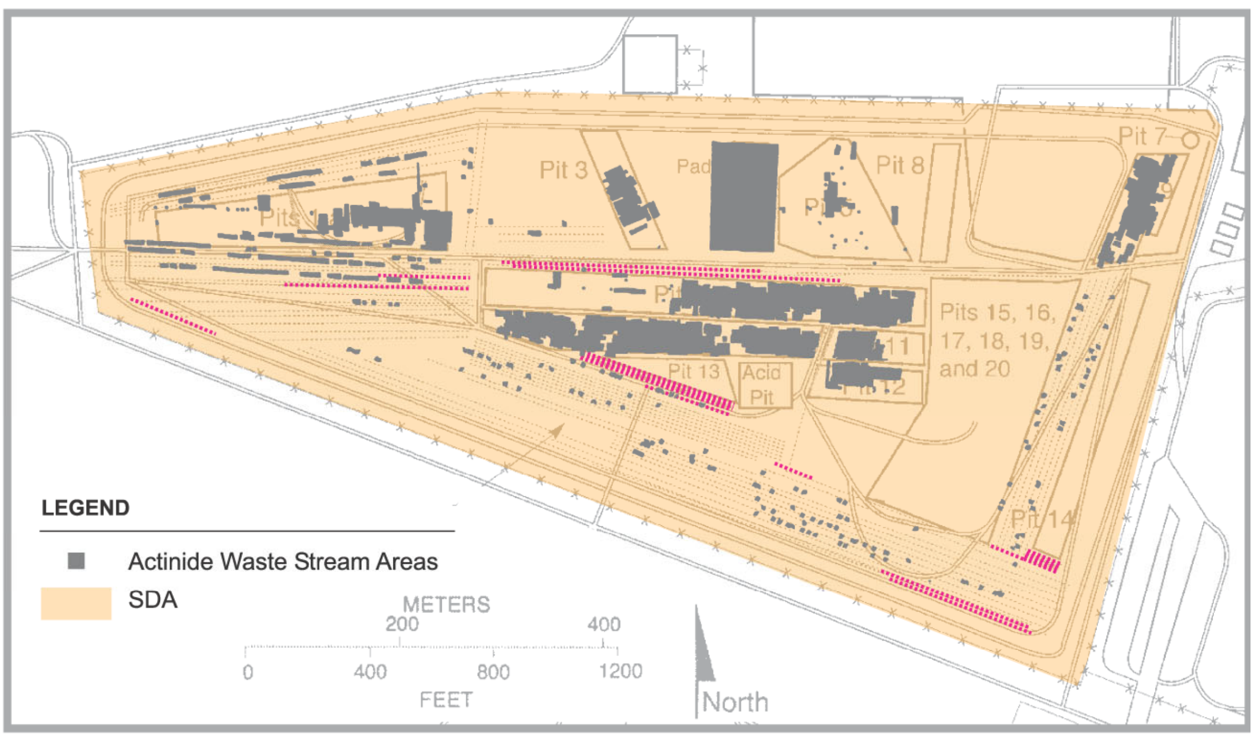

Figure B-1. Actinide waste distribution in the Subsurface Disposal Area based on a preliminary dataset.

Activation product waste streams include C-14, Nb-94, and Tc-99, and fission product waste streams include C-14 and I-129. Both types of waste streams were generated primarily from Idaho National Engineering and Environmental Laboratory reactor operations and consist mainly of metal and scrap metal pieces, core loop components, core structural pieces, resins, and irradiated fuel material. Waste was buried in various container types, primarily in the trenches and as remote-handled waste in the soil vault rows. Distribution of waste is depicted in Figure B-2.

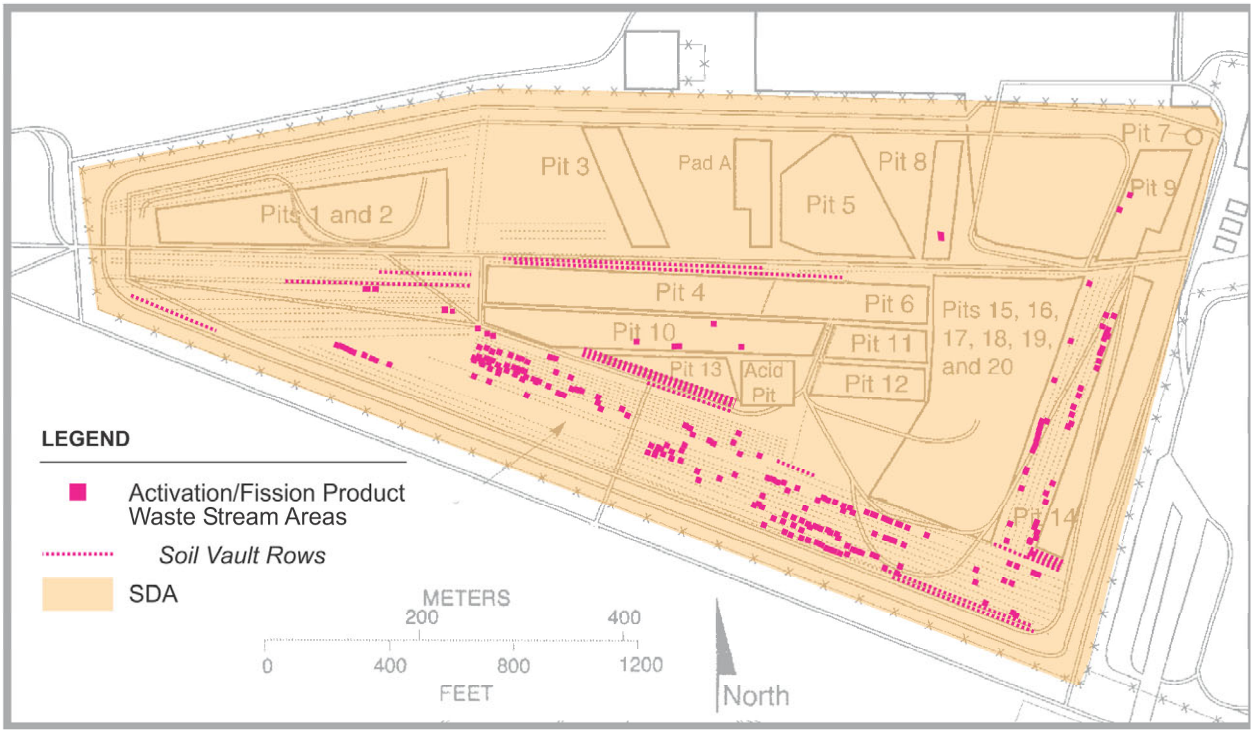

Figure B-2. Activation and fission waste distribution in the Subsurface Disposal Area based on a preliminary dataset.

Volatile organic compound COCs include CCl_4, PCE, and methylene chloride. Almost all CCL_4 and PCE are contained in organic sludge (i.e., Series 743 sludge) from the RFP. Methylene chloride is also contained almost entirely in the RFP waste streams consisting of sludge, paper, rags, plastic, equipment, and assorted debris. Distribution of volatile organic compound waste within the SDA is presented in Figure B-3. Waste streams are located primarily in Pits 1 through 6 and 9 through 12 and Trenches 1 through 10.

Nitrates within the SDA are located almost entirely in the drummed waste stream (i.e., Series 745 sludge) shipped from the RFP between 1967 and 1970. Nitrate waste in the SDA is located within Pad A, and Pits 4, 6, 9, 10, and 11 as shown in Figure B-4.

The distribution of the waste types and the requirements to protect the environment from the COC exposure pathways precludes the idea of making specialized barrier designs for portions of the SDA. The surface barrier would need to minimize percolation to minimize solute transport to the groundwater, vent waste gasses beneath the surface barrier to protect groundwater and as a surface release, mitigate direct surface exposure, and prevent biotic intrusion. Actinides are a percolation minimization problem; fission and activation products are both a percolation minimization problem, as well as a gas problem (i.e., C-14); volatile organic compounds are dominantly transported in the gas phase; and nitrates are a percolation minimization problem. Because the waste types are widely distributed across the SDA, single barrier designs should be evaluated.

Figure B-3. Volatile organic compound waste distribution in the Subsurface Disposal Area based on a preliminary dataset.

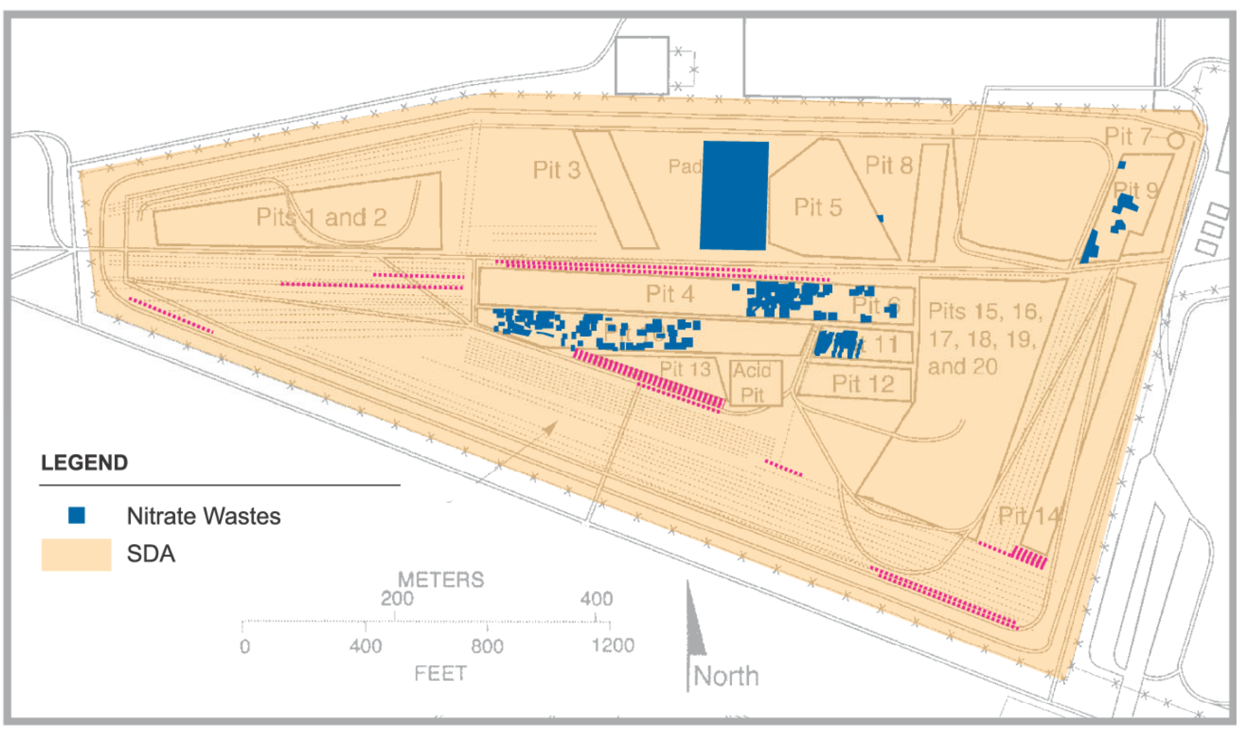

Figure B-4. Nitrate waste distribution in the Subsurface Disposal Area based on a preliminary dataset.

B-2. REFERENCES

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Appendix C

Detailed Description of Landfill Barriers in Use at the Idaho National Engineering and Environmental Laboratory

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Detailed Description of Landfill Barriers in Use at the Idaho National Engineering and Environmental Laboratory

C-1. HISTORICAL REVIEW OF LANDFILLS AT THE IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

A number of landfills have been established on the Idaho National Engineering and Environmental Laboratory (INEEL) that contain municipal, hazardous, or radiological waste (Figure C-1). Several of these landfills have been closed (or are approved to be closed) with surface barriers emplaced over the buried waste. Surface barriers range from simple evapotranspiration designs to protect human health and the environment for existing historical disposal sites at the Central Facilities Area (CFA) and the Naval Reactor Facility (NRF) to a complex multilayered surface barrier at the INEEL Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF) that was developed for an engineered, long-term treatment, storage, and disposal facility. In addition, two sets of research barriers have been studied at the INEEL to provide experimental data in support of developing alternative barriers for landfills at the INEEL. The Protective Cap/Biobarrier Experiment (PC/BE) landfill barriers mainly focused on the ecological relationship to barrier designs, and the Engineered Barrier Test Facility (EBTF) barriers examined surface barrier hydrologic performance with high surface infiltration rates. The following sections briefly describe each of the INEEL landfills and barriers, as well as the two sets of research barriers located at the INEEL.

C-1.1 Central Facility Area Landfills

CFA Landfills I, II, and III are located approximately 0.5 mi (0.8 km) north of CFA and began as excavations where waste (primarily construction-related waste) from INEEL operations was buried (Figure C-1). The landfills are no longer in use and have not received waste since 1984. A soil barrier was placed over each landfill at the time of closure (about 1984). A record of decision (ROD) was signed in September 1995 that required the placement of a uniform native soil barrier, the implementation of institutional controls, and periodic monitoring of groundwater, infiltration, and vadose zone (DOE-ID 1995). Each landfill is discussed in more detail below.

CFA Landfill I is approximately 3.3 hectares (8.25 acres) where waste was disposed of from the early 1950s until 1984. The landfill consisted of three subunits: the rubble landfill in a former gravel quarry, the western waste trench, and the northern waste trench. No disposal records were kept on the types of waste sent to Landfill I. Based on interviews with former landfill workers, waste included construction debris, paper, cafeteria garbage, and other solid and liquid waste typically found in municipal landfills. Waste, such as wood, paper, and flammable materials, disposed of in Landfill I was typically disposed of by open burning of the materials in the trenches. Metals and small amounts of liquid waste were also disposed of. When disposal operations ceased, the waste was buried to an estimated total depth of 5 m (15 ft) and then it was covered with 0.3 to 1.5 m (1 to 5 ft) of native soils.

CFA Landfill II was a former gravel quarry where waste was disposed of over an area of approximately 6 hectares (15 acres). Disposal of waste started in 1972 and continued until 1982. Approximately 95% of the solid waste disposed of in Landfill II consisted of trash sweepings, cafeteria garbage, wood and scrap lumber, and masonry/concrete. Much of the remaining 5% of solid waste consisted of weeds, dirt, gravel, asphalt, asbestos, and other waste building materials. Metals and small amounts of liquid waste consisting of oil sludge, solvents, paint, paint thinner, and chemicals was also disposed of in the landfill. Normal landfill operations consisted of disposal of waste at the edge of the excavation and compaction using heavy equipment. After compaction, the waste was covered with at least 0.15 to 0.20 m (0.5 to 0.7 ft) of soil each day. When disposal of waste at the landfill ceased, all the waste was compacted to an average depth of 5 m (16 ft), and then covered with 0.1 to 1 m (0.3 to 3 ft) of soil.

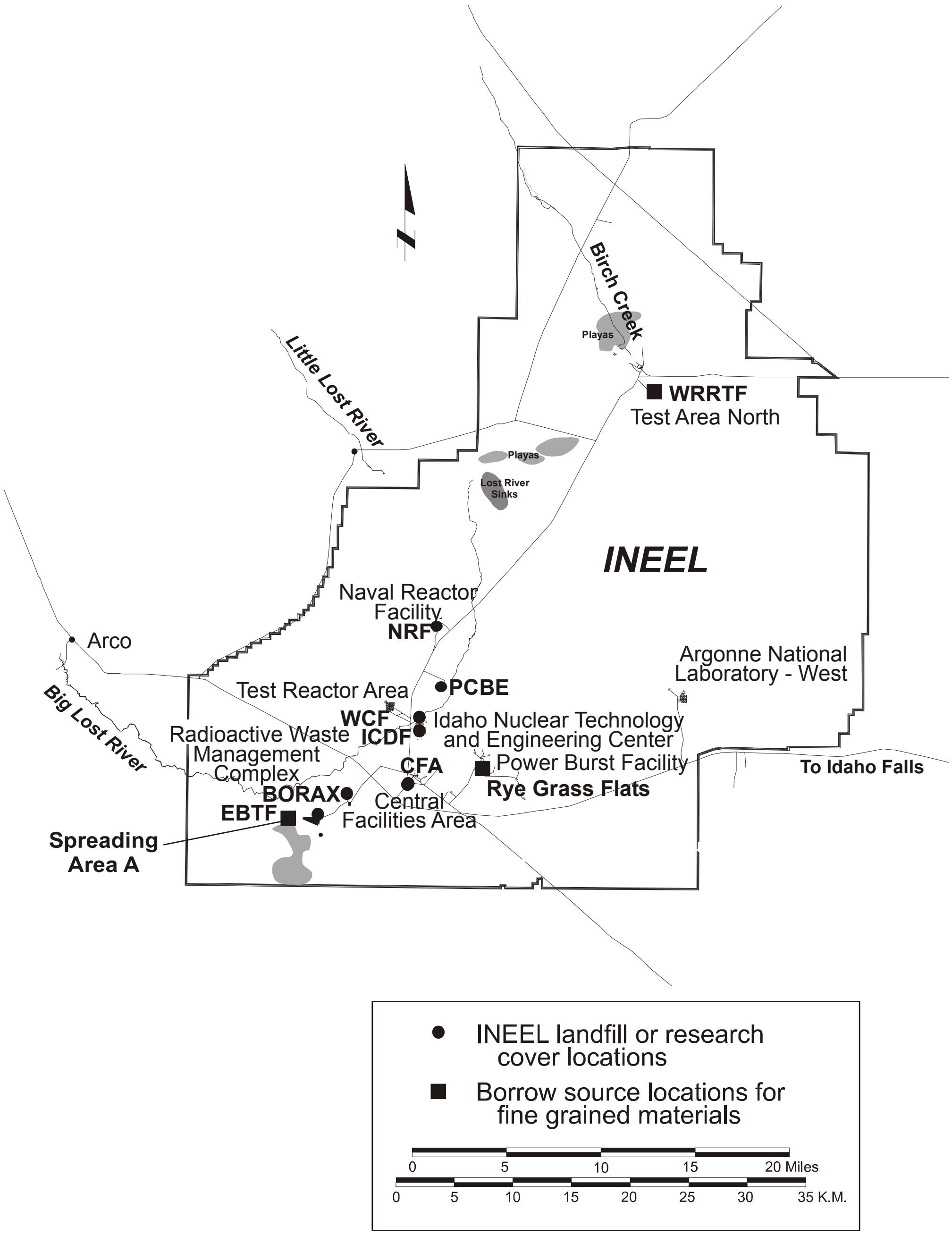

Figure C-1. Idaho National Engineering and Environmental Laboratory landfills, barrier test beds, and potential borrow source locations.

The main portion of Landfill III, covering approximately 5 hectares (12 acres), accepted waste from 1982 to 1984. During this period, waste was placed and compacted into 6 trenches, which measured approximately 7.3 × 3.7 × 732 m (24 ft wide, 12 ft deep, and 2,400 ft long). Heavy equipment was used to compact waste placed in the trenches and cover it daily with a layer of soil. Approximately 96% of the solid waste disposed of in Landfill III consisted of trash and sweepings, cafeteria garbage, wood and scrap lumber, and masonry/concrete. Much of the remaining 4% of solid waste consisted of weeds, grass, dirt, gravel, asphalt, asbestos, and other waste building materials. Liquid waste, such as waste asphalt and paint, was also disposed of in the landfill. When disposal of waste at the landfill ceased, with waste compacted to an average depth of 4 m (13 ft), the waste was covered with 0.3 to 1.2 m (1 to 4 ft) of soil.

In 1996, a remedial action under CERCLA was taken to place final surface barriers over each of the CFA landfills. The barrier placed over each landfill consisted of: (1) a general backfill layer that brought the existing grade up to the design slope (rough grade), (2) a compacted low-permeability soil layer, and (3) a topsoil layer that created the final grade and allowed for growth of a vegetative cover. The general background material is composed of clay with sand, and particle size analysis results show 84.1% of the material passing through a No. 200 sieve (less than 0.75 mm average diameter). Both the general backfill and low-permeability soil layers were compacted to a 95% of maximum dry density at 0 to + 4 percentage points from optimum moisture content. The general backfill layer was emplaced with a maximum of 0.5 m (1.6 ft) compacted lift thickness. The low-permeability soil layer was emplaced in maximum 8-in. loose lifts to attain a maximum 6-in. compacted lift thickness. The final topsoil layer was emplaced with no compaction. In addition, for Landfill II, a riprap layer was installed at the extreme northeast face of the landfill, rather than revegetating the area, in an effort to prevent erosion because of the steepness of the slope. A detailed description of the remedial action, including the installation of the landfill barriers, is provided in the *Remedial Action Report for CFA Landfills I, II, and III Native Soil Cover Project Operable Unit 4*-12 (DOE-ID 1997).

The monitoring plan for the CFA Landfills is designed to provide data for use in evaluating whether the remedial action is meeting the remedial action objectives stated in the ROD (DOE-ID 1995). In particular, the monitoring program data will be used to evaluate the remedial action objectives to minimize infiltration and ensure that drinking water standards are not exceeded in the Snake River Plain Aquifer because of contaminant migration from the landfills. Designed to monitor groundwater, vadose zone, and infiltration at all three landfills, the monitoring program integrates key objectives to:

- Monitor flux of moisture through the landfills barriers on a monthly basis
- Monitor soil gas volatile organic compounds and methane concentrations in the vadose zone near each landfill annually in the fall
- Monitor concentrations of contaminants in the groundwater near the landfills annually in the fall
- Establish a baseline of potential contaminant concentrations in the aquifer against which future data could be compared
- Monitor groundwater flow direction in the aquifer near the landfills annually in the fall.

C-1.2 Stationary Low-Power Reactor-1 and Boiling Water Reactor Experiment-1 Landfills

Stationary Low-Power Reactor-1 (SL-1) Background. The SL-1 landfill is located about 488 m (1,600 ft) northeast of the Auxiliary Reactor Area II in the south central portion of the INEEL.

The SL-1 landfill consists of three excavations in which 2,800 m^3 of contaminated material was deposited. The landfill is 183 × 91 m (600 × 300 ft) in size. The excavations were dug as close to basalt as the equipment allowed, and ranged from 2.3 to 4.3 m (8 to 14 ft) in depth. At least 0.6 m (2 ft) of clean backfill was placed over each excavation. Shallow mounds of soil over the excavations were added at the completion of cleanup activities in September 1962.

BORAX-1 Background. The Boiling Water Reactor Experiment-1 (BORAX-1) landfill is located about 2,730 ft (832 m) northwest of the Experimental Breeder Reactor-1, located in the southwest portion of the INEEL (Figure C-1). The BORAX-1 reactor was a small experimental reactor used in the summer months of 1953 and 1954 for testing boiling water reactor technology. In 1954, the design mission of BORAX-1 was completed. In 1954, one final test was conducted that resulted in the intentional destruction of the reactor. The destruction of the reactor contaminated approximately 7,800 m^2 of the surrounding terrain. Immediately following the final test of the BORAX-1 reactor, much of the radioactive debris, including some fuel residue, was collected and buried onsite in the reactor shield tank.

At BORAX-1, the 7,800-m^2 contaminated area was covered with approximately 0.15 m (0.5 ft) of gravel to reduce radiation levels at the ground surface. Buried materials at the site consist of uncovered uranium fuel residue, irradiated metal scrap, and contaminated soil and debris. The burial ground is contained within the foundation of the BORAX-1 installation. The dimensions of the foundation are 5.5 × 9.8 × 3.4 m (18 × 32 × 11 ft). A mounded gravel and dirt cover approximately 1.5 m (5 ft) high and 9 m (30 ft) in diameter is centered over the buried shield tank.

In the summer of 1997, under the purview of CERCLA, engineered long-term barriers were installed over the SL-1 and BORAX-1 landfills. The barriers were designed to provide shielding from penetrating radiation, a barrier to inadvertent human intrusion, and longevity through the use of predominantly naturally occurring materials. Additionally, the SL-1 barrier was designed to include a barrier to inhibit biotic intrusion barrier. Percolation of water into these landfills does not pose an unacceptable risk to the environment, so these surface barriers were not designed to preclude percolation.

The design life of the two barriers was based on reducing the total excess cancer risk for all contaminants to less than 1 in 10,000. The design life for the SL-1 barrier is 400 years; the design life of the BORAX-1 barrier is 320 years. The barriers were designed to endure the erosive effects of wind and water, allowing them to maintain an acceptable depth of barrier over the course of the design life.

The biotic barrier on the SL-1 landfill was designed as a gravel/cobble/gravel sandwich consisting, from bottom to top, of the following:

- 4 in. of gravel (1/4 to 1/2 in. in size)
- 12 in. of cobble (2 to 6 in. in size)
- 6 in. of gravel (1/4 to 1/2 in. in size).

The barrier to inadvertent human intrusion consists of a basaltic riprap layer of at least 24 in. deep. The riprap pieces range in size from 4 to 36 in., consisting primarily of pieces sized 12 to 24 in. The raw materials for the biotic barrier and riprap layers came from nearby borrow areas on the INEEL.

The BORAX-1 barrier was constructed with an under-layer consisting of the top 12 in. (6 in. of topsoil + 6 in. of gravel emplaced for shielding) of the surrounding contaminated 7,800-m^2 area. This soil was consolidated to a roughly 37 × 37 m (120 × 120 ft) area and compacted on top of where the reactor is buried. A riprap layer was placed over the consolidated soil to form the top layer of the barrier to minimize erosion.

The surface barriers were designed to experience minimal erosion over the design life, based on the soil types and the addition of the riprap layer. Erosion of the barrier would reduce the amount of radioactive shielding it provides. Areas adjacent to both barriers were graded to encourage drainage around and away from the capped landfill sites. The purpose of drainage control is to diminish erosion of the surface soils and barrier materials, not to avoid water infiltration. The surrounding area was also planted in native grass species to slow surface water flow velocities and provide additional erosion protection. A mixture of P-27 Siberian wheatgrass, *Ephraim* crested wheatgrass, and *Sodar* streambank wheatgrass in a 3:1:2 respective ratio was used to reestablish vegetation on the disturbed terrain adjacent to the landfills.

Although the surface barrier is operating as expected, additional rodent activity has been noted during the annual landfill inspections: specifically, "extensive evidence of rabbit activity around the barrier at SL-1" (INEEL 2003). Likely, the rabbits were using the boulder field as shelter. The annual inspection also noted that the new spring growth grass was well established.

C-1.3 Naval Reactors Facility Landfills

The NRF is located on the west central side of the INEEL (see Figure C-1). The NRF was established in 1949 as a testing site for the Naval Nuclear Propulsion Program. Three abandoned landfill areas are located at the NRF. When the landfills were active, waste from onsite activities was disposed of there. Primarily municipal waste was disposed of in the NRF landfills. About two-thirds of the waste consisted of office trash. Construction debris was also placed in these landfills. Less than 1% of the waste was solid and liquid chemicals, waste oil, and solvents. The typical waste disposal practice was to dump refuse in trenches, incinerate the combustible refuse, and then bury the residual. When the landfill sites were abandoned, the remains were left in place and covered with soil from the surrounding area.

Three surface barriers have been constructed over municipal waste at the NRF. Three additional barriers have been installed during the summer of 2004 to cover radiological waste.

The municipal landfill barriers were installed in June 1996. They consist of a soil layer that permits evapotranspiration and improves surface drainage away from the waste. The barriers have a slope of 3% and consist of a topsoil layer to support vegetation and a subsurface soil layer for percolation control. Design dimensions for these landfills were approximately 1-ft thickness for the topsoil layer and 2-ft thickness for the subsurface soil layer. The overall thickness of the barrier is approximately 1-m thick. The topsoil layer had a 30% gravel content to control erosion and the hydraulic conductivity of this soil was designed to be approximately 1×10^{-3} cm s^{-1}. The subsurface soil layer was designed to have a hydraulic conductivity of 1×10^{-5} cm s^{-1}. Source material to construct these layers came from barrier material from the Spreading Area B. Under the surface barrier is a base support layer consisting of a sandy gravel mixture. Figure C-2 illustrates a cross section of the municipal barrier design. The surface barriers were vegetated with two species of native grasses ("Sodar" streambank wheatgrass and bluebunch wheatgrass) and a non-native forb—Lewis flax.

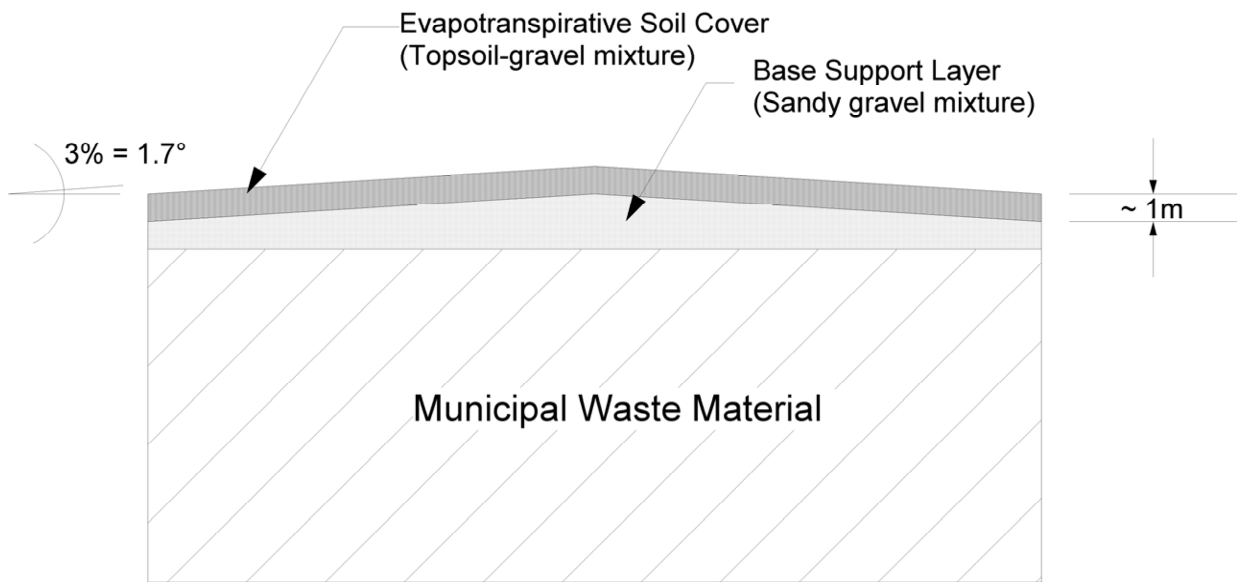

Figure C-2. Schematic of a municipal waste barrier installed at the Naval Reactors Facility in June 1996.

The 1997 annual inspection of the municipal barriers indicated that the vegetation was sparse and resulted in the barriers being reseeded. Above average precipitation during the following years helped establish the vegetation and currently the vegetation persists without irrigation. Other plant species have been noted encroaching on the barrier, particularly rabbitbrush. According to the 5-year annual report, the barriers are performing as designed with the exception of the problems with establishing the vegetation on the surface and minor erosion on one landfill (# 8-05-1). Monitoring of the landfill is accomplished using soil gas probes and groundwater wells.

Establishment of vegetation has been slightly problematic at the NRF municipal landfill barriers. Part of the problem is believed to be because of wind erosion of the seeds during planting. Although the NRF contractor used a straw admixture to place the seed, high winds appeared to have blown the straw and seeds off the landfill surface. The problem was solved during the subsequent replanting of the landfill barrier. A "tackifer," a sticky spray, was also used to hold the straw in place while the grass germinated.

The radiological barriers will be constructed during the summer of 2004 to cover radioactive contaminated soils at sites located southeast and immediately west of the NRF site. The three sites, designated as NRF-21A, NRF-19, and the combined sites of NRF-12B and NRF-14, were former leaching pits and beds and sewage basin areas. Each site received effluent containing a variety of radionuclides primarily consisting of Cs-137, Co-60, tritium, and Sr-90. Detail of the sites, extent of contamination, and the design of the barriers are presented in DOE (2002).

The primary objective of the radiological barriers is to prevent direct exposure to the contaminated soil. The potential pathways are exposure to gamma radiation, ingestion of soil and food crops, and direct contact exposure. The planned barriers are designed to prevent exposure to and direct contact with the contaminated soil, limit biotic intrusion, limit water flux, and provide erosion control. Selection of the final barrier design was based on results from INEEL research test barriers (e.g., the PC/BE [Anderson and Forman 2003]) and the Hydrologic Evaluation of Landfill Performance model.

The radiological barriers will be thicker than the municipal barriers at the NRF and approach an overall thickness of almost 2 m. The barrier design includes a 0.15 to 0.30 m (6 to 12 in.) top layer of a soil and gravel mixture to support vegetation and minimize erosion, a 120-cm (4-ft) thick water storage subsurface layer, and a 45-cm (1.5-ft) thick biobarrier. The top layer will have a 3 to 5% top slope and a maximum 3-to-1 side slope to promote surface runoff. The storage layer will be constructed out of silty clay loam materials and compacted to 95% of the maximum density. Potential location of the storage layer soil is from Spreading Area A or Rye Grass Flats. The biobarrier consists of a 30-cm (1-ft) thick cobble layer (7.5 to 15 cm [3-6 in.] in diameter) sandwiched between two gravel layers (No. 8 sieve to 3/4-in. diameter). These gradations were based on a recommendation in the Anderson and Forman (2003) report. Figure C-3 illustrates a cross section of the radiological barrier designs.

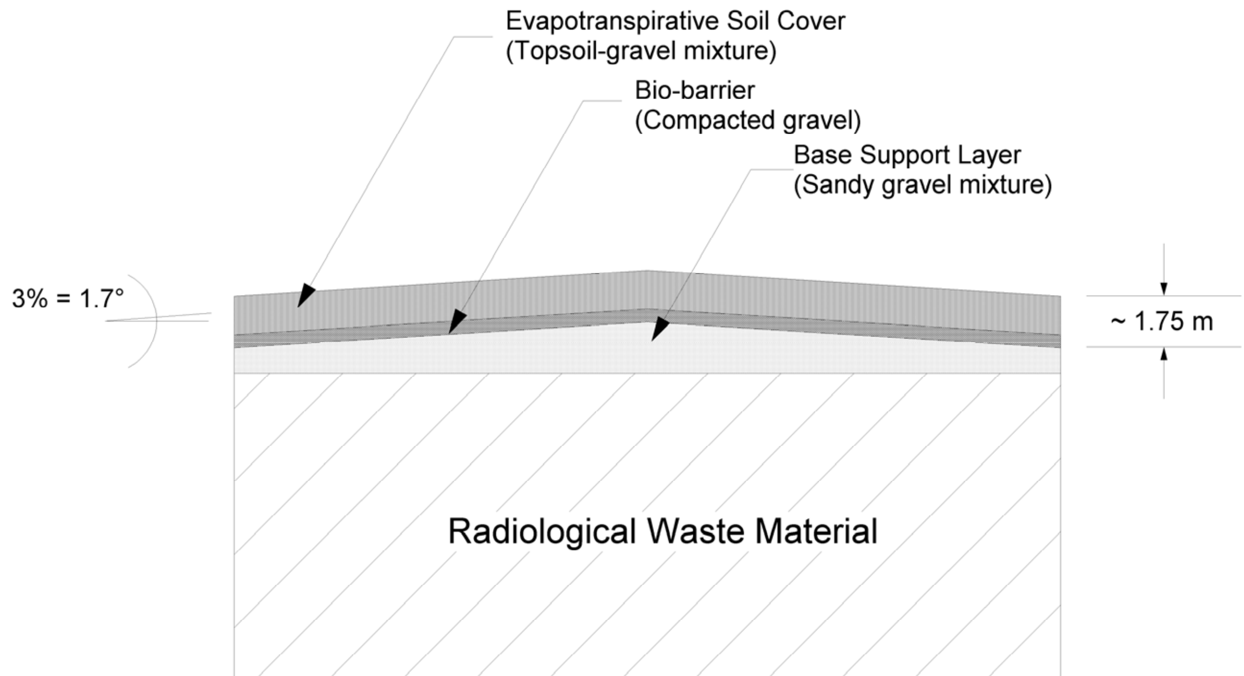

Figure C-3. Schematic of a proposed radiological waste barrier scheduled to be installed at the Naval Reactors Facility in summer 2004.

The proposed plant mixture for the radiological barriers closely matches that used in the PC/BE Project. Communities of indigenous plants with mores species tend to maintain a vegetative cover and fluctuate less as compared to barriers consisting with fewer species (Anderson and Inouye 1988). These more diverse plant community maintains higher cover and responds to changes in precipitation with greater sensitivity than a monoculture (Anderson and Forman 2003). Three types of perennial grasses (i.e., bluebunch wheatgrass, great basin wild rye, and streambank wheatgrass), two types of shrubs (i.e., sagebrush and rabbitbrush), and two perennial forbs (i.e., northern sweet vetch and scarlet globe-mallow) have been recommended for the preferred cover vegetation.

Postclosure monitoring of the radiological barrier sites includes radioactive surveys over the barriers and the collection of soil and vegetation samples to assess the effectiveness of the barrier in releasing contaminants. Percolation through the barrier will be assessed through soil moisture monitoring using a neutron probe in vertical access tubes. In addition, groundwater monitoring will be conducted to assess the effectiveness of the barriers.

C-1.4 Waste Calcining Facility Landfill

The Waste Calcining Facility (WCF) was the world's first plant-scale facility to achieve disposal of high-level radioactive liquid waste resulting from processing spent nuclear fuels for uranium recovery. From 1963 through 1981, WCF converted high-level radioactive liquid waste into granular solids. WCF was a reinforced concrete structure that included a ground level and two subsurface levels up to 50-ft below ground surface.

WCF was entombed because it was not practical to clean and close WCF because of the high radiation fields in a complex facility. Tanks and lines were filled with grout. Pipe penetrations were capped. The superstructure was demolished and waste was entombed in-place. The WCF structure was filled with grout. The grouted structure was capped with a reinforced concrete slab.

The WCF was closed with radioactive and hazardous constituents in place and met the closure requirements applicable to landfills by the construction of an engineered concrete barrier over the grouted cells, vessels, and superstructure (WCF96a). The barrier was constructed of a low permeability reinforced concrete, a minimum of 0.31-m (12-in.) thick with at least 1% slope from the center to the edges of the barrier. The barrier extends about 5 ft past the ground level footprint of the WCF building. Water stops were installed in the joints in the barrier and concrete has permeability in the order of 1×10^{-12} cm/sec (3.9×10^{-13} in./sec). The concrete had a minimum compressive strength of 4,500 psi after 28 days. The surface soils have a permeability of 2×10^{-2} to 2×10^{-1} cm/sec (7.8×10^{-3} to 7.8×10^{-2} in./sec) and the sedimentary interbed soils have a permeability of 1×10^{-3} to 9×10^{-5} cm/sec (3.9×10^{-4} to 3.5×10^{-5} in./sec). The concrete barrier functions with a minimum of maintenance, reduces erosion, and promotes drainage away from the barrier because of the grade of the surface. The belowground voids created by the vessels and cells were filled with grout to prevent subsidence and maintain the integrity of the barrier (Piet et al. 2003).

Postclosure monitoring will include groundwater monitoring. The postclosure maintenance and monitoring of the concrete barrier will be conducted at least annually for cracks in each section of the barrier and joints will be inspected for loss or degradation of the joint seal in between sections.

C-1.5 INEEL CERCLA Disposal Facility

The ICDF is located southwest of the Idaho Nuclear Technology and Engineering Center. The purpose of the ICDF landfill is to consolidate INEEL CERCLA waste into one engineered facility. It was designed to meet the requirements of the Resource Conservation and Recovery Act (RCRA) Subtitle C, and Toxic Substances Control Act (TSCA) polychlorinated biphenyl landfill design and construction requirements. The landfill is designed to minimize infiltration and maximize runoff and protection against inadvertent intrusion for greater than 1,000 years. Construction of the ICDF landfill has occurred and the landfill is currently operational.

The ICDF landfill accepts radioactive low-level, mixed low-level, hazardous, and TSCA waste generated from INEEL CERCLA activities. The current projections of site-wide CERCLA waste volumes total about 389,923 m^3 (510,000 yd^3) (DOE-ID 1999). Most of the waste will be contaminated soil, but debris and CERCLA investigation-derived waste will also be disposed of here.

The landfill is designed to be protective of the Snake River Plain Aquifer, such that groundwater contamination does not exceed a cumulative carcinogenic risk of 1E-04, a cumulative noncarcinogenic hazard index of 1, or applicable State of Idaho groundwater quality standards. It has been designed with an operational life of 15 years, a postclosure period of 30 years, and a landfill barrier design life of

1,000 years. The landfill will include a liner system and leachate collection and removal system. The liner system comprises (1) a top liner designed and constructed of materials (e.g., a membrane) to prevent the migration of hazardous constituents into the liner during the active and postclosure care period, and (2) a composite bottom liner with the lower component constructed of at least 0.91 m (3 ft) of compacted soil material with a hydraulic conductivity of no more than 1E-07 cm/sec. The leachate collection and removal system will operate and be maintained to collect and remove leachate from the landfill during the active life and postclosure care period.

The ICDF landfill will have a barrier to minimize infiltration and runon and maximize runoff by maintaining a sloped surface, storing water for later release to the atmosphere, lateral drainage, and providing a low-permeability composite liner barrier system (Figure C-4). Functional requirements of individual layers or zones within the barrier system include:

- Upper section—This is a water storage component (top 2.7 m [9 ft]) that provides water storage during wet periods for later release into the atmosphere during dry periods. The upper section will be seeded with native vegetation that will include wheatgrass, bluegrass, bottlebrush squirreltail, and green rabbitbrush.

- Middle section—This component is meant to protect against biointrusion from burrowing animals and provide a capillary break. This layer is located immediately below the upper section and is approximately 1.4-m (4.5-ft) thick where the top of the section is at least 2.7 m (9 ft) below the surface of the barrier.

- Lower section—The lower section includes a composite liner system that has a permeability less than or equal to the permeability of the landfill bottom liner system that complies with the Idaho Administrative Procedures Act 58.01.05.008 (40 CFR 264.310). Lateral drainage can occur above the composite liner system through a high permeability drainage material in the middle section. This layer is a minimum of 1.2 m (4-ft) thick and 4 m (13 ft) below the surface of the barrier.

C-1.6 Protective Cap/Biobarrier Experiment Studies

The PC/BE was initiated in 1993 at the Experimental Field Station (locally known as the Dairy Farm) approximately 6 miles north of CFA to compare four different evapotranspiration barrier designs. The goal of that experiment was to provide the data necessary for design of an "effective, economical barrier for the INEEL and climatically similar repositories, a barrier constructed of natural materials that will function with minimal maintenance over the long term as a natural ecosystem" (Anderson and Forman 2003). The experiment tested the ability of a variety of alternative landfill barriers to minimize water flux through the barriers. Four different landfill barrier configurations were constructed in a series of heavily instrumented 8 × 8-m plots. Soil moisture, changes in vegetative cover, and plant rooting depths were then monitored within each plot for a period of approximately 7 years. The four barrier designs tested were a 2-m-thick soil only barrier, two biobarrier (a shallow biobarrier design covered by 0.5 m of soil and a deep biobarrier design covered by 1 m of soil), and a RCRA barrier with 1 m of soil over a 0.6 m compacted clay layer (see Figure C-5). The soil used was a silty clay loam soil obtained from Spreading Area B. The biobarrier has a total thickness of 0.5 m and consists of 0.1- to 0.2-m-diameter river cobbles sandwiched between two 0.1-m-thick layers of crushed gravel (5- to 15-mm diameter) (Anderson and Forman 2003).

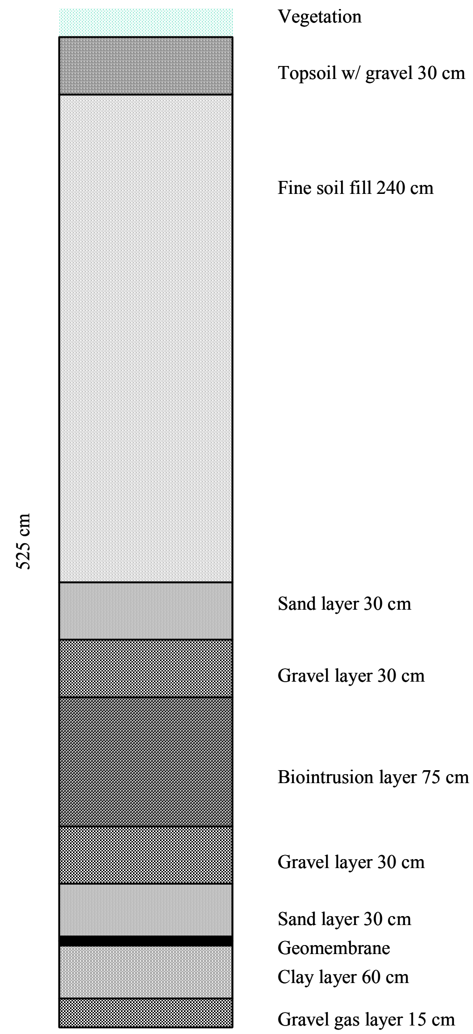

Figure C-4. Cross section of the INEEL CERCLA Disposal Facility barrier.

The effect of changing precipitation patterns, especially increased summer precipitation, was also investigated by including two supplemental irrigation treatments in addition to an ambient-precipitation control. Finally, the performance of two distinct plant community types on each of the four barrier designs was also tested. The first community type was crested wheatgrass (*Agropyron sp*.) planted in pure stand. This species has been used extensively on surface barriers at the INEEL. However, since ecological theory predicts that a diverse plant community will be more stable and more effective at using resources, such as soil moisture (McNaughton 1993), a mixture of 12 native species, including five shrubs, five perennial grasses, and two forbs was used as the second vegetation type in the experiment. The PC/BE was therefore designed to assess how differences in vegetation community and climate affect the performance of the four evapotranspiration barrier designs tested. Surface barrier performance under all combinations of these factors was assessed over a 7-year period, and all barrier configuration, vegetation type, and precipitation/irrigation combinations were replicated three times. Results of the first 7 years of the PC/BE are available in Anderson and Forman (2003).

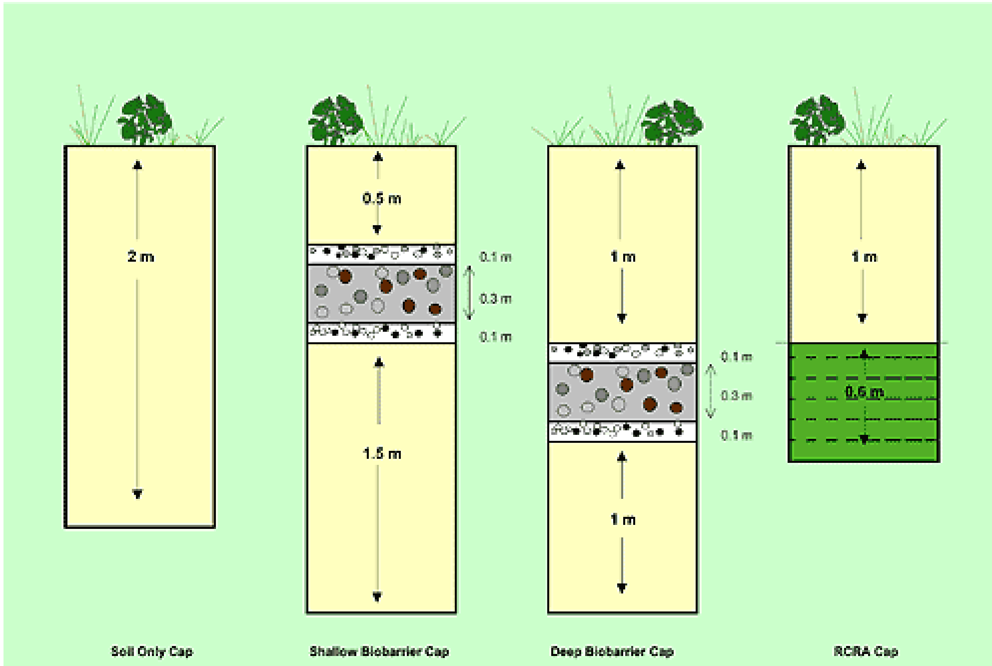

Figure C-5. Cross sections of the four Protective Cap/Biobarrier Experiment test cells.

Results of the water balance monitoring indicated that under ambient climatic conditions, all of the barrier types effectively eliminated water flux into the underlying material. Similarly low water flux rates were measured under each barrier type even under the scenario testing the effect of increased summer rainfall, presumably because of the ready available energy for ET at that time of year. Important differences, however, were observed in the treatment examining increased winter precipitation. Under those conditions, only the soil-only and biobarrier were able to preclude percolation through the barrier, and monitoring data indicated that such would be the case even under considerably larger increases in precipitation. This has critical import for barrier design at the INEEL because regional precipitation occurs primarily in the winter, and changes in the precipitation rates would most likely be felt in the seasonal spring snowmelt.

Examination of root development in the test plots demonstrated that roots of numerous plant species were able to bridge the 0.5-m thick biobarrier to extract water from underlying soil. This was exacerbated in the shallow biobarrier design because insufficient storage in the overlying 0.5 m of soil increased the water flux that penetrated the biobarrier, thereby increasing the availability of water in the soil directly beneath the barrier. This led to strong selection for gray rabbitbrush within the plot, a native shrub that relies primarily on deep moisture reserves. These results demonstrate that design of an evapotranspiration barrier should include consideration of the plant species that the design is likely to promote. Growth of some deep-rooted species may result in intrusion into buried waste. While in some cases, such intrusion might result in a potentially beneficial effects (e.g. the reduction of soil moisture near the waste), root growth in the waste materials could also present a pathway for undesired release to the environment. However, where roots penetrated the biobarriers, extraction of water from below the barrier was observed at water content that were generally high (greater than 25% by volume). Results from these field studies suggest that if water storage and evapotranspiration above the biobarrier are sufficiently matched, eliminating percolation through the biobarrier, the potential of plant root intrusion through the biobarriers should be reduced.

The PC/BE study provided an excellent dataset for determining whether an evapotranspiration barrier can effectively minimize water flux into the subsurface under climatic and ecological conditions similar to those prevalent at the INEEL. The authors of that study concluded that a mixture of native perennial plants developed on a soil barrier consisting of either 2 m of homogeneous soil or 1.2 m of soil overlying a 0.5-m animal intrusion barrier should "preclude virtually any precipitation water from reaching interred wastes" (Anderson and Forman 2003). They further demonstrated that a RCRA barrier of similar total thickness would be much less effective at limiting water flux.

C-1.7 Engineered Barrier Test Facility Studies

Landfill test barriers were evaluated at the EBTF located adjacent to the Radioactive Waste Management Complex in the southwestern corner of the INEEL. A schematic of the EBTF is provided in Figure C-6. The facility is a concrete structure consisting of five cells (i.e., plots) on either side of an enclosed access trench. Each cell has four walls and a floor and measuring 3.05 m wide × 3.05 m long × 3.05 m deep. The top of each cell is open to the atmosphere. Each cell has two floor drains that empty into separate sumps in the access trench. One drain drains a 10-cm wide trough that extends around the bottom perimeter of the cell. The other drain drains the remaining central portion of the cell.

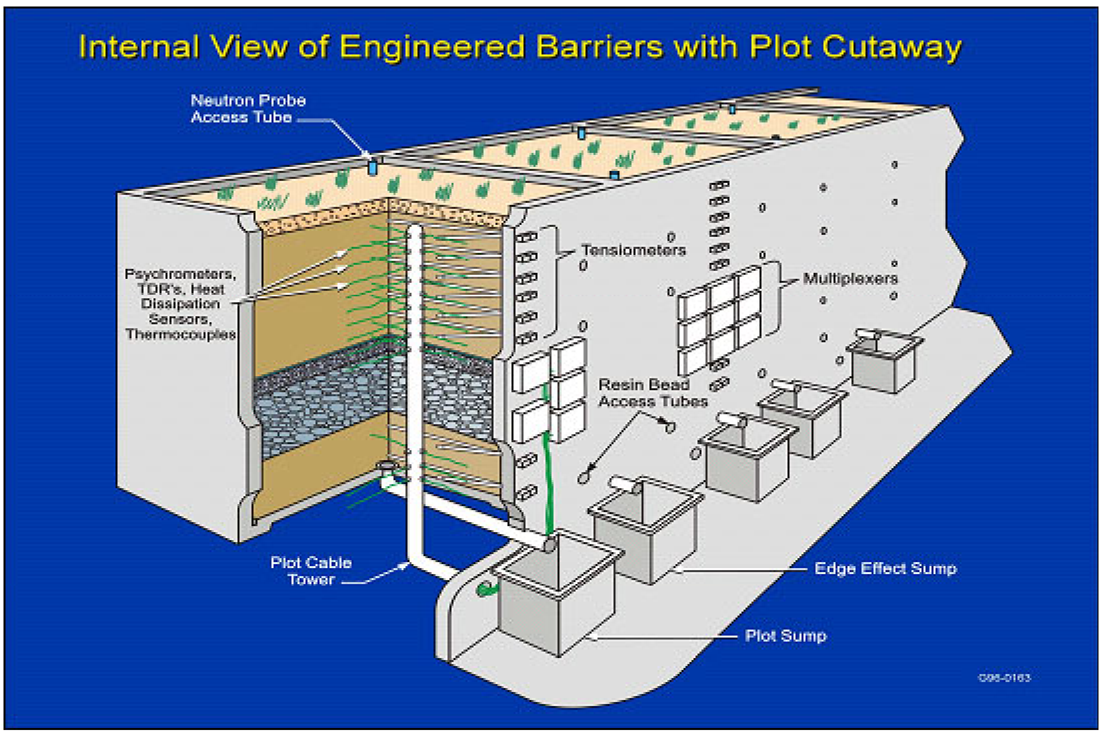

Figure C-6. Schematic of the Engineered Barrier Test Facility at the Radioactive Waste Management Complex.

The access trench is approximately 26.2 m long × 3.0 m wide × 3.8 m deep and serves primarily as a protected area for housing the data acquisition system and those instruments (e.g., tensiometers) that penetrate the cell walls. A separate room at the south end of the access trench houses the data acquisition computer and serves as an office area. The access trench is supplied with 115-V electrical service and a telephone line. A heat pump mounted on the south end of the roof of the access trench minimizes temperature variations and prevents freezing within the access trench.

Replicates of two surface barrier designs were constructed in the test cells. One barrier design consists of a uniform layer of silt loam soil. This soil is covered with a 15-cm-thick layer of mixed silt loam soil (75% by volume) and gravel (25% by volume) designed to increase the barrier's resistance to wind erosion. The other barrier design consists of a similar soil-gravel surface layer underlain by 1.45 m of silt loam soil. Beneath this soil are a 15-cm-thick layer of gravel and a 76-cm layer of cobbles. A sharp interface between the gravel and the overlying soil is maintained by a high conductivity geotextile. The interface forms a capillary barrier that impedes downward water flow during unsaturated conditions. The cobble layer is intended to minimize biointrusion beyond this depth. The cobble layer is underlain by more silt loam soil. Both types of barriers are designed to exploit the transpiration capabilities of plants to extract water that infiltrates into the barriers. However, all test plots were maintained devoid of vegetation during the current testing period. The absence of vegetation allows evaluation of the behavior of the barriers under the most extreme hydrologic conditions that are likely to occur. Each test plot is heavily instrumented to continuously measure soil moisture, soil moisture tension, soil temperature, and drainage.

A wetting test designed to subject the barriers to severe hydrologic stress was performed on all test plots in Fiscal Year 1997. Each wetting test consisted of applying water to the surface of the plot until drainage from the bottom of the plot began. Test plots were kept cleared of vegetation to maximize hydrologic stress during recovery. Following cessation of drainage resulting from the wetting irrigations, water storage levels in all plots were at elevated levels compared with pre-irrigation levels. As a result, infiltration of melting snow during the subsequent spring overloaded the storage capacity and produced drainage in all plots. Relatively rapid melting of accumulated snowfall produced the most significant infiltration events each year during the study. Capillary barriers yielded less total drainage than thick soil barriers. By limiting drainage, capillary barriers increased water storage in the upper portions of the test plots, which led to increased evaporation from the capillary barrier plots compared with thick soil plots. Increased evaporation in the capillary barrier plots allowed more water to infiltrate in the second season following the wetting tests without triggering drainage. All thick soil plots again yielded drainage in the second season. Within two years of intentionally induced breakthrough, evaporation alone (without transpiration) restored the capability of the capillary barrier to function as intended, although water storage in these barriers remained at elevated levels (Porro 2001).

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Appendix D

Requirements for Municipal Solid Waste Landfills

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The minimum requirements for municipal landfills are described in the Resource Conservation and Recovery Act (RCRA) Subtitle D in 40 CFR 258 (Figure D-1). These requirements are quantitative in as much as they define both minimal thickness and permeability requirements. The requirements are stated as:

1. Barrier permeability less than or equal to the permeability of the bottom liner/subsoil or no greater than 10^{-5} cm/sec

2. Minimize infiltration using no less than 45 cm of soil

3. Minimize erosion using no less than 15 cm of soil for plant growth.

The barrier layer's primary purpose is to minimize the water flux into the underlying waste. Soil with low saturated hydraulic conductivity should be used. These soils generally have large amounts of fines in them, including clay.

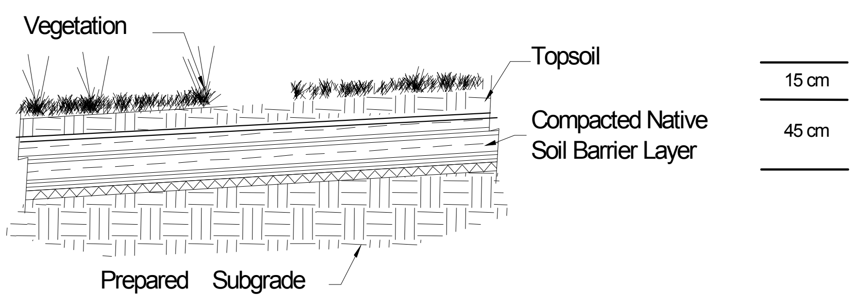

Figure D-1. Traditional Subtitle D barrier soil profile.

D-1. REQUIREMENTS FOR HAZARDOUS AND MIXED WASTE LANDFILLS

Minimum regulatory requirements for closure of hazardous and mixed waste landfills (40 CFR Parts 264 and 265) are defined less quantitatively than those for municipal landfills. The primary closure requirements of 264.310 and 265.310 specify that the owners/operators must design and construct a low-permeability barrier over the landfill to minimize migration of liquids into the waste and must provide 30 years of postclosure monitoring and maintenance to prevent waste migration into the environment. The barrier must:

1. Minimize liquid migration

2. Promote drainage while controlling erosion

3. Minimize maintenance

4. Have permeability equal to or less than the permeability of the natural subsoil

5. Account for freeze/thaw effects

6. Accommodate settling and subsidence so that the barrier's integrity is maintained.

A design guidance document issued by the Environmental Protection Agency (EPA) in 1989 (EPA 1991) recommends that landfill closures for RCRA Subtitle C and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) facilities incorporate the following layers in a barrier profile (see Figure D-2):

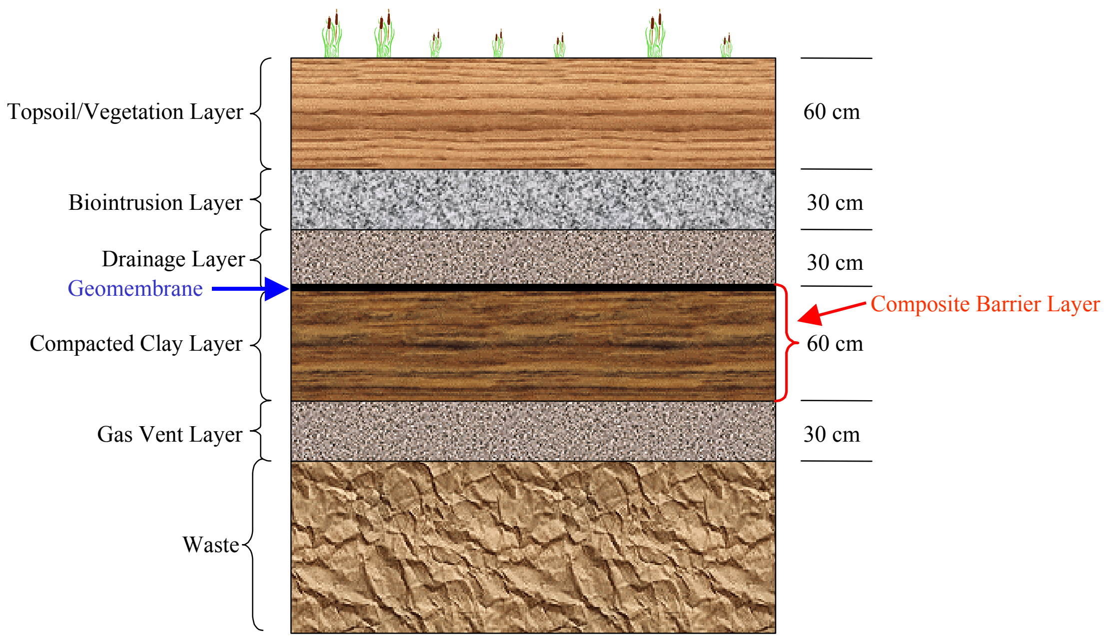

Figure D-2. Traditional Subtitle C barrier soil profile.

1. Composite barrier layer—A layer consisting of a low hydraulic conductivity geomembrane/soil layer. A 60-cm (24-in.) layer of compacted natural or amended soil with a maximum saturated hydraulic conductivity of 1×10^{-7} cm/sec in intimate contact with an overlying 0.5-mm (20-mil) thick (minimum) geomembrane liner. This composite barrier layer is to block moisture infiltration downward from the overlying drainage layer.

2. Drainage layer—A minimum 30-cm (12-in) soil layer having a minimum hydraulic conductivity of 1×10^{-2} cm/sec, or a layer of geosynthetic material having the same characteristics. This layer is to minimize the time the infiltrated water is in contact with the bottom composite barrier layer, and hence to lessen the potential for the water to reach the waste.

3. Topsoil vegetation layer—A top layer with vegetation (or an armored top surface) and a minimum of 60 cm (24 in.) of soil graded at a slope between 3 and 5%. This layer should be capable of sustaining nonwoody plants, have an adequate water-holding capacity, and be sufficiently deep to allow for expected, long-term erosion losses.

4. Optional layers include the following:

    a. Gas vent layer—This layer should be at least 30-cm (12-in.) thick and be above the waste and below the composite barrier layer. The layer is generally composed of coarse-grained soil, similar to that used for the drainage layer. Perforated, horizontal pipes within this layer should channel gases to a minimum number of vertical risers at a high point (in the cross section) to promote gas ventilation.

    b. Biointrusion layer—A 90-cm (3-ft) biotic barrier of cobbles directly beneath the top vegetation layer may stop the penetration of some deep-rooted plants and the invasion of burrowing animals.

The EPA's guidance for the design and construction of RCRA/CERCLA final barriers (EPA 1991) emphasizes that proper closure is essential to complete a waste landfill. The EPA's general approach to barrier design has been to prescribe generic design criteria for a final barrier design that meets the stringent closure regulations specified under RCRA. The EPA does allow for final barrier designs that consider site conditions and encourages alternative designs that are innovative and use site-specific information.

Alternative landfill barriers are being used at multiple facilities. These barriers have several advantages over the traditional regulatory barriers while being equally protective of human health and the environment. Some of the benefits include more readily available construction materials, ease of construction, less complex quality assurance/quality control programs, greater cost-effectiveness, and increased long-term sustainability with decreased maintenance (ITRC 2003). The two design concepts presented in this report are the evapotranspiration barrier and capillary barrier. These alternative design concepts are generally best suited for arid and semi-arid climates. Both design concepts capitalize on the naturally occurring high evapotranspiration rate coupled with a low precipitation rate. See Appendix H for details of the alternative landfill barrier designs.

D-2. REFERENCES

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Appendix E

Characteristics Specific to the Subsurface Disposal Area

Appendix E

Characteristics Specific to the Subsurface Disposal Area

E-1. PERCOLATION OF MOISTURE

Contaminant fate and transport associated with the Subsurface Disposal Area (SDA) have been modeled several times, beginning with screening level assessments and progressing to increasingly sophisticated simulations. Current risk-based modeling generally over-predicts the observed concentration of contaminants in the subsurface as compared to monitoring results. The most recent iteration of the model developed for assessing solute migration from the SDA is presented in the *Ancillary Basis for Risk Analysis* (ABRA) (Holdren et al. 2002). Attempts to calibrate the SDA dissolved-phase transport model were hampered by several factors, most important of which was the lack of adequate calibration targets. Despite an extensive monitoring network and quarterly sampling, most contaminants[a] are not detected at all or are detected at low concentrations near detection limits. Exceptions to this general monitoring behavior are too few and too sporadic to provide temporal trends that can be used for calibration. To compensate for the lack of calibration targets, the model was implemented using conservative parameters and therefore over-predicts contaminant concentrations. Simulated-to-actual contaminant concentrations for mobile long-lived contaminants, such as C-14, I-129, and Tc-99, are orders of magnitude higher than detected concentrations (see Table 5-17 in the ABRA). Although the SDA transport model is not calibrated sufficiently to confidently predict actual groundwater risks as a function of the percolation rate through the SDA, the modeling results using these conservative assumptions can provide an upper limit of allowable percolation through an SDA surface barrier.

The U.S. Department of Energy (DOE) requires a Composite Analysis (CA), in addition to either a Performance Assessment pursuant to DOE Order 435.1 or risk analysis pursuant to Comprehensive Environmental Response, Compensation, and Liability Act, for the SDA. The most updated CA for the SDA (McCarthy et al. 2000) assessed the cumulative impacts from disposals from on-going low-level waste disposal and previously radioactive disposals that could affect the future dose to the public. Since the final design of a surface barrier was not completed during the CA analysis, the CA analysis assumed that the SDA will not have any waste removed and the SDA will be covered with a surface barrier that will reduce infiltration and restrict land use. The CA assumed that the surface barrier would be constructed of local materials and will reduce water flux through the barrier to 1 cm/yr for perpetuity. Results from the CA study indicate performance compliance in the 1,000-year period specified by DOE with a reasonable assurance that public health and safety will be protected (McCarthy et al. 2000).

Updated modeling will be conducted for the remedial investigation and feasibility study. In the meantime, this preliminary conceptual design will assume a performance criterion of 1 cm/yr (3×10^{-8} cm/sec) as an acceptable percolation flux. This flux value was chosen based on the results of the RWMC Performance Assessment (Case et al. 2000) and CA (McCarthy et al. 2000). The 1-cm/yr flux was originally obtained from the barrier modeling study for the SDA by Magnuson (1993) and is consistent with water flux rates calculated by Cecil et al. (1992).

A second potential percolation performance issue for the SDA surface barrier is the requirement for the surface barrier to be less permeable than the underlying sediments. Few measured hydraulic properties

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a. The volatile organic compound carbon tetrachloride is routinely detected, but is not a good calibration target for dissolved-phase contaminants such as uranium, technetium, and nitrates.

have been made of undisturbed soils beneath the SDA. Kaminsky (1991) measured unsaturated hydraulic properties just outside at the SDA at the United States Geological Survey test trench facility and obtained a range of saturated hydraulic conductivity from 0.3 to 3.3 cm/hr (8×10^{-5} to 9×10^{-4} cm/sec) using the instantaneous profile method. In a subsequent study, Shakofsky (1993) measured saturated hydraulic conductivities from 11 undisturbed soil core samples from within the test trench that exhibited a range from 5.5×10^{-3} to 4.4×10^{-4} cm/sec. Within the SDA, Martian (1995) used an inverse modeling approach to neutron probe moisture data to obtain an average undisturbed hydraulic conductivity of 680 millidarcies (approximately 6.6×10^{-4} cm/sec) that is used in the current TETRAD modeling simulations. These results indicate that the surface barrier should be designed with a saturated hydraulic conductivity less than 1×10^{-5} cm/sec to minimize the development of perched water within the SDA waste.

Likely construction materials to be used to build the SDA surface barrier are sufficiently fine to meet the surface barrier permeability requirements. Two fine grain material borrow sites located at the Idaho National Engineering and Environmental Laboratory (INEEL) to obtain soil for the SDA surface barrier include Rye Grass Flats and Spreading Area A. A study conducted by Smith et al. (1994) includes the results of physical properties analysis of soil samples taken from these two areas. These samples were remolded soil core compacted near the maximum bulk density. Saturated hydraulic conductivity at Rye Grass Flats ranged from 4.7 × 10-5 to 3.2 × 10-8 cm/sec. Spreading Area A soils tested in a similar range (2.3 × 10-6 to 7.9 × 10-8 cm/sec). The hydraulic properties of both fine-grained soil borrow locations exhibit lower permeability than the undisturbed soil beneath the SDA.

E-1.1 Gas Venting

Sludge buried at the SDA contains volatile organic compounds (VOCs), radioactive contaminants, and other hazardous constituents. Transport-mechanism-controlling redistribution of these contaminants depends largely on the partitioning between solid, liquid, and gaseous phases. For many contaminants, transport in the gas phase may be as great or much greater than transport in the aqueous phase. While gas transport causes movement of contaminants upward toward the soil surface, and downward toward the water table, the proximity of the source term near the land surface indicates that gaseous transport to the atmosphere is significant. Design of a barrier for the SDA must either accommodate or minimize gas transport within the barrier. To illustrate the importance of designing the barrier with due consideration for gas transport, the impact of gaseous transport on some of the primary contaminants of concern (COCs) at the SDA is reviewed in this section.

The primary VOCs in the SDA are CCl_4, $CHCl_3$, TCE, PCE, and 1,1,1-TCA with an estimated combined mass of approximately 1.1 million kg. CCl_4 (approximately 820,000-kg mass) constitutes 75% of the total VOC mass (Miller and Varvel 2001). VOC concentrations in soil gas samples from within the SDA waste are in the range estimated to reflect equilibrium with liquid-phase product, indicating that VOCs are still an active source in the sludge. Numerical modeling studies indicate that a vast majority of the VOCs released from the SDA waste vent to the atmosphere. This result is not surprising considering the proximity of the waste to the soil surface as compared to the groundwater.

Activated metals disposed of in the SDA release radioactivity as they corrode. While some of the radioactive corrosion byproducts, such as Cl-36, are subject only to aqueous transport, a significant fraction of the released radioactivity is transported in the gas phase. For example, tritiated water and C-14 released from beryllium reflector blocks disposed of in the SDA are transported both in aqueous and gaseous phase. The need to properly assess the relative rates of transport via liquid and gas movement prompted investigations at the INEEL that examined the relative gaseous and aqueous transport rates via a suite of tracer and radionuclide transport experiments in a mesoscale column of unsaturated sediment

(Plummer et al. 2004). Results from those experiments confirmed measurements of transport parameters made in the laboratory and provided strong evidence that C-14 transport in the SDA soils is strongly dominated by gas transport processes.

The importance of gas transport in the redistribution of C-14 and tritium from activated metals in the SDA is demonstrated by the relatively high concentrations of those radionuclides measured in the soil and air above the beryllium block disposal site in Soil Vault Row 20. Recent measurements of surficial soil samples at that location yielded soil moisture tritium activities of up to 600 nCi/ml and activities of up to 100 nCi/m^3 have been measured in ambient air above the disposal area. Based on these measurements, fluxes to the atmosphere from Soil Vault Row 20 have ranged from 1 to 30 Ci/yr since measurements began in 1995. Carbon-14 is also readily measured in soil gas and ambient air above Soil Vault Row 20, though monitoring of that radionuclide has been much less intensive.

For this preliminary analysis, it is determined that the SDA surface barrier will require a venting system to remove VOCs and C-14 from beneath the barrier. Installation of a barrier over the SDA without a venting system would reduce the fraction of gas that is presently vented to the atmosphere through the soil surface. The barrier soil would reduce the surface flux and result in higher gaseous concentration in the waste zone. These gaseous contaminants would be vented around the barrier to the surface and be transported deeper into the subsurface. However, the transport of gas is a complex process that includes distance from the source to the boundary of interest, soil moisture content, gas-aqueous partitioning, water flux, solid-aqueous partitioning, soil-gas diffusion coefficients, and barometric pressure variations. The potential increase risk to the groundwater because of installation of an impermeable barrier has not been evaluated in the current SDA risk models. Before the final design of the barrier can be completed, a careful analysis of the effects on gas transport from the SDA should be made

E-2. HEAT PRODUCTION

Both biological degradation of organic waste and radionuclide decay produce heat within the SDA landfill. Chemical reaction rates and transport of contaminants are functions of the temperature. Microbial degradation of organic matter, corrosion rates of metals, and chemical transport in the subsurface are often accelerated at elevated temperatures. An analysis of the amount of heat produced at the SDA had not been previously evaluated. In an attempt to determine if heat production in the SDA can be ignored, a preliminary evaluation of potential SDA heat production was conducted. Both biological degradation of organics and radionuclide decay were examined. Results of this preliminary analysis suggest that the amount of heat released appears to be insignificant. However, a more complete analysis of heat production in the SDA is recommended and these results should be compared to the natural geothermal flux. For this report, it is determined that heat production in the SDA is not an issue driving the SDA surface barrier design.

E-2.1 Biological

In an effort to estimate the amount of heat produced from the degradation of organic waste in the SDA, the potential amount of heat produced from lubricating oil waste disposed of in the SDA was calculated. The conclusion of this analysis was that heat flux from microbial degradation of the lubricating oil is low (about 22 W/acre) and will not affect the performance of a surface barrier. For the preliminary SDA surface barrier discussed in this report, microbial heat production will be ignored. However, this analysis assumes that all the CO_2 flux measured is from this waste stream and the heat flux is reported as an average over the entire SDA. The following paragraphs describe the details and assumptions of this conclusion.

One of the potential sources of heat generation within the SDA is from subsurface biological degradation of organic wastes. Heat is generated through aerobic and anaerobic metabolism. Elevated temperatures are common in municipal landfills and composting. Factors affecting microbially driven temperature increases include moisture content, bulk density, and heat capacity of the waste materials and waste material composition.

Increased CO_2 evolution is often used as evidence of aerobic biodegradation of organic contaminants in soil (Alexander 1999). In a recently published paper, Conrad and DePaolo (2004) describe an anomalously high CO_2 concentration in portions of the SDA perhaps from degradation of lubricating oil (Texaco Regal Oil) and chlorinated solvents. Carbon isotopic evidence suggests that only the oil is undergoing aerobic microbial degradation, and the authors estimate degradation rates of 1 metric ton of carbon per year over 1.5×10^6 m^3.

Using the observations of Conrad and DePaolo (2004), heat generated from degradation of the organic waste at the SDA is estimated from stoichiometric analysis. The data collected by Conrad and DePaolo (2004) suggest that the Texaco Regal oil contained in the organic sludge is the primary organic compound currently undergoing mineralization (degradation to carbon dioxide and water) through an aerobic process. Texaco Regal R&O 68 has a molecular weight of 414 g/mole and is 99% saturated hydrocarbon.[b] The hydrocarbon n-nonacosane ($C_{29}H_{60}$) has a molecular weight of 409 g/mole and is also saturated; this makes it a reasonable approximation for Texaco Regal oil.

The aerobic mineralization of n-nonacosane is described by:

$$C_{29}H_{60} + 44\,O_2 \rightarrow 29\,CO_2 + 30\,H_2O$$

The mineralization rate of hydrocarbon in the SDA has not been measured directly. However, the rate of CO_2 release at the SDA has been measured and is estimated to be approximately 3,400 m^3 CO_2 per year. It has been determined for this preliminary analysis that all of the CO_2 was generated by hydrocarbon mineralization in the SDA and that 460 kJ of heat released per mole of O_2 consumed during aerobic carbon source oxidation (Lanini et al. 2001). Using these assumptions and the reaction equation for the degradation of n-nonacosane, the calculation of 2.02×10^4 kJ of heat is released per mole of hydrocarbon consumed, and 348 kJ of heat is released per mole of CO_2 produced can be made. Therefore, if the 3,400 m^3 of CO_2 being produced per year is converted (at standard temperature and pressure), then 1.52×10^5 mole CO_2 produced per year, which is equivalent to a heat generation rate of 1.68×10^3 W, is obtained. This analysis represents an order of magnitude estimate of the heat generation term from biological activity and makes the following assumptions: (1) n-nonacosane ($C_{29}H_{60}$) is a reasonable surrogate for Texaco Regal R&O 68 oil, (2) biodegradation of Texaco Regal R&O 68 oil is the most significant contributor to heat generation in the SDA, and (3) no other biodegradation (anaerobic and chlorinated hydrocarbons) contributes significantly to the heat generation.

E-2.1.1 Radionuclide Heat Generation

The total amount of heat generation at the SDA from the decay of radionuclides and its distribution within the SDA is not known at this time. Waste Area Group (WAG) 7 is having a best-estimate curie inventory determined for the SDA, and this information should be available sometime in the spring of 2004. The curie inventory will cover the major waste generators that have contributed radioactive waste to the SDA from 1952 until the present. Inventories are currently available for Argonne National Laboratory-West (ANL-W), the Idaho Nuclear Technology and Engineering Center, and Test Area North.

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b. Okazaki, Mark, Product Specialist Industrial Oil Technology, Chevron Texaco, 2004, Personal Conversation with Earl Mattson, INEEL.

Information from the Naval Reactors Facility and the Test Reactor Area will be available in the near future. These analyses will provide the most complete information that defines the radionuclides that are of particular concern to the SDA risk analysis. This list is limited to 43 long-lived radionuclides and fortunately appears to represent the most important ones for present day heat generation analysis. Although it does not account for the short-lived radionuclides like Cr-51 and Mn-54, approximately 80% of the total waste activity (as measured at the time of disposal) is accounted for by these 43 radionuclides selected by WAG 7.

An estimate of the radioactive heat generation can be calculated if the disposal year, type, and amount of radionuclides are known. As a simple example, in 1979, according to Radioactive Waste Management Information System records, 234,386 Ci was buried at the SDA from waste produced from ANL-W operations. Of these wastes, some 198,254 Ci are accounted for in the above list of 43 radionuclides. The activity that is not accounted for is mainly because of short-lived radionuclides that are not of particular concern for decay times amounting up to a few years. In other words, the calculated decay heat for the year 2004 should be reasonably accurate based on the 43 radionuclides. Using the computer model, ORIGEN2, and decaying ANL-W inventory to the year 2004, the decay heat for this single waste stream can be calculated. In this example, in 1979, the decay heat associated with the disposal of this radioactive waste from ANL-W at the SDA was 3,022 W, and the projected decay heat for 2004 is 113 W.

For the preliminary design calculations being preformed for this report, it is assumed that heat production from radionuclides is negligible and will not affect the performance of the surface barrier. However, before final design, it is recommended that this assumption be evaluated. To determine the radioactive decay heat that is currently being generated in the SDA, because of radioactive decay from these wastes, the total SDA inventory (as documented by WAG 7) should be obtained when possible, and an ORIGEN2 calculation should be performed with this inventory. This inventory will define the activity of 43 long-lived radionuclides as a function of each disposal year from 1952 until the present. The input to the ORIGEN2 code will be performed for each disposal year, and then decayed to the future years producing estimates of heat generation as a function of time for each waste stream. These data ,if combined with geographical information system information, could produce a map heat generation as W/m^2.

Subsidence in earthen caps (i.e., slumps, potholes, and settlement) is a common problem at existing landfills and hazardous waste sites (Nyhan, Hakonson, and Drennon 1989; Kahle and Rowlands 1983) and has the potential to damage liners and barriers and increase the potential for water percolation. Lack of compaction to remove voids (and subsequent collapse and deterioration of containers) in both waste and barrier soil causes settlement and cracking (Kahle and Rowlands 1983), which are potential pathways for the preferential flow of water (Kahle and Rowlands 1983).

E-3. SUBSIDENCE

Designing landfill barriers would not be so complex if settlement were uniform; however, differential settlement will occur because the character and depth of the waste are not uniform. "Predicting subsidence is very difficult because of the heterogeneous nature of the waste types, backfill materials, and local climatic conditions" (Hakonson 1997). Waste was disposed of in the SDA in multiple trenches, pits, and soil vaults. The waste in the SDA includes a wide variety of materials, containers, and void space. In some areas, waste containers were dumped randomly, in other areas the waste containers are stacked. Metal drums (55-gal), cardboard boxes, 4 × 4 × 8-ft plywood boxes, 4 × 4 × 7-ft metal boxes, and softside waste boxes have been placed in the SDA. The variety of wastes, containers, and configurations present in the waste in the SDA makes differential subsidence likely to occur.

Waste subsidence in the SDA is well documented and has been occurring for over 20 years (Keck and Seitz 2002). Subsidence events with areal extents of yards and depths of feet have been observed with regularity, but appear to be more common in certain locations (i.e., Pad A) (Keck and Seitz 2002). Dimensions, depths, and specific locations for some, but not all, individual occurrences were recorded during routine inspections (Keck and Seitz 2002). In some years, subsidence was recorded in more than one location within individual trenches and pits (Keck and Seitz 2002).

Most subsidence in the SDA has occurred in the spring (i.e., March through April) and of the recorded subsidence events, waste was exposed only once (Keck and Seitz 2002). A statistical evaluation of subsidence data collected between 1983 and 1997 show a maximum recorded depth of 8 ft (2.44 m) and an average of 1.99± 1.55 ft (0.61± 0.47 m) (Keck and Seitz 2002). However, more recent occurrences measure as deep as 10 ft (Keck and Seitz 2002).

While subsidence is expected to increase, then decrease with time over most of the SDA, several low-level waste pits at the SDA are still in operation so that portions of the SDA can be expected to experience significant subsidence after the barrier is constructed (Keck and Seitz 2002). Keck and Seitz (2002) predict moderate to high potential for future subsidence and estimate average depths of 0.9 m to 1.5 m (3 to 5 ft). Although substantial data have been collected, current information has not been mapped to generate a detailed map of subsidence in the SDA.

The final closure design will be affected for a given landfill site if large amounts of differential settlement or subsidence are expected. In general, landfills that are expected to experience large amounts of differential settlement such as the SDA should not be closed with barriers that possess a geomembrane, thin multiple layers, and rely on a drainage layer. Geomembranes can tear under these circumstances, because of the high tensile stresses produced. These tears will occur at the worst-case location where a large tear will be at the barrier low point and serve as a funnel for surface water into the landfill thus producing large amounts of leachate. In addition, these large tears are difficult and expensive to repair. Multiple layers used for drainage, such as those found in a traditional Subtitle ‘C’ or the INEEL CERCLA Disposal Facility barrier could be severely harmed because of discontinuities formed as a result of continued differential settlement.

For this report, it is assumed that some differential subsidence will occur at the SDA after the surface barrier is installed. For this reason, the preliminary barrier design will not include geomembrane layers, asphalt layers, or a series of thin multiple layers. Precover treatment can be beneficial to reduce the amount of subsidence in critical areas of the SDA. Before final design, additional analyses of the SDA waste types, location, and subsidence history should be used to develop a potential subsidence map of the SDA to assist in evaluating critical areas of future subsidence.

E-3.1 Biotic Intrusion

Landfill barriers that use soil as part of the barrier design must also consider the biota that use the soil and how that biota may impact the performance of the barrier. Penetration of protective caps by living organisms (including humans) has the potential to change water flux rates and erosion patterns that could compromise cap integrity (Gee and Ward 1997) and initiate/accelerate release of contamination to groundwater. Subsurface contamination transported through biological activities can also result in migration of contamination outside facility boundaries through biological (i.e., food web) and physical (e.g. wind) pathways (Arthur 1982; Arthur, Grant, and Markham 1983; Dabrowski 1973; O’Farrell et al. 1975).

Biological intrusion is generally controlled through the incorporation of barriers that are designed to prevent or limit the contact of plant roots or burrowing animals with buried waste. The ABRA identified seven ecological COCs where the primary pathways of ecological concern were associated with burrowing animals and insects and plant uptake. Therefore, a biobarrier layer to protect the SDA waste from biotic intrusion will be a required element of the future cap (DOE-ID 1998; Holdren and Broomfield 2003).

Whereas vegetation growing on a soil barrier is necessary to remove stored water, plants, and animals may also contribute to the degradation of the barrier. To be able to effectively predict how barriers will perform over time, an understanding of the plant/soil system is critical, and substantial research has been conducted over the years to understand the effects—both positive and negative—of biota on barrier performance.

Intrusion by plant roots or burrowing animals can result in the development of preferential flow paths in clay barriers, ultimately compromising the performance of the barrier. Although this possibility has been widely discussed, Hauser et al. (2001) concluded that preferential flow is unlikely to contribute significantly to water flow in a vegetative landfill barrier. Studies examining test sites. as well as evidence from natural analogs. indicate that a moderate amount of macrochannel development will not likely compromise barrier performance.

Plant roots serve as conduits for deepening/developing the soil horizon and encourage deeper penetration by organisms (e.g. worms and ants). Roots can also clog lateral drainage layers by following water/soil collected in gravel barriers. Extensive rooting can change the bulk density and texture of soil, thereby affecting infiltration rates. Root interactions with clay barriers may cause failure through desiccation and cracking.

Intrusion barriers, using both physical and chemical control mechanisms, have been tested to limit plant root penetration. Results from these tests indicate that use of herbicides is not feasible over the long-term, and chemical control of vegetation may jeopardize the potential benefits of transpiration in cap water balance. Polymer beads that release root-growth inhibitors have also been investigated (Burton et al. 1982).

Gravel, scoria, and cobble barriers have proven more effective in inhibiting intrusion by plants than have other barrier materials (e.g. clay and tuff) (Reynolds 1990). Increased layer thickness generally results in improved clay, cobble, and cobble/gravel barrier effectiveness. In a small-scale lysimeter study a barrier of 25 cm gravel over 75 cm of cobble was shown to effectively reduce root intrusion. Compacted or clay layers have been shown to be damaged through desiccation by plant water extraction and can be more easily breached. Roots follow soil/water accumulated in spaces between gravel/cobble of barrier layers, and the presence of moisture in profile below the biobarrier may encourage root intrusion through barrier layers to use underlying water (Anderson and Forman 2002).

Studies conducted at the PC/BE field site (Anderson and Forman 2003) examined root development in the test plots and demonstrated that roots of numerous plant species were able to bridge the 0.5-m thick biobarrier and subsequently extracted water from underlying soil. Root penetration through the biobarrier was exacerbated in the shallow biobarrier design as compared to biobarriers that were placed deeper in the soil profile. Plant roots can become deformed by shallow barriers, which could reduce the viability of the vegetative cover. Anderson and Forman (2003) conclude that the biobarrier should be placed deeper in the soil profile to minimize potential intrusion into underlying waste and recommend a soil barrier of at least 1.2 m.

Animal (e.g. small mammals and insects) burrows have been investigated as possible conduits for water flux that could increase migration of hazardous constituents through earthen barriers to groundwater (Gee and Ward 1997; Cadwell, Eberhardt, and Simmons 1989; Landeen 1994). Soil loosened through excavation can increase moisture-holding capacity and accumulated soil may also act to divert large areas of surface runoff, causing water to pond in low-lying areas and larger burrows (Cadwell, Eberhardt, and Simmons 1989). However, burrowing may also convey some benefits in sustaining vegetation cover and may aid drying soil in profile (Cadwell, Eberhardt, and Simmons 1989; Link et al. 1995; and Gaglio et al. 1998). The current body of research indicates that insect and mammal burrows have relatively small impacts on the infiltration of water through earthen barriers (Gaglio et al. 1998; Gaglio et al. 2000; Gee and Ward 1997). Anderson and Forman (2002) do not recommend exclusion of burrowing animals and ants since effects on water flux through the barrier are not considered important. However, long-term impacts of animal intrusion have not been investigated. Extensive burrowing by rodents into archaeological mounds has been shown to substantially alter the original form of the structures over hundreds of years (Suter, Luxmore, and Smith 1993).

Sixteen burrowing species can be found at the INEEL, all of which may frequent the SDA (Hampton 2001). A trapping survey near the SDA performed in 2002 indicated that deer mice (*Peromyscus maniculatus*) and Great Basin pocket mice (*Perognathus parvus*) are the most abundant rodent species, followed by chipmunks (*Eutamias minimus*), Ord's kangaroo rats (*Dipodomys ordii*), and Townsend's ground squirrels (*Spermophilus townsendii*) (Piet et al. 2003). Previous research conducted in the SDA shows a similar species composition, but also indicates that montane voles (*Microtus montanus*) may outnumber other burrowing species (Boone and Keller 1993; Koehler 1988; Groves and Keller 1983). Other burrowing animals documented on and around the SDA include harvester ants (*Pogonomyrmex salinus*), burrowing owl (*Athene cunicularia*), pygmy (*Brachylagus idahoensis*), cottontail rabbits (*Sylvilagus nuttallii*), Northern pocket gopher (*Thomomys talpoides*), yellowbellied marmots (*Marmota flaviventris*), coyotes (*Canis latrans*), and badgers (*Taxidea taxus*).

Burrow depths for voles, deer mice, kangaroo rats, marmots, least chipmunks, pocket gophers, rabbits, and marmots do not generally exceed 100 cm (Holdren et al. 2002; Hampton 2001). However, maximum depths from the literature for Great Basin pocket mice (193 cm), harvester ants (270 cm), Townsend's ground squirrels (147 cm), and badgers (230 cm) indicate that these species could penetrate the full soil profile and some distance into the barrier (Holdren et al. 2002; Hampton 2001). Depths of burrows can also vary between disturbed and undisturbed soil profiles (Hampton 2001).

Although tests of intrusion by burrowing show that geotextile is not a deterrent (Gee and Wing 1994), the Environmental Protection Agency indicates 0.5 mm geomembrane barriers are adequate to deter burrowing by animals (Daniel 1994). In tests of loose rock barriers (1.2 m layer of cobbles 3.8 to 7.6 cm in diameter), no breach of the barriers by ants or pocket mice was observed, but ant nests penetrated a small distance into the barrier (Cline, Gano, and Rogers 1980). Results of preliminary studies at the INEEL also indicate that gravel /cobble barriers limit the depth to which harvester ant nests are excavated (Gaglio et al. 1998, 2000). The depth of burrows constructed by Townsend's ground squirrels was restricted by a 0.15-m layer of 2.5- to 4-cm diameter crushed rock (Cline et al. 1982). However, white-tailed prairie dogs (*Cynomys leucurus*), which are approximately 4 times the size of ground squirrels, penetrated the crushed rock and other barrier designs (Cline et al. 1982). The effectiveness of barrier design and material in preventing intrusion by larger animals (e.g. coyotes and badgers) has not been extensively investigated (Mackay and Gaglio 1999; Gee and Wing 1994; Waugh et al 1994a; Waugh et al. 1994b).

Caldwell and Rieth (1993 in Stormont 1997) recommend cobble 1.5 times the body size of potential burrowing animals to prevent displacement. The biobarrier tested by Anderson and Forman (2003) incorporates 0.3 m layer of 0.10 to 0.2 m diameter cobble between 0.1 m layers of 5- to 15-mm diameter crushed gravel. The cobble size is apparently adequate to prevent all species having the potential to burrow deep enough to penetrate a barrier except badgers. Badgers burrow primarily in "friable soils" when pursuing underground prey, but are large, powerful diggers and could conceivably displace even 0.20 cm diameter cobble. However, increasing the particle size to resist intrusion by badgers (or coyotes) may create larger, unfilled voids that could facilitate deeper penetration of small mammals, plant roots, and harvester ants.

Plant interactions and community succession can affect function of the cap through alteration of soil physical and chemical properties and influence the composition and function of above- and below-ground animal communities over time. A native vegetation and burrowing animal community model for the SDA was constructed to support contaminant transport calculations performed for the ABRA (Holdren et al. 2002). The model, which may serve as a foundation for further SDA biobarrier evaluations, includes successional transitions from initial community composition over a period greater than 100 years. Biotic data, including plant and animal species composition, estimated animal populations, burrow volumes and root distribution with depth, were combined with models of subsurface to surface transport, burrow collapse, and root death to estimate contaminant transport from surface to subsurface by plants and animals for current and future conditions on the SDA (Holdren et al. 2002).

The establishment and monitoring of cap vegetative cover is a critical component of maintaining cap integrity. Alteration or removal of vegetation by natural processes must be managed and mitigated to ensure long-term physical and functional integrity of the cap. Initial establishment of plants can be accelerated by using gravel or various soil admixtures, which also function to reduce erosion (Waugh et al. 1994a; Cadwell, Link, and Gee 1993).

Anderson and Forman (2002, 2003) found that a mixture of plant species is preferred over monocultures. The best plant community for water extraction consists of a mixture of perennial species and native species have been shown to be more efficient at extracting water from caps (Anderson and Forman 2002). Any of several native species can extract all "plant-available soil water even during a very wet growing season" (Anderson et al. 1993). Fourteen plant species recommended for evapotranspiration caps at the INEEL are listed in Table E-2 (Anderson and Forman 2002).

Table E-2. Perennial plant species suitable for Subsurface Disposal Area evapotranspiration cap.

Shrubs	Grasses (cultivars)	Forbs
Big sagebrush (*Artemisia tridentata*)	"Sodar" Streambank wheatgrass	Northern sweetvetch (Hedysarum boreale)
Fringed sagebrush (Artemisia frigida)	"Bannock" Thick-spiked wheatgrass	Tapertip hawksbeard (Crepis acuminata)
Green rabbitbrush (Chrysothamnus viscidiflorus)	"Secar" Bluebunch wheatgrass[a]	Lupine (Lupinus argenteus)
Winterfat (Krascheninnikovia lanata)	"Rosana" Western wheatgrass[a]	Scarlet globe-mallow (Sphaeralcea munroana)
	"Magnar" Great Basin wild rye[a]	
	"Shoshone" Beardless wild rye	

a. Additional cultivars are available.

E-4. LONGEVITY OF BARRIER

The design criteria used to develop the conceptual design described in this document will use the DOE specified 1,000-year performance period for a SDA surface barrier. DOE Order 435.1 specifies that the low-level waste facilities that accept waste after September 26, 1988 shall have a Performance Assessment that "include calculations for a 1,000 year period after closure of potential doses to representative future members of the public and potential releases from the facility to provide a reasonable expectation that the performance objectives identified in this Chapter are not exceeded as a result of operation and closure of the facility." In addition, this order also requires a CA that "performance measures shall be consistent with DOE requirements for protection of the public and environment and evaluated for a 1,000 year period following disposal facility closure." The SDA CA assumed a more conservative flux through the barrier for 1,000 years of 1 cm/year. The 1,000-year of performance and the 1-cm/yr flux will be used in this analysis to be consistent with the CA analysis. Longevity issues not described elsewhere in this report affecting the SDA surface barrier design include effect of water/wind erosion of the surface and wild fires killing the vegetation on the surface barrier.

Water erosion could be the most likely threat to an SDA surface barrier and is addressed through adding moderate amounts of gravel mixed into the barrier topsoil. This addition of gravel is found to control both water and wind erosion with little effect on the vegetation or the soil-water balance (Ligotke 1994; Waugh et al. 1994a). As wind and water pass over the landfill barrier surface, some winnowing of fines from the admixture is expected, creating a vegetated erosion-resistant surface sometimes referred to as a "desert pavement". Near surface freeze/thaw cycles will also assist in establishing the desert pavement as these cycles will tend to transport gravels to the surface.

The design of a gravel admixture layer should be based primarily on the need to protect the soil barrier from water and wind erosion. A gravel admixture generally protects a barrier from long-term wind erosion. The protection from water erosion will depend on the depth, velocity, and duration of water flowing across the landfill barrier. These flow values can be established from the physical properties of the barrier (i.e., slope, convex or concave grading, slope uniformity, and length of flow paths) and the intensity of the precipitation water (i.e., precipitation rates, infiltration versus runoff relationships, snowmelt, and offsite flows).

The need to use any gravel admixture for a soil barrier can be established using either a geomorphologic or an empirical procedure. A geomorphologic evaluation involves the consideration of the geology, hydrology, and specific landforms at a site; and comparing the results with similar conditions to predict what will happen over time. WEPP erosion software is considered to be a state-of-the-art tool for simulating water erosion. WEPP simulates or mimics the hydrologic and erosion processes that occur on small watersheds or slopes on hills within those watersheds. WEPP is process based, not statistically based. It emulates scientifically known physical soil erosion processes. A number of studies have been conducted examining soil erosion at the field scale that could be used as analog sites. Finely (1985) looked at rock sizes needed to control water erosion. Ligotke (1994) determined gravel sizes of an admixture needed to control wind erosion. Waugh evaluated the effects of gravel admixtures on plant growth and the soil water balance at PNNL (Waugh et al. 1994a).

Changes in ecological community composition and function that could influence cap surface stability and water infiltration may also be expected as a result of altered climatic conditions and vegetation cover (Waugh et al. 1994b; Peterson 1994). Fire is a natural event that can be expected to occur every 20 to 100 or more years on a sagebrush steppe environment (Houston 1973; Wright and Bailey 1982). However, the invasion of exotic annuals has resulted in conversion of vast areas of sagebrush to annual grasslands and shortened the fire cycle to 5 to 7 years (Whisenant 1990). Further reductions in sagebrush communities are anticipated as a result of both increased frequency of fire and a southern to northern shift in plant species ranges associated with regional change to drier climatic conditions (Mote 1999; Snover 1997). Therefore, in the life of an evapotranspiration barrier, it is reasonable to assume that the barrier will experience a number of fires and plant species composition may change.

Fire that destroys all vegetation followed by an extremely wet winter (i.e., "more than 3 times ambient precipitation") before recovery of vegetation is an example of a worst-case scenario (Link et al. 1995). Fire removes the transpiration component from the system, at least temporarily. Lack of vegetation also generally increases susceptibility of cap surface soils to wind and water erosion (Kahle and Rowlands 1983). Link et al. (1995) have summarized a number of studies that address water erosion, including a study by Goff et al. (1993) in which vegetation removal and soil disturbance in an INEEL sagebrush-steppe community increased water erosion rates as high as 1,000 times the rate measured in vegetated control plots. Link et al. acknowledge, however, that the study addresses only "short-term, high-intensity summer storms." Loss of soil under simulated storm events has also been demonstrated on bare silt-loam plots on the 200-BP-1 Hanford Prototype barrier (DOE 1999).

Concurrent studies indicate that gravel admixtures are effective in reducing wind erosion, runoff, and sedimentation. Soil loss is decreased as vegetation becomes established and matures (DOE 1999), although initial recovery usually takes at least a full growing season. As for a full diverse community, Colket (2003) concluded that it could take up to 90 years for sagebrush to become fully reestablished on burned areas; however, Patrick-Buckwalter (2002) concluded that if a healthy and diverse plant community was present before a fire, the post-fire plant community will also be healthy and diverse; the only major difference between the two plant communities in the presence of sagebrush. Many other researchers have concluded that within 3 to 5 years, post-fire plant cover is similar on burned areas to adjacent unburned areas. Grasses and resprouting shrubs make up the cover difference from the missing sagebrush.

Analog studies can address both the long-term effects of plant evolution, fires, and changes in hydraulic properties on percolation. Using chloride data collected by Cecil et al. (unpublished data from their 1992 study), preliminary calculation indicate that the soil moisture at a depth of 5.5 m is approximately 20,000 years old indicating a flux rate of 0.1 mm/yr. These results suggest that percolation rates beneath the root zone of the plants is very small and has been very small over the last 20,000 years in soils near the SDA. It is determined that these results are the effective percolation rates that also incorporate thousand of years of plant evolution, fires, and potential changes in soil evolution. It should be noted that these results are from a single borehole near the SDA and may not be totally representative of how an evapotranspiration barrier may perform.

Based on the above concerns, a gravel admixture for a landfill barrier should be focused on maintaining long-term ecological stability and protection of the soil barrier from runoff generated by a major storm event. The degree of which the surface barrier is sloped should be examined to find a balance between surface runoff and allowable infiltration into the surface evapotranspiration barrier. Anderson and Forman (2003) recommend a very shallow slope to ensure sufficient moisture in the barrier for the survival of the vegetation.

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Appendix F

Subsurface Disposal Area Potential Remedial Action Alternatives

Appendix F

Subsurface Disposal Area Potential Remedial Action Alternatives

All remedial action alternatives under consideration for the Subsurface Disposal Area (SDA) include a surface barrier and institutional controls in perpetuity (Holdren and Broomfield 2003). Remedial decisions for the SDA ultimately will be determined in a Comprehensive Environmental Response, Compensation, and Liability Act record of decision (ROD). The feasibility study being prepared to support the ROD will examine several remedial action alternatives, including in situ grouting to reduce migration of contaminants, retrieval for selected waste streams, and containment with a surface barrier. The Preliminary Evaluation of Remedial Alternatives (PERA) (Zitnik et al. 2002) contains a complete description of these alternatives. Those remaining under consideration are summarized in the discussions that follow.

F-1. IN SITU GROUTING

In situ grouting is a technique developed in the construction industry and adapted for environmental use. The process entails injecting a slurry-like mixture of grouts (including cements, chemical polymers, or petroleum-based waxes) into contaminated soil or a waste landfill. As used in the environmental industry, the process employs nondisplacement jet grouting, whereby soil and waste debris are mixed with grout-forming materials in the subsurface, creating a large grout monolith (DOE-ID 1999; Loomis, Zdinak, and Bishop 1997) or a series of columns. Overall volume of the waste site remains constant, but density of the site is substantially increased as grout fills void spaces between discreet waste components.

At the SDA, in situ grouting would be performed using a jet-grouting system. Jet grouting has been demonstrated using full-scale equipment in several cold demonstrations and in a hot field demonstration at the Acid Pit within the SDA (Armstrong, Arrenholz, and Weidner 2002). Results of past testing and the Idaho National Engineering and Environmental Laboratory (INEEL) research are promising (Armstrong, Arrenholz, and Weidner 2002). Jet grouting can be used to reduce the potential for subsidence, and in certain cases, reduce the access of water to contaminants or reduce the mobility of contaminants.

Jet grouting may be used to form pillars or monoliths to provide physical stabilization of the waste and support of the cap. The regions of the waste most likely to benefit are those with low organic sludge or nitrate sludge content (poor grout compatibility) and regions with high void volume or low compressive strength (miscellaneous large odd-shaped objects, partially filled stacked containers, boxes of low-density materials such as filters and personal protective equipment). Forming monoliths with jet grouting can restrict the access of water to contaminants, which can reduce their mobility. A reduction in mobility of contaminants within the waste could reduce design requirements for the cap.

F-1.1 Retrieval, Treatment, and Disposal

Retrieval, treatment, and disposal consist of excavating and removing Rocky Flats Plant transuranic (TRU) waste from pits and trenches within the SDA. Overburden soil, interstitial soil, and possibly impacted underlying soil would be removed as well. TRU pits (Pits 1 through 6 and 9 through 12) and trenches (Trenches 1 through 10) contain TRU, low-level waste, and mixed waste. Retrieving low-level radioactive and hazardous soil and buried waste from a site is a proven and reliable approach that offers many potential benefits. A summary of historical retrieval actions conducted at the Department of Energy facilities, including Hanford, Rocky Flats, Los Alamos, Fernald, and the INEEL, is provided in the supporting report Sykes 2002. The report additionally offers a summary of special excavators used at different facilities. Fewer retrieval actions have been conducted for TRU wastes, but actions at the Rocky Flats Plant and the Glovebox Excavator Method Project at the INEEL demonstrate the feasibility of conducting retrievals.

Waste removed from a site can be treated to reduce toxicity and mobility of many chemicals. Removed and treated material can then be disposed of in an approved engineered facility. Retrieval removes or greatly reduces risk associated with the site if the retrieved waste is disposed of offsite or is isolated from the environment. Typically, removing waste and reducing the contaminant source can reduce long-term site monitoring and maintenance requirements. For some sites, complete removal of waste can satisfy requirements for unrestricted land use. However, for the SDA it is assumed that long-term institutional controls will be required in perpetuity (Holdren and Broomfield 2003).

Portions of the Rocky Flats Plant TRU waste in the SDA may be removed before capping. The retrieval regions would require backfilling with soil or grout before capping.

Retrieval of portions of the waste would allow proper compaction of the excavated areas and possibly preclude the need for in situ grouting. Removal of waste containing high concentrations of volatile organic compounds (VOCs) could simplify the capping process two ways: (1) simplifying the use of in situ grouting for pillars or monoliths, and (2) decreasing the amount of VOCs that must be released from the cap by passive or active (i.e., vapor extraction) and thereby simplify cap design.

F-1.2 Soil Vapor Extraction

In soil vapor extraction (SVE), also known as soil venting or vacuum extraction, a vacuum is applied through wells near or within the contamination source. Volatile constituents of contaminant mass evaporate, and vapors are drawn toward extraction wells. Extracted vapor is then treated, commonly with carbon adsorption, and then released to the atmosphere. Alternatively, treated vapor can be injected to the subsurface if permitted by applicable state laws. Increased airflow through the subsurface also can stimulate biodegradation of some contaminants, especially those that are less volatile. Extraction and injection wells may be installed either vertically or horizontally. SVE would accelerate the removal of VOCs from the waste and increase the void volume of the waste in those areas. If the areas are small and are surrounded by well compacted soil or waste, or if in situ grouting has been used to create pillars within the area, then the cap should not be affected.

A second potential option is to perform SVE after the cap is in place. The SVE system would draw vapor from the gas permeable layer of the cap; this process might also accelerate the removal of other vapor-phase contaminants, such as tritium and C-14. Assuming that in situ grouting or some other techniques were used to enhance the physical stability of the waste before capping, removal of the VOCs would not threaten the physical stability of the cap.

F-1.3 Pad A Removal

Pad A waste presents a challenge to in situ grouting and capping activities if the waste remains in its current location. The waste currently sits on an asphalt pad. Over 20,000 waste containers, including 55-gal drums and plywood boxes, were placed on the pad. The stacked waste consists primarily of nitrate salt, depleted uranium, and sludge. Over 70% of all waste on Pad A, nearly 7,600 m^3 (10,000 yd^3), is evaporator salt consisting of approximately 60% sodium nitrate, 30% potassium nitrate, and 10% other compounds (DOE-ID 1994). The containers are not full and significant subsidence is expected to continue to occur in the current configuration. In 1994, the Pad A barrier was reinforced with a 3- to 5-ft-thick vegetated soil layer and a rock armor barrier on the south face as a remedial action in accordance with the Operable Unit 7-12 ROD (DOE-ID 1994). The covered waste area extends to an average height of 9 m. Since remediation, annual maintenance activities have included repairing subsidence-related damage to the soil barrier.

Leaving Pad A on the surface of the SDA would hamper the construction of a low profile barrier; it is assumed that for this evaluation Pad A waste would be retrieved and treated. This assumption is consistent with the analysis of remedial alternatives in the PERA. The treated material would then be disposed of back onsite beneath the ground surface before construction of the proposed surface barrier.

F-1.4 Dynamic Compaction

Dynamic compaction is the use of lower energy soil impact as a standard geotechnical tool for compacting soft soils to support buildings, roadways, and surface barriers. The method involves the systematic dropping of a heavyweight, 10 to 40,000 kg, from a height of 5 to 25 m in a pattern designed to improve the underlying density of soils, such that engineered structures may be more readily placed on the surface. In soft ground areas, dynamic compaction has proved to be an effective and economical alternative to preloading, foundation piling, deep vibratory compaction, and soil undercutting and replacement. Energy delivered to the soil per blow can exceed 12,000 kNm. Shock waves can penetrate to a depth of 10 m. In coarser soil, the shock waves create liquefaction that leads to compaction. In finer textured soil, shock waves create positive pore water pressures and are followed by soil consolidation.

Although not discussed at length in the PERA, dynamic compaction is a viable alternative to be examined for foundation stability of a surface barrier. It would be best used in waste areas that have poor structural waste containers, such as plywood boxes that contain poorly consolidated wastes. Other than foundation stability, dynamic compaction does not, however, provide any additional remedial benefit to the SDA. Before implementing a dynamic compaction pretreatment alternative, additional evaluation is necessary to ensure no unintentional release from adjacent wastes and damage to previously implemented remedial engineered systems.

F-1.5 No Pretreatment

For the purposes of this discussion, it is assumed that the waste on Pad A will be moved from its current location and either disposed of offsite or placed in a pit or trench regardless of what other pretreatment alternatives are considered for the SDA.

One option is to place the surface barrier with no pretreatment of the waste. If the waste is expected to experience only minimal subsidence over time, this approach may be cost effective. The potential for subsidence within the waste and the potential detrimental consequences for the surface barrier are the main reasons for considering pretreatment. The waste in the SDA includes a wide variety of materials, containers, and void space. In some areas, waste containers were dumped randomly; in other areas, the waste containers are stacked. Metal drums (e.g., 55-gal), cardboard boxes, 4 × 4 × 8-ft plywood boxes, 4 × 4 × 7-ft metal boxes, and soft-sided waste boxes have been placed in the SDA. The variety of wastes, containers, and configurations present in the waste in the SDA makes subsidence likely to occur. Subsidence events have been regularly recorded at the SDA for over 20 years (Keck and Seitz 2002). Addressing subsidence strictly through the surface barrier design would likely significantly increase the complexity and cost of the cap.

A second option is to place the surface barrier on the SDA without any pretreatment and deal with zones of major subsidence and retrieval issues after the barrier has been constructed. Most of the pretreatment options discussed in the previous sections could be implemented after the barrier was constructed with minimum engineering consequences. Conducting in situ grouting, vitrification, thermal desorption, or soil vapor extraction are all viable alternatives after barrier placement. Minimum damage to the surface barrier would occur through the drill access holes to employ these treatments; however, the completion of these holes can be made compatible with the long-term longevity issues associated with a surface barrier. Waste retrieval and dynamic compaction treatments options would be harder, although not impossible, to implement after the final barrier placement.

F-1.6 Summary of Pre-treatment Options

Overall, careful use of pretreatment technologies in the SDA could enhance the physical stability of the surface barrier and even reduce the amount of contaminants to be contained. Pretreatment will not decrease the required lifespan of the surface barrier, since long-lived radionuclides will remain in the SDA. Pretreatment applications would be best applied to creating a stable foundation for the barrier and removing high VOC source term, potentially reducing the barrier venting requirements.

Subsidence is probably the greatest threat from the waste to the performance of the surface barrier. Subsidence in the waste at the SDA is well documented and has been occurring for over 20 years. None of the recorded subsidence events have exposed waste, but subsidence events with areal extents of yards and depths of feet have been observed with some regularity. While subsidence is expected to decrease with time, several low-level waste pits at the SDA are still in operation so that portions of the SDA can be expected to experience significant subsidence after the cap is constructed (Keck and Seitz 2002). Jet grouting and dynamic compaction would be beneficial to the barrier integrity.

The regions most susceptible to subsidence may not be the regions containing high concentrations of VOCs and other organic compounds. Dynamic compaction would be appropriate in these areas. Soil vapor extraction would reduce the amount of VOCs in the waste and would increase the void volume in those regions Selective retrieval of regions containing TRU waste can also reduce the amount of VOCs remaining in the waste and may also remove potentially low-density waste, such as boxes of filters. Retrieved regions could be backfilled with compacted soil or grout and would therefore be unlikely to subside in the future.

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Appendix G

Review of Conventional Barrier Designs

Appendix G

Review of Conventional Barrier Designs

G-1. MUNICIPAL SURFACE BARRIERS

Simple earthen evapotranspiration (ET) barriers, such as those at the Central Facilities Area and the 1996 Naval Reactors Facility barriers, will reduce the water flux through the waste. However, these barriers do not have a biotic intrusion layer; therefore, they would not meet the biological intrusion requirement for the Subsurface Disposal Area (SDA).

G-2. BIOTIC BARRIERS

A biotic barrier is an engineered barrier system designed to prevent direct contact with site contaminants and future intrusions into waste by plants and animals. Two designs of the biotic barriers exist at the Idaho National Engineering and Environmental Laboratory (INEEL): the Stationary Low-Power Reactor No. 1 Burial Ground barrier and the Boiling Water Reactor Experiment-I barrier. These surface barrier designs provide a degree of protection in restricting future biotic intrusions, but increase surface water infiltration relative to undisturbed soil; any rainfall or snowmelt on the barrier rapidly moves through the depth of the very porous rock-armor and gravel-cobble layers beyond the depth of evaporation. Biobarrier alone is rejected because of its failure to minimize percolation through the waste.

G-3. SPECIALLY ENGINEERED SURFACE BARRIERS

In theory, a concrete barrier could meet the performance requirement for an SDA surface barrier; however, the maintenance would be substantial and the potential for cracking would be significant. Waste subsidence would cause significant stress cracking. Freeze/thaw of a surface concrete barrier would also deteriorate the effectiveness of such an engineered system. Water could infiltrate through these cracks defeating one of the main purposes of the barrier, minimize infiltration. Longevity of a barrier, such as that used at the Waste Calcining Facility, would be the major drawback of this barrier design. Because of these factors, the concrete barrier is rejected because it fails to provide adequate protection from freeze/thaw and the subsequent maintenance issue.

G-4. MODIFIED RESOURCE CONSERVATION AND RECOVERY ACT SUBTITLE C

The modified Resource Conservation and Recovery Act Subtitle C cap is composed of seven layers with a combined minimum thickness of 1.7 m (5.6 ft) and a vegetated erosion-control surface. Layers include topsoil with or without pea gravel, sand filter, gravel filter, lateral drainage layer, asphalt, and base course over grading fill. The asphalt layer controls both drainage and biotic intrusion. An optional gravel layer can be included in the design to control future gas migration from the waste.

The main problem with this barrier design for the SDA is its reliance on the asphalt drainage layer. Nonuniform subsidence is expected over the SDA with or without pretreatment activities to enhance stabilization. The continuous slope of the drainage layer could be compromised over pits and trenches with a greater probability of preferential flow in these areas. The Resource Conservation and Recovery Act barrier is rejected because of subsidence issues jeopardizing the integrity of the drainage layer.

G-5. INEEL CERCLA DISPOSAL FACILITY

The INEEL CERCLA Disposal Facility (ICDF) barrier is designed to provide containment and hydraulic protection for a performance period of 1,000 years. The barrier is composed of nine layers with a combined thickness of 5.25 m (17.5 ft) and a vegetated erosion control surface. Layers include silt loam topsoil, sand and gravel filter layers, a cobble biointrusion layer, drainage gravel, a geomembrane, and compacted silt loam over a site-grading fill. The INEEL-specific design includes a 0.75 m (2.5 ft) layer of fractured basalt to prevent biotic intrusion. An optional gravel layer can be included in the design to control future gas migration from the waste.

The ICDF barrier would perform adequately at the SDA and is an accepted Comprehensive Environmental Response, Compensation, and Liability Act design at the INEEL. The ICDF surface barrier would control the percolation through the barrier, provide biotic protection, and has a gas venting layer; therefore, it meets the performance requirements of the SDA identified in this report. However, although it meets the performance requirements, the ICDF is not optimally designed to the SDA conditions.

The ICDF's water storage layer is likely too thick and provides minimal additional long-term water storage capacity in its upper soil layers. According to the engineering drawings, there is a 30 cm topsoil layer over 240 cm of engineered earth fill (Preliminary Evaluation of Remedial Alternatives) for a total thickness of 270 cm. The surface vegetation for the ICDF is mixture of perennial grasses that have a bulk of their root density near the soil surface implying that the lower portion of the water storage layer is not affected by the vegetation allowing for little water extraction by transpiration. The Protective Cap/Biobarrier Experiment study results suggest that a shallower water storage layer is adequate for the INEEL climate.

As discussed in the previous sections, differential subsidence at the SDA could render much of the drainage layers of the ICDF barrier useless. The ICDF barrier uses a geomembrane material as the base of the drainage layer. The ICDF waste is being placed in a controlled disposal configuration with restrictions on void space and waste compaction requirements, such that a much more uniform subsidence of the ICDF barrier is expected, as compared to the differential subsidence expected at the SDA. Differential subsidence at the SDA could create localized zones of negative slope and potentially cause tears in the geomembrane material.

Appendix H

Alternative Landfill Barrier Designs

Appendix H

Alternative Landfill Barrier Designs

H-1. EVAPOTRANSPIRATION BARRIER CONCEPT

The evapotranspiration (ET) barrier consists of a single, vegetated soil layer constructed to represent an optimum mix of soil texture, soil thickness, and vegetation cover (Dwyer 1997). The ET barrier is a monolithic soil profile that by design has adequate water storage capacity to retain any infiltrated water in the soil barrier until it can be removed through ET.

The concept relies on the soil to act similar to a sponge (i.e., infiltrated water is held in this sponge or soil profile until it can be removed through ET). ET is defined as the combination of water removal because of both evaporation and transpiration through vegetation. Previous research has shown that a simple soil barrier can be very effective at minimizing percolation and erosion, particularly in dry environments (Dwyer 2001, 2003).

One mechanism of an ET barrier for removing stored water from the barrier soil layer is by surface evaporation. Evaporation from the soil surface increases the matric potential of the surface soil, resulting in an upward matric potential gradient and inducing upward soil water flow. The second mechanism of ET is plant transpiration, which also relies upon matric potential gradients to remove water from the barrier soil layer. Figure H-1 illustrates that the matric potential difference between the soil and atmosphere can be up to -1000 bars (Hillel 1998). The larger the soil-plant-atmospheric potential gradient, the more effective an ET barrier is in removing water from the soil. An index that measures the ability of the atmosphere to remove water from the surface through evaporation and transpiration, assuming no control on the water supply, is the potential evapotranspiration. Potential evapotranspiration is often calculated using Penman's equation.

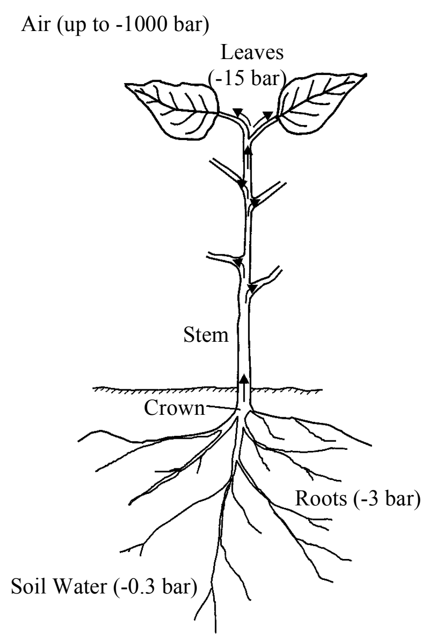

Figure H-1. Typical soil-plant-atmosphere water potential variation (Hillel 1998).

Besides an expected improved long-term performance, a secondary advantage of ET barriers is that they are less expensive to construct and maintain than their traditional counterparts. The soil used will, for economic reasons, generally come from a nearby borrow site, saving substantial transportation costs A comparison of constructed costs showed that the cost savings for an ET barrier versus a traditional compacted clay barrier is in excess of 50% (Dwyer 1998a). Other advantages of ET barrier systems are low maintenance and relative ease of repair for such things as differential settlement problems. For example, if differential settlement occurs, more soil can simply be applied to the surface to bring the ET barrier back to its original grade. With a traditional Resource Conservation and Recovery Act (RCRA) Subtitle ‘C’ barrier, significant differential settlement may lead to tearing of the geomembrane within the profile and cracking in the underlying clay barrier layer.

The ET barrier is easier to build and requires less complex quality assurance during construction than its traditional counterpart (Dwyer 1998b). The ET barriers are usually less susceptible to side slope instability than a RCRA Subtitle ‘C’ barrier because ET barriers do not have a geomembrane, which creates a slip plane. The ET barrier performance also increases with time as the plant community becomes fully established, while the compacted clay layer continues to decline in its effectiveness because of barrier layer deterioration (Suter, Luxmoore, and Smith 1993, Waugh and Smith 1997, Mulder and Haven 1995). The main concern with ET barriers is the establishment and maintaining of plants on the barrier surface.

The ET barrier design concept can be summarized in the following steps: (1) select the performance criteria, (2) select a conceptual design, (3) examine site characteristics, (4) use numerical and analog models along with field test research to design the barrier, and (5) conduct the final design (ITRC 2003).

Barrier thickness is typically determined from estimates of the water holding or storage capacity of the soil and the amount of infiltrated water that has to be stored. In arid and semi-arid climates, loams and silts are the best choice for the soil to be used because of their relatively high storage capacity and minimal potential for desiccation cracking compared to clays. The maximum water content a soil can hold after all drainage downward resulting from gravitational forces is referred to as its field capacity. Field capacity is often arbitrarily reported as the water content (Figure H-2) at about –330 cm of matric potential head (Jury et al. 1991). The storage capacity of a soil layer is thus calculated by multiplying its field capacity by the soil layer thickness. Vegetation is generally assumed to reduce the soil moisture content to the permanent wilting point, which is typically defined as the water content (Figure H-2) at -15,000 cm of matric potential head (Cassel and Nielsen 1986). Evaporation from the soil surface can further reduce the soil moisture below the wilting point to the residual saturation, which is the water content ranging from below -15,000 cm to an infinite matric potential. Generally, the available water-holding capacity of a soil layer can be approximated by calculating the difference between the soil’s field capacity and its permanent wilting point moisture contents multiplied by the soil thickness. It is important to note that the use of field capacity and permanent wilting point here is arbitrary (Jury et al. 1991; Cassel and Nielsen 1986). Nevertheless, these are simple and commonly used concepts and are applicable for approximating the water storage capacity of a soil layer.

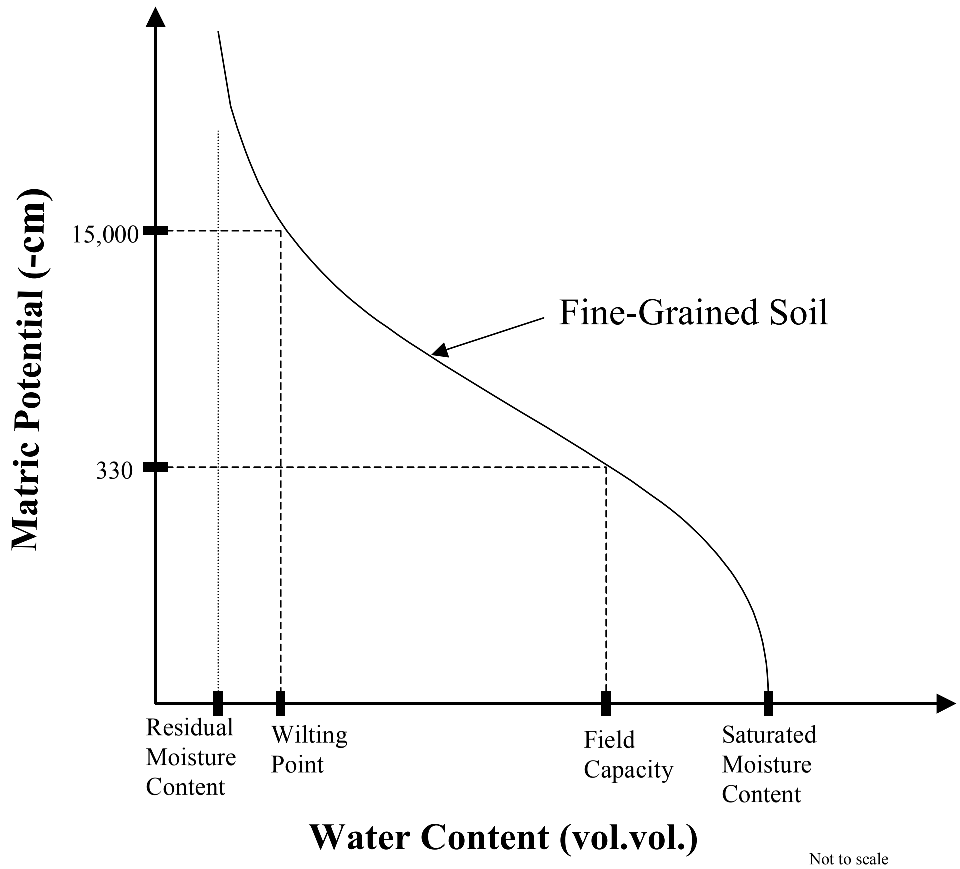

Figure H-2. Typical soil moisture characteristic curve.

Commonly in dry environments, plants will reduce the water content of a near-surface soil to the permanent wilting point every growing season (Anderson et al. 1993), making the soil's entire net storage capacity available for subsequent precipitation when ET is low and plants are dormant. Thus, one potential worst-case estimate of the required amount of infiltration that an ET barrier has to store annually is the total precipitation input during the dormant period(s), such as spring snowmelt.

H-2. CAPILLARY BARRIER

Capillary barriers, consisting of fine-over-coarse soil layers (Figure H-3), are another alternative barrier system suggested for use in final landfill closures in dry climates. The system physically operates identically to an ET barrier in terms of using plants to remove precipitation that has infiltrated into the barrier. The additional aspect of the capillary barrier is the inclusion of the coarse layer beneath the upper water storage fine layer. Differences in pore size distribution between two soil layers cause infiltrated water to be retained in the upper soil layer under unsaturated flow conditions, as long as the contrast in unsaturated properties (e.g., soil-moisture characteristics and unsaturated hydraulic conductivities) of the soils in the two soil layers is sufficiently large (Dwyer 1997). The capillary pressure head in the fine-grained upper soil layer typically must approach a value near zero (i.e., saturated conditions) before any appreciable flow occurs into the lower coarse-grained layer (Dwyer 1997).

Figure H-3. Profile of capillary barrier.

Design considerations for the fine-textured soil layer of the capillary barrier system include all of those listed for the ET barrier system. In general, the capillary barrier enhances the water storage capacity of the fine-textured soil layer. Consequently, the fine-textured soil layer will not need to be as thick as that in the ET barrier system. In fact, the fine-textured soil layer must be thick enough to store infiltrating water, yet thin enough so that all of the stored water can later be removed through ET. Thus, the design considerations for a capillary barrier involve determining the proper fine-textured soil layer thickness, plant rooting depths, and slope gradient to minimize the percolation of water through this layer.

Soil-water is removed from a nonsloped capillary barrier system only by ET, or by percolation (i.e., breakthrough) into the underlying coarse layer. If the water storage capacity of the fine-textured soil layer is sufficient to store the expected infiltration at a particular site, then nonsloping capillary barriers can prevent vertical water infiltration (breakthrough) into the underlying waste.

Lateral diversion within a sloped capillary barrier system provides an additional means of removing soil water from the fine-textured soil layer. Lateral diversion is essentially gravity-driven unsaturated drainage within the fine layer. Because the water content in the fine layer is usually greatest near its interface with the underlying coarse-textured soil layer, and the hydraulic conductivity (K) of an unsaturated soil increases with water content (θ), lateral diversion is concentrated near this interface. Laterally diverted water will result in increasing water content in the down-dip direction. The diversion length is the distance which water is diverted along the fine/coarse interface before there is appreciable breakthrough into the coarse layer (Figure H-4).

Some advantages of incorporating a capillary barrier in a landfill barrier system include:

1. The fine-textured soil layer of a capillary barrier system will store more water than a comparable layer without the capillary break (i.e., a free-draining layer). Compared to a simple soil barrier, the additional storage capacity will either serve to reduce overall percolation, or reduce the total thickness requirements of the overlying barrier soil to yield the same degree of percolation inhibition.

2. The additional water stored within a capillary barrier system will tend to encourage the establishment and development of the surface vegetation. The increased vegetation cover, in turn, will remove more soil water because of greater ET. Furthermore, plants serve an important function in reducing surface erosion.

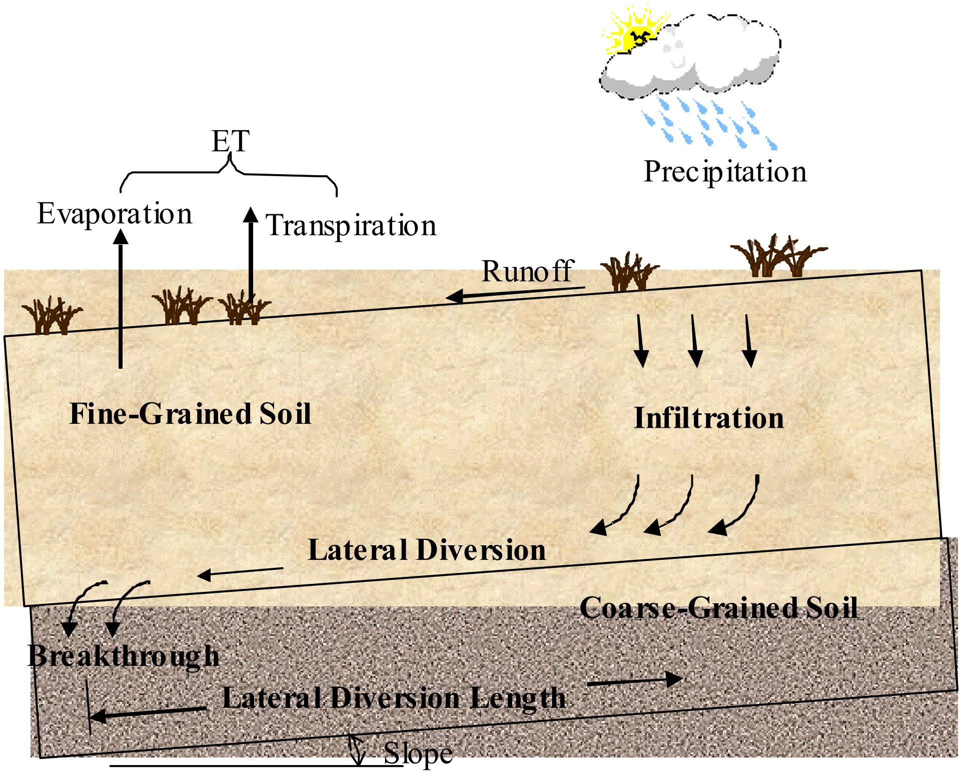

Figure H-4. Sloped capillary barrier.

3. In addition to providing the capillary break, the coarse layer of the capillary barrier system can serve as a biointrusion barrier or gas collection layer.

Some disadvantages of incorporating a capillary barrier system in a landfill carrier system include:

1. Significant desiccation cracking in the fine-textured soil layer can be detrimental to a capillary barrier system. Every reasonable effort should be made to avoid desiccation cracking (e.g., compacting the soil “dry of optimum” rather than “wet of optimum,” use soils that are less susceptible to desiccation cracking, such as sandy silts or silty sands rather than clay).

2. A capillary barrier system may not be effective in wetter climates or where appropriate soil materials are not readily available.

3. Slope can be an advantage in laterally diverting water, but in turn, can be a huge disadvantage if the diversion length of the barrier system is inadequate, thereby resulting in significant breakthrough. If a capillary barrier system is sloped, the two-dimensional (i.e., lateral and vertical) effects of soil-water movement must be taken into account.

4. Differential settlement can introduce significant discontinuities in the fine-over-coarse soil layer interface, thus rendering the capillary barrier system less effective. This is especially true for sloped capillary barrier systems.

In general, the greater the contrast in texture or particle-size distribution of the fine and coarse materials, the greater the effectiveness of the capillary break (Stormont 1997). There is concern, however, that fine soil particles will move into the pores of the coarse soil, degrading the interface and reducing the effectiveness of the capillary break. The conventional approach for evaluating the stability of the fine-over-coarse system is to ensure the soils satisfy a soil retention or filtering criterion. Although a large number of criteria have been developed, most are similar in that they are based on some measure of the particle-size distributions of the fine and coarse soils. The following criterion is widely used:

$$\frac{D_{15}}{d_{85}} \leq 5$$

where:

D_{15} = particle size of the coarse soil for which 15% of the particles are finer

d_{85} = particle size of the fine soil for which 85% of the particles are finer.

From conventional criteria, interface stability is favored by soils having similar particle-size distributions, apparently in conflict with maximizing the effectiveness of a capillary break. Conventional criteria, however, have been developed using high hydraulic gradients for applications such as dams. In contrast, capillary barriers would only rarely, if ever, experience positive pore pressures, and the associated hydraulic gradients would be small. Furthermore, capillary barriers will be subjected to cycles of wetting and drying in response to climatic conditions. Thus, interface stability should be considered under dry conditions, as well as under relatively small positive water pressures.

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Appendix I

Estimating the Performance of Alternative Barriers

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Estimating the Performance of Alternative Barriers

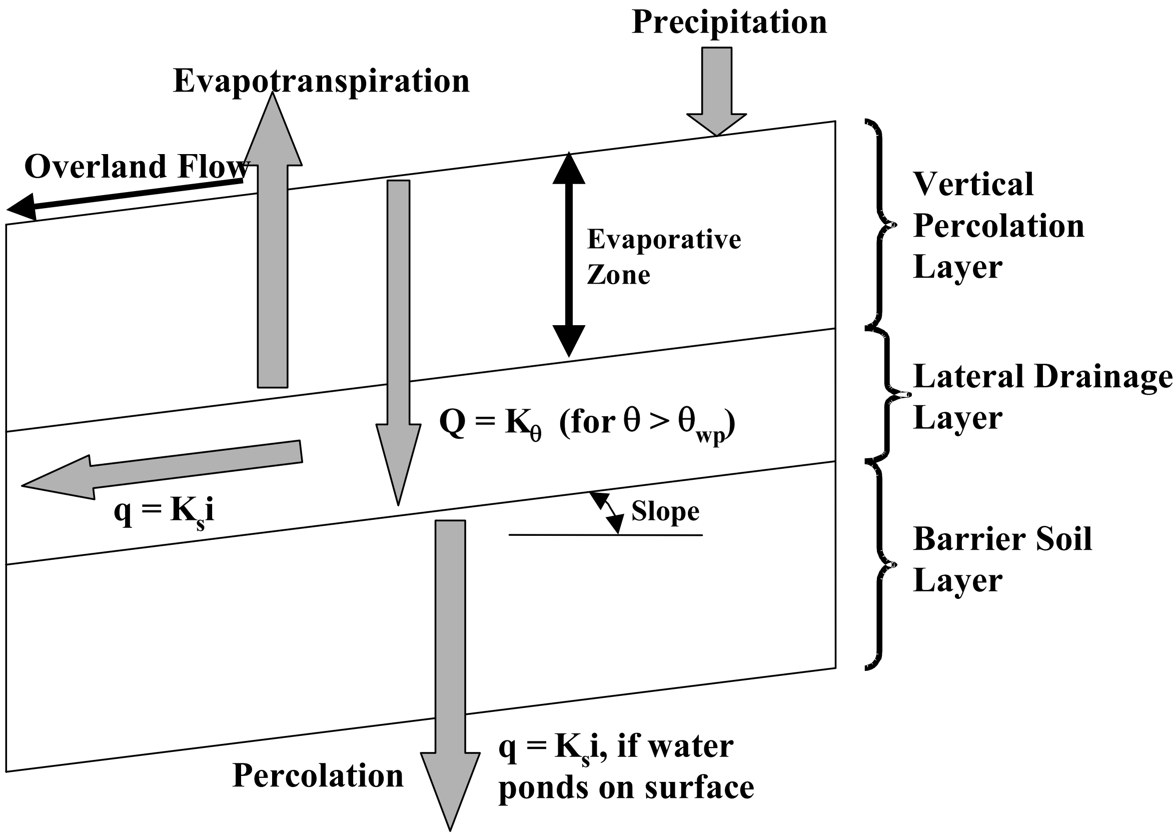
The preceding discussion highlights how the water storage and lateral diversion capacity of a capillary barrier performance is affected by factors such as the soil type and thickness and the slope of the interface. In addition to the influence of material properties and configuration, the “stress” provided by the climate will have a major impact on the performance of a capillary barrier. To accommodate these factors into the development of designs and estimating the performance of capillary barriers, numerical simulations can be used. However, numerical simulations have two challenging aspects that must be addressed to enable reasonable representation of actual field conditions. First, for near-surface applications, it is necessary to account for the effect of time- and climate-dependent processes, including precipitation, soil water evaporation, and plant transpiration. Second, the water infiltration within the near-surface soils is transient, unsaturated flow involving materials of widely varying properties. Accuracy and stability of numerical solutions involving these types of flow behavior can be difficult to achieve.

The principal tool available to assist in the design of landfill barrier profiles is a computer program used to predict water balance. Many design engineers use these programs with little knowledge of their internal workings or sensitivities. This may be a factor in inadequate designs, which contribute to failure of many landfill closures. Two types of programs are used: water balance codes, such as the Hydrologic Evaluation of Landfill Performance (HELP) program (Schroeder et al. 1994), and unsaturated flow codes, such as UNSAT-H (Fayer and Jones 1990) or HYDRUS (Simunek et al. 1996).

It should be noted that numerical models are one tool that is used to design surface barriers, but not the only tool. Numerical models are a quantitative description of a simplified reality. In other words, attempts are made to describe the physical processes operating within surface barriers adequately, so that design decisions can be made given a specific set of surface boundary conditions and material properties. From these analyses, sensitivity of water flux through the barrier as a function of these model input parameters are examined. Finally, this information is used along with natural analog information to make decision on the final design.

HELP is a quasi-two-dimensional program developed by the U.S. Army Corp of Engineers for the Environmental Protection Agency. This program not only estimates percolation, surface runoff, soil water storage, lateral drainage, and evapotranspiration for landfill barriers, but also calculates flow through the underlying waste, leachate collection system, and the liner. Schroeder et al. (1994) provides a detailed description of the algorithm HELP uses to route water into different components of the water balance. A schematic illustration of how HELP handles the water balance in a landfill barrier profile is shown in Figure I-1.

HELP requires that each layer of the landfill barrier be specified as a vertical percolation layer, barrier soil liner, lateral drainage layer, or geomembrane liner, depending on the function and hydraulic properties of the layer. A vertical percolation layer generally has moderate- to high-saturated hydraulic conductivity, and unsaturated flow of water occurs in the vertical downward direction. A barrier soil layer has a low-saturated hydraulic conductivity and is assumed to be fully saturated. A lateral drainage layer has a relatively high hydraulic conductivity and is underlain by a barrier layer. A lateral drainage layer allows for the vertical downward infiltration of water similar to a vertical percolation layer, as well as lateral saturated flow.



HELP Program

Figure I-1. Schematic representation of water balance computations by Hydrologic Evaluation of Landfill Performance.

HELP divides precipitation into surface runoff and infiltration based on a modified version of the Soil Conservation Service (SCS) runoff curve number method. The SCS runoff curve number used by HELP is based on the hydraulic conductivity of the surface layer, condition of vegetation (i.e., LAI), and the slope and slope-length of the barrier. If the air temperature is less than or equal to 0°C, precipitation is stored as a snowpack. The snowpack is allowed to melt only when the air temperature rises above 0°C. The infiltrated water either remains in storage or is subjected to evapotranspiration (ET), lateral drainage, and percolation.

Water removal via ET occurs from the evaporative depth of the barrier. A vertical percolation layer is the only layer type that allows for water removal via ET. Consequently, the evaporative depth of the barrier cannot be greater than the top vertical percolation layer. HELP provides default values for evaporative depth based on the location of the site and the condition of the vegetation. The quantity of water removed by ET is computed using an approach recommended by Ritchie (1972) and was a function of potential evapotranspiration and the availability of water stored in the soil profile. Potential evapotranspiration is calculated using a modified form of the Penman (1963) equation.

If the layer is a vertical percolation layer, the water stored in the soil layer is routed under a unit hydraulic gradient in the vertically downward direction (Figure I-1) using the unsaturated hydraulic conductivity (K_θ) computed by Campbell's (1974) equation. ET removes water from the vertical percolation layer if the water content is above the permanent wilting point (θ_{WP}). The permanent wilting point is defined as the lowest amount of water that remains in the soil because a plant is unable to extract it. Field capacity is the amount of water in a wetted soil after it has drained. The size of the reservoir of water in a soil that can be used by plants to maintain life is the moisture range between the permanent wilting point and field capacity.

If the layer is a barrier soil layer, the saturated hydraulic conductivity and the depth of ponded water on the surface of the barrier soil layer are used with Darcy's law to compute percolation. The soil's saturated hydraulic conductivity is used because the barrier layer is assumed to be fully saturated.

UNSAT-H is a one-dimensional, finite-difference computer program developed at Pacific Northwest Laboratory by Fayer and Jones (1990). UNSAT-H can simulate the water balance of landfill barriers as well as soil heat flow by solving Richards' equation and Fourier's heat conduction equation. This approach for analyzing water flow in earthen barriers is distinctly different from the approach used by HELP.

A schematic illustration on how UNSAT-H computes the water balance is shown in Figure I-2. UNSAT-H separates precipitation falling on a landfill barrier into infiltration and overland flow. The quantity of water that infiltrates depends on the infiltration capacity of the soil profile immediately before rainfall (e.g., total available porosity). The fraction of precipitation shed as overland flow depends on the saturated and unsaturated hydraulic conductivities of the soils characteristic of the final barrier. If the rate of precipitation exceeds the infiltration capacity, the extra water is shed as surface runoff. UNSAT-H does not consider absorption and interception of water by the plant canopy, or the effect of slope and slope-length when computing surface runoff.

Water that has infiltrated a soil profile during an UNSAT-H simulation moves upward or downward as a consequence of gravity and matric potential gradients (Figure I-2). Water removal by transpiration of plants is treated as a sink term in Richards' equation (Figure I-2). Potential evapotranspiration is computed from the daily wind speed, relative humidity, net solar radiation, and daily minimum and maximum air temperatures using a modified form of Penman's equation given by Doornbos and Pruitt (1977). Soil water storage is computed by integrating the water content profile. Flux from the lower boundary is via percolation (Figure I-2). UNSAT-H, being a one-dimensional program, does not compute lateral drainage.

Like UNSAT-H, the HYDRUS 1-D program is a finite element model for simulating the one dimensional infiltration of water, heat, and multiple solutes in variably saturated media. The program numerically solves the Richards' equation for saturated-unsaturated water flow and Fickian-based advection dispersion equations for heat and solute transport. The flow equation incorporates a sink term to account for water uptake by plant roots.

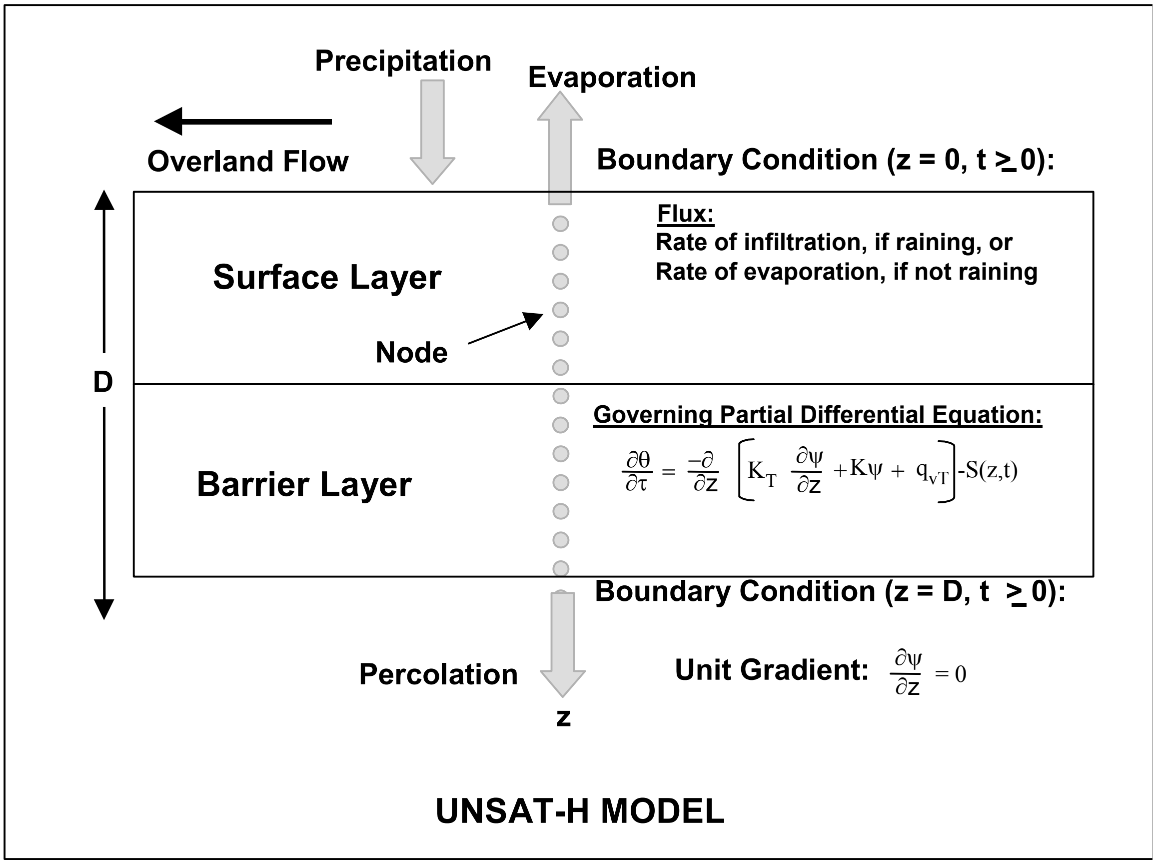


Figure I-2. Schematic representation of water balance computation by UNSAT-H.

I-1. REFERENCES

Fayer, M. J. and T. L. Jones, 1990, *UNSAT-H Version 2.0, Unsaturated Soil Water and Heat Flow Model*, PNL-6779, Pacific Northwest Laboratory, Richland, Washington.

Simunek, J., M. Sejna, and M. T. van Genuchten, 1996. *HYDRUS-2D: Simulating Water Flow and Solute Transport in Two-Dimensional Variable Saturated Media,* International Groundwater Modeling Center, Colorado School of Mines, Golden, Colo.

Appendix J

Preliminary Modeling of the Hydraulic Performance of Surface Barriers at the Idaho National Engineering and Environmental Laboratory

Appendix J

Preliminary Modeling of the Hydraulic Performance of Surface Barriers at the Idaho National Engineering and Environmental Laboratory

To estimate the annual water flux through the prescribed soil barrier under the current climate, soil moisture influx, redistribution, and removal from the soil barrier were simulated with the one-dimensional unsaturated flow model, Hydrus 1-D. In order to more accurately simulate conditions under the existing climate, a 55-year daily time-series record of historical meteorological data was used to define the temporal distribution of precipitation and evapotranspiration potential throughout each year of a 55-year flow simulation. Examination of this dataset indicates that potential evapotranspiration is typically on the order of five times the precipitation input to the surface at the Idaho National Engineering and Environmental Laboratory (INEEL). If sufficient water storage is available in the root zone, evaporation and transpiration should readily remove all infiltrating precipitation, as long as the wetting front does not migrate past the root zone faster than plant roots are able to remove it. The effects of the temporal distribution of precipitation events on the water flux past the root zone can be evaluated using the Hydrus 1-D model.

As a simple model of an evapotranspirative barrier, flux through a 180-cm thickness porous media comprising two layers, an upper, topsoil/vegetation, layer of fine-grained material with high porosity and low saturated conductivity and a lower, biointrusion layer consisting of coarse material (Figure J-1) was simulated. As a starting point for the topsoil/vegetation layer, it was determined that the material might have hydraulic properties similar to that of the spreading area B sediment, and the material was modeled with descriptive parameters derived from a host of tests using that sediment. For the biointrusion layer, it was determined that it had the hydraulic properties of a common sand, with a saturated hydraulic conductivity of approximately 10^{2} cm sec^{-1}.

The thickness and hydraulic properties of the topsoil/vegetation layer are critical in determining the ultimate flux through the profile, because evaporation and transpiration can only occur from the near surface layers. Sands and gravels typically have high conductivity under wet conditions, and lower porosity than more clayey materials. Infiltration of precipitation can move faster and penetrate much further in coarse materials than in finer materials. The relative importance of evaporation in removing water from a soil profile is also heavily influenced by soil type. While coarse materials have higher conductivity under wet conditions, they typically have much lower conductivity under dry conditions. Thus, in coarse materials, infiltrating precipitation moves deep in the soil profile during precipitation events and then, as drying progresses, the upward flux to the surface is severely limited because of the rapidly decreasing conductivity.

The complicated interdependence of water infiltration, soil type, vegetation rooting depth and other factors, as well as the sporadic nature of precipitation (Figure J-2), require that a relatively sophisticated model of the primary processes controlling moisture infiltration be used to estimate the net flux through the root zone under a particular set of conditions. For these simulations, a numerical model, Hydrus 1-D, was used that incorporates basic root water uptake and evaporation functionality and solves Richard's equation to describe the redistribution of water in the soil.

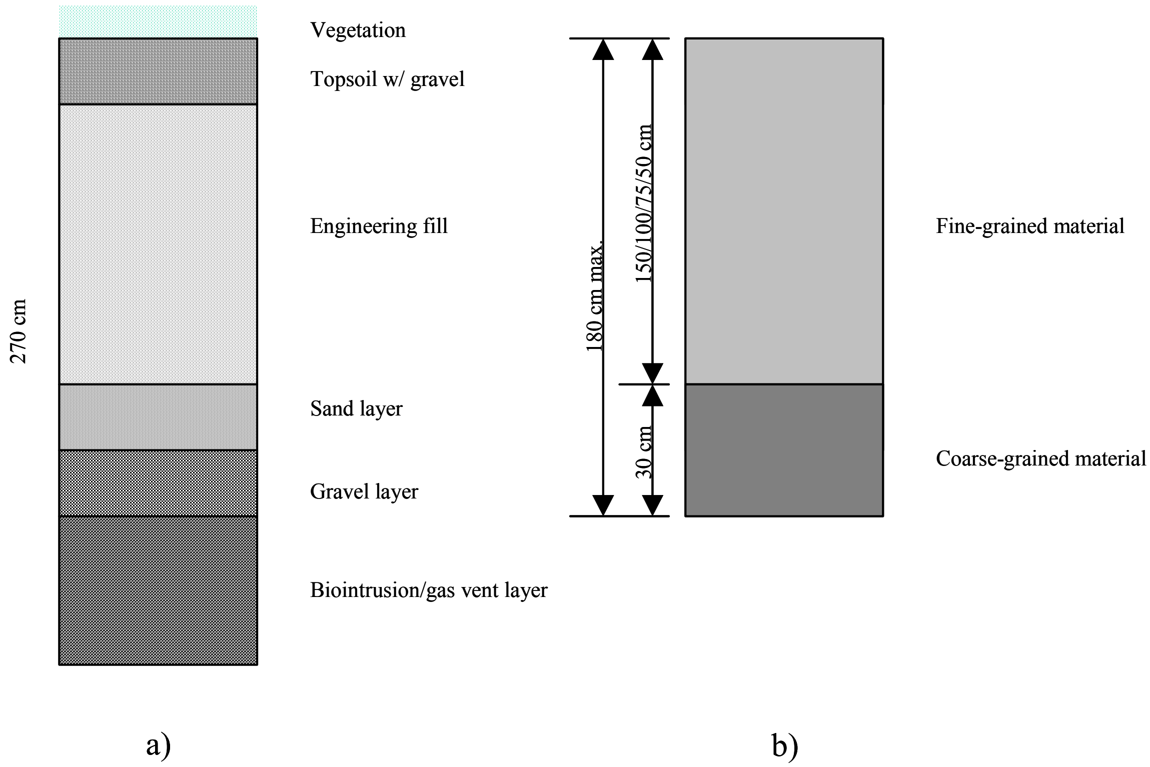


Figure J-1. Prescribed barrier design; simulations described here considered a simplified 180-cm model of this system. a) Represents the actual evapotranspiration/biobarrier design, b) Is the simplified material design used for the numerical simulations.

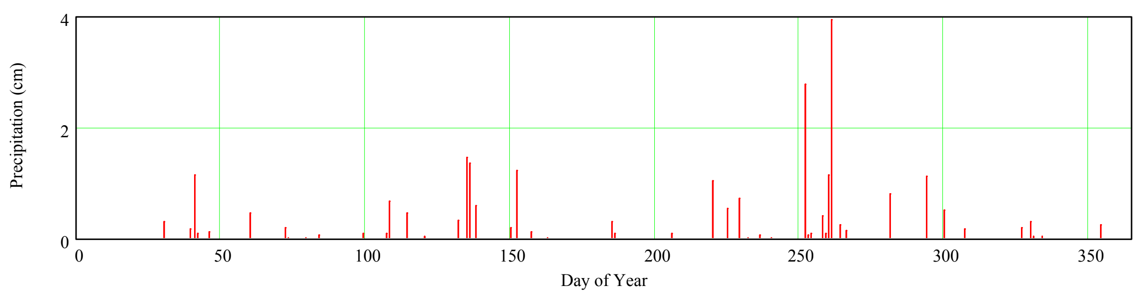


Figure J-2. An example of daily precipitation (cm) for a typical precipitation year in the 55-year meterological dataset used in this study.

Evapotranspiration in these simulations is determined using an approach that assumes that heat fluxes into the soil during the year represent an insignificant part of the overall water and energy cycle, so that the annual potential evapotranspiration can be determined using the Penman approach. Potential evapotranspiration is then partitioned into potential evaporation and potential transpiration according to the type of plants present, their total biomass, and growth cycle. Finally, actual evaporation and transpiration are calculated based on their maximum rates (defined by potential evaporation and potential transpiration) and the availability of water, which depends on the frequency and magnitude of precipitation events and how that water is distributed by subsurface flow. Using historical meteorological data from the area and assuming that the vegetation on the prescribed barrier might have a transpiration potential similar to cheatgrass, a common grass in the arid western U.S., calculated potential transpiration is typically much smaller than potential evaporation, and effective only during the summer months (Figure J-3). Although cheatgrass was used as the barrier material, final modeling of the barriers should include a plant community (and their evapotranspiration parameters) that are more representative of the plant community specified for the Subsurface Disposal Area surface barrier.

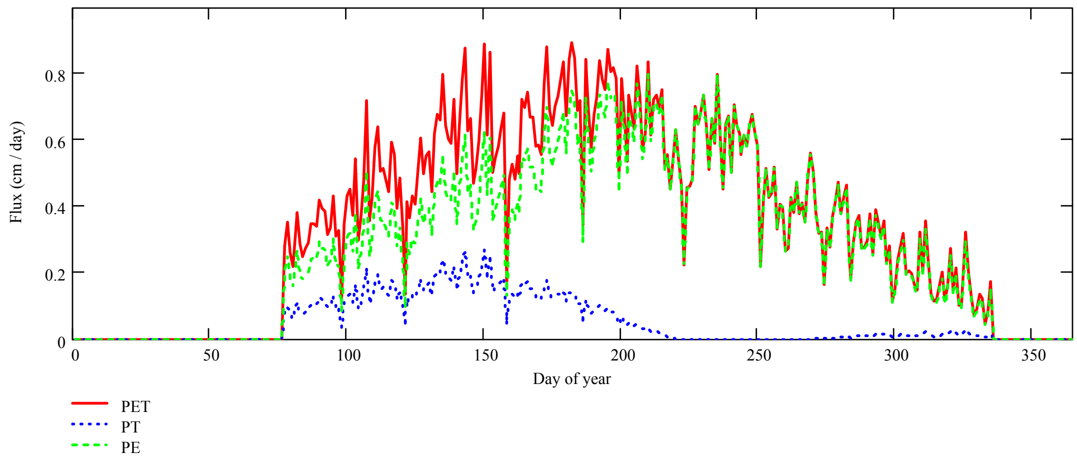


Figure J-3. Potential evapotranspiration, potential evaporation, and potential transpiration calculated for the prescribed barrier using historical (1950 in this plot) data and assuming a vegetation cover with potential transpiration characteristics similar to cheatgrass.

Water removal via transpiration also depends on the distribution of roots in the subsurface. Deep-rooted species, such as shrubs, often have a root zone one to several meters deep, while arid-region grass species typically root to a maximum depth of about 1 m. For these simulations, a root zone that extended the full depth of the topsoil/vegetation layer, but with a linear decrease in root density across that distance was considered.

Using the parameters and model described above, subsurface flow over 55 years (i.e., 19,710 days) for four different vegetation/topsoil layer thicknesses was simulated to estimate the thickness of spreading area B-type sediment necessary to yield a through-barrier flux less than approximately 0.5 cm/yr. The thicknesses tested were 1.8 m, 1.0 m, 0.5 m, and 0.25 m. In each case, plant roots were assumed to extend throughout the entire thickness of the vegetation/topsoil layer, but not below it. Results of the numerical tests of these barriers indicated that the flux through surface barriers with greater than 0.5-m vegetation/topsoil layer was essentially negligible (i.e., approximately 0.01 mm/yr). While the flux cumulative bottom flux (Figure J-4) in the barrier with the 0.25-m thick topsoil layer appeared to respond to interannual-scale variations in upper boundary conditions, the average flux through that barrier was still very small, approximately 1.5 mm/yr (Figure J-4).

Figure J-4 shows a comparison of the cumulative surface flux and the cumulative root water uptake from the simulation, while the 25-cm vegetation/topsoil layer demonstrates the importance of water vegetation in the water balance of these barriers. The annual infiltration rate into the surface (Figure J-5A) in this example is relatively constant, with an average value of about 5 cm/yr, or about 22% of average annual precipitation. The other 78% of the annual precipitation is removed via evaporation. Of the water that does infiltrate through the soil surface, virtually all of that water is removed via root water uptake (Figure J-5B), so that the net flux through the barrier is very small (Figure J-6).

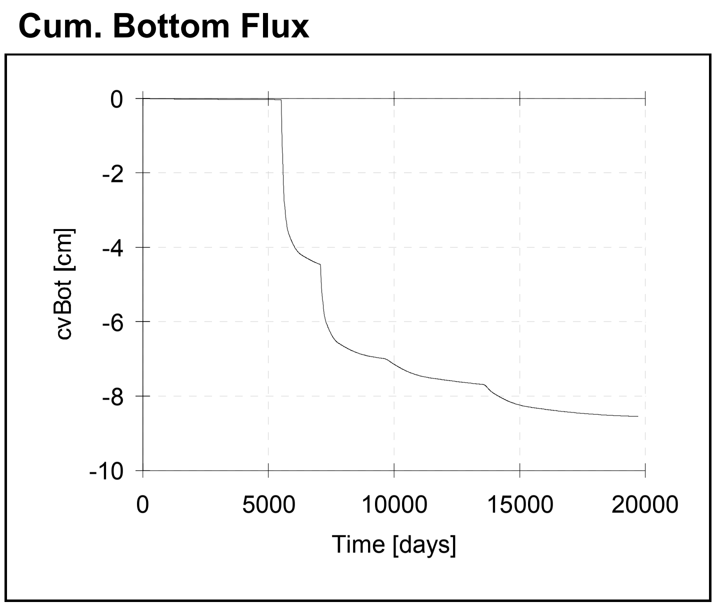


Figure J-4. Cumulative bottom flux (cm) for a 55-year simulation of flow through an evapotranspiration barrier with a 25-cm thick vegetation/topsoil layer of material with hydraulic properties similar to the spreading area B soil used at the Radioactive Waste Management Complex.

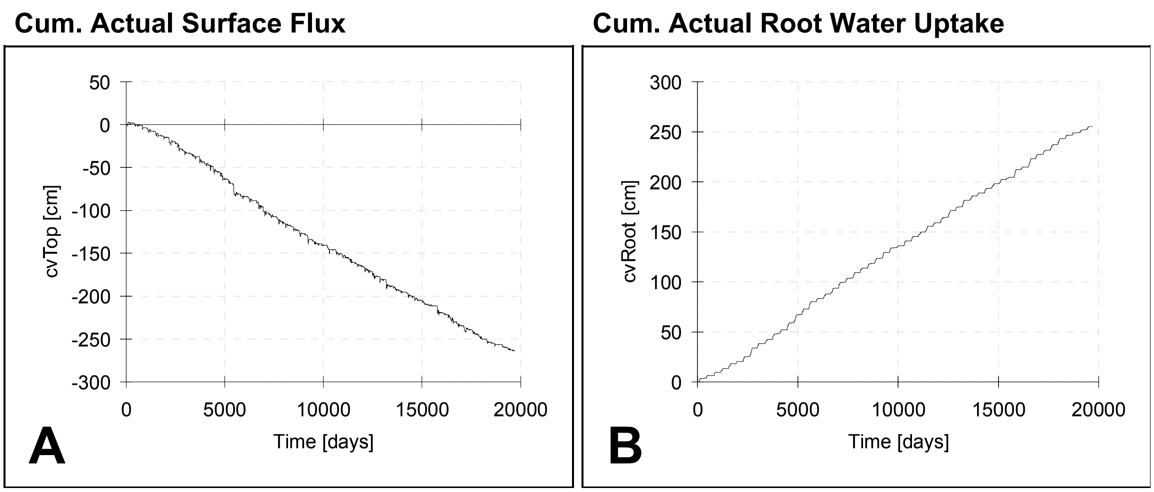


Figure J-5. Cumulative surface flux and root water uptake for a 55-year simulation of flow through an evapotranspiration barrier with a 25-cm thick vegetation/topsoil layer of material with hydraulic properties similar to the spreading area B soil used at the Radioactive Waste Management Complex.

As a preliminary test of the sensitivity of these results to the hydraulic properties of the vegetation/topsoil layer, two additional simulations of a 100-cm thick topsoil layer were conducted using hydraulic properties of loam and sandy loam. A typical loam is similar to the spreading area B sediment in many ways and results of that simulation were essentially identical to those using that material and the same topsoil thickness. Changing the 100-cm thick topsoil to a sandy loam, however, produced a significant increase in net flux through the barrier, yielding an average annual flux of approximately 3 mm/yr, which is very low but in excess of the value obtained for a 25-cm topsoil thickness of the spreading area B sediment.

These numerical modeling results are not meant to exactly simulate the INEEL surface barrier, but to allow confidence in defining a reasonable thickness of the water storage layer of the surface barrier. The real value of these simulations is to define the processes that greatly affect the sensitivity of the numerical results. In summary, these preliminary simulations describe a reasonable hydraulic model of how the soil barrier summarized in Figure J-1 would respond to the typical changes in boundary conditions that characterize our current climate. These simulations suggest that the net flux past the barrier would be very small, and are consistent with existing chloride-mass-balance based estimates of deep percolation in naturally vegetated areas of the INEEL. All simulations were conservative in their prediction of flux through an evapotranspiration surface barrier and well below the performance flux value of 1 cm/yr, and support the conclusion of the Protective Cap/Biobarrier Experiment field experiment that a 1.2 m water storage barrier is sufficiently thick at the INEEL.

The net flux past the root zone in a vegetated cover is highly dependent on a number of factors and the sensitivity of the flux through the surface barrier to these factors has not been adequately addressed in this study. In particular, the actual transpiration is highly dependent on the thickness of the root zone, total aboveground biomass, and the growth cycle of the vegetation (on both seasonal and interannual timescales), and root response to water stress have not been adequately defined in the prescribed model. The likely sensitivity of the resultant flux calculations to those parameters, as well as to uncertainty in the hydraulic properties models of the various layers within the barrier, should be considered in using the results of this preliminary modeling study.

Figure J-6. Net flux past the root zone for a 5-year simulation with (A) a hydraulic properties distribution that is generally representative of the prescribed soil barrier (Figure J-1) and (B) the same distribution with the bottom clay replaced with sand identical to that of the biointrusion and drainage layers.

Appendix K

Soil Availability at the Idaho National Engineering and Environmental Laboratory

Appendix K

Soil Availability at the Idaho National Engineering and Environmental Laboratory

A preliminary assessment of borrow sources at the Idaho National Engineering and Environmental Laboratory (INEEL) evaluated the potential amounts of the two least available soils—topsoil and silty loam material—necessary to construct a surface barrier for the Subsurface Disposal Area (SDA). Additional analysis of potential borrow sources will be necessary to evaluate engineering options and to estimate barrier construction costs.

The INEEL contains eight permitted gravel/borrow sources that support onsite maintenance operations, new construction, and environmental restoration and waste management activities (Minkin et al. 1994). The Central Facilities Area (CFA) Landlord has developed a permitting process to regulate excavations within all active INEEL gravel/borrow pits to facilitate scheduling and compliance with necessary environmental, safety, and permitting requirements. Archived information provides a history of past gravel/borrow demand and provides a basis for future planning. Presently, approvals for the use of gravel/borrow materials are provided to projects on a first-come first-served basis.

There is no formal mechanism at the INEEL to "save" borrow source material for a specific project. Form 450.19, "INEEL Gravel/Borrow Source Request," is being replaced by a new automated Form 450.AP01.[c] The new form eliminates the old "sign and fax for approval" process and significantly decreases the process time for a material removal permit. In addition to providing authorization for material removal (which all users are required to obtain), the new form also tracks material type, quantities, and users of the material from the eight onsite borrow pits. Most of these established pits produce gravel, but one currently active pit (i.e., Ryegrass Flats Pit, located 5.5 miles east of CFA) supports INEEL needs for silt/clay, which is commonly used in the construction of soil barriers, to seal ponds and lagoons, and in a variety of revegetation efforts. Ryegrass Flats was opened in 2001 when borrow operations were halted at the Spreading Area B Soil Borrow Pit. At Ryegrass Flats, current operations are restricted to a 40-acre area, where approximately nine acres have been mined (145,200 yd^3) and approximately 500,133 yd^3 still remain for immediate use. Expansion of Ryegrass Flats, up to 24 new acres each year (425,920 yd^3), is approved under the current Environmental Assessment (EA), and an additional 232 acres (3,742,933 yd^3) is considered viable for mining. Additional environmental review will be necessary to open areas outside the original 40-acre plot or to exceed the 24-acre limitation.

An EA completed in 1997 (DOE 1997) provides for the future establishment of two additional silt/clay sources on the INEEL: Spreading Area A, in the southwestern corner of the INEEL, and Water Reactor Research Test Facility (WRRTF), at the north end of the INEEL. Under the Finding of No Significant Impact issued under this EA, these onsite silt/clay sources can be opened individually or concurrently to meet INEEL needs through 2005, but new mining in all areas combined must not exceed 24 new acres in any one year. At the two areas that have not yet been brought into production, additional environmental review and some road construction will be necessary. Additional environmental review will also be necessary to extend operations at all locations beyond 2005, when the current EA expires. Since approval of the EA, the WRRTF site has also been incorporated into a special management area, the INEEL Sagebrush Steppe Ecosystem Reserve, which may result in different management priorities.

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According to this preliminary borrow source assessment, there is a sufficient amount of soil to complete construction of a surface barrier over the SDA. The potential total amount of silt/clay available for INEEL use from the three approved INEEL silt/clay sources is in excess of 13 million yd^3 (Table K-1). However, under the current approved regulations, only 24 acres (426,000 yd^3) can be excavated each year and this amount is insufficient to supply the amount of silty/clay material needed to complete the barrier construction in a single year. Multiple years of excavation or modifications to the current EA will be necessary for an SDA surface barrier.

Table K-1. Soil characteristics and mining potential at Idaho National Engineering and Environmental Laboratory silt/clay sources.

Name of Pit	Acreage Suitable for Mining	Average Depth of Silt/Clay Deposits	In-Place Volume of Silt/Clay Deposits	U.S. Dept. of Agriculture Soil Class	Unified Soil Classification System Soil Class
Ryegrass Flats	272 acres	10.5 ft (including 0.5 ft of topsoil)	4,388,266 yd^3	Lean clays and silt/clay mixtures	CL
Spreading Area A	248 acres	11.5 ft (including 0.5 ft of topsoil)	4,401,173 yd^3	Lean clays and silt/clay mixtures	CL
WRRTF	228 acres	12.5 ft (including 0.5 ft of topsoil)	4,414,080 yd^3	Lean to medium fat clays	CL (with more clay properties than other sites)

Obtaining adequate amounts of topsoil for an SDA barrier from the INEEL is likely to be problematic. Topsoil appropriate for use as a growing medium in various revegetation efforts is quite rare at the INEEL. Small stockpiles are located at each gravel/borrow source, but these materials are reserved for future rehabilitation of the pits themselves. A few larger stockpiles have also been accumulated, but these have been claimed for use by current projects (i.e., the current construction of the Naval Reactors Facility landfills). Construction projects at the INEEL also generate stockpiles of topsoil that become available as projects are completed. If the topsoil from these projects is not needed immediately, it is often stockpiled for later use in inactive portions of active gravel pits. Subsoils from Ryegrass Flats and other silt/clay sources may also be amended to serve as topsoil. Determining the amendment to the fine-grain INEEL soils to make it suitable for sustaining a healthy vegetative community is beyond the scope of this report, but should to be addressed during final design.

Spreading Area A is the nearest potential source of silt/clay for projects at the Radioactive Waste Management Complex and would be the most efficient source in terms of transportation for potential barrier construction activities planned at the SDA. Ryegrass Flats, approximately 13 miles from the Radioactive Waste Management Complex, would also be a suitable source, though transportation costs will be higher.

Although not examined in detail for this preliminary borrow source evaluation, material for sand and gravel layers should be less problematic for construction of an SDA surface barrier, as both materials are common on-site. Processed sand and gravel would be needed for constructing the transition from the water storage layer to the biointrusion layer. According to the Preliminary Evaluation of Remedial Alternatives, these materials could be obtainable from the Borax Gravel Pit located about 2.5 miles from the SDA.

Biointrusion materials were also not evaluated in detail but may be obtained from several potential sources, including an offsite vendor (cobble), onsite stockpiles of basalt rubble, or through blasting of in-place volcanic rock. Blasting of basalt rock near the SDA was assumed to be the best option for obtaining coarse materials. Coarse-fractured basalt will be needed for constructing biotic barriers, and likely for riprap erosion control. The Preliminary Evaluation of Remedial Alternatives identified a basalt outcrop about 5 miles from the SDA for mining to supply these materials. Though cobbles also could be used for the biotic barriers, the nearest apparent source for cobbles is located approximately 45 miles from the SDA in Idaho Falls making river cobbles an unattractive option from a cost perspective. Evaluations, therefore, assume that the basalt outcrop will be mined and the rock will be processed to provide coarse-fractured basalt and rip rap for constructing surface barriers.

K-1. REFERENCE

DOE, 1997, "Environmental Assessment and Plan for New Silt/Clay Source Development and Use at the Idaho National Engineering and Environmental Laboratory," DOE/EA-1083.

Minkin, S. C., M. R. Jackson, C. Knutson, P. N. Middleston, B. L. Ringe, R. C. Rope, and R. P. Smith, 1994, *INEL Gravel/Borrow Resources and Compliance Assessment,* EGG-FM-1126.

Appendix L

Performance Monitoring

Appendix L

Performance Monitoring

This section addresses monitoring issues with respect to barrier design and performance evaluation, construction quality control, and long-term stewardship. This preliminary discussion of issues is consistent with guidance developed by the Environmental Protection Agency (EPA 2003) and the Interstate Technology and Regulatory Council (ITRC 2003) for designing and monitoring the performance of alternative barriers, like the proposed Subsurface Disposal Area (SDA) surface barrier, that rely on soil water storage and evapotranspiration (ET).

L-1. SURFACE BARRIER DESIGN EVALUATION

An ET/biobarrier design is proposed for the SDA. The design is based on results of the Protective Cap/Biobarrier Experiment field study and preliminary Hydrologic Evaluation of Landfill Performance modeling results. As the design process progresses, it will be necessary to integrate all components using a design, performance, and risk evaluation methodology that considers all project elements (e.g., contaminants, environmental setting, engineering design, construction verification, and monitoring) to predict barrier performance and evaluate risks for all exposure pathways. The process may involve field installation, testing, and monitoring of the prototype design to demonstrate construction methods and short-term performance, and a combination performance modeling, risk modeling, and natural analogs to address features, events, and processes associated with the long-term performance of the design.

L-2. PROTOTYPE TESTS

Field-scale tests and monitoring of prototype designs are commonly conducted in lysimeters. Lysimeters offer the most direct and reliable means for evaluating the soil-water balance parameters (Gee and Hillel 1988) and have been used extensively to test the hydrologic performance of barrier designs for hazardous waste (Gee and Ward 1997; Dwyer 2001). Engineering construction and revegetation designs can also be demonstrated in large-scale lysimeters.

The Alternative Cover Assessment Project (ACAP) is a noteworthy example of prototype tests of alternative barriers (Albright et al. 2003). ACAP, initiated in 1998 by the Environmental Protection Agency, is conducting a comprehensive lysimeter test of prototype final barriers at sites across the country in climates ranging from arid to humid and from hot to cold. Both conventional and alternative barriers are monitored in side-by-side comparisons.

The ACAP prototype tests are 10 × 20 m drainage lysimeters instrumented for direct measurement of runoff, soil water storage, lateral drainage, and percolation flux for a full-depth barrier profile, and mass-balance calculation of evapotranspiration. Although the primary focus is on soil water balance and percolation flux, the ACAP lysimeter design and size would provide an efficient means for monitoring and evaluating other factors influencing the performance of the proposed SDA surface barrier, such as vegetation establishment and growth, physical stability and settlement, wind and water erosion, gas control, and biointrusion.

L-3. LONG-TERM PERFORMANCE EVALUATION

A goal of designing and building a sustainable SDA surface barrier that accommodates natural processes is to reduce long-term risks and maintenance costs. Current design guidelines (EPA 1989a) are not risk-based and do not address long-term changes in the environmental setting that may contribute to long-term risk. Long-term processes and episodic events associated with climate change, ecological succession, geomorphology, and soil development (pedogenisis) are not considered. Furthermore, traditional approaches for predicting the long-term performance of barrier designs rely on deterministic models of soil water balance, flow, and transport that neglect uncertainty in the processes influencing flow and transport. The implicit assumption is that long-term changes in the performance of engineered barriers can be predicted with model extrapolations based on the current environmental setting and a few years of monitoring field tests of the surface barrier. The design approach for the SDA surface barrier will link modeling with evidence from natural analog to bound reasonable ranges of long-term change in the environmental setting of the barrier.

L-4. LONG-TERM PERFORMANCE MODELING

One approach for bounding long-term change is to use a risk-based, probabilistic performance assessment process (DOE 1998; Meyer and Gee 1999). The general steps of a systematic performance modeling approach include (based on Holdren et al. 2002):

1. Develop and screen future environmental scenarios based on regulatory requirements and performance objectives. A scenario is a well-defined sequence of processes or events that describe possible future conditions at the disposal cell. For example, a scenario might include a future climate based on global change models, future ecological conditions (vegetation, burrowing animal habitat, and soil development), and a different land use. Reasonable future ecological changes would be inferred from analog studies.

2. Develop models of relevant future scenarios. Broad conceptual models of future scenarios are developed first to guide the selection of mechanistic models. Detailed models are then selected and integrated into a total system model framework that links performance with risk. An example is the Framework for Risk Analysis in Multimedia Environmental Systems developed by Pacific Northwest National Laboratory (mepas.pnl.gov/FRAMESV1/index.html).

3. Develop values and uncertainty distributions for input parameters. Single deterministic values might be assigned to some well-characterized parameters, but uncertainty distributions are preferable. The uncertainty and/or variability in other parameters may require the use of uncertainty distributions to define values. Uncertainty distributions for many environmental values will be based on the characterization of natural analogs. Some uncertainty distributions may be derived from literature, from prototype tests in lysimeters, or from monitoring results at sites similar to the SDA.

4. Perform calculations and sensitivity/uncertainty analyses. Because performance calculations (runs) will include stochastic parameters, a Monte Carlo approach is often used to rapidly create large suites of simulations that input different combinations of parameter values sampled from the uncertainty distributions. The results are a collection of uncertainty distributions that can be compared to the performance objectives. Sensitivity analyses indicate which input parameters the performance metrics are most sensitive to.

5. Document results and iterate previous steps as needed. The results are presented as the probability (risk) of exceeding a performance objective. Results can be used to iteratively evaluate alternative designs and components and to select the most suitable barrier design for the SDA.

6. Monitor key performance indicators for the completed barrier. Use results of sensitivity analyses to help select parameters for post-closure performance monitoring as part of stewardship activities.

The objectives of performance include (1) provide leading indicators of possible deterioration or failure of the barrier, (2) compare actual performance results with model predictions, and (3) reiterate and refine long-term projections, particularly in response to changes in the environmental setting.

L-5. NATURAL ANALOGS

An objective for designing the SDA barriers, given unprecedented longevity requirements, is to accommodate long-term environmental processes with the goal of sustaining performance with as little maintenance as possible. The performance of the SDA surface barrier will change in the long term as the environmental setting inevitably evolves in response to natural processes. Understanding how environmental conditions may change is crucial to designing, constructing, and maintaining long-term surface barrier systems. Effective modeling and performance assessment will require scenarios based on both current and possible future environmental settings.

Natural analog studies help identify and evaluate likely changes in environmental processes that may influence the performance of engineered barriers, processes that cannot be addressed with short-term field tests or existing numerical models (Waugh et al. 1994b). Natural analog information is needed to (1) engineer barrier systems that mimic favorable natural systems, (2) bound possible future conditions for input to predictive models and field tests, and (3) provide clues about the possible evolution of engineered barriers as a basis for monitoring leading indicators of change. Natural analogs also help demonstrate to the public that numerical predictions have real-world complements.

Evidence from natural analogs can improve our understanding of (1) meteorological variability associated with possible long-term changes in climate; (2) vegetation responses to climate change and disturbances; (3) effects of vegetation dynamics on ET, soil permeability, soil erosion, and animal burrowing; and (4) effects of soil development processes on water storage, permeability, and site ecology. Examples follow of natural and archaeological analogs for waste disposal sites similar to the SDA that were characterized to discern possible long-term changes in environmental settings, including climate change, pedogenesis (i.e., soil development), and ecological succession.

Climate data are required for design and performance evaluations of engineered barriers (Holdren et al., 2002). Evaluations may require projections of long-term extreme events and shifts in climate states over 100s and 1,000s of years, as well as annual and decadal variability in meteorological parameters. The Department of Energy (DOE) and its partners have demonstrated methods based on global change models and paleoecological evidence to establish a first approximation of possible future climatic states at other sagebrush steppe sites, including Hanford and Monticello (Waugh and Petersen 1995). A preliminary analysis of paleoclimate data for Monitcello yielded average annual temperature and precipitation ranges of 2 to 10°C and 80 to 60 cm, respectively, corresponding to late glacial and mid-Holocene periods. Instrumental records for regional stations were then used as a basis for selecting soil and vegetation analog sites that span a reasonable range of future climate states.

Pedogenic (i.e., soil development) processes will change soil physical and hydraulic properties that are fundamental to the performance of engineered barriers. Pedogenesis includes processes such as (1) formation of macropores for preferential flow associated with root growth, animal holes, and soil structural development; (2) secondary mineralization, deposition, and illuviation of fines, colloids, soluble salts, and oxides that can alter water storage and infiltration; and (3) soil mixing caused by freeze-thaw activity, animal burrows, and the shrink-swell action of expansive clays (Chadwick and Graham 2000). DOE, and its partners, have measured key soil physical and hydraulic properties in natural and archaeological soil profiles at climate analog sites to infer possible future pedogenic effects on the performance of the Monticello barrier (Waugh et al. 2003). The Environmental Protection Agency and its partners have conducted similar investigations at eastern disposal sites (Benson et al. 2004).

Plant communities will establish and change on soil barriers, whether intended or not, in response to climate, to soil development, and to disturbances such as fire, grazing, or noxious plant invasion. Changes in plant abundance, evapotranspiration rates, root penetration, and animal burrowing may alter the soil water balance and stability of a surface barrier. DOE and their partners have quantified evidence of possible future ecological changes from successional chronosequences. For example, at the Lakeview, Oregon, disposal site (perhaps a reasonable wet climate analog site for the SDA), possible future responses of plant community composition and LAI to fire were evaluated using a nearby fire chronosequence (Waugh 2004). In addition, possible vegetation responses to climate change scenarios were evaluated at regional climate-change analog sites. LAI, as an index of plant transpiration, ranged from 0.15 to 1.28 for the fire chronosequence and from 0.43 to 1.62 for dry and wet climate analog sites.

L-6. CONSTRUCTION QUALITY CONTROL

Monitoring during construction is required to ensure with a reasonable degree of certainty that components of the SDA surface barrier satisfy design specifications. The following is a summary of construction quality control from the ITRC (2003) guidance for alternative barriers. Detailed discussion of construction specifications and associated monitoring and testing is beyond the scope of this preliminary design report.

Monitoring requirements to ensure quality construction will be detailed in a Construction Quality Assurance (CQA) Plan that will incorporate the concepts of “quality control” and “quality assurance.” EPA (1993) defines these terms as follows:

- CQA—A planned series of observations and tests to ensure that the final product meets project specifications. CQA plans, specifications, observations, and tests are used to *provide quantitative criteria* with which to accept the final product.

- Construction Quality Control—An ongoing process of measuring and controlling the characteristics of the product that is employed by the manufacturer of materials and by the contractor installing materials at the site.

The purpose of a CQA test or observation is to compare the material used or the construction activity performed with a specification. Design specifications for barriers establish the parameters that will be measured to evaluate acceptability. Monitoring and testing of materials both before and during construction will determine whether material properties and material installation are within limits of design specifications and procedures.

L-7. POST-CLOSURE MONITORING OF BARRIER PERFORMANCE

The overall purpose of post-closure monitoring and care of the SDA surface barrier is to ensure protection of human health and the environment. A principal objective of post-closure monitoring is to detect releases of contaminants to ground water, air, and the surrounding ecology. Detection of significant concentrations of contaminants at or near exposure points may be an indication that the barrier has failed. Therefore, post-closure monitoring should also measure leading indicators of changes in barrier performance—precursors of failure—so that measures can be taken to prevent failures on a scale that threatens human health or the environment and are costly to repair.

The post-closure monitoring issues for the SDA surface barrier are associated with leachate and groundwater contamination, barrier water balance and percolation flux, release of gas contamination to the atmosphere, barrier integrity and subsidence, soil erosion and deposition, vegetation establishment and growth, animal intrusion, and radiological monitoring of surface soil and ecology.

L-8. LEACHATE AND GROUNDWATER MONITORING

Groundwater monitoring beneath or downgradient of the SDA may be required by law to detect leachate released from the facility and any changes, positive or negative, in water quality. Continuation of the groundwater monitoring system already in place before closure may be all that is required during the postclosure period. In any case, the groundwater monitoring program should include, in addition to a monitoring plan, a complete sampling and analysis plan and a statistical methodology to evaluate the adequacy of sample locations and frequency. Placement of any additional monitoring wells can be optimized given a good understanding of the hydrogeology of the site. Fewer, better-placed monitoring wells are usually better capable of detecting leachate in groundwater than many wells placed randomly or arbitrarily.

L-9. WATER BALANCE AND FLUX

A primary performance goal for the SDA barrier is to limit water percolation into the waste. Water passing through the barrier may mobilize and leach contaminants into groundwater. A final percolation flux criterion will be determined on the basis of performance assessment modeling, but for the purpose of exploring monitoring options, a percolation flux criterion of 3×10^{-8} cm/s (1 cm/yr) is assumed to be acceptable.

Field tests of ET/biobarrier designs, estimates of natural water flux rates, and numerical modeling studies all suggest that the proposed SDA surface barrier design can satisfy a 1 cm/yr percolation flux criterion. However, it may become necessary for a variety of reasons to directly monitor or estimate percolation flux through the barrier after construction. First, material properties and hydraulic performance of large-scale barriers constructed with heavy equipment rarely match conditions achieved in small-scale prototype tests (Waugh 2004; Albright et al. 2002). Second, uncertainty in percolation flux predictions using water balance models may be one to several orders of magnitude greater than the 1-cm/yr percolation flux criterion (Roesler et al. 2002). Furthermore, regulatory agencies may require DOE to demonstrate that percolation flux from the as-built barrier is less than the performance criterion, or is equal to or less than flux from a prescribed Resource Conservation and Recovery Act Subtitle C design.

L-10. INDIRECT MONITORING

Percolation flux from barriers is typically estimated from indirect methods, including water balance evaluations and numerical estimators. Much of the following summary of indirect methods is paraphrased from Gee et al. (2002).

For estimates of percolation flux using water budget methods, all of the components of the water balance equation except the flux across a lower observation boundary are measured, and the drainage flux is calculated by difference. For a simple on-dimensional estimation, precipitation (P), evapotranspiration (ET), and change in soil water storage (ΔS) are measured directly, and drainage (D) is estimated as:

$$D = \Delta S + ET - P \quad .$$

Water-balance measurements can be made directly in the field or in lysimeters (Boast and Robertson 1982; Allen et al. 1991). Uncertainty in percolation flux using water budget methods is usually unacceptably high because of high uncertainty in methods for direct measurement of ET. Percolation flux can also be derived from water-potential gradients if the unsaturated hydraulic conductivity is known. However, measurement of unsaturated hydraulic conductivity in the field is rarely attempted, and laboratory measurements are tedious and often highly uncertain (Gee et al. 2002).

Percolation flux can also be derived from water-potential gradients if the unsaturated hydraulic conductivity is known. However, measurement of unsaturated hydraulic conductivity in the field is rarely attempted, and laboratory measurements are tedious and often highly uncertain (Gee et al. 2002).

Percolation flux is often inferred from estimates of water storage changes (ΔS). If the soil water characteristic is known, the ΔS can be estimated from time-dependent measurements of soil water potential (ψ) using tensiometers (Richards 1950), thermocouple psychrometers (Richards and Ogata 1958), or heat-dissipation probes (Phene et al. 1971). The soil water characteristic is the functional relationship between soil water content (θ) and ψ. Soil water storage changes can also be inferred from time-dependent measurements of θ at various depths, z, using techniques like neutron scattering (Gardner and Kirkham 1952) and time-domain reflectometry (Topp et al. 1980). However, drainage can occur from barrier soils even when water content profiles and water storage appear constant, particularly in barriers with sandy soils.

Therefore, indirect estimates of percolation flux, based on water content and water potential sensors, are generally inadequate, because they do not measure flux rates directly. Water content or water potential sensing data must be coupled with estimates of the soil's unsaturated hydraulic conductivity giving rise to drainage estimates that are uncertain often by more than an order of magnitude. Similarly large uncertainties exist with water budget methods.

L-11. ONSITE AND OFFSITE LYSIMETERS

Lysimetry can also be used to monitor the water balance of the final surface barrier as constructed (as-built). Lysimeters have been installed both within final surface barriers to obtain a direct measure of drainage (onsite or in situ), and adjacent to final surface barriers (offsite) in an attempt to match the materials and construction as occurs for the actual barrier. An advantage of onsite monitoring is confidence in a direct measure of percolation flux; a disadvantage is cost. Conversely, offsite lysimeters can be less expensive, but uncertainty in matching the conditions of the large-scale construction may be high.

For onsite monitoring, the size of the subsurface lysimeter used to intercept flow is important. Percolation flux has been measured with pan lysimeters consisting of a gravel-filled pan placed below a barrier. For barriers like the SDA conceptual design that rely on a thick water storage layer, unless the pan is very large, the gravel in a pan lysimeter can create an unintended capillary barrier that causes lateral flow or divergence of water past the edges of the lysimeter (Chiu and Shackelford 2000). Divergence of flow results in an underestimation of percolation flux. Large in situ lysimeters, if installed correctly, can provide the most reliable monitoring of percolation flux. For example, a 3-hectare lysimeter was installed to intercept flow below an alternative barrier at the Monticello, Utah, Superfund Site. Less than 0.05 mm total drainage was measured between August 1999 and April 2004 (Waugh 2004a), well below the Environmental Protection Agency standard for Monticello of less than 3.0 mm/yr. Like the SDA conceptual barrier design, the Monticello barrier consists of a thick water storage layer overlying a capillary barrier (ET/biobarrier design, also called an ET/capillary barrier design).

Lysimeters designed to monitor percolation flux can also be installed adjacent to final barriers to mimic as-built conditions in the actual barrier. For example, two large drainage lysimeters were constructed adjacent to a uranium mill tailings disposal cell at Monticello to monitor the water balance for a range of conditions in the actual barrier (Waugh 2004b). One lysimeter contained a soil water storage layer that matched less desirable materials and compaction of *as built* during the early stages of construction; a gravelly clay loam subsoil compacted to 1.65 g/cm^2. The other lysimeter contained a water storage layer that matched the improved materials and compaction *as built* during the latter stages of construction; a loam topsoil compacted to 1.45 g/cm^2. The water storage layer in this second lysimeter also matched the favorable conditions in nearby native soils that the barrier was designed to mimic. Less that 0.1 mm/yr drainage was measured in both lysimeters during a 4-year period; however, the lysimeter with the less-compacted loam topsoil for a water storage layer had an almost 40% greater water storage capacity than the lysimeter constructed with overly-compacted clay loam subsoil for a water storage layer. Seemingly subtle discrepancies in materials and construction can have significant impacts on performance.

L-12. WATER FLUX METER

An instrument was recently developed, a small lysimeter or water flux meter, that can be easily installed within or below the SDA barrier profile and is capable of directly monitoring unsaturated water fluxes ranging from less than 10 mm/yr to more than 1,000 mm/yr (Gee et al. 2002). The water flux meter features a funnel to direct water from the soil into a passive wick for moisture tension control, a miniature tipping bucket for real-time flux measurements that can be calibrated from the surface, and a pipe or chimney extending above the funnel to minimize divergent flow.

Sources of uncertainty in monitoring percolation flux with the new water flux meter include heterogeneity in barrier soil hydraulic properties and plant ecology and effects of installation. Given that soils materials, layer construction, or vegetation will vary from on location to another on the barrier, then it must be shown that the number and placement of water flux meters is representative of that variability. If water flux meters are installed during construction of the SDA surface barrier, then care must be taken to maintain continuity of soil conditions above and surrounding the flux meters. If flux meters are installed after construction by augering holes into or through a barrier, then care must be taken to reconstruct continuity of soil conditions. Preferential flow within or divergence of flow away from the backfilled hole above the flux meter will cause either overestimation or underestimation of percolation flux.

L-13. GAS RELEASE

Landfill gasses have been observed to inhibit plant growth on landfill barriers. Well-established plant growth and deep root penetration are critical to the success and effectiveness of vegetated landfill barriers. Poor vegetative stands can result in reduced transpiration, increased percolation, and increased erosion regardless of the thickness of the surface barrier.

Bare (i.e., vegetation free) areas are not uncommon on landfill barriers. Often, shallow digging in these areas shows reducing conditions that are not present in vegetated areas at similar depths. Methane and carbon dioxide moving up from waste into an overlying soil barrier displaces oxygen, which is required in the soil-rooting medium to maintain healthy root activity. In addition, soil microbes consume oxygen in the presence of methane that reduces oxygen available for plant root respiration. Typically, even low methane levels indicate minimal oxygen concentrations.

A landfill gas monitoring system in the surface barrier can determine if the barrier venting system is operating properly and can serve as an early warning of a landfill gas problem before it is visually obvious at the landfill surface. Soil gas monitoring ports, easily installed using conventional techniques, could periodically sample for methane and carbon dioxide concentrations to evaluate if landfill gasses are a potential problem.

L-14. SUBSIDENCE

Differential settlement has been occurring in the SDA for over 20 years and will likely continue to occur in the future because of the heterogeneous nature and haphazard placement of the waste types. Pretreatments to stabilize the waste and barrier foundation, such as dynamic compaction, will reduce, but will not likely eliminate, differential settlement. Monitoring subsidence or settlement can involve a combination of periodic inspections of surface features for evidence of settlement, monitoring, and mapping surface topographic changes using high precision surveying equipment and monitoring settlement plates installed during construction. Soil cracking or areas with ponded water after a rain are examples of evidence of settlement.

Settlement plates placed below and within the barrier during construction can provide a means for measuring the amount and location of settlement occurring both within the waste and within the barrier, and for distinguishing between the two (ITRC 2003). Settlement plates are placed on the foundation material during construction, and the barrier layers are constructed to specified bulk densities around vertical rods that extend from the plates to the surface. During inspections, measurements of the northing, easting, and elevation of the rod tip extending above the barrier surface using a global positioning system with an accuracy of at least ±3.0 cm. The distance from the rod tip or a marking ring on the rod to the barrier surface is also measured. Changes form one inspection to another in the distance from the barrier surface to the rod tip or marking ring indicates that either settlement or erosion of the barrier materials has occurred. A change in the global positioning system-measured position of the rod tip indicates that settlement in waste materials below the barrier has occurred.

L-15. EROSION AND DEPOSITION

Soil erosion by water and wind is a likely long-term threat to the integrity of an SDA surface barrier. Removal of fine-grained soil by sheetflow erosion, rilling, gullying, and wind deflation could expose and disperse tailings under extreme conditions, or, more likely, reduce the thickness of barrier soil layers leading to contaminant transport by other pathways (e.g., water percolation). Soil loss by sheetflow erosion involves the detachment of soil particles from the barrier by raindrop splash and overland flow. If storm runoff is intense, flow may concentrate, cutting rills and gullies deep into the barrier (Walters and Skaggs 1986). Wind transports soil particles by surface creep, saltation, and resuspension, and may be particularly rapid leeward of topographic highs formed by mounded disposal cells (Ligotke 1994).

Periodic inspection of the barrier surface may be the most efficient means for monitoring evidence of erosion and taking corrective action, although measurements may be necessary to document long-term changes. Inspectors should document the following types of erosion evidence and conditions that could lead to erosion:

- Formation of rills (channels measuring up to 15 cm wide × 10 cm deep)
- Formation of gullies (channels measuring greater than 15 cm wide × 10 cm deep)
- Displacement of loose soil to the surface by burrowing animals, particularly if a gravel admixture or armor is needed for erosion control
- Disturbance of vegetation, such as by fire, excessive grazing, or animal trails
- Damage from vehicular traffic, including tire ruts in the admixture layer and damage to vegetation.

Installation of erosion control monuments or markers during construction is a common means for measuring erosion of soil barriers (ITRC 2003). Erosion control monuments are placed at an elevation that positions them just above the surface of the barrier once it is completed. The baseline elevation and state plane coordinates of the top of the monument are then surveyed. Monitoring involves measuring the barrier surface at each erosion control monument and at multiple, predetermined locations (usually four or more) away from each monument using a global positioning system with horizontal and vertical accuracy of at least ±3.0 cm. Monitoring data are statistically compared to baseline measurements to determine mean deflation of (or deposition on) the surface and spatial patterns of erosion and deposition.

L-16. Vegetation Establishment

Revegetation goals for the SDA surface barrier include establishment of plant communities that (1) are well-adapted to the engineered soil habitat, (2) are capable of high transpiration rates, (3) limit soil erosion, and (4) are structurally and functionally resilient. Seeding of monocultures or low-diversity mixtures on engineered barriers is common; however, on the SDA surface barrier, the revegetation goal is to emulate the structure, function, diversity, and dynamics of native plant communities in the area. Diverse mixtures of native and naturalized plants will maximize water removal and remain more resilient given variable and unpredictable changes in the environment resulting from pathogen and pest outbreaks, disturbances (overgrazing and fire), and climatic fluctuations. Local indigenous ecotypes that have been selected over thousands of years are usually best adapted. In contrast, the exotic grass plantings common on engineered barriers are genetically and structurally rigid, are more vulnerable to disturbance or eradication by single factors, and will require continual maintenance.

Successful establishment of a diverse and resilient plant community will require the enlistment of practitioners knowledgeable in the science and methods of disturbed land revegetation. One approach is to contract a revegetation specialist to develop and carry out the revegetation plan. Idaho National Engineering and Environmental Laboratory personnel would establish reasonable revegetation success criteria linked to performance, and then develop and implement a statistically sound monitoring plan to evaluate success relative to the criteria. Acceptance criteria can be adapted from those described by Waugh et al. (2002) and would include species composition, plant canopy cover, species frequency, shrub density, and leaf area index, or the health of the barrier plant community could be compared to reference areas adjacent to the SDA.

L-17. Animal Intrusion

Barrier designs that rely on vegetation for water extraction and erosion control also create habitat for animals that may contribute to the degradation of the barrier. Burrowing animals can mobilize contaminants by vertical displacement or by altering erosion, water balance, and gas release processes (Hakonson et al. 1982; Suter et al. 1993). Vertical displacement results as animals excavate burrows, and can be followed by ingestion or external contamination on skin and fur (Hakonson et al. 1982; McKenzie et al. 1982). Once in the surface environment, contaminants may then be transferred through higher trophic levels and carried offsite (O'Farrell et al. 1975; Arthur and Markham 1983). Loose soil cast to the surface by burrowing animals is vulnerable to wind and water erosion (Winsor and Whicker 1980; Cadwell et al. 1989). Burrowing influences soil water balance and gas releases by decreasing runoff, increasing rates of water infiltration and gas diffusion, but also increasing evaporation because of natural drafts (Cadwell et al. 1989; Landeen 1994).

The SDA surface barrier thickness is the primary biointrusion deterrent. Water retention in the soil water storage layer creates habitat for relatively shallow-rooted plants, and the thickness of the water storage layer exceeds the depth of most burrowing vertebrates in the area. A layer of cobble-size rock 30.5 cm above the capillary barrier is an added deterrent should deeper burrowers move onto the barrier.

As with other secondary performance issues, periodic inspection is the most efficient means for monitoring encroachment and intrusion of barriers by animals. Inspectors look for and document evidence of animal traffic on the surface barrier, such as tracks, trails, and droppings. If evidence of animals that could damage the barrier is observed, such as fecal material from large ungulates that could overgraze or trample vegetation, then institutional controls, such as fencing, should be considered to prevent animal access. Inspectors also look for animal burrows and holes that are large enough to cause channeling of water or displacement of loose soil to the surface where it is vulnerable to erosion.

L-18. REFERENCES

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Appendix M

Details of Construction Cost Estimate

Appendix M

Details of Construction Cost Estimate

M-1. Soil Material Volume Estimation

M-1.1 Area

For these preliminary calculations of soil volumes needed to construct a surface barrier, the assumption is that the surface barrier footprint is equal to the current Subsurface Disposal Area (SDA) area of 39 ha (97 acres [470,000 yd^2]) plus a 13-acre slope area for a total of 110 acres. This surface barrier footprint is consistent with that used in the Preliminary Evaluation of Remedial Alternatives (PERA) calculations and is consistent among all three cost estimates.

Calculating potential barrier edge effects, such as increased infiltration because of surface water run-on, and potential lateral flow beneath the barrier is beyond the scope of this effort.

M-1.2 Material Volumes

Material volumes were based on the design thickness and an area of 110 acres (see Table M-1 for a list of the material layer thickness and calculated volume of material needed for each layer). Also included in the volume calculations is a grade fill material—necessary as an engineering base material—on which the surface barrier would be constructed that is sufficient to cover the SDA. The material volume for this grade fill was obtained from the PERA and is included in all three barrier volume estimates. It should be noted that the PERA included a 100-ft-wide flood berm around the perimeter of the landfill barrier and the values in the Idaho National Engineering and Environmental Laboratory (INEEL) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF) and Resource Conservation and Recovery Act (RCRA) design volumes have been included to be consistent with the PERA. However, based on review of the historical data, surface water flooding at the SDA is a local phenomenon and could be controlled through tying the barrier into the local topography, since the flood berm is not an integral part of the evapotranspiration (ET)/biobarrier option and it was not included in the volume estimates of the ET/biobarrier option. In addition, the ICDF and RCRA designs also include slide slope armor, in part because of the internal drainage layers. The ET/biobarrier design recommends a blending of the barrier into the natural topography, and therefore, no side armor is necessary for this design and these volumes are not included in the volume estimates. Figure M-1 illustrates a cross section of the SDA landfill surface barrier used to estimate the approximate volume of soil.

Using the assumptions discussed in the previous paragraph, the RCRA subtitle C barrier requires the least amount of soil at approximately 3.0 million yd^3 plus asphalt. The ET/biobarrier would need approximately 3.3 million yd^3 of material and no additional asphalt or geomembrane material. The ICDF barrier requires approximately 5.3 million yd^3 of material and additional geomembrane material. The grade fill material volume is approximately 1.8 million yd^3 of the total volumes.

Table M-1. Estimated volume of construction materials needed for three potential barrier options for the Subsurface Disposal Area.

RCRA Modified Subtitle C

Function	Layer	Thickness (cm)	Volume (yd^3)
storage	topsoil w/gravel	50	291,120
storage	fine soil fill	50	291,120
biobarrier	sand filter	15	87,336
biobarrier	gravel layer	15	87,336
drain	drainage	15	87,336
drain	asphalt layer	10	58,224
gas	gas vent layer	15	87,336
Grade fill	*engineering fill*	*data from PERA*	*1,775,000*
Slope armor	*fine sand*	*data from PERA*	*6,000*
Slope armor	*gravel layer*	*data from PERA*	*6,000*
Slope armor	*basalt*	*data from PERA*	*6,000*
Slope armor	*Riprap*	*data from PERA*	*18,000*
perimeter berm	*Unprocessed silt*	*data from PERA*	*244,200*
berm armor	*riprap*	*data from PERA*	*15,600*
		Total Material =	3,060,608
		Asphalt Volume =	58,224

ICDF cover

Function	Layer	Thickness (cm)	Volume (yd^3)
storage	topsoil	30	174,672
storage	fine soil fill	240	1,397,375
biobarrier	fine soil	30	174,672
biobarrier	coarse sand	30	174,672
biobarrier	biointrusion	75	436,680
drain	coarse sand	30	174,672
drain	fine sand	30	174,672
drain	compacted clay	60	349,344
gas	gas vent layer	15	87,336
Grade fill	*engineering fill*	*data from PERA*	*1,775,000*
Slope armor	*fine sand*	*data from PERA*	*15,200*
Slope armor	*gravel layer*	*data from PERA*	*15,200*
Slope armor	*basalt*	*data from PERA*	*15,200*
Slope armor	*Riprap*	*data from PERA*	*45,600*
perimeter berm	*Unprocessed silt*	*data from PERA*	*244,200*
berm armor	*riprap*	*data from PERA*	*15,600*
		Total Material =	5,270,094
		Geomembrane area =	532000 yd^2

ET cover

Function	Layer	Thickness (cm)	Volume (yd^3)
storage	topsoil/gravel	30	174,672
storage	fine soil fill	120	698,688
biobarrier	garvel filter	60	349,344
biobarrier/gas	biointrusion/vent	60	349,344
Grade fill	*engineering fill*	*data from PERA*	*1,775,000*
		Total Material =	3,347,047

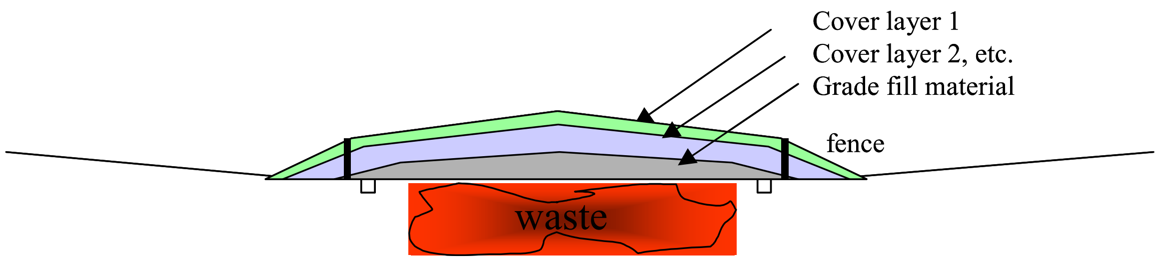

Figure M-1. Schematic cross section of the Subsurface Disposal Area barrier to calculate the volumes of materials needed for initial cost estimations.

M-2. ASSUMPTIONS FOR COST ESTIMATION

The estimates of cost for the preferred ET/biobarrier option include the following assumptions:

1. This project is owned and funded by the Idaho Completion Project
2. Includes construction costs only
3. No costs are included for project execution, construction management, project management, engineering or design, quality assurance, safety oversight, or project closeout.

The basis for this estimate includes:

1. The INEEL Cost Estimating Guide, dated August 2003; Company Guide (GDE)-112, Section 3.6, dated July 18, 2003, Rev. 03; and MCP-2871, Rev. 2, dated August 2001 were used to define estimating requirements.
2. The estimate development method was established using a detailed bottoms-up quantifiable technique. Resources, costs, and productions are derived from these individual detailed item quantities.
3. Quantities and types of materials that make up each type of barrier were provided Table M-1.
4. Costs were developed using success estimating software by U. S. Cost to a level of detail consistent with the available documents and information.
5. All labor units have been factored considering working conditions and requirements at the INEEL.

Additional assumptions include:

1. Per current accounting practices, allocation account of 32% of total project cost is included for each option of this estimate.
2. The project construction will begin in Fiscal Year (FY)-2010 and finish in FY-2014.
3. Subcontractors familiar with working at the INEEL will perform project construction and the contract shall be awarded through the bid and award process.
4. No radiologically contaminated or hazardous materials will be encountered.

5. Sufficient fill materials will be available at the INEEL and within approximately 15 miles of the SDA.

6. Blasting will be required to reduce basalt to a size that may be used for riprap.

7. Contingency of 25% has been assigned for this project.

Besides the ET barrier option, two additional preliminary cost estimations were prepared for comparison purposes, an ICDF design and a modified RCRA C design. The ET design was the lowest of the estimates at approximately 46.7M dollars. The RCRA modified C design was estimated to cost 58.1M, whereas the ICDF design was highest of the estimates at $101.5M. Details of the estimates can be found in the next pages.

Idaho National Engineering and Environmental Laboratory

INTEROFFICE MEMORANDUM

Date:	June 28, 2004		
To:	E. D. Mattson	MS 2107	6-4084
From:	D. A. Rowley	MS 3655	6-2978
Subject:	COST ESTIMATE – PRELIMINARY SDA SURFACE COVER – THREE OPTIONS		

Estimating Services has prepared risk adjusted Planning Cost Estimates for three options for the above referenced project. Total Estimated Cost (TEC) includes costs for Construction (direct and indirect costs), Allocation Account, Escalation, and Contingency.

Three estimate options are as follows:
Option 1 - ICDF Type Cover consisting of topsoil, fine soil, coarse sand, fine sand, compacted clay, engineered fill, basalt, riprap, and unprocessed silt.
Option 2 - RCRA Modified C Type Cover consisting of topsoil, fine soil, sand, gravel, asphalt, engineered fill, basalt, riprap, and unprocessed silt.
Option 3 - ET Type Cover consisting of topsoil, fine soil, sand, gravel, and engineered fill.

Each option represents a different configuration of fill material types and thickness and will cover 110 acres.

Please note that this project:

- Has been identified as an INEEL "ICP" owned/funded project.
- Construction will commence in FY 2010 and be completed FY 2014, therefore ICP Allocation Account costs are included at 32% of total construction cost.
- Does not include costs for BBWI project execution, construction management, project management, safety oversight, engineering and design, quality oversight, and project closeout in the total cost.
- Has not been analyzed by Construction Management for assignment within the Nine Block Matrix (Safety Risk/Operational Interface) in the consideration of construction scope and execution.

TEC for Option 1 with 25% contingency including allocation account is ....$101,500,000.
TEC for Option 1 with 25% contingency without allocation account is ....$76,900,000.

TEC for Option 2 with 25% contingency including allocation account is ....$58,100,000.
TEC for Option 2 with 25% contingency without allocation account is ....$44,000,000.

TEC for Option 3 with 25% contingency including allocation account is ....$46,700,000.
TEC for Option 3 with 25% contingency without allocation account is ....$35,400,000.

TEC is rounded to the nearest $100K.

Due to minimal detail and scoping definition, this estimate is assumed to be used for planning purposes and is not intended to be used to establish a cost baseline.

Please refer to the attached TEC Summary Report, Project Summary Report, Cost Estimate Support Data Recapitulation, and Detail Item Report sheets for cost breakdowns, descriptions, cost estimating basis, and risk analysis.

If you have any questions or comments please contact me at 526-2978 or e-mail "drowley."

DAR

Attachments

cc: Estimate File 5410
D. A. Rowley File (DAR-14-04)

Uniform File Code: 8000
Disposition Authority: A16-1.5-b
Retention Schedule: Cut off at the end of each fiscal year. Destroy 15 years after cutoff.

NOTE: Original disposition authority, retention schedule, and Uniform Filing Code applied by the sender may not be appropriate for all recipients. Make adjustments as needed.

Bechtel BWXT Idaho, LLC

COST ESTIMATE SUPPORT DATA RECAPITULATION

Project Title: Preliminary SDA Surface Cover – Options 1, 2, and 3
Estimator: D. A. Rowley
Date: June 28, 2004
Estimate Type: Planning
File: 5410
Approved By:

I. **PURPOSE:** *Brief description of the intent of how the estimate is to be used, i.e., for engineering study, comparative analysis, DWP, LCB out-year planning, BCP, etc.*

The purpose of these estimate options is to compare costs for the three types of possible engineered soil covers for the Subsurface Disposal Area (SDA) near the Radioactive Waste Management Complex (RWMC) .

II. **SCOPE OF WORK:** *Brief statement of the project's objective. Thorough overview and description of the proposed project. Identify work to be accomplished, as well as any specific work to be excluded.*

This project is an ICP owned / funded project.

This estimate includes construction costs only. No costs are included for project execution, construction management, project management, engineering / design, quality assurance, safety oversight, or project closeout.

Each cap option will cover 110 acres.

The scope for this project includes but is not limited to the following:

A. Option 1 is to construct an engineered cover for the SDA identified as the ICDF Type Cover and shall consist of topsoil, fine soil, coarse sand, fine sand, compacted clay, engineered fill, basalt, riprap, and unprocessed silt. The cover type indicates thickness and type of each layer of fill material. Total cover thickness is 29.7 feet.

B. Option 2 is to construct a cover for the SDA identified as the RCRA Modified C Type Cover and shall consist of topsoil, fine soil, sand, gravel, asphalt, engineered fill, basalt, riprap, and unprocessed silt. Total cover thickness is 17.25 feet.

C. Option 3 is to construct a cover for the SDA identified as the ET Type Cover and shall consist of topsoil, fine soil, sand, gravel, and engineered fill. Total cover thickness is 18.86 feet.

III. **BASIS OF THE ESTIMATE:** *Overall methodology and rationale of how the estimate was developed. Source documents to include drawings, design reports, engineers' notes and/or other documentation upon which the estimate is originated. Overall explanation of sources for resource pricing.*

A. The INEEL Cost Estimating Guide, dated August 2003; Company Guide GDE-112, Section 3.6, dated July 18, 2003, Rev. 03; and MCP-2871, Rev. 2, dated August 2001 were used to define estimating requirements.
B. The estimate development method was established using a detailed bottoms-up quantifiable technique. Resources, costs, and productions are derived from these individual detailed item quantities.
C. The estimate scope is defined in the scope of work provided by the requester. Quantities and types of materials that make up each type of cover were provided by the requester (E. D. Mattson). Some quantity information was provided by the Preliminary Evaluation of Remedial Alternative (PERA).
D. Equipment and labor units were calculated by J. C. Grenz (February 24, 2004) for the original estimating effort. This estimate was not finalized.
E. Costs were developed using the Success© estimating software by U. S. Cost to a level of detail consistent with the available documents and information.
F. All labor units have been factored considering working conditions and requirements at the INEEL.

IV. **ASSUMPTIONS:** *Condition statements accepted or supposed true without proof of demonstration; statements adding clarification to scope. An assumption has a direct impact on total estimated cost.*

A. Per current accounting practices, allocation account of 32% of TEC is included for each option of this estimate.
B. The project construction will begin in FY 2010 and finish in FY 2014.
C. Project construction will be performed by subcontractors familiar with working at the INEEL and the contract shall be awarded through the bid and award process.
D. No radiologically contaminated or hazardous materials will be encountered.
E. Sufficient fill materials will be available at the INEEL and within a proximity within 15 miles of the SDA.
F. Blasting will be required to reduce basalt to a size that may be used for riprap.

V. **CONTINGENCY GUIDELINE IMPLEMENTATION:** *Explanation of methodology used in determining overall contingency. Identify any specific drivers or items of concern.*

Contingency of 25% has been assigned for this project.

Items of risk considered for contingency include but are not limited to:
1. Potential that the project schedule will change.
2. Potential that the cover configuration will change.
3. Potential that potential haul areas will either be unavailable or will contain insufficient amounts of materials.

4. Potential that an unusually large number of lost days due to inclement weather will occur.
5. Potential that INEEL accounting practices for calculating allocation account will change prior to construction.

VI. **ESTIMATE SUMMARY**: *Total dollars/hours and Rough Order Magnitude (ROM) allocations of the methodologies used to develop the cost estimate.*

Option 1 – ICDP Type

Cost Elements		Estimate
Labor (BBWI)	$	0
Hours (BBWI)	Hrs	0
Material (BBWI)	$	0
ODC (Other Direct Costs)	$	81,200,000
Contingency	$	20,300,000
Total Cost	$	101,500,000

Estimate Methodology	ROM Percentage %	
SME (Unrecorded Observations)	0	%
Recorded Actuals	0	
Parametric	0	
Vendor Quotes	0	
Other	100	
Total	100	%

Option 2 – RCRA Modified Type C

Cost Elements		Estimate
Labor (BBWI)	$	0
Hours (BBWI)	Hrs	0
Material (BBWI)	$	0
ODC (Other Direct Costs)	$	46,481,000
Contingency	$	11,619,000
Total Cost	$	58,100,000

Estimate Methodology	ROM Percentage %	
SME (Unrecorded Observations)	0	%
Recorded Actuals	0	
Parametric	0	
Vendor Quotes	0	
Other	100	
Total	100	%

Option 3 – ET Type

Cost Elements		**Estimate**
Labor (BBWI)	$	0
Hours (BBWI)	Hrs	0
Material (BBWI)	$	0
ODC (Other Direct Costs)	$	37,366,000
Contingency	$	9,334,000
Total Cost	$	46,700,000

Estimate Methodology	**ROM Percentage %**	
SME (Unrecorded Observations)	0	%
Recorded Actuals	0	
Parametric	0	
Vendor Quotes	0	
Other	100	
Total	100	%

VII. **OTHER COMMENTS/CONCERNS SPECIFIC TO THE ESTIMATE:**

A. Activities have been escalated to the activity midpoint.
B. Subcontractor labor costs reflect INEEL Site Stabilization Agreement craft labor rates.
C. No INEEL (ICP or INL) labor is included in this estimate.
D. Allocation account costs are included in the estimate.

Project Name: *Preliminary SDA Surface Cover - Opt. 1 - ICDF Type*

TEC Summary Report

Project Location: *RWMC*
Project Number: *5410 - Opt. 1*

ESTIMATE ELEMENT	Estimate Subtotal	Escalation	Contingency	TOTAL
		24.16%	*25.00%*	
Total Estimated Cost (TEC)	**$65,400,938**	**$15,800,867**	**$20,300,451**	**$101,502,257**

		24.16%	*25.00%*	
Total Estimated Cost (TEC)	**$65,400,938**	**$15,800,867**	**$20,300,451**	**$101,502,257**
Rounded TEC (Rounded to the nearest $ 100000)				**$101,500,000**

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		Remarks
Type of Estimate:	Planning	ICDF Type Cover
Estimator:	J. C. Grenz / D. A. Rowley	
Checked By:		
Approved By:		

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

Project Summary Report

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL		Estimate Subtotal	Escalation	Contingency	Contingency %	TOTAL
9000	**CONSTRUCTION**	**$49,546,218**	**$11,970,366**	**$15,379,146**	**25.00%**	**$76,895,731**
9100	**--CONSTRUCTION SUBCONTRACTS**	**$49,546,218**	**$11,970,366**	**$15,379,146**	**25.00%**	**$76,895,731**
9101	**----GENERAL CONDITIONS**	**$514,623**	**$124,333**	**$159,739**	**25.00%**	**$798,694**
9102	**----SITEWORK**	**$49,031,596**	**$11,846,034**	**$15,219,407**	**25.00%**	**$76,097,037**
9102.01	------Agg Pit Screening Plant	$3,014,830	$728,383	$935,803	25.00%	$4,679,016
9102.02	------Drill & Shoot Quarry	$2,289,457	$553,133	$710,647	25.00%	$3,553,237
9102.03	------Quarry Screening Plant	$876,487	$211,759	$272,062	25.00%	$1,360,308
9102.04	------Spreading Area Pit	$636,270	$153,723	$197,498	25.00%	$987,491
9102.05	------Place Topsoil - Storage	$892,354	$215,593	$276,987	25.00%	$1,384,934
9102.06	------Place Fine Soil Fill - Storage	$7,139,985	$1,725,020	$2,216,251	25.00%	$11,081,256
9102.07	------Place Fine Soil - Biobarrier	$892,354	$215,593	$276,987	25.00%	$1,384,934
9102.08	------Place Course Sand - Biobarrier	$814,981	$196,899	$252,970	25.00%	$1,264,851
9102.09	------Place Biointrusion	$3,312,671	$800,341	$1,028,253	25.00%	$5,141,265
9102.10	------Place Course Sand - Drain	$814,981	$196,899	$252,970	25.00%	$1,264,851
9102.11	------Place Fine Sand - Drain	$814,981	$196,899	$252,970	25.00%	$1,264,851
9102.12	------Make Clay - Drain	$3,162,622	$764,089	$981,678	25.00%	$4,908,389
9102.13	------Place Compacted Clay - Drain	$1,784,709	$431,186	$553,974	25.00%	$2,769,868
9102.14	------Place Gas Vent Layer	$407,491	$98,450	$126,485	25.00%	$632,425
9102.15	------Place Engineered Fill - Grade Fill	$9,071,886	$2,191,768	$2,815,913	25.00%	$14,079,567
9102.16	------Place Fine Sand - Slope Armor	$71,284	$17,222	$22,127	25.00%	$110,633
9102.17	------Place Gravel Layer - Slope Armor	$71,284	$17,222	$22,127	25.00%	$110,633
9102.18	------Place Unprocessed Silt - Perimeter Berm	$1,139,484	$275,299	$353,696	25.00%	$1,768,479

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

Project Summary Report

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL		Estimate Subtotal	Escalation	Contingency	Contingency %	TOTAL
9102.19	------Blasting Riprap - Slope Armor	$6,840,000	$1,652,544	$2,123,136	25.00%	$10,615,680
9102.20	------Place Riprap - Slope Armor	$212,789	$51,410	$66,050	25.00%	$330,248
9102.21	------Blasting Basalt - Slope Armor	$2,280,000	$550,848	$707,712	25.00%	$3,538,560
9102.22	------Place Basalt - Slope Armor	$71,284	$17,222	$22,127	25.00%	$110,633
9102.23	------Blasting Riprap - Berm Armor	$2,280,000	$550,848	$707,712	25.00%	$3,538,560
9102.24	------Place Riprap - Berm Armor	$73,412	$17,736	$22,787	25.00%	$113,936
9102.25	------Seed Cap	$66,000	$15,946	$20,486	25.00%	$102,432
	ICP ALLOCATION	**$15,854,720**	**$3,830,500**	**$4,921,305**	**25.00%**	**$24,606,525**
Total	**5410 - PRELIMINARY SDA SURFACE COVER - OPTION 1 - ICDF TYPE**	**$65,400,938**	**$15,800,867**	**$20,300,451**	**25.00%**	**$101,502,257**

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9101 GENERAL CONDITIONS											
	cDIRT	U.C. per Wks		40	CN-EQLT	1448.8	0	0	0	0	1448.8
WORKABILITY WALKDOWN - 1/2 HR/DAY X 20 WORKERS X 4 DAY/WK			250.00	10,000	$36.22	$362,200	$0	$0	$0	$0	$362,200
	cDIRT	U.C. per LOT		10	CN-EQHV	381.3	0	0	0	0	381.3
POST JOB REVIEW			1.00	10	$38.13	$381	$0	$0	$0	$0	$381
Subtotal						$362,581	$0	$0	$0	$0	$362,581
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$152,041	$0	$0	$0	$0	$152,041
Subtotal Estimate											**$514,623**
Escalation						$124,333	$0	$0	$0	$0	$124,333
Contingency						$159,739	$0	$0	$0	$0	$159,739
---Total 9101 GENERAL CONDITIONS				**10,010**		**$798,694**	**$0**	**$0**	**$0**	**$0**	**$798,694**
--- 9102.01 Agg Pit Screening Plant											
Memo: ***To make 1-1/2" - 3/4" material, pit-run must be put thru the plant. This makes all of the gravel filter.***											
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			7,700.00	7,700		$0	$55,902	$0	$0	$0	$55,902
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			7,700.00	7,700	$38.13	$293,601	$0	$0	$0	$0	$293,601
00E0522	cDIRT	U.C. per hr		1	00E0522	0	96.29	0	0	0	96.29
6 Deck Screening Plant			7,700.00	7,700		$0	$741,433	$0	$0	$0	$741,433
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			7,700.00	7,700		$0	$456,379	$0	$0	$0	$456,379
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			7,700.00	7,700	$38.13	$293,601	$0	$0	$0	$0	$293,601
CN-EQMD	cDIRT	U.C. per hr		1	CN-EQMD	36.78	0	0	0	0	36.78
EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)			7,700.00	7,700	$36.78	$283,206	$0	$0	$0	$0	$283,206
Subtotal						$870,408	$1,253,714	$0	$0	$0	$2,124,122
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$364,988	$525,720	$0	$0	$0	$890,708
Subtotal Estimate											**$3,014,830**
Escalation						$298,472	$429,911	$0	$0	$0	$728,383
Contingency						$383,467	$552,336	$0	$0	$0	$935,803
---Total 9102.01 Agg Pit Screening Plant				**23,100**		**$1,917,335**	**$2,761,681**	**$0**	**$0**	**$0**	**$4,679,016**

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.02 Drill & Shoot Quarry										
Memo: To make 12" - 6" material, pit-run must be put thru the plant. This makes all of the biointrusion.										
	cDIRT	U.C. per lb			0	0	0.25	0	0	0.25
Purchase Amonia Nitrate		616,800.00	0		$0	$0	$154,200	$0	$0	$154,200
	cDIRT	U.C. per gal			0	0	1.5	0	0	1.5
Purchase Fuel		6,900.00	0		$0	$0	$10,350	$0	$0	$10,350
	cDIRT	U.C. per ea			0	0	5	0	0	5
Purchase Primers		2,315.00	0		$0	$0	$11,575	$0	$0	$11,575
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		4,630.00	4,630		$0	$33,614	$0	$0	$0	$33,614
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		4,630.00	4,630	$38.13	$176,542	$0	$0	$0	$0	$176,542
00E0830	cDIRT	U.C. per hr	1	00E0830	0	127.7	0	0	0	127.7
Robins RRT35 Drill		4,630.00	4,630		$0	$591,251	$0	$0	$0	$591,251
CN-LABE	cDIRT	U.C. per hr	2	CN-LABE	65.02	0	0	0	0	65.02
LABORER EXCAVATION, BACKFILL, FOUNDATIONS, TRENCHES		4,630.00	9,260	$32.51	$301,043	$0	$0	$0	$0	$301,043
00E2050	cDIRT	U.C. per hr	1	00E2050	0	34	0	0	0	34
ANFO Truck		4,630.00	4,630		$0	$157,420	$0	$0	$0	$157,420
CN-TRHV	cDIRT	U.C. per hr	1	CN-TRHV	36.34	0	0	0	0	36.34
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		4,630.00	4,630	$36.34	$168,254	$0	$0	$0	$0	$168,254
Subtotal					$645,839	$782,285	$176,125	$0	$0	$1,604,248
Sales Tax					$0	$0	$8,806	$0	$0	$8,806
INEEL ORG Labor/Subcontractor Overheads					$270,820	$328,035	$77,547	$0	$0	$676,402
Subtotal Estimate										**$2,289,457**
Escalation					$221,465	$268,253	$63,415	$0	$0	$553,133
Contingency					$284,531	$344,643	$81,473	$0	$0	$710,647
---Total 9102.02 Drill & Shoot Quarry			**18,520**		**$1,422,654**	**$1,723,217**	**$407,367**	**$0**	**$0**	**$3,553,237**
--- 9102.03 Quarry Screening Plant										
Memo: To make 12" - 6" material, pit-run must be put thru the plant. This makes all of the biointrusion.										
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		2,420.00	2,420		$0	$17,569	$0	$0	$0	$17,569
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		2,420.00	2,420	$38.13	$92,275	$0	$0	$0	$0	$92,275
00E0520	cDIRT	U.C. per hr	1	00E0520	0	21.34	0	0	0	21.34
300 TPH Screen Plant (run at 250 for large rock)		2,420.00	2,420		$0	$51,643	$0	$0	$0	$51,643
00E0942	cDIRT	U.C. per hr	1	00E0944	0	113.54	0	0	0	113.54
Cat 988 8cy Loader		2,420.00	2,420		$0	$274,767	$0	$0	$0	$274,767

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LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.03 Quarry Screening Plant											
Memo:	***To make 12" - 6" material, pit-run must be put thru the plant. This makes all of the biointrusion.***										
CN-EQHV EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <.100' BOOM)	cDIRT	U.C. per hr	2,420.00	1 2,420	CN-EQHV $38.13	38.13 $92,275	0 $0	0 $0	0 $0	0 $0	38.13 $92,275
CN-EQMD EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)	cDIRT	U.C. per hr	2,420.00	1 2,420	CN-EQMD $36.78	36.78 $89,008	0 $0	0 $0	0 $0	0 $0	36.78 $89,008
Subtotal						$273,557	$343,979	$0	$0	$0	$617,536
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$114,711	$144,241	$0	$0	$0	$258,951
Subtotal Estimate											**$876,487**
Escalation						$93,805	$117,954	$0	$0	$0	$211,759
Contingency						$120,518	$151,543	$0	$0	$0	$272,062
---Total 9102.03 Quarry Screening Plant				**7,260**		**$602,591**	**$757,717**	**$0**	**$0**	**$0**	**$1,360,308**
--- 9102.04 Spreading Area Pit											
Memo:	***Doze material into piles so 966 can load the belly dumps.***										
00E2060 3/4 tn 4x4 Pickup	cDIRT	U.C. per hr	2,780.00	0.5 1,390	00E2060	0 $0	3.63 $10,091	0 $0	0 $0	0 $0	3.63 $10,091
CN-EQHV EQUIPMENT OPERATOR FOREMAN	cDIRT	U.C. per hr	2,780.00	0.5 1,390	CN-EQHV $38.13	19.065 $53,001	0 $0	0 $0	0 $0	0 $0	19.065 $53,001
00E0963 Cat D8 Dozer	cDIRT	U.C. per hr	2,780.00	1 2,780	00E0963	0 $0	101.78 $282,948	0 $0	0 $0	0 $0	101.78 $282,948
CN-EQMD EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)	cDIRT	U.C. per hr	2,780.00	1 2,780	CN-EQMD $36.78	36.78 $102,248	0 $0	0 $0	0 $0	0 $0	36.78 $102,248
Subtotal						$155,249	$293,040	$0	$0	$0	$448,289
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$65,101	$122,880	$0	$0	$0	$187,981
Subtotal Estimate											**$636,270**
Escalation						$53,236	$100,486	$0	$0	$0	$153,723
Contingency						$68,397	$129,102	$0	$0	$0	$197,498
---Total 9102.04 Spreading Area Pit				**4,170**		**$341,983**	**$645,508**	**$0**	**$0**	**$0**	**$987,491**
--- 9102.05 Place Topsoil - Storage											
Memo:	***Haul material from spreading area and place in SDA (174,700 cy). See haul from spreading area. 5 trucks hauling 225 cy per hour.***										
00E2060 3/4 tn 4x4 Pickup	cDIRT	U.C. per hr	776.00	1 776	00E2060	0 $0	7.26 $5,634	0 $0	0 $0	0 $0	7.26 $5,634
CN-EQHV EQUIPMENT OPERATOR FOREMAN	cDIRT	U.C. per hr	776.00	1 776	CN-EQHV $38.13	38.13 $29,589	0 $0	0 $0	0 $0	0 $0	38.13 $29,589

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
-- **9102.05 Place Topsoil - Storage**										
Memo:	***Haul material from spreading area and place in SDA (174,700 cy). See haul from spreading area. 5 trucks hauling 225 cy per hour.***									
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		776.00	776		$0	$45,994	$0	$0	$0	$45,994
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		776.00	776		$0	$42,983	$0	$0	$0	$42,983
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		776.00	776		$0	$83,816	$0	$0	$0	$83,816
CN-EQHV	cDIRT	U.C. per hr	3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		776.00	2,328	$38.13	$88,767	$0	$0	$0	$0	$88,767
00E1910	cDIRT	U.C. per hr	5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor		776.00	3,880		$0	$190,935	$0	$0	$0	$190,935
CN-TRHV	cDIRT	U.C. per hr	5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		776.00	3,880	$36.34	$140,999	$0	$0	$0	$0	$140,999
Subtotal					$259,355	$369,360	$0	$0	$0	$628,715
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$108,755	$154,884	$0	$0	$0	$263,639
Subtotal Estimate										$892,354
Escalation					$88,935	$126,657	$0	$0	$0	$215,593
Contingency					$114,261	$162,725	$0	$0	$0	$276,987
---Total 9102.05 Place Topsoil - Storage			**6,984**		**$571,307**	**$813,627**	**$0**	**$0**	**$0**	**$1,384,934**
--- **9102.06 Place Fine Soil Fill - Storage**										
Memo:	***Haul material from spreading area and place in SDA (1,397,400 cy). 5 trucks hauling 225 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		6,209.00	6,209		$0	$45,077	$0	$0	$0	$45,077
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		6,209.00	6,209	$38.13	$236,749	$0	$0	$0	$0	$236,749
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		6,209.00	6,209		$0	$368,007	$0	$0	$0	$368,007
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		6,209.00	6,209		$0	$343,917	$0	$0	$0	$343,917
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		6,209.00	6,209		$0	$670,634	$0	$0	$0	$670,634
CN-EQHV	cDIRT	U.C. per hr	3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		6,209.00	18,627	$38.13	$710,248	$0	$0	$0	$0	$710,248

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.06 Place Fine Soil Fill - Storage											
Memo: ***Haul material from spreading area and place in SDA (1,397,400 cy). 5 trucks hauling 225 cy per hour.***											
00E1910	cDIRT	U.C. per hr		5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor			6,209.00	31,045		$0	$1,527,724	$0	$0	$0	$1,527,724
CN-TRHV	cDIRT	U.C. per hr		5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			6,209.00	31,045	$36.34	$1,128,175	$0	$0	$0	$0	$1,128,175
Subtotal						$2,075,172	$2,955,360	$0	$0	$0	$5,030,532
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$870,182	$1,239,271	$0	$0	$0	$2,109,453
Subtotal Estimate											**$7,139,985**
Escalation						$711,597	$1,013,423	$0	$0	$0	$1,725,020
Contingency						$914,238	$1,302,013	$0	$0	$0	$2,216,251
---Total 9102.06 Place Fine Soil Fill - Storage				**55,881**		**$4,571,189**	**$6,510,067**	**$0**	**$0**	**$0**	**$11,081,256**
--- 9102.07 Place Fine Soil - Biobarrier											
Memo: ***Haul material from spreading area and place in SDA (174,700 cy). See haul from spreading area. 5 trucks hauling 225 cy per hour.***											
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			776.00	776		$0	$5,634	$0	$0	$0	$5,634
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			776.00	776	$38.13	$29,589	$0	$0	$0	$0	$29,589
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			776.00	776		$0	$45,994	$0	$0	$0	$45,994
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			776.00	776		$0	$42,983	$0	$0	$0	$42,983
00E0612	cDIRT	U.C. per hr		1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot			776.00	776		$0	$83,816	$0	$0	$0	$83,816
CN-EQHV	cDIRT	U.C. per hr		3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			776.00	2,328	$38.13	$88,767	$0	$0	$0	$0	$88,767
00E1910	cDIRT	U.C. per hr		5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor			776.00	3,880		$0	$190,935	$0	$0	$0	$190,935

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.07 Place Fine Soil - Biobarrier**											
Memo:	***Haul material from spreading area and place in SDA (174,700 cy). See haul from spreading area. 5 trucks hauling 225 cy per hour.***										
CN-TRHV	cDIRT	U.C. per hr		5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			776.00	3,880	$36.34	$140,999	$0	$0	$0	$0	$140,999
Subtotal						$259,355	$369,360	$0	$0	$0	$628,715
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$108,755	$154,884	$0	$0	$0	$263,639
Subtotal Estimate											**$892,354**
Escalation						$88,935	$126,657	$0	$0	$0	$215,593
Contingency						$114,261	$162,725	$0	$0	$0	$276,987
---Total 9102.07 Place Fine Soil - Biobarrier				**6,984**		**$571,307**	**$813,627**	**$0**	**$0**	**$0**	**$1,384,934**
--- **9102.08 Place Course Sand - Biobarrier**											
Memo:	***Haul material and place in SDA (174,700cy). 6 trucks hauling 228 cy per hour.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			766.00	766		$0	$5,561	$0	$0	$0	$5,561
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			766.00	766	$38.13	$29,208	$0	$0	$0	$0	$29,208
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			766.00	766		$0	$45,401	$0	$0	$0	$45,401
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			766.00	766		$0	$42,429	$0	$0	$0	$42,429
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			766.00	1,532	$38.13	$58,415	$0	$0	$0	$0	$58,415
00E1910	cDIRT	U.C. per hr		6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor			766.00	4,596		$0	$226,169	$0	$0	$0	$226,169
CN-TRHV	cDIRT	U.C. per hr		6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			766.00	4,596	$36.34	$167,019	$0	$0	$0	$0	$167,019
Subtotal						$254,641	$319,560	$0	$0	$0	$574,201
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$106,779	$134,001	$0	$0	$0	$240,780
Subtotal Estimate											**$814,981**
Escalation						$87,319	$109,580	$0	$0	$0	$196,899
Contingency						$112,185	$140,785	$0	$0	$0	$252,970
---Total 9102.08 Place Course Sand - Biobarrier				**6,894**		**$560,924**	**$703,927**	**$0**	**$0**	**$0**	**$1,264,851**

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Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.09 Place Biointrusion										
Memo: ***Haul material from quarry and place in SDA (436,700 cy). See haul from Quarry. 7 trucks hauling 168 cy per hour.***										
00E2060 3/4 tn 4x4 Pickup	cDIRT	U.C. per hr 2,600.00	1 2,600	00E2060	0 $0	7.26 $18,876	0 $0	0 $0	0 $0	7.26 $18,876
CN-EQHV EQUIPMENT OPERATOR FOREMAN	cDIRT	U.C. per hr 2,600.00	1 2,600	CN-EQHV $38.13	38.13 $99,138	0 $0	0 $0	0 $0	0 $0	38.13 $99,138
00E0942 Cat 966 5 cy Loader	cDIRT	U.C. per hr 2,600.00	1 2,600	00E0942	0 $0	59.27 $154,102	0 $0	0 $0	0 $0	59.27 $154,102
00E1014 Cat 350 3 cy Hoe	cDIRT	U.C. per hr 2,600.00	1 2,600	00E1014	0 $0	124.7 $324,220	0 $0	0 $0	0 $0	124.7 $324,220
CN-EQHV EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)	cDIRT	U.C. per hr 2,600.00	2 5,200	CN-EQHV $38.13	76.26 $198,276	0 $0	0 $0	0 $0	0 $0	76.26 $198,276
00E1930 24 tn End Dump w/Tractor	cDIRT	U.C. per hr 2,600.00	7 18,200	00E1930	0 $0	337.68 $877,968	0 $0	0 $0	0 $0	337.68 $877,968
CN-TRHV TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)	cDIRT	U.C. per hr 2,600.00	7 18,200	CN-TRHV $36.34	254.38 $661,388	0 $0	0 $0	0 $0	0 $0	254.38 $661,388
Subtotal					$958,802	$1,375,166	$0	$0	$0	$2,333,968
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$402,054	$576,648	$0	$0	$0	$978,703
Subtotal Estimate										**$3,312,671**
Escalation					$328,783	$471,558	$0	$0	$0	$800,341
Contingency					$422,410	$605,843	$0	$0	$0	$1,028,253
--Total 9102.09 Place Biointrusion			**26,000**		**$2,112,049**	**$3,029,216**	**$0**	**$0**	**$0**	**$5,141,265**
--- 9102.10 Place Course Sand - Drain										
Memo: ***Haul material place in SDA (174,700cy). 6 trucks hauling 228 cy per hour.***										
00E2060 3/4 tn 4x4 Pickup	cDIRT	U.C. per hr 766.00	1 766	00E2060	0 $0	7.26 $5,561	0 $0	0 $0	0 $0	7.26 $5,561
CN-EQHV EQUIPMENT OPERATOR FOREMAN	cDIRT	U.C. per hr 766.00	1 766	CN-EQHV $38.13	38.13 $29,208	0 $0	0 $0	0 $0	0 $0	38.13 $29,208
00E0942 Cat 966 5 cy Loader	cDIRT	U.C. per hr 766.00	1 766	00E0942	0 $0	59.27 $45,401	0 $0	0 $0	0 $0	59.27 $45,401
00E0914 Cat 163 Grader	cDIRT	U.C. per hr 766.00	1 766	00E0914	0 $0	55.39 $42,429	0 $0	0 $0	0 $0	55.39 $42,429
CN-EQHV EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)	cDIRT	U.C. per hr 766.00	2 1,532	CN-EQHV $38.13	76.26 $58,415	0 $0	0 $0	0 $0	0 $0	76.26 $58,415

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.10 Place Course Sand - Drain**										
Memo: ***Haul material place in SDA (174,700cy). 6 trucks hauling 228 cy per hour.***										
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		766.00	4,596		$0	$226,169	$0	$0	$0	$226,169
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		766.00	4,596	$36.34	$167,019	$0	$0	$0	$0	$167,019
Subtotal					$254,641	$319,560	$0	$0	$0	$574,201
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$106,779	$134,001	$0	$0	$0	$240,780
Subtotal Estimate										**$814,981**
Escalation					$87,319	$109,580	$0	$0	$0	$196,899
Contingency					$112,185	$140,785	$0	$0	$0	$252,970
--Total 9102.10 Place Course Sand - Drain			**6,894**		**$560,924**	**$703,927**	**$0**	**$0**	**$0**	**$1,264,851**
--- **9102.11 Place Fine Sand - Drain**										
Memo: ***Haul material and place in SDA (174,700cy). 6 trucks hauling 228 cy per hour.***										
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		766.00	766		$0	$5,561	$0	$0	$0	$5,561
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		766.00	766	$38.13	$29,208	$0	$0	$0	$0	$29,208
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		766.00	766		$0	$45,401	$0	$0	$0	$45,401
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		766.00	766		$0	$42,429	$0	$0	$0	$42,429
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		766.00	1,532	$38.13	$58,415	$0	$0	$0	$0	$58,415
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		766.00	4,596		$0	$226,169	$0	$0	$0	$226,169

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.11 Place Fine Sand - Drain										
Memo:	***Haul material and place in SDA (174,700cy). 6 trucks hauling 228 cy per hour.***									
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		766.00	4,596	$36.34	$167,019	$0	$0	$0	$0	$167,019
Subtotal					$254,641	$319,560	$0	$0	$0	$574,201
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$106,779	$134,001	$0	$0	$0	$240,780
Subtotal Estimate										**$814,981**
Escalation					$87,319	$109,580	$0	$0	$0	$196,899
Contingency					$112,185	$140,785	$0	$0	$0	$252,970
—Total 9102.11 Place Fine Sand - Drain			**6,894**		**$560,924**	**$703,927**	**$0**	**$0**	**$0**	**$1,264,851**
— 9102.12 Make Clay - Drain										
Memo:	***Doze material into piles so 966 can load the belly dumps. (356,350 cy)***									
	cDIRT	U.C. per tn			0	0	80	0	0	80
Purchase Bentonite		14,050.00	0		$0	$0	$1,124,000	$0	$0	$1,124,000
	cDIRT	U.C. per cy			0.75	2.25	0	0	0	3
Mix in Pug Mill		349,350.00	0		$262,013	$786,038	$0	$0	$0	$1,048,050
Subtotal					$262,013	$786,038	$1,124,000	$0	$0	$2,172,050
Sales Tax					$0	$0	$56,200	$0	$0	$56,200
INEEL ORG Labor/Subcontractor Overheads					$109,870	$329,609	$494,893	$0	$0	$934,372
Subtotal Estimate										**$3,162,622**
Escalation					$89,847	$269,540	$404,703	$0	$0	$764,089
Contingency					$115,432	$346,297	$519,949	$0	$0	$981,678
—Total 9102.12 Make Clay - Drain			**0**		**$577,161**	**$1,731,484**	**$2,599,745**	**$0**	**$0**	**$4,908,389**
— 9102.13 Place Compacted Clay - Drain										
Memo:	***Haul material from spreading area and place in SDA (349,350 cy). Haul from spreading area. 5 trucks hauling 225 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		1,552.00	1,552		$0	$11,268	$0	$0	$0	$11,268
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		1,552.00	1,552	$38.13	$59,178	$0	$0	$0	$0	$59,178
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		1,552.00	1,552		$0	$91,987	$0	$0	$0	$91,987
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		1,552.00	1,552		$0	$85,965	$0	$0	$0	$85,965
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		1,552.00	1,552		$0	$167,632	$0	$0	$0	$167,632

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.13 Place Compacted Clay - Drain											
Memo:	*Haul material from spreading area and place in SDA (349,350 cy). Haul from spreading area. 5 trucks hauling 225 cy per hour.*										
CN-EQHV	cDIRT	U.C. per hr		3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			1,552.00	4,656	$38.13	$177,533	$0	$0	$0	$0	$177,533
00E1910	cDIRT	U.C. per hr		5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor			1,552.00	7,760		$0	$381,870	$0	$0	$0	$381,870
CN-TRHV	cDIRT	U.C. per hr		5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			1,552.00	7,760	$36.34	$281,998	$0	$0	$0	$0	$281,998
Subtotal						$518,709	$738,721	$0	$0	$0	$1,257,430
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$217,510	$309,768	$0	$0	$0	$527,278
Subtotal Estimate											**$1,784,709**
Escalation						$177,871	$253,315	$0	$0	$0	$431,186
Contingency						$228,523	$325,451	$0	$0	$0	$553,974
—Total 9102.13 Place Compacted Clay - Drain				**13,968**		**$1,142,613**	**$1,627,255**	**$0**	**$0**	**$0**	**$2,769,868**
— 9102.14 Place Gas Vent Layer											
Memo:	*Haul material and place in SDA (87,350 cy). 6 trucks hauling 228 cy per hour.*										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			383.00	383		$0	$2,781	$0	$0	$0	$2,781
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			383.00	383	$38.13	$14,604	$0	$0	$0	$0	$14,604
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			383.00	383		$0	$22,700	$0	$0	$0	$22,700
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			383.00	383		$0	$21,214	$0	$0	$0	$21,214
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			383.00	766	$38.13	$29,208	$0	$0	$0	$0	$29,208
00E1910	cDIRT	U.C. per hr		6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor			383.00	2,298		$0	$113,085	$0	$0	$0	$113,085

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.14 Place Gas Vent Layer**											
Memo:	***Haul material and place in SDA (87,350 cy). 6 trucks hauling 228 cy per hour.***										
CN-TRHV	cDIRT	U.C. per hr		6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			383.00	2,298	$36.34	$83,509	$0	$0	$0	$0	$83,509
Subtotal						$127,321	$159,780	$0	$0	$0	$287,101
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$53,389	$67,001	$0	$0	$0	$120,390
Subtotal Estimate											**$407,491**
Escalation						$43,660	$54,790	$0	$0	$0	$98,450
Contingency						$56,092	$70,393	$0	$0	$0	$126,485
---Total 9102.14 Place Gas Vent Layer				**3,447**		**$280,462**	**$351,963**	**$0**	**$0**	**$0**	**$632,425**
--- **9102.15 Place Engineered Fill - Grade Fill**											
Memo:	***Haul material from spreading area and place in SDA (1,775,000 cy). Haul from spreading area. 5 trucks hauling 225 cy per hour. Quantity from PERA.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			7,889.00	7,889		$0	$57,274	$0	$0	$0	$57,274
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			7,889.00	7,889	$38.13	$300,808	$0	$0	$0	$0	$300,808
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			7,889.00	7,889		$0	$467,581	$0	$0	$0	$467,581
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			7,889.00	7,889		$0	$436,972	$0	$0	$0	$436,972
00E0612	cDIRT	U.C. per hr		1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot			7,889.00	7,889		$0	$852,091	$0	$0	$0	$852,091
CN-EQHV	cDIRT	U.C. per hr		3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			7,889.00	23,667	$38.13	$902,423	$0	$0	$0	$0	$902,423
00E1910	cDIRT	U.C. per hr		5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor			7,889.00	39,445		$0	$1,941,088	$0	$0	$0	$1,941,088

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.15 Place Engineered Fill - Grade Fill**										
Memo: ***Haul material from spreading area and place in SDA (1,775,000 cy). Haul from spreading area. 5 trucks hauling 225 cy per hour. Quantity from PERA.***										
CN-TRHV	cDIRT	U.C. per hr	5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		7,889.00	39,445	$36.34	$1,433,431	$0	$0	$0	$0	$1,433,431
Subtotal					$2,636,662	$3,755,006	$0	$0	$0	$6,391,668
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$1,105,631	$1,574,587	$0	$0	$0	$2,680,218
Subtotal Estimate										**$9,071,886**
Escalation					$904,138	$1,287,630	$0	$0	$0	$2,191,768
Contingency					$1,161,608	$1,654,306	$0	$0	$0	$2,815,913
---Total 9102.15 Place Engineered Fill - Grade Fill			**71,001**		**$5,808,039**	**$8,271,528**	**$0**	**$0**	**$0**	**$14,079,567**
--- 9102.16 Place Fine Sand - Slope Armor										
Memo: ***Haul material and place in SDA (15,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		67.00	67		$0	$486	$0	$0	$0	$486
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		67.00	67	$38.13	$2,555	$0	$0	$0	$0	$2,555
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		67.00	67		$0	$3,971	$0	$0	$0	$3,971
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		67.00	67		$0	$3,711	$0	$0	$0	$3,711
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		67.00	134	$38.13	$5,109	$0	$0	$0	$0	$5,109
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		67.00	402		$0	$19,782	$0	$0	$0	$19,782

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL / Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.16 Place Fine Sand - Slope Armor									
Memo: ***Haul material and place in SDA (15,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
CN-TRHV cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)	67.00	402	$36.34	$14,609	$0	$0	$0	$0	$14,609
Subtotal				$22,273	$27,951	$0	$0	$0	$50,224
Sales Tax				$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads				$9,340	$11,721	$0	$0	$0	$21,060
Subtotal Estimate									**$71,284**
Escalation				$7,638	$9,585	$0	$0	$0	$17,222
Contingency				$9,813	$12,314	$0	$0	$0	$22,127
--Total 9102.16 Place Fine Sand - Slope Armor		**603**		**$49,063**	**$61,571**	**$0**	**$0**	**$0**	**$110,633**
--- 9102.17 Place Gravel Layer - Slope Armor									
Memo: ***Haul material and place in SDA (15,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
00E2060 cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup	67.00	67		$0	$486	$0	$0	$0	$486
CN-EQHV cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN	67.00	67	$38.13	$2,555	$0	$0	$0	$0	$2,555
00E0942 cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader	67.00	67		$0	$3,971	$0	$0	$0	$3,971
00E0914 cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader	67.00	67		$0	$3,711	$0	$0	$0	$3,711
CN-EQHV cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)	67.00	134	$38.13	$5,109	$0	$0	$0	$0	$5,109
00E1910 cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor	67.00	402		$0	$19,782	$0	$0	$0	$19,782

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.17 Place Gravel Layer - Slope Armor**										
Memo:	***Haul material and place in SDA (15,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		67.00	402	$36.34	$14,609	$0	$0	$0	$0	$14,609
Subtotal					$22,273	$27,951	$0	$0	$0	$50,224
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$9,340	$11,721	$0	$0	$0	$21,060
Subtotal Estimate										**$71,284**
Escalation					$7,638	$9,585	$0	$0	$0	$17,222
Contingency					$9,813	$12,314	$0	$0	$0	$22,127
—Total 9102.17 Place Gravel Layer - Slope Armor			**603**		**$49,063**	**$61,571**	**$0**	**$0**	**$0**	**$110,633**
--- **9102.18 Place Unprocessed Silt - Perimeter Berm**										
Memo:	***Haul material and place in SDA (244,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		1,071.00	1,071		$0	$7,775	$0	$0	$0	$7,775
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		1,071.00	1,071	$38.13	$40,837	$0	$0	$0	$0	$40,837
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		1,071.00	1,071		$0	$63,478	$0	$0	$0	$63,478
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		1,071.00	1,071		$0	$59,323	$0	$0	$0	$59,323
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		1,071.00	2,142	$38.13	$81,674	$0	$0	$0	$0	$81,674
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		1,071.00	6,426		$0	$316,223	$0	$0	$0	$316,223

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.18 Place Unprocessed Silt - Perimeter Berm										
Memo:	***Haul material and place in SDA (244,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
CN-TRHV TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)	cDIRT	U.C. per hr 1,071.00	6 6,426	CN-TRHV $36.34	218.04 $233,521	0 $0	0 $0	0 $0	0 $0	218.04 $233,521
Subtotal					$356,033	$446,800	$0	$0	$0	$802,832
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$149,295	$187,357	$0	$0	$0	$336,652
Subtotal Estimate										**$1,139,484**
Escalation					$122,087	$153,212	$0	$0	$0	$275,299
Contingency					$156,854	$196,842	$0	$0	$0	$353,696
---Total 9102.18 Place Unprocessed Silt - Perimeter Berm			**9,639**		**$784,269**	**$984,211**	**$0**	**$0**	**$0**	**$1,768,479**
--- 9102.19 Blasting Riprap - Slope Armor										
Memo:	***Quantity from PERA.***									
Blasting To Provide Riprap	SPEC	U.C. per Cy 45,600.00	0		0 $0	0 $0	0 $0	150 $6,840,000	0 $0	150 $6,840,000
Subtotal					$0	$0	$0	$6,840,000	$0	$6,840,000
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										**$6,840,000**
Escalation					$0	$0	$0	$1,652,544	$0	$1,652,544
Contingency					$0	$0	$0	$2,123,136	$0	$2,123,136
---Total 9102.19 Blasting Riprap - Slope Armor			**0**		**$0**	**$0**	**$0**	**$10,615,680**	**$0**	**$10,615,680**
--- 9102.20 Place Riprap - Slope Armor										
Memo:	***Haul material and place in SDA (45,600cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
00E2060 3/4 tn 4x4 Pickup	cDIRT	U.C. per hr 200.00	1 200	00E2060	0 $0	7.26 $1,452	0 $0	0 $0	0 $0	7.26 $1,452
CN-EQHV EQUIPMENT OPERATOR FOREMAN	cDIRT	U.C. per hr 200.00	1 200	CN-EQHV $38.13	38.13 $7,626	0 $0	0 $0	0 $0	0 $0	38.13 $7,626
00E0942 Cat 966 5 cy Loader	cDIRT	U.C. per hr 200.00	1 200	00E0942	0 $0	59.27 $11,854	0 $0	0 $0	0 $0	59.27 $11,854
00E0914 Cat 163 Grader	cDIRT	U.C. per hr 200.00	1 200	00E0914	0 $0	55.39 $11,078	0 $0	0 $0	0 $0	55.39 $11,078
CN-EQHV EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)	cDIRT	U.C. per hr 200.00	2 400	CN-EQHV $38.13	76.26 $15,252	0 $0	0 $0	0 $0	0 $0	76.26 $15,252

Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 1*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.20 Place Riprap - Slope Armor										
Memo:	*Haul material and place in SDA (45,600cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.*									
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		200.00	1,200		$0	$59,052	$0	$0	$0	$59,052
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		200.00	1,200	$36.34	$43,608	$0	$0	$0	$0	$43,608
Subtotal					$66,486	$83,436	$0	$0	$0	$149,922
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$27,880	$34,987	$0	$0	$0	$62,867
Subtotal Estimate										**$212,789**
Escalation					$22,799	$28,611	$0	$0	$0	$51,410
Contingency					$29,291	$36,759	$0	$0	$0	$66,050
---Total 9102.20 Place Riprap - Slope Armor			**1,800**		**$146,455**	**$183,793**	**$0**	**$0**	**$0**	**$330,248**
--- 9102.21 Blasting Basalt - Slope Armor										
Memo:	*Quantity from PERA.*									
	SPEC	U.C. per Cy			0	0	0	150	0	150
Blasting Basalt		15,200.00	0		$0	$0	$0	$2,280,000	$0	$2,280,000
Subtotal					$0	$0	$0	$2,280,000	$0	$2,280,000
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										**$2,280,000**
Escalation					$0	$0	$0	$550,848	$0	$550,848
Contingency					$0	$0	$0	$707,712	$0	$707,712
---Total 9102.21 Blasting Basalt - Slope Armor			**0**		**$0**	**$0**	**$0**	**$3,538,560**	**$0**	**$3,538,560**
--- 9102.22 Place Basalt - Slope Armor										
Memo:	*Haul material and place in SDA (15,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.*									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		67.00	67		$0	$486	$0	$0	$0	$486
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		67.00	67	$38.13	$2,555	$0	$0	$0	$0	$2,555
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		67.00	67		$0	$3,971	$0	$0	$0	$3,971
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		67.00	67		$0	$3,711	$0	$0	$0	$3,711

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.22 Place Basalt - Slope Armor										
Memo:	*Haul material and place in SDA (15,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.*									
CN-EQHV EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <.100' BOOM)	cDIRT	U.C. per hr 67.00	2 134	CN-EQHV $38.13	76.26 $5,109	0 $0	0 $0	0 $0	0 $0	76.26 $5,109
00E1910 30 tn Bottom Dump w/Tractor	cDIRT	U.C. per hr 67.00	6 402	00E1910	0 $0	295.26 $19,782	0 $0	0 $0	0 $0	295.26 $19,782
CN-TRHV TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)	cDIRT	U.C. per hr 67.00	6 402	CN-TRHV $36.34	218.04 $14,609	0 $0	0 $0	0 $0	0 $0	218.04 $14,609
Subtotal					$22,273	$27,951	$0	$0	$0	$50,224
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$9,340	$11,721	$0	$0	$0	$21,060
Subtotal Estimate										$71,284
Escalation					$7,638	$9,585	$0	$0	$0	$17,222
Contingency					$9,813	$12,314	$0	$0	$0	$22,127
—Total 9102.22 Place Basalt - Slope Armor			**603**		**$49,063**	**$61,571**	**$0**	**$0**	**$0**	**$110,633**
— 9102.23 Blasting Riprap - Berm Armor										
Memo:	*Quantity from PERA.*									
Blasting To Provide Riprap	SPEC	U.C. per Cy 15,200.00	0		0 $0	0 $0	0 $0	150 $2,280,000	0 $0	150 $2,280,000
Subtotal					$0	$0	$0	$2,280,000	$0	$2,280,000
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										$2,280,000
Escalation					$0	$0	$0	$550,848	$0	$550,848
Contingency					$0	$0	$0	$707,712	$0	$707,712
—Total 9102.23 Blasting Riprap - Berm Armor			**0**		**$0**	**$0**	**$0**	**$3,538,560**	**$0**	**$3,538,560**
— 9102.24 Place Riprap - Berm Armor										
Memo:	*Haul material and place in SDA (15,600cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.*									
00E2060 3/4 tn 4x4 Pickup	cDIRT	U.C. per hr 69.00	1 69	00E2060	0 $0	7.26 $501	0 $0	0 $0	0 $0	7.26 $501
CN-EQHV EQUIPMENT OPERATOR FOREMAN	cDIRT	U.C. per hr 69.00	1 69	CN-EQHV $38.13	38.13 $2,631	0 $0	0 $0	0 $0	0 $0	38.13 $2,631
00E0942 Cat 966 5 cy Loader	cDIRT	U.C. per hr 69.00	1 69	00E0942	0 $0	59.27 $4,090	0 $0	0 $0	0 $0	59.27 $4,090

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.24 Place Riprap - Berm Armor**										
Memo:	***Haul material and place in SDA (15,600cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
00E0914 Cat 163 Grader	cDIRT	U.C. per hr 69.00	1 69	00E0914	0 $0	55.39 $3,822	0 $0	0 $0	0 $0	55.39 $3,822
CN-EQHV EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)	cDIRT	U.C. per hr 69.00	2 138	CN-EQHV $38.13	76.26 $5,262	0 $0	0 $0	0 $0	0 $0	76.26 $5,262
00E1910 30 tn Bottom Dump w/Tractor	cDIRT	U.C. per hr 69.00	6 414	00E1910	0 $0	295.26 $20,373	0 $0	0 $0	0 $0	295.26 $20,373
CN-TRHV TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)	cDIRT	U.C. per hr 69.00	6 414	CN-TRHV $36.34	218.04 $15,045	0 $0	0 $0	0 $0	0 $0	218.04 $15,045
Subtotal					$22,938	$28,785	$0	$0	$0	$51,723
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$9,618	$12,071	$0	$0	$0	$21,689
Subtotal Estimate										**$73,412**
Escalation					$7,866	$9,871	$0	$0	$0	$17,736
Contingency					$10,105	$12,682	$0	$0	$0	$22,787
--Total 9102.24 Place Riprap - Berm Armor			**621**		**$50,527**	**$63,409**	**$0**	**$0**	**$0**	**$113,936**
— **9102.25 Seed Cap**										
Seed & Fertilize	SPEC	U.C. per Acre 110.00	0		0 $0	0 $0	0 $0	600 $66,000	0 $0	600 $66,000
Subtotal					$0	$0	$0	$66,000	$0	$66,000
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										**$66,000**
Escalation					$0	$0	$0	$15,946	$0	$15,946
Contingency					$0	$0	$0	$20,486	$0	$20,486
—Total 9102.25 Seed Cap			**0**		**$0**	**$0**	**$0**	**$102,432**	**$0**	**$102,432**
--- **ICP ALLOCATION**										
ICP Allocation - 32% of Total	ICP	U.C. per total$ 49,546,000.00	0		0 $0	0 $0	0 $0	0 $0	0.32 $*,***,***	0.32 $15,854,720

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Project Name:
Preliminary SDA Surface Cover - Opt. 1 - ICDF Type
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 1***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL / Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- ICP ALLOCATION									
Subtotal				$0	$0	$0	$0	$15,854,720	$15,854,720
Sales Tax				$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads				$0	$0	$0	$0	$0	$0
Subtotal Estimate									$15,854,720
Escalation				$0	$0	$0	$0	$3,830,500	$3,830,500
Contingency				$0	$0	$0	$0	$4,921,305	$4,921,305
--Total ICP ALLOCATION		0		$0	$0	$0	$0	$24,606,525	$24,606,525
Subtotal 5410 - PRELIMINARY SDA SURFACE COVER - OPTION 1 - ICDF				$10,681,220	$14,783,363	$1,300,125	$11,466,000	$15,854,720	$54,085,428
Sales Tax TYPE				$0	$0	$65,006	$0	$0	$65,006
INEEL ORG Labor/Subcontractor Overheads				$4,478,956	$6,199,108	$572,440	$0	$0	$11,250,504
Subtotal Estimate				$3,662,699	$5,069,365	$468,117	$2,770,186	$3,830,500	$65,400,939
Escalation				$4,705,719	$6,512,959	$601,422	$3,559,046	$4,921,305	$15,800,867
Contingency									$20,300,451
Total 5410 - PRELIMINARY SDA SURFACE COVER - OPTION 1 - ICDF TYPE		281,876		$23,528,594	$32,564,794	$3,007,111	$17,795,232	$24,606,525	$101,502,257

TEC Summary Report

Project Name: *Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C*

Project Location: *RWMC*
Project Number: *5410 - Opt. 2*

ESTIMATE ELEMENT	Estimate Subtotal	Escalation	Contingency	TOTAL
		24.16%	*25.00%*	
Total Estimated Cost (TEC)	$37,432,301	$9,043,644	$11,618,986	$58,094,932

		24.16%	*25.00%*	
Total Estimated Cost (TEC)	**$37,432,301**	**$9,043,644**	**$11,618,986**	**$58,094,932**
Rounded TEC (Rounded to the nearest $ 100000)				**$58,100,000**

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	Remarks
Type of Estimate: Planning	RCRA Modified Type C
Estimator: J. C. Grenz / D. A. Rowley	
Checked By:	
Approved By:	

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 2***

Project Summary Report

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL		Estimate Subtotal	Escalation	Contingency	Contingency %	TOTAL
9000	**CONSTRUCTION**	**$28,357,741**	**$6,851,230**	**$8,802,243**	**25.00%**	**$44,011,215**
9100	**--CONSTRUCTION SUBCONTRACTS**	**$28,357,741**	**$6,851,230**	**$8,802,243**	**25.00%**	**$44,011,215**
9101	**----GENERAL CONDITIONS**	**$372,226**	**$89,930**	**$115,539**	**25.00%**	**$577,695**
9102	**----SITEWORK**	**$27,985,515**	**$6,761,300**	**$8,686,704**	**25.00%**	**$43,433,520**
9102.01	------Agg Pit Screening Plant	$459,104	$110,919	$142,506	25.00%	$712,529
9102.02	------Place Topsoil With Gravel - Storage	$1,488,024	$359,507	$461,883	25.00%	$2,309,413
9102.03	------Place Fine Soil Fill - Storage	$1,488,024	$359,507	$461,883	25.00%	$2,309,413
9102.04	------Place Sand Filter - Biobarrier	$440,427	$106,407	$136,709	25.00%	$683,543
9102.05	------Place Gravel Layer - Biobarrier	$407,491	$98,450	$126,485	25.00%	$632,425
9102.06	------Place Drainage - Drain	$407,491	$98,450	$126,485	25.00%	$632,425
9102.07	------Place Asphalt Layer - Drain	$6,486,452	$1,567,127	$2,013,395	25.00%	$10,066,973
9102.08	------Place Gas Vent Layer - Gas	$407,491	$98,450	$126,485	25.00%	$632,425
9102.09	------Place Engineered Fill - Grade Fill	$9,071,886	$2,191,768	$2,815,913	25.00%	$14,079,567
9102.10	------Place Fine Sand - Slope Armor	$28,726	$6,940	$8,917	25.00%	$44,584
9102.11	------Place Gravel Layer - Slope Armor	$28,726	$6,940	$8,917	25.00%	$44,584
9102.12	------Blasting Basalt - Slope Armor	$900,000	$217,440	$279,360	25.00%	$1,396,800
9102.13	------Place Basalt - Slope Armor	$28,726	$6,940	$8,917	25.00%	$44,584
9102.14	------Blasting Riprap - Slope Armor	$2,700,000	$652,320	$838,080	25.00%	$4,190,400
9102.15	------Place Riprap - Slope Armor	$84,052	$20,307	$26,090	25.00%	$130,448
9102.16	------Place Unprocessed Silt - Perimeter Berm	$1,139,484	$275,299	$353,696	25.00%	$1,768,479
9102.17	------Blasting Riprap - Berm Armor	$2,280,000	$550,848	$707,712	25.00%	$3,538,560
9102.18	------Place Riprap - Berm Armor	$73,412	$17,736	$22,787	25.00%	$113,936

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 2*

Project Summary Report

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL		Estimate Subtotal	Escalation	Contingency	Contingency %	TOTAL
9102.19	-----Seed Cap	$66,000	$15,946	$20,486	25.00%	$102,432
	ICP ALLOCATION	$9,074,560	$2,192,414	$2,816,743	25.00%	$14,083,717
Total	5410 - PRELIMNARY SDA SURFACE COVER - OPTION 2 - RCRA MODIFIED TYPE C	$37,432,301	$9,043,644	$11,618,986	25.00%	$58,094,932

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Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 2***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9101 GENERAL CONDITIONS											
WORKABILITY WALKDOWN - 1/2 HR/DAY X 20 WORKERS X 4 DAY/WK	cDIRT	U.C. per Wks	178.00	40 7,120	CN-EQMD $36.78	1471.2 $261,874	0 $0	0 $0	0 $0	0 $0	1471.2 $261,874
POST JOB REVIEW	cDIRT	U.C. per LOT	1.00	10 10	CN-EQHV $38.13	381.3 $381	0 $0	0 $0	0 $0	0 $0	381.3 $381
Subtotal						$262,255	$0	$0	$0	$0	$262,255
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$109,971	$0	$0	$0	$0	$109,971
Subtotal Estimate											**$372,226**
Escalation						$89,930	$0	$0	$0	$0	$89,930
Contingency						$115,539	$0	$0	$0	$0	$115,539
---Total 9101 GENERAL CONDITIONS				**7,130**		**$577,695**	**$0**	**$0**	**$0**	**$0**	**$577,695**
--- 9102.01 Agg Pit Screening Plant											
Memo: ***This makes all of the gravel filter.***											
00E2060 3/4 tn 4x4 Pickup	cDIRT	U.C. per hr	1,610.00	1 1,610	00E2060	0 $0	7.26 $11,689	0 $0	0 $0	0 $0	7.26 $11,689
CN-EQHV EQUIPMENT OPERATOR FOREMAN	cDIRT	U.C. per hr	1,610.00	1 1,610	CN-EQHV $38.13	38.13 $61,389	0 $0	0 $0	0 $0	0 $0	38.13 $61,389
00E0520 300 TPH Screen Plant	cDIRT	U.C. per hr	1,610.00	1 1,610	00E0520	0 $0	21.34 $34,357	0 $0	0 $0	0 $0	21.34 $34,357
00E0942 Cat 966 5 cy Loader	cDIRT	U.C. per hr	1,610.00	1 1,610	00E0942	0 $0	59.27 $95,425	0 $0	0 $0	0 $0	59.27 $95,425
CN-EQHV EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)	cDIRT	U.C. per hr	1,610.00	1 1,610	CN-EQHV $38.13	38.13 $61,389	0 $0	0 $0	0 $0	0 $0	38.13 $61,389
CN-EQMD EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)	cDIRT	U.C. per hr	1,610.00	1 1,610	CN-EQMD $36.78	36.78 $59,216	0 $0	0 $0	0 $0	0 $0	36.78 $59,216
Subtotal						$181,994	$141,471	$0	$0	$0	$323,465
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$76,316	$59,323	$0	$0	$0	$135,639
Subtotal Estimate											**$459,104**
Escalation						$62,408	$48,512	$0	$0	$0	$110,919
Contingency						$80,179	$62,326	$0	$0	$0	$142,506
---Total 9102.01 Agg Pit Screening Plant				**4,830**		**$400,897**	**$311,632**	**$0**	**$0**	**$0**	**$712,529**

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 2*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.02 Place Topsoil With Gravel - Storage										
Memo: *Haul material from spreading area and place in SDA (291,100cy). 5 trucks hauling 225 cy per hour.*										
00E2060	cDIRT U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		1,294.00	1,294		$0	$9,394	$0	$0	$0	$9,394
CN-EQHV	cDIRT U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		1,294.00	1,294	$38.13	$49,340	$0	$0	$0	$0	$49,340
00E0942	cDIRT U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		1,294.00	1,294		$0	$76,695	$0	$0	$0	$76,695
00E0914	cDIRT U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		1,294.00	1,294		$0	$71,675	$0	$0	$0	$71,675
00E0612	cDIRT U.C. per hr		1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		1,294.00	1,294		$0	$139,765	$0	$0	$0	$139,765
CN-EQHV	cDIRT U.C. per hr		3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		1,294.00	3,882	$38.13	$148,021	$0	$0	$0	$0	$148,021
00E1910	cDIRT U.C. per hr		5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor		1,294.00	6,470		$0	$318,389	$0	$0	$0	$318,389
CN-TRHV	cDIRT U.C. per hr		5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		1,294.00	6,470	$36.34	$235,120	$0	$0	$0	$0	$235,120
Subtotal					$432,481	$615,918	$0	$0	$0	$1,048,399
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$181,352	$258,273	$0	$0	$0	$439,625
Subtotal Estimate										$1,488,024
Escalation					$148,302	$211,205	$0	$0	$0	$359,507
Contingency					$190,534	$271,349	$0	$0	$0	$461,883
---Total 9102.02 Place Topsoil With Gravel - Storage			**11,646**		**$952,669**	**$1,356,745**	**$0**	**$0**	**$0**	**$2,309,413**
--- 9102.03 Place Fine Soil Fill - Storage										
Memo: *Haul material from spreading area and place in SDA (291,100cy). 5 trucks hauling 225 cy per hour.*										
00E2060	cDIRT U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		1,294.00	1,294		$0	$9,394	$0	$0	$0	$9,394
CN-EQHV	cDIRT U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		1,294.00	1,294	$38.13	$49,340	$0	$0	$0	$0	$49,340
00E0942	cDIRT U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		1,294.00	1,294		$0	$76,695	$0	$0	$0	$76,695
00E0914	cDIRT U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		1,294.00	1,294		$0	$71,675	$0	$0	$0	$71,675

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 2***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.03 Place Fine Soil Fill - Storage**										
Memo:	***Haul material from spreading area and place in SDA (291,100cy). 5 trucks hauling 225 cy per hour.***									
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		1,294.00	1,294		$0	$139,765	$0	$0	$0	$139,765
CN-EQHV	cDIRT	U.C. per hr	3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		1,294.00	3,882	$38.13	$148,021	$0	$0	$0	$0	$148,021
00E1910	cDIRT	U.C. per hr	5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor		1,294.00	6,470		$0	$318,389	$0	$0	$0	$318,389
CN-TRHV	cDIRT	U.C. per hr	5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		1,294.00	6,470	$36.34	$235,120	$0	$0	$0	$0	$235,120
Subtotal					$432,481	$615,918	$0	$0	$0	$1,048,399
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$181,352	$258,273	$0	$0	$0	$439,625
Subtotal Estimate										**$1,488,024**
Escalation					$148,302	$211,205	$0	$0	$0	$359,507
Contingency					$190,534	$271,349	$0	$0	$0	$461,883
--Total 9102.03 Place Fine Soil Fill - Storage			**11,646**		**$952,669**	**$1,356,745**	**$0**	**$0**	**$0**	**$2,309,413**
--- **9102.04 Place Sand Filter - Biobarrier**										
Memo:	***Haul material from spreading area and place in SDA (87,350cy). 6 trucks hauling 228 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		383.00	383		$0	$2,781	$0	$0	$0	$2,781
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		383.00	383	$38.13	$14,604	$0	$0	$0	$0	$14,604
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		383.00	383		$0	$22,700	$0	$0	$0	$22,700
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		383.00	383		$0	$21,214	$0	$0	$0	$21,214
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		383.00	383		$0	$41,368	$0	$0	$0	$41,368
CN-EQHV	cDIRT	U.C. per hr	3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		383.00	1,149	$38.13	$43,811	$0	$0	$0	$0	$43,811
00E1910	cDIRT	U.C. per hr	5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor		383.00	1,915		$0	$94,237	$0	$0	$0	$94,237

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Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 2*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.04 Place Sand Filter - Biobarrier**										
Memo:	***Haul material from spreading area and place in SDA (87,350cy). 6 trucks hauling 228 cy per hour.***									
CN-TRHV	cDIRT	U.C. per hr	5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		383.00	1,915	$36.34	$69,591	$0	$0	$0	$0	$69,591
Subtotal					$128,006	$182,300	$0	$0	$0	$310,307
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$53,677	$76,444	$0	$0	$0	$130,121
Subtotal Estimate										**$440,427**
Escalation					$43,895	$62,513	$0	$0	$0	$106,407
Contingency					$56,394	$80,314	$0	$0	$0	$136,709
---Total 9102.04 Place Sand Filter - Biobarrier			**3,447**		**$281,972**	**$401,571**	**$0**	**$0**	**$0**	**$683,543**
--- **9102.05 Place Gravel Layer - Biobarrier**										
Memo:	***Haul material from BORAX pit and place in SDA (87,350 cy). 6 trucks hauling 228 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		383.00	383		$0	$2,781	$0	$0	$0	$2,781
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		383.00	383	$38.13	$14,604	$0	$0	$0	$0	$14,604
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		383.00	383		$0	$22,700	$0	$0	$0	$22,700
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		383.00	383		$0	$21,214	$0	$0	$0	$21,214
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		383.00	766	$38.13	$29,208	$0	$0	$0	$0	$29,208
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		383.00	2,298		$0	$113,085	$0	$0	$0	$113,085
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		383.00	2,298	$36.34	$83,509	$0	$0	$0	$0	$83,509
Subtotal					$127,321	$159,780	$0	$0	$0	$287,101
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$53,389	$67,001	$0	$0	$0	$120,390
Subtotal Estimate										**$407,491**
Escalation					$43,660	$54,790	$0	$0	$0	- $98,450
Contingency					$56,092	$70,393	$0	$0	$0	$126,485
--Total 9102.05 Place Gravel Layer - Biobarrier			**3,447**		**$280,462**	**$351,963**	**$0**	**$0**	**$0**	**$632,425**

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 2***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.06 Place Drainage - Drain											
Memo:	***Haul material from BORAX pit and place in SDA (87,350cy). 6 trucks hauling 228 cy per hour.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			383.00	383		$0	$2,781	$0	$0	$0	$2,781
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			383.00	383	$38.13	$14,604	$0	$0	$0	$0	$14,604
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			383.00	383		$0	$22,700	$0	$0	$0	$22,700
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			383.00	383		$0	$21,214	$0	$0	$0	$21,214
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			383.00	766	$38.13	$29,208	$0	$0	$0	$0	$29,208
00E1910	cDIRT	U.C. per hr		6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor			383.00	2,298		$0	$113,085	$0	$0	$0	$113,085
CN-TRHV	cDIRT	U.C. per hr		6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			383.00	2,298	$36.34	$83,509	$0	$0	$0	$0	$83,509
Subtotal						$127,321	$159,780	$0	$0	$0	$287,101
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$53,389	$67,001	$0	$0	$0	$120,390
Subtotal Estimate											**$407,491**
Escalation						$43,660	$54,790	$0	$0	$0	$98,450
Contingency						$56,092	$70,393	$0	$0	$0	$126,485
---Total 9102.06 Place Drainage - Drain				**3,447**		**$280,462**	**$351,963**	**$0**	**$0**	**$0**	**$632,425**
— 9102.07 Place Asphalt Layer - Drain											
	cDIRT	U.C. per tn				0	0	30	0	0	30
Purchase Asphalt			115,300.00	0		$0	$0	$3,459,000	$0	$0	$3,459,000
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			3,000.00	3,000		$0	$21,780	$0	$0	$0	$21,780
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			3,000.00	3,000	$38.13	$114,390	$0	$0	$0	$0	$114,390
00E0530	cDIRT	U.C. per hr		1	00E0530	0	101.6	0	0	0	101.6
BG-240B Asphalt Paver			3,000.00	3,000		$0	$304,800	$0	$0	$0	$304,800
00E0630	cDIRT	U.C. per hr		1	00E0630	0	27.14	0	0	0	27.14
Cat CS-433 Vib Smooth Drum Compactor			3,000.00	3,000		$0	$81,420	$0	$0	$0	$81,420
CN-EQMD	cDIRT	U.C. per hr		2	CN-EQMD	73.56	0	0	0	0	73.56
EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)			3,000.00	6,000	$36.78	$220,680	$0	$0	$0	$0	$220,680

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.07 Place Asphalt Layer - Drain										
CN-LABE	cDIRT	U.C. per hr	2	CN-LABE	65.02	0	0	0	0	65.02
LABORER EXCAVATION, BACKFILL, FOUNDATIONS, TRENCHES		3,000.00	6,000	$32.51	$195,060	$0	$0	$0	$0	$195,060
Subtotal					$530,130	$408,000	$3,459,000	$0	$0	$4,397,130
Sales Tax					$0	$0	$172,950	$0	$0	$172,950
INEEL ORG Labor/Subcontractor Overheads					$222,299	$171,087	$1,522,986	$0	$0	$1,916,372
Subtotal Estimate										**$6,486,452**
Escalation					$181,787	$139,907	$1,245,432	$0	$0	$1,567,127
Contingency					$233,554	$179,748	$1,600,092	$0	$0	$2,013,395
---Total 9102.07 Place Asphalt Layer - Drain			**15,000**		**$1,167,770**	**$898,742**	**$8,000,460**	**$0**	**$0**	**$10,066,973**
--- 9102.08 Place Gas Vent Layer - Gas										
Memo:	***Haul material from BORAX pit and place in SDA (87,350 cy). 6 trucks hauling 228 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		383.00	383		$0	$2,781	$0	$0	$0	$2,781
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		383.00	383	$38.13	$14,604	$0	$0	$0	$0	$14,604
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		383.00	383		$0	$22,700	$0	$0	$0	$22,700
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		383.00	383		$0	$21,214	$0	$0	$0	$21,214
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		383.00	766	$38.13	$29,208	$0	$0	$0	$0	$29,208
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		383.00	2,298		$0	$113,085	$0	$0	$0	$113,085
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		383.00	2,298	$36.34	$83,509	$0	$0	$0	$0	$83,509
Subtotal					$127,321	$159,780	$0	$0	$0	$287,101
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$53,389	$67,001	$0	$0	$0	$120,390
Subtotal Estimate										**$407,491**
Escalation					$43,660	$54,790	$0	$0	$0	$98,450
Contingency					$56,092	$70,393	$0	$0	$0	$126,485
---Total 9102.08 Place Gas Vent Layer - Gas			**3,447**		**$280,462**	**$351,963**	**$0**	**$0**	**$0**	**$632,425**

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 2***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.09 Place Engineered Fill - Grade Fill											
Memo:	***Haul material from spreading area and place in SDA (1,775,000 cy). 5 trucks hauling 225 cy per hour. Quantity from PERA.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			7,889.00	7,889		$0	$57,274	$0	$0	$0	$57,274
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			7,889.00	7,889	$38.13	$300,808	$0	$0	$0	$0	$300,808
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			7,889.00	7,889		$0	$467,581	$0	$0	$0	$467,581
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			7,889.00	7,889		$0	$436,972	$0	$0	$0	$436,972
00E0612	cDIRT	U.C. per hr		1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot			7,889.00	7,889		$0	$852,091	$0	$0	$0	$852,091
CN-EQHV	cDIRT	U.C. per hr		3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			7,889.00	23,667	$38.13	$902,423	$0	$0	$0	$0	$902,423
00E1910	cDIRT	U.C. per hr		5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor			7,889.00	39,445		$0	$1,941,088	$0	$0	$0	$1,941,088
CN-TRHV	cDIRT	U.C. per hr		5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			7,889.00	39,445	$36.34	$1,433,431	$0	$0	$0	$0	$1,433,431
Subtotal						$2,636,662	$3,755,006	$0	$0	$0	$6,391,668
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$1,105,631	$1,574,587	$0	$0	$0	$2,680,218
Subtotal Estimate											**$9,071,886**
Escalation						$904,138	$1,287,630	$0	$0	$0	$2,191,768
Contingency						$1,161,608	$1,654,306	$0	$0	$0	$2,815,913
---Total 9102.09 Place Engineered Fill - Grade Fill				**71,001**		**$5,808,039**	**$8,271,528**	**$0**	**$0**	**$0**	**$14,079,567**
--- 9102.10 Place Fine Sand - Slope Armor											
Memo:	***Haul material and place in SDA (6,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			27.00	27		$0	$196	$0	$0	$0	$196
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			27.00	27	$38.13	$1,030	$0	$0	$0	$0	$1,030
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			27.00	27		$0	$1,600	$0	$0	$0	$1,600
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			27.00	27		$0	$1,496	$0	$0	$0	$1,496

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 2***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.10 Place Fine Sand - Slope Armor										
Memo:	***Haul material and place in SDA (6,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <.100' BOOM)		27.00	54	$38.13	$2,059	$0	$0	$0	$0	$2,059
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		27.00	162		$0	$7,972	$0	$0	$0	$7,972
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		27.00	162	$36.34	$5,887	$0	$0	$0	$0	$5,887
Subtotal					$8,976	$11,264	$0	$0	$0	$20,239
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$3,764	$4,723	$0	$0	$0	$8,487
Subtotal Estimate										**$28,726**
Escalation					$3,078	$3,862	$0	$0	$0	$6,940
Contingency					$3,954	$4,962	$0	$0	$0	$8,917
--Total 9102.10 Place Fine Sand - Slope Armor			**243**		**$19,771**	**$24,812**	**$0**	**$0**	**$0**	**$44,584**
— 9102.11 Place Gravel Layer - Slope Armor										
Memo:	***Haul material and place in SDA (6,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		27.00	27		$0	$196	$0	$0	$0	$196
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		27.00	27	$38.13	$1,030	$0	$0	$0	$0	$1,030
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		27.00	27		$0	$1,600	$0	$0	$0	$1,600
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		27.00	27		$0	$1,496	$0	$0	$0	$1,496
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <.100' BOOM)		27.00	54	$38.13	$2,059	$0	$0	$0	$0	$2,059
00E1910	cDIRT	U.C. per hr	6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor		27.00	162		$0	$7,972	$0	$0	$0	$7,972

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 2*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.11 Place Gravel Layer - Slope Armor											
Memo:	***Haul material and place in SDA (6,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
CN-TRHV	cDIRT	U.C. per hr		6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			27.00	162	$36.34	$5,887	$0	$0	$0	$0	$5,887
Subtotal						$8,976	$11,264	$0	$0	$0	$20,239
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$3,764	$4,723	$0	$0	$0	$8,487
Subtotal Estimate											$28,726
Escalation						$3,078	$3,862	$0	$0	$0	$6,940
Contingency						$3,954	$4,962	$0	$0	$0	$8,917
---Total 9102.11 Place Gravel Layer - Slope Armor				**243**		**$19,771**	**$24,812**	**$0**	**$0**	**$0**	**$44,584**
--- 9102.12 Blasting Basalt - Slope Armor											
Memo:	***Quantity from PERA.***										
	SPEC	U.C. per Cy				0	0	0	150	0	150
Blasting Basalt			6,000.00	0		$0	$0	$0	$900,000	$0	$900,000
Subtotal						$0	$0	$0	$900,000	$0	$900,000
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$0	$0	$0	$0	$0	$0
Subtotal Estimate											$900,000
Escalation						$0	$0	$0	$217,440	$0	$217,440
Contingency						$0	$0	$0	$279,360	$0	$279,360
---Total 9102.12 Blasting Basalt - Slope Armor				**0**		**$0**	**$0**	**$0**	**$1,396,800**	**$0**	**$1,396,800**
--- 9102.13 Place Basalt - Slope Armor											
Memo:	***Haul material and place in SDA (6,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			27.00	27		$0	$196	$0	$0	$0	$196
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			27.00	27	$38.13	$1,030	$0	$0	$0	$0	$1,030
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			27.00	27		$0	$1,600	$0	$0	$0	$1,600
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			27.00	27		$0	$1,496	$0	$0	$0	$1,496
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			27.00	54	$38.13	$2,059	$0	$0	$0	$0	$2,059

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 2*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.13 Place Basalt - Slope Armor**										
Memo: ***Haul material and place in SDA (6,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
00E1910 cDIRT 30 tn Bottom Dump w/Tractor	U.C. per hr	27.00	6 162	00E1910	0 $0	295.26 $7,972	0 $0	0 $0	0 $0	295.26 $7,972
CN-TRHV cDIRT TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)	U.C. per hr	27.00	6 162	CN-TRHV $36.34	218.04 $5,887	0 $0	0 $0	0 $0	0 $0	218.04 $5,887
Subtotal					$8,976	$11,264	$0	$0	$0	$20,239
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$3,764	$4,723	$0	$0	$0	$8,487
Subtotal Estimate										**$28,726**
Escalation					$3,078	$3,862	$0	$0	$0	$6,940
Contingency					$3,954	$4,962	$0	$0	$0	$8,917
--Total 9102.13 Place Basalt - Slope Armor			**243**		**$19,771**	**$24,812**	**$0**	**$0**	**$0**	**$44,584**
--- **9102.14 Blasting Riprap - Slope Armor**										
Memo: ***Quantity from PERA.***										
SPEC Blasting To Provide Riprap	U.C. per Cy	18,000.00	0		0 $0	0 $0	0 $0	150 $2,700,000	0 $0	150 $2,700,000
Subtotal					$0	$0	$0	$2,700,000	$0	$2,700,000
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										**$2,700,000**
Escalation					$0	$0	$0	$652,320	$0	$652,320
Contingency					$0	$0	$0	$838,080	$0	$838,080
---Total 9102.14 Blasting Riprap - Slope Armor			**0**		**$0**	**$0**	**$0**	**$4,190,400**	**$0**	**$4,190,400**
--- **9102.15 Place Riprap - Slope Armor**										
Memo: ***Haul material and place in SDA (18,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
00E2060 cDIRT 3/4 tn 4x4 Pickup	U.C. per hr	79.00	1 79	00E2060	0 $0	7.26 $574	0 $0	0 $0	0 $0	7.26 $574
CN-EQHV cDIRT EQUIPMENT OPERATOR FOREMAN	U.C. per hr	79.00	1 79	CN-EQHV $38.13	38.13 $3,012	0 $0	0 $0	0 $0	0 $0	38.13 $3,012
00E0942 cDIRT Cat 966 5 cy Loader	U.C. per hr	79.00	1 79	00E0942	0 $0	59.27 $4,682	0 $0	0 $0	0 $0	59.27 $4,682
00E0914 cDIRT Cat 163 Grader	U.C. per hr	79.00	1 79	00E0914	0 $0	55.39 $4,376	0 $0	0 $0	0 $0	55.39 $4,376

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.15 Place Riprap - Slope Armor**											
Memo:	*Haul material and place in SDA (18,000cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.*										
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			79.00	158	$38.13	$6,025	$0	$0	$0	$0	$6,025
00E1910	cDIRT	U.C. per hr		6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor			79.00	474		$0	$23,326	$0	$0	$0	$23,326
CN-TRHV	cDIRT	U.C. per hr		6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			79.00	474	$36.34	$17,225	$0	$0	$0	$0	$17,225
Subtotal						$26,262	$32,957	$0	$0	$0	$59,219
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$11,012	$13,820	$0	$0	$0	$24,832
Subtotal Estimate											**$84,052**
Escalation						$9,005	$11,301	$0	$0	$0	$20,307
Contingency						$11,570	$14,520	$0	$0	$0	$26,090
---Total 9102.15 Place Riprap - Slope Armor				**711**		**$57,850**	**$72,598**	**$0**	**$0**	**$0**	**$130,448**
--- **9102.16 Place Unprocessed Silt - Perimeter Berm**											
Memo:	*Haul material and place in SDA (244,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.*										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			1,071.00	1,071		$0	$7,775	$0	$0	$0	$7,775
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			1,071.00	1,071	$38.13	$40,837	$0	$0	$0	$0	$40,837
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			1,071.00	1,071		$0	$63,478	$0	$0	$0	$63,478
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			1,071.00	1,071		$0	$59,323	$0	$0	$0	$59,323
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			1,071.00	2,142	$38.13	$81,674	$0	$0	$0	$0	$81,674
00E1910	cDIRT	U.C. per hr		6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor			1,071.00	6,426		$0	$316,223	$0	$0	$0	$316,223

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LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.16 Place Unprocessed Silt - Perimeter Berm											
Memo:	***Haul material and place in SDA (244,200cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
CN-TRHV	cDIRT	U.C. per hr		6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			1,071.00	6,426	$36.34	$233,521	$0	$0	$0	$0	$233,521
Subtotal						$356,033	$446,800	$0	$0	$0	$802,832
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$149,295	$187,357	$0	$0	$0	$336,652
Subtotal Estimate											**$1,139,484**
Escalation						$122,087	$153,212	$0	$0	$0	$275,299
Contingency						$156,854	$196,842	$0	$0	$0	$353,696
---Total 9102.16 Place Unprocessed Silt - Perimeter Berm				**9,639**		**$784,269**	**$984,211**	**$0**	**$0**	**$0**	**$1,768,479**
--- 9102.17 Blasting Riprap - Berm Armor											
Memo:	***Quantity from PERA.***										
	SPEC	U.C. per Cy				0	0	0	150	0	150
Blasting To Provide Riprap			15,200.00	0		$0	$0	$0	$2,280,000	$0	$2,280,000
Subtotal						$0	$0	$0	$2,280,000	$0	$2,280,000
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$0	$0	$0	$0	$0	$0
Subtotal Estimate											**$2,280,000**
Escalation						$0	$0	$0	$550,848	$0	$550,848
Contingency						$0	$0	$0	$707,712	$0	$707,712
---Total 9102.17 Blasting Riprap - Berm Armor				**0**		**$0**	**$0**	**$0**	**$3,538,560**	**$0**	**$3,538,560**
--- 9102.18 Place Riprap - Berm Armor											
Memo:	***Haul material and place in SDA (15,600cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			69.00	69		$0	$501	$0	$0	$0	$501
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			69.00	69	$38.13	$2,631	$0	$0	$0	$0	$2,631
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			69.00	69		$0	$4,090	$0	$0	$0	$4,090
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			69.00	69		$0	$3,822	$0	$0	$0	$3,822
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			69.00	138	$38.13	$5,262	$0	$0	$0	$0	$5,262

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 2***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.18 Place Riprap - Berm Armor										
Memo:	***Haul material and place in SDA (15,600cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
00E1910 30 tn Bottom Dump w/Tractor	cDIRT	U.C. per hr 69.00	6 414	00E1910	0 $0	295.26 $20,373	0 $0	0 $0	0 $0	295.26 $20,373
CN-TRHV TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)	cDIRT	U.C. per hr 69.00	6 414	CN-TRHV $36.34	218.04 $15,045	0 $0	0 $0	0 $0	0 $0	218.04 $15,045
Subtotal					$22,938	$28,785	$0	$0	$0	$51,723
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$9,618	$12,071	$0	$0	$0	$21,689
Subtotal Estimate										**$73,412**
Escalation					$7,866	$9,871	$0	$0	$0	$17,736
Contingency					$10,105	$12,682	$0	$0	$0	$22,787
---Total 9102.18 Place Riprap - Berm Armor			**621**		**$50,527**	**$63,409**	**$0**	**$0**	**$0**	**$113,936**
— 9102.19 Seed Cap										
Seed & Fertilize	SPEC	U.C. per Acre 110.00	0		0 $0	0 $0	0 $0	600 $66,000	0 $0	600 $66,000
Subtotal					$0	$0	$0	$66,000	$0	$66,000
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										**$66,000**
Escalation					$0	$0	$0	$15,946	$0	$15,946
Contingency					$0	$0	$0	$20,486	$0	$20,486
---Total 9102.19 Seed Cap			**0**		**$0**	**$0**	**$0**	**$102,432**	**$0**	**$102,432**
— ICP ALLOCATION										
ICP Allocation - 32% of Total	ICP	U.C. per total$ 28,358,000.00	0		0 $0	0 $0	0 $0	0 $0	0.32 $9,074,560	0.32 $9,074,560
Subtotal					$0	$0	$0	$0	$9,074,560	$9,074,560
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										**$9,074,560**
Escalation					$0	$0	$0	$0	$2,192,414	$2,192,414
Contingency					$0	$0	$0	$0	$2,816,743	$2,816,743
---Total ICP ALLOCATION			**0**		**$0**	**$0**	**$0**	**$0**	**$14,083,717**	**$14,083,717**

Project Name:
Preliminary SDA Surface Cover - Opt. 2 - RCRA Modified Type C
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 2*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
Subtotal	5410 - PRELIMNARY SDA SURFACE COVER - OPTION 2 - RCRA MODIFIED TYPE C				$5,418,130	$6,740,287	$3,459,000	$5,946,000	$9,074,560	$30,637,977
Sales Tax					$0	$0	$172,950	$0	$0	$172,950
INEEL ORG Labor/Subcontractor Overheads					$2,271,984	$2,826,405	$1,522,986	$0	$0	$6,621,375
Subtotal Estimate										$37,432,301
Escalation					$1,857,932	$2,311,313	$1,245,432	$1,436,554	$2,192,414	$9,043,644
Contingency					$2,387,011	$2,969,501	$1,600,092	$1,845,638	$2,816,743	$11,618,986
Total 5410 - PRELIMNARY SDA SURFACE COVER - OPTION 2 - RCRA MODIFIED TYPE C			146,741		$11,935,057	$14,847,506	$8,000,460	$9,228,192	$14,083,717	$58,094,932

TEC Summary Report

Project Name: *Preliminary SDA Surface Cover - Opt. 3 - ET Cover*

Project Location: *RWMC*
Project Number: *5410 - Opt. 3*

ESTIMATE ELEMENT	Estimate Subtotal	Escalation	Contingency	TOTAL
		24.16%	*25.00%*	
Total Estimated Cost (TEC)	$30,072,615	$7,265,544	$9,334,540	$46,672,698

		24.16%	*25.00%*	
Total Estimated Cost (TEC)	**$30,072,615**	**$7,265,544**	**$9,334,540**	**$46,672,698**
Rounded TEC (Rounded to the nearest $ 100000)				**$46,700,000**

	Remarks
Type of Estimate: Planning	ET Cover
Estimator: J. C. Grenz / D. A. Rowley	
Checked By:	
Approved By:	

INEEL

Project Name:
Preliminary SDA Surface Cover - Opt. 3 - ET Cover
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 3***

Project Summary Report

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL		Estimate Subtotal	Escalation	Contingency	Contingency %	TOTAL
9000	CONSTRUCTION	$22,782,375	$5,504,222	$7,071,649	25.00%	$35,358,245
9100	--CONSTRUCTION SUBCONTRACTS	$22,782,375	$5,504,222	$7,071,649	25.00%	$35,358,245
9101	----GENERAL CONDITIONS	$322,111	$77,822	$99,983	25.00%	$499,917
9102	----SITEWORK	$22,460,263	$5,426,400	$6,971,666	25.00%	$34,858,328
9102.01	------Agg Pit Screening Plant	$1,248,990	$301,756	$387,687	25.00%	$1,938,433
9102.02	------Drill & Shoot Quarry	$2,000,910	$483,420	$621,082	25.00%	$3,105,412
9102.03	------Quarry Screening Plant	$894,596	$216,134	$277,683	25.00%	$1,388,413
9102.04	------Spreading Area Pit	$434,861	$105,062	$134,981	25.00%	$674,904
9102.05	------Place Topsoil / Gravel - Storage	$892,354	$215,593	$276,987	25.00%	$1,384,934
9102.06	------Place Fine Soil Fill - Storage	$3,570,567	$862,649	$1,108,304	25.00%	$5,541,520
9102.07	------Place Gravel Layer - Biobarrier	$1,629,962	$393,799	$505,940	25.00%	$2,529,701
9102.08	------Place Biointrusion / Vent	$2,650,137	$640,273	$822,602	25.00%	$4,113,012
9102.09	------Place Engineered Fill - Grade Fill	$9,071,886	$2,191,768	$2,815,913	25.00%	$14,079,567
9102.10	------Seed Cap	$66,000	$15,946	$20,486	25.00%	$102,432
	ICP ALLOCATION	$7,290,240	$1,761,322	$2,262,890	25.00%	$11,314,452
Total	5410 - PRELIMINARY SDA SURFACE COVER - OPTION 3 - ET COVER	$30,072,615	$7,265,544	$9,334,540	25.00%	$46,672,698

INEEL

Project Name: *Preliminary SDA Surface Cover - Opt. 3 - ET Cover*	**DETAIL ITEM REPORT**	Client: *E. D. Mattson*
Project Location: *RWMC*		Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Number: *5410 - Opt. 3*		Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
-- **9101 GENERAL CONDITIONS**										
	cDIRT	U.C. per Wks	40	CN-EQMD	1471.2	0	0	0	0	1471.2
WORKABILITY WALKDOWN - 1/2 HR/DAY X 20 WORKERS X 4 DAY/WK		154.00	6,160	$36.78	$226,565	$0	$0	$0	$0	$226,565
	cDIRT	U.C. per LOT	10	CN-EQHV	381.3	0	0	0	0	381.3
POST JOB REVIEW		1.00	10	$38.13	$381	$0	$0	$0	$0	$381
Subtotal					$226,946	$0	$0	$0	$0	$226,946
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$95,165	$0	$0	$0	$0	$95,165
Subtotal Estimate										**$322,111**
Escalation					$77,822	$0	$0	$0	$0	$77,822
Contingency					$99,983	$0	$0	$0	$0	$99,983
---Total 9101 GENERAL CONDITIONS			**6,170**		**$499,917**	**$0**	**$0**	**$0**	**$0**	**$499,917**
--- **9102.01 Agg Pit Screening Plant**										
Memo:	***To make 1-1/2 - 3/4 material. This makes all of the gravel filter.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		4,380.00	4,380		$0	$31,799	$0	$0	$0	$31,799
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		4,380.00	4,380	$38.13	$167,009	$0	$0	$0	$0	$167,009
00E0520	cDIRT	U.C. per hr	1	00E0520	0	21.34	0	0	0	21.34
300 TPH Screen Plant		4,380.00	4,380		$0	$93,469	$0	$0	$0	$93,469
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		4,380.00	4,380		$0	$259,603	$0	$0	$0	$259,603
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		4,380.00	4,380	$38.13	$167,009	$0	$0	$0	$0	$167,009
CN-EQMD	cDIRT	U.C. per hr	1	CN-EQMD	36.78	0	0	0	0	36.78
EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)		4,380.00	4,380	$36.78	$161,096	$0	$0	$0	$0	$161,096
Subtotal					$495,115	$384,871	$0	$0	$0	$879,986
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$207,617	$161,388	$0	$0	$0	$369,004
Subtotal Estimate										**$1,248,990**
Escalation					$169,780	$131,976	$0	$0	$0	$301,756
Contingency					$218,128	$169,559	$0	$0	$0	$387,687
---Total 9102.01 Agg Pit Screening Plant			**13,140**		**$1,090,640**	**$847,793**	**$0**	**$0**	**$0**	**$1,938,433**

Project Name:
Preliminary SDA Surface Cover - Opt. 3 - ET Cover
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 3***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.02 Drill & Shoot Quarry**										
Memo: *To make 12" - 6". This makes all of the biointrusion.*										
	cDIRT	U.C. per lb			0	0	0.25	0	0	0.25
Purchase Amonia Nitrate		493,600.00	0		$0	$0	$123,400	$0	$0	$123,400
	cDIRT	U.C. per gal			0	0	1.5	0	0	1.5
Purchase Fuel		3,500.00	0		$0	$0	$5,250	$0	$0	$5,250
	cDIRT	U.C. per ea			0	0	5	0	0	5
Purchase Primers		1,850.00	0		$0	$0	$9,250	$0	$0	$9,250
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		3,710.00	3,710		$0	$26,935	$0	$0	$0	$26,935
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		3,710.00	3,710	$38.13	$141,462	$0	$0	$0	$0	$141,462
00E0830	cDIRT	U.C. per hr	1	00E0830	0	127.7	0	0	0	127.7
Robins RRT35 Drill		3,710.00	3,710		$0	$473,767	$0	$0	$0	$473,767
CN-LABE	cDIRT	U.C. per hr	2	CN-LABE	65.02	0	0	0	0	65.02
LABORER EXCAVATION, BACKFILL, FOUNDATIONS, TRENCHES		3,710.00	7,420	$32.51	$241,224	$0	$0	$0	$0	$241,224
00E2050	cDIRT	U.C. per hr	1	00E2050	0	34	0	0	0	34
ANFO Truck		3,710.00	3,710		$0	$126,140	$0	$0	$0	$126,140
CN-TRHV	cDIRT	U.C. per hr	1	CN-TRHV	36.34	0	0	0	0	36.34
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		3,710.00	3,710	$36.34	$134,821	$0	$0	$0	$0	$134,821
CN-LABE	cDIRT	U.C. per hr	1	CN-LABE	32.51	0	0	0	0	32.51
LABORER EXCAVATION, BACKFILL, FOUNDATIONS, TRENCHES		3,710.00	3,710	$32.51	$120,612	$0	$0	$0	$0	$120,612
Subtotal					$638,120	$626,842	$137,900	$0	$0	$1,402,862
Sales Tax					$0	$0	$6,895	$0	$0	$6,895
INEEL ORG Labor/Subcontractor Overheads					$267,583	$262,853	$60,717	$0	$0	$591,153
Subtotal Estimate										**$2,000,910**
Escalation					$218,818	$214,950	$49,652	$0	$0	$483,420
Contingency					$281,130	$276,161	$63,791	$0	$0	$621,082
---Total 9102.02 Drill & Shoot Quarry			**18,550**		**$1,405,651**	**$1,380,807**	**$318,954**	**$0**	**$0**	**$3,105,412**
--- **9102.03 Quarry Screening Plant**										
Memo: *This makes all of the biointrusion.*										
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		2,470.00	2,470		$0	$17,932	$0	$0	$0	$17,932
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		2,470.00	2,470	$38.13	$94,181	$0	$0	$0	$0	$94,181
00E0520	cDIRT	U.C. per hr	1	00E0520	0	21.34	0	0	0	21.34
300 TPH Screen Plant (run at 250 for large rock)		2,470.00	2,470		$0	$52,710	$0	$0	$0	$52,710

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.03 Quarry Screening Plant											
Memo:	*This makes all of the biointrusion.*										
00E0942	cDIRT	U.C. per hr		1	00E0944	0	113.54	0	0	0	113.54
Cat 988 8cy Loader			2,470.00	2,470		$0	$280,444	$0	$0	$0	$280,444
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			2,470.00	2,470	$38.13	$94,181	$0	$0	$0	$0	$94,181
CN-EQMD	cDIRT	U.C. per hr		1	CN-EQMD	36.78	0	0	0	0	36.78
EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)			2,470.00	2,470	$36.78	$90,847	$0	$0	$0	$0	$90,847
Subtotal						$279,209	$351,086	$0	$0	$0	$630,295
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$117,081	$147,221	$0	$0	$0	$264,301
Subtotal Estimate											**$894,596**
Escalation						$95,744	$120,391	$0	$0	$0	$216,134
Contingency						$123,008	$154,674	$0	$0	$0	$277,683
---Total 9102.03 Quarry Screening Plant				**7,410**		**$615,041**	**$773,372**	**$0**	**$0**	**$0**	**$1,388,413**
--- 9102.04 Spreading Area Pit											
Memo:	*Doze material into piles so 966 can load the belly dumps. (944,500 cy)*										
00E2060	cDIRT	U.C. per hr		0.5	00E2060	0	3.63	0	0	0	3.63
3/4 tn 4x4 Pickup			1,900.00	950		$0	$6,897	$0	$0	$0	$6,897
CN-EQHV	cDIRT	U.C. per hr		0.5	CN-EQHV	19.065	0	0	0	0	19.065
EQUIPMENT OPERATOR FOREMAN			1,900.00	950	$38.13	$36,224	$0	$0	$0	$0	$36,224
00E0963	cDIRT	U.C. per hr		1	00E0963	0	101.78	0	0	0	101.78
Cat D8 Dozer			1,900.00	1,900		$0	$193,382	$0	$0	$0	$193,382
CN-EQMD	cDIRT	U.C. per hr		1	CN-EQMD	36.78	0	0	0	0	36.78
EQUIPMENT OPERATOR, MEDIUM EQUIPMENT GROUP 6 (>4 CYD)			1,900.00	1,900	$36.78	$69,882	$0	$0	$0	$0	$69,882
Subtotal						$106,106	$200,279	$0	$0	$0	$306,385
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$44,493	$83,983	$0	$0	$0	$128,476
Subtotal Estimate											**$434,861**
Escalation						$36,385	$68,678	$0	$0	$0	$105,062
Contingency						$46,746	$88,235	$0	$0	$0	$134,981
---Total 9102.04 Spreading Area Pit				**2,850**		**$233,729**	**$441,175**	**$0**	**$0**	**$0**	**$674,904**
--- 9102.05 Place Topsoil / Gravel - Storage											
Memo:	*Haul material from spreading area and place in SDA (174,700 cy). See haul from spreading area. 5 trucks hauling 225 cy per hour.*										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			776.00	776		$0	$5,634	$0	$0	$0	$5,634

Project Name:
Preliminary SDA Surface Cover - Opt. 3 - ET Cover
Project Location: *RWMC*
Estimate Number: *5410 - Opt. 3*

DETAIL ITEM REPORT

Client: *E. D. Mattson*
Prepared By: *J. C. Grenz / D. A. Rowley*
Estimate Type: *Planning*

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- **9102.05 Place Topsoil / Gravel - Storage**										
Memo:	***Haul material from spreading area and place in SDA (174,700 cy). See haul from spreading area. 5 trucks hauling 225 cy per hour.***									
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		776.00	776	$38.13	$29,589	$0	$0	$0	$0	$29,589
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		776.00	776		$0	$45,994	$0	$0	$0	$45,994
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		776.00	776		$0	$42,983	$0	$0	$0	$42,983
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		776.00	776		$0	$83,816	$0	$0	$0	$83,816
CN-EQHV	cDIRT	U.C. per hr	3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		776.00	2,328	$38.13	$88,767	$0	$0	$0	$0	$88,767
00E1910	cDIRT	U.C. per hr	5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor		776.00	3,880		$0	$190,935	$0	$0	$0	$190,935
CN-TRHV	cDIRT	U.C. per hr	5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		776.00	3,880	$36.34	$140,999	$0	$0	$0	$0	$140,999
Subtotal					$259,355	$369,360	$0	$0	$0	$628,715
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$108,755	$154,884	$0	$0	$0	$263,639
Subtotal Estimate										**$892,354**
Escalation					$88,935	$126,657	$0	$0	$0	$215,593
Contingency					$114,261	$162,725	$0	$0	$0	$276,987
—Total 9102.05 Place Topsoil / Gravel - Storage			**6,984**		**$571,307**	**$813,627**	**$0**	**$0**	**$0**	**$1,384,934**
--- **9102.06 Place Fine Soil Fill - Storage**										
Memo:	***Haul material from spreading area and place in SDA (698,700 cy). 5 trucks hauling 225 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		3,105.00	3,105		$0	$22,542	$0	$0	$0	$22,542
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		3,105.00	3,105	$38.13	$118,394	$0	$0	$0	$0	$118,394
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		3,105.00	3,105		$0	$184,033	$0	$0	$0	$184,033
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		3,105.00	3,105		$0	$171,986	$0	$0	$0	$171,986
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		3,105.00	3,105		$0	$335,371	$0	$0	$0	$335,371

Project Name:
Preliminary SDA Surface Cover - Opt. 3 - ET Cover
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 3***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor		QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.06 Place Fine Soil Fill - Storage											
Memo:	***Haul material from spreading area and place in SDA (698,700 cy). 5 trucks hauling 225 cy per hour.***										
CN-EQHV	cDIRT	U.C. per hr		3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			3,105.00	9,315	$38.13	$355,181	$0	$0	$0	$0	$355,181
00E1910	cDIRT	U.C. per hr		5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor			3,105.00	15,525		$0	$763,985	$0	$0	$0	$763,985
CN-TRHV	cDIRT	U.C. per hr		5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)			3,105.00	15,525	$36.34	$564,179	$0	$0	$0	$0	$564,179
Subtotal						$1,037,753	$1,477,918	$0	$0	$0	$2,515,671
Sales Tax						$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads						$435,161	$619,735	$0	$0	$0	$1,054,896
Subtotal Estimate											**$3,570,567**
Escalation						$355,856	$506,793	$0	$0	$0	$862,649
Contingency						$457,193	$651,112	$0	$0	$0	$1,108,304
—Total 9102.06 Place Fine Soil Fill - Storage				**27,945**		**$2,285,963**	**$3,255,558**	**$0**	**$0**	**$0**	**$5,541,520**
— 9102.07 Place Gravel Layer - Biobarrier											
Memo:	***Haul material and place in SDA (349,350cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***										
00E2060	cDIRT	U.C. per hr		1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup			1,532.00	1,532		$0	$11,122	$0	$0	$0	$11,122
CN-EQHV	cDIRT	U.C. per hr		1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN			1,532.00	1,532	$38.13	$58,415	$0	$0	$0	$0	$58,415
00E0942	cDIRT	U.C. per hr		1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader			1,532.00	1,532		$0	$90,802	$0	$0	$0	$90,802
00E0914	cDIRT	U.C. per hr		1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader			1,532.00	1,532		$0	$84,857	$0	$0	$0	$84,857
CN-EQHV	cDIRT	U.C. per hr		2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)			1,532.00	3,064	$38.13	$116,830	$0	$0	$0	$0	$116,830
00E1910	cDIRT	U.C. per hr		6	00E1910	0	295.26	0	0	0	295.26
30 tn Bottom Dump w/Tractor			1,532.00	9,192		$0	$452,338	$0	$0	$0	$452,338

Project Name:
Preliminary SDA Surface Cover - Opt. 3 - ET Cover
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 3***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- 9102.07 Place Gravel Layer - Biobarrier										
Memo:	***Haul material and place in SDA (349,350cy). 6 trucks hauling 228 cy per hour. Quantity from PERA.***									
CN-TRHV	cDIRT	U.C. per hr	6	CN-TRHV	218.04	0	0	0	0	218.04
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		1,532.00	9,192	$36.34	$334,037	$0	$0	$0	$0	$334,037
Subtotal					$509,283	$639,120	$0	$0	$0	$1,148,403
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$213,558	$268,002	$0	$0	$0	$481,560
Subtotal Estimate										$1,629,962
Escalation					$174,638	$219,161	$0	$0	$0	$393,799
Contingency					$224,370	$281,571	$0	$0	$0	$505,940
---Total 9102.07 Place Gravel Layer - Biobarrier			**13,788**		**$1,121,848**	**$1,407,853**	**$0**	**$0**	**$0**	**$2,529,701**
--- 9102.08 Place Biointrusion / Vent										
Memo:	***Haul material from quarry and place in SDA (349,350 cy). 7 trucks hauling 168 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		2,080.00	2,080		$0	$15,101	$0	$0	$0	$15,101
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		2,080.00	2,080	$38.13	$79,310	$0	$0	$0	$0	$79,310
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		2,080.00	2,080		$0	$123,282	$0	$0	$0	$123,282
00E1014	cDIRT	U.C. per hr	1	00E1014	0	124.7	0	0	0	124.7
Cat 350 3 cy Hoe		2,080.00	2,080		$0	$259,376	$0	$0	$0	$259,376
CN-EQHV	cDIRT	U.C. per hr	2	CN-EQHV	76.26	0	0	0	0	76.26
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		2,080.00	4,160	$38.13	$158,621	$0	$0	$0	$0	$158,621
00E1930	cDIRT	U.C. per hr	7	00E1930	0	337.68	0	0	0	337.68
24 tn End Dump w/Tractor		2,080.00	14,560		$0	$702,374	$0	$0	$0	$702,374
CN-TRHV	cDIRT	U.C. per hr	7	CN-TRHV	254.38	0	0	0	0	254.38
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		2,080.00	14,560	$36.34	$529,110	$0	$0	$0	$0	$529,110
Subtotal					$767,042	$1,100,133	$0	$0	$0	$1,867,174
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$321,644	$461,319	$0	$0	$0	$782,962
Subtotal Estimate										$2,650,137
Escalation					$263,026	$377,247	$0	$0	$0	$640,273
Contingency					$337,928	$484,675	$0	$0	$0	$822,602
---Total 9102.08 Place Biointrusion / Vent			**20,800**		**$1,689,639**	**$2,423,373**	**$0**	**$0**	**$0**	**$4,113,012**

Project Name:
Preliminary SDA Surface Cover - Opt. 3 - ET Cover
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 3***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL	Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
— 9102.09 Place Engineered Fill - Grade Fill										
Memo:	***Haul material from spreading area and place in SDA (1,775,000 cy). 5 trucks hauling 225 cy per hour.***									
00E2060	cDIRT	U.C. per hr	1	00E2060	0	7.26	0	0	0	7.26
3/4 tn 4x4 Pickup		7,889.00	7,889		$0	$57,274	$0	$0	$0	$57,274
CN-EQHV	cDIRT	U.C. per hr	1	CN-EQHV	38.13	0	0	0	0	38.13
EQUIPMENT OPERATOR FOREMAN		7,889.00	7,889	$38.13	$300,808	$0	$0	$0	$0	$300,808
00E0942	cDIRT	U.C. per hr	1	00E0942	0	59.27	0	0	0	59.27
Cat 966 5 cy Loader		7,889.00	7,889		$0	$467,581	$0	$0	$0	$467,581
00E0914	cDIRT	U.C. per hr	1	00E0914	0	55.39	0	0	0	55.39
Cat 163 Grader		7,889.00	7,889		$0	$436,972	$0	$0	$0	$436,972
00E0612	cDIRT	U.C. per hr	1	00E0612	0	108.01	0	0	0	108.01
Cat 825 Sheepsfoot		7,889.00	7,889		$0	$852,091	$0	$0	$0	$852,091
CN-EQHV	cDIRT	U.C. per hr	3	CN-EQHV	114.39	0	0	0	0	114.39
EQUIPMENT OPERATOR HEAVY EQUIP GROUP 7 (OVER 50T OR <,100' BOOM)		7,889.00	23,667	$38.13	$902,423	$0	$0	$0	$0	$902,423
00E1910	cDIRT	U.C. per hr	5	00E1910	0	246.05	0	0	0	246.05
30 tn Bottom Dump w/Tractor		7,889.00	39,445		$0	$1,941,088	$0	$0	$0	$1,941,088
CN-TRHV	cDIRT	U.C. per hr	5	CN-TRHV	181.7	0	0	0	0	181.7
TRUCK DRIVERS, HEAVY (GROUP 4 & FOREMAN) (LOWBOY<9600GVW)		7,889.00	39,445	$36.34	$1,433,431	$0	$0	$0	$0	$1,433,431
Subtotal					$2,636,662	$3,755,006	$0	$0	$0	$6,391,668
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$1,105,631	$1,574,587	$0	$0	$0	$2,680,218
Subtotal Estimate										**$9,071,886**
Escalation					$904,138	$1,287,630	$0	$0	$0	$2,191,768
Contingency					$1,161,608	$1,654,306	$0	$0	$0	$2,815,913
—Total 9102.09 Place Engineered Fill - Grade Fill			**71,001**		**$5,808,039**	**$8,271,528**	**$0**	**$0**	**$0**	**$14,079,567**
— 9102.10 Seed Cap										
	SPEC	U.C. per Acre			0	0	0	600	0	600
Seed & Fertilize		110.00	0		$0	$0	$0	$66,000	$0	$66,000
Subtotal					$0	$0	$0	$66,000	$0	$66,000
Sales Tax					$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads					$0	$0	$0	$0	$0	$0
Subtotal Estimate										**$66,000**
Escalation					$0	$0	$0	$15,946	$0	$15,946
Contingency					$0	$0	$0	$20,486	$0	$20,486
—Total 9102.10 Seed Cap			**0**		**$0**	**$0**	**$0**	**$102,432**	**$0**	**$102,432**

Project Name:
Preliminary SDA Surface Cover - Opt. 3 - ET Cover
Project Location: ***RWMC***
Estimate Number: ***5410 - Opt. 3***

DETAIL ITEM REPORT

Client: ***E. D. Mattson***
Prepared By: ***J. C. Grenz / D. A. Rowley***
Estimate Type: ***Planning***

LEVEL Org/Subcontractor	QTY	Hrs	Crew/Rate	Labor	Const Eqp	Matl	S/C	Other	TOTAL
--- ICP ALLOCATION									
ICP	U.C. per total$			0	0	0	0	0.32	0.32
ICP Allocation - 32% of Total	22,782,000.00	0		$0	$0	$0	$0	$7,290,240	$7,290,240
Subtotal				$0	$0	$0	$0	$7,290,240	$7,290,240
Sales Tax				$0	$0	$0	$0	$0	$0
INEEL ORG Labor/Subcontractor Overheads				$0	$0	$0	$0	$0	$0
Subtotal Estimate									$7,290,240
Escalation				$0	$0	$0	$0	$1,761,322	$1,761,322
Contingency				$0	$0	$0	$0	$2,262,890	$2,262,890
--Total ICP ALLOCATION		**0**		**$0**	**$0**	**$0**	**$0**	**$11,314,452**	**$11,314,452**
Subtotal 5410 - PRELIMINARY SDA SURFACE COVER - OPTION 3 - ET COVER				**$6,955,589**	**$8,904,614**	**$137,900**	**$66,000**	**$7,290,240**	**$23,354,344**
Sales Tax				**$0**	**$0**	**$6,895**	**$0**	**$0**	**$6,895**
INEEL ORG Labor/Subcontractor Overheads				**$2,916,687**	**$3,733,972**	**$60,717**	**$0**	**$0**	**$6,711,376**
Subtotal Estimate									**$30,072,615**
Escalation				**$2,385,142**	**$3,053,482**	**$49,652**	**$15,946**	**$1,761,322**	**$7,265,544**
Contingency				**$3,064,355**	**$3,923,017**	**$63,791**	**$20,486**	**$2,262,890**	**$9,334,540**
Total 5410 - PRELIMINARY SDA SURFACE COVER - OPTION 3 - ET COVER		**188,638**		**$15,321,773**	**$19,615,085**	**$318,954**	**$102,432**	**$11,314,452**	**$46,672,698**