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Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility

United States
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EXECUTIVE SUMMARY

The U.S. Department of Energy's (DOE) Hanford Facility near Richland, Washington has been operated by the Federal Government since 1943 for plutonium production for military use, and nuclear energy research and development. Past activities released waste to the environment that contaminated soil and groundwater with hazardous/dangerous waste, and radioactive contaminants. The remedy selection process for remediation of operable units located along the Columbia River is scheduled to commence in the fall of 1994. Based on significant public input to date, it is anticipated that the remedies selected for these operable units may include removal of waste from proximity to the Columbia River and isolation of the waste in a central location. The purpose of this remedial investigation/feasibility study (RI/FS) is to evaluate alternatives to allow the removal of contaminants from portions of the Hanford Site (including near the Columbia River) in a timely manner such that those remediated portions of the Site to be released for other productive uses.

This RI/FS evaluates alternatives for placement of remediation waste generated during remediation of CERCLA and RCRA past practice sites on the Hanford Site. With the exception of the no-action alternative, all of the alternatives evaluated in this RI/FS include a RCRA Corrective Action Management Unit (CAMU) referred to as the Environmental Restoration Disposal Facility (ERDF). The ERDF would serve as the receiving facility for most of the waste excavated during remediation of CERCLA and RCRA past-practice sites. The primary element of the ERDF is a single trench excavated below existing grade that will be filled with remediation waste and closed with a protective surface barrier. Supporting facilities, such as administrative buildings, railroad spurs, waste off-loading and transport equipment, decontamination facilities, etc, will also be included as part of the ERDF. In accordance with the CAMU regulations (40 CFR 264.552), only remediation waste that originates within the Hanford Site may be placed in the ERDF. The waste is expected to consist of dangerous/hazardous waste, PCB and asbestos waste, low-level radioactive waste, and low-level mixed waste (containing both dangerous and radioactive waste). The CAMU requirements are specifically addressed in a CAMU application document included as part of the regulatory package.

The Hanford Facility Federal Agreement and Consent Order (Tri-Party Agreement) was signed by the U.S. Environment Protection Agency (EPA), the Washington State Department of Ecology (Ecology), and DOE to provide for cleanup of the Hanford Site. In the most recent Tri-Party Negotiations (Ecology et al. 1994) it was agreed that a pilot project to demonstrate National Environmental Policy Act (NEPA)/CERCLA functional equivalency would be conducted for the ERDF project. Therefore, the scope of this document has been expanded to address NEPA values not normally considered in a CERCLA RI/FS. Many of the NEPA values, such as a description of the affected environment (including meteorology, hydrology, geology, ecological, and land-use), applicable laws and guidelines, short-term and long-term impacts on human health and the environment, emissions to water and air, and cost, are included within a typical CERCLA RI/FS. Other NEPA values not normally addressed in a CERCLA RI/FS, such as socioeconomics, cultural resources, and transportation, have been evaluated in this document. A NEPA roadmap document, which describes where NEPA values are addressed, has been prepared as part of this regulatory package.

ERDF Proposed Site. The proposed site will cover 4.1 square kilometers (1.6 square miles) on the 200 areas plateau at an elevation of 195 to 226 m (640 to 740 ft) above mean sea level (AMSL), approximately in the center of the Hanford Site, southeast of the 200 West Area and southwest of the 200 East Area. Placement of the ERDF on the 200 Area plateau would facilitate consolidation of waste management activities away from the Columbia River at a relatively high ground surface elevation (with a corresponding greater depth to groundwater).

No waste units are located within the ERDF site. However, contaminated groundwater related to discharge of chemical processing wastewater in the 200 West Area has migrated beneath the ERDF site. Contaminants present in groundwater at the site are: tritium, iodine 129, technetium 99, gross alpha, gross beta, chloroform, nitrate, chromium and carbon tetrachloride. The highest concentrations of contaminants are generally found at the points nearest the 200 West Area, which is at the west end of the ERDF. Remediation of these plumes will be addressed in the RI/FS process for the 200 Area operable units.

Hydrogeology. The vadose zone beneath the ERDF site is estimated to range from 70 to 90 m (230 to 300 ft) thick and consist of the following lithologic units: Hanford Formation sediments, Plio-Pleistocene, the upper Ringold unit and Ringold Gravel unit "E". The suprabasalt aquifers beneath the proposed ERDF site consists of the fluvial sands and gravels of the Ringold Formation and the lower Plio-Pleistocene Formation. The silts of the Plio-Pleistocene unit, the upper Ringold unit and the Ringold lower mud unit may act as aquitards or confining units within the aquifer. The uppermost aquifer beneath the proposed ERDF site is contained primarily within unit E of the Ringold Formation. The lower mud unit of the Ringold Formation is known to occur beneath this aquifer in the western side of the site but the lateral extent is not known beneath the eastern side of the ERDF. Where the lower mud unit is present, confined aquifer conditions exist in unit A of the Ringold Formation. Units A and E of the Ringold Formation would be combined in a single unconfined aquifer in areas where the lower mud unit is not present. The thickness of the uppermost aquifer beneath the ERDF generally appears to range from 20 to 70 m (65-230 ft). Groundwater flow beneath the site is generally from west to east. Groundwater discharge is ultimately to the Columbia River.

Cultural Resources. The Hanford Cultural Resources Laboratory (HCRL) conducted a cultural resources survey of the ERDF site and surrounding area during the summer of 1993. The survey identified four archaeological sites, one paleontological site and nine isolated artifacts. One isolated artifact (a cobble tool) was also identified during a previous survey. None of the sites were considered eligible for the National Register. However, HCRL stated that two of the archeological sites may represent part of the greater Euro-American ranching community in Southeast Washington State and may be considered regionally or locally significant viewed in this context. The two sites are located outside of the ERDF boundaries.

Ecological Resources. Ecological surveys of the ERDF site found it to be primarily undisturbed shrub-steppe habitat that had not sustained significant fire damage. The recent surveys identified long-billed curlews, sage sparrows, and loggerhead shrikes as nesting in the area. Grasshopper sparrows were present and possibly nesting at the site. Swainson's hawks were observed hunting in the area. Burrowing owls, while not observed during the surveys, have been seen at the site in the past and are presumed to currently inhabit the area.

Mature shrub-steppe provides important habitat for a number of plant and animal species of concern that depend on the shrub component, usually sagebrush, for nesting, food and protection. Bitterbrush shrubs provide browse for a resident herd of wild mule deer. Certain passerine birds rely on sagebrush or bitterbrush for nesting (i.e., sage sparrow, sage thrasher, and loggerhead shrike). Loggerhead shrikes are year round residents that are present at low densities. Sage sparrows are common summer residents of the Hanford Site that are restricted almost entirely to sagebrush stands. Mature shrub-steppe habitat also provides prime foraging habitat for a variety of raptor species. Shrub-steppe habitat available for species of concern on the Hanford Site may become a more critical issue as agricultural, industrial and urban development decrease the amount of this habitat type in eastern Washington.

The remaining undisturbed shrub-steppe habitat at the Hanford Site is considered priority habitat by the State of Washington due to its relative scarcity in the state and its importance as nesting, breeding and foraging habitat for state- and federal listed or candidate sensitive species.

No plants, birds, or mammals on the federal list of Endangered and Threatened Wildlife and Plants (50 CFR 17.11, 17.12) are known to reside or occur at the ERDF site. There are, however, several species of both plants and animals that are of concern or are under consideration for formal listing by the federal government and Washington State.

Waste Characteristics. It is anticipated that the ERDF will receive waste from the 100, 200, and 300 Areas. The total volume of waste is expected to be less than 21.4 million m^3 (28 million yd^3) and is expected to consist of the following: contaminated soil and demolition debris associated with process wastewater disposal units and unplanned releases (approximately 65-75%); burial ground waste (approximately 15-20%); and wastewater pipelines, ancillary equipment, and associated soil contamination (approximately 10-15%). Waste generating activities and *waste units* for each of the areas are briefly discussed below:

The 100 Area includes nine water-cooled, plutonium production reactors that were built along the shore of the Columbia River upstream from the now-abandoned town of Hanford. Waste units in the 100 Area include cooling water retention basins, pipelines, river outfall structures, subsurface process water disposal units (e.g., french drains), solid waste burial grounds, and unplanned releases (i.e., spills). 100 Area waste includes soil, sediments, sludges, burial ground waste, and demolition debris (e.g., pipe and concrete).

Historically, the 200 Area was used for nuclear fuel reprocessing, plutonium recovery, and waste management and disposal. Although highly radioactive liquid wastes were discharged to numerous subsurface disposal units in the 200 Area, the resulting high-activity contaminated soils are not considered likely waste materials for the ERDF. Waste units where remediation may result in disposal of materials in the ERDF include 24 migration sites (consisting of surface soils contaminated due to spills or wind-blown dispersion of radioactive materials) and an extensive network of pipelines and ancillary equipment with associated soil contamination due to leaks.

Activities in the 300 Area have historically been related primarily to the fabrication of nuclear fuel elements. In addition, many technical support, service support, and research and development activities related to fuel fabrication and reactor testing were carried out. Current R&D activities focus on peaceful uses of plutonium, liquid metal technology, fast-flux test facility support, gas-cooled reactor development, life science research, and Tri-Party Agreement support. The primary waste units in the 300 Area include unplanned releases, process sewer piping, process sewer ponds and trenches, and burial grounds.

Fate and Transport. Groundwater modeling was based on the following conceptual model: As recharge from the ground surface percolates through the waste it dissolves contaminants to form leachate. The contaminant concentration in the leachate is controlled by soil-water partitioning unless the leachate concentration is predicted to exceed the constituent solubility, in which case the concentration is solubility limited. Leachate from the facility migrates through the vadose zone to the groundwater table. The rate of migration is controlled by the rate of infiltration, the moisture content, and retardation. Constituent concentrations may be a function of radioactive decay, volatilization, biodegradation, and dilution. When the leachate reaches the saturated zone, it is subsequently diluted in groundwater. Finally, the leachate migrates towards the ERDF boundary in the direction of groundwater flow. Further retardation and decay can occur in the saturated zone.

A spreadsheet model was developed to simulate the conceptual model described above. Maximum concentrations are identified for all the constituents detected in wastes in the 100, 200, and 300 Areas and used as source concentrations in the fate and transport model. Parameters for the fate and transport spreadsheet model were developed to represent the hydrogeological conditions of the ERDF site, the physical and chemical properties of the waste form, and the fate and transport properties of each contaminant constituent. Constituent-specific parameters include soil/water partitioning coefficient (K_d), decay or degradation rate, and solubility. The parameter estimation relied first on ERDF-specific information and then on Hanford Site background information when available. Non-Hanford Site information was utilized as a last resort.

Groundwater background screening was conducted to identify the constituents which could occur in concentrations that are elevated over naturally-occurring chemical concentrations. Constituents were evaluated by comparing the predicted groundwater concentrations with the Hanford Site background groundwater concentrations. Those constituents with predicted groundwater concentrations less than background are not considered to represent risk to groundwater and are eliminated from further consideration. Calcium, iron, magnesium, strontium, and sulfate were eliminated from the list of groundwater contaminants.

Groundwater modeling results indicated that certain contaminants will be found in groundwater at extremely low concentrations (e.g., less than one part per trillion). To streamline the risk assessment process, it is helpful to define groundwater concentrations that, for all practical purposes, are indistinguishable from zero. For the purpose of this discussion, these concentrations are called de minimis concentrations. If a modeled groundwater concentration is less than a de minimis concentration, then the contaminant is considered absent in groundwater. The de minimis concentration is $5x10^{-7}$ mg/L for non-radioactive contaminants, and $1x10^{-2}$ pCi/L for radioactive contaminants. Most of the organic compounds and many of the radionuclides are eliminated in the de minimis screening. Due to their lack of degradation or decay, all of the toxic or carcinogenic metals and anions detected above background are retained.

Constituents of Potential Concern. A risk-based screening process and comparison to ARARs is used to identify contaminants of potential concern. The risk-based screening process involves the calculation of risk-based screening concentrations, which consider both non-carcinogenic and carcinogenic effects. Risk-based screening concentrations are soil or groundwater concentrations that correspond to a hazard quotient (HQ) of 0.1, or lifetime incremental cancer risk (ICR) of $1x10^{-7}$ using residential scenario exposure parameter values. These screening values are an order of magnitude less than CERCLA risk-based criteria.

If the maximum concentration detected for a contaminant exceeds a risk-based screening concentration and/or an ARAR for that contaminant, it is retained for evaluation in the risk assessment. Otherwise, the contaminant is eliminated from the risk assessment process. Because the screening criteria for ICR and HQ are an order of magnitude less than CERCLA risk-based criteria, the screening process provides a high degree of confidence that these eliminated contaminants pose only an insignificant risk to human health or the environment. Contaminants of potential concern are identified separately for soil and groundwater.

Base Conditions Risk Assessment. A base conditions risk assessment was conducted to determine the human and ecological impacts associated with placement of Hanford remediation waste in the ERDF with a minimal soil cover, no liner, and no treatment. This scenario was intended to represent the risk associated with a non-engineered ERDF design and does not account for any of the protective features of the design alternatives discussed below. Furthermore, it was assumed that all the waste in the ERDF was characterized by the maximum concentration detected in 100, 200, and 300 Area waste units. For these reasons, the predicted risks provided below for base-conditions are conservatively biased and are not actual risks that any receptor population would experience.

Risks are expressed in terms of incremental cancer risk (ICR) and hazard quotient (HQ). The ICR represents the additional cancer risk to a human receptor due to exposure to a carcinogenic (cancer-causing) contaminant. ICR is generally expressed in terms of the probability of cancer genesis, and is generally expressed in scientific notation. For example, a incremental cancer risk of $1x10^{-6}$ means that on average, 1 in a million receptors will contract cancer. CERCLA has established that incremental cancer risks between $1x10^{-6}$ and $1x10^{-4}$ are acceptable and that risk below 10^{-6} are inconsequential. Because the asumption used are only valid for risks less than $1x10^{-2}$, any predicted risks greater than this level are reported as "greater than $1x10^{-2}$." HQ is a measure of non-carcinogenic risk and is expressed as the ratio of contaminant intake to a reference dose. The reference dose is the dose at which adverse health impacts are believed to occur. Therefore, HQs below 1 should not result in any adverse health impacts.

Human health effects associated with soil exposure for the base conditions scenario were predicted to include an total incremental cancer risk (ICR) of greater than $1x10^{-2}$ (1 in a 100) and hazard quotients (HQs) greater than 1 for 11 contaminants. The contaminants with ICRs greater than $1x10^{-4}$ (1 in 10,000) were cesium-137, europium-152, and uranium. The 11 contaminants that exceeded a HQ of 1 were all metals and included aluminum, antimony, arsenic, barium, chromium, copper, mercury, nickel, silver, thallium, and vanadium.

As described above, groundwater fate and transport modeling was conducted to predict concentrations in groundwater downgradient of the ERDF under base conditions. The most mobile contaminants reached groundwater in approximately 500 years. Contaminants that did not reach groundwater within 10,000 years were not included in the risk estimates. Most of the contaminants were predicted to result in extremely low groundwater concentrations (i.e., less than one part per trillion) that present insignificant health risk. The total ICR associated with the groundwater pathways was $>1x10^{-2}$ (1 in a 100) and HQs greater than 1 were predicted for six contaminants. The contaminants with ICRs greater than $1x10^{-4}$ were arsenic, carbon-14, and uranium. The six contaminants that exceeded an HQ of 1 were antimony, arsenic, chromium, fluoride, nitrite, and selenium.

Ecological risk is expressed in terms of an environmental HQ (analogous to the human health HQ) for non-radionuclides and radiological dose for radionuclides. The ecological risk assessment predicted environmental HQs greater than 1 for seven contaminants: benzo(a)pyrene, aluminum, barium, copper, manganese, mercury, and zinc. The total radiological dose after 100 years was predicted to equal 0.8 rad/day (primarily due to cesium-137 and uranium). A dose of 1 rad/day is generally considered acceptable for ecological receptors.

Remedial Action Objectives. Remedial action objectives (RAO) were developed to focus the development, screening, and analysis of remedial alternatives to ensure that they are protective of human health and the environment. RAOs are based on a variety of factors, of which the primary driver are applicable or relevant and appropriate requirements (ARARs). A discussion of pertinent chemical, location, and action specific ARARs is provided in the main body of the text. The following remedial action objectives have been identified for the ERDF:

1) **Support the removal of contaminants from portions of the Hanford Site (including near the Columbia River) in a timely manner:** This is the overall objective of this action and to based on public opinion that contaminants should be removed from near the Columbia River as soon as possible. This opinion is based on concern regarding potential impacts of these contaminants on the Columbia River and the desire to release the remediated areas for other productive uses.

2) **Prevent unacceptable direct exposure to waste:** Direct exposure to the types of waste received at the ERDF, via external exposure, dermal contact, or ingestion, could result in unacceptable health risks to humans and biota. Preventing unacceptable exposure to wastes at the ERDF is important during operation of the facility (i.e., during waste transport and filling operations), and following closure. Once the ERDF is closed, direct exposure to waste is only possible if institutional controls fail and the surface barrier is breached.

3) **Prevent unacceptable contaminant releases to air:** Inhalation exposure to the types of waste received at the ERDF could result in unacceptable health risks. Similar to the direct exposure pathway, inhalation of waste could occur during operation of the ERDF. Once the ERDF is closed, air releases are only possible if institutional controls fail and the surface barrier is breached.

4) **Prevent contaminant releases to groundwater above ARARs and health-based criteria:** Migration of contaminants through the unsaturated zone to groundwater could result in unacceptable human exposure to contaminants hundreds to thousands of years in the future. Protecting groundwater beneath the ERDF also results in protecting the Columbia River.

5) **Minimize ecological impacts:** Construction of the ERDF will result in harmful impacts on the ecology of the ERDF site and the quarry sites providing materials for ERDF construction. Because significant value is attached to the ecology at these sites, ecological impacts will be minimized and/or mitigated to the maximum extent possible.

Screening of Remedial Technologies. The primary technologies evaluated in this report relate to the configuration and design of the waste containment unit, including geometry of the trench excavation, liners, and surface barriers. Technologies related to institutional controls, surface water management, dust control, and treatment of waste waters are also addressed. The remediation technologies are screened using the criteria specified in 40 CFR 300.430(e)(7) of the National Contingency Plan (NCP), including effectiveness, implementability, and cost.

Development of Alternatives. The retained technologies were assembled into 9 design alternatives (in addition to the no-action alternative). The nine alternatives represent combinations of three trench liner options with three surface barrier options. The purpose of the liner is to collect leachate generated due to precipitation percolating through the waste before the surface barrier is placed over the waste. The synthetic portions of the liners are not intended to last for more than several decades. The purpose of the surface barrier is to minimize the potential for intrusion into the waste and reduce or eliminate infiltration through the waste after closure.

The three trench liner options include no trench liner, a single composite liner, or a RCRA minimum technology requirements (MTR) double composite liner. The single composite liner consists of the following three primary units:

- Operations layer - clean fill 0.9 m (3 ft) thick, to protect the liner against damage from construction and waste placement equipment, and also against freezing in the exposed portions of the liner.
- Drainage layer - a drainage gravel layer overlain by a geotextile separator to prevent silting of the gravel by the operations layer. The gravel layer directs infiltration percolating through the waste to a collection sump where it is pumped out of the trench. A geocomposite (a geonet sandwiched between layers of geotextile) is used instead of gravel on the side slopes of the trench.
- Low-permeability liner - a synthetic high-density polyethylene (HDPE) geomembrane over 0.3 m (1 ft) of compacted clay with a permeability no greater than 1×10^{-9} m/s (2.8×10^{-4} ft/day). Use of two liners provides redundant low permeability; the synthetic membrane protects the clay against desiccation, and the clay provides a thick liner capable of some self-healing with settling and other geological stresses. A geotextile cushion overlies the HDPE geomembrane to minimize damage during placement of the drainage layer.

The double composite liner is similar to the single liner except that it includes a secondary HDPE liner and leachate collection system directly beneath the primary HDPE liner. In addition, the thickness of the clay is increased from 0.3 m (0.9 ft) to 1 m (3 ft).

The surface barrier options include a low-infiltration soil barrier, a Hanford barrier, or a modified Hanford Barrier. All three barriers are at least 4.6 m (15 ft) thick to preclude the excavation intrusion scenario and include passive controls (such as surface and subsurface markers) to deter intrusion. In addition, all the barriers include vegetated fine-grained soil layers at the surface to maximize moisture retention and evapotranspiration and thereby reduce the rate of infiltration. The Hanford and modified Hanford barriers also include a low-permeability asphalt layer to divert moisture that passes the evapotranspiration layers beyond the horizontal limits of the waste.

The alternatives are listed below:

- Alternative 1 - No action
- Alternative 2 - No liner and a low-infiltration soil barrier
- Alternative 3 - No liner and a modified Hanford barrier
- Alternative 4 - No liner and a Hanford Barrier
- Alternative 5 - Single composite liner and a low-infiltration soil barrier
- Alternative 6 - Single composite liner and a modified Hanford barrier
- Alternative 7 - Single composite liner and a Hanford Barrier
- Alternative 8 - RCRA double composite liner and a low-infiltration soil barrier
- Alternative 9 - RCRA double composite liner and a modified Hanford barrier
- Alternative 10 - RCRA double composite liner and a Hanford Barrier

Evaluation of the no-action alternative is required under CERCLA (40 CFR 300.430(e)(6)). The no-action alternative for this FS consists of not constructing a centralized CAMU on the Hanford Site to accommodate remediation waste from Hanford Site past-practice operable units. Implementation of the no-action alternative would result in the necessity for each operable unit to develop alternatives that include in-situ treatment and/or containment, or disposal facilities at the operable unit.

The remaining alternatives all include institutional controls, dust control, surface water management, wastewater treatment, transportation systems (such as a new rail spur), buildings, a grout batch plant, equipment for internal and external communications, emergency response equipment, and personnel protection. In addition, all of the alternatives (other than no-action) utilize the deep area-fill trench configuration, a single trench design approximately 20 m (70 ft) deep and 300 m (1,000 ft) across. This trench configuration minimizes the footprint (areal dimensions) of the facility. The reduced footprint of the deep area-fill design offers the following advantages in comparison to other configurations:

- Less habitat disruption,
- Less leachate generation,
- Reduced material needs (thus, reduced ecological and cultural impact on borrow areas),
- Lower costs for the liner and barrier.

Using the deep area-fill configuration, the disturbed area of the ERDF, including the trench, roads, and supporting facilities, is estimated to be 2.6 km^2 (650 acres or 1.0 mi^2).

Acceptable soil and leachate concentrations. Acceptable soil and leachate concentrations were developed for the contaminants identified in potential waste from the 100, 200, and 300 Areas. These concentrations will be included as part of the waste acceptance criteria for ERDF waste to ensure that human and ecological exposures will be less than acceptable standards for the foreseeable future.

The acceptable soil concentrations were based on exposure to soils due to the 500-year drilling scenario. This scenario was determined to be a reasonable exposure scenario given the protective measures included in the ERDF design such as active institutional controls, passive controls, and a minimum 15-foot thick surface barrier. Based on a comparison with maximum contaminant concentrations in 100, 200, and 300 Areas waste units, it appears that most of the waste will meet the acceptable soil concentrations. Waste with soil concentrations that exceed the acceptable levels will require mixing with cleaner soils to reduce concentrations to acceptable levels. For the contaminants that may exceed acceptable levels (metals and radionuclides) no treatment technology exists for reducing concentrations.

Acceptable leachate concentrations were developed to provide protection of groundwater. It is likely that much of the waste received at the ERDF will achieve the leachate criteria without treatment. If this is not the case, however, then the waste will likely require treatment before disposal in the ERDF. For purposes of the detailed evaluation in this report, it was assumed that the wastes would comply with the leachate criteria.

Detailed Evaluation. The NCP provides nine criteria for detailed evaluation of alternatives. Because the no-action alternative does not satisfy the overall objective of this action to "support the removal of contaminants from portions of the Hanford Site (including near the Columbia River) in a timely manner to allow those remediated portions of the Site to be released for other productive uses" it is not evaluated further. Results of the detailed evaluation of alternatives for the remaining alternatives are summarized below:

1) **Overall protection of human health and the environment:** This criteria draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. As discussed below under these criteria, all the alternatives (except the no-action alternative) fulfill the objectives specified regarding long-term protection of human health and the environment while insuring protection of worker and public health during operations.

2) **Compliance with ARARs:** The determinations provided in Chapter 7 for action- and location-specific ARARs are valid for all the alternatives except the no-action alternative. In general, all the alternative except the no-action alternative attain ARARs identified in Chapter 7. The only exception is the TSCA requirement that wastes with more than 50 ppm polychlorinated biphenols (PCBs) be disposed in a lined facility. In order to accept wastes with PCB concentrations greater than 50 mg/kg, Alternatives 2, 3, and 4 (no liner) would require a waiver under CERCLA. The remaining alternatives include liners and no waiver would be required. The TSCA waiver request could be applied for based on the equivalent standard of performance criteria provided under CERCLA. Demonstration of equivalent standard of performance is justified by the analyses in Appendix A of the RI/FS for an unlined trench, indicating that PCBs would not impact groundwater beneath the ERDF.

   The ERDF is being proposed as a Corrective Action Management Unit (CAMU). The CAMU rule provides an option for onsite management of remediation waste previously not available to facilities remediating materials subject to RCRA. The CAMU regulations were promulgated to promote active remediation of contaminated sites, as opposed to merely capping in place, by allowing more flexibility in management of remediation waste, without compromising human health or the environment. In the preamble to the CAMU Rule, EPA stated its expectation that the substantive CAMU

Rule requirements will be applicable or relevant and appropriate requirements (ARARs) for the remediation of many CERCLA sites, especially those sites where CERCLA remediation involves the management of RCRA hazardous wastes. An evaluation of the seven decision criteria required under the CAMU regulations determined that the ERDF will meet all CAMU decision criteria and designation of the ERDF as a CAMU is appropriate.

3) **Long-term effectiveness and permanence:** Long-term effectiveness was measured in terms of future risk to human health and the environment and qualitative assessments of reliability. Future risks are associated with soil exposure resulting from intrusion into the facility or exposure to groundwater impacted by migration of contaminants out of the facility. The risks provided below differ from those presented above for base conditions in that the benefits of protective measures such as passive controls and a barrier that reduces infiltration are accounted for in the analysis. However, it was still assumed that all the waste in the ERDF was characterized by the maximum concentration detected in 100, 200, and 300 Area waste units and thus the results are conservatively biased.

All of the alternatives (except the no-action alternative) include active institutional controls (e.g., fences, signs, patrols), passive controls (e.g., markers and off-site records), and a surface barrier that is at least 4.6 m (15 feet) thick. It is assumed that institutional controls prevent intrusion into the waste for at least 100 years and that passive controls prevent intrusion for 500 years. Furthermore, it is assumed that because the waste is covered with at least 4.6 m (15 ft) of cover materials, intrusion into the waste due to excavation is precluded. Since none of the evaluated barriers can prevent penetration by a drilling rig, however, it is reasonable to assume that someone might inadvertently drill through the waste sometime after 500 years. Therefore, soil exposures for both human and ecological health are calculated assuming the 500 yr drilling scenario.

Groundwater impacts were calculated assuming that an engineered barrier is constructed over the facility to minimize infiltration through the waste and maximize the travel time to groundwater. In addition, it was assumed that the waste met the maximum leachate concentration criteria (either with or without treatment) before it was placed in the facility. For alternatives with liners, it was further assumed that all leachate was retained by the HDPE liner and removed by the leachate collection system for the first 30 years of operation. In addition, the added travel time associated with migration though the clay layer was accounted for in the analysis.

The human health risks associated with soil exposure resulting from the 500-yr drilling scenario include a total ICR of 4×10^{-5} (dominated by uranium) and a maximum HQ of 0.03 (associated with copper). These risks are the same for all the alternatives (except no action). The predicted HQ and ICR associated with the 500-yr drilling scenario are below the goals established in the Tri-Party Agreement of 1 for HQ and 1×10^{-4} for ICR.

For all the alternatives except the no-action alternative, none of the contaminants are predicted to reach groundwater within 10,000 years under current climate conditions. Risks after 10,000 years are considered highly uncertain given the potential for climatic changes, geologic events, and human activities, and were not evaluated. Groundwater concentrations and associated risks were also predicted assuming that the rainfall rate increased from the current average for Hanford of 18 cm (7 in.) to 40 cm (16 in.) at 100 years. This scenario was intended to represent either a wetter climate or irrigation on top of the ERDF. Although the results of these analyses are intended to demonstrate potential effects associated with climate or land use changes, they should not be considered the most likely scenario. The increased rainfall rate resulted in contaminant travel times from the ERDF to groundwater that were as low as 150 years and the predicted risks ranged from $2x10^{-5}$ to $3x10^{-4}$ for ICR and 0.8 to 7 for HQ. Differences in the results were primarily due to differences in the type of barrier; the shorter travel times and higher risks occurred when the alternative included the low-infiltration soil barrier and the longer travel times and lower risks occurred when the alternative included the Hanford or modified Hanford barriers. Because leachate collection is assumed to last only 30 years and the rainfall rate does not increase for 100 years, only minor differences in risks and travel times can be attributed to the liners.

The maximum ecological health risks associated with soil exposure resulting from the 500-yr drilling scenario include a total radiological dose of 0.6 rad/day (dominated by uranium) and an environmental HQ of 12 for copper. The remaining environmental HQs were less than 0.05. It should be noted that the background concentration of copper in soil (28.2 mg/kg) results in an environmental HQ of 3, which has not resulted in adverse impact to the environment. It is evident that the environmental exposure analysis results in an overestimate of risk to environmental receptors and it is likely that the intrusion scenario will not result in adverse impacts to the environment from any potential contaminants disposed in the ERDF. These risks are the same for all the alternatives (except no action).

Reliability in terms of protection against intrusion and erosion will be important if institutional controls were no longer in place. All of the barriers include gravel in the upper soil layer to reduce erosion of the upper silt layers; however, this gravel admix layer is thicker in the Hanford Barrier. To discourage penetration by deep-rooted plants and burrowing animals, the Hanford Barrier employs a crushed basalt layer that provides a hostile environment for plants (little-to-no moisture, no nutrients, large grain size), and a densely compacted asphalt layer. The modified Hanford Barrier employs the asphalt layer and replaces the basalt with a thin layer of coarse-grained materials that is likely to be less effective in preventing root penetration. The low-infiltration soil barrier does not include an layers designed to prevent intrusion by plant roots and animals and relies on thickness alone. Resistance to human intrusion is considered to be primarily a function of barrier thickness, which is similar for all the barriers. In summary, the Hanford Barrier offers the greatest protection against erosion and intrusion in the absence of institutional controls and the modified Hanford barrier is considered to be more effective than the low-infiltration soil barrier in this regard. The barriers are considered to be equal with respect to resisting human intrusion.

Alternatives with trench liners offer several advantages over no-liner alternatives in terms of reliability. The primary advantage is that any leachate generated during the operational period will be retained by the trench liner and pumped out. A secondary advantage of a leachate collection system is that it allows characterization of the leachate generated in the waste. Knowledge of the leachate properties could be used to predict future impacts on groundwater once the leachate collection is terminated or the trench liner fails. The double composite liner offers a redundancy in leachate collection systems not available in the single composite liner. The potential for flaws in the primary liner is uncertain, although it is probably low given the high level of construction quality assurance planned for the ERDF. Furthermore, the rate of degradation of a double composite liner will probably be similar to the degradation rate for the single composite liner.

4) **Reduction of Toxicity, Mobility, or Volume through Treatment:** This criteria was not relevant to the evaluation since none of the alternatives include treatment. Treatment options will be evaluated in the RI/FSs for the source operable units.

5) **Short-Term Effectiveness:** Short-term effectiveness includes risks to workers and the public during implementation of an alternative, potential environmental impacts of the alternative, and time until protection is achieved.

Operation of the ERDF will involve potential releases of waste during transport to the ERDF and placement in the ERDF. Health risks for ERDF workers, other Hanford Site workers, and the public due to exposure to waste contaminants were significantly less than generally accepted standards under a variety of conditions, including: normal operating conditions, a 24-hour period of high winds, and rupture of a waste container due to a transportation accident. Since the operation of the ERDF will be the same for all the alternative, these risks would be the same for all the alternatives.

Environmental impacts associated with construction and operation of the ERDF will occur at the ERDF, along the new rail spur, and at any quarry sites for barrier materials. These impacts will include destruction of habitat, displacement of wildlife at these areas, and disturbance of wildlife near these areas and along transport routes due to noise and human activities. The impacted area at the ERDF site is estimated to be 2.6 km^2 (650 acres or 1.0 mi^2) although it may be greater depending on the final trench design and waste volume. Ecological impacts at the ERDF will be mitigated to the extent possible by using the deep area-fill trench configuration. Assuming a length of 8 km (outside the ERDF), and an impacted width of 50 m (160 ft), the area impacted by the new rail spur will be approximately 0.4 km^2. Ecological impacts associated with development of the borrow sites will depend on the type of barrier included in the alternative. The Hanford Barrier is the only barrier that requires basalt and it also requires the most silt. The modified Hanford barrier requires 50% and the low-infiltration soil barrier requires 25% of the silt required by the Hanford Barrier. Since none of the liners included in the alternatives will utilize any on-site materials, the environmental impacts are not impacted by the type of liner. DOE is currently developing a Hanford Site-wide plan in cooperation with the State of Washington Department of Fish and Wildlife and the U.S. Fish and Wildlife Service for mitigating these environmental impacts.

The time until remediation is achieved will depend on the rate that waste is delivered to the ERDF and will be the same for all the alternatives (except the no-action alternative).

6) **Implementability:** The factors included under this criteria include technical implementability, availability of materials and services, and administrative implementability.

Technical implementability is determined by the complexity of the trench liner and surface barrier designs. The complexity of the barriers decreases in the following order: the Hanford Barrier, the modified Hanford barrier, and the low-infiltration barrier. The complexity of the liners decreases in the following order: the double liner, the single liner, and no liner.

All the materials and services for construction of the liners are readily available from off-Hanford Site venders and their availability is not expected to pose any implementability problems. Some of the materials included in the barrier designs (silt and crushed basalt) will come from sources on the Hanford Site and concern has been raised regarding development of potential sources. In particular, cultural resources have been identified at McGee Ranch, the proposed source of silt, that will likely require mitigation before the site may be developed. In addition, basalt outcroppings on the Hanford Site have religious significance to native american tribes and development of a basalt source would require consideration of these cultural values.

None of the alternative require off-site transport, treatment, or disposal of waste. Since CERCLA excludes administrative requirements of ARARs for on-site actions, no permits will be necessary and no administrative difficulties are anticipated.

7) **Cost:** Common costs included within each of the alternatives (except the no-action alternative) are summarized below:

Common Costs

Type	Cost (millions)
Support Facilities	$75
Permitting and Design	$22
Trench Excavation	$109
Operational Cost (over 25 years) (Net Present Value)	$500 ($255 present worth)
Total Common Costs (Net Present Value)	$460

The net present values are calculated assuming a 6 percent discount rate. Total costs for the alternatives can be determined by summing the common costs, the liner costs, and the barrier cost for each of the alternatives in terms of net present worth. The net present worth of the barrier is calculated assuming that the barrier is constructed 20 years in the future. Total costs for each alternative are summarized below:

Total Costs for Remedial Alternatives.

Alternative	Total Cost[a] (millions)
1. No Action	Not Available
2. No Liner with Low-Infiltration Soil Barrier	$500
3. No Liner with Modified Hanford Barrier	$600
4. No Liner with Hanford Barrier	$740
5. Single Liner with Low-Infiltration Soil Barrier	$587
6. Single Liner with Modified Hanford Barrier	$690
7. Single Liner with Hanford Barrier	$826
8. Double Liner with Low-Infiltration Soil Barrier	$680
9. Double Liner with Modified Hanford Barrier	$779
10. Double Liner with Hanford Barrier	$920
[a] - Measured in terms of net present value assuming a discount rate of 6 percent.	

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8) **State acceptance:** The Washington Department of Ecology has reviewed the RI/FS and their comments have been resolved and incorporated.

9) **Community acceptance:** Assessment of this criteria may not be completed until comments on the proposed plan are received. Public comments will be considered in remedy selection for the record of decision.

Comparative Analysis. The results of the detailed evaluation are summarized in the following table:

Summary Ranking of the Alternatives Against the Criteria.

Alternative	Long-Term Effectiveness	Short-Term Effectiveness	Implementability	Cost
1	NA	NA	NA	NA
2	9	1	1	1
3	6	4	2(tie)	3
4	3	7	2(tie)	6
5	8	2	2(tie)	2
6	5	5	6(tie)	5
7	2	8	6(tie)	8
8	7	3	2(tie)	4
9	4	6	6(tie)	7
10	1	9	6(tie)	9

Notes:
1 - No Action
2 - No Liner with Low-Infiltration Soil Barrier
3 - No Liner with Modified Hanford Barrier
4 - No Liner with Hanford Barrier
5 - Single Liner with Low-Infiltration Soil Barrier
6 - Single Liner with Modified Hanford Barrier
7 - Single Liner with Hanford Barrier
8 - Double Liner with Low-Infiltration Soil Barrier
9 - Double Liner with Modified Hanford Barrier
10 - Double Liner with Hanford Barrier
NA - Not Available..

These results suggest the following conclusions regarding the primary components of the alternatives:

- Compared with the other barriers, the Hanford Barrier (Alternatives 4, 7, and 10) provide the best long-term protection of human health and the environment but at the expense of greater impacts on the environment and higher costs.

- Alternatives with the modified Hanford barrier provide similar long-term effectiveness as the Hanford Barrier, but with lower cost and less ecological impact.

- The low-infiltration soil barrier provides the same groundwater protection as the other two barriers under current climatic conditions for significantly less cost and ecological impact. However, under hypothetical wetter climatic conditions, this barrier allows greater infiltration (and thus shorter vadose zone travel times) and less protection against biointrusion than the other two barriers.

- Because of the low infiltration rates associated with the surface barriers, alternatives with no liner provide similar groundwater protection as alternatives with a liner. Furthermore, the single liner is virtually equivalent to the double liner in terms of groundwater protection.

- One advantage of lined alternatives is that they provide a means to determine the validity of assumptions regarding leachate generation and leachate quality. If these assumptions prove to be non-conservative, and potential groundwater impacts are deemed unacceptable, then it would be possible to initiate corrective action.

LIST OF ACRONYMS

ABS	dermal absorption factor
ACL	alternate concentration limit
ALARA	as low as reasonably achievable
ALI	annual limit on intake
ALE	Arid Land Ecology Reserve
amsl	above mean sea level
AR	Administrative Record
ARAR	applicable or relevant and appropriate requirement
ARCL	allowable residual contamination levels
ATSDR	Agency for Toxic Substances Disease Registry
ASTM	American Society for Testing and Materials
AWQC	ambient water quality criteria
BEIR	biological effects of ionizing radiation
BPA	Bonneville Power Administration
CAA	Clean Air Act
CAR	corrective action requirement
CED	committed effective dose
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
CRDL	contract required detection limit
CRQL	contract required quantitation limit
CWA	Clean Water Act
CsOPC	contaminants of potential concern
DCG	derived concentration guide
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy-Richland Field Office
Ecology	Washington State Department of Ecology
EHQ	environmental hazard quotient
EPA	U.S. Environmental Protection Agency
ERA	expedited response action
ERDA	Energy Research and Development Administration
ERDF	Environmental Restoration and Disposal Facility
FEMA	Federal Emergency Management Agency
FFTF	Fast Flux Test Facility
FML	flexible membrane liners
FS	feasibility study
GI	gastrointestinal
HCRL	Hanford Cultural Resources Laboratory
HDPE	high density polyethylene
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HLW	high-level waste
HMS	Hanford Meteorological Station
HDPE	high-density polyethylene
HQ	hazard quotient
HSWA	Hazardous and Solid Waste Amendments (of 1984)

LIST OF ACRONYMS (Cont.)

HSBRAM	Hanford Site Risk Assessment Methodology
IAREC	Irrigated Agriculture Research and Extension Center
IARC	International Agency for Research on Cancer
ICR	incremental cancer risk
ICRP	International Council on Radiation Protection
IRIS	Integrated Risk Information System
IRM	interim remedial measure
LDR	land disposal restrictions
LFI	limited field investigation
LICR	lifetime incremental cancer risk
LLW	low-level waste
LOAELS	lowest observed adverse effect levels
MCL	maximum contaminant level
MCLG	maximum contaminant level goals
MMI	Modified Mercalli Intensity
MTCA	Model Toxics Control Act
MTR	minimum technology requirement
NAAQS	national ambient air quality standards
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFFSC	National Severe Storms Forecast Center
NOAEL	no observed adverse effects level
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyl
PMF	probable maximum flood
PNL	Pacific Northwest Laboratory
PQL	practical quantification limits
PSD	Prevention of Significant Deterioration
PUREX	plutonium-uranium extraction (Plant)
PVC	polyvinylchloride
QRA	qualitative risk assessment
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objectives
RCRA	Resource Conservation and Recovery Act of 1976
RCW	Revised Code of Washington (State)
RfD	reference dose
RI/FS	remedial investigation/feasibility study
RO	reverse osmosis
ROD	record of decision
SDWA	Safe Drinking Water Act
SEPA	State Environmental Policy Act
SER	siting evaluation report

LIST OF ACRONYMS (Cont.)

SF	slope factor
SMCL	secondary maximum contaminant level
SPF	standard project flood
SQL	sample quantitation limit
SSE	safe-shutdown earthquake
TBC	to be considered
TRU	transuranic waste
TSCA	Toxic Substances Control Act
TSD	treatment, storage, or disposal
TWRS	Tank Waste Remediation System
UCL	upper confidence limit
UTL	upper tolerance limit
VF	volitilization factor
VOA	volatile organic analysis
VOC	volatile organic compounds
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company
WIDS	Waste Identification Data System
WIPP	Waste Isolation Pilot Plant
WISHA	Washington Industrial Safety and Health Act
WPPSS	Washington Public Power Supply System

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1.0 INTRODUCTION

This remedial investigation/feasibility study (RI/FS) document examines construction and operation of the Environmental Restoration Disposal Facility (ERDF) for the U.S. Department of Energy's (DOE's) Hanford Site in Richland, Washington. The ERDF has been proposed to serve as the receiving facility for waste generated due to remediation of *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) past practice units and *Resource Conservation and Recovery Act* (RCRA) corrective action activities at the Hanford Site. In accordance with the Code of Federal Regulations (40 CFR 264.552) and the Washington Administrative Code (WAC 173-303-646), a separate application for designation of the ERDF as a RCRA Corrective Action Management Unit (CAMU) is being prepared. In accordance with CERCLA RCRA CAMU requirements, only remediation waste that originates within the Hanford Site may be placed in the ERDF. Remediation waste is defined under 40 CFR 260.10 as all solid and hazardous wastes, and all media (including groundwater, surface water, soils, and sediments) and debris, which contain listed or characteristic hazardous wastes, that are managed for the purpose of implementing corrective action requirements. The remediation waste is expected to consist of hazardous/dangerous waste, polychlorinated biphenol (PCB) waste, asbestos waste, radioactive waste, and mixed waste (containing both hazardous/dangerous and radioactive waste).

The ERDF would initially be authorized with a Record of Decision under CERCLA and permitted as a CAMU under RCRA with EPA as the lead agency. Once the State is granted authority for administration of the Hazardous and Solid Waste Amendments of 1984 (HSWA), and the CAMU is included as a modification in the Hanford Facility RCRA permit, the State would be the RCRA Corrective Action lead agency. EPA will retain authority under CERCLA.

1.1 BACKGROUND

The Hanford Site is a 1,450 km^2 (560 mi^2) tract of land located along the Columbia River in southeastern Washington and covers portions of Benton, Grant, Franklin and Adams counties (Figure 1-1). Operated by the federal government since 1943, its primary mission has been plutonium production for military use, and nuclear energy research and development. These activities included releases of wastes to the environment that resulted in contamination of soils and groundwater with hazardous/dangerous and radioactive constituents.

The Hanford Site is divided into numerically designated operational areas, including the 100, 200, 300, 400, 600, and 1100 Areas. In November 1989, the U.S. Environmental Protection Agency (EPA) placed the 100, 200, 300, and 1100 Areas on the National Priorities List (NPL) contained within Appendix B of the *National Oil and Hazardous Substance Pollution Contingency Plan* (NCP, 53 FR 51391 et seq.). The EPA took this action pursuant to their authority under CERCLA (42 USC 9601 et seq.). Restoration of the CERCLA past practice sites at the Hanford Site is expected to result in the generation of wastes requiring further management. RI/FS's will be done for all of the individual operable units. It will be the responsibility of the individual operable units to determine if disposal at the ERDF is the preferred alternative and the need for treatment before disposal.

The Hanford Site is a single RCRA facility with over 60 treatment, storage and disposal (TSD) units conducting dangerous waste management activities. These TSD units are included in the *Hanford Facility Dangerous Waste Part A Permit Application* (DOE-RL, 1988). The

Washington State Department of Ecology (Ecology) has authority for RCRA implementation through the State's Dangerous Waste Regulations in the Washington Administrative Code (WAC 173-303). Closure and corrective actions related to TSD facilities on the Hanford Site are expected to result in the generation of wastes requiring further management. The WAC is not applicable to a CAMU at this time because Washington State does not have authority for administration of HSWA. However, the State is expected to have HSWA authority in the next few years.

Agreements between the DOE Richland Operations Office (DOE-RL), the EPA, and Ecology regarding environmental restoration activities and management of wastes at the Hanford Site are documented in the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1992) also referred to as the Tri-Party Agreement. This order was first issued in 1989 and has been renegotiated on several occasions, including the most recent negotiations in 1993 (Ecology et al. 1994).

Milestone M-70-00 of the Tri-Party Agreement calls for the design, approval, construction, and operation of the ERDF by September 1996. It is the stated purpose of the Tri-Party signatories that regulatory approval for the ERDF will be obtained under a CERCLA Record of Decision (ROD) and HSWA using applicable CAMU regulations. This RI/FS will provide the supporting information for a proposed plan that will become the basis for the CERCLA ROD. Preparation of the CAMU application is proceeding concurrently with preparation of this document. Eventually, the RI/FS, proposed plan, and CAMU application will constitute the regulatory package that provides the basis for regulatory approval as well as the compliance management framework for the ERDF.

1.2 PURPOSE

The purpose of the proposed action is to support the removal of contaminants from portions of the Hanford Site (including near the Columbia River) in a timely manner, to allow those remediated portions of the Site to be released for other productive uses. Several Tri-Party Agreement milestones exist for near-term remediation efforts, including issuance of CERCLA operable unit Records of Decision (ROD) in 1995. The remedies to be selected in the operable unit RODs are expected to require excavation and management of large volumes of remediation-generated waste, which will require disposition.

1.3 SCOPE OF THE RI/FS

The primary objectives of the RI/FS are clearly described in the NCP:

The purpose of the remedial investigation (RI) is to collect data necessary to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives. To characterize the site, the lead agency shall, as appropriate, conduct field investigations, including treatability studies, and conduct a baseline risk assessment. The RI provides information to assess the risks to human health and the environment and to support the development, evaluation, and selection of appropriate response alternatives. (40 CFR 300.400(d)(1)).

The primary objective of the feasibility study (FS) is to ensure that appropriate remedial alternatives are developed and evaluated such that relevant information *concerning the remedial action options can be presented to a decision-maker and an appropriate remedy selected. The lead agency may develop a feasibility study to address a specific site problem or the entire site. The development and evaluation of alternatives shall reflect the scope and complexity of the remedial action under consideration and the site problems being addressed. Development of alternatives shall be fully integrated with the site characterization activities of the remedial investigation described in paragraph (d) of this section. The lead agency shall include an alternatives screening step, when needed, to select a reasonable number of alternatives for detailed analysis.* (40 CFR 300.400(e)(1)).

As stated above, the lead agency may develop an FS to address a specific site problem. Consistent with this objective, the scope of the ERDF RI/FS is focused on the configuration of the waste containment unit (also referred to as the trench), the liner, and the surface barrier. Evaluation of the supporting facilities, including the transportation system, waste handling equipment and procedures, decontamination, and leachate treatment system, are also provided. These supporting facilities are not the focus of this analysis because they do not significantly affect long-term performance of the facility and are considered design details; they will be fully addressed during remedial design.

In addition, treatment of remediation wastes received at the ERDF will not be addressed in this RI/FS. It is not feasible to address treatment in this document because the remediation wastes to be delivered to the ERDF have not yet been sufficiently characterized. Furthermore, performance of different treatment technologies is specific to the characteristics of the waste and generally requires treatability information that is not yet available. Given the variability in waste characteristics for different source operable units and the need for site-specific treatability information, evaluation of treatment technologies will be conducted at the source operable unit level. Acceptable limits on soil and leachate concentrations designed to protect human health and the environment are defined in this document and in a separate document that is currently under preparation. These limits will be used for development of waste acceptance criteria. RI/FS efforts at the source operable units will assess treatment options including whether treatment is required to meet ERDF waste acceptance criteria.

In the most recent Tri-Party Negotiations (Ecology et al. 1994), it was agreed that a pilot project to demonstrate National Environmental Policy Act (NEPA)/CERCLA functional equivalency would be conducted for the ERDF project. Therefore, the scope of this document has been expanded to address NEPA values not normally considered in a CERCLA RI/FS. Many of the NEPA values, such as a description of the affected environment (including meteorology, hydrology, geology, ecological resources, and land-use), applicable laws and guidelines, short-term and long-term impacts on human health and the environment, emissions to water and air, and cost, are included within a typical CERCLA RI/FS. Other NEPA values not normally addressed in a CERCLA RI/FS, such as socioeconomics, cultural resources, and transportation, have been evaluated in this document. Although this document evaluates the implications if the ERDF is not constructed, the broad range of non-ERDF remedial actions for the Hanford Site are not addressed. Remediation of Hanford past-practice waste sites will be addressed in the Hanford Remedial Action Environmental Impact Statement (HRA-EIS), currently under preparation. The HRA-EIS will evaluate the implementation of action alternatives such as in-situ containment/treatment, multiple small waste management facilities on the Hanford Site, and disposal off the Hanford Site.

1.4 SITE SELECTION

Site selection is based on the evaluation in the *Siting Evaluation Report for the Environmental Restoration Disposal Facility* (WHC 1994a). This siting evaluation report (SER) evaluated three candidate sites that were at least 15 square kilometers (6 square miles) of contiguous land within the boundaries of the 200 Area plateau. This land requirement is based on early design assumptions for the ERDF that resulted in greater land use. By optimizing the trench design, the ERDF will occupy only 4.1 square kilometers (1.6 square miles).

Placement of the ERDF on the 200 Area plateau would facilitate consolidation of waste management activities away from the Columbia River at a relatively high ground surface elevation (with a corresponding greater depth to groundwater). The risk-management benefits of consolidating waste in the 200 Area was supported by the Hanford Future Site Uses Working Group. This group, which consisted of representatives from federal, state, and local governments, native american tribes, labor groups, economic development groups, and public interest groups, was chartered with developing a range of visions concerning future uses of the Hanford Site. A general recommendation by the group was that areas of high future use (e.g., near the Columbia River) be cleaned up and that the interior section of the 200 Area plateau be designated for waste management (Drummond 1992). Use of the 200 Area for waste management is also identified in the *Hanford Site Development Plan* (DOE-RL 1993d), which is revised on an annual basis to identify land use, infrastructure, and facility requirements to support DOE programs at the Hanford Site.

The three candidate sites in the SER are shown on Figure 1-2. As discussed in the SER, the primary screening criteria were based on the Washington State Dangerous Waste Regulations *Siting Criteria* (WAC 173-303-282), DOE Order 6430.1A (*General Design Criteria*), DOE Order 5820.2A (*Radioactive Waste Management*), and DOE-RL Order 4320.2C (*Site Selection*). Using these criteria, Site 3 was selected as the preferred location for the ERDF based on its following factors:

- Compatibility with the Hanford Future Site Uses Working Group recommendations to the degree technically feasible
- Greatest depth to groundwater
- Relatively flat topography
- Lowest cost.

The sites were also evaluated in the SER using the CERCLA criteria and the CAMU criteria. Site 3 was the preferred site for all the applicable CERCLA criteria and the following applicable CAMU criteria:

- Siting will facilitate implementation of reliable, effective, protective, and cost-effective remedies
- Placement will not create unacceptable risks to human health or to the environment resulting from exposure to hazardous wastes or constituents
- The site will not include uncontaminated areas of the facility

- The selected land area, to the extent practicable, upon which wastes will remain in place after closure of the CAMU will be minimized.

1.5 REPORT ORGANIZATION

The ERDF operable unit RI/FS report is organized in a format similar to that recommended by EPA (1988a) with the following 11 chapters and appendices following Chapter 1.0, Introduction:

- Chapter 2, Site Characteristics, provides a description of the relevant meteorologic, surface hydrologic, geologic, pedologic, hydrogeologic, human resources, and ecologic characteristics of the study area. Brief descriptions of the site characteristics for proposed borrow sites for basalt and fine-grained soils are also provided.

- Chapter 3, Waste Characteristics, provides a discussion of the physical and chemical characteristics of the wastes likely to be received at the ERDF.

- Chapter 4, Contaminant Fate and Transport, provides analysis of the environmental fate and transport of likely contaminants in the waste received at the ERDF. Transport modeling is applied in this section to estimate future contaminant concentrations in groundwater.

- Chapter 5, Contaminants of Potential Concern, compares predicted contaminant concentrations in ERDF waste and groundwater with regulatory limits and risk-based limits to identify the potential contaminants of concern.

- Chapter 6, Risk Assessment, estimates the human and environmental health threats posed by likely contaminants in the waste received at the ERDF.

- Chapter 7, Development of Remedial Action Objectives, identifies applicable or relevant and appropriate requirements and remedial action objectives for the ERDF.

- Chapter 8, Identification and Screening of Remedial Technologies, identifies and screens technologies and process options that are potentially applicable to the ERDF.

- Chapter 9, Detailed Evaluation and Comparative Analysis of Remedial Alternatives, assembles the retained technologies into remedial alternatives that are then evaluated against CERCLA criteria. Comparative analysis of the alternatives is also performed in this chapter.

- Chapter 10, Conclusions, summarizes results of the RI/FS.

- Chapter 11, References, provides a list of cited documents within the body of the report.

- Appendices are used to present technical analyses needed to support the findings of the RI/FS report.

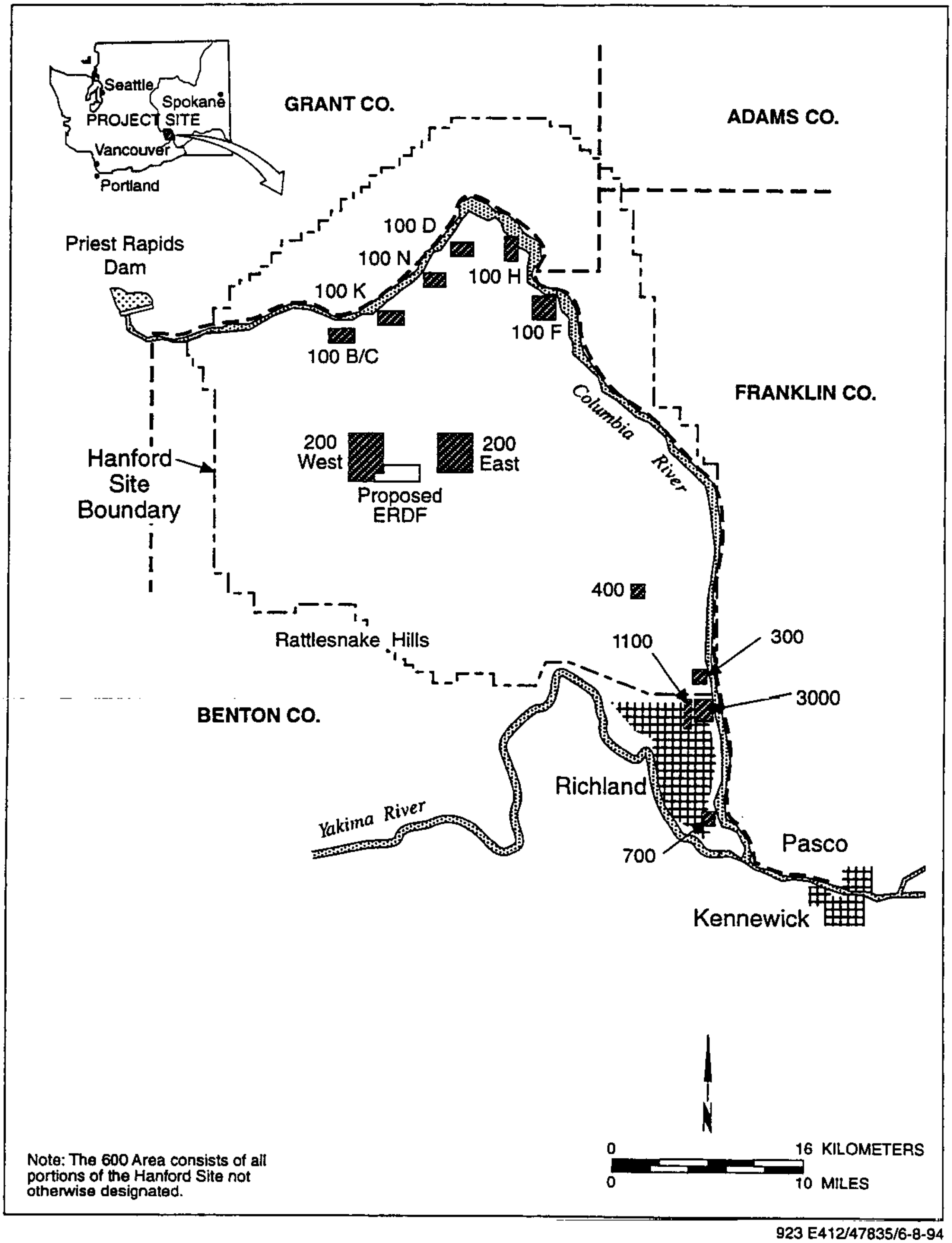

Figure 1-1. Hanford Site Map.

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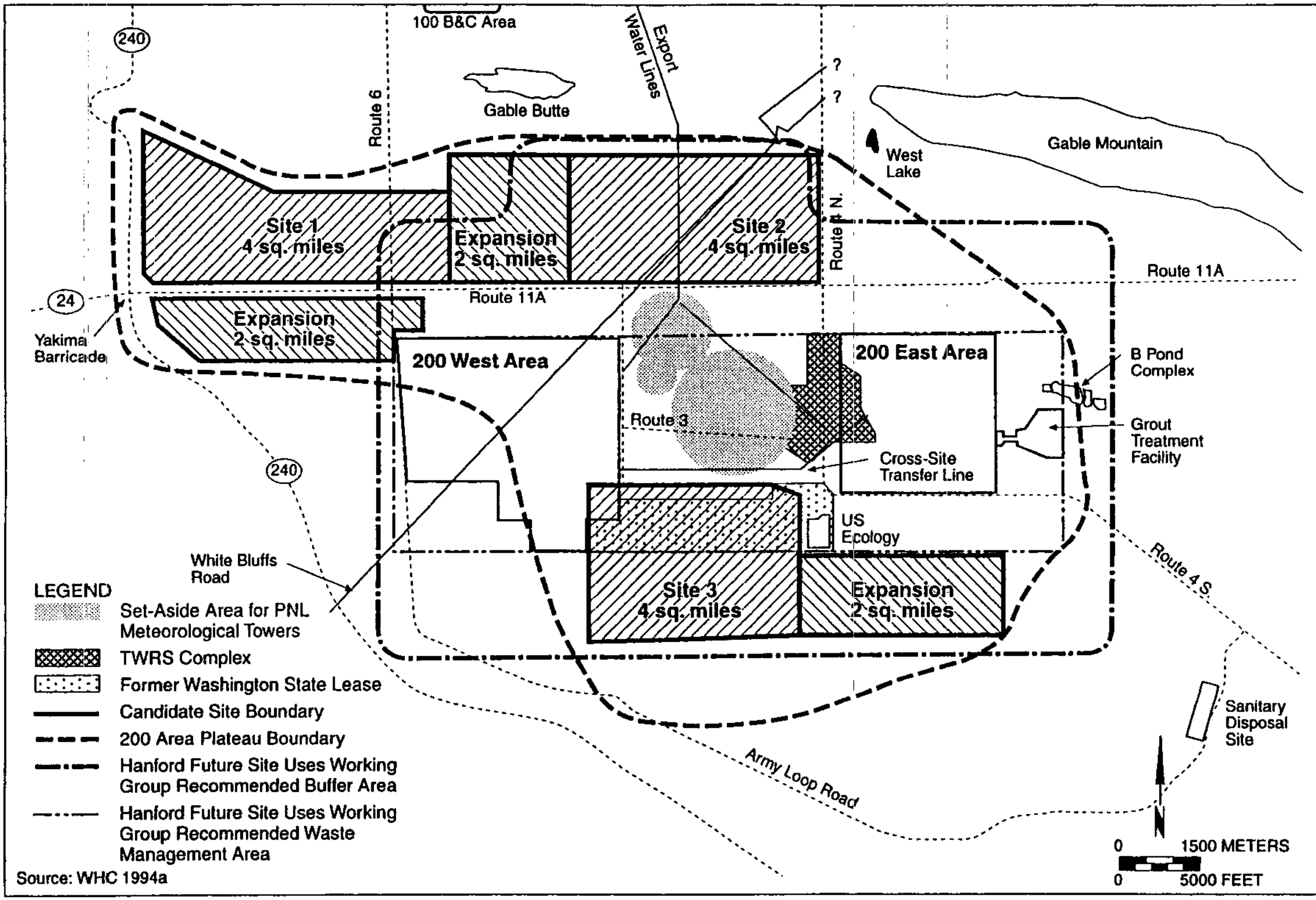

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Figure 1-2. ERDF Candidate Site Locations.

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2.0 SITE CHARACTERISTICS

This chapter describes the relevant characteristics of the Hanford site as a whole, the proposed ERDF site and likely borrow source areas impacted by construction of the ERDF. Descriptions of the location, meteorology, surface water hydrology, geology, soils, hydrogeology, human resources, and ecology are presented. Much of the regional information presented in this chapter has been adapted from Cushing (1992).

2.1 GENERAL SETTING

2.1.1 Regional Setting

The U.S. Department of Energy's Hanford Site lies within the semi-arid Pasco Basin of the Columbia Plateau in southeastern Washington State, and covers portions of Benton, Franklin, Grant and Adams counties (Figure 1-1). The Hanford Site occupies an area of about 1,450 km^2 (~560 mi^2) north of the confluence of the Snake and Yakima rivers with the Columbia River. The Hanford Site is about 50 km (30 mi) north to south and 40 km (24 mi) east to west. Hanford is located 190 km (120 mi) southwest of Spokane and 280 km (174 mi) southeast of Seattle. This land, with restricted public access, provides a buffer for the smaller areas used for storage of nuclear materials and waste management; only about 6% of the land area has been disturbed and is actively used. The Columbia River flows through the northern part of the Hanford Site, and turning south, it forms part of the Site's eastern boundary. The Yakima River runs along part of the southern boundary and joins the Columbia River south of the city of Richland, which bounds the Hanford Site on the southeast. Rattlesnake Mountain, the Yakima Ridge, and the Umtanum Ridge form the southwestern and western boundary. The Saddle Mountains form the northern boundary of the Hanford Site. Two small east-west ridges, Gable Butte and Gable Mountain, rise above the plateau of the central part of the Hanford Site. Adjoining lands to the west, north, and east are principally range and agricultural land. The cities of Richland, Kennewick, and Pasco (Tri-Cities) constitute the nearest population center and are located southeast of the Hanford Site.

The Hanford Site is divided into numerically designated operational areas, including the 100, 200, 300, 400, 600 and 1100 Areas. Land use in these areas is described in Section 2.7.1. The Hanford Site encompasses more than 1,500 waste management units and numerous groundwater contamination plumes that have been grouped into 73 operable units. Each operable unit has similar characteristics regarding geography, waste characteristics, type of facility, and relationship of contaminant plumes. This grouping into operable units allows for economies of scale to reduce the cost and the number of characterization investigations and remedial actions that will be required for the Hanford Site to complete cleanup efforts (WHC 1989). The 73 operable units have been aggregated into four areas: the 100 Area, the 200 Area, the 300 Area, and the 1100 Area.

2.1.2 Local Setting

The proposed ERDF site will cover 4.1 square kilometers (1.6 square miles) on the 200 Area plateau at an elevation of 205 to 230 m (670 to 750 ft) above mean sea level (AMSL), approximately in the center of the Hanford Site, southeast of the 200 West Area and southwest of the 200 East Area. A map of the ERDF site is shown in Figure 2-1. Topography of the ERDF site is also shown in Figure 2-1.

The proposed ERDF site is located within Sections 7, 8, 9, 14, 15, 16, 17, and 18 of Township 12N and Range 26E.

2.1.3 ERDF Site Contamination

No solid waste management units are located within the proposed ERDF area; however, solid waste is found in the western and southwestern portions of the land formerly leased to the state. Radiological contamination has been spread by animals to the area east of the ERDF from the nearby BC cribs and trenches. The BC cribs and trenches were used from 1956 to 1967 as a waste disposal site for the 200 and 300 areas. Currently, they contain quantities of plutonium, strontium, cesium, cobalt and uranium.

Animals spread contamination from the BC trenches and cribs from about 1958 to 1964 (O'Farrell et al. 1973). Trench 216-B-28 was burrowed by an animal and used by other animals as a salt lick. Subsequently, radioactivity was spread away from the trench via wind dispersion. The trench burrow was filled and sealed with asphalt in 1964, which effectively stopped further spreading of radioactive contaminants from the trench. The last aerial radiological survey of the Hanford site still showed elevated gross gamma readings south of the BC cribs as well as around the US Ecology Site (Reiman and Dahlstrom 1990).

Contamination may be present at the portion of the ERDF site east of the REDOX plant in the 200 West Area (Figure 2-1). This area was used as a storage area during the construction of the REDOX plant from 1950 to 1952. The site was used for heavy vehicle parking and maintenance, and as a concrete truck washdown area. Possible soil contaminants include gasoline, oil and other lubricants, and other vehicle-related fluids.

Due to the proximity of the ERDF site to the 200 West Area and its associated ground-surface liquid waste disposal operations, contaminated groundwater has migrated beneath the ERDF site. Contaminants present in the groundwater at the site are: tritium, iodine-129, technetium-99, gross alpha, gross beta, chloroform, nitrate, chromium and carbon tetrachloride. The highest concentrations of contaminants are generally found at the points nearest the 200 West Area, which is at the west end of the ERDF. Figures 2-2 through 2-10 present groundwater contaminant plume maps for the listed constituents.

2.2 METEOROLOGICAL CHARACTERISTICS

The Hanford Site is located in a semiarid region of southeastern Washington State. The Cascade Mountains beyond Yakima to the west greatly influence the climate of the Hanford area by means of their rain shadow effect; this range also serves as a source of cold air drainage, which has a considerable effect on the wind regime at the Hanford Site.

This section presents an interpretation of meteorological data for the Hanford Site and the ERDF site. The data have been collected primarily at the Hanford Meteorological Station (HMS), which is located at an elevation of 223m (733 ft) AMSL between the 200 East and 200 West Areas of the Hanford Site, approximately 4 km (2 mi) to the north of the ERDF site.

Data have been collected at the HMS since 1945. Temperature and precipitation data are also available from nearby locations for the period 1912 through 1943. A summary of these data through 1980 has been published by Stone et al. (1983) which is the primary source of information presented below. Data from the HMS are representative of the general climatic conditions for the region and describe the specific climate of the 200 Area plateau. Local variations in the topography of the Hanford Site may cause some aspects of climate at portions of the Hanford Site to differ significantly from those of the HMS. For example, winds near the Columbia River are different from those at the HMS. Similarly, precipitation along the slopes of the Rattlesnake Mountain differs significantly from that at the HMS. However, due to the close proximity and similar elevations of the HMS and the ERDF, the HMS data should accurately describe conditions at the ERDF.

In addition to the HMS, three 60-m (200-ft) towers and twenty-two 9.1-m (30-ft) towers that provide supplementary weather data are located on and around the Hanford site. These towers are equipped with instruments that measure temperature and wind velocity and direction. Figure 2-11 shows the locations of meteorological monitoring stations on and around the Hanford Site.

2.2.1 Precipitation

The Cascade Range is located approximately 130 km (80 mi) west of the Hanford Site and has an average crest elevation of about 1,800 m (6,000 ft) AMSL. This mountain range creates a rain shadow that limits the average total annual precipitation at the HMS to about 16 cm (6.3 in.). Annual precipitation (98 percentile) ranges from 8 to 27.9 cm (3.2 to 11 in.). The three months from November through January generally contribute approximately 42% of this total, while the three months from July through September contribute only 12%. January is the wettest month with an average of 2.3 cm (0.92 in.) while July is the driest month with an average of only 0.38 cm (0.15 in.). Monthly average precipitation amounts from 1912 through 1980 are shown in Figure 2-12. Precipitation intensity is greatest in the summer months. This seasonal intensity peak coincides with the thunderstorm season.

Days with greater than 1.3 cm (0.51 in.) precipitation occur less than 1% of the year. Data on the expected frequency of precipitation intensity and short-period duration (24 h or less) are presented in Figure 2-13. Rainfall intensities of 1.3 cm/h (0.51 in./h) persisting for 1 hour are expected once every 10 years. Rainfall intensities of 2.5 cm/h (0.98 in./h) for 1 hour are expected only once every 500 years.

Winter monthly average snowfall ranges from 0.8 cm (0.31 in.) in March to 13.5 cm (5.3 in.) in January. The unpublished record snowfall of 142 cm (56 in.) occurred during the winter of 1992 and 1993. The previous record snowfall of 62 cm (24 in.) occurred in February 1916. About 38% of annual precipitation occurs as snowfall during the months of December through February. However, in only one winter in four does an accumulation in excess of 15.2 cm (6 in.) occur. The average annual snowfall is 33 cm (13 in.). Complete snowmelt generally occurs within a month of a snow event.

2.2.2 Temperature and Humidity

Diurnal and monthly averages and extremes of temperature, dew point, and humidity are contained in Stone et al. (1983). Average of daily maximum and minimum temperatures vary from 2°C (36°F) in early January to 35°C (95°F) in late July. There are, on the average, 55 days during the summer months with maximum temperatures greater than or equal to 32°C (90°F) and 13 days with maxima greater than or equal to 38°C (100°F). From mid-November through mid-March, minimum temperatures average 0°C (32°F) or less with the minima in early January averaging -6°C (21°F). During the winter, there are, on average, 4 days with minimum temperatures less than or equal to -18°C (0°F); however, only about one winter in two experiences such temperatures. The record maximum temperature is 46°C (115°F), and the record minimum temperature is -32.8°C (-27°F). For the period 1912 through 1980, the average monthly temperatures ranged from a low of -1.5°C (29.3°F) in January to a high of 24.7°C (76.5°F) in July. During the winter, the highest monthly average temperature at the HMS was 6.9°C (44.4°F), and the record lowest was -5.9°C (21.4°F), both having occurred during February. During the summer, the record maximum monthly average temperature was 27.9°C (82.2°F) (in July), and the record lowest was 17.2°C (63°F) (in June).

Relative humidity/dew point temperature measurements are made at the HMS and at the three 60-m (200-ft) tower locations. The annual average relative humidity at the HMS is 54%. It is highest during the winter months, averaging about 75%, and lowest during the summer, averaging about 35%. Wet bulb temperatures greater than 24°C (75°F) had not been observed at the HMS before 1975; however, on July 8, 9, and 10 of that year, there were seven hourly observations with wet bulb temperatures greater than or equal to 24°C (75°F).

Due to low humidity, the diurnal temperature range is substantial. During summer months, when the average relative humidity is 30 to 40%, the diurnal temperature range is greatest, on the order of 15°C (27°F). In winter, with relative humidity ranging from 60 to 80%, the diurnal temperature range is reduced to about 8°C (14°F) (DOE-RL 1990a). Figure 2-14 depicts the monthly average high and low temperatures for the period 1951 to 1980. Figure 2-15 depicts average monthly temperature and relative humidity at the HMS.

2.2.3 Wind

Wind directions at the HMS vary over 360 degrees, with a prevailing wind direction from the northwest for every month of the year (average of 31.6% of the time). Secondary maxima occur for southwesterly winds. The months of June and July have the highest percentage of winds from the WNW and NW (38 and 37%, respectively). October has the lowest percentage (25%) from those directions. Monthly wind roses for the HMS are shown in Figure 2-16.

Monthly and annual joint frequency distributions of wind direction versus wind speed for the HMS are given in Stone et al. (1983). Monthly average wind speeds are lowest during the winter months, averaging 10 to 11 km/h (6 to 7 mph), and highest during the summer, averaging 14 to 16 km/h (9 to 10 mph). Wind speeds that are well above average in winter are usually associated with southwesterly winds. The summertime high winds are generally northwesterly and frequently reach 50 km/h (30 mph). These winds are most prevalent over the northern portion of the Hanford Site.

At the HMS, the strongest winds observed, with speeds up to 130 km/h (80 mph), generally are southwesterly. Most hourly wind speeds greater than 52 km/h (32 mph) are from the south-southwest to west-southwest and occur at the highest frequency from March through May (Hulstrom 1992).

Wind-blown dust accompanies strong winds on the Hanford Site. Blowing dust originating from the site itself has been observed at wind speeds greater than 32 km/h (20 mph). Dust entrained elsewhere and transported to the Hanford Site has been observed for lower wind speeds of 7 km/h (4 mph) (DOE-RL 1990a). Observations of blowing dust may occur with any wind direction, however, the strongest winds at the HMS are from the southwest and therefore there are more cases of blowing dust from that direction. Dust transported to the Hanford Site from elsewhere is most often associated with winds from the north and northeast.

2.2.4 Evapotranspiration

Pan evaporation data was obtained from the Washington State University Cooperative Extension for Prosser, WA located approximately 37 km (23 mi) southwest of the ERDF site. Monthly rates of pan evaporation at the Washington State University Irrigated Agriculture Research and Extension Center (IAREC) average from about 8.1 to 25.4 cm (3.2 to 10 in.). These averages are based upon data collected over the period 1924 to 1988 for the months April through October. Total pan evaporation over the April through October period averaged about 126.6 cm (49.9 in.). This seasonal component represents approximately 80% of the total annual pan evaporation. Average monthly pan evaporation at Prosser for April through October is depicted in Figure 2-17.

Free surface evaporation (or potential evaporation) is expected to equal approximately 70% of the pan evaporation for the Hanford Site vicinity, or about 110 cm (43 in.) (Weather Bureau 1966). Free water surface evaporation is of interest because it closely represents the potential evaporation from adequately watered surfaces, such as vegetation and soil, and the evaporation from a surface body of water.

Beginning in the late 1970s, a monitoring program was conducted to study groundwater recharge and measure parameters that affect recharge rates. Rockhold et al. (1990) reported on water balance data which was collected as part of this program from three sites in 1988 and 1989. The sites included the 300 Area buried waste test facility and grass site, and the 200 East Area closed-bottom lysimeter. While evapotranspiration was not specifically reported for the 200 East Area site, the measured water contents in the soil implied that significant recharge had not occurred within the lysimeter.

For the 300 Area buried waste test facility, evaporation and transpiration were determined to be about 14.3 cm (5.6 in.) for a bare surface and 19.9 cm (7.9 in.) for a vegetated surface, using measurements of changes in water storage, drainage, and precipitation. Precipitation during this period was approximately 18 cm (7.1 in.). Drainage was about 4 cm (1.6 in.) from the bare surface and 1 cm (0.4 in.) from the vegetated surface. The excess of evapotranspiration and drainage over precipitation was compensated for by a reduction in soil moisture.

Figure 2-18 presents a plot of monthly evapotranspiration totals for the north (bare) and south (vegetated) weighing lysimeters at the buried waste test facility during the period

December 1987 to August 1990 (Hulstrom 1992). This figure illustrates the large seasonal and annual variations in evapotranspiration and the large differences that can occur as a result of vegetation.

2.2.5 Severe Weather

The average occurrence of thunderstorms is 10 per year at the Hanford Site. They are most frequent during the summer; however, they have occurred in every month. The average winds during thunderstorms do not come from any preferred direction. Estimates of the extreme winds, based on peak gusts observed from 1945 through 1980, are given in Stone et al. (1983) and are shown in the following table. Using the National Weather Service criteria for classifying a thunderstorm as "severe" (i.e., hail with a diameter equal to or greater than 20 mm (0.8 in.) or wind gusts of 93 km/h (58 mph) or greater), only 1.9% of all thunderstorm events observed at the HMS have been "severe" storms, and all met the criteria based on wind gusts.

Estimates of Extreme Winds at Hanford Site
(Cushing 1992)

	Peak Gusts, km/h	
Return Period, yr	15.2 m (50 ft) Above Ground	61 m (200 ft) Above Ground
2	97	75
10	114	109
100	137	129
1000	159	151

Note: 1 km = 0.62 mi

Tornadoes are infrequent and generally small in the northwest portion of the United States. Grazulis (1984) lists no violent tornadoes for the region surrounding Hanford (DOE 1987). The HMS climatological summary (Stone et al. 1983) and the National Severe Storms Forecast Center (NSSFC) database list 22 separate tornado occurrences within 161 km (100 mi) of the Hanford Site from 1916 through August 1982. Two additional tornadoes have been reported since August 1982.

2.2.6 Hanford Site Air Quality

Air quality in the vicinity of the Hanford Site is considered good since there are only a few industrial sources of air pollutants located in the area. The Benton-Franklin Counties Clean Air Authority routinely compiles emission inventories for permitted major sources of pollutants. In areas where the National Ambient Air Quality Standards (NAAQS) have been achieved, the EPA has established the Prevention of Significant Deterioration (PSD) program to protect existing ambient air quality. The Hanford Site operates under a PSD permit issued by the EPA in 1980. The permit provides specific limits for emissions of oxides of nitrogen from the Plutonium Uranium Extraction (PUREX) and Uranium Oxide (UO_3) plants (Cushing 1992).

Limited ambient air quality monitoring has been performed in the vicinity of the Hanford Site for total suspended solids, particulates less than 10 microns in diameter (PM-10) and for nitrogen oxides. Nitrogen oxides were sampled at three locations within the Hanford Site using a bubbler assembly operated to collect 24-hour integrated samples (Woodruff et al. 1991). The highest annual average concentration was <0.006 ppmv, well below the applicable federal and Washington State annual ambient standard of 0.05 ppmv. Monitoring for TSP and PM-10 was conducted in two communities surrounding the Hanford Site during 1990. The annual geometric mean of TSP was 71 $\mu g/m^3$ in Sunnyside and 80 $\mu g/m^3$ in Wallula. Both these values exceeded the Washington State annual standard, 60 $\mu g/m^3$. The Washington State 24-hour standard, 150 $\mu g/m^3$, was exceeded six times during the year at Sunnyside and seven times at Wallula. PM-10 was monitored at two locations, at Columbia Center in Kennewick and at Wallula. The 24-hour PM-10 standard established by the state of Washington, 150 $\mu g/m^3$, was exceeded seven times at the Columbia Center monitoring location; the maximum 24-hour concentration at Wallula was 123 $\mu g/m^3$. Neither site exceeded the annual primary standard of 50 $\mu g/m^3$.

Airborne particulate concentrations may reach relatively high levels in eastern Washington due to exceptional natural events such as high winds and brush fires. In addition, elevated particulate levels have been associated with wheat farming. Ambient air quality standards do not consider "rural fugitive dust" from exceptional natural events or agriculture when estimating maximum background concentrations or when considering enforcement of air quality standards and permit applications.

2.3 SURFACE HYDROLOGICAL CHARACTERISTICS

This section provides a characterization of surface water hydrology, regionally within the Pasco Basin and locally in the vicinity of the ERDF site. The regional information is presented with attention focused on those aspects which are felt to relate directly to the ERDF site. Additional information on the regional hydrology may be found in DOE (1988), ERDA (1975) and Skaggs and Walters (1981).

2.3.1 Regional Surface Hydrology

The Pasco Basin occupies about 4,900 km^2 (1,900 mi^2) and is located centrally within the Columbia Plateau. Elevations within the Pasco Basin are generally lower than other parts of the plateau, and surface drainage enters it from other basins. Within the Pasco Basin, the Columbia River is joined by three major tributaries: the Yakima River, the Snake River, and the Walla Walla River. No perennial streams originate within the Pasco Basin (DOE 1988).

The Hanford Site occupies approximately one-third of the land area within the Pasco Basin. Primary surface-water features associated with the Hanford Site are the Columbia and Yakima rivers. Major watershed divides are shown in Figure 2-19. Several surface ponds and ditches are present, and are generally associated with fuel and waste processing activities.

Total estimated precipitation over the Pasco Basin is about $9x10^8$ m^3 ($3x10^{10}$ ft^3) annually, averaging less than 20 cm/yr (~8 in./yr). Mean annual runoff from the basin is estimated to be less than $3.1x10^7$ m^3/yr ($1.1x10^9$ ft^3/yr), or approximately 3% of the total precipitation. The basin-wide runoff coefficient is zero for all practical purposes. The remaining precipitation is assumed to be lost through evapotranspiration, with a small component (perhaps less than 1%) recharging the groundwater system (DOE 1988).

2.3.1.1 Major Rivers. The major surface water body in the Pasco Basin is the Columbia River, which flows from the Canadian Rocky Mountains through Washington State, and along the Oregon border, to the Pacific Ocean. Enroute to the Pacific, the Columbia River crosses the northern portion of the Hanford Site (approximately 15 km [9 mi] to the north of the ERDF site), then turns southward to form the Hanford Site's eastern boundary. About two-thirds of the Hanford Site drains into the Columbia River; the remaining one-third (in the western and southern portions of the Hanford Site) drains into the Yakima River (Figure 2-19). Both the Yakima and the Columbia rivers are important sources of water for domestic, agricultural, industrial, and recreational users in the Pasco Basin (DOE 1987, Jaquish and Bryce 1990). The Hanford Reach of the Columbia River is being considered for designation as a wild and scenic river (NPS 1992).

The Hanford Reach of the Columbia River extends from Priest Rapids Dam, approximately 8.5 km (5.3 mi) above the Hanford Site boundary, to the head of Lake Wallula approximately at the southeastern Hanford Site boundary. Lake Wallula is created by McNary Dam. The Hanford Reach, which is approximately 100 km (60 mi) in length, is the last non-tidal unimpounded segment of the Columbia River in Washington State and its shoreline remains largely undeveloped (Jaquish and Bryce 1990). Several active drains and intakes are present along this reach, including irrigation outfalls from the Columbia Basin Irrigation Project, the Washington Public Power Supply System (WPPSS) Nuclear Project 2, and the Hanford Site intakes for onsite water use.

Volumetric flow rates in the Columbia River along the Hanford Reach vary widely and erratically due to operations of the Priest Rapids Dam, operated by Public Utility District No. 2 of Grant County, and the operational practices of the nearby upstream dams. A minimum flow rate of 1,000 m^3/s (36,000 ft^3/s) has been established at Priest Rapids (PNL 1988a). The average daily flow varies from a high of approximately 8,000 m^3/s (283,000 ft^3/s) in June to a low of about 2,000 m^3/s (70,000 ft^3/s) in October and November. The average daily flow over the entire period of record is approximately 3,400 m^3/s (119,000 ft^3/s). Monthly average flows have ranged as high as 16,700 m^3/s (590,000 ft^3/s) which occurred in the month of June to about 600 m^3/s (21,000 ft^3/s) for January and February.

The Yakima River, bordering the southern portion of the Hanford Site, has a low annual flow compared to the Columbia River. For 57 years of record, the average annual flow of the Yakima River is about 104 m^3/s (3,673 ft^3/s) with monthly maximum and minimum flows of 490 m^3/s (17,000 ft^3/s) and 4.6 m^3/s (160 ft^3/s), respectively.

2.3.1.2 Other Naturally-Occurring Surface Waters. No perennial streams occur within the central portion of the Hanford Site. Cold Creek and its tributary, Dry Creek, are part of the Yakima River watershed and originate in the synclinal valleys west of the Hanford Site (Figure 2-19). Both streams receive some base flow from springs along portions of their reaches. Other reaches are ephemeral, responding to seasonal runoff from precipitation and snowmelt.

The Cold Creek drainage ultimately connects to the Yakima River about 2 km (1 mi) upstream from Horn Rapids Dam (Figure 2-19). Actual flow in Cold Creek and Dry Creek, which results from precipitation onto Rattlesnake Mountain, Umtanum Ridge, and Yakima

Ridge, is not well documented; however, flood magnitudes in Cold Creek, having recurrence intervals of 5 and 10 years, were estimated to be 60 and 125 m^3/s (2,100 and 4,400 ft^3/s), respectively, in the creek's lower reaches (Skaggs and Walters 1981).

West Lake, located about 6.4 km (4 mi) north-northeast of the ERDF site (Figure 2-19), is a shallow pond, with an average depth of about 1 m (3 ft) and a surface area of approximately 4 ha (10 ac) (Fuchs et al. 1985). The pond has previously been described as the "only naturally occurring pond on the Hanford Site" (DOE 1988, DOE-RL 1990b, DOE-RL 1990c). This statement is valid in the sense that the pond does not consist of a disposal pond built and constructed specifically as part of the Hanford Site operations. However, the source of recharge to the lake is groundwater which is locally mounded due to infiltration resulting from the 200 Areas operations and groundwater mounding (Graham 1983). It is expected that West Lake will shrink and perhaps disappear as 200 Area operations cease.

2.3.1.3 Man-Made Ditches and Ponds. On the Hanford Site, wastewater discharge into ponds and ditches occurs in the 200, 300, and 400 Areas. At these locations, several ponds and ditches exist to hold waste waters, which eventually evaporate or infiltrate. In addition, two new effluent disposal facilities (the Treated Effluent Disposal Facility Pond and the Effluent Treatment Facility Crib) are planned for operation in the 200 Area by 1995.

2.3.2 Flooding

Large Columbia River floods have occurred in the past (DOE 1987), but the likelihood of recurrence of large-scale flooding has been reduced by the construction of several flood control/water storage dams upstream of the Site. Major floods on the Columbia River are typically the result of rapid melting of the winter snowpack over a wide area augmented by above-normal precipitation. The maximum historical flood on record occurred June 7, 1894, with a peak discharge at the Hanford Site of 21,000 m^3/s (742,000 ft^3/s). The largest recent flood took place in 1948 with an observed peak discharge of 20,000 m^3/s (706,000 ft^3/s) at the Hanford Site. The probability of flooding at the magnitude of the 1894 and 1948 floods has been greatly reduced because of upstream regulation by dams.

There have been fewer than 20 major floods on the Yakima River since 1862 (DOE 1986). The most severe occurred in November 1906, December 1933, and May 1948; discharge magnitudes at Kiona, Washington, were 1,870, 1,900, and 1,050 m^3/s (66,000, 67,000, and 37,000 ft^3/s), respectively. The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively. The development of irrigation reservoirs within the Yakima River Basin has considerably reduced the flood potential of the river. Flooded areas could extend into the southern section of the Hanford Site, but the upstream Yakima River is physically separated from the Hanford Site by Rattlesnake Mountain, which would prevent major flooding of the Hanford Site.

Evaluation of flood potential is conducted in part through the concept of the probable maximum flood, which is determined from the upper limit of precipitation falling on a drainage area and other hydrologic factors, such as antecedent moisture conditions, snowmelt, and tributary conditions, that could result in maximum runoff. The probable maximum flood for the Columbia River below Priest Rapids Dam has been calculated to be 40,000 m^3/s (1.4 million ft^3/s) and is greater than the 500-year flood. The flood plain associated with the probable maximum flood is shown in Figure 2-20. This flood would inundate parts of the

100 Areas located adjacent to the Columbia River, but the central portion of the Hanford Site including the ERDF site, would not be flooded (DOE 1986).

A flood risk analysis of Cold Creek was conducted in 1980 as part of the characterization of a basaltic geologic repository for high-level radioactive waste. Such design work is usually done to the Probable Maximum Flood (PMF) rather than the worst case or 100-year flood scenario. Therefore, in lieu of 100- and 500-year floodplain studies, a PMF evaluation was made for a reference repository location directly west of the 200 East area and encompassing the 200 West Area (Skaggs and Walters 1981). Schematic mapping indicates that access to the reference repository would be unimpaired but that Route 240 along the southwestern and western areas would not be usable (see Figure 2-21).

2.3.3 Local Surface Water Hydrology

There are no perennial or ephemeral streams at the ERDF site. The ERDF site lies within the Cold Creek watershed, which covers much of the west central and south central portion of the Hanford Site. Cold Creek is located southwest of the ERDF and surface drainage from the site will be to the southwest toward Cold Creek. Surface drainage onto the ERDF site is from the northeast. Surface drainage from the northeast is expected to be limited since the ERDF site is located near the boundary of the Cold Creek watershed and the Columbia River watershed. Surface runoff in the Columbia River watershed runs to the northeast, toward the Columbia River. Figure 2-19 depicts the watersheds at the Hanford Site.

2.4 GEOLOGICAL CHARACTERISTICS

This section provides a description of the regional and local geologic characteristics of the ERDF site. The regional information has been largely summarized from a number of technical documents which address the geologic conditions of the Hanford Site, including the nearby 200 East and 200 West Areas. These include DOE (1988), Delaney et al. (1991), and Lindsey et al. (1992). The description of geologic conditions local to the ERDF site is also based upon these sources, as well as recent work undertaken at the ERDF site.

2.4.1 Topography and Physiography

The Hanford Site is situated within the Pasco Basin, one of a number of topographic and structural depressions located within the Columbia Plateau physiographic province, a broad basin located between the Cascade Range and the Rocky Mountains (Delaney et al. 1991). The Pasco Basin is bounded on the north by the Saddle Mountains; on the west by Umtanum Ridge, Yakima Ridge, and the Rattlesnake Mountain; and on the east by the Palouse slope. Topography of the Hanford Site is depicted in Figure 2-22.

The Hanford Site includes about 900 km^2 (350 mi^2) of terrace lands located south and west of the Columbia River within the semiarid Pasco Basin of south-central Washington. The terrace plains rise gradually north and west from an altitude of about 104 m (340 ft) at Richland to 213 to 244 m (700 to 800 ft) in the northwestern part of the site. From these high terraces the surface descends to 137-m (450-ft) at terraces along the river. Toward the west the terrace lands terminate against the slopes and inter-ridge valleys of low linear mountains known collectively as the Yakima Ridges. Rattlesnake Mountain, at the southwest edge of the site, rises to an elevation of 1,067 m (3,500 ft). A few bedrock outliers, such as Gable Mountain, outcrop above the terraces of the Hanford Site (Newcomb et al. 1972).

The 200 Area and the ERDF site are situated on a broad flat terrace called the 200 Areas plateau located near the center of the Hanford Site at an elevation of approximately 198 to 229 m (650 to 750 ft) AMSL. The plateau decreases in elevation to the north and east toward the Columbia River. The terrace escarpments are steep, with elevation changes between 15 and 30 m (50 and 100 ft).

2.4.2 Regional Geologic Structure and Stratigraphy

Structurally, the Columbia Plateau is divided into three informal subprovinces: the Palouse, Blue Mountains, and Yakima Fold Belt. These are not physiographic subprovinces, even though some of the names may be the same. All but the easternmost part of the Pasco Basin is within the Yakima Fold Belt structural subprovince (DOE 1988). The Yakima Fold Belt contains four major structural elements: the Yakima Folds, Cle Elum-Wallula disturbed zone, Hog Ranch-Naneum anticline, and northwest-trending wrench faults.

The Yakima Folds are a series of continuous, narrow, asymmetric anticlines that have wavelengths between about 5 and 30 km (3 to 19 mi) and amplitudes commonly less than 1 km (less than 0.6 mi). The anticlinal ridges are separated by broad synclines or basins. The Yakima Folds are believed to have developed under generally north-south compression, but the origin and timing of the deformation along the fold structures are not well known (DOE 1988).

The Cle Elum-Wallula disturbed zone is the central part of a larger topographic alignment called the Olympic-Wallowa lineament that extends from the northwestern edge of the Olympic Mountains to the northern edge of the Wallowa Mountains in Oregon. The Cle Elum-Wallula disturbed zone is a narrow zone about 10 km (6 mi) wide that transects the Yakima Fold Belt and has been divided informally into three structural domains: a broad zone of deflected or anomalous fold and fault trends extending south of Cle Elum, Washington, to Rattlesnake Mountain; a narrow belt of aligned domes and doubly plunging anticlines ("The Rattles") extending from Rattlesnake Mountain to Wallula Gap; and the Wallula fault zone, extending from Wallula Gap to the Blue Mountains.

The Hog Ranch-Naneum Ridge anticline is a broad structural arch that extends from southwest of Wenatchee, Washington, to at least the Yakima Ridge. This feature defines part of the northwestern boundary of the Pasco Basin, but little is known about the structural geology of this portion of the feature, nor is the southern extent of the feature known.

Northwest-trending wrench faults have been mapped west of 120°W longitude in the Columbia Plateau (DOE 1988). The mean strike direction of the dextral wrench fault is 320°, but there are less numerous northeast-trending sinistral wrench faults that strike 013°. These structures are not known to exist in the central Columbia Plateau.

Most known faults within the Hanford area are associated with anticlinal fold axes, are thrust or reverse faults although normal faults do exist, and were probably formed concurrently with the folding (DOE 1988). Existing known faults within the Hanford area include wrench faults as long as 3 km (1.9 mi) on Gable Mountain and the Rattlesnake-Wallula alignment, which has been interpreted as a right-lateral strike-slip fault. The faults in Central Gable Mountain are considered capable by the U.S. Nuclear Regulatory Commission (NRC) criteria (10 CFR 100) in that they have slightly displaced the Hanford formation gravels, but their relatively short lengths give them low seismic potential. Also, there is no observed seismicity on or near Gable Mountain. The Rattlesnake-Wallula alignment is interpreted as possibly being capable, in part because of lack of any distinct evidence to the contrary and because this structure continues along the northwest trend of faults that appear active at Wallula Gap, some 56 km (35 mi) southeast of the central part of the Hanford Site (DOE 1988).

The major geologic units of the Hanford Site are, in ascending order: subbasalt rocks (inferred to be sedimentary and volcanoclastic rocks), the Columbia River Basalt Group with intercalated sediments of the Ellensburg Formation, the Ringold Formation, the Plio-Pleistocene unit, and the Hanford formation. Locally, Holocene sand, silt, and loess exist as surficial material.

Knowledge of the sub-basalt rocks is limited to studies of exposures along the margin of the Columbia Plateau and to a few deep boreholes drilled in the interior of the plateau (DOE 1988). No sub-basalt rocks are exposed within the central interior of the Columbia Plateau, including the Pasco Basin. Interpretation of data from wells drilled in the 1980s by Shell Oil Company in the northwestern Columbia Plateau indicates that, in the central part of the Columbia Plateau, the Columbia River Basalt Group is underlain predominantly by Tertiary continental sediments (Campbell 1989).

The regional and Hanford Site geology is dominated by the thick sequence of Miocene tholeiitic continental flood basalts designated the Columbia River Basalt Group. This layered sequence consists of more than 170,600 km^3 (40,800 mi^3) of basalt covering more than 163,000 km^2 (63,000 mi^2) (Tolan et al. 1987).

Late Neogene (late Miocene to Pliocene) deposits younger than the Columbia River Basalt Group are represented by the Ringold Formation in the Pasco and Quincy basins. The fluvial- lacustrine Ringold Formation was deposited in generally east-west-trending valleys by the ancestral Columbia River and its tributaries in response to the development of the Yakima Fold Belt. The Ringold Formation is classified into three facies associations or stratigraphic section types: deposits of the migrating, thoroughgoing ancestral Columbia and/or Snake River systems; overbank materials beyond the influence of the main river channel(s); and fanglomerate deposits found around the margins of the basin (DOE 1988). Later work by Lindsey (1991) proposed a revised stratigraphy for the Ringold Formation, based on five facies associations: fluvial gravel, fluvial sand, overbank mud, lacustrine mud, and basaltic gravel.

An eolian silt and fine sand (the early "Palouse" soil) overlies the Ringold Formation in the western part of the Hanford Site (Brown 1960). This silty fine sand to sandy silt was deposited when the wind reworked and redeposited Ringold sediments. Relatively high caliche contents are found in much of this unit.

The Hanford formation lies on the eroded surface of the Plio-Pleistocene unit, the Ringold Formation, or locally on the basalt bedrock. The Hanford formation consists of cataclysmic flood sediments that were deposited when ice dams that formed Lake Missoula in western Montana and northern Idaho were breached and massive volumes of water spilled abruptly across eastern and central Washington. These Missoula floods scoured the land surface, locally eroding the Ringold Formation, the basalts, and sedimentary interbeds, leaving a network of buried channels crossing the Pasco Basin (Tallman et al. 1979). Thick sequences of sediments were deposited by several episodes of Pleistocene flooding with the last major flood sequence dated at about 13,000 years before present (Myers et al. 1979). These sediments have locally been divided into two main facies, termed the "Pasco Gravels" facies and the "Touchet Beds" facies (Myers et al. 1979).

Volcanic deposits in the Pasco Basin are limited to occasional, thin layers of airfall tephra from a few millimeters to 10 cm (4 in.) thick. Eolian sediments consisting of loess and sand dunes (both active and inactive) locally veneer the surface of the Hanford Site.

2.4.2.1 Suprabasalt Sediments. The suprabasalt sedimentary sequence at the Hanford Site is up to approximately 230 m (750 ft) thick in the west-central Cold Creek syncline, while it pinches out against the anticlinal ridges that bound or are present within the Pasco Basin. The suprabasalt sediments are dominated by laterally extensive deposits of the late Miocene to Pliocene-age Ringold Formation and the Pleistocene-age Hanford formation. Locally occurring strata separating the Ringold and Hanford formations are assigned to the informally defined Plio-Pleistocene unit, early "Palouse" soil, and pre-Missoula gravels comprising the remainder of the sequence.

Ringold Formation. Overlying the Columbia River Basalt Group is the late Miocene to Pliocene-age Ringold Formation (Fecht et al. 1987, DOE 1988). The Ringold Formation accumulated to thicknesses of up to 365 m (1,200 ft) in the Pasco Basin. On the Hanford Site, the Ringold Formation is up to 185 m (600 ft) thick in the deepest part of the Cold Creek syncline south of the 200 West Area and 170 m (560 ft) thick in the western Wahluke syncline near the 100-B Area. The Ringold Formation pinches out against the anticlinal flanks that bound or are present within the Pasco Basin, and is largely absent in the northern and northeastern parts of the 200 East Area and adjacent areas to the north (Delaney et al. 1991, Lindsey et al. 1992).

Post-Ringold Pre-Hanford Sediments. Thin alluvial deposits situated stratigraphically between the Ringold Formation and Hanford formation are found within the Pasco Basin. The three informally defined units include: (1) the Plio-Pleistocene unit; (2) the early "Palouse" soil; and (3) the Pre-Missoula gravels. The Plio-Pleistocene unit and early "Palouse" soil are described in detail in Last et al. (1989) and Lindsey et al. (1991). The pre-Missoula gravels are discussed in PSPL (1982a) and Fecht et al. (1987).

Hanford formation. The informally designated Hanford formation consists of unconsolidated, glaciofluvial sediments that were deposited during several episodes of cataclysmic flooding during the Pleistocene Epoch. The sediments are composed of pebble to boulder gravel, fine- to coarse-grained sand, and silt. These sediments are divided into three facies: (1) gravel dominated, (2) sand-dominated, and (3) silt-dominated (Lindsey et al. 1992). These facies are referred to as coarse-grained deposits, plane-laminated sand facies, and rhythmite facies, respectively (Baker et al. 1991). The silt-dominated deposits are also referred to as "Touchet" beds, and the gravel-dominated facies generally correspond to the Pasco gravels.

The Hanford formation is thickest in the vicinity of the 200 Areas where it is up to 107 m (350 ft) thick (Lindsey et al. 1992). The formation was deposited by cataclysmic flood waters that flowed out of glacial lake Missoula (Fecht et al. 1987, DOE 1988, and

Baker et al. 1991). The deposits are absent from ridges above approximately 360 m (1,180 ft) AMSL, the highest level of cataclysmic flooding in the Pasco Basin (Delaney et al. 1991).

Holocene Surficial Deposits. Holocene surficial deposits consist of silt, sand, and gravel that form a <4.9 m (<16 ft) veneer across much of the Hanford Site. These sediments were deposited by a mix of eolian and alluvial processes.

2.4.3 Local Geology

This section focuses on the geologic characteristics of the ERDF site and vicinity. Information presented has been compiled from a variety of sources, including technical reports and documents of the 200 Areas, as well as the results of the recent field investigative work undertaken for the ERDF site.

2.4.3.1 Topography and Geomorphic Setting. The surface topography and geomorphic features in the vicinity of the ERDF site are depicted in Figure 2-23. The topography in the vicinity of the proposed ERDF site was formed primarily by Pleistocene cataclysmic floods beginning at least 750,000 years ago and ending approximately 13,000 year ago (Baker et al. 1991). These floods left behind an array of unique landforms including anastomosing flood channels, giant current ripples, and giant flood bars. As shown in Figure 2-23, the proposed ERDF site is situated at an elevation of approximately 210 m (700 ft) AMSL on the south slope of one of these landforms, the Cold Creek Bar (Bretz et al. 1956). This flood bar is a compound bar built by multiple floods (DOE 1988). During flooding it prograded southward to its present position. The northern part of the bar has undergone erosion by flood waters receding from the basin, resulting in the creation of at least four major channels, as well as additional minor channels, that have been recognized near the Gable Mountain, Gable Butte area (Fecht 1978).

2.4.3.2 Local Stratigraphy. Figures 2-24, 2-25, 2-26, and 2-27 present geologic cross sections of the proposed ERDF site. The ERDF is in a geologic transitional zone between the 200 East and 200 West Areas where geologic units present in the western portion of the ERDF may not be present in the eastern portions. The proposed ERDF site is underlain by 159 to 177 m (521 to 580 ft) of suprabasalt sediments that rest on the Elephant Mountain Member of the Columbia River Basalt Group. The ascending geologic sequence from the Elephant Mountain Member basalt starts with the Ringold Formation, comprising gravel unit A, followed by the lower mud sequence, gravel unit E, and the upper unit. Overlying the Ringold Formation in this area is the Plio-Pleistocene unit, early "Palouse" soil, and the Hanford formation. Each geologic unit and its stratigraphic characteristics are discussed in the following sections.

The Elephant Mountain Member is the upper most basalt unit and existing information indicates that it is continuous beneath the proposed ERDF site (Weekes and Borghese, 1993). There is no evidence of significant erosion at the top of the Elephant Mountain Member and no indication of erosional "windows" through the basalt to the underlying Rattlesnake Ridge interbed. The basalt dips to the south into the Cold Creek syncline at about 60 m/km (317 ft/mi). The Elephant Mountain Member is about 39 m (128 ft) thick in the area of the ERDF site (Weekes and Borghese 1993).

The Ringold Formation overlies the uppermost basalts beneath the proposed ERDF site. The Ringold Formation generally dips to the south and ranges in thickness from 72 to 111 m

(235 to 363 ft). The Ringold Formation units present (in ascending order) are the fluvial gravels of unit A, the lower mud sequence, the gravels of unit E, and the sand and lesser muds of the Ringold Formation upper unit. The fluvial gravels of the B, C, and D units are not present beneath the site. The Ringold Formation "A" unit ranges in thickness from 15 to 36 m (50 to 118 ft), the lower mud unit ranges in thickness from 8 to 29 m (27 to 95 ft), and the "E" unit thickness varies from 19 to 83 m (61 to 273 ft). The upper Ringold unit is present in the western portion of the site and pinches out to the east. The thickness of the upper unit ranges from 0 to 13 m (0 to 42 ft).

The Plio-Pleistocene unit overlies the Ringold Formation and ranges in thickness from 0 to 11 m (0 to 35 ft). The unit is mostly present in the areas of the site adjacent to the 200 West Area and pinches out to the east within the proposed ERDF site. The unit is composed of laterally discontinuous interbedded carbonate-rich strata and carbonate-poor strata.

Although not shown on any of the cross-sections, the Early "Palouse" soil may be present in the extreme western side of the ERDF site. The Early "Palouse" soil consists of unconsolidated sands and muds. The upper contact of the unit with the Hanford Formation is poorly defined (Weekes and Borghese 1993).

The Hanford formation is present through the ERDF site and ranges in thickness from 41 to 97 m (135 to 319 ft). The formation is thickest on the north side of the proposed ERDF site and thins to the south. The Hanford formation is divided into three lithologic facies: gravel-dominated, sand-dominated, and silty. The sand-dominated facies is considered to be the principal facies under the site and consists of fine- to coarse-grained sand and gravel deposits. Clastic dikes are present within the Hanford formation as vertical to irregularly shaped dipping fissures filled with sand and gravel. Ash deposits are also present within sand-dominated facies of the Hanford formation at the ERDF site.

Sand dunes (Holocene eolian deposits) present above the Hanford formation cover most of the ERDF site and range in thickness from 0 to 3 m (0 to 10 ft).

2.4.4 Seismicity

A comprehensive network of seismic stations that provides accurate locating information for most earthquakes larger than magnitude 2.5 was installed in eastern Washington in 1969. DOE (1988) provides a summary of the seismicity of the Pacific Northwest, a detailed review of the seismicity in the Columbia Plateau region and the Hanford Site, and a description of the seismic networks used to collect the data. Seismicity of the Columbia Plateau, as determined by the rate of earthquakes per area and the historical magnitude of these events, is relatively low when compared to other regions of the Pacific Northwest, the Puget Sound area and western Montana/eastern Idaho. Figure 2-28 shows the locations of all earthquakes that occurred in the Columbia Plateau before 1969 with MMI of IV or larger and with magnitude of 3 or larger. The largest known earthquake in the Columbia Plateau occurred in 1936 around Milton-Freewater, Oregon. This earthquake had a magnitude of 5.75 and a maximum MMI of VII, and was followed by a number of aftershocks that indicate a northeast-trending fault plane.

In the central portion of the Columbia Plateau, the largest earthquakes near the Hanford Site occurred in 1918 and 1973. These two events had magnitudes of 4.4 and intensity V and were located north of the Hanford Site. Earthquakes often occur in spatial and temporal clusters in the central Columbia Plateau, and are termed "earthquake swarms." The region north and east of the Hanford Site is a region of concentrated earthquake swarm activity, but earthquake swarms have also occurred in several locations within the Hanford Site. The magnitude of these swarms is too small to show up on Figure 2-28.

Estimates for the earthquake potential of structures and zones in the central Columbia Plateau have been developed during the licensing of nuclear power plants at the Hanford Site. In reviewing the operating license application for the Washington Public Power Supply System Project WNP-2, the NRC (NRC 1982) concluded that four earthquake sources should be considered for the purpose of seismic design: the Rattlesnake-Wallula alignment, Gable Mountain, a floating earthquake in the tectonic province, and a swarm area.

For the Rattlesnake-Wallula alignment, which passes along the southwest boundary of the Hanford Site, the NRC estimated a maximum magnitude of 6.5, and for Gable Mountain, an east- west structure that passes through the northern portion of the Hanford Site, a maximum magnitude of 5.0. These estimates were based upon the inferred sense of slip, the fault length, and/or the fault area. The floating earthquake for the tectonic province was developed from the largest event located in the Columbia Plateau, the magnitude 5.75 Milton-Freewater earthquake. The maximum swarm earthquake for the purpose of WNP-2 seismic design was a magnitude 4.0 event, based on the maximum swarm earthquake in 1973. (The NRC concluded that the actual magnitude of this event was smaller than estimated previously.)

2.5 PEDOLOGICAL CHARACTERISTICS

The term "pedology" is used to refer broadly to the study of the nature, properties, formation, distribution, classification, function and use of soils. The term "soil" is also used broadly as a synonym for regolith, or all unconsolidated materials which overlie bedrock. Pertinent soil characteristics provided in this section include soil classification, and general engineering and physical properties for the regional and local scales.

The earliest study of soils in Benton County, which includes most of the Hanford Site, was performed in 1916 by Kocher et al. (1921). Maps generated from this survey indicate that the soils in the Hanford Site belong within four major groups that can be classified according to their origin. The four groups included:

- Soils derived from loessial or wind-blown material
- Soils derived from eolian or wind-blown material
- Soils derived from old valley-filling material, mainly lake-laid
- Soils derived from stream laid material.

Kocher et al. (1921) mapped 26 classes of soils within these four groups, and three classes of miscellaneous nonagricultural material, including scabland, river wash, and dune sand.

In a later study (Western States Land Grant Universities and Colleges and Soil Conservation Service [SCS] 1960), which consisted of a generalized soil survey of the western United States, the soils of the Hanford Site area were characterized as largely immature soils formed on unconsolidated upland materials and eolian sands with few clearly-defined horizons.

Few, or no, clearly defined soil horizons are present in regosols, or soils largely dominated by the characteristics of the parent materials. The regosols of the Hanford Site occur on glaciofluvial deposits that have been continually shifted and sorted by wind-erosion and deposition. These soils support a shrub-steppe vegetation community, and are principally used for grazing and limited irrigation crop production (SCS 1960). Hajek (1966) lists and describes 15 different soil types on the Hanford Site. The soil types vary from sand to silty and sandy loam. These are shown in Figure 2-29 and briefly described in Table 2-1. The ERDF is located in an area with Rupert Sand and Burbank Loamy Sand.

2.6 HYDROGEOLOGICAL CHARACTERISTICS

This subsection presents the regional and local hydrogeology for the ERDF site. The discussion on regional hydrogeology summarizes groundwater conditions in the Pasco Basin, detailing the primary aquifers and providing the regional context necessary to understand the local hydrogeology.

2.6.1 Regional Hydrogeology

The multiaquifer system within the Pasco Basin has been conceptualized as consisting of four geohydrologic units: (1) the Grande Ronde Basalt; (2) Wanapum Basalt; (3) Saddle Mountain Basalt; and (4) suprabasalt Hanford and Ringold Formation sediments. Geohydrologic units older than the Grande Ronde Basalt are probably of minor importance to the regional hydrologic dynamics and system. Lateral groundwater movement is known to occur within a shallow, unconfined aquifer consisting of fluvial and lacustrine sediments lying on top of the basalts, and within deeper confined to semi-confined aquifers consisting of basalt flow tops, flow bottom zones, and sedimentary interbeds (DOE 1988). These deeper aquifers are intercalated with aquitards consisting of basalt flow interiors. Vertical flow and leakage between geohydrologic units is inferred and estimated from water level or potentiometric surface data but is not quantified, and direct measurements are not available (DOE 1988).

Groundwater at the Hanford Site occurs under unconfined and confined conditions. The unconfined aquifer is contained within the glaciofluvial sands and gravels of the Hanford formation and the Ringold Formation. The bottom of the unconfined aquifer is the basalt surface or, in some areas, the clay zones of the lower member of the Ringold Formation. The confined aquifers consist of sedimentary interbeds and/or interflow zones that occur between dense basalt flows in the Columbia River Basalt Group. The main water-bearing portions of the interflow zones occur within a network of interconnecting vesicles and fractures of the flow tops or flow bottoms.

From the recharge areas to the west, the groundwater flows downgradient to the discharge areas, primarily along the Columbia River. This general west-to-east flow pattern is interrupted locally by the groundwater mounds in the 200 Areas. From the 200 Areas, there is also a component of groundwater flow to the north, between Gable Mountain and Gable Butte. These flow directions represent current conditions; the aquifer is dynamic, and responds to changes in natural and artificial recharge.

The uppermost aquifer is part of a flow system that is local to the Pasco Basin, as are the uppermost basalt interbed aquifers (Gephart et al. 1979, DOE 1988). Groundwater in these aquifer systems is probably recharged and discharged locally. Deeper in the basalt, interbed aquifer systems are part of the regional, or interbasin, flow system, which extends outside the margins of the Pasco Basin (DOE 1988). Groundwater in the uppermost aquifer system is regionally unconfined and occurs within the glaciofluvial sands and gravels of the Hanford formation and the fluvial/lacustrine sediments of the Ringold Formation. Confined to semi-confined aquifers of more limited extent also occur in the suprabasalt sediments of the Pasco Basin. These confined zones are generally located within the local flow system, between the unconfined aquifer and the underlying basalt surface. Further discussion of the aquifer system is provided below.

2.6.1.1 Unconfined Aquifer. The unconfined aquifer is laterally extensive, occurring below most of the Hanford Site with saturated thicknesses ranging up to 90 m (295 ft) under the 200 West Area. The unit thins and is locally absent along the flanks of anticlinal structures (i.e., Gable Mountain/Gable Butte and Yakima Ridge) (Gephart et al. 1979). The base of the unconfined aquifer is generally defined as the top of the uppermost basalt flow. Fine-grained overbank and lacustrine deposits of the Ringold Formation, however, locally form confining or semi-confining layers for underlying Ringold fluvial gravels.

The main body of the unconfined aquifer generally occurs within the sediments of the Ringold Formation. In the southwestern portion of the Pasco Basin, the position of the water table is generally within Ringold fluvial gravels. In the northern and eastern Pasco Basin, the water table generally occurs within the Hanford formation.

2.6.1.1.1 Recharge. Natural recharge to the unconfined aquifer occurs primarily from run-off of precipitation from higher elevation areas including Saddle Mountains, Umtanum and Yakima ridges, and Rattlesnake Mountain (Deju and Fecht 1979, Gephart et al. 1979, DOE 1988), as well as water infiltrating from small ephemeral streams. The Yakima and Columbia rivers also contribute to the natural recharge in places, as may the deep basalt aquifers (DOE 1988).

The movement of precipitation through the unsaturated (vadose) zone has been studied at several locations on the Hanford Site (Isaacson et al. 1974, Jones 1978, Gee and Heller 1985, Gee 1987, Routson and Johnson 1990, Rockhold et al. 1990). Although conclusions from these studies vary the estimates of deep percolation to the uppermost aquifer are consistently low (from 0 to 7.87 cm/yr [0 to 3.1 in/yr]). Little, if any, recharge to the groundwater occurs from percolating rainfall on the broad areas of the desert terrain because of the high rates of evapotranspiration. Gee (1987) and Routson and Johnson (1990) concluded that no downward percolation of precipitation occurs on the 200 Areas Plateau where the sediments are layered and vary in texture, and that all moisture penetrating the soil is removed by evapotranspiration.

Artificial recharge of the unconfined aquifer system occurs from the disposal of large volumes of wastewater on the Hanford Site and from large irrigation projects surrounding the Hanford Site. Recharge through ponds and cribs in the 200 Areas is the largest single artificial recharge source, beginning in the late 1940s and continuing to the present. Recharge from waste-water disposal was estimated to be about 5.5×10^7 L/d (1.4×10^7 gal/d) or about 10 times the amount of natural recharge entering the unconfined aquifer system within the Cold Creek Valley (DOE 1988). Other artificial recharge sources include irrigation loss west of the 200 Areas (Graham 1983), infiltration ponds at Advanced Nuclear Fuels Corp (USGS 1978), and infiltration ponds at the City of Richland well field (CWC-HDR, Inc. 1988).

2.6.1.1.2 Movement. Figures 2-30 and 2-31 illustrate the groundwater table for the Hanford Site during January 1944 and June-August 1990, respectively. As seen in the figures, effluent disposal has altered the groundwater flow directions and gradients at the Hanford Site. Before operations at the Hanford Site began in 1944, the hydraulic gradient in all but the southwestern-most portion of the Hanford Site was approximately 0.9 m/km (5 ft/mi). Regional groundwater flow was generally toward the east-northeast. Groundwater flow north of Gable Mountain now trends in a more northeasterly direction as a result of mounding near reactors and flow through Gable Gap. South of Gable Mountain, flow is interrupted locally by the groundwater mounds in the 200 Areas. Under the influence of mounding, groundwater flow in the 200 East Area is radial with portions heading northward, passing between Gable Mountain and Gable Butte (Delaney et al. 1991).

Over the period 1950 to 1980, water levels in the unconfined aquifer are reported to have risen by as much as 3.7 m (12 ft) in the 200 East Area and 24 m (80 ft) in the 200 West Area (DOE 1988). The rate of increase was most rapid from 1950 to 1960; the rate of increase was slower from 1960 to 1970. From 1970 to 1980, only small increases in water table elevation occurred, and the unconfined aquifer appears to have been in approximate steady-state with recharge sources. This rise in water-table elevations increased the potential for downward movement of groundwater from the unconfined to the confined basalt and interbed aquifers. The degree of exchange which occurred between the groundwater systems is not known.

Studies have shown that the existing general flow pattern may reverse and return to the pre-operational pattern if the artificial recharge were discontinued, allowing the groundwater mound to dissipate (DOE-RL 1990c). Data presented in Kasza et al. (1992) indicate that this expected mound dissipation is occurring in the 200 Areas. Water level data from 1988 most nearly corresponds to the highest groundwater levels measured in the recent past. A general lowering of the water table is occurring beneath the 200 Areas in response to the closure of the Gable Mountain pond and the U pond, and the decrease in disposal of process water to B pond. From December 1988 to December 1991, the water table beneath the 200 Areas decreased in elevation by as much as 1 m (3.3 ft). To the north of the 200 East Area, in the vicinity of West Lake, the decrease was lower (about 0.5 m [1.6 ft]).

2.6.1.1.3 Discharge. Groundwater discharge from the unconfined aquifer is almost exclusively to the Columbia River along the eastern and northeastern margins of the Pasco Basin (Deju and Fecht 1979, Gephart et al. 1979, DOE 1988). Downward leakage to the lower confined aquifers may be occurring under the eastern groundwater mound beneath B Pond and through features such as erosional windows discussed in Section 2.4.2 (Regional Geology).

West Lake is hydraulically connected to the unconfined aquifer and represents a topographic depression that intersects the water table. Because of high water evaporation rates and low surface overland flow, the lake is expected to result in a net loss of groundwater, and thus constitute a local discharge zone (DOE-RL 1990c).

2.6.1.1.4 Hydraulic Properties. Hydraulic conductivity estimates for the unconfined aquifer have been mapped over the Hanford Site, as shown in Figure 2-32 (DOE 1988). The hydraulic conductivities were obtained from pumping tests (Biershenk 1957, Kipp and Mudd 1973) and are not layer specific, but apply to the combined conductivity of all layers stressed during the test. The hydraulic conductivity range is from approximately 10^{-3} to 1 cm/s (1 to 10^3 ft/d), reflecting heterogeneity of the soils. Transmissivities vary widely regionally because of the variable saturated thickness of the unconfined aquifer.

Generally, saturated hydraulic conductivity is greater in the Hanford formation, where values from 10^{-1} to 10^{1} cm/s (10^{2} to 10^{4} ft/d) are typical, than in the Ringold Formation where hydraulic conductivities are generally from about 10^{-5} to 10^{-1} cm/s (10^{-2} to 10^{2} ft/d). The lower hydraulic conductivities are associated with the low-permeability aquitards.

Fewer data are available on specific yield for the unconfined aquifer. Storage coefficients determined in multiple well pumping tests from the unconfined aquifer ranged from 0.0002 to 0.2 (DOE 1988). Values determined at Hanford formation wells ranged from 0.03 to 0.2, whereas values in Ringold Formation wells were generally less than 0.06.

2.6.1.2 Confined Aquifers. Confined aquifers occur within the lower portion of the Ringold Formation, but are generally more limited in areal extent than the unconfined aquifer. In the western portion of the Pasco Basin, a confined-to-semi-confined aquifer is present within the basal unit of the Ringold Formation (as defined by DOE 1988). A thick silt deposit (the lower unit of the Ringold Formation as defined in DOE 1988) forms the aquitard between the unconfined and confined zones. Other confined-to-semi-confined zones occur locally within the middle and lower units of the Ringold Formation as a result of interfingering silt aquitards and more permeable lenses of sand and gravel. These zones appear to be laterally discontinuous and likely merge with the unconfined system.

A multiple confined aquifer system occurs within the Columbia River Basalt Group underlying the Pasco Basin (Deju and Fecht 1979, Gephart et al. 1979, DOE 1988). The confined aquifers consist primarily of interbeds within the basalt (DOE 1988). The interbeds occur between basalt flow tops of the older flows and basalt flow bottoms of the younger flows (Graham 1983). Flow interiors, comprised primarily of dense basalts, separate the interbeds forming confining aquitards.

The uppermost interbed aquifers are found in the Saddle Mountains Basalt and include, from youngest to oldest, the Rattlesnake Ridge, Selah, Cold Creek and Mabton interbeds. Interbed aquifers of the Saddle Mountains Basalt range in thickness from 6 to 35 m (20 to 110 ft) and are likely localized to the Pasco Basin by geologic structures along the basin margin (Gephart et al. 1979, DOE 1988). Deeper interbeds which occur in the underlying Wanapum and Grande Ronde Basalt formations, appear to be hydraulically connected with the regional flow system outside the Pasco Basin (DOE 1988).

2.6.1.2.1 Recharge. Recharge to the interbeds of the Saddle Mountains Basalt is obtained directly from precipitation onto the exposed basalt ridges surrounding and within the Pasco Basin (Deju and Fecht 1979, Gephart et al. 1979, DOE 1988). Leakage from the unconfined aquifer also recharges at least the uppermost interbed aquifer (the Rattlesnake Ridge interbed, which underlies the Elephant Mountain basalt member) below the 200 Areas plateau, especially where artificial recharge has caused mounding in the unconfined aquifer (Graham 1983, DOE 1988, Delaney et al. 1991, and Connelly et al. 1992). In this area, erosion of the Elephant Mountain member may have lead to an enhanced hydraulic connection between the Rattlesnake Ridge interbed and the unconfined aquifer (Graham 1983).

The deeper basalt interbed aquifers, between and within the Wanapum and Grande Ronde Basalt Formations, obtain recharge waters in the Pasco Basin from vertical leakage of overlying interbed aquifers within the Saddle Mountains Basalt, and horizontal inflow from the regional flow system to the east and west.

2.6.1.2.2 Movement. Within the Pasco Basin, groundwater potentials of Saddle Mountains Basalt indicate that groundwater flow is generally from topographically high to topographically low regions, similar to flow in the unconfined aquifer (DOE 1988). Steep groundwater gradients occur on the flanks of the major anticlines, including the Horse Heaven Hills, Frenchman Hills, Rattlesnake Mountain, and Saddle mountains. Lateral groundwater flow in the Saddle Mountains Basalt appears to mirror the surface topography and is generally toward major surface drainage features. The predominant generalized flow direction across the Hanford Site is from west to east (DOE 1988).

Groundwater flow in the Wanapum and Grande Ronde basalts is thought to be controlled less by local surface drainage patterns and more by the major rivers, streams, and coulees. Potentiometric levels in the deeper interbeds of the Wanapum and Grande Ronde basalts are interpreted to have a smoother form as a consequence of being less influenced by smaller surface drainage features (DOE 1988).

2.6.1.2.3 Discharge. Potentiometric and hydrochemical data presented in DOE (1988) portray the Pasco Basin, in relation to the surrounding Columbia Plateau, as an area of regional groundwater flow convergence and probably of groundwater discharge. Regional discharge from basalts appears to take place in the topographically low and well-dissected regions of the plateau where groundwater flows into stream courses (DOE 1988).

Within the Pasco Basin, the Saddle Mountains Basalt apparently discharges along the Columbia River from the confluence of the Columbia River with the Walla Walla northward, except across the northern portion of the Hanford Site. The Saddle Mountains Basalt potentiometric surface indicates that the Columbia River is the ultimate discharge for groundwater from these Basalts in most places where it flows over the unit. The Saddle Mountains Basalt may also discharge into the lower Snake and Yakima rivers. In much of the area of discharge, the Saddle Mountains Basalt discharges to the surface through the suprabasalt sediments (DOE 1988).

2.6.1.2.4 Hydraulic Properties. Hydraulic conductivities within the basalt interbeds are generally orders of magnitude lower than those observed in the unconfined aquifer. Aquifer testing in interbeds of the Saddle Mountains Basalt yielded hydraulic conductivities ranging from 10^{-4} to 10^{-3} cm/s (10^{-1} to 1 ft/d) (DOE 1988). No values of storativity are currently available. Storativity values, however, are anticipated to be within the range commonly reported (i.e., 10^{-5} to 10^{-3}) for confined aquifers (DOE 1988).

The flow interiors of the basalt formations have hydraulic conductivities orders of magnitude lower than the interbeds, ranging from 10^{-13} to 10^{-7} cm/s (10^{-10} to 10^{-4} ft/d) (DOE 1988). Storativity estimates for the basalts have not been made, but likely range from 10^{-5} to 10^{-3} (DOE 1988).

2.6.2 Local Hydrogeology

2.6.2.1 Vadose Zone. The vadose zone is the region above the water table in which the fluid pressures of the sediments are negative with respect to local atmospheric pressure. It occurs between the ground surface and the water table and is the zone through which natural and manmade recharge waters may flow to the water table. The vadose zone beneath the ERDF site is estimated to range from 70 to 100 m (230 to 330 ft) thick and consist of the following lithologic units: Hanford formation sediments, Plio-Pleistocene unit, the upper Ringold unit and Ringold Gravel unit "E". Flow characteristics through the vadose zone depend on a variety of properties, including particle and pore size, interconnectiveness of pores and moisture content.

2.6.2.2 Suprabasalt Aquifers. The suprabasalt aquifers beneath the proposed ERDF site consist of the fluvial sands and gravels of the Ringold Formation and the lower Plio-Pleistocene unit. The silts of the Plio-Pleistocene unit, the upper Ringold unit and the Ringold lower mud unit may act as aquitards or confining units within the aquifer. The uppermost aquifer is contained primarily within unit E of the Ringold Formation. The lower mud unit of the Ringold Formation is known to occur beneath this aquifer in the western side of the site but the lateral extent is not known beneath the eastern side of the ERDF. Where the lower mud unit is present, confined aquifer conditions exist in unit A of the Ringold Formation. Units A and E of the Ringold Formation would be combined in a single unconfined aquifer in areas where the lower mud unit is not present. As shown on the cross-sections (Figures 2-24 to 2-27, locations shown on Figure 2-33) the thickness of the uppermost aquifer beneath the ERDF generally appears to range from 20 to 70 m (65-230 ft).

Groundwater levels in the area have risen significantly since the 1950's as a result of wastewater disposal activities conducted in the 200 West Area. The groundwater levels stabilized in the late 1960's and started to decline in the mid 1980's. The groundwater level decrease is probably due to reductions in wastewater disposal occurring in the 200 West Area. As shown on Figure 2-33, the water table elevation generally ranges from 123 m (405 ft) along the east side of the proposed site to 139 m (455 ft) along the west side of the site.

Groundwater flow beneath the proposed ERDF site is predominately from west to east (see Figure 2-33). Saturated hydraulic gradients based on groundwater elevations shown in Figure 2-33 range from 0.0045 along the northern boundary of the site to 0.0025 along the southern boundary. Limited data are available for aquifer properties of transmissivity and hydraulic conductivity in the aquifer beneath the ERDF site. However, two wells near the site completed to the "E" unit of the Ringold Formation were tested in 1958 and 1973. Wells 299-W21-1 and 699-33-56 had transmissivity values of 2,700 m^2/day (29,000 ft^2/day) and 1,950 m^2/day (21,000 ft^2/day), respectively (Connelly et al. 1992) (Weekes and Borghese, 1993). Assuming a saturated thickness of 40 m (130 ft), the hydraulic conductivities equal 70 m/day (220 ft/day) and 50 m/day (160 ft/day).

2.7 HUMAN RESOURCES

2.7.1 Land Use

2.7.1.1 Regional Land Use. Land use in the areas surrounding the Hanford Site includes urban and industrial development, irrigated and dry-land farming, and grazing. Industries in the Tri-Cities are mainly those related to agriculture and energy production (DOE 1989). Wheat, corn, alfalfa, hay, barley, and grapes are the major crops in Benton and Franklin counties.

2.7.1.2 Hanford Site Land Use. The Hanford Site encompasses 1,450 km^2 (560 mi^2) and includes several DOE operational areas. The major areas are as follows:

- The entire Hanford Site has been designated a National Environmental Research Park (NERP).

- The 100 Areas, bordering on the south shore of the Columbia River, are the sites of the eight retired plutonium production reactors and the N Reactor (also for plutonium production), which was recently shutdown. The 100 Areas occupy about 11 km^2 (4 mi^2).

- The 200 West and 200 East Areas are located on a plateau about 8 and 11 km (5 and 7 mi), respectively, from the Columbia River. These areas have been dedicated to waste management and disposal activities. The 200 Areas cover about 16 km^2 (6.2 mi^2).

- The 300 Area, located just north of the City of Richland, is the site of nuclear research and development. This area covers 1.5 km^2 (0.6 mi^2).

- The 400 Area is about 8 km (5 mi) north of the 300 Area and is the site of the FFTF used in the testing of breeder reactor systems. Also included in this area is the Fuels and Material Examination Facility.

- The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, or 400 Areas. Land uses within the 600 Area include the Arid Land Ecology Reserve (ALE), a U.S. Fish and Wildlife Service wildlife refuge, support facilities for controlled access areas, and other lands leased to Washington state and the Washington Public Power Supply System (Cushing 1992).

- The 1100 Area includes the 3000 Area and the Horns Rapids Landfill. It is used for Hanford site support services.

Public Law 100-605 authorized a study of the Hanford Reach of the Columbia River. The purpose of this study was to identify and evaluate the outstanding features of the Hanford Reach of the Columbia River and immediate environment, and to examine alternatives for their preservation. The draft report recommends that Congress designate the Hanford Reach of the Columbia River a wild and scenic river (NPS 1992). The final report is expected for public release in 1994.

2.7.1.3 Land Use at the Proposed ERDF Site. The ERDF site (including the operational facilities and trench) extends east of the existing 200 West Area to near the US Ecology Area, and south of the proposed road from the 200 East Area to the 200 West Area. The area of the site is approximately 4.1 square kilometer (1.6 square miles) with dimensions of 3.2 km (2 mi) by 1.3 km (0.8 mi). The site is not currently used.

2.7.2 Water Use

2.7.2.1 Surface Water. Water use in the Pasco Basin is primarily from surface diversion. The Columbia River is the most significant surface-water body in the region. It is used as a source of drinking water, industrial process water, crop irrigation, and for a variety of recreational activities, including fishing, hunting, boating, water skiing, and swimming. Industrial and agricultural usage represent about 13% and 75%, respectively, and municipal use about 12%. The Hanford Site uses about 41% of the water withdrawn for industrial purposes (Cushing 1992).

The Hanford Reach of the Columbia River is a popular recreational sport fishing area. *Anadromous salmonids* represent the majority of the sport fish harvested. Other significant sport catches include white sturgeon (*Acipenser transmontanus*), smallmouth bass (*Micropterus dolomieui*) and walleye (*Stizostedion vitreum*) (DOE-RL 1990d).

Swimming and water skiing are popular recreational activities as well. The McNary Reservoir is the main location for these activities in the region. A public swimming area has also been established at Leslie R. Groves Park, which is approximately 0.8 km (0.5 mi) downstream from the city water intake (DOE-RL 1990d).

River water intakes that are downstream from the proposed ERDF location include the Ringold Fish Hatchery intake, the Ringold Flats irrigation intakes, the Taylor Flats irrigation intakes, the WPPSS intake, the 300 Area process and drinking water intake, the Battelle Farm Operations irrigation intake, the Washington State University Center irrigation intake, and the City of Richland drinking water intake (EPA 1987).

The PNL Observatory relies on water from a spring on the side of Rattlesnake Mountain (U.S. Army Corps of Engineers 1994).

2.7.2.2 Groundwater. Groundwater diversions account for less than 10% of water use in the Pasco Basin. Approximately 50% of the wells in the Pasco Basin are for domestic use and are generally shallow [less than 150 m (500 ft)]. Agricultural wells, used for irrigation and stock supply, make up the second-largest category of well use, about 24% for the Pasco Basin. Industrial users account for only about 3% of the wells (DOE 1988).

The principal users of groundwater within the Hanford Site are the FFTF, with a 1988 use of 142,000 m^3 (37 million gallons) from two wells in the unconfined aquifer.

Groundwater within aquifers in the immediate vicinity and hydraulically downgradient of the proposed ERDF site is not used for either drinking or irrigation. The nearest drinking water supply wells are those that serve the 400 Area. They are located about 15 km (9 mi) to the southeast of the proposed ERDF site (PNL 1988a). However, these wells are not directly downgradient from the proposed ERDF site.

2.7.3 Historical, Archaeological, and Cultural Resources

The Hanford Site contains numerous, well-preserved archaeological sites representing both the prehistoric and historical periods. Management of Hanford's cultural resources follows the Hanford Cultural Resources Management Plan (Chatters 1989) and is conducted by the Hanford Cultural Resources Laboratory (HCRL) of PNL (1988b).

2.7.3.1 Archaeological Resources. More than 10,000 years of prehistoric human activity in the Middle Columbia River region have left extensive archaeological deposits along the river shores (Leonhardy and Rice 1970, Greengo 1982, and Chatters 1989). Well-watered areas inland from the river show evidence of concentrated human activity (Chatters 1982, 1989, Daugherty 1952, Greene 1975, Leonhardy and Rice 1970, and Rice 1980), and recent surveys have indicated extensive, although dispersed, use of arid lowlands for hunting. Graves are common in various settings, and spirit quest monuments (rock cairns) may still be found on summits of the mountains and buttes (Rice 1968a). Throughout most of the region, hydroelectric development, agricultural activities, and domestic and industrial construction have destroyed or covered the majority of these deposits. Because of the limited public access to the Hanford Site, some of the archaeological deposits found in the Hanford Reach of the Columbia River and on adjacent plateaus have been preserved.

There are currently 228 prehistoric archaeological sites recorded in the files of the HCRL. Forty-seven of these sites are included on the National Register of Historic Places (National Register), two as single sites (45BN121, Hanford Island Site; 45GR137, Paris Site) and the remainder in seven archaeological districts, listed in the table below. In addition, a nomination has been prepared for one cultural district (Gable Mountain/Gable Butte), and renomination for two additional archaeological districts is pending (Wahluke, Coyote Rapids). Two other sites, 45BN90 and 45BN412, are considered eligible for the National Register. Archaeological sites include remains of numerous pithouse villages, various types of open campsites, and cemeteries along the river banks (Rice 1968a, 1980), spirit quest monuments, hunting camps, game drive complexes and quarries in mountains and rocky bluffs (Rice 1968b), hunting/kill sites in lowland stabilized dunes, and small temporary camps near perennial sources of water located away from the river (Rice 1968b).

Historic Properties on the Hanford Site Listed on the National Register of Historic Places (Cushing 1992):

Property Name	Site(s) Included
Wooded Island Archaeological District	45BN107 through 45BN112, 45BN168
Savage Island Archaeological District	45BN116 through 45BN119, 45FR257 through 45FR262
Hanford Island Site	45BN121
Hanford North Archaeological District	45BN124 through 45BN133, 45BN134, 45BN178
Locke Island Archaeological District	45BN137 through 45BN140, 45BN176, 45GR302 through 45GR305
Ryegrass Archaeological District	45BN149 through 45BN157
Paris Site	45GR137
Rattlesnake Springs Archaeological District	45BN170, 45BN171
Snively Canyon Archaeological District	45BN172, 45BN173
100-B Reactor	Not Applicable

2.7.3.2 Native American Cultural Resources. In prehistoric and early historic times, the Hanford Reach of the Columbia River was heavily populated by Native American people of various tribal affiliations. The Wanapum and the Chamnapum bands of the Yakama tribe dwelt along the Columbia River from south of Richland upstream to Vantage (Relander 1956, Spier 1936). Some of their descendants still live nearby at Priest Rapids, and others have been incorporated into the Yakama and Umatilla reservations. Palus people, who lived on the lower Snake River, joined the Wanapum and Chamnapum to fish the Hanford Reach and some inhabited the river's east bank (Relander 1956, Trafzer and Scheuerman 1986). Walla Walla and Umatilla people also made periodic visits to the area to fish. These peoples retain traditional secular and religious ties to the region, and many have knowledge of the ceremonies and practices of their aboriginal culture. The Washane, or Seven Drums religion, which has ancient roots and had its start on the Hanford Site, is still practiced by many people on the Yakama, Umatilla, Warm Springs, and Nez Perce reservations. Native plant and animal foods, some of which can be found on the Hanford Site, are used in the ceremonies performed by sect members. Tribal members have expressed an interest in renewing their use of these resources in accordance with the Treaties of 1855, and the DOE is assisting them in this effort. Certain landmarks, especially Rattlesnake Mountain, Gable Mountain, Gable Butte, Goose Egg Hill, the White Bluffs Road and various sites along the Columbia River, are considered important or sacred to them. The many cemeteries found along the river are also sacred.

The White Bluffs Road is a former Indian trail and freight road between White Bluffs Ferry landing on the Columbia River and Rattlesnake Springs in the western part of the Hanford Site (see Figure 2-34). This road was an important transportation route during the prehistoric era and during settlement, mining, and cattle ranching eras in the Washington Territory (Rice 1984). This history of the White Bluffs Road was reviewed by HCRL staff and was found to meet the criteria for nomination to the National Register of Historic Places. An area is considered eligible if it is "associated with events that have made a significant contribution to the broad patterns of our history" (36 CFR Part 60.4, criterion A).

2.7.3.3 Historic Resources. Sixty-eight historic archaeological sites and 11 other historic localities have been recorded in published literature. Localities include the Allard Pumping Plant at Coyote Rapids, the Hanford Irrigation Ditch, the Hanford townsite, Wahluke Ferry, the White Bluffs townsite, the Richmond Ferry, Arrowsmith townsite, a cabin at East White Bluffs ferry landing, the White Bluffs road, the old Hanford High School, and the Cobblestone Warehouse at Riverland (Rice 1980). Archaeological sites include the East White Bluffs townsite and associated ferry landings, and an assortment of trash scatters and dumps. Thirty-eight additional sites, including homesteads, corrals, and dumps, have been recorded by the HCRL since 1987. ERTEC Northwest was responsible for minor test excavations at some of the historic sites, including the Hanford townsite locality. In addition to the recorded sites, there are numerous areas of gold mine tailings along the river bank, and the remains of homesteads, farm fields, ranches, and abandoned Army installations are scattered over the entire Hanford Site.

More recent sites are the defense reactors and associated materials processing facilities that now dominate the area. The first reactors (100-B, 100-D, and 100-F) were constructed in 1943 as part of the Manhattan Project. Plutonium for the first atomic explosion and the bomb that destroyed Nagasaki at the end of World War II were produced in the 100-B Facility. Additional reactors and processing facilities were constructed after World War II, during the Cold War. All reactor containment buildings still stand, although many ancillary structures have been removed. The 100-B Reactor has been listed on the National Register of Historic Places. Other Manhattan Project facilities remain to be evaluated.

2.7.3.4 Cultural Resources at the Proposed ERDF Site. The HCRL conducted a cultural resources survey at the ERDF site during the summer of 1993. The survey identified four archaeological sites, one paleontological site and nine isolated artifacts. One isolated artifact (a cobble tool) was also identified during a previous survey. Based on the determination by the State of Washington Office of Archaeology and Historical Preservation in a letter to DOE/RL dated February 4, 1994, none of the sites were considered eligible for the National Register. However, two of the archeological sites may represent part of the greater Euro-American ranching community in Southeast Washington State and may be considered regionally or locally significant viewed in this context. The two sites are located outside of the ERDF boundaries and will not be impacted by the proposed activities at the ERDF.

2.7.4 Socioeconomics

Activity on the Hanford Site plays a dominant role in the socioeconomics of the Tri-Cities (Richland, Pasco, and Kennewick) and other parts of Benton and Franklin counties. The agricultural community also has a significant effect on the local economy. Any major changes in Hanford activity would potentially affect the Tri-Cities and other areas of Benton and Franklin counties. Detailed analyses of the socioeconomics are found in Scott et al. (1987) and Watson et al. (1984).

2.7.4.1 Employment and Income. Two major sectors are currently the principal driving forces of the economy in the Tri-Cities since the early 1970s: (1) the DOE and its contractors, operating the Hanford Site; and (2) the agricultural community, including a substantial food-processing component. Most of the goods and services produced by these sectors are exported outside the Tri-Cities. In addition to the direct employment and payrolls, these major sectors also support a sizable number of jobs in the local economy through their procurement of equipment, supplies, and business services. In addition to these two major employment sectors, three other components are contributors to the economic base of the Tri-Cities economy; other major employers, tourism, and retired persons.

The unemployment rate fluctuates seasonally due to the agricultural sector. The 1992 average unemployment for the Tri-Cities was 8.5%. Average unemployment in Benton and Franklin Counties in 1992 was 7.6% and 11.9%, respectively. The unemployment rate in Franklin County was higher due to the larger agricultural sector in Franklin County (Washington State Department of Employment Security 1993).

2.7.4.2 Hanford and the Local and State Economy. In 1991, Hanford employment accounted directly for 24% of total nonagricultural employment in Benton and Franklin counties and slightly more than 0.6% of all nonagricultural statewide jobs. In 1991, Hanford Site operations directly accounted for an estimated 42% of the payroll dollars earned in the area (Cushing 1992).

Hanford contractors spent nearly $154 million, or 47.5% of total procurement of $324 million, initially through Washington firms in 1986. About 18% of Hanford orders were filled by Tri-Cities firms. In many cases, these procurement filled by Tri-Cities firms only result in retail and wholesale markups; however, a significant portion of all Hanford orders, $6.6 million, are placed directly to Washington manufacturers (Cushing 1992).

Hanford contractors paid a total of $10.9 million in FY 1988 in state taxes on operations and purchases. Estimates show that Hanford employees paid $27.0 million in state sales tax, use taxes, and other taxes and fees in FY 1988. In addition, Hanford paid $0.9 million to local government in Benton, Franklin, and Yakima counties in local taxes and fees (Scott et al. 1989).

2.7.4.3 Demography. Estimates by the U.S. Bureau of the Census for 1990 (U.S. Department of Commerce 1991) placed the population totals for Benton and Franklin counties at 112,560 and 37,473, respectively. When compared to the 1980 census data in which Benton County had 109,444 residents and Franklin County's population totaled 35,025, the 1990 Census figures reflect the current growth occurring in these two counties. Within each county, the 1990 estimates distribute the Tri-Cities population as follows: Richland, 32,315; Kennewick, 42,159; and Pasco, 20,337. The combined populations of Benton City, Prosser, and West Richland totaled 10,244 in 1990. The unincorporated population of Benton County was 27,842. In Franklin County, incorporated areas other than Pasco have a total population of 2,424. The unincorporated population of Franklin County was 14,712 (Cushing 1992).

2.7.4.4 Housing. In 1990, nearly 92% of all housing (of 38,781 total units) in the Tri-Cities was occupied. Single-unit housing, which represents nearly 58% of the total units, has a 96% occupancy rate throughout the Tri-Cities. Multiple-unit housing, defined as housing with two or more units, has an occupancy rate of nearly 91%, a 10% increase from 1989. Pasco has the lowest occupancy rate, 89%, in all categories of housing; followed by Kennewick, 93%, and Richland, 94%. Representing 9% of the housing unit types, mobile homes have the lowest occupancy rate, 81%. In 1989, mobile homes had the highest occupancy rate, 93% (Cushing 1992).

2.7.4.5 Transportation.

2.7.4.5.1 Tri-Cities Area. The Tri-Cities serve as a regional transportation and distribution center with major air, land, and river connections. The Tri-Cities have direct rail service, provided by Burlington Northern and Union Pacific, that connects the area to more than 35 states. Docking facilities at the Ports of Benton, Kennewick, and Pasco are important aspects of this region's infrastructure. These facilities are located on the 525-km-long (326-mi-long) commercial waterway, which comprises the Snake and Columbia rivers, that extends from the Ports of Lewiston-Clarkston in Idaho to the deep-water ports of Portland, Oregon, and Vancouver, Washington (Evergreen Community Development Association 1986). Daily air passenger and freight services connect the area with most major cities through the Tri-Cities Airport, located in Pasco. The airport is currently served by one national and two commuter-regional airlines. The Tri-Cities are linked to the region by five major highways; Route 395, Route 240, Interstate 84, Interstate 82, and Route 14 (Cushing 1992).

2.7.4.5.2 Hanford Site Transportation. The transportation network for the Hanford Site is shown in Figure 2-35. The Hanford Site railroad system extends from the west side of Richland, Washington, throughout the Hanford Site. The DOE controls the rail access into the Hanford Site; the agency trackage ties in with the Union Pacific Railroad tracks southeast of the Richland "Y" area near the U.S. Highway 12 and Route 240 interchange. The Burlington Northern and Union Pacific have trackage rights over the DOE trackage between the Richland "Y" area and the DOE 1100 Area. The DOE tracks serving the Hanford Site are installed parallel to the Route 240 bypass around the Richland, Washington urban area (DOE 1986). The roads and highways on the Hanford Site are also shown in Figure 2-35. Routes 240 and

24 traverse the Hanford Site and are maintained by Washington State. Other roads within the reservation are maintained by the DOE (Cushing 1992).

2.7.4.5.3 ERDF Transportation. The existing transportation network in the ERDF area is shown in Figure 2-36.

2.7.4.6 Educational Services. Primary and secondary education are served by the Richland, Kennewick, Pasco, and Kiona-Benton school districts. Post-secondary education in the Tri-Cities area is provided by a junior college, Columbia Basin College (CBC), and the Tri-Cities branch campus of Washington State University (WSU-TC). These institutions emphasize technical and vocational programs (Cushing 1992).

2.7.4.7 Health Care and Human Services. The Tri-Cities have three major hospitals and four minor emergency centers. The three hospitals are the Kadlec Medical Center, located in Richland, the Kennewick General Hospital and Our Lady of Lourdes Hospital, located in Pasco. All three hospitals offer general medical services and include a 24-hour emergency room, basic surgical services, intensive care, and neonatal care (Cushing 1992).

The Tri-Cities offer a broad range of social services. State human service offices in the Tri-Cities include the Job Services office of the Employment Security Department; Food Stamp offices; the Division of Developmental Disabilities; Financial and Medical Assistance; the Child Protective Service; emergency medical service; a senior companion program; and vocational rehabilitation (Cushing 1992).

2.7.4.8 Police and Fire Protection. Police protection in Benton and Franklin counties is provided by Benton and Franklin counties' sheriff departments, local municipal police departments, and the Washington State Patrol Division headquartered in Kennewick. The Kennewick, Richland, and Pasco municipal departments maintain the largest staffs of commissioned officers with 53, 44, and 38, respectively (Cushing 1992).

There were 117 paid fire-fighters in the Tri-Cities in 1992. The Hanford site has its own fire fighters. There are 126 firefighters in the Hanford Fire Patrol, trained to dispose of hazardous/dangerous waste and to fight chemical fires. Each station has access to a Hazardous Material Response Vehicle that is equipped with chemical fire extinguishing equipment, an attack truck that carries foam, halon, and Purple-K dry chemical, a mobile air truck that provides air for gasmasks; and a transport tanker that supplies water to six brush trucks. They have five ambulances and contact with local hospitals (Cushing 1992).

2.7.4.9 Parks and Recreation. The convergence of the Columbia, Snake, and Yakima rivers offers the residents of the Tri-Cities a variety of recreational opportunities. The Lower Snake River Project provides boating, camping, and picnicking facilities in nearly a dozen different areas along the Snake River. In 1986, nearly 385,000 people visited the area and participated in activities along the river. The Columbia River also provides ample water recreational opportunities on the lakes formed by the dams. Lake Wallula, formed by McNary Dam, offers a large variety of parks and activities, which attracted more than 3 million visitors in 1986. The Columbia River Basin is also a popular area for migratory waterfowl and upland game bird hunting (Cushing 1992).

2.7.4.10 Utilities.

2.7.4.10.1 Water. The principal source of water in the Tri-Cities and the Hanford Site is the Columbia River from which the water systems of Richland, Pasco, and Kennewick draw a large portion of the average 11.38 billion gallons used in 1991. Each city operates its own supply and treatment system (Cushing 1992). More information on water use is presented in Section 2.7.2.

The major incorporated areas of Benton and Franklin counties are served by municipal wastewater treatment systems, whereas the unincorporated areas are served by onsite septic systems. Richland's wastewater treatment system is designed to treat a total capacity of 27 million m^3/yr (7,100 million gal/yr). Currently, the daily average flow is 34,000 m^3/day (8.9 million gal/day) with a peak flow of 170,000 m^3/day (144 million gal/day) (Cushing 1992).

2.7.4.10.2 Electricity. In the Tri-Cities, electricity is provided by the Benton County Public Utility District, Benton Rural Electrical Association, Franklin County Public Utility District, and City of Richland Energy Services Department. All the power that these utilities provide in the local area is purchased from the Bonneville Power Administration (BPA), a federal power marketing agency. Natural gas, provided by the Cascade Natural Gas Corporation, serves a small portion of residents, with 4,800 residential customers in June 1992 (Cushing 1992).

Electrical power for the Hanford Site is purchased wholesale from BPA. Energy requirements for the Site during FY 1988 exceeded 550 average MW (Cushing 1992). The Hanford electrical distribution system is used to distribute power to the bulk of the Hanford Site. The City of Richland distributes power to the 700, 1100, and 3000 areas, which constitute approximately 2% of the total Hanford Site usage (DOE-RL 1993d).

2.7.4.10.3 200 Area Utilities. Sanitary wastes are currently disposed of through septic tanks and drain fields at the 200 Area. The construction of a central collection and treatment evaporation plant is being considered to handle the sanitary sewer (DOE-RL 1993d).

The 200 Areas have two types of water: sanitary (potable) water used for sanitary uses such as drinking water, showers, and laundry; and raw (export) water used for fire protection and other non-potable uses. The sanitary water is pumped and treated. Raw water is drawn from the Columbia River. A looped water system was installed in the 200 areas in 1992. This allows for fire protection and repairs to take place at the same time (DOE-RL 1993d). The communication system is a fiber network system.

2.7.4.11 Visual Resources. The land in the vicinity of the Hanford Site is generally flat with little relief. Rattlesnake Mountain, rising to 1060 m above mean sea level, forms the western boundary of the site, and Gable Mountain and Gable Butte are the highest land forms within the site. Both the Columbia River, flowing across the northern part of the site and forming the eastern boundary, and the spring-blooming desert flowers provide a visual source of enjoyment to people. The White Bluffs, steep bluffs above the northern boundary of the river in this region, are a striking feature of the landscape (Cushing 1992).

2.7.5 Noise

Studies at Hanford of the propagation of noise have been concerned primarily with occupational noise at work sites. Environmental noise levels have not been extensively evaluated because of the remoteness of most Hanford Site activities and isolation from receptors that are covered by federal or state statutes. The majority of available information consists of model predictions, which in many cases have not been verified because the predictions indicate that the potential to violate state or federal standards is remote or unrealistic (Cushing 1992).

2.7.5.1 Background Noise Levels at the Hanford Site. Environmental noise measurements were made in 1981 during site characterization of the Skagit/Hanford Nuclear Power Plant Site (PSPL 1982b). Fifteen sites were monitored and noise levels ranged from 30 to 60.5 dBA (Leq). The values for isolated areas ranged from 30 to 38.8 dBA. Measurements taken around the sites where the Supply System was constructing nuclear power plants (WNP-1, WNP-2, and WNP-4) ranged from 50.6 to 64 dBA. Measurements taken along the Columbia River near the intake structures for WNP-2 were 47.7 and 52.1 dBA compared to more remote river noise levels of 45.9 dBA (measured about 5 km [3 mi] upstream of the intake structures). Community noise levels in North Richland (3000 Area at Horn Rapids Road and the By-Pass Highway) were 60.5 BA (Cushing 1992).

In addition, site characterization studies performed in 1987 included measurement of background environmental noise levels at five sites on the Hanford Site. Noise levels are expressed as equivalent sound levels for 24 hours (Leq-24). Wind was identified as the primary contributor to background noise levels with winds exceeding 12 mph significantly affecting noise levels. Coleman concludes that background noise levels in undeveloped areas at Hanford can best be described as a mean Leq-24 of 24 to 36 dBA. Periods of high wind, which normally occur in the spring, would elevate background noise levels (Cushing 1992).

2.7.5.2 Hanford Site Sound Levels. Although most industrial facilities on the Hanford Site are located far enough away from the site boundary that noise levels at the boundary are not distinguishable from background noise levels, there is the potential for producing noise from field activities, such as well drilling and sampling (Cushing 1992).

In the interest of protecting Hanford workers and complying with Occupational Safety and Health Administration (OSHA) standards for noise in the workplace, the Hanford Environmental Health Foundation has monitored noise levels resulting from several routine operations performed at Hanford. Occupational sources of noise propagated in the field are summarized in the table below. These levels are reported here because operations such as well sampling are conducted in the field away from established industrial areas and have the potential for disturbing sensitive wildlife (Cushing 1992).

Monitored Levels of Noise Propagated from Outdoor Activities at the Hanford Site
(Cushing 1992)

Activity	Average Noise Level (Decibels)	Maximum Noise Level (Decibels)	Year Measured
Water wagon operation	104.5	111.9	1984
Well sampling Truck Compressor Generator	74.8 - 78.2 78 - 83 88 - 90 93 - 95		1987 1989
Well drilling, Well 32-2	98 - 102	102	1987
Well drilling, 32-3	105 - 11	120 - 125	1987
Well drilling, 33-29	89 - 91		1987
Pile driver (diesel 5 ft from source)	118 - 119		1987
Tank farm filter building (30 ft from source)	86		1976

2.8 ECOLOGY

The Hanford Site is a relatively large, undisturbed area [1450 km^2 (~560 mi^2)] of shrub-steppe habitat that contains numerous plant and animal species adapted to the region's semiarid environment. The relatively undisturbed native sagebrush-steppe habitat, riparian habitat, sand dunes and unique habitats associated with canyons, basalt outcrops and cliffs, promote biodiversity and support ecologically important species. Important species include plant species of medicinal and dye value, commercial and recreational wildlife including state- and federal-listed and candidate threatened or endangered species, as well as species making up critical habitat used by listed and candidate species. The site consists of mostly undeveloped land with widely spaced clusters of industrial buildings located along the western shoreline of the Columbia River and at several locations in the interior of the site. The industrial buildings are interconnected by roads, railroads, and electrical transmission lines. The major facilities and activities occupy about 6% of the total available land area, and their impact on the surrounding ecosystems is minimal. Most of the Hanford Site has not experienced tillage or livestock grazing since the early 1940s. Fire can affect the distribution of vegetation. The wildfires that occurred in 1981 and 1984 burned much of the sagebrush from Rattlesnake Mountain. This is discussed further in Section 2.8.1.1.

The Columbia River flows through the Hanford Site, and although the river flow is not directly impeded by artificial dams within the Hanford Site, the historical daily and seasonal water fluctuations have been changed by dams upstream and downstream of the site (Rickard and Watson 1985). The Columbia River and other water bodies on the Hanford Site provide habitat for aquatic organisms. The Columbia River is also accessible for public recreational use and commercial navigation. Other descriptions of the ecology of the Hanford Site can be found in ERDA (1975), Rogers and Rickard (1977), Jamison (1982), and Watson et al. (1984), among others. Some of the information presented in this section is adapted from Downs et. al. (1993).

2.8.1 Hanford Site Terrestrial Ecology

2.8.1.1 Vegetation. The Hanford Site has been botanically characterized as shrub-steppe habitat (Daubenmire 1970) and is considered to contain one of the largest tracts of undisturbed native sagebrush steppe remaining in the State of Washington. The vegetation mosaic of the Hanford Site currently consists of 10 major kinds of plant communities:

- sagebrush/bluebunch wheatgrass
- sagebrush/cheatgrass or sagebrush/Sandberg's bluegrass
- sagebrush-bitterbrush/cheatgrass
- greasewood/cheatgrass-saltgrass
- winterfat/Sandberg's bluegrass
- thyme buckwheat/Sandberg's bluegrass
- cheatgrass-tumble mustard
- willow or riparian
- spiny hopsage
- sand dunes.

The distribution of the dominant plant communities is shown in Figure 2-37. The sagebrush/cheatgrass (Sandberg's bluegrass) community is perhaps the most common in the 200 Area. In the early 1800s, the dominant plant in the area was big sagebrush with an understory of perennial bunchgrasses, especially Sandberg's bluegrass and bluebunch wheatgrass. Livestock grazing and crop raising have altered the natural vegetation mosaic and subjected it to persistent invasion by alien annuals, especially cheatgrass. Today, cheatgrass is the dominant plant on fields that were cultivated 40 years ago and is also well established on rangelands at elevations less than 244 m (800 ft) (Rickard and Rogers 1983).

The dryland areas of the Hanford Site were treeless in the years before land settlement; however, for several decades before 1943, trees were planted and irrigated on most of the farms to provide windbreaks and shade. When the farms were abandoned in 1943, some of the trees died but others have persisted. Today these trees are ecologically important because they serve as nesting platforms for several species of birds, including hawks and owls, and as night roosts for wintering bald eagles (Rickard and Watson 1985).

The release of water used as industrial process coolant streams at the Hanford Site facilities created several semi-permanent artificial ponds that did not exist before these industrial releases commenced. Over the years, stands of cattails, reeds, and trees, especially willow, cottonwood, and Russian olive, have developed around the ponds. These ponds are ephemeral and will disappear if the industrial release of water is terminated; in fact, many of these have been discontinued and no longer exist. No ponds or ditches are located at the ERDF site.

Almost 600 species of plants have been identified on the Hanford Site (Sackschewsky et al. 1992). More than 100 species of plants have been identified in the 200 Area Plateau (ERDA 1975). The dominant plants on the 200 Area Plateau are big sagebrush, rabbitbrush, cheatgrass, and Sandberg's bluegrass, with cheatgrass providing half of the total plant cover.

Cheatgrass and Russian thistle, which are annuals introduced to the United States from Eurasia in the late 1800s, invade areas where the ground surface has been disturbed. A food web centered on cheatgrass is shown in Figure 2-38 (modified from Watson et al. 1984). The main links leading to man would be through mule deer and chukars. Other pathways leading to man through terrestrial food webs could be via upland game birds and elk. Certain desert plants have roots that grow to depths approaching 10 m (33 ft) (Napier 1982); however, root penetration to these depths has not been demonstrated for plants in the 200 Areas. Rabbitbrush roots have been found at a depth of 2.4 m (8 ft) near the 200 Areas (Klepper et al. 1979). Mosses and lichens appear abundantly on the soil surface; lichens commonly grow on the shrub stems.

The important desert shrubs, big sagebrush and bitterbrush, are widely spaced and usually provide less than 20% canopy cover. The important understory plants are grasses, especially cheatgrass, Sandberg's bluegrass, Indian ricegrass, June grass, and needle-and-thread grass. A list of plants is given in Table 2-2.

Mature shrub-steppe provides important habitat for a number of plant and animal species of concern that depend on the shrub component, usually sagebrush, for nesting, food and protection. Bitterbrush shrubs provide browse for a resident herd of wild mule deer. Certain passerine birds rely on sagebrush or bitterbrush for nesting (i.e., sage sparrow, sage thrasher, and loggerhead shrike). Certain species of birds nest only in the mature big sage located south of the 200 Areas. For example, loggerhead shrikes prefer to nest in shrubs with an average height of about 2 meters (6 feet). Loggerhead shrikes are year-round residents that are present at low densities. Sage sparrows are common summer residents of the Hanford Site that are restricted almost entirely to sagebrush stands. Mature shrub-steppe habitat also provides prime foraging habitat for a variety of raptor species. Shrub-steppe habitat available for species of concern on the Hanford Site may become a more critical issue as agricultural, industrial and urban development decrease the amount of this habitat type in eastern Washington.

Sagebrush and bitterbrush are easily killed by summer wildfires, but the grasses and other herbs are relatively resistant and usually recover in the first growing season after burning. The most recent and extensive wildfire occurred in the summer of 1984. Fire usually opens the community to wind erosion. The severity of erosion depends on the severity and areal extent of the fire. Hot fires incinerate entire shrubs and damage grasscrowns. Less intensive fires leave dead stems standing, and recovery of herbs is prompt. Bitterbrush shrubs are slow to recolonize burned areas because bitterbrush does not re-sprout even when fire damage is light. Re-establishment of bitterbrush occurs using seeds.

2.8.1.2 Insects. More than 300 species of terrestrial and aquatic insects have been found on the Hanford Site (ERDA 1975). Grasshoppers and darkling beetles are among the more conspicuous groups and, along with other species, are important in the food web of the local birds and mammals. Most species of darkling beetles occur throughout the spring to fall period, although some species are present only during 2 or 3 months in the fall (Rogers and Rickard 1977). Grasshoppers are evident during the late spring to fall. Both groups are subject to wide annual variations in abundance. Grasshoppers are a food source for the Swainson's hawk, which is a federal candidate for threatened and endangered designation.

2.8.1.3 Reptiles and Amphibians. Twelve species (Table 2-3) of amphibians and reptiles are known to occur on the Hanford Site (Fitzner and Gray 1991). The occurrence of these species is infrequent when compared with similar fauna of the southwestern United States. The side-blotched lizard is the most abundant reptile and can be found throughout the Hanford Site. Short-horned and sagebrush lizards are also common in selected habitats. The most common snakes are the gopher snake, the yellow-bellied racer, and the Western rattlesnake, which are found throughout the Hanford Site. Striped whipsnakes and desert night snakes are rarely found, but some sightings have been recorded for the site. Toads and frogs are found near the permanent water bodies and along the Columbia River.

2.8.1.4 Birds. Fitzner and Gray (1991) and Landeen et al. (1992) have presented data on birds observed on the Hanford Site. The horned lark and western meadowlark are the most abundant nesting birds in the shrub-steppe. Some of the more common birds present on the Hanford Site are listed in Table 2-4. The game birds inhabiting terrestrial habitats at Hanford are the chukar, gray partridge, and mourning dove. The chukar and grey partridge are year-round residents, but mourning doves are migrants. Although a few doves overwinter in south-eastern Washington State, most leave the area by the end of September (Cushing 1992). Mourning doves nest on the ground and in trees all across the Hanford Site. Chukars are most numerous on Rattlesnake Mountain, Yakima Ridge, Umtanum Ridge, Saddle Mountains, and Gable Mountain areas of the Hanford Site and are somewhat rare on the 200 Area Plateau, but a few birds are known to inhabit the plateau. Gray partridges are not as numerous as chukars, and their numbers also vary greatly from year to year. Sage grouse populations have declined on the Hanford Site since the 1940s, and it is likely that there are no nesting sage grouse on the Site at this time. The nearest viable population is located on the U.S. Army's Yakima Training Center, located to the north and west of the Hanford Site. Other game birds present on the Hanford Site include ring-necked pheasant and California quail.

In recent years, the number of nesting ferruginous hawks has increased, at least in part because the hawks have accepted steel powerline towers as nesting sites. Only about 50 pairs are believed to be nesting in the state of Washington. Other raptors that nest on the Hanford Site are the prairie falcon, northern harrier, red-tailed hawk, Swainson's hawk, and kestrel. Burrowing owls, great horned owls, barn owls, and long-eared owls also nest on the Site but in smaller numbers.

Passerine species inhabiting terrestrial habitats at Hanford include the loggerhead shrike, sage sparrow, and the Western meadowlark. Loggerhead shrikes are year-round residents, although they occur at relatively low densities (Poole 1992). They nest from March through August in undisturbed portions of the big Sagebrush/Sandberg's bluegrass community. The approximate density of the loggerhead shrike is 3.5 pairs/km^2 (9.1 pairs/mi^2). Sage sparrows are a common summer resident of the Hanford Site (Fitzner and Rickard 1975). These small passerines are restricted in their distribution almost entirely to sagebrush stands (Schuler et.al. 1988). Sage sparrow abundance on the 200 Area Plateau has been shown to be related to sagebrush density (Schuler et. al. 1988). Sage sparrow density is up to 7.5 birds/km^2 (19 birds/mi^2) in undisturbed areas of the 200 Area Plateau.

2.8.1.5 Mammals. Approximately 39 species of mammals have been identified on the Hanford Site (Fitzner and Gray 1991) (Table 2-5). The largest vertebrate predator inhabiting the Hanford Site is the coyote, which ranges all across the Site. Bobcats and badgers also inhabit the Hanford Site but in low numbers. Black-tailed jackrabbits are common on the Hanford Site, mostly associated with mature stands of sagebrush. Cottontails are also common but appear to be more closely associated with the buildings, debris piles, and equipment laydown areas associated with the onsite laboratory and industrial facilities.

Townsend's ground squirrels occur in colonies of various sizes scattered across the Hanford Site and marmots are scarce. The most abundant mammal inhabiting the Site is the Great Basin pocket mouse. It occurs all across the Columbia River plain and on the slopes of the surrounding ridges. Other small mammals include the deer mouse, harvest mouse, grasshopper mouse, montane vole, vagrant shrew, and Merriam's shrew.

Seven species of bats inhabit the Hanford Site, occurring mostly as fall or winter migrants. The pallid bat frequents deserted buildings and is thought to be the most abundant of the various species. Other species include the hoary bat, silver-haired bat, California brown bat, little brown bat, Yuma brown bat, and Townsend's big-eared bat.

Mule deer are found throughout the Hanford Site, although areas of highest concentrations are on the ALE Reserve and along the Columbia River. Deer populations on the Hanford Site appear to be relatively stable. The herd is characterized by a large proportion of very old animals (Eberhardt et al. 1982). Islands in the Hanford Reach of the Columbia River are used extensively as fawning sites by the deer (Eberhardt et al. 1979) and thus are a very important habitat for this species. Hanford Site deer frequently move offsite and are killed by hunters on adjacent public and private lands (Eberhardt et al. 1984).

2.8.2 Species of Special Concern at the Hanford Site

The remaining undisturbed shrub-steppe habitat at the Hanford Site has been designated priority habitat by the Washington State Department of Wildlife due to its relative scarcity in the state and its importance as nesting, breeding and foraging habitat for state- and federal listed or candidate sensitive species. This designation is a proactive measure to prevent species from becoming threatened or endangered. Threatened and endangered plants and animals identified on the Hanford Site, as listed by the federal government (50 CFR 17) and Washington State (Washington Natural Heritage Program 1994), are shown in Tables 2-3, 2-4, 2-5, and 2-6. No plants or mammals on the federal list of Endangered and Threatened Wildlife and Plants are known to occur on the ERDF Site. There are, however, several species of both plants and animals that are of concern or are under consideration for formal listing by the federal government and Washington State.

2.8.2.1 Plants. The Washington Natural Heritage Program, administered by the Department of Natural Resources, is tasked with monitoring the status of vascular plants in the state of Washington. Plant species are designated as endangered, threatened, sensitive, or monitored according to the species' status in Washington state. Columbia milkvetch (*Astragalus columbianus*) and Hoover's desert parsley (*Lomatium tuberosum*) are listed as threatened, and persistentsepal yellowcress (*Rorippa columbiae*) and northern wormwood (*Artemisia campestris borealis* var. *wormskioldii*) are designated as endangered. These four plant species are also listed as candidate species by the Federal government. Columbia milkvetch occurs on dry land benches along the Columbia River in the vicinity of Priest Rapids Dam, Midway, and Vernita; it also has been found on top of Umtanum Ridge and in Cold Creek Valley near the present vineyards. Hoover's desert parsley grows on steep talus slopes in the vicinity of Priest Rapids Dam, Midway, and Vernita. Yellowcress occurs in the wetted zone of the water's edge along the Columbia River. Northern wormwood is known to occur near Beverley and could inhabit the northern shoreline of the Columbia River across from the 100 Areas.

Thompson's sandwort (*Arenaria franklinii v. thompsonii*) is listed as a monitored species and is known to occur in stabilized sand dunes in the vicinity of the 200 Area (DOE 1987). Other plant species designated as sensitive by the Washington State National Heritage program and likely to be found in the dryland areas of the Hanford Site are Piper's daisy (*Erigeron piperianus*), and gray cryptantha (*Cryptantha leucophaea*) (DOE 1989). False yarrow *(Chaenactis douglassii* var. *glandulosa)* is also likely to be found in these areas but it has been re-classified from a sensitive species to a monitor species. A recent survey of the proposed ERDF site identified stalked-pod milkvetch (*Astragalus sclerocarpus*), a Washington State monitored species, as the only state listed plant present. Table 2-6 lists plant species of special concern and their state and federal status that have been identified at the 200 Area and other locations on the Hanford Site.

2.8.2.2 Animals. Both the Washington Department of Wildlife and U.S. Fish and Wildlife Service are responsible for monitoring the status of animal species (Woodruff and Hanf 1992). The sage sparrow (*Amphispiza belli*), and sage thrasher (*Oreoscoptes montanus*) are listed as state candidate species, and depend on sagebrush and bitterbrush for nesting although the sage thrasher is not known to nest near the 200 Area (DOE 1987). The loggerhead shrike (*Lanius ludovicianus*) is listed as a state and federal candidate species and also inhabits the sagebrush-bitterbrush environment. The grasshopper sparrow (*Ammodramus savannarum*) is a state monitored species found at the Hanford Site. Golden eagles (*Aquila chrysaetos*) are winter visitors to the Hanford Site and forage in the vicinity of the 200 Area. Burrowing owls (*Athene cunicularia*) nest on the ground and forage in the vicinity of the 200 Area. Swainson's hawks (*Buteo swainsoni*) are known to use planted trees in the 200 Area for nesting sites and forage in the area. The golden eagle, burrowing owl, and Swainson's hawk are Washington state candidate species. The long-billed curlew *(Numenius americanus)* has been proposed for monitor status in Washington state, is a federal candidate species, and is known to nest on the ground in the vicinity of the 200 Area. Table 2-4 lists bird species known to occur at the Hanford Site and their state and federal status.

The pallid bat (*Antrozous pallidus*), a state monitored species, is likely to inhabit the 200 Area. Merriam's shrew (*Sorex merriami*), a state candidate species, and Townsend's big-eared bat (*Plecotus townsendii*), a federal candidate species, are also found at the Hanford Site. The pygmy rabbit (*Brachylagus idahoensis*), a federal candidate and is a state endangered species, is a potential inhabitant of the Hanford Site, but none have been found at the Site. The striped whipsnake (*Masticophis taeniatus*) listed by the state as candidate species, and the woodhouse toad (*Bufo woodhousei*) and the desert night snake (*Hypsiglena torquata desertia*) are listed as monitored species. Table 2-5 lists mammals known to occur at the Hanford Site and their state and federal status. Table 2-3 lists amphibians and reptiles known to occur at the Hanford Site and their state status (none are listed by the Federal government).

2.8.3 Wildlife Refuges

Several national and state wildlife refuges are located on or adjacent to the Hanford Site. These refuges are shown in Figure 2-39.

2.8.4 ERDF Ecology

A recent survey of the planned ERDF site found it to be primarily undisturbed sagebrush habitat that had not sustained significant fire damage. The recent surveys identified long-billed curlews, sage sparrows, and loggerhead shrikes as nesting in the area. Grasshopper sparrows were present and possibly nesting at the site. Swainson's hawks were observed hunting in the area. Burrowing owls, while not observed during the surveys, have been seen at the site in the past and are presumed to currently inhabit the area.

2.9 CHARACTERISTICS OF FINE-GRAINED SOILS BORROW SITE (MCGEE RANCH)

2.9.1 Site Description

The McGee Ranch area is the proposed borrow site for fine-textured soils, although a complete evaluation of the impacts on cultural, historical, and ecological resources and a mitigation plan remain to be completed before the site can be developed. As shown in Figure 2-40, McGee Ranch is located approximately 5 km (3 mi) northwest of the 200 West Area. Figure 2-41 illustrates the general site topography. The ground surface generally slopes to the east or southeast and is dissected by approximately 10 east-trending ephemeral streams. The McGee Ranch has been identified as a potential borrow site for fine-grained sediments that may be used in the construction of closure covers at the ERDF and other locations at the Hanford Site. The fine-grained materials would be used in the closure covers as top-soil material and also as low-permeability barrier material. Use of this site as a source of fine-textured soils is not impacted by inclusion of the McGee Ranch as part of the 100-IU-1 operable unit.

2.9.2 Characteristics of Site Sediments and Fine-Grained Sediment Volume Estimates

2.9.2.1 Geological Characteristics. The geological characteristics of the McGee Ranch discussed in this section are based on two characterization efforts conducted within the McGee Ranch. The first characterization effort investigated an area of the site referenced as Area A on Figure 2-41 (Last et al. 1987). The second effort evaluated the area referenced as Area B on Figure 2-41 (Lindberg 1994).

The evaluation of Area A was based on a series of boreholes drilled, sampled and logged to the first significant gravel layer detected. Sediments from each boring were classified based on grain-size into one of 19 sediment classifications. A layer of fine-grained sediments was identified immediately below the surface at Area A and ranges in thickness from 0.5 to 10 m (1.6 to 32.8 ft). A layer of silty-sandy gravel was identified directly beneath the surficial layer of fine-grained sediments.

Characterization of Area B of the McGee Ranch is also based on a series of boreholes. In most cases, borehole sampling was discontinued when carbonate-cemented, silty, sandy gravels were intercepted. However, a few boreholes were drilled into the gravels as far as 4 m (13 ft). The gravel units encountered at the bottom of the boreholes consist of angular basalt gravel weakly cemented with calcium carbonate and lesser amounts of silica. The gravel size distribution was not determined because the drilling technique used did not allow representative sampling. Observations of recovered fractured gravels indicated the gravels consist primarily of pebbles with some cobbles. Carbonate concentrations were also estimated to be the strongest in the upper 0.3 to 0.6 m (1 to 2 ft) of the gravel unit. These gravels are characteristic of the geologic strata referred to as the Plio-Pleistocene Unit found elsewhere on the Hanford Site.

Hanford formation sediments at the site overlay the Plio-Pleistocene unit and range in thickness from 0.15 m to 12.2 m (0.5 to 40 ft). The Hanford formation sediments consist of a series of graded beds composed of silt to fine sands referred to as the Touchet Beds. The beds of fine sands and silts were occasionally interspersed with small amounts of fine gravels. Clastic dikes also are identified. These dikes consist of sediment layers aligned parallel to the dike walls and composed of sediments similar to the Hanford formation sediments.

Surficial sediments consisting of eolian silt to sandy silt (loess) overlay the Hanford formation and range in thickness up to 1 m (3 ft). The interface of the upper Hanford formation and the surficial deposits was difficult to determine due to bioturbation and because the local loess has been derived from Touchet Bed sediments. Soils in the area investigated are typical of soils that develop at this altitude under similar conditions. The upper soil layer contains an abundant quantity of roots and the next lower soil level consists of sandy silt graded downward to carbonate-cemented sandy silt. The ground surface at the McGee Ranch is covered with pebbles, some cobble gravels and occasional boulders. The gravels generally occur in low densities, however areas of significantly high density are also present. Gravels are composed of both basalt colluvium and exotic gravels. Exotic gravel deposition is the result of ice rafting during prehistoric glacial flooding.

2.9.2.2 Volume Estimates for Fine-Grained Sediments. The volume of suitable sediments identified at Area A of the McGee Ranch was calculated based on the information collected during borehole sampling and logging. The estimated total volume of fine-grained sediments in Area A suitable for closure cover construction is 3.47 Mm^3 (4.55 Myd^3) (Lindberg 1994).

Estimated volumes of fine-grained sediments for Area B were developed using three dimensional modeling. Contour structure maps and isopach maps of intervening intervals were constructed using data collected from borehole sampling. The isopach maps identify an east-sloping wedge of fine-grained sediments (Touchet Beds and eolian sediments) thickening in the direction of the slope. The sediments range in thickness from 3 m (10 ft) in the western section to over 12 m (40 ft) in the east. An isopach map was constructed by subtracting the lower surface of the Touchet Beds from the upper ground surface at each borehole and then contouring the difference. This method considers data between boreholes and adjusts for surficial topographic features between boreholes. The combined volume of suitable Touchet Bed and eolian sediments estimated using this technique was estimated by Lindberg (1994) at 32.7 Mm^3 (42.8 Myd^3).

2.9.3 Archaeological and Cultural Characteristics

A cultural resources pedestrian survey has identified a number of historic and prehistoric resources at the McGee Ranch Site (Skelly and Wing 1992). Plans are being developed to address mitigation of impacts to cultural resources at the McGee Ranch.

2.9.4 Wildlife Ecology

Reconnaissance surveys have been carried out at the proposed borrow site by qualified professionals. No resident species of plants or animals of special concern were identified. However, one or more protected species of birds may use the area during the nesting season, or may exhibit variable patterns of habitation from year to year (Skelly and Wing 1992).

2.10 CHARACTERISTICS OF BASALT BORROW SITE

The borrow site for crushed basalt for the Hanford Barrier is currently being evaluated.

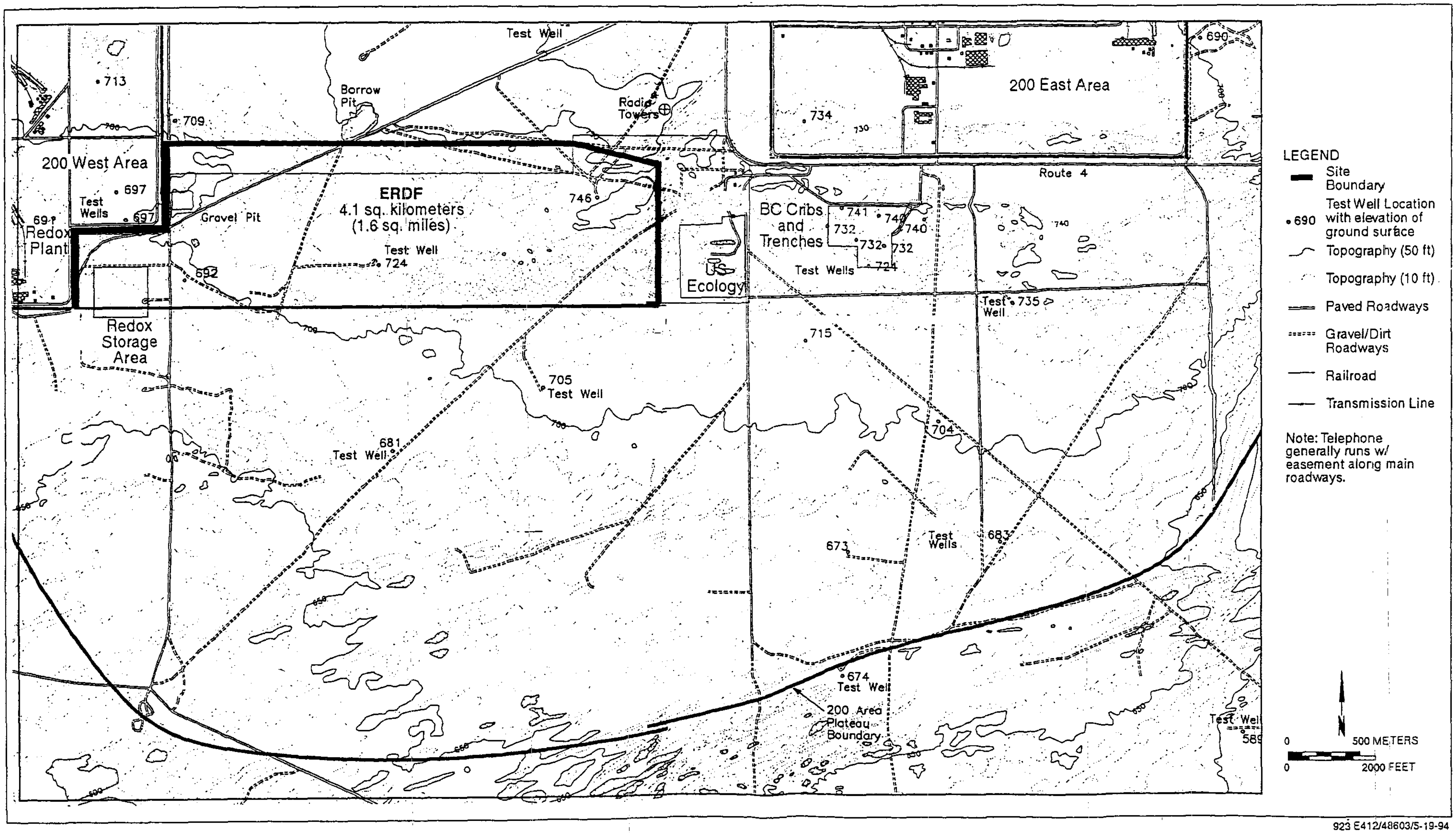

Figure 2-1. Location of the Proposed Environmental Restoration Disposal Facility.

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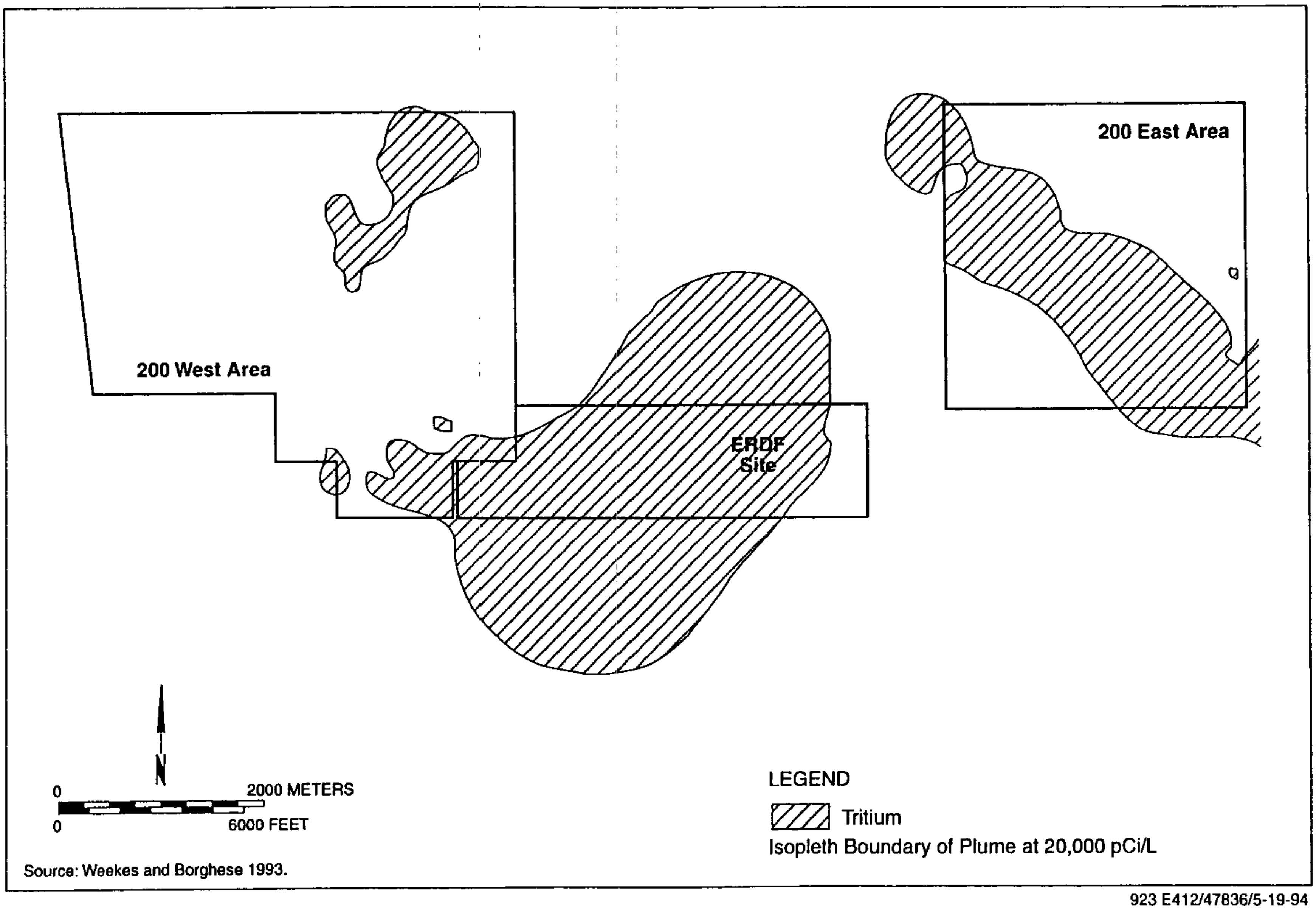

Figure 2-2. Tritium Groundwater Plume Map.

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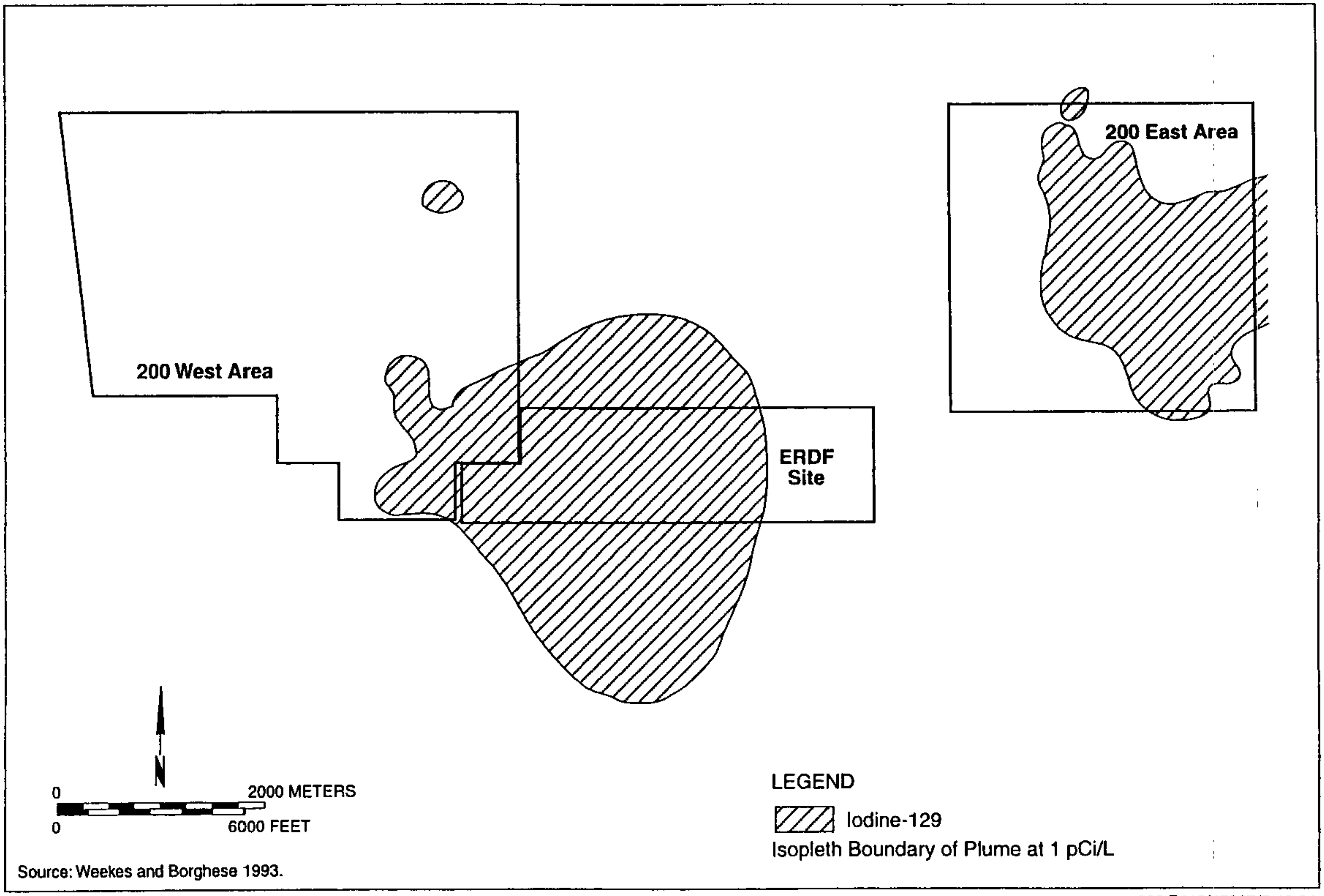

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Figure 2-3. Iodine-129 Groundwater Plume Map.

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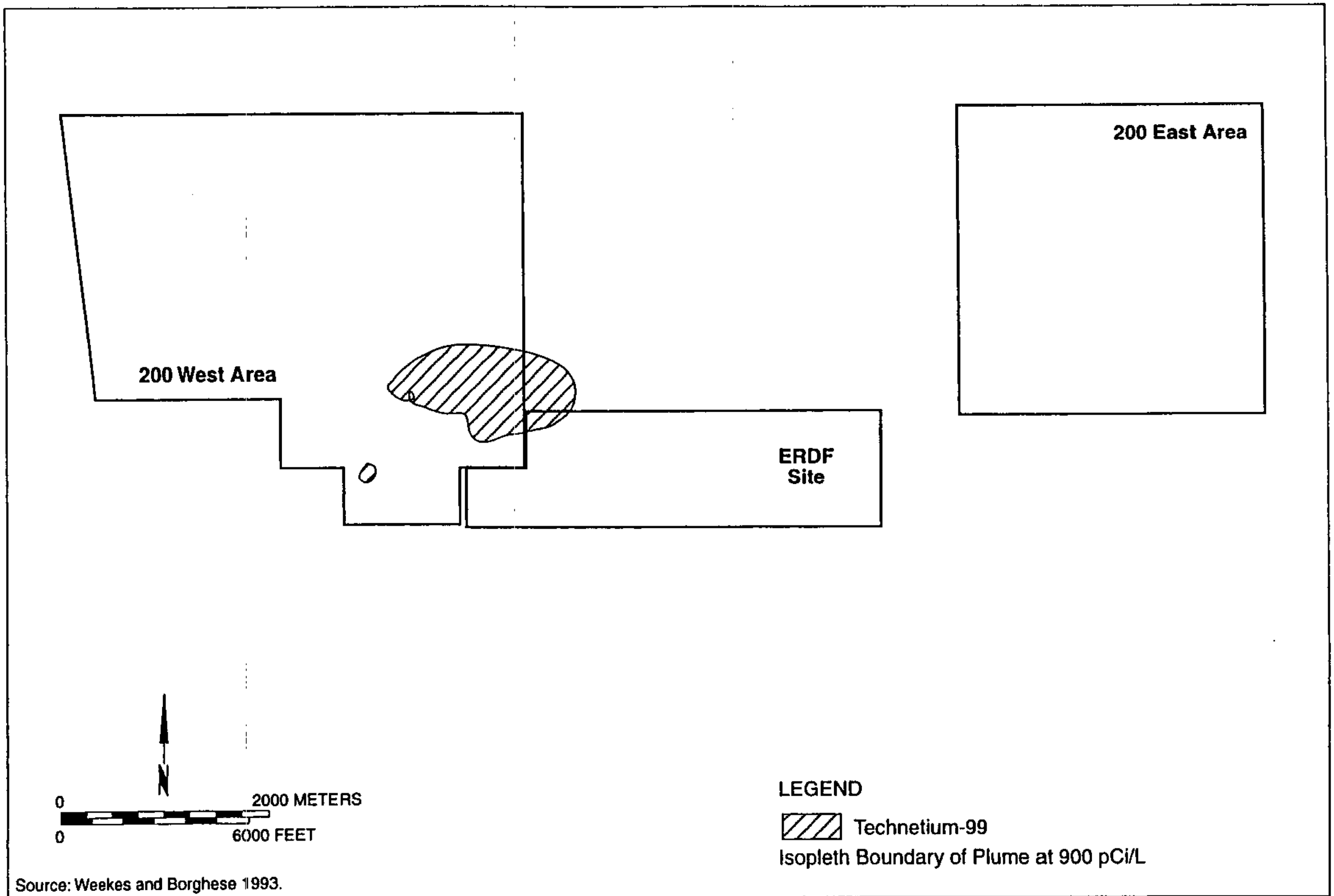

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Figure 2-4. Technetium-99 Groundwater Plume Map.

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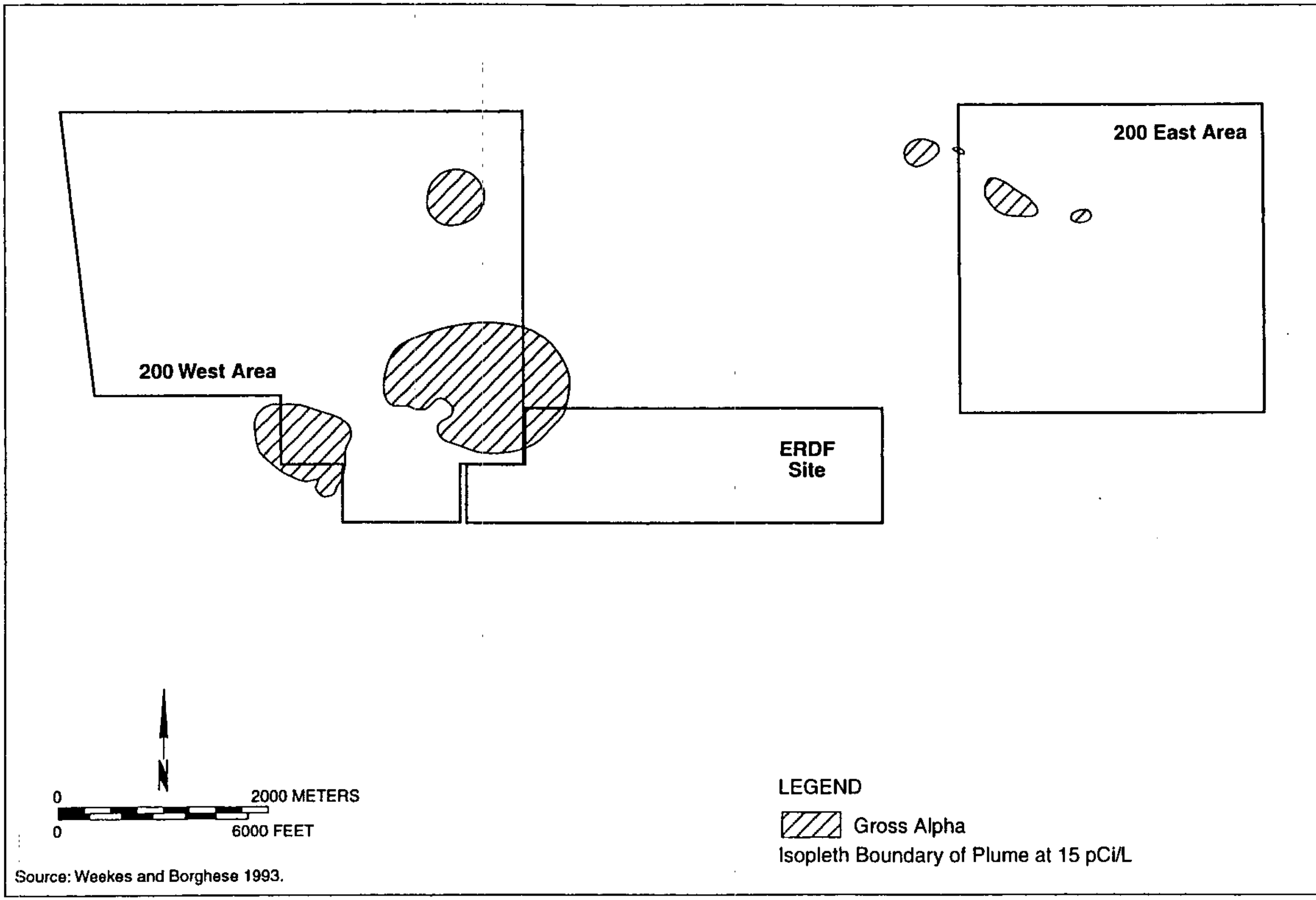

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Figure 2-5. Gross Alpha Groundwater Plume Map.

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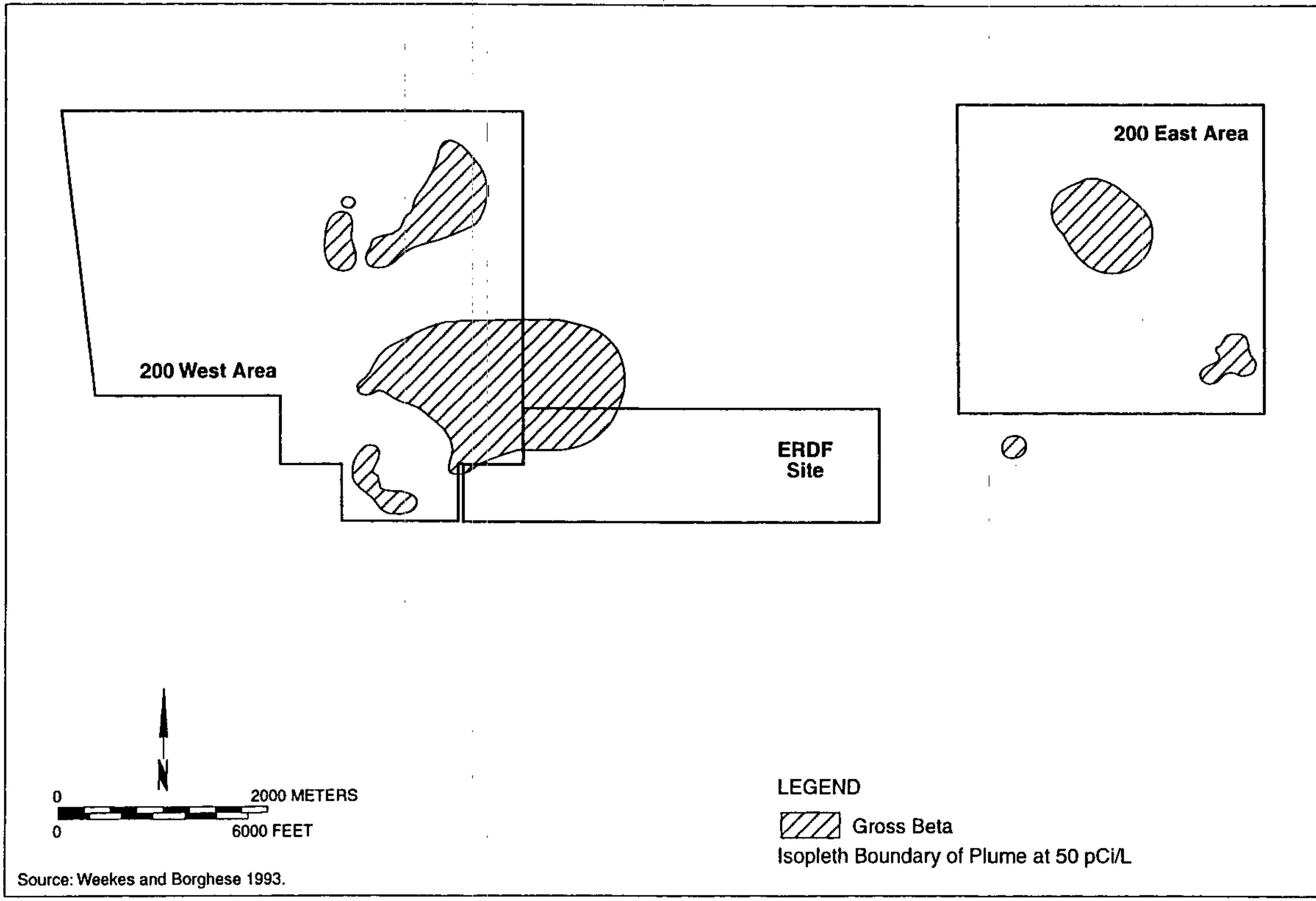

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Figure 2-6. Gross Beta Groundwater Plume Map.

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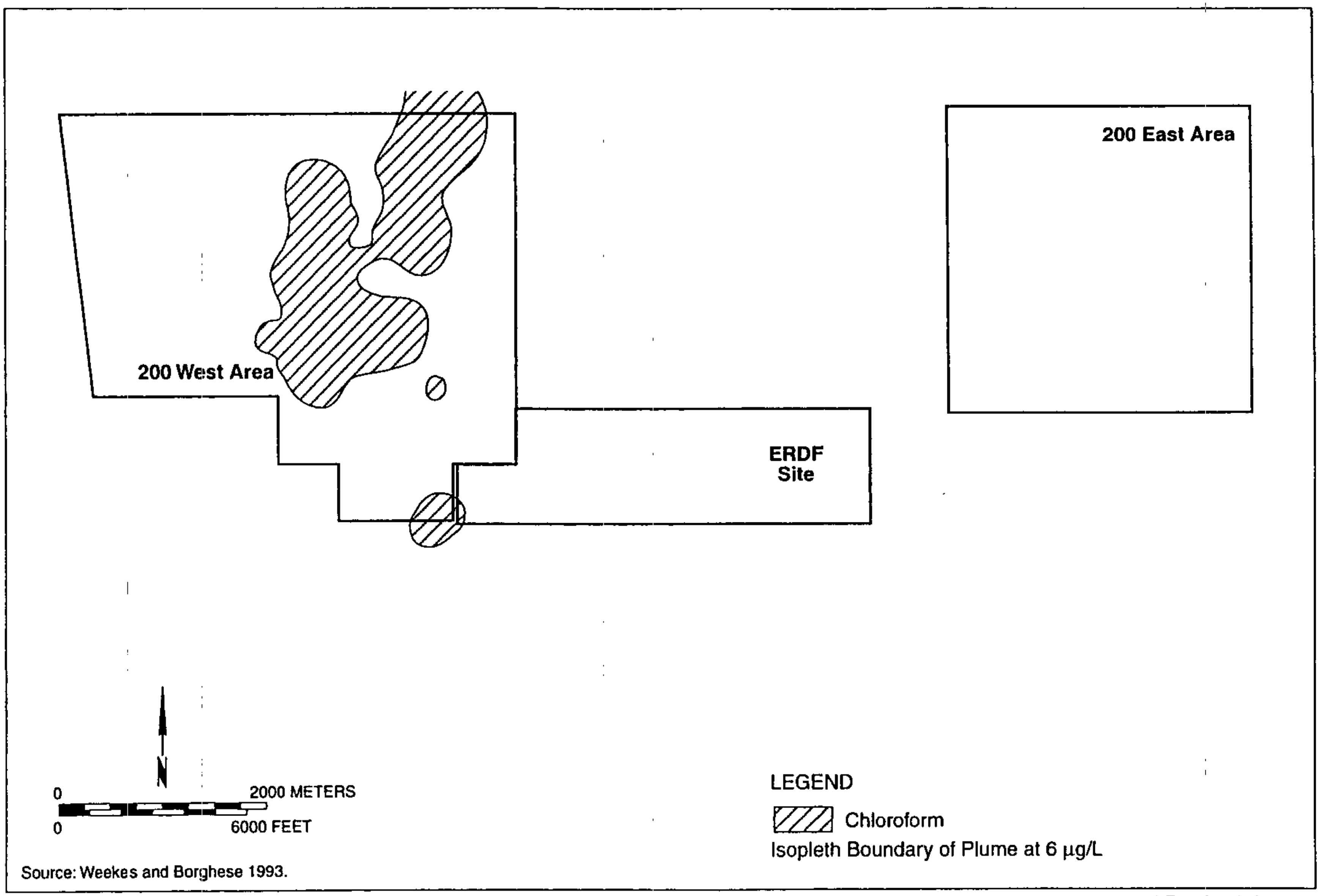

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Figure 2-7. Chloroform Groundwater Plume Map.

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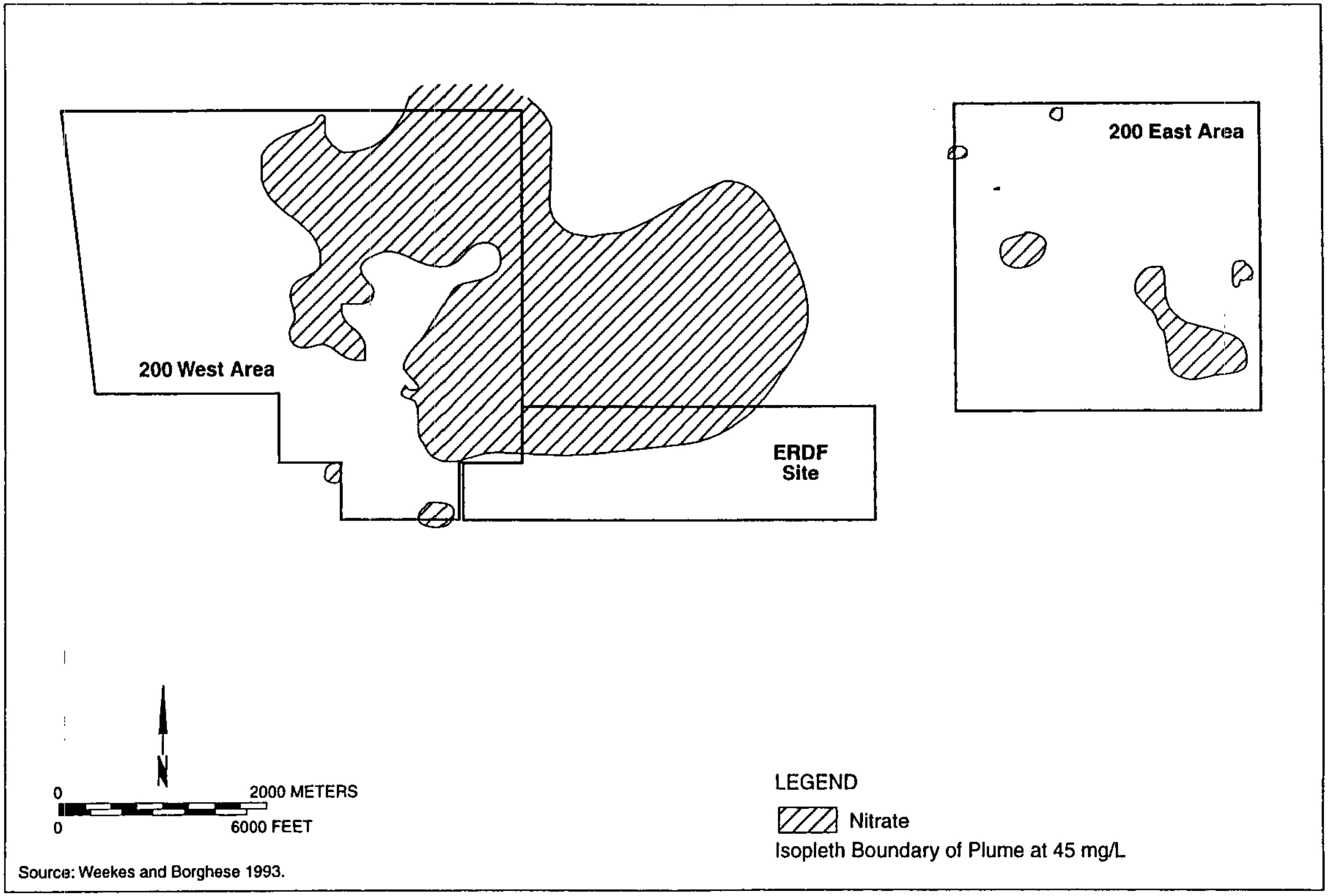

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Figure 2-8. Nitrate Groundwater Plume Map.

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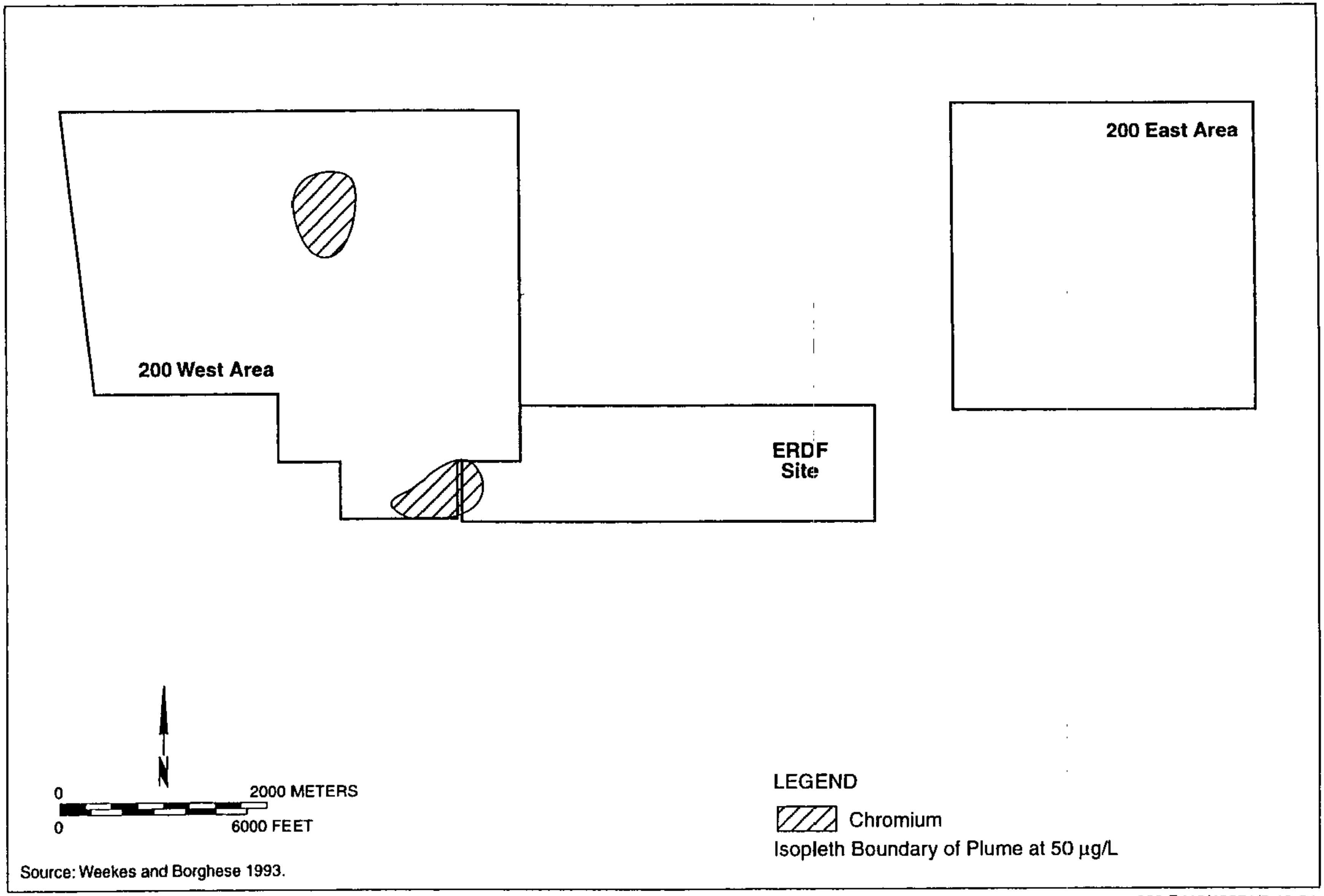

923 E412/48571/5-19-94

Figure 2-9. Chromium Groundwater Plume Map.

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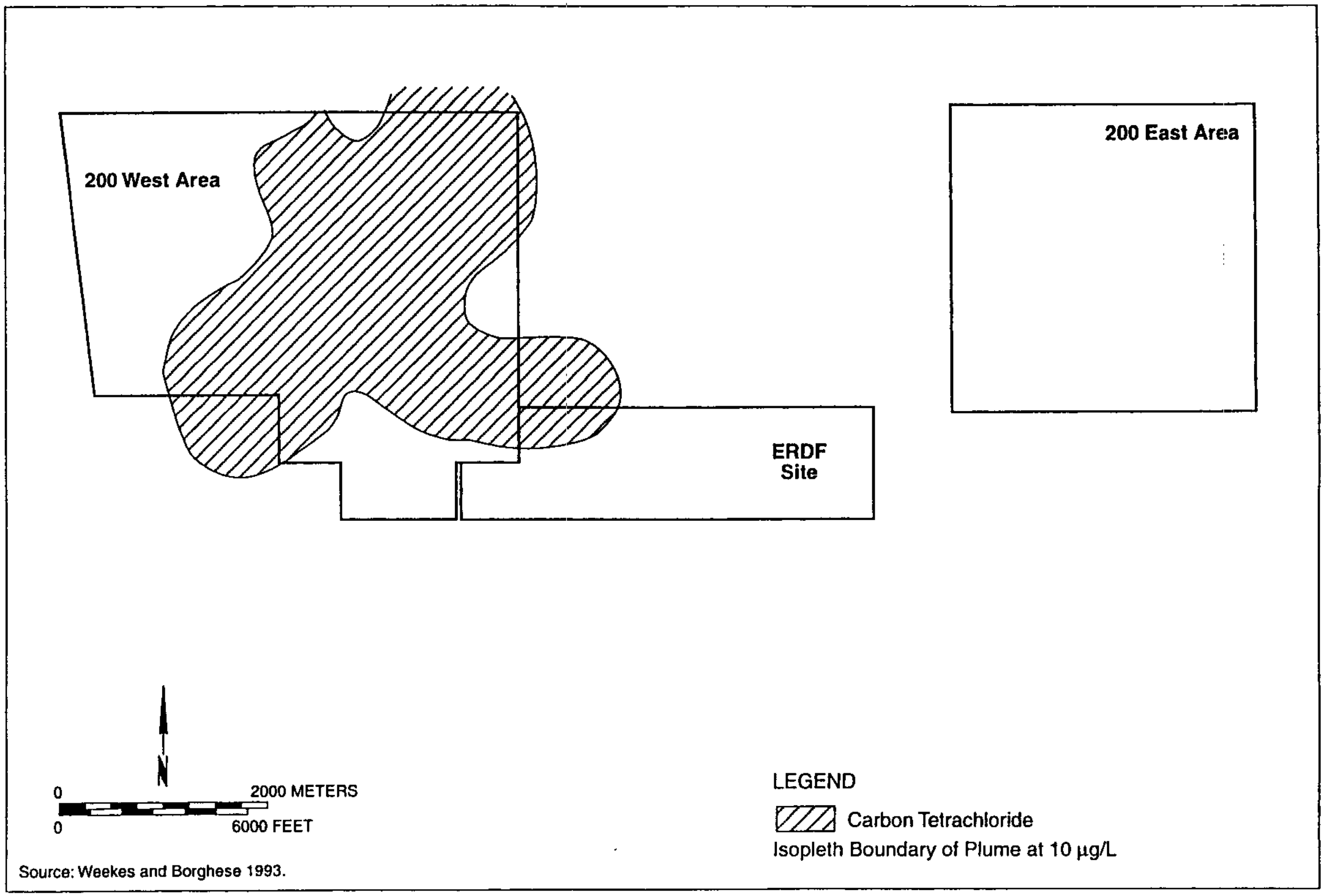

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Figure 2-10. Carbon Tetrachloride Groundwater Plume Map.

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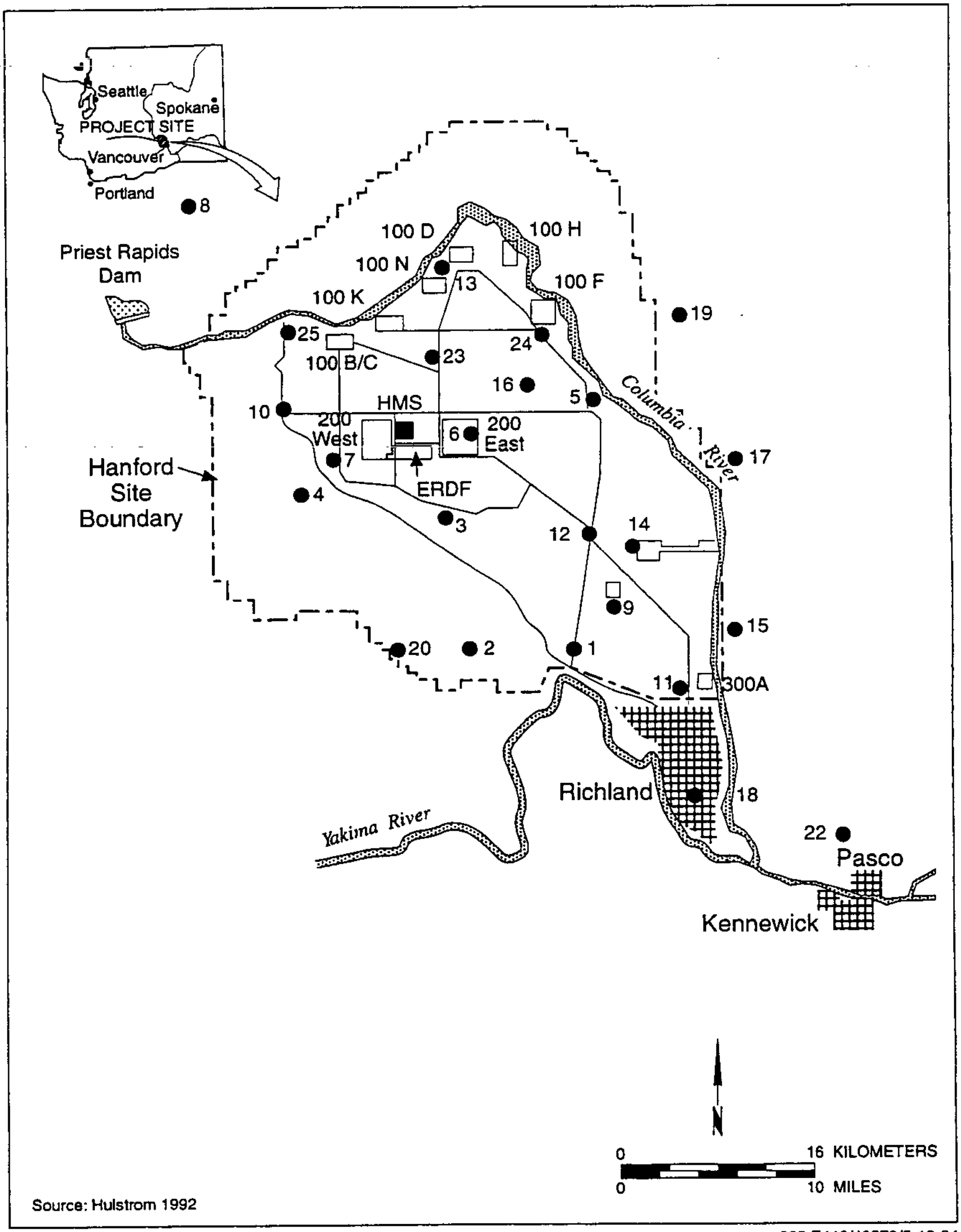

Figure 2-11. Meteorologic Monitoring Stations at the Hanford Site.

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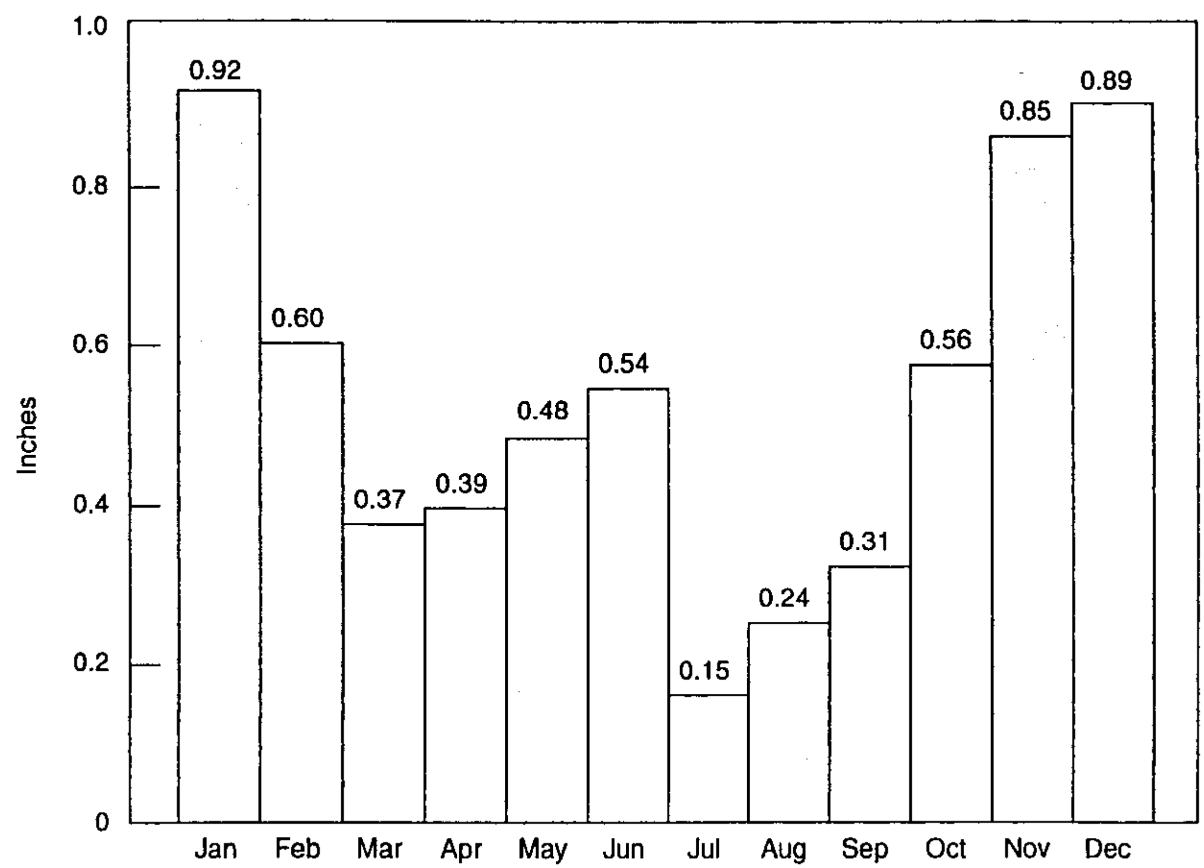

1 in = 2.54 cm

Source: Stone et al. 1983

923 E412/48574/5-19-94

Figure 2-12. Monthly Average Precipitation Amounts, 1912 through 1980.

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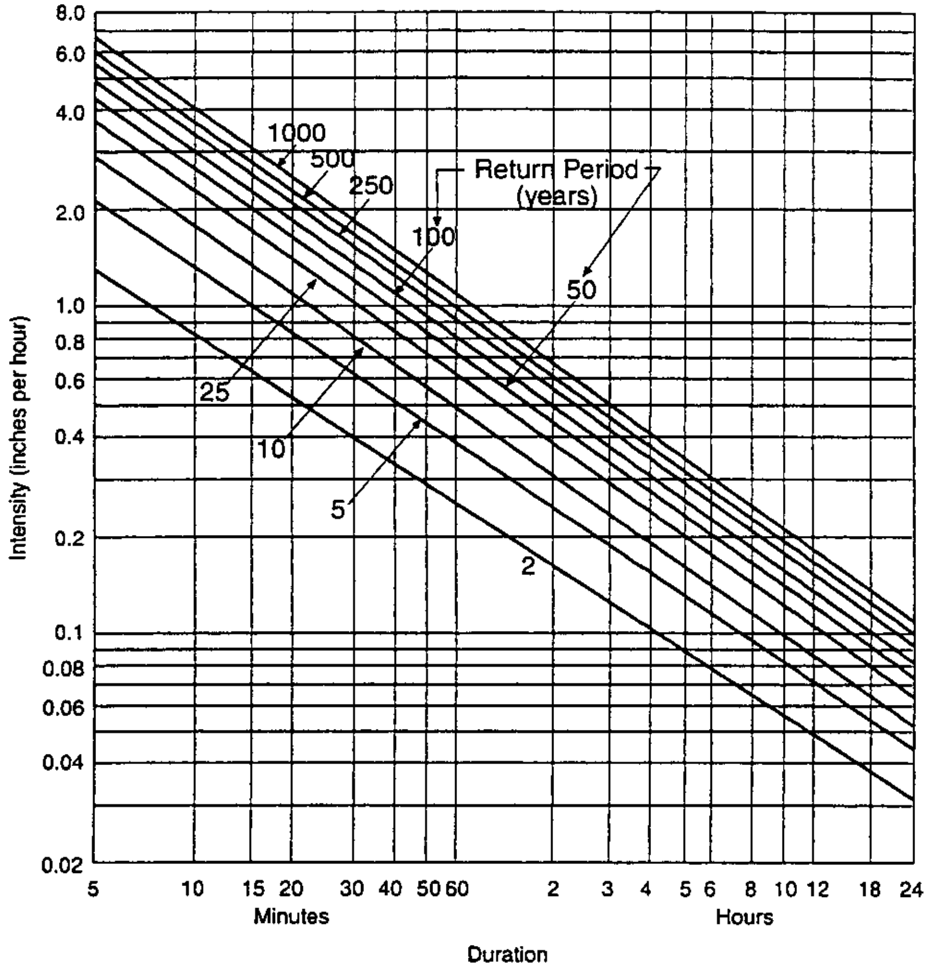

Source: Stone et al. 1983.

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Figure 2-13. Rainfall Intensity Duration and Frequency Based on the Period 1947 to 1969 at Hanford.

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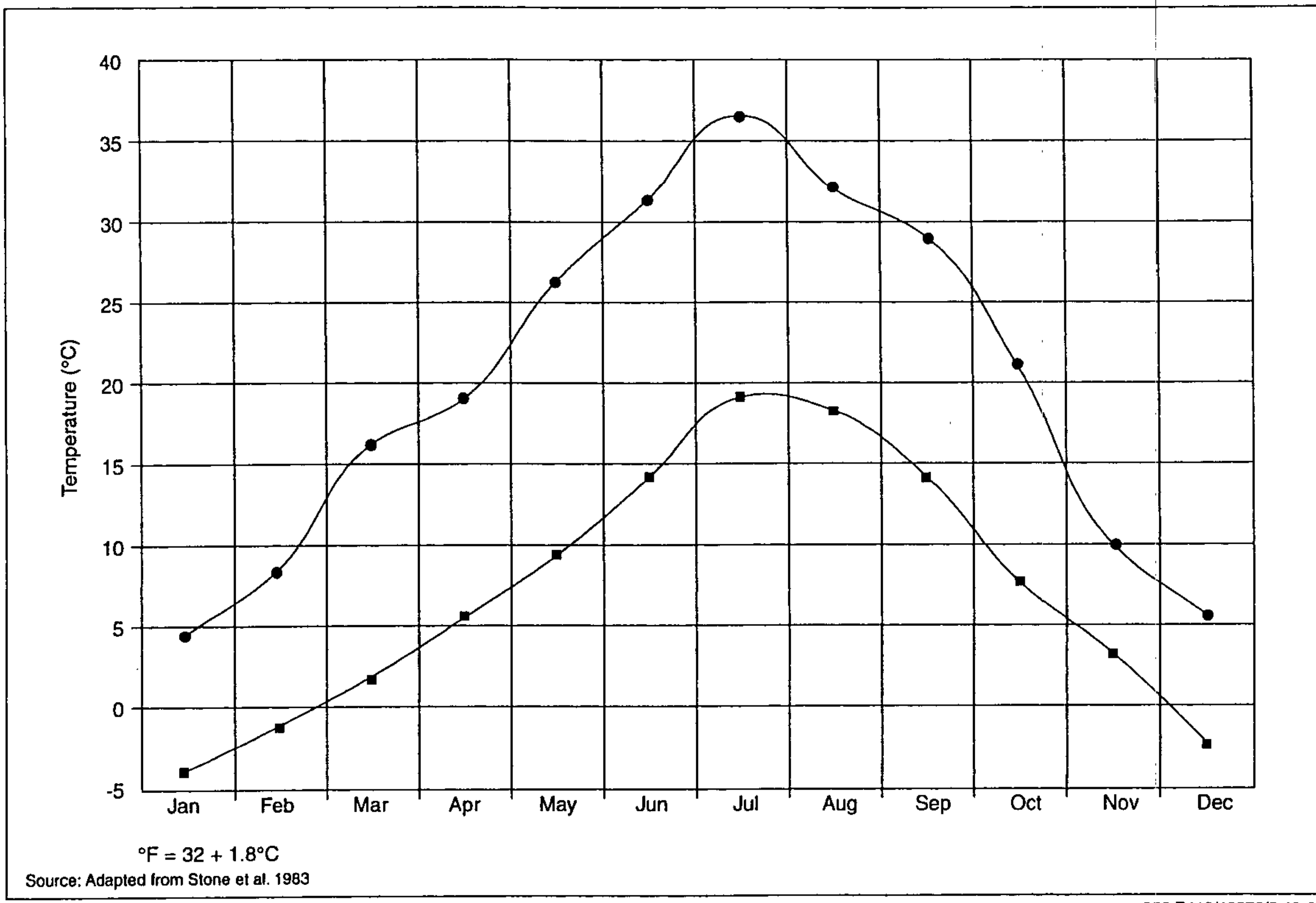

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Figure 2-14. HMS Monthly Average High and Low Air Temperatures, 1951 through 1980.

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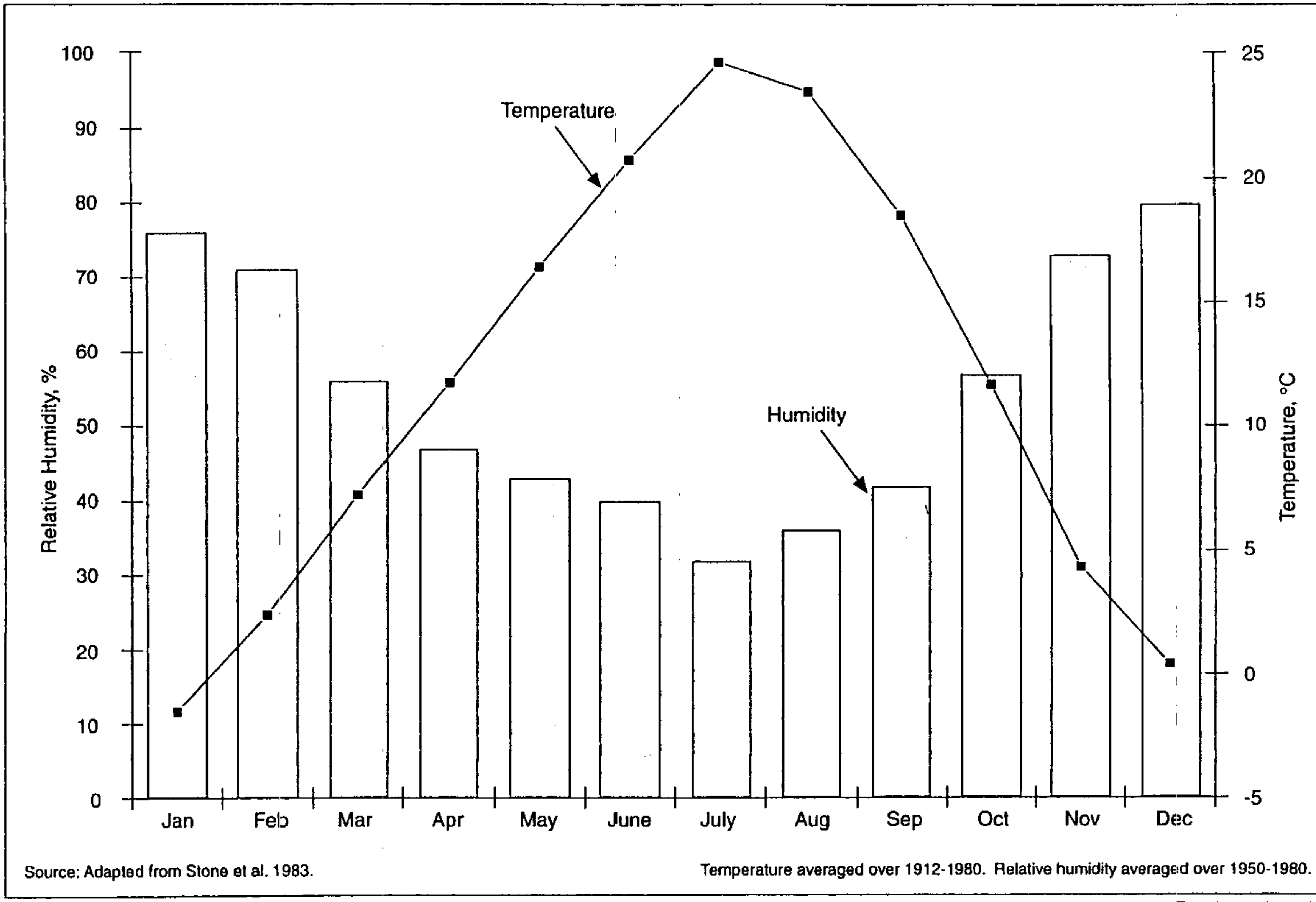

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Figure 2-15. Average Monthly Temperature and Relative Humidity at the HMS.

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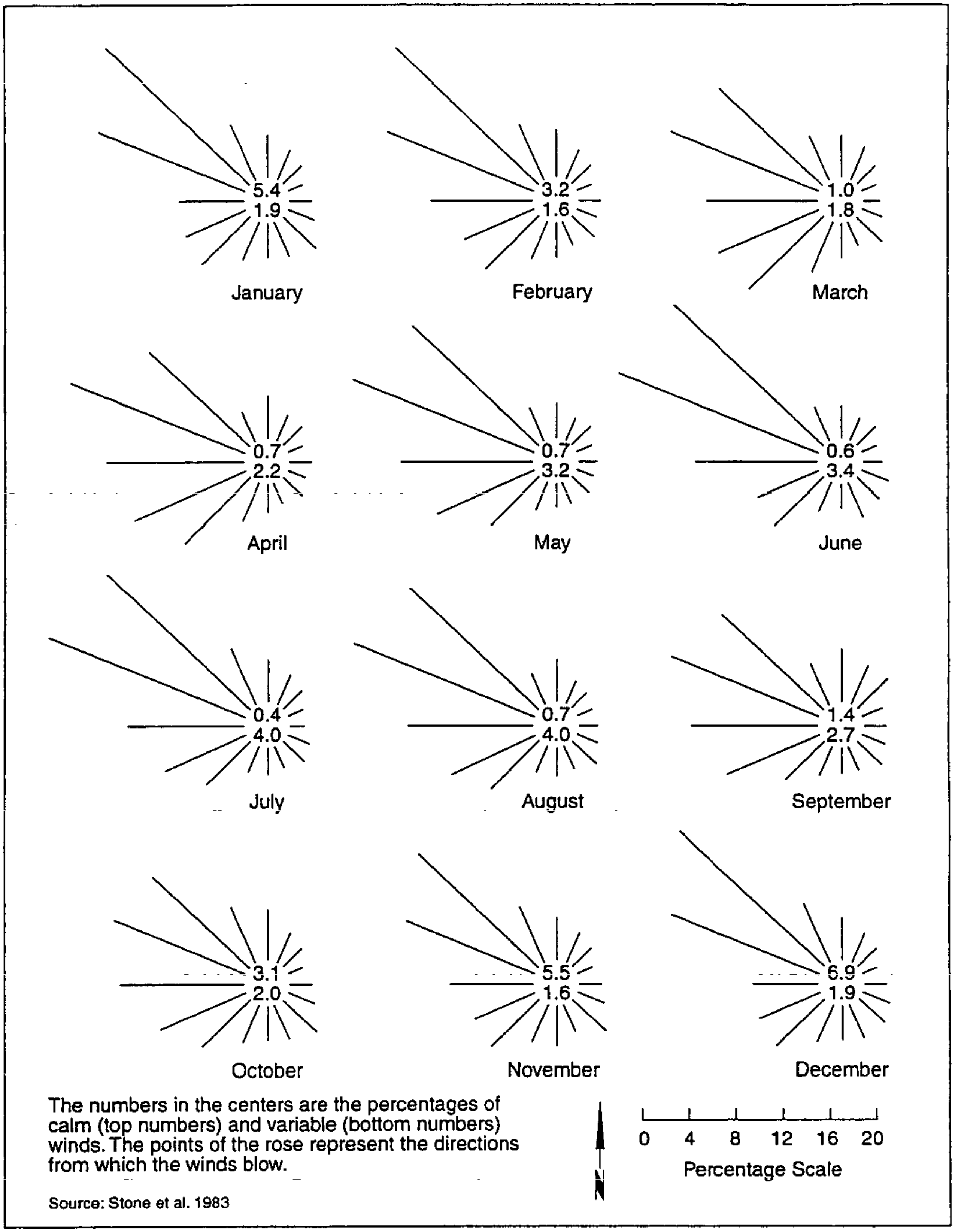

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Figure 2-16. Monthly Wind Roses for HMS Based on 50 foot Wind Data, 1955 through 1980.

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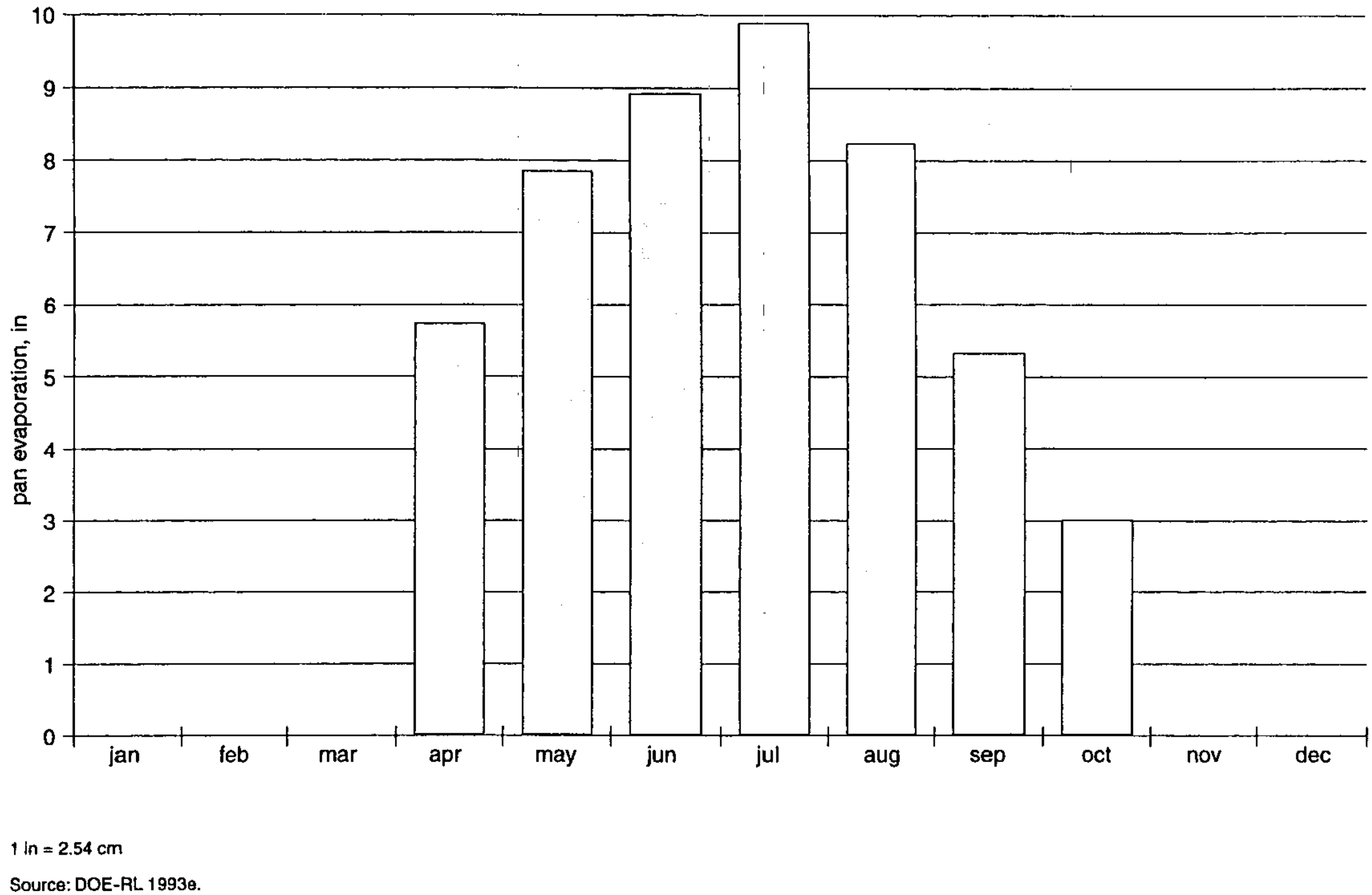

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Figure 2-17. Average Monthly Pan Evaporation at Prosser, WA for the Period 1924-1988. (Measurements not taken for November through March)

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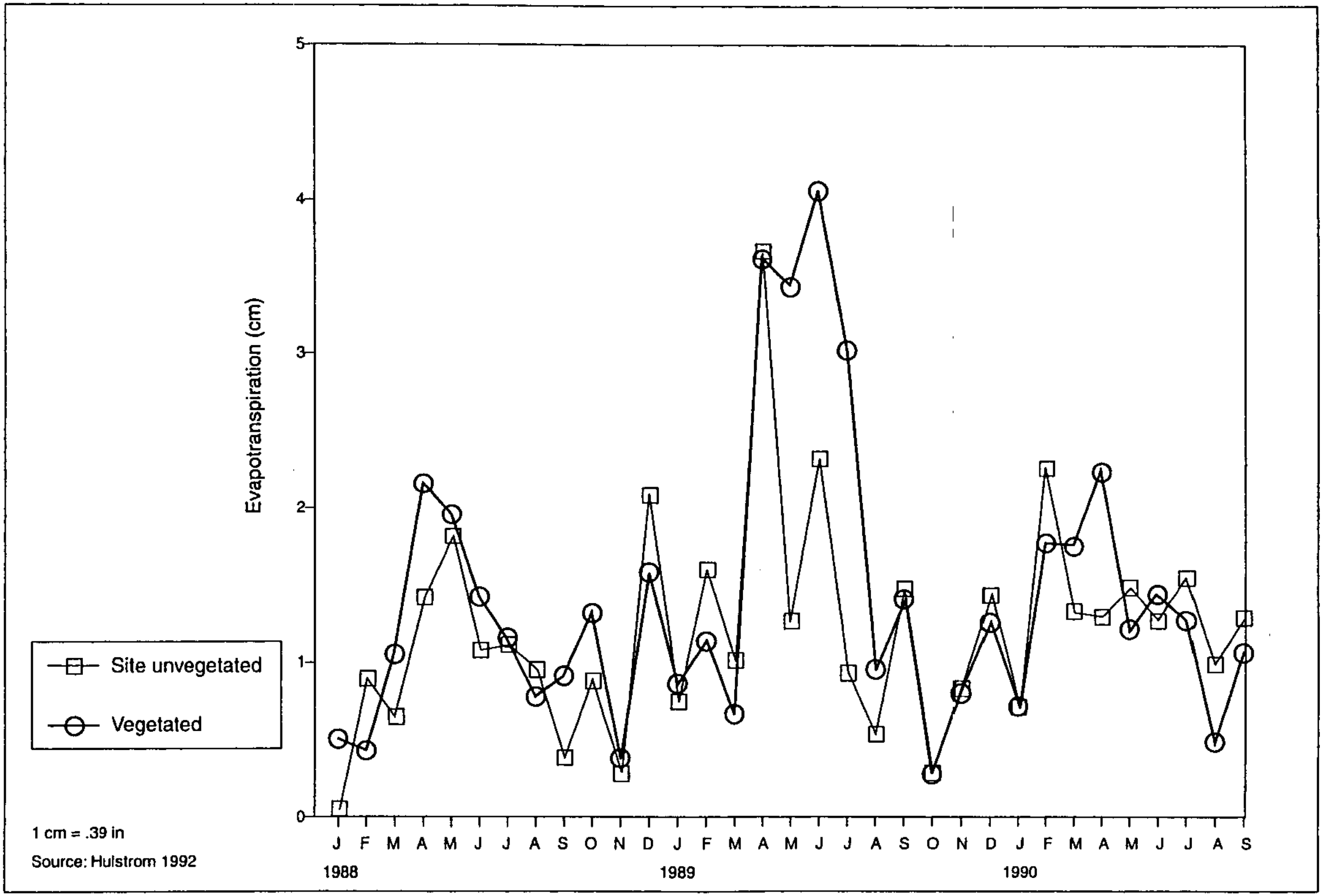

923 E412/48581/5-19-94

Figure 2-18. Total Monthly Evapotranspiration Near the 300 Area.

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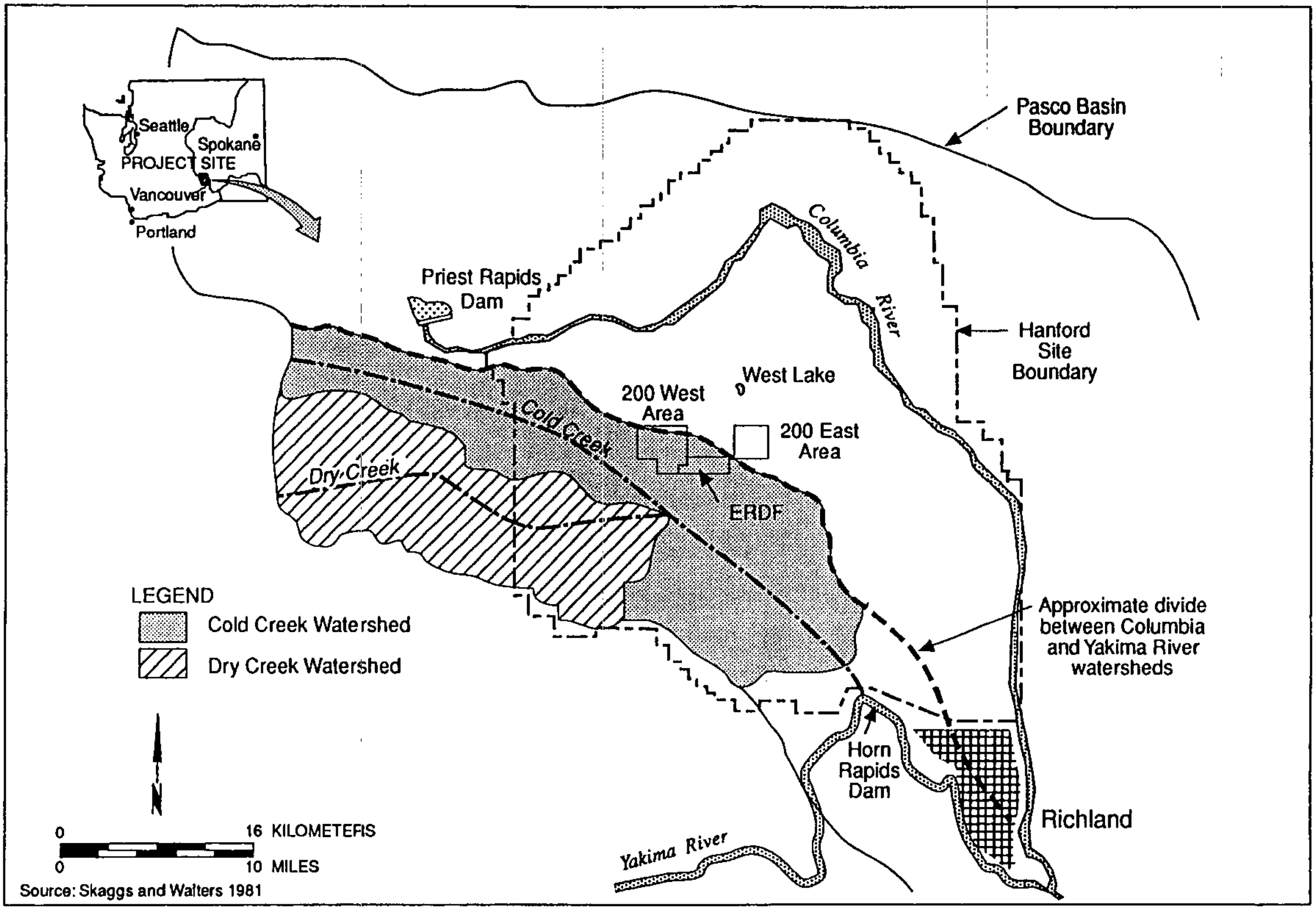

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Figure 2-19. Approximate Location of Major Drainage Divides.

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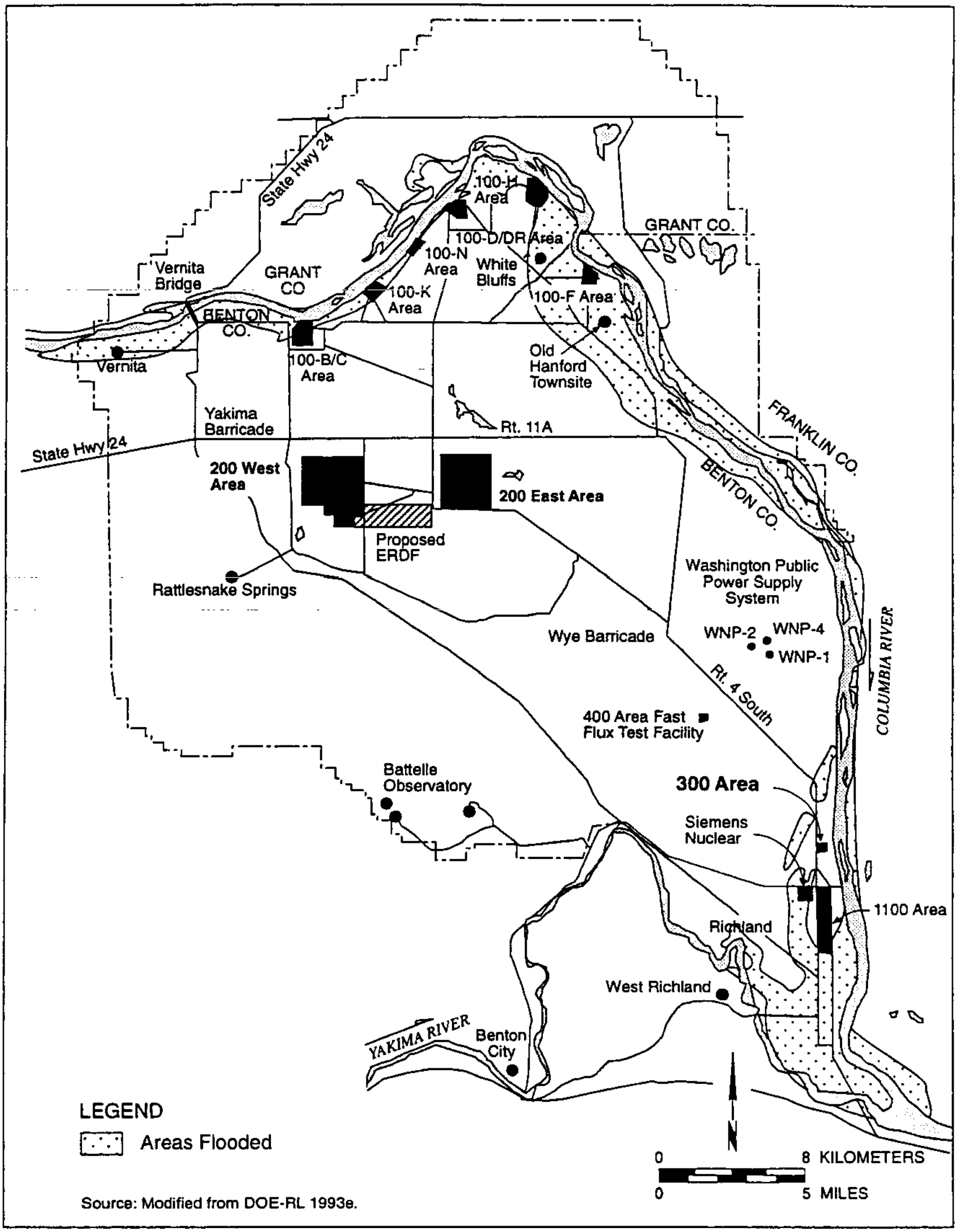

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Figure 2-20. Probable Maximum Flood Areas on the Columbia River.

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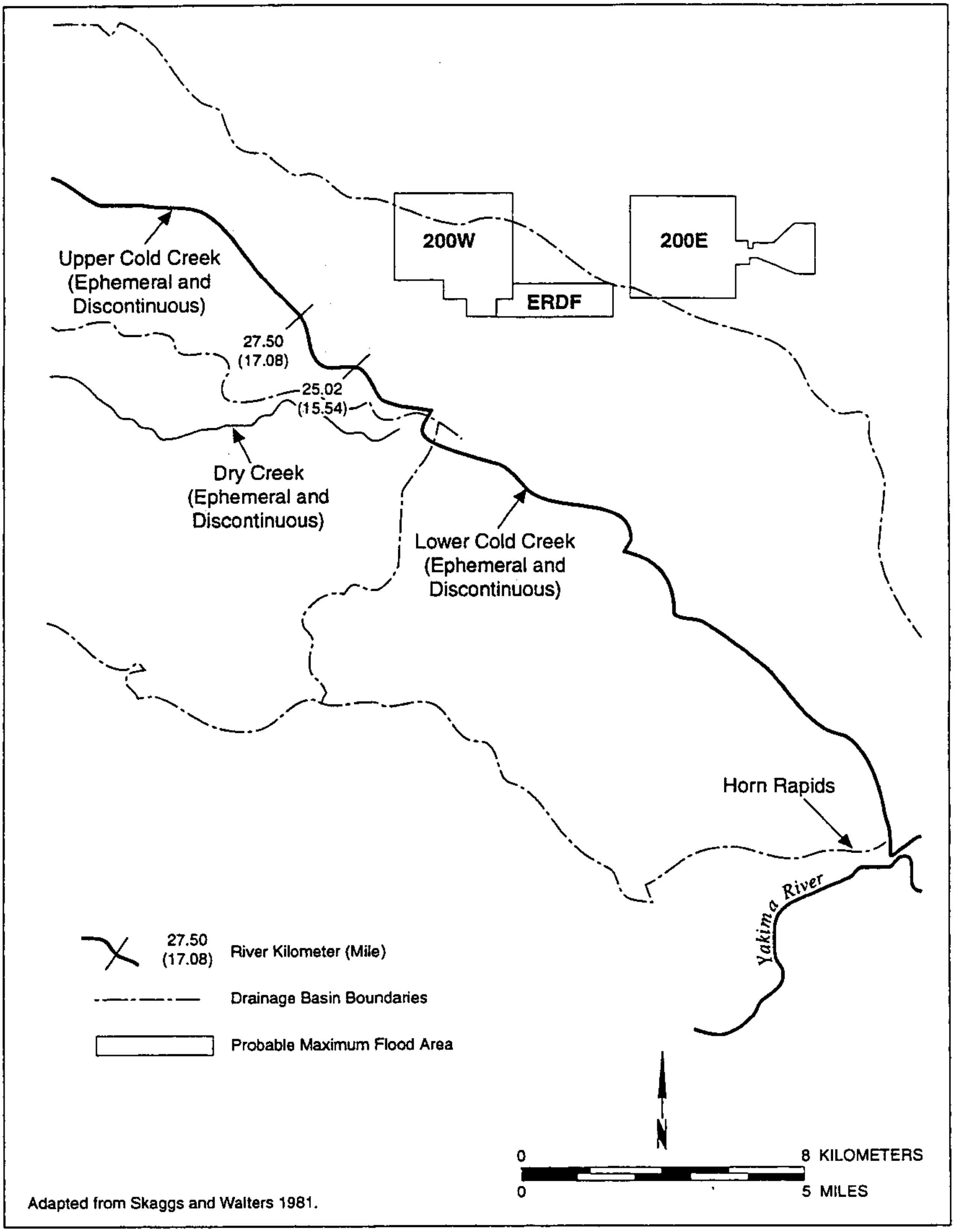

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Figure 2-21. Extent of Probable Maximum Flood in Cold Creek Area.

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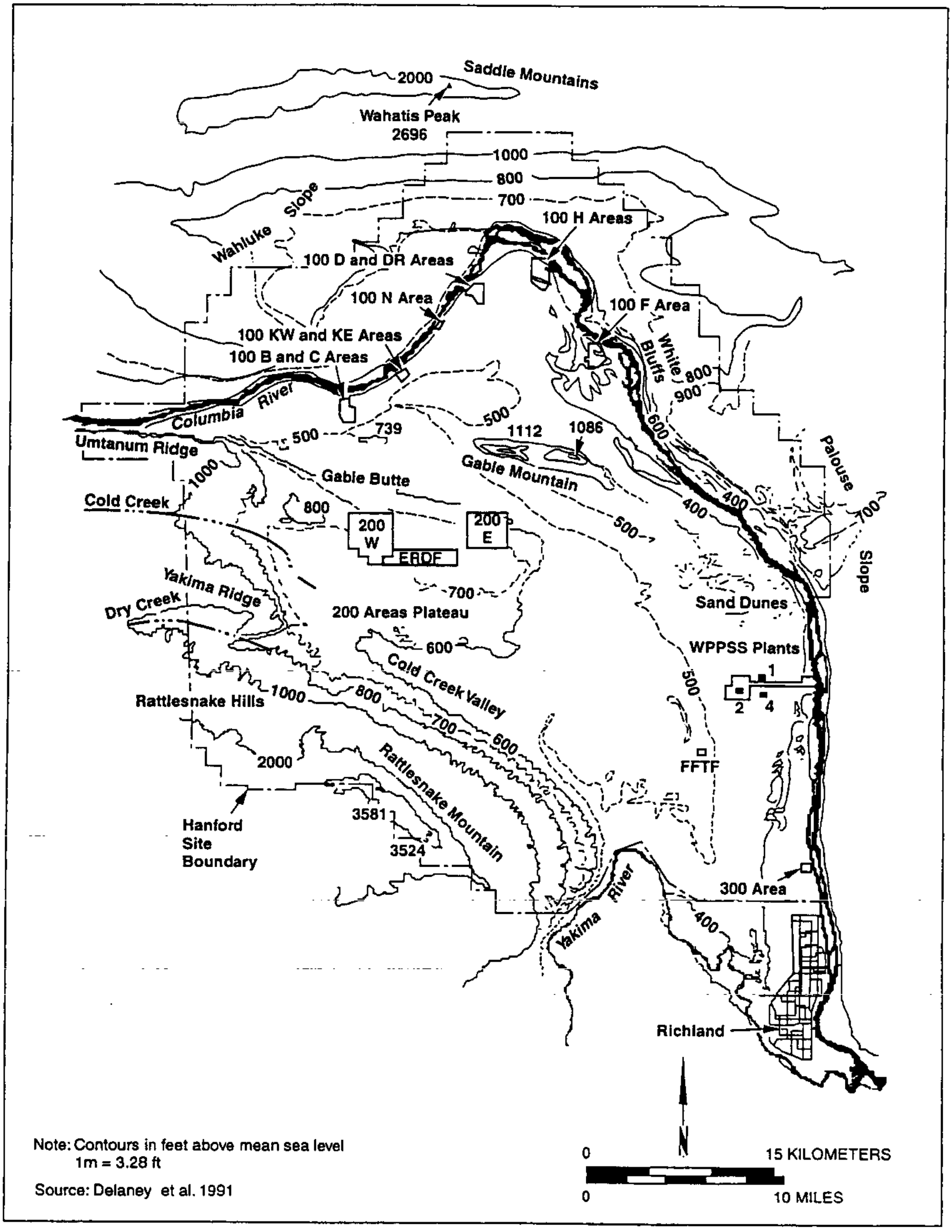

Figure 2-22. Topography of the Hanford Site.

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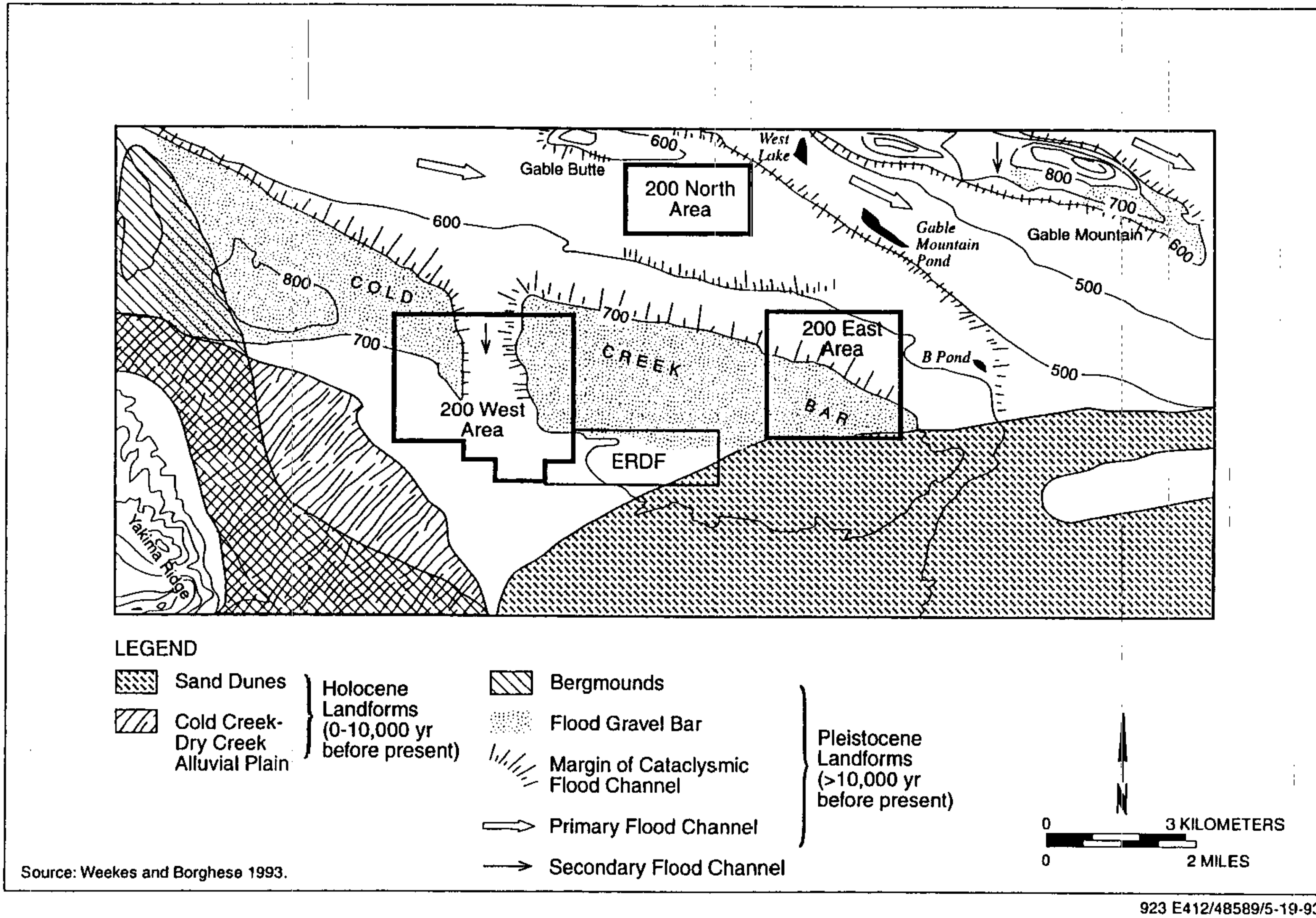

Figure 2-23. General Topography and Geomorphic Features in the West-Central Portion of the Hanford Site.

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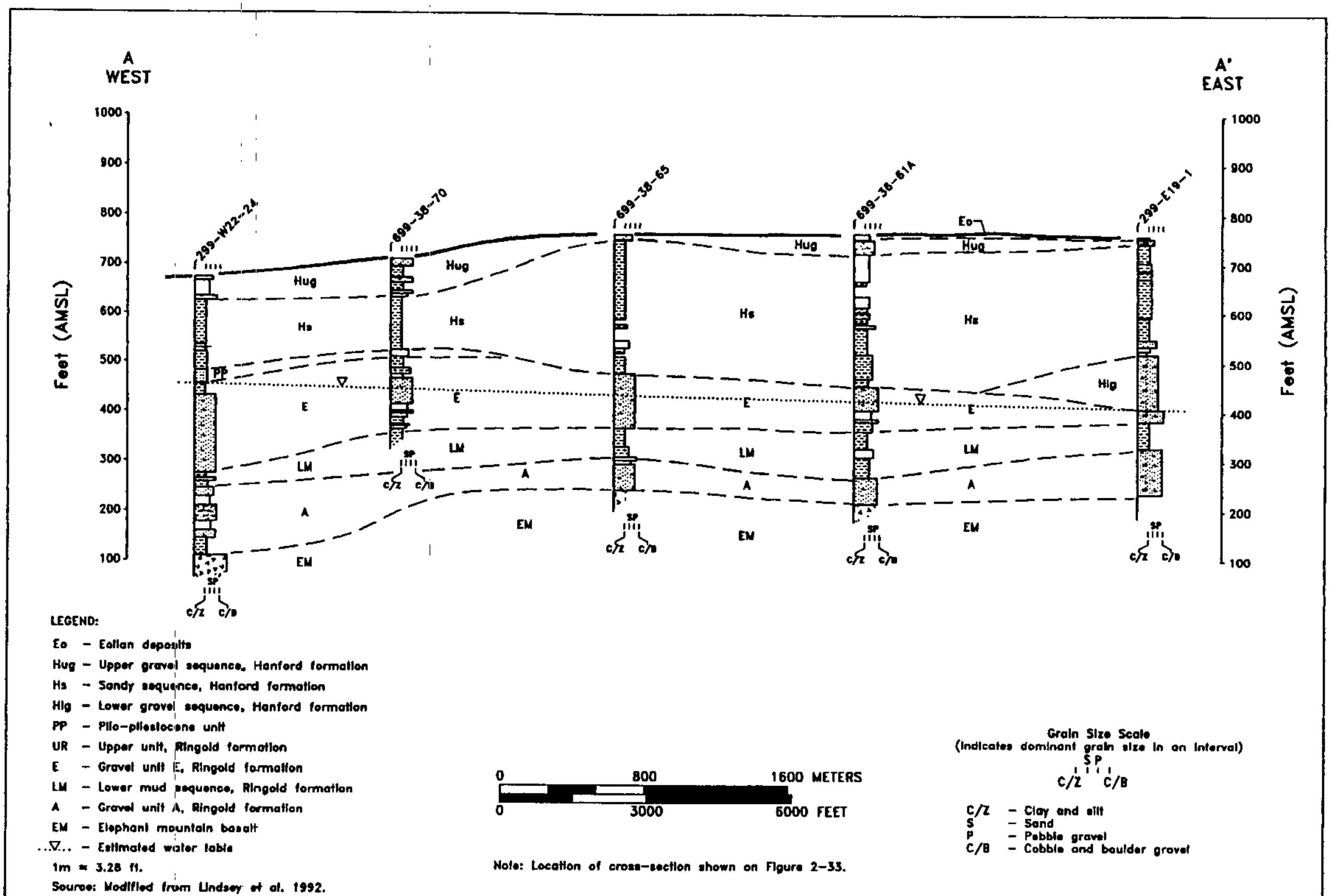

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Figure 2-24. A-A' Cross Section at the ERDF Site.

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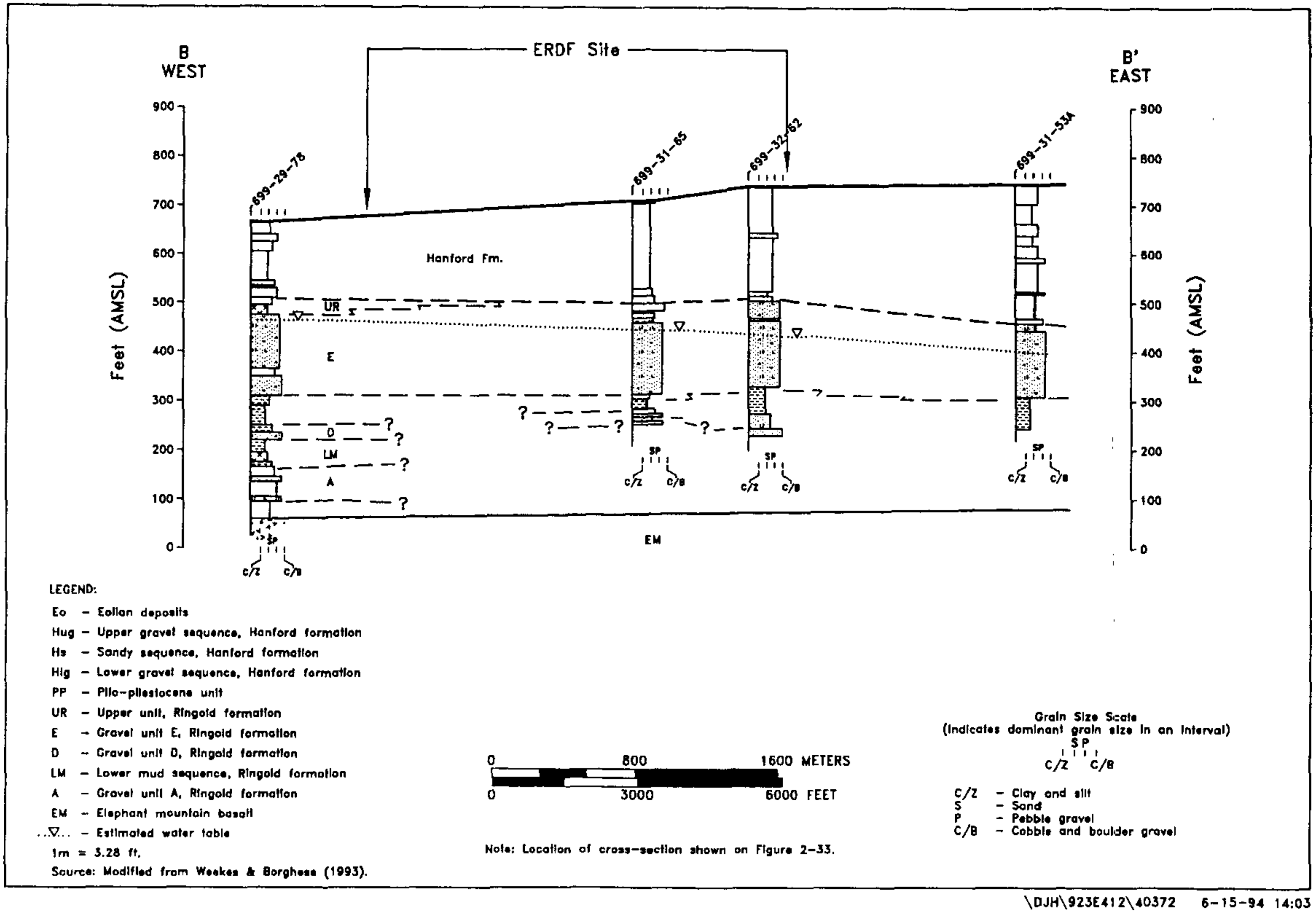

Figure 2-25. B-B' Cross Section at the ERDF Site.

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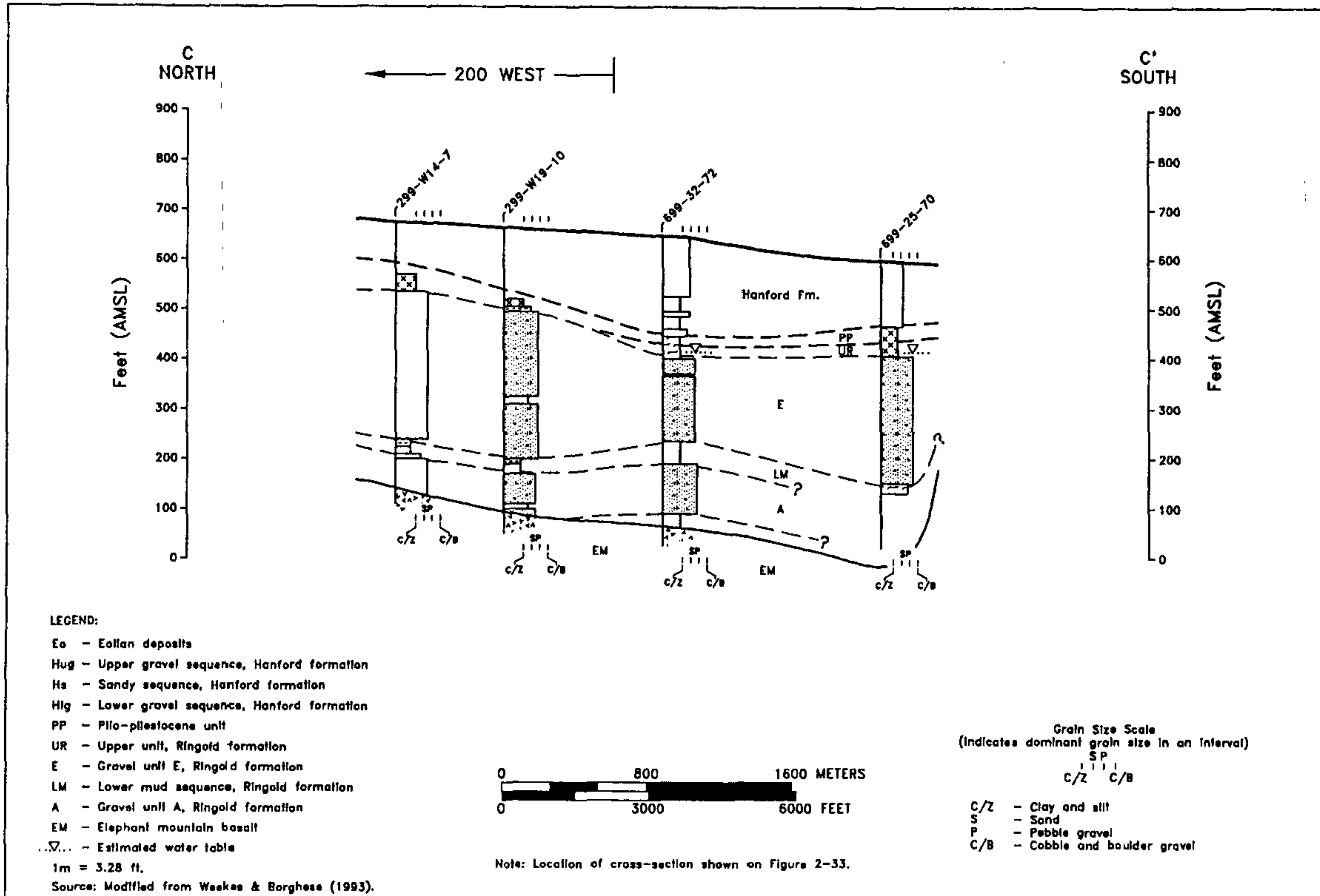

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Figure 2-26. C-C' Cross Section at the ERDF Site.

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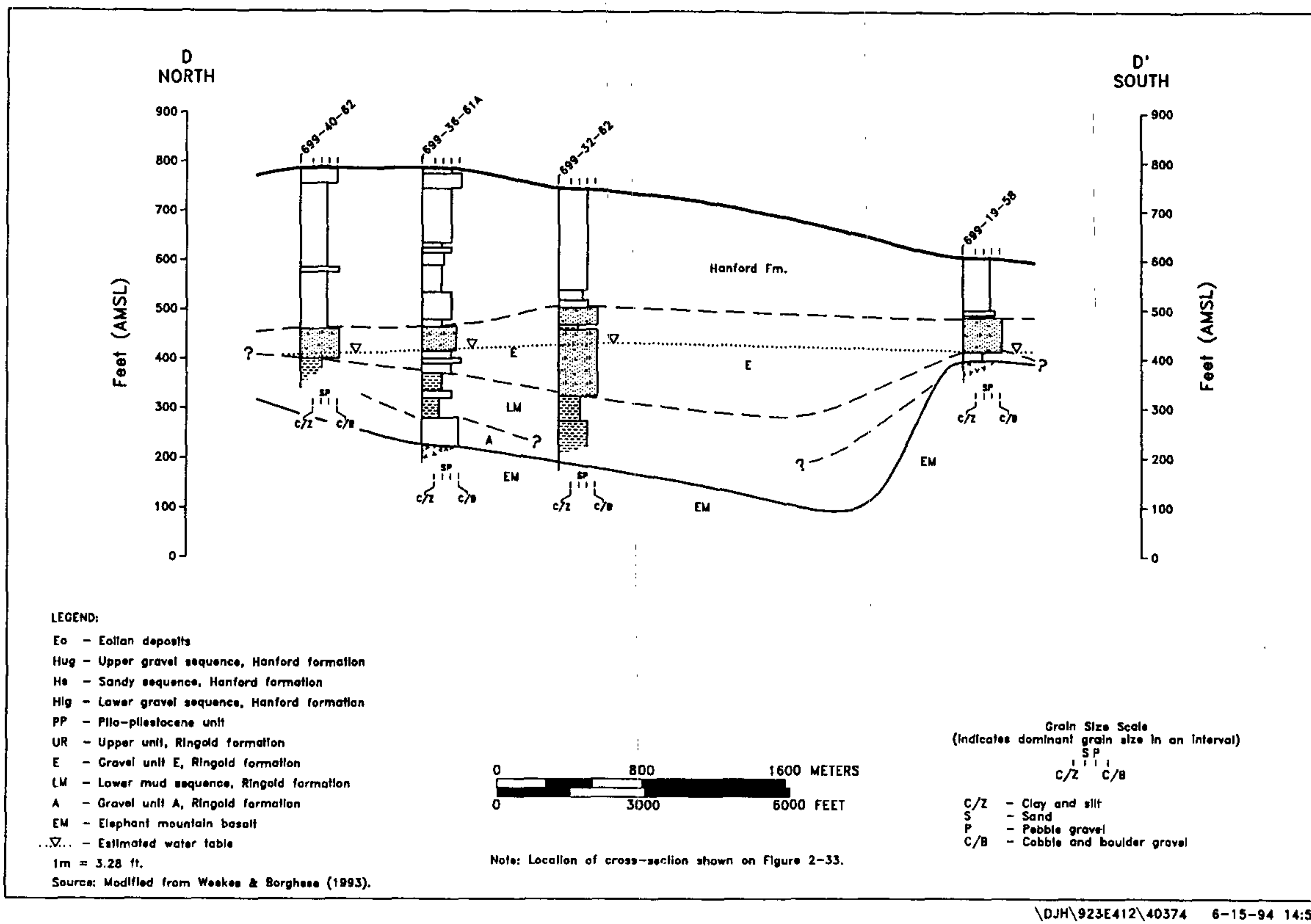

Figure 2-27. D-D' Cross Section at the ERDF Site.

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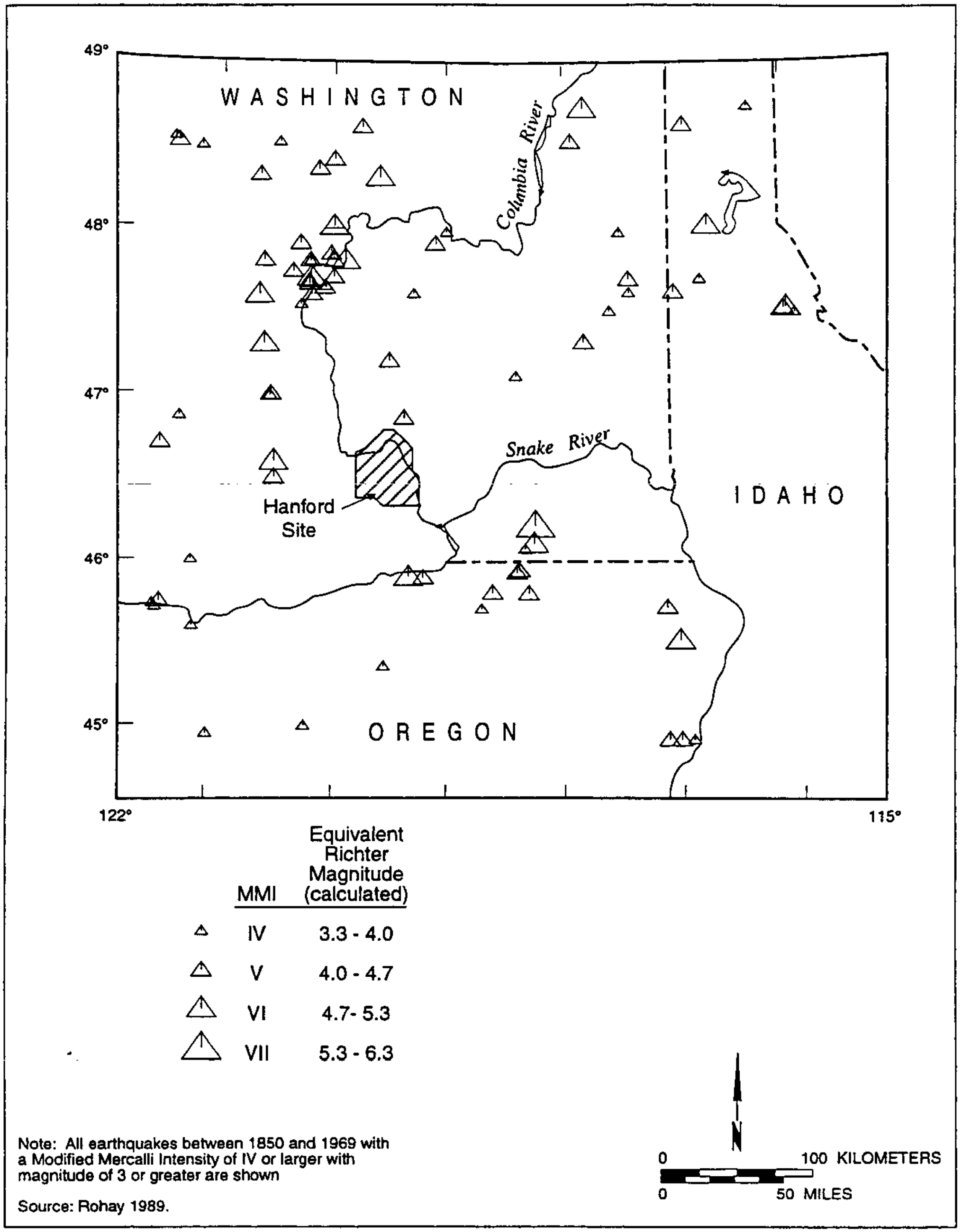

Figure 2-28. Historical Seismicity of the Columbia Plateau and Surrounding Areas.

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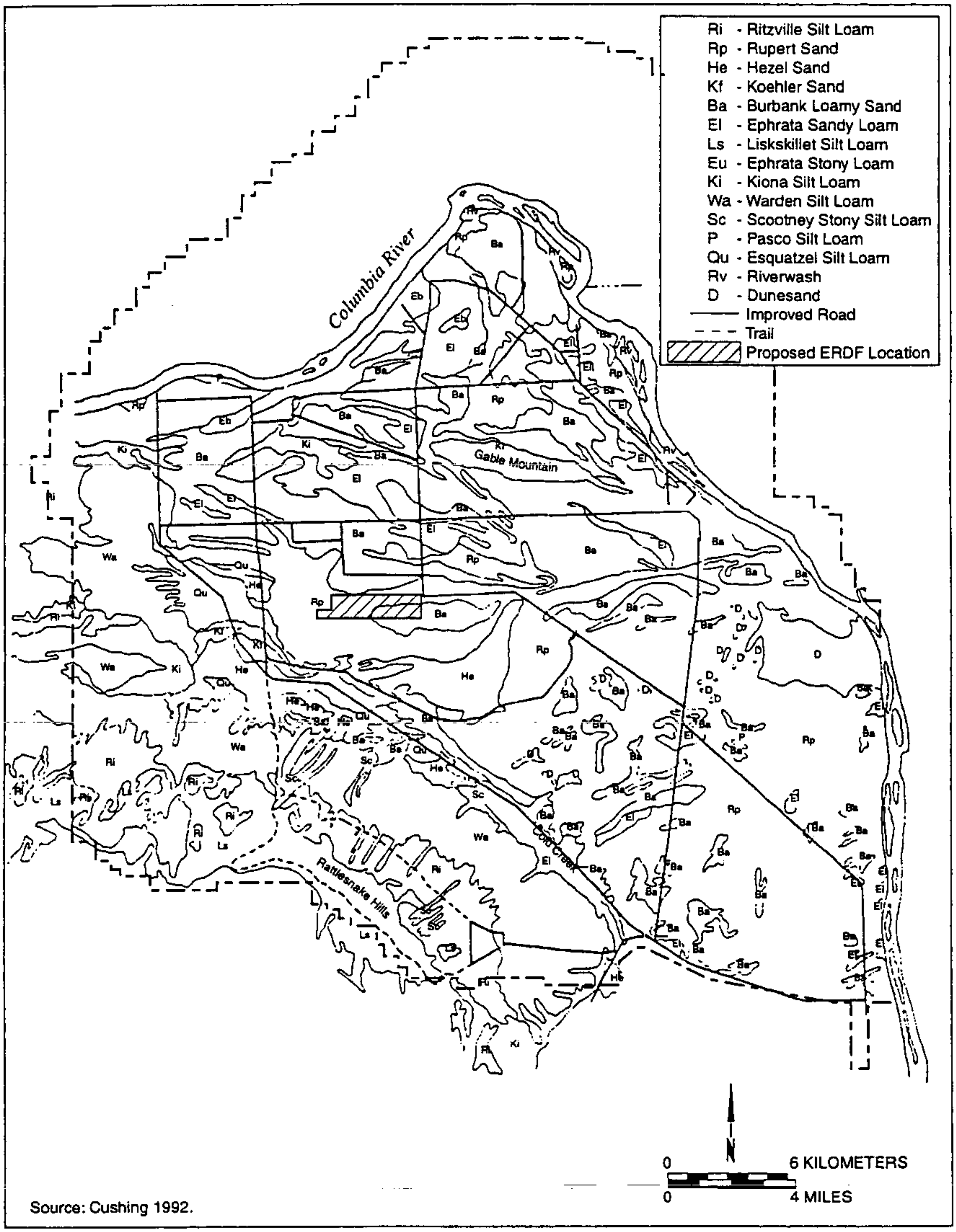

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Figure 2-29. Soil Map of the Hanford Site.

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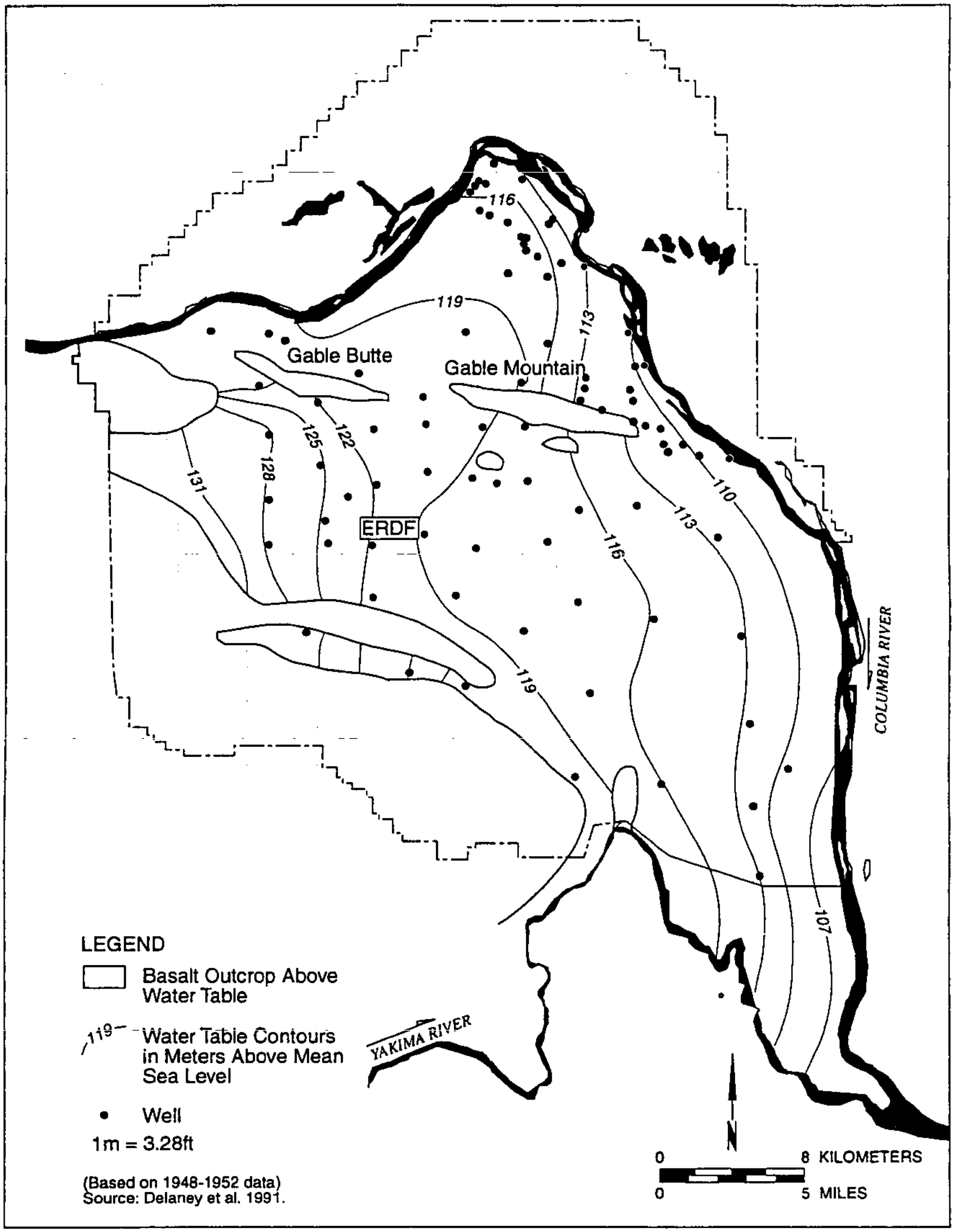

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Figure 2-30. Hanford Site Water Table Map, January 1944.

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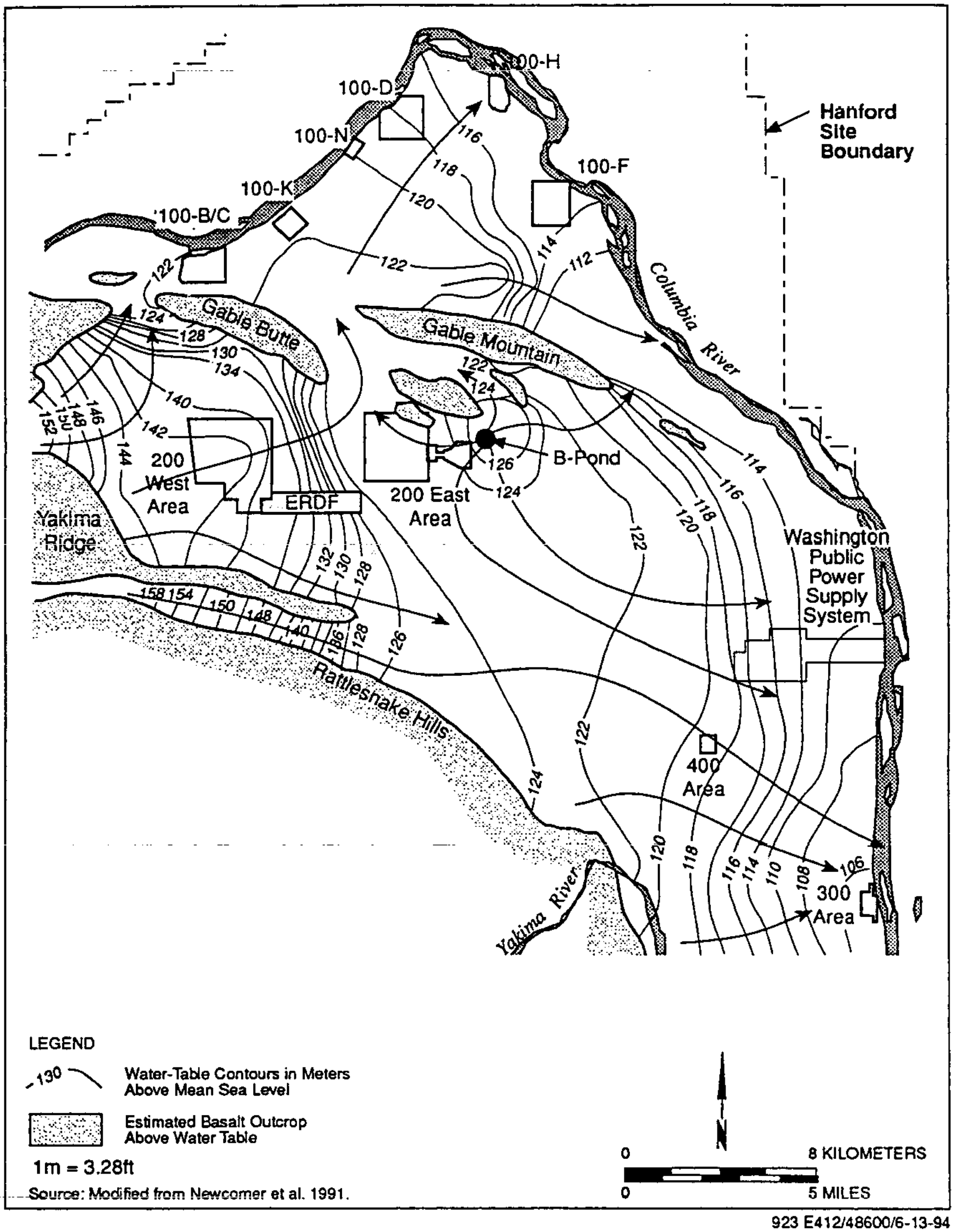

Figure 2-31. Hanford Site Water Table Map, June - August 1990.

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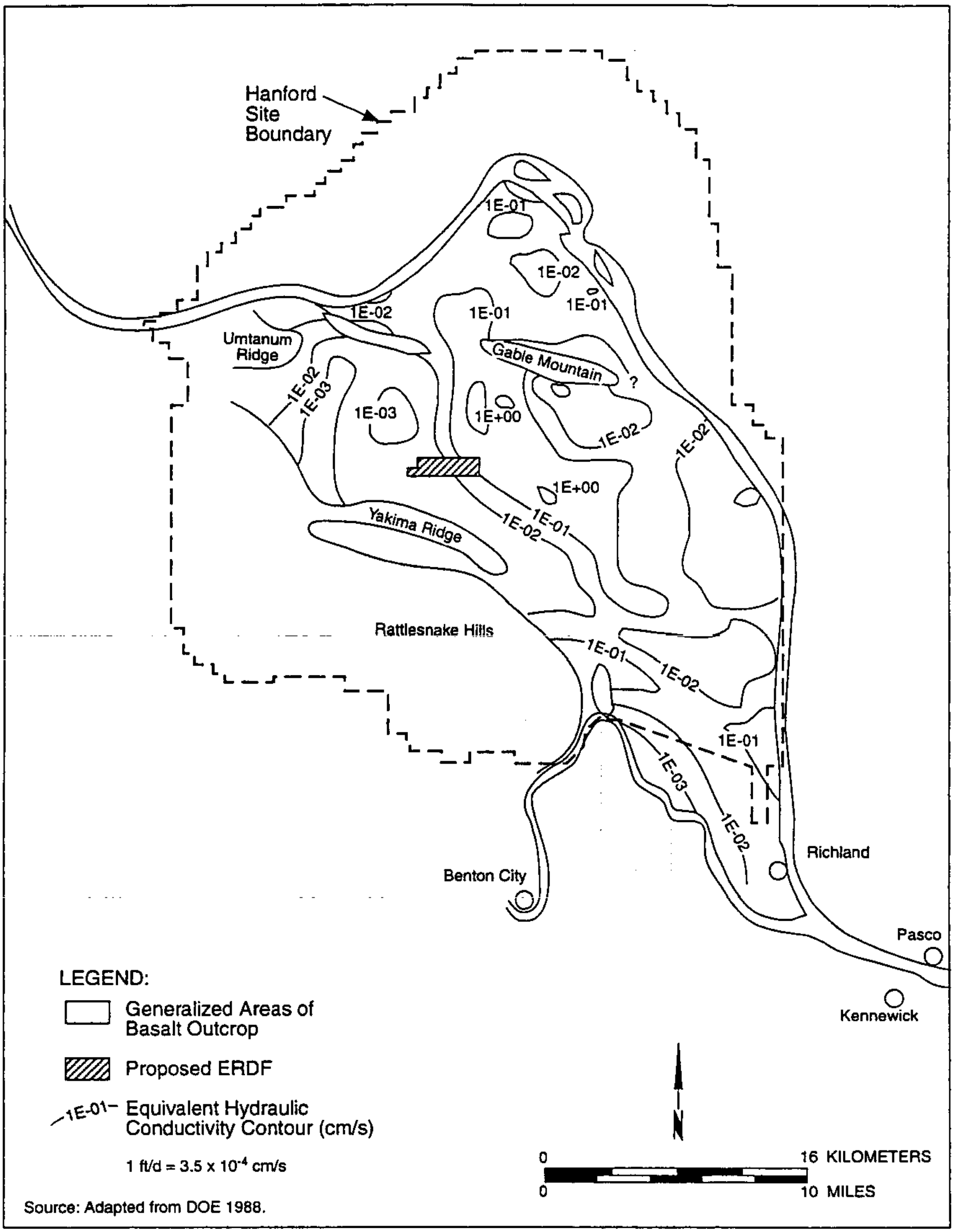

Figure 2-32. Areal Distribution of Hydraulic Conductivity for the Unconfined Aquifer.

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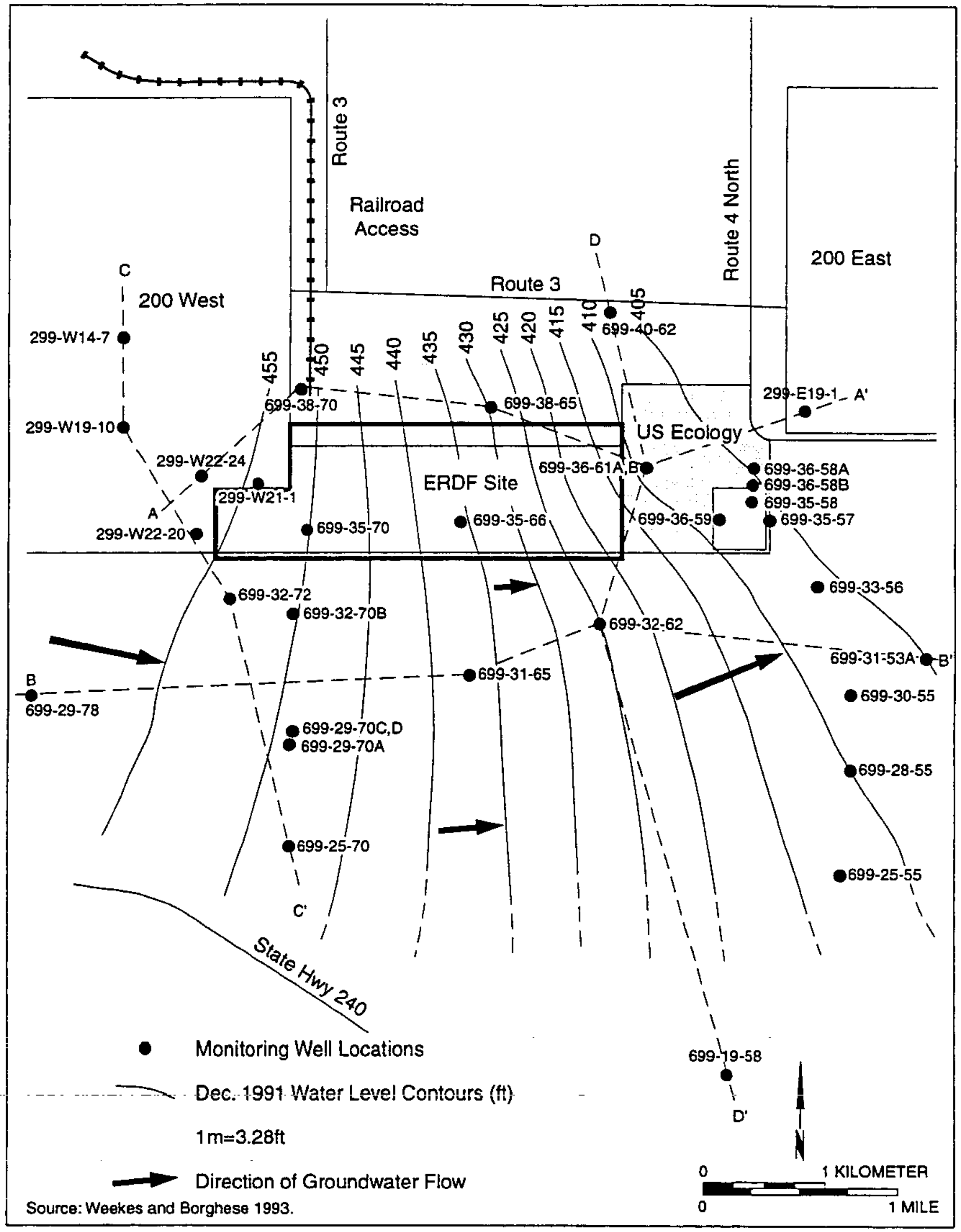

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Figure 2-33. Water Table Elevations at the ERDF.

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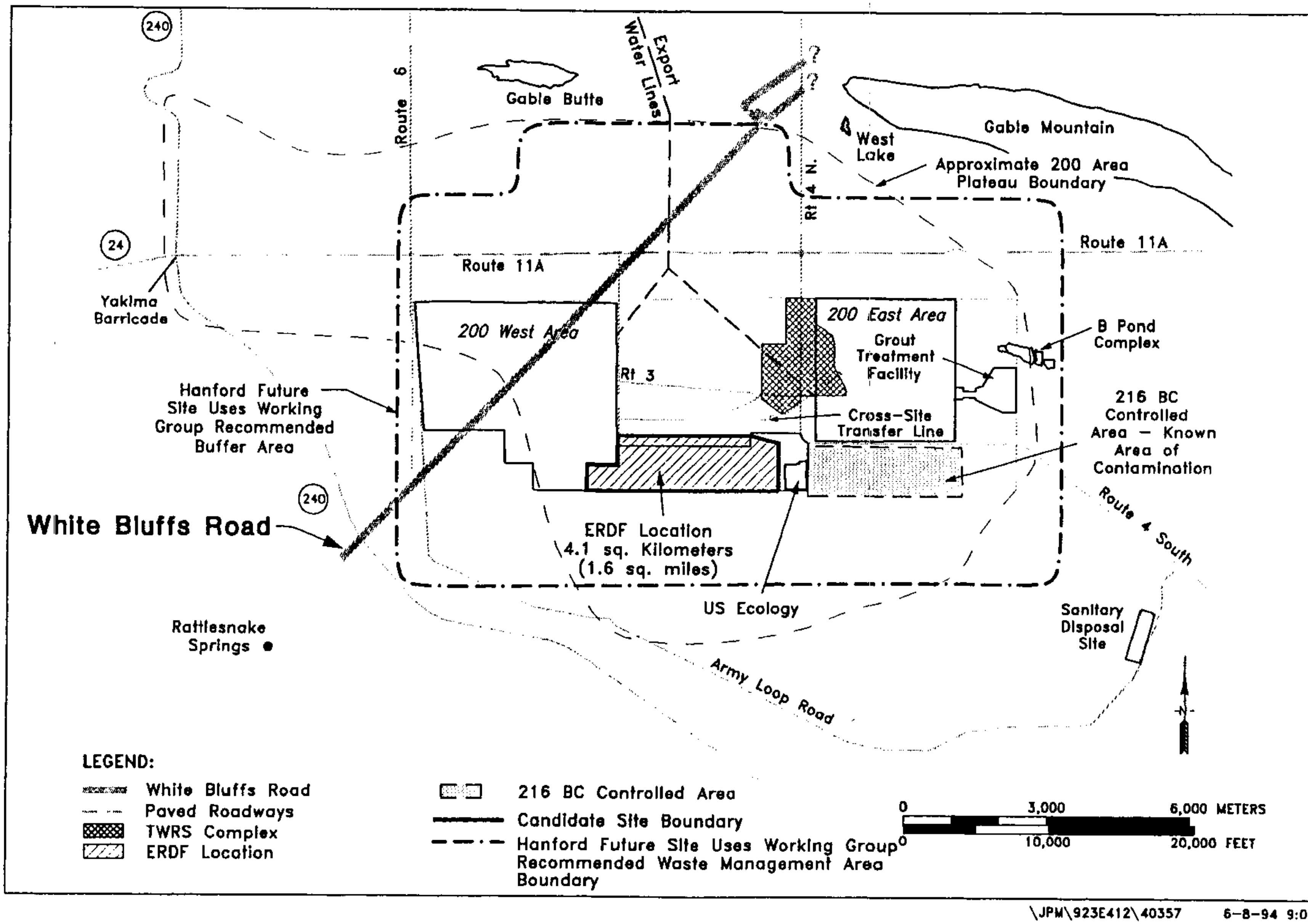

Figure 2-34. Approximate Location of the White Bluffs Road on the 200 Area Plateau

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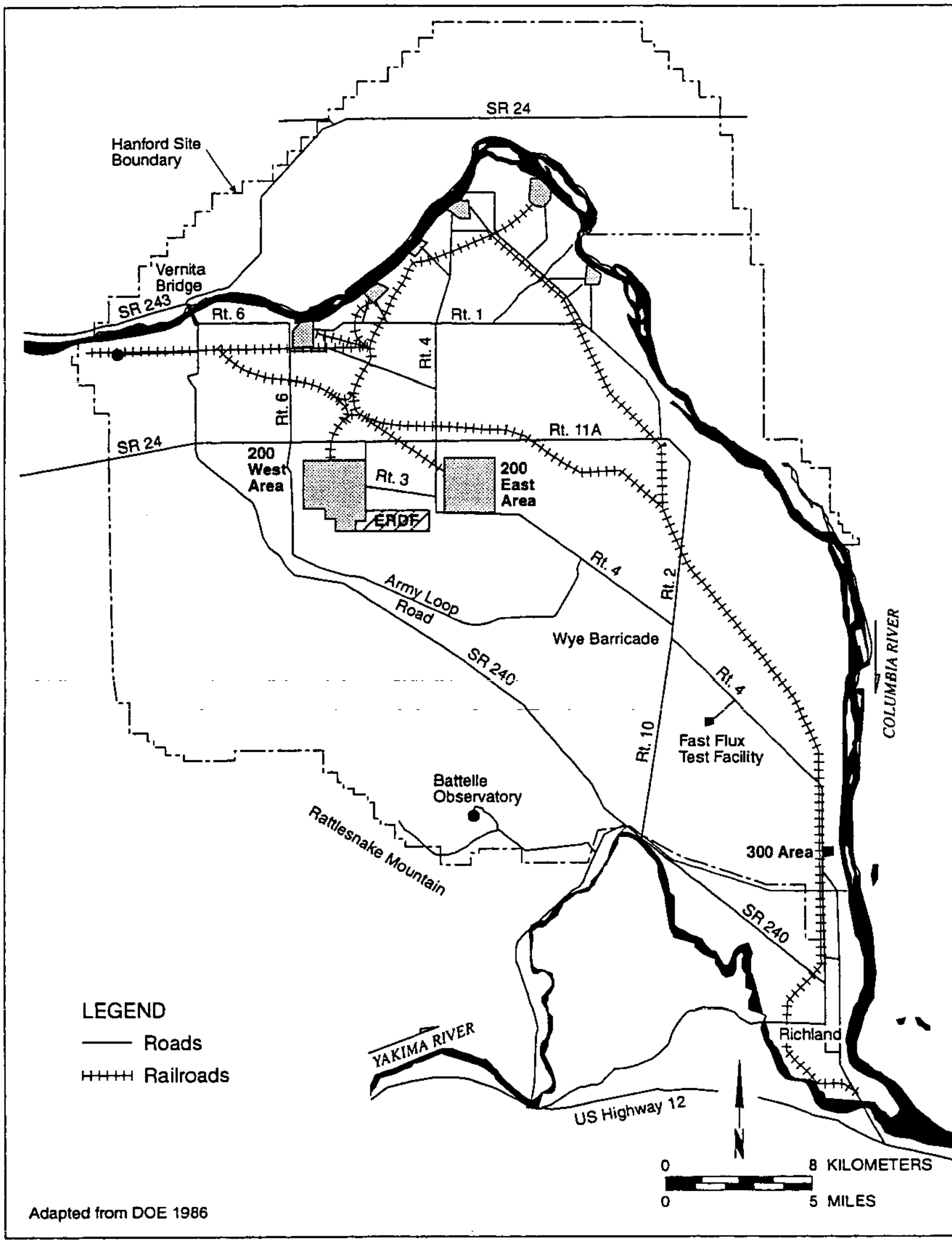

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Figure 2-35. Existing Transportation Network Within the Hanford Site.

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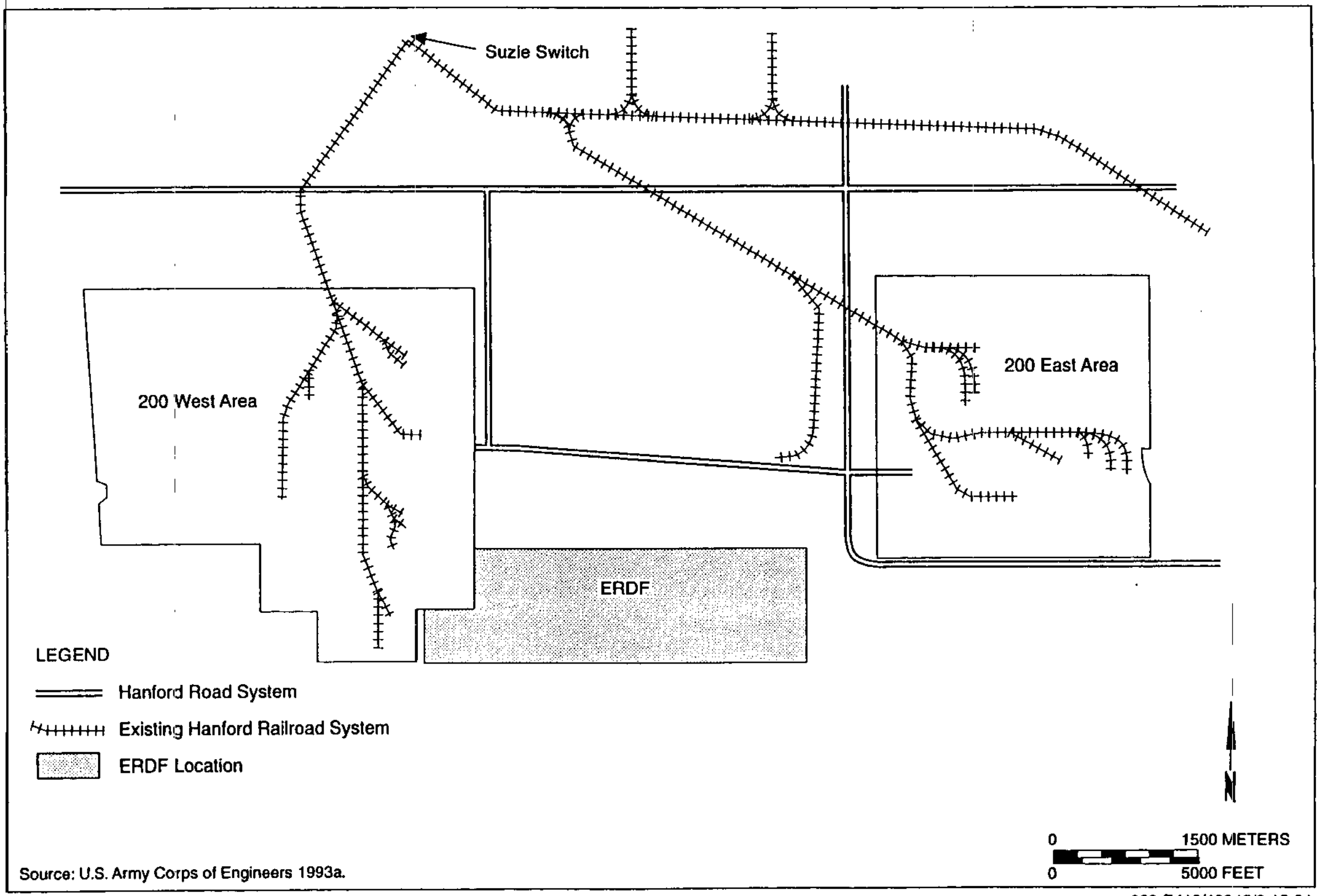

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Figure 2-36. Existing Transportation Network Near ERDF.

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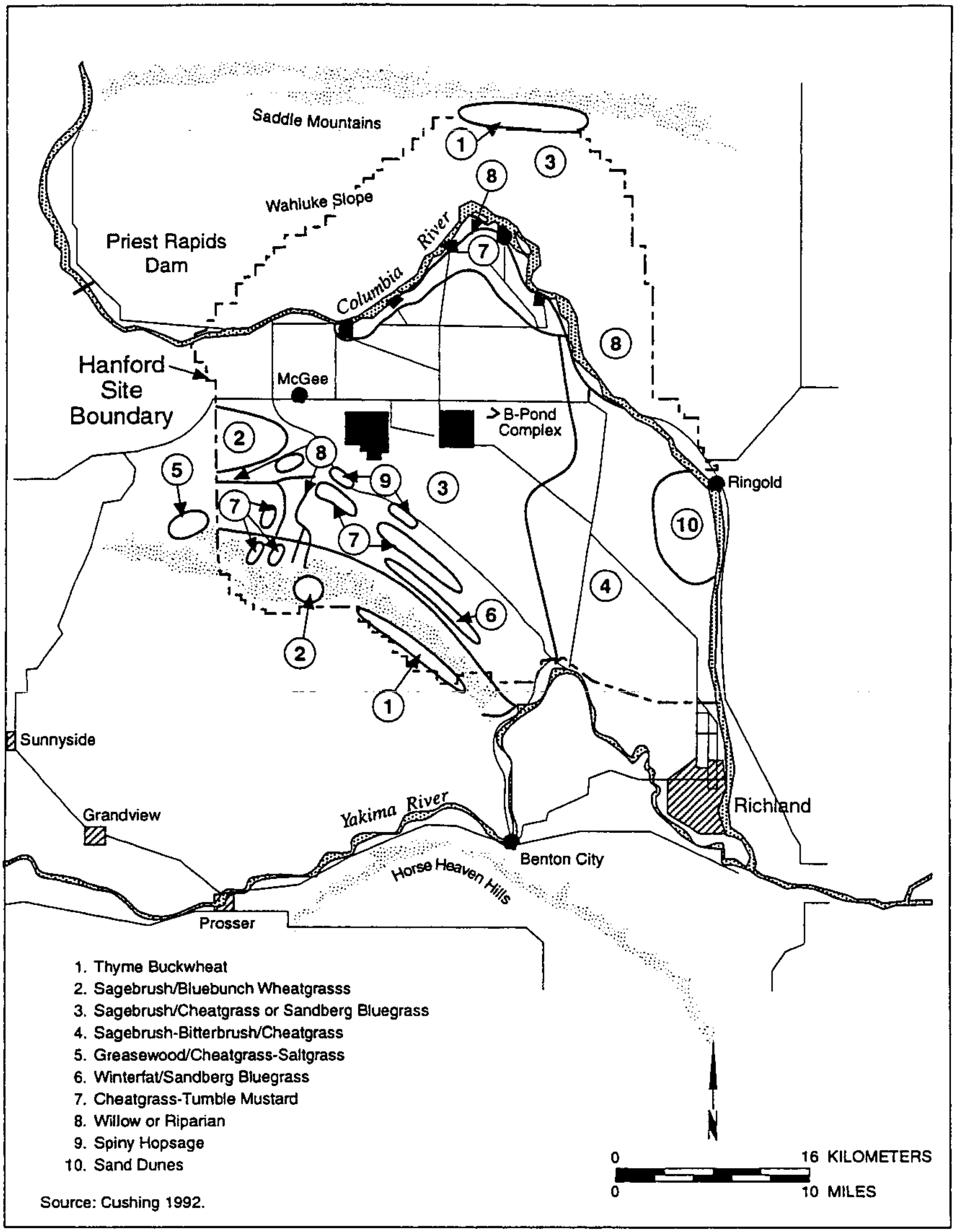

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Figure 2-37. Distribution of Vegetation Types on the Hanford Site.

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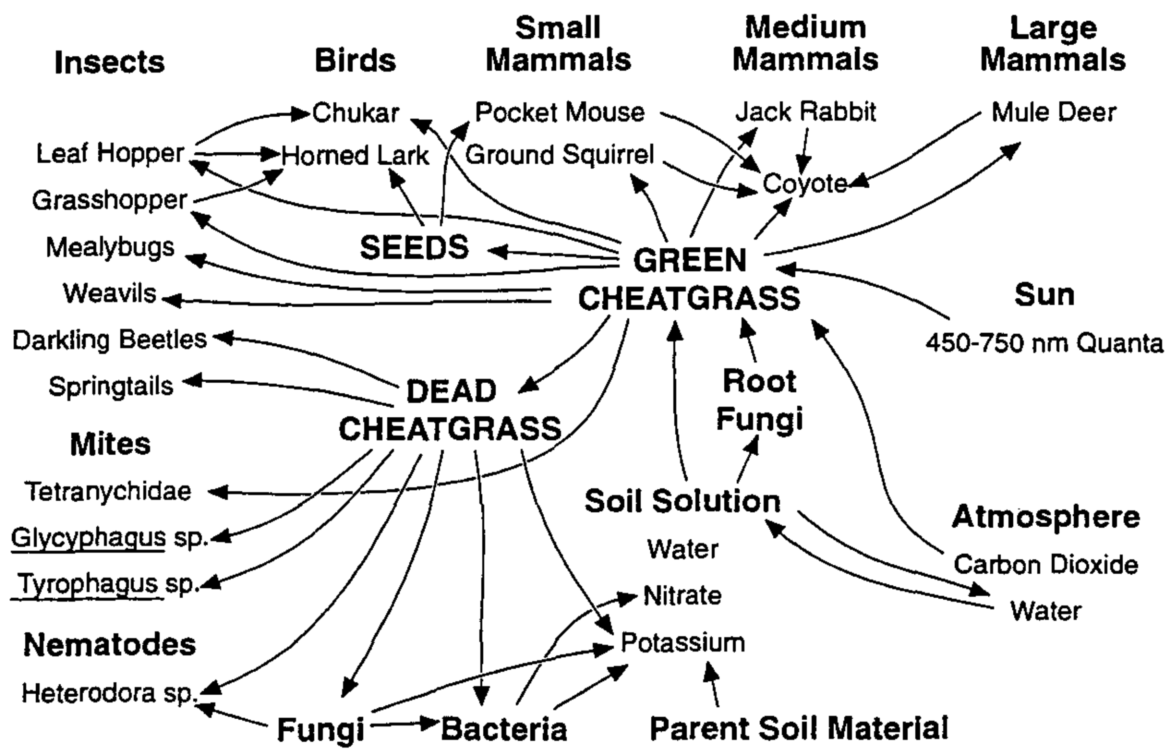

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Figure 2-38. Food Web Centered on Cheatgrass (arrows indicate direction of energy and mass transfer).

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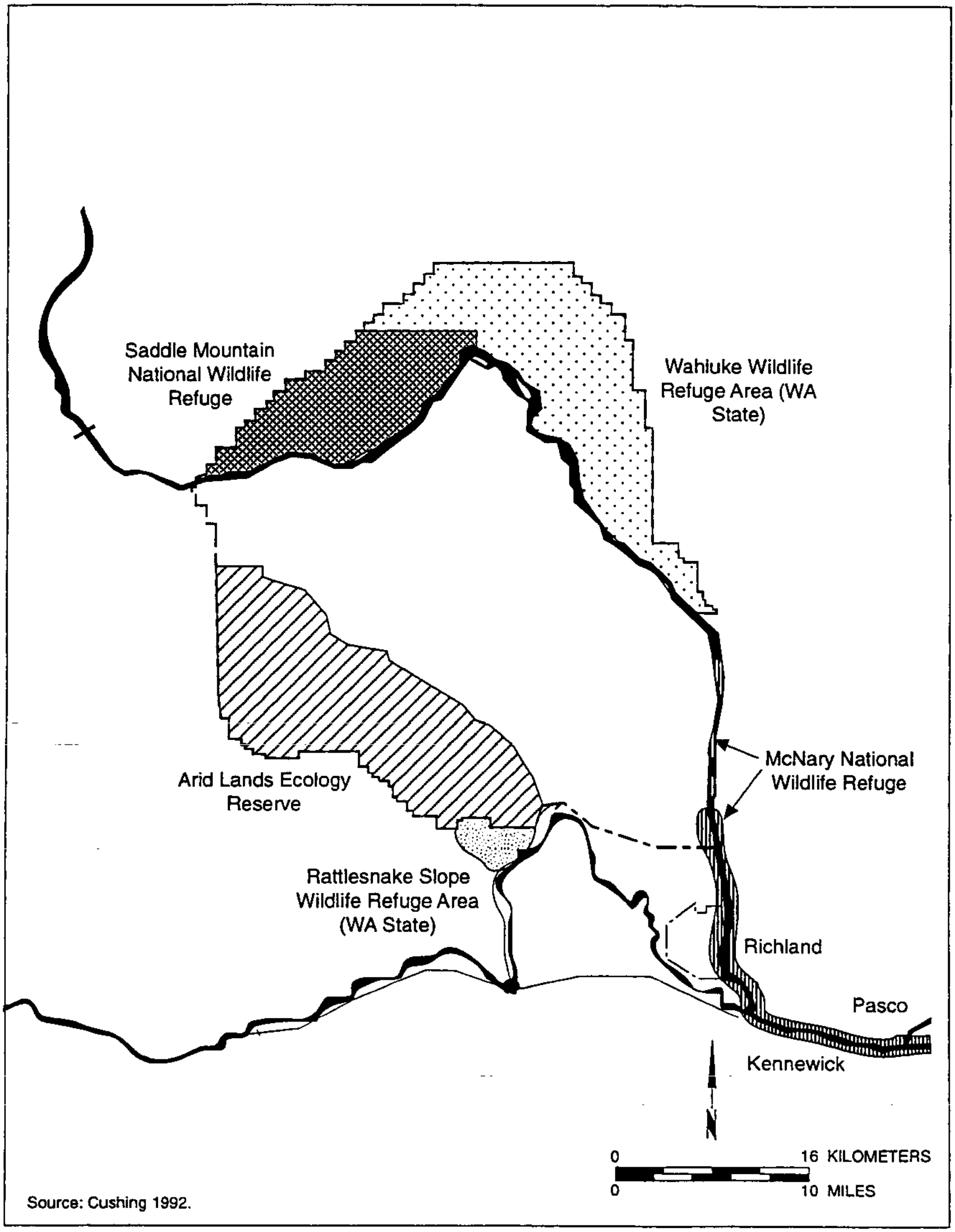

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Figure 2-39. National and State Wildlife Refuges in the Vicinity of the Hanford Site.

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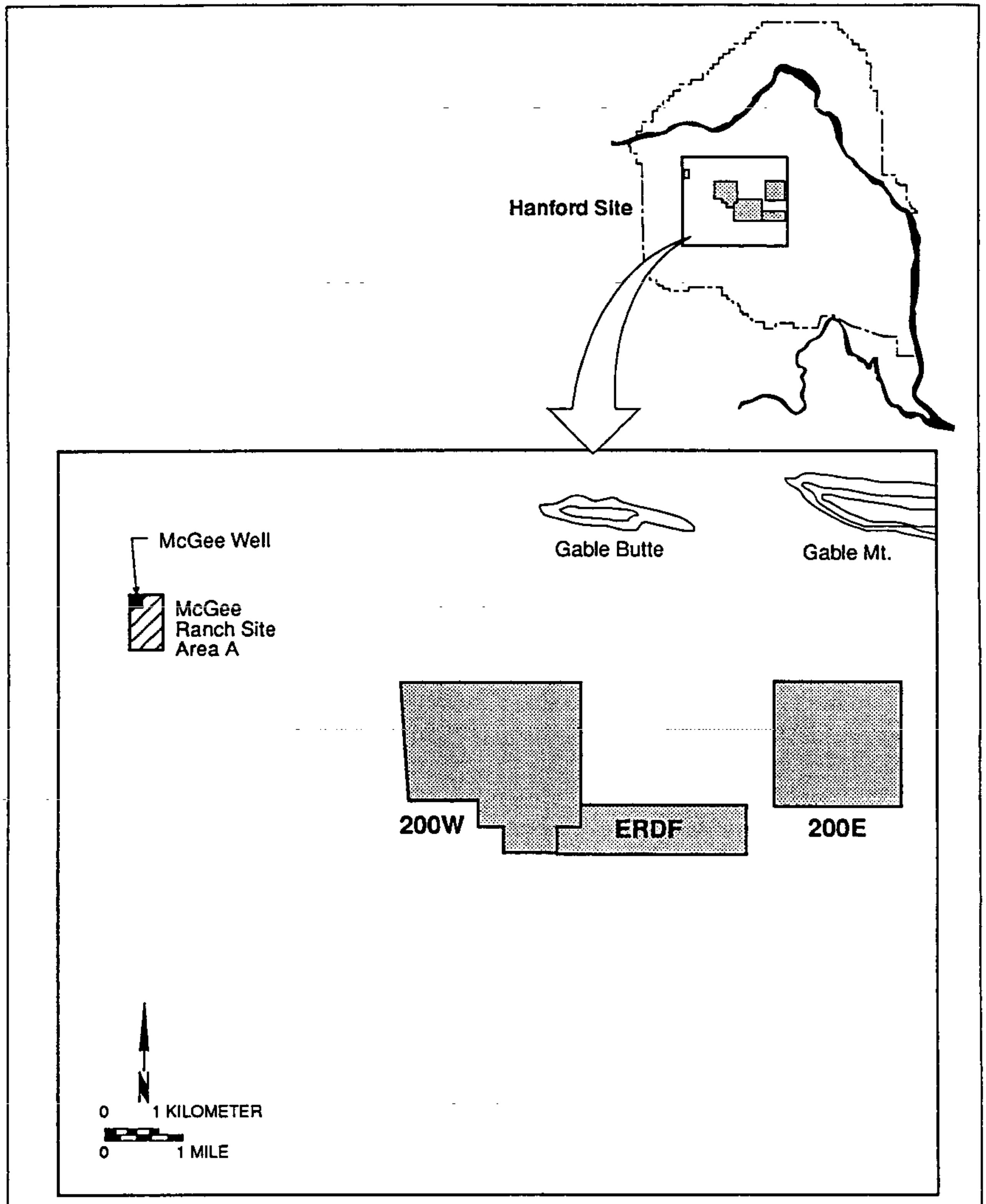

Source: Last et al., 1987.

923 E412/47787/6-13-94

Figure 2-40. Location Map McGee Ranch Borrow Soil Site.

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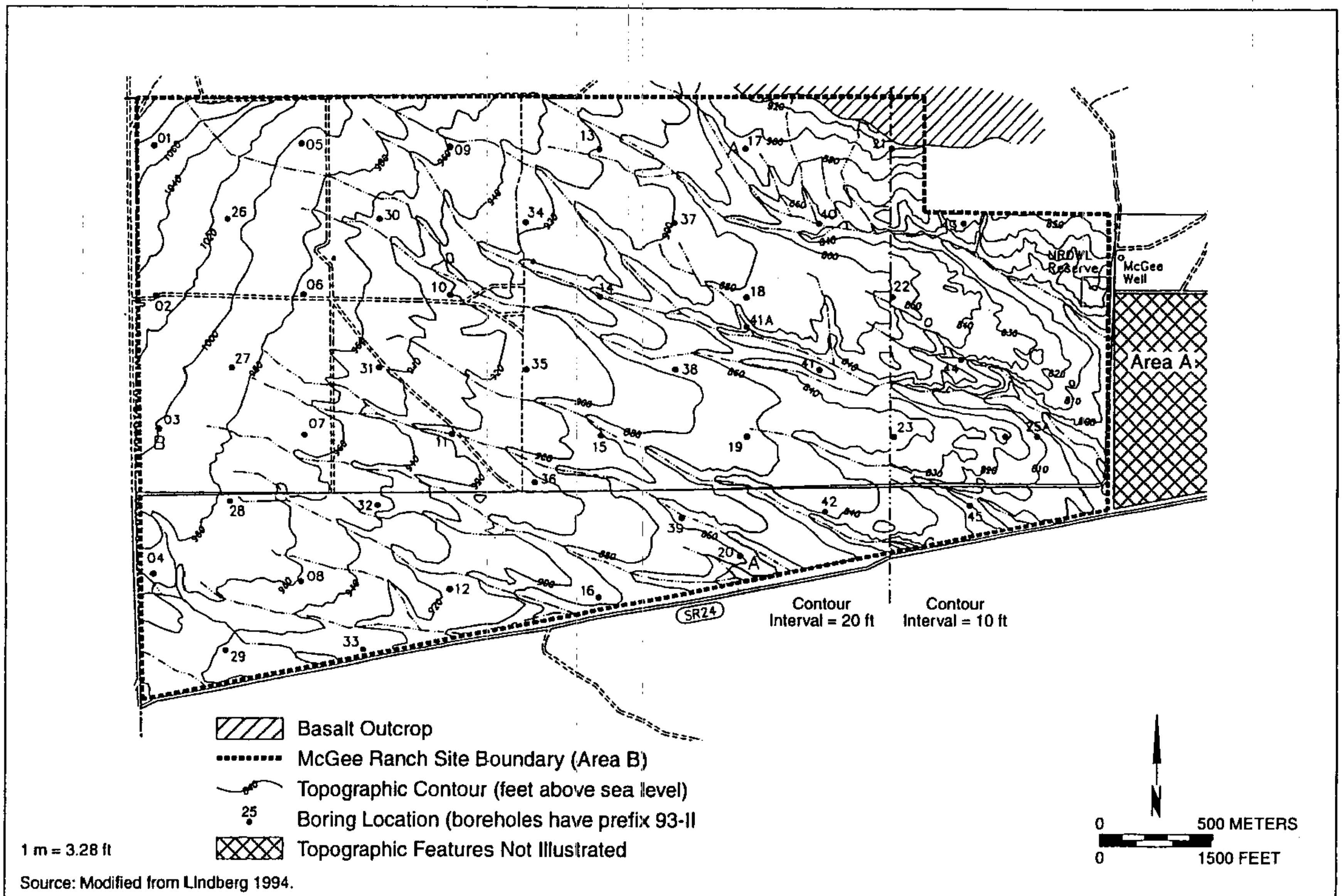

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Figure 2-41. Locational Map of Areas A and B of the McGee Ranch Site.

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Table 2-1. Soil Types on the Hanford Site. (Sheet 1 of 2)

Name (symbol)	Description
Ritzville Silt Loam (Ri)	Dark-colored silt loam soils midway up the slopes of the Rattlesnake Hills. Developed under bunch grass from silty wind-laid deposits mixed with small amounts of volcanic ash. Characteristically >150 cm deep, but bedrock may occur at <150 cm but >75 cm.
Rupert (Quincy) Sand (Rp)	One of the most extensive soils on the Hanford Site. Brown-to- grayish-brown coarse sand grading to dark grayish-brown at about 90 cm. Developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by wind-blown sand. Hummocky terraces and dunelike ridges.
Hazel Sand (He)	Similar to Rupert sands; however, a laminated grayish-brown strongly calcareous silt loam subsoil is usually encountered within 100 cm of the surface. Surface soil is very dark brown and was formed in wind-blown sands that mantled lake-laid sediments.
Koehler Sand (Kf)	Similar to other sandy soils on the Hanford Site. Developed in a wind-blown sand mantle. Differs from other sands in that the sand mantles a lime-silica cemented layer "Hardpan." Very dark grayish-brown surface layer is somewhat darker than Rupert. Calcareous subsoil is usually dark grayish-brown at about 45 cm.
Burbank Loamy Sand (Ba)	Dark-colored, coarse-textured soil underlain by gravel. Surface soil is usually about 40 cm thick but can be 75 cm thick. Gravel content of subsoil ranges from 20% to 80%.
Kiona Silt Loam (Ki)	Occupies steep slopes and ridges. Surface soil is very dark grayish-brown and about 10 cm thick. Dark brown subsoil contains basalt fragments 30 cm and larger in diameter. Many basalt fragments found in surface layer. Basalt rock outcrops present. A shallow stony soil normally occurring in association with Ritzville and Warden soils.
Warden Silt Loam (Wa)	Dark grayish-brown soil with a surface layer usually 23 cm thick. Silt loam subsoil becomes strongly calcareous at about 50 cm and becomes lighter colored. Granitic boulders are found in many areas. Usually >150 cm deep.
Ephrata Sandy Loam (El)	Surface is dark colored and subsoil is dark grayish-brown medium-textured soil underlain by gravelly material, which may continue for many feet. Level topography.
Ephrata Stony Loam (Eb)	Similar to Ephrata sandy loam. Differs in that many large hummocky ridges are presently made up of debris released from melting glaciers. Areas between hummocks contain many boulders several feet in diameter.

Table 2-1. Soil Types on the Hanford Site. (Sheet 2 of 2)

Name (symbol)	Description
Scootney Stony Silt	Developed along the north slope of Rattlesnake Loam (Sc) Hills; usually confined to floors of narrow draws or small fan-shaped areas where draws open onto plains. Severely eroded with numerous basaltic boulders and fragments exposed. Surface soil is usually dark grayish-brown grading to grayish-brown in the subsoil.
Pasco Silt Loam (P)	Poorly drained very dark grayish-brown soil formed in recent alluvial material. Subsoil is variable, consisting of stratified layers. Only small areas found on Hanford Site, located in low areas adjacent to the Columbia River.
Esquatzel Silt Loam (Qu)	Deep dark-brown soil formed in recent alluvium derived from loess and lake sediments. Subsoil grades to dark grayish-brown in many areas, but color and texture of the subsoil are variable because of the stratified nature of the alluvial deposits.
Riverwash (Rv)	Wet, periodically flooded areas of sand, gravel, and boulder deposits that make up overflowed islands in the Columbia River and adjacent land.
Dune Sand (D)	Miscellaneous land type that consists of hills or ridges of sand-sized particles drifted and piled up by wind and are either actively shifting or so recently fixed or stabilized that no soil horizons have developed.
Lickskillet Silt Loam (Ls)	Occupies ridge slopes of Rattlesnake Hills and slopes >765 m elevation. Similar to Kiona series except surface soils are darker. Shallow over basalt bedrock, with numerous basalt fragments throughout the profile of suggests a location within a broad region between Lake Chelan, Washington, and the British Columbia border.
Source: Modified from Hajek 1966.	

Table 2-2. Common Vascular Plants on the Hanford Site. (Sheet 1 of 4)

A. Shrub-Steppe Species	
Shrubs	**Scientific Name**
Big sagebrush*	*Artemisia tridentata*
Spiny hopsage*	*Grayia (Atriplex) spinosa*
Grey rabbitbrush*	*Chrysothamnus nauseous*
Green rabbitbrush*	*Chrysothamnus viscidiflorus*
Bitterbrush*	*Purshia tridentata*
Snowy buckwheat	*Eriogonum niveum*
Prickly phlox*	*Leptodactylon pungens*
Perennial Grasses	
Bluebunch wheatgrass	*Agropyron spicatum*
Bottlebrush squirreltail*	*Sitanion hystrix*
Sandberg's bluegrass*	*Poa sandbergii (secunda)*
Needle and thread grass*	*Stipa comata*
Indian ricegrass*	*Oryzopsis hymenoides*
Crested wheatgrass	*Agropyron desertorum (cristatum)*[a]
Thick-spike wheatgrass*	*Agropyron dasystachyum*
Sand dropseed	*Sporobolus cryptandrus*
Prairie Junegrass*	*Koeleria cristata*
Perennial Forb	
False yarrow*	*Chaenactis douglasii*
Turpentine spring parsley*	*Cymopteris terebinthinus*
Toad flax*	*Comandra umbellata*
Scurf pea	*Psoralea lanceolata*
Pale evening primrose*	*Oenothera pallida*
Cluster lily*	*Brodiaea douglasii*
Yellow bell*	*Frittillaria pudica*
Franklin's sandwort*	*Arenaria franklinii*
Wallflower	*Erysimum asperum*
Long-leaved phlox*	*Phlox longifolia*
Slender hawksbeard*	*Crepis atrabarba*
Carey's balsamroot*	*Balsamorhiza careyana*
Cusick's sunflower	*Helianthus cusickii*
Desert mallow	*Sphaeralcea munroana*
Sand beard tongue*	*Penstemon acuminatus*
Sandy dock*	*Rumex venosus*
Yarrow*	*Achillea millefolium*

Table 2-2. Common Vascular Plants on the Hanford Site. (Sheet 2 of 4)

Perennial Forb	**Scientific Name**
Stalked-pod milkvetch*	*Astragalus sclerocarpus*
Gray's desert parsley	*Lomatium grayi*
Threadleaf fleabane*	*Erigeron filifolius*
Buckwheat milkvetch*	*Astragalus caricinus*
Flat topped broomrape	*Orobanche corymbosa*
Threadleaf milkbane	*Erigeron filifolius*
Whiteleaf Scorpionweed*	*Phacelia hastata*
Hoary aster*	*Machaeranthera canescens*
Mariposa lily*	*Calochortus macrocarpus*
Biennial Forbs	
Cutleaf ladysfoot mustard*	*Thelypodium laciniatum*
Yellow salsify*	*Tragopogon dubius*[a]
Annual Forbs	
Jim Hill (tumble) mustard*	*Sisymbrium altissimum*[a]
Tansy mustard*	*Descurainia pinnata*
Flixweed	*Descurainia sophia*
Pink microsteris*	*Microsteris gracilis*
Matted cryptantha*	*Cryptantha circumscissa*
Broom buckwheat*	*Eriogonum vimineum*
Hawk's beard	*Crepis atribarba*
Low lupine*	*Lupinus pusillus*
Western wall flower	*Erysimum asperum*
Jagged chickweed*	*Holosteum umbellatum*[a]
Annual Jacob's ladder*	*Polemonium micranthum*
Blazing star*	*Mentzelia albicaulis*
Threadleaf scorpionweed*	*Phacelia linearis*
Russian thistle (tumbleweed)*	*Salsola kali*[a]
Indian wheat	*Plantago patagonica*
Spring Whitlowgrass*	*Draba verna*[a]
Tarweed fiddleneck*	*Amsinckia lycopsoides*
Pepperweed	*Lepidium perfoliatum*
Purple mustard	*Chorispora tenella*[a]
Winged cryptantha*	*Cryptantha pterocarya*
Tall willow-herb	*Epilobium paniculatum*
White cupseed*	*Plectritis macrocera*
Bur ragweed*	*Ambrosia acanthicarpa*
Prickly lettuce	*Lactuca serriola*[a]
Tidytips*	*Layia glandulosa*
Filaree (crane's bill)	*Erodium cicutarium*[a]

Table 2-2. Common Vascular Plants on the Hanford Site. (Sheet 3 of 4)

Annual Grasses	
Cheatgrass*	*Bromus tectorum*[a]
Six-weeks fescue*	*Festuca octoflora*
Small fescue	*Festuca microstachys*
B. Riparian Plants	
Trees and Shrubs	
Black cottonwood	*Populus trichocarpa*
Black locust	*Robinia pseudo-acacia*
Peach, apricot, cherry	*Prunus* spp.
Sand bar willow	*Salix exigua*
Peachleaf willow	*Salix amygdaloides*
Willow	*Salix* spp.
Mulberry	*Morus alba*[a]
Dogbane	*Apocynum cannabinum*
Perennial Grasses and Forbs	
Reed canary grass	*Phalaris arundinacea*[b]
Cattail	*Typha latifolia*[b]
Bulrushes	*Scirpus* spp.[b]
Tickseed	*Coreopsis atkinsoniana*
Golden aster	*Heterotheca villosa*
Gumweed	*Grindelia columbiana*
Goldenrod	*Solidago occidentalis*
Prairie sage	*Artemisia ludoviciana*
Pacific sage	*Artemisia campestris*
Horsetails	*Equisetum* spp.
Gaillardia	*Gaillardia aristata*
Lupine	*Lupinus* spp.
Smartweed	*Polygonum persicaria*
Sedge	*Carex* spp.[b]
Wiregrass	*Eleocharis* spp.[b]
Speedwell	*Veronica anagallis-aquatica*
Wild onion	*Allium* spp.
Russian knapweed	*Centaurea repens*[a]
Rushes	*Juncus* spp.

Table 2-2. Common Vascular Plants on the Hanford Site. (Sheet 4 of 4)

Aquatic Vascular	
Water milfoil	*Myriophyllum spicatum*
Waterweed	*Elodea canadensis*
Pondweed	*Potamogeton* spp.
Persistent sepal yellowcress	*Rorippa columbiae*
Watercress	*Rorippa nasturium-aquaticum*
Duckweed	*Lemna minor*

* Plants identified at the ERDF site.
[a]Exotic.
[b]Perennial grasses and graminoids.
Source: Modified from Cushing 1992.

Table 2-3. Partial List and Status of Amphibians and Reptiles Occurring on the Hanford Site.

Common Name	Scientific Name	State Status
<u>Amphibians</u>		
Great Basin spadefoot toad	*Spea intermontanus*	M
Woodhouse's toad	*Bufo woodhouseii*	
Pacific treefrog	*Hyla regilla*	
<u>Reptiles</u>		
Sagebrush lizard	*Sceloporus graciosus*	
Side-blotched lizard*	*Uta stansburiana*	
Short-horned lizard	*Phrynosoma douglassii*	
Striped whipsnake	*Masticophis taeniatus*	C
Western yellow-bellied racer*	*Coluber constrictor*	
Gopher snake*	*Pituophis catenifer*	
Desert night snake	*Hypsiglena torquata desertia*	M
Western rattlesnake	*Crotalus viridis*	
Painted turtle	*Chrysemys picta*	

*Identified at the ERDF site.
M, Monitor group. wildlife species that:
1. were at one time classified as endangered, threatened, or sensitive;
2. require habitat that has limited availability during some portion of its life cycle;
3. are indicators of environmental quality;
4. require further field investigations to determine population status;
5. have unresolved taxonomy which may bear upon their status classification;
6. may be competing with and impacting other species of concern; or
7. have significant popular appeal.

C, state candidate; wildlife species native to the State of Washington that the Department of Wildlife will review for possible listing as sensitive, threatened or endangered. Candidate species are desginated in Wildlife Policy 4802.

Source: Modified from Cushing 1992.

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Table 2-4. Partial List and Status of Birds Found on the Hanford Site.
(Sheet 1 of 2)

Common Name	Scientific Name	State Status	Federal Status
Aleutian Canada Goose	*Branta canadensis leucopareia*	E	E
American coot	*Fulica americana*		
American kestrel	*Falco sparverius*		
American robin	*Turdus migratorius*		
Bald Eagle	*Haliaeetus leucocephalus*	T	T
Bank swallow*	*Riparia riparia*		
Barn swallow*	*Hirundo rustica*		
Black-billed magpie	*Pica pica*		
Bufflehead	*Bucephala albeola*		
California gull	*Larus californicus*		
California quail	*Callipepla californica*		
Canada goose	*Branta canadensis moffitti*		
Chukar partridge	*Alectoris chukar*		
Cliff swallow	*Hirundo pyrrhonota*		
Common nighthawk*	*Chordeiles minor*		
Common raven*	*Corvus corax*		
European starling	*Sturnus vulgaris*		
Ferruginous hawk	*Buteo regalis*	T	C3
Golden eagle	*Aquila chrysaetos*	C	
Grasshopper sparrow*	*Ammodramus savannarum*	M	
Gray (Hungarian) partridge	*Perdix perdix*		
Great blue heron	*Ardea herodias*	M	
Horned lark*	*Eremophila alpestris*		
House finch	*Carpodacus mexicanus*		
House sparrow	*Passer domesticus*		
Killdeer	*Charadrius vociferus*		
Loggerhead shrike*	*Lanius ludovicianus*	C	C2
Magpie*	*Pica pica*		
Mallard	*Anas platyrhynchos*		
Mourning dove*	*Zenaidura macroura*		
Northern harrier*	*Circus cyaneus*		
Northern shoveler	*Anas clypeata*		
Peregrine falcon	*Falco peregrinus*	E	E
Pied-billed grebe	*Podilymbus podiceps*		
Red-tailed hawk*	*Buteo jamaicensis*		
Red-winged blackbird	*Agelaius phoeniceus*		
Ring-billed gull	*Larus delawarensis*		
Ring-necked pheasant	*Phasianus colchicus*		
Rock dove	*Columba livia*		
Rough-legged hawk	*Buteo lagopus*		

Table 2-4. Partial List and Status of Birds Found on the Hanford Site.
(Sheet 2 of 2)

Common Name	Scientific Name	State Status	Federal Status
Sage sparrow*	*Amphispiza belli*	C	
Sage thrasher	*Oreoscoptes montanus*	C	
Sandhill crane	*Grus canadensis*	E	
Short-eared owl	*Asio flammeus*		
Swainson's hawk*	*Buteo swainsoni*	C	
Western kingbird	*Tyrannus verticalis*		
Western meadowlark*	*Sturnella neglecta*		
White-crowned sparrow*	*Zonotrichia leucophrys*		
White pelican	*Pelecanus erythrorhynchos*	E	
Ash-throated flycatcher	*Myiarchus cinerascens*	M	
Black-crowned night heron	*Nycticorax nycticorax*	M	
Burrowing owl*	*Athene cunicularia*	C	
Caspian tern	*Sterna caspia*	M	
Common loon	*Gavia immer*	C	
Forster's tern	*Sterna forsteri*	M	
Horned grebe	*Podiceps auritus*	M	
Long-billed curlew*	*Numenius americanus*	M	C2
Northern goshawk	*Accipiter gentilis*	C	
Osprey	*Pandion haliaetus*	M	
Prairie falcon	*Falco mexicanus*	M	
Sage grouse	*Centrocercus urophasianus*	C	C2
Snowy owl	*Nyctea scandiaca*	M	
Western grebe	*Aechmophorus occidentalis*	M	

*Bird identified at the ERDF site.
[a]Abbreviations:
E, endangered; a species in danger of extinction throughout all or a significant portion of its range;
T, threatened; a species which is likely to become endangered within the foreseeable future;
S, sensitive; taxa vulnerable or declining, and could become endangered or threatened without active management or removal of threats;
M, Monitor group. wildlife species that:
1. were at one time classified as endangered, threatened, or sensitive;
2. require habitat that has limited availability during some portion of its life cycle;
3. are indicators of environmental quality;
4. require further field investigations to determine population status;
5. have unresolved taxonomy which may bear upon their status classification;
6. may be competing with and impacting other species of concern; or
7. have significant popular appeal.

C, state candidate; wildlife species native to the State of Washington that the Department of Wildlife will review for possible listing as sensitive, threatened or endangered. Candidate species are desginated in Wildlife Policy 4802.
C2, Federal candidate; more information is being sought.
C3, Federal candidate; species that was once considered for listing under the Endangered Species Act which is no longer being considered.
Source: Compiled from Cushing 1992, Downs et al. 1993, Landeen et al. 1992 and DOW 1993.

Table 2-5. List of Mammals Occurring on the Hanford Site. (Sheet 1 of 2)

Common Name	Scientific Name	State	Federal
Merriam's shrew	*Sorex merriami*	C	
Vagrant shrew	*Sorex vagrans*		
Townsend's big-eared bat	*Plecotus townsendii*	C	C2
Little brown bat	*Myotis lucifugus*		
Silver-haired bat	*Lasionycteris noctivagans*		
California brown bat	*Myotis californicus*		
Yuma brown bat	*Myotis yumanensis*		
Pallid bat	*Antrozous pallidus*	M	
Hoary bat	*Lasiurus cinereus*		
Raccoon	*Procyon lotor*		
Mink	*Mustela vison*		
Long-tailed weasel	*Mustela frenata*		
Short-tailed weasel	*Mustela erminea*		
Badger*	*Taxidea taxis*		
Striped skunk	*Mephitis mephitis*		
Coyote*	*Canis latrans*		
Bobcat	*Felis rufus*		
Least chipmunk	*Eutamias minimus*		
Yellow-bellied marmot	*Marmota flaviventris*		
Townsend's ground squirrel	*Spermophilus townsendii*		
Northern pocket gopher	*Thomomys talpoides*		
Great Basin pocket mouse*	*Perognathus parvus*		
Beaver	*Castor canadensis*		
Western harvest mouse	*Reithrodontomys megalotis*		
Deer mouse	*Peromyscus maniculatus*		
Northern grasshopper mouse	*Onychomys leucogaster*	M	
Montane meadow mouse	*Microtus montanus*		
Bushy-tailed woodrat	*Neotoma cinerea*		
Sagebrush vole	*Lagurus curtatus*		
Muskrat	*Ondatra zibethicus*		
House mouse	*Mus musculus*		
Norway rat	*Rattus norvegicus*		
Porcupine	*Erethizon dorsatum*		
Black-tailed jackrabbit*	*Lepus californicus*		
White-tailed jackrabbit	*Lepus townsendi*		
Nuttall's cottontail rabbit	*Sylvilagus nuttallii*		

Table 2-5. List of Mammals Occurring on the Hanford Site. (Sheet 2 of 2)

Common Name	Scientific Name	State	Federal
Pygmy rabbit	*Brachylagus idahoensis*	E	C2
Mule deer*	*Odocoileus hemionus*		
White-tailed deer	*Odocoileus virginianus*		
Elk	*Cervus elaphus*		
Otter	*Lutra canadensis*		

*Mammals identified at the ERDF site.

[a] Abbreviations:
E, endangered; a species in danger of extinction throughout all or a significant portion of its range;
T, threatened; a species which is likely to become endangered within the foreseeable future;
S, sensitive; taxa vulnerable or declining, and could become endangered or threatened without active management or removal of threats;
M, Monitor group. wildlife species that:
1. were at one time classified as endangered, threatened, or sensitive;
2. require habitat that has limited availability during some portion of its life cycle;
3. are indicators of environmental quality;
4. require further field investigations to determine population status;
5. have unresolved taxonomy which may bear upon their status classification;
6. may be competing with and impacting other species of concern; or
7. have significant popular appeal.

C, state candidate; wildlife species native to the State of Washington that the Department of Wildlife will review for possible listing as sensitive, threatened or endangered. Candidate species are desginated in Wildlife Policy 4802.
C2, Federal candidate; more information is being sought.
Source: Compiled from Cushing 1992, Downs et al. 1993, and DOW 1993.

Table 2-6. Plant Species of Special Concern Occurring on the Hanford Site.

Common Name	Scientific Name	Federal	State
Columbia milkvetch	*Astragalus columbianus*	C	T
Persistentsepal yellowcress	*Rorippa columbiae*	C	E
Hoover's desert parsley	*Lomatium tuberosum*	C	T
Northern wormwood	*Artemisia campestris borealis* var. *wormskioldii*	C	E
Dense sedge	*Carex densa*		S
Gray cryptantha	*Cryptantha leucophaea*		S
Shining flatsedge	*Cyperus rivularis*		S
Piper's daisy	*Erigeron piperianus*		S
Southern mudwort	*Limosella acaulis*		S
False-pimpernel	*Lindernia anagallidea*		S
Dwarf evening primrose	*Oenothera pygmaea*		S
Tooth-sepal dodder	*Cuscuta denticulata*		M
Thompson's sandwort	*Arenaria franklinii* v. *thompsonii*		M
Robinson's onion	*Allium robinsonii*		M
Columbia River mugwort	*Artemisia lindleyana*		M
Stalked-pod milkvetch*	*Astragalus sclerocarpus*		M
Medic milkvetch	*Astragalus speirocarpus*		M
Crouching milkvetch	*Astragalus succumbens*		M
Rosy balsamroot	*Balsamorhiza rosea*		M
Palouse thistle	*Cirsium brevifolium*		M
Bristly cyptantha	*Cryptantha interrupta*		M
Smooth cliffbrake	*Pellaea glabella*		M
Fuzzy-tongue penstemon	*Penstemon eriantherus*		M
False yarrow	*Chaenactis douglassii var. glandulosa*		M
The following species may inhabit the Hanford Site, but have not been recently collected, and the known collections are questionable in terms of location and/or identification.			
Palouse milkvetch	*Astragalus arrectus*		S
Few-flowered blue-eyed Mary	*Collinsia sparsiflora*		S
Coyote tobacco	*Nicotiana attenuata*		S

* Occurs at ERDF site.
[a]Abbreviations:
E, endangered; a species in danger of extinction throughout all or a significant portion of its range;
T, threatened; a species which is likely to become endangered within the foreseeable future;
S, sensitive; taxa vulnerable or declining, and could become endangered or threatened without active management or removal of threats;
M, Monitor group. wildlife species that:
1. were at one time classified as endangered, threatened, or sensitive;
2. require habitat that has limited availability during some portion of its life cycle;
3. are indicators of environmental quality;
4. require further field investigations to determine population status;
5. have unresolved taxonomy which may bear upon their status classification;
6. may be competing with and impacting other species of concern; or
7. have significant popular appeal.
C, Federal Candidate Species
Source: Compiled from Cushing 1992, Downs et al. 1993, DNR 1994, and DOW 1993.

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3.0 WASTE CHARACTERISTICS

This chapter describes general characteristics of remediation wastes that may be placed in the ERDF. Information provided below includes descriptions of waste generating activities and waste units, physical characteristics of the waste, and chemical characteristics of the waste. The waste characteristics described in this chapter provide the basis for the risk assessment and comparative analysis of alternatives performed in later chapters, as well as the starting point for definition of acceptable waste concentrations and leachate concentrations provided in Appendix C.

Investigations of source operable units that may result in waste suitable for disposal in the ERDF are currently on-going. The status of RI/FS reports for 100 and 300 Area operable units are provided in the table below. Note that a Limited Field Investigation (LFI) is synonymous to a limited RI.

Source Operable Unit	RI and LFI/QRA	FS Report	
		Phase I/II	Phase III
100-BC-1	Complete	Complete	In Progress
100-BC-2		Complete	In Progress
100-DR-1	Complete	Complete	In Progress
100-DR-2		Complete	
100-FR-1	Draft	Complete	
100-HR-1	Complete	Complete	In Progress
100-HR-2		Complete	
100-KR-1	Draft	Complete	
300-FF-1	Complete	Complete	In Progress

The completed reports identified in the above table are listed below:

- Limited Field Investigation Report for the 100-BC-1 Operable Unit (IT Corp 1993a)
- Limited Field Investigation Report for the 100-DR-1 Operable Unit (DOE-RL 1993k)
- Limited Field Investigation Report for the 100-HR-1 Operable Unit (IT Corp. 1993b)
- Qualitative Risk Assessment for the 100-BC-1 Source Operable Unit (WHC 1994b)

- Qualitative Risk Assessment for the 100-DR-1 Source Operable Unit (WHC 1994c)
- Qualitative Risk Assessment for the 100-HR-1 Source Operable Unit (WHC 1994d)
- Qualitative Risk Assessment for the 100-KR-1 Source Operable Unit (WHC 1994e)
- 100 Area Feasibility Study Phases 1 and 2 (DOE-RL 1992g)
- Phase I Remedial Investigation Report for the 300- FF-1 Operable Unit (DOE-RL 1993f)
- Phase I and II Feasibility Study Report for the 300-FF-1 Operable Unit (DOE-RL 1993l)

The RI and LFI reports include information regarding physical characteristics of the waste, constituent background data, and contaminant concentration data. In addition, they identify the contaminants of concern and the high priority waste sites. Risk assessment information is provided in the QRA and RI reports. The FS reports provided information regarding ARARs, remedial objectives, areas and volumes of affected media, and screening and evaluation of technologies and alternatives. In conjunction with the RI/FS investigations, several treatability tests have been conducted. These include bench, lab, and pilot-scale soil washing in the 300 Area (DOE-RL 1994b); bench and lab-scale soil washing on 100 Area contaminated soils (DOE-RL 1994a); in-situ vitrification testing of 100-BC Area soils (Ludowise 1994); and pilot-scale treatability testing on various methods for excavating soils contaminated with radionuclides (unpublished). Future treatability tests currently scheduled include: pilot-scale test for the exhumation of a burial ground in the 100-BC Area; and ex-situ vitrification in 100 Area soils.

Waste characterization is not yet complete and the information summarized below is considered preliminary. It is anticipated that some of the wastes encountered during remediation will differ from the characterization provided below. In particular, the maximum chemical concentrations reported in this document are based on currently available information. It is possible that higher maximum concentrations will be encountered during future investigations and during remediation. For this reason, the waste acceptance chemical concentration criteria are established as high as possible without resulting in unacceptable risk.

Most of the waste in the ERDF will have chemical concentrations less than the maxima reported in this report. Therefore, the risk estimates provided in Chapters 6 and 9 are conservative and it is likely that actual exposures will be significantly lower. Maximum concentrations are used because of the uncertainty regarding actual waste received at the ERDF and the difficulty in estimating representative "average" exposure concentrations for most of the waste units. The maximum total quantity of waste from the 100, 200, and 300 Areas is estimated to be 21.4 million m^3 (28 million yd^3). The percentage breakdown of the types of waste is presented for each area.

It is anticipated that the ERDF will receive remediation waste from the 100, 200, and 300 Areas. This chapter includes three subsections, one for each of these aggregate areas. This division reflects the difference in waste-generating activities at each of the aggregate areas: the 100 Area waste is primarily associated with operation of plutonium production reactors; the primary waste-generating activities in the 200 Area were fuel reprocessing and plutonium recovery; and the 300 Area waste is primarily associated with nuclear fuel fabrication and research laboratories. A final subsection summarizes maximum waste concentrations and provides screening against background soil concentrations.

3.1 100 AREA WASTE CHARACTERISTICS

Most of the recent investigations of the 100 Area operable units have been conducted as Limited Field Investigations (LFIs). Consistent with the Hanford Site Past-Practice Strategy (DOE-RL 1992f), these investigations have been less extensive than traditional RIs. The objectives of the *Hanford Site Past-Practice Strategy* are to accelerate decision-making by maximizing the use of existing data and facilitating implementation of expedited response actions (ERAs) and/or interim remedial measures (IRMs) in a timely manner. The information in Section 3.1.1 and 3.1.2 was derived from *100 Area Feasibility Study Phases 1 and 2* (DOE-RL 1992g) unless otherwise referenced.

3.1.1 Waste Generating Activities

Between 1943 and 1962, nine water-cooled, graphite-moderated plutonium production reactors were built along the shore of the Columbia River upstream from the now-abandoned town of Hanford. Eight of these reactors (B, C, D, DR, F, H, KE, and KW) have been retired from service and will be decommissioned. The ninth reactor, N, was recently shutdown and will also be retired. In some of the reactor areas, after the reactor was retired from plutonium production service, the ancillary facilities were used as laboratories for special studies or for storage/treatment purposes.

3.1.1.1 Reactor Operations (Excluding N Reactor). The principal components of the original eight reactors consisted of the reactor, the reactor cooling water loop, the reactor gas and ventilation system, and the irradiated fuel handling system.

Reactor. Each reactor was graphite moderated and cooled with water pumped through on a single-pass basis. The reactor moderator stack consisted primarily of graphite blocks, some of which were cored to allow water flow and equipment placement. Aluminum process tubes held aluminum-clad, uranium-metal fuel elements and provided channels for cooling water. Boron was used for control and safety rods. A boron solution was used as a backup safety system requiring the insertion of aluminum thimbles into the channels to protect the graphite. The boron solution system was later replaced with a system utilizing nickel-plated boron balls.

Reactor Cooling Water Loop. Cooling water for the reactor was taken from the Columbia River, alum with excess sulfuric acid was added to aid in the removal of particulates, and then passed through flocculators to settling basins where an organic polyelectrolyte was added as a filter aid. Hydrated calcium oxide, chlorine, and sodium dichromate were also added to the water to control pH, algae, and corrosion, respectively.

After passage through the reactor, the water was sent to retention basins where it was kept for a period of time to allow for thermal cooling and partial decay of short-lived radionuclides. The water was then released via outfall structures and pipelines to the middle of the river.

Reactor Inert Gas and Ventilation System. Inert gas, composed of helium with carbon dioxide or nitrogen, was used to remove moisture and foreign gases, transfer heat, and detect water leaks within the reactor.

Irradiated Fuel Handling. Refueling occurred on a regular basis and the removed irradiated fuel elements were transferred to the fuel storage basin for radioactive decay. Following the decay period, the fuel elements were transferred to the 200 Areas for reprocessing.

Decontamination Activities. Decontamination activities took place both in the reactor buildings and in nearby facilities. Decontamination solutions consisted of various acids and solvents that were used to remove radionuclides from equipment, tools, reactor hardware, wall surfaces, and other items contaminated during reactor operations (DOE-RL 1992h).

3.1.1.2 Laboratory Operations. Laboratory operations at the 100 Area included a tritium extracting facility at the 100 B Area, a mechanical development laboratory at the 108-D building, thermal hydraulic laboratories at the 185-D and 189-D buildings, a pharmacology laboratory at the 1705-F building, and biological research laboratories at the 100 F Area (General Electric 1964). These are described below.

The tritium extracting facility was located at the 132-B-1 building in the 100 B Area. It was originally designed to be a water treatment facility, but in 1948 it was converted to a laboratory for extracting tritium from lithium-aluminum targets irradiated in the B, C, D, DR, F, and H reactors. There were two tritium recovery campaigns, one using a stainless steel line and one a glass line. The major contaminants from tritium recovery were tritium and mercury. The mercury was generated as a result of using mercury vapor pumps in the process. In 1954, the process was discontinued and the building used as an aluminum process tube examination facility (DOE-RL 1992h).

The mechanical development laboratory at the 108-D building contained various reactor mock-up facilities such as segments of the C- and K-Reactor lattices, flow mock-ups and simulated elevator and reactor face equipment. The thermal hydraulic laboratories at the 185-D and 189-D buildings were used for boiler burnout, fog cooling, transient heat transfer, and flow instability studies. No information was provided on wastes generated from these laboratory operations (General Electric 1964).

The main biological laboratory (108-F) for studying the effects of radiation on animals and plants operated from 1945 until 1976. The earliest research activities were fish studies conducted in the 146-F laboratory and in adjacent ponds. Effluent water was supplied to the laboratory facilities via the 147-F pump house, and discharged to the PNL outfall via the pump house. Sheep studies began in the late 1940s. Dose studies with sheep used iodine-131, strontium-90, plutonium-239, and cesium-137. Studies were also performed on pigs, goats, milk cows, chickens, and ducks. Animals were housed in buildings 141-F, 141-C, 141-P, and 141-S. The animal monitoring laboratory, which contained a whole body counter, was in building 145-F. Animal research was also conducted on beagle dogs. Approximately 300 to

400 dogs were housed in the 144-R dog kennel. Plutonium-239 was the main isotope used in the dog studies. Laboratory facilities for the experiments were located in the 132-F-2 inhalation laboratory (DOE-RL 1992i).

In addition to the animal studies, radioecology experiments also took place in the 100-F Area. Greenhouses in the 1705-F building were used for growing potted plants. In addition, the "strontium gardens" plots, located in the southwest corner of the site, were used for growing cereal grains, alfalfa, and other crops in soil containing strontium-90 and cesium-137 (DOE-RL 1992i).

After the F reactor operations ceased in 1965, the animal research operations took over some of the office buildings and maintenance shops formerly associated with reactor operations (Tipton 1975). Building 1707-F was converted to a dog inhalation laboratory and the 1707-FA building was converted to a rodent inhalation laboratory. Building 1713-F was used for a pathology laboratory, and the 1719-F building was converted to an animal care facility. Small animals were housed in the 1701-FA building. It is not known what radioisotopes or other chemicals were used in these buildings (DOE-RL 1992i).

3.1.1.3 N Reactor Operations. The following information was derived from RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-2 Operable Unit, Hanford Site, Richland, Washington, Draft C (DOE-RL 1994e).

The N reactor was the last reactor to be constructed as a major production reactor at the Hanford Site. The N reactor is a graphite-moderated, light-water cooled, horizontal-pressure-tube nuclear reactor. It differs from the other reactors at Hanford in that it was designed as a dual purpose reactor capable of producing special nuclear materials and steam. The steam produced from the N reactor core cooling systems was piped to the Hanford Generation Plant (HGP) and used for production of electrical power.

Confinement System. The N reactor used a confinement system based on the concept to release the initial burst of steam resulting from a postulated reactor coolant pipe break. When the confinement pressure subsided, the steam vents were closed and ventilation valves opened. The ventilated steam was filtered through charcoal and high efficiency filters to prevent any release of fission products from fuel failure.

Nuclear Fuel System. The fuel used for operation of the N reactor was slightly enriched uranium-235 (U-235) (0.94% to 1.25%), clad with a zirconium alloy. At shutdown, a concentric tube-in-tube fuel design was in use. In the past, other materials have been used as a target in connection with an enriched uranium driver fuel element to produce useable isotopes such as tritium (H-3) and plutonium-238 (Pu-238). The fuel cladding is zircaloy-2 metallurgically bonded to the uranium by a co-extrusion process.

Heat Dissipation System. The secondary steam system for the N reactor removed the reactor heat from the reactor coolant system by boiling secondary water in the shell side of the steam generator. During operation solely for the production of special nuclear material the major fraction of this steam was routed to 16 dump condensers which were arranged in parallel and cooled by untreated Columbia River water.

During dual purpose operation, the major fraction of steam generated was routed to the HGP. A portion of the steam generated was used to drive the reactor coolant pumps, the onsite turbine generator and to keep the dump condensers warm so they were ready to accept full steam load in the event of a Hanford Generation Plant turbine generator shutdown.

Water Supply System. Strained untreated water from the Columbia River was supplied as coolant to the dump condensers as well as the reactor coolant pump drive turbine surface condensers and the local turbine generator condensers. This condenser cooling water was then returned to the river. Untreated water was also supplied to the water treatment facility for the filtered water, sanitary water, and demineralized water systems.

Decontamination. Facilities were provided for chemical decontamination of the entire reactor coolant system or for any of several major portions of the system, including the individual heat exchanger cells. The graphite and shield cooling system could also be chemically decontaminated. Included were equipment for storage and preparation of the necessary chemicals and piping for injection at appropriate points. Chemical wastes from decontamination, along with rinse waters, were normally routed to the 116-N-2 storage tank, then shipped by tank truck or rail car to the 200 Area of the Hanford Site for disposal.

3.1.2 Waste Units

Retention Basins. The 100 Area retention basins were rectangular concrete or circular steel structures used to retain reactor effluent for radioactive decay and thermal cooling before release to the Columbia River. The basins ranged in capacity from 60 to 90 million L (16 to 24 million gal). Initially, effluent to the basins was controlled in a manner that allowed redirection of effluent contaminated by ruptured fuel elements to a crib. This practice was found to cause structural damage to the basins due to differential pressures and stresses on the retention basin walls, and was changed to protect the integrity of the basins. The new procedure precluded redirection of the more highly contaminated effluent to alternate disposal sites, resulting in all effluent being discharged to the river. Some of the retention basins have been partially demolished and buried in place. Some have also been used for disposal of contaminated demolition materials.

Each retention basin contains from 1/2 cm (1/4 in.) to 8 cm (3 in.) of sludge covered by 0.6 to 1.2 m (2 to 4 ft) of soil fill. Cobalt-60, europium-152, europium-154, and nickel-63 account for approximately 94% of the radionuclide inventory located within the retention basins. In addition to radionuclide contamination, the basins may be contaminated with chemical constituents used as additives in the cooling water. A major contaminant is chromium which was used extensively in the 100 Area reactor cooling water to minimize corrosion.

Pipelines. Effluent pipelines ran from the reactors to the retention basins, from the retention basins to the outfall structures, and from the outfall structures to the middle of the river. The 100 Area contained approximately 19,000 m (62,000 ft) of effluent pipeline ranging in size from 31 to 213 cm (12 to 84 in.) in diameter. The pipelines were constructed of carbon steel, reinforced concrete, or vitreous tile, and included manholes, junction boxes, tie-lines, and valves. Except for a portion of pipeline in the F Area that was removed and placed in its retention basin, the on-land pipelines are still in place underground. The river pipelines are still in place with the exception of approximately 15 m (50 ft) in the F Area that washed downstream.

The pipelines contain accumulated sludge. Radionuclide and chemical contamination is expected to be similar to that found in the retention basins.

Outfall Structure. Outfall structures were compartmentalized, reinforced concrete boxes used to direct effluent to the middle of the Columbia River. The spillways associated with them were of concrete or rip-rap construction, and were used only in case of overflow. In the F Area, the PNL outfall structure was used to direct wash water from animal pens to the river.

With the exception of the PNL outfall, radionuclide and chemical contaminants associated with the outfall structures are presumed to be similar to those associated with the retention basins. Contaminants associated with the PNL outfall include strontium-90 and small amounts of cesium-137 and plutonium-239.

Cribs. Cribs received effluent during fuel cladding failures, decontamination activities, and other facilities associated with reactor operations. In general, cribs were buried rock-filled structures with open bottoms of wood construction.

The pluto cribs received effluent from process tubes following fuel cladding failures. Fission products and water additives (such as chromium) are potential contaminants.

The dummy/perf decontamination cribs/drains received radioactive liquid waste from decontamination of dummy fuel element spacers in the F, H, and B reactors. Acids, including nitric, sulfuric, oxalic, and hydrofluoric, were used extensively in the decontamination process. Therefore, in addition to radionuclides, nitrate and other acid residues are likely contaminants in soils beneath these cribs.

The 108 building cribs/drains at the 100 BC Area received contaminated liquid effluents from the 108 laboratory operations. Tritium has been identified as a waste constituent in the 116-B-5 crib.

The 115 building cribs received condensate and liquid waste from the reactor gas purification systems. Waste passed through a pipe to a 3.2 m (10.5 ft) long perforated pipe and into the soil column. Tritium and carbon-14 were the principal radionuclides released to these cribs.

The 117 building cribs received drainage from the confinement system seal pits. These cribs generally received only short-lived radionuclides and were released from radiological control prior to 1967.

Special use cribs include the 116-F-5 ball washer crib, the 116-KE-2 crib, and the 116-DR-7 inkwell crib. The 116-F-5 crib received liquid wastes from decontamination of boron-steel balls used in the ball 3X system. The principal radionuclides in the 116-F-5 crib are strontium-90, europium-154, europium-155, and cesium-137. The 116-KE-2 crib received liquid wastes from the 1706-KER loop and was found to contain strontium-90 and cobalt-60, and a maximum concentration of 2.1 pCi/g of plutonium 239/240. The 116-DR-7 crib received liquid potassium borate solution from the 3X system prior to the ball 3X system upgrade.

French Drains. French drains were generally gravel-filled concrete or vitreous pipe. In the K Area, sulfuric acid sludge was disposed to the drains from the acid storage tanks. The

120-KE-1 french drain contains approximately 200 kg of mercury. Drains in the F Area received liquid waste from botany experiments and decontamination processes, while drains in the other areas received liquid waste only from decontamination processes.

Trenches. Trenches were generally open excavations with sloped sides, used as backup for the retention basins when effluent was too contaminated to be released to the river. The 100 Area has five types of trenches that differ in terms of purpose and construction: liquid waste disposal trenches, the K trench, the 1608 trench, sludge trenches, and the Lewis Canal.

The liquid waste disposal trenches received effluent from retention basins during fuel cladding failures. Fission products and chromium are likely contaminants.

The K trench regularly received wastes from all contaminated floor drains in the reactor buildings, overflow from the storage basins, and leakage from the effluent basin. Periodic sources of contaminated flow emanated from dummy decontamination, rear face decontamination, storage basin during rod exchange, and retention basins during fuel cladding failures. The trench contained a maximum concentration of 130 pCi/g of plutonium-239/240. Sodium dichromate, sulfamic acid, sulfuric acid, and copper sulfate were also discharged to the trench.

The 1608 trenches in the F and H Areas received effluent during the Ball 3X Project. (This project involved modification of the emergency reactor control system from a liquid boron system to a solid boron and carbon ball system). Both trenches have overflowed and contaminated adjacent soils. The trenches have since been backfilled. Contaminants include strontium-90, tritium, europium-152, europium-154, cobalt-60, and cesium-137. The maximum plutonium concentration is less than 1 pCi/g.

The sludge trenches in the B Area received sludge removed from the B Area retention basin.

The Lewis Canal in the F Area received miscellaneous waste from the reactor and 190-F buildings in the F Area as well as decontamination waste from the 189-F building. It also received effluent during the Ball 3X outage. Occasionally, coolant from the reactor face was discharged to the trench. All but 450 m (1500 ft) at the inlet has been released from radiological control. The major radionuclides include europium-152 and -154, cobalt-60, and cesium-137. Sodium dichromate and sulfamic acid are known to have been discharged to the trench.

Solid Waste Disposal Facilities. Solid waste disposal units consisted of burial grounds, landfills, ash/burn pits, and storage caves/vaults. Investigations by Dorian and Richards (1978) found that plutonium-239/240 generally was not detected, that cobalt-60 comprised 90% of the radionuclide inventory, and other radionuclides included europium-152, -154, -155, cesium-134, -137, strontium-90, and nickel-63.

A total of 28 radioactive burial grounds have been identified in the 100 Area including seven major burial grounds associated with reactor operations, two burial grounds used for biological wastes, and one burial ground used during the tritium separation project at the 100 B Area.

Each reactor had an associated burial ground which was used for disposal of high-dose equipment. The total radionuclide inventory for these burial grounds is estimated to be 4,000 Ci, mostly from cobalt-60 and nickel-63. Metallic wastes include lead, cadmium, lead-cadmium alloy, boron, mercury, and graphite. The 118-B-1 burial ground also received waste associated with the tritium separation program, including lithium-aluminum alloy. This waste contained a tritium inventory of about 3,800 Ci and approximately 900 kg (2,000 lbs) of mercury.

Ball 3X Burial Grounds. The Ball 3X burial grounds were located in the B, D, F, and H Areas and were used to dispose of highly contaminated waste (containing activation products) removed from the reactor buildings during the Ball 3X Project. Wastes included thimbles (aluminum components used to provide a sealed access to the reactor for the control and safety rods and for a boron solution used as a shutdown device) and step plugs (an aluminum shielding device used in the reactor tubes). The burial grounds in the B, F, and H Areas consisted of a single trench; the D Area burial grounds contained two 12 x 6 x 3 m (40 x 20 x 10 ft) trenches. The F Area burial ground was 50 x 15 x 5 m (175 x 50 x 15 ft) deep, the B Area burial ground was 15 x 15 x 6 m (50 x 50 x 20 ft) deep, and the H Area burial ground was 46 x 9 x 3 m (150 x 30 x 10 ft) deep.

Tritium Separations Project Burial Ground. Wastes associated with the metal lines used in the tritium separations project were disposed in this burial ground. An estimated 510 metric tons (560 tons) of waste, including 16 metric tons (18 tons) of lead and 23 metric tons (25 tons) of aluminum, were disposed. This included 11,000 Ci of tritium.

Biological Burial Grounds. Two burial grounds in the F Area were used for the disposal of biological wastes. Strontium-90 and plutonium-239/240 are expected contaminants.

Ash Pits. The ash pits received coal ash sluiced with water from the powerhouse. Ash from selected power plants at the Hanford Site has been characterized as nonradioactive and nonhazardous. Common sources of coal were used throughout the site so the ash in the pits will probably be comparable to these analyses. The ash was analyzed using the extraction procedure (EP) toxicity test in accordance with WAC 173-303-090 and no hazardous/dangerous materials were found.

Burn Pits. Burn pits in the 100 Area were used to dispose of nonradioactive combustibles such as paints, solvents, laboratory wastes, and office wastes. Evidence of burning exists at the sites and several of the pits are also believed to have been used to dispose of rubble from demolition projects and debris and soil from retention basin repairs. Other materials which may have been disposed in the burn pits include scrap metal, glass, and asbestos. Sizes of the burn pits range from 890 to 21,000 m^2 (9,600 to 224,000 ft^2).

Storage Caves/Vaults. The storage caves/vaults were used for temporary storage of horizontal control rods for decay prior to disposal. One vault was used for the storage of miscellaneous reactor hardware and the hardware still remains in the vault. The caves were 12 m (40 ft) by 8 m (25 ft) concrete tunnels covered with mounds of dirt. The vault in the F Area was a 5 x 2.4 x 2.4 m (16 x 8 x 8 ft) concrete box with a wooden cover. No information is available on specific inventories of radionuclides.

Demolition Sites and Landfills. Demolition sites and landfills in the 100 Area received very low-level construction and demolition wastes. Little or no radiological contamination is expected in these sites.

Unplanned Releases. Unplanned releases occurred in the 100-F, 100-K, and 100-N Area. The 100-F Area release occurred on March 13, 1971 when the main sewer line between the 141-C and 141-M buildings became plugged. The spill consisted of wash water from the clean out of animal pens and contained strontium-90 and plutonium-239. The area was stabilized with clean gravel.

The unplanned release in the K Area occurred in April 1979 when the 105-KE pickup chute area of the fuel storage basin leaked approximately 1,700 L/hr (450 gal/hr) of fuel storage basin effluent and debris for an unknown period of time. Total activity was estimated at 2,530 Ci including 1.3 Ci of plutonium-239/240.

Documented unplanned releases for the N Area include:

- two releases associated with the 1314-N Liquid Waste Loadout Station
- two releases at the 119-N Air Sampling and Monitoring Building
- three releases at the 166-N tank farm
- one release at the 116-N-1 crib and trench
- two releases at the 1322-N and 1322-NA Sample Buildings
- three releases at the 116-N-2 radioactive chemical waste treatment and storage facility
- one release at the 181-N River Pumphouse (that violated NPDES permit conditions)
- six releases at the 1304-N Emergency Dump Tank
- three releases associated with the 118-N-1 Spacer Storage Silos and associated piping
- two releases associated with the N reactor fuel storage basin and its drainage system
- three significant releases at the 108-N facility associated with unloading and transfer operations (various small spills have occurred over the years; these are the larger ones)
- four significant releases at the 120-N-5 Acid/Caustic Transfer Trench and Neutralization Unit
- two releases associated with the regeneration waste transport system
- three releases associated with the 184-N day tank Area
- five releases from the 166-N - 184-N Pipelines

- one unplanned release near the 100-N Sewer System.

The RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit (DOE-RL 1994f) should be referred to for more detailed information on unplanned releases at the 100-N Area.

Undocumented releases of hydrocarbon products and chemicals may have resulted in contamination of the soils in the 100 Area.

3.1.3 Physical Characteristics and Components of 100 Area Waste

Limited characterization of soils has taken place at the 100 Area. Physical properties samples were taken during limited field investigations at 100-BC-1, 100-DR-1, and 100-KR-1. Samples were analyzed for the following parameters using American Society for Testing and Materials (ASTM) methods (where applicable):

- particle size distribution
- specific gravity
- moisture content
- moisture retention
- saturated hydraulic conductivity (K_{sat})
- porosity.

Samples were taken from 116-DR-1, 116-B-1, and 116-KE-4. The following information on physical properties was taken from *Limited Field Investigation Report for the 100-DR-1 Operable Unit* (DOE-RL 1993k), *Limited Field Investigation Report for the 100-BC-1 Operable Unit* (IT Corp. 1993a), and *Limited Field Investigation Report for the 100-KR-1 Operable Unit* (DOE-RL 1994d). Three split tube samples were collected from vadose borehole 116-DR-1. The samples were dry, slightly gravelly sand, composed of about 5-10% pebbles and 90-95% sand. Two split tube samples were collected from vadose borehole 116-B-1. These were dry, dense, sandy gravel composed of about 50% sand and 50% gravel. Four split spoon samples were collected from vadose borehole 116-KE-4A, at approximately 5 ft intervals. These samples were described in the field as silty sandy gravel with 30% to 45% gravel, 45% to 50% sand, and 10% to 25% silt (fines). Laboratory analysis on particle size showed 49% to 73% gravel, 22% to 42% sand, and 5% to 9% fines.

The specific gravity was determined for both the coarse and fine fraction of the samples. For the 116-DR-1 borehole samples, the average sG was 2.78. The average sG for the 116-B-1 samples was 2.61. Specific gravity was not reported for the 116-KE-4 samples.

The moisture contents for the 116-DR-1 borehole samples were 4.05%, 3.15%, and 4.01%. For the 116-B-1 borehole, the moisture content of the 22 ft and 27 ft samples were 0.7% and 1.66%, respectively. The moisture contents for the 116-KE-4 borehole samples were 2.46%, 3.86% and 4.49%. These values are consistent with the 116-DR-1 borehole values.

The hydraulic conductivity ranged from 1.4×10^{-3} to 4.9×10^{-3} cm/s for the 116-DR-1 borehole samples. For the 116-B-1 borehole, the hydraulic conductivity ranged from 8.0×10^{-4} to 1.6×10^{-3}. Hydraulic conductivity analysis had not been completed at the publication time of the Limited Field Investigation Report for the 100-KR-1 Operable Unit.

The porosity ranged from 35.2% to 43.2% for the 116-DR-1 borehole samples. For the 116-B-1 borehole, the porosity ranged from 16.9% to 25.4%. The porosity ranged from 23.4% to 27.1% for the 116-KE-1 borehole samples.

100 Area waste includes soil, solid wastes, sediments, and sludges. Solid waste encompasses hard waste, soft waste, demolition waste, and pipes. Soft waste includes collapsed cardboard boxes, paper, rags, clothing, plastic, and miscellaneous trash. Hard waste includes aluminum tubes and spacers, failed steel and stainless steel equipment, timbers, and metal drums. Demolition waste includes concrete with and without rebar, steel plate, and timbers. Pipes range from 1.3 to 61 cm (1/2 to 24 in.) in diameter. The estimated percentages of the different types of waste are presented below:

Estimated Distribution of Waste in the 100 Area.

Medium	Percent of Volume
Low Activity Soil	70%
High Activity Soil	2.2%
Riverbank Sediments, all low activity	5.3%
Low Activity Solid Waste (except pipe >24 inches, diameter)	17%
High Activity Solid Waste (except pipe)	1.2%
Low Activity Pipe (diameter >24 inches)	5.0%
High Activity Pipe	0.061%

This breakdown was derived based on the following assumptions:

- All radioactive or radioactive mixed waste removed from contaminated solid media is considered low-level waste. However, in the *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991b), radioactive waste from the 100 Area is divided into two categories: low activity and high activity wastes. Low activity waste contains less than 100 nCi/g total transuranium radionuclides and emits beta/gamma radiation at any point resulting in a dose rate less than 200 mrem/hr. High activity waste emits beta/gamma radiation at any point resulting in a dose rate greater than 200 mrem/hr, regardless of the activity level of the transuranium radionuclides.

- Riverbank sediments include all vadose zone soils between the low and high water elevations of the Columbia River inland to the location where the difference between the high water and low water elevations is minimal. This varies from approximately 15 m (48 ft) to 55 m (180 ft) from the river. The riverbank sediments thus represent vadose soils near the river which have been contaminated as a result of fluctuation in the levels of contaminated groundwater which is caused by river stage fluctuations.

The percentages of types of waste are based on the volume estimates from *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991b) and *100 Area Feasibility Study Phases 1 and 2* (DOE-RL 1992g).

3.1.4 Chemical Characteristics of 100 Area Waste

The following data sources were used for the 100 Area chemical waste characteristics evaluation:

- *Qualitative Risk Assessment for the 100-BC-1 Source Operable Unit* (WHC 1994b)
- *Qualitative Risk Assessment for the 100-DR-1 Source Operable Unit* (WHC 1994c)
- *Qualitative Risk Assessment for the 100-HR-1 Source Operable Unit* (WHC 1994d)
- *Qualitative Risk Assessment for the 100-KR-1* (WHC 1994e)
- *Source Inventory Development Engineering Study for the Environmental Restoration Disposal Facility* (U.S. Army Corps of Engineers 1993b).

QRA Data. Analytical data in the Qualitative Risk Assessments (QRAs) were derived from the Limited Field Investigations (LFI) for operable units 100-BC-1, 100-DR-1, 100-HR-1, 100-KR-1 (IT Corp. 1993a, DOE-RL 1993k, IT Corp. 1993b, DOE-RL 1994d) and historical information (Dorian and Richards 1978).

The sampling and analysis conducted for these LFIs were limited in nature, with generally one shallow borehole for each of the high priority waste units. In addition, data from one waste unit were considered representative for analogous waste units at other operable units (for example, all septic tanks were assumed to be analogous to sites 1607-H2 and 1607-H4, pluto cribs or other sites receiving similar liquid waste were considered to be analogous to sites 116-B-3 and 116-D-2A, etc.) and therefore no additional sampling was conducted at these analogous waste units. The analogous site approach is consistent with the Hanford Past Practice Strategy (DOE-RL 1992f). The analogous sites list is presented in Appendix H of the *Source Inventory Development Engineering Study for the Environmental Restoration Disposal Facility* (U.S. Army Corps of Engineers 1993b). LFIs did not address chemical characteristics of the burial grounds. In general, limited information is available regarding constituents in the burial grounds.

In the QRAs, the concentration used for risk assessment was the maximum of the LFI and historical data for samples located in the upper 4.6 m (15 ft) of soil. For the purposes of this evaluation, maximum concentrations were selected from LFI and historical data regardless of sample depth.

Source Inventory Data. Data for the 100-NR-1 operable unit and data for the septic tank waste units were taken from the *Source Inventory Development Engineering Study for the Environmental Restoration Disposal Facility* (U.S. Army Corps of Engineers 1993b) since these data were not available in the QRAs.

Data Compilation. Tables 3-1, 3-2, and 3-3 contain the 100 Area summaries of the maximum concentrations for radionuclides, organic compounds, and chemistry data, respectively. Summary tables also reference the waste site where the maximum concentration was encountered.

3.2 200 AREA WASTE CHARACTERISTICS

The information in this section was derived from unpublished documents.

3.2.1 Waste Generating Activities

Historically, the 200 Areas were used for fuel reprocessing, plutonium recovery, and waste management and disposal. Because of significant human health and environmental risks associated with the excavation of the majority of contaminated sites in the 200 Areas, in-situ remediation methods will probably be used for most sites. For the purposes of this document, it is assumed that only the sites with lower environmental risks will be excavated and placed in the ERDF, as discussed below.

3.2.2 Waste Units

There are two primary groupings of waste units: 1) low-activity sites where radioactive contamination produces radiation dose rates below 200 mrem/hr and 2) high-activity sites where radiation dose rates are above 200 mrem/hr. High-activity sites include a diversity of highly contaminated materials in a variety of underground structures, including cribs, burial grounds, and trenches. For the purpose of this document, it is assumed that higher activity sites will likely be stabilized in place and capped with a protective barrier. The low-activity sites at the 200 Areas resulted from various unplanned releases of radioactive materials and/or from the wind-blown dispersion of radioactive materials. The contaminated media at low-activity sites is almost exclusively soil, with smaller (approximately 10% of total quantity) quantities of other materials such as pipe. Low-activity sites are generally not contaminated below a depth of 15 cm (6 in). For the purpose of this document, it is assumed that these sites will be excavated and the resulting waste materials will be treated and placed at the ERDF. These sites are grouped into migration sites, and pipelines and ancillary structures, as described below.

Migration Sites. There are 24 migration sites located in and adjacent to the 200-East and 200-West Areas. Many of these migration sites include unplanned release sites which are identified as surface contamination sites, several of which have been partially remediated by removal of contaminated soil and the addition of stabilizing backfill. The majority of these migration sites were associated with spills and leaks of radioactive and mixed liquid wastes. The quantities of spills and leaks ranged from a few liters to thousands of liters.

Pipelines. An extensive network of pipelines and ancillary equipment was used to transfer liquid wastes from the generating source to disposal areas, and from one disposal area to another. Pipelines (also referred to as transfer lines, process lines, and process sewer lines) vary in materials of construction (from stainless steel to vitrified clay), size (from 5 cm (2 in.) to 150 cm (60 in.) in diameter), and length (from a few meters to several thousand meters).

Ancillary equipment used includes valve pits, pumps, pumphouses, transfer boxes, diversion boxes, instrumentation, localized sumps, pits, and storage pads. The materials of construction, operations and maintenance, and years of service varied.

Pipelines and ancillary equipment are the most frequently referenced source of unplanned releases. Pipeline failures were associated with unplanned releases as a result of corrosion, joint expansion or contraction, rupture from construction activities, thermal expansion and other means of failure. Ancillary equipment was associated with unplanned releases as a result of failed seals, corrosion, material failure, overflow or overtopping, plugging and other similar events. Many of the older pipelines most likely have contaminated soils along some portion of their lengths.

3.2.3 Physical Characteristics and Components of 200 Area Waste

A breakdown of the components of 200 Area waste that will likely be disposed in the ERDF is presented below. The percentages are based on relative volume estimates. There is no information available on physical characterization of 200 Area soils likely to be disposed in the ERDF.

Components of 200 Area Waste

Source	Percentage
Migration Sites	75%
Pipelines	25%

3.2.4 Chemical Characteristics of 200 Area Waste

No analytical data has been located for the pipeline sites and only radionuclide data was found for migration sites. These radionuclide data are summarized in Table 3-4. Only radionuclides with one or more values greater than 1 pCi/g are reported.

3.3 300 AREA WASTE CHARACTERISTICS

3.3.1 Waste Generating Activities

The information in this section is derived primarily from *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* (DOE-RL 1993f), *Phase I Remedial Investigation Report for the 300-FF-5 Operable Unit* (DOE-RL 1993g), and *Source Inventory Development Engineering Study for the Environmental Restoration Disposal Facility* (U.S. Army Corps of Engineers 1993b).

Activities in the 300 Area have historically been related primarily to the fabrication of nuclear fuel elements. In addition, many technical support, service support, and research and development activities related to fuel fabrication were carried out. As fuel fabrication activities have decreased with the shut-down of the Hanford Site production reactors, research and development activities in the 300 Area have increased. The newer buildings in the area house primarily laboratory and large test facilities.

3.3.1.1 Fuel Fabrication. Fuel elements were fabricated in the 300 Area by a coextrusion process. This process formed the zirconium cladding and the uranium/silicon fuel core from primary material components and bonded the two together in one operation. The fuel elements were protected with a copper jacket for the extrusion process. The jacket also prevented atmospheric contamination of the reactive fuel element, and the copper was easily lubricated for extrusion. Lubricants were removed using organic solvents such as trichloroethylene. After extrusion into billets, the copper was removed by dissolution in nitric acid (Stenner et al. 1988).

The uranium core was recessed by chemical milling so that the billets could receive an end cap. The chemical milling was performed using copper sulfate, nitric acid, and sulfuric acid. A zirconium end cap was then brazed on with beryllium. The fuel elements were tested for cap attachment, cap to core bonding, cladding to core bonding, and cladding to cap bonding before fuel-element supports and locking clips were attached. Next, the tubes were autoclaved in steam to detect any perforations in the cladding or end caps. Finally, the elements were packed for storage and shipment (Stenner et al. 1988).

Prior to the late 1960's, aluminum-clad fuel was manufactured in the 300 Area as well, and thorium fuel fabrication was initiated in 1969 (Stenner et al. 1988).

Other chemicals routinely used in the fuel fabrication processes included (Douglas United Nuclear 1967; Stenner et. al. 1988):

chromic acid
chromium trioxide
hydrofluoric acid
oxalic acid
phosphoric acid
potassium nitrite
sodium aluminate
sodium bisulfate
sodium carbonate
sodium dichromate
sodium fluorosilicate
sodium gluconate
sodium hydroxide
sodium nitrate
sodium nitrite
sodium pyrophosphate
sodium silicate.

3.3.1.2 Laboratory Operations. Many of the laboratory buildings in the 300 Area provided support for fuel fabrication process development. The wastes generated by these facilities are probably of a nature similar to that of the process wastes.

The research and development activities generated waste radioactive fission products, most of which were discharged to the radioactive liquid waste sewer system. Some of these substances, however, occasionally entered the process sewer. Radioactive isotopes known to be generated in the 300 Area include (Douglas United Nuclear 1967):

scandium-46
chromium-51
cobalt-58
iron-59
cobalt-60
zinc-65
zirconium/niobium isotopes
cesium-137
promethium-147
thorium-234
uranium isotopes
plutonium isotopes.

Current research and development activities focus on peaceful uses of plutonium, liquid metal technology, fast-flux test facility support, gas-cooled reactor development, life science research, and Tri-Party Agreement support.

3.3.1.3 Miscellaneous Operations. Other operations at the 300 Area include(d) sign shop operations which discharged photochemicals to the sanitary sewer system, powerhouse generation which generated flyash when coal was burned, and water treatment.

3.3.2 Waste Units

The information in this section was primarily derived from *Source Inventory Development Engineering Study for the Environmental Restoration Disposal Facility* (U.S. Army Corps of Engineers 1993b) and *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* (DOE-RL 1993f).

Process Sewer System. The process sewer system receives or has received process water from fuel fabrication operations, cooling water, steam condensate, water treatment processes, and a wide variety of waste liquids from laboratory drains throughout the 300 Area. Due to the number of laboratories in the area, and the diverse nature of the research and development activities over the years, a wide range of chemicals may have been discharged to the system. Numerous chemical spills are known to have entered the process sewer system through the many floor drains in 300 Area buildings.

300 Area Radioactive Liquid Waste Sewer. This sewer has been in use since 1954. It receives radioactive wastes from various 300 Area research and development laboratories. Wastes consist primarily of water with small quantities of various chemicals from the laboratories, decontamination solutions, and acids and bases. Waste is accumulated in stainless steel tanks at the 340 Complex. The waste is stored for less than 90 days and is then transported to the 200 West Area for storage and disposal.

Process Ponds and Trenches. The south process pond received liquid wastes from the process sewer, including cooling water, low-level liquid wastes, and organic wastes. This pond contained large amounts of copper and uranium, but most of these contaminants were removed when the bottom of the unit was periodically dredged. The north process pond received liquid waste from the process sewer. Liquid wastes were also trucked to the pond from fuel fabrication operations. The north process pond scraping disposal area was used to dispose of dredged soils from the north process pond as well as flyash (Stenner et al. 1988).

The process trenches constitute the active liquid process waste disposal facility for the 300 Area. They receive condensates, janitorial solutions from cleaning floors, water treatment wastes (mainly salt), laboratory wastes, ethylene glycol, process water from fuel fabrication, and other aqueous solutions. No dangerous wastes have been intentionally discharged to the unit since November 1985. An unplanned release of ethylene glycol occurred in 1994. Sediments in these trenches were removed from contact with infiltrating process water during a 1991 expedited response action (ERA).

The retired 307 disposal trenches were used from 1953 to 1963. These received wastes from the Hot Semiworks Laboratory area and sludge from 316-1 pond. Wastes went through the 307 retention basin before being released to this unit. The 307 retention basin consisted of four 190,000 L (50,000 gal) basins.

Sanitary Sewer System. Sewage from the 300 Area is routed through vitreous tile pipes to septic tanks. Overflow from the septic tanks drains into the sanitary trenches. In addition to sanitary wastes from the 300 Area, the sanitary sewer system received an estimated 4 L/wk (1 gal/wk) of miscellaneous photochemicals from sign shop operations. Current sign and paint shop contributions consist of trace, nonhazardous concentrations of carry-over fixers, developers, inks, thinners, solvents, and rinsewaters from the spray booth fume scrubbing system (DOE-RL 1989). The 315, 335, and 336 retired sanitary drain fields received sanitary waste from office buildings.

Ash Pits. Coal flyash generated from the convertible fuel power house for the 300 Area is suspended in a water slurry and transported to the two ash pits within 300-FF-1 operable unit. Once the flyash dries, it is currently hauled for disposal to a pit west of the 300 Area (DOE-RL 1989). In the past, these ashes have been deposited in areas of the north process pond and were used, in part, to backfill the 307 trenches (Dennison et al. 1989; Schalla et al. 1988).

Burial Grounds. Little historical information is available on the burial grounds within the 300-FF-1 operable unit. Burial ground No. 4 is only known to contain miscellaneous materials which are contaminated with uranium (Stenner et al. 1988). It is not known whether liquid wastes were disposed here. Burial ground No. 5 was a trash burning pit from 1945 through 1962. Some of the trash was contaminated with uranium (Stenner et al. 1988). The site was also used as an above-ground storage area for uranium-bearing materials (U.S. Army Corps of Engineers 1993b).

The solid waste burial grounds in the 300-FF-2 operable unit consisted of trenches and/or pits for the disposal of waste products primarily from fuel fabrication with some laboratory waste. Wastes contained plutonium and fission products, uranium-contaminated equipment, and solid metallic uranium oxides. Burial ground No. 1 was primarily used for disposal of plutonium and fission products from the 300 Area laboratories. Burial ground No. 2 was primarily used for disposal of solid metallic uranium oxides in the form of metal cuttings from reactor fuel fabrication facilities in the 300 Area. The solid waste burial ground No. 3 was primarily used for the disposal of uranium waste in the form of contaminated building material derived from the 313 buildings. Burial ground No. 6 no longer exists. Solid waste burial ground No. 7 also contains drummed containers of solvent with moderate amounts of uranium. This material was segregated and disposed in this site because of the pyrolytic and explosive hazard of the solvent. Materials buried at this site were derived primarily from the 321 Building. Burial ground No. 8 was used for disposal of uranium-contaminated solid waste derived from reactor fuels manufacturing. Burial ground No. 9 has been excavated but previously contained drums of uranium-contaminated solvent. The 300 North Solid Waste Burial Ground (618-10) and the 300 Wye Burial Ground (618-11) consisted of trenches and vertical pipe storage units. Low-level wastes were buried in the trenches and high-level wastes were stored in the pipe units. Burial ground No. 13 (the 303 Area Contaminated Soil Burial Site) received topsoil containing radioactive contaminants from the 303 Building area (U.S. Army Corps of Engineers 1993b). The 300 West burial ground contained drums of uranium-contaminated organic solvent from the 321 Building, but the solvent and other debris were removed from the site.

Storage Tanks. Storage tanks were used in the 300 Area for storing the following:

- radioactive wastes from the Plutonium Recycle Test Reactor
- methanol for use as a drying agent for the aluminum cleaning process
- neutralized liquid from the nonrecoverable uranium stream and filtrate from processing of uranium-bearing waste stream from the 313 Building recovery operations
- uranium-contaminated water and acid solutions from reprocessing research and development
- waste acids containing nonrecoverable uranium from the fuel fabrication process
- spent etch acids (nitric and sulfuric acid with uranium in solution)
- materials contaminated with alkali metal wastes.

Tanks were also used for evaporation of radioactive contaminated spent solvents generated in the fuel fabrication process.

Ion Exchange Vaults. These sites consist of underground vaults with ion exchange columns inside. The reactor ion exchange pit and vault were used to remove contaminants from heavy water coolant and shield cooling systems. The rupture loop ion exchange pit was used to remove contaminants and fission fragments from light water coolant.

Hazardous Material and Waste Storage Areas. Hazardous waste and material storage areas were, and are presently, used in the 300 Area for staging and storing the following materials:

- waste oils
- waste oils contaminated with uranium

- waste oils contaminated with PCBs
- uranium and beryllium/zirconium metal chips and fines
- byproduct waste materials from the fuel fabrication process
- corrosives and ignitables
- solidified waste heat-treat salts from the Fuel Fabrication Facility
- uranium scrap (to be used in recovery)
- solvents and paint shop solids from paint shop operations
- wastes from the alkali metal treatment facility, including sodium, lithium, and sodium-potassium alloys.

300 Area Waste Acid Treatment System. Equipment associated with this treatment system includes the 313 filter press, the 313 waste acid neutralization tank and the 313 centrifuge.

316-4 Crib. This crib was active from 1948 until 1955 or 1956. It received hexone-bearing uranium wastes and limited amounts of other uranium-bearing wastes from the 321 buildings. Liquid containing a total of 560 kg (1,230 lb) of uranium was discharged to this site.

3718-F Burn Shed. This facility has been inactive since 1968. Wastes consisted of sodium, lithium, and sodium-potassium alloys.

Unplanned Releases. Unplanned releases included releases to the process sewer system (with ultimate disposal in the north process pond, south process pond, or process trenches) a release to burial ground No. 4, and airborne contamination. Releases to the process sewer included waste acids, uranium contaminated acid, degreasing solvent and deoxidation chemicals. The release at burial ground No. 4 constituted the improper disposal of depleted uranium fuel elements.

3.3.3 Physical Characteristics and Components of 300 Area Waste

The information in this section was derived from *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit* (DOE-RL 1993f) and *300 Area Cleanup and Restoration Conceptual Study* (WHC 1991c) unless otherwise noted.

Limited characterization of soils took place at the 300 Area during the 300-FF-1 Operable Unit Remedial Investigation. Based on dry soil sieve analysis, soils in the 300 Area can generally be described as "gravel, some sand with trace fines". More specifically, the soil samples were composed of approximately 1.5% fines, 29% sand and 70% gravel (a small fraction of which may be classified as cobbles) by percent weight. Sieve analysis was not conducted for cobbles. The sand portion of the soil may further be classified as medium sand (67%) (DOE-RL 1994b). The specific gravity (sG) was determined for both the coarse and fine fraction of the samples. The specific gravity for the fine samples ranged from 2.67 to 2.87, with an average of 2.77. The specific gravity for the coarse samples ranged from 2.61 to 2.75, with an average of 2.70. The average overall specific gravity was 2.74. The dry density ranged from 1.49 to 2.28 g/cc, with an average of 1.94 g/cc. The moisture content varied from 1.4 to 35.0%, with an average of 8.1%. The porosity ranged from 19.2 to 44.8%, with an average of 29.1%.

300 Area waste includes soil and solid wastes. Sites have been grouped into four categories based on similarities of cleanup requirements: (1) unplanned releases, (2) process sewer piping, (3) process ponds and trenches, and (4) burial grounds.

The components of 300 Area waste are summarized below:

Components of 300 Area Waste

Source	Percentage
Unplanned Releases	7%
Process Sewer Piping Units	17%
Process Ponds and Trenches	40%
Burial Grounds	36%

3.3.4 Chemical Characteristics of 300 Area Waste

Analytical data from the field investigations for operable unit 300-FF-1 (DOE-RL 1990a) were used for the 300 Area chemical waste characteristics evaluation. The maximum concentration in the 300-FF1 operable unit for each detected constituent was identified. Tables 3-5, 3-6, and 3-7 contain the 300 Area summaries of the maximum concentrations for radionuclides, organic compounds and chemistry data, respectively. Summary tables also provide the reference information for the waste site where the maximum concentration was encountered.

3.4 MAXIMUM ERDF WASTE CONCENTRATIONS AND BACKGROUND SCREENING

Table 3-8 presents the maximum soil concentration in 100, 200, and 300 Area waste for radionuclides. Tables 3-9, and 3-10 present the maximum soil concentrations in 100 and 300 Area wastes for organic compounds and inorganic constituents, respectively. These concentrations are considered representative of the maximum concentration in wastes to be received at the ERDF. The tables also list the waste units where the maximum concentrations occurred. Maximum soil concentrations for organic compounds and inorganic constituents for 200 Area wastes are not included on Tables 3-9 and 3-10 because 200 Area wastes have not been sufficiently characterized.

Table 3-10 also includes Hanford Site background screening for inorganic constituents. Maximum concentrations of constituents detected in soil were compared to Hanford Site background values as a first step in identifying contaminants of potential concern. Background concentrations were only available for inorganic constituents. Background levels for organics and radionuclides are not provided because they are generally not naturally occurring or are below detection limits at the Hanford Site. (Note that uranium and some other radionuclides are present at detectable levels in background soils and groundwater). Hanford Site background concentrations were obtained from Table 6-9.b in *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (DOE-RL 1993i). The 95/95 upper tolerance limit (UTL) results were used (noted as the "95% upper confidence limit (UCL)" in Table 6-9.b). The 95/95 UTL is the 95% UCL on the 95th percentile. These values are based on lognormal distributions (the title of the table is incorrect; the values are not based on Weibull distributions).

If the ERDF maximum waste concentration exceeded the Hanford soil background concentration, the concentration was considered to be representative of actual contamination and the constituent was retained for further evaluation. Maximum waste concentrations for chloride, nitrate and phosphate were less than background concentrations. Therefore, chloride, nitrate and phosphate were eliminated from further evaluation. The nitrite plus nitrate concentration was compared to the 95/95 UTL for nitrate and this parameter was also eliminated. All other constituents were retained for further evaluation.

Table 3-1. Maximum Concentrations for Radionuclides in 100 Area Wastes. (Sheet 1 of 2)

Radionuclide	Maximum Concentration (pCi/g)	Waste Unit
Americium-241	34	116-C-5 Retention Basin
Barium-140	400	116-D-1A Storage Basin Trench No. 1
Beryllium-7	90	116-D-1A Storage Basin Trench No. 1
Carbon-14	640	116-C-5 Retention Basin
Cerium-141	3	116-D-1A Storage Basin Trench No. 1
Cerium-144	0.5	116-D-1A Storage Basin Trench No. 1
Cesium-134	56	116-B-11
Cesium-137	110,000	Process effluent pipeline (BC1)
Cobalt-58	14.1	116-DR-1 Liquid Waste Disposal Trench No. 1
Cobalt-60	11,000	(HR1) Process effluent pipeline (sludge)
Europium-152	29,000	116-B-11
Europium-154	9,200	116-D-7
Europium-155	9,600	Process effluent pipeline (BC1)
Gross Alpha	78	116-K-2 Miscellaneous Trench
Gross Beta	3,700	116-C-5 Retention Basin
Iron-59	1	116-D-1A Storage Basin Trench No. 1
Manganese-54	0.07	116-D-1A Storage Basin Trench No. 1
Nickel-63	62,000	Process effluent pipeline (BC1)
Plutonium-238	140	Process effluent pipeline (BC1)
Plutonium-239/240	2,800	Process effluent pipeline (BC1)
Potassium-40	33	116-H-7 Retention Basin
Radium-226	42.8	116-D-1A Storage Basin Trench No. 11
Ruthenium-103	1	116-D-1A Storage Basin Trench No. 1
Ruthenium-106	0.8	116-D-1A Storage Basin Trench No. 1
Sodium-22	9.9	116-DR-1 Liquid Waste Disposal Trench No. 1
Strontium-90	2,000	Process effluent pipeline (BC1)
Technetium-99	1.1	116-DR-2 Liquid Waste Disposal Trench No. 2
Thorium-228	8.6	H-2 Septic Tank
Thorium-232	1.4	116-KW-3B Retention Basin
Thorium-234	1	116-D-1A Storage Basin Trench No. 1

Table 3-1. Maximum Concentrations for Radionuclides in 100 Area Wastes. (Sheet 2 of 2)

Radionuclide	Maximum Concentration (pCi/g)	Waste Unit
Tritium	29,000	116-B-5
Uranium-233/234	17	116-KW-3B Retention Basin
Uranium-235	1.7	116-KW-3B Retention Basin
Uranium-238	17	116-KW-3B Retention Basin
Zinc-65	0.3	116-D-1A Storage Basin Trench No. 1
Zirconium-95	0.56	116-H-7 Retention Basin

Table 3-2. Maximum Concentrations for Organic Compounds in 100 Area Wastes.
(Sheet 1 of 3)

Compound	Maximum Concentration (μg/kg)	Waste Unit
VOLATILE ORGANIC COMPOUNDS		
1,1,1-Trichloroethane	6	100-D-Pond
1,1,2,2-Tetrachloroethane	3	100-D-Pond
2-Butanone	390	100-D-Pond
2-Hexanone	9	100-D-Pond
4-Methyl-2-Pentanone	11	116-B-2 Storage Basin Trench
Acetone	2,800	UN-100-N-17 Diesel Oil Supply Line Leak
Benzene	190	UN-100-N-17 Diesel Oil Supply Line Leak
Carbon Disulfide	200	116-B-5 Crib
Carbon Tetrachloride	8	116N1
Chloroform	4	130-D-1 Gasoline Storage Tank
Ethylbenzene	330	UN-100-N-17 Diesel Oil Supply Line Leak
Methylene Chloride	110	100-D-Pond
Tetrachloroethene	4	116-K-2 Effluent Trench
Toluene	77	116-B-5 Crib
Trichloroethene	6	116-DR-9C Process Effluent Retention Basin
Xylenes (Total)	1,100	130-D-1 Gasoline Storage Tank
SEMIVOLATILE ORGANIC COMPOUNDS		
1,3-Dichlorobenzene	48	116-DR-1 Liquid Waste Disposal Trench No. 1
1,4-Dichlorobenzene	51	116-N-2 Chemical Waste Storage Tank
2-Methylnaphthalene	13,000	UN-100-N-17
4-Chloro-3-Methylphenol	38	116-DR-1 Liquid Waste Disposal Trench No. 1
Acenaphthene	210	116-H-1 Liquid Waste Disposal Trench
Anthracene	6,300	UN-100-N-17

Table 3-2. Maximum Concentrations for Organic Compounds in 100 Area Wastes. (Sheet 2 of 3)

Compound	Maximum Concentration (µg/kg)	Waste Unit
Benzo(a)anthracene	1,800	1607-H-4 Septic Tank Discharge Pipe
Benzo(a)pyrene	940	1607-H-4 Septic Tank Discharge Pipe
Benzo(b)fluoranthene	2,400	1607-H-4 Septic Tank Discharge Pipe
Benzo(g,h,i)perylene	460	1607-H-4 Septic Tank Discharge Pipe
Benzo(k)fluoranthene	760	116-H-1 Liquid Waste Disposal Trench
Bis(2-ethylhexyl)phthalate	5,500	130-D-1 Gasoline Storage Tank
Butylbenzylphthalate	2,600	130-D-1 Gasoline Storage Tank
Carbazole	54	116-D-1B Fuel Storage Basin Trench No. 2
Chrysene	920	116-H-1 Liquid Waste Disposal Trench
Di-n-butylphthalate	1,100	120-D-1
Dibenzofuran	130	116-H-1 Liquid Waste Disposal Trench
Diethylphthalate	1,000	100-D-Pond
Fluoranthene	2,900	1607-H4 Septic Tank Discharge Pipe
Fluorene	1,700	UN-100-N-17
Indeno(1,2,3-cd)pyrene	520	116-H-1 Liquid Waste Disposal Trench
Naphthalene	4,100	UN-100-N-17
N-Nitrosodiphenylamine	110	116-B-2 Storage Basin Trench
Pentachlorophenol	920	116-C-5 Retention Basin
Phenanthrene	2,500	UN-100-N-17
Phenol	240	100-D-Pond
Pyrene	2,700	1607-H4 Septic Tank Discharge Pipe

Table 3-2. Maximum Concentrations for Organic Compounds in 100 Area Wastes. (Sheet 3 of 3)

Compound	Maximum Concentration (μg/kg)	Waste Unit
PESTICIDES/AROCLORS		
4,4'-DDD	110	1607-H4 Septic Tank Discharge Pipe
4,4'-DDE	170	100-D-Pond
Aroclor-1254	6,400	190-B
Aroclor-1260	2,300	100-D-Pond
Beta-HCH (Beta-BHC)	7.8	116-D-1A Fuel Storage Basin Trench No. 1
Chlordane, Gamma-	18	1607-H4 Septic Tank Discharge Pipe
Dieldrin	21	116-D-1A Fuel Storage Basin Trench No. 1
Methoxychlor	83	100-D-Pond

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Table 3-3. Maximum Concentrations for Inorganic and General Chemistry Constituents in 100 Area Wastes. (Sheet 1 of 2)

Constituent	Maximum Concentration (mg/kg)	Waste Unit
INORGANIC CONSTITUENTS		
Aluminum	78,400	100-D Pond - Liquid Waste Disposal
Antimony	18.6	H-2 Septic Tank
Arsenic	62.2	100-D Pond - Liquid Waste Disposal
Barium	4,260	H-2 Septic Tank
Beryllium	4.7	116-H-9 Crib
Cadmium	28.5	H-2 Septic Tank
Calcium	79,000	116-H-9 Crib
Cobalt	90.4	116-KW-3B Retention Basin
Copper	627	H-2 Septic Tank
Chromium	2,510	H-2 Septic Tank
Iron	184,000	116-H-9 Crib
Lead	564	116-C-5 Retention Basin
Magnesium	50,000	116-H-9 Crib
Manganese	3,050	116-H-9 Crib
Mercury	37	H-2 Septic Tank
Nickel	132	116-H-9 Crib
Potassium	13,000	116-H-9 Crib
Selenium	11.1	100-D Pond - Liquid Waste Disposal
Silver	119	H-2 Septic Tank
Sodium	2,010	116-H-9 Crib
Thallium	5.4	H-2 Septic Tank
Vanadium	389	116-H-9 Crib
Zinc	6,160	H-2 Septic Tank
GENERAL CHEMISTRY		
Chloride	13.1	116-C-5 Retention Basin
Chromium VI	5.03	116-C-5 Retention Basin
Fluoride	4.4	116-B-3 Pluto Crib
Nitrate	122.3	116-B-5 Crib
Nitrate/Nitrite	37	116-C-5 Retention Basin

Table 3-3. Maximum Concentrations for Inorganic and General Chemistry Constituents in 100 Area Wastes. (Sheet 2 of 2)

Constituent	Maximum Concentration (mg/kg)	Waste Unit
Nitrite	1.2	H-2 Septic Tank
Phosphate	15	116-KW-3B Retention Basin
Sulfate	7,115	H-2 Septic Tank

Table 3-4. Maximum Radionuclide Concentrations Detected in Soils in 200 Area Waste Units.

Constituent	U Plant[a]	Z Plant[b]	S Plant[c]	T Plant[d]	PUREX[e]	B Plant[f]	Semi-Works[g]	Max. Concentration (pCi/g)
Cesium-137	256.0	6.4	24.6	47.5	36.7	157.0	3.7	256.0
Plutonium-239	3.0	-	-	1.3	-	-	-	3.0
Potassium-40	14.5	15.9	14.7	17.1	18.0	15.8	14.8	18.0
Strontium-90	70.0	-	4.7	5.3	16.8	7.6	-	70.0

Notes: Only values greater than 1 pCi/g are cited.

[a]DOE-RL, 1992c.
[b]DOE-RL, 1992d.
[c]DOE-RL, 1992a.
[d]DOE-RL, 1992b.
[e]DOE-RL, 1993b.
[f]DOE-RL, 1993a.
[g]DOE-RL, 1993c.

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Table 3-5. Maximum Concentrations for Radionuclides in 300 Area Wastes.

Radionuclide	Maximum Concentration (in pCi/g)	Waste Unit
Cerium-141	0.28	316-1 South (old) Pond
Cesium-134	0.45	Drums
Cesium-137	50	Drums
Chromium-51	3.5	618-5 Burial Ground No. 5
Cobalt-60	81	316-1 South (old) Pond
Gross Alpha	4,450	316-5 3904 Process Waste Trenches
Gross Beta	12,200	316-5 3904 Process Waste Trenches
Potassium-40	19.5	307 T-1 trench
Radium-226	2.1	316-2 North (new) Pond
Strontium-90	18	316-5 3904 Process Waste Trenches
Thorium-228	17	316-5 3904 Process Waste Trenches
Thorium-232	3.5	316-2 North (new) Pond
Total Uranium	20,000	316-5 3904 Process Waste Trenches
Uranium-234	2,100	618-4 Burial Ground No. 4
Uranium-235	640	316-5 3904 Process Waste Trenches
Uranium-238	9,100	316-5 3904 Process Waste Trenches
Zinc-65	0.32	316-2 North (new) Pond

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Table 3-6. Maximum Concentrations for Organic Compounds in 300 Area Wastes.
(Sheet 1 of 2)

Compound	Maximum Concentration (in $\mu g/kg$)	Waste Unit
VOLATILE ORGANIC COMPOUNDS		
1,2-Dichloroethene (Total)	1,000	316-5W 3904 Process Waste Trenches
Acetone	700	316-2 North (new) Pond
Carbon Disulfide	100	316-5W 3904 Process Waste Trenches
Chloroform	80	316-5W 3904 Process Waste Trenches
Methylene Chloride	4,500	316-2 North (new) Pond
Tetrachloroethene	1,100	316-5W 3904 Process Waste Trenches
Toluene	150	316-2 North (new) Pond
Trichloroethene	390	618-4 Burial Ground No. 4
Vinyl Chloride	24	316-5W 3904 Process Waste Trenches
SEMIVOLATILE ORGANIC COMPOUNDS		
2-Methylnaphthalene	8,700	316-5E 3904 Process Waste Trenches
4-Chloroaniline	6,300	C-Sanitary Trench
4-Methylphenol	1,000	C-Sanitary Trench
Acenaphthene	850	316-5W 3904 Process Waste Trenches
Anthracene	1,200	316-5W 3904 Process Waste Trenches
Benzo(a)anthracene	1,400	316-5E 3904 Process Waste Trenches
Benzo(a)pyrene	27,000	316-5E 3904 Process Waste Trenches
Benzo(b)fluoranthene	1,700	316-5E 3904 Process Waste Trenches
Benzo(g,h,i)perylene	3,700	316-5E 3904 Process Waste Trenches
Benzo(k)fluoranthene	180	316-5W 3904 Process Waste Trenches
Benzoic Acid	1,300	316-5E 3904 Process Waste Trenches
Bis(2-ethylhexyl)phthalate	33,000	C-Sanitary Trench
Butylbenzylphthalate	230	C-Sanitary Trench
Chrysene	43,000	316-5E 3904 Process Waste Trenches
Di-n-butylphthalate	5,500	316-5E 3904 Process Waste Trenches
Dibenz(a,h)anthracene	1,700	316-5E 3904 Process Waste Trenches

Table 3-6. Maximum Concentrations for Organic Compounds in 300 Area Wastes. (Sheet 2 of 2)

Compound	Maximum Concentration (in μg/kg)	Waste Unit
Dibenzofuran	500	316-5W 3904 Process Waste Trenches
Diethylphthalate	810	316-5E 3904 Process Waste Trenches
Fluoranthene	2,800	316-5W 3904 Process Waste Trenches
Fluorene	850	316-5W 3904 Process Waste Trenches
Indeno(1,2,3-cd)pyrene	1,600	316-5E 3904 Process Waste Trenches
Naphthalene	190	316-5W
N-Nitrosodiphenylamine	1,800	316-5E 3904 Process Waste Trenches
Pentachlorophenol	1,500	316-5E 3904 Process Waste Trenches
Phenanthrene	3,900	316-5W 3904 Process Waste Trenches
Pyrene	12,000	316-5E 3904 Process Waste Trenches
PESTICIDES/AROCLORS		
4,4'-DDE	81	C-Sanitary Trench
PCBs	19,500	Process Trenches
Aroclor-1248	10,000	316-2 North Process Pond

Table 3-7. Maximum Concentrations for Inorganic and General Chemistry Constituents in 300 Area Wastes. (Sheet 1 of 2)

Constituent	Maximum Concentration (mg/kg)	Waste Unit
INORGANIC CONSTITUENTS		
Aluminum	58,600	618-4 Burial Ground No. 4
Antimony	15.4	316-1 South (old) Pond
Arsenic	23.3	316-1 South (old) Pond
Barium	3,130	618-5 Burial Ground No. 5
Beryllium	3.3	316-2 North (new) Pond
Cadmium	23	300 Area Sanitary Sewer system
Calcium	95,300	316-1 South (old) Pond
Cobalt	18	316-2 North (new) Pond
Copper	95,300	316-1 South (old) Pond
Chromium	960	618-4 Burial Ground No. 4
Iron	2,740	Process trenches (previous sampling)
Lead	747	618-4 Burial Ground No. 4
Magnesium	25,500	316-1 South (old) Pond
Manganese	2,480	316-5 3904 Process Waste Trenches
Mercury	9.3	316-1 South (old) Pond
Nickel	1,750	316-1 South (old) Pond
Potassium	4,860	307 T
Selenium	7.7	300 Area Sanitary Sewer system
Silver	362	316-1 South (old) Pond
Sodium	2,610	618-4 Burial Ground No. 4
Strontium	31	Process trenches (previous samples)
Thallium	0.8	300 Area Sanitary Sewer system
Vanadium	239	316-1 South (old) Pond
Zinc	3,830	300 Area Sanitary Sewer system
GENERAL CHEMISTRY		
Ammonia	138	Drums
Chloride	194	316-5 3904 Process Waste Trenches
Fluoride	40	316-2 North (new) Pond
Nitrate	125	316-2 North (new) Pond

Table 3-7. Maximum Concentrations for Inorganic and General Chemistry Constituents in 300 Area Wastes. (Sheet 2 of 2)

Constituent	Maximum Concentration (mg/kg)	Waste Unit
Nitrite	2.9	300 Area Sanitary Sewer system
Phosphate	14	300 Area Sanitary Sewer system
Sulfate	2,636	618-5 Burial Ground No. 5
Total Organic Carbon	43.7	Process trenches
Total Organic Halogen	7.2	Process trenches
Coliform (MPN)	110	Process trenches

Table 3-8. Maximum Concentrations for Radionuclides in 100, 200, and 300 Area Wastes. (Sheet 1 of 2)

Radionuclide	Maximum Concentration (in pCi/g)	Waste Unit
Americium-241	34	116-C-5 Retention Basin
Barium-140	400	116-D-1A Storage Basin Trench No. 1
Beryllium-7	90	116-D-1A Storage Basin Trench No. 1
Carbon-14	640	116-C-5 Retention Basin
Cerium-141	3	116-D-1A Storage Basin Trench No. 1
Cerium-144	0.5	116-D-1A Storage Basin Trench No. 1
Cesium-134	56	116-B-11
Cesium-137	110,000	Process effluent pipeline (BC1)
Chromium-51	3.5	618-5 Burial Ground No. 5
Cobalt-58	14	116-DR-1 Liquid Waste Disposal Trench No. 1
Cobalt-60	11,000	(HR1) Process effluent pipeline (sludge)
Europium-152	29,000	116-B-11
Europium-154	9,200	116-D-7
Europium-155	9,600	Process effluent pipeline (BC1)
Gross Alpha	4,450	316-5 3904 Process Waste Trenches
Gross Beta	12,210	316-5 3904 Process Waste Trenches
Iron-59	1	116-D-1A Storage Basin Trench No. 1
Manganese-54	0.07	116-D-1A Storage Basin Trench No. 1
Nickel-63	62,000	Process effluent pipeline (BC1)
Plutonium-238	140	Process effluent pipeline (BC1)
Plutonium-239/240	2,800	Process effluent pipeline (BC1)
Potassium-40	33	116-H-7 Retention Basin
Radium-226	42.8	116-D-1A Storage Basin Trench No. 1
Ruthenium-103	1	116-D-1A Storage Basin Trench No. 1
Ruthenium-106	0.8	116-D-1A Storage Basin Trench No. 1
Sodium-22	9.9	116-DR-1 Liquid Waste Disposal Trench No. 1
Strontium-90	2,000	Process effluent pipeline (BC1)
Technetium-99	1.1	116-DR-2 Liquid Waste Disposal Trench No. 2
Thorium-228	17	316-5 3904 Process Waste Trenches
Thorium-232	3.5	316-2 North (new) Pond

Table 3-8. Maximum Concentrations for Radionuclides in 100, 200, and 300 Area Wastes. (Sheet 2 of 2)

Radionuclide	Maximum Concentration (in pCi/g)	Waste Unit
Thorium-234	1	116-D-1A Storage Basin Trench No. 1
Tritium	29,000	116-B-5
Uranium-233/234	2,100	618-4 Burial Ground No. 4
Uranium-235	640	316-5 3904 Process Waste Trenches
Uranium-238	9,100	316-5 3904 Process Waste Trenches
Zinc-65	0.3	116-D-1A Storage Basin Trench No. 1
Zirconium-95	0.56	116-H-7 Retention Basin
Total Uranium	20,000	316-5 3904 Process Waste Trenches

Table 3-9. Maximum Concentrations for Organic Compounds in 100 and 300 Area Wastes. (Sheet 1 of 3)

Compound	Maximum Concentration (μg/kg)	Waste Unit
VOLATILE ORGANIC COMPOUNDS		
1,2-Dichloroethene (Total)	1,000	316-5W 3904 Process Waste Trenches
1,1,1-Trichloroethane	6	100-D-Pond
1,1,2,2-Tetrachloroethane	3	100-D-Pond
2-Butanone	390	100-D-Pond
2-Hexanone	9	100-D-Pond
4-Methyl-2-Pentanone	11	116-B-2 Storage Basin Trench
Acetone	2,800	UN-100-N-17 Diesel Oil Supply Line Leak
Benzene	190	UN-100-N-17 Diesel Oil Supply Line Leak
Carbon Disulfide	200	116-B-5 Crib
Carbon Tetrachloride	8	116N1
Chloroform	80	316-5W 3904 Process Waste Trenches
Ethylbenzene	330	UN-100-N-17 Diesel Oil Supply Line Leak
Methylene Chloride	4,500	316-2 North (new) Pond
Tetrachloroethene	1,100	316-5W 3904 Process Waste Trenches
Toluene	150	316-2 North (new) Pond
Trichloroethene	390	618-4 Burial Ground No. 4
Vinyl Chloride	24	316-5W 3904 Process Waste Trenches
Xylenes (Total)	1,100	130-D-1 Gasoline Storage Tank
SEMI-VOLATILE ORGANIC COMPOUNDS		
4-Chloroaniline	6,300	C-sanitary trench (300 Area)
1,3-Dichlorobenzene	48	116-DR-1 Liquid Waste Disposal Trench No. 1
1,4-Dichlorobenzene	51	116-N-2 Chemical Waste Storage Tank
2-Methylnaphthalene	13,000	UN-100-N-17

Table 3-9. Maximum Concentrations for Organic Compounds in 100 and 300 Area Wastes.
(Sheet 2 of 3)

Compound	Maximum Concentration (μg/kg)	Waste Unit
4-Chloro-3-Methylphenol	38	116-DR-1 Liquid Waste Disposal Trench No. 1
4-Methylphenol	1,000	C-sanitary trench (300 Area)
Acenaphthene	850	316-5W Process Waste Trenches
Anthracene	6,300	UN-100-N-17
Benzo(a)anthracene	1,800	1607-H-4 Septic Tank Discharge Pipe
Benzo(a)pyrene	27,000	316-5E 3904 Process Waste Trenches
Benzo(b)fluoranthene	2,400	1607-H-4 Septic tank Discharge Pipe
Benzo(g,h,i)perylene	3,700	316-5E 3904 Process Waste Trenches
Benzo(k)fluoranthene	760	116-H-1 Liquid Waste Disposal Trench
Benzoic Acid	1,300	316-5E 3904 Process Waste Trenches
Bis(2-ethylhexyl)phthalate	33,000	C-Sanitary Trench (300 Area)
Butylbenzylphthalate	2,600	130-D-1 Gasoline Storage Tank
Carbazole	54	116-D-1B Fuel Storage Basin, Trench No. 2
Chrysene	43,000	316-5E 3904 Process Waste Trenches
Di-n-butylphthalate	5,500	316-5E 3904 Process Waste Trenches
Dibenz(a,h)anthracene	1,700	316-5E 3904 Process Waste Trenches
Dibenzofuran	500	316-5W 3904 Process Waste Trenches
Diethylphthalate	1,000	100-D-Pond
Fluoranthene	2,900	1607-H4 Septic Tank Discharge Pipe
Fluorene	1,700	UN-100-N-17

Table 3-9. Maximum Concentrations for Organic Compounds in 100 and 300 Area Wastes. (Sheet 3 of 3)

Compound	Maximum Concentration (μg/kg)	Waste Unit
Indeno(1,2,3-cd)pyrene	1,600	316-5E 3904 Process Waste Trenches
Naphthalene	4,100	UN-100-N-17
N-Nitrosodiphenylamine	1,800	316-5E 3904 Process Waste Trenches
Pentachlorophenol	1,500	316-5E 3904 Process Waste Trenches
Phenanthrene	3,900	316-5W 3904 Process Waste Trenches
Phenol	240	100-D-Pond
Pyrene	12,000	316-5E 3904 Process Waste Trenches
PESTICIDES/AROCLORS		
4,4'-DDD	110	1607-H4 Septic Tank Discharge Pipe
4,4'-DDE	170	100-D-Pond
Aroclor-1248	10,000	316-2 North Process Pond
Aroclor-1254	6,400	190-B
Aroclor-1260	2,300	100-D Pond
Beta-HCH (Beta-BHC)	7.8	116-D-1A Fuel Storage Basin, Trench No. 1
Chlordane, Gamma-	18	1607-H4 Septic Tank Discharge Pipe
Dieldrin	21	116-D-1A Fuel Storage Basin, Trench No. 1
Methoxychlor	83	100-D-Pond
PCBs	19,500	Process trenches (300 Area)

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Table 3-10. Maximum Concentrations and Background Screening for Inorganic and General Chemistry Constituents in 100 and 300 Area Wastes. (Sheet 1 of 2)

Constituent	Maximum Concentration (mg/kg)	Waste Unit	Background (95/95 UTL)[a] (mg/kg)
INORGANIC CONSTITUENTS			
Aluminum	78,400	100-B Pond	15,600
Antimony	18.6	H-2 Septic Tank	NC
Arsenic	62.2	100-D Pond	8.92
Barium	4,260	H-2 Septic Tank	171
Beryllium	4.7	116-H-9 Crib	1.77
Cadmium	28.5	H-2 Septic Tank	NC
Calcium	95,300	316-1 South (old) Pond	23,920
Chromium	2,510	H-2 Septic Tank	27.9
Cobalt	90	116-KW-3B Retention Basin	19.6
Copper	95,300	316-1 South (old) Pond	28.2
Iron	184,000	116-H-9 Crib	39,160
Lead	747	618-4 Burial Ground No. 4	14.75
Magnesium	50,000	116-H-9 Crib	8,760
Manganese	3,050	116-H-9 Crib	612
Mercury	37	H-2 Septic Tank	1.25
Nickel	1,750	316-1 South (old) Pond	25.3
Potassium	13,000	116-H-9 Crib	3,120
Selenium	11	100-B Pond	NC
Silver	362	316-1 South (old) Pond	2.7
Sodium	2,610	618-4 Burial Ground No. 4	1,290
Strontium	31	Process trenches (previous sampling)	NC
Thallium	5.4	H-2 Septic Tank	NC
Vanadium	389	116-H-9 Crib	111
Zinc	6,160	H-2 Septic Tank	79

Table 3-10. Maximum Concentrations and Background Screening for Inorganic and General Chemistry Constituents in 100 and 300 Area Wastes. (Sheet 2 of 2)

Constituent	Maximum Concentration (mg/kg)	Waste Unit	Background (95/95 UTL)[a] (mg/kg)
GENERAL CHEMISTRY			
Ammonia	138	Drums	28.2
Chloride	194	316-5 3904 Process Waste Trenches	763
Fluoride	40	316-2 North (new) Pond	12
Nitrate	125	316-2 North (new) Pond	199
Nitrite	2.9	300 Area Sanitary Sewer system	NC
Phosphate	15	116-KW-3B Retention Basin	16
Sulfate	7,115	H-2 Septic Tank	1,320
Total Organic Halogen	7.2	Process trenches (previous sampling)	NC
Total Organic Carbon	43.7	Process trenches (previous sampling)	NC
Coliform (MPH)	110	Process trenches (previous sampling)	NC
Nitrate/Nitrite	37	116-C-5 Retention Basin	199[b]

Notes:
NC - not calculated
[a]95/95 UTL is the 95% UCL on the 95th percentile; Source: Table 6-9b in Hanford Site Background Part 1, Soil Background for Nonradioactive Analytes (DOE-RL 1993i).
[b]The background concentration for nitrate is used.

4.0 CONTAMINANT FATE AND TRANSPORT

The purpose of this chapter is to identify potential groundwater contaminants at the ERDF. A fate and transport model was used to predict groundwater concentrations at the ERDF boundary, based on soil concentrations of constituents presented in Chapter 3. Predicted groundwater concentrations are compared to Hanford Site background groundwater concentrations to identify contaminants that exceed background. Predicted groundwater concentrations are also compared to risk-based de minimis concentrations, as described in Section 4.3. If a predicted groundwater concentration is less than the de minimis concentration, it is excluded from the list of groundwater contaminants. The final list of groundwater contaminants developed in this chapter is carried into Chapter 5 to develop the list of contaminants of potential concern.

4.1 MODEL DEVELOPMENT

The fate and transport model was used to identify groundwater contaminants, perform contaminant screening and evaluate alternative ERDF designs. This chapter focuses on the base conditions scenario (no engineered barrier and no liner) used for identification of groundwater contaminants and for the contaminant screening performed in Chapter 5. The base conditions scenario is a worst case analysis that does not correspond to any of the alternatives considered in Chapter 9. The alternatives considered in Chapter 9 all include engineered barriers that are expected to perform better than the assumed performance in the base conditions scenario.

4.1.1 Conceptual Model

In general, the mechanisms controlling contaminant fate and transport in the vadose zone are highly coupled, unsteady, and non-linear. Furthermore, the hydrogeologic strata are heterogeneous and anisotropic. Although multi-dimensional numerical models can provide a more accurate representation of these non-linear dynamic processes and complex hydrogeological conditions, they are still limited by uncertainties in many of the controlling factors, such as source term concentrations, soil-water partitioning, and infiltration rate. Since the purpose of this modeling is a screening analysis to identify potential groundwater contaminants at the ERDF and evaluate alternative ERDF designs, a multidimensional numerical model was not considered warranted for this study. Instead, a spreadsheet model was developed based on the conceptual model of the site described below.

The conceptual model assumes the following:

- the media are homogeneous and isotropic
- the flow is plug flow (i.e., no longitudinal dispersion) in both the vadose zone and the saturated zone
- constituent release from ERDF is controlled by either solubility or partitioning between the waste and pore water.

As recharge from the ground surface percolates through the waste it dissolves contaminants to form leachate. The contaminant concentration in the leachate is controlled by soil-water partitioning unless the leachate concentration is predicted to exceed the constituent solubility, in which case the concentration is solubility limited.

Leachate from the facility migrates through the vadose zone to the groundwater table. The rate of migration is controlled by the rate of infiltration, the moisture content, and retardation. Constituent concentrations may be reduced due to radioactive decay, volatilization, biodegradation, and dilution.

When the leachate reaches the saturated zone, it is subsequently diluted in groundwater. Finally, the leachate migrates towards the ERDF boundary in the direction of groundwater flow. Further retardation and decay can occur in the saturated zone.

The mathematical expressions for the conceptual model described above and the spreadsheet model developed based on the conceptual model are presented in Appendix A.

4.1.2 Model Parameters

Parameters for the fate and transport spreadsheet model were developed to represent the hydrogeological conditions of the ERDF site, the physical and chemical properties of the waste form, and the fate and transport properties of each contaminant constituent. The parameter estimation relied first on ERDF-specific information and then on Hanford Site background information when available. Non-Hanford Site information was utilized as a last resort.

4.1.2.1 General Parameters. General parameters include the dimensions of the disposal trench, the natural infiltration rate, and the physical and hydrogeological properties of both vadose zone and saturated zone soils. These parameters are summarized in Table 4-1.

ERDF and Trench Dimensions. Cross-sections of the trench dimensions assumed in the base conditions scenario are shown in Figure 4-1. The trench width is 420 m (1,300 ft) at the ground surface and 300 m (1,000 ft) at the base of the trench. The trench depth is assumed to equal 20 m (70 ft). The trench will be approximately 3,000 m (9,000 ft) long to accommodate the entire design waste capacity (U.S. Army Corps of Engineers, 1994).

Natural Infiltration Rate. To estimate the natural infiltration rate at the ERDF site, information from a variety of lysimeter and modeling studies was evaluated. The longest running lysimeter study was conducted using a pair of lysimeters (one open-bottom, the other closed-bottom) installed in the 200 East Area in 1971. Moisture content data from these lysimeters indicate a relatively constant moisture content of 6 percent below a depth of 5 m (17 ft). An analysis of the unsaturated hydraulic conductivity of the lysimeter soils (which were primarily sands) in the late 1970's suggested an infiltration rate of approximately 0.5 cm/yr (0.2 in./yr) (Jones 1978). Coring of the closed-bottom lysimeter in 1985 revealed little change in moisture content below a depth of 3 m (10 ft) and no accumulation of moisture in the bottom of the lysimeter, suggesting that the 0.5 cm/yr (0.2 in./yr) interpretation was too high. Routson et al. (1988) concluded that the infiltration rate at this location was negligible (less than 0.2 cm/year). Deep-rooted tumbleweeds and other vegetation are believed to have been present on the 200 Area lysimeter for much of the study period. Computer modeling (using UNSAT-H) of the closed-bottom lysimeter indicated that the rate of infiltration was primarily controlled by the surface vegetation; infiltration was much higher when transpiration due to vegetation was eliminated from the model. The barrier surface over the ERDF will be vegetated.

Lysimeters have been installed at a variety of other facilities (such as the Buried Waste Test Facility). As summarized in Gee et al. (1992) infiltration rates for these lysimeters range from 0 (for silty loam soils) to 20 cm/yr (8.0 in./yr) (for gravelly soils with no vegetation) and illustrate a strong dependence on soil type and vegetation type. With the exception of one lysimeter which had an infiltration rate of 1.0 cm/yr (0.4 in./yr), no infiltration occurred in lysimeters with deep-rooted vegetation (Gee et al. 1992). The HELP modeling results presented in Appendix B for the non-engineered soil cover indicate an infiltration rate of 0.035 cm/yr (0.014 in./yr). Based on both empirical and modeling results, a natural infiltration rate of 0.5 cm/yr (0.2 in./yr) was used for the model. This infiltration rate is a reasonably conservative (high) value for vegetated soils. The base conditions scenario modeled in this chapter assumes the infiltration rate through the non-engineered barrier equals the natural infiltration rate of 0.5 cm/yr.

Vadose Zone Parameters. The range of moisture content in 200 Area soils of the Hanford formation is 2% to slightly over 6% (Last et al. 1989). Data from the 200-East Area lysimeters indicate soil moisture values less than 3% to a depth of 18.3 m (60 ft) (Gee 1987). The vadose zone moisture content selected for modeling purposes was 4.5 percent.

A geologic cross section of the northern edge of the proposed ERDF site is shown in Figure 2-24. The ground elevation across the proposed ERDF site ranges from approximately 200 m (660 ft) to 230 m (760 ft). As shown in Figure 2-25, the water table elevation ranges from approximately 140 m (460 ft) to 120 m (400 ft). The vadose zone thickness ranges from approximately 70 m (230 ft) to 100 m (330 ft), and is about 80 m (260 ft) thick in the center of the ERDF site. The value of 80 m (260 ft) is a good average representation of the vadose zone thickness at this site, and was used in the model.

Vadose zone dilution and travel time are determined in part by the vadose zone mixing width, the vadose zone mixing depth, and the vadose zone mixing factor. As shown on Figure 4-2, the vadose zone mixing width is the width of infiltration on each side of the trench that mixes with the leachate in the vadose zone. The vadose zone mixing depth is the depth at which the leachate mixes with clean vadose zone moisture infiltrating outside the footprint of the ERDF. The amount of dilution is specified by the vadose zone mixing factor. The vadose zone mixing depth used in the base-case scenario is based on the geologic cross section provided in Figure 2-24. The Plio-Pleistocene unit, which has a lower permeability than the rest of the vadose zone materials and may encourage horizontal migration, is found in the western portion of the ERDF site at a depth of approximately 50 m (165 ft). Therefore, a depth of 50 m (165 ft) was used in the model. The vadose zone mixing factor was assumed to equal 0, which corresponds to no dilution in the vadose zone. Although mixing with clean infiltration will occur on the edge of the facility, little or no mixing would occur beneath the center of the facility. A mixing factor of 0 reflects a conservative bias. The vadose zone mixing width was assumed to be 100m (330 ft). The dry density of soil in the vadose zone was assumed to equal 1.6 kg/L.

Saturated Zone Parameters. The saturated hydraulic gradient was estimated based on the water table elevation shown on Figure 2-33. The gradients at the ERDF range from 0.0045 along the northern boundary of the site to 0.0025 along the southern boundary. The gradient used in the model (0.0035) represents the value of the gradient at a location approximately half of a mile south of the northern boundary of the ERDF.

The saturated hydraulic conductivity of the uppermost aquifer unit was estimated based on pump test results for wells near the ERDF (discussed in Section 2.6.2.) and more general information shown on Figure 2-32. The results from the 2 ERDF wells are within the range indicated on Figure 2-32 for the ERDF (1-100m/d). A value of 30 m/d (100 ft/d) was used in the modeling.

The saturated zone porosity used in the model was assumed to equal 0.3 (Graham et al. 1981). The dry density was assumed to equal 1.6 kg/L. As shown on Figure 4-2, the saturated zone mixing depth was assumed to equal 5 m (16 ft). This saturated mixing depth is based on a reasonable vertical capture thickness for a water supply well.

4.1.2.2 Constituent-Specific Parameters. Constituent-specific parameters include soil/water partitioning coefficient (K_d), decay or degradation rate, and solubility. The values of these parameters used in the modeling are summarized in Tables 4-2 through 4-8 and are briefly discussed below. There was no data available for carbazole. Since carbazole is a polynuclear aromatic hydrocarbon (PAH), all parameters for PAH's were compiled and the most conservative values selected as model parameters for carbazole.

Partitioning Coefficient (K_d). The partitioning coefficient (K_d) is defined as the ratio of adsorbed chemical concentration in the soil matrix to the aqueous solute concentration. Some literature values for organic constituents are presented in terms of K_{oc}, the organic carbon partitioning coefficient, or as K_{ow}, the octanal-water partitioning coefficient. For the purpose of this report, K_{ow} was considered equivalent to K_{oc}. In general, K_{oc} represents partitioning within a 100 percent organic carbon matrix. K_{oc} can be assumed to relate to K_d according to the following relationship:

$$K_d = K_{oc} f_{oc}$$ (Dragun, 1988)

where:

K_{oc} = soil adsorption normalized for soil organic matter content
f_{oc} = organic content

It should be noted that factors other than f_{oc}, such as pH, clay content, and salinity, can also influence K_d, but methods for incorporating these factors are not available. In general, K_d's calculated using the approach described above should be accurate to within a factor of 2 to 10 (Lyman et al. 1982). K_d values in Table 4-2 assume that f_{oc} in soil is 0.1%. This value is based on results presented in DOE/RL (1994a) for three soil samples from 100 Area waste sites. The f_{oc} in these samples (reported at total organic carbon) was 0.06%, 0.1% and 0.16%.

There were two sources for K_{oc} data: (1) the Hazardous Substance Data Bank (HSDB 1993) and (2) Montgomery and Welkom (1990). If information was not available in the first source, the second source was consulted.

Table 4-2 includes measured K_{oc} data and K_{oc}'s that were estimated based on octanol-water partition coefficients (K_{ow}'s) or solubility information. K_{oc}'s calculated based on K_{ow}'s are calculated using empirical equations, and are thus associated with a higher uncertainty than measured K_{oc} values.

The best estimate for K_{oc} was selected in the following manner:

- if measured data were available, these were given preference over estimated values
- if data were available specifically for sand or sandy soils, these were given preference
- soil data were given preference over sediment suspensions
- if no data were available, the K_{oc} was assumed to equal zero
- if specific data points were given for measured K_{oc}, these were averaged to calculate the best estimate
- if average values were given for measured K_{oc}, the best estimate was calculated from the average of the minimum and maximum data points.

Partitioning coefficients (K_d's) for radionuclides and inorganic constituents are presented in Tables 4-3 and 4-4, respectively. These values are based on Hanford-specific data in Ames and Serne (1991) and Serne and Wood (1990) for a solution with neutral pH and low organic carbon. The best estimate of K_d and the range were given in the references. If more than one estimate was provided, the values were averaged to obtain a best estimate for the K_d.

Decay (or Degradation) Rate. The degradation half-life for organic constituents is the time needed for half of the concentration to be degraded or volatilized (Dragun 1988). The half-life ($T_{1/2}$) and its decay or degradation constant (λ) are related by the following equation (Faure 1977):

$$T_{1/2} = 0.693 / \lambda$$

Organic chemicals can be degraded biologically or chemically. Many literature values are based on laboratory experiments designed to optimize biodegradation and may not be representative of natural conditions. Three sources were reviewed for half-life data for organic compounds: the Hazardous Substance Data Bank (HSDB 1993), *Handbook of Environmental Degradation Rates* (Howard et al. 1991), and *The Soil Chemistry of Hazardous Materials* (Dragun 1988). Since there is much uncertainty associated with half-lives for organic compounds, the data was reviewed and a range was selected (<1, 1 - 10, 10 - 100 years). The results are shown in Table 4-5. The maximum value in the range was used in the model. For compounds with no data, the half-life was set at 10,000 years.

The half-life for an unstable nuclide is the time required for one-half of a given number of atoms to decay. Half-lives for the radionuclides are readily available and are presented in Table 4-6. Metals were assumed not to degrade or volatilize.

Solubility. Solubilities for organic compounds are relatively insensitive to changes in water chemistry (except when multiple organic compounds are involved and they begin to behave as co-solvents). Solubilities used in the modeling for organic compounds are included in Table 4-7. The primary source for solubility data for organic compounds was Montgomery and Welkom (1990). If no information was available from the primary source, the HSDB (1993 and 1994) was consulted. Solubilities were often available for a range of temperatures. The best estimate for solubility was selected for the temperature closest to 15 degrees Celsius (59 degrees Farenheit). Reported solubilities for a few organic constituents (e.g., tetrachloroethene) ranged over an order of magnitude. This variability is likely due to experimental differences. The average of the reported values was used in the simulations. No quantitative data was available for carbazole, however the HSDB (1993) indicated that carbazole is insoluble. A solubility of 1 mg/L was chosen as a conservative estimate. No data was available for gamma-chlordane (an isomer of chlordane); therefore the data for chlordane was used.

Solubilities for most inorganic constituents and radionuclides are a function of the controlling solids and are highly dependent upon physio-chemical parameters such as pH, Eh, and the concentrations of other ionic constituents. Consequently, these solubilities are highly variable and are difficult to predict. Solubilities for inorganic constituents and radionuclides are presented in Tables 4-8 and 4-6, respectively. These values are based on Hanford-specific data, for a solution with neutral pH and low organic carbon. Solubilities are listed as LS (low solubility; <1 mg/L), MS (moderate solubility; 1 - 25 mg/L), and VS (very soluble; >1000 mg/L). These ranges are based on data in the references Ames and Serne (1991) and Serne and Wood (1990).

In the case of elements with multiple isotopes, the isotope-specific solubilities are equal to the element solubility multiplied by the relative mass abundance of the isotope. Unfortunately, for isotopes associated with nuclear activation and fission products, the relative abundances can be highly variable and difficult to determine. On the other hand, relative abundances for some naturally occurring isotopes, including K-40 and the uranium isotopes, can be predicted. Crustal uranium consists of three isotopes, U-234 (0.0057 percent), U-235 (0.72 percent), and U-238 (99.374 percent) (Faure 1977). Assuming the solubility of total uranium is 25 mg/L, the solubility of U-234 used in the model was:

$$25 \text{ mg/L} \times 0.000057 = 0.0014 \text{ mg/L}$$

An isotope-specific solubility of 0.12 mg/L was calculated for K-40 assuming a relative abundance of 0.0119 percent (Faure 1977).

4.1.3 Fate and Transport Modeling Results

Modeling results are presented as deterministic values, which rely upon the input parameters discussed above. The groundwater screening model provides the following results for each constituent: the initial leachate concentration, the vadose zone travel time, the saturated zone travel time, the vadose and saturated zone dilution factors, the groundwater concentration at the water table, and the groundwater concentration at the ERDF boundary. The results for organic compounds, radionuclides, metals, and anions are presented in Tables A-4 through A-7, respectively.

4.1.4 Sensitivity of Modeling Results to Site Location

The input parameters used in the modeling were based on the proposed location of the ERDF. Alternative locations may or may not result in significantly different risks and travel times to the saturated zone. The parameters that might change for other sites include the following:

- width and length of the trench
- thickness of the vadose zone
- vadose zone mixing depth
- vadose zone moisture content
- soil density
- saturated zone porosity
- saturated zone hydraulic conductivity
- saturated zone hydraulic gradient.

Parameters that are unlikely to change significantly from site to site include vadose zone moisture content, soil density, and saturated zone porosity. These parameters are relatively consistent across the Hanford Site. The remaining parameters are variable across the Hanford Site and the consequences of these variations are discussed below:

- Travel time through the vadose zone is directly proportional to changes in the thickness of the vadose zone. For example, travel time through the vadose zone decreases as thickness of the vadose zone decreases.

- Travel time through the vadose zone is directly proportional to changes in vadose zone mixing depth. For example, if the vadose zone mixing depth decreases, the infiltrating leachate mixes with the clean infiltration higher in the stratigraphic column, resulting in a decreased travel time through the vadose zone.

- Concentration in the saturated zone is inversely proportional to changes in the saturated zone hydraulic conductivity. As the saturated zone hydraulic conductivity increases, the velocity of groundwater in the saturated zone increases, resulting in greater dilution of the vadose zone infiltration and lower constituent concentrations.

- Concentration in the saturated zone is inversely proportional to changes in the saturated zone hydraulic gradient. As the saturated zone hydraulic gradient increases, the velocity of groundwater in the saturated zone increases, resulting in greater dilution of the vadose zone infiltration and lower constituent concentrations.

4.2 GROUNDWATER BACKGROUND SCREENING

Groundwater background screening is presented in Table 4-9. It was conducted to identify the constituents which occur in concentrations that are elevated over naturally-occurring chemical concentrations. Constituents were evaluated by comparing the predicted groundwater concentrations with the Hanford Site background groundwater concentrations (DOE-RL 1992e).

chemical concentrations. Constituents were evaluated by comparing the predicted groundwater concentrations with the Hanford Site background groundwater concentrations (DOE-RL 1992e). Background concentrations used in this screening are the one-sided, 95/95 upper tolerance limits (UTLs) (i.e., the 95 percent upper confidence limit of the 95th percentile for the distribution) of each parameter. The method for calculation of the background UTLs is presented in EPA (1989a). Hanford Site background UTLs are only available for the target analyte list (TAL) metals and inorganic anions. Those constituents with predicted groundwater concentrations less than background are not considered groundwater contaminants and are eliminated from further consideration. Calcium, iron, magnesium, non-radioactive strontium, and sulfate were eliminated from the list of groundwater contaminants based on comparison to background.

4.3 GROUNDWATER DE MINIMIS SCREENING

Groundwater modeling results indicate that certain contaminants will be found in groundwater at extremely low concentrations (e.g., less than one part per trillion). To streamline the risk assessment process, it is helpful to define groundwater concentrations that, for all practical purposes, are indistinguishable from zero. For the purpose of this discussion, these concentrations are called de minimis concentrations. If a modeled groundwater concentration is less than a de minimis concentration, then the contaminant is considered absent in groundwater. The de minimis concentration for non-radioactive contaminants is 5×10^{-7} mg/L. This is slightly less than the dieldrin concentration associated with a 1×10^{-7} lifetime incremental cancer risk, assuming residential scenario parameters (see section 5.4). This de minimis concentration is based on dieldrin because the dieldrin ingestion slope factor is the largest of any non-radioactive soil contaminant being evaluated in this report (i.e., dieldrin has the greatest carcinogenic potential; see Table 5-1). The de minimis concentration for radioactive contaminants is 1×10^{-2} pCi/L. This is slightly less than the plutonium-239/240 concentration associated with a 1×10^{-7} lifetime incremental cancer risk, assuming residential scenario parameters. This de minimis concentration is based on plutonium-239/240 because the plutonium-239/240 ingestion slope factor is the largest of any radioactive soil contaminant being evaluated in this report (Table 5-1).

Although neptunium-237 is not a constituent of potential concern identified in Chapter 3, it is a daughter product of americium-241. Americium-241 decays to neptunium-237 with a half-life of 432 years, and neptunium-237 has a half-life of 2.14 million years. For simulating neptunium-237, it was conservatively assumed that the americium-241 decayed to neptunium-237 instantaneously. The concentration of neptunium-237 can be calculated using the following equation:

$$M_w^{Np\text{-}237} = (\lambda^{Np\text{-}237}/\lambda^{Am\text{-}241})\ M_w^{Am\text{-}241}$$

where:

$M_w^{Np\text{-}237}$ = the concentration of neptunium-237 (pCi/gm)

$\lambda^{Np\text{-}237}$ = the decay coefficient of neptunium-237 (3.24×10^{-7} yr^{-1})

$M_w^{Am\text{-}241}$ = the concentration of americium-241 (pCi/gm)

$\lambda^{Am\text{-}241}$ = decay coefficient of americium-241 (1.60×10^{-3} yr^{-1})

Assuming the americium-241 concentration is 34 pCi/gm, the maximum neptunium-237 concentration would be 6.86×10^{-3} pCi/gm. This analysis does not account for the decay or leaching of neptunium-237. As shown in Table 4-10, neptunium was eliminated because it reached groundwater after 10,000 years.

Most of the organic compounds and many of the radionuclides are eliminated in the de minimis screening. All of the metals and anions are retained; this is due to their lack of decay.

4.4 TRAVEL TIME CRITERION

Based on the Tri-Party Agreement (Ecology et al. 1994), the time of assessment is 10,000 years. The 10,000 year time constraint was used as one criterion to identify groundwater contaminants. If the travel time of a constituent to the ERDF boundary exceeds 10,000 years, the constituent is not considered a groundwater contaminant.

4.5 GROUNDWATER CONTAMINANTS

The final list of groundwater contaminants is presented in Table 4-11. Table 4-11 also includes travel times for groundwater contaminants to reach the ERDF boundary.

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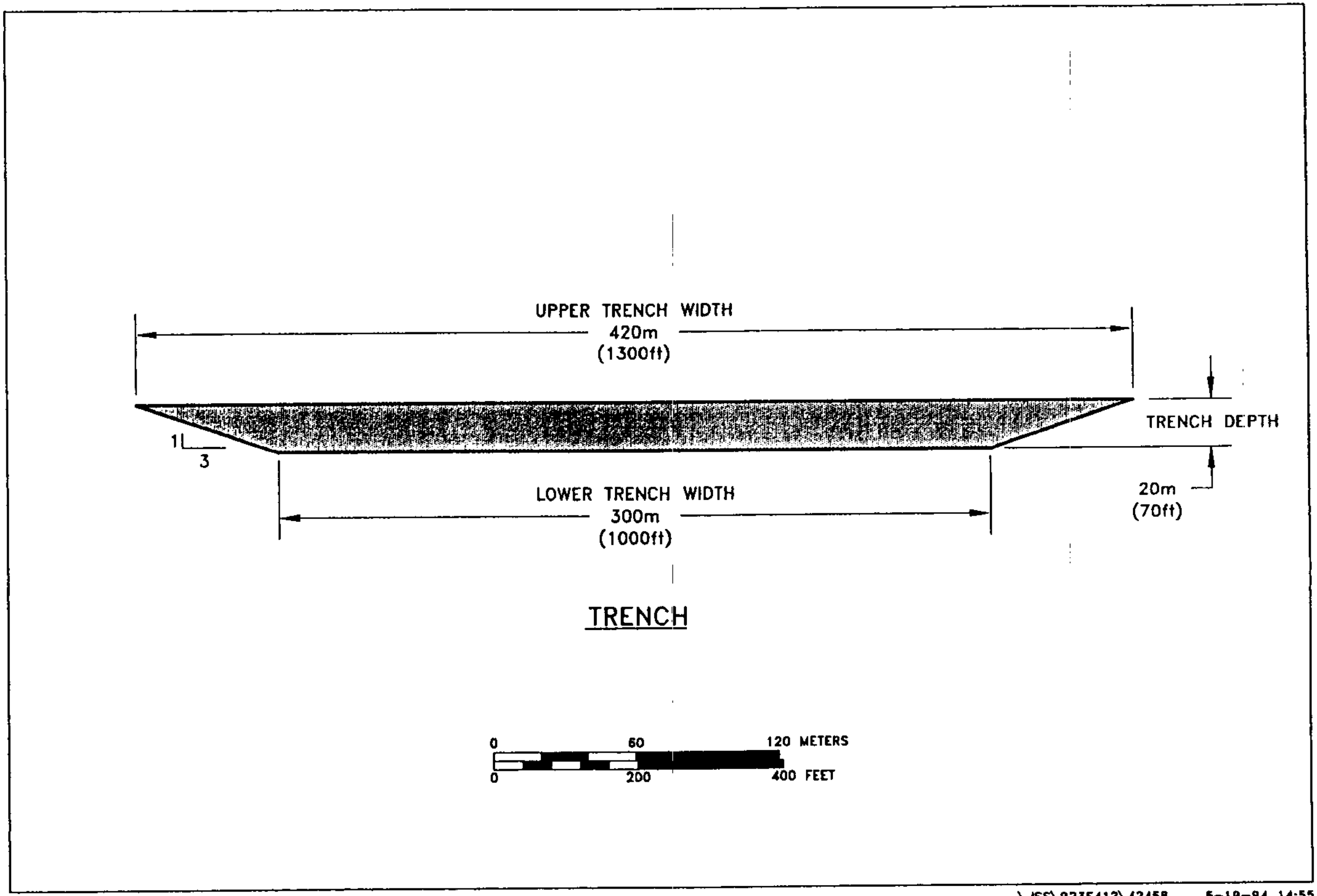

Figure 4-1. Cross-Sectional Dimensions for ERDF Trench.

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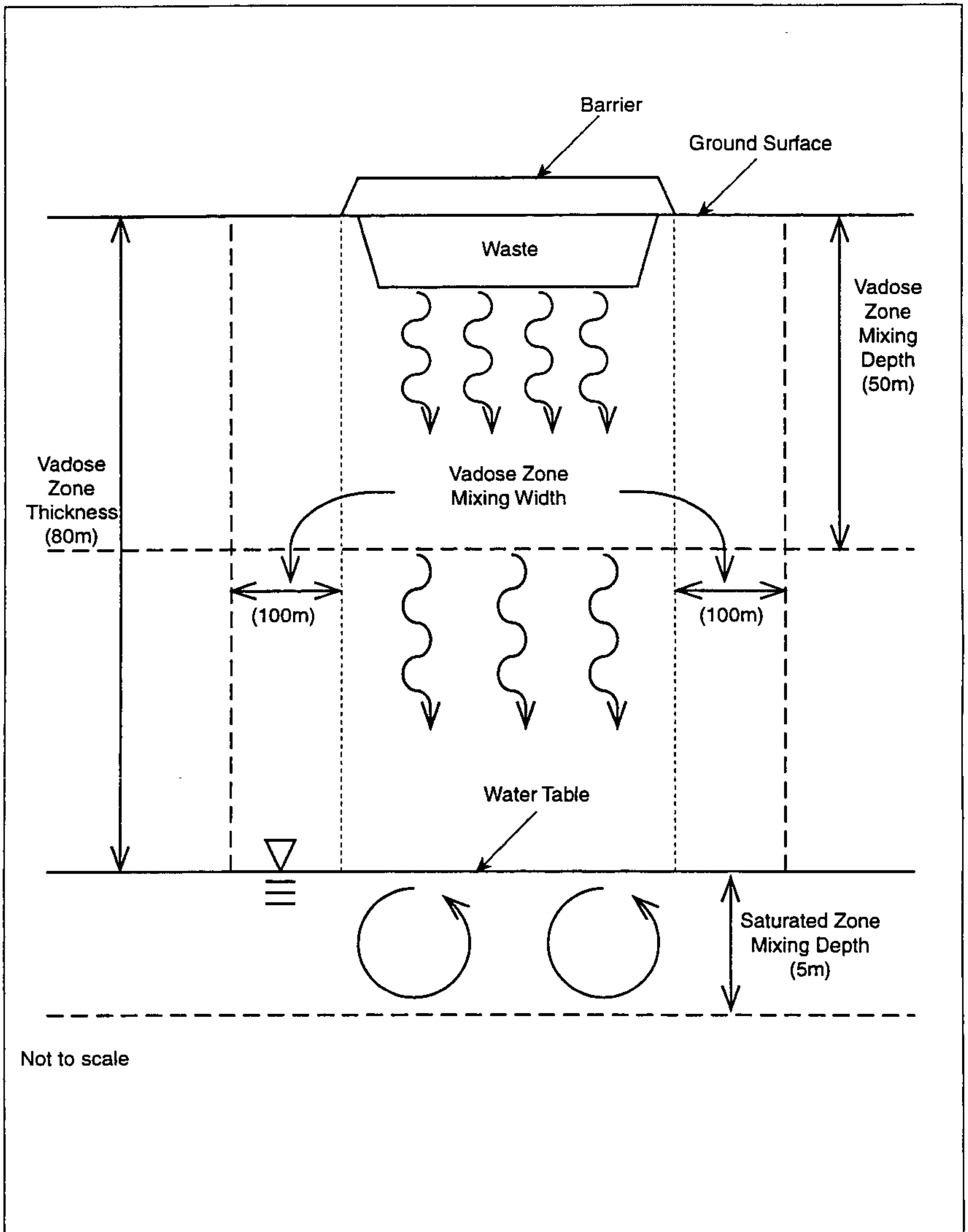

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Figure 4-2. Vadose Zone and Saturated Zone Parameters.

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Table 4-1. General Parameters Used for the ERDF Modeling.

Parameter	Most Likely Value
Upper Trench Width	420 m
Lower Trench Width	300 m
Trench Length	3000 m
Trench Depth	20 m
Distance to ERDF Boundary	100 m
Vadose Zone Water Content	0.045
Vadose Zone Thickness	80 m
Vadose Zone Mixing Depth	50 m
Vadose Zone Mixing Width	100 m
Vadose Zone Mixing Factor	0
Saturated Zone Porosity	0.3
Saturated Zone Hydraulic Conductivity	30 m/d
Saturated Zone Hydraulic Gradient	0.0035
Saturated Zone Mixing Depth	5 m
Soil Density (Dry)	1.6 kg/L
Natural Infiltration Rate	0.5 cm/yr

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Table 4-2. Partitioning Coefficients for Organic Compounds. (Sheet 1 of 7)

Constituent	Measured K_{oc}	Estimated K_{oc} (based on K_{ow} or solubility)	Source of K_{oc} Data	Best Estimate for K_{oc}	Comments	K_d Used in Model (K_{oc} X 0.001 organic content)
Acenaphthene	ND	2065 - 3230 (log Kow= 3.92)	HSDB	2.7E+03	best estimate is average of range	2.7
Acetone	no appreciable adsorption	ND	HSDB	0	no data	0
Anthracene	26,000 1,600	ND	HSDB	1.4E+04	best estimate is average of range	14
Aroclor-1248	ND	437,000	M&W	4.4E+05	range based on standard deviation of 50%	440
Aroclor-1254	110,000 to 1,330,000 (review of experimental data)	42,500 (not clear how derived)	HSDB	7.2E+05	best estimate is average of measured data only	720
Aroclor-1260	61,000 to 7,400,000 (review of experimental data) [for congener hexa]	1E+06 (not clear how derived) [for congener hepta]	HSDB	2.3E+06	best estimate is average of range and other data; since there are two congeners	2,300
Benzene	Woodburn silt loam: 31 31.7-143 83	98 (K_{ow}=2.13)	HSDB	8.7E+01	best estimate is average of range	0.087
Benzo(a)anthracene	5.5 E+05 - 1.87 E+06 (sediments)	ND	HSDB	1.2E+06	best estimate is average of range	1,200
Benzo(a)pyrene	3.95E+06 - 5.83E+06 (experimental) 18,000 - 52,000 (dissolved o.c. in natural waters) 890,000 (Aldrich humates)	ND	HSDB	2.9E+06	best estimate is average of range	2,900
Benzo(b)fluoranthene	ND	7.59E+05 (solubility-based)	HSDB	7.6E+05	range based on standard deviation of 50%	760

Table 4-2. Partitioning Coefficients for Organic Compounds. (Sheet 2 of 7)

Constituent	Measured K_{oc}	Estimated K_{oc} (based on K_{ow} or solubility)	Source of K_{oc} Data	Best Estimate for K_{oc}	Comments	K_d Used in Model (K_{oc} X 0.001 organic content)
Benzo(g,h,i)perylene	>1E+06 (not clear how est.)	9E+04 - 4E+05 (K_{ow} = 6.58)	HSDB	5E+05	best estimate is average of range	500
Benzo(k)fluoranthene	ND	3.31E+06 (log K_{oc}=6.52; log K_{ow} = 6.84)	HSDB	3.3E+06	range based on standard deviation of 50%	3,300
Benzoic acid	did not adsorb appreciably	ND	HSDB	0	insufficient data	0
Beta-HCH (beta-BHC)	2,897; 2,099; 3,573	ND	M&W	2.9E+03	best estimate is average of measured data	2.9
Bis(2-ethylhexyl) phthalate	1E+04 - 1E+05	ND	HSDB	1.5E+04	best estimate is average of range	15
2-Butanone (MEK)	ND	1	M&W	1E+00	range based on standard deviation of 50%	0.001
Butylbenzylphthalate	68 - 350	ND	HSDB	2.0E+02	best estimate is average of range	0.2
Carbazole	ND	ND	ND	0	no data	7[a]
Carbon disulfide	ND	63	HSDB	6.3E+01	range based on standard deviation of 50%	0.063
Carbon tetrachloride	71	220 440 420	HSDB M&W	2.9E+02	Best estimate is average of data from HSDB and M&W because HSDB value seemed low.	0.29
4-Chloro-3-methylphenol	ND	50 (solubility-based)	HSDB	5E+01	range based on standard deviation of 50%	0.05
4-Chloroaniline	230 - 469 (Belgium soils) 96 - 1530 (German soils)	ND	HSDB	8.1E+02	best estimate is average of range	0.81

Table 4-2. Partitioning Coefficients for Organic Compounds. (Sheet 3 of 7)

Constituent	Measured K_{oc}	Estimated K_{oc} (based on K_{ow} or solubility)	Source of K_{oc} Data	Best Estimate for K_{oc}	Comments	K_d Used in Model (K_{oc} X 0.001 organic content)
Chloroform	34 no appreciable adsorption poorly retained by aquifer material	ND	HSDB	3.4E+01	range based on standard deviation of 50%	0.034
Chrysene	ND	251,000-501,000 (K_{ow} = 5.61 - 5.91)	HSDB	3.8E+05	best estimate is average of range	380
4,4-DDD	ND	80,500 (not clear how estimated)	HSDB	8.1E+04	range based on standard deviation of 50%	81
4,4-DDE	50,000	8,300 (solubility-based)	HSDB	5E+04	best estimate is measured value	50
Di-n-butylphthalate	ND	160; 6400 (solubility-based)	HSDB	3.3E+03	best estimate is average of range	3.3
Dibenzo(a,h)anthracene	805,292 to 3,059,425 (11 values) 565,014 to 3,020,262 (3 values; soils) 2,029,000 (avg sed. and soils)	ND	HSDB	1.8E+06	best estimate is average of range	1,800
Dibenzofuran	ND	4600 (based on solubility), 5350 - 6350 (log K_{ow} = 4.12)	HSDB	5.5E+03	best estimate is average of range	5.5
1,2-Dichloroethene (total)	ND	36 - 49 (solubility-based)	HSDB	4.3E+01	best estimate is average of range	0.043

Table 4-2. Partitioning Coefficients for Organic Compounds. (Sheet 4 of 7)

Constituent	Measured K_{oc}	Estimated K_{oc} (based on K_{ow} or solubility)	Source of K_{oc} Data	Best Estimate for K_{oc}	Comments	K_d Used in Model (K_{oc} X 0.001 organic content)
1,3-Dichlorobenzene	293 (silt loam soil, 1.9% o.c.) 31600, 12600 (suspended sediment-water).	296 (solubility-based) 2450 (log K_{ow} = 3.6)	HSDB	2.9E+02	best estimate is value measured in soil	0.29
1,4-Dichlorobenzene	273 (silt loam soil, 1.9% o.c.) 390 (fine sand, .087-0.13 o.c.) 603 - 1833 (low o.c.) 700	409 (solubility-based) 1514 (log K_{ow} = 3.39)	HSDB	3.9E+02	best estimate is value measured in sand	0.39
Dieldrin	7,413 (measured)	ND	HSDB	7.4E+03	range based on standard deviation of 50%	7.4
Diethylphthalate	ND	94 (log K_{ow} = 2.47); 526 (solubility-based)	HSDB	3.1E+02	best estimate is average of range	0.31
Ethylbenzene	164 (silt loam)	871	HSDB	1.6E+02	best estimate is measured value	0.16
Fluoranthene	ND	66,000 (log K_{ow} = 5.22)	HSDB	6.6E+04	range based on standard deviation of 50%	66
Fluorene	Koc = 5010 (log K_{oc} = 3.70)	ND	M&W	5.0E+03	range based on standard deviation of 50%	5.0
Gamma-chlordane	ND	1720 (log K_{ow} = 3.32) 15,500 (solubility-based)	HSDB	8.6E+03	based on chlordane (no data available for gamma-chlordane) best estimate is average of range	8.6

Table 4-2. Partitioning Coefficients for Organic Compounds. (Sheet 5 of 7)

Constituent	Measured K_{oc}	Estimated K_{oc} (based on K_{ow} or solubility)	Source of K_{oc} Data	Best Estimate for K_{oc}	Comments	K_d Used in Model (K_{oc} X 0.001 organic content)
2-Hexanone	ND	134 (log K_{ow} = 1.38)	HSDB	1.3E+02	range based on standard deviation of 50%	0.13
Indeno (1,2,3-cd)pyrene	20,146 (not sure how estimated)	ND	HSDB	2.0E+04	range based on standard deviation of 50%	20
Methoxychlor	9,700 to 41,000 (sand) 80,000 to 86,000 (coarse silt) 73,000 to 100,000 (med. silt) 80,000 to 100,000 (fine silt) 73,000 to 92,000 (clay) 620 (water/sed.) 80,000	107,000	HSDB	2.5E+04	best estimate is average of measured values for sand	25
4-Methyl-2-pentanone (MIBK)	ND	19 (log K_{ow} = 1.19) 106 (solubility-based)	HSDB	5.0E+01	best estimate is average of all data values	0.05
Methylene chloride	48 	 25	HSDB M&W	3.7E+01	best estimate is average of values from both data sources, because HSDB value was high	0.037
2-Methylnaphthalene	8,500	ND	HSDB	8.5E+03	range based on standard deviation of 50%	8.5
4-Methylphenol (p-Cresol)	49 (Brookston clay loam) 650 (Coyote Creek sediment)	0.9 (solubility-based)	HSDB	3.5E+02	best estimate is average of measured data only	0.35
N-Nitrosodiphenylamine	ND	1200 (log K_{ow} = 3.13)	HSDB	1.2E+03	range based on standard deviation of 50%	1.2

Table 4-2. Partitioning Coefficients for Organic Compounds. (Sheet 6 of 7)

Constituent	Measured K_{oc}	Estimated K_{oc} (based on K_{ow} or solubility)	Source of K_{oc} Data	Best Estimate for K_{oc}	Comments	K_d Used in Model (K_{oc} X 0.001 organic content)
Naphthalene	871 (mean for 17 soils and sed.) 812 (soils/ Switzerland) 2,400 (mean; 4 silt loams, sandy loam soil) 594 (mean; range 420-830; 5 soils)	ND	HSDB	1.4E+03	best estimate is average of range	1.4
Pentachlorophenol	3,000 to 4,000 (soil and sed.)	1,000 (not clear how estimated)	HSDB	3.5E+03	best estimate is average of measured data only	3.5
Phenanthrene	K_{oc} = 22,900	ND	HSDB	2.3E+04	range based on standard deviation of 50%	23
Phenol	39; 91 (silt loams)	148 (log K_{ow} = 1.46)	HSDB	6.5E+01	best estimate is average of measured data only	0.065
Pyrene	57, 763-764, 706 (soils) 48, 236-285, 256 (sediments) 11,000 (sand) - 130,000 (med. silt) [pond sed.] 12,000 (sand) - 120,000 (med. silt) [river sed.] 8,318 84,000	ND	HSDB	1.2E+04	best estimate is average of measured values for sand	12
Tetrachloroethene	209, 210 238 (K_{ow}=137.7)	1685 (log K_{ow}=3.4)	HSDB	2.2E+02	best estimate is average of measured data only	0.22
1,1,2,2-Tetrachloroethane	79 (silt loam)	ND	HSDB	7.9E+01	range based on standard deviation of 50%	0.079

Table 4-2. Partitioning Coefficients for Organic Compounds. (Sheet 7 of 7)

Constituent	Measured K_{oc}	Estimated K_{oc} (based on K_{ow} or solubility)	Source of K_{oc} Data	Best Estimate for K_{oc}	Comments	K_d Used in Model (K_{oc} X 0.001 organic content)
Toluene	37 (Wendover silty loam) 160 (Grimsby silt loam) 46 (Vaudreil silt loam) 178 (sandy soil) 100, 151	ND	HSDB	1.8E+02	best estimate is measured value for sandy soil	0.18
1,1,1-Trichloroethane	183 (silt loam) mean range = 81-89 (silty clay and sandy loam)	ND	HSDB	1.3E+02	best estimate is average of range	0.13
Trichloroethene	100 87, 150 (silty clay loams)	ND	HSDB	1.1E+02	best estimate is average of measured data	0.11
Vinyl chloride	ND	56 (solubility-based)	HSDB	5.6E+01	range based on standard deviation of 50%	0.056
Xylenes(total)	46 - 68	ND	HSDB	5.7E+01	best estimate is average of range	0.057

Notes:
ND = No Data Available
ID = Insufficient Data Available
[a] Carbazole Kd is the most conservative value (lowest Kd) for PAH's.
References:
HSDB = Hazardous Substance Data Bank 1993-1994.
M&W = Montgomery and Welkom 1990.

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Table 4-3. Partitioning Coefficients for Radionuclides. (Sheet 1 of 2)

Radionuclide	Hanford-Specific K_d Data[a]	Best Estimate for K_d
Amerium-241	200 (100 - 500) (Ames and Serne 1991)	200
Barium-140	25 (20-200) (Ames and Serne 1991)	25
Beryllium-7	20 (15-200) (Ames and Serne (1991)	20
Carbon-14	0 (0 to <5) (Serne and Wood 1990)	0
Cerium-141	200 (100 - 500) (Ames and Serne 1991)	200
Cerium-144	200 (100 - 500) (Ames and Serne 1991)	200
Cesium-134	50 (6 - >1000) (Serne and Wood 1990)	50
Cesium-137	50 (50 - 3000) (Serne and Wood 1990)	50
Chromium-51	0 (Ames and Serne 1991)	0
Cobalt-58	50 (10 - 3000) (Ames and Serne 1991)	50
Cobalt-60	50 (10 - 3000) (Ames and Serne 1991)	50
Europium-152	200 (100 - 500) (Ames and Serne 1991)	200
Europium-154	200 (100 - 500) (Ames and Serne 1991)	200
Europium-155	200 (100 - 500) (Ames and Serne 1991)	200
Iron-59	50 (10 - 3000) (Ames and Serne 1991)	50
Manganese-54	20 (Serne and Wood 1990) 50 (10-3000) (Ames and Serne 1991)	35
Neptunium-237	2 (2-2,000) (Ames and Serne 1991)	2
Nickel-63	15 (variable) (Serne and Wood 1990) 30 (100 - 200) (Ames and Serne 1991)	23
Plutonium-238	100 (80 - 2000) (Serne and Wood 1990) 25 (100 - 2000) (Ames and Serne 1991)	63
Plutonium-239/240	100 (80 - 2000) (Serne and Wood 1990) 25 (100 - 2000) (Ames and Serne 1991)	63
Potassium-40	4 (1 - 30) (Ames and Serne 1991)	5
Radium-226	20 (Serne and Wood 1990)	20
Ruthenium-103	20 (10 - 1000) (Ames and Serne 1991)	20
Ruthenium-106	20 (10 - 1000) (Ames and Serne 1991)	20
Sodium-22	4 (1 - 30) (Ames and Serne 1991)	4
Strontium-90	25 (20 - 200) (Ames and Serne 1991) 10 (5 - 100) (Serne and Wood 1990)	18
Technetium-99	0 (0 - <1) (Serne and Wood 1990)	0

Table 4-3. Partitioning Coefficients for Radionuclides. (Sheet 2 of 2)

Radionuclide	Hanford-Specific K_d Data[a]	Best Estimate for K_d
Thorium-228	50 (FF-5) (Serne and Wood 1990)	50
Thorium-232	50 (FF-5) (Serne and Wood 1990)	50
Thorium-234	50 (FF-5) (Serne and Wood 1990)	50
Tritium	0 (Ames and Serne 1991)	0
Total Uranium	2 (2- 2000) (Ames and Serne 1991) 0 (0- < 10) (Serne and Wood 1990)	0
Uranium-233/234	2 (2- 2000) (Ames and Serne 1991) 0 (0- < 10) (Serne and Wood 1990)	0
Uranium-235	2 (2- 2000) (Ames and Serne 1991) 0 (0- < 10) (Serne and Wood 1990)	0
Uranium-238	2 (2- 2000) (Ames and Serne 1991) 0 (0- < 10) (Serne and Wood 1990)	0
Zinc-65	15 (Serne and Wood 1990) 30 (100 - 200) (Ames and Serne 1991)	23
Zirconium-95	40 (10 - 1000) (Ames and Serne 1991) 30 (Variable) (Serne and Wood 1990)	35

[a]Ranges are shown in parentheses.

Table 4-4. Partitioning Coefficients for Inorganic Constituents. (Sheet 1 of 2)

Constituent	Hanford-Specific Partitioning Coefficient (K_d) (L/kg)	Source of K_d	Best Estimate for K_d
Aluminum	20 (10-2000)	Ames and Serne 1991	20
Antimony	0 (0-40)	Ames and Serne 1991	0
Arsenic	0	Serne and Wood 1990	0
Barium	50 25 (20-200)	Serne and Wood 1990 Ames and Serne 1991	50
Beryllium	20 (15-200)	Serne and Wood 1990	20
Cadmium	15 (variable range) 30 (100-200)	Serne and Wood 1990 Ames and Serne 1991	23
Calcium	10 (Variable) 20 (15-200)	Serne and Wood 1990 Ames and Serne 1991	15
Chromium (VI)	0 (variable)	Serne and Wood 1990	0
Cobalt	10 (500-2,000) 50 (10-3000)	Serne and Wood 1990 Ames and Serne 1991	30
Copper	15 (variable) 30 (100-200)	Serne and Wood 1990 Ames and Serne 1991	23
Iron	50 (10-3000) 20	Ames and Serne 1991 Serne and Wood 1990	35
Lead	30 30 (100-200)	Serne and Wood 1990 Ames and Serne 1991	30
Magnesium	20 (15-200)	Ames and Serne 1991	20
Manganese	20 50 (10-3000)	Serne and Wood 1990 Ames and Serne 1991	35
Mercury	30 (100-200)	Ames and Serne 1991	30
Nickel	15 (variable range) 30 (100-200)	Ames and Serne 1991 Ames and Serne 1991	23
Potassium	4 (1-30)	Ames and Serne 1991	4
Selenium	0	Serne and Wood 1990	0
Silver	20 (unknown range) 30 (100-200)	Serne and Wood 1990 Ames and Serne 1991	25
Sodium	3 4 (1-30)	Serne and Wood 1990 Ames and Serne 1991	3
Strontium	25 (20-200) 10 (5-100)	Serne and Wood 1990 Ames and Serne 1991	18

Table 4-4. Partitioning Coefficients for Inorganic Constituents. (Sheet 2 of 2)

Constituent	Hanford-Specific Partitioning Coefficient (K_d) (L/kg)	Source of K_d	Best Estimate for K_d
Thallium	50	Serne and Wood 1990	50
Vanadium	50 (50 - 3000)	Ames and Serne 1991	50
Zinc	15 (variable) 30 (100 - 200)	Serne and Wood 1990 Ames and Serne 1991	23
Ammonia Ammonium	4 (1-30)	Ames and Serne 1991	4
Chloride	0 (0 to <1) 0	Serne and Wood 1990 Ames and Serne 1991	0
Fluoride	0 (0 to <1) 0	Serne and Wood 1990 Ames and Serne 1991	0
Nitrate	0 (0 to <1) 0	Serne and Wood 1990 Ames and Serne 1991	0
Nitrite	0 (0 to <1)	Serne and Wood 1990	0
Nitrite+Nitrate		use same value as for nitrate and nitrite	0
Phosphate	10 (variable) 50 (50-3000)	Serne and Wood 1990 Ames and Serne 1991	30
Sulfate	0 (variable) 0	Serne and Wood 1990 Ames and Serne 1991	0

Table 4-5. Half-lives for Organic Compounds. (Sheet 1 of 3)

Constituent	Half-Life HSDB 1993	Half-life Howard et. al 1991	Half-Life Dragun 1988	Range	Comments
Acenaphthene	< 1	< 1	< 1	1	
Acetone	< 1	< 1	ND	1	
Anthracene	< 1	1 - 10	1 - 10	1 - 10	
Aroclor-1248	< 1	ND	ID	1	
Aroclor-1254	ID	ND	ID	ID	use 10,000 years
Aroclor-1260	ID	ND	ID	ID	use 10,000 years
Benzene	< 1	1 - 10	< 1	1 - 10	
Benzo(a)anthracene	ID	1 - 10	1 - 10	1 - 10	
Benzo(a)pyrene	10 - 100	1 - 10	1 - 10	1 - 100	
Benzo(b)fluoranthene	ID	1 - 10	1 - 10	1 - 10	
Benzo(g,h,i)perylene	1 - 10	1 - 10	1 - 10	1 - 10	
Benzo(k)fluoranthene	1 - 10	10 - 100	1 - 10	1 - 100	
Benzoic acid	< 1	ND	< 1	1	
Beta-HCH (beta-BHC)	ND	ND	ID	ID	use 10,000 years
Bis(2-ethylhexyl) phthalate	< 1	1 - 10	ID	1 - 10	
2-Butanone	ID	< 1	ND	1	
Butylbenzylphthalate	ID	< 1	< 1	1	
Carbazole[a]	ND	ND	ND	ND	use 100 years
Carbon disulfide	< 1	ND	ND	1	
Carbon tetrachloride	ID	1 - 10	ND	1 - 10	
4-Chloro-3-methylphenol	ID	ND	ND	ID	"readily biodegradable" (HSDB); use 1 year based on analogy with phenol
4-Chloroaniline	< 1	ND	ND	1	
Chloroform	< 1	1 - 10	ND	1 - 10	
Chrysene	ID	1 - 10	ND	1 - 10	
4,4-DDD	ID	10 - 100	ID	10 - 100	
4,4-DDE	1 - 10	10 - 100	ID	1 - 100	
Di-n-butylphthalate	< 1	< 1	< 1	1	
Dibenzo(a,h)anthracene	< 1	1 - 10	1 - 10	1 - 10	
Dibenzofuran	ID	<1	< 1	1	
1,2-Dichloroethene (total)	< 1	1 - 10	ND	1 - 10	
1,3-Dichlorobenzene	< 1	< 1	< 1	1	
1,4-Dichlorobenzene	< 1	< 1	< 1	1	

Table 4-5. Half-lives for Organic Compounds. (Sheet 2 of 3)

Constituent	Half-Life HSDB 1993	Half-life Howard et. al 1991	Half-Life Dragun 1988	Range	Comments
Dieldrin	1 - 10	1 - 10	ID	1 - 10	
Diethylphthalate	< 1	< 1	< 1	1	
Ethylbenzene	< 1	< 1	< 1	1	
Fluoranthene	1 - 10	1 - 10	1 - 10	1 - 10	
Fluorene	ID	< 1	< 1	1	
Gamma-chlordane	ND	1 - 10	ND	1 - 10	based on chlordane (no data available for gamma-chlordane)
2-Hexanone	< 1	ND	ND	1	
Indeno(1,2,3-cd)pyrene	ND	1 - 10	1 - 10	1 - 10	
Methoxychlor	< 1	1 - 10	ND	1 - 10	
4-Methyl-2-pentanone	ID	< 1	ND	1	
Methylene chloride	< 1	< 1	< 1	1	
2-Methylnaphthalene	< 1	ND	< 1	1	
4-Methylphenol	ID	< 1	ND	1	
N-Nitrosodiphenylamine	< 1	< 1	< 1	1	
Naphthalene	< 1	< 1	< 1	1	
Pentachlorophenol	< 1	1 - 10	< 1	1 - 10	
Phenanthrene	ID	1 - 10	< 1	1 - 10	
Phenol	< 1	< 1	< 1	1	
Pyrene	ID	10 - 100	1 - 10	1 - 100	
Tetrachloroethene	< 1	1 - 10	< 1	1 - 10	
1,1,2,2-Tetrachloroethane	< 1	< 1	< 1	1	
Toluene	< 1	< 1	< 1	1	
1,1,1-Trichloroethane	< 1	1 - 10	< 1	1 - 10	
Trichloroethene	< 1	1 - 10	< 1	1 - 10	
Vinyl chloride	< 1	1 - 10	< 1	1 - 10	

Table 4-5. Half-lives for Organic Compounds. (Sheet 3 of 3)

Constituent	Half-Life HSDB 1993	Half-life Howard et. al 1991	Half-Life Dragun 1988	Range	Comments
Xylenes(total)	< 1	1 - 10	< 1	1 - 10	

Notes:
ND = No data.
ID = Insufficient data.
[a]Half-life for carbazole is based on most conservative value (highest) for all PAH's.

Sources:
Dragun 1988.
Howard et al. 1991.
HSDB = Hazardous Substance Data Bank 1993-1994.

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Table 4-6. Half-lives and Solubilities for Radionuclides. (Sheet 1 of 2)

Radionuclide	Solubility (mg/L)	Source	Best Estimate for Solubility (mg/L)	Half-Life (yr)
Amerium-241	LS (< 1)	Ames and Serne 1991	1	432
Barium-140	LS (< 1)	Ames and Serne 1991	1	0.0350
Beryllium-7	Insoluble	Weast 1989	1	0.146
Carbon-14	30	Wood 1994	30	5,730
Cerium-141	ND		1,000	0.0890
Cerium-144	ND		1,000	0.0778
Cesium-134	ND		1,000	2.06
Cesium-137	VS (> 1000)	Ames and Serne 1991	1,000	30.2
Chromium-51	MS (> 1)	Serne and Wood 1990	25	0.0759
Cobalt-58	ND (use Co-60)		25	0.194
Cobalt-60	MS (1-25)	Ames and Serne 1991	25	5.27
Europium-152	ND		1,000	13.6
Europium-154	ND		1,000	8.80
Europium-155	ND		1,000	4.96
Iron-59	LS (< 1)	Ames and Serne 1991	1	0.122
Manganese-54	LS (< 1)	Serne and Wood 1990 Ames and Serne 1991	1	0.86
Neptunium-237	MS (1-25)	Serne and Wood 1990	25	2.14E+06
Nickel-63	MS (> 1)	Serne and Wood 1990	25	100
Plutonium-238	ND (use Pu-239/240)		1	87.8
Plutonium-239/240	LS (< 1)	Serne and Wood 1990 Ames and Serne 1991	1	24,100[a]
Potassium-40	VS (> 1000)	Ames and Serne 1991	0.12[b]	1.28E+09
Radium-226	ND		1,000	1,600
Ruthenium-103	ND		1,000	0.108
Ruthenium-106	ND		1,000	1.01
Sodium-22	VS (> 1000)	Serne and Wood 1990	1,000	2.60
Strontium-90	MS (1-25)	Ames and Serne 1991	25	28.6

Table 4-6. Half-lives and Solubilities for Radionuclides. (Sheet 2 of 2)

Radionuclide	Solubility (mg/L)	Source	Best Estimate for Solubility (mg/L)	Half-Life (yr)
Technetium-99	VS (> 1000)	Ames and Serne 1991	1,000	2.13E+05
Thorium-228	LS (< 1)	Serne and Wood 1990	1	1.91
Thorium-232	LS (< 1)	Serne and Wood 1990	1	1.41E+10
Thorium-234	LS (< 1)	Serne and Wood 1990	1	0.0660 years
Tritium	VS (> 1000)	Ames and Serne 1991	2.7E+05[c]	12.3
Total Uranium	MS (1-25)	Ames and Serne 1991	25	4.47E+09[d]
Uranium-233/234	MS (1-25)	Ames and Serne 1991	0.0014[b]	2.45E+05[e]
Uranium-235	MS (1-25)	Ames and Serne 1991	0.18[b]	7.04E+08
Uranium-238	MS (1-25)	Ames and Serne 1991	24.8[b]	4.47E+09
Zinc-65	MS (1-25)	Ames and Serne 1991	25	0.668
Zirconium-95	LS (< 1) LS (< 1)	Ames and Serne 1991 Serne and Wood 1990	1	0.175

Notes:

LS = low solubility
MS = moderately soluble
VS = very soluble

[a] Using half-life of Pu-239. (Half-life of Pu-240 = 6.57E+03 yr)
[b] Accounts for crustal isotopic abundance (Faure, 1977).
[c] The solubility of tritium was calculated based on the assumption that all hydrogen in water is tritium.
[d] Using half-life of U-238.
[e] Using half-life of U-234. (Half-life of U-233 = 1.59E+05 yr)

Sources:
1. Ames and Serne 1991.
2. Serne and Wood 1990.
3. Weast et al. 1989.

Table 4-7. Solubilities for Organic Compounds. (Sheet 1 of 3)

Constituent	Solubility (mg/L)	Source	Best Estimate
Acenaphthene	3.47 at 25°C 3.93at 25°C	M&W	3.7
Acetone	Miscible with water	M&W and HSDB	1E+99[a]
Anthracene	0.075 at 15°C	M&W	0.075
Aroclor-1248	0.05 at 20°C	M&W	0.05
Aroclor-1254	0.05 at 20°C	M&W	0.05
Aroclor-1260	0.08 at 24°C	M&W	0.08
Benzene	1,780 at 20°C	M&W	1,800
Benzo(a)anthracene	0.0057 at 20°C	M&W	0.0057
Benzo(a)pyrene	0.004 at 25°C	M&W	0.004
Benzo(b)fluoranthene	0.0012 at 25°C	M&W	0.0012
Benzo(g,h,i)perylene	0.00026 at 25°C	M&W	0.00026
Benzo(k)fluoranthene	0.00055 at 25°C	M&W	0.00055
Benzoic acid	3,000 at 18°C 2,700 at 18°C	M&W	2,900
Beta-HCH (beta-BHC)	5 at 20°C	M&W	5
Bis(2-ethylhexyl) phthalate	0.041 at 20°C	M&W	0.041
2-Butanone	353,000 at 10°C	M&W	353,000
Butylbenzylphthalate	2.9	HSDB	2.9
Carbazole	Insoluble	HSDB	22[b]
Carbon disulfide	2,000 at 20°C 2,940 at 20°C	M&W	2,500
Carbon tetrachloride	770 at 15°C	M&W	770
4-Chloro-3-methyphenol	3,850 at 20°C	M&W	3,900
4-Chloroaniline	3,900 at 20 - 25°C	M&W	3,900
Chloroform	8,520 at 15°C	M&W	8,500
Chrysene	0.0015 at 15°C	M&W	0.0015
4,4-DDD	0.05 at 15°C	M&W	0.05
4,4-DDE	0.055 at 15°C	M&W	0.055
Di-n-butylphthalate	10.1 at 20°C	M&W	10
Dibenzo(a,h)anthracene	0.0005 at 25°C 0.0025 at 25°C	M&W	0.0015
Dibenzofuran	10 at 25°C	M&W	10
1,2-Dichloroethene (total)	600 at 20°C	M&W	600
1,3-Dichlorobenzene	69 at 22°C	M&W	69

Table 4-7. Solubilities for Organic Compounds. (Sheet 2 of 3)

Constituent	Solubility (mg/L)	Source	Best Estimate
1,4-Dichlorobenzene	49 at 22°C	M&W	49
Dieldrin	0.09 at 15°C	M&W	0.09
Diethylphthalate	600 at 20°C 928 at 20°C	M&W	760
Ethylbenzene	140 at 15°C	M&W	140
Fluoranthene	0.275 at 15°C	M&W	0.275
Fluorene	1.69, 1.98, 0.19, 1.66 at 25°C	M&W	1.4[c]
Gamma-chlordane	0.009, 0.056, 1.85 at 25°C	M&W	0.64[d]
2-Hexanone	3.5E+04 at 25°C	M&W	3.5E+04
Indeno(1,2,3-cd)pyrene	0.062	M&W	0.062
Methoxychlor	0.02 at 15°C	M&W	0.02
4-Methyl-2-pentanone (MIBK)	17,000 at 20°C	M&W	17,000
Methylene chloride	20,000 at 20°C	M&W	20,000
2-Methylnaphthalene	24.6 to 25.4 at 25°C	M&W	25
4-Methylphenol	19,400 at 20°C	M&W	19,000
N-nitrosodiphenylamine	35.1 at 25°C	M&W	35
Naphthalene	21.64 at 15.4°C	M&W	22
Pentachlorophenol	14 at 20°C 20 at 20°	M&W	17
Phenanthrene	1.6, 0.601 at 15°C	M&W	1.1
Phenol	82,000 at 15°C	M&W	82000
Pyrene	0.135 at 24°C	M&W	0.14
Tetrachloroethene	149, 150, 2,200 at 20°C	M&W	830
1,1,2,2-Tetrachloroethane	2,900 at 20°C 3,230 at 20°C	M&W	3,100
Toluene	515 at 20°C	M&W	520
1,1,1-Trichloroethane	4,400; 480; 730; 1,550; 1,360	M&W	1,700
Trichloroethene	1,100; 1,080 at 20°C	M&W	1,100
Vinyl chloride	1,100; 2,700 at 25°C	M&W	1900

Table 4-7. Solubilities for Organic Compounds. (Sheet 3 of 3)

Constituent	Solubility (mg/L)	Source	Best Estimate
Xylenes(total)	152 at 20°C	M&W	150

Notes:

[a]Assume infinite solubility.
[b]Based on most conservative value for PAH's.
[c]Average of all values.
[d]Chlordane values are used for gamma-chlordane.

Source:
HSDB = Hazardous Substance Data Bank (1993-1994).
M&W = Montgomery and Welkom (1990).

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Table 4-8. Solubilities for Inorganic Constituents. (Sheet 1 of 2)

Constituent	Solubility (mg/L)	Source of Solubility Data	Best Estimate of Solubility
Aluminum	LS (< 1)	Ames and Serne 1991	1
Antimony	VS (>1000)	Ames and Serne 1991	1,000
Arsenic	VS (> 1000)	Serne and Wood 1990 Ames and Serne 1991	1,000
Barium	LS (<1)	Serne and Wood 1990 Ames and Serne 1991	1
Beryllium	Unknown insoluble	Serne and Wood 1990 Weast 1989	1
Cadmium	MS (>1) MS (1 - 25)	Serne and Wood 1990 Ames and Serne 1991	25
Calcium	MS (> 1) MS (1 - 25)	Serne and Wood 1990 Ames and Serne 1991	25
Chromium (VI)	VS(>1000)	Ames and Serne 1991	1,000
Cobalt	MS (1 - 25)	Ames and Serne 1991	25
Copper	MS (>1) MS (1 -25)	Serne and Wood 1990 Ames and Serne 1991	25
Iron	LS (<1)	Ames and Serne 1991 Serne and Wood 1990	1
Lead	LS (<1)	Serne and Wood 1990 Ames and Serne 1991	1
Magnesium	MS (1 -25)	Ames and Serne 1991	25
Manganese	LS (<1)	Serne and Wood 1990 Ames and Serne 1991	1
Mercury	Unknown Insoluble	Serne and Wood 1990 Weast 1989	1
Nickel	MS (>1)	Serne and Wood 1990	25
Potassium	VS (>1000)	Ames and Serne 1991	1,000
Selenium	VS (>1000)	Serne and Wood 1990	1,000
Silver	MS (>1) LS (<1)	Serne and Wood 1990 Ames and Serne 1991	25
Sodium	VS (>1000)	Serne and Wood 1990 Ames and Serne 1991	1,000
Strontium	MS (1 - 25)	Serne and Wood 1990 Ames and Serne 1991	25
Thallium	Insoluble	Weast 1989	1

Table 4-8. Solubilities for Inorganic Constituents. (Sheet 2 of 2)

Constituent	Solubility (mg/L)	Source of Solubility Data	Best Estimate of Solubility
Vanadium	MS (1 - 25)	Ames and Serne 1991	25
Zinc	MS (>1) MS (1 - 25)	Serne and Wood 1990 Ames and Serne 1991	25
Ammonia (Ammonium)	VS (>1000)	Ames and Serne 1991	1,000
Chloride	VS (>1000)	Ames and Serne 1991	1,000
Fluoride	VS (>1000) MS (1 - 25)	Serne and Wood 1990 Ames and Serne 1991	1,000
Nitrate	VS (>1000)	Serne and Wood 1990	1,000
Nitrite	VS (>1000)	Ames and Serne 1991	1,000
Nitrite+Nitrate			1,000
Phosphate	LS (<1)	Serne and Wood 1990 Ames and Serne 1991	1
Sulfate	MS (>1) MS (1 - 25)	Serne and Wood 1990 Ames and Serne 1991	25

Notes:

LS = low solubility
MS = moderately soluble
VS = very soluble

Table 4-9. Groundwater Background Screening for Inorganic Constituents.
(Sheet 1 of 2)

Constituent	Maximum Detected Soil Concentration (mg/kg)	Predicted Groundwater Concentration (mg/L)[a]	Hanford Site Groundwater Background (mg/L)[b]
Metals			
Aluminum	78400	0.06	ND
Antimony	18.6	39	NR
Arsenic	62.2	60	0.01
Barium	4260	0.06	0.0685
Beryllium	4.7	0.014	ND
Cadmium	28.5	0.074	ND
Calcium	95300	1.5	63.6
Chromium-VI	2510	60	ND
Cobalt	90.4	0.18	NR
Copper	95300	1.5	ND
Iron	184000	0.06	0.086
Lead	747	0.06	ND
Magnesium	50000	1.5	16.48
Manganese	3050	0.06	0.0245
Mercury	37.0	0.06	ND
Nickel	1750	1.5	ND
Potassium[c]	13000	60	7.975
Selenium	11.1	24	ND
Silver	362	0.86	ND
Sodium[c]	2610	51	33.5
Strontium	31	0.10	0.2641
Thallium	5.4	0.0064	NR
Vanadium	389	0.46	0.015
Zinc	6160	1.5	ND
Anions			
Ammonia[d]	138.3	2.0	0.12
Fluoride	40.3	60	0.775
Nitrite	2.9	6.1	NR

Table 4-9. Groundwater Background Screening for Inorganic Constituents.
(Sheet 2 of 2)

Constituent	Maximum Detected Soil Concentration (mg/kg)	Predicted Groundwater Concentration (mg/L)[a]	Hanford Site Groundwater Background (mg/L)[b]
Sulfate	7115	1.5	90.5

Notes:
NR = Not Reported
ND = Not Detected
The shaded areas indicate retained groundwater contaminants.
[a]Source: Appendix A, Tables A-3 and A-4.
[b]Source: Hoover and Le Gore (1991).
[c]Potassium and sodium are eliminated because they are not considered toxic to humans under normal circumstances (DOE-RL 1993j).
[d]Ammonia is eliminated because it converts to nitrate under aerobic conditions (HSDB 1994). Assuming all ammonia converts to nitrate, the resulting nitrate concentration of 2.35 mg/L is below the background concentration of 12.4 mg/L.

Table 4-10. De Minimis and Travel Time Groundwater Contaminant Screening. (Sheet 1 of 5)

Constituent	Maximum Detected Soil Concentration	Predicted Groundwater Concentration	Travel Time to ERDF Boundary
Organic Compounds	(μg/kg)	(mg/L)	(Year)
Acenaphthene	850	<5E-07	>10,000
Acetone	2800	<5E-07	520
Anthracene	6300	<5E-07	>10,000
Aroclor-1248	10000	<5E-07	>10,000
Aroclor-1254	6400	<5E-07	>10,000
Aroclor-1260	2300	<5E-07	>10,000
Benzo(a)anthracene	1800	<5E-07	>10,000
Benzene	190	<5E-07	2,200
Benzo(a)pyrene	27000	<5E-07	>10,000
Benzo(b)fluoranthene	2400	<5E-07	>10,000
Benzo(g,h,i)perylene	3700	<5E-07	>10,000
Benzo(k)fluoranthene	760	<5E-07	>10,000
Benzoic acid	1300	<5E-07	520
Beta-HCH (beta-BHC)	7.8	3.2E-06	>10,000
Bis(2-ethylhexyl) phthalate	33000	<5E-07	>10,000
2-Butanone (MEK)	390	<5E-07	530
Butylbenzylphthalate	2600	<5E-07	4,400
Carbazole	54	<5E-07	>10,000
Carbon disulfide	200	<5E-07	1,700
Carbon tetrachloride	8.0	<5E-07	6,100
Chlordane (gamma)	18	<5E-07	>10,000
4-Chloro-3-methyplhenol	38	<5E-07	1,500
4-Chloroaniline	6300	<5E-07	>10,000
Chloroform	80	<5E-07	1,200
Chrysene	43000	<5E-07	>10,000
4,4-DDD	110	<5E-07	>10,000
4,4-DDE	170	<5E-07	>10,000
Di-n-butylphthalate	5500	<5E-07	>10,000
Dibenzo(a,h)anthracene	1700	<5E-07	>10,000

Table 4-10. De Minimis and Travel Time Groundwater Contaminant Screening. (Sheet 2 of 5)

Constituent	Maximum Detected Soil Concentration	Predicted Groundwater Concentration	Travel Time to ERDF Boundary
Dibenzofuran	500	<5E-07	>10,000
1,3-Dichlorobenzene	48	<5E-07	6,100
1,4-Dichlorobenzene	51	<5E-07	8,000
1,2-Dichloroethene	1000	<5E-07	1,300
Dieldrin	21	<5E-07	>10,000
Diethylphthalate	1000	<5E-07	6,500
Ethyl benzene	330	<5E-07	3,600
Fluoranthene	2900	<5E-07	>10,000
Fluorene	1700	<5E-07	>10,000
2-Hexanone	9	<5E-07	3,000
Indeno(1,2,3-cd)pyrene	1600	<5E-07	>10,000
Methoxychlor	83	<5E-07	>10,000
4-Methyl-2-pentanone	11	<5E-07	1,500
Methylene chloride	4500	<5E-07	1,200
2-Methylnaphthalene	13000	<5E-07	>10,000
4-Methylphenol	1000	<5E-07	7,200
Naphthalene	4100	<5E-07	>10,000
N-Nitrosodiphenylamine	1800	<5E-07	>10,000
Pentachlorophenol	1500	<5E-07	>10,000
Phenanthrene	3900	<5E-07	>10,000
Phenol	240	<5E-07	1,800
Pyrene	12000	<5E-07	>10,000
1,1,2,2-Tetrachloroethane	3	<5E-07	2,000
Tetrachloroethene	1100	<5E-07	4,700
Toluene	150	<5E-07	4,000
1,1,1-Trichloroethane	6	<5E-07	3,100
Trichloroethene	390	<5E-07	2,600
Vinyl chloride	24	<5E-07	1,600
Xylenes(total)	1100	<5E-07	1,600

Table 4-10. De Minimis and Travel Time Groundwater Contaminant Screening.
(Sheet 3 of 5)

Constituent	Maximum Detected Soil Concentration	Predicted Groundwater Concentration	Travel Time to ERDF Boundary
Radionuclides	(pCi/g)	(pCi/L)	(Year)
Americium-241	34	<1E-06	>10,000
Barium-140	400	<1E-06	>10,000
Beryllium-7	90	<1E-06	>10,000
Carbon-14	640	1.3E+06	520
Cerium-141	3	<1E-06	>10,000
Cerium-144	0.5	<1E-06	>10,000
Cesium-134	56	<1E-06	>10,000
Cesium-137	110000	<1E-06	>10,000
Chromium-51	3.465	<1E-06	520
Cobalt-58	14.1	<1E-06	>10,000
Cobalt-60	11000	<1E-06	>10,000
Europium-152	29000	<1E-06	>10,000
Europium-154	9200	<1E-06	>10,000
Europium-155	9600	<1E-06	>10,000
Iron-59	1	<1E-06	>10,000
Manganese-54	0.07	<1E-06	>10,000
Neptunium-237	34	2.0E-01	>10,000
Nickel-63	62000	<1E-06	>10,000
Plutonium-238	140	<1E-06	>10,000
Plutonium-239/240	2800	<1E-06	>10,000
Potassium-40	33	3.9E+02	>10,000
Radium-226	42.8	<1E-06	>10,000
Ruthenium-103	1	<1E-06	>10,000
Ruthenium-106	0.8	<1E-06	>10,000
Sodium-22	9.91	<1E-06	>10,000
Strontium-90	2000	<1E-06	>10,000
Technetium-99	1.1	2.3E+03	520
Thorium-228	16.79	<1E-06	>10,000
Thorium-232	3.546	4.2E+00	>10,000
Thorium-234	1	<1E-06	>10,000

Table 4-10. De Minimis and Travel Time Groundwater Contaminant Screening. (Sheet 4 of 5)

Constituent	Maximum Detected Soil Concentration	Predicted Groundwater Concentration	Travel Time to ERDF Boundary
Tritium	29000	4.2E-06	520
Total Uranium	20034	1.1E+03	520
Uranium-233/234	2100	5.3E+02	520
Uranium-235	638.4	2.3E+01	520
Uranium-238	9143	4.9E+02	520
Zinc-65	0.3	< 1E-10	> 10,000
Zirconium-95	0.56	< 1E-10	> 10,000
Metals	(mg/kg)	(mg/L)	(Year)
Aluminum	78400	6.0E-02	> 10,000
Antimony	18.6	3.9E+01	520
Arsenic	62.2	6.0E+01	520
Beryllium	4.7	1.4E-02	> 10,000
Cadmium	28.5	7.4E-02	> 10,000
Chromium-VI	2510	6.0E+01	520
Cobalt	90.4	1.8E-01	> 10,000
Copper	95300	1.5E+00	> 10,000
Lead	747	6.0E-02	> 10,000
Manganese	3050	6.0E-02	> 10,000
Mercury	37.0	6.0E-02	> 10,000
Nickel	1750	1.5E+00	> 10,000
Selenium	11.1	2.4E+01	520
Silver	362	8.6E-01	> 10,000
Thallium	5.4	6.4E-03	> 10,000
Vanadium	389	4.6E-01	> 10,000
Zinc	6160	1.5E+00	> 10,000

Table 4-10. De Minimis and Travel Time Groundwater Contaminant Screening. (Sheet 5 of 5)

Constituent	Maximum Detected Soil Concentration	Predicted Groundwater Concentration	Travel Time to ERDF Boundary
Anions	(mg/kg)	(mg/L)	(Year)
Fluoride	40.3	6.0E+01	520
Nitrite	2.9	6.1E+00	520

Notes: N/A = Not Available
Shaded areas indicate de minimis screening criteria exceeded.
De minimis value for organic compounds is 5E-07 mg/L.
De minimis value for radionuclides is 1E-02 pCi/L.

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Table 4-11. Potential Groundwater Contaminants at the ERDF.

Constituent	Maximum Detected Soil Concentration	Predicted Groundwater Concentration	Travel Time to ERDF Boundary
Radionuclides	(pCi/g)	(pCi/L)	(yr)
Carbon-14	640	1.3E+06	520
Technetium-99	1.1	2.3E+03	520
Total Uranium	20034	1.1E+03	520
Uranium-233/234	2100	5.3E+02	520
Uranium-235	638.4	2.3E+01	520
Uranium-238	9143	4.9E+02	520
Metals	(mg/kg)	(mg/L)	(yr)
Antimony	18.6	3.9E+01	520
Arsenic	62.2	6.0E+01	520
Chromium-VI	2510	6.0E+01	520
Selenium	11.1	2.4E+01	520
Anions	(mg/kg)	(mg/L)	(yr)
Fluoride	40.3	6.0E+01	520
Nitrite	2.90	6.1E+00	520

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5.0 CONTAMINANTS OF POTENTIAL CONCERN

5.1 APPROACH

The purpose of this chapter is to identify chemical and radiological contaminants at the 100, 200, and 300 Areas which may potentially pose risk to human health and the environment once placed in the ERDF. For this purpose, a risk-based screening process and comparison to ARARs is used to identify contaminants of potential concern (COPC). The risk-based screening process involves the calculation of risk-based screening concentrations, which consider both non-carcinogenic and carcinogenic effects. Risk-based screening concentrations are soil or groundwater concentrations that correspond to a hazard quotient (HQ) of 0.1, or lifetime incremental cancer risk (ICR) of $1x10^{-7}$ using residential scenario exposure parameter values (see Chapter 6 for a discussion of HQ and ICR). The equations and parameter values used to perform the risk-based screening are provided in Revision 3 of the Hanford Site Risk Assessment Methodology (HSRAM, DOE-RL 1994c).

If the maximum concentration detected for a contaminant exceeds a risk-based screening concentration and/or an ARAR for that contaminant, it is retained for evaluation in the risk assessment as a COPC. Otherwise, the contaminant is eliminated from the risk assessment process. The screening process provides a high degree of confidence that these eliminated contaminants pose only an insignificant risk to human health or the environment. COPC are identified separately for soil and groundwater.

The process for selecting COPC is shown in the flow chart in Figure 5-1. The process begins with the soil contaminants identified in Chapter 3, and the groundwater contaminants identified in Chapter 4. Concentrations of these contaminants are compared to risk-based screening concentrations and ARARs to determine COPC in soils and groundwater.

The human health screening process is also used to determine COPC for which ecological risks are evaluated. This is justified in part because most of the data used to develop human health toxicity values [i.e., reference doses (RfDs) and slope factors (SFs)] are from animal studies. For this report, the primary indicator species is the Great Basin pocket mouse, for which the animal study data are expected to be generally applicable. The adjustments used in developing RfDs and SFs assumptions (see Section 6.1.2) regarding human exposure patterns (i.e., residential scenario), and restrictive criteria (i.e., target ICR of $1x10^{-7}$ and target HQ of 0.1) used in developing human health risk-based screening concentrations ensure that these concentrations will also be protective of most non-human receptors at the ERDF. It is possible that human health screening values for some contaminants are inappropriate for ecological receptors. However, it is expected that the contaminants of greatest concern from an ecological perspective will be identified with a human health risk-based screening process.

5.2 HUMAN HEALTH TOXICITY VALUES

Table 5-1 presents RfDs and SFs for soil and groundwater contaminants. The contaminants listed in Table 5-1 are the soil contaminants identified in Tables 3-8, 3-9, and 3-10, and the groundwater contaminants identified in Table 4-11. In some cases, toxicity values from one contaminant (i.e., a surrogate) are used to permit screening of another contaminant for which toxicity values are not available. The following surrogates are used in this report:

- Aroclor-1248, -1254, and -1260 are evaluated separately using toxicity values for PCBs, which are based on a mixture of Aroclors
- benzo(a)pyrene is used as a surrogate for other B2 cancer class polyaromatic hydrocarbons (i.e., benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene)
- 2-butanone is used as a surrogate for 2-hexanone
- naphthalene is used as a surrogate for 2-methylnaphthalene
- pyrene is used as a surrogate for phenanthrene
- uranium-238+D is used as a surrogate for total uranium.

Radionuclide slope factors presented in Table 5-1 are those that account for the contribution of radioactive daughter products. This is what is meant by the "+D" notation.

Although there is an inhalation slope factor for nickel, it is only appropriate for evaluating nickel refinery dust, and is therefore not used to develop a risk-based screening concentration for nickel.

5.3 SOIL RISK-BASED SCREENING

Appendix D of HSRAM (DOE-RL 1994c) provides the equations and exposure parameter values used to calculate preliminary risk-based screening concentrations. Appendix D indicates how these parameter values can be combined into summary screening factors. These factors (originally presented in Table D-1 of HSRAM) are provided in Table 5-2. Summary screening factors are combined with toxicity values presented in Table 5-1 to yield risk-based screening concentrations. For carcinogens, a risk-based screening concentration is determined by dividing the summary screening factor by the contaminant-specific SF. For noncarcinogens, a risk-based screening concentration is determined by multiplying the summary screening factor by the contaminant-specific RfD.

For the purpose of screening soil contaminants, risk-based screening concentrations are calculated using residential scenario exposure parameter values and four exposure pathways: soil ingestion, fugitive dust inhalation, inhalation of volatile compounds, and external radiation exposure. Risk-based screening concentrations for soils are provided in Tables 5-3 (non-radioactive contaminants) and Table 5-4 (radioactive contaminants).

Contaminant-specific/site-specific volatilization factors (VFs) are required to determine risk-based screening concentrations for volatile contaminants. The VFs used in this report are taken directly from the original RIs or QRAs identified as the source of the maximum contaminant concentrations. For example, the maximum concentration of trichloroethene (0.39 mg/kg) is from Burial ground No. 4 of the 300-FF-1 operable unit. The 300-FF-1 RI

(DOE-RL 1993f; Table 4-14) indicates that the VF for trichloroethene at Burial ground No. 4 is $1.2x10^3$ m^3/kg. VFs are provided in Table 5-3.

Previous reports provide VFs for only seven of the volatile contaminants being evaluated. Volatile contaminants for which VFs are not available are assigned a VF of $1x10^3$ m^3/kg. This value is more conservative than all but one of the VFs from previous reports (vinyl chloride is most conservative with a VF of $6x10^2$ m^3/kg). Volatilization factors were determined only for volatile contaminants that have inhalation RfDs or SFs.

The maximum detected concentration in the 100 and 300 Areas and the minimum risk-based screening concentration for each contaminant are provided in Table 5-5. If a maximum detected contaminant concentration exceeds its associated risk-based screening concentration, then it is a contaminant of potential concern. Shading in Table 5-5 indicates that a contaminant is a COPC.

Several contaminants do not have toxicity values (with which to calculate risk-based screening concentrations) or ARARs for comparison with the maximum detected concentration. These contaminants are benzo(g,h,i)perylene, 4-chloro-3-methylphenol, dibenzofuran, 1,3-dichlorobenzene, 4-methylphenol, and sulfate. All except 4-methylphenol are group D carcinogens (not classifiable as to human carcinogenicity); 4-methylphenol is a group C carcinogen (possible human carcinogen). All except sulfate have maximum detected concentrations less than 4 mg/kg. Because of the lack of evidence of carcinogenity and low concentrations, none of these contaminants are considered COPC.

It is unknown whether the maximum concentration for total chromium ($2.5x10^3$ mg/kg) represents trivalent or hexavalent chromium. Therefore, the risk-based screening concentrations for both chromium (III) and (VI) are provided in Table 5-5. These values indicate that, if total chromium data represents chromium (III), chromium would not be considered a COPC. However, all chromium is conservatively assumed to be hexavalent, and chromium is considered a COPC. Because the total chromium concentration of $2.5x10^3$ mg/kg is assumed to represent chromium (VI), and this value is greater than the maximum detected chromium (VI) concentration of 5.0 mg/kg, only the larger of these two values is carried forward into the risk assessment.

Gross alpha and gross beta activity measurements are general indicators of radioactivity. They are not useful data for quantitative risk assessment because toxicity data for radionuclides is isotope-specific. Because the radionuclide inventory is well characterized with a large number of radioisotopes, gross alpha and gross beta are not carried forward into the risk assessment.

Potassium-40 is also eliminated from further consideration. Potassium-40 is a naturally-occurring, primordial radionuclide which is present in all soils (Eisenbud 1987). It is not produced in fission reactions, nor is it a daughter product of any radionuclide which is produced in fission reactions. Therefore, any measurements of potassium-40 in any medium can be attributed to natural potassium, and are not indicative of environmental contamination.

Total uranium as well as the individual isotopes of uranium all exceed their respective risk-based screening concentrations. However, only total uranium is carried forward into the risk assessment. Total uranium is made up of the individual isotopes, such that adding the risk of total uranium to those of individual isotopes essentially means counting the same risk twice.

It is conservative to evaluate total uranium instead of the individual isotopes because the maximum detected concentration of total uranium is greater than the sum of the isotope concentrations.

5.4 GROUNDWATER RISK-BASED SCREENING

Risk-based screening concentrations for groundwater contaminants are calculated using the toxicity factors in Section 5.2 and the same calculation methods as those for soil contaminants (see Section 5.3). Groundwater contaminants are identified in Table 4-11. Toxicity values for these contaminants are provided in Table 5-1, and summary screening factors are provided in Table 5-2. Risk-based screening concentrations are calculated only for the groundwater ingestion pathway. Risk-based screening concentrations for the volatile inhalation are not calculated because none of the volatile soil contaminants are considered groundwater contaminants. Risk-based screening concentrations for groundwater contaminants are provided in Table 5-6.

The predicted groundwater concentration and minimum risk-based screening concentration for each contaminant are provided in Table 5-7. The minimum ARAR concentration (see Chapter 7) for each contaminant is also identified in Table 5-7. If a predicted groundwater concentration exceeds either its associated risk-based screening or ARAR concentration, then it is a contaminant of potential concern. Shading in Table 5-7 indicates that a contaminant is a COPC.

The predicted groundwater concentration of chromium (VI) is based on total chromium data. However, it is conservatively assumed that all chromium is hexavalent.

As with the soil risk-based screening, total uranium is retained for the risk assessment while individual uranium isotopes are not.

5.5 SUMMARY OF CONTAMINANTS OF POTENTIAL CONCERN

Contaminants of potential concern for soil and groundwater are provided in Tables 5-8 and 5-9, respectively. Also provided in these tables are the maximum detected soil concentrations and predicted groundwater concentrations. Soil COPC are carried forward into the risk assessment (Chapter 6) to evaluate human health and ecological risks associated with exposure to contaminated soils. Groundwater COPC are used in the risk assessment to evaluate human health risks associated with groundwater exposures.

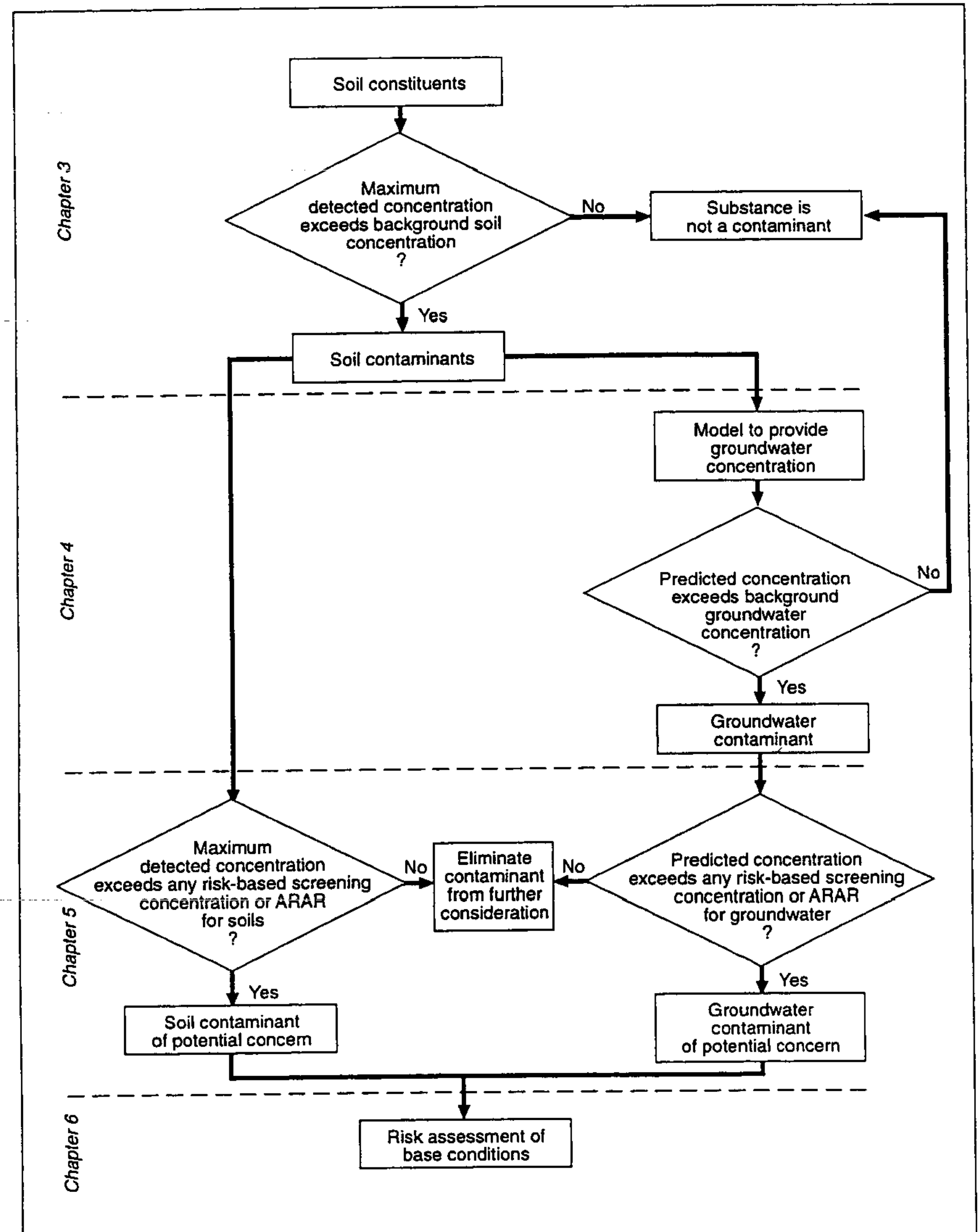

Figure 5-1. Overview of Contaminant Identification Process.

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Table 5-1. Contaminant Reference Doses and Slope Factors. (Sheet 1 of 4)

Contaminant	Ingestion		Inhalation		External
	RfD	SF	RfD	SF	SF
Organic Compounds	(mg/kg-d)	(mg/kg-d)$^{-1}$	(mg/kg-d)	(mg/kg-d)$^{-1}$	NA
Acenaphthene	6.0E-02[h]	-	-	-	
Acetone	1.0E-01[h]	-	-	-	
Anthracene	3.0E-01[h]	-	-	-	
Aroclor-1248[a]	-	7.7E+00[h]	-	-	
Aroclor-1254[a]	-	7.7E+00[h]	-	-	
Aroclor-1260[a]	-	7.7E+00[h]	-	-	
Benzo(a)anthracene[b]	-	7.3E+00[h]	-	-	
Benzene	-	2.9E-02[h]	-	2.9E-02[h]	
Benzo(a)pyrene	-	7.3E+00[h]	-	-	
Benzo(b)fluoranthene[b]	-	7.3E+00[h]	-	-	
Benzo(g,h,i)perylene	-	-	-	-	
Benzo(k)fluoranthene[b]	-	7.3E+00[h]	-	-	
Benzoic acid	4.0E+00[h]	-	-	-	
Bis(2-ethylhexyl)phthalate	2.0E-02[h]	1.4E-02[h]	-	-	
2-Butanone	6.0E-01[h]	-	2.9E-01[h]	-	
Butylbenzylphthalate	2.0E-01[h]	-	-	-	
Carbazole	-	2.0E-02[h]	-	-	
Carbon disulfide	1.0E-01[h]	-	3.0E-03[i]	-	
Carbon tetrachloride	7.0E-04[h]	1.3E-01[h]	-	5.3E-02[h,i]	
Chlordane (gamma)	6.0E-05[h]	1.3E+00[h]	-	1.3E+00[h,i]	
4-Chloro-3-methyphenol	-	-	-	-	
4-Chloroaniline	4.0E-03[h]	-	-	-	
Chloroform	1.0E-02[h]	6.1E-03[h]	-	8.1E-02[h,i]	
Chrysene[b]	-	7.3E+00[h]	-	-	
4,4-DDD	-	2.4E-01[h]	-	-	
4,4-DDE	-	3.4E-01[h]	-	-	
Di-n-butylphthalate	1.0E-01[h]	-	-	-	
Dibenzo(a,h)anthracene[b]	-	7.3E+00[h]	-	-	
Dibenzofuran	-	-	-	-	
1,3-Dichlorobenzene	-	-	-	-	
1,4-Dichlorobenzene	-	2.4E-02[i]	2.0E-01[i]	-	
1,2-Dichloroethene (total)	9.0E-03[i]	-	-	-	
Dieldrin	5.0E-05[h]	1.6E+01[i]	-	1.6E+01[h]	
Diethylphthalate	8.0E-01[h]	-	-	-	
Ethyl benzene	1.0E-01[h]	-	2.9E-01[h]	-	
Fluoranthene	4.0E-02[h]	-	-	-	
Fluorene	4.0E-02[h]	-	-	-	
Beta-HCH (Beta-BHC)	-	1.8E+00[h]	-	1.8E+00[i]	
2-Hexanone[c]	6.0E-01[h]	-	2.9E-01[h]	-	
Indeno(1,2,3-cd)pyrene[b]	-	7.3E+00[h]	-	-	

Table 5-1. Contaminant Reference Doses and Slope Factors. (Sheet 2 of 4)

Contaminant	Ingestion		Inhalation		External
	RfD	SF	RfD	SF	SF
Methoxychlor	5.0E-03[h]	-	-	-	
4-Methyl-2-pentanone	5.0E-02[i]	-	2.0E-02[i]	-	
Methylene Chloride	6.0E-02[h]	7.5E-03[h]	9.0E-01[i]	1.6E-03[h]	
2-Methylnaphthalene[d]	4.0E-03[j]	-	-	-	
4-Methylphenol	-	-	-	-	
Naphthalene	4.0E-03[j]	-	-	-	
N-Nitrosodiphenylamine	-	4.9E-03[h]	-	-	
Pentachlorophenol	3.0E-02[h]	1.2E-01[h]	-	-	
Phenanthrene[e]	3.0E-02[h]	-	-	-	
Phenol	6.0E-01[h]	-	-	-	
Pyrene	3.0E-02[h]	-	-	-	
1,1,2,2-Tetrachloroethane	-	2.0E-01[h]	-	2.0E-01[h,i]	
Tetrachloroethene	1.0E-02[h]	5.2E-02[k]	-	2.0E-03[k]	
Toluene	2.0E-01[h]	-	1.0E-01[h]	-	
1,1,1-Trichloroethane	-	-	3.0E-01[l]	-	
Trichloroethene	6.0E-03[m]	1.1E-02[m]	-	6.0E-03[m]	
Vinyl Chloride	-	1.9E+00[i]	-	3.0E-01[i]	
Xylenes (total)	2.0E+00[h]	-	-	-	
Inorganic Constituents	(mg/kg-d)	(mg/kg-d)$^{-1}$	(mg/kg-d)	(mg/kg-d)$^{-1}$	NA
Aluminum	1.0E+00[n]	-	-	-	
Ammonia	-	-	2.9E-02[h]	-	
Antimony	4.0E-04[h]	-	-	-	
Arsenic	3.0E-04[h]	2.0E+00[h]	-	1.5E+01[h]	
Barium	7.0E-02[h]	-	1.0E-04[i]	-	
Beryllium	5.0E-03[h]	4.3E+00[h]	-	8.4E+00[h,i]	
Cadmium (food)	1.0E-03[h]	-	-	6.3E+00[h]	
Chromium (III)	1.0E+00[h]	-	-	-	
Chromium (VI)	5.0E-03[h]	-	-	4.2E+01[i]	
Cobalt	6.0E-02[o]	-	-	-	
Copper	4.0E-02[p]	-	-	-	
Fluoride	6.0E-02[h]	-	-	-	
Lead	-	-	-	-	
Manganese (food)	1.4E-01[h]	-	1.1E-04[h]	-	
Mercury	3.0E-04[i]	-	9.0E-05[i]	-	
Nickel	2.0E-02[h]	-	-	8.4E-01[f,h]	
Nitrite (as N)	1.0E-01[h]	-	-	-	
Selenium	5.0E-03[h]	-	-	-	
Silver	5.0E-03[h]	-	-	-	
Strontium	6.0E-01[h]	-	-	-	
Sulfate	-	-	-	-	

Table 5-1. Contaminant Reference Doses and Slope Factors. (Sheet 3 of 4)

Contaminant	Ingestion		Inhalation		External
	RfD	SF	RfD	SF	SF
Thallium (oxide)	7.0E-05[i]	-	-	-	
Vanadium	7.0E-03[i]	-	-	-	
Zinc	3.0E-01[h]	-	-	-	
Radionuclides	NA	$(pCi)^{-1}$	NA	$(pCi)^{-1}$	$(pCi\text{-}yr/g)^{-1}$
Americium-241		2.4E-10[i]		3.2E-08[i]	4.9E-09[i]
Barium-140		2.7E-12[i]		2.0E-12[i]	5.4E-07[i]
Beryllium-7		3.0E-14[i]		2.7E-13[i]	1.5E-07[i]
Carbon-14		9.0E-13[i]		6.4E-15[i]	0.0E+00[i]
Cerium-141		8.3E-13[i]		8.4E-12[i]	1.3E-07[i]
Cerium-144		6.1E-12[i]		3.4E-10[i]	2.5E-08[i]
Cesium-134		4.1E-11[i]		2.8E-11[i]	5.2E-06[i]
Cesium-137+D		2.8E-11[i]		1.9E-11[i]	2.0E-06[i]
Chromium-51		4.3E-14[i]		3.0E-13[i]	9.2E-08[i]
Cobalt-58		1.6E-12[i]		9.8E-12[i]	3.3E-06[i]
Cobalt-60		1.5E-11[i]		1.5E-10[i]	8.6E-06[i]
Europium-152		2.1E-12[i]		1.1E-10[i]	3.6E-06[i]
Europium-154		3.0E-12[i]		1.4E-10[i]	4.1E-06[i]
Europium-155		4.5E-13[i]		1.8E-11[i]	5.9E-08[i]
Gross Alpha		-		-	-
Gross Beta		-		-	-
Iron-59		2.8E-12[i]		9.7E-12[i]	4.1E-06[i]
Manganese-54		1.1E-12[i]		5.3E-12[i]	2.9E-06[i]
Nickel-63		2.4E-13[i]		1.8E-12[i]	0.0E+00[i]
Plutonium-238		2.2E-10[i]		3.9E-08[i]	2.8E-11[i]
Plutonium-239/240		2.3E-10[i]		3.8E-08[i]	2.7E-11[i]
Potassium-40		1.1E-11[i]		7.6E-12[i]	5.4E-07[i]
Radium-226+D		1.2E-10[i]		3.0E-09[i]	6.0E-06[i]
Ruthenium-103		9.0E-13[i]		8.4E-12[i]	1.5E-06[i]
Ruthenium-106		9.5E-12[i]		4.4E-10[i]	0.0E+00[i]
Sodium-22		6.8E-12[i]		4.8E-12[i]	7.2E-06[i]
Strontium-90+D		3.6E-11[i]		6.2E-11[i]	0.0E+00[i]
Technetium-99		1.3E-12[i]		8.3E-12[i]	6.0E-13[i]
Thorium-228+D		5.5E-11[i]		7.8E-08[i]	5.6E-06[i]
Thorium-232		1.2E-11[i]		2.8E-08[i]	2.6E-11[i]
Thorium-234		4.0E-12[i]		3.2E-11[i]	3.5E-09[i]
Tritium (Hydrogen-3)		5.4E-14[i]		7.8E-14[i]	0.0E+00[i]
Uranium (total)[g]		2.8E-11[i]		5.2E-08[i]	3.6E-08[i]
Uranium-233/234		1.6E-11[i]		2.7E-08[i]	4.2E-11[i]
Uranium-235+D		1.6E-11[i]		2.5E-08[i]	2.4E-07[i]
Uranium-238+D		2.8E-11[i]		5.2E-08[i]	3.6E-08[i]

Table 5-1. Contaminant Reference Doses and Slope Factors. (Sheet 4 of 4)

Contaminant	Ingestion		Inhalation		External
	RfD	SF	RfD	SF	SF
Zinc-65		8.5E-12[i]		1.6E-11[i]	2.0E-06[i]
Zirconium-95		9.9E-13[i]		1.0E-11[i]	2.5E-06[i]

a Each Aroclor is evaluated using toxicity values for PCBs.
b Benzo(a)pyrene used as surrogate for benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
c 2-Butanone used as surrogate for 2-hexanone.
d Naphthalene used as surrogate for 2-methylnaphthalene.
e Pyrene used as surrogate for phenanthrene.
f Inhalation SF for nickel is for refinery dust, and is not used to evaluate nickel at the ERDF.
g Uranium-238+D slope factors used to evaluate uranium (total).
h IRIS (EPA 1993c)
i HEAST (EPA 1993d)
j Superfund Technical Support Center (EPA 1992a)
k Superfund Technical Support Center (EPA 1993a)
l Superfund Technical Support Center (EPA 1993b)
m Superfund Technical Support Center (EPA 1992b)
n Superfund Technical Support Center (EPA 1992c)
o Superfund Technical Support Center (EPA 1992d)
p Superfund Technical Support Center (EPA 1991a). Value used as oral RfD for copper is the lower end of the recommended range (4E-02 to 7E-02 mg/kg-d).

Note: +D designation indicates radionuclide slope factors that account for the contribution of radioactive daughter products.
RfD = reference dose
SF = slope factor
NA = not applicable
- = quantitative toxicity values not currently available

Table 5-2. Summary Screening Factors for Risk-Based Screening.

Media	Exposure Route	Summary Screening Factor		
		Noncarcinogen	Carcinogen (Non-radioactive)	Radioactive
Soil	Ingestion	8.0E+03	6.4E-02	7.6E-11
	Inhalation[a]	3.2E+06	1.6E+01	9.1E-09
	Inhalation	1.6E-01 x VF[b]	8.2E-07 x VF[b]	NA
	External Exposure	NA	NA	4.2E-09
Groundwater	Ingestion	1.6E+00	8.2E-06	4.6E-12

[a]Assuming a particulate emission factor = 2E+07 m^3/kg.
[b]VF = volatilization factor (m^3/kg).
NA = not applicable.

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Table 5-3. Risk-Based Screening Concentrations (mg/kg) for Soil Pathways - Non-Radioactive Contaminants. (Sheet 1 of 4)

Contaminant	Soil Ingestion		Fug. Dust Inhalation		Inhalation of Volatiles			
	Noncarc. RBC	Carc. RBC	Noncarc. RBC	Carc. RBC	volatile?	VF (m3/kg)	Noncarc. RBC	Carc. RBC
Organic Compounds								
Acenaphthene	4.8E+02							
Acetone	8.0E+02				yes		no toxicity values	
Anthracene	2.4E+03							
Aroclor-1248		8.3E-03						
Aroclor-1254		8.3E-03						
Aroclor-1260		8.3E-03						
Benzo(a)anthracene		8.8E-03						
Benzene		2.2E+00		5.5E+02	yes	2.6E+03		7.4E-02
Benzo(a)pyrene		8.8E-03						
Benzo(b)fluoranthene		8.8E-03						
Benzo(g,h,i)perylene								
Benzo(k)fluoranthene		8.8E-03						
Benzoic acid	3.2E+04							
Bis(2-ethylhexyl)phthalate	1.6E+02	4.6E+00						
2-Butanone	4.8E+03		9.3E+05		yes	1.0E+03	4.6E+01	
Butylbenzylphthalate	1.6E+03							
Carbazole		3.2E+00						
Carbon disulfide	8.0E+02		9.6E+03		yes	1.0E+03	4.8E-01	
Carbon tetrachloride	5.6E+00	4.9E-01		3.0E+02	yes	3.0E+03		4.6E-02
Chlordane (gamma)	4.8E-01	4.9E-02		1.2E+01				
4-Chloro-3-methyphenol								
4-Chloroaniline	3.2E+01							
Chloroform	8.0E+01	1.0E+01		2.0E+02	yes	1.0E+03		1.0E-02
Chrysene		8.8E-03						
4,4-DDD		2.7E-01						
4,4-DDE		1.9E-01						

Table 5-3. Risk-Based Screening Concentrations (mg/kg) for Soil Pathways - Non-Radioactive Contaminants. (Sheet 2 of 4)

Contaminant	Soil Ingestion		Fug. Dust Inhalation		Inhalation of Volatiles			
	Noncarc. RBC	Carc. RBC	Noncarc. RBC	Carc. RBC	volatile?	VF (m3/kg)	Noncarc. RBC	Carc. RBC
Di-N-butylphthalate	8.0E+02							
Dibenzo(a,h)anthracene		8.8E-03						
Dibenzofuran								
1,3-Dichlorobenzene								
1,4-Dichlorobenzene		2.7E+00	6.4E+05					
1,2-Dichloroethene (total)	7.2E+01				yes		no toxicity values	
Dieldrin	4.0E-01	4.0E-03		1.0E+00				
Diethylphthalate	6.4E+03							
Ethyl benzene	8.0E+02		9.3E+05		yes	7.8E+03	3.6E+02	
Fluoranthene	3.2E+02							
Fluorene	3.2E+02							
Beta-BHC (Beta-BHC)		3.6E-02		8.9E+00				
2-Hexanone	4.8E+03		9.3E+05		yes	1.0E+03	4.6E+01	
Indeno(1,2,3-cd)pyrene		8.8E-03						
Methoxychlor	4.0E+01							
4-Methyl-2-pentanone	4.0E+02		6.4E+04		yes	1.0E+03	3.2E+00	
Methylene Chloride	4.8E+02	8.5E+00	2.9E+06	1.0E+04	yes	1.0E+03	1.4E+02	5.1E-01
2-Methylnaphthalene	3.2E+01							
4-Methylphenol								
Naphthalene	3.2E+01							
N-Nitrosodiphenylamine		1.3E+01						
Pentachlorophenol	2.4E+02	5.3E-01						
Phenanthrene	2.4E+02							
Phenol	4.8E+03							
Pyrene	2.4E+02							
1,1,2,2-Tetrachloroethane		3.2E-01		8.0E+01	yes	1.0E+03		4.1E-03
Tetrachloroethene	8.0E+01	1.2E+00		8.0E+03	yes	4.1E+03		1.7E+00

Table 5-3. Risk-Based Screening Concentrations (mg/kg) for Soil Pathways - Non-Radioactive Contaminants. (Sheet 3 of 4)

Contaminant	Soil Ingestion		Fug. Dust Inhalation		Inhalation of Volatiles			
	Noncarc. RBC	Carc. RBC	Noncarc. RBC	Carc. RBC	volatile?	VF (m3/kg)	Noncarc. RBC	Carc. RBC
Toluene	1.6E+03		3.2E+05		yes	2.2E+03	3.5E+01	
1,1,1-Trichloroethane			9.6E+05		yes	1.0E+03	4.8E+01	
Trichloroethene	4.8E+01	5.8E+00		2.7E+03	yes	1.2E+03		1.6E-01
Vinyl Chloride		3.4E-02		5.3E+01	yes	6.0E+02		1.6E-03
Xylenes (total)	1.6E+04				yes		no toxicity values	
Inorganic Constituents								
Aluminum	8.0E+03							
Ammonia			9.3E+04		yes	1.0E+03	4.6E+00	
Antimony	3.2E+00							
Arsenic	2.4E+00	3.2E-02		1.1E+00				
Barium	5.6E+02		3.2E+02					
Beryllium	4.0E+01	1.5E-02		1.9E+00				
Cadmium	8.0E+00			2.5E+00				
Chromium (III)	8.0E+03							
Chromium (VI)	4.0E+01			3.8E-01				
Cobalt	4.8E+02							
Copper	3.2E+02							
Fluoride	4.8E+02							
Lead								
Manganese	1.1E+03		3.5E+02					
Mercury	2.4E+00		2.9E+02					
Nickel	1.6E+02							
Nitrite (as N)	8.0E+02							
Selenium	4.0E+01							
Silver	4.0E+01							
Strontium	4.8E+03							
Sulfate								

Table 5-3. Risk-Based Screening Concentrations (mg/kg) for Soil Pathways - Non-Radioactive Contaminants. (Sheet 4 of 4)

Contaminant	Soil Ingestion		Fug. Dust Inhalation		Inhalation of Volatiles			
	Noncarc. RBC	Carc. RBC	Noncarc. RBC	Carc. RBC	volatile?	VF (m3/kg)	Noncarc. RBC	Carc. RBC
Thallium	5.6E-01							
Vanadium	5.6E+01							
Zinc	2.4E+03							

Blank cells indicate that toxicity values are not currently available with which to calculate risk-based screening concentrations.
Toxicity values used to calculate risk-based screening concentrations are provided in Table 5-1.
RBC = Risk-based screening concentration
VF = volatilization factor
Minimum RBC for each contaminant is shaded.

Table 5-4. Risk-Based Screening Concentrations (pCi/g) for Soil Pathways - Radioactive Contaminants.

Radionuclide	Soil Ingestion RBC	Fugitive Dust Inhalation RBC	External Exposure RBC
Americium-241	3.2E-01	2.8E-01	8.6E-01
Barium-140	2.8E+01	4.6E+03	7.8E-03
Beryllium-7	2.5E+03	3.4E+04	2.8E-02
Carbon-14	8.4E+01	1.4E+06	a
Cerium-141	9.2E+01	1.1E+03	3.2E-02
Cerium-144	1.2E+01	2.7E+01	1.7E-01
Cesium-134	1.9E+00	3.3E+02	8.1E-04
Cesium-137	2.7E+00	4.8E+02	2.1E-03
Chromium-51	1.8E+03	3.0E+04	4.6E-02
Cobalt-58	4.8E+01	9.3E+02	1.3E-03
Cobalt-60	5.1E+00	6.1E+01	4.9E-04
Europium-152	3.6E+01	8.3E+01	1.2E-03
Europium-154	2.5E+01	6.5E+01	1.0E-03
Europium-155	1.7E+02	5.1E+02	7.1E-02
Iron-59	2.7E+01	9.4E+02	1.0E-03
Manganese-54	6.9E+01	1.7E+03	1.4E-03
Nickel-63	3.2E+02	5.1E+03	a
Plutonium-238	3.5E-01	2.3E-01	1.5E+02
Plutonium-239/240	3.3E-01	2.4E-01	1.6E+02
Potassium-40	6.9E+00	1.2E+03	7.8E-03
Radium-226	6.3E-01	3.0E+00	7.0E-04
Ruthenium-103	8.4E+01	1.1E+03	2.8E-03
Ruthenium-106	8.0E+00	2.1E+01	a
Sodium-22	1.1E+01	1.9E+03	5.8E-04
Strontium-90	2.1E+00	1.5E+02	a
Technetium-99	5.8E+01	1.1E+03	7.0E+03
Thorium-228	1.4E+00	1.2E-01	7.5E-04
Thorium-232	6.3E+00	3.3E-01	1.6E+02
Thorium-234	1.9E+01	2.8E+02	1.2E+00
Tritium	1.4E+03	1.2E+05	a
Uranium (total)	2.7E+00	1.8E-01	1.2E-01
Uranium-233/234	4.8E+00	3.4E-01	1.0E+02
Uranium-235	4.8E+00	3.6E-01	1.8E-02
Uranium-238	2.7E+00	1.8E-01	1.2E-01
Zinc-65	8.9E+00	5.7E+02	2.1E-03
Zirconium-95	7.7E+01	9.1E+02	1.7E-03

[a]Radionuclide is not an external exposure hazard.
RBC = Risk-based screening concentration
Minimum RBC for each contaminant is shaded

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Table 5-5. Comparison of Maximum Soil Contaminant Concentrations to Risk-Based Screening Concentrations and ARARs. (Sheet 1 of 5)

Contaminant	Maximum Contaminant Concentration[a]	Minimum Risk-Based Concentration[b]
Organic Compounds	(mg/kg)	(mg/kg)
Acenaphthene	8.5E-01	4.8E+02
Acetone	2.8E+00	8.0E+02
Anthracene	6.3E+00	2.4E+03
Aroclor-1248	1.0E+01	8.3E-03
Aroclor-1254	6.4E+00	8.3E-03
Aroclor-1260	2.3E+00	8.3E-03
Benzo(a)anthracene	1.8E+00	8.8E-03
Benzene	1.9E-01	7.4E-02
Benzo(a)pyrene	2.7E+01	8.8E-03
Benzo(b)fluoranthene	2.4E+00	8.8E-03
Benzo(g,h,i)perylene	3.7E+00	-
Benzo(k)fluoranthene	7.6E-01	8.8E-03
Benzoic acid	1.3E+00	3.2E+04
Bis(2-ethylhexyl)phthalate	3.3E+01	4.6E+00
2-Butanone	3.9E-01	4.6E+01
Butylbenzylphthalate	2.6E+00	1.6E+03
Carbazole	5.4E-02	3.2E+00
Carbon disulfide	2.0E-01	4.8E-01
Carbon tetrachloride	8.0E-03	4.6E-02
Chlordane (gamma)	1.8E-02	4.9E-02
4-Chloro-3-methyphenol	3.8E-02	-
4-Chloroaniline	6.3E+00	3.2E+01
Chloroform	8.0E-02	1.0E-02
Chrysene	4.3E+01	8.8E-03
4,4-DDD	1.1E-01	2.7E-01
4,4-DDE	1.7E-01	1.9E-01
Di-N-butylphthalate	5.5E+00	8.0E+02
Dibenzo(a,h)anthracene	1.7E+00	8.8E-03
Dibenzofuran	5.0E-01	-
1,3-Dichlorobenzene	4.8E-02	-

Table 5-5. Comparison of Maximum Soil Contaminant Concentrations to Risk-Based Screening Concentrations and ARARs. (Sheet 2 of 5)

Contaminant	Maximum Contaminant Concentration[a]	Minimum Risk-Based Concentration[b]
1,4-Dichlorobenzene	5.1E-02	2.7E+00
1,2-Dichloroethene (total)	1.0E+00	7.2E+01
Dieldrin	2.1E-02	4.0E-03
Diethylphthalate	1.0E+00	6.4E+03
Ethyl benzene	3.3E-01	3.6E+02
Fluoranthene	2.9E+00	3.2E+02
Fluorene	1.7E+00	3.2E+02
Beta-HCH (Beta-BHC)	7.8E-03	3.6E-02
2-Hexanone	9.0E-03	4.6E+01
Indeno(1,2,3-cd)pyrene	1.6E+00	8.8E-03
Methoxychlor	8.3E-02	4.0E+01
4-Methyl-2-pentanone	1.1E-02	3.2E+00
Methylene chloride	4.5E+00	5.1E-01
2-Methylnaphthalene	1.3E+01	3.2E+01
4-Methylphenol	1.0E+00	-
Naphthalene	4.1E+00	3.2E+01
N-Nitrosodiphenylamine	1.8E+00	1.3E+01
Pentachlorophenol	1.5E+00	5.3E-01
Phenanthrene	3.9E+00	2.4E+02
Phenol	2.4E-01	4.8E+03
Pyrene	1.2E+01	2.4E+02
1,1,2,2-Tetrachloroethane	3.0E-03	4.1E-03
Tetrachloroethene	1.1E+00	1.2E+00
Toluene	1.5E-01	3.5E+01
1,1,1-Trichloroethane	6.0E-03	4.8E+01
Trichloroethene	3.9E-01	1.6E-01
Vinyl chloride	2.4E-02	1.6E-03
Xylenes (total)	1.1E+00	1.6E+04

Table 5-5. Comparison of Maximum Soil Contaminant Concentrations to Risk-Based Screening Concentrations and ARARs. (Sheet 3 of 5)

Contaminant	Maximum Contaminant Concentration[a]	Minimum Risk-Based Concentration[b]
Inorganic Constituents	(mg/kg)	(mg/kg)
Aluminum	7.8E+04	8.0E+03
Ammonia	1.4E+02	4.6E+00
Antimony	1.9E+01	3.2E+00
Arsenic	6.2E+01	3.2E-02
Barium	4.3E+03	3.2E+02
Beryllium	4.7E+00	1.5E-02
Cadmium	2.9E+01	2.5E+00
Chromium (total)	2.5E+03	8.0E+03[c]/3.8E-01[d]
Chromium (VI)	5.0E+00	3.8E-01
Cobalt	9.0E+01	4.8E+02
Copper	9.5E+04	3.2E+02
Fluoride	4.0E+01	4.8E+02
Lead	7.5E+02	500-1000[e]
Manganese	3.1E+03	3.5E+02
Mercury	3.7E+01	2.4E+00
Nickel	1.8E+03	1.6E+02
Nitrite (as N)	2.9E+00	8.0E+02
Selenium	1.1E+01	4.0E+01
Silver	3.6E+02	4.0E+01
Strontium	3.1E+01	4.8E+03
Sulfate	7.1E+03	-
Thallium	5.4E+00	5.6E-01
Vanadium	3.9E+02	5.6E+01
Zinc	6.2E+03	2.4E+03
Radionuclides	(pCi/g)	(pCi/g)
Americium-241	3.4E+01	2.8E-01
Barium-140	4.0E+02	7.8E-03
Beryllium-7	9.0E+01	2.8E-02
Carbon-14	6.4E+02	8.4E+01

Table 5-5. Comparison of Maximum Soil Contaminant Concentrations to Risk-Based Screening Concentrations and ARARs. (Sheet 4 of 5)

Contaminant	Maximum Contaminant Concentration[a]	Minimum Risk-Based Concentration[b]
Cerium-141	3.0E+00	3.2E-02
Cerium-144	5.0E-01	1.7E-01
Cesium-134	5.6E+01	8.1E-04
Cesium-137	1.1E+05	2.1E-03
Chromium-51	3.5E+00	4.6E-02
Cobalt-58	1.4E+01	1.3E-03
Cobalt-60	1.1E+04	4.9E-04
Europium-152	2.9E+04	1.2E-03
Europium-154	9.2E+03	1.0E-03
Europium-155	9.6E+03	7.1E-02
Iron-59	1.0E+00	1.0E-03
Manganese-54	7.0E-02	1.4E-03
Nickel-63	6.2E+04	3.2E+02
Plutonium-238	1.4E+02	2.3E-01
Plutonium-239/240	2.8E+03	2.4E-01
Potassium-40	3.3E+01	7.8E-03
Radium-226	4.3E+01	7.0E-04
Ruthenium-103	1.0E+00	2.8E-03
Ruthenium-106	8.0E-01	8.0E+00
Sodium-22	9.9E+00	5.8E-04
Strontium-90	2.0E+03	2.1E+00
Technetium-99	1.1E+00	5.8E+01
Thorium-228	1.7E+01	7.5E-04
Thorium-232	3.5E+00	3.3E-01
Thorium-234	1.0E+00	1.2E+00
Tritium	2.9E+04	1.4E+03
Uranium (total)	2.0E+04	1.2E-01
Uranium-233/234	2.1E+03	3.4E-01
Uranium-235	6.4E+02	1.8E-02
Uranium-238	9.1E+03	1.2E-01

Table 5-5. Comparison of Maximum Soil Contaminant Concentrations to Risk-Based Screening Concentrations and ARARs. (Sheet 5 of 5)

Contaminant	Maximum Contaminant Concentration[a]	Minimum Risk-Based Concentration[b]
Zinc-65	3.0E-01	2.1E-03
Zirconium-95	5.6E-01	1.7E-03

a From Tables 3-8, 3-9, and 3-10.
b From Tables 5-3 and 5-4.
c Screening value for chromium (III).
d Screening value for chromium (VI).
e No toxicity values are currently available, value shown is based on Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites, EPA Office of Solid Waste and Emergency Response, Final, September 1989d.
- = quantitative toxicity values not currently available.
NT = contaminant considered non-toxic under typical environmental exposure conditions.
Note: Shading indicates contaminants for which the maximum concentration exceeds a risk-based screening concentration.

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Table 5-6. Risk-Based Screening Concentrations for Groundwater Pathways.

Contaminant	Groundwater Ingestion	
	Noncarcinogen RBC	Carcinogen RBC
Inorganic Constituents	(mg/L)	(mg/L)
Antimony	6.4E-04	
Arsenic	4.8E-04	4.1E-06
Chromium (VI)	8.0E-03	
Fluoride	9.6E-02	
Nitrite (as N)	1.6E-01	
Selenium	8.0E-03	
Radionuclides	NA	(pCi/L)
Carbon-14		5.1E+00
Technetium-99		3.5E+00
Uranium (total)		1.6E-01
Uranium-233/234		2.9E-01
Uranium-235		2.9E-01
Uranium-238		1.6E-01

Toxicity values used to calculate RBCs are provided in Table 5-1.
RBC = Risk-based screening concentration
NA = Not applicable
Minimum RBC for each contaminant is shaded.

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Table 5-7. Comparison of Predicted Groundwater Contaminant Concentrations to Risk-Based Screening Concentrations and ARARs.

Contaminant	Predicted Groundwater Concentration[a]	Minimum Risk-Based Concentration[b]	Minimum ARAR[c]
Inorganic Constituents	(mg/L)	(mg/L)	(mg/L)
Antimony	3.9E+01	6.4E-04	6.0E-03
Arsenic	6.0E+01	4.1E-06	5.2E-05
Chromium (VI)	6.0E+01	8.0E-03	1.8E-02
Fluoride	6.0E+01	9.6E-02	9.6E-01
Nitrite (as N)	6.1E+00	1.6E-01	1.0E+00
Selenium	2.4E+01	8.0E-03	5.0E-02
Radionuclides	(pCi/L)	(pCi/L)	(pCi/L)
Carbon-14	1.3E+06	5.1E+00	2.0E+03
Technetium-99	2.3E+03	3.5E+00	9.0E+02
Uranium (total)	1.1E+03	1.6E-01	20 µg/L
Uranium-233/234	5.3E+02	2.9E-01	3.0E+02
Uranium-235	2.3E+01	2.9E-01	3.0E+02
Uranium-238	4.9E+02	1.6E-01	3.0E+02

[a]From Table 4-11.
[b]From Table 5-6.
[c]From Tables 7-3 and 7-4.
- = quantitative toxicity values not currently available.
Note: Shading indicates contaminants for which the predicted groundwater concentration exceeds a risk-based screening concentration and/or ARAR.

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Table 5-8. Contaminants of Potential Concern in Soils. (Sheet 1 of 3)

Contaminant	Maximum Contaminant Concentration[a]
Organic Compounds	(mg/kg)
Aroclor-1248	1.0E+01
Aroclor-1254	6.4E+00
Aroclor-1260	2.3E+00
Benzo(a)anthracene	1.8E+00
Benzene	1.9E-01
Benzo(a)pyrene	2.7E+01
Benzo(b)fluoranthene	2.4E+00
Benzo(k)fluoranthene	7.6E-01
Bis(2-ethylhexyl)phthalate	3.3E+01
Chloroform	8.0E-02
Chrysene	4.3E+01
Dibenzo(a,h)anthracene	1.7E+00
Dieldrin	2.1E-02
Indeno(1,2,3-cd)pyrene	1.6E+00
Methylene chloride	4.5E+00
Pentachlorophenol	1.5E+00
Trichloroethene	3.9E-01
Vinyl chloride	2.4E-02
Inorganic Constituents	(mg/kg)
Aluminum	7.8E+04
Ammonia	1.4E+02
Antimony	1.9E+01
Arsenic	6.2E+01
Barium	4.3E+03
Beryllium	4.7E+00
Cadmium	2.9E+01
Chromium	2.5E+03
Copper	9.5E+04
Lead	7.5E+02

Table 5-8. Contaminants of Potential Concern in Soils. (Sheet 2 of 3)

Contaminant	Maximum Contaminant Concentration[a]
Manganese	3.1E+03
Mercury	3.7E+01
Nickel	1.8E+03
Silver	3.6E+02
Thallium	5.4E+00
Vanadium	3.9E+02
Zinc	6.2E+03
Radionuclides	(pCi/g)
Americium-241	3.4E+01
Barium-140	4.0E+02
Beryllium-7	9.0E+01
Carbon-14	6.4E+02
Cerium-141	3.0E+00
Cerium-144	5.0E-01
Cesium-134	5.6E+01
Cesium-137	1.1E+05
Chromium-51	3.5E+00
Cobalt-58	1.4E+01
Cobalt-60	1.1E+04
Europium-152	2.9E+04
Europium-154	9.2E+03
Europium-155	9.6E+03
Iron-59	1.0E+00
Manganese-54	7.0E-02
Nickel-63	6.2E+04
Plutonium-238	1.4E+02
Plutonium-239/240	2.8E+03
Radium-226	4.3E+01
Ruthenium-103	1.0E+00

Table 5-8. Contaminants of Potential Concern in Soils. (Sheet 3 of 3)

Contaminant	Maximum Contaminant Concentration[a]
Sodium-22	9.9E+00
Strontium-90	2.0E+03
Thorium-228	1.7E+01
Thorium-232	3.5E+00
Tritium	2.9E+04
Uranium (total)	2.0E+04
Zinc-65	3.0E-01
Zirconium-95	5.6E-01

[a]From Tables 3-8, 3-9, and 3-10.

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Table 5-9. Contaminants of Potential Concern in Groundwater.

Contaminant	Predicted Groundwater Concentration[a]
Inorganic Constituents	(mg/L)
Antimony	3.9E+01
Arsenic	6.0E+01
Chromium (VI)	6.0E+01
Fluoride	6.0E+01
Nitrite (as N)	6.1E+00
Selenium	2.4E+01
Radionuclides	(pCi/L)
Carbon-14	1.3E+06
Technetium-99	2.3E+03
Uranium (total)	1.1E+03

[a]From Table 4-11.

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6.0 RISK ASSESSMENT

The risk assessment presented below evaluates potential adverse effects that could be associated with contaminants that may be disposed of in the ERDF. Only those risks that could potentially occur following completion of the ERDF (i.e., long-term risks) are evaluated in this chapter. Worker and public risk associated with construction and operation of the ERDF is discussed in Chapter 9. The primary focus in this chapter is risk associated with the "base conditions" scenario, that is, a reasonable worst case scenario. The base conditions scenario utilizes the following assumptions:

- The waste is characterized by the maximum concentrations detected in 100, 200, and 300 Area waste units that may generate remediation waste for placement at the ERDF;
- The waste is untreated;
- The ERDF is an unlined trench and the infiltration rate through the waste is a conservatively high 0.5 cm/yr;
- The cover does not prevent inadvertent exposure to contaminants.

This set of "base conditions" does not incorporate any of the protective features of the design alternatives. Therefore, the risks presented in this chapter are not actual risks that any receptor population would experience. The results of the evaluation presented in this chapter are used to identify adequate design alternatives. In addition, the toxicity and exposure information presented in this chapter is further used to evaluate the remedial alternatives (see Appendix A and Chapter 9) and define acceptable soil and leachate concentration limits for waste placed in the ERDF (See Appendix C).

Figure 6-1 outlines the organization of this chapter. Human exposure to groundwater under base conditions is evaluated in Section 6.1. (Human exposure to groundwater given conditions associated with each of the remedial alternatives is evaluated in Appendix A and summarized in Chapter 9). Inadvertent intrusion and exposure of human and other ecological receptors to contaminated soils under base conditions are evaluated in Section 6.2. The information presented in Section 6.2 is expanded Section 6.3 to provide an evaluation of the inadvertent intrusion scenario for the remedial alternatives. Because all the alternatives (except the no-action alternative) include a barrier that is at least 4.6 m (15 ft) thick, the intrusion scenario for the remedial alternatives assumes contact with the waste occurs due to drilling through the waste 500 years after closure of the ERDF.

6.1 HUMAN HEALTH EVALUATION OF GROUNDWATER EXPOSURE

Infiltration and leaching of contaminants from the ERDF to groundwater would be expected to occur if the ERDF were an unlined trench without a low-infiltration surface barrier. Exposure to groundwater contaminants would occur if a person installed a groundwater well and used groundwater without testing for contamination. For this evaluation, exposure to contaminated groundwater is only evaluated for human receptors; use of contaminated groundwater for crops or livestock is assumed not to occur.

6.1.1 Human Exposure Assessment

6.1.1.1 Conceptual Model. In accordance with the Tri-Party Agreement negotiations (Ecology et al. 1993), this risk assessment evaluates exposure to groundwater via a well installed at the edge of the ERDF. All contaminants are evaluated for 10,000 yr. Groundwater COPC are identified and discussed in Chapter 5.0, and are listed in Table 5-9. Groundwater concentrations used to characterize these contaminants are based on maximum detected soil concentrations.

Human use of groundwater is assumed to be for residential purposes. Exposure pathways are those stipulated in HSBRAM (DOE-RL 1993j) for evaluation of in-home groundwater use. These pathways are groundwater ingestion, and dermal absorption while showering. Dermal absorption is evaluated only for non-radioactive contaminants. Dermal uptake is generally not an important route of uptake for radionuclides, which have small skin permeability coefficients (EPA 1989a). External exposure to radionuclides due to immersion in water is not evaluated because of the short durations of exposure. None of the groundwater COPC are volatile, so a volatile inhalation pathway is not evaluated.

All exposures are evaluated assuming residential exposure parameter values specified in HSBRAM (DOE-RL 1993j). Use of a residential scenario is only appropriate if institutional controls are lost. Institutional controls are assumed to be lost 100 yr after the ERDF begins receiving remediation waste in 1996 (Ecology et al. 1993). The first contaminant is estimated to reach groundwater in 520 years (see Table 4-11). Therefore, institutional controls are assumed not to prevent exposure to groundwater contaminants in the future.

6.1.1.2 Quantification of Human Exposures. The exposure assessment provides quantitative exposure factors for the pathways that have been identified for the receptor population. An exposure point concentration (i.e., a contaminant concentration to which a receptor is subjected over the exposure period) is combined with exposure parameters (e.g., contact rate, body weight, and exposure frequency) to determine intake. Exposure point concentrations are predicted groundwater concentrations based on maximum detected soil concentrations (see Chapter 4). The following sections describe the assumptions and calculations used to quantify exposure intakes for the residential receptor population.

6.1.1.2.1 Intake Equations. Standard EPA equations, as provided in Risk Assessment Guidance for Superfund (RAGS) (EPA 1989a) and HSBRAM (DOE-RL 1993j), are used as the basis for all intake calculations. Intakes of non-radioactive and radioactive contaminants are calculated and presented separately.

Non-Radioactive Contaminants. The basic equation for calculating intakes of non-radioactive contaminants via groundwater ingestion is:

$$\text{Intake} = \frac{C \times IR \times EF \times ED}{BW \times AT} \qquad \text{6-1}$$

where:

Intake	=	chronic daily intake of the contaminant (mg/kg-d)
C	=	contaminant concentration in the medium (mg/L)

IR	=	contact rate (L/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)

Intake equation 6-1 may be used to calculate the absorbed dose resulting from dermal exposure to contaminated groundwater. In this case, the calculated value is an absorbed dose (i.e., the amount entering the bloodstream). Although it uses the same units, this is different from the intake calculated using equation 6-1, which is the amount ingested (i.e., an administered dose). To calculate the absorbed dose resulting from dermal exposure to contaminated groundwater, the contact rate is determined as follows:

$$IR_{derm} = SA \times K_p \times ET \times CF \qquad \textbf{6-2}$$

where:

IR_{derm}	=	groundwater/dermal exposure contact rate (L/d)
SA	=	skin surface area available for contact (cm^2)
K_p	=	chemical-specific permeability coefficient (cm/hr)
ET	=	event time (hr/d)
CF	=	conversion factor (1L/1000 cm^3)

The dermal exposure contact rate is inserted into Equation 6-1 to yield the intake value for the dermal pathway. See Section 6.1.1.2.2 for a description of the chemical-specific permeability coefficients (K_p) used in this evaluation.

Radioactive Contaminants. The quantification of exposures to radioactive contaminants requires a separate treatment. The units used to express environmental concentrations of radioactive and non-radioactive contaminants are different. Unlike non-radioactive contaminants, intake estimates for radionuclides should not be divided by body weight or averaging time. Instead, the calculated intakes represent radionuclide activity ingested over the exposure duration.

The basic equation for calculating intakes of radioactive contaminants via groundwater ingestion is:

$$Intake = C \times IR \times EF \times ED \qquad \textbf{6-3}$$

where:

Intake	=	radionuclide-specific lifetime intake (pCi)
C	=	radionuclide concentration in the medium (pCi/L)
IR	=	contact rate (L/d)
EF	=	exposure frequency (d/yr)
ED	=	exposure duration (yr)

6.1.1.2.2 Calculation of Contaminant Intakes. All exposure parameters (e.g., body weight, averaging time, contact rate, exposure frequency, and exposure duration) presented below are those recommended by HSBRAM (DOE-RL 1993j). These exposure parameters have been specifically developed for a residential population, and are used to evaluate the groundwater ingestion and dermal exposure pathways. Exposure parameters for the noncarcinogenic, carcinogenic (non-radioactive), and radioactive contaminants are summarized in Tables 6-1, 6-2, and 6-3, respectively.

Contaminant intakes are calculated by combining exposure parameters presented in Tables 6-1 through 6-3 and intake Equations 6-1 and 6-3. Example calculations of this process are provided in Appendix D of the Hanford Site Risk Assessment Methodology (HSRAM, Rev. 3) (DOE-RL 1994c).

It is noted that the exposure factors listed in Tables 6-1 through 6-3 can be combined to provide a single numeric value called a summary intake factor. The summary intake factor is specific for each exposure pathway, exposure scenario, and class of contaminant. The only parameter from Equations 6-1 through 6-3 that is not included in the summary intake factor is the contaminant concentration, such that the intake equations can be rewritten as follows:

$$\text{Intake} = C \times \text{Summary Intake Factor} \qquad \textbf{6-4}$$

where:

Intake	=	contaminant intake [mg/kg-d (non-radioactive) or pCi (radioactive)]
C	=	contaminant groundwater concentration [mg/L (non-radioactive) or pCi/L (radioactive)]

Associated summary intake factors have units of L/kg-d (non-radioactive) or L (radioactive). Summary intake factors for each of the exposure scenarios are provided in Table 6-4. These are multiplied by groundwater concentrations provided in Table 5-9 to provide intake values. Intake values for groundwater ingestion and dermal exposure pathways are provided in Tables 6-5 and 6-6, respectively.

Summary intake factors for dermal exposure require the use of constituent-specific permeability coefficients, K_p. Permeability coefficients are provided in EPA (1992b). However, K_p values have not been developed for all constituents. The EPA report indicates that the inorganic contaminants listed in Table 6-6 can all be characterized by the same K_p (1×10^{-3} cm/hr).

6.1.2 Human Health Toxicity Assessment

The purpose of the toxicity assessment is to identify the potential adverse effects associated with exposure to site-related contaminants and to evaluate, using numerical toxicity values, the likelihood that these adverse effects may occur. The toxicity assessment for this risk assessment is conducted in accordance with RAGS (EPA 1989a) and HSBRAM (DOE-RL 1993j).

Toxicity information on chemicals and radionuclides is available in the on-line database, Integrated Risk Information System (IRIS, EPA 1993a), Health Effects Assessment Summary Tables (HEAST, EPA 1993b), the Agency for Toxic Substances Disease Registry (ATSDR) Toxicological Profiles, and the scientific literature. Toxicological profiles for the contaminants of potential concern for the ERDF are presented in appendices of operable unit-specific remedial investigation reports (e.g., DOE-RL 1993e,f,g).

6.1.2.1 Toxicity Information for Noncarcinogenic Effects. Systemic toxic effects other than cancer can be associated with exposures to both chemicals and radionuclides. The RfD is the toxicity value which is used to evaluate the noncarcinogenic effects resulting from exposure to toxic chemicals. The RfD has been developed on the premise that protective mechanisms exist that must be overcome before an appreciable risk of adverse health effects is manifested during a defined exposure period. That is, there is a threshold dose which must be exceeded before adverse effects can occur. The RfD is developed for a specific duration of exposure (e.g., subchronic and chronic exposures), and the route of exposure (i.e., inhalation and ingestion).

Chronic exposure is defined in RAGS (EPA 1989a) as a repeated or prolonged exposure (i.e., from seven years to a lifetime). The chronic RfD is a daily exposure level that is likely to be without an appreciable risk of deleterious effects from lifetime exposure to the general population, including sensitive subpopulations. For purposes of this risk assessment, the chronic RfD is utilized to evaluate noncarcinogenic effects that may be associated with potential exposure to the chemicals of potential concern at this site.

Carcinogens may also have systemic effects other than cancer. Carcinogens are also evaluated for potential noncarcinogenic toxic effects and are included in the determination of chronic toxicity hazard indices which characterize noncancer hazards. Carcinogenic effects, however, are usually manifested at levels that are significantly lower than those associated with systemic toxic effects; thus, cancer is usually the predominant adverse effect for contaminants that elicit carcinogenic as well as noncarcinogenic responses. Exposure to radionuclides need not consider acute toxicity effects because the quantities of radionuclides required to cause adverse effects from acute exposure are extremely large, and such levels will not be encountered via groundwater exposure.

Two chronic toxicity parameters that are used in establishing RfDs are the lowest-observed-adverse-effect levels (LOAELs) and the no-observed-adverse-effect levels (NOAELs). The LOAEL may be defined as the lowest exposure level at which there is a demonstrated statistically and/or biologically significant increase in adverse effects between the exposed animal population and the control group in a toxicological study. The NOAEL is the exposure level at which there are no demonstrated adverse effects in a dose-response toxicity study. Uncertainty factors in multiples of 10 may be further applied to the reported NOAELs or LOAELs in order to adjust for data limitations, and for differences between experimental animal exposure conditions and human exposures (National Academy of Science 1977). These factors are intended to account for inherent variability in human responses to chemical agents, and for general imprecision in extrapolating from laboratory animals to humans.

Table 6-7 summarizes the noncarcinogenic toxicity values (i.e., RfDs) for the groundwater contaminants of potential concern. Also presented in this table are the corresponding critical effects, confidence level in the RfD, and the uncertainty and modifying factors used in the development of each RfD.

6.1.2.2 Toxicity Information for Carcinogenic Effects. Potential human carcinogenic effects are evaluated using contaminant-specific SFs and the weight-of-evidence classification of the EPA. The weight-of-evidence classification is a qualitative description of the probability of cancer occurrence in humans, based on the strength of human epidemiological and/or animal study data. This system, originally developed by the International Agency for Research on Cancer (IARC), has been slightly modified by the EPA (1986). Carcinogens are classified by the EPA according to the following weight-of-evidence categories:

- Group A - Human Carcinogen
  There is sufficient evidence from epidemiological studies that substantiates a causal association between exposure and carcinogenicity in humans.

- Group B1 - Probable Human Carcinogen
  There is limited evidence of carcinogenicity in humans from available epidemiological data.

- Group B2 - Probable Human Carcinogen
  There is sufficient evidence of carcinogenicity in animals, but inadequate or no evidence in humans.

- Group C - Possible Human Carcinogen
  There is limited evidence of carcinogenicity in animals.

- Group D - Not Classifiable as to Human Carcinogenicity
  The evidence for carcinogenicity in animals and humans is inadequate to support classification.

- Group E - Human Noncarcinogen
  There is evidence of noncarcinogenicity in humans.

6.1.2.2.1 Non-Radioactive Substances. The SF is the toxicity value that quantitatively defines the dose-response relationship of a known or suspected carcinogen. The SF is an estimate of an upperbound lifetime probability of an individual developing cancer due to chronic exposure to a potential cancer causing agent. In this evaluation, arsenic is the only non-radioactive COPC, for which EPA assigns a unit risk of $5x10^{-5}$ $(\mu g/L)^{-1}$. This unit risk can be converted into a slope factor [2 $(mg/kg\text{-}d)^{-1}$] by dividing by an ingestion rate of 2 L/d, and multiplying by a body weight of 70 kg and the appropriate conversion factor (10^3 $\mu g/mg$). The unit risk for arsenic is based on a maximum likelihood estimate (not a 95% upper confidence limit) and the use of an absolute-risk linear dose extrapolation model. The Carcinogen Assessment Group of the EPA has developed SFs for carcinogens based on the premise that there is no threshold or level of exposure below which carcinogenic effects will not be elicited.

Table 6-8 presents the carcinogenicity weight-of-evidence classifications and the SFs for the ingestion exposure route for non-radioactive contaminants of potential concern. Group D and E contaminants are not considered carcinogenic, and are not included in this table.

6.1.2.2.2 Radioactive Substances. Cancer induction is the only health effect being evaluated resulting from exposure to environmental radioactive contamination. Systemic toxic effects occur only following relatively high doses of radiation that are not typical of environmental exposure. Uranium is known to cause toxic effects that are associated with its chemical (not radiological) characteristics. The proposed MCL for uranium (30 pCi/L) is based on the chemical effects of uranium. This concentration is noted as an ARAR in Table 7-3. According to EPA (56 FR 33050), this proposed MCL is associated with an ICR of $2x10^{-5}$ (assuming an ingestion rate of 2 L/d for 70 yr). However, while nephrotoxic effects are a threshold response, cancer induction is assumed to have no threshold. For this reason, the potential for cancer induction remains a concern (with a risk greater than $1x10^{-6}$) even when the threat of nephrotoxic effects is negligible. Therefore, carcinogenic potential of uranium is considered the primary health effect of concern because carcinogenesis remains a concern at concentrations that are below the threshold for toxic effects of uranium.

Chemical toxicity associated with other radionuclides is not a concern because it is far outweighed by the estimated radiological hazards. The mass of most radionuclides associated with high radiogenic cancer risk levels are so exceedingly small that they are unlikely to pose a chemical hazard. For example, the total activity of strontium-90 associated with a $1x10^{-4}$ cancer risk (from ionizing radiation) via residential scenario soil ingestion is approximately 3 μCi. This is the equivalent of $2x10^{-8}$ g of strontium-90. In terms of chemical hazard, this mass of strontium is associated with a hazard quotient of $3x10^{-10}$.

Currently, the EPA classifies all radionuclides as Group A (human) carcinogens due to their property of emitting ionizing radiation. Other low dose and low dose rate effects (such as mutagenesis, teratogenesis, and life shortening) have a quantifiable probability of occurrence, but the risk of cancer appears to be the limiting health effect (EPA 1989b). The SFs for radionuclides are individually determined by the EPA, based on the unique chemical, metabolic, and radiological properties of each radionuclide.

Many radionuclides have radioactive daughters that are expected to be in equilibrium with their respective parent. For this risk assessment, the radionuclides evaluated in this report account for the contribution of these daughter products, using the techniques provided in HEAST (EPA 1993b). Daughter products in general have different chemical properties than their parent nuclides, and are not always expected to be in equilibrium as they migrate through environmental media. In this evaluation, the only radioactive contaminants of potential concern with radioactive daughter products are isotopes of uranium. Most of the radioactive daughters accounted for in the "+D" slope factors for uranium have half-lives less than 1 day (maximum half-life is 24 days), such that the assumption of equilibrium does not contribute to an overestimate of risk.

Radionuclide SFs represent best estimates (i.e., median or 50% confidence limit values) of excess cancer risk in a population per unit intake or exposure during a 70-year lifetime. As with non-radioactive carcinogens, a non-threshold dose is assumed in the evaluation of carcinogenesis related to potential exposure to radionuclides.

Table 6-8 summarizes the carcinogenicity weight-of-evidence classification and the SFs for the ingestion exposure pathway for radioactive groundwater contaminants of potential concern.

6.1.2.3 Adjustment of Toxicity Factors. There are currently no toxicity values specifically developed for evaluating dermal exposures. As a result, current risk assessment guidance suggests deriving dermal toxicity values from oral toxicity values. This results in significant uncertainty (see Section 6.1.4.4). For the purpose of this risk assessment, oral RfDs and SFs are adjusted in accordance with RAGS (EPA 1989a). Oral toxicity values are generally appropriate for evaluating administered doses (i.e., intake-based). However, dermal intake calculations (see Section 6.1.1.2.1) provide absorbed doses. Therefore, oral toxicity values are adjusted (from administration-basis to absorbed-basis) by accounting for the oral absorption fraction of each contaminant. The oral, or gastrointestinal (GI), absorption fraction is the fraction of an orally administered dose that crosses from the GI tract into the bloodstream. This adjustment is made only for non-radioactive contaminants. Dermal exposure to radionuclides is not evaluated due to their small skin permeability coefficients (EPA 1989a).

Toxicokinetic information from the available literature is generally used to determine the extent of GI absorption for non-radioactive contaminants of potential concern. An appropriate GI absorption fraction (expressed as fraction absorbed) is identified, and the factor is applied to the RfD and/or SF to determine the corresponding dermally adjusted toxicity value. Oral RfD values are adjusted by multiplying by the GI absorption fraction, while SF values are adjusted by dividing by the GI absorption fraction.

In the case of inorganic compounds, the available information in the literature suggests that GI absorption efficiencies for these chemicals are typically in the range of 1% to 10%. Gastrointestinal absorption is likely to be affected by such factors as chemical form, physical state of the compound (e.g., solid or solution), particle size, dosing regimen, age, and diet. In general, the degree of absorption in humans is independent of the exposure level.

Table 6-9 presents the dermally adjusted RfDs and SFs for contaminants of potential concern, including the corresponding GI absorption fractions.

6.1.3 Human Health Risk Characterization

The information from the exposure assessment and the toxicity assessment is integrated to form the basis for the characterization of risks and human health hazards. The risk characterization presents quantitative and qualitative descriptions of risk.

6.1.3.1 Quantification of Noncarcinogenic Effects. Potential human health hazards associated with exposure to noncarcinogenic substances, or carcinogenic substances with systemic toxicities, are evaluated separately from carcinogenic risks. The daily intake over a specified time period (e.g., lifetime or some shorter time period) is compared with an RfD for a similar time period (e.g., chronic RfD or subchronic RfD) to determine a ratio called the hazard quotient (HQ). Estimates of intakes for this risk assessment are based on chronic exposures. The nature of the contaminant source precludes short-term fluctuations in contaminant concentrations that might produce acute or subchronic effects. The formula used to estimate the HQ is:

$$HQ = \frac{Intake}{RfD} \qquad 6\text{-}5$$

where:

HQ	=	hazard quotient
Intake	=	contaminant chronic daily intake (mg/kg-d)
RfD	=	chronic reference dose (mg/kg-d)

If the HQ exceeds unity, the possibility exists for systemic toxic effects and the contaminant is considered a contaminant of concern (COC). The HQ is not a mathematical prediction of the severity or incidence of the effects, but rather is an indication that adverse effects may occur, especially in sensitive subpopulations. It should be noted that due to the conservative bias in the analysis (see Section 6.1.4) a HQ greater than 1 may not result in systemic toxic effects.

Table 6-7 lists the contaminants of potential concern that are evaluated for systemic toxicity. Only ingestion RfDs are presented; an inhalation pathway is not evaluated because none of the COPC are volatile. Dermal RfDs are presented in Table 6-9.

Hazard quotients for the groundwater ingestion and dermal exposure pathways are presented in Tables 6-5 and 6-6, respectively. These tables indicate that the largest HQ is $1x10^4$, which is associated with ingestion of arsenic.

The hazard quotients for the ingestion and dermal pathways may be added to provide a total HQ for each inorganic contaminant. These values are presented in Table 6-10. All six inorganic constituents (antimony, arsenic, chromium VI, fluoride, nitrite, and selenium) have hazard quotients greater than 1. These contaminants are considered contaminants of concern, and are used in the evaluation of ERDF design alternatives.

The HQs may be added together to provide a hazard index (HI) for all of the systemic toxins. However, it is only appropriate to add HQs for contaminants that produce similar adverse effects because the effects associated with such contaminants are assumed to be additive. In contrast, it is not appropriate to add the HQs for contaminants with different effects. For example, the HQs for arsenic and antimony should not be added together because the critical effect for arsenic is hyperpigmentation (i.e., blackfoot disease), while the critical effect for antimony is reduced lifespan and disturbances in glucose and cholesterol metabolism. Based on the critical effects presented in Table 6-7, none of the HQs should be added together. Instead, each HQ (presented in Table 6-10) should be examined separately.

6.1.3.2 Quantification of Carcinogenic Risk. For carcinogens, risks are estimates of the likelihood of an individual developing cancer over a lifetime [i.e., lifetime incremental cancer risk (ICR)] as a result of exposure to a potential carcinogen. The SF converts an intake value, as derived in the exposure assessment, to the estimated lifetime incremental risk of an individual developing cancer. The equation used to estimate cancer risk is:

$$ICR = Intake \times SF \qquad (6\text{-}5)$$

where:

ICR	=	lifetime incremental cancer risk
Intake	=	contaminant intake [mg/kg-d (non-radioactive) or pCi (radioactive)]

SF = slope factor [(mg/kg-d)$^{-1}$ (non-radioactive) or (pCi)$^{-1}$ (radioactive)]

For non-radioactive carcinogens, intake values represent a daily intake averaged over a lifetime of exposure. Intake values for radionuclides are defined to represent lifetime (not daily) exposures. ICRs should be expressed using one significant figure only.

Risk estimates made using the above equation become increasingly inaccurate as they approach a value of 1. This is because the stochastic nature of cancer induction implies that no exposure level is high enough to ensure a carcinogenic response (i.e., ICRs must have values less than 1). It is stated in EPA (1989a) that this linear equation is valid only at low risk levels (i.e., below estimated risks of 1×10^{-2}). For the purposes of this risk assessment, ICR values that exceed 1×10^{-2} are reported as "$> 1 \times 10^{-2}$". The ICR value calculated using the linear equation is provided in parentheses. These values are not intended to represent accurate cancer risk estimates; they are provided as an aid in determining the degree of risk reduction required to reach an ICR level of interest.

The NCP [40 CFR 300.430(e)(2)(i)(A)(2)] states that acceptable exposure levels represent an excess upper bound lifetime cancer risk of between 10^{-4} and 10^{-6}. The 10^{-6} risk level is considered a point of departure for determining remediation goals when ARARs are not available or are not considered sufficiently protective. Thus, cancer risks of 10^{-6} or less are considered insignificant for regulatory purposes. A contaminant for which the ICR value exceeds 1×10^{-6} is considered a contaminant of concern (COC).

Table 6-8 lists the contaminants of potential concern that are evaluated for carcinogenicity and their associated SFs. Only ingestion SFs are presented; an inhalation pathway is not evaluated because none of the COPC are volatile. Dermal SFs are presented in Table 6-9.

ICRs for the groundwater ingestion and dermal pathways are presented in Tables 6-5 and 6-6, respectively. ICRs for these pathways may be added to provide a total ICR for each contaminant. These values are presented in Table 6-10, which indicates that the largest ICR (1×10^{0}) is associated with ingestion of arsenic and is greater than 1×10^{-2}. Four contaminants (arsenic, carbon-14, technetium-99, and total uranium) are considered contaminants of concern because each has a total ICR greater than 1×10^{-6}. Since it is assumed that cancer risks associated with different contaminants are additive (i.e., ICRs may be added together), the total ICR is greater than 1×10^{-2}.

ICR values ideally represent risk associated with contamination, excluding background levels of naturally occurring constituents. However, the predicted groundwater concentrations (from which ICR values are calculated) are based on maximum detected soil concentrations which include background concentrations. Hanford Site background soil data are currently available only for non-radioactive, inorganic constituents (see Table 3-10). The average background soil concentration (Table 3-10) represents a significant fraction of the maximum detected soil concentration for arsenic (6%). Similarly, carbon-14 and uranium in soil represent naturally occurring terrestrial radioactivity as well as contamination. Therefore, a significant fraction of the groundwater risk may be attributed to the naturally occurring fraction of soil constituents.

6.1.4 Uncertainty Analysis

The risks, both noncarcinogenic and carcinogenic, presented in this assessment are not probabilistic estimates, but instead are deterministic estimates given multiple assumptions about exposures, toxicity, and other variables. This discussion focuses on the uncertainty surrounding the projected risks and hazards due to uncertainty in these variables. Current EPA guidance (EPA 1991b, EPA-10 1991) characterizes input parameters with single point values, not probability distributions. As a result, the uncertainty associated with estimated health impacts cannot be quantified; only a qualitative description of uncertainty is presented.

In order to compensate for the uncertainty associated with selecting single point values to characterize input parameters, estimates used to characterize these parameters are often conservatively biased. As a result, the risk estimates provided in this assessment represent a set of assumptions which, as a whole, is extremely unlikely. For this reason, these risk estimates do not represent actual exposure conditions, and may even exceed reasonable bounding estimates. Therefore, HQ values less than 1 and ICR values less than $1x10^{-6}$ are expected to actually be much smaller, and do not require further treatment in the uncertainty analysis. HQ values greater than 1 and ICR values greater than $1x10^{-6}$ warrant further attention, and are examined with respect to the conservative assumptions which inflate these risk estimates.

6.1.4.1 Uncertainty Associated with Identification of Contaminants of Potential Concern. Contaminants are evaluated in the risk assessment if they are associated with an ICR greater than $1x10^{-7}$ or a HQ greater than 0.1 via preliminary screening of a residential scenario groundwater ingestion pathway. Consideration of a volatile inhalation pathway is unnecessary because none of the groundwater contaminants are volatile. This process by which COPC are identified is designed to remove contaminants from consideration only if they pose an insignificant hazard under any potential scenario. Therefore, one can be assured that the contaminants that pose potential adverse health effects have been identified and carried through the risk assessment.

The screening process described in Chapter 5.0 uses maximum detected contaminant soil concentrations and associated predicted groundwater concentrations. Maximum values are used rather than mean values or upper confidence limits to compensate for the lack of knowledge about true contaminant conditions. However, maximum values may not represent bulk soil concentrations. In some cases, maximum detected concentration refers to product inside of drums (e.g., ammonia; Table 3-10), or residue inside of pipelines (e.g., cesium-137; Table 3-8). Maximum concentrations are also likely to represent outlying data points that would be dismissed as the result of an analysis of the whole data set. Because data sets are not 100% validated, some maximum detects may represent erroneous data. Therefore, by using maximum detected concentrations, it is likely that more contaminants are labeled COPC than are justified.

6.1.4.2 Uncertainty Associated with Environmental Transport. The most significant conservative bias in fate and transport parameters for metals and radionuclides (no organic compounds are identified as a contaminants of potential concern) is due to the assumed solubilities. Tables 4-6, 4-7, and 4-8 provide contaminant-specific solubility values available in the literature. Very little site-specific information was available regarding solubilities for metals and radionuclides in 100 and 300 Area wastes. Consequently, it was necessary to rely on general information in literature and to assume conservative values. In all likelihood, actual solubilities for the specific chemical forms of the constituents of concern in 100, 200, and 300 Area wastes are much lower than the solubilities used in this analysis.

The other significant sources of uncertainty are associated with K_d values and the infiltration rate through the barrier. The uncertainty in K_d's are illustrated in Tables 4-2, 4-3, and 4-4. The uncertainty in infiltration rate is discussed in section 4.1.2.1.

6.1.4.3 Uncertainty Associated with the Exposure Assessment. One of the greatest sources of uncertainty associated with the exposure assessment is the choice of exposure point concentrations. For this analysis, contaminants are characterized by the same maximum detected soil concentrations (and associated predicted groundwater concentrations) used in the risk-based screening process (i.e., Chapter 5.0). The conservative biases associated with these concentrations are described in Section 6.1.4.1. Because the maximum detected contaminant concentrations do not reflect realistic estimates of contaminant conditions, the HQs and ICRs provided in this chapter are not realistic estimates of risk.

It is assumed for this assessment that groundwater is used for in-home residential purposes. Other uses of groundwater would be associated with different risk estimates. More important, however, is the likelihood that groundwater would be used at all. Without groundwater use there is no exposure and therefore no risk. For the purpose of this report, it is assumed that groundwater exposure would occur; no evaluation of the likelihood of this event has been accounted for. If the probability of residential use of groundwater were to be quantified (e.g., there may be a 0.1% chance that a person would install a well close to the ERDF), then the risks could be adjusted to account for this probability (e.g., multiplying all ICRs and HQs by a factor of 0.001).

Equally important is the number of potential groundwater users. Exposure parameter values and toxicological data developed for risk assessment purposes are applicable to large populations, not individuals. In addition, the importance of a risk value is different if it applies to one person, several persons, or a large population. This report does not qualify the risks with respect to the number of people that may be impacted; a contaminant is considered to be of concern if the risk to one or more persons exceeds an ICR of 1×10^{-6} or HQ of 1.

Exposure parameter (i.e., body weight, averaging time, contact rate, exposure frequency, and exposure duration) are represented by the estimates of reasonable maximum exposure (RME) values as defined in the HSBRAM (DOE-RL 1993j), but may not reflect actual future exposure conditions. In addition, the combination of RME values does not necessarily result in a RME risk estimate. For example, the ingestion rate (IR) and exposure duration (ED) parameters may be described by lognormal distributions with means of 1.1 and 15, and standard deviations of 0.7 and 14, respectively. With these distributions, the 90th percentiles are 2 L/d (IR) and 30 yr (ED). In the risk assessment, IR and ED are multiplied together, such that the point estimate of this product is 60. However, the value of 60 represents the 97th percentile of the product distribution. The risk assessment also uses several other biased parameter values, such that the combination of these values yields a risk estimate which is likely to exceed the 99th percentile of the risk distribution.

The use of average (rather than RME) parameter values, as provided by EPA Region 10 (1991), could remove some conservative bias. For the residential groundwater ingestion and dermal pathways, average intake values are approximately an order of magnitude lower than RME values. Therefore, all of the risk estimates for groundwater exposure would be lower by about an order of magnitude if average parameter values were used.

6.1.4.4 Uncertainty Associated with the Toxicity Assessment. An understanding of the degree of uncertainty associated with toxicity values is an important part of interpreting and using these values. A high degree of uncertainty in the information used to derive a toxicity value contributes to less confidence in the assessment of risk associated with exposure to a contaminant.

The RfDs and SFs have multiple conservatively biased adjustments built into them (i.e., factors of 10 for up to four different levels of uncertainty for RfDs, and the use of an upperbound estimate derived from the linearized multi-stage carcinogenic model for SFs) that can contribute to overestimation of actual risk. For example, Table 6-7 indicates that an uncertainty factor of 1,000 is used to derive the oral RfD for antimony from a NOAEL. For this reason, EPA qualifies this RfD with a low confidence rating. Therefore, the HQ associated with antimony (7×10^3, Table 6-10) should also be characterized as having a low confidence level. The only contaminants of concern that have RfDs with a high confidence level are fluoride (HQ = 60) and nitrite (HQ = 4).

One non-radioactive contaminant (arsenic) is evaluated for carcinogenic potential, and is classified as a Group A (human) carcinogen. Arsenic exposure via drinking water is associated with an increased prevalence of skin cancers in humans. However, the IRIS (EPA 1993a) file on arsenic states that "in reaching risk management decisions in a specific situation, risk managers must recognize and consider the qualities and uncertainties of risk estimates. The uncertainties associated with ingested inorganic arsenic are such that estimates could be modified downwards as much as an order of magnitude, relative to risk estimates associated with most other carcinogens." Therefore, the arsenic SF, as well as ICR values, are also conservatively biased. However, even if the arsenic ICR is adjusted downward by an order of magnitude, the ICR value will still be $> 1 \times 10^{-2}$.

Although there is substantial evidence to indicate that exposure to ionizing radiation causes cancer in humans, the scenarios upon which this assumption is based are largely acute, external exposures. Sources of uncertainty specific to radionuclide carcinogenicity include the following: the extrapolation of risks observed in populations exposed to relatively high doses, delivered acutely, to populations receiving relatively low dose chronic exposures; estimates of doses delivered to target cells from the inhalation or ingestion of alpha-emitters (e.g., isotopes of uranium and thorium); and statistical variation in the human exposure data.

EPA classifies all radionuclides as Group A (human) carcinogens based on the fact that they emit ionizing radiation. Studies have shown that uranium, like radium, accumulates primarily in bone, and that bone sarcomas may result from radium ingestion (56 FR 33050, notice of proposed rulemaking, National Primary Drinking Water Regulations for Radionuclides). However, studies using natural uranium do not provide direct evidence of carcinogenic potential, and existing human epidemiology data are inadequate to assess the carcinogenicity of uranium ingested in drinking water. The remaining two radioactive contaminants of concern (carbon-14 and technetium-99) are considered carcinogenic because of their property of emitting ionizing radiation. However, the available information indicates that there is inadequate evidence of carcinogenicity in humans associated with these specific isotopes (56 FR 33050).

Radionuclide slope factors are the median (50th percentile) values of the slopes of their respective dose-response curves. However, more than one dose-response curve can be developed. The EPA (1989b) estimate of average lifetime risk attributable to exposure to ionizing radiation incorporates the most conservative model assumptions utilized by the Biological Effects of Ionizing Radiation (BEIR) III Committee. Therefore, radionuclide SFs are median values from conservatively biased dose-response curves. In addition, the updated risk estimates provided by BEIR V (NRC 1990) are qualified with the statement that "the possibility that there may be no risks from exposures comparable to external natural background radiation cannot be ruled out. At such low doses and dose rates, it must be acknowledged that the lower limit of the range of uncertainty in the risk estimates extends to zero."

The uncertainty associated with absorption from dermal exposure is another significant source of uncertainty that is reflected in the estimated risks associated with this pathway for some contaminants. The lack of toxicity information to adequately determine RfDs and SFs for dermal exposures forces extrapolation from oral toxicity values, and compounds the uncertainty associated with the calculations. It is a common practice in risk assessment to adopt oral RfDs and SFs as the dermal toxicity values. In this risk assessment, dermal RfDs and SFs were calculated by accounting for the GI absorption fraction. The uncertainty in this approach should be emphasized. For example, the response to an oral dose may be significantly different from the response to a dermal dose because the risk associated with point-of-entry (skin) effects for locally acting toxicants cannot be estimated from oral toxicity data. Also, dermally applied chemicals would not be subjected to "first-pass" hepatic metabolism prior to systemic circulation, as is the case for orally administered compounds. Consequently, the application of these oral dose-response relationships to dermal exposure doses is a source of a high degree of uncertainty in the estimated potential health risk.

Uncertainty is also present in the overall toxicity assessment because of the route-to-route extrapolation of toxicity values, and potential synergistic or antagonistic interactions of substances. In spite of these uncertainties, it is expected that the contaminants of concern have been adequately identified.

6.1.4.5 Uncertainty Associated with the Risk Characterization. Hazard quotients and risk values provided by risk assessment by themselves do not fully characterize the health impacts associated with environmental contamination. Such a quantitative evaluation must be understood in light of the uncertainties presented above, and interpreted with respect to their significance.

Hazard quotients and cancer risks are calculated by combining multiple factors (e.g., contaminant concentrations, exposure parameters, toxicity values). In an effort to compensate for the uncertainty and/or natural variability in these factors, single point estimates used to characterize these factors are often conservatively biased. However, even if this bias for each factor can be considered reasonable, the product of these factors is likely to far exceed a reasonable maximum exposure. In assessing the effect of bias in the selection of parameter values, the National Council on Radiation Protection and Measurements (NCRP 1985) notes the following:

> ...substantial overestimation is expected when conservatism is applied in the selection of each parameter in a deterministic model. For example, in a model composed of ten or more multiplicative parameters..., the selection of only the 84th percentile for each parameter results in a predicted value that exceeds the 99.9th percentile of the distribution of model output.

This means that the risk estimates presented in a deterministic risk assessment are representative of a set of assumptions which, as a group, is extremely unlikely. Use of a more realistic set of assumptions is likely to yield significantly lower risk estimates.

The significance of numerical results requires interpretation. Although a 10^{-6} cancer risk may be considered insignificant, this does not imply that larger risks are necessarily significant. The NCP [40 CFR 300.430(e)(2)(i)(A)(2)] states that acceptable exposure levels represent an excess upper bound lifetime cancer risk of between 10^{-4} and 10^{-6}. In presenting the quantification of carcinogenic risk (Section 6.1.3.2), contaminants and pathways are described if their associated ICRs exceed 10^{-6}. However, this does not imply that ICRs greater than this value are unacceptable.

6.1.5 Human Health Risk Characterization Summary for Groundwater Exposure

This section of the risk assessment evaluates the human health risks associated with exposure to estimates of potential future groundwater contamination caused by disposal of wastes at the ERDF. A number of key assumptions upon which this analysis is based (e.g., conservative exposure point concentrations, residential scenario use of a groundwater well at the edge of the ERDF facility) are not intended to represent actual site or exposure conditions. For this reason, the risk values presented should be used in conjunction with risks associated with ERDF design alternatives as indicators of relative risk, not actual risk.

Pathways used to evaluate exposure are groundwater ingestion and dermal exposure while showering. Non-radioactive contaminants are evaluated for both noncarcinogenic and carcinogenic effects, as appropriate. Radioactive contaminants are evaluated only for their carcinogenic potential.

The hazard quotients associated with each contaminant of potential concern are presented in Table 6-10. The HQs are not summed to provide a hazard index because the critical health effects are different. Six inorganic contaminants (antimony, arsenic, chromium, fluoride, nitrite, and selenium) have HQs greater than 1, and are considered contaminants of concern.

A summary of ICRs associated with contaminants of potential concern is also presented in Table 6-10. Four contaminants (arsenic, carbon-14, technetium-99, and uranium) have ICRs greater than $1x10^{-6}$ and the total ICR is greater than $1x10^{-2}$.

ICR values are calculated using soil concentrations which include naturally occurring fractions. Average background concentration of arsenic represents a significant fraction of the maximum detected soil concentration (6%). Carbon-14 and uranium are also present in uncontaminated soils.

In order to compensate for uncertainty associated with selecting single point estimates to quantify exposure conditions and toxicity characteristics, input parameters are often conservatively biased. As a result, the risk estimates provided in this assessment do not represent actual exposure conditions, and may even exceed reasonable bounding estimates. Risk estimates must be accompanied by a description of the assumptions upon which they are based, the uncertainties inherent in the input parameters, and the conservative biases employed to compensate for these uncertainties. Without an understanding of these issues (see

Section 6.1.4), the reader is likely to draw erroneous conclusions regarding the impact of ERDF contaminants on groundwater.

Because this is a deterministic risk assessment, the uncertainty associated with these risk estimates cannot be quantified. However, techniques for quantifying uncertainty in risk assessment have been developed, and can be used to remove conservative biases and risk management decisions from the risk assessment. Use of such techniques to evaluate impact of ERDF contaminants on groundwater is likely to indicate that actual risks are much lower than the estimates presented in this report.

6.2 RISK ASSESSMENT OF EXPOSURE TO CONTAMINATED SOILS

Section 6.2 provides an evaluation of possible human health and ecological risks resulting from exposure to contaminated soils, assuming that the ERDF cover does not inhibit these exposures. In reality, each ERDF alternative is designed to inhibit inadvertent intrusion by humans, and eliminate exposure to non-human ecological receptors. Therefore, the results of this section are only valid in the case of a design failure scenario in conjunction with a loss of institutional controls. This evaluation does not calculate or incorporate the likelihood of this occurrence.

Institutional controls are assumed to exist at least 100 yr after the ERDF begins receiving remediation wastes in 1996 (Ecology et al. 1993). Therefore, risks associated with exposure to soil contaminants are adjusted for degradation and radioactive decay to indicate potential risk in the year 2096. Risk are also calculated for the years 2496 (500 yr from ERDF operation) and 11996 (10,000 yr from ERDF operation).

The only loss mechanisms accounted for in this analysis are radioactive decay and degradation of organic contaminants. Contaminant loss via transport (e.g., leaching, erosion, and volatilization) are assumed not to occur. Because the analysis of Section 6.1 is based on the assumption that all contaminants eventually migrate to groundwater, the results of the groundwater exposure and soil exposure analyses should not be combined.

This section evaluates only those risks that could occur following completion of the ERDF (i.e., long-term risks). Worker risk associated with construction and operation of the ERDF is discussed in Chapter 9. Short-term ecological effects are also discussed in Chapter 9.

6.2.1 Human Health Evaluation

Much of the risk assessment information provided previously in Section 6.1 is applicable to the human health evaluation of exposure to contaminated soils. Such information is not duplicated in this section; only methods and data specific to soil exposures are presented.

6.2.1.1 Human Exposure Assessment

6.2.1.1.1 Conceptual Model. Figure 6-2 illustrates the conceptual model for human exposures to contaminated soils. The exposure pathways evaluated in this human health evaluation are soil ingestion, dermal exposure, fugitive dust inhalation, inhalation of volatiles, and external exposure to radionuclides. An evaluation of these pathways is expected to adequately identify risk-driving contaminants. For comparison purposes, risks associated with a produce ingestion pathway are calculated for strontium-90. Strontium-90 was chosen for this analysis because it is a potentially important internal hazard, and the uptake of strontium by plants tends to be relatively high. Dermal absorption is evaluated only for non-radioactive contaminants. Dermal uptake is generally not an important route of uptake for radionuclides, which have small skin permeability coefficients (EPA 1989a).

All exposures are evaluated assuming residential exposure parameter values specified in HSBRAM (DOE-RL 1993j). This scenario is intended to simulate an inadvertent intruder scenario in which a person unknowingly removes the facility cover. Use of this scenario is only appropriate if institutional controls are lost.

6.2.1.1.2 Quantification of Human Exposures. The reader is referred to Section 6.1.1.2 for a description of the general methods associated with quantification of exposures.

Exposure Point Concentrations. An exposure point concentration is the contaminant concentration in each media to which a receptor is assumed to be exposed. For the soil ingestion and dermal exposure pathways, the exposure point concentration is the maximum detected soil concentration for each contaminant (presented in Table 5-8). For the fugitive dust inhalation pathway, contaminant air concentrations are calculated by dividing the maximum detected soil concentration by a particulate emission factor (PEF) as follows:

$$C_{air} = \frac{C_{soil} \times CF}{PEF} \qquad (6\text{-}6)$$

where:

C_{air}	=	contaminant concentration in air [mg/m^3 (non-radioactive), pCi/m^3 (radioactive)]
C_{soil}	=	contaminant concentration in soil [mg/kg (non-radioactive), pCi/g (radioactive)]
CF	=	conversion factor [1x10^3 g/kg (radionuclides only)]
PEF	=	particulate emission factor (m^3/kg)

The PEF used in this evaluation (3.0x10^7 m^3/kg) is based on the annual average for total suspended particulates in the 200-W Area (33 μg/m^3; Jaquish and Mitchell 1988). An important conservative assumption associated with the use of a PEF is that all of the suspended particulates originate within the ERDF, and are not diluted by dust blowing in from off-site. Another assumption is that the percentage (by weight) of each contaminant in the dust is equal to its percentage in the soil.

In addition to using the PEF approach, air concentrations of volatile contaminants are calculated using a volatilization factor (VF). The air concentration is calculated using Equation B-1, substituting the VF for the PEF. The VFs used in this evaluation are taken directly from the original RIs or QRAs identified as the source of the maximum contaminant concentrations. These VFs were also used in the risk-based screening process for soils (see Section 5.2). The VFs are listed in Table 5-3.

Intake Equations. Standard EPA equations, as provided in RAGS (EPA 1989a) and HSBRAM (DOE-RL 1993j), are used as the basis for all intake calculations. Intakes of non-radioactive and radioactive contaminants are calculated and presented separately.

Non-Radioactive Contaminants. Equation 6-1 (see Section 6.1.1.2.1) is the basic equation for calculating intakes of non-radioactive contaminants via ingestion (e.g., soil and water) or inhalation. In the case of soil ingestion, the contaminant concentration is in units of mg/kg, and the contact rate is in units of mg/d. In the case of inhalation (of either fugitive dust or volatiles), the contaminant concentration is in units of mg/m^3, and the contact rate is in units of m^3/d.

Equation 6-1 may be used to determine the absorbed dose resulting from dermal exposure to contaminated soil by calculating the contact rate as follows:

$$IR_{derm} = SA \times AF \times ABS \qquad 6\text{-}7$$

where:

IR_{derm}	=	dermal exposure contact rate (mg/event)
SA	=	skin surface area available for contact (m^2)
AF	=	soil-to-skin adherence factor (mg/cm^2-event)
ABS	=	contaminant-specific dermal absorption factor (unitless)

The dermal exposure contact rate is inserted into Equation 6-1 to yield the intake value for the dermal pathway. For the purpose of this risk assessment, it is conservatively assumed that receptors do not wear protective clothing that would limit dermal exposures. A description of the dermal absorption fraction (ABS) values used in this evaluation is provided in the Calculation of Contaminant Intakes discussion.

Radioactive Contaminants. Equation 6-3 is the basic equation for calculating intakes of radioactive contaminants via ingestion or inhalation. In the case of soil ingestion, the contaminant concentration is in units of pCi/g, and the contact rate is in units of mg/d. In the case of inhalation (of fugitive dust), the contaminant concentration is in units of pCi/m^3, and the contact rate is in units of m^3/d. For biota ingestion, the contaminant concentration is in units of pCi/g (wet weight), and the contact rate is in units of g (wet weight)/d.

Equation 6-3 may also be used to evaluate external exposures. In this case, the "intake" has units of pCi-yr/g, and represents the time a receptor is in close proximity to a particular radionuclide soil concentration. The "contact rate" is determined as follows:

$$IR_{ext} = ET \times RF \times CF \qquad 6\text{-}8$$

where:

IR_{ext}	=	external exposure contact rate (yr/d)
ET	=	exposure time (hr/d)
RF	=	dose reduction factor (unitless)
CF	=	conversion factor (1.14×10^{-4} yr/hr)

The external exposure contact rate is then inserted into Equation 6-3 to yield the intake value for the external exposure pathway. A dose reduction factor is used to obtain a more realistic estimate of external exposures by taking into account the effects of shielding while indoors and ground roughness.

Calculation of Contaminant Intakes. All exposure parameters (e.g., body weight, averaging time, contact rate, exposure frequency, and exposure duration) presented below are those recommended by HSBRAM (DOE-RL 1993j). These exposure parameters have been specifically developed for a residential population, and are used to evaluate the soil ingestion, dermal exposure, inhalation (fugitive dust and volatiles), external radiation exposure, and biota ingestion pathways. The parameters for the noncarcinogenic, non-radioactive carcinogenic, and radioactive carcinogenic contaminants of potential concern are summarized in Tables 6-11, 6-12, and 6-13, respectively.

Contaminant intakes are calculated by combining exposure parameters presented in Tables 6-11 through 6-13 and intake Equations 6-1 and 6-3 (as modified by Equations 6-6 and 6-7). Example calculations of this process are provided in Appendix D of the Hanford Site Risk Assessment Methodology (HSRAM, Rev. 3) (DOE-RL 1994c). Summary intake factors (see Section 6.1.1.2.2) are provided in Table 6-14.

Summary intake factors for dermal exposure to soil require the use of contaminant-specific dermal absorption factors (ABS). The ABS is the fraction of the contaminant that crosses the skin and enters the bloodstream. ABS values are either assumed or derived from the literature. Contaminants bound to a soil matrix are less dermally bioavailable than pure or dilute solutions of contaminants applied directly to the skin. Specific information on the dermal absorption of most of the COPC in this risk assessment is limited.

The use of an upper bound estimate of 6% as an absorption factor for PCBs based on studies of 3,3',4,4'-tetrachlorobiphenyl is recommended in EPA (1992b). For the purposes of this risk assessment, 6% is used as the ABS for all Aroclors.

Dermal Exposure Assessment (EPA 1992b) does not recommend ABS values for other organic contaminants of potential concern. However, Hawkins et al. (1990) recommend ranges of ABS values for different classes of constituents. The recommended ABS range for volatile organics is 10 to 50%. For this risk assessment, all volatile COPC (i.e., benzene, chloroform, methylene chloride, trichloroethene, vinyl chloride, and ammonia) are assumed to have an ABS of 30%, based on the average of the low and high end values of the recommended range.

For semi-volatiles and pesticides, Hawkins et al. (1990) recommend an absorption fraction range of 1 to 10%. For this risk assessment, the remaining organic COPC are assumed to have an ABS of 5%, based on the average of the low and high end values of the recommended range.

For metals, Hawkins et al. (1990) recommend an absorption fraction range of 1 to 10%. EPA (1992b) recommends a range of 0.1 % to 1.0% for cadmium. For this risk assessment, all metals are assumed to have an ABS of 1%.

For the produce ingestion pathway (evaluated for strontium-90), the contaminant concentration in the edible portion of plants needs to be estimated. This is performed by multiplying the strontium-90 soil concentration ($2.0x10^3$ pCi/g) by a plant uptake factor and dry weight/wet weight conversion factor. The uptake factor used for this analysis (0.25) is from Baes et al. (1984), and is intended to represent uptake by fruits, seeds, and tubers. The dry weight/wet weight conversion factor is 0.32. The result is a strontium-90 plant concentration of 160 pCi/g (wet). This concentration is multiplied by the summary intake factor for biota ingestion (Table 6-14) to yield the produce intake value (Table 6-19).

6.2.1.1.3 Summary of Human Exposure Assessment. Intake values are calculated by multiplying exposure point concentrations (see Section 6.2.1.1.2) by summary intake factors (Table 6-14). Intake values for non-radioactive contaminants are provided in Tables 6-15 (soil ingestion), 6-16 (dermal exposure), 6-17 (fugitive dust inhalation), and 6-18 (volatile inhalation). Intake values for radioactive contaminants are provided in Table 6-19 for all three exposure pathways. All intake values represent current exposures. The analysis of future risks is provided in Section 6.2.1.3. Actual future intakes (assuming an intrusion into contaminated soils) would be smaller due to a variety of loss mechanisms (e.g., radioactive decay, volatilization, contaminant degradation).

6.2.1.2 Human Health Toxicity Assessment. The toxicity assessment for this risk assessment is conducted in accordance with RAGS (EPA 1989a) and HSBRAM (DOE-RL 1993j). The reader is referred to Section 6.1.2 for a description of the general characteristics of a human health toxicity assessment. Toxicological profiles for the COPC are presented in appendices of operable unit-specific RI reports (DOE-RL 1993e,f,g).

Table 6-20 summarizes the noncarcinogenic toxicity values (i.e., RfDs) and the corresponding critical effects for the COPC at the site. It is noted that the recommended concentration level for ingestion of ammonia (as published in HEAST, EPA 1993b) is for sensory threshold; it is not intended for use in the characterization of health risk. Table 6-21 presents the carcinogenicity weight-of-evidence classifications and the SFs for the ingestion, inhalation, and external radiation exposure routes for non-radioactive and radioactive contaminants of potential concern.

There are currently no toxicity values specifically developed for evaluating dermal exposures. For the purpose of this risk assessment, oral toxicity values (RfDs and SFs) are adjusted for evaluating dermal intakes. The reader is referred to Section 6.1.2.3 for a complete discussion of the methods used to estimate dermal toxicity values. Table 6-22 presents the dermal RfDs and SFs for COPC, including the corresponding GI absorption factors.

6.2.1.3 Human Health Risk Characterization. The information from the exposure assessment and toxicity assessment is integrated to form the basis for the characterization of human health risks. The risk characterization presents quantitative and qualitative descriptions of risk. The reader is referred to Section 6.1.3 for a more complete description of the methods used in this risk characterization.

The HQs and ICRs calculated using the intake values provided in Tables 6-15 through 6-19 represent risks assuming current residential exposure. The HQs and ICRs for each contaminant are summed across pathways to provide contaminant totals. Current non-radioactive contaminant HQ and ICR totals are provided in Table 6-23; current radioactive contaminant ICR totals are provided in Table 6-24.

Table 6-19 indicates that the produce ingestion ICR for strontium-90 is approximately fifty times higher than the soil ingestion ICR ($5x10^{-3}$ vs. $9x10^{-5}$). This indicates that a produce ingestion pathway could be the dominant risk pathway for strontium-90. See Section 6.2.1.4.2 for additional discussion on the expected importance of a produce ingestion pathway for other contaminants.

HQ and ICR values are decay-corrected for 103 yr to provide future risk values (assuming residential exposure to maximum concentrations) in the year 2096. The decay correction is calculated for organic compounds, ammonia, and radionuclides. All loss mechanisms are assumed to follow exponential decay, which is characterized by a half-life. Assumed half-lives of organic compounds are presented in Table 6-25. These are the same half-lives used in the groundwater transport model to account for contaminant degradation. Although ammonia is known to degrade to nitrate, a characteristic half-life was not found in the literature. Ammonia was assumed to completely degrade within 100 yr. Metals are assumed not to degrade. Radionuclide loss is assumed to be entirely due to radioactive decay. Table 6-25 presents half-lives and decay-corrected HQs and ICRs for non-radioactive contaminants. Table 6-26 presents half-lives and decay-corrected ICRs for radioactive contaminants.

The HQ and ICR values are also decayed for 500 yr and 10,000 yr and are presented in Table 6-27 for organic compounds, and in Table 6-28 for radioactive contaminants.

6.2.1.3.1 Quantification of Noncarcinogenic Effects. The HQs for future exposure (summed across the soil ingestion, dermal exposure, fugitive dust inhalation, and volatile inhalation pathways for each contaminant) are presented in Table 6-25 (for year 2096). Eleven contaminants have estimated HQs greater than 1, and are considered contaminants of concern. The COC are aluminum, antimony, arsenic, barium, chromium, copper, mercury, nickel, silver, thallium, and vanadium. The highest HQ of any single contaminant is for copper (HQ = 30). Assuming no loss mechanisms, the HQs at 500 yr and 10,000 yr are expected to remain the same.

The HQs may be added together to provide a HI for all of the systemic toxins. However, it is only appropriate to add HQs for contaminants that produce similar adverse effects because the effects associated with such contaminants are assumed to be additive. In contrast, it is not appropriate to add the HQs for contaminants with different effects. For example, the HQs for copper and arsenic should not be added together because the critical effect for copper exposure (GI irritation) is different than the critical effect for arsenic (hyperpigmentation). Based on the critical effects presented in Table 6-20, the HQs for antimony and thallium may be added (for a HI of 2). The HQs from the remaining contaminants of concern should be examined separately.

6.2.1.3.2 Quantification of Carcinogenic Risk. ICRs for future exposure to non-radioactive contaminants (summed across the soil ingestion, dermal exposure, fugitive dust inhalation, and volatile inhalation pathways for each contaminant) are presented in Table 6-25 (for the year 2096). Seven contaminants (four organics and three inorganics) have ICRs greater than 1×10^{-6}, and are considered contaminants of concern. These are Aroclor-1254, Aroclor-1260, benzo(a)pyrene, benzo(k)fluoranthene, arsenic, beryllium, and chromium. The largest ICR for a single contaminant is 4×10^{-4}, associated with fugitive dust inhalation of chromium (assumed to be chromium VI). It is assumed that cancer risks associated with different contaminants are additive (i.e., ICRs may be added together). The total ICR for the year 2096 is 1×10^{-3}.

Table 6-27 indicates that in 500 yr and 10,000 yr only two organic compounds (both PCBs) have ICRs greater than 1×10^{-6}. Adding the organic risks from Table 6-27 to the inorganic risk from Table 6-25 indicates that the total ICRs in 500 yr and 10,000 yr are both estimated to be 9×10^{-4}.

ICRs for future exposure to radioactive contaminants via soil ingestion, fugitive dust inhalation, and external exposure are presented in Table 6-26 (for year 2096). An important consideration for repositories of radioactive waste is the ingrowth of radioactive daughter products. Ingrowth is a condition by which the concentration of a radionuclide temporarily increases due to the decay of its parent radionuclide(s). For example, thorium-232 is the head of the thorium series, of which the decay products are relatively short-lived. Assuming no migration of the thorium series members takes place, radioactive equilibrium will be reached in about 60 yr. HEAST (EPA 1993b) does not provide a thorium-232+D slope factor to account for this effect. Therefore, as shown in Tables 6-26 and 6-28, ICRs are calculated for the radioactive daughters of thorium-232 (radium-228, thorium-228, and their associated subchains). These radionuclides are expected to be in equilibrium with thorium-232 within 100 yr, such that radium-228 and thorium-228 are characterized by the thorium-232 soil concentration and half-life. The slope factors used to calculate ICR values associated with radium-228 and thorium-228 are the radium-228+D and thorium-228+D SFs provided in HEAST (EPA 1993b). For the time frames being evaluated in this appendix, the effect of daughter ingrowth is only important for thorium-232. The "+D" slope factor provided in HEAST adequately account for this effect for the uranium and actinium series.

Table 6-26 (radionuclide risk in the year 2096) indicates that thirteen radionuclides have ICR values greater than 1×10^{-6}, and are considered contaminants of concern. Table 6-28 indicates that following 500 and 10,000 yr of decay, the contaminant of concern list is reduced to eight and five radionuclides, respectively. In all cases, the risk is dominated by uranium (and its associated daughter products). The pathways of concern for uranium are external exposure and inhalation (see Table 6-19). The external exposure hazard is not due to uranium itself, but protactinium-234m (a daughter product of uranium-238).

For the produce ingestion pathway, Table 6-26 indicates that the future (year 2096) strontium-90 ICR is 5×10^{-4}. Inclusion of a produce ingestion pathway does not change the status of strontium-90 as a contaminant of concern; the risk via other pathways (mostly soil ingestion) is still greater than 1×10^{-6} in 100 yr. By the year 2496, the produce ingestion ICR value drops to 3×10^{-8}, such that strontium-90 is not considered a contaminant of concern after 500 yr.

ICR values ideally represent risk associated with contamination, excluding background levels of naturally occurring constituents. However, contaminant soil concentrations (from which ICR values are calculated) are based on maximum detected concentrations, which include background concentrations. Hanford Site background soil data are currently available only for non-radioactive, inorganic constituents (see Table 3-10). The average background soil concentration represents a significant fraction of the maximum detected concentration for arsenic (6%) and beryllium (23%). Using the same risk assessment calculations provided in this chapter, the ICR values associated with the background concentrations for arsenic and beryllium are $1x10^{-5}$ and $5x10^{-5}$, respectively. The maximum detected soil concentration (33 pCi/g) of potassium-40, a naturally occurring radionuclide, has an associated ICR of $4x10^{-4}$. Several radioactive contaminants (carbon-14, uranium, thorium) are also naturally occurring; however, Hanford Site background data are currently unavailable.

Naturally occurring terrestrial radionuclides result in a measurable external radiation field. Woodruff and Hanf (1992) provide external radiation dose measurement results for distant communities, which indicate that the average naturally occurring dose rate in 1991 was approximately 87 mrem/yr. Using the current EPA radiation risk factor for cancer incidence ($6.2x10^{-7}$/mrem, EPA 1989b), this dose rate is associated with an ICR of $1x10^{-3}$ (using the exposure parameters provided in Table 6-13. Only five of the thirteen radioactive contaminants of concern (in 2096, Table 6-26) have ICR values greater than the $1x10^{-3}$ ICR associated with naturally occurring terrestrial radiation. In 500 yr (Table 6-28), only three radionuclides (plutonium-238/239, radium-226, and uranium) have associated ICRs greater than background risk. In 10,000 yr, only uranium has an associated ICR greater than background risk.

6.2.1.4 Uncertainty Analysis. The uncertainty analysis for the groundwater risk assessment provided in Section 6.1.4 is largely applicable to this analysis. Only sources of uncertainty specific to the evaluation of soil exposures and risks are presented below.

6.2.1.4.1 Uncertainty Associated with Environmental Fate and Transport. Environmental degradation half-lives are used in this analysis (originally presented in Section 4.1.2) to calculate decay-corrected HQs and ICRs. Since there is much uncertainty associated with half-lives for organic compounds, several sources of data were reviewed, and a range of half-lives was selected for each compound (< 1, 1-10, 10-100 yr). The maximum value in the range is used in this analysis. For compounds with no data, the half-live was arbitrarily set at 10,000 yr.

There is a high degree of uncertainty with respect to the choice of half-lives for organic compounds. Much of the current data is not appropriate for conditions expected in the ERDF. Therefore, half-lives presented in Table 6-25 are not precise. The most obvious indication of this is the difference in half-lives for the different Aroclors. Experimental data is available for Aroclor-1248 (indicating a half-life less than 1 yr), but data are not available for the other two PCBs. It is unlikely the degradation rates for all three PCBs are that different, but it is conservatively assumed that Aroclor-1254 and Aroclor-1260 have half-lives of 10,000 yr. It is unlikely that these are accurate half-lives for PCBs, and the associated ICRs for these Aroclors are conservatively biased.

Choice of half-life is an important issue because future risk values are very sensitive to this parameter. For example, the maximum detected concentration of Aroclor-1248 is about twice the maximum detected value of Aroclor-1254 (see Table 3-9). However, because of the choice of half-lives, Aroclor-1248 apparently degrades to insignificant levels while Aroclor-1254 remains a contaminant of concern with an ICR of $9x10^{-5}$. Better information on the half-life of Aroclor-1254 and -1260 would probably eliminate these contaminants as a significant risk in the future.

This analysis conservatively assumed that the repository waste will not migrate away from the ERDF. However, contaminant leaching may be an important loss mechanism. This means that, if the ERDF design allows leaching, then the waste will eventually be depleted of contaminants, starting with the most mobile species. This loss mechanism applies to all contaminants, not just organics and radionuclides. For example, Table 6-10 indicates that (assuming an unlined trench and an infiltration rate of 0.5 cm/yr) arsenic is expected to migrate from the ERDF to groundwater in 540 yr. In another 400 yr, the groundwater plume is expected to have completely passed beyond the ERDF boundary. This also means that arsenic is no longer present in the ERDF. The risk values in this chapter do not account for this potential loss mechanism; it is conservatively assumed that the waste is stable and will not migrate away from the ERDF.

6.2.1.4.2 Uncertainty Associated with the Exposure Assessment. It is important to note that this chapter provides an evaluation of exposure conditions that the ERDF is expected to prevent. Risk values presented in this chapter do not account for the probability that exposure to repository wastes will occur. However, it is likely that as time following completion of the ERDF increases, the probability of inadvertent intrusion also increases. For this reason, risk values calculated for 500 yr or more in the future are expected to be more representative of potential exposure conditions than risk values calculated for the year 2096.

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The produce ingestion pathway appears to be the dominant risk pathway for strontium-90. However, there is a high degree of uncertainty associated with this pathway. It is assumed that a person grows enough produce on contaminated soils to support an intake rate of 80 g/d. The strontium-90 uptake factor (0.25) is a default value for fruits, seeds, and tubers. Baes et al. (1984) indicates that the range of reference mean values for strontium-90 uptake is 0.077 to 17.

Strontium-90 was chosen for the evaluation of the produce ingestion pathway because it is a relatively important internal hazard, and has a relatively high uptake value. A produce ingestion pathway may be important for other contaminants as well, but probably only those contaminants that pose a high risk via the soil ingestion pathway. Of the contaminants that are COC in the year 2096 (see Tables 6-25 and 6-26) the soil ingestion pathway is the dominant risk pathway for nearly all non-radioactive contaminants as well as americium-241, nickel-63, and isotopes of plutonium. Of all of these contaminants, current literature (Baes et al. 1984, Travis and Arms 1988) indicates that strontium-90 has the highest uptake factor. In most cases, the strontium-90 uptake factor is higher by more than an order of magnitude. This suggests that, while a produce ingestion pathway may contribute to the overall risk, it is unlikely to be a dominant risk pathway for more than a few contaminants.

6.2.1.4.3 Uncertainty Associated with the Toxicity Assessment. Table 6-20 provides the confidence level assigned by EPA to each RfD. All of the contaminants of concern that exhibit systemic toxic effects (Table 6-25) have confidence levels of medium or low (several contaminants do not have assigned confidence levels). Because of the conservative assumptions inherent in the development of these RfDs, it is unlikely that contaminants of concern represent a significant systemic toxic hazard.

The copper RfD ($4x10^{-2}$ mg/kg-d), which results in the highest HQ (30), may be considered to have high confidence. This RfD is slightly lower than a LOAEL (in humans) of $7x10^{-2}$ mg/kg-d (EPA 1991a). However, the National Academy of Science recommend an intake equal to or greater than the RfD to protect against the adverse health effects associated with copper deficiency.

The EPA slope factors developed to assess external exposure to radionuclides are likely to be particularly conservative. External exposure SFs are appropriate for a uniform contaminant distribution (i.e., an infinite slab source). Because of the penetrating ability of high-energy photons, this assumption can only be satisfied if the contamination extends to nearly 2 m (6.6 ft) below ground surface, and over a distance of a few hundred meters or more. Although the ERDF will exceed these dimensions, the soil concentrations used in this evaluation are maximum detects, and are unlikely to represent large volumes of repository waste.

6.2.1.4.4 Uncertainty Associated with the Risk Characterization. The reader is referred to Section 6.2.4.5 for a discussion of risk characterization uncertainty.

6.2.2 Ecological Risk Assessment

6.2.2.1 Problem Formulation. The purpose of this ecological risk assessment is to evaluate the likelihood that adverse ecological effects may occur if organisms are exposed to contaminants that may be disposed in the ERDF. The organisms would include all plants and animals, except humans and domestic animals, that could be potentially exposed to site contaminants. This risk assessment is intended to evaluate base conditions at the ERDF. These base conditions are that the ERDF has a soil cover that can be breached by the organisms. This base condition is then used to evaluate alternative designs. To account for temporal changes in contaminant concentrations (e.g., decay), four exposure scenarios are evaluated: current, 103 years in the future, 500 years in the future and 10,000 years in the future.

The ecological evaluation was conducted using biotransfer modeling to account for exposure of ecological receptors to contaminants that might be disposed at the ERDF. Biotransfer modeling is a common method for evaluating ecological risk (Suter 1993). For the ERDF, biotransfer modeling was conducted using available site-specific information, best available information where appropriate, and professional judgment, if necessary. This evaluation calculates risks for a limited set of exposure scenarios. Namely, vegetation uptake of contaminants in soil, ingestion of vegetation (seeds) by the Great Basin pocket mouse (*Perognathus parvus*), and external exposure of the mouse to radionuclides present in the soil. This evaluation does not consider the potential for bioaccumulation to higher trophic levels because of the high degree of uncertainty associated with biotransfer factors for terrestrial receptors. These scenarios were judged adequate for evaluation of ecological risks at the ERDF because the cover barrier will be at least 15 feet thick, which is sufficient to prevent access to wastes by environmental receptors.

6.2.2.1.1 Stressors. Soil material proposed for disposal at the ERDF will originate from environmental restoration activities at waste management sites in the 100 and 300 Areas. Remedial investigations have been conducted at several of the waste management units. Contaminants recorded at these sites included volatile and semi-volatile organics, pesticides, metals, and radionuclides. Biological monitoring studies have been conducted by PNL (or its predecessors) for much of the time that the Hanford Site has been operating. Although these studies show that biota have been contaminated by contaminants attributable to site activities (especially radionuclides), there has been no report of significant adverse effects to the ecological communities present at the Hanford Site to date.

The contaminants recorded at various waste management units could present a hazard to the environment because of toxicity and persistence in the environment. Soil contaminants of potential concern are identified and discussed in Chapter 5.0 and listed in Table 5-8. Soil concentrations used to characterize contaminant conditions are maximum detected concentrations from the 100 and 300 Areas. All organic, inorganic, and radioactive COPC identified in the human risk assessment were considered to be of concern for the ecological risk assessment. The COPC were selected after screening of constituents for human health risk (see Sections 5.2).

6.2.2.1.2 Ecosystem Components. The regional and site-specific ecology of the proposed ERDF site is presented in Section 2.8. Given that the proposed location of the ERDF is on the 200 Area plateau of the Hanford Site, only terrestrial organisms that are resident on the 200 Area plateau are considered for the evaluation of base conditions.

6.2.2.1.3 Endpoint Selection. The risk assessment combined soil data and modeled data with other supportive information to evaluate potential exposure of receptor species to organic, inorganic, and radiological contaminants. The assessment endpoint for study is the health of selected receptor organisms and their populations. The measurement endpoint is the estimated contaminant intake by individuals. Because the ERDF is in planning stages, no mortality studies can be conducted on indicator species.

The focus is on site-wide risks associated with contaminants present in soils that could be disposed of in the ERDF. It is not possible to evaluate all potential effects on all potential receptors. Consequently, this assessment focuses on the potential receptor that is most likely to be exposed to contaminants buried in the ERDF. The organism selected for evaluation is the Great Basin pocket mouse (*Perognathus parvus*).

6.2.2.1.4 Conceptual Model. Based on the descriptions of ecological resources present at, or near, the proposed ERDF site and assuming a contaminant source limited to the soil, a conceptual ecological model can be derived for the key ecological resources of the area (Figure 6-3). The key receptor evaluated in this risk assessment is the Great Basin pocket mouse which is considered a small herbivorous mammal. In this model, uptake of contaminants from soil by vegetation serves as the basic source of contaminant entry into the food chain. The herbivore component, represented in the model by insects and several herbivorous mammals, acts as the primary conduit between contaminants in vegetation and contaminants in carnivores. Two levels of carnivores are common to the 200 Area plateau. Primary carnivores prey almost entirely on herbivores; therefore, three levels of bioaccumulation are possible (soil to plant, plant to herbivore; herbivore to primary carnivore). Second-order carnivores prey on other carnivores as well as on herbivores. The projected size of the ERDF [1.6 sq mi (410 ha)] is extremely large relative to the home range of mice [5,400 to 43,000 ft^2 (0.05 to 0.4 ha)]. Thus, it is assumed that mice spend their entire lives within the ERDF boundary and ingest only vegetation that grows on the site.

6.2.2.2 Analysis. The analysis phase of the ecological risk assessment is a technical evaluation of the available data to assess the potential effects of exposure to the stressors on the target receptors previously discussed. This analysis is based on the conceptual model and characterizes exposure and ecological effects. The section on exposure characterization focuses on developing the exposure relationship between receptors and site contaminants. Because of the lack of site-specific data for plants and wildlife, this risk analysis can only be considered a screening-level analysis.

6.2.2.2.1 Characterization of Exposure. For the purpose of the exposure characterization, the maximum detected concentration for any potential contaminant was used to establish the exposure scenario concentration. It was assumed these concentrations were uniformly distributed over the site and were biologically active and available for transport into the biosphere. It was also assumed that the measured activities for the radionuclides were appropriate at the time of the risk assessment.

6.2.2.2.1.1 Exposure Analysis. Because of the need to provide an assessment of base conditions, it was assumed the evaluated receptor spends some fraction of its life in the ERDF, and obtains all its their food from the site when present, and all consumed food is contaminated. There is no source of water within the site, therefore, water ingestion was not considered a route of exposure. Ingestion of vegetation (seeds) is the only food chain exposure pathway presented for the mouse.

The ecological risk assessment focuses on potential effects to vegetation and wildlife potentially exposed to contaminants present in the ERDF. Terrestrial vegetation is represented as a generic plant species for uptake from the soil and as a food source for wildlife. The pocket mouse was selected based upon its presence at the site, trophic position, and habitat requirements.

The major route of contaminant exposure for plants is assumed to be direct uptake of contaminants from soil. Ingestion from food is assumed to be the major route of exposure to wildlife species for both non-radiological and radiological contaminants. For non-radiological contaminants, the receptor exposure to contaminants is based on the intake rate of contaminants within the food source. Uptake factors and transfer coefficients are considered only for determining concentrations in potential food sources. For radiological contaminants, the exposure pathways consider uptake and incorporation of radionuclides from contaminated external food that results in internal exposure and the dose due to direct external exposure. The dose from direct exposure to radionuclides was calculated for the mouse because it spends its life on the ground or in burrows.

6.2.2.2.1.2 Contaminant Intake by Terrestrial Receptors. The intake of contaminants by environmental receptors is estimated from maximum soil concentrations, appropriate transfer coefficients, and species specific intake factors. This section is focused on intake of nonradiological contaminants, but applies to radiological contaminants by the appropriate substitution of radionuclide activity concentration and conversion factors.

Plants

Direct uptake from soil is assumed to be the dominant exposure route for plants. Uptake of contaminants via deposition is not considered. The contaminant concentration within a generic plant was estimated from results of remedial investigation studies at operable units in the 100 and 300 Areas. Soil-to-plant transfer coefficients for organic contaminants (Table 6-29) were derived using the equations of Travis and Arms (1988). Soil-to-plant (seeds) transfer factors for inorganic contaminants (Table 6-30) and radionuclides (Table 6-31) were obtained from available literature (Baes et al. 1984, Coughtrey et al. 1985). Transfer factors to seeds were chosen because seeds represent a significant proportion of the diet of the mouse. The transfer factors do not take into account contaminant bioavailability, biodegradation, or metabolic transformation of compounds. Contaminant concentration (or activity) in plants is calculated by

$$C_{i,v} = (C_{s,i})(Sp)(Dw)(Cf_1) \tag{6-9}$$

where

$C_{i,v}$ = concentration (activity) of contaminant i in vegetation (mg/kg plant or Ci/kg plant, wet weight)
$C_{s,i}$ = concentration (activity) of contaminant i in soil (mg/kg soil or pCi/g soil, dry weight)
Sp = soil-to-plant transfer coefficient (kg soil/kg plant, dry weight)
Dw = dry-to-wet weight conversion (0.32)
Cf_1 = conversion factor for radionuclides (1000 g/kg*1E-12Ci/pCi)

The transfer factors used in this assessment are for soil to reproductive parts (i.e. seeds).

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Wildlife

The estimated contaminant intake (or activity) by the mouse is estimated using species specific intake parameters. The intake of contaminants is estimated using an equation adapted from the Human Health Evaluation Manual (EPA 1989a) in which

$$I_{i,o} = \frac{(C_{i,v})(IR)(FI)(EF)(ED)}{(BW)(AT)} \tag{6-10}$$

where

$I_{i,o}$ = intake rate of contaminant i by organism (mg/kg/day)
$C_{i,v}$ = concentration of contaminant i in vegetation (mg/kg, wet weight)
IR = ingestion rate (0.0067 kg/day)
FI = fraction of food ingested from contaminated area
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (0.0235 kg)
AT = averaging time (days)

This equation is used to estimate intake rate of contaminants by herbivores.

The ingestion rate is based on an allometric equation from Calder (1984):

IR (kg/day) = $0.157\ BW^{0.84}$. The mouse body weight is based on Burt and Grossenheider (1976). For this assessment, exposure frequency, exposure duration, and averaging time are assumed to be one year, and can therefore be ignored. The fraction of food ingested from a contaminated area is an estimate based on the home range or species density of the organism. For the mouse whose home range is smaller than the ERDF, it was assumed that 100% of their diet consisted of contaminated foodstuffs.

6.2.2.2.1.3 Estimation of Radiation Dose to Terrestrial Receptors. Uptake of radionuclides from soils by plants was estimated the same way as uptake for non-radioactive contaminants but substituting appropriate transfer coefficients and conversion factors (equation 6-9). The activity of any radionuclide in mice was calculated based on an equation developed by Baker and Soldat (1992) which shows:

$$A_{i,m} = \left[\frac{(A_{i,v})(IR_m)(UF_i)}{(BW)}\right]\left[\frac{1-e^{-\lambda T}}{\lambda}\right] \qquad (6\text{-}11)$$

where

$A_{i,m}$ = activity of radionuclide i in mouse (Ci/kg, wet weight)
$A_{i,v}$ = activity of radionuclide i in vegetation (Ci/kg, wet weight)
IR_m = food ingestion rate of mouse (kg/day)
UF_i = radionuclide i uptake fraction (unitless)
BW = body weight
λ = effective decay constant of radionuclide i in organism (1/day), and $\lambda = \lambda_b + \lambda_r$ where $\lambda_b = \ln(2)/T_b$ is the biological removal rate constant for the radionuclide in the organism with T_b being the biological half-life (days) and $\lambda_r = \ln(2)/T_r$ is the radiological decay constant for the radionuclide and T_r is the radiological half-life (days)
T = time of exposure (days)

The internal dose rate to an organism by a radionuclide i is then given by

$$R_{i,c} = \left[\frac{(b_i)(IR_m)(UF_i)}{(BW)}\right]\left[\frac{1-e^{-\lambda T}}{\lambda}\right](E_{i,c}) \qquad (6\text{-}12)$$

where

$R_{i,c}$ = dose rate to total body of organism c by radionuclide i (rad d^{-1})
b_i = specific body burden of radionuclide i in food (Ci/kg)
$E_{i,c}$ = effective absorbed energy rate for nuclide i per unit activity in organism c (kg-rad/Ci/d), where $E_{i,c}$=5.12E+04 $e_{i,c}$ and $e_{i,c}$ is the effective absorbed energy (MeV/dis) for radionuclide i in organism c

The total dose is determined by summing the dose rate for each radionuclide. A summary of exposure parameters for the mouse is shown in Table 6-32. In the absence of specific data, the removal constants, λ, and uptake fractions, UF_i, are taken to be that of standard man (Baker and Soldat 1992, ICRP 1959). For regulatory purposes, the exposure time (T) is assumed to be one year. For a more complete derivation of the dose equations, see Baker and Soldat (1992).

The external dose to wildlife is calculated for the mouse. These organisms spend a significant portion of time either on the ground surface or burrowing into the soil. The external dose due to burrowing beneath the soil surface for any given radionuclide i is estimated by

$$R_{b,c} = \frac{(A_{s,i})(DF_{b,i})(EF_{b,c})(CF_1)}{(T)(CF_2)} \qquad (6\text{-}13)$$

where

$R_{b,c}$ = dose rate to organism c by burrowing (rad/d)
$A_{s,i}$ = soil activity of radionuclide i (pCi/g)
$DF_{b,i}$ = burrowing dose factor for radionuclide i (mrad/y/mCi/g)
$EF_{b,c}$ = exposure frequency for burrowing for organism c (unitless)
CF_1 = conversion factor 1 (1E-06 mCi/pCi)
T = time of exposure (1 year)
CF_2 = conversion factor 2 (1000 mrad/rad)

The external dose from exposure at the soil surface is estimated by

$$R_{a,c} = \frac{(A_{s,i})(DF_{a,i})(EF_a)(RF)(CF_1)}{(T)(CF_2)} \tag{6-14}$$

where

$R_{a,c}$ = aboveground dose rate to organism c (rad/d)
$DF_{a,i}$ = aboveground dose factor for radionuclide i (mrad/y/mCi/g)
$EF_{a,c}$ = aboveground exposure frequency for organism c (unitless)
RF = roughness factor (0.2)

The total dose for external exposure for a radionuclide is the sum of burrowing and aboveground exposure. The exposure frequencies for the mouse are chosen by best professional judgment, and are judged suitable for evaluating base conditions of the ERDF.

6.2.2.1.4 Exposure Profile. The estimated exposure for the mouse for each evaluated pathway are reported below. The risks associated with these exposures are reported in Section 6.2.2.3. The estimated concentrations (or activities) in vegetation of the organic, inorganic, and radiological contaminants are shown in Tables 6-33, -34, and -35, respectively. There are no site-specific data to evaluate the estimated concentration. These concentrations were used to estimated the contaminant intake rates for the receptors.

Calculated contaminant intake or dose to wildlife species for organics, inorganics, and radionuclides are given in Tables 6-36, 6-37, and 6-38, respectively. These estimates are based on the exposure pathways chosen for evaluation.

This assessment is only for evaluating the base condition of the ERDF facility and the intakes are not predictive or representative of actual contaminant concentrations or activities in receptors. These estimates of contaminant concentrations are used together with toxicity information to evaluate potential risk posed by the ERDF under the assumption that there is a loss of institutional control and the cover barrier is breached. There are no representative biota sampling data that can be used for verification or comparison with these estimates.

6.2.2.2.2 Characterization of Ecological Effects. The ecological risk assessment focuses on potential adverse effects to wildlife receptors as a consequence of exposure to contaminants that will be disposed at the ERDF. Ecological effects are characterized by identifying critical intake or exposure values that could result in adverse effects to wildlife receptors. The risk to wildlife was assessed by comparisons of predicted intakes to intakes associates with observed (or unobserved) effects.

For organic and inorganic contaminants, the desired toxic endpoint is the NOAEL. The NOAELs used in this assessment were derived using data and methodology cited in Opresko et al. (1993). For several chemicals or analytes, no toxicity information could be identified. These were not evaluated and are so noted in the results.

For radionuclides, Rose (1992) provides an inclusive review on the effects of ionizing radiation on terrestrial organisms that includes the sensitivities of wildlife to ionizing radiation. Rose (1992) reported the lower limits of lethal effects for chronic irradiation was 360 rad/yr or roughly 1 rad/d for several American rodents. The lower dose limit for red pine (*Pinus resinosa*) was reported to be around 0.82 to 1.64 rad/d for continuous exposure. A dose of 0.008 rad/d was the lowest dose that produced an effect on the fetuses of laboratory rats irradiated during the third period of intrauterine life. It was found that body mass was reduced and brain mass increased at birth. The increase in brain mass was the result of nerve tissue and not edema. An exposure of 0.49 rad/d did not effect the growth rate of several American rodents, e.g., *Peromyscus leucopus*. Pocket mice (*Pergnathus formosus*) were reported unaffected at a dose of 0.96 rad/d.

In another extensive review of the affects of ionizing radiation on terrestrial organisms, the International Atomic Energy Agency (IAEA 1992) concluded that a "dose rate of approximately 10 mGy/d (1 rad/d) represents the threshold at which slight effects of radiation become apparent in those attributes, e.g., reproduction capacity, which are of importance for the maintenance of the population." The IAEA concluded that "reproduction was the population attribute most sensitive to damage from chronic irradiation and also the attribute of greatest significance in the ecological context." On the basis of the studies reported in the scientific literature, a dose rate of 1 rad/d is the benchmark dose chosen to evaluate potential effects to wildlife receptors from exposure to radionuclides.

6.2.2.3 Risk Characterization

6.2.2.3.1 Risk to Receptors. The likelihood of eliciting an adverse effect to receptor species was estimated through an environmental hazard quotient (EHQ). The EHQ is defined as the ratio of the contaminant dose to some benchmark dose (e.g., NOAEL). The EHQ ratio is used to assess the potential adverse effect to an individual. For example, an EHQ that approaches or exceeds unity would strongly indicate a potential for adverse effects to an individual. Community effects are addressed qualitatively, based on the potential for adverse effects to an individual. The EHQ was only calculated for non-radiological contaminants.

The calculated EHQ for contaminants that will be disposed of at the ERDF are reported in Tables 6-36 and 6-37 for organic and inorganic contaminants, respectively. For radionuclides (Table 6-38), those exposures that exceed the 1 rad/day benchmark are shaded.

The presence of an uncontrolled waste site would pose a significant risk to the environment based primarily on the heavy metal concentrations. The results show that there are organic and inorganic contaminants that represent a potential hazard to the wildlife receptors due to ingestion through the food chain. The total dose (from ingestion and external exposure) to the mouse from radionuclides would exceed 1 rad/d. This assessment shows that the dose from external exposure was more significant than ingestion. Cesium-137, cobalt-60, europium-152, strontium-90, and uranium-238 (total) were the principal radionuclides that contribute to the dose received by the receptors.

In addition to evaluating current hazards associated with the ERDF as an uncontrolled waste site, the hazards are evaluated for different times in the future: 103 years, 500 years, and 10,000 years. This analysis accounts for the degradation of organic chemicals and radioactive decay. It was assumed that inorganics do not degrade with time. Tables 6-39 (organics) and 6-40 (radionuclides) show the estimated current and future hazard to the pocket mouse. After 500 years, the organic chemicals evaluated would degrade to levels that pose minimal risk. After 103 years, radionuclide activity would decay to levels that pose minimal risk.

6.2.2.3.2 Uncertainty. This ecological risk assessment is based only on estimates of an assumed exposure to the maximum concentration of all contaminants that may be disposed of at the ERDF. There is little likelihood that the evaluated scenario would occur. This evaluation does not calculate or incorporate the likelihood of this occurrence. There are no empirical data that can be used to validate the exposure estimates in this risk assessment. Estimating the potential exposure of a receptor to contaminants also required the use of a number of parameters for which there are no data. Many of these parameters are based on professional judgment in the absence of site- or species-specific information. Modeling from soil to potential ecological receptors required a number of assumptions including soil-to-plant, and plant-to-animal transfer factors or coefficients. If the review of the literature produced a range of values, the highest transfer factor was used in an attempt to be protective of the environment. No evaluation or critical review was conducted to determine if these transfer coefficients are relevant to conditions at the proposed ERDF site. The lack of species specific toxicity information and the assumptions and uncertainties incorporated into the estimates of NOAELs is another source of uncertainty.

6.3 RISK ASSESSMENT OF SOILS FOR THE 500-YEAR DRILLING SCENARIO

This section extends the risk assessment provided in Section 6.2 (for current exposure to soils) to determine the risks associated with the 500-year drilling scenario. As discussed below, this scenario is considered a reasonable soil exposure scenario for all the remedial alternatives (except no action) evaluated in Chapter 9.

All of the alternatives evaluated in Chapter 9 include active institutional controls (e.g., fences, signs, patrols), passive controls (e.g., markers and off-site records), and a surface barrier that is at least 4.6 m (15 feet) thick. It is assumed that institutional controls prevent intrusion into the waste for at least 100 years and that passive controls prevent intrusion for 500 years. Furthermore, it is assumed that because the waste is covered with at least 4.6 m (15 ft) of cover materials, intrusion into the waste due to excavation is precluded. Since none of the evaluated barriers can prevent penetration by a drilling rig, however, it is reasonable to assume that someone might inadvertently drill through the waste sometime after 500 years. The likelihood that someone will drill through the waste is not addressed.

This scenario assumes that 500 years of decay have occurred before the waste is brought to the surface. The decay parameters for organic contaminants and radionuclides are provided in Table 4-5 and 4-6 (inorganics are assumed not to decay). The drilling scenario assumes that waste is brought to the surface in the form of drill cuttings and eventually spread over an area of 100 m (328 ft) by 50 m (164 ft) to a depth of 15 cm (5.9 in.) for a total volume of 750 m^3

($26,000\ ft^3$). Assuming a drill bit diameter of 20 cm (7.9 in.) and a waste thickness of 20 m (66 ft) the total volume of waste brought to the surface is $0.63\ m^3$ ($22\ ft^3$). Dividing the volume of surface soil by the amount of waste results in a dilution factor of 1,190, which is rounded down to 1,000.

6.3.1 Human Health Evaluation

The human health risks associated with soil exposure to contaminants 500 years after the ERDF is closed are summarized in Table 6-27 for organic contaminants and Table 6-28 for radionuclides. Since metals do not decay, risks associated with metal contaminants 500 years after the ERDF is closed are the same as current risks (presented in Table 6-23). These risks are then diluted by a factor of 1,000 to reflect dilution with clean surface soils and the results are presented in Table 6-41 for non-radionuclides and Table 6-42 for radionuclides. The total hazard quotient is 0.05 and the maximum HQ is associated with copper (0.03). The total ICR is 9×10^{-7} for non-radionuclides (dominated by arsenic, beryllium, and chromium) and 3×10^{-5} for radionuclides (dominated almost entirely by uranium). Because uptake factors for these contaminants are relatively low, inclusion of a produce ingestion pathway is unlikely to significantly increase these risk values. The predicted HQ and ICR associated with the drilling scenario are below the goals established in the Tri-Party Agreement of 1 for HQ and 1×10^{-4} for ICR.

6.3.2 Ecological Evaluation of the Intruder Scenario

The intruder scenario results in a release of contaminants buried in the ERDF to the environment. This scenario occurs 500 years in the future and the circumstances of the release (well drilling) results in a thousand-fold dilution of the contaminant concentration. The ecological evaluation of base conditions (Section 6.2.2) showed that after 500 years of decay and degradation, radiological and organic contaminants had EHQs less than one. Therefore, there is little possibility of ecological impacts resulting from an intrusion into the ERDF waste at 500 years in the future. For inorganic contaminants, there is no change in concentration due to decay or degradation. The thousand-fold dilution results, however, in a thousand-fold reduction in the EHQs for inorganic contaminants. These results are shown in Table 6-43. The only contaminant that results in an EHQ that is greater than one is copper with an EHQ of 12. This indicates that there is a possibility of risk to environmental receptors associated with the intrusion scenario. It should be noted, however, that the background concentration of copper in soil (28.2 mg/kg; DOE-RL 1993i) results in an EHQ of 3, which has not resulted in an identifiable adverse impact to the environment. It is evident that the environmental exposure analysis results in an overestimate of risk to environmental receptors. The estimate of an EHQ of 12 for the intrusion scenario (due to copper) is within an order of magnitude of the EHQ calculated for background soils, which is typical of the uncertainty associated with risk estimates. Thus, it is likely that the intrusion scenario will not result in adverse impacts to the environment from any potential contaminants disposed in the ERDF.

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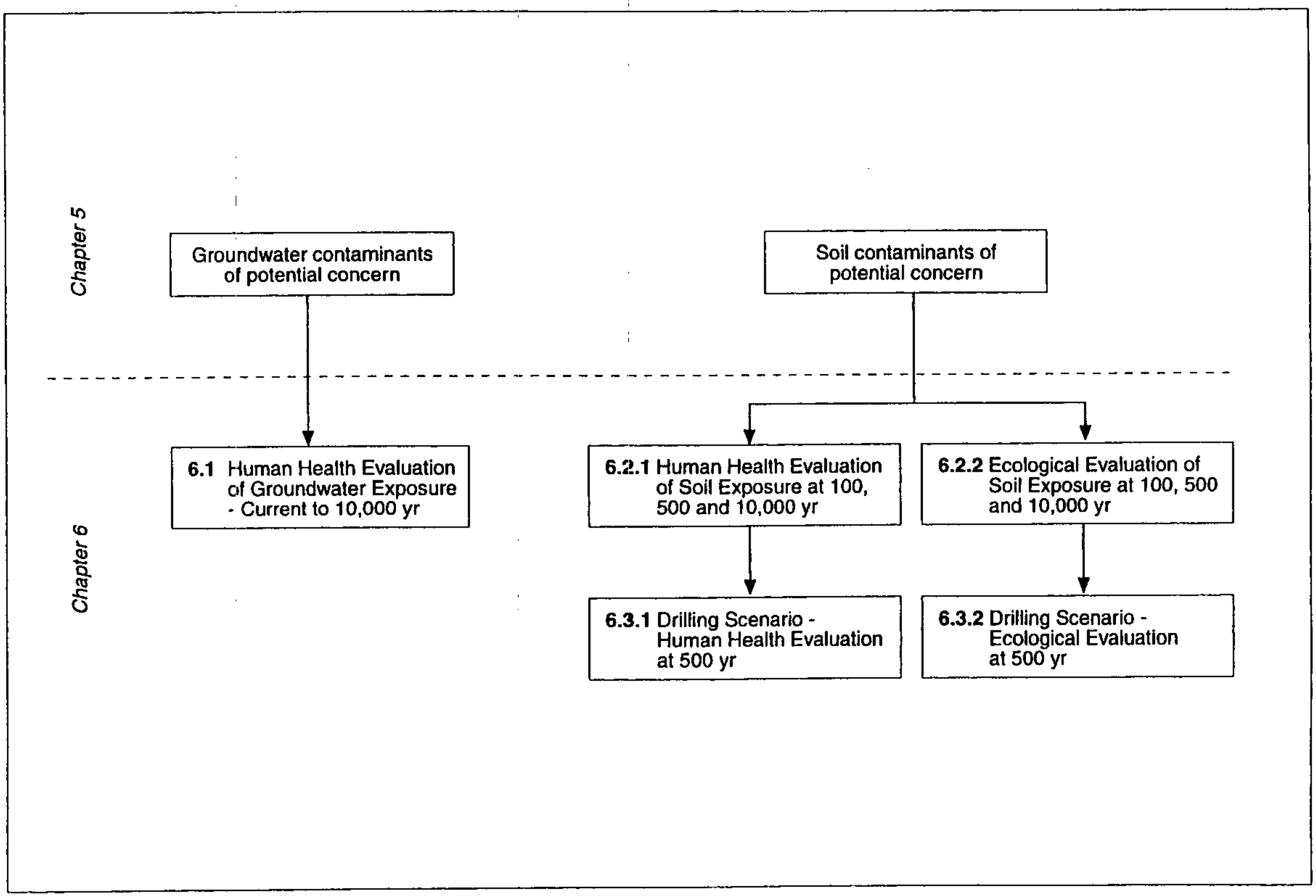

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Figure 6-1. Overview of Risk Assessment of Base Conditions.

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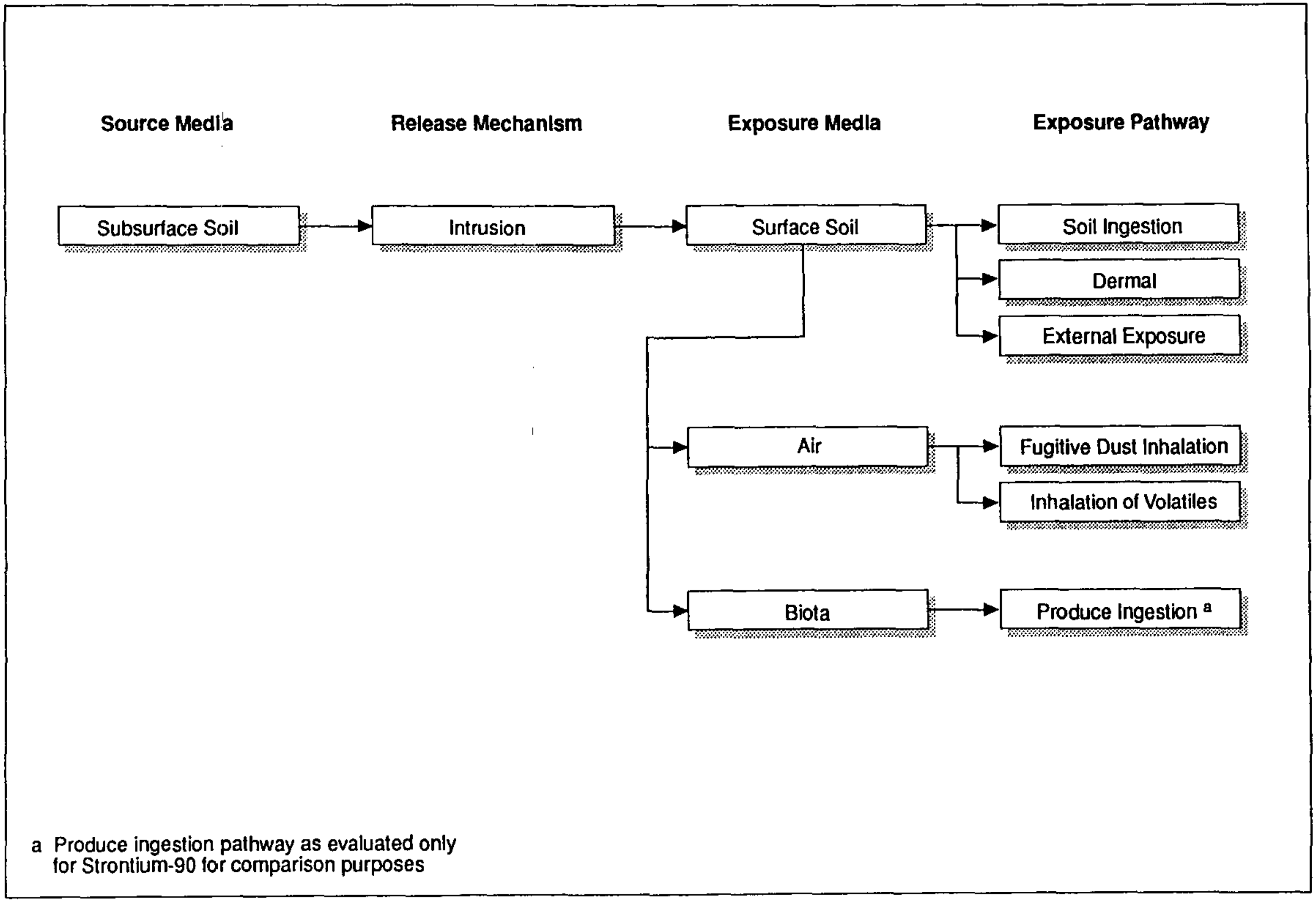

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Figure 6-2. Human Health Conceptual Model for Exposure to Contaminated Soils.

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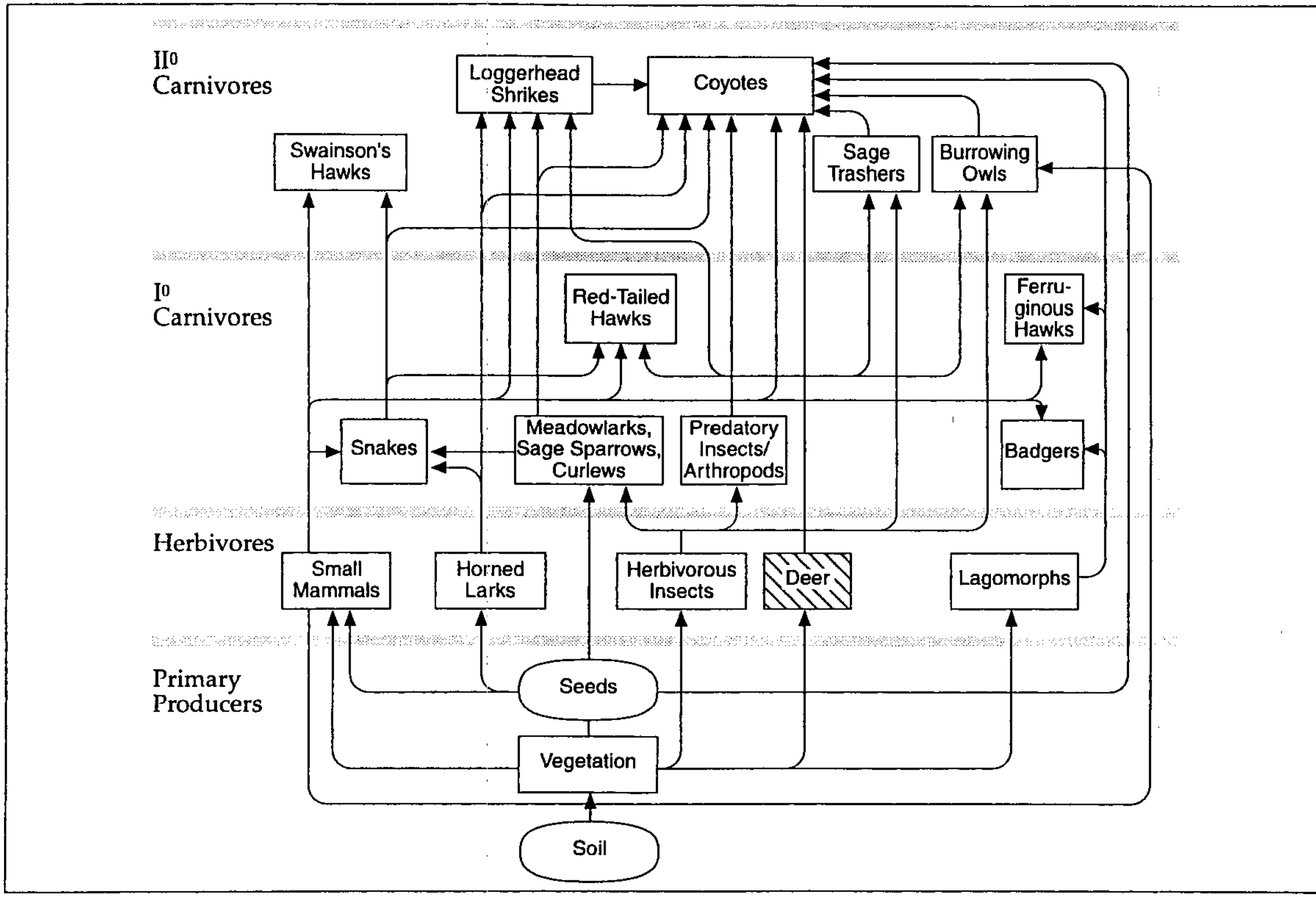

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Figure 6-3. Conceptual Model for the Ecological Risk Assessment of the Environmental Restoration Disposal Facility.

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Table 6-1. Residential Scenario Exposure Factors for Noncarcinogenic Contaminants[a].

Exposure Pathway		Exposure Parameters						
Media	Route	Daily Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors
Groundwater	Ingestion	1L	365	6	16	6 x 365	--	--
	Dermal	0.17 hr	365	30	70	30 x 365	1L/1,000cm^3	20,000cm^2 K_p

[a]Exposure parameters recommended in HSBRAM (DOE-RL 1993j).

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Table 6-2. Residential Scenario Exposure Factors for Carcinogenic (Non-Radioactive) Contaminants[a].

Exposure Pathway		Exposure Parameters						
Media	Route	Daily Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors
Groundwater	Ingestion	2L	365	30	70	70 x 365	--	--
	Dermal	0.17 hr	365	30	70	70 X 365	1 L/1,000 cm^3	20,000cm^2 K_p

[a]Exposure parameters recommended in HSBRAM (DOE-RL 1993j).

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Table 6-3. Residential Scenario Exposure Factors for Radioactive Contaminants[a].

Exposure Pathway		Exposure Parameters				
Media	Route	Daily Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors
Groundwater	Ingestion	2L	365	30	--	--

[a]Exposure parameters recommended in HSBRAM (DOE-RL 1993j).

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Table 6-4. Residential Summary Intake Factors[a].

Exposure Pathway		Summary Intake Factors		
Media	Route	Noncarcinogenic	Carcinogenic (Non-Radioactive)	Radioactive
Groundwater	Ingestion	6.3E-02	1.2E-02	2.2E+04
	Dermal	4.9E-02 x K_p[b]	2.1E-02 x K_p[b]	NA

[a]Based on default exposure parameter values provided in HSBRAM (DOE-RL 1993j) and Tables 6-1, 6-2, and 6-3. Summary intake factors are appropriate for water concentrations of mg/L (non-radioactive) and pCi/L (radioactive).
[b]Chemical-specific permeability coefficient (cm/hr) (Table 6-6 of this report).

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Table 6-5. Intakes and Risk Values for Groundwater Contaminants via Ingestion.

Contaminant	Noncarcinogen		Carcinogen	
	Intake	HQ	Intake	ICR
Inorganic Constituents	(mg/kg-d)		(mg/kg-d)	
Antimony	2.4E+00	6E+03		
Arsenic	3.8E+00	1E+04	7.2E-01	>1E-02 (1E+00)
Chromium (VI)	3.8E+00	8E+02		
Fluoride	3.8E+00	6E+01		
Nitrite (as N)	3.8E-01	4E+00		
Selenium	1.5E+00	3E+02		
Radionuclides	NA	NA	(pCi)	
Carbon-14			2.9E+10	>1E-02 (3E-02)
Technetium-99			5.1E+07	7E-05
Uranium (total)			2.4E+07	7E-04

HQ = hazard quotient
ICR = lifetime incremental cancer risk
NA = not applicable
Note: Blank cells indicate that toxicity values are currently unavailable with which to evaluate groundwater ingestion.
ICR values in parentheses are calculated using a linear cancer risk equation (Equation 6-5), and are not intended to represent accurate cancer risk estimates.

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Table 6-6. Intakes and Risk Values for Dermal Exposure to Groundwater[a].

Contaminant	Permeability Factor, K_p (cm/hr)[b]	Noncarcinogen		Carcinogen	
		Intake	HQ	Intake	ICR
Inorganic Constituents		(mg/L)		(mg/L)	
Antimony	1.0E-03	1.9E-03	5E+02		
Arsenic	1.0E-03	2.9E-03	2E+01	1.3E-03	5E-03
Chromium (VI)	1.0E-03	2.9E-03	6E+00		
Fluoride	1.0E-03	2.9E-03	5E-02		
Nitrite (as N)	1.0E-03	3.0E-04	3E-03		
Selenium	1.0E-03	1.2E-03	5E+00		

HQ = hazard quotient
ICR = lifetime incremental cancer risk

[a]Radionuclides are not evaluated for the dermal pathway.
[b]EPA 1992b.

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Table 6-7. Summary of Systemic Toxicity Information for Contaminants of Potential Concern.

Contaminant	Oral RfD mg/kg-d	Oral RfD (basis/source)	Confidence Level[a]	Critical Effect	Uncertainty Factors	Modifying Factors
Antimony	4.0E-04	water/IRIS	L	longevity, altered blood chemistry	1,000	1
Arsenic	3.0E-04	water/IRIS	M	hyperpigmentation, keratosis	3	1
Chromium (VI)	5.0E-03	water/IRIS	L	none observed	500	1
Fluoride	6.0E-02	water/IRIS	H	cosmetic effect of dental fluorosis	1	1
Nitrite (as N)	1.0E-01	water/IRIS	H	methemoglobinemia	1	10
Selenium	5.0E-03	food/IRIS	M	selenosis	3	1

[a] L = low, M = medium, H = high

RfD = refernce dose
IRIS = Integrated Risk Information System (EPA 1993a)

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Table 6-8. Summary of Carcinogenic Toxicity Information for Contaminants of Potential Concern.

Contaminant	Weight of Evidence Classification	Type of Cancer	Oral SF	Source
Non-radioactive			$(mg/kg\text{-}d)^{-1}$	
Arsenic	A	lung, skin	2E+00[a]	IRIS
Radioactive			$(pCi)^{-1}$	
Carbon-14	A	ND[b]	9.0E-13	HEAST
Technetium-99	A	ND[b]	1.3E-12	HEAST
Uranium (total)[c]	A	ND[b]	2.8E-11	HEAST

[a]Based on proposed arsenic unit risk of 5E-05 $(\mu g/L)^{-1}$.
[b]Carcinogenic effects of radioactive contaminants are based on effects of ionizing radiation generally. Human epidemiology data provide inadequate evidence of carcinogenicity for these isotopes.
[c]Uranium-238+D slope factor is used to evaluate total uranium.

SF = slope factor
ND = not determined
IRIS = Integrated Risk Information System (EPA 1993a)
HEAST = Health Effects Assessment Summary Tables (EPA 1993b)

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Table 6-9. Dermal Toxicity Values for Groundwater Contaminants of Potential Concern.[a]

Contaminant	GI Absorption Fraction	Dermal	
		RfD	SF
	(unitless)	(mg/kg-d)	$(mg/kg\text{-}d)^{-1}$
Inorganic Constituents			
Antimony	1E-02[c]	4.0E-06	
Arsenic	5E-01[c]	1.5E-04	4.0E+00
Chromium (VI)	1E-01[c]	5.0E-04	
Fluoride	1E+00[b]	6.0E-02	
Nitrite (as N)	1E+00[b]	1.0E-01	
Selenium	5E-02[c]	2.5E-04	

[a]See Table 5-1 for ingestion toxicity value.
[b]Data are currently unavailable to quantify absorption; contaminants are assumed to be 100% absorbed.
[c]EPA 1988b, Table 3.
Note: Radionuclides are not evaluated for the dermal pathway.

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Table 6-10. Summary of Groundwater Contaminants Risks and Travel Times.

Contaminant	Contaminant HQ Total	Contaminant ICR Total	Travel Time[a] (yr)
Inorganic Constituents			
Antimony	7E+03		5.2E+02
Arsenic	1E+04	>1E-02 (1E+00)	5.2E+02
Chromium (VI)	8E+02		5.2E+02
Fluoride	6E+01		5.2E+02
Nitrite (as N)	4E+00		5.2E+02
Selenium	3E+02		5.2E+02
Radionuclides			
Carbon-14	NA	>1E-02 (3E-02)	5.2E+02
Technetium-99	NA	7E-05	5.2E+02
Uranium (total)	NA	7E-04	5.2E+02

[a]From Table 4-11.
HQ = hazard quotient
ICR = lifetime incremental cancer risk
NA = not applicable
Shading indicates contaminants of concern.
Note: ICR values in parentheses are calculated using a linear cancer risk equation (Equation 6-5), and are not intended to represent accurate cancer risk estimates.

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Table 6-11. Residential Scenario Exposure Factors for Noncarcinogenic Contaminants[a].

Pathway		Exposure Parameters						
Media	Route	Daily Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg	365	6	16	6 x 365	1E-06 kg/mg	-
	Dermal	0.2 mg/cm^2	180	6 (C) 24 (A)	16 (C) 70 (A)	30 x 365	1E-06 kg/mg	2,500 cm^2(C) 5,000 cm^2(A) ABS
Air	Inhalation	10 m^3	365	6	16	6 x 365	-	-

[a]Exposure parameters recommended in HSBRAM (DOE-RL 1993j).
C = child
A = adult
ABS = chemical-specific absorption fraction

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Table 6-12. Residential Scenario Exposure Factors for Carcinogenic (Non-Radioactive) Contaminants[a].

Pathway		Exposure Parameters						
Media	Route	Daily Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Body Weight (kg)	Averaging Time (yr x d/yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg (C) 100 mg (A)	365	6 (C) 24 (A)	16 (C) 70 (A)	70 x 365	1E-06 kg/mg	-
	Dermal	0.2 mg/cm^2	180	6 (C) 24 (A)	16 (C) 70 (A)	70 x 365	1E-06 kg/mg	2,500 cm^2(C) 5,000 cm^2(A) ABS
Air	Inhalation	20 m^3	365	30	70	70 x 365	-	-

[a]Exposure parameters recommended in HSBRAM (DOE-RL 1993j).
C = child
A = adult
ABS = chemical-specific absorption fraction

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Table 6-13. Residential Scenario Exposure Factors for Radioactive Contaminants[a].

Pathway		Exposure Parameters				
Media	Route	Daily Intake Rate	Exposure Frequency (d/yr)	Exposure Duration (yr)	Conversion Factors	Other Factors
Soil	Ingestion	200 mg (C) 100 mg (A)	365	6 (C) 24 (A)	1E-03 g/mg	-
	External	24 hr	365	30	1.14E-04 yr/hr	0.8
Air	Inhalation	20 m^3	365	30	-	-
Biota	Ingestion	80 g	365	30	-	-

[a]Exposure parameters recommended in HSBRAM (DOE-RL 1993j).
C = child
A = adult

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Table 6-14. Residential Scenario Summary Intake Factors[a].

MEDIA	ROUTE	NONCARCINOGENIC	CARCINOGENIC (Non-Radioactive)	RADIOACTIVE
Soil	Ingestion	1.3E-05 $(d)^{-1}$	1.6E-06 $(d)^{-1}$	1.3E+03 g
	Dermal	8.75E-06 x ABS[a] $(d)^{-1}$	3.75E-06 x ABS[a] $(d)^{-1}$	NA
	External Exposure	NA	NA	2.4E+01 yr
Air	Inhalation	6.3E-01 m^3/kg-d	1.2E-01 m^3/kg-d	2.2E+05 m^3
Biota[b]	Ingestion	-	-	8.8E+06g

[a] Exposure parameters recommended in HSBRAM (DOE-RL 1993j).
[b] For this report, the biota pathway is evaluated only for strontium-90.
ABS = Chemical-specific absorption fraction (unitless).
NA = not applicable

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Table 6-15. Intakes and Risk Values for Non-Radioactive Soil Contaminants via Soil Ingestion[a]. (Sheet 1 of 2)

Contaminant	Noncarcinogen		Carcinogen	
	Intake (mg/kg-d)	HQ	Intake (mg/kg-d)	ICR
Organic Compounds				
Aroclor-1248			1.6E-05	1E-04
Aroclor-1254			1.0E-05	8E-05
Aroclor-1260			3.6E-06	3E-05
benz(a)anthracene			2.8E-06	2E-05
benzene			3.0E-07	9E-09
benzo(a)pyrene			4.2E-05	3E-04
benzo(b)fluoranthene			3.7E-06	3E-05
benzo(k)fluoranthene			1.2E-06	9E-06
bis(2-ethylhexyl)phthalate	4.1E-04	2E-02	5.1E-05	7E-07
chloroform	1.0E-06	1E-04	1.2E-07	8E-10
chrysene			6.7E-05	5E-04
dibenz(a,h)anthracene			2.7E-06	2E-05
dieldrin	2.6E-07	5E-03	3.3E-08	5E-07
indeno(1,2,3-cd)pyrene			2.5E-06	2E-05
methylene chloride	5.6E-05	9E-04	7.0E-06	5E-08
pentachlorophenol	1.9E-05	6E-04	2.3E-06	3E-07
trichloroethene	4.9E-06	8E-04	6.1E-07	7E-09
vinyl chloride			3.7E-08	7E-08
Inorganic Constituents				
aluminum	9.8E-01	1E+00		
ammonia				
antimony	2.3E-04	6E-01		
arsenic	7.8E-04	3E+00	9.7E-05	2E-04
barium	5.3E-02	8E-01		
beryllium	5.9E-05	1E-02	7.3E-06	3E-05

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Table 6-15. Intakes and Risk Values for Non-Radioactive Soil Contaminants via Soil Ingestion.[a] (Sheet 2 of 2)

Contaminant	Noncarcinogen		Carcinogen	
	Intake (mg/kg-d)	HQ	Intake (mg/kg-d)	ICR
cadmium	3.6E-04	4E-01		
chromium	3.1E-02	6E+00		
copper	1.2E+00	3E+01		
lead				
manganese	3.8E-02	3E-01		
mercury	4.6E-04	2E+00		
nickel	2.2E-02	1E+00		
silver	4.5E-03	9E-01		
thallium	6.8E-05	1E+00		
vanadium	4.9E-03	7E-01		
zinc	7.7E-02	3E-01		

[a] Assuming current residential exposure to maximum detected contaminant concentrations.
HQ = hazard quotient
ICR = lifetime incremental cancer risk
Note: Blank cells indicate that toxicity values are currently unavailable with which to evaluate soil ingestion.

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Table 6-16. Intake and Risk Values for Non-Radioactive Soil Contaminants via Dermal Pathway.[a] (Sheet 1 of 2)

Contaminant	ABS (unitless)	Noncarcinogen		Carcinogen	
		Intake (mg/kg-d)	HQ	Intake (mg/kg-d)	ICR
Organic Compounds					
Aroclor-1248	6E-02[b]			2.2E-06	2E-05
Aroclor-1254	6E-02[b]			1.4E-06	1E-05
Aroclor-1260	6E-02[b]			5.2E-07	4E-06
benz(a)anthracene	5E-02[c]			3.4E-07	2E-06
benzene	3E-01[c]			2.1E-07	6E-09
benzo(a)pyrene	5E-02[c]			5.0E-06	4E-05
benzo(b)fluoranthene	5E-02[c]			4.5E-07	3E-06
benzo(k)fluoranthene	5E-02[c]			1.4E-07	1E-06
bis(2-ethylhexyl)phthalate	5E-02[c]	1.4E-05	7E-04	6.2E-06	9E-08
chloroform	3E-01[c]	2.1E-07	2E-05	9.0E-08	5E-10
chrysene	5E-02[c]			8.0E-06	6E-05
dibenz(a,h)anthracene	5E-02[c]			3.2E-07	2E-06
dieldrin	5E-02[c]	9.2E-09	2E-04	3.9E-09	6E-08
indeno(1,2,3-cd)pyrene	5E-02[c]			3.0E-07	2E-06
methylene chloride	3E-01[c]	1.2E-05	2E-04	5.0E-06	4E-08
pentachlorophenol	5E-02[c]	6.5E-07	2E-05	2.8E-07	3E-08
trichloroethene	3E-01[c]	1.0E-06	2E-04	4.4E-07	5E-09
vinyl chloride	3E-01[c]			2.7E-08	5E-08
Inorganic Constituents					
aluminum	1E-02[b,c]	6.8E-03	7E-01		
ammonia	3E-01[c]				
antimony	1E-02[b,c]	1.6E-06	4E-01		
arsenic	1E-02[b,c]	5.4E-06	4E-02	2.3E-06	9E-06
barium	1E-02[b,c]	3.7E-04	5E-02		
beryllium	1E-02[b,c]	4.1E-07	2E-02	1.8E-07	2E-04

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Table 6-16. Intake and Risk Values for Non-Radioactive Soil Contaminants via Dermal Pathway.[a] (Sheet 2 of 2)

Contaminant	ABS (unitless)	Noncarcinogen		Carcinogen	
		Intake (mg/kg-d)	HQ	Intake (mg/kg-d)	ICR
cadmium	1E-02[b,c]	2.5E-06	5E-02		
chromium	1E-02[b,c]	2.2E-04	4E-01		
copper	1E-02[b,c]	8.3E-03	4E-01		
lead	1E-02[b,c]				
manganese	1E-02[b,c]	2.7E-04	2E-02		
mercury	1E-02[b,c]	3.2E-06	5E-01		
nickel	1E-02[b,c]	1.5E-04	2E-01		
silver	1E-02[b,c]	3.2E-05	1E-01		
thallium	1E-02[b,c]	4.7E-07	7E-03		
vanadium	1E-02[b,c]	3.4E-05	5E-01		
zinc	1E-02[b,c]	5.4E-04	4E-03		

[a]Assuming current residential exposure to maximum detected contaminant concentrations.
[b]EPA 1992b.
[c]Hawkins, et al. 1990.
ABS = dermal absorption factor
HQ = hazard quotient
ICR = lifetime incremental cancer risk
Note: Blank cells indicate that toxicity values are currently unavailable with which to evaluate dermal exposures. Radionuclides are not evaluated for the dermal pathway.

Table 6-17. Intake and Risk Values for Non-Radioactive Soil Contaminants via Fugitive Dust Inhalation.[a] (Sheet 1 of 2)

Contaminant	Noncarcinogen		Carcinogen	
	Intake (mg/kg-d)	HQ	Intake (mg/kg-d)	ICR
Organic Compounds				
Aroclor-1248				
Aroclor-1254				
Aroclor-1260				
benz(a)anthracene				
benzene			7.6E-10	2E-11
benzo(a)pyrene				
benzo(b)fluoranthene				
benzo(k)fluoranthene				
bis(2-ethylhexyl)phthalate				
chloroform			3.2E-10	3E-11
chrysene				
dibenz(a,h)anthracene				
dieldrin			8.5E-11	1E-09
indeno(1,2,3-cd)pyrene				
methylene chloride	9.3E-08	1E-07	1.8E-08	3E-11
pentachlorophenol				
trichloroethene			1.6E-09	9E-12
vinyl chloride			9.7E-11	3E-11
Inorganic Constituents				
aluminum				
ammonia	2.8E-06	1E-04		
antimony				
arsenic			2.5E-07	4E-06
barium	8.8E-05	9E-01		
beryllium			1.9E-08	2E-07

Table 6-17. Intake and Risk Values for Non-Radioactive Soil Contaminants via Fugitive Dust Inhalation.[a] (Sheet 2 of 2)

Contaminant	Noncarcinogen		Carcinogen	
	Intake (mg/kg-d)	HQ	Intake (mg/kg-d)	ICR
cadmium			1.1E-07	7E-07
chromium			1.0E-05	4E-04
copper				
lead				
manganese	6.3E-05	6E-01		
mercury	7.6E-07	8E-03		
nickel				
silver				
thallium				
vanadium				
zinc				

[a]Assuming current residential exposure to maximum detected contaminant concentrations.
HQ = hazard quotient
ICR = lifetime incremental cancer risk
Note: Blank cell indicate that toxicity values are currently unavailable with which to evaluate an inhalation pathway. Intake values based on particulate emission factor of 3.0E+07 m^3/kg.

Table 6-18. Intake and Risk Values for Non-Radioactive Soil Contaminants via Inhalation of Volatiles[a].

Contaminant	Noncarcinogen			Carcinogen	
	VF (m^3/kg)	Intake (mg/kg-d)	HQ	Intake (mg/kg-d)	ICR
Organic Compounds					
benzene	2.6E+03			8.9E-06	3E-07
chloroform	1.0E+03			9.8E-06	8E-07
methylene chloride	1.0E+03	2.8E-03	3E-03	5.5E-04	9E-07
trichloroethene	1.2E+03			4.0E-05	2E-07
vinyl chloride	6.0E+02			4.9E-06	1E-06
Inorganic Constituents					
ammonia	1.0E+03	8.6E-02	3E+00		

[a]Assuming current residential exposure to maximum detected contaminant concentrations.
VF = volatilization factor
HQ = hazard quotient
ICR = lifetime incremental cancer risk
Note: Intakes and risks are calculated only for volatile contaminants.
Blank cells indicate that toxicity values are currently unavailable with which to evaluate volatile inhalation.

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Table 6-19. Intake and Risk Values for Radioactive Soil Contaminants (All Pathways).[a] (Sheet 1 of 2)

Radionuclide	Soil Ingestion		Fugitive Dust Inhalation		External Exposure	
	Intake (pCi)	ICR	Intake (pCi)	ICR	Intake (pCi)	ICR
americium-241	4.5E+04	1E-05	2.5E+02	8E-06	8.2E+02	4E-06
barium-140	5.2E+05	1E-06	2.9E+03	6E-09	9.6E+03	5E-03
beryllium-7	1.2E+05	4E-09	6.5E+02	2E-10	2.2E+03	3E-04
carbon-14	8.4E+05	8E-07	4.6E+03	3E-11	1.5E+04	0
cerium-141	3.9E+03	3E-09	2.2E+01	2E-10	7.2E+01	9E-06
cerium-144	6.6E+02	4E-09	3.6E+00	1E-09	1.2E+01	3E-07
cesium-134	7.3E+04	3E-06	4.0E+02	1E-08	1.3E+03	7E-03
cesium-137	1.4E+08	4E-03	7.9E+05	2E-05	2.6E+06	5E+00
chromium-51	4.5E+03	2E-10	2.5E+01	8E-12	8.3E+01	8E-06
cobalt-58	1.8E+04	3E-08	1.0E+02	1E-09	3.4E+02	1E-03
cobalt-60	1.4E+07	2E-04	7.9E+04	1E-05	2.6E+05	2E+00
europium-152	3.8E+07	8E-05	2.1E+05	2E-05	7.0E+05	3E+00
europium-154	1.2E+07	4E-05	6.6E+04	9E-06	2.2E+05	9E-01
europium-155	1.3E+07	6E-06	6.9E+04	1E-06	2.3E+05	1E-02
hydrogen-3	3.8E+07	2E-06	2.1E+05	2E-08	7.0E+05	0
iron-59	1.3E+03	4E-09	7.2E+00	7E-11	2.4E+01	1E-04
manganese-54	9.2E+01	1E-10	5.1e-01	3E-12	1.7E+00	5E-06
nickel-63	8.1E+07	2E-05	4.5E+05	8E-07	1.5E+06	0

Table 6-19. Intake and Risk Values for Radioactive Soil Contaminants (All Pathways).[a] (Sheet 2 of 2)

Radionuclide	Soil Ingestion		Fugitive Dust Inhalation		External Exposure	
	Intake (pCi)	ICR	Intake (pCi)	ICR	Intake (pCi)	ICR
plutonium-238	1.8E+05	4E-05	1.0E+03	4E-05	3.4E+03	9E-08
plutonium-239/240	3.7E+06	8E-04	2.0E+04	8E-04	6.7E+04	2E-06
radium-226	5.6E+04	7E-06	3.1E+02	9E-07	1.0E+03	6E-03
ruthenium-103	1.3E+03	1E-09	7.2E+00	6E-11	2.4E+01	4E-05
sodium-22	1.3E+04	9E-08	7.2E+01	3E-10	2.4E+02	2E-03
strontium-90[b]	2.6E+06	9E-05	1.4E+04	9E-07	4.8E+04	0
thorium-228	2.2E+04	1E-06	1.2E+02	9E-06	4.0E+02	2E-03
thorium-232	4.6E+03	6E-08	2.6E+01	7E-07	8.5E+01	2E-09
uranium (total)	2.6E+07	7E-04	1.4E+05	8E-03	4.8E+05	2E-02
zinc-65	3.9E+02	3E-09	2.2E+00	3E-11	7.2E+00	1E-05
zirconium-95	7.3E+02	7E-10	4.0E+00	4E-11	1.3E+01	3E-05

[a] Assuming current residential exposure to maximum detected contaminant concentrations.
[b] The biota ingestion intake value for strontium-90 is 1.4E+08 pCi, with an associated ICR of 5E-03.
ICR = lifetime incremental cancer risk

Table 6-20. Summary of Systemic Toxicity Information for Soil Contaminants of Potential Concern (COPC) at the ERDF. (Sheet 1 of 3)

Contaminant	Oral RfD mg/kg-d	Oral RfD[a,b] (basis/source)	Confidence Level	Critical Effect	Uncertainty Factors	Modifying Factors	Inhalation RfD mg/kg-d	Inhalation RfD[a,b] (basis/source)	Confidence Level	Critical Effect	Uncertainty Factors	Modifying Factors
INORGANIC CONSTITUENTS												
Aluminum	1.0E+00	oral/STSC	M	decreased body weight, neurotoxicity	100	1	ND	--	--	--	--	--
Ammonia	34[e]	oral/HEAST	--	taste	1	1	2.9E-02	air/IRIS	M	respiratory effects	30	1
Antimony	4.0E-04	water/IRIS	L	longevity, altered blood chemistry	1000	1	ND	--	--	--	--	--
Arsenic	3.0E-04	water/IRIS	M	hyper-pigmentation, keratosis	3	1	ND	--	--	--	--	--
Barium	7.0E-02	water/IRIS	M	increased blood pressure	3	1	1E-04	HEAST	--	reproductive effects	1000	--
Beryllium	5.0E-03	water/IRIS	L	none observed	100	1	ND	--	--	--	--	--
Cadmium	1.0E-03	food/IRIS	H	proteinuria	10	1	ND	--	--	--	--	--
Chromium (VI)	5.0E-03	water/IRIS	L	none observed	500	1	ND	--	--	--	--	--
Copper	4.0E-02	oral/STSC[d]	--	GI irritation	--	--	ND	--	--	--	--	--
Lead	ND	IRIS	--	blood enzyme level changes, neuro behavioral development of children	--	--	ND	--	--	--	--	--
Manganese	1.4E-01	food/IRIS	M	CNS effect	1	1	1.1E-04	air/IRIS	M	respiratory symptoms, psychomotor disturbances	300	3
Mercury	3.0E-04	oral/HEAST	--	kidney toxicity	1000	--	8.6E-05	oral/HEAST	--	neurotoxicity	30	--

Table 6-20. Summary of Systemic Toxicity Information for Soil Contaminants of Potential Concern (COPC) at the ERDF. (Sheet 2 of 3)

Contaminant	Oral RfD mg/kg-d	Oral RfD[a,b] (basis/source)	Confidence Level	Critical Effect	Uncertainty Factors	Modifying Factors	Inhalation RfD mg/kg-d	Inhalation RfD[a,b] (basis/source)	Confidence Level	Critical Effect	Uncertainty Factors	Modifying Factors
Nickel	2.0E-02	food/IRIS	M	decreased body, organ weight	300	--	ND	--	--	--	--	--
Silver	5.0E-03	intravenous/ IRIS	L	argyria	3	1	ND	--	--	--	--	--
Thallium (oxide)	7.0E-05	oral/IRIS	--	increased SGOT	3000	--	ND	--	--	--	--	--
Vanadium	7.0E-03	water/HEAST	--	none observed	100	--	ND	--	--	--	--	--
Zinc	3.0E-01	oral/IRIS	M	decrease in erythrocyte superoxide dismutase	3	1	ND	--	--	--	--	--
ORGANIC COMPOUNDS												
Aroclor-1248	ND	--	--	--	--	--	ND	--	--	--	--	--
Aroclor-1254	ND	--	--	--	--	--	ND	--	--	--	--	--
Aroclor-1260	ND	--	--	--	--	--	ND	--	--	--	--	--
Benz(a)anthracene	ND	--	--	--	--	--	ND	--	--	--	--	--
Benzene	ND	--	--	--	--	--	ND	--	--	--	--	--
Benzo(a)pyrene	ND	--	--	--	--	--	ND	--	--	--	--	--
Benzo(b)fluoranthene	ND	--	--	--	--	--	ND	--	--	--	--	--
Benzo(k)fluoranthene	ND	--	--	--	--	--	ND	--	--	--	--	--
Bis-2(ethylhexyl)-phthalate	2.0E-02	oral/IRIS	M	increased liver weight	1000	1	ND	--	--	--	--	--
Chloroform	1.0E-02	oral/IRIS	M	fatty cyst formation in liver	1000	1	ND	--	--	--	--	--
Chrysene	ND	--	--	--	--	--	ND	--	--	--	--	--

Table 6-20. Summary of Systemic Toxicity Information for Soil Contaminants of Potential Concern (COPC) at the ERDF. (Sheet 3 of 3)

Contaminant	Oral RfD mg/kg-d	Oral RfD[a,b] (basis/source)	Confidence Level	Critical Effect	Uncertainty Factors	Modifying Factors	Inhalation RfD mg/kg-d	Inhalation RfD[a,b] (basis/source)	Confidence Level	Critical Effect	Uncertainty Factors	Modifying Factors
Dibenz(a,h)anthracene	ND	--	--	--	--	--	ND	--	--	--	--	--
Dieldrin	5.0E-05	oral/IRIS	--	--	--	--	ND	--	--	--	--	--
Indeno(1,2,3-cd) pyrene	ND	--	--	--	--	--	ND	--	--	--	--	--
Methylene Chloride	6.0E-02	water/IRIS	M	liver toxicity	100	1	9.0E-01	air/HEAST	--	liver toxicity	100	--
Pentachlorophenol	3.0E-02	oral/IRIS	M	liver & kidney pathology	100	1	ND	--	--	--	--	--
Trichloroethene	6.0E-03	-/STSC	L	--	3000	1	ND	--	--	--	--	--
Vinyl chloride	ND	--	--	--	--	--	--	--	--	--	--	--

[a]Integrated Risk Information System (IRIS, EPA 1993a).
[b]Health Effects Assessment Summary Tables (HEAST, EPA 1993b).
[c]2-Butanone is used as a surrogate for 2-Hexanone [HEAST EPA (1993b) indicates that 2-Hexanone data are inadequate for quantitative risk assessment].
[d]Superfund Technical Support Center (EPA 1991a).
[e]Value based on taste threshold, expressed as mg/L.
L = Low
M = Medium
H = High
RfD = Reference Dose
ND = Not determined
STSC = Superfund Technical Support Center
-- = Not applicable

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Table 6-21. Summary of Carcinogenic Toxicity Information for Soil Contaminants of Potential Concern at the ERDF. (Sheet 1 of 3)

Contaminant	Weight of Evidence Classification	Type of Cancer	Oral SF[a]	Inhalation SF[a]	External SF[a]
RADIONUCLIDES			$(pCi)^{-1}$	$(pCi)^{-1}$	$(pCi\text{-}yr/g)^{-1}$
Americium-241	A	-[g]	2.4E-10	3.2E-08	4.9E-09
Barium-140	A	-[g]	2.7E-12	2.0E-12	5.4E-07
Beryllium-7	A	-[g]	3.0E-14	2.7E-13	1.5E-07
Carbon-14	A	-[g]	9.0E-13	6.4E-15	-[b]
Cerium-141	A	-[g]	8.3E-13	8.4E-12	1.3E-07
Cerium-144	A	-[g]	6.1E-12	3.4E-10	2.5E-08
Cesium-134	A	-[g]	4.1E-11	2.8E-11	5.2E-06
Cesium-137	A	-[g]	2.8E-11	1.9E-11	2.0E-06
Chromium-51	A	-[g]	4.3E-14	3.0E-13	9.2E-08
Cobalt-58	A	-[g]	1.6E-12	9.8E-12	3.3E-06
Cobalt-60	A	-[g]	1.5E-11	1.5E-10	8.6E-06
Europium-152	A	-[g]	2.1E-12	1.1E-10	3.6E-06
Europium-154	A	-[g]	3.0E-12	1.4E-10	4.1E-06
Europium-155	A	-[g]	4.5E-13	1.8E-11	5.9E-08
Iron-59	A	-[g]	2.8E-12	9.7E-12	4.1E-06
Manganese-54	A	-[g]	1.1E-12	5.3E-12	2.9E-06
Nickel-63	A	-[g]	2.4E-13	1.8E-12	-[b]
Plutonium-238	A	-[g]	2.2E-10	3.9E-08	2.8E-11
Plutonium-239/240	A	-[g]	2.3E-10	3.8E-08	2.7E-11
Radium-226	A	bone	1.2E-10	3.0E-09	6.0E-06
Ruthenium-103	A	-[g]	9.0E-13	8.4E-12	1.5E-06

Table 6-21. Summary of Carcinogenic Toxicity Information for Soil Contaminants of Potential Concern at the ERDF. (Sheet 2 of 3)

Contaminant	Weight of Evidence Classification	Type of Cancer	Oral SF[a]	Inhalation SF[a]	External SF[a]
Sodium-22	A	-[g]	6.8E-12	4.8E-12	7.2E-06
Strontium-90	A	-[g]	3.6E-11	6.2E-11	-[b]
Thorium-228	A	liver	5.5E-11	7.8E-08	5.6E-06
Thorium-232	A	liver	1.2E-11	2.8E-08	2.6E-11
Tritium (hydrogen-3)	A	-[g]	5.4E-14	7.8E-14	-[b]
Uranium (total)[c]	A	-[g]	2.8E-11	5.2E-08	3.6E-08
Zinc-65	A	-[g]	8.5E-12	1.6E-11	2.0E-06
Zirconium-95	A	-[g]	9.9E-13	1.0E-11	2.5E-06
INORGANIC CONSTITUENTS			$(mg/kg\text{-}d)^{-1}$	$(mg/kg\text{-}d)^{-1}$	NA
Arsenic	A	lung, skin	1.8E+00[d,e]	1.5E+01[d,f]	NA
Beryllium	B2	-	4.3E+00[d]	8.4E+00[d]	NA
Cadmium	B1	lung	ND	6.3E+00[d]	NA
Chromium (as VI)	A	lung	-[h]	4.2E+01[d]	NA
Nickel	A	lung	ND	8.4E-01[a,i]	NA
ORGANIC COMPOUNDS			$(mg/kg\text{-}d)^{-1}$	$(mg/kg\text{-}d)^{-1}$	NA
Aroclor-1248[j]	B2	liver	7.7E+00[d]	ND	NA
Aroclor-1254[j]	B2	liver	7.7E+00[d]	ND	NA
Aroclor-1260	B2	liver	7.7E+00[d]	ND	NA
Benz(a)anthracene	B2	liver, lung	7.3E+00[k]	-	NA
Benzene	A	leukemia	2.9E-02[d]	2.9E-02[d]	NA
Benzo(a)pyrene	B2	gross tissue tumors	7.3E+00[d]	-	NA
Benzo(b)fluoranthene	B2	liver, lung	7.3E+00[k]	-	NA

Table 6-21. Summary of Carcinogenic Toxicity Information for Soil Contaminants of Potential Concern at the ERDF. (Sheet 3 of 3)

Contaminant	Weight of Evidence Classification	Type of Cancer	Oral SF[a]	Inhalation SF[a]	External SF[a]
Benzo(k)fluoranthene	B2	liver, lung	7.3E+00[k]	-	NA
Bis(2-ethylhexyl)phthalate	B2	liver	1.4E-02[d]	ND	NA
Chloroform	B2	hepatocellular carcinomas, kidney	6.1E-03[d]	8.1E-02[d]	NA
Chrysene	B2	liver, lung, lymph glands	7.3E+00[k]	-	NA
Dibenz(a,h)anthracene	B2	lung, mammary	7.3E+00[k]	-	NA
Dieldrin	B2	liver	1.6E+01[d]	1.6E+01[d]	NA
Indeno(1,2,3-cd)pyrene	B2	skin, lung/thorax	7.3E+00[k]	-	NA
Methylene Chloride	B2	-	7.5E-03[d]	1.6E-03[d]	NA
Pentachlorophenol	B2	hepatocellular carcinomas	1.2E-01[d]	-	NA
Trichloroethene	C-B2[l]	-	1.1E-02[l]	6.0E-03[l]	NA

[a] All radionuclide slope factors are from Health Effects Summary Tables (HEAST, EPA 1993b). Sources for other SFs are as indicated.
[b] Not an external exposure hazard.
[c] As uranium-238+D
[d] Integrated Risk Information System (IRIS, EPA 1993a).
[e] Based on the proposed arsenic unit risk of 5E-05 ug/L (IRIS, EPA 1993a).
[f] This slope factor is used for the amount inhaled, does not account for the 30% absorption of arsenic.
[g] Carcinogenic effects of radioactive contaminants are based on effects of ionizing radiation generally. Human epidemiology data provide inadequate evidence of carcinogenicity for these isotopes.
[h] Not considered carcinogenic through this exposure pathway.
[i] Nickel as refinery dust is considered carcinogenic.
[j] The potency of PCB cogeners vary greatly, Aroclor 1260 is assumed to be representative of all PCB cogener mixtures.
[k] SF value for benzo(a)pyrene used as a surrogate based on structure-activity relationships.
[l] Superfund Technical Support Center (EPA 1992c).
NA - Not applicable
ND = Not Determined
SF = Slope factor

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Table 6-22. Dermal Toxicity Values for Soil Contaminants of Potential Concern.[a] (Sheet 1 of 2)

Contaminant	GI Absorption Fraction (unitless)	Dermal	
		RfD (mg/kg-d)	SF $(mg/kg\text{-}d)^{-1}$
Organic Compounds			
Aroclor-1248	9E-01[b]		8.6E+00
Aroclor-1254	9E-01[b]		8.6E+00
Aroclor-1260	9E-01[b]		8.6E+00
benz(a)anthracene	1E+00[c]		7.3E+00
benzene	1E+00[d]		2.9E-02
benzo(a)pyrene	1E+00[c]		7.3E+00
benzo(b)fluoranthene	1E+00[c]		7.3E+00
benzo(k)fluoranthene	1E+00[c]		7.3E+00
bis(2-ethylhexyl)phthalate	1E+00[c]	2.0E-02	1.4E-02
chloroform	1E+00[d]	1.0E-02	6.1E-03
chrysene	1E+00[c]		7.3E+00
dibenz(a,h)anthracene	1E+00[c]		7.3E+00
dieldrin	1E+00[c]	5.0E-05	1.6E+01
indeno(1,2,3-cd)pyrene	1E+00[c]		7.3E+00
methylene chloride	1E+00[d]	6.0E-02	7.5E-03
pentachlorophenol	1E+00[e]	3.0E-02	1.2E-01
trichloroethene	1E+00[d]	6.0E-03	1.1E-02
vinyl chloride	1E+00[d]		1.9E+00
Inorganic Constituents			
aluminum	1E-02[f]	1.0E-02	
ammonia	-	no toxicity values	
antimony	1E-02[f]	4.0E-06	
arsenic	5E-01[f]	1.5E-04	4.0E+00
barium	1E-01[f]	7.0E-03	
beryllium	5E-03[f]	2.5E-05	8.6E+02

Table 6-22. Dermal Toxicity Values for Soil Contaminants of Potential Concern.[a] (Sheet 2 of 2)

Contaminant	GI Absorption Fraction (unitless)	Dermal	
		RfD (mg/kg-d)	SF $(mg/kg\text{-}d)^{-1}$
cadmium (food)	5E-02[f]	5.0E-05	
chromium (VI)	1E-01[f]	5.0E-04	
copper	5E-01[f]	2.0E-02	
lead	-	no toxicity values	
manganese (food)	1E-01[f]	1.4E-02	
mercury	2E-02[f]	6.0E-06	
nickel	5E-02[f]	1.0E-03	
silver	5E-02[f]	2.5E-04	
thallium (oxide)	1E+00[f]	7.0E-05	
vanadium	1E-02[f]	7.0E-05	
zinc	5E-01[f]	1.5E-01	

[a]See Table 5-1 for ingestion toxicity values.
[b]SRC 1991.
[c]Assumption. Data are not currently available to quantify absorption.
[d]Assumption. Volatile contaminants are assumed to be completely absorbed.
[e]Clement Associates 1989.
[f]EPA 1988b, Table 3.
GI = gastrointestial
RfD = reference dose
SF = slope factor
Note: Radionuclides are not evaluated for the dermal pathway.

Table 6-23. Summary of Current Non-Radioactive Soil Contaminant Risks.[a] (Sheet 1 of 2)

Contaminant	Contaminant HQ Total	Contaminant ICR Total
Organic Compounds		
Aroclor-1248		1E-04
Aroclor-1254		9E-05
Aroclor-1260		3E-05
benz(a)anthracene		2E-05
benzene		3E-07
benzo(a)pyrene		3E-04
benzo(b)fluoranthene		3E-05
benzo(k)fluoranthene		1E-05
bis(2-ethylhexyl)phthalate	2E-02	8E-07
chloroform	1E-04	8E-07
chrysene		5E-04
dibenz(a,h)anthracene		2E-05
dieldrin	5E-03	6E-07
indeno(1,2,3-cd)pyrene		2E-05
methylene chloride	4E-03	1E-06
pentachlorophenol	6E-04	3E-07
trichloroethene	1E-03	2E-07
vinyl chloride		2E-06
Inorganic Constituents		
aluminum	2E+00	
ammonia	3E+00	
antimony	1E+00	
arsenic	3E+00	2E-04
barium	2E+00	
beryllium	3E-02	2E-04
cadmium	4E-01	7E-07
chromium	7E+00	4E-04

Table 6-23. Summary of Current Non-Radioactive Soil Contaminant Risks.[a] (Sheet 2 of 2)

Contaminant	Contaminant HQ Total	Contaminant ICR Total
copper	3E+01	
lead		
manganese	9E-01	
mercury	2E+00	
nickel	1E+00	
silver	1E+00	
thallium	1E+00	
vanadium	1E+00	
zinc	3E-01	
Total	-[b]	2E-03

[a]Assuming current residential exposure to maximum detected contaminant concentrations. Exposure pathways include soil ingestion, dermal, fugitive dust inhalation, and inhalation of volatiles.
[b]Contaminant HQs are not summed because they represent different critical effects
HQ = hazard quotient
ICR = lifetime incremental cancer risk

Table 6-24. Summary of Current Radioactive Soil Contaminant Risks.[a]

Radionuclide	Radionuclide ICR Total
americium-241	2E-05
barium-140	5E-03
beryllium-7	3E-04
carbon-14	8E-07
cerium-141	9E-06
cerium-144	3E-07
cesium-134	7E-03
cesium-137	>1E-02 (5E+00)
chromium-51	8E-06
cobalt-58	1E-03
cobalt-60	>1E-02 (2E+00)
europium-152	>1E-02 (3E+00)
europium-154	>1E-02 (9E-01)
europium-155	1E-02
hydrogen-3	2E-06
iron-59	1E-04
manganese-54	5E-06
nickel-63	2E-05
plutonium-238	8E-05
plutonium-239/240	2E-03
radium-226	6E-03
ruthenium-103	4E-05
sodium-22	2E-03
strontium-90[b]	9E-05
thorium-228	2E-03
thorium-232	8E-07
uranium (total)	>1E-02 (3E-02)
zinc-65	1E-05
zirconium-95	3E-05
Total	>1E-02 (1E+01)

[a]Assuming current residential exposure to maximum detected contaminant concentrations. Exposure pathways include soil ingestion, fugitive dust inhalation, and external exposure.
[b]The produce ingestion ICR is 5E-03.
ICR = lifetime incremental cancer risk
Note: ICR values greater than 1E-02 are reported as ">1E-02". ICR values in parentheses are calculated using a linear cancer risk equation (Equation 6-5), and are not intended to represent accurate cancer risk estimates.

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Table 6-25. Summary of Future Non-Radioactive Soil Contaminants Risks.[a] (Sheet 1 of 2)

Contaminant	Half-life[b] (yr)	Future HQ Total (2096)	Future ICR Total (2096)
Organic Compounds			
Aroclor-1248	1		1E-35
Aroclor-1254	10000		9E-05
Aroclor-1260	10000		3E-05
benz(a)anthracene	10		2E-08
benzene	10		2E-10
benzo(a)pyrene	100		2E-04
benzo(b)fluoranthene	10		2E-08
benzo(k)fluoranthene	100		5E-06
bis(2-ethylhexyl)phthalate	10	2E-05	6E-10
chloroform	10	1E-07	6E-10
chrysene	10		4E-07
dibenz(a,h)anthracene	10		2E-08
dieldrin	10	4E-06	5E-10
indeno(1,2,3-cd)pyrene	10		2E-08
methylene chloride	1	4E-34	1E-37
pentachlorophenol	10	5E-07	2E-10
trichloroethene	10	8E-07	2E-10
vinyl chloride	10		1E-09
Inorganic Constituents			
aluminum	-[c]	2E+00	
ammonia	-[d]	0E+00	
antimony	-[c]	1E+00	
arsenic	-[c]	3E+00	2E-04
barium	-[c]	2E+00	
beryllium	-[c]	3E-02	2E-04
cadmium	-[c]	4E-01	7E-07

Table 6-25. Summary of Future Non-Radioactive Soil Contaminants Risks.[a] (Sheet 2 of 2)

Contaminant	Half-life[b] (yr)	Future HQ Total (2096)	Future ICR Total (2096)
chromium	-[c]	7E+00	4E-04
copper	-[c]	3E+01	
lead	-[c]		
manganese	-[c]	9E-01	
mercury	-[c]	2E+00	
nickel	-[c]	1E+00	
silver	-[c]	1E+00	
thallium	-[c]	1E+00	
vanadium	-[c]	1E+00	
zinc	-[c]	3E-01	
Total		5E+01	1E-03

[a] Risk values decayed for 103 yr.
[b] From Table 4-5.
[c] Assumed not to degrade.
[d] Half-life not available; assumed to completely degrade. Ammonia converts to nitrate under aerobic conditions (HSDB 1994).
HQ = hazard quotient
ICR = lifetime incremental cancer risk
Shading indicates contaminants of concern.

Table 6-26. Summary of Future Radioactive Soil Contaminant Risk.[a] (Sheet 1 of 2)

Radionuclide	Half-life[b] (yr)	Future ICR Total (2096)
americium-241	4.32E+02	2E-05
barium-140	3.50E-02	0
beryllium-7	1.46E-01	0
carbon-14	5.73E+03	7E-07
cerium-141	8.90E-02	0
cerium-144	7.78E-01	0
cesium-134	2.06E+00	6E-18
cesium-137	3.02E+01	>1E-02 (5E-01)
chromium-51	7.58E-02	0
cobalt-58	1.94E-01	0
cobalt-60	5.27E+00	3E-06
europium-152	1.36E+01	1E-02
europium-154	8.80E+00	3E-04
europium-155	4.96E+00	8E-09
hydrogen-3	1.23E+01	6E-09
iron-59	1.22E-01	0
manganese-54	8.57E-01	0
nickel-63	1.00E+02	1E-05
plutonium-238	8.78E+01	4E-05
plutonium-239/240	2.41E+04	2E-03
radium-226	1.60E+03	6E-03
radium-228[c]	1.41E+10[c]	3E-04
ruthenium-103	1.08E-01	0
sodium-22	2.60E+00	2E-15
strontium-90[d]	2.86E+01	8E-06
thorium-228[c]	1.41E+10[c]	5E-04
thorium-232	1.41E+10	8E-07
uranium (total)	4.47E+09	>1E-02 (3E-02)

Table 6-26. Summary of Future Radioactive Soil Contaminant Risk.[a] (Sheet 2 of 2)

Radionuclide	Half-life[b] (yr)	Future ICR Total (2096)
zinc-65	6.68E-01	0
zirconium-95	1.75E-01	0
Total		>1E-02 (5E-01)

[a]Risk values decayed for 103 yr.
[b]From Table 4-6.
[c]Assumed to be in equilibrium with thorium-232. Radium-228 and thorium-228 are evaluated using "+D" slope factors, thorium-232 soil concentration, and thorium-232 half-life.
[d]The future ICR for strontium-90 via produce ingestion is 5E-04.
ICR = lifetime incremental cancer risk
Note: ICR values greater than 1E-02 are reported as ">1E-02". ICR values in parentheses are calculated using a linear cancer risk equation (Equation 6-5), and are not intended to represent accurate cancer risk estimates.
Shading indicates contaminants of concern.

Table 6-27. Future Risks Associated with Organic Contaminants in Soil (500 and 10,000 yr).[a]

Contaminant	Decay Time = 500 yr		Decay Time = 10,000 yr	
	HQ Total	ICR Total	HQ Total	ICR Total
Organic Compounds				
Aroclor-1248	0	0	0	0
Aroclor-1254	0	8E-05	0	4E-05
Aroclor-1260	0	3E-05	0	2E-05
benz(a)anthracene	0	2E-20	0	0
benzene	0	2E-22	0	0
benzo(a)pyrene	0	1E-05	0	3E-34
benzo(b)fluoranthene	0	2E-20	0	0
benzo(k)fluoranthene	0	3E-07	0	8E-36
bis(2-ethylhexyl)phthalate	2E-17	7E-22	0	0
chloroform	1E-19	7E-22	0	0
chrysene	0	5E-19	0	0
dibenz(a,h)anthracene	0	2E-20	0	0
dieldrin	5E-18	5E-22	0	0
indeno(1,2,3-cd)pyrene	0	2E-20	0	0
methylene chloride	0	0	0	0
pentachlorophenol	6E-19	3E-22	0	0
trichloroethene	9E-19	2E-22	0	0
vinyl chloride	0	1E-21	0	0
Total	3E-17	1E-04	0	6E-05

[a]Half-lives listed in Table 6-25.
HQ = hazard quotient
ICR = lifetime incremental cancer risk
Shading indicates contaminants of concern.

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Table 6-28. Future Risks Associated with Radioactive Contaminants in Soil (500 yr and 10,000 yr).[a] (Sheet 1 of 2)

Radionuclide	ICR after Decay Time = 500 yr	ICR after Decay Time = 10,000 yr
americium-241	1E-05	2E-12
barium-140	0	0
beryllium-7	0	0
carbon-14	7E-07	2E-07
cerium-141	0	0
cerium-144	0	0
cesium-134	0	0
cesium-137	5E-05	0
chromium-51	0	0
cobalt-58	0	0
cobalt-60	6E-29	0
europium-152	2E-11	0
europium-154	7E-18	0
europium-155	6E-33	0
hydrogen-3	1E-18	0
iron-59	0	0
manganese-54	0	0
nickel-63	6E-07	2E-35
plutonium-238	2E-06	4E-39
plutonium-239/240	2E-03	1E-03
radium-226	5E-03	8E-05
radium-228[b]	3E-04	3E-04
ruthenium-103	0	0
sodium-22	0	0
strontium-90[c]	5E-10	0
thorium-228[b]	5E-04	5E-04
thorium-232	8E-07	8E-07

Table 6-28. Future Radioactive Contaminants in Soil (in 500 yr and 10,000 yr).[a] (Sheet 2 of 2)

Radionuclide	ICR after Decay Time = 500 yr	ICR after Decay Time = 10,000 yr
uranium (total)	> 1E-02 (3E-02)	> 1E-02 (3E-02)
zinc-65	0	0
zirconium-95	0	0
Total	> 1E-02 (3E-02)	> 1E-02 (3E-02)

[a]Half-lives listed in Table 6-26.
[b]Accounts for ingrowth from Th-232 decay.
[c]The future ICRs for strontium-90 via produce ingestion are 3E-08 (Time=500 yr) and 0 (Time=10,000 yr).
ICR = lifetime incremental cancer risk.
Note: ICR values greater than 1E-02 are reported as "> 1E-02". ICR values in parentheses are calculated using a linear cancer risk equation (Equation 6-5), and are not intended to represent accurate cancer risk estimates. Shading indicates contaminants of concern.

Table 6-29. Soil-to-Plant Transfer Coefficients Used for Organic Contaminants.

	$\log K_{ow}$	Transfer Coefficients
		Soil-to-Plant[a] (kg soil/kg plant)
Aroclor-1248	5.6	0.022
Aroclor-1254	6.47	7.1E-03
Aroclor-1260	6.11	0.011
benzo(a)anthracene	5.61	0.022
benzene	2.13	2.274
benzo(a)pyrene	6.04	0.012
benzo(b)fluoranthene	6.57	6.2E-03
benzo(k)fluoranthene	6.85	4.3E-03
bis(2-ethylhexyl)phthalate	5.11	0.043
chloroform	1.97	2.814
chrysene	5.61	0.022
dibenzo(a,h)anthracene	5.79	0.017
dieldrin	5.16	0.040
indeno(1,2,3-cd)pyrene	7.66	1.4E-03
methylene chloride	1.25	7.337
pentachlorophenol	5.06	0.046
trichloroethene	2.29	1.838
vinyl chloride	1.38	6.171

$\log K_{ow}$ = log octanol-water partition coefficient.
Source: Travis and Arms 1988.
[a]Soil-to-plant transfer coefficient (TC_p) estimated using $\log TC_p = 1.588 - 0.578 \log K_{ow}$.

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Table 6-30. Soil-to-Plant Transfer Coefficient for Inorganic Contaminants.

	Transfer Coefficients
	Soil-to-Seeds
aluminum	6.5E-04
antimony	3.0E-02
arsenic	6.0E-03
barium	1.5E-02
beryllium	1.5E-03
cadmium	1.5E-01
chromium (VI)	4.5E-03
copper	2.5E-01
lead	9.0E-03
manganese	5.0E-02
mercury	2.0E-01
nickel	6.0E-02
silver	1.0E-01
thallium	4.0E-04
vanadium	3.0E-03
zinc	9.0E-01
Source: Baes et al. 1984	

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Table 6-31. Soil-to-Plant Factors for Radionuclide Contaminants.

Radionuclide	Transfer Coefficients	
	Soil to Plant Seed	Animal uptake
americium-241	2.5E-04	0.001
barium-140	1.5E-02	0.1
beryllium-7	1.5E-03	0.005
carbon-14	5.5E+00	1
cerium-141	4.0E-03	0.0003
cerium-144	4.0E-03	0.0003
cesium-134	3.0E-02	1
cesium-137 + D	3.0E-02	1
chromium-51	4.5E-03	0.1
cobalt-58	7.0E-03	0.3
cobalt-60	7.0E-03	0.3
europium-152	4.0E-03	0.001
europium-154	4.0E-03	0.001
europium-155	4.0E-03	0.001
hydrogen-3	4.8E+00	1
iron-59	1.0E-03	0.1
manganese-54	5.0E-02	0.1
nickel-63	6.0E-02	0.05
plutonium-238	4.5E-03	0.001
plutonium-239/240	4.5E-03	0.001
radium-226 + D	1.5E-03	0.2
ruthenium-103	2.0E-02	0.05
sodium-22	5.5E-02	1
strontium-90 + D	2.5E-01	0.3
thorium-228 + D	8.5E-03	0.0002
thorium-232	8.5E-03	0.0002
uranium (total)(U-238+D)	4.0E-03	0.05
zinc-65	9.0E-01	0.5
zirconium-95	5.0E-04	0.002
Source: Baes et al. 1984, Coughtrey et al. 1985, Baker and Soldat 1992.		

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Table 6-32. Parameters for Assessing Radiological Exposure to the Great Basin Pocket Mouse.

Radionuclide	Radiological Half-life (days)	Biological Half-life (days)	Decay Energy (mev/dis)	Direct Exposure Dose Factor	
				Immersion	External
				(mRad/y/μCi/g)	
americium-241	157753	20000	5.51	1.47E+05	4.66E+04
barium-140	12.74	65	0.32	1.45E+06	1.10E+06
beryllium-7	53.3	180	0.0049	4.01E+05	3.07E+05
carbon-14	2091450	10	0.05	3.42E+01	1.43E+01
cerium-141	32.501	563	0.174	5.93E+05	3.39E+05
cerium-144	284.3	563	1.32	1.49E+05	7.65E+04
cesium-134	752.63	115	0.259	1.28E+07	1.01E+07
cesium-137 + D	10950	115	0.267	4.87E+06	3.85E+06
chromium-51	27.706	616	0.0028	2.57E+05	1.86E+05
cobalt-58	70.8	9.5	0.0905	8.00E+06	6.36E+06
cobalt-60	1923.915	9.5	0.237	2.13E+07	1.73E+07
europium-152	4865.45	635	0.12	9.60E+06	7.48E+06
europium-154	3212	635	0.311	1.03E+07	8.19E+06
europium-155	1810.4	635	0.064	4.37E+05	1.94E+05
hydrogen-3	4507.75	10	0.0058	0.00	0.00
iron-59	44.529	800	0.191	1.01E+07	8.15E+06
manganese-54	312.5	17	0.0514	6.93E+06	5.50E+06
nickel-63	35040	667	0.0176	0.00	0.00
plutonium-238	32025.1	65000	5.51	8.87E+02	1.61E+02
plutonium-239/240	8783725	65000	5.15	8.67E+02	1.57E+02
radium-226 + D	584000	8100	11	1.50E+07	1.19E+07
ruthenium-103	39.28	7.3	0.125	3.81E+06	2.93E+06
sodium-22	949.73	11	0.325	1.83E+07	1.46E+07
strontium-90 + D	10628.8	4000	1.14	2.94E+04	2.62E+04
thorium-228 + D	698	57000	5.6	1.36E+07	1.09E+07
thorium-232	5.1465E+12	57000	4.1	1.55E+03	5.56E+02
uranium (total) (U-238+D)	1.6308E+12	100	4.3	1.59E+07	1.24E+07
zinc-65	243.9	933	0.0386	4.90E+06	3.95E+06
zirconium-95	63.98	450	0.254	6.09E+06	4.82E+06

Source: Baker and Soldat 1992, ICRP 1959.

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Table 6-33. Estimated Concentrations of Organic Contaminants in Environmental Media Used to Estimate Intake Rates for the Great Basin Pocket Mouse.

Contaminant	Vegetation mg/kg (wet)
Aroclor-1248	7.2E-02
Aroclor-1254	1.4E-02
Aroclor-1260	8.4E-03
benzo(a)anthracene	1.3E-02
benzene	1.4E-01
benzo(a)pyrene	1.1E-01
benzo(b)fluoranthene	4.7E-03
benzo(k)fluoranthene	1.0E-03
bis(2-ethylhexyl)phthalate	4.6E-01
chloroform	7.2E-02
chrysene	3.0E-01
dibenzo(a,h)anthracene	9.5E-03
dieldrin	2.7E-04
indeno(1,2,3-cd)pyrene	7.4E-04
methylene chloride	1.1E+01
pentachlorophenol	2.2E-02
trichloroethene	2.3E-01
vinyl chloride	4.7E-02

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Table 6-34. Estimated Inorganic Contaminant Concentrations in Environmental Media Used to Estimate Intake Rates for the Great Basin Pocket Mouse.

Contaminant	Vegetation (seeds) mg/kg (wet)
aluminum	16
antimony	0.18
arsenic	0.12
barium	20
beryllium	0.0023
cadmium	1.4
chromium (VI)	3.6
copper	7,624
lead	2.2
manganese	49
mercury	2.4
nickel	34
silver	12
thallium	0.0007
vanadium	0.37
zinc	1,774

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Table 6-35. Estimated Activities of Radiological Contaminants in Environmental Media Used to Estimate Intake Rates for the Great Basin Pocket Mouse.

Contaminant	Vegetation (seeds) (Ci/kg) Wet Wt.
americium-241	2.7E-12
barium-140	1.9E-09
beryllium-7	4.3E-11
carbon-14	1.9E-06
cerium-141	3.8E-12
cerium-144	6.4E-13
cesium-134	5.4E-10
cesium-137 + D	1.1E-06
chromium-51	5.0E-12
cobalt-58	3.2E-11
cobalt-60	2.5E-08
europium-152	3.7E-08
europium-154	1.2E-08
europium-155	1.2E-08
hydrogen-3	4.4E-05
iron-59	3.2E-13
manganese-54	1.1E-12
nickel-63	1.2E-6
plutonium-238	2.0E-10
plutonium-239/240	4.0E-09
radium-226 + D	2.0E-11
ruthenium-103	6.4E-12
sodium-22	1.7E-10
strontium-90 + D	1.6E-07
thorium-228 + D	4.6E-11
thorium-232	9.7E-12
uranium-238+D (total)	2.7E-08
zinc-65	8.6E-11
zirconium-95	9.0E-14

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Table 6-36. Estimated Intakes and Hazards to Great Basin Pocket Mouse Due to Ingestion of Organic Contaminants.

	Intake from vegetation (mg/kg-d)	Adjusted Wildlife NOAEL (mg/kg-day)	Environmental Hazard Quotient (EHQ)	Exceeds EHQ of 1
Aroclor-1248	2.05E-02	1.66E-01[a]	0.1	no
Aroclor-1254	4.12E-03	1.66E-01[a]	0.1	no
Aroclor-1260	2.39E-03	1.66E-01[a]	0.0	no
benzo(a)anthracene	3.64E-03	NA	NA	
benzene	3.94E-02	6.26E+00[a]	0.0	no
benzo(a)pyrene	3.08E-02	1.08E-02[a]	3	yes
benzo(b)fluoranthene	1.35E-03	NA	NA	
benzo(k)fluoranthene	2.95E-04	NA	NA	
bis(2-ethylhexyl)phthalate	1.3E-01	1.57E+00[a]	0.1	no
chloroform	2.05E-02	2.25E+01[a]	0.0	no
chrysene	8.69E-02	NA	NA	
dibenzo(a,h)anthracene	2.7E-03	NA	NA	
dieldrin	7.72E-05	5.00E-04[b]	0.2	no
indeno(1,2,3-cd)pyrene	2.11E-04	NA	NA	
methylene chloride	3.01E+00	1.47E+01[a]	0.2	no
pentachlorophenol	6.30E-03	7.38E+00[a]	0.0	no
trichloroethene	6.54E-02	1.89E+02[a]	0.0	no
vinyl chloride	9.22E-02	NA	NA	

Data Sources for NOAELS:
[a]Opresko et al. 1993
[b]IRIS (EPA 1993a).
NA - Not available

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Table 6-37. Estimated Intakes and Hazards to the Great Basin Pocket Mouse from Ingestion of Inorganic Contaminants.

	Mouse (inorganic)			
	Intake from vegetation (mg/kg-day)	Wildlife NOAEL (mg/kg-day)	Environmental Hazard Quotient (EHQ)	Exceeds EHQ of 1
aluminum	4.65E+00	1.06E-01	4	yes
antimony	5.09E-02	8.61E-02	0.6	no
arsenic	3.4E-02	1.08E-01	0.3	no
barium	5.83E+00	1.28E+00	5	yes
beryllium	6.43E-04	1.36E+00	0.0	no
cadmium	3.9E-01	5.29E-01	0.7	no
chromium (VI)	1.03E+00	6.04E+00	0.2	no
copper	2.17E+03	1.86E-01	11,686	yes
lead	6.13E-01	1.97E+00	0.3	no
manganese	1.39E+01	2.02E+00	7	yes
mercury	6.75E-01	6.07E+02	11	yes
nickel	9.58E+00	6.07E+01	0.2	no
silver	3.30E+00	2.19E+01	0.2	no
thallium	1.97E-04	NA	NA	
vanadium	1.06E+01	4.4E-01	0.2	no
zinc	5.06E+02	2.44E+01	21	yes
Data Sources for NOAELS: Opresko et al. 1993 NA - Not available				

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Table 6-38. Estimated Doses and Hazards to the Great Basin Pocket Mouse from Ingestions and Exposure to Radionuclide Contaminants.

Radionuclides	Great Basin Pocket Mice			
	Ingestion Dose Rate (rad/day)	External Exposure		
		Burrowing	Surface	Total
		(rad/day)		
americium-241	0.00	0.00	0.00	0.00
barium-140	0.00	0.00	0.00	0.00
beryllium-7	0.00	0.00	0.00	0.00
carbon-14	0.01	0.00	0.00	0.00
cerium-141	0.00	0.00	0.00	0.00
cerium-144	0.00	0.00	0.00	0.00
cesium-134	0.04	0.00	0.00	0.00
cesium-137 + D	0.60	1.03	0.07	1.10
chromium-51	0.00	0.00	0.00	0.00
cobalt-58	0.00	0.00	0.00	0.00
cobalt-60	0.17	0.45	0.03	0.48
europium-152	0.00	0.53	0.04	0.57
europium-154	0.00	0.18	0.01	0.19
europium-155	0.00	0.01	0.00	0.01
hydrogen-3	0.05	0.00	0.00	0.00
iron-59	0.00	0.00	0.00	0.00
manganese-54	0.00	0.00	0.00	0.00
nickel-63	0.05	0.00	0.00	0.00
plutonium-238	0.00	0.00	0.00	0.00
plutonium-239/240	0.01	0.00	0.00	0.00
radium-226 + D	0.11	0.00	0.00	0.00
ruthenium-103	0.00	0.00	0.00	0.00
sodium-22	0.00	0.00	0.00	0.00
strontium-90 + D	0.28	0.00	0.00	0.00
thorium-228 + D	0.00	0.00	0.00	0.00
thorium-232	0.00	0.00	0.00	0.00
uranium-238+D (total)	0.01	0.61	0.04	0.65
zinc-65	0.00	0.00	0.00	0.00
zirconium-95	0.00	0.00	0.00	0.00
TOTAL	0.96	2.81	0.19	3.00

Notes: Shaded values exceed critical dose rate of 1 rad/day; values less than 0.005 recorded as 0.00.

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Table 6-39. Estimated Current and Future Environmental Hazard Quotient for the Great Basin Pocket Mouse from Ingestion of Organic Contaminants.

Contaminant	Half-life[a] (yr)	Current EHQ[b]	Future EHQ at 103 years[b]	Future EHQ at 500 years[b]	Future EHQ at 10,000 years[b]
Organic					
Aroclor-1248	1	0.1	0.0	0.0	0.0
Aroclor-1254	10,000	0.0	0.0	0.0	0.0
Aroclor-1260	10,000	0.0	0.0	0.0	0.0
benz(a)anthracene	10	ND	ND	ND	ND
benzene	10	0.0	0.0	0.0	0.0
benzo(a)pyrene	100	2.9	1.4	0.1	0.0
benzo(b)fluoranthene	10	ND	ND	ND	ND
benzo(k)fluoranthene	100	ND	ND	ND	ND
bis(2-ethylhexyl)phthalate	10	0.1	0.0	0.0	0.0
chloroform	10	0.0	0.0	0.0	0.0
chrysene	10	ND	ND	ND	ND
dibenz(a,h)anthracene	10	ND	ND	ND	ND
dieldrin	10	0.02	0.0	0.0	0.0
indeno(1,2,3-cd)pyrene	10	ND	ND	ND	ND
methylene chloride	1	0.02	0.0	0.0	0.0
pentachlorophenol	10	0.0	0.0	0.0	0.0
trichloroethene	10	0.0	0.0	0.0	0.0
vinyl chloride	10	ND	ND	ND	ND

Notes:
[a]Half-lives based on values from Table 4-5.
[b]Based on seed ingestion.
ND = Not determined
EHQ = Environmental Hazard Quotient

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Table 6-40. Estimated Current and Future Dose to the Great Basin Pocket Mouse from Ingestion of and External Exposure to Radionuclides. (Sheet 1 of 2)

Contaminant	Halflife (yr)	Current Dose from Ingestion (rad/day)	Future Dose at 103 years (rad/day)	Future Dose at 500 years (rad/day)	Future Dose at 10,000 years (rad/day)
americium-241	4.32E+02	0.0	0.0	0.0	0.0
barium-140	3.50E-02	0.0	0.0	0.0	0.0
beryllium-7	1.46E-01	0.0	0.0	0.0	0.0
carbon-14	5.73E+03	0.0	0.0	0.0	0.0
cerium-141	8.90E-02	0.0	0.0	0.0	0.0
cerium-144	7.78E-01	0.0	0.0	0.0	0.0
cesium-134	2.06E+00	0.0	0.0	0.0	0.0
cesium-137	3.02E+01	0.6	0.1	0.0	0.0
chromium-51	7.58E-02	0.0	0.0	0.0	0.0
cobalt-58	1.94E-01	0.0	0.0	0.0	0.0
cobalt-60	5.27E+00	0.0	0.0	0.0	0.0
europium-152	1.36E+01	0.0	0.0	0.0	0.0
europium-154	8.80E+00	0.0	0.0	0.0	0.0
europium-155	4.96E+00	0.0	0.0	0.0	0.0
hydrogen-3	1.23E+01	0.1	0.0	0.0	0.0
iron-59	1.22E-01	0.0	0.0	0.0	0.0
manganese-54	8.57E-01	0.0	0.0	0.0	0.0
nickel-63	1.00E+02	0.0	0.0	0.0	0.0
plutonium-238	8.78E+01	0.0	0.0	0.0	0.0
plutonium-239/240	2.41E+04	0.0	0.0	0.0	0.0
radium-226	1.60E+03	0.0	0.0	0.0	0.0
ruthenium-103	1.08E-01	0.0	0.0	0.0	0.0
sodium-22	2.60E+00	0.0	0.0	0.0	0.0
strontium-90	2.86E+01	0.3	0.0	0.0	0.0
thorium-228	1.91E+00	0.0	0.0	0.0	0.0
thorium-232	1.41E+10	0.0	0.0	0.0	0.0
uranium (total)	4.47E+09	0.0	0.0	0.0	0.0
zinc-65	6.68E-01	0.0	0.0	0.0	0.0
zirconium-95	1.75E-01	0.0	0.0	0.0	0.0

Scenario based on seed ingestion.
Values less than 0.05 reported as 0.0.

Table 6-40. Estimated Current and Future Dose to the Great Basin Pocket Mouse from Ingestion of and External Exposure to Radionuclides. (Sheet 2 of 2)

Contaminant	Halflife (yr)	Current Dose from External Exposure (rad/day)	Future Dose at 103 years (rad/day)	Future Dose at 500 years (rad/day)	Future Dose at 10,000 years (rad/day)
americium-241	4.32E+02	0.0	0.0	0.0	0.0
barium-140	3.50E-02	0.0	0.0	0.0	0.0
beryllium-7	1.46E-01	0.0	0.0	0.0	0.0
carbon-14	5.73E+03	0.0	0.0	0.0	0.0
cerium-141	8.90E-02	0.0	0.0	0.0	0.0
cerium-144	7.78E-01	0.0	0.0	0.0	0.0
cesium-134	2.06E+00	0.0	0.0	0.0	0.0
cesium-137	3.02E+01	1.1	0.1	0.0	0.0
chromium-51	7.58E-02	0.0	0.0	0.0	0.0
cobalt-58	1.94E-01	0.0	0.0	0.0	0.0
cobalt-60	5.27E+00	0.5	0.0	0.0	0.0
europium-152	1.36E+01	0.6	0.0	0.0	0.0
europium-154	8.80E+00	0.2	0.0	0.0	0.0
europium-155	4.96E+00	0.0	0.0	0.0	0.0
hydrogen-3	1.23E+01	0.0	0.0	0.0	0.0
iron-59	1.22E-01	0.0	0.0	0.0	0.0
manganese-54	8.57E-01	0.0	0.0	0.0	0.0
nickel-63	1.00E+02	0.0	0.0	0.0	0.0
plutonium-238	8.78E+01	0.0	0.0	0.0	0.0
plutonium-239/240	2.41E+04	0.0	0.0	0.0	0.0
radium-226	1.60E+03	0.0	0.0	0.0	0.0
ruthenium-103	1.08E-01	0.0	0.0	0.0	0.0
sodium-22	2.60E+00	0.0	0.0	0.0	0.0
strontium-90	2.86E+01	0.0	0.0	0.0	0.0
thorium-228	1.91E+00	0.0	0.0	0.0	0.0
thorium-232	1.41E+10	0.0	0.0	0.0	0.0
uranium (total)	4.47E+09	0.6	0.6	0.6	0.6
zinc-65	6.68E-01	0.0	0.0	0.0	0.0
zirconium-95	1.75E-01	0.0	0.0	0.0	0.0

Scenario based on seed ingestion.
Values less than 0.05 reported as 0.0.

Table 6-41. Non-Radioactive Contaminant Human Health Risks for the 500-Year Drilling Scenario

Contaminant	HQ	ICR
Organic		
Aroclor-1248	0E+00	0E+00
Aroclor-1254	0E+00	9E-08
Aroclor-1260	0E+00	3E-08
benz(a)anthracene	0E+00	2E-23
benzene	0E+00	2E-25
benzo(a)pyrene	0E+00	1E-08
benzo(b)fluoranthene	0E+00	3E-23
benzo(k)fluoranthene	0E+00	3E-10
bis(2-ethylhexyl)phthalate	2E-20	7E-25
chloroform	1E-22	7E-25
chrysene	0E+00	5E-22
dibenz(a,h)anthracene	0E+00	2E-23
dieldrin	5E-21	5E-25
indeno(1,2,3-cd)pyrene	0E+00	2E-23
methylene chloride	0E+00	0E+00
pentachlorophenol	6E-22	3E-25
trichloroethene	9E-22	2E-25
vinyl chloride	0E+00	1E-24
Inorganic		
aluminum	2E-03	0E+00
ammonia	3E-03	0E+00
antimony	1E-03	0E+00
arsenic	3E-03	2E-07
barium	2E-03	0E+00
beryllium	3E-05	2E-07
cadmium	4E-04	7E-10
chromium	7E-03	4E-07
copper	3E-02	0E+00
lead	0E+00	0E+00
manganese	9E-04	0E+00
mercury	2E-03	0E+00
nickel	1E-03	0E+00
silver	1E-03	0E+00
thallium	1E-03	0E+00
vanadium	1E-03	0E+00
zinc	3E-04	0E+00
Total	5E-02	9E-07

HQ = Hazard Quotient
ICR = Lifetime Incremental Cancer Risk

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Table 6-42. Radionuclide Human Health Risks for the 500-Year Drilling Scenario.

RADIONUCLIDES	ICR
americium-241	1E-08
barium-140	0E+00
beryllium-7	0E+00
carbon-14	7E-10
cerium-141	0E+00
cerium-144	0E+00
cesium-134	0E+00
cesium-137	5E-08
chromium-51	0E+00
cobalt-58	0E+00
cobalt-60	6E-32
europium-152	2E-14
europium-154	7E-21
europium-155	6E-36
hydrogen-3	1E-21
iron-59	0E+00
manganese-54	0E+00
nickel-63	6E-10
plutonium-238	2E-09
plutonium-239/240	2E-06
radium-226	5E-06
radium-228[a]	2E-07
ruthenium-103	0E+00
sodium-22	3E-64
strontium-90[b]	5E-13
thorium-228[a]	5E-07
thorium-232	8E-10
uranium (total)	3E-05
zinc-65	0+00
zirconium-95	0+00
Total ICR	3E-05

[a] Assumed to be in equilibrium with Th-232.
ICR = Lifetime Incremental Cancer Risk.
[b] The produce ingestion ICR for strontium-90 is 3E-11.

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Table 6-43. Inorganic Contaminant Risks to Environmental Receptors for the 500-Year Drilling Scenario

Contaminant	Environmental Hazard Quotient (EHQ)
aluminum	0.04
antimony	0.00
arsenic	0.00
barium	0.00
beryllium	0.00
cadmium	0.00
chromium (VI)	0.00
copper	12
lead	0.00
manganese	0.01
mercury	0.01
nickel	0.00
silver	0.00
thallium	NE
vanadium	0.00
zinc	0.02
Notes: NE = not evaluated	

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7.0 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

Development of remedial action objectives (RAOs) is the initial activity of a feasibility study (FS). The primary purpose of RAOs is to focus the development, screening, and analysis of remedial alternatives to ensure that they are protective of human health and the environment. RAOs are based on a variety of factors (described in Section 7.2), of which the primary drivers are applicable or relevant and appropriate requirements (ARARs). Section 7.1 includes a discussion of chemical, location, and action specific ARARs that may be pertinent to the remedial alternatives developed and evaluated in later chapters. The chemical-specific ARARs were also used for constituent-screening performed in Chapter 5.0. Remedial action objectives (RAOs) for the ERDF are developed in Section 7.2.

7.1 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This section consists of a review of potential federal and state applicable or relevant and appropriate requirements (ARARs) which may be pertinent to the siting, design, operation and closure of the ERDF. The ARARs development process is based on CERCLA guidance (EPA 1988a and EPA 1988c). The review of ARARs included herein is an update of the preliminary ARAR identification presented in the Regulatory Strategy for Macro Engineering Implementation (Lauterbach 1992). Identification of ARARs is directly impacted by characteristics of the site, contaminants present, and remedial alternatives developed, therefore, only specific sections of the regulations may be ARAR. The identification of ARARs will be refined following identification of a preferred alternative.

Section 121 (d) of CERCLA, as amended, establishes cleanup standards for remedial actions. This section requires that any applicable or relevant and appropriate standard, requirement, criteria or limitation under any federal environmental law, or any more stringent state requirement promulgated pursuant to a state environmental statute, be met for any hazardous substance, pollutant, or contaminant remaining on-site. A requirement promulgated under other environmental laws may be either "applicable" or "relevant and appropriate", but not both. Identification of ARARs must be done on a site-specific basis and involves a two-part analysis: first, a determination is made whether a given requirement is applicable; then if it is not applicable, a determination is made whether it is nevertheless both relevant and appropriate. The EPA guidance also includes To-Be-Considered (TBC) materials which are advisories and non-promulgated guidance issued by federal or state governments that are non-statutory requirements evaluated along with ARARs as part of the risk assessment used to establish protective cleanup limits. These standards will be evaluated for use as performance criteria for siting, design, operation and closure of the ERDF.

The EPA may waive ARARs and select a remedial action that does not attain the same level of cleanup as identified by ARARs. Section 121 (d)(4) of CERCLA identifies six circumstances where EPA may waive ARARs for on-site remedial actions. The six circumstances are:

- The remedial action selected is only a part of a total remedial action (such as an interim action) and the final remedy will attain the ARAR upon its completion.

- Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.
- Compliance with the ARAR is technically impracticable from an engineering perspective.
- An alternative remedial action will attain an equivalent standard of performance through the use of another method or approach.
- The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.
- In the case of Section 104, Superfund-financed remedial actions, compliance with the ARAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.

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The different types of requirements that CERCLA actions may have to comply with are identified as chemical-specific, location-specific and action-specific ARARS. The following definitions are excerpts from EPA guidance in *CERCLA Compliance with Other Laws Manual: Interim Final* (EPA 1988c). However, some requirements may not fall neatly into the classification system.

> Chemical-specific requirements are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These numbers establish the acceptable amount or concentration of a chemical that can be found in, or discharged to the ambient environment.
>
> Location-specific requirements are restrictions placed on the concentration of hazardous substances or the conduct of activities because they occur in special or sensitive locations or environments.
>
> Action-specific requirements are those that place either technology-based or activity-based requirements on remedial actions at CERCLA sites.

Federal and state regulations along with other guidance were evaluated as potential ARARs and TBC materials. Tables 7-1 and 7-2 present the full list of laws and regulations that were evaluated as potentially applicable or relevant and appropriate requirements for management of Hanford Site remediation waste at the ERDF. The following discussion of ARARs focuses only on the most significant potential ARARs.

7.1.1 Chemical-Specific ARARs

Chemical-specific ARARs may be federal, state statutory or regulatory requirements and other guidance that identify acceptable health- or risk-based contaminant levels for different media known to be contaminated. Chemical-specific ARARs may be used as criteria during ERDF performance evaluations. The list of contaminants of concern established in Chapter 5 was used to identify potential chemical-specific ARARs.

7.1.1.1 Federal Chemical-Specific ARARs. Federal chemical-specific requirements, criteria, or guidance for the contaminants of concern identified at the Hanford Site are listed in Table 7-1.

National Primary Drinking Water Regulations - 40 CFR 141

The National Primary Drinking Water Regulations (40 CFR 141) promulgated under the Safe Drinking Water Act (SDWA) establish maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) for community drinking water systems. MCLs and MCLGs have been established for a large number of both non-radioactive contaminants and radionuclides. The regulations are not applicable to the ERDF because Hanford Site ground and surface waters are not used as public drinking water supplies. However, the regulations may be considered relevant and appropriate to the ERDF as performance criteria for groundwater protection. Section 300.430 (e)(2)(i)(B) of the NCP states that remedial actions for ground or surface water that are current or potential sources of drinking water shall attain standards established under the SDWA, where the MCL or MCLG is relevant and appropriate to the circumstances of the release. Although groundwater affected by the Hanford Site is not currently used for drinking, it could be used in the future if the site is released from institutional controls. If portions of the Hanford Site convert to other land uses, and the ground and/or surface water is considered as a potential source of drinking water, the operation of the ERDF must be protective of ground and surface water. There is also potential for groundwater beneath the ERDF site to discharge to the Columbia River which is used for drinking water. Design, operation and closure of the ERDF needs to prevent migration of contaminants from soils to groundwater at concentrations that cause the groundwater to exceed MCLGs and MCLs. Drinking water MCLGs and MCLs for radionuclide and non-radionuclide contaminants of concern are listed in Tables 7-3 and 7-4.

National Secondary Drinking Water Regulations - 40 CFR 143

The National Secondary Drinking Water Regulations control contaminants in drinking water that primarily affect aesthetic qualities of the water that relate to public acceptance. These regulations are not applicable to the ERDF because they are not federally enforceable. However, under Washington State regulations (173-340-720(2)(9)(ii)) they are a potential ARAR because the regulation specifies secondary maximum contaminant levels (SMCLs) as cleanup standards.

Resource Conservation and Recovery Act - Title 42 USC 6901 et seq

The Resource Conservation and Recovery Act (RCRA) regulates the generation, transportation, storage, treatment and disposal of hazardous waste. These regulations also provide authority for the cleanup of spills and environmental releases of hazardous waste to the environment as a result of past practices. Hazardous waste management regulations promulgated pursuant to RCRA are codified at 40 CFR 260 through 270. Washington State Dangerous Waste Regulations implement the federal hazardous waste regulations and are administered by the Washington State Department of Ecology (Ecology).

Regulations established under RCRA are applicable to the ERDF as chemical-specific ARARs because the facility may generate hazardous waste. Operation and design requirements for hazardous waste management facilities in the RCRA regulations are discussed in Section 7.1.3.1, as they are action-specific ARARs. In addition, RCRA regulations for solid waste include groundwater protection standards in 40 CFR 264.92 that establish three remediation levels of groundwater protection: background, MCLs, or alternate concentration levels (ACLs). MCLs are set at the same levels as SDWA MCLs and where no SDWA MCL has been set, health based

ACLs may be established that are protective of human health and environment. Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR 257) establish groundwater protection requirements for solid waste disposal facilities at the same level as MCLs published under 40 CFR 141.

National Primary and Secondary Ambient Air Quality Standards - 40 CFR 50

National primary and secondary ambient air quality standards were established pursuant to the Clean Air Act in order to protect air quality and maintain public health. The EPA has promulgated national primary air quality standards for six criteria pollutants; sulfur oxides, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. The requirements of this standard are applicable because potential airborne emission of particulates or lead may result during operation of the facility. Under the Clean Air Act, states are required to develop State Implementation Plans that outline how the state will implement, maintain and enforce the national ambient air quality standards (NAAQS). Upon EPA approval, State plans become enforceable, and state requirements may become federal requirements.

National Emission Standards for Hazardous Air Pollutants - 40 CFR 61

The Clean Air Act directs the EPA to develop and periodically revise a list of National Emission Standards for Hazardous Air Pollutants (NESHAPs). Hazardous air pollutants are air contaminants that affect human welfare for which no ambient air quality standard exists. The NESHAPs are promulgated for emissions from specific sources, and only the NESHAPs established for radionuclide emissions from DOE facilities are applicable to the ERDF. The remaining NESHAPs may be considered relevant and appropriate to the ERDF if operation of the facility incorporates operations similar to operations associated with the sources identified in the NESHAP.

EPA standards for radionuclide emissions from facilities owned and operated by DOE under 40 CFR 61.90, National Emission Standards for Hazardous Air Pollutants are potentially applicable because radionuclides will be present in wastes managed at the facility and there is potential for airborne release. The regulation establishes general radiation dose limits to members of the public from radionuclides emitted into the air from DOE facilities. The dose equivalent rate to any member of the public shall not exceed 25 mrem/yr to the whole body or 75 mrem/yr to any critical organ. Also, no member of the public may receive a continuous exposure, excluding natural background and medical exposure, of more than 100 mrem/yr effective dose equivalent and a noncontinuous exposure of more than 500 mrem/yr effective dose equivalent from all sources.

Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste - 40 CFR 191

The final rule published in the December 20, 1993 Federal Register (58 FR 66398) establishes a 10,000 year performance standard for groundwater protection for radioactive waste disposal facilities regulated under the Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Waste (40 CFR 191). Requirements of the final rule are effective January 20, 1994. The requirements of 40 CFR 191 are not applicable or relevant and appropriate requirements to ERDF because remediation waste to be disposed at the ERDF does not meet the definition of waste subject to the regulation. However, the Tri-Party Agreement between DOE, Ecology and EPA identifies 10,000 yrs as a long-term performance standard for protection to be used as a parameter in the ERDF risk assessments. Groundwater protection standards established under the regulation specify that disposal systems shall be designed so that for 10,000 yr after disposal, they shall not cause the levels of radioactivity to exceed the limits specified in 40 CFR 141 (as the limits exist on the date the implementing agency determines compliance). Under the final rule, disposal methods would be required to limit radiation exposure to an individual for an undisturbed performance period of 10,000 years to no more than 15 mrems committed effective dose (CED) per year. The CED is the risk-weighted sum of the doses to the individual organs of the body. If compliance assessments indicate that a disposal system design will fail to meet the 10,000-year individual dose standard, more robust engineered barriers to control releases of radionuclides may be required.

Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings - 40 CFR 192

Requirements of 40 CFR 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings are potentially relevant and appropriate requirements to the ERDF because they establish performance standards for radioactive waste disposal facilities. The standard requires that waste disposal facilities be designed for an effective life up to 1,000 years, to an extent reasonably achievable, and in any case, no less than 200 years. This is a design standard and monitoring after disposal is not required to demonstrate compliance. These requirements are not applicable to the ERDF because the facility is not associated with uranium or thorium milling.

Standards for Protection Against Radiation - 10 CFR 20

The NRC Standards for Protection Against Radiation found in 10 CFR 20 are relevant and appropriate to the facility because the regulation establishes standards for protection against radiation hazards that may result from occupational exposure or discharges to air and water. The standard is not applicable because it only applies to operations licensed by the Nuclear Regulatory Commission.

These regulations establish standards for protection against radiation hazards at facilities licensed by the Nuclear Regulatory Commission (NRC). The regulations were amended on May 21, 1991 and are effective as of January 1, 1994. The previous regulation was based upon scientific knowledge from more than 30 years ago. The new regulation modifies the radiation protection standards in order to reflect updated scientific information on radionuclide uptake and metabolism, as well as changes in the basic philosophy of radiation protection. These changes are based upon recommendations of the International Commission on Radiological Protection (ICRP) in ICRP Publication 26 (1977 guidance) and subsequent ICRP publications.

NRC licensed facilities must limit occupational dose to the following:

(1) an annual limit, which is the more limiting of
 (i) a total effective dose of 5 rems
 (ii) the total dose to any organ or tissue, other than the eye, equal to 50 rems

(2) the annual limits to the lens of the eye, to the skin, and to the extremities, which are:
 (i) An eye dose equivalent of 15 rems and
 (ii) A shallow-dose equivalent of 50 rems to the skin or to any extremity.

Derived air concentration (DAC) and annual limit on intake (ALI) values, presented in Table 1 of Appendix B of 10 CFR 20, were calculated based upon the occupational dose limits described above. The regulation also describes how to add external and internal doses to calculate the total effective dose equivalent. Dose limits for minors are ten percent of the annual dose limits specified for adult workers.

In addition, the licensee must conduct operations so that the total effective dose equivalent to individual members of the public may not exceed 0.1 rem/year. The dose in any unrestricted area from external sources may not exceed 0.002 rem/hr. The licensee must survey radiation levels in unrestricted areas and radioactive materials in effluent released to unrestricted areas in order to demonstrate compliance with the dose limits for individual members of the public. The licensee must show compliance with the annual dose limit by:

(1) Demonstrating by measurement or calculation that the total effective dose equivalent to the individual likely to receive the highest dose from the licensed operation does not exceed the annual dose limit or

(2) Demonstrating that
(i) The annual average concentrations of radioactive material released in gaseous and liquid effluent do not exceed the values specified in Table 2 of Appendix B of 10 CFR 20
(ii) If an individual were continually present in an unrestricted area, the dose from external sources would not exceed 0.002 rem/hour and 0.05 rem/year.

The concentration limits for radionuclides in airborne and liquid effluent discharged to unrestricted areas established under the standard are summarized in Table 7-3.

Radiation Protection of the Public and Environment - DOE Order 5400.5

Radiation protection and radioactive waste management requirements issued under the Atomic Energy Act are implemented at DOE facilities as DOE orders. Under CERCLA these standards are TBC for activities conducted at the ERDF facility because they are not promulgated regulations. However, compliance with DOE Orders is required at Hanford.

DOE Order 5400.5, Radiation Protection of the Public and Environment, establishes the standards and requirements for radiation protection of the public and the environment at DOE and DOE contractor facilities. This DOE Order defines members of the public as persons not occupationally associated with the DOE facility or operations. However, this DOE Order is discussed because it presents exposure limits for airborne and liquid effluent that may be useful as comparisons to occupational limits. DOE policy is to implement all legally applicable radiation protection standards, and to adopt or consider recommendations from authoritative organizations, such as the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection. DOE policy also includes implementation of standards generally consistent with Nuclear Regulatory Commission (NRC) for DOE facilities not subject to NRC regulation.

The DOE Order applies the "As Low As is Reasonably Achievable" (ALARA) process to radiation protection. The ALARA process is not a dose-based limit, but a feasibility limit, in that exposures should be as far below applicable limits as practical. The feasibility limit should account for social, economic, technical, and public policy considerations. As part of the ALARA process DOE operations monitor routine and non-routine exposure and assess the dose to members of the public. The ALARA process includes procedures for evaluating alternative operations and other factors to reduce radiation exposures.

This DOE Order adopts radiation protection dose standards consistent with the 1977 ICRP guidance which has been adopted and implemented world wide by countries with nuclear programs. Dose limits presented in this DOE Order are expressed both in terms of effective dose equivalents (ICRP guidance) and dose equivalents to specific organs or whole body in order to be consistent with pre-1977 standards or public dose limits established by EPA for selected exposure pathways or sources.

The DOE primary standard for allowable effective dose equivalent to members of the public in a year is 0.1 rem. The DOE Headquarters are to be notified if an annual public exposure in excess of 0.01 rems occurs or is anticipated to occur. This dose considers all exposure modes resulting from DOE activities. "Effective Dose Equivalent", developed by the ICRP is calculated by the weighted summation of doses to various organs of the body. The 0.1 rem effective dose equivalent in a year is the sum of all exposures from external sources plus the committed effective dose equivalent from sources taken into the body during the year. The public dose limit does not include medical exposures, exposure resulting from consumer products, residual fallout from past nuclear accidents and weapons tests or naturally occurring radiation sources.

The DOE Order 5400.5 identifies circumstances where supplemental limits or exceptions to the standards may be implemented. A temporary public dose limit higher than 0.1 rem but not to exceed 0.5 rem for the year may be approved from the DOE Field office in coordination with their Program Office. Situations identified by DOE that may warrant use of a supplemental standard include situations where remedial action would pose a clear and present risk to workers or members of the public using reasonable measures to reduce or avoid the risk.

Exposure to members of the public to airborne emissions released to the atmosphere that result from DOE operations must not cause members of the public to receive in a year, an effective dose equivalent greater than 0.01 rem, the same dose limit established by EPA regulation 40 CFR 61, Subpart H authorized under the Clean Air Act. Compliance may be demonstrated using models specifically approved in accordance with 40 CFR 61 requirements, or may also be demonstrated through environmental measurements using EPA approved methods.

The DOE Order also adopts 40 CFR 191 exposure limits that members of the public may receive as a direct result of DOE management and operation of a disposal facility for spent nuclear fuel, high level or transuranic radioactive wastes that are not regulated by the NRC. The dose resulting from management of these wastes must not cause members of the public to receive, in a year, a dose equivalent greater than 0.025 rem to the whole body, or a committed dose equivalent greater than 0.075 rem to any organ.

Drinking water systems operated by the DOE must meet the level of protection defined in 40 CFR 141, National Interim Primary Drinking Water Standards for community drinking water systems. The standard requires that community drinking water systems must not cause an effective dose equivalent greater than 0.004 rem in a year, the combined activity levels for radium-226 and radium-228 must not exceed 5 pCi/L and gross alpha activity must not exceed 15 pCi/L.

The DOE Order presents derived concentration guides (DCGs) for conducting radiological environmental monitoring programs at DOE facilities. The DCGs are presented for three exposure modes; ingestion of water, inhalation of air and immersion in a gaseous cloud. The DCGs are not designed as occupational intake limits. The DCGs for internal exposure are based on a committed effective dose equivalent of 0.1 rem per year for radionuclides taken into the body through ingestion or inhalation. The DCGs may be used for evaluating compliance to the drinking water limit of 0.004 rem per year by using 4% of the DCG for ingestion. The exposure conditions used for development of the ingestion and inhalation DCGs are presented with the DCGs in table format.

Radiological protection requirements are also established for residual radioactive material and cleanup of residual materials. The basic public dose limit is 0.1 rem effective dose equivalent per year in excess of naturally occurring background. Additional guidelines for residual radioactive material in soils for radium and thorium are set at the levels issued under 40 CFR 192.

The proposed DOE rule, Radiation Protection of the Public and the Environment (10 CFR 834) published in the March 23, 1993 Federal Register (58 FR 16268), promulgates the standards presently found in DOE Order 5400.5. The proposed rule retains the substantive portions of the DOE Order and differs from the existing DOE Order in format, enhanced emphasis on the ALARA process, and changes in the usage of DCGs. The proposed rule identifies DCGs not as "acceptable" discharge limits, but to be used as reference values for estimating potential dose and determining compliance with the requirements of the proposed rule. Where residual radioactive materials remain, the proposed rule states that various disposal modes should address impacts beyond the 1,000 year time period identified in the existing DOE Order.

Toxic Substances Control Act 15 USC 2601 et seq.

TSCA requirements are potentially applicable to the ERDF because PCBs have been identified as potential contaminants of concern and may be disposed of at the ERDF above the regulated concentration of 50 ppm. This regulation establishes handling, storage and disposal requirements for wastes with PCB concentrations greater than 50 ppm. In particular, this act requires that wastes greater than 50 ppm PCB be disposed in a lined facility.

7.1.1.2 State of Washington Chemical-Specific ARARs. CERCLA 121(d) requires that, in addition to satisfying federal ARARs, any state standard, requirement, criterion, or limitation that is more stringent must also be met. State requirements must be legally enforceable regulations or statutes, identified in a timely manner, and be of general applicability to all circumstances covered by the requirement. Table 7-2 identifies preliminary chemical-specific Washington State ARARs for the ERDF facility.

Model Toxics Control Act Cleanup Regulation - WAC 173-340

Regulations under Chapter 173-340 WAC, which implement requirements of the Model Toxics Control Act (MTCA) establish the administrative processes and standards to identify, investigate and cleanup facilities where hazardous substances have been released. These regulations are not applicable to the ERDF because no contaminant releases have occurred, however, the regulation may be considered relevant and appropriate. These standards may be used in evaluating performance of ERDF design alternatives. The state regulations have the potential to be stricter than federal standards. For example, MTCA specifies secondary drinking water MCLs as applicable requirements. Secondary MCLs are nonenforceable standards under 40 CFR 143 and are based on non-human health-based goals relating to qualities of taste and odor.

The MTCA regulations under WAC 173-340-700 establish three basic methods for determining cleanup levels. These include Method A - Tables, Method B - standard method, and Method C - Conditional method. Groundwater cleanup standards are presented in WAC 173-340-720 and soil cleanup standards are presented in WAC 173-340-740 and WAC 173-340-745. The MTCA regulations specify procedures for establishing levels that are protective of human health and the environment based on reasonable maximum exposure assuming either a residential site use (WAC 173-340-720 for groundwater and WAC 173-340-740 for soil) or industrial site use (WAC 173-340-745 for soil cleanup). Sections 720 and 740 establish standards under all three methods and Section 745 uses only Methods A and C.

By definition (WAC 173-340-200) radionuclides are hazardous substances under MTCA, and are considered Group A (known human) carcinogens by EPA (56FR33050). However, Methods B and C equations are designed to provide cleanup levels for non-radioactive contaminants, not radionuclides.

Method A is generally used for routine cleanups with relatively few contaminants. Method A values come from: tables in the MTCA rule, ARAR values (these do not include values established under WAC 173-360-720, -740, or -745 unless specifically listed in the tables), practical quantitation limits, and natural background. Standards for Method A cleanups are established based on other federal or state ARARs, including those developed:

- at a 10^{-6} risk-level, based on residential site use in WAC 173-340-720, -740
- at a 10^{-5} risk level, based on industrial site use in WAC 173-340-745
- based on natural background concentrations
- based on practical quantification limits (PQLs).

Method B is the standard method for determining cleanup levels and assumes a residential site use. Method B levels are determined using federal or state ARARs or are based on risk equations specified in WAC 173-340-720, and -740. For individual carcinogens, the cleanup levels are based on the upper bound of the excess lifetime cancer risk of one in one million (1×10^{-6}). Total excess cancer risk under Method B for multiple substances and pathways cannot exceed one in one hundred thousand (1×10^{-5}). Residential use of the ERDF facility is not a likely scenario either currently or in the future; therefore, Method B is not considered to be an appropriate requirement.

Method C cleanup levels are used where: Method A or B cleanup levels are below area background concentrations; cleanup to Method A or B levels has the potential for creating greater overall threat to human health and the environment than Method C; cleanup to Method A or B is not technically possible; or the site meets the definition of an industrial site. The requirements for qualification as a Method C site are specified in WAC 173-340-720, -740 and -745. Method C cleanups must comply with other federal or state ARARs, must use all practical levels of treatment and must incorporate institutional controls as specified in WAC 173-340-706(1). Total excess cancer risk for Method C cannot exceed 1 in one hundred thousand (1×10^{-5}). Method C cleanup levels are most appropriate for use at the ERDF facility based on current and projected future land use.

All three MTCA methods for determining cleanup levels require minimum compliance with other federal or state ARARs, and consideration of cross-media contamination. For example, performance goals for the ERDF may be based on protection of groundwater. Fate and transport modeling has been performed for the ERDF to determine the potential of hazardous substances released from the facility to impact groundwater. The results of the contaminant fate and transport modeling may be compared to the cleanup levels presented in Table 7-3.

The point of compliance based on protection of groundwater and for human exposure via direct contact are defined under MTCA. The point of compliance is defined as the point or points throughout the site where cleanup levels are established in accordance with the cleanup requirements for groundwater and soil specified in Sections 173-340-720 through 750.

Dangerous Waste Regulations - WAC 173-303

The Washington State Dangerous Waste Regulations implement the federal Hazardous Waste Regulations promulgated pursuant to RCRA. The regulation establishes requirements for generation, storage, treatment and disposal of dangerous waste. General requirements for dangerous waste management facilities are discussed as action-specific ARARs, and requirements for facility siting are presented as location-specific ARARs. However, Section WAC 173-303-070 establishes procedures and methods to determine if solid waste requires management as dangerous waste. These requirements are considered applicable as chemical-specific ARARs to wastes generated at the ERDF. Section WAC 173-303-090 identifies classification of wastes based on specific characteristics such as ignitability, corrosivity, reactivity, and toxicity. Classification of wastes as either dangerous or extremely hazardous is also considered as an applicable chemical-specific ARAR.

Minimum Functional Standards for Solid Waste Handling - WAC 173-304

This regulation establishes the standards and requirements for the handling of all solid waste. The requirements of this standard are not applicable to the ERDF because the standard does not address dangerous wastes regulated under WAC 173-303. However, the regulation is considered relevant and appropriate because it establishes groundwater protection requirements for solid waste management facilities.

State Radiation Protection Standards - CH. 70.98 RCW

Washington State Radiation Standards (Ch. 70.98 RCW) were developed pursuant to the Atomic Energy Act of 1954 and are implemented in WAC 246-220 through WAC 246-255. Not all the standards in the referenced chapters are specifically applicable to the ERDF and only the following standards are considered as chemical-specific ARARs. The WAC 246-221, Radiation Protection Standards is applicable because it establishes the maximum allowable radiation dose to individuals in restricted areas, exposure to minors and permissible levels of radiation from external sources in unrestricted areas. The occupational dose limit for adults, excluding planned special exposures, shall not exceed an annual limit of a total effective dose equivalent equal to 5 rem, or the sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye should not exceed 50 rem. An eye dose equivalent of 15 rem is set for exposure to the eye. The shallow dose equivalent for the skin or any extremities is 50 rem. Occupational dose limits for minors are set at 10% of the annual occupational dose limits for adults.

The standard identifies the methods required to demonstrate compliance and provides derived air concentration (DAC) and annual limit on intake (ALI) values that may be used to determine an individual's occupational dose limits. Dose limits that individual members of public may receive in unrestricted areas or from radioactive effluent are not to cause an individual continually present in an unrestricted area, to receive from external sources, more than 0.002 rem in an hour or 0.50 rem in a year. Chapter 246-221 also establishes concentration limits in effluent released to unrestricted areas. The WAC 246-247, Radiation Protection- Air Emissions, promulgates air emission limits for airborne radionuclide emissions at the same levels as defined in WAC 173-480 which are consistent with federal NESHAPs. The ambient standard requires that emission of radionuclides to the air must not cause a dose equivalent of 25 mrem per year to the whole body or 75 mrem per year to any critical organ. Radiation protection standards for uranium and thorium milling sites are presented in WAC 246-252 and are not applicable to the ERDF because it was not used for uranium or thorium milling. However, the regulation is considered relevant and appropriate because it presents specific radiation protection standards for groundwater.

7.1.2 Location-Specific ARARs

Location-specific ARARs at the ERDF are restrictions placed on the conduct of activities associated with the ERDF based solely on the characteristics of the ERDF location.

7.1.2.1 Federal Location-Specific ARARs. Federal location-specific requirements that were evaluated are summarized in Table 7-1.

The National Historic Preservation Act of 1966 - 16 USC 470 et seq.

The National Historic Preservation Act requires that historically significant properties be protected. The Act requires that impacts posed by the ERDF to property listed on or eligible for inclusion on the National Register of Historic Places must be evaluated. The National Register of Historic Places is a list of sites, buildings or other resources identified as significant to United States history. Cultural resource surveys have been performed in the area impacted by the ERDF and no facilities identified on the National Register of Historic Places or eligible for inclusion on the list were identified. Based on the survey results, the National Historic Preservation Act is neither applicable nor relevant and appropriate to the ERDF.

The Archeological and Historic Preservation Act - 16 USC 469a

The Archeological and Historic Preservation Act is not ARAR because no archaeologic or historic sites have been identified at the ERDF location (see Section 2.7). This act is similar to the National Historic Preservation Act but differs in that it mandates only protection of historic or archaeologic data and not the actual archaeologic or historical site. If activities in connection with any federal project or federally approved project may cause irreparable loss to significant scientific, prehistorical, or archeological data, the Act requires that the agency responsible for the project preserve the data.

The Endangered Species Act - 16 USC 1531

The Endangered Species Act of 1973 is applicable and must be considered during siting, design, operation and closure of the ERDF because the Act establishes requirements to protect species threatened by extinction and habitats important to their survival. The Endangered Species

Act is designed as a means for the conservation of flora and fauna that are threatened with extinction. Endangered species are identified under the Act as species which are in danger of extinction throughout all or a significant portion of their range. Threatened species are identified as species that are anticipated to be in danger of extinction within the foreseeable future. The Endangered Species Act provides for the designation of critical habitat, defined as "specific areas within the geographical area occupied by the [endangered or threatened] species ... on which are found those physical or biological features essential to the conservation of the species..." Endangered species and critical habitats have been evaluated throughout the Hanford Site, including the location of the ERDF. No species of flora or fauna listed by the federal or state lists of endangered or threatened species were identified during an ecological survey of the ERDF location. Endangered or threatened species are found elsewhere on the Hanford Site (WHC 1993). However, the survey identified both plant and animal species considered as candidates for inclusion on federal and/or state lists of endangered or threatened species. The survey also noted areas of undisturbed sagebrush habitat considered important to the candidate species identified. The Fish and Wildlife Service will be consulted to determine management policies for the candidate species and evaluate the biological importance of the these species.

Site Selection - DOE-RL Order 4320.2C

The purpose of this DOE-RL Order is to ensure that Hanford Site facilities meet program requirements and consider economic, engineering and site planning guidelines presented in this Order. Under CERCLA, DOE-RL Orders are TBC because they are not promulgated standards. However, compliance with DOE-RL Orders is required at the Hanford Site. Site selection criteria should address such factors as safety, security, ecological, archeological and cultural resources. Engineering considerations such as proximity to utilities, transportation, adjacent land use and available buffer zones to minimize facility impacts should be evaluated. Area topography, geology, hydrology and meteorology are also siting criteria identified in the DOE-RL Order.

Radioactive Waste Management - DOE Order 5820.2A

Chapter III of DOE Order 5820.2A specifies the policies, guidelines and minimum requirements for siting DOE LLW management facilities. The disposal site selection criteria are TBC for ERDF and are not applicable because they are non-promulgated standards. The DOE Order requires that disposal site selection evaluate the method of waste confinement proposed, that the location is protective of groundwater resources, and located in areas with low potential for natural disasters. The DOE Order specifies that site selection address impacts to local populations, land use plans, available utilities and transportation routes.

Hanford Future Site Uses Working Group Recommendations

The Hanford Future Site Uses Working Group was chartered with developing a range of visions concerning future uses of the Hanford Site. The Group considered a range of cleanup scenarios necessary to make the future use visions possible (Drummond 1992). The recommendations of this group are TBC because they are not promulgated standards. The Group was comprised of representatives from federal, state, and local governments, along with interested tribal, labor, economic development and public interest groups. The Group proposed that areas of the Hanford Site having high future use value be cleaned up and that the interior section of the 200 Area plateau be designated for waste management. The group recommended that wastes from Hanford Site be concentrated in the 200 Area plateau. However, the Group further stated that waste management, storage, and disposal activities should be concentrated within a limited area and whenever possible, minimize the amount of land devoted to or impacted. The central portion of the 200 Area plateau was identified as the "squared off" boundaries of the current 200 Areas, expanded east of the 200 East Area in order to incorporate the location of the proposed grout vaults, plus a buffer zone sufficient to minimize risks associated with waste management (Drummond 1992).

7.1.2.2 State Location-Specific ARARs.

Department of Game State Environmental Policy Act Procedures - WAC 232-012

The regulations include the State of Washington Department of Fish and Wildlife procedures for compliance with the Washington State Environmental Policy Act (SEPA). The act requires that management plans be developed if threatened, endangered, or sensitive wildlife or habitat are affected by remedial actions at the site. Although no endangered or threatened species of flora or fauna have been identified within the area of the ERDF, this regulation should be considered applicable because threatened and endangered species are found elsewhere on the Hanford Site and ecological surveys of the ERDF site identified species considered as candidates for inclusion on state and/or federal lists of endangered or threatened species. The Washington State Department of Fish and Wildlife will be consulted to determine management policies and any mitigation that may be necessary to minimize ecological impacts.

Dangerous Waste Regulations, Siting Criteria - WAC 173-303-282

The Washington State Dangerous Waste Regulations implement the federal hazardous waste regulations promulgated under RCRA. The siting criteria in WAC 173-303-282 are applicable to the ERDF because the facility will manage hazardous waste. This regulation requires that the proposed location of a hazardous waste facility demonstrate compliance with the location-specific criteria presented in the regulation. The criteria limit waste management facilities to locations that are protective of water resources, ecological resources, human health, and in areas with low potential of natural disasters.

Radioactive Waste, Licensing Land Disposal - WAC 246-250-300

Requirements established for licensing land disposal facilities for radioactive waste are relevant and appropriate to the ERDF because Section WAC 246-250-300 identifies criteria and considerations used to evaluate site suitability for land disposal of LLW. The requirements of this regulation are not applicable to the ERDF because the regulation only addresses land disposal of radioactive wastes received from others. The ERDF will manage only LLW resulting from Hanford Site remediation. The regulation specifies that LLW land disposal facilities only be sited in areas that are capable of being characterized, have sufficient depth to groundwater, are not subject to natural disasters and are not in areas where natural resources are known to occur.

7.1.3 Action Specific ARARs

Action-Specific ARARs are presented in Tables 7-1 and 7-2 and will be refined once general response actions have been formulated and alternative formulation and screening have been completed.

7.1.3.1 Federal Action Specific ARARs

Resource Conservation and Recovery Act, as amended - Title 42 USC 6901

The Resources Conservation and Recovery Act (RCRA) regulates the generation, transportation, storage, treatment and disposal of hazardous waste. Federal regulations promulgated under 40 CFR 260 through 268 implement RCRA requirements for disposal facilities including specific financial, siting, design, operation, monitoring, closure and post-closure care requirements. Washington State Dangerous Waste Regulations implement the federal hazardous waste regulations and provide for regulation of state designated dangerous waste. On November 23, 1987, Ecology was given authorization by EPA to regulate mixed waste within the state.

Because the Hanford Facility RCRA permit has not been issued, Hanford Site TSDs currently operate under interim status standards promulgated in 40 CFR 265. Sections of the regulations are applicable to the ERDF if hazardous wastes are generated by the facility. General facility requirements specify waste management practices such as waste analysis, waste segregation, facility inspection, personnel training, emergency preparedness planning and facility siting criteria. Interim status facility requirements for closure and post-closure care are also defined under the regulations. The ERDF will be included in the Hanford wide permit and after permit approval, the ERDF will be required to comply with the standards for owners and operators of Hazardous Waste Treatment, Storage and Disposal Facilities in 40 CFR 264.

The Corrective Action for Solid Waste Management Units regulation (40 CFR 264.552) presents provisions for the use of corrective action management units (CAMUs) and temporary units as remediation waste management units. Previous EPA experience found that implementing RCRA Subtitle C rules to remediation wastes provided disincentives to the implementation of more protective remedies and remediation was negatively impacted by RCRA regulatory controls. Specific areas where increased flexibility in the management of remediation wastes is provided by this regulation include: placement of remediation waste into a CAMU is not considered land disposal of waste and is not subject to LDRs; CAMUs do not have to meet minimum technology requirements for landfills; and finally, CAMUs are only subject to closure requirements as deemed necessary by the EPA Regional Administrator and as appropriate to the waste management unit. The creation of CAMUs allows decision makers and facility operators increased flexibility in order to expedite remediation of environmental releases from operating hazardous waste TSD facilities. The ERDF CAMU would be incorporated in the Hanford Facility RCRA permit as a permit modification.

Radiation Protection for Occupational Workers - DOE Order 5480.11

DOE Order 5480.11, Radiation Protection for Occupational Workers establishes radiation protection requirements for worker protection from ionizing radiation at DOE and DOE contractor operations. These standards are TBC under CERCLA because they are not promulgated standards. However, compliance with DOE Orders is required at the Hanford Site. DOE policy is to implement all radiation protection requirements that are consistent with EPA guidance or based on the recommendations of authoritative organizations such as the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP). The DOE policy states that DOE operations are to be conducted so that radiation exposures are within the limits established by this Order and as far below the limits set in this Order as reasonably achievable. The DOE adheres to the "As Low As Reasonably Achievable" (ALARA) policy on radiation exposure. The ALARA policy represents a process for monitoring and evaluating work practices so that radiation exposure is reduced to levels as far below the acceptable dose as socially, technically and economically feasible.

Radiation protection standards for internal and external exposure for occupational workers are expressed in terms of stochastic and non-stochastic effects. Stochastic effects are effects such as malignancy or hereditary diseases which have a probability of occurring as a function of dose and which have no threshold dose for radiation protection purposes. Non-stochastic effects are effects for which the severity of the effect is related to the dose received and for which a threshold dose may exist. The exposure to workers as a result of DOE operations shall not result in exposure in excess of the limits established under this Order. The exposure limit for stochastic effects resulting from internal and external sources of exposure to any occupational worker must not exceed 5 rem per year. The annual dose equivalent received by an occupational worker for non-stochastic effects to individual organs and tissue is 15 rem to the lens of the eye, and 50 rem to any other organ, tissue (including skin of the whole body), or extremity of the body.

The maximum annual dose equivalent established for the protection of the unborn child (from conception to birth) as a result of occupational exposure is 0.5 rem. The employee is responsible for providing written notification of the pregnancy to their employer. Individuals under the age of 18 are not to be employed in or allowed to enter controlled areas if they will exceed an effective dose equivalent of 0.1 rem per year resulting from the sum of the committed effective dose equivalent from internal exposure and the annual effective dose equivalent from external exposure. This same exposure limit also applies to students and is considered as part of the minor's occupational exposure.

The DOE Order establishes annual dose limits for members of the public entering controlled areas at 0.1 rem effective dose equivalent per year. The effective dose equivalent includes the committed internal exposure and the effective dose equivalent external exposure.

Procedural requirements for calculating and evaluating the combined internal and external dose equivalents are provided in the Order. The methodology for calculating dose differentiates external dose to skin and extremities from the dose to external whole body exposures. Methods for calculating non-uniform exposures to skin are based on the surface area of the exposed skin. The Order also presents air and water concentration guides. Derived air concentration (DAC) values for radiation exposure control in the workplace were developed from ICRP publications and converted to units of rem and curie. The DAC are for use in monitoring radiation control and are not to be used in the calculation of internal dose equivalent received by a worker. DOE maintains a policy that drinking water in controlled areas is to meet EPA 40 CFR 141 drinking water standards.

Monitoring of occupational workers is required to demonstrate compliance with the radiation protection standards and under normal circumstances not to calculate the annual effective dose equivalent received from internal and external sources of radiation. Methods used for personnel dosimetry must be effective for monitoring compliance, be performed using equipment that can be periodically calibrated and is maintained by an accredited laboratory. Ambient air monitoring is to be performed in any workplace where the potential to exceed 10% of the DAC is anticipated. Air samples are to be representative of locations where air borne contaminant concentrations are expected to be elevated. The results of ambient air monitoring are to be used in assessing radiation control practices and are not for use in evaluating the annual effective dose equivalent to workers.

The DOE Order outlines the requirements for release of equipment and materials from controlled to uncontrolled areas and general practices for facility design. Areas within DOE facilities are to be posted if radioactive materials are present in sufficient quantity to cause a worker to receive a dose equivalent greater than 5 mrem but less than 100 mrem in one hour at 30 cm. Areas are to be posted as "high radiation areas" if the dose equivalent received in 1 hr at 30 cm exceeds 100 mrem but is less than 5 rem, and posted as a "very high radiation area" if the dose received in 1 hr at 30 cm exceeds 5 rem. Access to any area where airborne radioactive material concentration are greater than 10% of the DAC are to be posted. Entry and exit points from all radiological areas are to be controlled and equipped with visual or audio alarm systems. Records of employee training and exposure are to be maintained. Specific levels of training are required dependent on job function.

Radioactive Waste Management - DOE Order 5820.2A

This Order specifies the policies, guidelines and minimum requirements for DOE management of radioactive and mixed waste at contaminated facilities. The DOE Order provides management requirements for high-level waste (HLW), transuranic waste (TRU) and low-level waste (LLW). HLW and TRU waste will not be accepted at the ERDF. These standards are TBC under CERCLA because they are not promulgated standards. However, compliance with DOE Orders is required at the Hanford Site. Chapter III of DOE Order 5820.2A requires that LLW management practices limit external exposure to radioactive material released to the environment to levels that will not result in an effective dose equivalent to any member of the public in excess of 25 mrem/yr and that any air release meet the emission limits specified in 40 CFR 61. The DOE Order also specifies radiation exposure be limited to as low as reasonably achievable (ALARA). LLW disposal systems must be capable of limiting the effective dose equivalent received by inadvertent intruders into the disposal system after institutional controls cease, to not more than 100 mrem/yr or 500 mrem for a single acute exposure.

Guidelines for LLW management require that wastes are to be accurately characterized to allow proper management, and to be tracked using a manifest system. Specific requirements are to be developed for the shipment and receipt of waste between the generator and treatment, storage or disposal facilities. The LLW may require treatment in order that the ERDF meets the established performance objectives. LLW disposal facilities are to be designed and operated according to the performance standards established in Chapter III of DOE Order 5820.2A. Facility operating requirements include specifications for waste placement, protection of public and worker health, and security. Specific closure performance requirements are also specified in Chapter III of DOE Order 5820.2A. Residual radioactivity must meet DOE decommissioning guidelines, and site specific closure plans are required that identify how the facility will meet performance objectives. Environmental monitoring is required to measure release of radioactive contaminants to the air, soil and groundwater, or any other parameter that may affect the long-term performance of the facility.

Chapter II of DOE Order 5820.2A specifies that disposal of TRU waste is to be managed in compliance with the specifications of the Waste Isolation Pilot Plant (WIPP). The DOE Order specifies that material with transuranic waste concentrations greater than 100 nCi/g shall be managed as TRU waste. Interim storage requirements for TRU waste specified in DOE Order 5820.2A are consistent with RCRA requirements and require that interim storage facilities comply with the permitting requirements from all applicable DOE Orders, federal and state regulations. The implementation plan provides facility closure in compliance with CERCLA and other DOE, EPA, and state requirements.

Chapter I of DOE Order 5820.2A addresses the management of high-level radioactive waste. Retrievable HLW is to be disposed in a geologic repository according to the requirements of the Nuclear Waste Policy Act of 1982, as amended. This DOE Order notes that HLW which is difficult to retrieve may be disposed of in place. In-situ disposal requires periodic monitoring capable of determining the need for corrective measures. Requirements for existing facilities that manage HLW prior to disposal are also specified in the DOE Order.

Clean Air Act of 1977, as amended - Title 42 USC 4201 et seq.

The Clean Air Act (CAA) regulates emission of hazardous pollutants to the air. Requirements established under this Act are implemented by federal, state and local regulations. Pursuant to the CAA, the EPA has promulgated National Ambient Air Quality Standards (40 CFR 50), National Emission Standards for Hazardous Air Pollutants (40 CFR 61), and New Source Review Standards (NSPS)(40 CFR 60). The National Ambient Air Quality Standards are applicable to airborne releases of radionuclides and criteria pollutants specified under the standard. Specific release limits for particulates are set at 50 ug/m^3 annually or 150 ug/m^3 per 24-hour period.

Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAP) for emissions of radionuclides other than radon from DOE facilities are applicable to ERDF because the potential to release radionuclides in air emission to unrestricted areas exists. The Subpart H emission limits to ambient air from the entire facility are not to exceed an amount that would cause any member of the public to receive an effective dose equivalent of 10 mrem/yr. The definition of facility includes all buildings, structures and operations on one contiguous site. Radionuclide emissions from operation of the ERDF are required to be monitored and an effective dose equivalent value to members of the public calculated.

New Source Performance Standards established under 40 CFR 60 are not applicable to the ERDF because the ERDF is not one of the industrial sources identified in the regulation. However, the CAA also requires that states regulate emissions from existing sources for specific designated contaminants. Therefore, New Source Performance Standards are considered relevant and appropriate because criteria established under this regulation may be used to evaluate ERDF impacts on air quality.

Licensing Requirements for Land Disposal of Radioactive Waste - 10 CFR 61

The regulations under 10 CFR 61 establish the licensing requirements for land disposal of LLW. These regulations are not applicable to the ERDF because the regulation is not applicable to DOE generated waste at DOE-owned sites. However, the regulation is relevant and appropriate because it establishes performance objectives for land disposal of waste and requirements for siting, design, operation, closure, and long-term control for near-surface land disposal of LLW waste. The regulation specifies that the ALARA be applied to limit releases to the environment and also to workers during operation and includes specific annual release limits of radionuclides. The regulation establishes closure performance objectives for the facility following closure that require the facility to provide long term stability at the site with minimal use of on-going active maintenance, and to provide protection for inadvertent intruders after institutional controls are removed. The regulation identifies a time period of 100 years for institutional control.

Methods for the classification of wastes as to their suitability for near-surface disposal are established under 10 CFR 61.55. Two considerations are involved, the concentration of long-lived radionuclides whose potential hazard will persist for extended periods, and the second consideration is given to the concentration of shorter-lived radionuclides for which requirements on institutional control, waste form, and disposal methods are effective. Wastes acceptable for near-surface disposal are grouped into three categories, Class A, B, and C. Class A waste must meet the minimum requirements presented in 10 CFR 61.56; Class B waste must meet the minimum requirements in 10 CFR 61.56 and also the stability requirements in 10 CFR 61.56; Class C must meet the minimum and stability requirements presented in 10 CFR 61.56 and also must meet additional requirements for protection against inadvertent intrusion. Wastes exceeding the Class C characteristics must be disposed in a deep geologic repository as defined in 10 CFR 60 or as directed by the Nuclear Regulatory Commission.

7.1.3.2 State Action Specific ARARs. The most significant Washington state laws and regulations considered to be potential action-specific ARARs are discussed in the following section. Table 7-2 presents a complete list of potential state action-specific ARARs evaluated for the ERDF.

Dangerous Waste Regulations - WAC 173-303

The Washington State Dangerous Waste Regulations (WAC 173-303) implement the federal hazardous waste regulations for generation, treatment, storage and disposal of dangerous waste. These regulations are applicable to the ERDF because the facility is designed to be permitted as a corrective action management unit (CAMU) for remediation waste resulting from Hanford Site remediation activities. General requirements for dangerous waste management facilities specified in WAC 173-303-280 identify acceptable treatment, storage, and disposal practices for designated dangerous waste. Requirements address facility permitting, employee training, emergency preparedness planning, contingency planning, security, waste analysis, and recordkeeping. Additional requirements for landfills and surface impoundments are also specified.

Facilities are to be designed, operated and closed using practices and methods that minimize release of dangerous wastes or constituents to the environment. The regulation identifies maximum contaminant levels allowed in groundwater that insure protection of the resource. Facilities are required to implement monitoring and reporting programs. The regulation presents methods to determine the point where the facility must demonstrate compliance. These requirements may assist in determining if corrective actions are required. Corrective action requirements may be fulfilled through the use of enforcement actions implemented under MTCA, or as established under the Corrective Action requirements of WAC 137-303-646. The Corrective Action program allows increased flexibility for facility operators to address dangerous waste releases from the facility.

Model Toxics Control Act - WAC 173-340

The Model Toxics Control Act (MTCA) Cleanup Regulations established under WAC 173-340 are potentially applicable to the ERDF as operational and performance requirements. This regulation establishes cleanup requirements that are protective of human health and the environment, and the methods necessary to achieve these goals. The MTCA has statutory preference for permanent solutions that minimize the quantity of hazardous contaminants remaining on-site. The hierarchy of preference for remediation favors destruction and treatment over disposal, containment and institutional controls. WAC 173-340-400 outlines specific requirements that insure cleanup actions are designed, constructed, and implemented in a manner consistent with accepted engineering practices. Compliance monitoring requirements are specified in section WAC 173-340-400, and requirements for institutional controls are specified in WAC 173-340-440.

State Waste Discharge Permit Program - WAC 173-216

The Washington State Waste Discharge Permit Program implements a permit system applicable to industrial and commercial operations that discharge wastes into ground or surface waters and into municipal sewerage systems. The waste discharge program excludes NPDES waste discharges. Although wastewaters will not be discharged to ground or surface waters, storm water run-off may occur; therefore, this program is ARAR. The permit program prohibits waste discharges that are regulated under the Washington State Dangerous program or exhibit a pH less than 5 or greater than 11. Waste discharges may also be prohibited based on other characteristics which are known to upset municipal sewerage systems, or are likely to pass through the system unaffected by treatment. Under, CERCLA, on-site remedial actions are exempt from administrative requirements, such as permit acquisition. However, CERCLA actions must meet the substantive ARAR requirements; therefore, this regulation is relevant and appropriate. The ERDF must meet the highest possible standards for waste discharges based on all known available and reasonable methods to prevent and control the discharge of wastes.

Washington Clean Air Act - Ch. 70.94 and Ch. 43.21A RCW

The Washington Clean Air Act was enacted to comply with the federal Clean Air Act, as amended. The intent of the Clean Air Act is to insure the protection of public health and the air resources of the state. Washington State regulations implemented pursuant to the Clean Air Act considered potential ARARs for the ERDF are presented in the following discussion.

The General Regulations for Air Pollution Sources (WAC 173-400) define the policies and authority of the Department of Ecology to control air pollution from air contaminant sources. The regulation is applicable to the ERDF because it establishes both technical and procedural standards for the control of air contaminant sources. Emission limits are established for visibility, particulates, fugitive odor, and hazardous air emissions. Section WAC 173-400-040 establishes standards for maximum emissions for source units identified under the regulation. The standard is not applicable to the ERDF because the ERDF does not meet any of the source categories identified under the standard. However, the standard is relevant and appropriate because it establishes emission limits and requires that all emission units use reasonably available control technology, which for some source categories may be more stringent than the emission limitations listed.

Emission Standards for Sources Emitting Hazardous Air Pollutants are established in Section WAC 173-400-075. Requirements of this standard are applicable to the ERDF because waste disposal activities could result in the emission of hazardous air pollutants. The regulation requires monitoring, source testing, and the use of specific analytical methods for determining hazardous air pollutant emissions. Section WAC 173-400-115, Standards of Performance for New Sources, adopts and incorporates Title 40 CFR Part 60 as standards of performance for new sources. The standards are not applicable because the ERDF is not considered one of the source categories identified in the regulation. However, the regulation may be considered relevant and appropriate because it establishes review criteria that may be used to evaluate ERDF impacts on air quality.

Requirements of Section WAC 173-480 are applicable to the ERDF. The Ambient Air Quality Standards and Emission Limits for Radionuclides specifies that the maximum allowable level for radionuclides in the ambient air shall not cause a maximum accumulated dose equivalent of 25 mrems/yr to the whole body, or 75 mrems/yr to any critical organ. The standard also states that the more stringent of any federal or state standard for the control of radionuclides supersedes the standards of WAC 173-480. The regulation also defines monitoring and compliance procedures, and defines enforcement authority to Ecology and local air pollution control authorities.

Licensing Radioactive Waste Land Disposal Facilities - WAC 246-250

Section WAC 246-250, establishes the procedures, criteria and conditions for licensing of low-level radioactive waste land disposal for wastes received from others. The requirements of this regulation are not applicable to the ERDF because the ERDF will only manage DOE wastes resulting from Hanford Site remediation. This section may be considered relevant and appropriate because it presents specific levels of radiation protection and technical requirements for land disposal of radioactive waste. The licensing process requires the facility to identify how the following requirements will be achieved: protection of the public from releases of radioactivity, worker protection, facility stability following closure, protection for inadvertent intruders after closure, environmental monitoring and recordkeeping. Requirements for siting a disposal facility are discussed as potential location-specific ARARs.

7.2 REMEDIAL ACTION OBJECTIVES

The NCP states that remedial action objectives (RAOs) should include the media and contaminants of concern, the exposure pathways, and the remediation goals (40 CFR 300.430(e)(2)(i)). Development of RAOs should consider the following factors:

1) ARARs

2) Acceptable exposure levels for systemic toxicants are less than the concentrations that result in adverse effects (i.e., a hazard quotient of 1)

3) Acceptable exposure levels for carcinogens are less than the concentrations that result in an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}

4) Technical limitations such as detection limits for contaminants

5) Uncertainty

6) Threats to the environment, especially sensitive habitats and critical habitats of protected species.

Development of RAOs for this RI/FS is unusual in that the scope is limited to configuration of a waste management facility and does not address remediation of contaminated sites. Current risks and RAOs for the contaminated sites are evaluated in the operable unit RI/FSs. The following remedial action objectives have been identified for the ERDF:

1) **Support the removal of contaminants from portions of the Hanford Site (including near the Columbia River) in a timely manner:** This is the overall objective of this action given public opinion that contaminants should be removed from near the Columbia River as soon as possible. This opinion is based on

concern regarding potential impacts of these contaminants on the Columbia River and the desire to release the remediated areas for other productive uses.

2) **Prevent unacceptable direct exposure to waste.** As demonstrated in Chapter 6, direct exposure to the types of waste received at the ERDF could result in unacceptable health risks. Direct exposure of workers and biota to waste could occur during operation of the ERDF (i.e., during waste transport and filling operations). Due to access control at the Hanford Site, the direct exposure pathway does not apply to the public during operations. Once the ERDF is closed, direct exposure to waste is only possible if institutional controls fail and the surface barrier is breached.

3) **Prevent unacceptable contaminant releases to air.** As demonstrated in Chapter 6, inhalation exposure to the types of waste received at the ERDF could result in unacceptable health risks. Similar to the direct exposure pathway, inhalation of waste by workers and biota could occur during operation of the ERDF (i.e., during waste transport and filling operations). Airborne transport of waste off the Hanford Site could result in exposures to the public, but these exposures would be negligible compared with worker risks. Once the ERDF is closed, air releases are only possible if institutional controls fail and the surface barrier is breached.

4) **Prevent contaminant releases to groundwater above ARARs and health-based criteria.** This RAO addresses the conclusion in Chapter 6 that migration of contaminants through the vadose zone to groundwater could result in unacceptable human exposure to contaminants. This RAO has been acknowledged in the TPA, which states: "the point of [risk] assessment will be the intersection of the groundwater and the vertical line drawn from the edge of the disposal facility". Other agreements contained within the TPA are the time of assessment (10,000 years) and the compliance standard (10^{-5} for the first 100 years and 10^{-4} thereafter). Since the risk assessment indicates that the risk associated with the groundwater pathway should remain below 10^{-5} for the first 100 years, the relevant compliance standard is 10^{-4}. Maximum acceptable groundwater concentrations for contaminants of potential concern in waste disposed of in the ERDF are provided in Table 7-5. These concentrations summarize the lowest of the ARAR-based concentrations, as well as the concentration equivalent to either a HQ of 1, or an ICR of 10^{-5}, whichever is lower.

5) **Minimize Ecological Impacts.** Construction of the ERDF will result in harmful impacts on the ecology of the ERDF site and the borrow sites providing materials for ERDF construction. As discussed in Chapter 2, significant value is attached to the ecology at these sites. As a result, ecological impacts should be minimized and/or mitigated to the maximum extent possible.

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Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 1 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
CHEMICAL SPECIFIC		
Safe Drinking Water Act of 1974 Title 42 USC 300, et seq.		
National Primary Drinking Water Standards 40 CFR 141	Relevant & Appropriate	The NCP identifies maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) established under the Safe Drinking Water Act as clean up goals for groundwater and surface waters that are current or future sources of drinking water where the MCLG or MCL are relevant and appropriate to the situation. In addition, WAC 173-340-720 (2)(a)(ii) specifies that MCLs, MCLGs and SMCLs are ARARs for groundwater cleanup, where groundwater has a current or potential future use as drinking water. Groundwater at the ERDF location is currently not used for drinking, however it could be used in the future, if the site is released from institutional controls. In addition, there is potential for discharge of groundwater to the Columbia River, which is used for drinking water. Design, operation and closure of the ERDF should prevent migration of contaminants from the facility to groundwater at concentrations that cause groundwater to exceed MCLs and MCLGs.
National Secondary Drinking Water Standards 40 CFR 143	Relevant and Appropriate	Federal secondary standards are not enforceable standards and are not typically applicable or relevant and appropriate requirements, however, WAC 173-340-720 (2)(a)(ii) specifies that MCLs, MCLGs and SMCLs are ARARs for groundwater cleanup, where groundwater has a current or potential future use as drinking water.
Resource Conservation and Recovery Act 42 USC 6901 et seq		
Ground Water Protection Standards 40 CFR 264	Applicable	This regulation establishes groundwater protection standards for hazardous waste management facilities. The requirements of this section are applicable to the ERDF because the facility is anticipated to receive hazardous waste.
Land Disposal Restrictions 40 CFR 268	Not ARAR	Land disposal restrictions are applicable to wastes generated during operation of the ERDF and disposed off-site. However, LDRs are not ARAR to disposal of waste within the ERDF because the facility falls under RCRA Subpart S - Corrective Action for Solid Waste Management Units (CAMUs) requirements. Land disposal restrictions will also be evaluated as potential action-specific ARARs.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 2 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Clean Air Act of 1977, as amended 42 USC 7401 et seq.		
National Ambient Air Quality Standards 40 CFR 50	Applicable	Requirements of these regulations are applicable to airborne releases of radionuclides and criteria pollutants specified under the statue. Specific release limits for particulates are set at 50 ugm/m³ annually or 150 ugm/m³ per 24-hour period. Standards for airborne lead measured as elemental lead are set at 1.5 ugm/m³, maximum arithmetic mean averaged over a calendar quarter.
National Emission Standard for Hazardous Air Pollutants (NESHAPs), Subpart H - National Emission Standards for Emissions of Radionuclides Other than Radon From Department of Energy Facilities 40 CFR 61	Applicable	These requirements are applicable to the ERDF because the potential to release air emissions to unrestricted areas exists. Subpart H sets emissions limits from the entire facility to ambient air not exceed an amount that would cause any member of the public to receive an effective dose equivalent of 10 mrem/yr. The definition of facility includes all buildings, structures and operations on one contiguous site.
Atomic Energy Act of 1954, as amended Title 42 USC 2011 et seq.		
Environmental Radiation Protection Standards for Nuclear Power Operations 40 CFR 190	Not ARAR	The regulation specifies the levels below which normal operations of the uranium fuel cycle are determined to be environmentally acceptable. These standards are not applicable and not relevant and appropriate because the standard excludes operations at disposal sites and the definition of the uranium fuel cycle focuses on those processes that result in generation of electrical power. The standard sets dose equivalents from the facility which are not to exceed 25 mrems/yr to whole body, 75 mrems/yr to thyroid, or 25 mrems/yr to any other organ. Release limits at .5 mCi for Pu-239 and other alpha emitting transuranics with half-lives greater than one year.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 3 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level Waste and Transuranic Radioactive Waste 40 CFR Part 191	Not ARAR	Standards under this regulation contain environmental protection requirements for management and disposal of spent nuclear fuel, high-level waste and transuranic wastes at facilities operated by the Department of Energy. The standard addresses all disposal methods. These requirements are not applicable or relevant and appropriate because waste materials to be disposed within the ERDF do not meet the definition of waste subject to this regulation. However, the Tri-Party Agreement between Ecology, EPA and DOE identify the same long-term performance standard, 10,000 yrs, to be one of the parameters evaluated in the ERDF risk assessment. Subpart A applies to facilities regulated by the Nuclear Regulatory Commission and sets maximum committed effective dose (CED) of 15 mrem/ yr for any member of the public. Environmental standards set in Subpart B address protection of individual members of the public and groundwater at disposal facilities. Disposal systems are to be designed to provide protection for up to 10,000 yr following disposal and undisturbed performance should limit individual members of the public to a CED of less than 15 mrem/yr. Groundwater protection standard for radiological contaminants will be set at the levels promulgated under 40 CFR 141.
Uranium Mill Tailings Radiation Control Act of 1978 42 USC 2022		
Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings 40 CFR 192	Relevant & Appropriate	Requirements of this act are relevant and appropriate because radioactive waste containing uranium will be disposed at the ERDF. The standard is not applicable because the ERDF will not be used for disposal of uranium or thorium millings. Subpart B concentration limits may be used as performance criteria for the ERDF. Groundwater protection requirements Ra-226, Ra-228 and gross alpha particle activity are set at EPA established drinking water levels.
Nuclear Regulatory Standards for Protection Against Radiation 10 CFR 20	Relevant & Appropriate	The regulation establishes standards for protection of the public against radiation arising from the use of regulated materials and as such are relevant and appropriate. Radioactive material from sources not licensed by the NRC are not subject to these regulations, therefore this standard is not applicable because the ERDF will not be NRC licensed. Operation of the ERDF should limit external and internal exposure from releases to levels that do not exceed 100 mrem/yr, or 2 mrem/ hr from external exposure in unrestricted areas. Specific concentration limits of contaminants of concern resulting from airborne releases allowed in unrestricted areas are based on annual effective dose equivalent from internal exposure of 50 mrem for adults.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 4 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
DOE Order 5400.5 - Radiation Protection of the Public and the Environment	To Be Considered	This DOE Order sets radiation standards for protection of the public in the vicinity of DOE facilities. This DOE Order is TBC under CERCLA because DOE Orders are not promulgated standards. However, compliance with DOE Orders is required at the Hanford Site. The DOE Order sets limits for the annual effective dose equivalent of 100 mrem, but allows temporary limits of 500 mrem if avoidance of higher exposures is impractical. The standard sets annual dose limits for any organ at 5 mrem. An annual dose equivalent from drinking water supplies operated by DOE is set at 4 mrem and notes that liquid effluent from DOE activities will not cause public drinking water systems to exceed EPA MCLs. The DOE Order also establishes design lifetime control and stabilization features as given in 40 CFR 192, including control and access features to be effective to reasonable extent for 1000 yrs, and in any case no less than 200 yrs.
Toxic Substance Control Act 15 USC 2601 et seq.		
Regulation of PCBs 40 CFR 761	Applicable	TSCA requirements are potentially applicable to the ERDF because PCBs have been identified as potential contaminants of concern and may be disposed of at the ERDF above the regulated concentration of 50 ppm. This regulation establishes handling, storage and disposal requirements for wastes with PCB concentrations greater than 50 ppm.
LOCATION SPECIFIC		
National Historic Preservation Act of 1966 USC 470 et seq.	Not ARAR	Requirements established under this act are not applicable or relevant and appropriate to the ERDF because no facilities located at site are currently listed on or proposed for inclusion on the National Register of Historic Places.
Archeological and Historic Preservation Act 16 USC 469a-1	Not ARAR	This act requires that actions conducted at the site must not cause the loss of any archeological and historic data. This act varies from the National Historic Preservation Act in that it mandates only preservation of the data and not the actual facility. This Act is not applicable or relevant and appropriate because no archeological or historic sites have currently been identified within the ERDF area, however, if archeological or historic sites are identified, then these requirements may be applicable.
Endangered Species Act of 1973 16 USC 1531 et seq.	Applicable	This law is applicable and must be considered during design, operation and closure of the ERDF because it establishes requirements to protect species threatened by extinction and habitats critical to their survival. No animal or plant species on the federal or state lists of endangered or threatened species where identified during an ecological survey of the ERDF site. Endangered and threatened species and critical habitat are found elsewhere on the Hanford Site. However, the survey identified both plant and animal species considered as candidates for inclusion on federal and/or state lists of threatened or endangered species. The Washington State Department of Wildlife and the federal Fish and Wildlife Service should be consulted to determine management policies for candidate species and evaluate the biological importance of these species.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 5 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Resource Conservation and Recovery Act 42 USC 6901 et seq		
Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities 40 CFR 264		
Location standards 40 CFR 264.18	Applicable	The regulations under this section establish specific facility siting and design requirements based on facility location. The requirements of this section are applicable to the ERDF because the facility will manage hazardous waste.
Site Selection - DOE-RL Order 4320.2C	TBC	The purpose of this DOE-RL Order is to ensure that Hanford Site facilities meet program requirements and consider economic, engineering and site planning guidelines presented in this Order. Under CERCLA, DOE-RL Orders are TBC because they are not promulgated standards. However, compliance with DOE-RL Orders is required at the Hanford Site. Site selection criteria should address such factors as geology, engineering limitations, ecological, archeological and cultural resources.
Radioactive Waste Management - DOE Order 5820.2A	TBC	Chapter III of DOE Order 5820.2A specifies the policies, guidelines and minimum requirements for siting DOE LLW management facilities. The disposal site selection criteria are TBC for ERDF and are not applicable because they are non-promulgated standards. The DOE Order requires that disposal site selection evaluate the method of waste confinement proposed, that the location is protective of groundwater resources, and located in areas with low potential for natural disasters.
Hanford Future Site Uses Working Group Recommendations	TBC	The Hanford Future Site Uses Working Group was chartered with developing a range of visions concerning future uses of the Hanford Site. The Group considered a range of cleanup scenarios necessary to make the future use visions possible. The recommendations of this group are TBC because they are not promulgated standards. The Group was comprised of representatives from federal, state, and local governments, along with interested tribal, labor, economic development and public interest groups. The Group proposed that areas of the Hanford Site having high future use value be cleaned up and that the interior section of the 200 Area plateau be designated for waste management. The group recommended that wastes from Hanford Site be concentrated in the 200 Area plateau. However, the Group further stated that waste management, storage, and disposal activities should be concentrated within a limited area and whenever possible, minimize the amount of land devoted to or impacted.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 6 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Wild and Scenic Rivers Act 16 USC 1271 et seq	Not ARAR	Requirements of this act are not applicable or relevant and appropriate because the Columbia River is not included in the national system of wild and scenic rivers. The Columbia River has been proposed for inclusion in the system, however, the ERDF is distant from the Columbia River and the facility will be designed and operated to minimize migration of contaminants from the facility to groundwater and is not anticipated impact to the Columbia River.
Compliance With Floodplain/ Wetlands Environmental Review Requirements 10 CFR 1022	Not ARAR	This regulation is not ARAR to the ERDF because the facility is not sited within a floodplain and no wetlands are present at the site. This regulation requires DOE and other federal agencies to comply with the requirements of Executive Order 11990 - Protection of Wetlands, and Executive Order 11988 - Floodplain Management. Executive Order 11988 requires DOE procedures to insure that any action conducted in a floodplain consider flood hazards. Executive Order 11990 requires protection of wetlands from destruction. This regulation requires federal agencies to implement these considerations through existing federal standards, such as the National Environmental Policy Act. The U.S. Army Corp of Engineers has established a nationwide permitting program for actions the impact wetlands. Under CERCLA, on-site actions are not required to comply with administrative permit requirements of federal, state and local regulations; however, CERCLA actions ,must comply with substantive portions of the regulations.
ACTION SPECIFIC		
Resource Conservation and Recovery Act, as amended 42 USC 6901		
Criteria for Municipal Solid Waste Landfills 40 CFR 258	Relevant and Appropriate	This rule establishes the minimum national criteria for the location, design, operation, cleanup and closure of municipal solid waste landfills. This rule applies only to municipal solid waste landfills as defined under the standard that received waste on or after October 9, 1993. The standard defines a municipal solid waste landfill as a discrete area of land that receives household waste and is not a land application unit, surface impoundment or waste pile as defined under 40 CFR 257. This standard is not applicable because the ERDF does not meet this definition. However, the regulation is relevant and appropriate and criteria specified in this regulation may be used for ERDF performance evaluations.
Identification and Listing of Wastes 40 CFR 261	Applicable	These requirements are applicable for all waste generated at or received for disposal in the ERDF. Waste must be identified and evaluated to determine if it is hazardous waste.
Generator Standards 40 CFR 262	Applicable	Regulatory requirements for facilities that generate hazardous waste are applicable if hazardous waste is generated at the ERDF.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 7 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Standards Applicable to Transporters of Hazardous Waste 40 CFR 263	Relevant and Appropriate	This section of the regulation establishes requirements for transporters of hazardous waste. The regulations are relevant and appropriate to the ERDF because the facility will receive only Hanford Site remediation waste for disposal. The standard specifies that transporters must maintain records concerning delivery to treatment, storage or disposal facilities, proper labeling of transported wastes and manifest system compliance.
Standards for Owners and Operators of TSD Facilities 40 CFR 264	Applicable	Regulatory requirements for owners and operators of hazardous waste storage, treatment or disposal facilities are applicable to the ERDF and may include specific disposal requirements, such as the minimum technical requirements (MTR) for RCRA landfill covers. The general requirements established for TSD facilities are applicable to CAMUs unless specifically identified in the CAMU rule, 40 CFR 264.552. For example, CAMUs are exempt from MTRs since they are not regulated as landfills or surface impoundments.
General Facility Standards 40 CFR 264.10 - 264.18	Applicable	This section of the regulation specifies general facility requirements that are applicable to the ERDF. Requirements include employee training, emergency preparedness planning, contingency planning, and identifies specific requirements for landfills and surface impoundments.
Preparedness and Prevention 40 CFR 264.30 - 264.37	Applicable	Facilities must be maintained and operated in a manner that minimizes potential for fire, explosion or unplanned release of hazardous waste to air, water or soil. These requirements are applicable because the ERDF will manage hazardous waste.
Releases From Solid Waste Management Units (40 CFR 264.90-264.120)	Applicable	The requirements of this regulation are applicable to the ERDF because it is a landfill unit created to dispose of RCRA hazardous waste. The regulation establishes a program for groundwater detection and compliance monitoring.
Use and Management of Containers 40 CFR 264.170 - 264.178	Applicable	The requirements of this section are applicable to the ERDF if hazardous waste is stored prior to disposal. Subpart I provides standards and management practices for containers that include inspection, segregation, containment and closure.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 8 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Tank Systems 40 CFR 264.190	Applicable	The requirements in this section may be applicable to the ERDF if hazardous wastes are generated and managed using tanks. The section contains performance, operation, monitoring and closure requirements that apply to management of hazardous waste using tanks.
Closure and Post Closure 40 CFR 264.110-264.120	Applicable	This regulation describes closure performance requirements designed to minimize or eliminate the escape of hazardous waste constituents to ground and surface waters. Requirements of this regulation are applicable to the ERDF because the facility will manage hazardous waste. Requirements for closure of a CAMU will be identified at the time the CAMU is designated and will incorporate requirements deemed necessary to protection the public and minimize releases to the environment.
Landfills 40 CFR 264.300 - 264.317	Applicable	The regulations in this section are applicable to the ERDF because they address disposal of hazardous waste in landfills. Requirements are established for design and operation, monitoring, recordkeeping and closure and post-closure care at hazardous waste landfills. Under the CAMU rule, closure requirements will be established at the time the CAMU is designated and will incorporate requirements deemed by the EPA Regional Director to protect the public and minimize releases to the environment.
Corrective Action for Solid Waste Management Units (CAMUs) 40 CFR 264.552	Applicable	The Corrective Action for Solid Waste Management Units regulation (40 CFR 264.552) is applicable to the ERDF. This regulation presents provisions for the use of corrective action management units (CAMUs) and temporary units as remediation waste management units. Specific areas where increased flexibility in the management of remediation wastes provided by this regulation include; placement of remediation waste into a CAMU is not considered land disposal of waste and is not subject to LDRs; CAMUs do not have to meet minimum technology requirements for landfills; and finally, CAMUs are only subject to closure requirements as deemed necessary by the EPA Regional Administer and as appropriate to the waste management unit. The creation of CAMUs allows decision makers and facility operators increased flexibility in order to expedite remediation of environmental releases resulting from hazardous waste TSD facilities.
Land Disposal Restrictions 40 CFR 268	Applicable	These requirements are only applicable to the off-site disposal of restricted waste generated during operation of the ERDF. These requirements are not applicable to disposal of Hanford Site remediation wastes because the ERDF will be managed under the CAMU regulations, which specifically exempts wastes disposed in CAMUs from the LDRs.
Treatment Standards 40 CFR 268.40	Applicable	Hazardous wastes generated at the ERDF that are not treated to BDAT or do not meet the extract or constituent concentration limit are prohibited from off-site land disposal. This regulation is potentially applicable to any hazardous waste generated at the ERDF and disposed off-site.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 9 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Prohibition on Storage 40 CFR 268.50	Applicable	Wastes are also prohibited from being stored longer than one year, unless storage is necessary to facilitate proper recovery, treatment or disposal. Land ban wastes, generated from the operation of the ERDF and stored for longer than one year must be placed in tanks and containers that meet the requirements, unless wastes have been treated, treatment has been waived, a treatment variance has been set for the waste, an equivalent treatment method petition has been approved, or the waste has been delisted.
Clean Water Act of 1977, 33 USC 1251, as amended		
EPA National Pollutant Discharge Elimination System (NPDES) Permit regulations 40 CFR 122	Not ARAR	Both on-site and off-site discharge of waste water to surface waters from CERCLA site are required to meet the substantive requirements under NPDES. These requirements are not ARAR at the ERDF since waste water will not be discharged. NPDES requirements include discharge limitations, monitoring, and incorporation of best management practices. Substantive requirements for on-site discharges from a CERCLA site must be identified and complied with even though an NPDES Permit will not be obtained. Off-site discharges from a CERCLA site directly to receiving waters must comply with applicable federal, state and local requirements. For off-site discharge, a NPDES application must be made 180 days before discharges actually begin.
Criteria and Standards for the National Pollutant Discharge Elimination System 40 CFR 125	Not ARAR	Under Part 301(b) of the Clean Water Act, all direct discharges to waters of the U.S. shall meet technology based requirements. This section is not ARAR since the ERDF will not discharge directly to surface waters. Best available technology economically achievable will be used for toxic and non-conventional pollutants. Best management practices are required for any discharge containing pollutants listed as toxic or hazardous. Best Management Practices shall be incorporated into the NPDES Permit and may reflect requirements for Spill Prevention Control and Counter (SPCC) measure plans under Section 311 of the Act and 40 CFR 151.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 10 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Occupational Safety and Health Act of 1970 (OSHA) 20 USC 333 as amended		
OSHA Standards 29 CFR 1910	Not ARAR	Occupational health and safety requirements, including Sections 1910.9, Ionizing Radiation, and 1910.120, Hazardous Waste Operations and Emergency Response, are not ARAR to activities conducted at the ERDF. Certain OSHA regulations are included in CERCLA and SARA, and thus apply directly to CERCLA actions. However, in general OSHA regulations are not considered environmental regulations or standards and are not evaluated in remedy selection.
OSHA Safety and Health Regulations for Construction 29 CFR 1926	Not ARAR	The safety and health standards under this OSHA regulation are not considered ARAR, however, all construction activities at the ERDF are required to meet these occupational standards. Refer to OSHA 29 CFR 1910 for additional discussion. Subparts of the standard address construction activities such as safety, training, operation of mechanized equipment, materials handling, and excavation.
Radiation Protection for Occupational Workers, DOE Order 5480.011	To be Considered	DOE Order 5480.11 implements radiation protection standards and program requirements for worker protection at DOE and DOE contractor operations. These standards are TBC under CERCLA because they are not promulgated regulations. However, compliance with DOE Orders is required at the Hanford Site. These standards were developed to be consistent with EPA standards and are based on recommendations by organizations recognized as authorities in the area of radiation protection. DOE policy is to maintain radiation exposure as low as reasonably achievable (ALARA). The allowable effective dose equivalent to a worker from both internal and external sources received in any year is 5 rem. Radiation protection standards for the public entering controlled areas are set at .1 rem/yr from the committed effected dose equivalent from any external radiation. In addition, exposure shall not cause a dose equivalent to any tissue to exceed 5 rem/yr.
Radioactive Waste Management DOE Order 5820.2A	To Be Considered	This DOE Order establishes DOE policies and guidelines for the management of radioactive waste and contaminated facilities. These standards are TBC under CERCLA because they are not federally promulgated regulations. However, compliance with DOE Orders is required at the Hanford Site. These guidelines set performance objectives to limit the annual effective dose equivalent beyond the facility boundary to 25 mrems. Disposal methods selected must be sufficient to limit the annual effective dose equivalent to 100 mrem for continuous exposure or 500 mrem for acute exposures when institutional controls are removed.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 11 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Chapter III-Management of Low-Level Waste	To Be Considered	This section establishes the DOE policies and requirements for the management of low-level waste at DOE facilities and should be considered during development of the ERDF. The DOE Order establishes an effective dose equivalent to members of the public not to exceed 25 mrem/yr from releases of radioactive material. The DOE Order identifies performance objectives to limit external exposure and protection of groundwater. The DOE Order includes siting, design, operation and closure requirements for LLW disposal facilities. These requirements should be considered during the development of waste acceptance criteria.
Clean Air Act of 1977, as amended 42 USC 7401 et seq.		
National Ambient Air Quality Standards 40 CFR 50	Applicable	Requirements of these regulations are applicable to airborne releases of radionuclides and criteria pollutants specified under the statue. Specific release limits for particulates are set at 50 ugm/m³ annually or 150 ugm/m³ per 24-hour period. Standards for airborne lead measured as elemental lead are set at 1.5 ugm/m³, maximum arithmetic mean averaged over a calendar quarter.
New Source Performance Standards 40 CFR 60	Relevant and Appropriate	The requirements of this regulation are not applicable to the ERDF because the ERDF is not one of the industrial categories specifically identified in the regulation. However, the standards may be considered relevant and appropriate if the ERDF has the potential to emit a contaminant or utilizes a technology similar to the pollutant or technology regulated by a New Source Performance Standard.
National Emission Standard for Hazardous Air Pollutants (NESHAPs), Subpart H - National Emission Standards for Emissions of Radionuclides Other than Radon From Department of Energy Facilities 40 CFR 61	Applicable	These requirements are applicable to the ERDF because the potential to release air emissions to unrestricted areas exists. Subpart H sets emissions limits from the entire facility to ambient air not exceed an amount that would cause any member of the public to receive an effective dose equivalent of 10 mrem/yr. The definition of facility includes all buildings, structures and operations on one contiguous site.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 12 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Atomic Energy Act of 1954, as amended Title 42 USC 2011 et seq.		
Nuclear Regulatory Standards for Protection Against Radiation 10 CFR 20	Relevant & Appropriate	The regulation establishes standards for protection of the public against radiation arising from the use of regulated materials and as such are relevant and appropriate. Radioactive material from sources not licensed by the NRC are not subject to these regulations, therefore this standard is not applicable because wastes received at the ERDF are not from NRC licensed facilities. The ERDF should be operated to limit external and internal exposures from releases to levels that do not exceed 100 mrem/yr, or 2 mrem/hr from external exposure in unrestricted areas. Specific concentration limits for contaminants are addressed. These limits are under chemical-specific ARARs.
Licensing Requirements for Land Disposal of Radioactive Waste 10 CFR 61	Relevant & Appropriate	These regulations establish the licensing requirements for land disposal of LLW waste at NRC licensed facilities. These regulations are not applicable to the ERDF because the regulation is not applicable to DOE generated waste at DOE-owned sites. However, the requirement that disposal systems must be designed to limit the annual dose equivalent beyond the facility boundary below 25 mrems to the whole body, 75 mrems to the thyroid, or 25 mrem to any other organ are relevant and appropriate to the ERDF. The regulation identifies specific technical requirements for disposal of LLW that may be considered relevant and appropriate to the ERDF.
Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes 40 CFR Part 191	Relevant and Appropriate	Containment requirements established by this standard are not applicable to the ERDF because no wastes meeting the definition established in 40 CFR 191.02 (ii) will be disposed at the facility. However, the standard may be relevant and appropriate because the regulation establishes performance standards for radioactive waste disposal facilities. The final rule published in the December 20, 1993 Federal Register (58 FR 66398), effective January 20, 1994, states that radionuclide release to the environment for a period of 10,000 yr after disposal shall not exceed the limits for drinking water established in 40 CFR 141, as they exist on the date the implementing agency determines compliance. The final rule requires that disposal methods control radiation exposure for at least 10,000 years and limits the radiation exposure to an individual of no more than 15 mrems committed effective dose (CED) per year.
Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings 40 CFR 192	Relevant & Appropriate	Standards for cleanup set under this program may be considered as performance criteria for the ERDF and as such are relevant and appropriate. The standard is not applicable because radioactive wastes from uranium or thorium milling sites will not be disposed at the ERDF.

Table 7-1. Identification of Potential Federal ARARs for the ERDF. (Sheet 13 of 13)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered,	Comment
Hazardous Materials Transportation Act (49 USC 1801, et seq)		
Hazardous Materials Regulation 49 CFR 171	Applicable	The standards established under this regulation specify that no person may offer or accept hazardous material for transportation in commerce unless the material is properly classed, described, packaged, marked, labeled and in condition for shipment. These requirements are applicable to hazardous material generated by or shipped from the ERDF.
Hazardous Materials Tables, Hazardous Materials Communications Requirements and Emergency Response Information Requirements 49 CFR 172	Applicable	This regulation is applicable to hazardous materials generated at or shipped from the ERDF. The class of each hazardous material is identified in tables with requirements for packaging, labeling and transportation. Small quantities of radioactive materials are not subject to any other requirements of the chapter if the activity level does not exceed levels specified under §§173.421, 173.422, or 173.424. Packages used for shipping hazardous materials shall be designed and constructed, and its contents so limited, that under conditions normally incident to transportation, there is no significant release of hazardous materials to the environment.

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Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 1 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
CHEMICAL SPECIFIC		
Hazardous Waste Clean Up/ Model Toxics Control Act Ch. 70.105D RCW		
Model Toxics Control Act WAC 173-340	Relevant and Appropriate	Requirements under this standard may be considered relevant and appropriate to the ERDF. These regulations are not applicable because they address cleanup of contaminants released into the environment and there have been no releases at the ERDF. Specific cleanup goals and methods established in the standard require implementation of the strictest federal or state cleanup criteria. For groundwater remediation under MTCA, MCLGs and secondary drinking water standards are identified as cleanup criteria. The MTCA also establishes requirements for soil cleanup based on protection of groundwater which are set at 100 times the most stringent federal or state standard, or calculated using standard methods incorporated in the regulation, unless it can be demonstrated these methods are not appropriate for the site. These cleanup standards may be used as performance objectives for the ERDF.
Dangerous Waste Regulations Ch. 70.105 RCW		
Dangerous Waste Regulations WAC 173-303		
Designation of Dangerous Waste WAC 173-303-070	Applicable	The Washington State Dangerous Waste Regulations implement the federal Hazardous Waste Regulations promulgated pursuant to RCRA. Requirements found in WAC 173-303-070 establish the procedures and methods to determine if solid waste requires management as dangerous waste. These requirements are applicable as chemical-specific ARARS for the ERDF because the facility may generate dangerous wastes. These requirements are not applicable to the Hanford Site remediation wastes.
Dangerous Waste Characteristics WAC 173-303-90	Applicable	This section sets forth the methods to classify wastes as dangerous or extremely hazardous based on characteristics of ignitability, corrosivity, reactivity, and toxicity. Classification of wastes is only applicable to wastes generated at the ERDF and are not applicable to remediation wastes disposed of at the ERDF.

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 2 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
Solid Waste Management, Recovery and Recycling Act Ch. 70.95 RCW		
Minimum Functional Standards for Solid Waste Handling WAC 173-304	Relevant and Appropriate	The standard sets the minimum requirements for the handling of all solid waste, including operation, monitoring and closure requirements. The requirements of this standard are not applicable to the ERDF because the standard does not address wastes regulated under WAC 173-303. However, the standard is relevant and appropriate because it sets maximum contaminant levels (MCLs) for groundwater at the same levels as the drinking water standards under 40 CFR 141.
State Radiation Protection Standards Ch. 70.98 RCW		
Radiation Protection Standards WAC 246-221	Applicable	This regulation is considered applicable because it establishes standards for acceptable levels of exposure to radiation. The occupational dose limit for adults, excluding planned special exposures, shall not exceed an annual limit of a total effective dose equivalent equal to 5 rem, or the sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye should not exceed 50 rem. An eye dose equivalent of 15 rem is set for exposure to the eye. The shallow dose equivalent for the skin or any extremities is 50 rem. Occupational dose limits for minors are set at 10% of the annual occupational dose limits for adults. The standard identifies the methods required to demonstrate compliance and provides derived air concentration (DAC) and annual limit on uptake (ALI) values that may be used to determine an individuals occupational dose limits. Dose limits that individual members of public may receive in unrestricted areas or from radioactive effluent, are not to cause an individual, if continually present in an unrestricted area, to receive from external sources, not to exceed 0.002 rem in an hour or 0.50 rem in a year. The standard species the requirements for monitoring personnel exposure from both external and internal exposure. Chapter 246-221-290 establishes annual average concentration limits for radioactive releases in gaseous or liquid effluent released to unrestricted areas.
Radiation Protection- Air Emissions WAC 246-247	Applicable	This regulation promulgates air emission limits for airborne radionuclide emissions as defined in WAC 173-480 and is consistent with federal NESHAPs. The ambient standard requires that emission of radionuclides to the air must not cause a dose equivalent of 25 mrem per year to the whole body or 75 mrem per year to any critical organ.

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 3 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
Radiation Protection at Uranium and Thorium Milling Operations WAC 246-252	Relevant and Appropriate	Requirements established under the Radiation Protection at Uranium and Thorium Milling Operations regulations are not applicable to the ERDF because the site was not a uranium or thorium milling operation. However, the regulations are relevant and appropriate because they contain specific concentration limits for protection of groundwater set at the same level, or more stringent than the level established by the EPA under 40 CFR 192.
LOCATION SPECIFIC		
Department of Game SEPA Procedures WAC 232-12	Applicable	This regulation defines actions the Department of Fish and Wildlife must take to protect endangered or threatened wildlife and sensitive habitat. An ecological survey of the ERDF site failed to identify any species listed on state and/or federal lists of endangered or threatened species. However, the requirements of this regulation are considered applicable to the ERDF because threatened or endangered species, and sensitive or critical habitat are present elsewhere on the Hanford Site. Even though the majority of these requirements are administrative in nature, activities at ERDF are required to meet the substantive aspects of the regulation and to adhere to the goals of protecting and enhancing wildlife resources. The Washington State Department of Fish and Wildlife will be consulted concerning management policies and mitigation that may be necessary to minimize ecological impacts.
Washington State Dangerous Waste Regulations, Siting Criteria - WAC 173-303-282	Applicable	The Washington State Dangerous Waste Regulations implement the federal hazardous waste regulations promulgated under RCRA. The siting criteria in WAC 173-303-282 are applicable to the ERDF because the facility will manage hazardous waste. This regulation requires that the proposed location of a hazardous waste facility demonstrate compliance with the location-specific criteria presented in the regulation. The criteria limit waste management facilities to locations that are protective of water resources, ecological resources, human health, and in areas with low potential of natural disasters.
State Radiation Protection Requirements CH. 70.98 RCW		
Radioactive Waste - Licensing Land Disposal WAC 246- 250		

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 4 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
Disposal Site Suitability Requirements for Land Disposal WAC 246-250-300	Relevant and Appropriate	The requirements of this section of the regulation identify criteria and considerations used to evaluate site suitability for land disposal of LLW. The requirements of this regulation are not applicable to the ERDF because the regulation only addresses land disposal of radioactive wastes received from others. The ERDF will manage only LLW resulting from Hanford Site remediation. The regulation specifies that LLW land disposal facilities only be sited in areas that are capable of being characterized, have sufficient depth to groundwater, are not subject to natural disasters and are not in areas where natural resources are known to occur.
ACTION SPECIFIC		
Hazardous Waste Management Act 70.105 RCW		
Dangerous Waste Regulations WAC 173-303		
Land Disposal Restrictions WAC 173-303-140	Not ARAR	This section of the regulation is only applicable to dangerous wastes generated by the ERDF. The section identifies wastes that are restricted from land disposal, describes requirements for managing restricted wastes, and defines the circumstances under which a prohibited waste may continue to be landfilled. These standards are not applicable to disposal of remediation because remediation wastes are exempt from LDRs under the CAMU rule (WAC 173-303-646), unless otherwise identified by Ecology.
Spills and Discharges into the Environment WAC 173-303-145	Applicable	Applicable to the ERDF site because it sets forth the requirements that apply when any dangerous waste or hazardous substance is intentionally or accidentally spilled or discharged into the environment, regardless of the quantity of dangerous waste or hazardous substance.

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 5 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
General Requirements for Dangerous Waste Management Facilities 173-303-280	Applicable	General requirements for dangerous waste management facilities are applicable to the ERDF and defines requirements that identify acceptable treatment, storage, or disposal practices for designated dangerous waste. The facility siting standards presented under this section are discussed as location-specific ARARs. General requirements specified in this section include procedures for facility permitting, employee training, emergency preparedness, contingency planning, and management of containers. Additional requirements for landfills, and surface impoundments are also included in the regulation.
General Waste Analysis WAC 173-303-300	Applicable	Waste is required to be analyzed to determine the presence of dangerous waste before it is stored, treated, or disposed. These requirements are applicable to wastes generated by, and disposed in, the ERDF.
Security WAC 173-303-310	Applicable	Security procedures are required so that the ERDF will not cause injuries to personnel at the site or to the public, and that access to the site is controlled. These requirements are applicable because dangerous wastes will be managed at the ERDF.
General Inspection WAC 173-303-320	Applicable	Requirements to inspect facilities to prevent malfunctions and deterioration, operator errors, and discharges that may cause or lead to the release of dangerous waste constituents to the environment, or a threat to human health, are applicable to the ERDF.

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Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 6 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
Personnel Training WAC 173-303-330	Relevant and Appropriate	This section requires a program of classroom instruction, or on-the-job training, for facility personnel and is relevant and appropriate to the ERDF because CERCLA already establishes specific personnel training requirements.
Preparedness and Prevention WAC 173-303-340	Relevant and Appropriate	This section describes preparations and preventive measures, which help avoid or mitigate fire, explosion, or unplanned sudden or nonsudden releases of dangerous waste or dangerous waste constituents. This section is relevant and appropriate to the ERDF because CERCLA already requirements preparation of a health and safety plan that includes emergency preparedness preparations.
Contingency Plan and Emergency Procedures WAC 173-303-350	Relevant and Appropriate	Contingency plans are required for dangerous waste management facilities, however, this requirement is considered relevant and appropriate at the ERDF because CERCLA already requires development of a contingency plan as part of the site health and safety plan. The contingency plan describes actions and procedures to be implemented during an emergency that lessen the potential impact on public health and the environment.
Other General Requirements WAC 173-303-395	Applicable	The regulations in this section define specific precautions for the management of ignitable, reactive, or incompatible wastes. This section is applicable to the ERDF.
Use and Management of Containers WAC 173-303-630	Applicable	This section discusses procedures for management of containers used to store dangerous waste and is applicable if a dangerous waste is generated at the ERDF.
Releases From Regulated Units 173-303-645	Applicable	The requirements of this section establish criteria for operation and closure of dangerous waste management facilities, that are designed to minimize releases into the environment. The section identifies monitoring requirements, the point where compliance is to be achieved and the duration for which compliance must be demonstrated. The section also identifies reporting requirements that assist in determining if corrective action may be necessary. This section is applicable to the ERDF because dangerous wastes will be disposed at the ERDF. Allowable contaminant concentrations based on protection of groundwater are discussed as chemical-specific ARARs.

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 7 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
Corrective Action WAC 173-303-646	Applicable	This section establishes the requirements for corrective action for releases of dangerous wastes and dangerous constituents from solid waste management units. These requirements are applicable to the ERDF because they apply to facilities seeking or required to have a permit to treat, store or dispose of dangerous waste. Corrective action requirements may be fulfilled using an enforceable action issued pursuant to the Washington State Model Toxics Control Act or as established under the requirements of this chapter. For the purpose of performing a corrective action, the regulation allows one or more sections of the facility to be designated as corrective action management units (CAMUs). The use of CAMUs provides the operator greater flexibility to implement remedial measures. For example, placement of remediation waste into a CAMU is not subject to LDRs, unless specifically identified by Ecology. The LDRs exemption is also applicable to remedial actions when wastes removed from various parts of the facility are consolidated. The regulation identifies seven criteria that the Director of Ecology may use to designate a CAMU. The operational, monitoring and closure requirements for a CAMU are defined when the CAMU is designated.
Hazardous Waste Cleanup - Model Toxics Control Act Ch. 70.105D RCW		
Model Toxic Control Act Cleanup Regulations WAC 173-340	Applicable	MTCA is potentially applicable to the ERDF. The standard establishes cleanup requirements that identify acceptable contaminant levels or risks, and procedures to insure that cleanup actions meet the specified requirements. Cleanup requirements for non-radionuclides established under MTCA may be used to evaluate ERDF performance.
Groundwater Cleanup Standards WAC 173-340-720	Applicable	Groundwater cleanup levels shall be based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use. The use of groundwater as a source of drinking water is considered the maximum beneficial use.
Soil Cleanup Standards WAC 173-340-740	Applicable	Soil cleanup levels and procedures established under this section are potentially applicable to the ERDF. Soil cleanup concentrations are based on a maximum expected exposure resulting from a residential use scenario. Alternate cleanup levels may be established if appropriate use restrictions are placed on the property, if it can be shown that the site is not a residential area or the site does not have the potential to serve as such in the future. Soil cleanup levels for industrial/commercial sites are established under WAC 173-340-745 and alternate levels for other non-residential scenarios may be set on a case by case basis.

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 8 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
Compliance Monitoring Requirements WAC 173-340-410	Applicable	Compliance monitoring is potentially applicable to the ERDF and would be conducted according to an approved plan. The plan should include procedures for sampling and analysis. Statistical parameters may be used to determine compliance with groundwater cleanup levels.
Solid Waste Management, Recovery and Recycling Act Ch. 70.95 RCW		
Minimum Functional Standards for Solid Waste Handling WAC 173-304	Not ARAR	Requirements of this section not considered ARAR to the ERDF because the regulation specifies that dangerous wastes identified under WAC 173-303 are to be managed as dangerous waste.
Water Pollution Control/ Water Resource Act of 1971 Ch. 90.48 RCW/ Ch.90.54 RCW		
Protection of Upper Aquifer Zones WAC 173-154	Relevant & Appropriate	This regulation directs Ecology to provide for protection of upper aquifers and upper aquifer zones to avoid depletions, excessive water level declines, or reductions in water quality. This regulation is not applicable to the ERDF because the regulation only establishes the policy and program for Ecology. However, the regulation may be considered relevant and applicable because the ERDF will be designed to protect the upper aquifer zones.
Minimum Standards for Construction and Maintenance of Water Wells WAC 173-160	Applicable	Requirements established under this regulation are applicable to construction of wells used for monitoring at the ERDF. This regulation establishes standards for the construction, use and abandonment of water wells.
Water Quality Standards for Groundwater WAC 173-200	Relevant & Appropriate	This standard establishes groundwater quality standards. These requirements are relevant and appropriate to the ERDF because the potential for contaminants to migrate from the facility to groundwater exists. The standard is not applicable because CERCLA actions are specifically exempted by the regulation The standard explicitly notes that groundwater remediation cleanup levels are to be determined using the standards presented in 173-340-720. The ERDF should be designed and operated in a manner that will protect future beneficial uses of groundwater.

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 9 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
State Waste Discharge Program WAC 173-216	Relevant and Appropriate	Athough no wastewaters will be discharged to soils or surface waters, storm water run-off may occur. The chapter implements a permit system applicable to industrial and commercial operations that discharge wastes. CERCLA actions are exempt from administrative permitting requirements. However, the ERDF is required to meet substantive requirements of the regulation, which are to maintain the highest possible standards using all known available and reasonable methods to prevent and control the discharge of wastes.
Underground Injection Control Program WAC 173-218	Not ARAR	The requirements of this regulation are not ARAR at the ERDF because the facility will not use underground injection wells. The regulation sets procedures and practices designed to meet Safe Drinking Water Act requirements under 40 CFR 124, 141, 144, and 146.
National Pollution Discharge Elimination System Permit Program WAC 173-220	Not ARAR	Establishes a state permit program pursuant to the National NPDES system created under the Federal Water Pollution Control Act. This regulation is not ARAR at the ERDF since operation of the facility will not result in surface water discharges.
Washington Clean Air Act Ch. 70.94 RCW and Ch. 43.21A RCW		
General Regulations for Air Pollution WAC 173-400	Applicable	The substantive standards established for the control and prevention of air pollution under this regulation are applicable to the ERDF. The regulation requires that all sources of air contaminants meet emission standards for visibility, particulates, fugitive odor, and hazardous air emissions.
General Standards for Maximum Emissions WAC 173-400-040	Relevant and Appropriate	This section requires that all emission units use reasonably available control technology which may be determined for some source categories to be more stringent than the emission limitations listed in this chapter. The requirements of this section are not applicable to the ERDF because the facility does not meet any of the source categories defined under the regulation. However, the standard may be considered relevant and appropriate because it establishes maximum allowable air emissions.
Emission Standards for Sources Emitting Hazardous Air Pollutants WAC 173-400-075	Applicable	Requirements of this standard are applicable to the ERDF because waste disposal activities could result in the emission of hazardous air pollutants. The regulation requires monitoring, source testing, and the use of specific analytical methods for determining hazardous air pollutant emissions.

Table 7-2. Identification of Potential State ARARs for the ERDF. (Sheet 10 of 10)

REQUIREMENTS	Applicable, Relevant & Appropriate, To be Considered	COMMENT
Standards of Performance for New Sources WAC 173-400-115	Relevant and Appropriate	This section adopts and incorporates Title 40 CFR Part 60 as standards of performance for new sources. The standards are not applicable because the ERDF is not considered one of the source categories identified in the regulation. However, the regulation may be considered relevant and appropriate because it establishes review criteria that may be used to evaluate ERDF impacts on air quality.
Ambient Air Quality Standards and Emission Limits for Radionuclides WAC 173-480	Applicable	Requirements of this standard are applicable to the ERDF. The standard specifies that the maximum allowable level for radionuclides in the ambient air shall not cause a maximum accumulated dose equivalent of 25 mrems/yr to the whole body, or 75 mrems/yr to any critical organ.
State Radiation Protection Requirements CH. 70.98 RCW		Washington State Radiation Protection Requirements are implemented under specific sections of WAC 246.
Radioactive Waste- Licensing Land Disposal WAC 246-250	Relevant and Appropriate	WAC 246-250, establishes the procedures, criteria and conditions for licensing of LLW radioactive waste land disposal for wastes received from others. The requirements of this regulation are not applicable to the ERDF because the ERDF will only manage DOE wastes resulting from Hanford Site remediation. This section may be considered relevant and appropriate because it presents specific levels of radiation protection and technical requirements for land disposal of radioactive waste.
Washington Industrial Safety and Health Act Ch. 49.17 RCW		
Worker Safety and Health (WAC 173-340-810) and General Safety and Health Standards (WAC 296-24)	Not ARAR	Regulations under the Washington Industrial Safety and Health Act are not considered ARAR under CERCLA since they are not environmental standards. However, as occupational safety requirements, the ERDF, must meet the requirements established under this regulation such as the Worker Safety and Health (WAC 173-340-810) and General Safety and Health Standards (WAC 296-24).

Table 7-3. Preliminary Air and Groundwater Chemical-Specific ARARs for the ERDF Contaminants of Potential Concern (Radionuclides).

Contaminant	Drinking Water 40 CFR 141[a]	NRC Standards 10 CFR 20[b,c]		Atomic Energy Act, Protection of the Public and Environment, DOE Order 5400.5[d]	
	MCL/Proposed MCL (pCi/L)	Water (pCi/L)	Air (pCi/m^3)	Water (pCi/L)	Air (pCi/m^3)
Carbon-14	2000/-	30,000	3,000	70,000	6,000
Chromium-51	6000/38,000[e]	5E+05	30,000	1E+06	50,000
Plutonium-238	-/7.1[e]	20	0.02	40	0.03
Plutonium-239	-/65[e]	20	0.02	30	0.02
Potassium-40	-/-	4,000	600	7,000	900
Technicium-99	900/3,790[e]	6E+04	900	1E+05	2,000
Thorium-228 + D	-/153[e]	200	0.02	400	0.04
Thorium-232	-/92[e]	30	4E-03	50	7E-03
Uranium-233/234	-/f	300	5E-03	500	0.09
Uranium-235	-/f	300	0.06	600	0.1
Uranium-238	-/f	300	0.06	600	0.1

[a]State Drinking Water Standards, WAC 246-290, are as stringent as current federal MCLs, unless otherwise noted.
[b]Appendix B, Table II, Column 2, Concentration Limits for Radionuclides in Liquid Effluent Released to Unrestricted Areas.
[c]Appendix B, Table II, Column 1, Concentration Limits for Radionuclides in Air Effluent Released to Unrestricted Areas.
[d]Derived concentration guides for air and water.
[e]Proposed MCL as reported in the Advanced Notice of Proposed Rule published in 56 FR 33050, July 18, 1991.
[f]Proposed MCL for uranium is 20 μg/L (56 FR 33050, July 18, 1991)
- Criteria not listed

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Table 7-4. Preliminary Chemical-Specific ARARs for the ERDF Groundwater Contaminants (Non-Radioactive Contaminants) (Sheet 1 of 2)

Contaminant	Drinking Water Standards 40 CFR 141[a] and 40 CFR 143[b]		Washington State Model Toxics Cleanup Act WAC 173-340	
	MCLs	MCLGs	Method B	Method C
			Ground Water 173-340-720[c]	Ground Water 173-340-720[c]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Aluminum	0.05[b]	-	16	35
Ammonia	-	-	-	-
Antimony	0.006	0.006	.064	0.014
Arsenic	0.05	-	5.17E-05 (0.005[e])	5.17E-04 (0.005[e])
Barium	2	2	1.12	2.45
Beryllium	0.004	0.004	2.5E-05[d]	2E-04
Cadmium	0.005	0.005	0.016	0.035
Chromium (VI)	0.1[d]	0.1[d]	0.08	0.018
Chloride	250[b]	-	-	-
Cobalt	-	-	-	-
Copper	1.3[g] (1[b])	-	0.64[f]	1.4[f]
Fluoride	4 (2[b])	4	0.96	2.1[d]
Lead	0.015[g]	0	-	-
Magnesium	-	-	-	-
Manganese	0.05[b]	-	0.08	0.175
Mercury	0.002	0.002	0.0048	0.01
Nickel	0.1	0.1	.32	0.7
Nitrate (NO3 as N)	10	10	26	56
Nitrate (NO3 as NO3)	44	44	-	-
Nitrite (NO2 as N)	1	1	-	-
Nitrite (NO2 as NO2)	3.3	3.3	1.6	3.5
Selenium	0.05	0.05	0.08	0.175
Silver	0 .1[b]	-	0.08	0.175
Sulfate	250[b]	-	-	-
Thallium (oxide)	0.002[h]	0.0005[g]	0.001	0.002
Vanadium	-	-	0.11	0.25

Table 7-4. Preliminary Chemical-Specific ARARs for the ERDF Groundwater Contaminants (Non-Radioactive Contaminants) (Sheet 2 of 2)

Contaminant	Drinking Water Standards 40 CFR 141[a] and 40 CFR 143[b]		Washington State Model Toxics Cleanup Act WAC 173-340	
	MCLs	MCLGs	Method B	Method C
			Ground Water 173-340-720[c]	Ground Water 173-340-720[c]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Zinc	5[b]	-	4.8	10.5

[a]State MCLs and MCLGs are based on federal standards, as amended.
[b]Secondary Drinking Water Standards are established under 40 CFR 143. Under CERCLA, Secondary MCLs are not ARAR because they are not federally enforceable standards. However, under Washington State regulation, WAC-173-340-720(2)(a)(ii) identifies secondary MCLs as applicable groundwater cleanup levels.
[c]Reference doses and carcinogenic slope factors taken from IRIS (EPA 1993a), or HEAST (EPA 1993b).
[d]Valance not specified under 40 CFR 141.
[e]Cleanup level based on concentration for the State of Washington as noted in Table 1, footnote b, WAC 173-340-720.
[f]HEAST notes that data for copper is insufficient to develop an RfD, however, the Superfund Technical Support Center indicates an interim RfD between 4E-02 and 7E-02 (EPA 1991a).
[g]Action levels established by the EPA for water systems serving the public. Water systems exceeding these levels are required to implement additional treatment.
[h]Reported MCL and MCLG are for thallium.

Table 7-5. Groundwater Standards for Contaminants.

Contaminant	Risk-Based Groundwater Standard[a]	Minimum ARAR-Based Groundwater Standard[b]
RADIONUCLIDES	(pCi/L)	(pCi/L)
Carbon-14	510	2,000
Chromium-51	11,000	6,000
Hydrogen-3	8,500	20,000
Plutonium-238	2.1	7.1
Plutonium-239	2.0	20
Potassium-40	4.2	4,000
Technicium-99	350	900
Thorium-228 + D	8.4	153
Thorium-232	38	30
Uranium-234	29	300
Uranium-235	29	300
Uranium-238	16	300
Total Uranium	-	20 μg/L
INORGANICS	(mg/L)	(mg/L)
Aluminum	16	0.05
Ammonia	0.27	-
Antimony	6.4E-03	6E-03
Arsenic	4.1E-04	5.2E-05
Barium	1.1	1.12
Beryllium	1.9E-03	2.5E-05
Cadmium	8.0E-03	5.0E-03
Chromium (VI)	8.0E-02	0.018
Chloride	2.5E+04	250
Cobalt	0.96	-
Copper	0.64	0.64
Fluoride	0.96	0.96
Lead	no tox	0
Magnesium	no tox	-
Manganese	8.0E-02	0.05
Mercury	4.8E-03	2.0E-03
Nickel	0.32	0.1
Nitrite (NO_2 and N)	1.6	1
Selenium	8.0E-02	0.05
Silver	8.0E-02	0.08
Sulfate	no tox	250
Thallium (oxide)	1.1E-03	5.0E-04
Vanadium	0.11	0.11
Zinc	4.8	4.8

[a]Based on an ICR of 10^{-5} and a HQ of 1 assuming the groundwater exposure scenarios described in Chapter 6.
[b]Based on ARARs shown in Table 7-3 and Table 7-4.

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8.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This chapter identifies and screens technologies and process options that are potentially applicable to the ERDF. Chapter 9 assembles the retained technologies into alternatives and provides the detailed evaluation and comparative analysis of the alternatives.

As discussed in Section 1.3, this RI/FS is limited in scope to the technologies and alternatives directly applicable to design of the ERDF facility. To fulfill the CERCLA requirement to address the no-action alternative (i.e., no ERDF), options that do not include the ERDF are also addressed. General response actions other than disposal (such as in-situ containment and treatment) are not addressed in this RI/FS. The 100, 200, and 300 Area source operable unit FSs will address the full range of remedial actions applicable to remediation of the contaminated sites, including institutional controls, in-situ containment, excavation, disposal, ex-situ treatment, and in-situ treatment.

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The primary technologies identified in this chapter relate to the configuration of the waste containment unit (also referred to as the trench or trenches). These include geometry of the trench excavation(s), liners, and surface barriers. This FS does not focus on technologies related to institutional controls, surface water management, dust control, and treatment of waste waters, although brief descriptions of such technologies are presented for completeness. These elements are not the focus of this analysis because they do not significantly affect long-term performance of the facility and are considered design details.

The list of identified technologies is screened to develop a refined list of potentially feasible technologies that can be used to develop alternatives for the facility. The remediation technologies are screened using the criteria specified in 40 CFR 300.430(e)(7) of the NCP for screening of alternatives.

Effectiveness. This criterion focuses on the degree to which a technology reduces toxicity, mobility, or volume through treatment; minimizes residual risks and affords long-term protection; complies with ARARs; minimizes short-term impacts; and how quickly it achieves protection. Technologies providing significantly less effectiveness than other technologies may be eliminated. Technologies that do not provide adequate protection of human health and the environment shall be eliminated from further consideration. It should be noted that treatment technologies are not addressed in this document.

Implementability. This criterion focuses on the technical feasibility and availability of the technology and the administrative feasibility of implementing the technology. Technologies that are not technically or administratively feasible or that would require equipment, specialists, or facilities that are not available within a reasonable period of time may be eliminated from further consideration.

Cost. The costs of construction and any long-term costs to operate and maintain the technology shall be considered. Costs that are grossly excessive compared to the overall effectiveness of the technology may be considered as one of several factors used to eliminate technologies. Technologies providing effectiveness and implementability similar to that of another technology by employing a similar method of treatment or engineering control, but at greater cost, may be eliminated.

The technologies and process options were screened against the criteria in the priority order listed above using the "fatal flaw" approach. This approach was adopted for efficiency, and is based on ranking the criteria in order of importance, as listed above. The ranking is based on CERCLA Guidance (EPA 1988a). Once a technology is rejected, based on effectiveness, it is not further evaluated based on implementability or cost. Similarly, if a technology is effective, but not implementable, the technology is rejected; evaluation of cost is not undertaken. This approach streamlined the evaluation of technologies while maintaining the screening methodology required under CERCLA.

Evaluation and screening of technologies are performed in a single step. The key criterion in selecting the screening level (technology class, individual technology, or process option) is whether there is a significant difference between the technologies or process options when evaluated against the screening criteria (effectiveness, implementability, and cost). Technologies and process options that are judged to have significant differences are screened separately, and the retained technologies or process options will be developed into separate remediation alternatives to allow full evaluation and comparison.

Process options retained for any given technology that are screened together (i.e., not evaluated separately) are considered equally suitable (at the screening level of evaluation). Selection of representative process options is performed during the development of alternatives, so that best engineering judgement may be used to select and combine appropriate technologies and process options into cohesive, integrated remediation alternatives.

The potentially applicable technologies considered for the ERDF are presented in Table 8-1. The technology screening is also summarized in this table. Brief descriptions of the listed technologies and discussions of the screening evaluations are provided below. Technologies retained through this screening process are then incorporated into remediation alternatives in Chapter 9.

8.1 DISPOSAL

General disposal options considered in this FS include on-Hanford Site near-surface disposal, off-Hanford Site near-surface disposal, or a geologic repository.

8.1.1 Centralized Engineered Waste Management Facility on the Hanford Site (ERDF)

A centralized engineered waste management facility (ERDF) has been proposed to serve as the receiving facility for the majority of wastes excavated during remediation of waste management sites in the 100, 200, and 300 Areas. This facility would be located on the 200 Area plateau. The primary features of the ERDF include the trench(es), rail and tractor/trailer container handling capability, decontamination and wastewater treatment facilities, railroads, inventory control systems, and operations offices. Conventional, well-developed technologies and methods will be used to construct and operate the facility.

The risks associated with the primary exposure paths (direct exposure, surface water and airborne transport, and transport to groundwater) are minimized for an ERDF located on the 200 Area plateau. Such a location is characterized by an arid climate with low precipitation and low natural infiltration, a thick vadose zone, absence of nearby surface water bodies, and relative isolation from the public. The Hanford Site also provides excellent institutional controls to limit public access to the vicinity of the 200 Area plateau. In contrast to offsite disposal facilities, transportation of waste from Hanford Site operable units is not a major concern in terms of public risk and public perception. Hauling distances would be short and contaminated materials would not leave the Hanford Site. Standard Hanford Site safety and environmental controls, including packaging standards and personnel protection, would be used. Additional controls would be used if appropriate.

While waste management facilities could be constructed at individual operable units within the Hanford Site, the ERDF offers economies of scale in construction, monitoring, and administration. A centralized waste management facility provides centralized inventory of wastes disposed and uniform waste screening, handling, and disposal procedures. In addition, removing all waste from the 100 and 300 Areas allows these areas to be released for uses other than waste management. Placement of Hanford Site derived wastes in an ERDF on the 200 Area plateau is retained for further consideration.

8.1.2 Engineered Waste Management Facilities at Individual Source Operable Unit Sites

Landfills similar in design to the ERDF but with smaller capacities could be constructed at source operable unit sites in the 100, 200, and 300 Areas. Waste management facilities located in operable units along the Columbia River would overlie much thinner vadose zones and would be much closer to surface water than a 200 Area ERDF; therefore they would be less protective of human health and the environment. In addition, construction, administration, and monitoring of multiple, smaller waste management facilities is expected to be more difficult to implement and more costly than a single, centralized Hanford Site waste management facility. Furthermore, long-term management of wastes along the Columbia River would conflict with recommendations by the Hanford Future Site Uses Working group (Drummond 1992). Construction of multiple waste management facilities at the source operable units is considered less effective, more difficult to implement, and more expensive than a centralized waste management facility on the 200 Area plateau and is not retained for further evaluation.

8.1.3 Offsite Waste Management Facility

Use of an offsite waste management facility for permanent disposal is similar in concept to the other waste management facility options discussed above. The offsite facility would probably be a general low-level waste facility serving a state or regional area, and would most likely offer similar long-term effectiveness as a centralized Hanford Site waste management facility. The disadvantages of using an offsite waste management facility are:

1) There are few existing or planned facilities prepared to accept significant quantities of mixed waste. The nearest existing facility is Envirocare of Utah, Inc., located west of Salt Lake City, Utah, approximately 1,100 km (700 mi) from the Hanford Site.

2) The potential for accidental contaminant release over long transportation distances outside of Hanford Site controlled areas presents significantly greater short-term public risk than an on-site waste management facility.

3) Public opposition to offsite disposal of Hanford waste is likely to be high, resulting in significant administrative difficulties.

4) Transportation distances and costs associated with an off-site facility would be significantly greater than for an on-site facility.

Therefore, while an effective off-site waste management facility may be constructed, this technology is not retained based on poor short-term effectiveness, low implementability, and high cost.

8.1.4 Geologic Repository

A geologic repository is an underground disposal facility constructed in a stable geologic setting with low rates of groundwater movement. The design goal of a geologic repository is to prevent exposure of biological receptors to radioactive waste or radioactive constituents for at least 10,000 years. A properly located and designed geologic repository would be a very effective disposal technology for Hanford Site remediation wastes.

A geologic repository for high-level nuclear waste (spent nuclear fuel and byproduct wastes) is proposed for construction at Yucca Mountain, Nevada. Another repository for TRU Waste, the Waste Isolation Pilot Plant (WIPP), is presently under construction near Carlsbad, New Mexico and may be operational within a few years. These facilities will not be large enough to accommodate the estimated quantity of Hanford waste. In addition, transportation of radioactive materials presents significant administrative difficulties and has the potential for release of contaminants during transport (see Section 8.1.3 above).

Development of another geologic repository, either on or off the Hanford Site, would be a very expensive undertaking. Several billion dollars have already been spent at Yucca Mountain and WIPP for facilities that are designed for waste volumes several orders of magnitude smaller than expected at the Hanford Site. A new geologic repository of sufficient capacity would cost billions of dollars.

Use of existing or planned geologic repositories is not retained because they do not have the capacity to accept the volume of waste expected from remediation of Hanford Site operable units. A geologic repository constructed on the Hanford Site is not retained based on the very high estimated cost of such a facility relative to other effective and implementable on-site alternatives.

8.2 TRENCH CONFIGURATION

The implications associated with different trench configurations for the waste management facility are evaluated as individual technologies. A comparison of three configurations that address different depths and widths is presented in the following subsections. The comparisons are based on information provided in U.S. Army Corp of Engineers (1993c). The following assumptions are common to all the configurations:

- The quantity of excavated soils is assumed to be 23.3 million m^3 (30.5 million yd^3), comprised of 21.8 million m^3 (28.5 million yd^3) of waste and an additional 1.5 million m^3 (2 million yd^3) for interim soil cover.

- Unshored excavations may be used providing side slopes are flat enough to be stable. Current conceptual designs include 3H:1V (horizontal to vertical) side slopes, which are not expected to require shoring.

- Stockpiled soils are expected to be used for liner construction, clean soil cover during filling operations, cover construction, and as clean backfill for source operable units from which contaminated materials originate.

- Because the soils being excavated are believed to be clean, no excavation health and safety precautions beyond normal construction practices are expected to be required. As part of normal construction practice at the Hanford Site, a radiation survey will be conducted before excavation begins.

Three different cross-section configurations, shown in Figure 8-1, are considered in this analysis: a shallow multiple-trench design, a shallow area-fill design, and a deep area-fill design. There are no implementability problems related to construction or operations identified for any of the trench configurations discussed below. Therefore, the differences between the designs are confined to effectiveness and cost.

8.2.1 Shallow Trench Design

The shallow trench design, shown in Figure 8-1, is a trapezoidal trench with a depth of 10 m (33 ft), a bottom width of 30 m (100 ft), and a top width of 90 m (300 ft). The unit capacity of this design is 650 m^3 per linear meter (260 yd^3 per linear foot) of trench, corresponding to a total trench length of 35,000 m (117,000 ft). The shallow trench configuration is most similar to existing practice at the Hanford Site low-level burial grounds.

The advantage of the shallow excavation versus the deep excavation is that the waste is 10 m (33 ft) further from groundwater, resulting in longer migration times to the saturated groundwater system. Assuming that the average thickness of the vadose zone is 80 m (260 ft), the travel times will be 17 percent longer for the shallow excavation design than for the deep excavation design.

A significant disadvantage of the shallow design compared with the deep excavation design is the greater land usage. As described in U.S. Army Corp of Engineers (1993d), the total area required to accommodate the shallow trench design is 6.5 km^2 (1,600 acres), compared with 2.6 km^2 (645 acres) for the shallow area-fill design and 1.5 km^2 (375 acres) for the deep area-fill design. Greater land usage will result in greater impacts to surrounding ecological habitat and cultural resources. Furthermore, given that total infiltration through the trench is proportional to the area of the facility, the shallow trench design results in significantly more leachate generation than the area-fill designs.

The high surface area of the shallow excavation also results in higher liner and surface barrier cost. As described in U.S. Army Corp of Engineers (1993c), the total costs for the liner and cover using the shallow trench design are approximately two to three times greater than the cost using the area-fill designs.

The shallow trench design is eliminated from further evaluation because it results in greater impacts on ecological and cultural resources and greater leachate generation than the area fill designs, as well as substantially higher costs.

8.2.2 Shallow Area-Fill Design

The shallow area-fill design, shown in Figure 8-1, is a trapezoidal trench with a depth of 10 m (33 ft), a bottom width of 300 m (1,000 ft), and a top width of 370 m (1,200 ft). The unit capacity of this design is 4,000 m^3 per linear meter (1,600 yd^3 per linear foot) of trench, corresponding to a total trench length of 5,700 m (19,000 ft).

This design retains the advantage of the shallow excavation regarding distance above groundwater. Assuming that the average thickness of the vadose zone is 80 m (260 ft), the travel times will be 17% longer for the shallow excavation design than the deep excavation design.

The shallow area-fill design represents a compromise between the shallow trench design and the deep area-fill design regarding land usage. As described in U.S. Army Corp of Engineers (1993c) the total area required to accommodate the shallow area fill design is 2.6 km^2 (645 acres), approximately 60% less than the shallow trench design, and 70% more than the deep area-fill design. The compromise in land usage results in a compromise in terms of impacts to surrounding ecological and cultural resources and the amount of leachate generation. This design results in total liner and cover costs that are approximately twice the costs for the deep area-fill design (U.S. Army Corp of Engineers 1993c).

The shallow area-fill design is eliminated from further evaluation because, in comparison to the deep area-fill design, it results in greater impacts on ecological and cultural resources and greater leachate generation. These effectiveness disadvantages are considered more important than the 17% advantage in travel time. In addition, costs for this design are significantly greater than the deep area-fill design.

8.2.3 Deep Area-Fill Design

The deep area-fill design, shown in Figure 8-1, is a trapezoidal trench with a depth of 20 m (70 ft), a bottom width of 300 m (1,000 ft), and a top width of 430 m (1,400 ft). The unit capacity of this design is 8,800 m^3 per linear meter (3,500 yd^3 per linear foot) of trench, corresponding to a total trench length of 2,600 m (8,700 ft).

The disadvantage of this design compared with the shallow excavation designs is the smaller distance between the waste and groundwater. Assuming that the average thickness of the vadose zone is 80 m (260 ft), the travel times will be 17% longer for the shallow excavation design than for the deep excavation design.

The deep area-fill design results in the smallest land usage requirements for all three of the trench configurations considered in this report. As described in U.S. Army Corp of Engineers (1993c) the total area required to accommodate the deep area-fill design is 1.5 km^2 (375 acres), approximately 40% less than the shallow area-fill design. This reduced area will result in the least impact to surrounding ecological and cultural resources and the least amount of leachate generation. Furthermore, this design results in significantly lower costs for the liner and cover (U.S. Army Corps of Engineers 1993c).

The deep area-fill design is retained for further evaluation because it results in the least impacts on ecological and cultural resources and the least leachate generation. In addition, costs for this design are significantly less than the other designs.

8.3 DUST CONTROL

Dust control includes measures to prevent wind dispersion of contaminated material. Because most types of dust control are surficial treatments, they do not prevent humans or animals from directly contacting contaminated soil at the site and are generally ineffective in preventing offsite migration of contaminants in surface water run-off. Several approaches to dust control are available:

- Adding water to increase the moisture content and reduce dust generation during waste placement.

- Materials such as cement, clay, and organic polymers can be sprayed on or mixed with waste before or during placement to bind the soil matrix or on high traffic areas to minimize dust from equipment. This type of dust control is relatively inexpensive and well-suited for dust control in construction zones over the short term. Because binding additives deteriorate relatively quickly they generally must be re-applied on a regular basis (a few weeks to months) and are not well-suited for long-term stabilization of soil surfaces.

- Vegetation can be planted to hold the soil together, reduce wind velocity at the ground surface, and reduce the velocity of surface water run-off. Vegetation is useful for long-term stabilization of soil surfaces and also increases evapotranspiration, which results in reduced infiltration. Because vegetation requires time to grow and is not resistant to equipment traffic, it is not useful for dust control in construction zones. It should be noted that vegetation could potentially bring contaminants to the surface if roots penetrate into the waste.

- The waste can be contained within containers to prevent dust releases. Although some waste (primarily high activity wastes) will likely be placed in the ERDF within single-use containers, the costs associated with containerizing all the waste would be prohibitive with minimal additional benefit.

- Temporary structures (domes) can be used to cover an excavation. This is the most effective and most expensive dust control measure.

- Terminate construction activities at wind speeds approaching 7 m/sec (15 mph).

In itself, dust control is not considered effective for permanent remediation of soil. It is retained for consideration in combination with other technologies that involve handling of contaminated soil and dust generation. In addition, vegetation is retained as an important element of surface barriers.

8.4 SURFACE WATER MANAGEMENT

Surface water management involves controlling surface water run-on and run-off at the site. The purpose of these controls is to minimize erosion and run-off of contaminated soil, minimize erosion of cover/barrier materials, and prevent ponding that could increase the amount of water infiltrating through contaminated soils. The controls must eventually be incorporated into the unloading area to prevent run-off of contaminants.

The most common surface water control is grading the ground surface to promote adequate drainage without excessive erosion. In addition, diversion measures, such as berms and ditches, are commonly used to prevent clean surface water from entering a site (run-on) and prevent potentially contaminated surface water from leaving a site (run-off). Potentially contaminated surface water can be collected and treated, if required, prior to discharge. Revegetation can also be used to reduce erosion by stabilizing the soil. Vegetation can be difficult to reestablish in arid climates. However, once established, revegetation requires little or no maintenance.

Surface water controls by themselves are not generally effective as a permanent remedy. These controls may be used as short-term measures, such as during excavation, or as long-term measures as a component of a surface barrier, for example. Routine maintenance is required for continuing effectiveness. This technology is therefore retained for use in conjunction with other remediation technologies.

8.5 SURFACE BARRIERS

Surface barriers are constructed on the ground surface over contaminated materials and may include a variety of materials such as clay and other types of soils, synthetic membranes, asphalt, and concrete. They may consist of a single layer or be composite barriers with several layers. Barriers provide containment in three primary ways:

- The barrier serves as a physical barrier to prevent humans, other animals, and vegetation from coming in contact with contaminated materials.
- The barrier prevents erosion of contaminated soil by surface water and wind, thereby preventing offsite transport of contaminants via these media.
- The barrier can have low permeability and thus function as a barrier to infiltration of surface water. Less infiltration will reduce the potential for transport of contaminants through the vadose zone to the saturated groundwater zone.

Barriers can be designed to be compatible with many potential future site uses. Institutional controls (deed restrictions) are often used along with barriers to prevent future site activities that could violate the integrity of the barrier. For example, foundation pilings would not be allowed to penetrate an impermeable barrier.

All the barriers addressed below are generally readily implemented using standard design and construction techniques. Although the different barriers have different resource requirements that may affect implementability, these factors are not considered significant at the screening stage. Resource requirements will be evaluated in the detailed evaluation of alternatives in Chapter 9. The evaluation provided in this section focuses on differences in effectiveness and cost.

8.5.1 Soil Barrier

One or more layers of soil may be used to cover a contaminated site. For discussion purposes, soils barriers can be divided into non-engineered and engineered barriers. Engineered soil covers include amendments to improve their effectiveness. For example, adding gravel to the top layer may enhance protection against wind erosion, and adding a compacted or fine-grained component to the top layer may reduce surface infiltration.

Non-engineered Soil Cover. The standard practice at the Hanford Site for interim remediation of contaminated waste units and non-RCRA waste management trenches is to use 2.5 to 5 m (8 to 16 ft) of non-engineered native soil as backfill to provide a thick soil cover. A sufficiently thick soil barrier is effective in providing shielding from radiation, preventing humans, other animals, and shallow-rooting vegetation from contacting contaminants, and preventing offsite migration of contaminated materials via surface water or wind erosion. Generally these barriers do not reduce infiltration compared to native undisturbed surface soils. In fact, the lack of vegetation and topsoil can result in greater infiltration than in undisturbed vegetated areas. Furthermore, unless they are extremely thick, non-engineered barriers do not provide long-term protection against penetration of deep-rooting plants into the waste. Non-engineered soil barriers may be used as interim covers during ERDF operations to control air releases and provide a working surface for equipment. However, due to low effectiveness regarding infiltration, non-engineered soil barriers are not retained for further consideration as the long-term ERDF barrier.

Biological Intrusion Barrier. One type of engineered soil cover utilizes one or more layers of coarse materials at the surface to promote free drainage and minimize establishment of rooting plants. These layers may also be designed to discourage burrowing animals. This type of cover, sometimes referred to as a biointrusion barrier, should only be applied on the Hanford Site in situations where infiltration of precipitation is not a concern. Non-vegetated coarse materials at the surface enhance infiltration, permitting more rapid percolation of water through the waste and into the soil column. Since protection of groundwater is a RAO for the ERDF, biointrusion soil barriers are not considered further in development of alternatives.

Low-Infiltration Soil Barrier. Another type of engineered soil cover includes a surface layer of fine-grained soils and gravel admix to retain moisture and promote growth of vegetation, thereby minimizing infiltration. The surface layer may consist of natural silty soils or bentonite-amended native soils mixed with gravel. The gravel provides protection against erosion. As discussed in Section 4.2.2, fine-grained, vegetated surface soils appear capable of reducing infiltration to zero or close to zero under Hanford Site conditions. Similar to the non-engineered soil barrier, the low-infiltration soil barrier does not provide long-term protection against penetration of deep-rooting plants into the waste (other than protection due to thickness of the barrier). If maintenance of the facility included removal of deep-rooting plants before they penetrate the waste, the effectiveness of this type of barrier could be enhanced.

A typical cross-section of a low-infiltration soil barrier is shown in Figure 8-2. The total thickness of this barrier is 4.6 m (15 ft). Based on the unit costs shown in Table 8-2, this barrier would cost $21/m^2$ ($2.0/ft^2) to construct. This unit cost is significantly less than composite barriers discussed below. The low-infiltration soil barrier is retained for further consideration.

8.5.2 Asphalt Barrier

Asphalt can be used to provide a single-layer, low-permeability barrier (not counting foundation layers, if required). When maintained, asphalt can be an effective barrier against wind erosion, intrusion from burrowing animals and deep rooting plants, and surface water erosion. While effective in the short-term, asphalt requires relatively high maintenance to offset degradation and cracking due to weathering and settlement. Because asphalt barriers are not effective for long-term, reliable protection, they are not retained for further consideration. However, an asphalt layer is used as a component in some of the composite barriers discussed in Section 8.5.6.

8.5.3 Concrete Barrier

Concrete can be used to provide a single-layer, low-permeability barrier and has many of the same properties as asphalt. When maintained, concrete can be an effective barrier against wind erosion, intrusion from burrowing animals and deep rooting plants, and surface water erosion. Over the long term, concrete requires relatively high maintenance to offset degradation and cracking due to shrinkage, weathering, and settlement. Because concrete barriers are not effective for long-term, reliable protection, they are not retained for further consideration.

8.5.4 Low-Permeability Clay Barrier

A clay barrier is generally constructed with a layer of low-permeability, high plasticity clay covered by clean native soil for vegetative growth and to prevent the clay structure from deteriorating due to freezing. This barrier is similar to the low-infiltration soil barrier described in Section 8.5.1 except the clay barrier is engineered more for low-permeability rather than moisture retention and evapotranspiration. The clay layer may be constructed of native or imported clay, or may use native soils amended with bentonite or other materials. In wet climates, clay barriers are generally considered effective and reliable for reducing infiltration into the waste. However, Hanford's arid climate subjects clay to desiccation, which can result in cracking and increased permeability. For this reason, stand-alone clay barriers are not retained for further evaluation.

8.5.5 Synthetic Membrane Barrier

Flexible membrane liners (FMLs) made from synthetic materials such as polyvinylchloride (PVC), high-density polyethylene (HDPE), and neoprene, are commonly used in landfill liners and covers. Their primary purpose is to serve as a barrier to infiltration of precipitation and to promote surface runoff to drainage collection systems. A synthetic membrane can provide lower permeability than clay or other soils so long as the membrane does not puncture, tear or deteriorate. A hydraulic barrier relying primarily on a synthetic membrane would have a bedding layer of soil to provide a foundation and protect the membrane during installation. The membrane is then covered with soil to protect against damage and exposure to ultraviolet components of sunlight, which can weaken or degrade the membrane.

Provided they are constructed with no leaks and are protected by the overlying soil, synthetic membrane barriers can virtually eliminate infiltration. However, synthetic membranes are subject to stresses after installation, such as waste settlement, that can tear the membrane. Aging and deterioration can also be a problem with some types of FMLs. Furthermore, widespread use of synthetic membranes began in the early 1980's; consequently, long-term effectiveness and reliability of synthetic membranes as impermeable barriers is uncertain. Therefore, this barrier type is not retained for further consideration.

8.5.6 Low-Permeability Composite Barriers

Composite (multi-media) barriers are designed using multiple layers of different materials to achieve highly effective and reliable, long-term protection of contaminated sites. The four composite barriers discussed below include the standard RCRA barrier, the Hanford Barrier, the modified Hanford barrier, and the diversion barrier.

Standard RCRA Barrier. The most well-known composite barrier is the standard RCRA Subtitle C barrier, which is designed to meet the minimum technology requirements (MTRs) specified in 40 CFR 264.310 for hazardous waste landfills. EPA has published guidance for complying with MTRs (EPA 1989c). A RCRA barrier design will typically contain the following layers (top to bottom):

- Vegetative layer - vegetated silt and gravel admix, typically 0.6 to 0.9 m (2 to 3 ft) thick, to protect the barrier against damage (e.g., erosion), and provide moisture retention and evapotranspiration to decrease infiltration.

- Drainage layer - either 0.3 m (1 ft) of sand or a synthetic geonet to divert infiltration away from the covered area and minimize hydraulic head on the infiltration barrier.

- Low-permeability layer - typically a synthetic membrane over 0.6 to 0.9 m (2 to 3 ft) of compacted clay with a permeability no greater than $1x10^{-9}$ m/s ($2.8x10^{-4}$ ft/day). Use of both the synthetic membrane and the clay provides redundant low permeability; the synthetic membrane protects the clay against desiccation, and the clay provides a thick barrier capable of some self-healing if settling occurs.

A typical section for a standard RCRA barrier is shown in Figure 8-3. The synthetic materials and clay layer will be subject to the same degradation effects discussed in Section 8.5.4 and 8.5.5, and the ability of these layers to maintain their integrity over hundreds or thousands of years is uncertain. It is likely that over the long-term, the low-infiltration soil barrier (Section 8.5.1) would provide an equivalent reduction in long-term infiltration rates. The total thickness of the RCRA barrier is 1.5 m (5 ft), considerably less than the low-infiltration soil barrier.

The RCRA barrier will be significantly more expensive to construct than the less complex barriers described above. Based on the unit costs shown in Table 8-3, this barrier would cost \$51/m^2 (\$4.8/ft^2) to construct, approximately 250 percent more than the low-infiltration soil barrier. Since the long-term effectiveness of the standard RCRA barrier is probably similar or less than the low-infiltration soil barrier and the low-infiltration soil barrier is less expensive, this barrier is not retained for further evaluation.

Hanford Barrier. The Hanford Barrier, shown in Figure 8-4, is a composite barrier system specifically designed for the Hanford Site. The Hanford Barrier is comprised of 11 layers in three functional groups:

- A water retention and evapotranspiration zone divided into two layers: an upper layer of silt and gravel, and a lower layer of silt only;
- A biotic intrusion barrier consisting primarily of coarse granular soils and a thick crushed basalt layer; this group also provides a capillary break at the base of the first functional group to increase the water retention capacity;
- A low permeability barrier consisting primarily of asphalt.

This design reflects the current thinking of the Hanford Site Permanent Isolation Surface Barrier Development Program, as discussed in Wing (1993). In order to achieve a design life of at least 1,000 years, natural materials are used to the extent possible. The functions of the Hanford Barrier are based on the following rationale:

- Control of surface water infiltration and percolation is provided primarily by the first functional group. This group retains infiltration near the surface where high evaporation of the arid climate and the high transpiration provided by various species of vegetation can recycle moisture to the atmosphere. The capillary break provided by the second functional group has been demonstrated to double the moisure retention capacity of the first functional group (Wing 1993). Any moisture that does break through the second group layers is finally diverted from the waste by the low permeability barrier provided by the third functional group.
- Biointrusion of plant roots and burrowing animals is prevented primarily by the coarse grained layers of the second functional group. Plant roots do not readily extend into these "hostile" layers due to their very low moisture content, lack of nutrients, and large grain size. Both small and large mammals tend not to burrow more than 1 m (3.3 ft) into fine grained soils. While some animals are known to burrow deeper than 2 m (6.6 ft), particularly the Western harvester ant, such animals are expected to be deterred by the highly compacted asphalt layer of the third functional group.
- Wind and water erosion are controlled by a careful mix of gravel into the surface layer of the barrier that is sufficient to limit wind and water erosion but

that is not excessive to the point of enhancing infiltration or limiting plant growth.

- Human interference, both accidental and intentional, is discouraged by use of offsite markers, surface markers, subsurface markers that will be exposed by even relatively shallow excavation, and by the overall thickness of the barrier design and the coarse basalt layer of the second functional group.

The total thickness of the Hanford Barrier is 4.5 m (15 ft). This added thickness, combined with the basalt and asphalt layers, provide additional protection against intrusion and erosion compared to the RCRA barrier. Based on the unit costs shown in Table 8-4, the Hanford Barrier would cost \$135/m^2 (\$12.6/ft^2) to construct, approximately 260% more than the RCRA barrier. The Hanford Barrier is retained for further consideration.

Modified Hanford Barrier. The modified Hanford barrier is conceptually similar to the Hanford Barrier but has been modified to reduce costs and impacts on borrow sources. The cross-section of the modified Hanford barrier, provided in Figure 8-5, indicates that this barrier includes 10 layers and a total thickness of 4.7 m (15.4 ft). Modifications from the Hanford Barrier design include:

- The uppermost moisture retention layer has been reduced in thickness from 2m (6.6 ft) to 1m (3.3 ft).
- The basalt has been eliminated and a general fill layer added to provide at least 4.5m (15 ft) thickness. Capillary breaks will be provided at the top and the bottom of the general fill layer.
- Elimination of the geotextile filter.

The protection provided by the modified Hanford barrier is similar to that of the Hanford Barrier. However, the reduction in thickness of the upper silt layers means that the moisture retention capacity is reduced in half. Futhermore, the absence of the crushed basalt layer means that plant roots and burrowing animals can penetrate deeper than permitted by the Hanford Barrier design. Ultimately, the asphalt layer, provides a final deterrant against penetration into the waste.

Based on the unit costs shown in Table 8-5, this barrier would cost \$79/m^2 (\$7.3/ft^2) to construct, approximately 40% less than the Hanford Barrier. Furthermore, the amount of silt required is significantly reduced and no basalt is required. The modified Hanford Barrier is carried forward for further evaluation.

Diversion Barrier. The diversion barrier is similar to the Hanford Barrier except all the layers above the crushed basalt are eliminated. The total thickness of this barrier is 2 m (6.7 ft) including two functional groups:

- A biotic intrusion barrier consisting of a crushed basalt layer,
- A low-permeability barrier consisting primarily of asphalt for diversion of infiltration.

This barrier has been proposed because of concerns that the moisture-retaining silt layers in the Hanford Barrier may actually encourage future generations to plant crops on the barrier. By placing the basalt at the surface, agricultural development is discouraged. The disadvantage of this barrier is that it only provides one line of defense (the asphalt layer) against infiltration, and the amount of water reaching the asphalt will be much greater than for the Hanford Barrier or modified Hanford barrier. Even if the asphalt results in complete diversion of the infiltration, the amount of water that will be diverted to the sides of the barrier will be significantly greater, thereby increasing the amount of infiltration near the outer limits of the waste. For these reasons, this barrier is not retained for further consideration.

8.6 TRENCH LINERS

Liners are constructed on excavated surfaces of the waste management trench, and provide the bottom and sides of the containment system for contaminated materials. Liners may be constructed of a variety of materials such as clay, other types of soils, synthetic membranes, asphalt, and concrete. They may consist of a single layer or be composite liners with several layers. Liners provide containment in two primary ways:

- The primary purpose of a liner is to provide a barrier beneath the waste to allow collection of leachate, thereby reduce the migration of contaminants into the vadose and saturated zones beneath the facility. This function is only fulfilled while leachate is removed from the liner. If leachate is allowed to accumulate on the liner it will eventually migrate out of the facility.

- A secondary function of the liner is to serve as a physical barrier to prevent lateral intrusion by burrowing animals, insects, and plant roots.

All the liners addressed below are generally readily implemented using standard design and construction techniques. Therefore, the evaluation provided in this section focuses on differences in effectiveness and cost.

8.6.1 Asphalt Liner

Asphalt can be used to provide a single-layer, low-permeability liner (not counting foundation layers, if required). Because of its low strength, however, asphalt may be prone to cracking under the loads from the waste and cover. Once cracked, permeability increases and the effectiveness of the liner is significantly reduced. Asphalt liners are therefore not retained.

8.6.2 Concrete Liner

Similar to asphalt, concrete can be used to provide a single-layer low-permeability liner. Although concrete has higher strength than asphalt, it is still prone to cracking due to its brittle nature and tendency to shrink as it cures. Once cracked, concrete becomes more permeable and its effectiveness is significantly reduced. Concrete liners are therefore not retained.

8.6.3 Low-Permeability Clay Liner

Clay liners are generally constructed with a layer of low-permeability, high plasticity clay covered by clean native soil as an operations layer. The clay layer may use native or imported clay, or may use native soils amended with bentonite or other materials that lower its permeability. If not permitted to desiccate, clay liners are self-healing and are plastic in their response to external forces. In wet climates, clay liners are generally considered effective and reliable. However, the arid climate at Hanford increases the likelihood of desiccation, which can crack the clay and significantly raise its permeability. Clay liners are therefore not retained as a stand-alone liner because of their potential for low effectiveness. However, they are included in the composite liner designs in the following sections.

8.6.4 Composite Liner Designs

Composite liners are designed using multiple layers of different materials to achieve highly effective and reliable, long-term protection at waste management units. Low-permeability is a key design consideration. Design and installation of composite liner requires specialized expertise, and synthetic liners particularly require specialized installation. However, this expertise and equipment are readily available. Composite liners are generally more expensive than less complex liners. Two types of liners are considered in this RI/FS: a single liner and a standard RCRA Subtitle C double liner.

Single Composite Liner. The single composite liner system, shown on Figure 8-6, consists of the following layers (from top to bottom):

- Operations layer - clean fill 0.9 m (3 ft) thick, to protect the liner against damage from construction and waste placement equipment, and also against freezing in the exposed portions of the liner.

- Drainage layer - a drainage gravel layer overlain by a geotextile separator to prevent silting of the gravel by the operations layer. The gravel layer directs infiltration percolating through the waste to a collection sump where it is pumped out of the trench. A geocomposite (a geonet sandwiched between layers of geotextile) is used instead of gravel on the side slopes of the trench.

- Low-permeability liner - a synthetic high-density polyethylene (HDPE) geomembrane over 0.3 m (1 ft) of compacted clay with a permeability no greater than $1x10^{-9}$ m/s ($2.8x10^{-4}$ ft/day). Use of two liners provides redundant low permeability; the synthetic membrane protects the clay against desiccation, and the clay provides a thick liner capable of some self-healing with settling and other geological stresses. A geotextile cushion overlies the HDPE geomembrane to minimize damage during placement of the drainage layer.

This liner will be effective in capturing leachate during the operational phase and afterwards, as long as the leachate in the sumps is removed. In contrast with the RCRA double liner, this liner does not provide a secondary leachate collection system.

Based on the unit costs provided in Table 8-6, the unit costs for the single composite are \$32/m^2 (\$3.0/ft^2) for the bottom and \$29/m^2 (\$2.7/ft^2) for the sideslope. The single composite liner system is retained for further consideration

RCRA Double Liner. The most widely used composite liner type is the RCRA Subtitle C liner, which is designed to meet the MTRs specified in 40 CFR 264.310 for hazardous waste landfills. EPA has published guidance for complying with MTRs (EPA 1989c). An example of a RCRA double liner is provided in Figure 8-7. The RCRA MTR double composite liner system is similar to the single composite, with the following changes and additions:

- The clay admix layer is increased in thickness from 0.3 m (1 ft) to 0.9 m (3 ft)

- A second FML and leachate collection system is installed above the lower liner and leachate collection system. The individual components of the upper liner system are the same as those of the lower system.

As with the single composite liner, the gravel drainage layers used on the floor are replaced by drainage geocomposites for both the secondary and primary leachate collection systems on the sideslopes.

The RCRA double liner system provides a redundancy not present in the single liner system, whereby any leachate that leaks through the upper liner is captured in the secondary system. In addition, the RCRA double liner contains a thicker clay layer at the liner base. Based on the unit costs provided in Table 8-7, the unit costs for the double composite liner are \$71/m^2 (\$6.6/ft^2) for the bottom and \$64/m^2 (\$6.0/ft^2) for the sideslope. The RCRA double composite liner system is retained for further consideration

8.7 INSTITUTIONAL CONTROLS

Institutional controls, including monitoring, are usually included as a component of any alternative that relies on containment. Institutional controls prevent or minimize direct exposure to contaminated waste, thereby reducing risk. They do not prevent offsite transport of contaminants via air, surface water, or infiltration into groundwater, and are often ineffective in preventing ecological exposures (e.g., to birds). They also require ongoing maintenance, albeit simple and inexpensive, to remain effective. Institutional controls and monitoring are effective within their limitations, are easily implemented, and are low in cost (and thus very cost-effective). Institutional controls are typically included in any remedy where contaminants will remain after completion of remediation. All of the institutional controls discussed below are retained.

Access Restrictions. Access restrictions involve preventing access by unauthorized personnel. Risk is minimized by preventing exposure except in cases of trespass. Fencing the site perimeter is the most common means of restricting site access. Security personnel at entrance gates or patrolling can also be used to restrict site access and prevent or discourage trespass. Security personnel are significantly more expensive than other access restriction measures, and therefore use of security personnel is often limited to the period of active remediation. Long-term use of security would probably be limited to occasional patrols. Security costs could be reduced by use of remote TV cameras for monitoring the facility.

Warning Markers. Warning markers would be installed to discourage site trespass by warning potential intruders of the hazards of entering the area. Warning markers have been developed for long-term isolation of radioactive waste at the Hanford site. Markers could include large stone pylons with pictorial and verbal warnings that most people could understand. In addition, ceramic disks with similar information would be buried at the site where they would be encountered by anyone digging there.

Land Use Restrictions. Land use restrictions can include zoning and deed restrictions. At present, the Hanford site is not subject to zoning. However, zoning could become relevant under some future uses. Deed restrictions involve specific limitations on future land use that are incorporated in the deed of ownership to the property. Such restrictions would prevent activities that could cause direct exposure or releases of contaminants. Deed restrictions accompany the deed to the property in a manner that is legally binding and must be transferred to all subsequent owners of the property. The restrictions would include a description of the site and reasons for the limits on future activity.

Monitoring. Under CERCLA, site monitoring is a required component of any site remedy (including "no action"). Short-term monitoring is conducted to ensure that potential risks to human health and the environment are controlled while a site remedy is being implemented. Long-term monitoring is conducted to measure the effectiveness of the remedy and thereby ensure that the remedy continues to be protective of human health and the environment. A monitoring plan will be developed for the selected remedial action. The type of monitoring performed will depend on the nature of the remedy. Monitoring would include sampling and analysis of air, surface water run-off, and groundwater as appropriate. Monitoring would also include periodic site inspections to determine maintenance needs.

Air monitoring would be used to detect airborne contamination generated during remedial activities, so that appropriate mitigation measures could be taken. Long-term air monitoring is normally not necessary if no contaminated soil remains exposed on the surface following completion of remediation.

Surface water would be monitored for contamination in waters that contact or might have contacted contaminated materials from the site. As with air monitoring, surface water monitoring is normally a short-term measure conducted during remedial activities. It would not be necessary if no contaminated soil remains exposed on the surface following completion of remediation. There are no surface water bodies near the proposed ERDF location.

Groundwater monitoring would consist of establishing a network of groundwater wells (using existing wells where possible) upgradient and downgradient of contaminated soil, and collecting and analyzing water samples from them on a regular basis. For the ERDF unit, groundwater monitoring would be conducted on a long-term basis to determine if the containment system is functioning adequately.

8.8 WASTEWATER TREATMENT

Potential sources of contaminated wastewater at the ERDF include sanitary wastewater, decontamination facility wastewater, and trench leachate. The sanitary wastewater will be treated in a septic system and disposed to an on-site drain field. The decontamination facility wastewater and the trench leachate will be combined and treated in a single treatment facility. Estimated flow rates are as high as 6.3 million L/yr (1.7 million gal/yr) (U.S. Army Corps of

Engineers 1994). The primary contaminants in the wastewater are likely to be metals and radionuclides, although organic compounds may also occur. Potential treatment technologies are discussed below.

Gravity Separation. Gravity separation is a common, well-established technology for removal of suspended solids from water. It is effective only on larger particle sizes; very small particles must be removed by filtration. Sedimentation or clarification are common gravity separation processes. However, gravity separation would be usable as an ancillary technology. This technology is therefore retained for further consideration.

Filtration. Filtration is a method for removing suspended solids from a liquid using a porous medium. Filtration cannot directly remove chemicals that are dissolved in water. However, filtration is very effective at removing solids created by precipitation technology. Filtration is typically used at the beginning of many treatment systems to remove particulates that may affect later treatment operations. Filtration is retained for further consideration.

Ion Exchange. Ion exchange has been widely applied to the treatment of high flows of wastewaters with dilute concentrations of metals. The contaminant ions are exchanged with ions on the resin (e.g., Na^+). When the exchange capacity for a bed is reached, the resin is regenerated with a brine solution. The regenerant exchanges the original resin ion with the contaminant ion, using an acidic, basic, or brine solution (depending on the specific resin). The regenerant stream then contains the contaminants in a more concentrated form. Cation resins can be weak acid, strong acid, and chelating-type resins. Anion resins are weak or strong base types. The resin is chosen to selectively remove the target contaminant. A mixture of resins may be used to remove multiple contaminants.

Ion exchange resins are easily fouled by suspended solids and organic compounds. The ion exchange influent is usually treated to remove high levels of organic compounds (if present) and filtered to remove suspended solids. The regenerant solution is treated to remove the metals for disposal, generally by precipitation. The sludge from precipitation is then dewatered and disposed. Ion exchange is a proven technology and can be applied to a range of contaminants; therefore, it is retained for further consideration.

Reverse Osmosis. Reverse osmosis (RO) can be used to remove the inorganic and some organic compounds from water. RO separates dissolved materials in solution by diffusion through a semi-permeable membrane. Pressure is used to overcome the osmotic pressure caused by the dissolved compounds. Treatment by RO results in a permeate stream with low concentrations of ions and organic compounds, and a low-volume reject stream that contains the concentrated dissolved compounds. RO is effective for a wide range of metals. Removal efficiency is dependent on membrane type, operating pressure, and the specific compounds.

Equipment from a large number of vendors is available commercially. RO has been used to concentrate metals from dilute solutions and also has been used to remove uranium from solution. Membranes are easily fouled by suspended solids and some organic compounds and are expensive to replace. Pre-treatment by filtration is usually required. RO is a proven technology for removal of inorganic contaminants in wastewater, and is retained for further consideration.

Electrodialysis. Electrodialysis uses a direct current electrical field and ion-exchange membranes to separate ionic species from solution. The electrodialysis process consists of an electrolytic cell containing an anode and a cathode separated by cation-selective and anion-selective membranes. The feed material enters the cell between the two selective membranes. When a direct current charge is applied to the cell, cations are attracted to the cathode and anions to the anode. Ions pass through the appropriate membrane and are concentrated in two brine solutions. The process has limited waste treatment applications because of the sensitivity of the membranes to fouling. Based on its sensitivity to membrane fouling and cost, this technology is not retained.

Evaporation. Evaporation can be used to achieve physical separation of water from a dissolved or suspended solid. Evaporation can be accomplished using boilers to evaporate the water (and possibly condensers to recover the water) or using solar energy to evaporate water from evaporation ponds or tanks. Evaporation is feasible for low flow rates and is retained for further evaluation.

Electrolysis. Electrolysis is a process in which there is electrochemical reduction of metal ions at the cathode. These ions are reduced to elemental metal. Electrolytic recovery is used primarily to remove metal ions from concentrated solutions such as metal plating and etching solutions. Treatment of dilute solutions using conventional electrolysis is not practical because of high power consumption. The process is not feasible for treatment of ERDF wastewaters because of the low concentrations of metals, and the technology is therefore not retained.

Precipitation. Dissolved metals in wastewaters are typically found as metal cations. The addition of specific chemicals to the solution causes the metal cations to react and precipitate out of solution as insoluble compounds. The most common chemical precipitation technology uses lime ($Ca(OH)_2$) to produce insoluble hydroxides. Other common precipitation chemicals are caustic soda ($NaOH$), sulfides, and carbonates. Selection of precipitation chemicals is based on a number of site-specific parameters. Precipitates are then removed from solution by flocculation and sedimentation or filtration. Sludge from precipitation is then dewatered for disposal. Additional treatment (e.g., chemical fixation) may be required or desired.

Precipitation is generally more effective for wastewater with influent metals concentrations in the mg/L range rather than the μg/L range. Low influent concentrations may not provide enough driving force for the precipitation reactions to occur quickly, and overdosing of treatment chemicals would be required. Over-dosing will result in a larger amount of solids for final disposal. Precipitation is better suited to treatment of a concentrated secondary stream (e.g., regenerant from ion exchange). Chemical precipitation is retained for further consideration.

Air Stripping. Air stripping is a process that transfers a contaminant from the liquid phase to the vapor phase. Air stripping is an effective process for removing volatile and slightly soluble organic compounds from water. The effectiveness of air stripping is related to the air/water partitioning of the contaminant determined by Henry's Constant. The stripping takes place in a column where the groundwater flows downward over trays or packing, and air flows upward from the bottom of the column, countercurrent to the water flow. The air stripping process results in an effluent stripped of volatile compounds, and an air stream containing the stripped volatile compounds. Volatile organic compounds are not likely to be significant contaminants in ERDF wastewater and air stripping is therefore not retained for further consideration.

Carbon Adsorption. The carbon adsorption process utilizes activated carbon to provide a solid surface where organic compounds can be removed by adsorption. Carbon adsorption may used in liquid-phase or vapor-phase media. For treatment, the medium is passed through beds containing activated carbon where the contaminants are adsorbed. When the adsorptive capacity for the contaminants has been exceeded, the activated carbon must be replaced. The adsorptive capacity of activated carbon depends on the target compound and the individual characteristics of the carbon. Performance characteristics of activated carbon vary by source and manufacturing methods. Volatile organic compounds are not likely to be significant contaminants in ERDF wastewater and carbon adsorption is therefore not retained for further consideration.

Enhanced Oxidation. This technology includes processes in which the oxidation state of a substance is increased with subsequent destruction or conversion of undesirable organic chemicals to CO_2 and H_2O or other less harmful materials. This technology is not normally applicable to metals. UV photo-oxidation utilizes strong oxidants, such as hydrogen peroxide or ozone, combined with ultraviolet (UV) radiation to oxidize organic contaminants. Volatile organic compounds are not likely to be significant contaminants in ERDF wastewater and enhanced oxidation is therefore not retained for further consideration.

Chemical Oxidation/Reduction. Chemical oxidation-reduction reactions are used to reduce toxicity or to transform a substance to one more easily handled. For example oxidation-reduction reactions between waste components and added chemicals in which the oxidation state of one reactant is raised while that of another is lowered. An example of chemical reduction is the conversion of hexavalent chromium to trivalent chromium, which is less toxic and more easily removed from solution than hexavalent chromium. Chemical oxidation or reduction generally requires the addition of relatively large quantities of chemical oxidizing or reducing agents and is therefore generally expensive. Other effective and less costly technologies are available for treatment and this technology is therefore not retained.

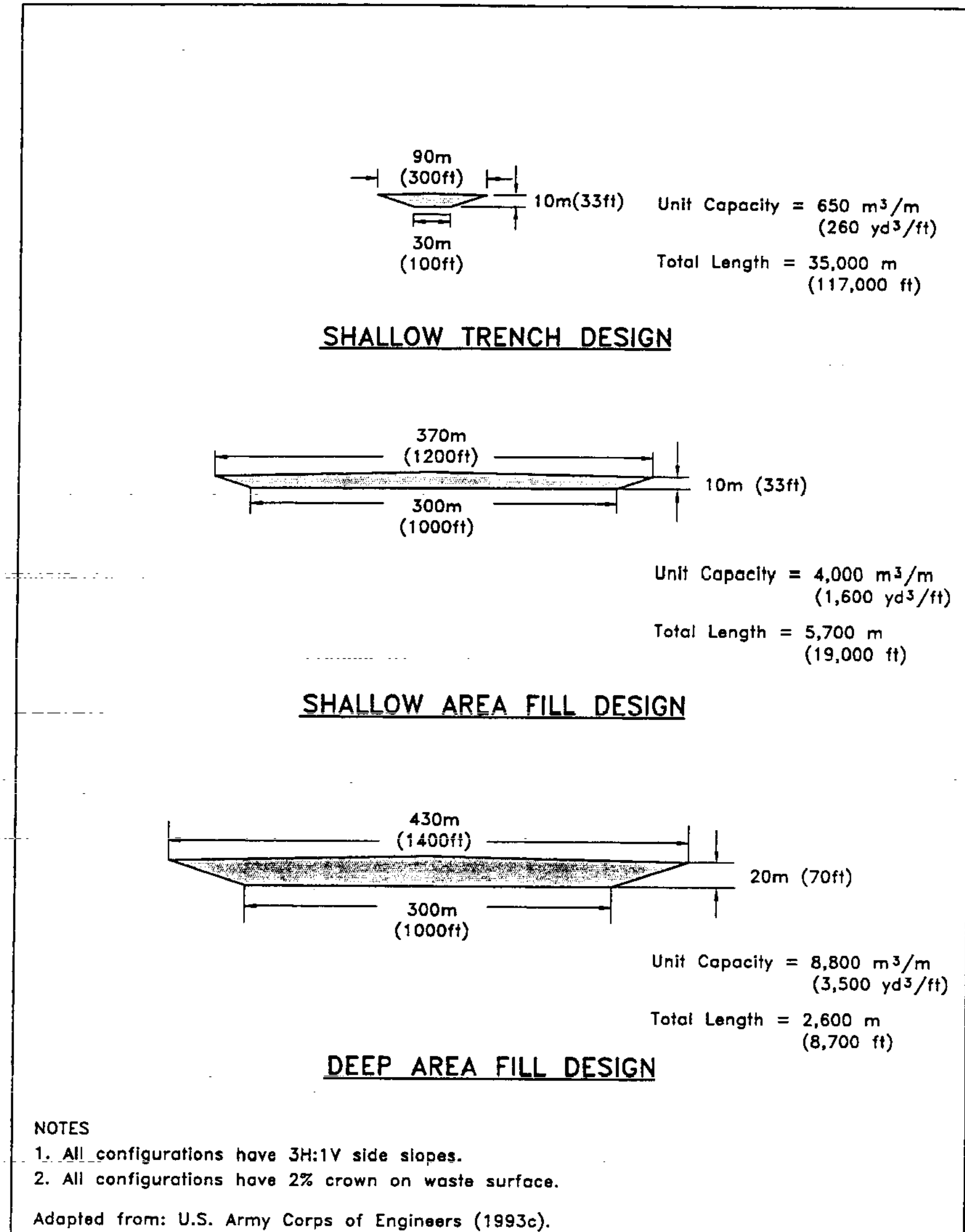

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Figure 8-1. Cross Sections of Potential ERDF Trench Configurations.

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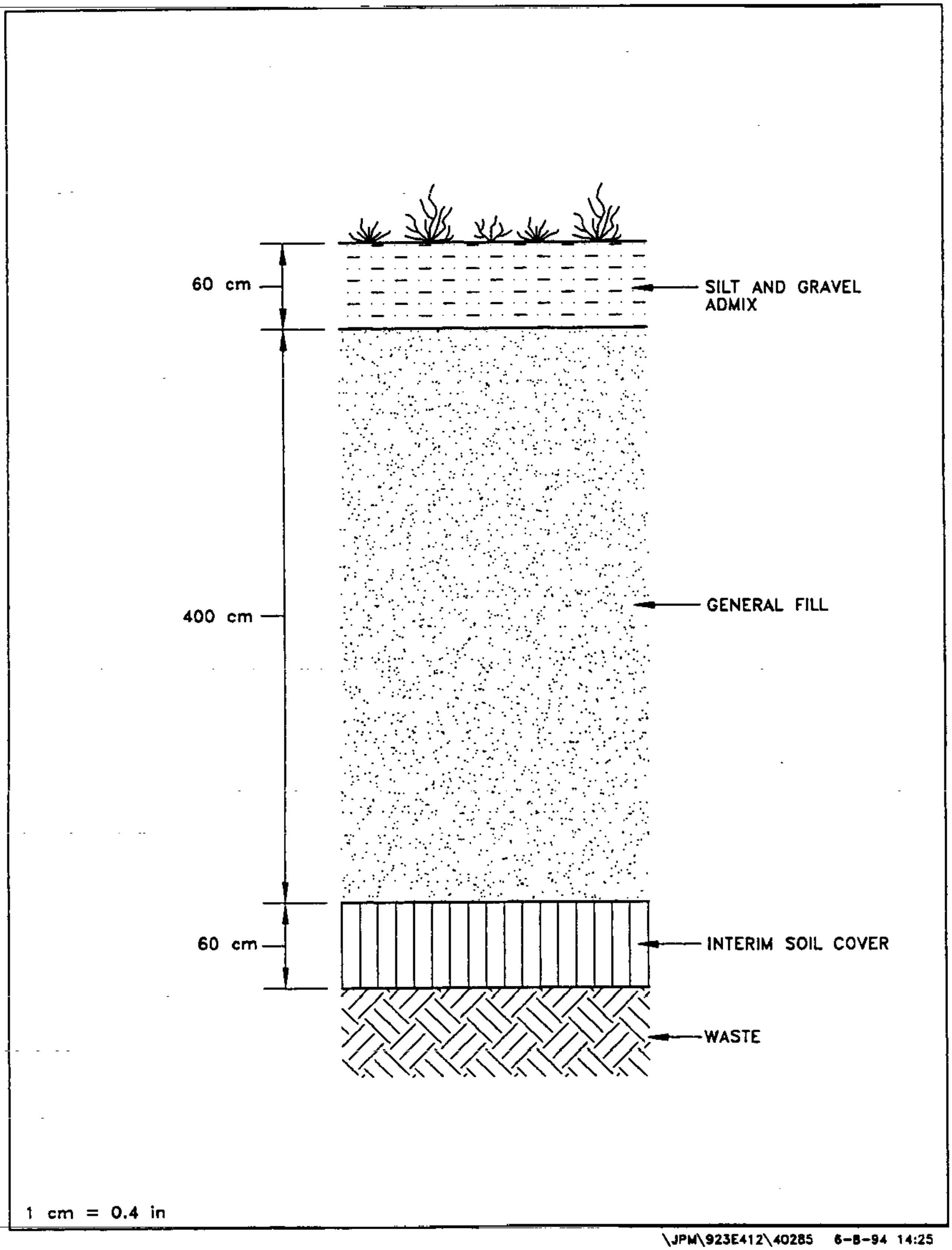

Figure 8-2. Cross Section for a Typical Low Infiltration Soil Cover.

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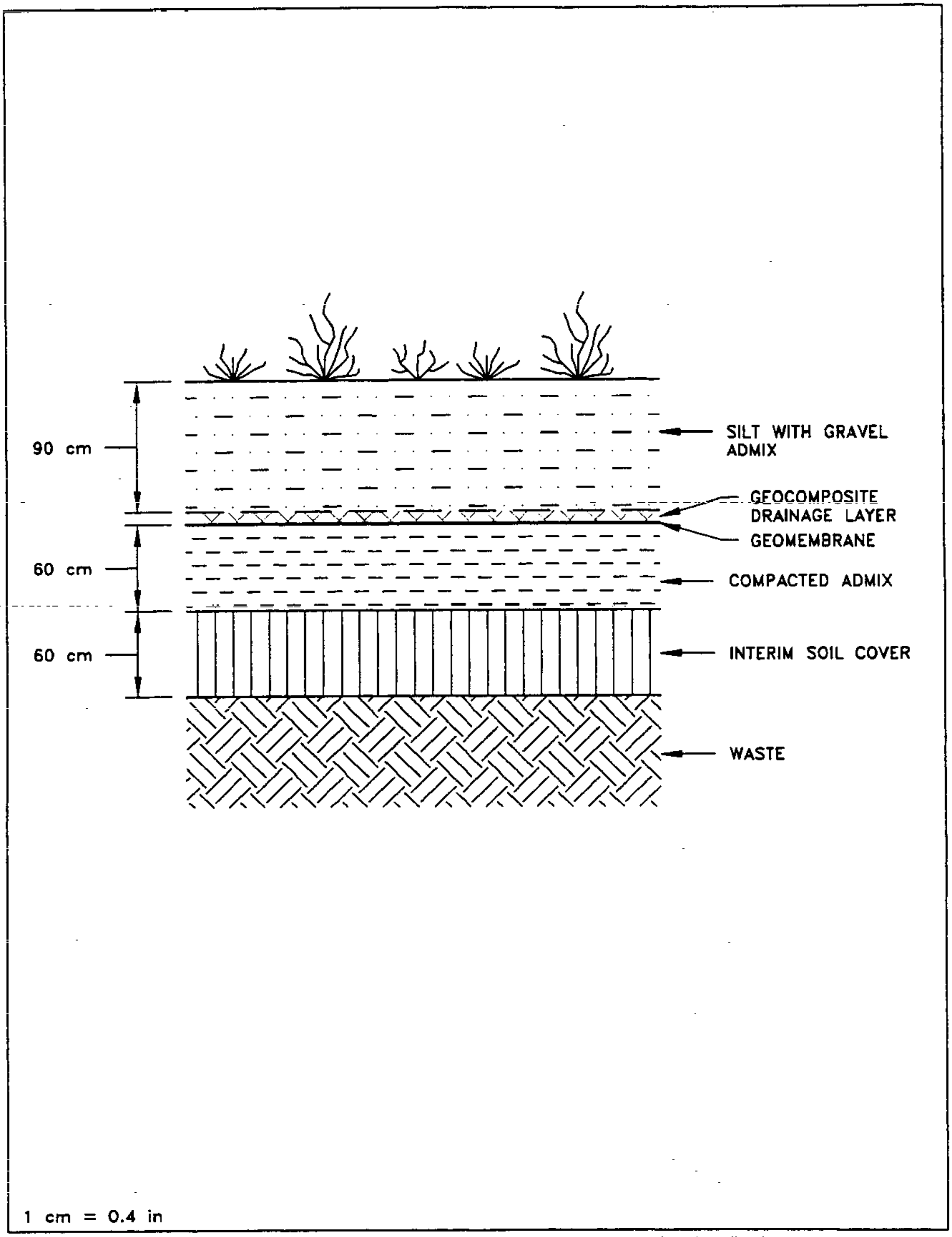

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Figure 8-3. Typical Cross Section of a Standard RCRA Subtitle C Barrier.

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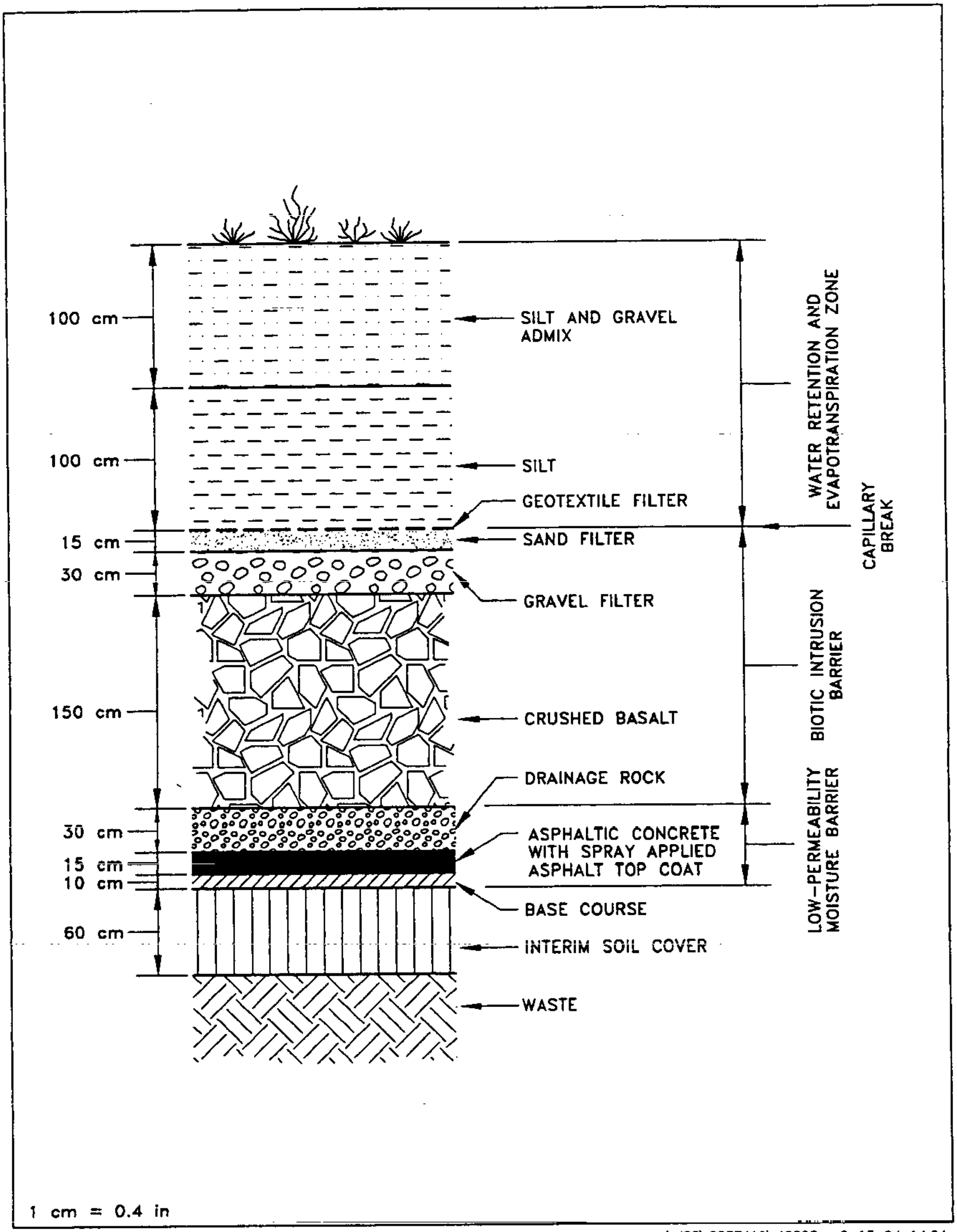

Figure 8-4. Cross Section of the Hanford Barrier.

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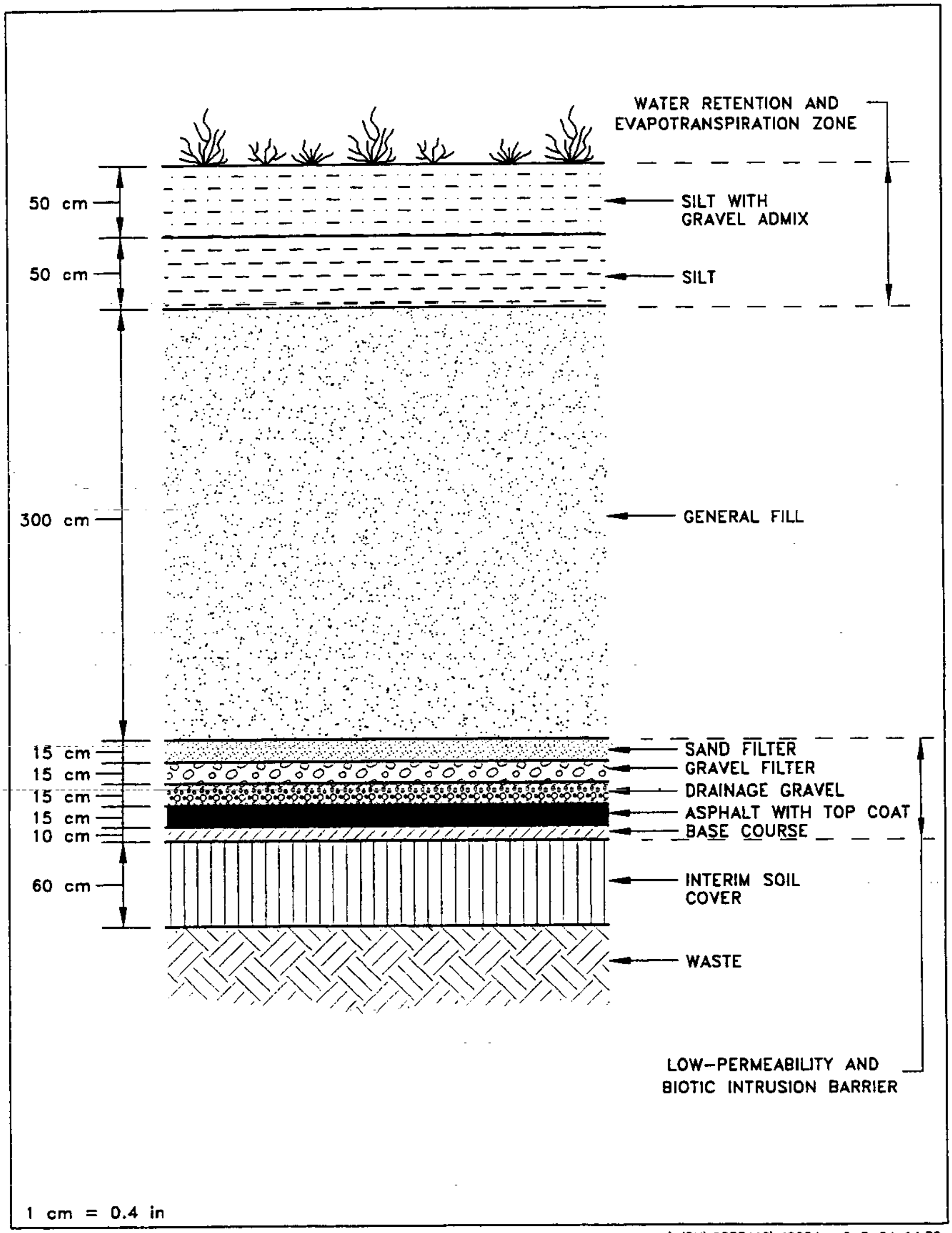

Figure 8-5. Cross Section of the Modified Hanford Barrier.

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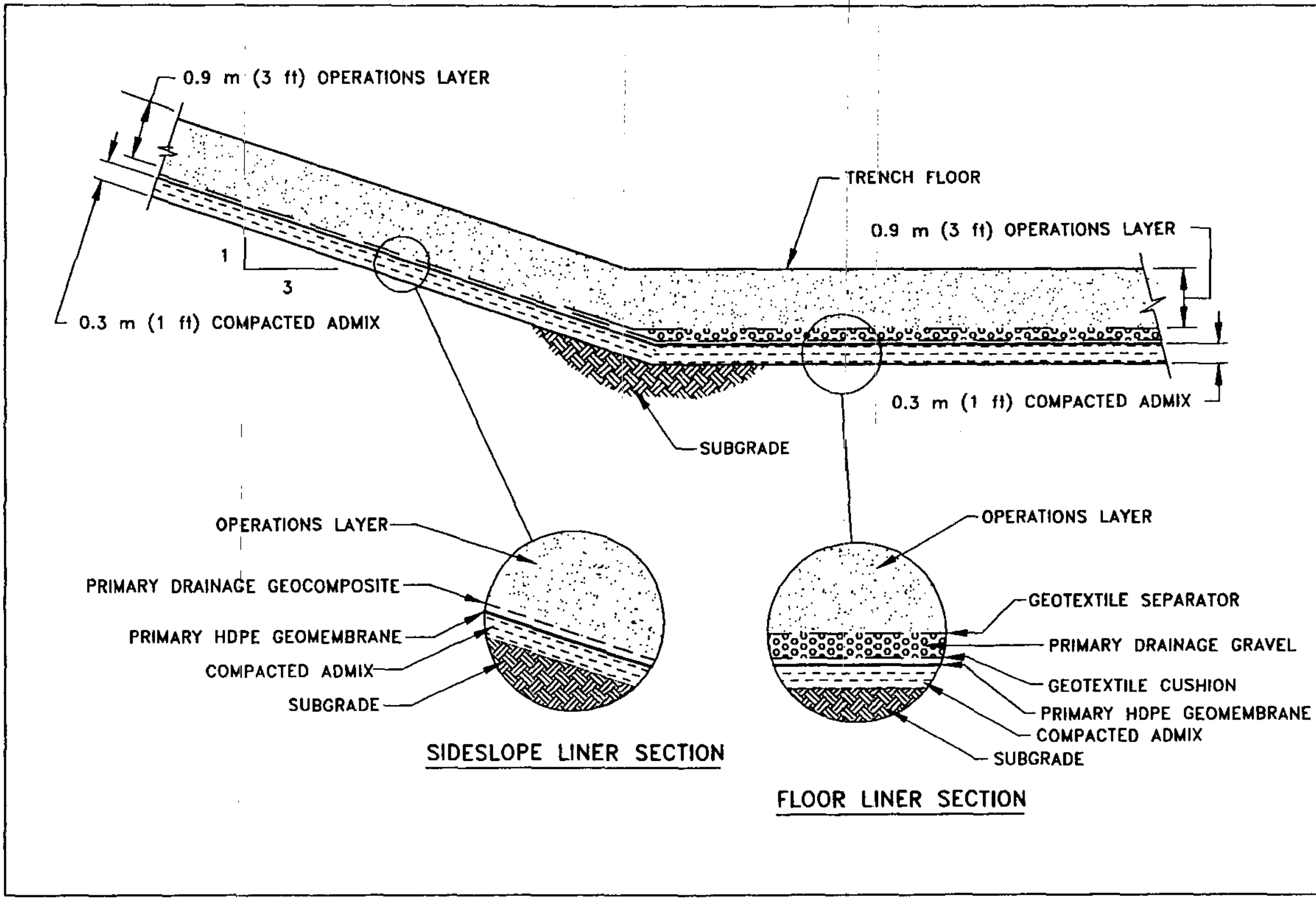

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Figure 8-6. Cross Section of a Single Liner System.

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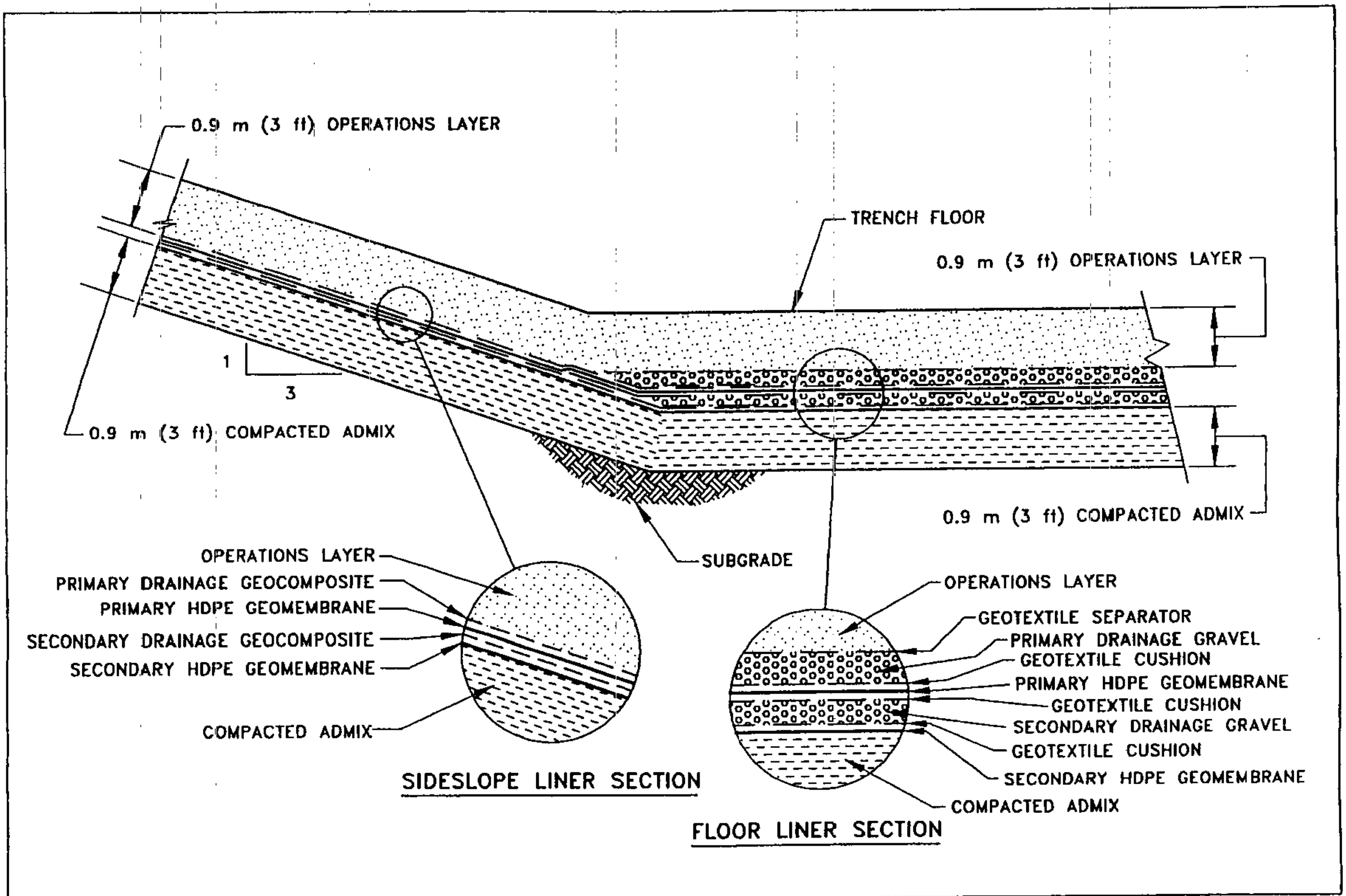

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Figure 8-7. Cross Section of a Typical RCRA Subtitle C Double Liner System.

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Table 8-1. Summary of Screening Results for Groundwater Remediation Technologies and Process Options. (Sheet 1 of 3)

Technology/Process Option	Screening Comments	Retain
Disposal		
Centralized Engineered Facility on the Hanford Site (ERDF)	Effective, relatively easy to implement, low-cost compared with other options.	Yes
Engineered Facilities at Individual Source Operable Unit Sites	Less effective, more difficult to implement, and more expensive than a centralized landfill.	No
Off-site Facility	Good long-term effectiveness, but poor short-term effectiveness, low implementability, and high cost.	No
Geologic Repository	Very effective, but low implementability and very high cost.	No
Trench Configuration		
Shallow Trench Design	Less effective and more costly compared with the deep area-fill design.	No
Shallow Area-Fill Design	Less effective and more costly compared with the deep area-fill design.	No
Deep Area-Fill Design	Effective and relatively cost-effective.	Yes
Dust Control	Not effective in itself, but effective in combination with other technologies.	Yes
Surface Water Management	Not effective in itself, but effective in combination with other technologies.	Yes
Surface Barrier		
Soil Barrier		
Non-engineered Soil Cover	Not effective.	No
Biological Intrusion Barrier	Not effective for protection of groundwater.	No
Low-Infiltration Soil Barrier	Effective for protection of groundwater. Moderately effective against intrusion.	Yes

Table 8-1. Summary of Screening Results for Groundwater Remediation Technologies and Process Options. (Sheet 2 of 3)

Technology/Process Option	Screening Comments	Retain
Asphalt	Not effective for long-term.	No
Concrete Barrier	Not effective for long-term.	No
Low-Permeability Clay Barrier	Not effective in Hanford's arid climate.	No
Synthetic Membrane Barriers	Not certain for long-term.	No
Low-Permeability Composite Barriers		
Standard RCRA Barrier	Groundwater protection is similar to the low-permeability soil cover, but the low-permeability soil cover provides better protection against intrusion at lower cost.	No
Modified Hanford Barrier	More resistant to biointrusion and long-term degradation than the standard RCRA Subtitle C design.	Yes
Hanford Barrier	About 90 percent more expensive than the modified Hanford barrier, but its added thickness provides additional protection against intrusion.	Yes
Diversion Barrier	Less redundant than the Hanford Barrier	No
Trench Liners		
Asphalt Liner	Prone to cracking. Once cracked, permeability increases and the effectiveness of the liner is significantly reduced.	No
Concrete Liner	Prone to cracking. Once cracked, permeability increases and the effectiveness is significantly reduced.	No
Low-Permeability Clay Liner	Not suitable for the arid climate at Hanford.	No
Composite Liner Designs		
Single Composite Liner	Effective in capturing leachate.	Yes
RCRA Double Liner	Most effective in capturing leachate.	Yes
Institutional Controls		
Access Restrictions	Effective and feasible. May be used in conjunction with other technologies.	Yes
Warning Markers	Effective and feasible. May be used in conjunction with other technologies.	Yes

Table 8-1. Summary of Screening Results for Groundwater Remediation Technologies and Process Options. (Sheet 3 of 3)

Technology/Process Option	Screening Comments	Retain
Land Use Restrictions	Effective and feasible. May be used in conjunction with other technologies.	Yes
Monitoring	Groundwater monitoring is a necessary component of all alternatives.	Yes
Wastewater Treatment		
Gravity Separation	Effective for removal of suspended solids. May be used in conjunction with other technologies.	Yes
Filtration	Effective for removal of suspended solids. May be used in conjunction with other technologies.	Yes
Ion Exchange	Effective for removal of metals and radionuclides.	Yes
Reverse Osmosis	Effective for removal of metals and radionuclides.	Yes
Electrodialysis	Susceptible to membrane fouling. Eliminated because of high cost.	No
Evaporation	Effective for low flow rates.	Yes
Electrolysis	Not effective for dilute wastewaters.	No
Precipitation	Effective for treatment of concentrated secondary stream.	Yes
Air Stripping	Not effective for metals.	No
Carbon Absorption	Not effective for metals.	No
Enhanced Oxidation	Not effective for metals.	No
Chemical oxidation/reduction	Eliminated because of high cost.	No

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Table 8-2. Unit Costs for a Typical Low-Infiltration Soil Barrier.

	Units	Quantity	Unit Cost	Total Cost
Vegetation	m^2	1	$0.86	$0.86
Silt and Gravel Admix	m^3	0.6	$15.48	$9.29
General Fill	m^3	4.0	$2.61	$10.44
Total Unit Cost (m^2)				$21.00

Notes:
m^2 = 10.7 ft^2
m^3 = 35.2 ft^3

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Table 8-3. Typical Costs for a Standard RCRA Subtitle C Barrier.

	Units	Quantity	Unit Cost	Total Cost
Vegetation	m^2	1	$0.86	$0.86
Silt and Gravel Admix	m^3	0.9	$15.49	$13.94
Geocomposite	m^2	1	$7.49	$7.49
Geomembrane	m^2	1	$9.10	$9.10
Compacted Admix	m^3	0.6	$32.59	$19.55
Total Unit Cost (m^2)				$51.00
Notes: m^2 = 10.7 ft^2 m^3= 35.2 ft^3				

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Table 8-4. Typical Unit Costs for the Hanford Barrier.

	Units	Quantity	Unit Cost	Total Cost
Vegetation	m^2	1	$0.86	$0.86
Silt and Gravel Admix	m^3	1.0	$15.49	$15.49
Silt	m^3	1.0	$13.02	$13.02
Geotextile Filter	m^2	1	$3.21	$3.21
Sand Filter	m^3	0.15	$18.30	$2.75
Gravel Filter	m^3	0.3	$13.02	$3.91
Crushed Basalt	m^3	1.5	$27.46	$41.19
Drainage Rock	m^3	0.3	$13.02	$3.91
Asphalt Coating	m^2	1	$32.10	$32.10
Asphaltic Concrete	m^3	0.15	$104.19	$15.63
Asphalt Base Course	m^3	0.1	$20.77	$2.08
Total Unit Cost (m^2)				$134.00

Notes:
m^2 = 10.7 ft^2
m^3 = 35.2 ft^3

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Table 8-5. Typical Unit Costs for the Modified Hanford Barrier.

	Units	Quantity	Unit Cost	Total Cost
Vegetation	m^2	1	$0.86	$0.86
Silt and Gravel Admix	m^3	0.5	$15.49	$7.75
Silt	m^3	0.5	$13.02	$6.51
General Fill	m^3	3.0	$2.60	$7.80
Sand Filter	m^3	0.15	$18.30	$2.75
Gravel Filter	m^3	0.15	$13.02	$1.95
Drainage Gravel	m^3	0.15	$13.02	$1.95
Asphalt Coating	m^2	1	$32.10	$32.10
Asphaltic Concrete	m^3	0.15	$104.19	$15.63
Asphalt Base Course	m^3	0.1	$20.77	$2.08
Total Unit Cost (m^2)				$79.00

Notes:
$m^2 = 10.7\ ft^2$
$m^3 = 35.2\ ft^3$

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Table 8-6. Typical Unit Costs for a Single Liner System.

Bottom Liner	Units	Quantity	Unit Cost	Total Cost
Operations Layer	m^3	0.9	$2.61	$2.35
Geotextile Separator	m^2	1	$3.21	$3.21
Primary Drainage Gravel	m^3	0.3	$13.02	$3.91
Geotextile Cushion	m^2	1	$3.21	3.21
Primary HDPE Geomembrane	m^2	1	$9.10	$9.10
Compacted Admix	m^3	0.3	$32.59	$9.78
Total Unit Cost (m^2)				$32.00
Sideslope Liner				
Operations Layer	m^3	0.9	$2.61	$2.35
Primary Drainage Geocomposite	m^2	1	$7.49	$7.49
Primary HDPE Geomembrane	m^2	1	$9.10	$9.10
Compacted Admix	m^3	0.3	$32.59	$9.78
Total Unit Cost (m^2)				$29.00

Notes:
m^2 = 10.7 ft^2
m^3 = 35.2 ft^3

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Table 8-7. Typical Unit Costs for a RCRA Subtitle C Double Liner System.

Bottom Liner	Units	Quantity	Unit Cost	Total Cost
Operations Layer	m^3	0.9	$2.61	$2.35
Geotextile Separator	m^2	1	$3.21	$3.21
Primary Drainage Gravel	m^3	0.3	$13.02	$3.91
Geotextile Cushion	m^2	1	$3.21	$3.21
Primary HDPE Geomembrane	m^2	1	$9.10	$9.10
Geotextile Cushion	m^2	1	$3.21	$3.21
Secondary Drainage Gravel	m^3	0.3	$13.02	$3.91
Geotextile Cushion	m^2	1	$3.21	$3.21
Secondary HDPE Geomembrane	m^2	1	$9.10	$9.10
Compacted Admix	m^3	0.9	$32.59	$29.33
Total Unit Cost (m^2)				$71.00
Sideslope Liner				
Operations Layer	m^3	0.9	$2.61	$2.35
Primary Drainage Geocomposite	m^2	1	$6.42	$6.42
Primary HDPE Geomembrane	m^2	1	$9.10	$9.10
Secondary Drainage Geocomposite	m^2	1	$7.49	$7.49
Secondary HDPE Geomembrane	m^2	1	$9.1	$9.10
Compacted Admix	m^3	0.9	$32.59	$29.33
Total Unit Cost (m^2)				$64.00

Notes:
m^2 = 10.7 ft^2
m^3 = 35.2 ft^3

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9.0 ASSEMBLY AND DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

Technologies retained following the screening process in Chapter 8 are assembled into alternatives and evaluated in this chapter. Screening of alternatives was not considered useful for this RI/FS and all the alternatives are carried into detailed evaluation. In Section 9.1, the technologies are assembled to create a range of alternatives that represent various approaches to achieving remedial action objectives. The criteria used to evaluate the alternatives are discussed in Section 9.2. Elements common to one or more of the alternatives are described and evaluated in Section 9.3. Section 9.4 describes and evaluates the alternatives against the applicable CERCLA criteria. Section 9.5 provides a comparative analysis of the alternatives to assist selection of the preferred alternative.

9.1 ASSEMBLY OF ALTERNATIVES

A range of alternatives is formulated from the technologies and process options retained in Chapter 8. The key elements of each alternative are described and briefly discussed below. Other than the no-action alternative, all the alternatives rely on a centralized waste management facility at the proposed ERDF location. Treatment of the incoming waste is not included in any of the alternatives; as has been stated previously, treatment is considered in the feasibility studies for the individual operable units. Institutional controls, dust control, surface water management, transportation, and wastewater treatment are components of all of the alternatives (except no action), and are discussed as common elements in Section 9.3. These elements are considered to be necessary for each of these alternatives, but are not expected to affect the relative performance of the alternatives.

In addition to a no-action alternative, nine alternatives were developed by selecting combinations of barrier and liner technologies retained after the screening conducted in Chapter 8. The nine alternatives represent combinations of either no liner, a single composite liner, or a RCRA MTR double composite liner; with either a low-infiltration soil barrier, a modified Hanford barrier, or a Hanford Barrier. As discussed in Chapter 8, the shallow trench and shallow area-fill designs were eliminated due to their high cost and the large area required to provide sufficient waste capacity. Therefore, each of the nine alternatives is based on the deep area-fill design, which minimizes the area impacted by construction of the facility. The alternatives assembled for detailed evaluation include:

- Alternative 1 - No action
- Alternative 2 - No liner and a low-infiltration soil barrier
- Alternative 3 - No liner and a modified Hanford barrier
- Alternative 4 - No liner and a Hanford Barrier
- Alternative 5 - Single composite liner and a low-infiltration soil barrier
- Alternative 6 - Single composite liner and a modified Hanford barrier
- Alternative 7 - Single composite liner and a Hanford Barrier
- Alternative 8 - RCRA double composite liner and a low-infiltration soil barrier
- Alternative 9 - RCRA double composite liner and a modified Hanford barrier
- Alternative 10 - RCRA double composite liner and a Hanford Barrier

The components included in each of the alternatives are summarized in Table 9-1.

9.2 EVALUATION CRITERIA

The NCP provides nine criteria for detailed evaluation of alternatives. These criteria are described below. Application of the criteria to the ERDF RI/FS is developed based on the directive in the NCP that "*the analysis of alternatives under review shall reflect the scope and complexity of site problems and alternatives being evaluated and consider the relative significance of the factors within each criteria*" (40 CFR 300.430(e)(9)(iii)). The significance of each criteria and how they will be evaluated for the detailed evaluation is explained below:

1) Overall protection of human health and the environment: Alternatives shall be assessed to determine whether they can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during development of remediation goals. Overall protection of human health and the environment draws on the assessments of other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

This criteria is considered a threshold criteria that must be attained. Assuming the waste acceptance criteria provided in Appendix C will be implemented, all the retained alternatives will fulfill the RAOs specified in Section 7.2. Assuming appropriate worker safety measures and dust controls, all the alternatives will be sufficiently protective of short-term human and environmental health. Therefore, overall protection of human health and the environment is not further addressed in the detailed evaluation of alternatives.

2) Compliance with ARARs: The alternatives shall be assessed to determine whether they attain applicable or relevant and appropriate requirements under federal environmental laws and state environmental or facility siting laws. This criterion is also considered a threshold criterion that must be attained. Assuming the acceptable soil and leachate concentrations provided in Appendix C will be implemented, all the retained alternatives will comply with chemical-specific ARARs. The determinations provided in Chapter 7 for action- and location-specific ARARs are valid for all the alternatives except the no-action alternative. Furthermore, all the alternatives satisfy the ARAR requirements with the exception of the TSCA requirement that PCB's greater than 50 mg/kg must be disposed in a lined facility. In order to accept wastes with PCB concentrations greater than 50 mg/kg, alternatives that do not include a liner (i.e., Alternatives 2, 5, and 8) would require a waiver under CERCLA. The circumstances under which CERCLA waivers may be granted are listed in Section 7.1. The TSCA waiver request would be applied for based on the equivalent standard of performance criteria. Demonstration of equivalent standard of performance is provided by the analyses in Appendix A for an unlined trench, indicating that PCBs would not impact groundwater beneath the ERDF. Since all the alternatives (except the no-action alternative) include a CAMU, evaluation of the CAMU criteria is provided in Section 9.3.

3) Long-term effectiveness and permanence: Alternatives shall be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. Factors that shall be considered, as appropriate, include the following:

- Magnitude of residual risk remaining from untreated waste or treatment residuals remaining at the conclusion of the remedial activities. Residual risk is associated with migration of contaminants to groundwater and will be addressed by predicting the risk via the groundwater pathway for each alternative. The risk will be predicted using both current climatic conditions and hypothetical wet climatic conditions. As discussed in Appendix A, none of the alternatives result in contaminants reaching groundwater within 10,000 years under current climate conditions. Therefore, the only difference between the alternatives occur under the hypothetical wetter climate conditions.

- Adequacy and reliability of controls such as containment systems and institutional controls. This factor addresses the uncertainties regarding long-term protection from residuals, the assessment of the potential need to replace technical components of the alternative, and the potential exposure pathways and risks posed should the remedial action need replacement. This factor will be addressed by qualitatively evaluating the durability and redundancy in the liner and barrier provided by each of the alternatives. In addition, to facilitate assessment of the no-action alternative, the reliability of location (near the Columbia River or the 200 Area) will also be assessed.

- Reduction of toxicity, mobility, or volume through treatment. This factor is not relevant to this evaluation since none of the alternatives include treatment.

Long-term effectiveness will be measured in terms of future groundwater risk and qualitative assessments of liner reliability and barrier reliability. For scoring purposes, barrier reliability is weighted 0.5, groundwater risk is weighted 0.4, and liner reliability is weighted 0.1. Liner reliability is considered least important because the liner is expected to fail over the long-term and does not significantly affect risk estimates (see Appendix A). Barrier reliability is weighted slightly more than groundwater risk because barrier reliability impacts intrusion in addition to groundwater impacts.

4) Reduction of toxicity, mobility, or volume through treatment: This criteria is not relevant to this evaluation since none of the alternatives include treatment. Treatment will be addressed in the source operable unit FSs.

5) Short-term effectiveness: The short-term impacts of alternatives shall be assessed considering the following:

- Short-term risks that might be posed to the community during implementation of an alternative. Risks to the community during implementation are associated with potential air releases of waste constituents during waste transport and placement. Since operations would be conducted in the same manner for all the alternatives (except the no-action alternative), this criteria will not differentiate between the alternatives. The dust controls included in all the alternatives will be sufficient to protect worker health. Since the proposed ERDF is isolated from the public, public risk is considered negligible compared with worker risk.

- Potential impacts on workers during remedial action and the effectiveness and reliability of protective measures. Risks to workers include both exposure to hazardous substances in the waste and physical hazards associated with construction activities and equipment operation. Potential worker exposure to waste contaminants during waste transport and placement would be the same for all the alternatives (except the no-action alternative). Since all the alternatives involve similar types of construction activities, the magnitude of physical hazard associated with an alternative would be approximately proportional to the amount of labor necessary to construct the facility. Generally the more complex liners and covers require the most labor.

- Potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation. Since all the alternatives (except the no-action alternative) utilize the same trench configuration, environmental impacts at the ERDF are virtually the same. However, since the three barriers require different quantities of silt and crushed basalt, impacts on environmental and cultural resources at the borrow sources will vary.

- Time until protection is achieved. Assuming that all alternatives will result in a facility ready to receive waste by September, 1996, this factor would be the same for all the alternatives. As discussed below under implementability, however, those alternatives that include non-RCRA MTR liners may require greater technical effort to defend and consequently may take longer to permit. Since the final cover will not be constructed until after waste is received, non-RCRA MTR barriers should not impede Hanford's restoration program.

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Given these factors, short-term effectiveness will be measured primarily in terms of the expected number of fatalities due to physical accidents and the impacted areas at the borrow sites (a surrogate for environmental and cultural impacts). For scoring purposes, the 2 borrow site impacts subcriteria are weighted 0.4 each, and the worker accidents criterion is weighted 0.2. Worker accidents is weighted less than the other criteria because the differences between the alternatives are relatively minor for this criterion. The timeliness factor will be evaluated under implementability. Short-term risk to workers and the public due to exposure to wastes is addressed in Section 9.3.16.

6) **Implementability:** The ease or difficulty of implementing the alternatives shall be assessed by considering the following types of factors as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy. In general, all the alternatives are technically feasible. However, the more complex alternatives that include liners and barriers that require certain weather conditions for construction are more likely to have problems resulting in schedule delays. The number of layers in the liner and barrier will be considered a relative measure of technical complexity.

- Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for off-site actions). CERCLA waives administrative requirement (such as permitting) for on-site activities. Since none of the alternatives include off-site transport, treatment, or disposal, this factor is not relevant to the detailed evaluation.

- Availability of services and materials, including the availability of adequate off-site treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies. The primary differences between the alternatives regarding this factor is related to the types and quantities of materials included in the liners and covers. Off-the-shelf materials or materials that utilize soil excavated at the ERDF are considered easy to obtain. Materials that must be obtained from borrow sources on the Hanford Site (primarily silt and basalt) will be considered the most difficult to obtain because of their potential impact on ecological and cultural resources. Impacts at the borrow sources are addressed under short-term effectiveness and are not further addressed under implementability.

In summary, the only factor included within implementability is technical implementability.

7) Cost: The types of cost factors that shall be assessed include the following:

- Capital costs, including both direct and indirect costs. Construction costs for the different liners and barriers will vary significantly. Therefore, capital costs will be the primary factor for this criteria in evaluation of the alternatives. Costs for excavating the trench and supporting facilities will also be determined to provide a perspective on the relative significance of the liner and barrier costs. Accuracy of the cost estimates is generally in the + or - 25% range. More than 2 significant figures were retained in the cost estimates to minimize rounding inaccuracies.

- Annual operation and maintenance costs. These are similar for all the alternatives (except the no-action alternative) and therefore will not differentiate between the alternatives. Only costs incurred during operation of the ERDF will be considered. Long-term, post closure monitoring and maintenance costs will be relatively small and are not included.

- Net present value of capital and O&M costs. The net present value will include capital costs and operation and maintenance costs. Since the barrier will be constructed after the trench is full, net present value of the barrier costs will be calculated assuming the barrier will be built 20 years after the liner and supporting facilities are constructed. A 6 percent discount rate will be assumed.

Comparative performance of the alternatives will be based on the total net present value of capital and O & M costs.

8) State acceptance: The state concerns that shall be assessed include the following:

- The state's position and key concerns related to the preferred alternative and other alternatives.

- State comments on ARARs or the proposed use of waivers.

The State's concerns have been identified and resolved during the RI/FS review process. This is a modifying criteria that will also be considered in remedy selection for the ROD.

9) Community acceptance: This assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until comments on the proposed plan are received; therefore, this criteria is not addressed in the RI/FS. This is a modifying criteria that will also be considered in remedy selection for the ROD.

9.3 COMMON ELEMENTS AND IMPACTS

This section describes elements that will be included in one or more of the alternatives and impacts that will generally be common to one or more of the alternatives. Elements in all the alternatives (except the no-action alternative) are institutional controls, dust control, surface water management, wastewater treatment, transportation, supporting facilities, and the deep area-fill trench configuration. Elements included in more than one alternative (but not all) are the different liners and barriers. Common impacts discussed in this section include ecological, air quality, historical resources, socioeconomic, transportation, visual, noise, and worker risk. In addition, cost assumptions and estimates for all common elements are provided.

9.3.1 Institutional Controls

Surveillance and access controls are currently maintained for the entire Hanford Site for protection of government property, classified information, and special nuclear materials. Additional institutional controls will be implemented at the ERDF during the operational period and after closure. These include 24-hour surveillance, fencing, entry control, and warning signs. Approximately 3 m (10 ft) high chain-link fencing would be built around the ERDF to prevent inadvertent entry to the trench and operations areas. Radiation and hazard warning signs would be placed every 30 m (100 ft) around the fence to discourage trespass. Groundwater use restrictions would prevent withdrawals of groundwater near the site boundary and would be coordinated with remedial actions undertaken in the neighboring 200 Area.

Institutional controls also include monitoring and maintenance activities. Environmental monitoring stations will be installed at various locations around the facility (some possibly off-site). These stations will monitor some or all of the following parameters:

- Weather - wind direction and speed, temperature (off the proposed ERDF site)
- Radiological air monitoring
- Groundwater well monitoring
- Continuous air quality monitoring system.

Maintenance activities include maintenance of the fence and warning signs, maintenance of the leachate collection/detection and removal system, maintenance and repairs to the cover system, and the monitoring systems described above. Maintenance activities may be required for the tubing, pumps, and piping system of the leachate collection/detection and removal system. Maintenance of the cover system will include controls and repairs of any damage due to wind erosion, water erosion, deep-rooted plants, burrowing animals, subsidence and settlement, seismic events, cover drainage and run-on, and freeze/thaw effects. Periodic inspections will be conducted to prevent malfunctions and deterioration, human errors, and discharges that may cause or lead to the release of radioactive or dangerous waste to the environment or pose a threat to human health.

Preventing site access and maintaining the cover would minimize the potential for direct human and environmental exposure to contaminated soils and wastes associated with the ERDF.

Therefore, institutional controls address the first RAO: prevent unacceptable direct exposure to waste. Since it is not known how long institutional controls will remain effective, the surface barrier provides additional protection against intrusion into the waste. In addition, the surface barrier provides the primary mechanism for achieving long-term compliance with the third and fourth remedial action objectives (preventing unacceptable contaminant release to air and groundwater, respectively) because it would detect contaminant releases to groundwater and signal the need for corrective actions. In addition, groundwater monitoring will be conducted to provide an additional level of protection against exposure to contaminated groundwater.

9.3.2 Dust Control

Dust control will be conducted to minimize contaminant release to air during the ERDF operations. Dust control will be achieved by using dust suppressant sprays and controlling moisture content in the waste. At the end of each shift, the top of the trench fill will be covered with clean (uncontaminated) soil and the working face will be covered with clean soil or sprayed with a dust suppressant. Dust control will help achieve short-term compliance with the third remedial action objective (prevent unacceptable contaminant release to air) as well as comply with any ARARs regarding releases to air.

9.3.3 Surface Water Management

A drainage system will be developed to be compatible with runoff volume. Stormwater run-on/runoff systems will be designed to meet the requirements of 40 CFR 264.301. The stormwater runoff from clean areas of the site will be collected and routed through ditches to a detention storage pond. Stormwater entering this pond will be metered and discharged to an existing drainage channel in a controlled manner. Drainage ditches will be vegetation-lined where feasible, and asphalt and/or concrete channels where flows are too great for vegetation channels.

It is anticipated that stormwater runoff in potentially contaminated areas will not require treatment under normal conditions. If spillage of waste material occurs, however, the stormwater runoff may become contaminated and require treatment. Therefore, stormwater runoff from potentially contaminated areas will be collected separately from runoff from clean areas and routed to RCRA-compliant detention tanks. The wastewater contained in these tanks will be sampled and uncontaminated drainage will be released to natural drainage areas near the southwest side of the ERDF trench. If the sampling indicates that treatment is needed, either lime will be added or the water will be pumped to either the wastewater treatment facility, the grout plant, or into tankers for off-site treatment.

Potential sources of radioactive contamination include accidental spillage of small amounts of materials from the tractor/trailer/container or an accident where a tractor/trailer carrying a full container tips. Special precautions and measures will be taken in transportation of the radioactive materials. Therefore, the potential for radioactive materials being in the storm runoff will be minimized. Due to the expectation that only very low amounts of radioactivity will occur in the runoff, the use of a dedicated treatment system is not justified.

9.3.4 Wastewater Treatment

Wastewater at the ERDF includes sanitary wastewater, leachate, and decontamination wastewater. The sanitary wastewater from the operations building and decontamination facility will be collected and treated in septic tanks located near each facility in uncontaminated areas. The liquid from the septic tanks will be diverted to drain field systems.

The decontamination facility wastewater and the trench leachate will be combined and treated in the wastewater treatment system. Off-the-shelf reverse-osmosis (RO) units may be used to treat the wastewater. The concentrate from the RO unit will be stored in tanks and transferred to evaporation basins or used for grout production. The treated (clean) effluent will be recycled for use in the decontamination facility or used in tanker trucks for dust control.

9.3.5 Transportation Expansion and Impacts

Hanford Site Transportation. The ERDF is expected to receive 150 rail containers of waste per shift. The location of the existing railroad system is shown on Figure 2-35 and 2-36. In order to accommodate waste transport to the ERDF, a new railroad track will be constructed from the existing Hanford rail system north of the 200 West Area to the proposed ERDF site. The new railroad spur is shown on Figure 9-1. The existing railroad system combined with the new railroad system will provide sufficient capacity for the additional rail traffic associated with the ERDF.

Additional car and truck traffic on Hanford roads due to the ERDF will include primarily truck-hauled waste, truck-hauled clean fill (for filling excavations at the waste units), commuting workers, and transport of materials for construction of the liner and barrier. Primary existing surface roads on the Hanford Site are shown on Figure 2-35. Existing and planned surface roads near the ERDF are shown on Figure 9-1. The ERDF is expected to receive 65 truckloads of waste per shift. Assuming 80 percent of the excavated waste is replaced with clean fill from the ERDF, 52 truckloads of clean fill will be transported to the source operable units each shift. Clean fill will be transported in dedicated "clean" containers; therefore, a total of 107 truckloads will be transported each shift. Commuting traffic is expected to include 167 full-time employees for operations, less than 163 workers for construction of the ERDF, and a negligible number of Hanford site-wide service personnel. Since some employees ride the bus and others carpool, commuting traffic will likely be less than 150 vehicles per day. The amount of traffic associated with liner and barrier construction will depend on the specific liner and barrier design and the rate of construction; estimates are provided in Sections 9.3.8 and 9.3.9. As discussed in these sections, the material hauling traffic ranges from a low of 14 trucks per day for the single liner to a maximum of 41 trucks per day for the double liner.

Adding together the traffic loads associated with waste transport, commuting, and material delivery, a maximum of 310 additional vehicles per day on Hanford roads will be associated with the ERDF.

Transportation Within the ERDF. The transportation network inside the ERDF facility will include the following elements:

- Incoming waste operations,

- Waste transfer to the internal ERDF transport trucks,
- Transport of waste within the ERDF,
- Decontamination operations,
- Waste grouting,
- Waste cover,
- Construction.

These transportation elements are discussed below.

Waste-receiving facilities will accommodate delivery of waste materials to the proposed ERDF from the source operable units and the return of empty containers after external decontamination. Inbound operations will include waste delivery by tractor/trailer or rail, waste container transfer to tractor/trailers for internal ERDF transport, manifest checking, and tractor/trailers dispatching to the burial trenches. Waste is expected to arrive at the ERDF in both single-use and reusable containers. Containers will be transferred from railcars and tractor/trailers by wheeled container handlers. The tractor/trailers will travel along dedicated paved ERDF haul roads between the railhead and the trench and on gravel roads within the trench.

After the waste is emptied into the ERDF trench, containers will be transported to the decontamination facility where they will pass though the washing system on conveyors to a position for transfer back to railcars. Single-use containers will be placed on the floor of the working area within the ERDF trench by a crane. Backhauled soil will be transported in "clean" containers that are not used for waste transport.

Materials excavated from the ERDF trench will be used for grout aggregate. Cement will be imported from off-site. Grout production will include transport of aggregate materials to the batch plant, mixing of the grout in the batch plant, and transfer to a mixer/transport truck. The grout mixer/transport truck will deliver the grout to the designated grouting area, unload the grout using the mixer drum and unloading chute, and return to the batch plant.

Materials excavated from the ERDF trench will be used for daily cover. Cover material will be spread and compacted by a dozer unit towing a vibratory roller compactor. At the end of each shift, the exposed working face areas will be covered by a dust suppressant material.

Traffic requirements associated with construction of the ERDF include transport of excavated materials from the trench excavation to stockpiles within the ERDF and transport of liner and barrier construction materials within the ERDF. The maximum on-site traffic load would be associated with simultaneous trench excavation and liner construction. Trench excavation is expected to include 33 pieces of equipment (see Section 9.3.7) and liner construction would include a maximum of 41 trucks (see Section 9.3.8) for a total of 74 vehicles.

9.3.6 Other Supporting Facilities and Activities

Other supporting facilities and activities include buildings, a grout batch plant, equipment for internal and external communications, emergency response, and personnel protection.

Three buildings will be included in the ERDF: the operations building, the decontamination facility, and the wastewater treatment facility. The operations building will include personnel decontamination (showers and change rooms), a lunch room, maintenance shops, and offices. The decontamination facility will provide a control room for decontamination operations personnel, a personnel decontamination area, restrooms, and a container decontamination, monitoring, and storage area. The wastewater treatment facility will include treatment equipment.

Although most of the waste to be received at the ERDF is expected to be bulk soils that can be easily compacted and stabilized, some of the waste will be metal and construction debris that may result in voids that could cause settlement of the waste and surface barrier. Therefore, void space will be filled with grout and a portable grout batch plant will be included at the ERDF. The grout plant will mix cement, fly ash, aggregate, water, and pozzolans (as necessary). The batch plant will be placed over a buried leak-collection liner to prevent water releases to the subsurface.

The ERDF will use a combination of telephone communications, radio communications, computer and alarm systems to provide immediate emergency instruction to facility personnel. The external communications will be provided through a telephone system to be installed in the operations buildings at the ERDF site.

Emergency equipment will be available for use at the ERDF site and personnel will be trained in the use of emergency equipment. Facility buildings will have fire sprinklers connected to a raw water supply system. Water for fire control in other areas of the ERDF is supplied by the main raw water line connected to adequately spaced fire hydrants located near the operations and decontamination buildings.

At a minimum, all personnel will be required to wear radiation protection coveralls, cloth shoe covers plus rubber boots or shoe covers, gloves, and a cloth cap when working in the ERDF site. In addition, various types of respiratory devices will be available if required and personnel will be trained in their use.

9.3.7 Deep Area-Fill Configuration

The deep area-fill design (described in Section 8.2.3) is used for all the alternatives except no-action. The assumed cross-sectional dimensions of the trench are shown in Figure 4-1. In order to accommodate the estimated final waste volume of 21.9 million m^3 (28.5 million yd^3), the trench would need to be approximately 3,000 m (9,800 ft) long. Assuming these dimensions, the footprint of such a trench would be 1.26 km^2 (315 acres). Because the final waste volume may be significantly different than anticipated, trench construction will proceed in stages such that capacity expands to fit the immediate needs of the Hanford Site restoration program.

As discussed in Section 8.2, the reduced footprint of the deep area-fill design offers the following advantages in comparison to other configurations:

- Less habitat disruption at the ERDF,
- Less leachate generation,

- Reduced material needs (thus, reduced ecological and cultural impact on borrow areas),
- Lower costs for the liner and barrier.

The proposed site for the ERDF extends east of the 200 West Area to the state leased land (the US Ecology area) and south of the proposed 16th Avenue extension (see Figure 1-2). The area of the ERDF is estimated to be 4.1 square kilometers (1.6 square miles).

Soils removed from the trench excavation will be stockpiled within the ERDF site. Excavation of the trench is anticipated to be accomplished in the following manner:

- The crew will consist of 50 workers who will operate 33 pieces of equipment (primarily scrapers, dozers, graders, loaders, and water trucks),
- The crew will move 10,000 m^3 (13,000 yd^3) per shift,
- A week will include 10 shifts (double shifting),
- One cell of 0.7 million m^3 (0.9 million yd^3) will be excavated every 7 weeks.

Labor Requirements. Based on the assumptions listed above, trench excavation of all 32 cells is expected to require 110,000 worker days. Assuming 50 workers per shift, trench excavation will result in 100 jobs over a period of 4.5 years.

9.3.8 Liners

Two liner systems are included in the remedial alternatives, the single composite liner and the RCRA Subtitle C double composite liner. Features of these two liner systems that are applicable to multiple alternatives are presented in this section, including implementability, cost, labor requirements for construction, material usage, traffic loading, modeling assumptions, and reliability.

Implementability. Technical implementability is scored qualitatively based on the number of layers in each liner system. As described in Section 8.6.4, the single liner has six layers on the bottom and 4 layers on the sideslope for an average of 5. The double liner has 10 layers on the bottom and 6 layers on the sideslope for an average of 8.

Raw Cost. Material unit costs for the liners were presented in Section 8.6.4. The areas for the bottom and sideslope portions of the liners were calculated assuming a top trench width of 420 m (1,400 ft) a bottom trench width of 300 m (980 ft), a top length of 3,000 m (9,800 ft) and a bottom length of 2,880 m (9,400 ft). The plan area of the sideslope liner was converted to actual surface area by dividing by the cosine of 18.4 degrees (0.95) to account for the 3H:1V sideslopes. Total raw costs for the two types of liners are shown in Table 9-2. The cost for the single liner ($39 million) is less than half the total cost for the double liner ($88 million).

Labor Requirements. Only labor associated with construction and Hanford Site material transport is addressed. Labor for production of materials included in the liners is not addressed in this section. The assumed crew sizes for placement of each type of material are provided in Table 9-3. Labor requirements for material transport are based on traffic loading information provided below. The estimated labor associated with each liner, provided in Table 9-3, ranges from 40,000 worker-days for the single liner to 79,000 worker-days for the double liner. Assuming that the liner construction will occur over a 5 year (1,250 working days) period, construction of the liner will result in between 32 and 63 jobs over a five year period.

Material Usage. Thicknesses for each component in the liners are discussed in Section 8.6.4. The assumptions for the area estimates are provided above in the cost discussion. Quantities of material used in each liner are summarized in Table 9-4 and are based on the following assumptions:

- The operations layer will consist of general fill
- The compacted admix at the base of the liners will consist of 80 percent silty fine sand and 20 percent bentonite (by volume).

The sand, gravel, and general fill will likely be obtained from native soils excavated for the ERDF trench. Therefore, they will have no impact on cultural and ecological resources at borrow sources. If materials excavated for the ERDF are not suitable, these granular materials will likely be obtained from gravel pits located between the 200 East and 200 West Areas. The vegetation seed, bentonite, and geotextiles will likely be obtained from off-Hanford Site suppliers.

Traffic Loads. The only materials included in the liners that must be imported from off the ERDF site are geosynthetics and bentonite. The remaining materials are derived from ERDF trench excavation soils. The assumed truckload size is provided for each material and the daily traffic loads are calculated assuming that the synthetic materials for each layer in each cell (each cell equals approximately 1/32th of the complete facility) arrive over a period of 5 working days and the bentonite arrives over a period of 20 days. The results are summarized below.

Traffic Associated with Liner Construction (Trucks per day)			
	Daily Quantity Per Truck	Single Liner	Double Liner
Geotextile Separator	20,000 m^2	<1	<1
Geotextile Cushion	20,000 m^2	<1	1
Drainage Geocomposite	15,000 m^2	<1	<1
HDPE Geomembrane	10,000 m^2	1	2
Bentonite	10 m^3	12.5	37.5
Maximum Total		14	41

The maximum total traffic loads per day range from 14 trucks/day for the single liner to 41 trucks/day for the double liner. These maximums assume that the delivery days for different materials overlap.

Modeling Assumptions. The contaminant transport simulations presented in Appendix A assume that no leakage occurs through the liners during operations (i.e., while leachate is removed). The operational time period is assumed to equal 30 years. At the end of the operational time period, it is assumed that the synthetic membranes have degraded and all leachate migrates through the underlying admix layer. As discussed in Appendix A, liner parameters used in the equations are thickness, bulk density, moisture content, and liner K_d's. The admix thickness of the double liner (0.9 m [3 ft]) is three times greater than the admix thickness of the single liner (0.3 m [1 ft]). The bulk density of the admix is assumed to equal 1.5 gm/cm^3, and the moisture content of the admix is assumed to equal 22.5 percent. The liner K_d's are constituent specific and are assumed to be 5 times greater than the K_d's used for the vadose zone (see Section 4.1.2.2).

Reliability. Alternatives that include liners offer several advantages over no-liner alternatives. The primary advantage is that any leachate generated during the operational period will be retained by the liner and pumped out. This means that constituent release to the vadose zone is delayed by the length of the operational period. Conceivably, the operational period could extend for hundreds or thousands of years. However, the effectiveness of the leachate collection system is limited by the lifetime of the synthetic membranes. Once the synthetic membranes degrade and develop leaks, the permeability of the liner is controlled by the permeability of the admix material. Since the infiltration rate is generally less than the design permeability of the admix material (10^{-7} cm/sec), leachate will migrate through the admix layer and leachate collection will not be possible. This element of reliability is addressed in the risk estimates for the alternatives.

A secondary advantage of a leachate collection system is that it allows characterization of the leachate generated in the waste. Knowledge of constituent concentrations in the leachate, and the K_d's of the leachate constituents, could be used to predict future impacts on groundwater once the leachate collection is terminated or the liner fails. If these future impacts are considered unacceptable, then corrective actions (such as excavation and further treatment of the waste) could be implemented before groundwater is impacted.

The double composite liner offers a redundancy in leachate collection systems not available in the single composite liner. The potential for flaws in the primary liner is uncertain, although it is probably low given the high level of construction quality assurance planned for the ERDF. Furthermore, the rate of degradation of a double composite liner will probably be similar to the degradation rate for the single composite liner. The value of the redundancy in the double composite liner is uncertain.

The advantages discussed above for the lined trench only apply if leachate is generated during the operational period. In other words, an unlined facility performs just as well as a lined facility if no infiltration occurs during the first 30 years (i.e., the operational period). Given the lysimeter results indicating zero infiltration in vegetated soils at the Hanford Site, it may be that a properly constructed barrier will eliminate leachate generation and a liner is superfluous.

Given the advantages of the single and double liners over no liner, alternatives that have no liner will be given a liner reliability score of low. Given the advantages of the double liner over the single liner, alternatives that include the single liner will be given a liner reliability score of medium and alternatives with the double liner will be will be given a liner reliability score of high.

9.3.9 Surface Barriers

Three surface barriers are included in the remedial alternatives, the low-infiltration soil barrier, the modified Hanford barrier, and the Hanford Barrier. Features of these barriers that are applicable to multiple alternatives are presented in this section, including implementability, cost, material usage, impacted areas at the borrow areas, traffic loading, labor requirements for construction, modeling assumptions, and reliability.

Implementability. Technical implementability is semi-qualitatively measured based on the number of layers in each barrier. As described in Section 8.5, the low-infiltration soil barrier has 3 layers, the modified Hanford barrier has 10 layers, and the Hanford Barrier has 11 layers.

Raw Cost. Unit costs for the barriers were presented in Section 8.5. The areas for the barriers are calculated assuming a top trench width of 420 m (1,400 ft) and a length of 3,000 m (9,800 ft). In addition, the overhang beyond the edge of the trench is assumed to be 30 m (100 ft) for the Hanford Barrier and 15 m (50 ft) for the other two barriers. Total costs for the three barriers are developed below:

Total Barrier Costs			
	Low-Infiltration Soil Barrier	Modified Hanford Barrier	Hanford Barrier
Unit Cost (per m^2)	$21	$79	$134
Total Area (m^2)	1.36 million	1.36 million	1.47 million
Total Barrier Cost	$29 million	$107 million	$197 million
Note: 1 m = 3.28 ft			

As shown in this table, the cost for the low-infiltration soil barrier is approximately 27% of the cost of the modified Hanford barrier and approximately 15% of the Hanford Barrier. The modified Hanford barrier costs are approximately 55% of the Hanford Barrier costs.

Labor Requirements. Only labor associated with construction and Hanford Site material transport is addressed in this section. Labor for production of materials included in the barriers is not addressed. Labor requirements for construction of each barrier are estimated assuming that all granular materials are placed using crews made up of the following personnel:

- 3 Scraper Operators
- 2 Dozer Operators
- 1 Blade Operator
- 1 Water Truck Operator
- 1 Grade Checker
- 1 Foreman
- 1 Supervisor
- 1 Oiler
- 1 Quality Control Technician.

for a total of 12 workers per crew. Placement of the asphalt is also assumed to require a crew of 12 workers. Material transport labor estimates are based on the number of trucks per day discussed below and a construction duration of 1,000 working days. The estimated labor associated with each barrier, provided in Table 9-5, ranges from 21,000 worker-days for the low-infiltration barrier to 84,000 worker-days for the Hanford Barrier. Assuming that the construction period is 4 years (1,000 working days), multiple crews will be needed and construction of the barriers will result in between 21 and 84 jobs over a four year period.

Material Usage. Thicknesses for each component in the barriers are discussed in Section 8.5. The assumptions for the area estimates are provided above in the cost discussion. Estimated quantities of materials used for each barrier, summarized in Table 9-6, are based on the following assumptions:

- The silt quantities include silt layers and 85 percent of the silt and gravel admix,
- The gravel quantities include gravel filter material, drainage gravel, drainage rock, the asphalt base course, and 15 percent of the silt and gravel admix.

The silt will likely be obtained from the McGee Ranch site. The Hanford Barrier requires twice as much silt as the modified Hanford barrier and four times as much silt as the low-infiltration soil barrier. Furthermore, only the Hanford Barrier uses crushed basalt, which will likely be obtained from a quarry to be developed somewhere on the Hanford Site.

The sand, gravel, and general fill will likely be obtained from native soil excavated for the ERDF trench. Therefore, they will have no impact on cultural and ecological resources at borrow sources. If materials excavated for the ERDF are not suitable, these granular materials will likely be obtained from gravel pits located between the 200 East and 200 West Areas. The vegetation seed, geotextiles, and asphalt materials will likely be obtained from off-Hanford Site suppliers.

Impacted Areas at the Borrow Sources. Assuming the silt and basalt usage estimates provided in Table 9-6, areas impacted at McGee Ranch and at the basalt borrow source can be estimated. The estimated areas provided below assume that the excavation depths will average 5 m (16 ft) at McGee Ranch and 10 m (33 ft) at the basalt borrow source.

Impacted Areas at the Borrow Sources			
	Low-Infiltration Soil Barrier (km^2)	Modified Hanford Barrier (km^2)	Hanford Barrier (km^2)
McGee Ranch	0.14	0.26	0.54
Basalt Borrow Source	0	0	0.22
Note: 1 km^2 = 250 acres = 0.4 mi^2			

Traffic Loads. Materials included in the barriers that must be imported from off the ERDF site are vegetation (seed), silt, geotextile filter, crushed basalt, asphalt coating, and asphalt. Volumes of seed and asphalt coating are much less that the other materials and will not be evaluated in terms of traffic load. The assumed daily quantity of material transported per truck is provided for each material. The daily traffic loads are calculated assuming that the barriers are built over a period of 1,000 working days (approximately 4 years). The results are summarized below:

Traffic Associated with Barrier Construction (Trucks per day)				
	Daily Quantity Per Truck	Low-Infiltration Soil Barrier	Modified Hanford Barrier	Hanford Barrier
Silt	150 m^3	5	9	18
Geotextile Filter	20,000 m^2	0	0	<1
Crushed Basalt	150 m^3	0	0	15
Asphalt	100 m^3	0	2	2
Total		5	11	35

Fate and Transport Parameters. The only barrier-specific parameter used in the simulations presented in Appendix A is the infiltration rate. Based on the HELP modeling results presented in Appendix B, the infiltration rates through the three barriers are similar for current climatic conditions and are very close to zero. Results are also presented in Appendix B for a hypothetical wetter climate that uses Spokane climatic data. Infiltration increases for all three barriers under these wetter conditions. Under wet conditions, the infiltration rate for the low permeability soil barrier is approximately 15 times greater than for the modified Hanford and Hanford Barriers (which are virtually identical). The infiltration rates assumed for the simulations in Appendix A are summarized below:

Barrier Infiltration Rates (cm/yr)			
	Low-Infiltration Soil Barrier	Modified Hanford Barrier	Hanford Barrier
Current Climate	0.01	0.01	0.01
Wet Climate	5	0.4	0.4
Notes: 1 cm = 0.39 in.			

Since the waste may be coarse-grained material and will not be vegetated, operational infiltration may be significantly higher than infiltration after placement of the barrier. The analysis in Appendix B suggests that infiltration before the waste is covered could be up to 3 cm/yr (1.2 in./yr). Therefore, the fate and transport simulations in Appendix A assumed that the initial infiltration rate would be 3 cm/yr for the first 5 years. If the trench is lined, then it is assumed that all of this excess infiltration (in addition to the long-term infiltration that occurs during the operational period) is intercepted by the leachate collection system and pumped out.

Reliability. Assuming that the barriers maintain their design capabilities, all three barriers appear to perform similarly under current climatic conditions. Based on HELP analyses, however, the modified Hanford barrier and the Hanford Barrier would provide greater infiltration protection than the low-infiltration soil barrier in a wetter climate. Therefore, the low-infiltration soil barrier should be considered less reliable over the long term with respect to groundwater protection. This element of reliability is addressed in the predicted risks for the alternatives assuming a wet climate.

Reliability in terms of protection against intrusion and erosion would be important if institutional controls were no longer in place. Qualitative evaluations are provided below for all three barriers in terms of protection against erosion, plant intrusion, animal and insect intrusion, and human intrusion.

All of the barriers include gravel in the upper soil layer. The gravel-size fraction is sufficient to help to minimize erosion due to surface water and wind processes but not so great as to promote increased infiltration. The gravel admix layer is approximately 0.5 m (1.6 ft) thick in the low-infiltration soil and modified Hanford barriers, and 1.0 m (3.3 ft) thick in the Hanford Barrier. In addition, the presence of the basalt rip-rap layer in the Hanford Barrier provides additional erosion resistance should the upper layers be completely eroded away.

To discourage penetration by deep-rooted plants, the Hanford Barrier employs a large overall thickness of 4.5 m (15 ft), a series of layers in the second functional group that provide a hostile environment for plants (little-to-no moisture, no nutrients, large grain size), and a densely compacted asphalt layer. Although the modified Hanford Barrier employs a thin layer of coarse-grained materials, these layers are not expected to be as effective as the basalt layer in preventing root penetration. As a result, plant roots may extend deeper into the barrier, although the asphalt layer should prevent penetration into the waste. The low-infiltration soil barrier employs thickness alone, without a zone that is hostile to plant roots and without a dense asphalt layer. Therefore, the Hanford Barrier appears to provide the best resistance to root penetration, followed by the modified Hanford barrier, with the low-infiltration soil barrier providing the least resistance to root penetration.

Burrowing animals, including large and small mammals, and insects, have the potential to disturb barrier layers and penetrate into buried wastes. Studies at the Hanford Site indicate that animal burrows do not significantly increase the net deep percolation of precipitation into barrier soils (Wing 1993). Mammals appear to have little need to burrow below depths of 1 m (3.3 ft) on the Hanford Site (Wing 1993). Therefore, each of the barriers should be effective at preventing disturbance of the waste by mammals. As with root penetration resistance, the basalt rip-rap layer and the asphalt layer in the Hanford barrier appear to offer the most resistance to intrusion from burrowing mammals and insects. The modified Hanford barrier is slightly more effective than the low-infiltration soil barrier at preventing intrusion, due to the presence of the asphalt layer.

Resistance to human intrusion is considered to be primarily a function of barrier thickness. None of the barriers will resist drilling or deep excavation, although warning markers should alert humans to the dangers associated with such activities. The basalt rip-rap layer of the Hanford barrier may be more obvious and difficult to penetrate, but will not withstand concerted excavation efforts. Surficial disturbances such as agricultural tilling or residential foundations will probably not penetrate any of the 4.5 m (15 ft) thick barriers. On this basis, the barriers are considered to be equal with respect to resisting human intrusion.

In summary, the Hanford Barrier offers the greatest protection against erosion and intrusion in the absence of institutional controls. The modified Hanford barrier is considered to be more effective than the low-infiltration soil barrier in this regard. Alternatives will be scored high for long-term reliability if they include the Hanford Barrier, medium if they include the modified Hanford barrier, and low if they include the low-infiltration soil barrier.

9.3.10 Ecological Impacts

Ecological impacts will occur at the ERDF site, along the new rail spur, and at any borrow sites for materials in the liner and cover. These impacts will include destruction of habitat, displacement of wildlife at these areas, and disturbance of wildlife near these areas and along transport routes due to noise and human activities. As discussed in Section 2.8, the shrub-steppe habitat at the ERDF site is considered priority habitat by the State of Washington. The DOE recognizes that contiguous blocks of mature shrub-steppe habitat are important for many plant and animal species, and this habitat is rapidly shrinking elsewhere in Eastern Washington. Habitat value will be assessed before start of construction and losses will be mitigated based on the ecological value of the habitat disturbed. However, rather than implementing mitigation measures on a project-by-project basis, DOE is developing a Hanford Site-wide mitigation plan in cooperation with the State of Washington Department of Fish and Wildlife and the U.S. Fish and Wildlife Service. Negotiations with these agencies are in progress.

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The impacted area at the ERDF site is estimated to be 2.6 km^2 (650 acres or 1.0 mi^2) (U.S. Army Corps of Engineers 1994). Ecological impacts at the ERDF will be mitigated to the extent possible by using the deep area-fill trench configuration.

Ecological impacts will occur during construction of the rail spur. As shown in Figure 9-1, the rail spur passes through a variety of habitats containing sagebrush, Sandburg's bluegrass, cheatgrass, and Russian thistle. Assuming a length of 8 km (outside the ERDF), and an impacted width of 50 m (160 ft), the area impacted by the new rail spur will be approximately 0.4 km^2.

Ecological impacts associated with development of the borrow sites will depend on the type of barrier included in the alternative. Estimated quantities of silt from McGee Ranch and basalt included in each barrier are provided in Section 9.3.9. The areas impacted are calculated assuming that the excavation depth will average 5 m (16 ft) at McGee Ranch and 10 m (33 ft) at the basalt borrow source.

9.3.11 Impacts on Air Quality

As discussed in Section 2.2.6, air quality at the Hanford Site is generally good. Construction and operation of the ERDF will result in dust generation and engine fumes (associated with vehicle and equipment operation). These impacts are discussed below.

As discussed in Section 9.3.5, ERDF construction and operation will result in a maximum of 310 vehicles per day on Hanford roads. Operation and construction of the ERDF is expected to result in an additional 50-100 vehicles per day within the ERDF. Air quality impacts associated with these vehicles are considered negligible. Dust generation will be monitored and kept below allowable limits using dust controls discussed in Section 9.3.2.

9.3.12 Impacts on Historical and Cultural Resources

Significant historical or cultural resources have not been identified at the ERDF site or the proposed route of the new rail spur. Historic and prehistoric resources have been identified at McGee Ranch which could be disturbed or destroyed if the site was developed. Mitigation plans are currently being prepared. Development of a basalt borrow source may result in the degradation of basalt outcroppings that have cultural significance to Native Americans. This issue will be resolved with the Native Americans before development of the borrow source begins.

9.3.13 Socioeconomic Impacts

Construction of the ERDF will provide jobs and an influx of federal funds to the Tri-city area. Although construction of the ERDF will be conducted in phases and the level of employment will fluctuate, it is estimated that construction will employ an average of 45 workers on the Hanford Site. Operation of the ERDF is expected to provide 167 full-time positions. It is expected that construction and operations would be spread over a period of approximately 30 years. The total number of jobs associated with the ERDF, approximately 210, is a small percentage of the total employment at the Hanford Site.

As discussed in Section 9.4, the estimated total capital costs for the ERDF range from $246 million to $663 million for the different alternatives. Assuming that the costs are spread over 30 years, plus an annual operating budget of $20 million, the total annual costs for the ERDF are estimated to range from $28 million to $42 million. This is approximately 2% of Hanford's current annual budget of approximately $1,600 million.

Given the relatively small percentage of employment and funding associated with the ERDF compared with the Hanford Site as a whole, socioeconomic impacts due to the ERDF are considered negligible.

9.3.14 Impacts on Visual Resources and Noise

The ERDF is a low-lying facility that will result in minimal visual impact from ground level. Although construction and operation of the ERDF will detract from the natural beauty of the sagebrush ecology from elevated locations (such as the top of Rattlesnake Mountain), the barrier will be revegetated and natural vegetation will eventually return to impacted areas. The long-term impacts on visual resources at the Hanford Site are considered negligible.

Noise will be generated due to operation of equipment at the ERDF, the borrow sources, and during transport of waste and construction materials to the ERDF. If OSHA noise standards are exceeded, appropriate measures to protect workers will be employed. The ERDF, the borrow sources, and the transportation routes on the Hanford Site are not located near any residential communities. Consequently, noise impacts on humans are considered negligible. Wildlife will be impacted by noise near the ERDF, borrow sources, and transport routes.

9.3.15 Common Cost Factors

Estimated costs for construction of ERDF facilities, permitting, trench excavation, liners, and barriers are provided in Table 9-7. The cost multipliers, which include overhead, profit, contingency and management, result in final costs that are approximately 90 percent higher than raw construction cost. The multipliers are added to raw construction costs to obtain the total cost for each item. The total cost for each alternative will include the costs for the liner, the barrier, excavation, permitting, and the supporting facilities. Costs for supporting facilities, permitting, and excavation (which will be the same for all the alternatives) are $75 million, $22 million, and $109 million, respectively. Liner costs range from zero for the no-liner alternatives to $167 million for the RCRA double composite liner. Costs for the leachate collection system are $11 million and are only included in alternatives with liners. Barrier costs range from $53 million for the low-infiltration soil barrier to $373 million for the Hanford Barrier. Since the barrier will be built after the trench is excavated and lined, a present worth adjustment is applied to the barrier costs. The present worth adjustment assumes that barrier costs will be incurred an average of 20 years after the rest of the cost are incurred and that the discount rate is 6 percent.

Operational costs are estimated to range from $15 million to $25 million per year over 25 years. The total operational cost is estimated to range from $375 million to $625 million with a present worth of $192 million to $320 million.

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9.3.16 Short-Term Worker and Public Risk

Short-term risks associated with construction and operation of the ERDF are evaluated below for the ERDF workers, non-ERDF workers on the Hanford Site, and the public.

ERDF Worker Risk. This evaluation of ERDF worker risk during operation of the ERDF relies upon the methods and conclusions provided in the *Source Inventory Development Engineering Study for the Environmental Restoration Disposal Facility* (U.S. Army Corps of Engineers 1993b), also known as the Source Inventory Report (SIR). The SIR develops contaminant-specific soil concentrations associated with occupational regulatory limits. The exposure pathways evaluated are inhalation of fugitive dust, inhalation of volatile organics, and external exposure to radiation. Therefore, the regulatory limits of interest are those related to occupational air exposure and external radiation dose (see Chapter 5 of the SIR for a listing of the occupational criteria considered). Limits for ingestion, dermal absorption and skin and/or eye contact were not determined because they are not probable exposure pathways. Personnel normally occupying the ERDF trench will include heavy equipment operators and truck drivers. These personnel will normally be inside an enclosed cab with filtered air, so there will not be direct contact with constituents under normal operating conditions.

In order to relate occupational air concentration criteria to soil concentrations, the SIR assumes a dust concentration (in air) of 10 mg/m^3. Using this factor, the SIR provides constituent soil concentrations associated with occupational limits for exposure to contaminants in air. Soil concentrations of volatile contaminants are also calculated by using contaminant-specific volatilization factors. These "occupational soil concentration limits" are provided in Tables 8, 9, and 10 of the SIR for inorganic constituents, organic compounds, and radionuclides, respectively. In addition, radionuclide soil concentration limits based on external exposure are provided in Appendix J of the SIR.

The maximum detected soil concentration of each contaminant (presented in Tables 3-8, 3-9, and 3-10 of this report) are compared to its respective occupational soil concentration limit(s) (found in Tables 4, 5, and 6 of the SIR) to determine which contaminants pose potential health hazards to the working population. The results are discussed below:

- For the inorganic contaminants, most maximum detected concentrations are less than the occupational soil concentration limits by more than an order of magnitude. Only copper and iron are roughly equal to or exceed the soil criteria (95,300 mg/kg vs. 100,000 mg/kg, and 184,000 mg/kg vs. 100,000 mg/kg, respectively).

- All of the organic compound soil concentrations are less than the occupational limits, most by at least three orders of magnitude.

- For the inhalation pathway, plutonium-239/240 (2,800 pCi/g) and uranium-238 (9,143 pCi/g) are present at concentrations that exceed occupational soil concentration limits (500 pCi/g and 3,000 pCi/g, respectively). In addition, plutonium-238 and uranium-234 have maximum detected soil concentrations that are slightly below their occupational soil concentration limits. It is important to note that the maximum plutonium concentrations are associated with a process effluent pipeline, such that these concentrations are not representative of a large volume of a material, and may be in a form that is not readily suspended as dust.

For the external exposure pathway, maximum detected radionuclide concentrations (presented in Table 3-8 of this report) are compared to criteria based on 5 rem/yr (Appendix J of SIR). This comparison indicates that cesium-137 (110,000 pCi/g vs. 10,000 pCi/g), cobalt-60 (11,000 pCi/g vs. 2,000 pCi/g), europium-152 (29,000 pCi/g vs. 5,000 pCi/g), and europium-154 (9,200 pCi/g vs. 5,000 pCi/g) all exceed their respective criteria.

It is important to note the conservative biases inherent in this analysis. The occupational air concentration limits and radiation dose criteria used in this evaluation assume continuous exposure during a working year. The maximum detected soil concentrations assumed in this analysis are not representative of average contaminant concentrations that would be deposited in the ERDF (see Section 6.1.4 for a more thorough discussion). The period of exposure to the maximum detected concentrations would be small because these concentrations are expected to represent only small volumes of waste. Furthermore, this analysis does not account for institutional controls, field monitoring during ERDF operation, and use of personal protective equipment, each of which will reduce exposure to contaminants.

An additional conservative bias is that the assumed dust concentration of 10 mg/m^3 is probably not representative of actual exposure conditions. To put this in perspective, the SIR indicates that the maximum dust concentration observed in the Tri-City area during a dust storm is approximately 1.7 mg/m^3. Travis et al. (in press) use a resuspension factor of 0.5 mg/m^3 for earth-moving activities. This factor assumes that 10% of the resuspended dust particles are of respirable size (<20μm) and that dust is suppressed by surface wetting. Therefore, it is reasonable to assume that the dust concentration used in this analysis (10 mg/m^3) is potentially an order of magnitude too high. Given the conservative bias of the assumptions, this analysis should be considered a screening of potential hazards associated with worker exposure to contaminants.

The analysis presented above only considered exposure to soil contaminants. Bulk materials present in burial grounds (containing waste from reactor operations) present an additional potential external exposure hazard. Historical field measurements indicate that dose rates as high as 1 to 5 rem/hr were common for the 105-B burial ground. However, such data do not differentiate between short-lived radionuclides (many of which will have decayed to negligible levels) and those that may still be a concern. Chapter 6 of the SIR provides an evaluation of burial grounds based on historical field data. With respect to ERDF operations, such materials will require characterization during remediation to determine appropriate handling practices.

This analysis indicates that there are a number of contaminants of potential concern to workers during ERDF operation. These contaminants are alpha-emitting radionuclides (a concern via inhalation) and high-energy gamma emitters (a concern via external exposure).

It is noted that it is not acceptable to expose workers to contaminants at the occupational soil concentration limits without justification. A number of contaminants are known or probable human carcinogens, and it is generally assumed that there is no safe dose which will not elicit a carcinogenic response. Although it is likely that occupational exposure criteria will not be exceeded, the as low as reasonably achievable (ALARA) principle should be practiced.

Physical Hazards to ERDF Workers. Construction and operation of the ERDF will expose workers to physical hazards that can result in accidental injury to workers. The risk associated with these physical hazards can be quantified by multiplying the labor requirements by the injury rate to estimate the expected number of accidents. Injury rates can vary considerably for different activities and a detailed analysis of physical risk would account for these variations. For purposes of this document, however, a more general approach that treats all labor as general construction activity will be utilized.

The number of person days for trench excavation, liner construction, and barrier construction are provided in Sections 9.3.7, 9.3.8, and 9.3.9. Although operation of the ERDF is not truly a construction activity, many of the associated activities are similar to construction. The total number of employees for operation of the ERDF is estimated to be 167. Approximately 40 of these jobs are administrative or supervisory in nature and would entail relatively little physical risk. Assuming 230 work days in a year, the total number of worker days associated with operation of the ERDF is 29,000 days per year. Assuming the facility operates for 25 years, the total number of worker days is 725,000.

Based on statistics from the U.S. Department of Labor (1992), construction workers have a fatality rate of 6×10^{-7} per person day and a lost-time injury rate of 2×10^{-4} per person day. Since fatalities are of most concern, only the fatality rate is used in the evaluations. The expected number of fatalities for each construction activity and ERDF operation are summarized below.

Expected Number of Worker Fatalities Due to Physical Hazards

Activity	Worker Days	Expected Fatalities
Trench Excavation	110,000	0.066
Single Liner	40,000	0.024
Double Liner	79,000	0.047
Low-Infiltration Soil Barrier	21,000	0.013
Modified Hanford Barrier	27,000	0.016
Hanford Barrier	84,000	0.050
ERDF Operation	725,000	0.44

Risks to Non-ERDF Hanford Workers and the Public. The facility hazard classification (Cain 1994) provides qualitative evaluations of potential radiological impacts of ERDF operations and accident conditions to non-ERDF Hanford Site workers and the public. The impacts were evaluated for three scenarios: normal operations, abnormal occurrence of continuous strong winds (113 km/hr [70 mph]) for 24 hours, and a container breach. In all cases, risks were characterized as low. Impacts from hazardous (non-radioactive) contaminants were not evaluated.

9.3.17 Irreversible and Irretrievable Commitment of Resources

The ERDF will require an irreversible and irretrievable commitment of the following resources:

- liner material
- borrow material
- natural resources
- building and facility construction materials
- energy

The liner and borrow materials required are discussed in Sections 9.3.8 and 9.3.9, respectively. The natural resources affected are described in Section 9.3.10. The buildings and support facilities will require standard construction materials that are readily available, and constitute a resource commitment that is relatively minor compared to the materials required for construction of the ERDF trench. The primary energy usage will be for operation of equipment.

9.3.18 Indirect and Cumulative Effects

Indirect effects associated with construction and operation of the ERDF include influencing remedial decisions across the Hanford Site. The existence of a Hanford Site-wide waste management facility for remedial wastes will minimize implementability difficulties associated with alternatives that include excavation of the waste. Without a centralized waste management facility to receive the treated or untreated waste, remedies that include excavation would score lower in terms of implementability. This is because of the potential difficulties associated with permitting and constructing such a facility. As a result, in-situ remedies (e.g., in-situ treatment and in-situ containment) would score higher and would have a higher likelihood of being the preferred remedy. In-situ remedies for operable units in the 100 and 300 Areas would result in more waste being left near the Columbia River.

Cumulative impacts will be associated with other actions on the Hanford Site. Actions that will have similar impacts as the ERDF include primarily construction and remediation activities. These activities will potentially involve destruction of habitat, disturbance of wildlife, utilization of borrow materials, increased traffic, job creation, and releases of waste constituents to air and water.

Current or planned Hanford Site activities not addressed in this analysis that may increase cumulative effects include the following:

- Construction of new double-shelled tanks in the 200 Area;
- Terminal cleanout of chemical processing facilities (such as PUREX, PFP, UO3) in the 200 Area and decontamination and decommissioning of these and other retired Hanford Site surface facilities;
- Potential construction of a waste vitrification facility in the 200 Area;
- Operation of the US Ecology commercial low-level landfill located just east of the ERDF location;
- Operation of the low-level burial grounds in the 200 Area and the Non-Radioactive Dangerous Waste Landfill located approximately 8 km (5 mi) southeast of the ERDF;
- Environmental restoration activities in the 100, 200, and 300 Areas; these activities may involve soil excavation and disposal activities, groundwater extraction, treatment, and disposal, construction and operation of treatment facilities, and construction of containment structures such as slurry walls and barriers;
- Operation of the 200 Area Effluent Treatment Facility Disposal Site.

9.3.19 Mitigation of Impacts from the ERDF

Impacts on resources due to construction and operation of the ERDF will be mitigated to the extent possible. Mitigation considerations that have been incorporated into the facility design include the following:

- Use of the deep area-fill trench configuration (described in Section 9.3.7) to minimize the amount of land disturbed at the ERDF and the quantity of liner and cover materials;
- Rerouting of the rail spur to avoid impacts on undisturbed portions of potentially historic White Bluffs road;
- Limiting consideration of barriers to those that are specifically designed to minimize infiltration through the waste and therefore minimize groundwater impacts and are at least 15 feet thick to eliminate the inadvertent intrusion pathway associated with foundation excavation;
- Implementation of institutional controls (described in Section 9.3.1) to minimize hazards to workers and the public during construction, operation, and post-closure;
- Implementation of dust controls (described in Section 9.3.2) to minimize airborne releases during waste transport and placement;
- Implementation of surface water management (described in Section 9.3.3) controls to minimize the potential for releases due to surface water transport;
- Grouting void space in the waste (described in Section 9.3.6) to minimize the potential for settlement that might reduce the effectiveness of the barrier;
- As described in Section 9.3.6, emergency equipment will be available on site and the workers will receive emergency response training to minimize the impacts of any accidents;
- Any clearing of the site in preparation for construction will not be conducted during nesting season to ensure that wildlife is not destroyed, but only displaced.

In addition, habitat value will be assessed before the start of construction and losses will be mitigated based on the value of the disturbed habitat. DOE is currently developing a Hanford Site-wide mitigation plan in cooperation with the State of Washington Department of Fish and Wildlife and the U.S. Fish and Wildlife Service.

9.3.20 Corrective Action Management Unit (CAMU) Evaluation

The ERDF is proposed to accept both CERCLA and RCRA remediation waste as part of the overall remediation strategy at Hanford. As such, evaluation of ERDF suitability is following both RCRA and CERCLA decision processes. Evaluation of the ERDF could have occurred solely as part of the operable units' RODs or permit modifications. However, this separate evaluation of ERDF provides several advantages: it allows a more thorough evaluation of the entire proposed facility (as opposed to merely the portion that may be required for any single operable unit), and it expedites remediation by allowing design and construction of the ERDF prior to final RODs/permit modifications for the operable units, thereby allowing movement of waste to occur quickly once the remediation strategy for the operable units is finalized. A separate evaluation of the suitability of ERDF for receipt of specific operable unit waste streams will be included in the remedy selection process for each operable unit. Each individual operable unit's ROD/permit modification will specify how waste from that operable unit may be managed and will reference, as appropriate, placement of waste in the ERDF.

The ERDF is being proposed as a Corrective Action Management Unit (CAMU). The CAMU rule provides an option for on-site management of remediation waste previously not available to facilities remediating materials subject to RCRA. The CAMU regulations were promulgated to promote active remediation of contaminated sites, as opposed to merely capping in place, by allowing more flexibility in management of remediation waste, without compromising human health or the environment.

In the preamble to the CAMU rule, EPA stated its expectation that the substantive CAMU rule requirements will be applicable or relevant and appropriate requirements (ARARs) for the remediation of many CERCLA sites, especially those sites where CERCLA remediation involves the management of RCRA hazardous wastes. EPA determined that, in the CERCLA context, CAMU requirements that are designated to be ARARs would be incorporated into CERCLA decision documents, rather than RCRA permits or orders. This would allow remediation under CERCLA of RCRA hazardous waste at Federal facilities that are listed on the National Priorities List. For this reason, the seven decision criteria required under the CAMU regulations are evaluated below.

<u>CAMU Criterion No. 1</u>: **The CAMU shall facilitate the implementation of reliable, effective, protective, and cost-effective remedies:**

As demonstrated by the risk assessment in Appendix A, operation of the ERDF as a CAMU for placement of waste that meets the risk-based ERDF leachate criteria will be protective of human health and the environment for at least 10,000 years. Alternatives considered are both effective and reliable.

Current conditions consist of waste sites immediately adjacent to the Columbia River without significant engineered controls over infiltration or migration of constituents. Among the range of remedial options for these sites available in the absence of a CAMU are capping the waste in place; consolidation of wastes within the areas of contamination along the river; in-situ stabilization or treatment; and excavation, full LDR characterization, and best demonstrated available technology (BDAT) treatment of the waste prior to disposal.

The ERDF site is located in an area remote from the Columbia River and the public with a thick (approximately 80 m [260 ft]) unsaturated zone. For these reasons, consolidation of remediation waste at the ERDF Site will be more reliable, effective, and protective than either current conditions, capping the waste in place or in-situ treatment at the multitude of small sites along the river, or consolidation of the untreated waste within the riverside areas of contamination.

Based on the demonstration of protectiveness in the risk assessment, waste characterization sufficient to demonstrate achievement of the ERDF waste acceptance criteria standards can be performed consistent with the observational approach and need not meet the restrictive standards that might apply were LDRs fully applicable to the waste. Without a CAMU designation, waste excavated in remediation of the 100 and 300 Areas may require full LDR waste code characterization and BDAT treatment, without providing any significant benefit in risk reduction, at a cost estimated to be approximately five to ten billion dollars. Expenditure of an additional five to ten billion dollars without significant risk reduction is not cost-effective.

Operation of the ERDF as a CAMU therefore will be: protective, effective, and reliable when measured independently against risk standards; significantly more protective, effective, and reliable than remedial options that would leave untreated waste near the river; and equally as protective but significantly less costly than other excavation and disposal waste management options.

ERDF will be protective of human health and the environment and a reliable, effective, protective, and cost-effective remedy because it will:

- Isolate hazardous/dangerous waste and radioactive waste and constituents to a single, manageable facility in a remote, arid, hydrogeologically protected area;
- Remove hazardous/dangerous materials from current locations close to the Columbia River and to sensitive environmental receptors;
- Contain hazardous/dangerous and radioactive material within a unit designed to offer both long-term and short-term protection of the environment;
- Accept only those remediation wastes in a concentration or form that will not allow the contaminants to migrate to groundwater at a concentration in excess of health-based standards at the point of assessment;
- Be much more cost-effective than other active remediation alternatives.

<u>CAMU Criterion No. 2</u>: **Waste management activities associated with the CAMUs shall not create unacceptable risks to humans or to the environment resulting from exposure to hazardous wastes or hazardous constituents:**

The risk assessment in Appendix A demonstrates that operation of ERDF as a CAMU will not pose long-term risks to human health or the environment from exposure to hazardous or radioactive wastes or constituents. Furthermore, the evaluation of short-term effectiveness demonstrates that there will be no significant risk to workers or the public due to waste releases during operation of the ERDF.

Although risk due to waste releases during operations will be below acceptable levels, placement of interim cover materials on a daily basis and use of dust suppression technology at the ERDF will mitigate potential airborne contaminant transport to the extent possible. In addition, use of equipment such as dust filters will further protect worker health by decreasing potential for inhalation of dust particles.

Significant operational constraints and controls shall be in place to minimize both the risk of occurrence of air emissions, and the potential impact if any emissions were to occur. The operations plan will assure waste management activities are properly conducted within the ERDF; the site-specific emergency and training plan will establish procedures to prevent hazards; personnel will be appropriately trained and emergency situations handled appropriately, or avoided altogether.

In summary, the ERDF will not create unacceptable risks to human health or the environment because it: provides long-term protection from unacceptable risks by deterring intrusion and preventing contaminant migration in excess of health-based risk levels; mitigates short-term exposure to contaminants from air transport by use of interim cover, dust suppression, and HEPA filters; and ensures that ERDF personnel are appropriately trained and procedures are in place to avoid, reduce, and mitigate potential hazards.

CAMU Criterion No. 3: The CAMU shall include uncontaminated areas of the facility, only if including such areas for the purpose of managing remediation waste is more protective than management of such waste at contaminated areas of the facility:

Because the contaminants of concern in the 100 and 300 Area waste consist of long-lived radionuclides and metals, the main factor that will provide long-term protection to human health and the environment is isolation of the waste from the public, the river and groundwater. Such isolation cannot physically be accomplished within the riverside areas of contamination to the degree possible at the ERDF site.

Consolidation of waste within one facility rather than dispersing it among several locations on the 200 Area plateau will be more protective both in the short term and in the long term. Use of a single ERDF site rather than multiple sites allows for better performance monitoring, is less costly, and offers less opportunity for hazards to arise because there is only one site at which such situations could arise. Prevention of degradation of the cover or inadvertent intrusion would be easier in the long term for a single ERDF site than for multiple dispersed waste locations.

Although the proposed ERDF site does not contain surface soil contamination, preexisting groundwater contamination is present below the ERDF site. The source of this contamination is upgradient of the ERDF. The ERDF site, therefore, is not a pristine location.

Because of the nature of the radioactive contaminants found in the surface-contaminated areas of the Hanford Site, construction of the ERDF in an area of surface contamination would pose greater risk to workers, the public, and the environment than construction at the proposed location. Construction of the ERDF in an area of surface contamination could expose the construction workers to radiation, and would involve a higher short-term risk to the public and the environment because radioactive contaminants could become air borne during facility construction. The proposed ERDF location is completely within the boundaries of the exclusive waste management area selected by the Hanford Future Site Uses Working Group for consolidation of long-term waste management activities. In evaluating the possible locations for ERDF, significant weight was given to the public input represented by the Future Site Uses Group Report.

Criterion No. 3 is met because the ERDF site will provide a more protective location than management of the wastes within the riverside areas of contamination or at locations on the 200 Area plateau with surface contaminated areas.

CAMU Criterion No. 4: Areas within the CAMU, where wastes remain in place after closure of the CAMU, shall be managed and contained so as to minimize future releases, to the extent practicable:

As described previously, the ERDF is planned to provide protective waste containment. The ERDF will be capped with a protective barrier designed to prevent infiltration, deter intrusion, and minimize releases to the extent practicable. The final barrier will minimize releases of contaminants by controlling dust and limiting infiltration.

The post-closure plan includes inspections and maintenance to ensure that the final barrier integrity is maintained. Groundwater monitoring will be conducted to detect any releases during the operational and post-closure periods. Institutional controls will prevent intrusion and unintentional releases during the post-closure period. Consolidation of waste into a single ERDF unit will facilitate long-term monitoring and maintenance and minimize the risk of inadvertent intrusion and release of contaminants.

The ERDF will therefore meet the requirement to minimize releases to the extent practicable, by means of its single unit design, protective barrier, groundwater protectiveness (as demonstrated in the RI/FS risk assessment) and release prevention procedures.

CAMU Criterion No. 5: The CAMU shall expedite the timing of remedial activity implementation, when appropriate and practicable:

As described previously, placement of waste in the ERDF that meets the ERDF leachate criteria will be protective of human health and the environment for 10,000 years. Performance of this evaluation and authorization of the ERDF as a CAMU will allow remediation to proceed quickly for those operable units that select ERDF as part of their preferred remedial option.

Consolidation of waste into the single ERDF CAMU requires only one analysis to determine whether the site and design will be protective of human health and the environment. If multiple sites or designs were to be used, multiple analyses would be required to demonstrate protectiveness, which would require significantly more time and resources to complete.

Operation of ERDF as a CAMU will allow for flexibility in the time consuming and expensive processes of full LDR characterization and BDAT treatment, while still providing full protectiveness of human health and the environment. The protectiveness sought to be achieved by LDRs can be attained by operating the ERDF in compliance with the ERDF waste acceptance criteria, and operations need not conform to the unnecessarily restrictive LDR requirements. Because operation of the ERDF as a CAMU using the ERDF leachate criteria provides a high level of protectiveness, characterization can be allowed to proceed consistent with the expedited timing that can be achieved under the observational approach.

CAMU Decision Criteria No. 6: The CAMU shall enable the use, when appropriate, of treatment technologies (including innovative technologies) to enhance the long-term effectiveness of remedial actions by reducing the toxicity, mobility, or volume of wastes that will remain in place after closure of the CAMU:

Acceptable soil and leachate concentrations to protect human health and the environment are developed in Appendix C. The acceptable soil concentrations are intended to address the risk associated with intrusion into the ERDF wastes and the acceptable leachate concentrations are intended to address impacts on groundwater.

In order to address the potential for intrusion into the waste, acceptable soil concentrations were determined based on the 500-year drilling scenario. Based on this evaluation, approximately 40 constituents are determined to have the potential for causing exposures resulting from intrusion greater than risk-based standards (although only copper has been detected at concentrations that exceed its acceptable soil concentration). These constituents are primarily metals or radionuclides and no treatment is available for reducing the toxicity of these constituents (except reduction of chromium VI to chromium III). Furthermore, treatment to reduce the mobility of the constituents will not reduce the risk associated with the intrusion scenario and treatment to reduce the volume of the wastes will increase contaminant concentrations and thus risk. Therefore, treatment of waste will not enhance long-term effectiveness in terms of the intrusion scenario.

As demonstrated in Appendix C, 10 chemicals have the potential to migrate into groundwater in excess of the health standards within 10,000 years. Of these ten contaminants, only three are subject to LDR treatment standards. The ERDF acceptable leachate concentrations establish standards for these three contaminants that are more stringent than the applicable LDRs. Any prospective ERDF waste found to exceed the ERDF waste acceptance criteria for one or more of these three constituents, therefore, will be treated to a level that would meet the LDR treatment standard, if it were applicable.

The other seven contaminants of concern are not subject to LDRs. For these contaminants, the ERDF leachate criteria establish stringent standards that will be protective of human health and the environment for 10,000 years. Any prospective ERDF waste found to exceed the ERDF leachate criteria for one or more of these constituents will be treated to conform to the ERDF health-based standard.

Treatment of waste will be undertaken based on evaluations and remedial decisions made at the operable units. Feasible treatment that will enhance long-term effectiveness and protectiveness will be undertaken. Treatment that will have no benefit to protectiveness will not be required. In particular, since treating to LDR requirements would not provide any significant benefits in terms of long-term effectiveness, it will not be required.

Because the Hanford Site remediation wastes will consist primarily of soil and debris contaminated with metals and radionuclides, there is no known destruction (toxicity reduction) treatment that can be applied. Significant quantities or concentrations of organics, for which destruction treatment technologies may exist, are not expected to be encountered. If any significant quantities or concentrations of organics are encountered during remediation, an evaluation of potential treatment options by the affected operable unit will be required.

Immobilization is considered to be the most likely treatment technology to be used if needed to meet the standards set for contaminants of concern in the ERDF waste acceptance criteria.

The feasibility of volume reduction treatment is heavily dependant on specific physical and chemical parameters of the target waste stream. It is believed that volume reduction technology may be a feasible option for some operable unit wastes. Volume reduction treatability tests are currently being conducted at operable units in the 100 and 300 Areas.

It is anticipated that the bulk of the waste to be emplaced at the ERDF will be high-volume, low concentration (e.g., toxicity). The CAMU preamble states that "Given the example, therefore, of a situation involving large volumes of low concentration contaminated soils or other wastes, the Regional Administrator would have the discretion to evaluate containment-based remedial approaches."

Based on the demonstration of protectiveness in the RI/FS, and the CAMU preamble which allows the discretion to consider containment for waste of the type expected to be received at ERDF, it is reasonable to authorize operation of ERDF as a CAMU subject only to the treatment limitations imposed by the ERDF waste acceptance criteria. Such authorization will not preclude use of treatment technologies where such technologies will have a beneficial result in reduction of risk to human health or the environment, but it also will not require the use of treatment when no significant benefit can be gained by such treatment.

<u>CAMU Criterion No. 7</u>: The CAMU shall, to the extent practicable, minimize the land area of the facility upon which wastes will remain in place after closure of the CAMU:

ERDF will consolidate, within a single unit, waste material from around the Hanford Facility, thereby maximizing the area which will be available for future use, and minimizing the land area upon which wastes would remain after closure. Because of the dispersed nature of the waste units and the need for sufficient buffer zones around each of the waste units, it is estimated that remediation wastes within the 100, 200, and 300 Areas cover as much as approximately 28.5 km^2 (11 mi^2). The ERDF trench covers approximately 1.24 km^2 (0.48 mi^2), which represents a reduction in areal extent of up to 95 percent.

Furthermore, the size of ERDF itself has been minimized to the extent practicable by designing it as a single evolving trench. The single trench design minimizes the space needed for waste placement, and the evolving trench concept assures that only the amount of trench actually needed for waste management will be built.

Thus, ERDF will meet the criterion for space minimization both by consolidating waste from multiple waste units and by minimizing the amount of space needed for the ERDF itself.

CAMU Specifications. In addition to the determination that the proposed CAMU will meet all of the substantive requirements of the seven CAMU criteria, the regulatory agency is required to specify certain information in its order, permit or remedy selection document relating to the physical and operational aspects of the CAMU. As described below, information sufficient to make these specifications is contained in the Regulatory Package.

The areal configuration of the ERDF CAMU will be a single trench built as a series of cells approximately 23,225 square meters (250,000 square feet) in area each. The total trench dimensions may be as much as 305 meters (1000 feet) wide, 2740 meters (9000 feet) long and 21.3 (70 feet) deep. The final size may be less than the projected maximum because only the amount of trench needed to contain remediation waste generated in Hanford Site cleanup will be built.

ERDF operations will be conducted in a manner that is protective of human health and the environment and consistent with the CAMU designation. Waste proposed for placement at the ERDF CAMU shall be characterized at the operable unit consistent with the observational approach. The operable unit will either determine that the waste will meet ERDF waste acceptance criteria, or determine appropriate treatment or other waste management options. The majority of waste will be sent in bulk containers either by rail or truck and tipped into the ERDF trench. Air emissions will be abated by use of interim cover and dust suppression technology.

ERDF will be closed with the waste in place, covered by a final barrier that will deter intrusion, limit infiltration and minimize the need for long-term maintenance. Equipment, devices and structures used in support operations will be removed and decontaminated, or if decontamination is not possible, placed into the trench prior to installation of the final barrier. The RI/FS modeling has demonstrated that closure of ERDF with the waste in place under a final barrier that limits infiltration will protect human health and the environment, and minimize post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground, to surface waters, or to the atmosphere.

The post-closure plan for ERDF shall assure protection of human health and the environment by means of monitoring and maintenance activities performed at a frequency that will ensure the integrity of the final barrier.

Groundwater will continue to be monitored around the ERDF site during operation and the closure/post-closure period by means of the groundwater well monitoring network described in the CAMU Application. The monitoring shall detect and characterize releases from ERDF or from other sources around ERDF.

Summary. As described above, the ERDF will meet all CAMU decision criteria, and operation of the ERDF as a CAMU will be fully protective of human health and the environment. Therefore, designation of the ERDF as a CAMU at this time is appropriate.

9.4 DETAILED EVALUATION

This section provides the detailed evaluation of each alternative in terms of the applicable CERCLA criteria described in Section 9.2. Alternative scores for each subcriteria are provided in Tables 9-8 through 9-12. Quantitative scores were utilized when available. For all the qualitative criteria, "high" is considered best and "low" is considered worse. Overall rankings for each primary criteria were determined by normalizing the subcriteria scores on a scale of zero to 1 and weighting the subcriteria. Qualitative scores were normalized by setting "low" equal to 0, "medium" equal to 0.5, and "high" equal to 1. Normalized quantitative scores are provided in the tables. The rationale for the subcriteria weighting is provided in

Section 9.2. Total scores for each criteria are obtained by summing the products of the weights and the subcriteria scores.

9.4.1 Alternative 1 - No Action

Evaluation of the no-action alternative is required under CERCLA (40 CFR 300.430(e)(6)). The no-action alternative for this FS consists of not constructing a centralized waste management unit on the Hanford Site to accommodate remediation waste from Hanford Site past-practice operable units. Implementation of the no-action alternative would likely result in the necessity for each operable unit to develop alternatives that are limited to in-situ remedial actions, or excavation and disposal at the operable unit. These alternatives would result in waste remaining dispersed across the Hanford site, including near the Columbia River. The no-action alternative is not evaluated against the standard CERCLA criteria given the uncertainty in the selected remedies if the ERDF is not constructed. It should be noted, however, that the no-action alternative will not satisfy the purpose stated in section 1.2 to "support the removal of contaminants from portions of the Hanford Site (including near the Columbia River) in a timely manner".

9.4.2 Alternative 2 - No Liner and the Low-Infiltration Soil Barrier

This alternative consists of an unlined trench and a low-infiltration engineered soil barrier (as described in Section 8.5.1). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 60 cm of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. Institutional controls and the other common elements described in Section 9.3 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, as presented in Table 9-8, this alternative results in a total ICR of $3x10^{-4}$ and a HQ of 7 within 10,000 years. This alternative, along with the other alternatives that utilize the low-infiltration soil barrier, performs slightly poorer than the alternatives with the modified Hanford or Hanford barriers and is scored low in terms of groundwater protection.

Reliability scores are provided in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores low for both liner and barrier reliability. This alternative performs worst in term of long-term effectiveness.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of worker fatalities was determined by summing the expected fatalities for excavation, construction of the low-infiltration soil barrier, and ERDF operations as presented in Section 9.3.16. The expected number of worker fatalities for this alternative (0.519) is the lowest for all the alternatives. The total impacted area at the silt borrow source is 0.14 km^2, which is tied for the lowest, and no basalt is used. Therefore, this alternative performs best in terms of short-term effectiveness.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has 3 layers in the barrier and no liner, giving it the best technical implementability score.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $500 million. This is the lowest cost alternative.

9.4.3 Alternative 3 - No Liner and the Modified Hanford Barrier

This alternative consists of an unlined trench and the modified RCRA barrier (as described in Section 8.5.6). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 50 cm (20 in.) of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. In addition, a 15-cm (6-in.) thick asphalt layer provides secondary protection against both infiltration and intrusion. Institutional controls and the other common elements described in Section 9.3 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of $2x10^{-5}$ and a maximum HQ of 0.8 within 10,000 years and this alternative scores high in terms of groundwater protection (Table 9-8).

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores low on liner reliability and medium on barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the modified Hanford barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.522) ranks second best. The total impacted area at the silt borrow source is 0.26 km^2, which is average, and no basalt is used. This alternative has the 4th best short-term effectiveness score.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has 9 layers in the barrier and no liner, resulting in a medium score for technical implementability.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $600 million. This is the third lowest cost alternative.

9.4.4 Alternative 4 - No Liner and the Hanford Barrier

This alternative consists of an unlined trench and the Hanford Barrier (as described in Section 8.5.6). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 1 m (3.28 ft) of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. A 1.5-m (4.9-ft) thick crushed basalt layer beneath the evapotranspiration zone provides additional protection against intrusion. In addition, a 15-cm (6-in.) thick asphalt layer provides additional protection against both infiltration and intrusion. Institutional controls and the other common elements described in Section 9.3 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of $2x10^{-5}$ and a HQ of 0.8 within 10,000 years (Table 9-8) and is considered high in terms of groundwater protection.

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores low on liner reliability and high on barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the Hanford barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.556) ranks 5th best. The total impacted area at the silt borrow source is 0.54 km^2, which is tied for last, and the impacted area at the basalt borrow source is 0.22 km^2. Overall, this alternative is ranked 7th for short-term effectiveness.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has 11 layers in the barrier and no liner, giving it a medium technical implementability score.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $740 million. This is the sixth lowest cost alternative.

9.4.5 Alternative 5 - Single Composite Liner and the Low-Infiltration Soil Barrier

This alternative consists of a single-composite liner (described in Section 8.6.4) and a low-infiltration engineered soil barrier (as described in Section 8.5.1). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 60 cm of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. The liner retains leachate within the trench which is then pumped out using a leachate collection system and treated. Institutional controls and the other common elements described in Section 9.3 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of $2x10^{-4}$ and a HQ of 7 within 10,000 years. This alternative, along with the other alternatives that utilize the low-infiltration soil barrier, performs slightly poorer that the alternatives with the modified Hanford or Hanford barriers and is scored low for groundwater protection.

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores medium for liner reliability and low for barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the single composite liner and the low-infiltration soil barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.543) ranks third best. The total impacted area at the silt borrow source is 0.14 km^2, which is tied for first, and no basalt is used. The overall short-term effectiveness score is ranked second.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has a total of 8 layers in the barrier and liner, giving it a medium score for technical implementability.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $587 million. This is the second lowest cost alternative.

9.4.6 Alternative 6 - Single Composite Liner and the Modified Hanford Barrier

This alternative consists of a single-composite liner (described in Section 8.6.4) and the modified RCRA barrier (as described in Section 8.5.6). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 50 cm (20 in.) of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. In addition, a 15-cm (6-in.) thick asphalt layer provides secondary protection against both infiltration and intrusion. The liner retains leachate within the trench which is then pumped out using a leachate collection system and treated. Institutional controls and the other common elements described in Section 9.3 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of 2×10^{-5} and a maximum HQ of 0.8 within 10,000 years and is scored high in terms of groundwater protection.

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores medium on both liner and barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the single composite liner and the modified Hanford barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.546) rank 4th best. The total impacted area at the silt borrow source is 0.26 km^2, which is tied for fourth, and no basalt is used. This alternative is fifth in terms of overall short-term effectiveness.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has a total of 14 layers in the barrier and liner, giving it a low score for technical implementability.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $690 million. This is the fifth lowest cost alternative.

9.4.7 Alternative 7 - Single Composite Liner and the Hanford Barrier

This alternative consists of a single composite liner (described in Section 8.6.4) and the Hanford Barrier (as described in Section 8.5.6). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 1 m (3.28 ft) of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. A 1.5-m (4.9-ft) thick crushed basalt layer beneath the evapotranspiration zone provides additional protection against intrusion. In addition, a 15-cm (6-in.) thick asphalt layer provides additional protection against both infiltration and intrusion. The liner retains leachate within the trench which is then pumped out using a leachate collection system and treated. Institutional controls and the other common elements described in Section 9.3 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of 2×10^{-5} and a HQ of 0.8 within 10,000 years and is scored high in terms of groundwater protection.

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores medium on liner reliability and high on barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the single composite liner and the Hanford barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.58) is the second worst score. The total impacted area at the silt borrow source is 0.54 km^2, which is tied for last, and the impacted area at the basalt borrow source is 0.22 km^2. This alternative has the second worst short-term effectiveness score.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has a total of 16 layers in the barrier and liner, giving it a low technical implementability score.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $826 million. This is the second most expensive alternative.

9.4.8 Alternative 8 - RCRA Double Composite Liner and the Low-Infiltration Soil Barrier

This alternative consists of a RCRA Subtitle C double-composite liner (described in Section 8.6.4) and a low-infiltration engineered soil barrier (as described in Section 8.5.1). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 60 cm of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. The liner retains leachate within the trench which is then pumped out using a leachate collection system and treated. A secondary leachate collection system retains any leachate that leaks through the primary leachate collection system. Institutional controls and the other common elements described in Section 9.3 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of $2x10^{-4}$ and a maximum HQ of 7 within 10,000 years. This alternative, along with the other alternatives that utilize the low-infiltration soil barrier, performs slightly poorer that the alternatives with the modified Hanford or Hanford barriers and is scored low on groundwater protection.

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores high for liner reliability and low for barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the double composite liner and the low-infiltration soil barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.566) is the fourth worst. The total impacted area at the silt borrow source is 0.14 km^2 and no basalt is used. This alternative has the third best overall short-term effectiveness score.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has a total of 11 layers in the barrier and liner, giving it a medium technical implementability score.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $680 million. This is the fourth cheapest alternative.

9.4.9 Alternative 9 - RCRA Double Composite Liner and the Modified Hanford Barrier

This alternative consists of a RCRA Subtitle C double-composite liner (described in Section 8.6.4) and the modified RCRA barrier (as described in Section 8.5.6). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 50 cm (20 in.) of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. In addition, a 15-cm (6-in.) thick asphalt layer provides secondary protection against both infiltration and intrusion. The liner retains leachate within the trench which is then pumped out using a leachate collection system and treated. A secondary leachate collection system retains any leachate that leaks through the primary leachate collection system. Institutional controls and the other common elements described in Section 9.2 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of $2x10^{-5}$ and a maximum HQ of 0.8 within 10,000 years and is scored high in terms of groundwater protection.

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores high on liner reliability and medium on barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the double composite liner and the modified Hanford barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.569) is the third worst. The total impacted area at the silt borrow source is 0.26 km^2, which is tied for fourth, and no basalt is used, resulting in the sixth best overall short-term effectiveness score.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has a total of 17 layers in the barrier and liner, giving it a low technical implementability score.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $779 million. This is the third most expensive alternative.

9.4.10 Alternative 10 - RCRA Double Composite Liner and the Hanford Barrier

This alternative consists of a RCRA Subtitle-C double-composite liner (described in Section 8.6.4) and the Hanford Barrier (as described in Section 8.5.6). The barrier prevents direct exposure to the waste and includes a vegetated surface layer of fine-grained soils to retain moisture and encourage evapotranspiration, thereby minimizing infiltration and vadose zone transport of contaminants to groundwater. The upper 1 m (3.28 ft) of the soil cover system is composed of an admixture of silt and gravels. This layer is intended to both reduce infiltration through the cover and to enhance the resistance of the cover to burrowing animals and long-term wind erosion. A 1.5-m (4.9-ft) thick crushed basalt layer beneath the evapotranspiration zone provides additional protection against intrusion. In addition, a 15-cm (6-in.) thick asphalt layer provides additional protection against both infiltration and intrusion. The liner retains leachate within the trench which is then pumped out using a leachate collection system and treated. A secondary leachate collection system retains any leachate that leaks through the primary leachate collection system. Institutional controls and the other common elements described in Section 9.2 are included with this alternative. Evaluations of this alternative against the relevant CERCLA criteria are provided below.

Long-Term Effectiveness and Permanence. Based on the results presented in Appendix A, none of the contaminants reach groundwater within 10,000 years for this scenario under current climate conditions. Under the hypothetical wetter climate, this alternative results in a total ICR of $2x10^{-5}$ and a maximum HQ of 0.8 within 10,000 years and is scored high in terms of groundwater protection.

Reliability scores are summarized in Table 9-9. As discussed in Sections 9.3.8 and 9.3.9, this alternative scores high on both liner and barrier reliability.

Short-Term Effectiveness. Scores for each of the short-term effectiveness sub-criteria are summarized in Table 9-10. The expected number of fatalities was determined by summing the expected fatalities for excavation, construction of the double composite liner and the Hanford barrier, and ERDF operations as presented in Section 9.3.16. The estimated worker fatalities for this alternative (0.603) is the worst score for all the alternatives. The total impacted area at the silt borrow source is 0.54 km^2, which is tied for last, and the impacted area at the basalt borrow source is 0.22 km^2. This alternative has the worst overall short-term effectiveness score.

Implementability. Implementability scores are summarized in Table 9-11. This alternative has a total of 19 layers in the barrier and liner, giving it a low technical implementability score.

Cost. As summarized on Table 9-12, the total net present value for this alternative is $920 million. This is the most expensive alternative.

9.5 COMPARATIVE ANALYSIS

A summary of the alternative rankings for each of the criteria is provided in Table 9-13. The following conclusions may be drawn from the summary ranking and other information provided in the detailed evaluations:

- Groundwater protection is primarily a function of the surface barrier. All three barriers provide equivalent groundwater protection under current climate conditions. Under hypothetical wetter climate conditions, however, alternatives with the Hanford Barrier and modified Hanford barrier provide better groundwater protection than alternatives with the low-infiltration soil barrier.

- The Hanford barrier is more reliable than the modified Hanford barrier which is itself more reliable than the low-infiltration soil barrier.

- Given the fate and transport assumptions used in this analysis, alternatives with no liner provide similar groundwater protection as alternatives with a liner. Furthermore, the single liner is virtually equivalent in effectiveness to the double liner.

- The most important advantage of alternatives with a liner is that they provide a means to determine the validity of assumptions regarding leachate generation and leachate quality. If these assumptions prove to be non-conservative, it would be possible to initiate corrective action.

- Alternatives with the Hanford Barrier provide the best long-term effectiveness but at the expense of greater impacts on the environment and higher costs.

- Worker risk is dominated by operations, which is the same for all the alternatives. Consequently, the expected number of worker fatalities ranges from 0.52 to 0.60 over the life of the facility, and is not a useful differentiator between the alternatives.

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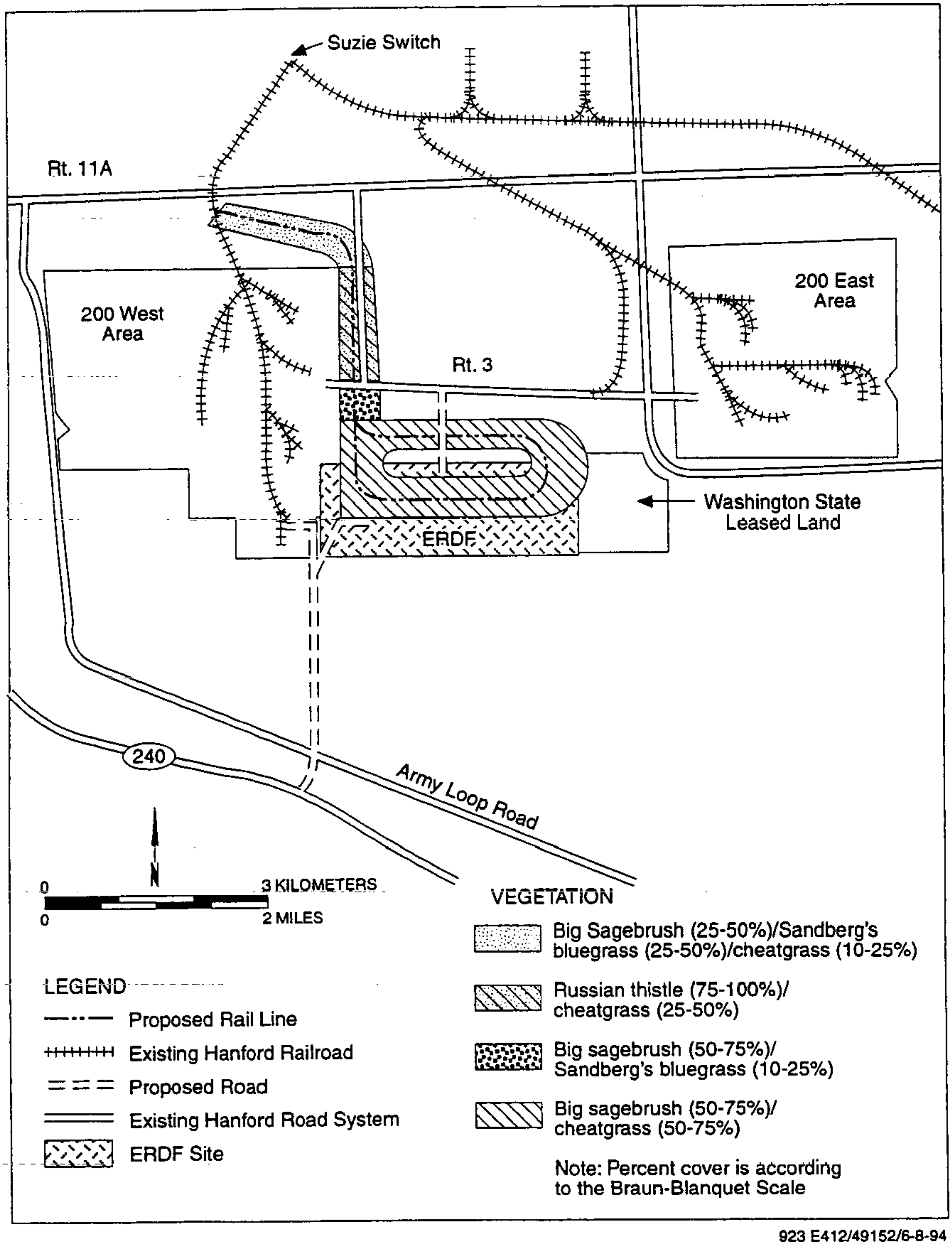

Figure 9-1. Location of Proposed Rail Lines and Roads.

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Table 9-1. Summary of Remedial Action Components for ERDF Alternatives.

Alternative Number	No Liner	Single Liner	Double Liner	Low Infiltration Soil Cover	Modified Hanford Barrier	Hanford Barrier
1						
2	X			X		
3	X				X	
4	X					X
5		X		X		
6		X			X	
7		X				X
8			X	X		
9			X		X	
10			X			X

Note: "X" indicates the technology is included in the alternative.
Blank spaces indicate the technology is not part of the alternative.

<u>ALTERNATIVE NAMES</u>

1. No Action Alternative
2. No Liner with a Low Infiltration Soil Cover
3. No Liner with a Modified Hanford Barrier
4. No Liner with a Hanford Barrier
5. Single Composite Liner with Low Infiltration Soil Cover
6. Single Composite Liner with a Modified Hanford Barrier
7. Single Composite Liner with a Hanford Barrier
8. Double Composite Liner with a Low Infiltration Soil Cover
9. Double Composite Liner with a Modified Hanford Barrier
10. Double Composite Liner with a Hanford Barrier

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Table 9-2. Raw Liner Construction Costs.

	Single Liner	Double Liner
Bottom Liner (864,000 m²)		
Unit Cost (per m²)	$31.56	$70.54
Total Cost for Bottom	$27 million	$61 million
Sideslope Liner (417,000 m²)		
Unit Cost (per m²)	$28.72	$63.79
Total Cost for Sideslope	$12 million	$27 million
Total Liner Cost	$39 million	$88 million
Note: Unit costs for liners are based on information provided in Section 8.6.		

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Table 9-3. Labor Requirements for Construction of the Liners.

Layer	Crew Size	Material Placement Rate (per day)	Single Liner		Double Liner	
			Material Quantity	Labor (days)	Material Quantity	Labor (days)
Operations Layer (m^3)	11	2,000	1.20E+06	6,600	1.20E+06	6,600
Geotextile Separator (m^2)	24	7,500	8.60E+05	2,752	8.60E+05	2,752
Drainage Gravel (m^3)	9	750	2.60E+05	3,120	5.20E+05	6,240
Drainage Geocomposite (m^2)	24	5,000	4.20E+05	2,016	8.30E+05	3,984
Geotextile Cushion (m^2)	24	7,500	8.60E+05	2,752	2.60E+06	8,320
HDPE (m^2)	24	2,500	1.30E+06	12,480	2.60E+06	24,960
Bentonite Admix (m^3)	18	1,500	3.90E+05	4,680	1.20E+06	14,400
Subgrade (m^2)	4	5,000	1.30E+06	1,040	1.30E+06	1,040
Material Transport				5,000		11,000
Total				40,440		79,296

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Table 9-4. Total Material Requirements for the Trench Liners.

	Single Liner		Double Liner	
	Thickness (m)	Quantity (million)	Thickness (m)	Quantity (million)
General Fill (Bottom and Sideslope)	0.9	1.2 m^3	0.9	1.2 m^3
Geotextile Separator (Bottom only)	(area)	0.86 m^2	(area)	0.86 m^2
Gravel (Bottom only)	0.3	0.26 m^3	0.3x2	0.52 m^3
Geotextile Cushion (Bottom only)	(area)	0.86 m^2	(area)x3	2.6 m^2
Drainage Geocomposite (Sideslope only)	(area)	0.42 m^2	(area)x2	0.83 m^2
HDPE Geomembrane (Bottom and Sideslope)	(area)	1.3 m^2	(area)x2	2.6 m^2
Sand (Bottom and Sideslope)	0.24	0.31 m^3	0.72	0.92 m^3
Bentonite (Bottom and Sideslope)	0.06	0.08 m^3	0.18	0.23 m^3

Notes:
(area) - Two-dimensional material that is considered to have a thickness of zero.
Assumes areas of 864,000 m^2 for the bottom liner and 417,000 m^2 for the sideslope liner.
1 m = 3.28 ft

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Table 9-5. Labor Requirements for Construction of the Barriers.

Layer	Material Placement Rate[a] (per day)	Low-Infiltration Soil Barrier		Modified Hanford Barrier		Hanford Barrier	
		Material Quantity	Labor (days)	Material Quantity	Labor (days)	Material Quantity	Labor (days)
Silt Admix (m^3)	3,000	8.16E+05	3,264	6.80E+05	2,720	1.47E+06	5,880
Silt (m^3)	1,500			6.80E+05	5,440	1.47E+06	11,760
General Fill (m^3)	5,000	5.44E+06	13,056	4.08E+06	9,792		
Geofilter (m^2)	7,500					1.46E+06	2,336
Sand Filter (m^3)	1,500			2.04E+05	1,632	2.20E+05	1,760
Gravel Filter (m^3)	1,500			2.04E+05	1,632	4.41E+05	3,528
Crushed Basalt (m^3)	1,500					2.21E+06	17,640
Drainage Gravel (m^3)	1,500			2.04E+05	1,632	4.41E+05	3,528
Asphalt (m^3)	2,000			2.04E+05	1,224	2.20E+05	1,320
Base Course (m^3)	1,500			1.36E+05	1,088	1.47E+05	1,176
Material Transport			5,000		11,000		35,000
Total			21,320		36,160		83,928

[a]Assumes a crew size of 12 workers.

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Table 9-6. Material Requirements for the Barriers.

	Low Infiltration Soil Barrier		Modified Hanford Barrier		Hanford Barrier	
	Thickness (m)	Quantity (million)	Thickness (m)	Quantity (million)	Thickness (m)	Quantity (million)
Vegetation	(area)	1.36 m^2	(area)	1.36 m^2	(area)	1.47 m^2
Silt	0.5	0.68 m^3	0.93	1.3 m^3	1.85	2.7 m^3
Sand	0	0	0.15	0.20 m^3	0.15	0.22 m^3
Gravel	0.1	0.14 m^3	0.47	0.64 m^3	0.85	1.2 m^3
General Fill	4.0	5.4 m^3	3.0	4.1 m^3	0	0
Geotextile Filter	0	0	0	0	(area)	1.47 m^2
Crushed Basalt	0	0	0	0	1.5	2.2 m^3
Asphalt Coating	0	0	(area)	1.36 m^2	(area)	1.47 m^2
Asphalt	0	0	0.15	0.20 m^3	0.15	0.22 m^3

Notes:
(area) - Two-dimensional material that is considered to have a thickness of zero.
Assumes areas of 1.36 million m^2 for the low permeability soil barrier and modified Hanford barrier and 1.47 million m^2 for the Hanford Barrier.
1 m = 3.28 ft

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Table 9-7. Capital Cost Estimates and Mulipliers for ERDF Elements ($ x 1,000).

Component	Base Construction Cost	Overhead/ Profit (23.30%)	Contingincy (28.00%)	Total Construction Cost	Project Management (6.50%)	Construction Management (13.40%)	Total Cost
Support Facilities							
Site Preparation	$3,467	$808	$1,197	$5,472	$356	$733	$6,561
Water Supply	$1,531	$357	$529	$2,416	$157	$324	$2,897
Railroad	$9,197	$2,143	$3,175	$14,515	$943	$1,945	$17,404
Landscaping	$86	$20	$30	$136	$9	$18	$163
Roads, walks, paved areas	$3,914	$912	$1,351	$6,177	$402	$828	$7,407
Operations Building	$3,553	$828	$1,227	$5,607	$364	$751	$6,723
Decon./Treatment Facility	$10,236	$2,385	$3,534	$16,155	$1,050	$2,165	$19,370
Container Storage Shed	$2,279	$531	$787	$3,597	$234	$482	$4,313
Data Processing Equipment	$2,770	$645	$956	$4,372	$284	$586	$5,242
Fuel and Chemical Storage	$51	$12	$18	$80	$5	$11	$97
Sanitary Waste System	$132	$31	$46	$208	$14	$28	$250
Secondary Containement	$25	$6	$9	$39	$3	$5	$47
Site Communications	$919	$214	$317	$1,450	$94	$194	$1,739
Site Electrical	$968	$226	$334	$1,528	$99	$205	$1,832
Substation	$235	$55	$81	$371	$24	$50	$445
Site Lighting	$171	$40	$59	$270	$18	$36	$324
Leachate Storage Tanks	$430	$100	$148	$679	$44	$91	$814
Subtotal Support Facilities	$39,534	$9,211	$13,649	$62,394	$4,056	$8,361	$75,000
Permitting, Design, Etc	-	-	-	-	-	-	$22,000
Trench Excavation	$57,696	$13,443	$19,919	$91,058	$5,919	$12,202	$109,000
Single Liner	$39,000	$9,087	$13,464	$61,551	$4,001	$8,248	$74,000
Double Liner	$88,000	$20,504	$30,381	$138,885	$9,028	$18,611	$167,000
Leachate Collection	$5,984	$1,394	$2,066	$9,444	$614	$1,266	$11,000
Low-Infil. Soil Barrier	$28,000	$6,523	$9,667	$44,191	$2,872	$5,922	$53,000
Modified Hanford Barrier	$107,000	$25,033	$37,083	$169,523	$11,019	$22,716	$203,000
Hanford Barrier	$197,000	$45,901	$68,012	$310,913	$20,209	$41,662	$373,000

Notes:
Raw costs for support facilities, permitting, design, trench excavation, and leachate collection based on U.S. Army Corps of Engineers (1994).
Raw costs for liners and barriers are developed in Sections 9.3.
Multipliers are based on U.S. Army Corps of Engineers (1994).

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Table 9-8. Predicted Groundwater Human-Health Risks for Remedial Alternatives under Hypothetical Wetter Climate Conditions.

Alternative	Total ICR	Maximum HQ
1. No Action	NA	NA
2. No Liner with Low Infiltration Soil Barrier	3E-04	7
3. No Liner with Modified Hanford Barrier	2E-05	0.8
4. No Liner with Hanford Barrier	2E-05	0.8
5. Single Liner with Low Infiltration Soil Barrier	2E-04	7
6. Single Liner with Modified Hanford Barrier	2E-05	0.8
7. Single Liner with Hanford Barrier	2E-05	0.8
8. Double Liner with Low Infiltration Soil Barrier	2E-04	7
9. Double Liner with Modified Hanford Barrier	2E-05	0.8
10. Double Liner with Hanford Barrier	2E-05	0.8
NA = Not Available.		

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Table 9-9. Scores for Long-Term Effectiveness.

Alternative	Groundwater Protection	Liner Reliability	Barrier Reliability	Score (Rank)
Weighting	0.4	0.1	0.5	
1. No Action	NA	NA	NA	NA
2. No Liner with Low Infiltration Soil Barrier	Low	Low	Low	0.00 (9)
3. No Liner with Modified Hanford Barrier	High	Low	Medium	0.65 (6)
4. No Liner with Hanford Barrier	High	Low	High	0.90 (3)
5. Single Liner with Low Infiltration Soil Barrier	Low	Medium	Low	0.05 (8)
6. Single Liner with Modified Hanford Barrier	High	Medium	Medium	0.70 (5)
7. Single Liner with Hanford Barrier	High	Medium	High	0.95 (2)
8. Double Liner with Low Infiltration Soil Barrier	Low	High	Low	0.10 (7)
9. Double Liner with Modified Hanford Barrier	High	High	Medium	0.75 (4)
10. Double Liner with Hanford Barrier	High	High	High	1.00 (1)

NA = Not Available.

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Table 9-10. Scores for Short-Term Effectiveness Sub-Criteria.

Alternative	Expected Worker Fatalities[a]	Silt Quarry Area[a] (km^2)	Basalt Quarry Area[a] (km^2)	Score (Rank)
Weighting	0.2	0.4	0.4	
1. No Action	NA	NA	NA	NA
2. No Liner with Low Infiltration Soil Barrier	0.519 (1)	0.14 (1)	0 (1)	1.00 (1)
3. No Liner with Modified Hanford Barrier	0.522 (0.96)	0.26 (0.7)	0 (1)	0.87 (4)
4. No Liner with Hanford Barrier	0.556 (0.56)	0.54 (0)	0.22 (0)	0.11 (7)
5. Single Liner with Low Infiltration Soil Barrier	0.543 (0.71)	0.14 (1)	0 (1)	0.94 (2)
6. Single Liner with Modified Hanford Barrier	0.546 (0.68)	0.26 (0.7)	0 (1)	0.82 (5)
7. Single Liner with Hanford Barrier	0.580 (0.27)	0.54 (0)	0.22 (0)	0.05 (8)
8. Double Liner with Low Infiltration Soil Barrier	0.566 (0.44)	0.14 (1)	0 (1)	0.89 (3)
9. Double Liner with Modified Hanford Barrier	0.569 (0.40)	0.26 (0.7)	0 (1)	0.76 (6)
10. Double Liner with Hanford Barrier	0.603 (0)	0.54 (1)	0.22 (0)	0.00 (9)

NA - Not Available.
[a]Normalized sub-criterion scores shown in parenthesis.

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Table 9-11. Scores for Implementability Sub-Criteria.

Alternative	Technical[a]	Rank
1. No Action	NA	NA
2. No Liner with Low Infiltration Soil Barrier	High	1
3. No Liner with Modified Hanford Barrier	Medium	2(tie)
4. No Liner with Hanford Barrier	Medium	2(tie)
5. Single Liner with Low Infiltration Soil Barrier	Medium	2(tie)
6. Single Liner with Modified Hanford Barrier	Low	6(tie)
7. Single Liner with Hanford Barrier	Low	6(tie)
8. Double Liner with Low Infiltration Soil Barrier	Medium	2(tie)
9. Double Liner with Modified Hanford Barrier	Low	6(tie)
10. Double Liner with Hanford Barrier	Low	6(tie)

NA - Not Available.
[a]Measured in terms of total layers in the liner and barrier.

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Table 9-12. Costs for Remedial Alternatives.

	General Costs[a]	Liner Costs[b]	Barrier Costs[c]	Operations Cost[d]	Total Present Value	Rank
1. No Action	NA	NA	NA	NA	NA	NA
2. No Liner with Low Infiltration Soil Barrier	$206	0	$40	$256	$502	1
3. No Liner with Modified Hanford Barrier	$206	0	$139	$256	$601	3
4. No Liner with Hanford Barrier	$206	0	$279	$256	$741	6
5. Single Liner with Low Infiltration Soil Barrier	$206	$85	$40	$256	$587	2
6. Single Liner with Modified Hanford Barrier	$206	$85	$139	$256	$686	5
7. Single Liner with Hanford Barrier	$206	$85	$279	$256	$826	8
8. Double Liner with Low Infiltration Soil Barrier	$206	$178	$40	$256	$680	4
9. Double Liner with Modified Hanford Barrier	$206	$178	$139	$256	$779	7
10. Double Liner with Hanford Barrier	$206	$178	$279	$256	$919	9

All costs are in millions.
NA - Not available.
[a] - Includes support facilities, permitting, design, and trench excavation.
[b] - Includes liner and leachate collection system.
[c] - Net present value of barrier costs assuming a discount rate of 6 percent over 20 years.
[d] - Net present value of annual operations cost of $20 million/yr for 25 years assuming a discount rate of 6 percent.

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Table 9-13. Summary Ranking of the Alternatives Against the Criteria.

Alternative	Long-Term Effectiveness	Short-Term Effectiveness	Implementability	Cost
1	NA	NA	NA	NA
2	9	1	1	1
3	6	4	2(tie)	3
4	3	7	2(tie)	6
5	8	2	2(tie)	2
6	5	5	6(tie)	5
7	2	8	6(tie)	8
8	7	3	2(tie)	4
9	4	6	6(tie)	7
10	1	9	6(tie)	9

Notes:
1 - No Action
2 - No Liner with Low Infiltration Soil Barrier
3 - No Liner with Modified Hanford Barrier
4 - No Liner with Hanford Barrier
5 - Single Liner with Low Infiltration Soil Barrier
6 - Single Liner with Modified Hanford Barrier
7 - Single Liner with Hanford Barrier
8 - Double Liner with Low Infiltration Soil Barrier
9 - Double Liner with Modified Hanford Barrier
10 - Double Liner with Hanford Barrier
NA - Not Available.

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10.0 CONCLUSIONS

The purpose of this RI/FS was to develop and evaluate design alternatives for the ERDF, a proposed CAMU intended to receive excavated soil and other wastes from CERCLA and RCRA operable units on the Hanford Site. The proposed location for the ERDF is on the 200 Area plateau, just south of the 200 West and 200 East Areas.

Development of Alternatives. Various technologies were evaluated and screened, although the primary focus was on surface barrier and trench liner technologies. The retained technologies were assembled into 9 design alternatives (in addition to the no-action alternative). The nine alternatives represent combinations of no liner, a single composite liner, or a RCRA MTR double composite liner, with a low-infiltration soil barrier, a modified Hanford barrier, or a Hanford Barrier. The alternatives are listed below:

- Alternative 1 - No action
- Alternative 2 - No liner and a low-infiltration soil barrier
- Alternative 3 - No liner and a modified Hanford barrier
- Alternative 4 - No liner and a Hanford Barrier
- Alternative 5 - Single composite liner and a low-infiltration soil barrier
- Alternative 6 - Single composite liner and a modified Hanford barrier
- Alternative 7 - Single composite liner and a Hanford Barrier
- Alternative 8 - RCRA double composite liner and a low-infiltration soil barrier
- Alternative 9 - RCRA double composite liner and a modified Hanford barrier
- Alternative 10 - RCRA Double composite liner and a Hanford Barrier

All of the alternatives, except no action, include institutional controls, dust control, surface water management, wastewater treatment, transportation systems, buildings, a grout batch plant, equipment for internal and external communications, emergency response equipment, and personnel protection. In addition, all of the alternatives (other than no-action) utilize the deep area-fill trench configuration, a single trench design approximately 20 m (70 ft) deep and 300 m (1,000 ft) across. This trench configuration minimizes the footprint of the facility. The reduced footprint of the deep area-fill design offers the following advantages in comparison to other configurations:

- Less habitat disruption at the ERDF
- Less leachate generation
- Reduced material needs (thus, reduced ecological and cultural impact on borrow areas)
- Lower costs for the liner and barrier.

Using the deep area-fill configuration, the disturbed area of the ERDF, including the trench, stockpiling areas, roads, and supporting facilities, is estimated to be 2.6 km^2 (650 acres or 1.0 mi^2).

Acceptable soil and leachate concentrations. Acceptable soil and leachate concentrations were developed for the contaminants identified in potential waste from the 100, 200, and 300 Areas. These concentrations will be included as part of the waste acceptance criteria for ERDF waste to ensure that human and ecological exposures will be less than acceptable standards for the foreseeable future.

The acceptable soil concentrations were based on exposure to soils due to the 500-year drilling scenario. This scenario was determined to be a reasonable exposure scenario given the protective measures included in the ERDF design such as active institutional controls, passive controls, and a minimum 15-foot thick surface barrier. Based on a comparison with maximum contaminant concentrations in 100, 200, and 300 Areas waste units, it appears that most of the waste will meet the acceptable soil concentrations. Waste with soil concentrations that exceed the acceptable levels will require mixing with cleaner soils to reduce concentrations to acceptable levels. For the contaminants that may exceed acceptable levels (metals and radionuclides) no treatment technology exists for reducing concentrations.

Acceptable leachate concentrations were developed to provide protection of groundwater. It is likely that much of the waste received at the ERDF will achieve the leachate criteria without treatment. If this is not the case, however, then the waste will likely require treatment before disposal in the ERDF. For purposes of the detailed evaluation in this report, it was assumed that the wastes would comply with the leachate criteria.

Detailed Evaluation. With the exception of no action, all of the alternatives satisfy the two threshold CERCLA criteria: 1) overall protection of human health and the environment, and 2) compliance with ARARs. The ten alternatives were therefore evaluated against the following CERCLA criteria for detailed evaluation:

- Long-term effectiveness and permanence
- Short-term effectiveness
- Implementability
- Cost.

The criterion that includes reduction of toxicity, mobility, or volume through treatment was not evaluated because it is not within the scope of this RI/FS. Treatment will be evaluated in the source operable units FS reports. The two modifying criteria, state acceptance and community acceptance, will be evaluated following comments on the RI/FS and Proposed Plan and incorporated into the record of decision (ROD).

Comparative Analysis. The results of the detailed evaluation resulted in the following conclusions regarding the primary components of the alternatives:

- Compared with the other barriers, the Hanford Barrier (Alternative 4, 7, and 10) provides the best long-term protection of human health, but at the expense of greater impacts on the environment (due to impacts at borrow sites for construction materials) and higher costs.

- The modified Hanford barrier provides the same groundwater protection as the Hanford Barrier, but with lower cost and less ecological impact. However, because the modified Hanford barrier does not include the crushed basalt layer it is less resistant to intrusion than the Hanford Barrier.

- The low-infiltration soil barrier provides the same groundwater protection as the other two barriers under current climatic conditions for significantly less cost and ecological impact. However, under hypothetical wetter climatic conditions, this barrier allows greater infiltration (and thus shorter vadose zone travel times) than the other two barriers.

- Because of the low infiltration rates associated with the surface barriers, alternatives with no liner provide similar groundwater protection as alternatives with a liner. Furthermore, the single liner is virtually equivalent to the double liner in terms of groundwater protection.

- One advantage of lined alternatives is that they provide a means to determine the validity of assumptions regarding leachate generation and leachate quality. If these assumptions prove to be non-conservative, and potential groundwater impacts are deemed unacceptable, then it would be possible to initiate corrective action.

Given the Tri-Party Agreement objective to have the ERDF ready to receive remediation waste by September of 1996, selection of the liner is a time-critical decision. Although the results provided above indicate that a liner may not provide significant benefits (given an effective surface barrier to prevent infiltration), it will provide some measure of redundancy and facilitate confirmation of leachate generation rates and quality.

Selection of the barrier hinges to some extent on the long-term objectives of the ERDF. If the objective is to construct a final remedy that will protect human health and the environment for thousands of years with or without institutional controls, then the extra expense and environmental impacts associated with the Hanford Barrier may be warranted. If the ERDF is expected to be an interim solution, or an evolving facility, that will remain under institutional controls as long as necessary, then a less expensive barrier may be more appropriate. For example, as long as institutional controls are maintained over the ERDF and long-term average precipitation does not increase significantly , the low-infiltration soil and modified Hanford barriers should be just as protective as the Hanford Barrier. Since construction of the barrier will not begin for many years (at least 10 years) selection of the barrier may be postponed until more information is available.

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11.0 REFERENCES

Ames, L.L., and R.J. Serne, 1991, *Compilation of Data to Estimate Groundwater Migration Potential for Constituents in Active Liquid Discharges at the Hanford Site*, PNL-7660, Pacific Northwest Laboratory, Richland, Washington.

Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shor, 1984, *Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL-5786, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Baker, V.R., B.N. Bjornstad, A.J. Busacca, K.R. Fecht, E.P. Kiver, U.L. Moddy, J.G. Rigby, D.F. Stradling, and A.M. Tallman, 1991, "Quaternary Geology of the Columbia Plateau", in *Quaternary Nonglacial Geology; Conterminus U.S.*, R.B. Morrison, Editor, Geology of North America, Geological Society of America, Vol. K-2, Boulder, Colorado.

Baker, D.A., and J. K. Soldat, 1992, *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment*, PNL-8150, Pacific Northwest Laboratory, Richland, Washington.

Bierschenk, W.H., 1957, *Hydraulic Characteristics of Hanford Aquifers*, HW-48916, General Electric Hanford Atomic Products Operation, Richland, Washington.

Bretz, J.H., H.T.U. Smith, and G.E. Neff, 1956, "Channel Scabland of Washington: New Data and Interpretation", *Geological Society of America Bulletin*, Vol. 67, pp. 957-1049.

Brown, D.J., 1960, *Eolian Deposit Beneath 200-West Area*, HW-67549, General Electric Company, Richland, Washington.

Burt, W.H., and R.P. Grossenheider, 1976, *Field Guide to the Mammals*, Houghton Mifflin Company, Boston, Massachusetts.

Cain, F.G., 1994, *Environmental Restoration Disposal Facilities (Project W-296) Preliminary Safety Evaluation*, WHC-SD-W296-PSE- 001, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Calder, W., 1984, *Size, Function, and Life History*, President and Fellows of Harvard College, Cambridge, Massachusetts.

Campbell, N.P., 1989, *Structural and Stratigraphic Interpretation of Rocks under the Yakima Fold Belt, Columbia Basin, Based on Recent Surface Mapping and Well Data*, Special Paper 239, Geological Society of America, Boulder, Colorado.

Chatters, J.C., 1989, *Hanford Cultural Resources Management Plan*, PNL-6942, Pacific Northwest Laboratory, Richland, Washington.

Chatters, J.C., 1982, "Prehistoric Settlement and Land Use in the Dry Columbia Basin", in *Northwest Anthropological Research Notes*, 16, pp. 125-147.

Clement Associates, 1989, *Toxicological Profile for Pentachlorophenol*, Syracuse Research Corporation for the Agency for Toxic Substances and Disease Registry, Atlanta, Georgia.

Connelly, M.P., J. V. Borghese, C. D. Delaney, B. H. Ford, J. W. Lindberg, and S.J. Trent, 1992, *Hydrogeologic Model for the 200 East Groundwater Aggregate Area*, WHC-SD-EN-TI-019, Westinghouse Hanford Company, Richland, Washington.

Coughtrey, P.J., D. Jackson, and M.C. Thorne, 1985, *Radionuclide Distribution and Transport in Terrestrial and Aquatic Ecosystems: A Compendium of Data*, A.A. Balkema, Boston, Massachusetts.

Cushing, C.E., editor, 1992, *Hanford Site National Environmental Policy Act (NEPA) Characterization*, PNL-6415, Rev. 5, Pacific Northwest Laboratory, Richland, Washington.

CWC-HDR, Inc., 1988, *Water Filtration Plant and North Richland Well Field Evaluation: City of Richland Water and Waste Utilities*, City of Richland, Richland, Washington.

Daubenmire, R.A., 1970, *Steppe Vegetation of Washington*, Washington Agricultural Experiment Station, Technical Bulletin 62, Washington State University, Pullman, Washington.

Daugherty, R.D., 1952, "Archaeological Investigations of O'Sullivan Reservoir, Grant County, Washington", in *American Antiquity*, 17, pp. 274-278.

Deju, R.A., and K.R. Fecht, 1979, *Preliminary Description of Hydrologic Characteristics and Contaminant Transport Potential of Rocks in the Pasco Basin, South-Central Washington*, RHO-BWI-LD-20, Rockwell Hanford Operations, Richland, Washington.

Delaney, C.D., K.A. Lindsey, and S.P. Reidel, 1991, *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports*, WHC-SD-ER-TI-003, Westinghouse Hanford Company, Richland, Washington.

Dennison, D.I., D.R. Sherwood, and J.S. Young, 1989, *Status Report on Remedial Investigation of the 300 Area Process Ponds*, PNL-6442, Pacific Northwest Laboratory, Richland, Washington.

DNR, 1994, *Endangered, Threatened and Sensitive Vascular Plants of Washington*, Washington State Department of Natural Resources, Washington Natural Heritage Program, Olympia, Washington.

DOE, 1986, *Environmental Assessment - Reference Repository Location, Hanford Site, Washington, Volume 1*, DOE/RW-0070, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, D.C.

DOE, 1987, *Final Environmental Impact Statement - Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes: Hanford Site, Richland, Washington*, DOE/EIS-0113, Vols. 1 through 5, U.S. Department of Energy, Washington, D.C.

DOE, 1988, *Site Characterization Plan, Reference Repository Location, Hanford Site, Washington; Consultation Draft*, DOE/RW-0164, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, D.C.

DOE, 1989, *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington; Draft Environmental Statement*, DOE/EIS-0119D, U.S. Department of Energy, Washington, D.C.

DOE-RL, 1988, *Hanford Facility Dangerous Waste Part A Permit Application*, DOE/RL 88-21, Vols. 1-3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1989, *Hanford Site Waste Management Units Report*, DOE/RL 88-30, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1990a, *Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1 Operable Unit, Hanford Site, Richland, Washington*, DOE-RL 88-31, Draft D, U.S. Department of Energy, Richland, Washington.

DOE-RL, 1990b, *Phase I Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit*, DOE-RL-90-18, U.S. Department of Energy, Richland, Washington.

DOE-RL, 1990c, *Remedial Investigation/Feasibility Study Work Plan for the 200-BP-1 Operable Unit Hanford Site, Richland, Washington*, DOE/RL 88-32, U.S. Department of Energy, Richland, Washington.

DOE-RL, 1990d, *Hanford Site Development Plan*, DOE/RL 89-15, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992a, *S Plant Aggregate Area Management Study Report*, DOE/RL-91-60 Rev. 0, U.S. Department of Energy, Richland Office Operations, Richland, Washington.

DOE-RL, 1992b, *T Plant Source Aggregate Area Management Study Report*, DOE/RL-91-61 Rev. 0, U.S. Department of Energy, Richland Office Operations, Richland, Washington.

DOE-RL, 1992c, *U Plant Source Aggregate Area Management Study Report*, DOE/RL-91-52 Rev. 0, U.S. Department of Energy, Richland Office Operations, Richland, Washington.

DOE-RL, 1992d, *Z Plant Source Aggregate Area Management Study Report*, DOE/RL-91-58 Rev. 0, U.S. Department of Energy, Richland Office Operations, Richland, Washington.

DOE-RL, 1992e, *Hanford Site Groundwater Background*, DOE/RL-92-23, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992f, *Hanford Site Past-Practice Strategy*, DOE/RL-91-40, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992g, *100 Area Feasibility Study Phases 1 and 2*, DOE/RL-92-11, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992h, *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-5 Operable Unit, Hanford Site, Richland, Washington*, Rev. 0, DOE/RL 90-08, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992i, *Remedial Investigation/Feasibility Study Work Plan for the 100-FR-1 Operable Unit, Hanford Site, Richland, Washington*, DOE/RL 90-33, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992j, *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-1 Operable Unit, Hanford Site, Richland Washington*, Rev. 0, DOE/RL 90-07, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992k, *Remedial Investigation/Feasibility Study Work Plan for the 100-DR-1 Operable Unit, Hanford Site, Richland Washington*, DOE/RL 89-09, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992l, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-HR-1 Operable Unit, Hanford Site, Richland, Washington*, DOE/RL-88-35, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992m, *Remedial Investigation/Feasibility Study Work Plan for the 100-KR-1 Operable Unit, Hanford Site, Richland, Washington*, DOE/RL-90-20 Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993a, *B Plant Source Aggregate Area Management Study Report*, DOE/RL-92-05 Rev. 0, U.S. Department of Energy, Richland Office Operations, Richland, Washington.

DOE-RL, 1993b, *PUREX Source Aggregate Area Management Study Report*, DOE/RL-92-04 Rev. 0, U.S. Department of Energy, Richland Office Operations, Richland, Washington.

DOE-RL, 1993c, *Semiworks Source Aggregate Area Management Study Report*, DOE/RL-92-18 Rev. 0, U.S. Department of Energy, Richland Office Operations, Richland, Washington.

DOE-RL, 1993d, *Hanford Site Development Plan*, DOE/RL-93-19, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993e, *Phase 1 Remedial Investigation Report for the 200-BP-1 Operable Unit*, DOE/RL-92-76 Rev. 0, U.S. Department of Energy, Richland, Washington.

DOE-RL, 1993f, *Phase I Remedial Investigation Report for the 300-FF-1 Operable Unit*, DOE/RL-92-43 Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993g, *Phase I Remedial Investigation Report for the 300- FF-5 Operable Unit*, DOE/RL-93-21, Rev. 0, Vol. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993h, *300-FF-1 Operable Unit Remedial Investigation Phase II Report: Physical Separation of Soils Treatability Study*, DOE/RL-93-96, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993i, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, DOE/RL-92-24, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993j, *Hanford Site Baseline Risk Assessment Methodology*, DOE/RL 91-45, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993k, *Limited Field Investigation Report for the 100-DR- 1 Operable Unit*, DOE/RL-93-29 Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1993l, *Phase I and II Feasibility Study Report for the 300-FF-1 Operable Unit*, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1994a, *100 Area Soil Washing Bench-Scale Tests*, Draft A, DOE/RL-93-107, U.S. Department of Energy, Richland, Washington.

DOE-RL, 1994b, *300-FF-1 Operable Unit Remedial Investigation Phase II Report: Physical Separation of Soils Treatability Study*, DOE/RL-93-96, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1994c, *Hanford Site Risk Assessment Methodology*, DOE/RL 91-45, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1994d, *Limited Field Investigation Report for the 100-KR- 1 Operable Unit*, DOE/RL-93-78, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1994e, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-2 Operable Unit, Hanford Site, Richland, Washington; Draft C*, DOE/RL 91-46, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1994f, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington; Draft D*, DOE/RL 90-22, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Dorian, J.J., and V.R. Richards, 1978, *Radiological Characterization of the Retired 100 Areas*, UNI-946, United Nuclear Industries, Richland, Washington.

Douglas United Nuclear, 1967, *Investigation of Effluent Control Standards and Practices*, DUN-3155, Douglas United Nuclear, Richland, Washington.

DOW, 1993, *Washington Department of Wildlife Species of Special Concern in Washington - State and Federal Status*, Washington State Department of Wildlife, Olympia, Washington.

Downs, J.L., W.H. Rickard, C.A. Brandt, L.L. Cadwell, C.E. Cushing, D.R. Geist, R.M. Mazaika, D.A. Neitzel, L.E. Rogers, M.R. Sackschewsky, and J.J. Nugent, 1993, *Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern*, PNL-8942, Pacific Northwest Laboratory, Richland, Washington.

Dragun, J., 1988, *Soil Chemistry of Hazardous Materials*, Hazardous Materials Control Research Institute, Silver Spring, Maryland.

Drummond, M.E., 1992, *Future for Hanford: Uses and Cleanup, A Final Report of the Hanford Future Site Uses Working Group*, Hanford Future Site Uses Working Group.

Eberhardt, L.E., E.E. Hanson, and L.L. Cadwell, 1982, *Analysis of Radionuclide Concentrations and Movement Patterns of Hanford Site Mule Deer*, PNL-4420, Pacific Northwest Laboratory, Richland, Washington.

Eberhardt, L.E., E.E.Hanson, and L.L.Cadwell, 1984, "Movement and Activity Patterns of Mule Deer in the Sagebrush-Steppe", *Journal of Mammalogy*, Vol. 65, pp. 404-409.

Eberhardt, L.E., J.E. Hedland, and W.H. Rickard, 1979, *Tagging Studies of Mule Deer Fawns on the Hanford Site*, PNL-3147, Pacific Northwest Laboratory, Richland, Washington.

Ecology, EPA, and DOE-RL, 1992, *Hanford Federal Facility Agreement and Consent Order*, 89-10 Rev. 2, Washington State Department of Ecology, Olympia, Washington, U.S. Environmental Protection Agency, Region X, Seattle, Washington, and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE-RL, 1993, *Tentative Agreement of Tri-Party Agreement Negotiations*, Washington State Department of Ecology, Olympia, Washington; U.S. Environmental Protection Agency, Region X, Seattle, Washington, and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE-RL, 1994, *Hanford Federal Facility Agreement and Consent Order, Fourth Amendment*, Washington State Department of Ecology, Olympia, Washington, U.S. Environmental Protection Agency, Region X, Seattle, Washington, and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Eisenbud, M., 1987, *Environmental Radioactivity*, Academic Press, Inc., San Diego, California.

EPA, 1986, "Guidelines for Carcinogenic Risk Assessment", *Federal Register*, Vol. 51, pp. 33992-34002.

EPA, 1987, *Documentation Records for Hazard Ranking System; NPL Candidate: U.S. DOE Hanford 200 Area*, U.S. Environmental Protection Agency, Region X, Seattle, Washington.

EPA, 1988a, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA; Interim Final*, EPA/540/G-89/004, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1988b, *Limiting Values of Radionuclide Intakes and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, EPA/520/1-88/020, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C.

EPA, 1988c, *CERCLA Compliance with Other Laws Manual; Interim Final*, EPA/540/G-89/006, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA, 1989a, *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual, Part A; Interim Final*, EPA/540/1-89/002, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1989b, *Risk Assessment Methodology: Environmental Impact Statement for NESHAPS Radionuclides. Volume I: Background Information Document*, EPA/520/1-89/005, U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, D.C.

EPA, 1989c, *Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments*, EPA/530/SW-89/047, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

EPA, 1989d, *Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites*, U.S. Environmental Protection Agency.

EPA, 1991a, *Interim Oral RfD for Copper*, U.S. Environmental Protection Agency, Superfund Health Risk Technical Support Center, Cincinnati, Ohio.

EPA, 1991b, *Standard Default Exposure Factors*, OSWER Directive 9285.6-03, U.S. Environmental Protection Agency, Washington, D. C.

EPA, 1992a, *Risk Assessment for Polyaromatic Hydrocarbons*, U.S. Environmental Protection Agency, Superfund Health Risk Technical Support Center, Chemical Mixtures and Assessment Branch, Cincinnati, Ohio.

EPA, 1992b, *Dermal Exposure Assessment: Principles and Applications*, EPA/600/8-91/011B, U.S. Environmental Protection Agency, Exposure Assessment Group, Washington, D.C.

EPA, 1992c, *Provisional Oral RfD for Trichloroethylene*, U.S. Environmental Protection Agency, Superfund Health Risk Technical Support Center, Chemical Mixtures Assessment Branch, Cincinnati, Ohio.

EPA, 1993a, *Integrated Risk Information System (IRIS)*, data file, U.S. Department of Health and Human Services, National Library of Medicine Toxicology Data Network (TOXNET), Bethesda, Maryland.

EPA, 1993b, *Health Effects Assessment Summary Tables: Annual FY- 1993*, EPA/540/R-93/058, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

EPA-10, 1991, *Supplemental Risk Assessment Guidance for Superfund*, U.S. Environmental Protection Agency, Region X, Seattle, Washington.

ERDA, 1975, *Waste Management Operations: Hanford Reservations, Richland, Washington, Final Environmental Statement*, ERDA-1538, Energy Research and Development Administration, Richland, Washington.

Evergreen Community Development Association, 1986, *Tri-Cities Enterprise Center Business Development Plan*, Evergreen Community Development Association, Richland, Washington.

Faure, G., 1977, *Principles of Isotope Geology*, John Wiley & Sons, New York, New York.

Fecht, K.R., 1978, *Geology of Gable Mountain -- Gable Butte Area*, RHO-BWI-LD-5, Rockwell Hanford Operations, Richland, Washington.

Fecht, K.R., S.P. Reidel, and A.M. Tallman, 1987, *Paleodrainage of the Columbia River System on the Columbia Plateau of Washington: A Summary*, RHO-BW-SA-318P, Rockwell Hanford Operations, Richland, Washington.

Fitzner, R.E., and W.H. Rickard, 1975, *Avifauna of Waste Ponds, ERDA Hanford Reservation, Benton County, Washington*, BNWL-1885, Battelle Northwest Laboratory, Richland, Washington.

Fitzner, R.E., and R.H. Gray, 1991, "The Status, Distribution and Ecology of Wildlife on the U.S. DOE Hanford Site: A Historical Overview of Research Activities", *Environmental Monitoring and Assessment*, Vol. 18, pp. 173-202.

Fuchs, M.R., W.H. Chapman-Riggsbee, K.L. Dillon, R.C. Routson, and M.G. Snow, 1985, *Request for Waiver from WAC Requirement for Ground-Water Monitoring at the Non-Radioactive Dangerous Waste Landfill, Hanford Site, Washington State*, Rockwell International, Richland, Washington.

Gee, G.W., 1987, *Recharge at the Hanford Site: Status Report*, PNL-6403, Pacific Northwest Laboratory, Richland, Washington.

Gee, G.W., M.J. Fayer, M.L. Rockhold, and M.D. Campell, 1992, "Variations in Recharge at the Hanford Site", *Northwest Science*, Vol. 66, pp. 237-250.

Gee, G.W., and P.R. Heller, 1985, *Unsaturated Water Flow at the Hanford Site: A Review of Literature and Annotated Bibliography*, PNL-5428, Pacific Northwest Laboratory, Richland, Washington.

General Electric, 1964, *Catalog of Hanford Buildings and Facilities*, General Electric, Hanford Atomic Products Operation, Richland, Washington.

Gephart, R.E., R.C. Arnett, R.G. Baca, L.S. Leonhart, and F.A. Spane Jr., 1979, *Hydrologic Studies Within the Columbia Plateau, Washington: An Integration of Current Knowledge*, RHO-BWI-ST-5, Rockwell Hanford Operations, Richland, Washington.

Graham, J.J., 1983, *Hydrogeochemical and Mathematical Analysis of Aquifer Intercommunication, Hanford Site, Washington State*, Indiana University, Bloomington, Indiana.

Graham, M.J., M.D. Hall, S.R. Strait, and W.R. Brown, 1981, *Hydrology of the Separations Area*, RHO-ST-42, Rockwell Hanford Operations, Richland, Washington.

Grazulis, T.P., 1984, *Violent Tornado Climatology, 1880-1982*, NUREG/CR-3670, U.S. Nuclear Regulatory Commission, Washington, D.C.

Greene, G.S., 1975, "Prehistoric Utilization of the Channeled Scablands of Eastern Washington", Ph.D. Dissertation, Washington State University, Department of Anthropology, Pullman, Washington.

Greengo, R.E., 1982, *Studies in Prehistory: Priest Rapids and Wanapum Reservoir Areas, Columbia River, Washington*, University of Washington, Department of Anthropology, Pullman, Washington.

Hajek, B.F., 1966, *Soil Survey: Hanford Project in Benton County, Washington*, BNWL-243, Battelle Northwest Laboratories, Richland, Washington.

Hawkins, E.T., E.A. Ryan, and S.L. Santos, 1990, "Assessing Risk from Dermal Exposure at Hazardous Waste Sites", in *New Risks*, Cox, L.A.Jr., and P.F. Ricci, editors, Plenum Press, New York, New York.

Hoover, J.D., and T. LeGore, 1991, *Characterization and Use of Soil and Groundwter Background for the Hanford Site*, WHC-MR-0246, Westinghouse Hanford Company, Richland, Washington.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko, 1991, *Handbook of Environmental Degradation Rates*, Lewis Publishers, Inc., Chelsea, Michigan.

HSDB Scientific Review Panel, 1993-1994, *Hazardous Substance Data Bank*, National Library of Medicine Toxicological Data Network (TOXNET), Bethesda, Maryland.

Hulstrom, L.C., 1992, *Climatological Summary of the 300 Area for the 300-FF-1 Operable Unit Remedial Investigation*, WHC-SD-EN-TI-005, Westinghouse Hanford Company, Richland, Washington.

IAEA, 1992, *Effects on Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*, STI/DOC/10/332, Technical Report Series 332, International Atomic Energy Agency, Vienna, Austria.

ICRP, 1959, "Report of ICRP Committee II on Radiological Protection", in *ICRP Publication 2*, International Commission on Radiological Protection, Pergamon Press, New York, New York.

Isaacson, R.E., L. E. Brownell, and J. C. Hanson, 1974, *Soil Moisture Transport in Arid Site Vadose Zones*, ARH-2983, Atlantic Richfield Hanford, Richland, Washington.

IT Corporation, 1993a, *Limited Field Investigation Report for the 100-BC-1 Operable Unit*, DOE/RL-93-06, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

IT Corporation, 1993b, *Limited Field Investigation Report for the 100-HR-1 Operable Unit*, DOE/RL-93-51, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Jamison, J.D., 1982, *Standardized Input for Hanford Environmental Impact Statements Part II: Site Descriptions*, PNL-3509, Pt 2, Pacific Northwest Laboratory, Richland, Washington.

Jaquish, R.E., and P.J. Mitchell, editors, 1988, *Environmental Monitoring at Hanford for 1987*, PNL-6464, Pacific Northwest Laboratory, Richland, Washington.

Jaquish, R.E., and R.W. Bryce, editors, 1990, *Hanford Site Environmental Report for Calendar Year 1989*, PNL-7346, Pacific Northwest Laboratory, Richland, Washington.

Jones, T.L., 1978, *Sediment Moisture Relations Lysimeter Project 1976-1977 Water Year*, RHO-ST-15, Rockwell Hanford Operations, Richland, Washington.

Kasza, G.L., M.J. Hartman, F.N. Hodges, and D.C. Weekes, 1992, *Ground Water Maps of the Hanford Site, December 1991*, WHC-EP-0394-4, Westinghouse Hanford Company, Richland, Washington.

Kipp, K.L., and R.D. Mudd, 1973, *Collection and Analysis of Pump Test Data for Transmissivity Values*, BNWL-1709, Pacific Northwest Laboratory, Richland, Washington.

Klepper, E.L., L.E. Rogers, J.D. Hedland, and R.G. Schreckhise, 1979, *Radioactivity Associated with Biota and Soils of the 216-A- 24 Crib*, PNL-1948, Pacific Northwest Laboratory, Richland, Washington.

Kocher, A.E., A.T. Strahorn, and M.H. Lapham, 1921, *Soil Survey of Benton County, Washington*, U.S. Department of Agriculture, Bureau of Soils, Washington, D.C.

Landeen, D.S., A.R. Johnson, and R.M. Mitchell, 1992, *Status of Birds at the Hanford Site in Southeastern Washington*, WHC-EP-0402, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Last, G.V., B.N. Bjornstad, M.P. Bergeron, D.W. Wallace, D.R. Newcomer, J.A. Schramke, M.A. Chamness, C.S. Cline, S.P. Airhart, and J.S. Wilbur, 1989, *Hydrogeology of the 200 Areas Low-Level Burial Grounds - An Interim Report*, PNL-6820, Pacific Northwest Laboratory, Richland, Washington.

Last, G.V., M.A. Glennon, M.A. Young, and G.W. Gee, 1987, *Protective Barrier Materials Analysis: Fine Soil Site Characterization*, PNL-6314, Pacific Northwest Laboratory, Richland, Washington.

Lauterbach, M.J., 1992, *Westinghouse Hanford Company Regulatory Strategy for Macroengineering Implementation*, WHC-SD-EN-EE-008, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Ledgerwood, R.K., C.W. Myers, and R.W. Cross, 1978, *Pasco Basin Stratigraphic Nomenclature*, RHO-BWI-LD-1, Rockwell Hanford Operations, Richland, Washington.

Leonhardy, F.C., and D.G. Rice, 1970, "Proposed Culture Typology for the Lower Snake River Region, Southeastern Washington", in *Northwest Anthropological Resource Notes*, 4, pp. 1-29.

Lindberg, J.W., 1994, *Geology of the McGee Ranch Site, Area B: Phase II Characterization*, WHC-SD-EN-TI-206, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K.A., 1991, *Revised Stratigraphy for the Ringold Formation, Hanford Site, South Central Washington*, WHC-SD-EN-EE-004, Westinghouse Hanford Company, Richland, Washington.

Lindsey, K.A., B.N. Bjornstad, J. W. Lindberg, and K. M. Hoffman, 1992, *Geologic Setting of the 200 East Area: An Update*, WHC-SD-EN-TI-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Ludowise, J.D., 1994, *Vitrification Testing of Soil Fines from Contaminated Hanford 100 Area and 300 Area Soils*, WHC-SD-EN-TI- 240, Westinghouse Hanford Company, Richland, Washington.

Lyman, W.J., W.F. Reehl, and D.H. Rosenblatt, 1990, *Handbook of Chemical Property Estimation Methods - Environmental Behavior of Organic Compounds*, American Chemical Society, Washington, D.C.

Montgomery, J.H., and L.M. Welkom, 1990, *Groundwater Chemicals Desk Reference*, Lewis Publishers, Chelsea, Michigan.

Myers, C.W., S.M. Price, J.A. Caggiano, M.P. Cochran, W.H. Czimer, N.J. Davidson, R.C. Edwards, K.R. Fecht, G.E. Holmes, M.G. Jones, J.R. Kunk, R.D. Landon, R.K. Legerwood, J.T. Lillie, P.E. Long, T.H. Mitchell, E.H. Price, S.P. Reidel, and A.M. Tallman, 1979, *Geologic Studies of the Columbia Plateau: A Status Report*, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.

Napier, B.A., 1982, *Method for Determining "Allowable Residual Contamination Levels" of Radionuclide Mixtures in Soils*, PNL-3852, Pacific Northwest Laboratory, Richland, Washington.

National Academy of Science (NAS), 1977, "Drinking Water and Health", National Research Council, Washington, D.C., pp. 22-55.

NCRP, 1985, *Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment*, National Council on Radiation Protection and Measurements NCRP Report No. 76, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

Newcomb, R.C., J.R. Strand, and F.J. Frank, 1972, *Geology and Ground-Water Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington*, Professional Paper 717, U.S. Geological Survey, Denver, Colorado.

Newcomer, D.R., K.D. Pohlod, and J.P. McDonald, 1991, *Water-Table Elevations on the Hanford Site, 1990*, PNL-7693, Pacific Northwest Laboratory, Richland, Washington.

NPS, 1992, Draft, *Hanford Reach of the Columbia River, Comprehensive River Conservation Study and Environmental Impact Statement*, Draft, U.S. National Park Service, Seattle, Washington.

NRC, 1982, *Draft Environmental Statement Related to the Construction of Skagit/Hanford Nuclear Projects, Units 1 and 2*, NUREG-0894, U.S. Nuclear Regulatory Commission, Washington, D.C.

NRC, 1990, *Health Effects of Exposure to Low Levels of Ionizing Radiation (BEIR V)*, National Research Council, National Academy Press, Washington, D. C.

O'Farrell, T.P., R.E. Fitzner, and R.O. Gilbert, 1973, *Distribution of Radioactive Jackrabbit Pellets in the Vicinity of the B-C Cribs, 200 East Area, U. S. A. E. C. Hanford Reservation*, BNWL-1794, Pacific Northwest Laboratory, Richland, Washington.

Opresko, D.M., B.E. Sample, and G.W. Suter, 1993, *Toxicological Benchmarks for Wildlife*, ES/ER/TM-86, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

PNL, 1988a, *Environmental Monitoring at Hanford for 1987*, PNL-6464, Pacific Northwest Laboratory, Richland, Washington.

PNL, 1988b, *Hanford Site Groundwater Monitoring for April through June 1987*, PNL-6315-1, Pacific Northwest Laboratory, Richland, Washington.

Poole, L.D., 1992, *Reproductive Success and Nesting Habitat of Loggerhead Shrikes in Shrubsteppe Communities*, Master's Thesis, Oregon State University, Corvallis, Oregon.

PSPL, 1982a, *Skagit/Hanford Nuclear Project, Preliminary Safety Analysis Report*, Vol. 4, App. 2O, Amendment 23, Puget Sound Power and Light Company, Bellevue, Washington.

PSPL, 1982b, *Draft Environmental Statement Related to the Construction of Skagit/Hanford Nuclear Project, Unit 1 and 2*, Puget Sound Power & Light Company, Pacific Power and Light Company, Washington Water Power Company, and Portland General Electric Company, NUREG-0894, Nuclear Regulatory Commission, Washington, D.C.

Reiman, R.T., and T.S. Dahlstrom, 1990, *An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland, Washington*, EGG-10617-1062, EG&G Energy Measurements, Inc., Richland, Washington.

Relander, C., 1956, *Drummers and Dreamers*, Pacific Northwest National Parks and Forests Association, Seattle, Washington.

Rice, D.G., 1968a, *Archaeological Reconnaissance: Ben Franklin Reservoir Area, 1968*, Washington State University, Laboratory of Anthropology, Pullman, Washington.

Rice, D.G., 1968b, *Archaeological Reconnaissance: Hanford Atomic Works*, U.S. Atomic Energy Commission, National Park Service, Washington State University, Pullman, Washington.

Rice, D.G., 1980, *Overview of Cultural Resources on the Hanford Reservation in South Central Washington State*, U.S. Department of Energy, Richland, Washington.

Rice, D.G., 1984, *Archaeological Inventory of the Basalt Waste Isolation Project, Hanford Reservation, Washington*, SD-BWI-TA- 007, Rockwell Hanford Operations, Richland, Washington.

Richard, W.H., and D.G. Watson, 1985, "Four Decades of Environmental Change and Their Influence Upon Native Wildlife and Fish Along the Mid-Columbia River, Washington", *Environmental Conservation*, Vol. 12, pp. 241-248.

Rickard, W.H., and L.E. Rogers, 1983, "Industrial Land Use and the Conservation of Native Biota in the Shrub-Steppe Region of Western North America", *Environmental Conservation*, Vol. 10, pp. 205-211.

Rickard, W.H., R.E. Fitzner, and C.E.Cushing, 1981, "Biological Colonization of an Industrial Pond", *Environmental Conservation*, Vol. 8, pp. 241-247.

Rockhold, M.L., M.J. Fayer, G.W. Gee, and M.J. Kanyid, 1990, *Natural Groundwater Recharge and Water Balance at the Hanford Site*, PNL-7215, Pacific Northwest Laboratory, Richland, Washington.

Rogers, L.E., and W.H. Rickard, 1977, *Ecology of the 200 Area Plateau Waste Management Environs: A Status Report*, PNL-2253, Pacific Northwest Laboratory, Richland, Washington.

Rohay, A.C., 1989, "Earthquake Recurrence Rate Estimates for Eastern Washington and the Hanford Site", in *Proceedings, Second DOE Natural Phenomena Hazards Mitigation Conference*, CONF-8910192, U.S. Department of Energy, Office of Nuclear Safety.

Rose, K.S.B., 1992, "Lower Limits of Radiosensitivity in Organisms, Excluding Man", *Journal of Environmental Radioactivity*, Vol. 15, pp. 113-133.

Routson, R.C., M.R. Fuchs, and W.A. Jordan, 1988, *Recharge Estimates for the Hanford Sites 200 Areas Plateau*, WHC-EP-0046, Westinghouse Hanford Company, Richland, Washington.

Routson, R.C., and V.G. Johnson, 1990, "Recharge Estimates for the Hanford Site 200 Areas Plateau", *Northwest Science*, Vol. 64,

Sackschewsky, M.R., D.S. Landeen, G.I. Baird, W.H. Rickard, and J.L. Downs, 1992, *Vascular Plants of the Hanford Site*, WHC-EP-0554, Westinghouse Hanford Company, Richland, Washington.

Schalla, R., R.W. Wallace, R.L. Aaberg, S.P. Airhart, D.J. Bates, J.V.M. Carlile, C.S. Cline, D.I. Dennison, M.D. Freshley, P.R. Heller, E.J. Jensen, K.B. Olsen, R.G. Parkhurst, J.T. Rieger, and E.J. Westergard, 1988, *Interim Characterization Report for the 300 Area Process Trenches*, PNL-6716, Pacific Northwest Laboratory, Richland, Washington.

Schuler, C.A., W.H. Rickard, and G.A. Sargeant, 1988, *Bird Associations with Shrubsteppe Plant Communities at the Proposed Repository Location in Southeastern Washington*, PNL-6493, Pacific Northwest Laboratory, Richland, Washington.

Scott, M.J., D.B. Belzer, R.J. Nesse, R.J. Schultz, P.A. Stokowski, and D.C. Clark, 1987, *Economic and Community Impacts of Closing Hanford's N Reactor and Nuclear Materials Production Facilities*, PNL-6295, Pacific Northwest Laboratory, Richland, Washington.

Scott, M.J., D.B. Belzer, S.J. Marsh, D.M. Beck, R.W. Schultz, and S.A. Harkreader, 1989, *Hanford and the Tri-Cities Economy: Review and Outlook, March 1989*, PNL-6813, Pacific Northwest Laboratory, Richland, Washington.

SCS, 1960, *Soil Classification: A Comprehensive System, 7th Approximation*, U.S. Soil Conservation Service, Washington, D.C.

Serne, R.J., and M.I. Wood, 1990, *Hanford Waste-Form Release and Sediment Interaction: A Status Report with Rationale and Recommendations for Additional Studies*, PNL-7297, Pacific Northwest Laboratory, Richland, Washington.

Skaggs, E., and W.H. Walters, 1981, *Flood Risk Analysis of Cold Creek Near the Hanford Site*, RHO-BWI-C-120, PNL-4219, Rockwell Hanford Operations, Richland, Washington.

Skelly, W.A., and N.R. Wing, 1992, Site Evaluation Report for a Borrow Site Fine-Textured Soils, WHC-SD-EN-SE-002, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Spier, L., 1936, *Tribal Distribution in Washington*, General Services in Anthropology No. 3, George Banta Publishing Co., Menasha, Wisconsin.

SRC, 1991, *Toxicological Profile for Polychlorinated Biphenyls*, Syracuse Research Corporation for the Agency for Toxic Substances and Disease Registry, Atlanta, Georgia.

Stenner, R.D., K.H. Cramer, K.A. Higley, S.J. Jette, D.A. Lamar, T.J. McLaughlin, D.R. Sherwood, and N.E. Van Houten, 1988, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford*, PNL-6456, Pacific Northwest Laboratory, Richland, Washington.

Stone, W.A., J.M. Thorpe, O.P. Gifford, and D.J. Hoitink, 1983, *Climatological Summary for the Hanford Area*, PNL-4622, Pacific Northwest Laboratory, Richland, Washington.

Suter II, G.W., 1993, *Ecological Risk Assessment*, Lewis Publishers, Chelsea, Michigan.

Tallman, A.M., K.R. Fecht, M.C. Marratt, and G.V. Last, 1979, *Geology of the Separation Areas, Hanford Site, South-Central Washington*, RHO-ST-23, Rockwell Hanford Operations, Richland, Washington.

Terres, J.K., 1980, *Audubon Society Encyclopedia of North American Birds*, Alfred A. Knopf, New York, New York.

Tipton, W.J., 1975, *An Aerial Radiological Survey of the U.S. Energy Research and Development Administration Hanford Reservation*, EGG-1183-1661, Energy Research and Development Administration, Washington, D.C.

Tolan, T.L., S.P. Reidel, M.H. Beeson, J.L. Anderson, K.R. Fecht, and D.A. Swanson, 1987, "Revisions to the Areal Extent and Volume of the Columbia River Basalt Group", *Geological Society of America Abstracts with Programs*, Vol. 19, pp. 458.

Trafzer, C.E., and R.D. Scheuerman, 1986, *Renegade Tribe: The Palouse Indians and the Invasion of the Inland Pacific Northwest*, Washington State University Press, Pullman, Washington.

Travis, C.C., and A.D. Arms, 1988, "Bioconcentration of Organics in Beef, Milk, and Vegetation", *Environmental Science & Technology*, Vol. 22, pp. 271-274.

U.S. Army Corps of Engineers, Walla Walla District, 1993a, *On-Site Transportation Network Engineering Study for the Environmental Restoration Storage and Disposal Facility*, DOE/RL/12074-12 Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. Army Corps of Engineers, Walla Walla District, 1993b, *Source Inventory Development Engineering Study for the Environmental Restoration Disposal Facility*, DOE/RL/12074-29 Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. Army Corps of Engineers, Walla Walla District, 1993c, *Engineering Study for the Conveyor and Area Fill Systems for the Environmental Restoration Disposal Facility*, DOE/RL/12074-15, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. Army Corps of Engineers, Walla Walla District, 1994, *Conceptual Design Report for the Environmental Restoration Storage and Disposal Facility*, DOE/RL/12074-28, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

U.S. Department of Commerce, 1991, *1990 U.S. Census of Population and Housing, State and County Profiles, Washington*, U.S. Department of Commerce, Office of Financial Management, Washington, D.C.

U.S. Department of Labor, 1992, *Occupational Injuries and Illnesses in the United States by Industry*, 1990, Bulletin 2399, U.S. Department of Labor, Bureau of Labor Statistics, Washington, D.C.

USGS, 1978, *Richland, Washington, 7.5 Minute Topographic Quadrangle*, Scale 1:24,000, U.S. Geological Survey, Denver, Colorado.

Washington National Heritage Program, 1994, Endangered, Threatened and Sensitive Vascular Plants of Washington, Washington State Department of Natural Resources, Olympia, Washington.

Washington State Department of Employment Security, 1993, *Labor Force and Employment in Washington State*, Washington State Department of Employment Security, Labor Market and Economic Analysis Branch, Olympia, Washington.

Watson, E.C., C.D. Becker, R.E. Fitzner, K.A. Gano, K.L. Imhoff, R.F. McCallum, D.A. Myers, T.L. Page, K.R. Price, J.V. Ramsdell, D.G. Rice, D.L. Schreiber, L.A. Skumatz, D.J. Sommer, J.J. Tawil, R.W. Wallace, and D.G. Watson, 1984, *Environmental Characterization of Two Potential Locations at Hanford for a New Production Reactor*, PNL-5275, Pacific Northwest Laboratory, Richland, Washington.

Weather Bureau, 1966, *Pan and Lake Evaporation*, from Weather Bureau Technical Paper No. 37, Weather Bureau.

Weekes, D.C., and J.V. Borghese, 1993, *Site Characterization Plan for the Environmental Restoration Disposal Facility*, WHC-SD-EN-AP-128, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Western States Land-Grant Universities and Colleges and SCS, 1964, *Soils of the Western United States*, Washington State University, Pullman, Washington.

WHC, 1989, *Preliminary Operable Units Designation Project*, WHC-EP-0216, Westinghouse Hanford Company, Richland, Washington.

WHC, 1991a, *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1990*, DOE-RL-91-03, U.S. Department of Energy, Richland, Washington.

WHC, 1991b, *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study, [Macroengineering study report]*, Predecisional draft, WHC-EP-0457.

WHC, 1991c, *300 Area Cleanup and Restoration Conceptual Study*, WHC-EP-0459, Draft, Westinghouse Hanford Company, Richland, Washington.

WHC, 1993, Environmental Technology Assessment [Internal Memo to F.V. Roeck, WHC] August 2, 1993

WHC, 1994a, *Siting Evaluation Report for the Environmental Restoration Disposal Facility*, WHC-SD-EN-EV-009, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994b, *Qualitative Risk Assessment for the 100-BC-1 Source Operable Unit*, WHC-SD-EN-RA-003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994c, *Qualitative Risk Assessment for the 100-DR-1 Source Operable Unit*, WHC-SD-EN-RA-005, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994d, *Qualitative Risk Assessment for the 100-HR-1 Source Operable Unit*, WHC-SD-EN-RA-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC, 1994e, *Qualitative Risk Assessment for the 100-KR-1 Source Operable Unit*, WHC-SD-EN-RA-009, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Wing, 1993, *Permanent Isolation Surface Barrier: Functional Performance*, WHC-EP-0650, Westinghouse Hanford Company, Richland, Washington.

Woodruff, R.K., and R.W. Hanf, 1992, *Hanford Site Environmental Report for Calendar Year 1991*, PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R.K., R.W. Hanf, M.G. Hefty, and R.E. Lundgren, 1991 Dec., *Hanford Site Environmental Report for Calendar Year 1990*, PNL-7930, Pacific Northwest Laboratory, Richland, Washington.

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APPENDIX A

FATE AND TRANSPORT MODELING

REFERENCE

DOE-RL, 1993, *Hanford Site Baseline Risk Assessment Methodology*, DOE/RL 91-45, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

WHC, 1993, *Screening Performance Assessment/Risk Assessment for the Proposed Environmental Restoration Disposal Facility (ERDF)*, WHC-SD-EN-TI-201, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

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FIGURES:

TABLES:

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TABLES (cont.):

A.1 INTRODUCTION

This appendix describes the modeling conducted to identify the contaminants of potential concern (COPC) and predict the performance of the alternatives regarding future impacts on groundwater. An analytical model is developed to predict the groundwater concentration of each compound detected above soil background at the 100 and 300 Areas operable units. The predicted groundwater concentration of the compound is evaluated against Hanford Site groundwater background concentration and risk-based screening concentration. If the predicted groundwater concentration exceeds both the Hanford Site groundwater background concentration and the risk-based screening concentration, the compound is identified as a COPC. Those identified COPC are further evaluated in the risk assessment to identify contaminants of concern (COC). Groundwater concentrations for the COC are modeled for each of the disposal design alternatives for the proposed ERDF facility. As discussed in Chapter 9, design alternatives differ by barrier type and liner type. Performance is measured in terms of maximum risk and travel time at the facility boundary. This appendix describes the analytical approach for calculation of maximum constituent concentrations in groundwater and travel times to the compliance points. Results of the simulations are also provided.

A.2 MODEL FORMULATION

A.2.1 General Approach

Analytical approximations previously described in WHC (1993) are used to approximate maximum concentrations in groundwater at the ERDF boundary for each constituent of interest. This approximate approach attempts to consider all major controlling processes, while still remaining analytically tractable. The equations described in the following sections are implemented in a spreadsheet model. In order to evaluate system performance using the analytical approximations described below, the following major assumptions have been made:

- The media are homogenous and isotropic with no layering.
- All input parameters are time invariant (although decay is accounted for).
- Discrete disruptive events (such as earthquakes, volcanic activity, or human intrusion) or gradual deterioration (such as erosion) which may affect the facility are not considered.
- All travel time calculations assume plug flow (i.e., no longitudinal dispersion).
- No leachate leaks through the liner as long as leachate is pumped from the trench. This period of leachate pumping is referred to as the operational period.
- The synthetic materials in the liners are expected to deteriorate or breach relatively rapidly and are not included in the simulated liners beyond the operational period.

- Climatic conditions are assumed to remain the same over the duration of the simulations.

Additional assumptions are discussed in subsequent sections.

The model is based on travel time and it accounts for horizontal dilution in the vadose zone and vertical dilution in the saturated zone. The algorithm presented below relies on a stepwise approach to simulate migration from the waste to groundwater at the ERDF boundary. The four points at which concentrations are computed are shown in Figure A-1. C_0 is the initial leachate concentration at the bottom of the waste. C_1 is the maximum leachate concentration at the base of the trench (below the liner, if present); C_2 is the maximum groundwater concentration at the water table (before mixing in the saturated zone); and C_3 is the maximum groundwater concentration in the saturated zone at the facility boundary. C_0 is calculated based on the waste release mechanisms discussed below. C_1 is then computed as a function of C_0 and transport through the liner. C_2 is computed as a function of C_1 and transport through the vadose zone. C_3 is computed as a function of C_2 and transport in the saturated zone.

A.2.2 Source Concentration (C_0)

Previous modeling using this screening approach for comparing alternative ERDF designs incorporated waste release mechanisms appropriate for grouted and vitrified waste (WHC 1993). These mechanisms, which include waste dissolution and diffusional release, are not addressed in this discussion since only untreated waste is simulated.

For untreated waste, it is assumed that C_0 is controlled by the solubility of the contaminant, the amount of contamination in the waste soil, and the partition coefficient between water and soil for the contaminant. Assuming that the contaminant has reached equilibrium between the soil and pore water, C_0 can be computed as follows:

$$C_0 = \mathrm{MIN}\left[\frac{M_w}{(K_{d,w} + \frac{\theta_w}{\rho_w})}, C_{sol}\right] \qquad \text{(A-1)}$$

where:

M_w = concentration of contaminant in the waste (mg/kg);

$K_{d,w}$ = partition coefficient between the waste and infiltrating water (L/kg);

$\hat{\theta}_w$ = volumetric moisture content of the waste (unitless);

ρ_w = dry density of the waste (kg/L); and

C_{sol} = solubility of contaminant in water (mg/L).

This equation indicates that the concentration is controlled by the sorption equilibrium, with the constraint that the concentration can never exceed the solubility.

Given these assumptions, C_0 should decrease with time if the constituent degrades or decays. This is a reasonable approach given the large uncertainty associated with the radionuclide solubilities. For simplicity, the algorithm relies on the conservative assumption that the leachate is released at time zero with no decay. Furthermore, changes in solubility due to interactions with other waste constituents are not considered.

A.2.3 Concentration Directly Beneath the Facility (C_l)

C_l is computed directly as a function of C_0. Assuming plug-flow movement of mass through the liner material (i.e., no longitudinal dispersion), the following equation can be used:

$$C_l = C_0 e^{-\lambda t_l} \qquad \text{(A-2)}$$

where:

λ = decay coefficient (yr^{-1}), and
t_l = travel time through liner (yr).

This equation assumes no dilution; therefore, if the contaminant does not decay, $C_l = C_0$. The travel time through the liner, t_l, is computed by dividing the liner thickness by the advective transport velocity, and multiplying by the retardation factor:

$$t_l = \frac{L_l\left(1 + \frac{\rho_l}{\theta_l}K_{d,l}\right)}{\left(\frac{I_{FC}}{\theta_l}\right)} + t_{op} \qquad \text{(A-3)}$$

where:

L_l = liner thickness (m);

$K_{d,l}$ = partition coefficient between liner material and water for contaminant (L/kg);

ρ_l = bulk density of liner material (kg/L);

I_{FC} = infiltration rate through final cover (m/yr);

θ_l = moisture content of liner material (unitless);

t_{op} = duration of the operational period (yr).

This equation is based on the assumption that leachate is removed during the operational period and that no leakage occurs through the liner during this time. After the operational period, migration through the liner is determined by the advective transport velocity. The advective transport velocity is the rate of migration of a contaminant front assuming plug flow (no diffusion) and is calculated by dividing the rate of infiltration through the final cover by the moisture content.

Previous versions of this model (WHC 1993) also accounted for diffusion through the liner. Including diffusion through the liner could reduce the predicted constituent travel times for liners. Therefore, excluding diffusion means that the model results may over-estimate the benefits of liners. At the proposed ERDF site, travel time through a 1.0 m thick liner (assuming advective transport) is approximately 8 percent of the vadose zone travel time. Given the greater importance of vadose zone travel time, the advantage of accounting for diffusion through the liner is not warranted. Additional reasons to ignore this mechanism include the computational difficulties in simulating diffusion as a plug flow process and the lack of information regarding constituent-specific diffusion coefficients.

A.2.4 Concentration at the Water Table Directly Beneath the Facility (C_2)

C_2 is computed directly as a function of C_1. Assuming plug-flow movement of mass through the unsaturated zone (i.e., no longitudinal dispersion), the following equation can be used:

$$C_2 = DIL_2 C_1 e^{-\lambda t_2} \qquad \text{(A-4)}$$

where:

DIL_2 = dilution factor for unsaturated zone; and

t_2 = travel time through unsaturated zone (yr).

As illustrated in this equation, the contaminant concentration is affected by both decay and dilution.

The dilution factor and travel time depend on the hydrogeological behavior of the unsaturated zone. These factors are affected by the degree to which clean water infiltration beyond the horizontal limits of the trench (and the waste) mixes with the contaminated water infiltrating through the trench (and the waste). If we assume that there is no mixing, then the dilution factor, DIL_2, is equal to one and the travel time, t_2, is computed as follows:

$$t_2 = \frac{L_u \, \theta_u \left(1 + \frac{\rho_u}{\theta_u} K_{d,u}\right)}{I_{FC}} - \frac{t_{IC}(I_{IC} - I_{FC})}{I_{FC}} \qquad \text{(A-5)}$$

where:

L_u = unsaturated zone thickness beneath the trench (m);

$K_{d,u}$ = partition coefficient between unsaturated zone soils and water (L/kg);

ρ_u = bulk density of unsaturated zone material (kg/L); and

θ_u = average moisture content of the unsaturated zone (unitless).

t_{IC} = length of time until long-term infiltration rate is achieved (yr); and

I_{IC} = infiltration rate before final cover is completed (m/yr).

The first term of Equation A-5 is the travel time if the long-term infiltration rate through the final cover controls migration for the entire simulation. The second term of this equation accounts for infiltration that occurs before the final cover is completed. If the interim cover will perform similar to the final cover, this second term can be used to account for infiltration before the interim cover is installed.

The second term of Equation A-5 is normally only relevant for unlined facilities. For lined facilities, the infiltration before installation of the final cover will presumably be retained by the liner (and pumped out) and will not affect vadose zone migration. Elimination of the second term can be accomplished by setting either t_{IC} or I_{IC} to zero.

Assuming some mixing between the contaminated infiltration and clean water infiltrating through the unsaturated zone, the dilution factor and travel time are computed as follows:

$$DIL_2 = \frac{I_{FC}\, w_b}{I_{FC}\, w_b + I_s\, w_s\, f_{mix}} \qquad \text{(A-6)}$$

and

$$t_2 = \left[\frac{\theta_u(d_m - d_t)}{I_{FC}} + \frac{\theta_u(d_u - d_m)}{I_{ave}}\right]\left[1 + \frac{\rho_u}{\theta_u}K_{d,u}\right] - \frac{t_{IC}(I_{IC} - I_{FC})}{I_{FC}} \qquad \text{(A-7)}$$

where:

$$I_{ave} = \frac{I_{FC}w_b + I_s w_s}{w_b + w_s} \qquad \text{(A-8)}$$

and

I_{ave} = average infiltration rate through unsaturated zone (m/yr);

I_s = average infiltration rate outside the areal extent of the waste (m/yr);

w_b = upper trench width (m);

d_t = depth of trench (m);

d_m = mixing depth (m);

d_u = depth to water table (m);

w_s = width of neighboring clean infiltration zone (m); and

f_{mix} = mixing factor (unitless fraction between 0 and 1).

The mixing factor, f_{mix}, quantifies the degree of mixing in the vadose zone between contaminated leachate and uncontaminated water that infiltrates outside the areal extent of the waste. If $f_{mix} = 0$, there is no mixing; if $f_{mix} = 1$, there is complete mixing. The mixing depth represents the point in the vadose zone where mixing occurs between contaminated infiltration and clean infiltration. Conceptually, this depth corresponds to a lithologic contrast where horizontal migration would likely occur. The travel time calculation assumes that the migration rate is determined by the barrier infiltration rate above the mixing depth and by the weighted average of the barrier and natural infiltration rates below the mixing depth. As a result, the travel time is reduced as the mixing depth moves closer to the bottom of the trench. In contrast, the dilution due to mixing is the same no matter what the mixing depth. In reality, any dilution and increased migration rates due to infiltration outside the foot print of the barrier will likely occur in multiple increments at distinct lithologic changes. The simplified approach utilized in this exercise is sufficient considering that the compliance point is in the saturated zone.

A.2.5 Concentration in Groundwater at the ERDF Boundary (C_3)

C_3 is computed directly as a function of C_2. Assuming plug-flow movement of mass through the saturated zone (i.e., no longitudinal dispersion), the following equation can be used:

$$C_3 = DIL_3 C_2 e^{-\lambda t_3} \quad \text{(A-9)}$$

where:

DIL_3 = dilution factor for saturated zone; and

t_3 = travel time through saturated zone (yr).

As illustrated in this equation, the contaminant concentration is affected by both decay and dilution.

The dilution factor and travel time depend on the hydrogeological behavior of the saturated zone. In particular, the dilution factor is determined by the extent that contaminated water at the surface of the aquifer is mixed with deeper clean water. This is, to a large extent, dependent on the assumptions made regarding the depth and pumping rate of the well through which individuals are exposed to concentration C_3. In this exercise, we assume DIL_3 is computed as follows:

$$DIL_3 = \frac{L_b \left(I_{FC}\, w_b + I_s\, w_s\, f_{mix}\right)}{\left(w_b + w_s\right) K\, i\, d_{mix} + L_b \left(I_{FC}\, w_b + I_s\, w_s\, f_{mix}\right)} \qquad \text{(A-10)}$$

where:

L_b = trench length (m);

K = hydraulic conductivity of saturated zone (m/yr);

i = hydraulic gradient of saturated zone (unitless); and

d_{mix} = mixing depth in saturated zone (m), generally assumed to be a minimum well screen length.

The travel time through the saturated zone is computed as follows:

$$t_3 = \frac{L_s\, n_s \left(1 + \frac{\rho_s}{n_s} K_{d,s}\right)}{K\, i} \qquad \text{(A-11)}$$

where:

L_s = travel distance in the saturated zone (m);

$K_{d,s}$ = partition coefficient between saturated zone material and water (L/kg);

ρ_s = bulk density of saturated zone material (kg/L);

n_s = effective porosity of saturated zone (unitless);

K = effective hydraulic conductivity of saturated zone (m/yr); and

i = hydraulic gradient in saturated zone (unitless).

A.2.6 Source Depletion Time

Source depletion time is defined as the period of time necessary to completely leach a constituent out of the waste. Assuming plug-flow migration of contaminant mass through the soil, the source depletion time, t_b, can be computed as follows:

$$t_b = \frac{\rho_w\, d_t\, M_w}{I_{FC}\, C_0} \qquad \text{(A-12)}$$

A.2.7 Exposure Assessment and Risk Characterization

Lifetime incremental cancer risk (ICR) and hazard quotient (HQ, an indicator of non-carcinogenic toxic effects) are calculated based on concentrations of the contaminants at the compliance point. Expressing performance in terms of risk allows combining the effects of multiple contaminants into two parameters (ICR and HQ) and also illustrates the general magnitude of potential health effects due to the ERDF. Risk calculations were performed using the approach described in the Hanford Site Baseline Risk Assessment Methodology (DOE-RL 1993) and presented in Chapter 5 of this report.

A.3 SIMULATION FOR BASE CONDITIONS SCENARIO

The base conditions scenario, described in Chapter 4, predicts groundwater concentrations resulting from an ERDF facility with no liner and a non-engineered barrier. Chemical specific parameters (initial concentrations, solubilities and K_d's) are provided in Chapter 4. Physical parameters used in this scenario are provided in Tables A-1, A-2, and A-3. HELP modeling results presented in Appendix B indicate that infiltration through a non-engineered soil barrier would be 0.035 cm/yr (0.014 in./yr) under current climate conditions (rainfall of 18 cm/yr [7.1 in./yr]), and 8.6 cm/yr (3.4 in./yr) under wetter climate conditions (rainfall of 40 cm/yr [16 in./yr]). Since future climate conditions are unknown, a conservative (compared to current conditions) barrier infiltration of 0.5 cm/yr (0.2 in./yr) was used for this base conditions scenario. Additional infiltration associated with the operational period is not included in the base conditions scenario. The effects associated with the operational period would be minimal considering that the operational infiltration rate of 3 cm/yr (1.2 in./yr) for five years would only shorten vadose zone travel times by 25 years (compared with a minimum vadose zone travel time of 520 years).

The predicted concentrations are compared to background groundwater concentrations and risk-based de minimis concentrations in Chapter 4 to reduce the list of potential contaminants carried into Chapter 5. The predicted concentrations are then compared to risk-based and ARAR-based screening concentrations in Chapter 5 to identify potential contaminants of concern. Finally, the predicted concentrations are used again in Chapter 6 to conduct the base conditions risk assessment.

Results for the base conditions scenario are presented in Tables A-4 for organic compounds, A-5 for radionuclides, A-6 for metal constituents, and A-7 for general chemistry constituents (primarily anions). The conservative biases in the analysis are discussed in Chapter 6.

A.4 SIMULATIONS FOR REMEDIAL ALTERNATIVES

This section provides predicted groundwater concentrations and associated risk estimates for each of the remedial alternatives (except no-action) and the base conditions scenario described in the previous section. In contrast to the simulation in Section A.3, which included all the identified soil contaminants, simulations in this section only include the constituents of potential concern (identified in Chapter 5). The simulated remedial alternatives, as well as the liner and surface barrier parameters, are described in Chapter 9. General parameters are provided in Table A-1, and the constituent-specific parameters are provided in Tables 4-2 through 4-8. Barrier and liner parameters used in the simulations are presented in Tables A-2 and A-3, respectively. Note that increased infiltration during the operational time period is included.

For the purposes of the simulations presented in this section, it was assumed that the waste would not generate leachate concentrations that exceeded the acceptable leachate limits described in Appendix C for a HQ of 1 and an ICR of $1x10^{-5}$. This was accomplished by ensuring that the input solubility did not exceed the leachate limits. Note that the leachate limits were calculated assuming the base conditions scenario. In addition, the risk-based criteria were determined using the minimum risk-based concentration for the ingestion and inhalation pathways. The combined effects from both pathways were not included in the waste acceptance criteria. Because the arsenic concentration that corresponds to an ICR of 10^{-5} (4.1×10^{-4} mg/L) is less than Hanford Site background (0.01 mg/L 95/95 UTL), the leachate limit for arsenic is equal to the background concentration. Since this criterion represents background conditions, arsenic is not included in the simulations.

Similar to the results presented in Section A.3 for the baseline scenario, these simulations result in predicted groundwater concentrations. In addition, the hazard quotients (HQ) and incremental cancer risks (ICR) associated with these concentrations are determined. The methodologies for calculating HQs and ICRs, as well as the conversion factors, are discussed in Chapter 6. These conversion factors account for both exposure pathways, ingestion and inhalation; this contrasts with the methodology used to determine the acceptable leachate limits which only includes the dominant pathway. The results presented below, which include both current climate conditions and hypothetical wetter climate conditions, are used in Chapter 9 to assist the detailed evaluation of long-term effectiveness for each of the alternatives.

A.4.1 Results for Current Climate Conditions

Infiltration rates through the barriers are based on HELP modeling results provided in Appendix B and are summarized in Chapter 9. In general, the HELP results indicate that infiltration through all three engineered barriers is very close to zero. Given uncertainties in the results, however, a conservatively high infiltration rate of 0.01 cm/yr (0.004 in./yr) was used for the low-infiltration soil barrier, the modified Hanford barrier, and the Hanford Barrier. Results for the base conditions scenario (assuming an infiltration rate of 0.5 cm/yr [0.2 in./yr]) as well as the nine alternatives are discussed below.

Base Conditions Scenario. The base conditions scenario presented in this section is the same as in Section A.3 except only constituents of potential concern are simulated, the input solubilities are limited by the acceptable leachate limits, and the effects of increased infiltration during the operational time period are included. The results for the base conditions scenario (non-engineered barrier and no liner) are provided in Table A-8. As discussed above, acceptable leachate limits were determined using only the dominant exposure pathway (ingestion in all cases), while these results account for both pathways. As a result, some of the calculated HQ's and ICR's for individual contaminants are slightly greater than the risk-based criteria of 1 for HQ and $1x10^{-5}$ for ICR. The most significant deviation is the ICR of $1.03x10^{-5}$ for uranium.

The risk drivers under this scenario are carbon-14, technetium-99, and uranium for the ICR and all the metals for the HQ. Summing the results for each constituent results in a total

ICR of $3x10^{-5}$. The maximum HQ is 1 for antimony. The travel time to the ERDF boundary for all the constituents is 520 years.

No-Liner Alternatives. Because infiltration rates for the low-infiltration soil barrier, the modified Hanford barrier, and the Hanford Barrier are predicted to be the same, the results for Alternatives 2, 3, and 4 (provided in Table A-9) are identical. When an engineered barrier is included in the remedial alternative, the ICRs and HQs drop by approximately two orders of magnitude for each constituent compared to the base conditions scenario except that the ICR of Carbon-14 drops by about three orders of magnitude. The risk drivers under this scenario are technetium-99 and uranium for the ICR (the ICR for carbon-14 is reduced due to decay) and all the metals except chromium (VI) for the HQ. Summing the results for each constituent results in a total ICR of $5x10^{-7}$. The maximum HQ is 0.02 for antimony and fluoride. The travel time to the ERDF boundary is 13,000 years. Therefore, the HQs and ICRs are zero for the 10,000-year time period.

Single-Liner Alternatives. Because infiltration rates for the low-infiltration soil barrier, the modified Hanford barrier, and the Hanford Barrier are the same, the results for Alternatives 5, 6, and 7 (provided in Table A-10) are identical. In comparison with the no-liner alternatives, the single liner increases travel time to the ERDF boundary in two ways:

- The increased infiltration during the operational time period is assumed to be retained by the single liner and pumped out. This adds approximately 2,200 years to the vadose zone travel time.

- The additional travel time through the liner is 710 years (these travel times include the 30 years of leachate removal).

The travel time to the ERDF boundary increases to 16,000 years. Although this additional travel time reduces the risk for decaying contaminants, the constituents that remain have such long half-lives that the effect is negligible. In comparison with the no-liner alternatives, the ICRs and HQs for the single-liner alternatives are essentially the same.

Double-Liner Alternatives. Because infiltration rates for the low-infiltration soil barrier, the modified Hanford barrier, and the Hanford Barrier are the same, the results for Alternatives 8, 9, and 10 (provided in Table A-11) are identical. Due to its greater thickness, the double liner results in a greater liner travel time compared with the single-liner alternatives. The travel time to the ERDF boundary increases to 17,000 years (these travel times include the 30 years of leachate removal). Although this additional travel time reduces the risk for decaying contaminants, the constituents that remain have such long half-lives that the effect is negligible. In comparison with the no-liner alternatives, the ICRs and maximum HQs for the double-liner alternatives are essentially the same.

A.4.2 Results for Hypothetical Wetter Climate Conditions

These simulations provide information regarding risk and travel time if the rate of infiltration increases due to a climate change or irrigation. Infiltration rates through the barriers under wetter climate conditions are based on HELP modeling results for Spokane climate (40 cm/yr [16 in/yr] of precipitation) provided in Appendix B and summarized in Chapter 9. In general, the HELP results indicate that the wetter climate increases infiltration rates through all four barriers, and the non-engineered soil cover and the low-infiltration soil barrier allow more infiltration than the modified Hanford barrier or the Hanford Barrier. These simulations use an infiltration rate of 9 cm/yr (3.7 in/yr) for the non-engineered soil cover, 5 cm/yr (2 in./yr) for the low-infiltration soil barrier, and 0.4 cm/yr (0.16 in./yr) for the modified Hanford and Hanford barriers.

Although this rate of water application is less than that associated with a typical irrigation rate, it turns out that the infiltration rate through the Hanford and modified Hanford barriers does not increase as the precipitation rate increases. This is because the rate of infiltration is limited by the permeability of the asphalt ($1x10^{-8}$ cm/sec). Because the low-infiltration soil barrier has no asphalt, the rate of infiltration does increase as precipitation increases. Since risk levels are already above CERCLA standards (see results below) the final conclusions are not significantly affected.

It is unreasonable to assume climate changes or irrigation would occur at time zero (when the facility is closed). Therefore, it was assumed that the infiltration rate for the first 100 years would be the same as the current climate assumptions (0.5 cm/yr [0.2 in./yr] for the base conditions scenario and 0.01 cm/yr [0.004 in./yr] for the engineered barrier alternatives). The wet climate infiltration rates were assumed to begin at a time of 100 years. Due to limitations of the spreadsheet model, infiltration before installation of the cover was not included in the wet climate scenarios.

For the base conditions scenario and alternatives that include the low-infiltration soil barrier, the travel times are less than the travel times calculated in the simulations used to screen constituents (see Section A.3). As a result, it was necessary to simulate the full un-screened list of constituents. Although the full list of constituents was simulated, only those constituents with predicted groundwater concentrations above the di-minimis values discussed in Section 4.3 and travel times less than 10,000 years are reported below. The additional constituents include neptunium-237, tritium (H-3), beta-BHC, chloroform, 1,2-dichloroethane, and xylenes.

Base Conditions Scenario. Results for the base conditions Scenario (no liner and a non-engineered soil cover) under wetter conditions are provided in Table A-12. Compared with results for the base conditions scenario under current conditions (Table A-8), the greater infiltration rate under wetter conditions reduces the travel time to the ERDF boundary and the amount of dilution in the saturated zone. The minimum travel time to the ERDF boundary is reduced from 520 years to 130 years. The risk drivers for this scenario are carbon-14, technetium-99, tritium, uranium, and beta-BHC for ICR, and all metals and anions for HQ. Summing the results for each constituent results in a total ICR of $9x10^{-4}$. The maximum HQ is 9 for antimony.

Alternative 2. Results for Alternative 2 (no liner and the low-infiltration soil barrier) under wetter conditions are provided in Table A-13. Compared with results for Alternative 2 under current conditions (Table A-9), the greater infiltration rate under wetter conditions reduces the travel time to the ERDF boundary and reduces the amount of dilution in the saturated zone. The travel time to the ERDF boundary ranges from 150 (e.g., for carbon-14) to 5,400 years (e.g., for beta-BHC).

The risk drivers for this alternative are carbon-14, technetium-99, tritium, uranium, and beta-BHC for ICR, and all the metals and anions for HQ. Summing the results for each constituent results in a total ICR of $3x10^{-4}$. The maximum HQ is 7 for antimony.

Alternatives 3 and 4. Alternatives 3 (no liner and the modified Hanford barrier) and 4 (no liner and the Hanford Barrier) have exactly the same results for wetter conditions (shown in Table A-14) since the modified Hanford and Hanford barriers have the same infiltration rates. Compared with results for these alternatives under current conditions (Table A-9), the greater infiltration rate under wetter conditions reduces the travel time to the ERDF boundary and reduces the amount of dilution in the saturated zone. The travel time to the ERDF boundary ranges from 500 yr (e.g., for carbon-14) to 42,000 yr (e.g., for beta-BHC).

The risk drivers for these alternatives are carbon-14, technetium-99, and uranium for ICR, and all the metals and anions for HQ. Summing the results for each constituent results in a total ICR of $2x10^{-5}$ within 10,000 years. The maximum HQ is 0.8 for antimony.

Alternative 5. Results for Alternative 5 (single liner and the low-infiltration soil barrier) under wetter conditions are provided in Table A-15. Compared with results for Alternative 5 under current conditions (Table A-10), the greater infiltration rate under wetter conditions reduces the travel time to the ERDF boundary and reduces the amount of dilution in the saturated zone. The travel time to the ERDF boundary is from 150 yr (e.g., for carbon-14) to 5,500 yr (e.g., for beta-BHC).

The risk drivers for this scenario are carbon-14, technetium-99, uranium, and beta-BHC for ICR, and all the metals and anions for HQ. Summing the results for each constituent results in a total ICR of $2x10^{-4}$. The maximum HQ is 7 for antimony. Due to the short source depletion time of tritium (18 yr), the tritium was completely pumped out by the leachate collection system in the liner before it leached out of trench.

Alternatives 6 and 7. Results for Alternatives 6 (single liner and the modified Hanford barrier) and 7 (single liner and the Hanford Barrier) are shown in Table A-16. These alternatives have exactly the same results because the modified Hanford and Hanford barriers have the same infiltration rates. Compared with results for these alternatives under current conditions (Table A-10), the greater infiltration rate under wetter conditions reduces the travel time to the ERDF boundary and reduces the amount of dilution in the saturated zone. Compared with the results for comparable no-liner alternatives (Alternatives 3 and 4) under wetter conditions, the travel times for these alternatives are increased slightly by the presence of the liner. The minimum travel time to the ERDF boundary for these alternatives is 520 yr. Although this additional travel time reduces the risk for decaying contaminants, the constituents that remain have such long half-lives that the effect is negligible. In comparison with the no-liner alternatives, the total ICRs and HQs for the single-liner alternatives are essentially the same.

The risk drivers for these alternatives are carbon-14, technetium-99, and uranium for ICR, and all the metals and anions for HQ. Summing the results for each constituent results in a total ICR of $2x10^{-5}$ within 10,000 years. The maximum HQ is 0.8 for antimony.

Alternative 8. Results for Alternatives 8 (double liner and the low infiltration soil barrier) under wetter conditions are provided in Table A-17. These results are essentially the same as for Alternative 5 except the travel time through the double liner is longer than the travel time through the single liner.

The risk drivers for this scenario are carbon-14, technetium-99, uranium, and beta-BHC for ICR, and all the metals and anions for HQ. Summing the results for each constituent results in a total ICR of $2x10^{-4}$. The maximum HQ is 7 for antimony.

Alternatives 9 and 10. The results for Alternatives 9 and 10 are provided in Table A-18. These alternatives have exactly the same results because the modified Hanford and Hanford barriers have the same infiltration rates. The results are essentially the same as for Alternatives 6 and 7 except the travel time through the double liner is longer than the travel time through the single liner.

The risk drivers for these alternatives are carbon-14, technetium-99, and uranium for ICR, and all the metals and anions for HQ. Summing the results for each constituent results in a total ICR of $2x10^{-5}$ within 10,000 years. The maximum HQ is 0.8 for antimony.

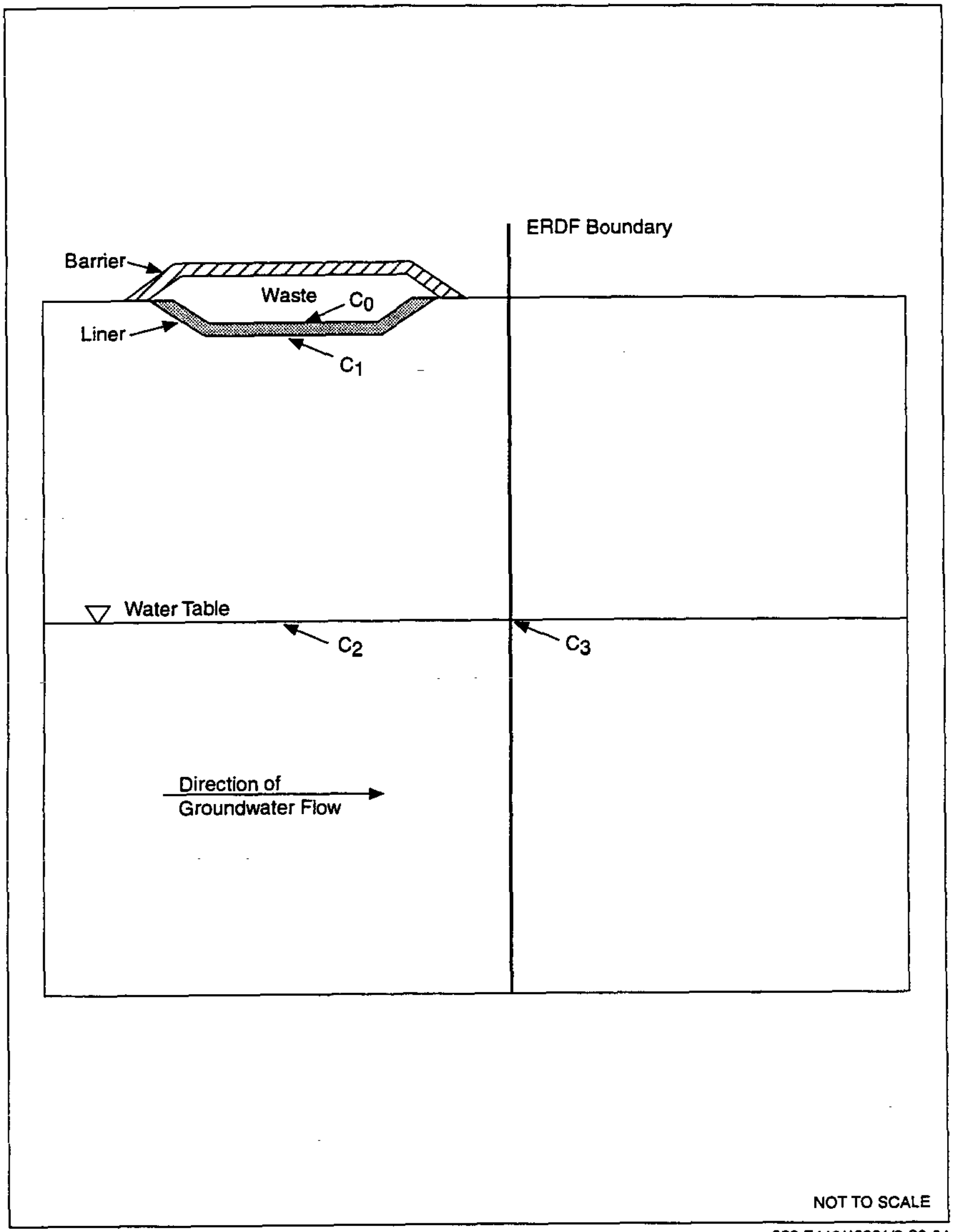

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Figure A-1. Locations of Compliance Points.

Table A-1. General Parameters Used for the ERDF Modeling.

Parameter	Value
Upper trench width, w_b (m)	420
Lower trench width, w_L (m)	300
Trench length, L_b (m)	3000
Trench depth, d_t (m)	20
Distance from edge of facility to nearest trench perpendicular to direction of groundwater flow, L_s (m)	100
Average moisture content of the unsaturated zone, θ_u (unitless)	0.045
Depth to water table from ground surface, d_u (m)	80
Vadose zone mixing depth, d_m (m)	50
Width of neighboring clean infiltration zone, w_s (m)	100
Vadose zone mixing factor, f_{mix}	0
Effective porosity of saturated zone, n_s (unitless)	0.3
Effective hydraulic conductivity of saturated zone, K (m/d)	30
Hydraulic gradient in saturated zone, i (unitless)	0.0035
Mixing depth in saturated zone, d_{mix} (m)	5
Soil or waste dry density, ρ_s, ρ_w (kg/L)	1.6
Average infiltration rate outside the boundaries of the facility (natural infiltration rate), I_t (cm/yr)	0.5 (under current climate) 9 (under wet climate)

Table A-2. Barrier Parameters Used in the Simulations.

	Current Climate	Wet Climate
Infiltration rate for base condition, I_{FC} (m/yr)	5E-3	9E-2
Infiltration rate for low infil. soil barrier, I_{FC} (m/yr)	1E-4	5E-2
Infiltration rate for modified Hanford barrier, I_{FC} (m/yr)	1E-4	4E-3
Infiltration rate for Hanford barrier, I_{FC} (m/yr)	1E-4	4E-3
Initial infiltration rate, I_{IC} (m/yr)	3E-2	5E-3 1E-4 (with barrier)
Length of time until long-term infiltration rate is achieved, t_{IC} (yr)	5	100

Table A-3. Liner Parameters Used in the Simulations.

	Single Liner	Double Liner
Liner thickness, L_l (m)	0.3	0.9
Bulk density of liner material, ρ_l (kg/L)	1.5	
Moisture content of liner material, θ_l (%)	22.5	
Duration of operation period, t_{op} (yr)	30	
K_d adjustment factor of liner material	5	

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Acenaphthene	Acetone	Anthracene	Aroclor-1248	Aroclor-1254	Aroclor-1260	Benzene
Bulk Soil Conc. = (mg/kg)	8.50E-01	2.80E+00	6.30E+00	1.00E+01	6.40E+00	2.30E+00	1.90E-01
Partitioning Coef. =	2.70E+00	0.00E+00	1.40E+01	4.40E+02	7.20E+02	2.30E+03	8.70E-02
Vadose Zone R =	9.70E+01	1.00E+00	4.99E+02	1.56E+04	2.56E+04	8.18E+04	4.09E+00
Saturated Zone R =	1.54E+01	1.00E+00	7.57E+01	2.35E+03	3.84E+03	1.23E+04	1.46E+00
Half-life	1.00E+00	1.00E+00	1.00E+01	1.00E+00	1.00E+04	1.00E+04	1.00E+01
Decay Rate =	6.93E-01	6.93E-01	6.93E-02	6.93E-01	6.93E-05	6.93E-05	6.93E-02
Solubility =	3.70E+00	1.00E+99	7.50E-02	5.00E-02	5.00E-02	8.00E-02	1.80E+03
Soil/Water Partition C0 =	3.12E-01	9.96E+01	4.49E-01	2.27E-02	8.89E-03	1.00E-03	1.65E+00
Leachate Conc.(C0)	3.12E-01	9.96E+01	7.50E-02	2.27E-02	8.89E-03	1.00E-03	1.65E+00
Vadose Travel Time(T2) =	5.24E+04	5.15E+02	2.69E+05	8.45E+06	1.38E+07	4.42E+07	2.19E+03
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	9.28E-154	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.69E-66
Sat. Travel Time(T3) = (Year)	1.21E+01	7.83E-01	5.92E+01	1.84E+03	3.01E+03	9.60E+03	1.15E+00
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	3.21E-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.48E-67

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Benzo(a)-anthracene	Benzo(a)-pyrene	Benzo(b)-fluoranthene	Benzo(g,h,i)-perylene	Benzo(k)-fluoranthene	Benzoic Acid	Beta-BHC
Bulk Soil Conc. = (mg/kg)	1.80E+00	2.70E+01	2.40E+00	3.70E+00	7.60E-01	1.30E+00	7.80E-03
Partitioning Coef. =	1.20E+03	2.90E+03	7.60E+02	5.00E+02	3.30E+03	0.00E+00	2.90E+00
Vadose Zone R =	4.27E+04	1.03E+05	2.70E+04	1.78E+04	1.17E+05	1.00E+00	1.04E+02
Saturated Zone R =	6.40E+03	1.55E+04	4.05E+03	2.67E+03	1.76E+04	1.00E+00	1.65E+01
Half-life	1.00E+01	1.00E+02	1.00E+01	1.00E+01	1.00E+02	1.00E+00	1.00E+04
Decay Rate =	6.93E-02	6.93E-03	6.93E-02	6.93E-02	6.93E-03	6.93E-01	6.93E-05
Solubility =	5.70E-03	4.00E-03	1.20E-03	2.60E-04	5.50E-04	2.90E+03	5.00E+00
Soil/Water Partition C0 =	1.50E-03	9.31E-03	3.16E-03	7.40E-03	2.30E-04	4.62E+01	2.66E-03
Leachate Conc.(C0)	1.50E-03	4.00E-03	1.20E-03	2.60E-04	2.30E-04	4.62E+01	2.66E-03
Vadose Travel Time(T2) =	2.30E+07	5.57E+07	1.46E+07	9.60E+06	6.34E+07	5.15E+02	5.62E+04
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.31E-154	5.42E-05
Sat. Travel Time(T3) = (Year)	5.01E+03	1.21E+04	3.17E+03	2.09E+03	1.38E+04	7.83E-01	1.29E+01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E-155	3.22E-06

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Bis(2-Ethylhexyl) Phthalate	Butanone-2	Butylbenzyl-phthaltate	Carbazole	Carbon Dissulfide	Carbon Tetrachloride	Chlordane, Gamma-
Bulk Soil Conc. = (mg/kg)	3.30E+01	3.90E-01	2.60E+00	5.40E-02	2.00E-01	8.00E-03	1.80E-02
Partitioning Coef. =	1.50E+01	1.00E-03	2.00E-01	7.00E+00	6.30E-02	2.90E-01	8.60E+00
Vadose Zone R =	5.34E+02	1.04E+00	8.11E+00	2.50E+02	3.24E+00	1.13E+01	3.07E+02
Saturated Zone R =	8.10E+01	1.01E+00	2.07E+00	3.83E+01	1.34E+00	2.55E+00	4.69E+01
Half-life	1.00E+01	1.00E+00	1.00E+00	1.00E+02	1.00E+00	1.00E+01	1.00E+01
Decay Rate =	6.93E-02	6.93E-01	6.93E-01	6.93E-03	6.93E-01	6.93E-02	6.93E-02
Solubility =	4.10E-02	3.53E+05	2.90E+00	2.20E+01	2.50E+03	7.70E+02	6.40E-01
Soil/Water Partition C0 =	2.20E+00	1.34E+01	1.14E+01	7.68E-03	2.19E+00	2.51E-02	2.09E-03
Leachate Conc.(C0)	4.10E-02	1.34E+01	2.90E+00	7.68E-03	2.19E+00	2.51E-02	2.09E-03
Vadose Travel Time(T2) =	2.89E+05	5.34E+02	4.36E+03	1.35E+05	1.72E+03	6.08E+03	1.66E+05
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	2.07E-160	0.00E+00	0.00E+00	0.00E+00	1.92E-185	0.00E+00
Sat. Travel Time(T3) = (Year)	6.34E+01	7.87E-01	1.62E+00	3.00E+01	1.05E+00	1.99E+00	3.67E+01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	7.14E-162	0.00E+00	0.00E+00	0.00E+00	9.96E-187	0.00E+00

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Chloro-3-Methylphenol, 4-	Chloroaniline, 4-	Chloroform	Chrysene	DDD-4,4	DDE-4,4'	Di - N - Butylphthalate
Bulk Soil Conc. = (mg/kg)	3.80E-02	6.30E+00	8.00E-02	4.30E+01	1.10E-01	1.70E-01	5.50E+00
Partitioning Coef. =	5.00E-02	8.10E-01	3.40E-02	3.80E+02	8.10E+01	5.00E+01	3.30E+00
Vadose Zone R =	2.78E+00	2.98E+01	2.21E+00	1.35E+04	2.88E+03	1.78E+03	1.18E+02
Saturated Zone R =	1.27E+00	5.32E+00	1.18E+00	2.03E+03	4.33E+02	2.68E+02	1.86E+01
Half-life	1.00E+00	1.00E+00	1.00E+01	1.00E+01	1.00E+02	1.00E+02	1.00E+00
Decay Rate =	6.93E-01	6.93E-01	6.93E-02	6.93E-02	6.93E-03	6.93E-03	6.93E-01
Solubility =	3.90E+03	3.90E+03	8.50E+03	1.50E-03	5.00E-02	5.50E-02	1.00E+01
Soil/Water Partition C0 =	4.86E-01	7.52E+00	1.29E+00	1.13E-01	1.36E-03	3.40E-03	1.65E+00
Leachate Conc.(C0)	4.86E-01	7.52E+00	1.29E+00	1.50E-03	1.36E-03	3.40E-03	1.65E+00
Vadose Travel Time(T2) =	1.48E+03	1.61E+04	1.17E+03	7.30E+06	1.56E+06	9.61E+05	6.39E+04
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	9.03E-36	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sat. Travel Time(T3) = (Year)	9.92E-01	4.16E+00	9.25E-01	1.59E+03	3.39E+02	2.10E+02	1.46E+01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	0.00E+00	5.03E-37	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Dibenzo(a,h) anthracene	Dibenzofuran	Dichloro-ethene-1,2	Dichloro-benzene-1,3	Dichloro-benzene-1,4	Dieldrin	Diethyl Phthalate
Bulk Soil Conc. = (mg/kg)	1.70E+00	5.00E-01	1.00E+00	4.80E-02	5.10E-02	2.10E-02	1.00E+00
Partitioning Coef. =	1.80E+03	5.50E+00	4.30E-02	2.90E-01	3.90E-01	7.40E+00	3.10E-01
Vadose Zone R =	6.40E+04	1.97E+02	2.53E+00	1.13E+01	1.49E+01	2.64E+02	1.20E+01
Saturated Zone R =	9.60E+03	3.03E+01	1.23E+00	2.55E+00	3.08E+00	4.05E+01	2.65E+00
Half-life	1.00E+01	1.00E+00	1.00E+01	1.00E+00	1.00E+00	1.00E+01	1.00E+00
Decay Rate =	6.93E-02	6.93E-01	6.93E-02	6.93E-01	6.93E-01	6.93E-02	6.93E-01
Solubility =	1.50E-03	1.00E+01	6.00E+02	6.90E+01	4.90E+01	9.00E-02	7.60E+02
Soil/Water Partition C0 =	9.44E-04	9.04E-02	1.41E+01	1.51E-01	1.22E-01	2.83E-03	2.96E+00
Leachate Conc.(C0)	9.44E-04	9.04E-02	1.41E+01	1.51E-01	1.22E-01	2.83E-03	2.96E+00
Vadose Travel Time(T2) =	3.46E+07	1.06E+05	1.34E+03	6.08E+03	8.00E+03	1.43E+05	6.47E+03
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	6.19E-40	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sat. Travel Time(T3) = (Year)	7.52E+03	2.37E+01	9.62E-01	1.99E+00	2.41E+00	3.17E+01	2.08E+00
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	0.00E+00	3.44E-41	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Ethylbenzene	Fluoranthene	Fluorene	Hexanone-2	Indeno(1,2,3-cd) pyrene	Methyl naphthalene-2	Methylene Chloride
Bulk Soil Conc. = (mg/kg)	3.30E-01	2.90E+00	1.70E+00	9.00E-03	1.60E+00	1.30E+01	4.50E+00
Partitioning Coef. =	1.60E-01	6.60E+01	5.00E+00	1.30E-01	2.00E+01	8.50E+00	3.70E-02
Vadose Zone R =	6.69E+00	2.35E+03	1.79E+02	5.62E+00	7.12E+02	3.03E+02	2.32E+00
Saturated Zone R =	1.85E+00	3.53E+02	2.77E+01	1.69E+00	1.08E+02	4.63E+01	1.20E+00
Half-life	1.00E+00	1.00E+01	1.00E+00	1.00E+00	1.00E+01	1.00E+00	1.00E+00
Decay Rate =	6.93E-01	6.93E-02	6.93E-01	6.93E-01	6.93E-02	6.93E-01	6.93E-01
Solubility =	1.40E+02	2.75E-01	1.40E+00	3.50E+04	6.20E-02	2.50E+01	2.00E+04
Soil/Water Partition C0 =	1.75E+00	4.39E-02	3.38E-01	5.69E-02	7.99E-02	1.52E+00	6.91E+01
Leachate Conc.(C0)	1.75E+00	4.39E-02	3.38E-01	5.69E-02	6.20E-02	1.52E+00	6.91E+01
Vadose Travel Time(T2) =	3.59E+03	1.27E+06	9.65E+04	3.01E+03	3.85E+05	1.64E+05	1.23E+03
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sat. Travel Time(T3) = (Year)	1.45E+00	2.76E+02	2.17E+01	1.33E+00	8.43E+01	3.63E+01	9.37E-01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Methoxychlor	Methyl 2-Pentanone, 4-	Methylphenol-4	N-Nitroso-diphenylamine	Naphthalene	Pentachloro-phenol	Phenanthrene
Bulk Soil Conc. = (mg/kg)	8.30E-02	1.10E-02	1.00E+00	1.80E+00	4.10E+00	1.50E+00	3.90E+00
Partitioning Coef. =	2.50E+01	5.00E-02	3.50E-01	1.20E+00	1.40E+00	3.50E+00	2.30E+01
Vadose Zone R =	8.90E+02	2.78E+00	1.34E+01	4.37E+01	5.08E+01	1.25E+02	8.19E+02
Saturated Zone R =	1.34E+02	1.27E+00	2.87E+00	7.40E+00	8.47E+00	1.97E+01	1.24E+02
Half-life	1.00E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+01	1.00E+01
Decay Rate =	6.93E-02	6.93E-01	6.93E-01	6.93E-01	6.93E-01	6.93E-02	6.93E-02
Solubility =	2.00E-02	1.70E+04	1.90E+04	3.50E+01	2.20E+01	1.70E+01	1.10E+00
Soil/Water Partition C0 =	3.32E-03	1.41E-01	2.64E+00	1.47E+00	2.87E+00	4.25E-01	1.69E-01
Leachate Conc.(C0)	3.32E-03	1.41E-01	2.64E+00	1.47E+00	2.87E+00	4.25E-01	1.69E-01
Vadose Travel Time(T2) =	4.81E+05	1.48E+03	7.24E+03	2.36E+04	2.74E+04	6.77E+04	4.42E+05
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sat. Travel Time(T3) = (Year)	1.05E+02	9.92E-01	2.24E+00	5.79E+00	6.63E+00	1.54E+01	9.68E+01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Phenol	Pyrene	Tetra-chloroethene	Tetrachloro-ethane-1,1,2,2	Toluene	Trichloro-ethene	Trichoro-ethane-1,1,1
Bulk Soil Conc. = (mg/kg)	2.40E-01	1.20E+01	1.10E+00	3.00E-03	1.50E-01	3.90E-01	6.00E-03
Partitioning Coef. =	6.50E-02	1.20E+01	2.20E-01	7.90E-02	1.80E-01	1.10E-01	1.30E-01
Vadose Zone R =	3.31E+00	4.28E+02	8.82E+00	3.81E+00	7.40E+00	4.91E+00	5.62E+00
Saturated Zone R =	1.35E+00	6.50E+01	2.17E+00	1.42E+00	1.96E+00	1.59E+00	1.69E+00
Half-life	1.00E+00	1.00E+02	1.00E+01	1.00E+00	1.00E+00	1.00E+01	1.00E+01
Decay Rate =	6.93E-01	6.93E-03	6.93E-02	6.93E-01	6.93E-01	6.93E-02	6.93E-02
Solubility =	8.20E+04	1.40E-01	8.30E+02	3.10E+03	5.20E+02	1.10E+03	1.70E+03
Soil/Water Partition C0 =	2.58E+00	9.98E-01	4.43E+00	2.80E-02	7.21E-01	2.82E+00	3.79E-02
Leachate Conc.(C0)	2.58E+00	1.40E-01	4.43E+00	2.80E-02	7.21E-01	2.82E+00	3.79E-02
Vadose Travel Time(T2) =	1.76E+03	2.31E+05	4.74E+03	2.03E+03	3.97E+03	2.63E+03	3.01E+03
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	9.74E-143	0.00E+00	0.00E+00	2.35E-79	8.69E-93
Sat. Travel Time(T3) = (Year)	1.05E+00	5.09E+01	1.70E+00	1.11E+00	1.53E+00	1.24E+00	1.33E+00
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	0.00E+00	0.00E+00	5.15E-144	0.00E+00	0.00E+00	1.28E-80	4.71E-94

Table A-4. Organic Compound Screening Modeling Results for the Base Conditions Scenario.

Organic Compounds	Vinyl Chloride	Xylenes (total)
Bulk Soil Conc. = (mg/kg)	2.40E-02	1.10E+00
Partitioning Coef. =	5.60E-02	5.70E-02
Vadose Zone R =	2.99E+00	3.03E+00
Saturated Zone R =	1.30E+00	1.30E+00
Half-life	1.00E+01	1.00E+01
Decay Rate =	6.93E-02	6.93E-02
Solubility =	1.90E+03	1.50E+02
Soil/Water Partition C0 =	2.85E-01	1.29E+01
Leachate Conc.(C0)	2.85E-01	1.29E+01
Vadose Travel Time(T2) =	1.59E+03	1.61E+03
Vadose Zone Dilution =	1.00E+00	1.00E+00
Water Table(C2) =	3.85E-49	4.61E-48
Sat. Travel Time(T3) = (Year)	1.02E+00	1.02E+00
Sat. Zone Dilution =	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	2.13E-50	2.55E-49

Table A-5. Radionuclide Screening Modeling Results for the Base Conditions Scenario.

Radionuclides	Americium-241	Barium-140	Beryllium-7	Carbon-14	Cerium-141	Cerium-144	Cesium-134
Bulk Soil Conc. = (pCi/g)	3.40E+01	4.00E+02	9.00E+01	6.40E+02	3.00E+00	5.00E-01	5.60E+01
Bulk Soil Conc. = (pCi/kg)	3.40E+04	4.00E+05	9.00E+04	6.40E+05	3.00E+03	5.00E+02	5.60E+04
Partitioning Coef. =	2.00E+02	2.50E+01	2.00E+01	0.00E+00	2.00E+02	2.00E+02	5.00E+01
Vadose Zone R =	7.11E+03	8.90E+02	7.12E+02	1.00E+00	7.11E+03	7.11E+03	1.78E+03
Saturated Zone R =	1.07E+03	1.34E+02	1.08E+02	1.00E+00	1.07E+03	1.07E+03	2.68E+02
Half-life (years)	4.32E+02	3.50E-02	1.46E-01	5.73E+03	8.90E-02	7.78E-01	2.06E+00
Decay Rate =	1.60E-03	1.98E+01	4.74E+00	1.21E-04	7.78E+00	8.91E-01	3.36E-01
Solubility = (mg/L)	1.00E+00	1.00E+00	1.00E+00	3.00E+01	1.00E+03	1.00E+03	1.00E+03
Specific Activity = (TBq/g)	1.27E-01	2.71E+03	1.29E+04	1.65E-01	1.05E+03	1.18E+02	4.79E+01
Solubility = (pCi/L)	3.43E+09	7.32E+13	3.48E+14	1.34E+11	2.84E+16	3.19E+15	1.29E+15
Soil/Water Partition C0 =	1.70E+02	1.60E+04	4.49E+03	2.28E+07	1.50E+01	2.50E+00	1.12E+03
Leachate Conc.(C0) =	1.70E+02	1.60E+04	4.49E+03	2.28E+07	1.50E+01	2.50E+00	1.12E+03
Vadose Travel Time(T2) =	3.84E+06	4.81E+05	3.85E+05	5.15E+02	3.84E+06	3.84E+06	9.61E+05
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	0.00E+00	2.14E+07	0.00E+00	0.00E+00	0.00E+00
Sat. Travel Time(T3) = (Year)	8.36E+02	1.05E+02	8.43E+01	7.83E-01	8.36E+02	8.36E+02	2.10E+02
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (pCi/L)	0.00E+00	0.00E+00	0.00E+00	1.27E+06	0.00E+00	0.00E+00	0.00E+00

Table A-5. Radionuclide Screening Modeling Results for the Base Conditions Scenario.

Radionuclides	Cesium-137	Chromium-51	Cobalt-58	Cobalt-60	Europium-152	Europium-154	Europium-155
Bulk Soil Conc. = (pCi/g)	1.10E+05	3.47E+00	1.41E+01	1.10E+04	2.90E+04	9.20E+03	9.60E+03
Bulk Soil Conc. = (pCi/kg)	1.10E+08	3.47E+03	1.41E+04	1.10E+07	2.90E+07	9.20E+06	9.60E+06
Partitioning Coef. =	5.00E+01	0.00E+00	5.00E+01	5.00E+01	2.00E+02	2.00E+02	2.00E+02
Vadose Zone R =	1.78E+03	1.00E+00	1.78E+03	1.78E+03	7.11E+03	7.11E+03	7.11E+03
Saturated Zone R =	2.68E+02	1.00E+00	2.68E+02	2.68E+02	1.07E+03	1.07E+03	1.07E+03
Half-life (years)	3.02E+01	7.59E-02	1.94E-01	5.27E+00	1.36E+01	8.80E+00	4.96E+00
Decay Rate =	2.30E-02	9.13E+00	3.57E+00	1.32E-01	5.10E-02	7.88E-02	1.40E-01
Solubility = (mg/L)	1.00E+03	2.50E+01	2.50E+01	2.50E+01	1.00E+03	1.00E+03	1.00E+03
Specific Activity = (TBq/g)	3.22E+00	3.42E+03	3.20E+04	4.18E+01	1.70E+02	2.60E+02	4.60E+02
Solubility = (pCi/L)	8.69E+13	2.31E+15	2.16E+16	2.82E+13	4.59E+15	7.02E+15	1.24E+16
Soil/Water Partition C0 =	2.20E+06	1.23E+05	2.82E+02	2.20E+05	1.45E+05	4.60E+04	4.80E+04
Leachate Conc.(C0) =	2.20E+06	1.23E+05	2.82E+02	2.20E+05	1.45E+05	4.60E+04	4.80E+04
Vadose Travel Time(T2) =	9.61E+05	5.15E+02	9.61E+05	9.61E+05	3.84E+06	3.84E+06	3.84E+06
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sat. Travel Time(T3) = (Year)	2.10E+02	7.83E-01	2.10E+02	2.10E+02	8.36E+02	8.36E+02	8.36E+02
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (pCi/L)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A-5. Radionuclide Screening Modeling Results for the Base Conditions Scenario.

Radionuclides	Iron-59	Manganese-54	Neptunium-237	Nickel-63	Plutonium-238	Plutonium-239/240	Potassium-40
Bulk Soil Conc. = (pCi/g)	1.00E+00	7.00E-02	6.86E-03	6.20E+04	1.40E+02	2.80E+03	3.30E+01
Bulk Soil Conc. = (pCi/kg)	1.00E+03	7.00E+01	6.86E+00	6.20E+07	1.40E+05	2.80E+06	3.30E+04
Partitioning Coef. =	5.00E+01	5.00E+01	2.00E+00	2.30E+01	6.30E+01	6.30E+01	5.00E+00
Vadose Zone R =	1.78E+03	1.78E+03	7.21E+01	8.19E+02	2.24E+03	2.24E+03	1.79E+02
Saturated Zone R =	2.68E+02	2.68E+02	1.17E+01	1.24E+02	3.37E+02	3.37E+02	2.77E+01
Half-life (years)	1.22E-01	8.60E-01	2.14E+06	1.00E+02	8.78E+01	2.41E+04	1.28E+09
Decay Rate =	5.67E+00	8.06E-01	3.24E-07	6.93E-03	7.89E-03	2.88E-05	5.42E-10
Solubility = (mg/L)	1.00E+00	1.00E+00	2.50E+01	2.50E+01	1.00E+00	1.00E+00	1.20E-01
Specific Activity = (TBq/g)	1.84E+03	2.86E+02	2.61E-05	2.19E+00	6.34E-01	2.30E-03	7.00E-06
Solubility = (pCi/L)	4.97E+13	7.72E+12	1.76E+07	1.48E+12	1.71E+10	6.21E+07	2.27E+04
Soil/Water Partition C0 =	2.00E+01	1.40E+00	3.38E+00	2.69E+06	2.22E+03	4.44E+04	6.56E+03
Leachate Conc.(C0) =	2.00E+01	1.40E+00	3.38E+00	2.69E+06	2.22E+03	4.44E+04	6.56E+03
Vadose Travel Time(T2) =	9.61E+05	9.61E+05	3.89E+04	4.42E+05	1.21E+06	1.21E+06	9.65E+04
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00	3.34E+00	0.00E+00	0.00E+00	3.41E-11	6.56E+03
Sat. Travel Time(T3) = (Year)	2.10E+02	2.10E+02	9.13E+00	9.68E+01	2.64E+02	2.64E+02	2.17E+01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (pCi/L)	0.00E+00	0.00E+00	1.99E-01	0.00E+00	0.00E+00	2.01E-12	3.90E+02

Table A-5. Radionuclide Screening Modeling Results for the Base Conditions Scenario.

Radionuclides	Radium-226	Ruthenium-103	Ruthenium-106	Sodium-22	Strontium-90	Technetium-99	Thorium-228
Bulk Soil Conc. = (pCi/g)	4.28E+01	1.00E+00	8.00E-01	9.91E+00	2.00E+03	1.10E+00	1.68E+01
Bulk Soil Conc. = (pCi/kg)	4.28E+04	1.00E+03	8.00E+02	9.91E+03	2.00E+06	1.10E+03	1.68E+04
Partitioning Coef. =	2.00E+01	2.00E+01	2.00E+01	4.00E+00	1.80E+01	0.00E+00	5.00E+01
Vadose Zone R =	7.12E+02	7.12E+02	7.12E+02	1.43E+02	6.41E+02	1.00E+00	1.78E+03
Saturated Zone R =	1.08E+02	1.08E+02	1.08E+02	2.23E+01	9.70E+01	1.00E+00	2.68E+02
Half-life (years)	1.60E+03	1.08E-01	1.01E+00	2.60E+00	2.86E+01	2.13E+05	1.91E+00
Decay Rate =	4.33E-04	6.42E+00	6.87E-01	2.67E-01	2.42E-02	3.25E-06	3.63E-01
Solubility = (mg/L)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	2.50E+01	1.00E+03	1.00E+00
Specific Activity = (TBq/g)	3.66E-02	1.19E+03	1.24E+02	2.31E+02	5.05E+00	6.30E-04	3.03E+01
Solubility = (pCi/L)	9.88E+11	3.21E+16	3.35E+15	6.24E+15	3.41E+12	1.70E+10	8.18E+11
Soil/Water Partition C0 =	2.14E+03	4.99E+01	3.99E+01	2.46E+03	1.11E+05	3.91E+04	3.36E+02
Leachate Conc.(C0) =	2.14E+03	4.99E+01	3.99E+01	2.46E+03	1.11E+05	3.91E+04	3.36E+02
Vadose Travel Time(T2) =	3.85E+05	3.85E+05	3.85E+05	7.73E+04	3.46E+05	5.15E+02	9.61E+05
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	9.68E-70	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.90E+04	0.00E+00
Sat. Travel Time(T3) = (Year)	8.43E+01	8.43E+01	8.43E+01	1.75E+01	7.59E+01	7.83E-01	2.10E+02
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (pCi/L)	5.55E-71	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.32E+03	0.00E+00

Table A-5. Radionuclide Screening Modeling Results for the Base Conditions Scenario.

Radionuclides	Thorium-232	Thorium-234	Tritium	Total Uranium	U-233/234	Uranium-235	Uranium-238
Bulk Soil Conc. = (pCi/g)	3.55E+00	1.00E+00	2.90E+04	2.00E+04	2.10E+03	6.38E+02	9.14E+03
Bulk Soil Conc. = (pCi/kg)	3.55E+03	1.00E+03	2.90E+07	2.00E+07	2.10E+06	6.38E+05	9.14E+06
Partitioning Coef. =	5.00E+01	5.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vadose Zone R =	1.78E+03	1.78E+03	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Saturated Zone R =	2.68E+02	2.68E+02	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Half-life (years)	1.41E+10	6.60E-02	1.23E+01	4.47E+09	2.45E+05	7.04E+08	4.47E+09
Decay Rate =	4.92E-11	1.05E+01	5.64E-02	1.55E-10	2.83E-06	9.85E-10	1.55E-10
Solubility = (mg/L)	1.00E+00	1.00E+00	2.70E+05	2.50E+01	1.43E-03	1.80E-01	2.48E+01
Specific Activity = (TBq/g)	4.05E-09	8.56E+02	3.57E+02	2.63E-08	2.31E-04	8.00E-08	1.24E-08
Solubility = (pCi/L)	1.09E+02	2.31E+13	2.60E+18	1.78E+04	8.89E+03	3.89E+02	8.31E+03
Soil/Water Partition C0 =	7.09E+01	2.00E+01	1.03E+09	7.12E+08	7.47E+07	2.27E+07	3.25E+08
Leachate Conc.(C0) =	7.09E+01	2.00E+01	1.03E+09	1.78E+04	8.89E+03	3.89E+02	8.31E+03
Vadose Travel Time(T2) =	9.61E+05	9.61E+05	5.15E+02	5.15E+02	5.15E+02	5.15E+02	5.15E+02
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	7.09E+01	0.00E+00	2.57E-04	1.77E+04	8.87E+03	3.89E+02	8.31E+03
Sat. Travel Time(T3) = (Year)	2.10E+02	2.10E+02	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (pCi/L)	4.21E+00	0.00E+00	1.46E-05	1.06E+03	5.28E+02	2.31E+01	4.94E+02

Table A-5. Radionuclide Screening Modeling Results for the Base Conditions Scenario.

Radionuclides	Zinc-65	Zirconium-95
Bulk Soil Conc. = (pCi/g)	3.00E-01	5.60E-01
Bulk Soil Conc. = (pCi/kg)	3.00E+02	5.60E+02
Partitioning Coef. =	2.30E+01	3.50E+01
Vadose Zone R =	8.19E+02	1.25E+03
Saturated Zone R =	1.24E+02	1.88E+02
Half-life (years)	6.68E-01	1.75E-01
Decay Rate =	1.04E+00	3.95E+00
Solubility = (mg/L)	2.50E+01	1.00E+00
Specific Activity = (TBq/g)	3.05E+02	7.95E+02
Solubility = (pCi/L)	2.06E+14	2.15E+13
Soil/Water Partition C0 =	1.30E+01	1.60E+01
Leachate Conc.(C0) =	1.30E+01	1.60E+01
Vadose Travel Time(T2) =	4.42E+05	6.73E+05
Vadose Zone Dilution =	1.00E+00	1.00E+00
Water Table(C2) =	0.00E+00	0.00E+00
Sat. Travel Time(T3) = (Year)	9.68E+01	1.47E+02
Sat. Zone Dilution =	5.95E-02	5.95E-02
ERDF Boundary(C3) = (pCi/L)	0.00E+00	0.00E+00

Table A-6. Metal Screening Modeling Results for the Base Conditions Scenario.

Metals	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium-VI	Cobalt
Bulk Soil Conc. = (mg/kg)	7.84E+04	1.86E+01	6.22E+01	4.26E+03	4.70E+00	2.85E+01	9.53E+04	2.51E+03	9.04E+01
Partitioning Coef. =	2.00E+01	0.00E+00	0.00E+00	5.00E+01	2.00E+01	2.30E+01	1.50E+01	0.00E+00	3.00E+01
Vadose Zone R =	7.12E+02	1.00E+00	1.00E+00	1.78E+03	7.12E+02	8.19E+02	5.34E+02	1.00E+00	1.07E+03
Saturated Zone R =	1.08E+02	1.00E+00	1.00E+00	2.68E+02	1.08E+02	1.24E+02	8.10E+01	1.00E+00	1.61E+02
Decay Rate =	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solubility = (mg/L)	1.00E+00	1.00E+03	1.00E+03	1.00E+00	1.00E+00	2.50E+01	2.50E+01	1.00E+03	2.50E+01
Soil/Water Partition C0 =	3.91E+03	6.61E+02	2.21E+03	8.52E+01	2.35E-01	1.24E+00	6.34E+03	8.92E+04	3.01E+00
Leachate Conc.(C0) =	1.00E+00	6.61E+02	1.00E+03	1.00E+00	2.35E-01	1.24E+00	2.50E+01	1.00E+03	3.01E+00
Vadose Travel Time(T2) =	3.85E+05	5.15E+02	5.15E+02	9.61E+05	3.85E+05	4.42E+05	2.89E+05	5.15E+02	5.77E+05
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	1.00E+00	6.61E+02	1.00E+03	1.00E+00	2.35E-01	1.24E+00	2.50E+01	1.00E+03	3.01E+00
Sat. Travel Time(T3) = (Year)	8.43E+01	7.83E-01	7.83E-01	2.10E+02	8.43E+01	9.68E+01	6.34E+01	7.83E-01	1.26E+02
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	5.95E-02	3.93E+01	5.95E+01	5.95E-02	1.40E-02	7.36E-02	1.49E+00	5.95E+01	1.79E-01

Table A-6. Metal Screening Modeling Results for the Base Conditions Scenario.

Metals	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium
Bulk Soil Conc. = (mg/kg)	9.53E+04	1.84E+05	7.47E+02	5.00E+04	3.05E+03	3.70E+01	1.75E+03	1.30E+04	1.11E+01
Partitioning Coef. =	2.30E+01	3.50E+01	3.00E+01	2.00E+01	3.50E+01	3.00E+01	2.30E+01	4.00E+00	0.00E+00
Vadose Zone R =	8.19E+02	1.25E+03	1.07E+03	7.12E+02	1.25E+03	1.07E+03	8.19E+02	1.43E+02	1.00E+00
Saturated Zone R =	1.24E+02	1.88E+02	1.61E+02	1.08E+02	1.88E+02	1.61E+02	1.24E+02	2.23E+01	1.00E+00
Decay Rate =	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solubility = (mg/L)	2.50E+01	1.00E+00	1.00E+00	2.50E+01	1.00E+00	1.00E+00	2.50E+01	1.00E+03	1.00E+03
Soil/Water Partition C0 =	4.14E+03	5.25E+03	2.49E+01	2.50E+03	8.71E+01	1.23E+00	7.60E+01	3.23E+03	3.95E+02
Leachate Conc.(C0) =	2.50E+01	1.00E+00	1.00E+00	2.50E+01	1.00E+00	1.00E+00	2.50E+01	1.00E+03	3.95E+02
Vadose Travel Time(T2) =	4.42E+05	6.73E+05	5.77E+05	3.85E+05	6.73E+05	5.77E+05	4.42E+05	7.73E+04	5.15E+02
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	2.50E+01	1.00E+00	1.00E+00	2.50E+01	1.00E+00	1.00E+00	2.50E+01	1.00E+03	3.95E+02
Sat. Travel Time(T3) = (Year)	9.68E+01	1.47E+02	1.26E+02	8.43E+01	1.47E+02	1.26E+02	9.68E+01	1.75E+01	7.83E-01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	1.49E+00	5.95E-02	5.95E-02	1.49E+00	5.95E-02	5.95E-02	1.49E+00	5.95E+01	2.35E+01

Table A-6. Metal Screening Modeling Results for the Base Conditions Scenario.

Metals	Silver	Sodium	Strontium	Thallium	Vanadium	Zinc
Bulk Soil Conc. = (mg/kg)	3.62E+02	2.61E+03	3.10E+01	5.40E+00	3.89E+02	6.16E+03
Partitioning Coef. =	2.50E+01	3.00E+00	1.80E+01	5.00E+01	5.00E+01	2.30E+01
Vadose Zone R =	8.90E+02	1.08E+02	6.41E+02	1.78E+03	1.78E+03	8.19E+02
Saturated Zone R =	1.34E+02	1.70E+01	9.70E+01	2.68E+02	2.68E+02	1.24E+02
Decay Rate =	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solubility = (mg/L)	2.50E+01	1.00E+03	2.50E+01	1.00E+00	2.50E+01	2.50E+01
Soil/Water Partition C0 =	1.45E+01	8.62E+02	1.72E+00	1.08E-01	7.78E+00	1.34E+02
Leachate Conc.(C0) =	1.45E+01	8.62E+02	1.72E+00	1.08E-01	7.78E+00	2.50E+01
Vadose Travel Time(T2) =	4.81E+05	5.81E+04	3.46E+05	9.61E+05	9.61E+05	4.42E+05
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	1.45E+01	8.62E+02	1.72E+00	1.08E-01	7.78E+00	2.50E+01
Sat. Travel Time(T3) = (Year)	1.05E+02	1.33E+01	7.59E+01	2.10E+02	2.10E+02	9.68E+01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	8.60E-01	5.13E+01	1.02E-01	6.42E-03	4.62E-01	1.49E+00

Table A-7. General Chemistry Screening Modeling Results for the Base Conditions Scenario.

General Chemistry Parameters	Ammonia	Fluoride	Nitrite	Sulfate
Bulk Soil Conc. = (mg/kg)	1.38E+02	4.03E+01	2.90E+00	7.12E+03
Partitioning Coef. =	4.00E+00	0.00E+00	0.00E+00	0.00E+00
Vadose Zone R =	1.43E+02	1.00E+00	1.00E+00	1.00E+00
Saturated Zone R =	2.23E+01	1.00E+00	1.00E+00	1.00E+00
Decay Rate =	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solubility =	1.00E+03	1.00E+03	1.00E+03	2.50E+01
Soil/Water Partition CO =	3.43E+01	1.43E+03	1.03E+02	2.53E+05
Leachate Conc.(CO) =	3.43E+01	1.00E+03	1.03E+02	2.50E+01
Vadose Travel Time(T2) =	7.73E+04	5.15E+02	5.15E+02	5.15E+02
Vadose Zone Dilution =	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Water Table(C2) =	3.43E+01	1.00E+03	1.03E+02	2.50E+01
Sat. Travel Time(T3) = (Year)	1.75E+01	7.83E-01	7.83E-01	7.83E-01
Sat. Zone Dilution =	5.95E-02	5.95E-02	5.95E-02	5.95E-02
ERDF Boundary(C3) = (mg/L)	2.04E+00	5.95E+01	6.13E+00	1.49E+00

Table A-8. Results for Base Conditions Scenario under Current Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Technetium-99	Total Uranium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)	Selenium		
Soil/Water Partition (mg/L)	5.11E-03	2.30E-03	1.00E+06	6.61E+02	8.92E+04	1.43E+03	1.03E+02	3.95E+02		
Source Conc. (C0) (mg/L)	2.04E-06	3.53E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Liner Retardation	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Conc. Beneath Trench (C1) (mg/L)	2.04E-06	3.53E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Vadose Travel Time (T2) (yr)	5.15E+02	5.15E+02	5.15E+02	5.15E+02	5.15E+02	5.15E+02	5.15E+02	5.15E+02		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	1.92E-06	3.52E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Sat. Travel Time (T3) (yr)	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01		
Saturated Zone Dilution (DIL3)	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059		
Conc. at ERDF Boundary (C3) (mg/L)	1.14E-07	2.09E-05	2.34E-02	5.95E-03	1.78E-02	9.51E-01	1.01E+00	5.00E-02		
Radionuclide Conc. (C3) (pCi/L)	5.08E+02	3.56E+02	1.67E+01							
Source Depletion Time w/o liner (yr)	4.50E+05	1.17E+03	4.58E+08	1.19E+06	5.35E+07	1.61E+04	1.09E+03	8.46E+04		
At ERDF Boundary									Total ICR	Max. HQ
Travel Time (yr)	516	516	516	516	516	516	516	516		
Incremental Cancer Risk (ICR)	1.02E-05	1.03E-05	1.03E-05						3E-05	
Hazard Quotient (HQ)				1.01E+00	2.32E-01	9.51E-01	6.37E-01	6.49E-01		1E+00
ICR at Time < 100 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
ICR at 100<Time< 1,000 Years	1.02E-05	1.03E-05	1.03E-05						3E-05	
ICR at 1,000<Time< 10,000 Years	1.02E-05	1.03E-05	1.03E-05						3E-05	
HQ at Time < 100 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years				1.01E+00	2.32E-01	9.51E-01	6.37E-01	6.49E-01		1E+00
HQ at 1,000<Time< 10,000 Years				1.01E+00	2.32E-01	9.51E-01	6.37E-01	6.49E-01		1E+00

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Table A-9. Results for Alternatives 2, 3, and 4 under Current Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Technetium-99	Total Uranium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)	Selenium		
Soil/Water Partition (mg/L)	5.11E-03	2.30E-03	1.00E+06	6.61E+02	8.92E+04	1.43E+03	1.03E+02	3.95E+02		
Source Conc. (C0) (mg/L)	2.04E-06	3.53E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Liner Retardation	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Conc. Beneath Trench (C1) (mg/L)	2.04E-06	3.53E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Vadose Travel Time (T2) (yr)	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04	1.33E+04		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	4.09E-07	3.38E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Sat. Travel Time (T3) (yr)	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01		
Saturated Zone Dilution (DIL3)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Conc. at ERDF Boundary (C3) (mg/L)	5.16E-10	4.27E-07	4.98E-04	1.26E-04	3.79E-04	2.02E-02	2.15E-02	1.06E-03		
Radionuclide Conc. (C3) (pCi/L)	2.30E+00	7.26E+00	3.54E-01							
Source Depletion Time w/o liner (yr)	2.25E+07	5.87E+04	2.29E+10	5.95E+07	2.68E+09	8.06E+05	5.46E+04	4.23E+06		
At ERDF Boundary									Total ICR	Max. HQ
Travel Time (yr)	13,301	13,301	13,301	13,301	13,301	13,301	13,301	13,301		
Incremental Cancer Risk (ICR)	4.60E-08	2.10E-07	2.19E-07						5E-07	
Hazard Quotient (HQ)				2.15E-02	4.93E-03	2.02E-02	1.35E-02	1.38E-02		2E-02
ICR at Time< 100 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
ICR at 100<Time< 1,000 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
ICR at 1,000<Time< 10,000 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
HQ at Time< 100 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 1,000<Time< 10,000 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00

Table A-10. Results for Alternatives 5, 6, and 7 under Current Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Technetium-99	Total Uranium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)	Selenium		
Soil/Water Partition (mg/L)	5.11E-03	2.30E-03	1.00E+06	6.61E+02	8.92E+04	1.43E+03	1.03E+02	3.95E+02		
Source Conc. (C0) (mg/L)	2.04E-06	3.53E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Liner Retardation	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Liner Travel Time (T1) (yr)	7.05E+02	7.05E+02	7.05E+02	7.05E+02	7.05E+02	7.05E+02	7.05E+02	7.05E+02		
Conc. Beneath Trench (C1) (mg/L)	1.88E-06	3.52E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Vadose Travel Time (T2) (yr)	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	3.13E-07	3.35E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Sat. Travel Time (T3) (yr)	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01		
Saturated Zone Dilution (DIL3)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Conc. at ERDF Boundary (C3) (mg/L)	3.96E-10	4.24E-07	4.98E-04	1.26E-04	3.79E-04	2.02E-02	2.15E-02	1.06E-03		
Radionuclide Conc. (C3) (pCi/L)	1.76E+00	7.20E+00	3.54E-01							
Source Depletion Time w/o liner (yr)	2.25E+07	5.87E+04	2.29E+10	5.95E+07	2.68E+09	8.06E+05	5.46E+04	4.23E+06		
Source Depletion Time-t(op) (yr)	2.25E+07	5.86E+04	2.29E+10	5.95E+07	2.68E+09	8.06E+05	5.46E+04	4.23E+06		
Source Depletion Time-t(op) (yr)	2.25E+07	5.86E+04	2.29E+10	5.95E+07	2.68E+09	8.06E+05	5.46E+04	4.23E+06		
At ERDF Boundary									Total ICR	Max. HQ
Travel Time (yr)	15,501	15,501	15,501	15,501	15,501	15,501	15,501	15,501		
Incremental Cancer Risk (ICR)	3.52E-08	2.09E-07	2.19E-07						5E-07	
Hazard Quotient (HQ)				2.15E-02	4.93E-03	2.02E-02	1.35E-02	1.38E-02		2E-02
ICR at Time< 100 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
ICR at 100<Time< 1,000 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
ICR at 1,000<Time< 10,000 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
HQ at Time< 100 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 1,000<Time< 10,000 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00

Table A-11. Results for Alternatives 8, 9, and 10 under Current Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Technetium-99	Total Uranium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)	Selenium		
Soil/Water Partition (mg/L)	5.11E-03	2.30E-03	1.00E+06	6.61E+02	8.92E+04	1.43E+03	1.03E+02	3.95E+02		
Source Conc. (C0) (mg/L)	2.04E-06	3.53E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Liner Retardation	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Liner Travel Time (T1) (yr)	2.06E+03	2.06E+03	2.06E+03	2.06E+03	2.06E+03	2.06E+03	2.06E+03	2.06E+03		
Conc. Beneath Trench (C1) (mg/L)	1.59E-06	3.50E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Vadose Travel Time (T2) (yr)	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04	1.48E+04		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	2.66E-07	3.34E-04	3.94E-01	1.00E-01	3.00E-01	1.60E+01	1.70E+01	8.40E-01		
Sat. Travel Time (T3) (yr)	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01		
Saturated Zone Dilution (DIL3)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
Conc. at ERDF Boundary (C3) (mg/L)	3.36E-10	4.22E-07	4.98E-04	1.26E-04	3.79E-04	2.02E-02	2.15E-02	1.06E-03		
Radionuclide Conc. (C3) (pCi/L)	1.50E+00	7.17E+00	3.54E-01							
Source Depletion Time w/o liner (yr)	2.25E+07	5.87E+04	2.29E+10	5.95E+07	2.68E+09	8.06E+05	5.46E+04	4.23E+06		
Source Depletion Time-t(op) (yr)	2.25E+07	5.86E+04	2.29E+10	5.95E+07	2.68E+09	8.06E+05	5.46E+04	4.23E+06		
Source Depletion Time-t(op) (yr)	2.25E+07	5.86E+04	2.29E+10	5.95E+07	2.68E+09	8.06E+05	5.46E+04	4.23E+06		
At ERDF Boundary									Total ICR	Max. HQ
Travel Time (yr)	16,851	16,851	16,851	16,851	16,851	16,851	16,851	16,851		
Incremental Cancer Risk (ICR)	2.99E-08	2.08E-07	2.19E-07						5E-07	
Hazard Quotient (HQ)				2.15E-02	4.93E-03	2.02E-02	1.35E-02	1.38E-02		2E-02
ICR at Time < 100 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
ICR at 100<Time< 1,000 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
ICR at 1,000<Time< 10,000 Years	0.00E+00	0.00E+00	0.00E+00						0E+00	
HQ at Time< 100 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 1,000<Time< 10,000 Years				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0E+00

Table A-12. Results for Base Conditions Scenario under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Neptunium-237	Technetium-99	Total Uranium	Tritium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)
Soil/Water Partition (mg/L)	5.11E-03	4.80E-06	2.30E-03	1.00E+06	1.07E-04	6.61E+02	8.92E+04	1.43E+03	1.03E+02
Source Conc. (C0) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Liner Retardation	1.00E+00	1.30E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Conc. Beneath Trench (C1) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Vadose Travel Time (T2) (yr)	1.24E+02	2.26E+03	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Conc. at Water Table (C2) (mg/L)	2.01E-06	4.80E-06	3.53E-04	3.94E-01	9.63E-08	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Sat. Travel Time (T3) (yr)	7.83E-01	9.13E+00	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Saturated Zone Dilution (DIL3)	0.532	0.532	0.532	0.532	0.532	0.532	0.532	0.532	0.532
Conc. at ERDF Boundary (C3) (mg/L)	1.07E-06	2.55E-06	1.88E-04	2.10E-01	4.90E-08	5.32E-02	1.60E-01	8.52E+00	9.05E+00
Radionuclide Conc. (C3) (pCi/L)	4.77E+03	1.80E+00	3.19E+03	1.49E+02	4.73E+05				
Source Depletion Time w/o liner (yr)	2.50E+04	7.21E+02	6.52E+01	2.54E+07	1.00E+01	6.61E+04	2.97E+06	8.96E+02	6.07E+01
At ERDF Boundary									
Travel Time (yr)	125	2,267	125	125	125	125	125	125	125
Incremental Cancer Risk (ICR)	9.54E-05	8.64E-06	9.26E-05	9.24E-05	5.67E-04				
Hazard Quotient (HQ)						9.05E+00	2.08E+00	8.52E+00	5.70E+00
ICR at Time < 100 Years	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
ICR at 100<Time< 1,000 Years	9.54E-05	0.00E+00	9.26E-05	9.24E-05	5.67E-04				
ICR at 1,000<Time< 10,000 Years	9.54E-05	8.64E-06	0.00E+00	9.24E-05	0.00E+00				
HQ at Time < 100 Years						0.00E+00	0.00E+00	0.00E+00	0.00E+00
HQ at 100<Time< 1,000 Years						9.05E+00	2.08E+00	8.52E+00	5.70E+00
HQ at 1,000<Time< 10,000 Years						9.05E+00	2.08E+00	8.52E+00	0.00E+00

Table A-12. Results for Base Conditions Scenario under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Selenium	Beta-BHC	Chloroform	1,2-Dichloroethene	Xylenes		
Soil/Water Partition (mg/L)	3.95E+02	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Source Conc. (C0) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Liner Retardation	1.00E+00	1.84E+01	1.20E+00	1.26E+00	1.34E+00		
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Conc. Beneath Trench (C1) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Vadose Travel Time (T2) (yr)	1.24E+02	3.22E+03	1.61E+02	1.70E+02	1.85E+02		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	8.40E-01	2.13E-03	1.87E-05	1.05E-04	3.43E-05		
Sat. Travel Time (T3) (yr)	7.83E-01	1.29E+01	9.25E-01	9.62E-01	1.02E+00		
Saturated Zone Dilution (DIL3)	0.532	0.532	0.532	0.532	0.532		
Conc. at ERDF Boundary (C3) (mg/L)	4.47E-01	1.13E-03	9.34E-06	5.23E-05	1.70E-05		
Radionuclide Conc. (C3) (pCi/L)							
Source Depletion Time w/o liner (yr)	4.70E+03	1.04E+03	2.21E+01	2.53E+01	3.03E+01		
At ERDF Boundary						Total ICR	Max. HQ
Travel Time (yr)	125	3,231	162	171	186		
Incremental Cancer Risk (ICR)		2.49E-05	3.45E-09			9E-04	
Hazard Quotient (HQ)	5.81E+00		1.68E-04	3.66E-04	5.61E-07		9E+00
ICR at Time< 100 Years		0.00E+00	0.00E+00			0E+00	
ICR at 100<Time< 1,000 Years		0.00E+00	3.45E-09			8E-04	
ICR at 1,000<Time< 10,000 Years		2.49E-05	0.00E+00			2E-04	
HQ at Time< 100 Years	0.00E+00		0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years	5.81E+00		1.68E-04	3.66E-04	5.61E-07		9E+00
HQ at 1,000<Time< 10,000 Years	5.81E+00		0.00E+00	0.00E+00	0.00E+00		9E+00

Table A-13. Results for Alternative 2 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Neptunium-237	Technetium-99	Total Uranium	Tritium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)
Soil/Water Partition (mg/L)	5.11E-03	4.80E-06	2.30E-03	1.00E+06	1.07E-04	6.61E+02	8.92E+04	1.43E+03	1.03E+02
Source Conc. (C0) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Liner Retardation	1.00E+00	1.30E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Conc. Beneath Trench (C1) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Vadose Travel Time (T2) (yr)	1.50E+02	3.73E+03	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Conc. at Water Table (C2) (mg/L)	2.01E-06	4.79E-06	3.53E-04	3.94E-01	2.26E-08	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Sat. Travel Time (T3) (yr)	7.83E-01	9.13E+00	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Saturated Zone Dilution (DIL3)	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387
Conc. at ERDF Boundary (C3) (mg/L)	7.77E-07	1.86E-06	1.37E-04	1.53E-01	8.36E-09	3.87E-02	1.16E-01	6.20E+00	6.58E+00
Radionuclide Conc. (C3) (pCi/L)	3.46E+03	1.31E+00	2.32E+03	1.08E+02	8.06E+04				
Source Depletion Time w/o liner (yr)	4.50E+04	1.30E+03	1.17E+02	4.58E+07	1.80E+01	1.19E+05	5.35E+06	1.61E+03	1.09E+02
At ERDF Boundary									
Travel Time (yr)	151	3,743	151	151	151	151	151	151	151
Incremental Cancer Risk (ICR)	6.92E-05	6.28E-06	6.74E-05	6.72E-05	9.67E-05				
Hazard Quotient (HQ)						6.58E+00	1.51E+00	6.20E+00	4.15E+00
ICR at Time < 100 Years	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
ICR at 100 < Time < 1,000 Years	6.92E-05	0.00E+00	6.74E-05	6.72E-05	9.67E-05				
ICR at 1,000 < Time < 10,000 Years	6.92E-05	6.28E-06	0.00E+00	6.72E-05	0.00E+00				
HQ at Time < 100 Years						0.00E+00	0.00E+00	0.00E+00	0.00E+00
HQ at 100 < Time < 1,000 Years						6.58E+00	1.51E+00	6.20E+00	4.15E+00
HQ at 1,000 < Time < 10,000 Years						6.58E+00	1.51E+00	6.20E+00	0.00E+00

Table A-13. Results for Alternative 2 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Selenium	Beta-BHC	Chloroform	1,2-Dichloroethene	Xylenes		
Soil/Water Partition (mg/L)	3.95E+02	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Source Conc. (C0) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Liner Retardation	1.00E+00	1.84E+01	1.20E+00	1.26E+00	1.34E+00		
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Conc. Beneath Trench (C1) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Vadose Travel Time (T2) (yr)	1.50E+02	5.35E+03	2.11E+02	2.27E+02	2.52E+02		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	8.40E-01	1.84E-03	5.68E-07	2.03E-06	3.27E-07		
Sat. Travel Time (T3) (yr)	7.83E-01	1.29E+01	9.25E-01	9.62E-01	1.02E+00		
Saturated Zone Dilution (DIL3)	0.387	0.387	0.387	0.387	0.387		
Conc. at ERDF Boundary (C3) (mg/L)	3.25E-01	7.12E-04	2.06E-07	7.35E-07	1.18E-07		
Radionuclide Conc. (C3) (pCi/L)							
Source Depletion Time w/o liner (yr)	8.46E+03	1.87E+03	3.98E+01	4.55E+01	5.45E+01		
At ERDF Boundary						Total ICR	Max. HQ
Travel Time (yr)	151	5,360	212	228	253		
Incremental Cancer Risk (ICR)		1.57E-05	7.63E-11			3E-04	
Hazard Quotient (HQ)	4.23E+00		3.71E-06	5.14E-06	3.90E-09		7E+00
ICR at Time < 100 Years		0.00E+00	0.00E+00			0E+00	
ICR at 100 < Time < 1,000 Years		0.00E+00	7.63E-11			3E-04	
ICR at 1,000 < Time < 10,000 Years		1.57E-05	0.00E+00			2E-04	
HQ at Time < 100 Years	0.00E+00		0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100 < Time < 1,000 Years	4.23E+00		3.71E-06	5.14E-06	3.90E-09		7E+00
HQ at 1,000 < Time < 10,000 Years	4.23E+00		0.00E+00	0.00E+00	0.00E+00		7E+00

Table A-14. Results for Alternatives 3 and 4 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Neptunium-237	Technetium-99	Total Uranium	Tritium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)
Soil/Water Partition (mg/L)	5.11E-03	4.80E-06	2.30E-03	1.00E+06	1.07E-04	6.61E+02	8.92E+04	1.43E+03	1.03E+02
Source Conc. (C0) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Liner Retardation	1.00E+00	1.30E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Conc. Beneath Trench (C1) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Vadose Travel Time (T2) (yr)	5.01E+02	2.92E+04	5.01E+02	5.01E+02	5.01E+02	5.01E+02	5.01E+02	5.01E+02	5.01E+02
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Conc. at Water Table (C2) (mg/L)	1.92E-06	4.75E-06	3.52E-04	3.94E-01	5.95E-17	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Sat. Travel Time (T3) (yr)	7.83E-01	9.13E+00	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Saturated Zone Dilution (DIL3)	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
Conc. at ERDF Boundary (C3) (mg/L)	9.26E-08	2.29E-07	1.70E-05	1.90E-02	2.74E-18	4.81E-03	1.44E-02	7.70E-01	8.18E-01
Radionuclide Conc. (C3) (pCi/L)	4.12E+02	1.61E-01	2.88E+02	1.35E+01	2.64E-05				
Source Depletion Time w/o liner (yr)	5.63E+05	1.62E+04	1.47E+03	5.72E+08	2.25E+02	1.49E+06	6.69E+07	2.02E+04	1.36E+03
At ERDF Boundary									
Travel Time (yr)	502	29,184	502	502	502	502	502	502	502
Incremental Cancer Risk (ICR)	8.25E-06	7.74E-07	8.36E-06	8.36E-06	3.17E-14				
Hazard Quotient (HQ)						8.18E-01	1.88E-01	7.70E-01	5.16E-01
ICR at Time< 100 Years	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
ICR at 100<Time< 1,000 Years	8.25E-06	0.00E+00	8.36E-06	8.36E-06	3.17E-14				
ICR at 1,000<Time< 10,000 Years	8.25E-06	0.00E+00	8.36E-06	8.36E-06	0.00E+00				
HQ at Time< 100 Years						0.00E+00	0.00E+00	0.00E+00	0.00E+00
HQ at 100<Time< 1,000 Years						8.18E-01	1.88E-01	7.70E-01	5.16E-01
HQ at 1,000<Time< 10,000 Years						8.18E-01	1.88E-01	7.70E-01	5.16E-01

Table A-14. Results for Alternatives 3 and 4 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Selenium	Beta-BHC	Chloroform	1,2-Dichloroethene	Xylenes		
Soil/Water Partition (mg/L)	3.95E+02	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Source Conc. (CO) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Liner Retardation	1.00E+00	1.84E+01	1.20E+00	1.26E+00	1.34E+00		
Liner Travel Time (T1) (yr)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		
Conc. Beneath Trench (C1) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Vadose Travel Time (T2) (yr)	5.01E+02	4.21E+04	9.88E+02	1.12E+03	1.32E+03		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	8.40E-01	1.44E-04	2.30E-30	3.28E-33	2.74E-39		
Sat. Travel Time (T3) (yr)	7.83E-01	1.29E+01	9.25E-01	9.62E-01	1.02E+00		
Saturated Zone Dilution (DIL3)	0.048	0.048	0.048	0.048	0.048		
Conc. at ERDF Boundary (C3) (mg/L)	4.04E-02	6.93E-06	1.04E-31	1.48E-34	1.23E-40		
Radionuclide Conc. (C3) (pCi/L)							
Source Depletion Time w/o liner (yr)	1.06E+05	2.34E+04	4.97E+02	5.69E+02	6.81E+02		
At ERDF Boundary						Total ICR	Max. HQ
Travel Time (yr)	502	42,091	989	1,118	1,319		
Incremental Cancer Risk (ICR)		1.53E-07	3.85E-35			3E-05	
Hazard Quotient (HQ)	5.26E-01		1.87E-30	1.03E-33	4.05E-42		8E-01
ICR at Time< 100 Years		0.00E+00	0.00E+00			0E+00	
ICR at 100<Time< 1,000 Years		0.00E+00	3.85E-35			2E-05	
ICR at 1,000<Time< 10,000 Years		0.00E+00	3.85E-35			2E-05	
HQ at Time< 100 Years	0.00E+00		0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years	5.26E-01		1.87E-30	0.00E+00	0.00E+00		8E-01
HQ at 1,000<Time< 10,000 Years	5.26E-01		1.87E-30	1.03E-33	4.05E-42		8E-01

Table A-15. Results for Alternative 5 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Neptunium-237	Technetium-99	Total Uranium	Tritium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)
Soil/Water Partition (mg/L)	5.11E-03	4.80E-06	2.30E-03	1.00E+06	1.07E-04	6.61E+02	8.92E+04	1.43E+03	1.03E+02
Source Conc. (C0) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Liner Retardation	1.00E+00	6.77E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Liner Travel Time (T1) (yr)	3.14E+01	1.21E+02	3.14E+01	3.14E+01	3.14E+01	3.14E+01	3.14E+01	3.14E+01	3.14E+01
Conc. Beneath Trench (C1) (mg/L)	2.03E-06	4.80E-06	3.53E-04	3.94E-01	0.00E+00	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Vadose Travel Time (T2) (yr)	1.20E+02	3.70E+03	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Conc. at Water Table (C2) (mg/L)	2.01E-06	4.79E-06	3.53E-04	3.94E-01	0.00E+00	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Sat. Travel Time (T3) (yr)	7.83E-01	9.13E+00	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Saturated Zone Dilution (DIL3)	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387
Conc. at ERDF Boundary (C3) (mg/L)	7.77E-07	1.86E-06	1.37E-04	1.53E-01	0.00E+00	3.87E-02	1.16E-01	6.20E+00	6.58E+00
Radionuclide Conc. (C3) (pCi/L)	3.46E+03	1.31E+00	2.32E+03	1.08E+02	0.00E+00				
Source Depletion Time w/o liner (yr)	4.50E+04	1.30E+03	1.17E+02	4.58E+07	1.80E+01	1.19E+05	5.35E+06	1.61E+03	1.09E+02
Source Depletion Time-t(op) (yr)	4.50E+04	1.27E+03	8.73E+01	4.58E+07	-1.20E+01	1.19E+05	5.35E+06	1.58E+03	7.92E+01
Source Depletion Time-t(op) (yr)	4.50E+04	1.27E+03	8.73E+01	4.58E+07	-1.20E+01	1.19E+05	5.35E+06	1.58E+03	7.92E+01
At ERDF Boundary									
Travel Time (yr)	152	3,835	152	152	152	152	152	152	152
Incremental Cancer Risk (ICR)	6.92E-05	6.28E-06	6.74E-05	6.72E-05	0.00E+00				
Hazard Quotient (HQ)						6.58E+00	1.51E+00	6.20E+00	4.15E+00
ICR at Time < 100 Years	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
ICR at 100 < Time < 1,000 Years	6.92E-05	0.00E+00	6.74E-05	6.72E-05	0.00E+00				
ICR at 1,000 < Time < 10,000 Years	6.92E-05	6.28E-06	0.00E+00	6.72E-05	0.00E+00				
HQ at Time < 100 Years						0.00E+00	0.00E+00	0.00E+00	0.00E+00
HQ at 100 < Time < 1,000 Years						6.58E+00	1.51E+00	6.20E+00	4.15E+00
HQ at 1,000 < Time < 10,000 Years						6.58E+00	1.51E+00	6.20E+00	0.00E+00

Table A-15. Results for Alternative 5 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Selenium	Beta-BHC	Chloroform	1,2-Dichloroethene	Xylenes		
Soil/Water Partition (mg/L)	3.95E+02	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Source Conc. (C0) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Liner Retardation	1.00E+00	9.77E+01	2.13E+00	2.43E+00	2.90E+00		
Liner Travel Time (T1) (yr)	3.14E+01	1.62E+02	3.29E+01	3.33E+01	3.39E+01		
Conc. Beneath Trench (C1) (mg/L)	8.40E-01	2.63E-03	1.32E-01	1.40E+00	1.23E+00		
Vadose Travel Time (T2) (yr)	1.20E+02	5.32E+03	1.81E+02	1.97E+02	2.22E+02		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	8.40E-01	1.82E-03	4.63E-07	1.61E-06	2.49E-07		
Sat. Travel Time (T3) (yr)	7.83E-01	1.29E+01	9.25E-01	9.62E-01	1.02E+00		
Saturated Zone Dilution (DIL3)	0.387	0.387	0.387	0.387	0.387		
Conc. at ERDF Boundary (C3) (mg/L)	3.25E-01	7.05E-04	1.68E-07	5.83E-07	8.97E-08		
Radionuclide Conc. (C3) (pCi/L)							
Source Depletion Time w/o liner (yr)	8.46E+03	1.87E+03	3.98E+01	4.55E+01	5.45E+01		
Source Depletion Time-t(op) (yr)	8.43E+03	1.84E+03	9.76E+00	1.55E+01	2.45E+01		
Source Depletion Time-t(op) (yr)	8.43E+03	1.84E+03	9.76E+00	1.55E+01	2.45E+01		
At ERDF Boundary						Total ICR	Max. HQ
Travel Time (yr)	152	5,492	215	232	257		
Incremental Cancer Risk (ICR)		1.55E-05	6.23E-11			2E-04	
Hazard Quotient (HQ)	4.23E+00		3.03E-06	4.08E-06	2.96E-09		7E+00
ICR at Time< 100 Years		0.00E+00	0.00E+00			0E+00	
ICR at 100<Time< 1,000 Years		0.00E+00	6.23E-11			2E-04	
ICR at 1,000<Time< 10,000 Years		1.55E-05	0.00E+00			2E-04	
HQ at Time< 100 Years	0.00E+00		0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years	4.23E+00		3.03E-06	4.08E-06	2.96E-09		7E+00
HQ at 1,000<Time< 10,000 Years	4.23E+00		0.00E+00	0.00E+00	0.00E+00		7E+00

Table A-16. Results for Alternatives 6 and 7 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Neptunium-237	Technetium-99	Total Uranium	Tritium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)
Soil/Water Partition (mg/L)	5.11E-03	4.80E-06	2.30E-03	1.00E+06	1.07E-04	6.61E+02	8.92E+04	1.43E+03	1.03E+02
Source Conc. (C0) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Liner Retardation	1.00E+00	6.77E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Liner Travel Time (T1) (yr)	4.69E+01	1.17E+03	4.69E+01	4.69E+01	4.69E+01	4.69E+01	4.69E+01	4.69E+01	4.69E+01
Conc. Beneath Trench (C1) (mg/L)	2.03E-06	4.80E-06	3.53E-04	3.94E-01	7.62E-06	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Vadose Travel Time (T2) (yr)	4.71E+02	2.91E+04	4.71E+02	4.71E+02	4.71E+02	4.71E+02	4.71E+02	4.71E+02	4.71E+02
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Conc. at Water Table (C2) (mg/L)	1.92E-06	4.75E-06	3.52E-04	3.94E-01	2.20E-17	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Sat. Travel Time (T3) (yr)	7.83E-01	9.13E+00	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Saturated Zone Dilution (DIL3)	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
Conc. at ERDF Boundary (C3) (mg/L)	9.24E-08	2.29E-07	1.70E-05	1.90E-02	1.01E-18	4.81E-03	1.44E-02	7.70E-01	8.18E-01
Radionuclide Conc. (C3) (pCi/L)	4.11E+02	1.61E-01	2.88E+02	1.35E+01	9.78E-06				
Source Depletion Time w/o liner (yr)	5.63E+05	1.62E+04	1.47E+03	5.72E+08	2.25E+02	1.49E+06	6.69E+07	2.02E+04	1.36E+03
Source Depletion Time-t(op) (yr)	5.63E+05	1.62E+04	1.44E+03	5.72E+08	1.95E+02	1.49E+06	6.69E+07	2.01E+04	1.33E+03
Source Depletion Time-t(op) (yr)	5.63E+05	1.62E+04	1.44E+03	5.72E+08	1.95E+02	1.49E+06	6.69E+07	2.01E+04	1.33E+03
At ERDF Boundary									
Travel Time (yr)	519	30,327	519	519	519	519	519	519	519
Incremental Cancer Risk (ICR)	8.23E-06	7.74E-07	8.36E-06	8.36E-06	1.17E-14				
Hazard Quotient (HQ)						8.16E-01	1.88E-01	7.70E-01	5.16E-01
ICR at Time< 100 Years	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
ICR at 100<Time< 1,000 Years	8.23E-06	0.00E+00	8.36E-06	8.36E-06	1.17E-14				
ICR at 1,000<Time< 10,000 Years	8.23E-06	0.00E+00	8.36E-06	8.36E-06	0.00E+00				
HQ at Time< 100 Years						0.00E+00	0.00E+00	0.00E+00	0.00E+00
HQ at 100<Time< 1,000 Years						8.16E-01	1.88E-01	7.70E-01	5.16E-01
HQ at 1,000<Time< 10,000 Years						8.16E-01	1.88E-01	7.70E-01	5.16E-01

Table A-16. Results for Alternatives 6 and 7 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Selenium	Beta-BHC	Chloroform	1,2-Dichloroethene	Xylenes		
Soil/Water Partition (mg/L)	3.95E+02	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Source Conc. (C0) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Liner Retardation	1.00E+00	9.77E+01	2.13E+00	2.43E+00	2.90E+00		
Liner Travel Time (T1) (yr)	4.69E+01	1.68E+03	6.60E+01	7.11E+01	7.89E+01		
Conc. Beneath Trench (C1) (mg/L)	8.40E-01	2.37E-03	1.33E-02	1.02E-01	5.43E-02		
Vadose Travel Time (T2) (yr)	4.71E+02	4.20E+04	9.59E+02	1.09E+03	1.29E+03		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	8.40E-01	1.29E-04	1.80E-31	1.81E-34	8.74E-41		
Sat. Travel Time (T3) (yr)	7.83E-01	1.29E+01	9.25E-01	9.62E-01	1.02E+00		
Saturated Zone Dilution (DIL3)	0.048	0.048	0.048	0.048	0.048		
Conc. at ERDF Boundary (C3) (mg/L)	4.04E-02	6.19E-06	8.14E-33	8.15E-36	3.92E-42		
Radionuclide Conc. (C3) (pCi/L)							
Source Depletion Time w/o liner (yr)	1.06E+05	2.34E+04	4.97E+02	5.69E+02	6.81E+02		
Source Depletion Time-t(op) (yr)	1.06E+05	2.34E+04	4.67E+02	5.39E+02	6.51E+02		
Source Depletion Time-t(op) (yr)	1.06E+05	2.34E+04	4.67E+02	5.39E+02	6.51E+02		
At ERDF Boundary						Total ICR	Max. HQ
Travel Time (yr)	519	43,740	1,026	1,160	1,369		
Incremental Cancer Risk (ICR)		1.36E-07	3.01E-36			3E-05	
Hazard Quotient (HQ)	5.26E-01		1.47E-31	5.70E-35	1.29E-43		8E-01
ICR at Time< 100 Years		0.00E+00	0.00E+00			0E+00	
ICR at 100<Time< 1,000 Years		0.00E+00	0.00E+00			2E-05	
ICR at 1,000<Time< 10,000 Years		0.00E+00	3.01E-36			2E-05	
HQ at Time< 100 Years	0.00E+00		0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years	5.26E-01		0.00E+00	0.00E+00	0.00E+00		8E-01
HQ at 1,000<Time< 10,000 Years	5.26E-01		1.47E-31	5.70E-35	1.29E-43		8E-01

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Table A-17. Results for Alternative 8 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Neptunium-237	Technetium-99	Total Uranium	Tritium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)
Soil/Water Partition (mg/L)	5.11E-03	4.80E-06	2.30E-03	1.00E+06	1.07E-04	6.61E+02	8.92E+04	1.43E+03	1.03E+02
Source Conc. (C0) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Liner Retardation	1.00E+00	6.77E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Liner Travel Time (T1) (yr)	3.41E+01	3.04E+02	3.41E+01	3.41E+01	3.41E+01	3.41E+01	3.41E+01	3.41E+01	3.41E+01
Conc. Beneath Trench (C1) (mg/L)	2.03E-06	4.80E-06	3.53E-04	3.94E-01	0.00E+00	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Vadose Travel Time (T2) (yr)	1.20E+02	3.70E+03	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02	1.20E+02
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Conc. at Water Table (C2) (mg/L)	2.00E-06	4.79E-06	3.53E-04	3.94E-01	0.00E+00	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Sat. Travel Time (T3) (yr)	7.83E-01	9.13E+00	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Saturated Zone Dilution (DIL3)	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387	0.387
Conc. at ERDF Boundary (C3) (mg/L)	7.77E-07	1.86E-06	1.37E-04	1.53E-01	0.00E+00	3.87E-02	1.16E-01	6.20E+00	6.58E+00
Radionuclide Conc. (C3) (pCi/L)	3.46E+03	1.31E+00	2.32E+03	1.06E+02	0.00E+00				
Source Depletion Time w/o liner (yr)	4.50E+04	1.30E+03	1.17E+02	4.58E+07	1.80E+01	1.19E+05	5.35E+06	1.61E+03	1.09E+02
Source Depletion Time-t(op) (yr)	4.50E+04	1.27E+03	8.73E+01	4.58E+07	-1.20E+01	1.19E+05	5.35E+06	1.58E+03	7.92E+01
Source Depletion Time-t(op) (yr)	4.50E+04	1.27E+03	8.73E+01	4.58E+07	-1.20E+01	1.19E+05	5.35E+06	1.58E+03	7.92E+01
At ERDF Boundary									
Travel Time (yr)	155	4,017	155	155	155	155	155	155	155
Incremental Cancer Risk (ICR)	6.92E-05	6.28E-06	6.74E-05	6.72E-05	0.00E+00				
Hazard Quotient (HQ)						6.56E+00	1.51E+00	6.20E+00	4.15E+00
ICR at Time< 100 Years	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
ICR at 100<Time< 1,000 Years	6.92E-05	0.00E+00	6.74E-05	6.72E-05	0.00E+00				
ICR at 1,000<Time< 10,000 Years	6.92E-05	6.28E-06	0.00E+00	6.72E-05	0.00E+00				
HQ at Time< 100 Years						0.00E+00	0.00E+00	0.00E+00	0.00E+00
HQ at 100<Time< 1,000 Years						6.56E+00	1.51E+00	6.20E+00	4.15E+00
HQ at 1,000<Time< 10,000 Years						6.56E+00	1.51E+00	6.20E+00	0.00E+00

Table A-17. Results for Alternative 8 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Selenium	Beta-BHC	Chloroform	1,2-Dichloroethene	Xylenes		
Soil/Water Partition (mg/L)	3.95E+02	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Source Conc. (C0) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Liner Retardation	1.00E+00	9.77E+01	2.13E+00	2.43E+00	2.90E+00		
Liner Travel Time (T1) (yr)	3.41E+01	4.26E+02	3.86E+01	3.99E+01	4.17E+01		
Conc. Beneath Trench (C1) (mg/L)	8.40E-01	2.59E-03	8.84E-02	8.88E-01	7.16E-01		
Vadose Travel Time (T2) (yr)	1.20E+02	5.32E+03	1.81E+02	1.97E+02	2.22E+02		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	8.40E-01	1.79E-03	3.11E-07	1.02E-06	1.44E-07		
Sat. Travel Time (T3) (yr)	7.83E-01	1.29E+01	9.25E-01	9.62E-01	1.02E+00		
Saturated Zone Dilution (DIL3)	0.387	0.387	0.387	0.387	0.387		
Conc. at ERDF Boundary (C3) (mg/L)	3.25E-01	6.92E-04	1.13E-07	3.69E-07	5.21E-08		
Radionuclide Conc. (C3) (pCi/L)							
Source Depletion Time w/o liner (yr)	8.46E+03	1.87E+03	3.98E+01	4.55E+01	5.45E+01		
Source Depletion Time-t(op) (yr)	8.43E+03	1.84E+03	9.76E+00	1.55E+01	2.45E+01		
Source Depletion Time-t(op) (yr)	8.43E+03	1.84E+03	9.76E+00	1.55E+01	2.45E+01		
At ERDF Boundary						Total ICR	Max. HQ
Travel Time (yr)	155	5,755	221	238	265		
Incremental Cancer Risk (ICR)		1.52E-05	4.18E-11			2E-04	
Hazard Quotient (HQ)	4.23E+00		2.03E-06	2.59E-06	1.72E-09		7E+00
ICR at Time < 100 Years		0.00E+00	0.00E+00			0E+00	
ICR at 100 < Time < 1,000 Years		0.00E+00	4.18E-11			2E-04	
ICR at 1,000 < Time < 10,000 Years		1.52E-05	0.00E+00			2E-04	
HQ at Time < 100 Years	0.00E+00		0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100 < Time < 1,000 Years	4.23E+00		2.03E-06	2.59E-06	1.72E-09		7E+00
HQ at 1,000 < Time < 10,000 Years	4.23E+00		0.00E+00	0.00E+00	0.00E+00		7E+00

Table A-18. Results for Alternatives 9 and 10 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Carbon-14	Neptunium-237	Technetium-99	Total Uranium	Tritium	Antimony	Chromium-VI	Fluoride	Nitrite (as N)
Soil/Water Partition (mg/L)	5.11E-03	4.80E-06	2.30E-03	1.00E+06	1.07E-04	6.61E+02	8.92E+04	1.43E+03	1.03E+02
Source Conc. (C0) (mg/L)	2.04E-06	4.80E-06	3.53E-04	3.94E-01	1.07E-04	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Liner Retardation	1.00E+00	6.77E+01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Liner Travel Time (T1) (yr)	8.06E+01	3.46E+03	8.06E+01	8.06E+01	8.06E+01	8.06E+01	8.06E+01	8.06E+01	8.06E+01
Conc. Beneath Trench (C1) (mg/L)	2.02E-06	4.79E-06	3.53E-04	3.94E-01	1.14E-06	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Vadose Travel Time (T2) (yr)	4.71E+02	2.91E+04	4.71E+02	4.71E+02	4.71E+02	4.71E+02	4.71E+02	4.71E+02	4.71E+02
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Conc. at Water Table (C2) (mg/L)	1.91E-06	4.75E-06	3.52E-04	3.94E-01	3.29E-18	1.00E-01	3.00E-01	1.60E+01	1.70E+01
Sat. Travel Time (T3) (yr)	7.83E-01	9.13E+00	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01	7.83E-01
Saturated Zone Dilution (DIL3)	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
Conc. at ERDF Boundary (C3) (mg/L)	9.20E-08	2.29E-07	1.70E-05	1.90E-02	1.52E-19	4.81E-03	1.44E-02	7.70E-01	8.16E-01
Radionuclide Conc. (C3) (pCi/L)	4.10E+02	1.61E-01	2.88E+02	1.35E+01	1.46E-06				
Source Depletion Time w/o liner (yr)	5.63E+05	1.62E+04	1.47E+03	5.72E+08	2.25E+02	1.49E+06	6.69E+07	2.02E+04	1.36E+03
Source Depletion Time-t(op) (yr)	5.63E+05	1.62E+04	1.44E+03	5.72E+08	1.95E+02	1.49E+06	6.69E+07	2.01E+04	1.33E+03
Source Depletion Time-t(op) (yr)	5.63E+05	1.62E+04	1.44E+03	5.72E+08	1.95E+02	1.49E+06	6.69E+07	2.01E+04	1.33E+03
At ERDF Boundary									
Travel Time (yr)	553	32,610	553	553	553	553	553	553	553
Incremental Cancer Risk (ICR)	8.20E-06	7.73E-07	8.36E-06	8.36E-06	1.75E-15				
Hazard Quotient (HQ)						8.18E-01	1.88E-01	7.70E-01	5.16E-01
ICR at Time < 100 Years	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
ICR at 100 < Time < 1,000 Years	8.20E-06	0.00E+00	8.36E-06	8.36E-06	1.75E-15				
ICR at 1,000 < Time < 10,000 Years	8.20E-06	0.00E+00	8.36E-06	8.36E-06	0.00E+00				
HQ at Time < 100 Years						0.00E+00	0.00E+00	0.00E+00	0.00E+00
HQ at 100 < Time < 1,000 Years						8.18E-01	1.88E-01	7.70E-01	5.16E-01
HQ at 1,000 < Time < 10,000 Years						8.18E-01	1.88E-01	7.70E-01	5.16E-01

Table A-18. Results for Alternatives 9 and 10 under Hypothetical Wetter Climate Condition (Accounting for Leachate Limits).

Parameter	Selenium	Beta-BHC	Chloroform	1,2-Dichloroethane	Xylenes		
Soil/Water Partition (mg/L)	3.95E+02	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Source Conc. (C0) (mg/L)	8.40E-01	2.66E-03	1.29E+00	1.41E+01	1.29E+01		
Liner Retardation	1.00E+00	9.77E+01	2.13E+00	2.43E+00	2.90E+00		
Liner Travel Time (T1) (yr)	8.06E+01	4.97E+03	1.36E+02	1.53E+02	1.77E+02		
Conc. Beneath Trench (C1) (mg/L)	8.40E-01	1.89E-03	9.03E-05	3.44E-04	6.15E-05		
Vadose Travel Time (T2) (yr)	4.71E+02	4.20E+04	9.59E+02	1.09E+03	1.29E+03		
Vadose Zone Dilution (DIL2)	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00		
Conc. at Water Table (C2) (mg/L)	8.40E-01	1.02E-04	1.23E-33	6.10E-37	9.89E-44		
Sat. Travel Time (T3) (yr)	7.83E-01	1.29E+01	9.25E-01	9.62E-01	1.02E+00		
Saturated Zone Dilution (DIL3)	0.048	0.048	0.048	0.048	0.048		
Conc. at ERDF Boundary (C3) (mg/L)	4.04E-02	4.92E-06	5.54E-35	2.75E-38	4.44E-45		
Radionuclide Conc. (C3) (pCi/L)							
Source Depletion Time w/o liner (yr)	1.06E+05	2.34E+04	4.97E+02	5.69E+02	6.81E+02		
Source Depletion Time-t(op) (yr)	1.06E+05	2.34E+04	4.67E+02	5.39E+02	6.51E+02		
Source Depletion Time-t(op) (yr)	1.06E+05	2.34E+04	4.67E+02	5.39E+02	6.51E+02		
At ERDF Boundary						Total ICR	Max. HQ
Travel Time (yr)	553	47,036	1,098	1,242	1,467		
Incremental Cancer Risk (ICR)		1.08E-07	2.05E-38			3E-05	
Hazard Quotient (HQ)	5.26E-01		9.97E-34	1.92E-37	1.46E-46		8E-01
ICR at Time< 100 Years		0.00E+00	0.00E+00			0E+00	
ICR at 100<Time< 1,000 Years		0.00E+00	0.00E+00			2E-05	
ICR at 1,000<Time< 10,000 Years		0.00E+00	2.05E-38			2E-05	
HQ at Time< 100 Years	0.00E+00		0.00E+00	0.00E+00	0.00E+00		0E+00
HQ at 100<Time< 1,000 Years	5.26E-01		0.00E+00	0.00E+00	0.00E+00		8E-01
HQ at 1,000<Time< 10,000 Years	5.26E-01		9.97E-34	1.92E-37	1.46E-46		8E-01

APPENDIX B

HELP MODELING RESULTS

REFERENCE

Skelly, W.A., 1990, *Hanford Site-Specific Climate Data Input Files for Use with the Help Model Software*, WHC-SD-EN-CSWD-028, Westinghouse Hanford Company, Richland, Washington.

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CONTENTS

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B.1 INTRODUCTION

Hydrologic modeling was conducted to predict the performance of the barriers and liners considered for use at the ERDF. Four barriers, including the non-engineered soil cover, the low-infiltration soil barrier, the modified Hanford barrier, and the Hanford Barrier, were simulated to determine representative infiltration rates to use in the fate and transport modeling (Appendix A). Two liners, the single composite liner and the RCRA double composite liner, were simulated to determine the rate of leakage through the liners.

HELP Model. The Hydrologic Evaluation of Landfill Performance (HELP) computer model was developed by the U.S. Army Corps of Engineers, Hydraulic Engineering Center, under contract to the U.S. Environmental Protection Agency. The model was originally developed to provide an easy-to-use tool for the comparison of alternative landfill designs in meeting the requirements of RCRA compliance standards for the disposal of hazardous waste. Use of the model has grown considerably in recent years, and it provides a convenient comparative evaluation of the hydraulic performance of barrier and liner technologies for the ERDF.

The HELP model is a sophisticated, daily average water balance that considers a wide variety of meteorological, soils, and geometric parameters, and simulates the hydraulic performance of landfill liners, waste layers, and cover systems under a variety of hydrologic conditions. The HELP model was developed to be a comparative tool for the selection of design approaches that meet RCRA regulatory criteria.

The model was designed to support rapid, detailed, and accurate comparison of landfill designs. To accomplish this goal, the model contains a series of 5-year default data sets for climatic conditions across the United States, and default soils and synthetic component parameters. In addition, the model allows use of site-specific climate, soils and design data, and supports stochastic generation of climatic parameters. Several sub-models simulate the following processes: 1) the growth of grass vegetation on the surface of landfill covers, 2) the change in the form of precipitation from rain to snow, and the melting of snow, and 3) the unsaturated routing of infiltration through the layers of the surface barrier or the liner system.

Approach. Version 2.05 of the HELP model is used to simulate the performance of four barrier and two liner technologies for the ERDF. Each of the systems is initially simulated using the existing 10-year Hanford Site-specific climatic data set. This data set is used in consecutive 10-year simulations until the system equilibrated or until 120 years of performance were simulated. At the end of each 10-year period, the ending moisture content for each layer is used as the initial moisture content of that layer for the next 10-year simulation. Equilibrium conditions are assumed when the moisture contents of the layers stabilized or when the percolation through the system approached a constant value.

The existing 10-year Hanford Site-specific climate data set was developed for the HELP model by Westinghouse Hanford Company (WHC) from Hanford Meteorological Station (HMS) data, collected between January 1, 1979 and December 31, 1988 (Skelly 1990). This 10-year record provides a reasonable yet conservative representation of historical precipitation for the site. A statistical analysis of the precipitation data, and presentation of all other meteorological and climatic data for use in supporting HELP modeling on the Hanford Site is contained in Skelly (1990).

The HELP model soil parameters for each of the barrier and cover systems (except the non-engineered soil cover) are summarized in Tables B-1 through B-5. The non-engineered soil cover is discussed in section B.2. The HELP model output files for the final simulation of each system using Hanford, Washington climatic data are presented in Attachments B-1 through B-6. Climatic data for Hanford, Washington used in the simulations were provided by Skelly (1990).

Sensitivity of the barrier and liner technologies being considered for the ERDF to changes in climatic conditions is simulated by using a wetter climatic data set. This second scenario assumes a change in climate over time, and uses the 5-year default HELP climatic data for Spokane, Washington. The Spokane climate is significantly wetter than the current Hanford climate, averaging 39.73 cm (15.64 in.) of rainfall, compared with 17.98 cm (7.08 in.) for the Hanford Site. In addition, average monthly temperatures are milder in Spokane.

For all of the scenarios of barrier systems, an evaporative zone depth of 91.5 cm (36 in.) is used, with a maximum leaf area index of 1.6, representing a poor grass cover. These values are considered typical for grass existing without maintenance under current Hanford climate conditions, and are not modified under future climate scenarios, although a fair grass cover would likely exist under wetter, milder conditions.

9113285.0558

The parameters describing the layers of the barrier and liner systems are developed to provide comparable results using site and layer-component specific data that are discussed in detail in the sections below. However, several generalizations can be made regarding the relative importance of parameters with respect to model performance. Based on sensitivity analyses conducted by the model's authors during development, and on experience using the model in arid climates, the most important parameters affecting model results are the saturated hydraulic conductivity of each layer, the depth of the rooting zone, and the maximum leaf area index of the vegetation growing on the surface of the barriers. The vegetation can be very effective at enhancing evapotranspiration, and limiting the amount of water available for deep infiltration. The hydraulic conductivity of the soils layers limits the rate at which infiltration migrates through the landfill components. Finally, the initial moisture content, the porosity, and the field capacity of each layer determine how much storage and free drainage may occur from each layer. The best estimates available for each of these parameters were used in simulating the barrier and liner technologies for the ERDF. The predicted hydraulic performance of each of the barrier and liner systems is discussed in the sections below. HELP model input files and output summaries of the parameters for each barrier and liner system are attached at the end of this appendix.

B.2 NON-ENGINEERED SOIL COVER

The non-engineered soil cover is simulated as a single vertical drainage layer. The barrier is composed of native soil, 460 cm (15 ft) thick, placed as an uncontrolled (uncompacted) fill, with a resulting hydraulic conductivity of $1x10^{-3}$ cm/sec. The initial moisture content of the fill was selected as .062 (6.2%), equal to the field capacity of the soil.

Under current Hanford Site climatic conditions, the moisture content of the single barrier layer stabilized at 0.0635 or 6.4% moisture within 80 years, and the average annual percolation through the layer stabilized at 0.035 cm/yr (0.014 in./yr).

The non-engineered soil cover is also simulated using the present Spokane climate data, representing a future change in climate to wetter conditions. This scenario is simulated for only a 20 year period, at which time the moisture content approaches equilibrium. Percolation through the cover at the end of 20 years exceeded 8.6 cm/yr (3.4 in./yr).

B.3 LOW-INFILTRATION SOIL BARRIER

The low-infiltration soil barrier is simulated as a three layer, vertical drainage system, with a total thickness of 460 cm (15 ft) from the surface to the top of the interim soil cover. The top layer is defined as a 30-cm thick uncompacted silt and gravel admixture with a hydraulic conductivity of $1x10^{-3}$ cm/sec. The second layer was defined as a 30-cm thick compacted silt with a hydraulic conductivity of $1.6x10^{-6}$ cm/sec. The bottom layer was defined as a 400-cm (13-ft) thick uncontrolled (uncompacted) fill using native soil. Initial moisture contents were set at field capacity for each layer. Layer parameters are summarized in Table B-1.

The low-infiltration soil barrier is simulated under current Hanford Site climatic conditions for a 110 year period. The percolation from the lowest layer was 0.00025 cm/yr (0.0001 in./yr) at 100 years. The moisture content of this layer was continuing to decrease as the barrier system dewatered, and at 100 years was mid-way between the field capacity and the wilting point defined for this soil type.

Under present day Spokane climatic conditions, percolation from the low-infiltration soil barrier after a 20 year simulation was 4.75 cm/yr (1.87 in./yr). The moisture content of the upper layer decreased while the moisture content of the lower layers increased from initial conditions during the simulation. Stable results were observed after 20 years.

B.4 MODIFIED HANFORD BARRIER

The modified Hanford barrier is a multi-layered barrier system with a total thickness of 470 cm (15.4 ft) from the surface to the top of interim soil cover. A brief summary of the layers is as follows:

- Surface layer - uncompacted 50-cm (20-in.) thick silt and gravel admix
- Second layer - compacted 50-cm (20-in.) thick silt
- Third layer - 300-cm (118-in.) thick uncontrolled (uncompacted) fill
- Fourth layer - 15-cm (6-in.) thick sand filter
- Fifth layer - 15-cm (6-in.) thick gravel filter
- Sixth layer - 15-cm (6-in.) thick gravel drainage layer
- Seventh layer - 15-cm (6-in.) thick asphalt with spray-applied top coat

- Eighth layer - 10-cm (4-in.) thick base course

The defining layer parameters are summarized in Table B-2.

Under the current Hanford Site climate, the estimated average annual percolation through the modified Hanford barrier is 0.0017 cm (0.0007 in.), and approaches a stable value at 120 years of simulation.

The estimated average annual percolation through the modified Hanford barrier under the present Spokane climate is 0.31 cm (0.12 in.) and has reached a stable value at the end of 20 years.

B.5 HANFORD BARRIER

The Hanford Barrier is a multi-layered barrier system with a total thickness of 450 cm (14.75 ft) from the surface to the top of interim soil cover. A brief summary of the layers is as follows:

- Surface layer - 100-cm (39-in.) thick silt and gravel admix
  - top 50-cm (19-in.) uncompacted; bottom 50-cm (19-in.) compacted.
- Second layer - compacted, 100-cm (39-in.) thick silt
- Third layer - 15-cm (6-in.) thick sand filter
- Fourth layer - 30-cm (12-in.) thick gravel filter
- Fifth layer - 150-cm (60-in.) thick crushed basalt
- Sixth layer - 30-cm (12-in.) thick drainage rock layer
- Seventh layer - 15-cm (6-in.) thick asphalt with spray applied top coat
- Eighth layer - 10-cm (4-in.) thick base course

The defining layer parameters are summarized in Table B-3. To accurately reflect the hydraulic properties of the top layer, the lower half of this layer was compacted and assigned the same properties as layer 2. Therefore, the thicknesses of the first two layers shown in attachment B-4 are 50-cm (19-in.) and 150-cm (59-in.), respectively.

Under the current Hanford Site climate, the estimated average annual percolation through the Hanford Barrier is zero; at no time during the 110 year simulation period did any infiltration percolate through the Hanford Barrier system. Under arid climatic conditions, the HELP Model does not adequately model the capillary break effect of the crushed basalt layer of the Hanford Barrier system. Water slowly accumulates (at a decreasing rate) in the crushed basalt layer as the layers above dewater, rather than remaining in the overlying silt layer. However, the water accumulating in the basalt does not migrate downward, and the results are unaffected. No water drains into the lateral drainage layers during the 110 year simulation. The water content in the crushed basalt rises at a decreasing rate from just over 2 percent at the beginning of the simulation to just under 7 percent at 110 years.

The behavior of the same layer under the Spokane climatic conditions is normal. Water accumulates more rapidly in the basalt layer and flows into the lateral drainage layer below, where it migrates laterally to the collection system and downward into the barrier layer. The similarity in behavior between the Hanford Barrier and the modified Hanford barrier under Spokane climatic conditions suggests that percolation through the Hanford Barrier is expected to be similar to percolation through the modified Hanford barrier.

The estimated average annual percolation through the Hanford Barrier under the present Spokane climate is 0.32 cm (0.12 in.), and is approaching a stable value at the end of 20 years.

B.6 SINGLE COMPOSITE LINER

The single composite liner is a multi-media, multi-component system designed to limit infiltration and collect any leachate generated during the construction and filling phases of facility operation. The total thickness of the liner system is 120 cm (4 ft) and is comprised of a 30-cm (12-in.) thick compacted clay admix, overlain by a geocomposite liner system and a 90-cm (36-in.) thick operations layer. The geocomposite is made up of a primary 60-mil high density polyethylene (HDPE) geomembrane liner, overlain by a primary drainage gravel sandwiched between layers of geotextile, which function as a bottom cushion and a top separator from the operations layer.

The HELP model formulation uses three layers to simulate the performance of this liner system: a vertical drainage layer represents the operations layer, a lateral drainage layer represents the geotextile/drainage gravel component, and a geomembrane/clay liner represents the barrier. Specific soil properties are summarized in Table B-4. The hydraulic conductivity of the barrier layer is $1x10^{-7}$ cm/sec; the leakance factor for the HDPE liner is $1x10^{-4}$. The HELP model simulations assumed that precipitation falls directly onto the operations layer of the liner system, and do not attempt to simulate the properties of waste or interim cover layers.

The results indicate that no infiltration passes through the single composite liner system during a 50 year simulation period. During the simulation period, all lateral drainage flow in the second layer is assumed to flow to a collection sump where it is removed by submersible pumps.

B.7 RCRA DOUBLE COMPOSITE LINER

The RCRA Subtitle-C double composite liner system is a more complex, redundant version of the single composite liner system described in the previous section, with a total thickness of 240 cm (8 ft). This liner system has a base compacted clay admix layer 90 cm (36 in.) thick that is overlain by a secondary geocomposite liner system. This geocomposite is identical to the geocomposite described in the pervious section; the secondary drainage gravel component is 30 cm (12 in.) thick. Over the secondary geocomposite is a primary geocomposite liner system. Its components are identical to the secondary geocomposite system. The primary HDPE liner is placed directly over the secondary geotextile separator layer. The primary drainage gravel layer is also 30 cm (12 in.) in thickness. The 90 cm (36 in.) operations layer is placed directly on the primary separator geotextile.

The HELP model formulation uses five layers to simulate the performance of this liner system: a vertical drainage layer represents the operations layer, a lateral drainage layer represents the primary geotextile/drainage gravel component, a geomembrane/clay liner represents the primary barrier, a lateral drainage layer represents the secondary geotextile/drainage gravel component, and a geomembrane/clay liner represents the secondary barrier. Specific soil properties are summarized in Table B-5.

The hydraulic conductivity of the secondary barrier layer is assumed to be 1×10^{-7} cm/sec. However, to simulate the performance of the secondary liner system requires modification of the parameters of the primary liner system. (The performance of the primary barrier layer alone is simulated in the previous section.) Therefore, the hydraulic conductivity of the primary barrier layer is assumed to be 1×10^{-2} cm/sec, an artificially high value. The leakance factor for the primary HDPE liner is assumed to be 1×10^{-4}. This combination of parameters provides an estimate of a leaky primary liner, allowing evaluation of the performance of the secondary liner system. The HELP model simulations assumed that precipitation falls directly onto the operations layer of the liner system, and do not attempt to simulate the properties of waste or interim cover layers.

The results indicate that no infiltration passes through the double composite liner system during a 50 year simulation period. During the simulation period, all lateral drainage flow in the second layer is assumed to flow to a collection sump where it is removed by submersible pumps.

B.8 SUMMARY AND CONCLUSIONS

Examination of the HELP model output for the ERDF barrier systems indicates the following:

- Under current Hanford Site climate conditions, the average percolation rate for the non-engineered soil cover was 0.035 cm/yr (.014 in./yr). The percolation rates for the remaining cover systems was below 0.002 cm/yr (.0008 in./yr) at the end of 110 years.

- Under wetter climatic conditions, using present day Spokane climate data, the non-engineered soil cover and the low-infiltration soil barrier systems allowed significantly more infiltration (between 5 and 8 cm/yr [2 to 3 in./yr]) than the modified Hanford and Hanford Barrier systems. The modified Hanford and Hanford Barriers perform better because lateral drainage occurs above the asphalt layers, thereby reducing the amount of water infiltrating through the bottom of the barriers.

- Under wetter climatic conditions, the Modified Hanford and Hanford Barriers systems have similar annual average infiltration rates on the order of 0.32 cm/yr (0.12 in./yr), which is equivalent to the saturated hydraulic conductivity of the barrier layer of 1 x 10^{-8} cm/sec.

- Under the arid conditions of the Hanford Site, the HELP model does not adequately model the performance of the crushed basalt layer (layer 5) of the Hanford Barrier. Under the conditions provided by the wetter Spokane climate data, the model appears to have adequately simulated the performance of the crushed basalt.

Examination of the HELP model output for the liner systems indicates the following:

- The two composite liner systems exhibit essentially identical performance. As long as the geomembrane/clay liner components remain intact, no percolation flows through the liner system.

Table B-1. HELP Parameters for Low-Infiltration Soil Barrier.

Layer	Hydraulic Conductivity (cm/sec)	Effective Porosity	Field Capacity	Wilting Point	Moisture Content		Percolation (cm/yr)	
					Initial	Final	Initial	Final
1	1×10^{-5}	.4603	.2272	.0632	.2272	.1173	NA	NA
2	1.6×10^{-6}	.3702	.2109	.0500	.2109	.0500	NA	NA
3	1×10^{-3}	.4370	.0620	.0240	.0620	.0394	.0200	.00025

NA - Not applicable.

Table B-2. HELP Parameters for Modified Hanford Barrier.

Layer	Hydraulic Conductivity (cm/sec)	Effective Porosity	Field Capacity	Wilting Point	Moisture Content		Percolation (cm/yr)	
					Initial	Final	Initial	Final
1	1×10^{-3}	.4603	.2272	.0632	.2272	.0944	NA	NA
2	1.6×10^{-6}	.3720	.2109	.0500	.2109	.0510	NA	NA
3	1.0×10^{-3}	.4370	.0620	.0240	.0400	.0528	NA	NA
4	1.6×10^{-4}	.3509	.0705	.0326	.0705	.0694	NA	NA
5	5×10^{-4}	.3178	.0391	.0200	.0391	.0347	NA	NA
6	1×10^{-9}	.4170	.0454	.0200	.0454	.0454	NA	NA
7	1×10^{-8}	.0220	.0210	.0200	.0220	.0220	.1400	.0015
8	1×10^{-2}	.4370	.0620	.0240	.0620	.0300	NA	NA

NA - Not applicable.

Table B-3. HELP Parameters for Hanford Barrier.

Layer	Hydraulic Conductivity (cm/sec)	Effective Porosity	Field Capacity	Wilting Point	Moisture Content		Percolation (cm/yr)	
					Initial	Final	Initial	Final
1	1×10^{-3}	.4603	.2272	.0632	.2272	.0954	NA	NA
2	1.6×10^{-6}	.3702	.2109	.0500	.2109	.0543	NA	NA
3	1.6×10^{-4}	.3509	.0705	.0326	.0705	.0706	NA	NA
4	5×10^{-4}	.3178	.0391	.0200	.0391	.0362	NA	NA
5	1×10^{-1}	.4170	.0210	.0200	.0210	.0699	NA	NA
6	1×10^{0}	.4170	.0454	.0200	.0454	.0454	NA	NA
7	1×10^{-8}	.0220	.0210	.0200	.0210	.0210	0	0
8	1×10^{-2}	.4170	.0450	.0200	.0450	.0259	NA	NA

NA - Not applicable

Table B-4. HELP Parameters for Single Composite Liner.

Layer	Hydraulic Conductivity (cm/sec)	Effective Porosity	Field Capacity	Wilting Point	Moisture Content		Percolation (cm/yr)	
					Initial	Final	Initial	Final
1	1×10^{-4}	.4370	.0622	.0240	.0622	.0454	NA	NA
2	1×10^{0}	.4170	.0454	.0200	.0454	.0454	NA	NA
3	1×10^{-7}	.4300	.3660	.2800	.3660	.3660	0	0

NA - Not applicable

Table B-5. HELP Parameters for RCRA Subtitle-C Double Composite Liner.

Layer	Hydraulic Conductivity (cm/sec)	Effective Porosity	Field Capacity	Wilting Point	Moisture Content		Percolation (cm/yr)	
					Initial	Final	Initial	Final
1	1×10^{-4}	.4370	.0622	.0240	.0622	.0454	NA	NA
2	1×10^{-2}	.4170	.0454	.0200	.0454	.0454	NA	NA
3	1×10^{-2}	.4300	.3660	.2800	.3660	.3660	NA	NA
4	1×10^{-2}	.4170	.0454	.0200	.0454	.0454	NA	NA
5	1×10^{-7}	.4300	.3660	.2800	.3660	.3660	0	0

NA - Not applicable.

Attachment B-1. HELP Output File for the Non-engineered Soil Cover.

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SAIC/ERDF, EIS/FS/ WA 923-E412
CASE 1 - NO ENGINEERED COVER
3/10/94 YEARS 70-80 CASE1JV5.OUT

****

Soils Data

LAYER 1
VERTICAL PERCOLATION LAYER

THICKNESS = 181.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0635 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.001000000047 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER = 77.00
TOTAL AREA OF COVER = 43560. SQ FT
EVAPORATIVE ZONE DEPTH = 36.00 INCHES
UPPER LIMIT VEG. STORAGE = 15.7320 INCHES
INITIAL VEG. STORAGE = 2.2860 INCHES
INITIAL SNOW WATER CONTENT = 0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN
SOIL AND WASTE LAYERS = 11.4935 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR YAKIMA, WASHINGTON

MAXIMUM LEAF AREA INDEX = 1.60
START OF GROWING SEASON (JULIAN DATE) = 124
END OF GROWING SEASON (JULIAN DATE) = 276

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	36.10	41.90	49.20	57.30	64.50
70.40	68.60	60.90	49.90	38.20	31.50

Results

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 79 THROUGH 88

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.78	0.75	0.66	0.44	0.50	0.42
	0.18	0.09	0.51	0.41	1.09	1.25
STD. DEVIATIONS	0.53	0.46	0.29	0.40	0.41	0.40
	0.14	0.12	0.28	0.40	0.57	0.60
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.630	1.060	0.818	0.487	0.730	1.257
	0.516	0.084	0.245	0.249	0.505	0.489
STD. DEVIATIONS	0.121	0.311	0.479	0.241	0.391	0.637
	0.436	0.092	0.132	0.120	0.268	0.137
PERCOLATION FROM LAYER 1						
TOTALS	0.0011	0.0010	0.0011	0.0011	0.0012	0.0012
	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
STD. DEVIATIONS	0.0004	0.0003	0.0004	0.0003	0.0004	0.0003
	0.0004	0.0004	0.0003	0.0004	0.0003	0.0004

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 79 THROUGH 88

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	7.08	(2.085)	25715.	100.00
RUNOFF	0.000	(0.000)	0.	0.00
EVAPOTRANSPIRATION	7.069	(1.762)	25662.	99.79
PERCOLATION FROM LAYER 1	0.0139	(0.0042)	51.	0.20
CHANGE IN WATER STORAGE	0.001	(0.708)	3.	0.01

PEAK DAILY VALUES FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	3375.9
RUNOFF	0.000	0.0
PERCOLATION FROM LAYER 1	0.0001	0.2
SNOW WATER	0.75	2734.6
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.1214	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0238	

FINAL WATER STORAGE AT END OF YEAR 88

LAYER	(INCHES)	(VOL/VOL)
1	11.50	0.0635

SNOW WATER 0.00

Attachment B-2. HELP Output File for the Low-Infiltration Soil Barrier.

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**************************************************************************

SAIC/ERDF-EIS,FS/ WA    923-E412
CASE 2B - THICK SOIL COVER, ANALYSIS "B"
3/10/94  YEARS 100-110  CAS2BJV6.OUT

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<u>Soils Data</u>

```
                    LAYER 1
            VERTICAL PERCOLATION LAYER
THICKNESS                       =    12.00 INCHES
POROSITY                        =    0.4603 VOL/VOL
FIELD CAPACITY                  =    0.2272 VOL/VOL
WILTING POINT                   =    0.0632 VOL/VOL
INITIAL SOIL WATER CONTENT      =    0.1173 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY   =   0.000989999971 CM/SEC

                    LAYER 2
            VERTICAL PERCOLATION LAYER
THICKNESS                       =    12.00 INCHES
POROSITY                        =    0.3702 VOL/VOL
FIELD CAPACITY                  =    0.2109 VOL/VOL
WILTING POINT                   =    0.0500 VOL/VOL
INITIAL SOIL WATER CONTENT      =    0.0500 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY   =   0.000001600000 CM/SEC

                    LAYER 3
            VERTICAL PERCOLATION LAYER
THICKNESS                       =   157.50 INCHES
POROSITY                        =    0.4370 VOL/VOL
FIELD CAPACITY                  =    0.0620 VOL/VOL
WILTING POINT                   =    0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT      =    0.0407 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY   =   0.001000000047 CM/SEC
```

<u>GENERAL SIMULATION DATA</u>

```
SCS RUNOFF CURVE NUMBER         =    77.00
TOTAL AREA OF COVER             =  43560. SQ FT
EVAPORATIVE ZONE DEPTH          =    36.00 INCHES
UPPER LIMIT VEG. STORAGE        =    15.2100 INCHES
INITIAL VEG. STORAGE            =    2.4960 INCHES
INITIAL SNOW WATER CONTENT      =    0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN
  SOIL AND WASTE LAYERS         =    8.4178 INCHES
```

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR YAKIMA, WASHINGTON

MAXIMUM LEAF AREA INDEX = 1.60
START OF GROWING SEASON (JULIAN DATE) = 124
END OF GROWING SEASON (JULIAN DATE) = 276

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	36.10	41.90	49.20	57.30	64.50
70.40	68.60	60.90	49.90	38.20	31.50

Results

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 79 THROUGH 88

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.78	0.75	0.66	0.44	0.50	0.42
	0.18	0.09	0.51	0.41	1.09	1.25
STD. DEVIATIONS	0.53	0.46	0.29	0.40	0.41	0.40
	0.14	0.12	0.28	0.40	0.57	0.60
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.535	1.015	1.289	0.565	0.649	1.166
	0.467	0.080	0.267	0.237	0.440	0.393
STD. DEVIATIONS	0.148	0.392	0.631	0.268	0.400	0.672
	0.412	0.089	0.140	0.117	0.254	0.125
PERCOLATION FROM LAYER 3						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 79 THROUGH 88

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	7.08	(2.085)	25715.	100.00
RUNOFF	0.000	(0.000)	0.	0.00
EVAPOTRANSPIRATION	7.104	(2.007)	25787.	100.28
PERCOLATION FROM LAYER 3	0.0001	(0.0000)	0.	0.00
CHANGE IN WATER STORAGE	-0.020	(0.958)	-73.	-0.28

PEAK DAILY VALUES FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	3375.9
RUNOFF	0.000	0.0
PERCOLATION FROM LAYER 3	0.0000	0.0
SNOW WATER	0.75	2734.6

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.1464

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0457

FINAL WATER STORAGE AT END OF YEAR 88

LAYER	(INCHES)	(VOL/VOL)
1	1.41	0.1173
2	0.60	0.0500
3	6.21	0.0394

SNOW WATER 0.00

Attachment B-3. HELP Output for the Modified Hanford Barrier.

****

SAIC/ ERDF - EIS,FS/ WA 923.E412
CASE 7 - MODIFIED HANFORD BARRIER, FSS & JSV ANALYSIS
5/23/94 Years 100-110 Cas7JV11.out

****

Soils Data

LAYER 1
VERTICAL PERCOLATION LAYER
THICKNESS = 19.70 INCHES
POROSITY = 0.4603 VOL/VOL
FIELD CAPACITY = 0.2272 VOL/VOL
WILTING POINT = 0.0632 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0944 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000989999971 CM/SEC

LAYER 2
VERTICAL PERCOLATION LAYER
THICKNESS = 19.70 INCHES
POROSITY = 0.3720 VOL/VOL
FIELD CAPACITY = 0.2109 VOL/VOL
WILTING POINT = 0.0500 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0510 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000001600000 CM/SEC

LAYER 3
VERTICAL PERCOLATION LAYER
THICKNESS = 118.10 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0529 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000989999971 CM/SEC

LAYER 4
VERTICAL PERCOLATION LAYER
THICKNESS = 5.90 INCHES
POROSITY = 0.3509 VOL/VOL
FIELD CAPACITY = 0.0705 VOL/VOL
WILTING POINT = 0.0326 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0793 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000154999987 CM/SEC

LAYER 5
VERTICAL PERCOLATION LAYER

THICKNESS	=	5.90 INCHES
POROSITY	=	0.3178 VOL/VOL
FIELD CAPACITY	=	0.0391 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0382 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000500000024 CM/SEC

LAYER 6
LATERAL DRAINAGE LAYER

THICKNESS	=	5.90 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0454 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	1.000000000000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	760.0 FEET

LAYER 7
BARRIER SOIL LINER

THICKNESS	=	5.91 INCHES
POROSITY	=	0.0220 VOL/VOL
FIELD CAPACITY	=	0.0210 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0220 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000000010000 CM/SEC

LAYER 8
VERTICAL PERCOLATION LAYER

THICKNESS	=	3.90 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0450 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0321 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.009999999776 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	77.00
TOTAL AREA OF COVER	=	43560. SQ FT
EVAPORATIVE ZONE DEPTH	=	36.00 INCHES
UPPER LIMIT VEG. STORAGE	=	15.1315 INCHES
INITIAL VEG. STORAGE	=	2.6910 INCHES
INITIAL SNOW WATER CONTENT	=	0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN SOIL AND WASTE LAYERS	=	10.3282 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR YAKIMA WASHINGTON

MAXIMUM LEAF AREA INDEX = 1.60
START OF GROWING SEASON (JULIAN DATE) = 124
END OF GROWING SEASON (JULIAN DATE) = 276

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	36.10	41.90	49.20	57.30	64.50
70.40	68.60	60.90	49.90	38.20	31.50

RESULTS

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 79 THROUGH 88

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.78	0.75	0.66	0.44	0.50	0.42
	0.18	0.09	0.51	0.41	1.09	1.25
STD. DEVIATIONS	0.53	0.46	0.29	0.40	0.41	0.40
	0.14	0.12	0.28	0.40	0.57	0.60
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.524	1.057	1.258	0.529	0.647	0.984
	0.644	0.083	0.249	0.237	0.435	0.438
STD. DEVIATIONS	0.166	0.416	0.678	0.278	0.442	0.667
	0.506	0.091	0.123	0.106	0.247	0.150
LATERAL DRAINAGE FROM LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

PERCOLATION FROM LAYER 7
TOTALS 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001
0.0001 0.0001 0.0001 0.0001 0.0001 0.0001

STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

PERCOLATION FROM LAYER 8
TOTALS 0.0001 0.0001 0.0001 0.0001 0.0001 0.0001
0.0001 0.0001 0.0001 0.0001 0.0001 0.0001

STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	7.08 (2.085)	25715.	100.00
RUNOFF	0.000 (0.000)	0.	0.00
EVAPOTRANSPIRATION	7.084 (2.070)	25715.	100.00
LATERAL DRAINAGE FROM LAYER 6	0.0000 (0.0000)	0.	0.00
PERCOLATION FROM LAYER 7	0.0017 (0.0000)	6.	0.02
PERCOLATION FROM LAYER 8	0.0017 (0.0000)	6.	0.02
CHANGE IN WATER STORAGE	-0.002 (0.984)	-6.	-0.02

PEAK DAILY VALUES FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	3375.9
RUNOFF	0.000	0.0
LATERAL DRAINAGE FROM LAYER 6	0.0000	0.0
PERCOLATION FROM LAYER 7	0.0000	0.0
HEAD ON LAYER 7	0.0	
PERCOLATION FROM LAYER 8	0.0000	0.0

SNOW WATER	0.75	2734.6
MAXIMUM VEG. SOIL WATER (VOL/VOL)		0.1594
MINIMUM VEG. SOIL WATER (VOL/VOL)		0.0570

FINAL WATER STORAGE AT END OF YEAR 88

LAYER	(INCHES)	(VOL/VOL)
1	1.86	0.0944
2	1.00	0.0510
3	6.23	0.0528
4	0.47	0.0792
5	0.23	0.0382
6	0.27	0.0454
7	0.13	0.0220
8	0.13	0.0321

SNOW WATER 0.00

Attachment B-4. HELP Output File for the Hanford Barrier.

****

SAIC/ ERDF EIS/RC/FS/ WA. 923-E412
CASE 4 - HANFORD BARRIER
3/10/94 YEARS 100-110 CAS4JV11.OUT

****

Soils Data

LAYER 1
VERTICAL PERCOLATION LAYER
THICKNESS = 19.37 INCHES
POROSITY = 0.4603 VOL/VOL
FIELD CAPACITY = 0.2272 VOL/VOL
WILTING POINT = 0.0632 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0954 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000992999994 CM/SEC

LAYER 2
VERTICAL PERCOLATION LAYER
THICKNESS = 59.37 INCHES
POROSITY = 0.3702 VOL/VOL
FIELD CAPACITY = 0.2109 VOL/VOL
WILTING POINT = 0.0500 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0556 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000001600000 CM/SEC

LAYER 3
VERTICAL PERCOLATION LAYER
THICKNESS = 5.91 INCHES
POROSITY = 0.3509 VOL/VOL
FIELD CAPACITY = 0.0705 VOL/VOL
WILTING POINT = 0.0326 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0714 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000154999987 CM/SEC

LAYER 4
VERTICAL PERCOLATION LAYER
THICKNESS = 11.81 INCHES
POROSITY = 0.3178 VOL/VOL
FIELD CAPACITY = 0.0391 VOL/VOL
WILTING POINT = 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0367 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000500000024 CM/SEC

LAYER 5
VERTICAL PERCOLATION LAYER

THICKNESS = 59.00 INCHES
POROSITY = 0.4170 VOL/VOL
FIELD CAPACITY = 0.0210 VOL/VOL
WILTING POINT = 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0697 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.100000001490 CM/SEC

LAYER 6
LATERAL DRAINAGE LAYER

THICKNESS = 11.80 INCHES
POROSITY = 0.4170 VOL/VOL
FIELD CAPACITY = 0.0454 VOL/VOL
WILTING POINT = 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 1.000000000000 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 760.0 FEET

LAYER 7
BARRIER SOIL LINER

THICKNESS = 5.91 INCHES
POROSITY = 0.0220 VOL/VOL
FIELD CAPACITY = 0.0210 VOL/VOL
WILTING POINT = 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0210 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000000010000 CM/SEC

LAYER 8
VERTICAL PERCOLATION LAYER

THICKNESS = 3.95 INCHES
POROSITY = 0.4170 VOL/VOL
FIELD CAPACITY = 0.0450 VOL/VOL
WILTING POINT = 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0261 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.009999999776 CM/SEC

<u>GENERAL SIMULATION DATA</u>

SCS RUNOFF CURVE NUMBER = 77.00
TOTAL AREA OF COVER = 43560. SQ FT
EVAPORATIVE ZONE DEPTH = 36.00 INCHES
UPPER LIMIT VEG. STORAGE = 15.0724 INCHES
INITIAL VEG. STORAGE = 2.7725 INCHES
INITIAL SNOW WATER CONTENT = 0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN
SOIL AND WASTE LAYERS = 10.8795 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR YAKIMA, WASHINGTON

MAXIMUM LEAF AREA INDEX = 1.60
START OF GROWING SEASON (JULIAN DATE) = 124
END OF GROWING SEASON (JULIAN DATE) = 276

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	36.10	41.90	49.20	57.30	64.50
70.40	68.60	60.90	49.90	38.20	31.50

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 79 THROUGH 88

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.78	0.75	0.66	0.44	0.50	0.42
	0.18	0.09	0.51	0.41	1.09	1.25
STD. DEVIATIONS	0.53	0.46	0.29	0.40	0.41	0.40
	0.14	0.12	0.28	0.40	0.57	0.60
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.526	1.065	1.254	0.546	0.591	1.024
	0.658	0.083	0.248	0.234	0.424	0.439
STD. DEVIATIONS	0.168	0.418	0.680	0.319	0.380	0.672
	0.515	0.091	0.123	0.106	0.241	0.152
LATERAL DRAINAGE FROM LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION FROM LAYER 7						

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION FROM LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	7.08 (2.085)	25715.	100.00
RUNOFF	0.000 (0.000)	0.	0.00
EVAPOTRANSPIRATION	7.092 (2.055)	25744.	100.11
LATERAL DRAINAGE FROM LAYER 6	0.0000 (0.0000)	0.	0.00
PERCOLATION FROM LAYER 7	0.0000 (0.0000)	0.	0.00
PERCOLATION FROM LAYER 8	0.0001 (0.0000)	0.	0.00
CHANGE IN WATER STORAGE	-0.008 (1.009)	-29.	-0.11

PEAK DAILY VALUES FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	3375.9
RUNOFF	0.000	0.0
LATERAL DRAINAGE FROM LAYER 6	0.0000	0.0
PERCOLATION FROM LAYER 7	0.0000	0.0
HEAD ON LAYER 7	0.0	
PERCOLATION FROM LAYER 8	0.0000	0.0
SNOW WATER	0.75	2734.6

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.1587

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0569

FINAL WATER STORAGE AT END OF YEAR 88

LAYER	(INCHES)	(VOL/VOL)
1	1.85	0.0954
2	3.22	0.0543
3	0.42	0.0706
4	0.43	0.0362
5	4.12	0.0699
6	0.54	0.0454
7	0.12	0.0210
8	0.10	0.0259

SNOW WATER 0.00

Attachment B-5. HELP Output File for the Single Composite Liner System.

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SAIC/ ERDF EIS-RI-FS /WA 923-E412
CASE 5 - SINGLE COMPOSITE LINER
3/7/94 YEARS 0 - 10 CASE5FS1.W51

****

Soils Data

LAYER 1
VERTICAL PERCOLATION LAYER
THICKNESS = 36.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0622 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0622 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000099999968 CM/SEC

LAYER 2
VERTICAL PERCOLATION LAYER
THICKNESS = 12.00 INCHES
POROSITY = 0.4170 VOL/VOL
FIELD CAPACITY = 0.0454 VOL/VOL
WILTING POINT = 0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 1.000000000000 CM/SEC

LAYER 3
BARRIER SOIL LINER
THICKNESS = 12.00 INCHES
POROSITY = 0.4300 VOL/VOL
FIELD CAPACITY = 0.3660 VOL/VOL
WILTING POINT = 0.2800 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3660 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000000100000 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER = 77.00
TOTAL AREA OF COVER = 43560. SQ FT
EVAPORATIVE ZONE DEPTH = 36.00 INCHES
UPPER LIMIT VEG. STORAGE = 15.7320 INCHES
INITIAL VEG. STORAGE = 2.2392 INCHES
INITIAL SNOW WATER CONTENT = 0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN
SOIL AND WASTE LAYERS = 7.1760 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR YAKIMA, WASHINGTON

MAXIMUM LEAF AREA INDEX = 1.60
START OF GROWING SEASON (JULIAN DATE) = 124
END OF GROWING SEASON (JULIAN DATE) = 276

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	36.10	41.90	49.20	57.30	64.50
70.40	68.60	60.90	49.90	38.20	31.50

Results

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 79 THROUGH 88

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.78	0.75	0.66	0.44	0.50	0.42
	0.18	0.09	0.51	0.41	1.09	1.25
STD. DEVIATIONS	0.53	0.46	0.29	0.40	0.41	0.40
	0.14	0.12	0.28	0.40	0.57	0.60
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPORATION						
TOTALS	0.565	1.020	0.919	0.513	0.713	1.232
	0.646	0.084	0.262	0.264	0.485	0.441
STD. DEVIATIONS	0.115	0.247	0.508	0.239	0.326	0.596
	0.603	0.089	0.138	0.140	0.267	0.112
PERCOLATION FROM LAYER 3						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	7.08 (2.085)	25715.	100.00
RUNOFF	0.000 (0.000)	0.	0.00
EVAPOTRANSPIRATION	7.145 (1.842)	25935.	100.85
PERCOLATION FROM LAYER 3	0.0000 (0.0000)	0.	0.00
CHANGE IN WATER STORAGE	-0.061 (0.762)	-220.	-0.85

PEAK DAILY VALUES FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	3375.9
RUNOFF	0.000	0.0
PERCOLATION FROM LAYER 3	0.0000	0.0
HEAD ON LAYER 3	0.0	
SNOW WATER	0.75	2734.6

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.1232

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0239

FINAL WATER STORAGE AT END OF YEAR 88

LAYER	(INCHES)	(VOL/VOL)
1	1.63	0.0454
2	0.55	0.0454
3	4.39	0.3660

SNOW WATER 0.00

Attachment B-6. HELP Output File for the RCRA Subtitle-C Double Composite Liner System.

****

SAIC /ERDF EIS-RI-FS/ WA 923-E412
CASE 6 - DOUBLE COMPOSITE LINER
3/7/94 Years 0 - 10 CASE6FS1.W51

****

Soils Data

LAYER 1
VERTICAL PERCOLATION LAYER

THICKNESS	=	36.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.0622 VOL/VOL
WILTING POINT	=	0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0622 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000099999968 CM/SEC

LAYER 2
VERTICAL PERCOLATION LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0454 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.009999999776 CM/SEC

LAYER 3
BARRIER SOIL LINER

THICKNESS	=	0.10 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.3660 VOL/VOL
WILTING POINT	=	0.2800 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3660 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.009999999776 CM/SEC

LAYER 4
VERTICAL PERCOLATION LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0454 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0454 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.009999999776 CM/SEC

LAYER 5
BARRIER SOIL LINER

THICKNESS = 36.00 INCHES
POROSITY = 0.4300 VOL/VOL
FIELD CAPACITY = 0.3660 VOL/VOL
WILTING POINT = 0.2800 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3660 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY = 0.000000100000 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER = 77.00
TOTAL AREA OF COVER = 43560. SQ FT
EVAPORATIVE ZONE DEPTH = 36.00 INCHES
UPPER LIMIT VEG. STORAGE = 15.7320 INCHES
INITIAL VEG. STORAGE = 2.2392 INCHES
INITIAL SNOW WATER CONTENT = 0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN
SOIL AND WASTE LAYERS = 16.5414 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR YAKIMA, WASHINGTON

MAXIMUM LEAF AREA INDEX = 1.60
START OF GROWING SEASON (JULIAN DATE) = 124
END OF GROWING SEASON (JULIAN DATE) = 276

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	36.10	41.90	49.20	57.30	64.50
70.40	68.60	60.90	49.90	38.20	31.50

Results

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 79 THROUGH 88

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.78	0.75	0.66	0.44	0.50	0.42
	0.18	0.09	0.51	0.41	1.09	1.25

STD. DEVIATIONS 0.53 0.46 0.29 0.40 0.41 0.40
0.14 0.12 0.28 0.40 0.57 0.60

RUNOFF

TOTALS 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000

STD. DEVIATIONS 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000

EVAPOTRANSPIRATION

TOTALS 0.565 1.020 0.919 0.513 0.713 1.232
0.646 0.084 0.262 0.264 0.485 0.441

STD. DEVIATIONS 0.115 0.247 0.508 0.239 0.326 0.596
0.603 0.089 0.138 0.140 0.267 0.112

PERCOLATION FROM LAYER 3

TOTALS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

PERCOLATION FROM LAYER 5

TOTALS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	7.08 (2.085)	25715.	100.00
RUNOFF	0.000 (0.000)	0.	0.00
EVAPOTRANSPIRATION	7.145 (1.842)	25935.	100.85
PERCOLATION FROM LAYER 3	0.0000 (0.0001)	0.	0.00
PERCOLATION FROM LAYER 5	0.0000 (0.0000)	0.	0.00
CHANGE IN WATER STORAGE	-0.061 (0.762)	-220.	-0.85

PEAK DAILY VALUES FOR YEARS 79 THROUGH 88

	(INCHES)	(CU. FT.)
PRECIPITATION	0.93	3375.9
RUNOFF	0.000	0.0
PERCOLATION FROM LAYER 3	0.0000	0.0
HEAD ON LAYER 3	0.0	
PERCOLATION FROM LAYER 5	0.0000	0.0
HEAD ON LAYER 5	0.0	
SNOW WATER	0.75	2734.6

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.1232

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0239

FINAL WATER STORAGE AT END OF YEAR 88

LAYER	(INCHES)	(VOL/VOL)
1	1.63	0.0454
2	0.54	0.0454
3	0.04	0.3660
4	0.55	0.0454
5	13.18	0.3660
SNOW WATER	0.00	

****

Attachment B-7. HELP Model Data File: DATA4 - Precipitation Data for Hanford, Washington.

79	0.	0.0	0.	0.	0.	0.	0.	0.0	0.0	0.2	1
79	0.16	0.	0.	0.11	0.	0.	0.	0.	0.0	0.0	2
79	0.0	0.	0.02	0.04	0.	0.0	0.0	0.	0.0	0.01	3
79	0.0	0.0	0.0	0.	0.	0.	0.0	0.	0.0	0.	4
79	0.0	0.01	0.08	0.	0.	0.0	0.03	0.0	0.	0.0	5
79	0.03	0.01	0.	0.0	0.0	0.01	0.0	0.	0.	0.	6
79	0.	0.04	0.06	0.0	0.02	0.	0.	0.	0.	0.	7
79	0.	0.	0.	0.0	0.0	0.	0.	0.	0.	0.	8
79	0.	0.	0.	0.	0.	0.42	0.	0.	0.	0.	9
79	0.0	0.1	0.	0.	0.	0.0	0.	0.01	0.0	0.	10
79	0.03	0.01	0.	0.	0.0	0.08	0.17	0.0	0.	0.	11
79	0.	0.0	0.0	0.04	0.	0.	0.	0.	0.	0.08	12
79	0.08	0.	0.	0.01	0.01	0.	0.	0.0	0.	0.	13
79	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	14
79	0.	0.0	0.0	0.	0.	0.	0.	0.0	0.	0.	15
79	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	16
79	0.0	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	17
79	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	18
79	0.	0.0	0.	0.	0.	0.	0.02	0.0	0.01	0.0	19
79	0.02	0.04	0.	0.	0.	0.	0.	0.	0.	0.	20
79	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0.	21
79	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	22
79	0.	0.	0.	0.	0.04	0.09	0.	0.	0.	0.	23
79	0.05	0.02	0.06	0.	0.	0.	0.	0.	0.	0.	24
79	0.01	0.11	0.	0.06	0.01	0.13	0.	0.	0.	0.	25
79	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	26
79	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	27
79	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	28
79	0.	0.	0.	0.	0.	0.	0.0	0.	0.	0.	29
79	0.28	0.12	0.06	0.	0.0	0.	0.11	0.07	0.	0.03	30
79	0.0	0.	0.	0.	0.	0.06	0.0	0.09	0.07	0.06	31
79	0.	0.0	0.0	0.	0.	0.	0.	0.0	0.0	0.42	32
79	0.0	0.	0.	0.	0.	0.37	0.	0.31	0.	0.05	33
79	0.	0.	0.	0.0	0.07	0.02	0.03	0.	0.04	0.	34
79	0.0	0.0	0.0	0.	0.	0.	0.	0.	0.03	0.0	35
79	0.04	0.05	0.0	0.0	0.0	0.	0.27	0.05	0.03	0.	36
79	0.0	0.02	0.07	0.15	0.12	0.	0.	0.	0.	0.	37
80	0.11	0.0	0.	0.09	0.	0.	0.05	0.22	0.20	0.0	38
80	0.17	0.01	0.33	0.06	0.	0.05	0.	0.	0.	0.	39
80	0.	0.	0.0	0.	0.0	0.	0.	0.	0.	0.	40
80	0.03	0.07	0.12	0.	0.	0.0	0.01	0.	0.	0.	41
80	0.	0.	0.	0.17	0.03	0.02	0.01	0.28	0.01	0.07	42
80	0.01	0.	0.	0.	0.	0.02	0.20	0.24	0.04	0.	43
80	0.	0.	0.0	0.0	0.04	0.	0.	0.	0.	0.06	44
80	0.	0.0	0.05	0.06	0.	0.	0.02	0.	0.	0.06	45
80	0.	0.	0.	0.	0.	0.0	0.	0.	0.01	0.	46

80	0.	0.	0.0	0.0	0.05	0.02	0.04	0.	0.0	0.12	47
80	0.	0.	0.	0.	0.	0.	0.	0.0	0.	0.02	48
80	0.56	0.0	0.	0.	0.	0.	0.	0.	0.01	0.	49
80	0.04	0.	0.	0.	0.	0.02	0.10	0.	0.0	0.08	50
80	0.15	0.	0.05	0.	0.03	0.0	0.	0.	0.	0.	51
80	0.	0.02	0.07	0.	0.	0.11	0.79	0.01	0.0	0.	52
80	0.	0.0	0.0	0.	0.	0.	0.	0.	0.	0.	53
80	0.0	0.	0.	0.22	0.35	0.	0.	0.14	0.	0.	54
80	0.	0.19	0.0	0.01	0.	0.02	0.02	0.01	0.	0.	55
80	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	56
80	0.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	57
80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	58
80	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	59
80	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.0	60
80	0.02	0.	0.	0.	0.	0.	0.	0.	0.	0.	61
80	0.	0.	0.0	0.	0.04	0.0	0.	0.	0.	0.	62
80	0.	0.	0.	0.	0.	0.0	0.79	0.01	0.	0.	63
80	0.	0.0	0.	0.01	0.	0.0	0.	0.	0.	0.	64
80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	65
80	0.	0.	0.	0.	0.	0.05	0.04	0.05	0.01	0.	66
80	0.	0.	0.	0.0	0.	0.	0.	0.06	0.12	0.	67
80	0.	0.	0.	0.	0.0	0.02	0.	0.02	0.	0.0	68
80	0.30	0.03	0.	0.0	0.	0.	0.	0.	0.03	0.	69
80	0.	0.0	0.	0.0	0.	0.01	0.	0.0	0.	0.0	70
80	0.	0.01	0.	0.02	0.	0.	0.34	0.56	0.02	0.0	71
80	0.01	0.	0.	0.0	0.	0.	0.	0.	0.0	0.	72
80	0.0	0.0	0.0	0.	0.15	0.30	0.	0.	0.15	0.26	73
80	0.	0.	0.	0.05	0.04	0.01	0.	0.	0.	0.	74
81	0.01	0.	0.	0.	0.	0.0	0.	0.	0.0	0.	75
81	0.0	0.0	0.0	0.0	0.0	0.	0.02	0.0	0.02	0.	76
81	0.11	0.02	0.0	0.	0.	0.02	0.20	0.14	0.02	0.0	77
81	0.	0.	0.	0.	0.	0.	0.0	0.	0.	0.0	78
81	0.	0.	0.0	0.21	0.0	0.02	0.0	0.	0.19	0.07	79
81	0.	0.	0.	0.	0.10	0.0	0.01	0.	0.	0.	80
81	0.	0.0	0.14	0.	0.	0.0	0.	0.	0.	0.	81
81	0.	0.	0.	0.	0.05	0.	0.	0.	0.	0.	82
81	0.	0.	0.	0.01	0.50	0.	0.	0.	0.	0.0	83
81	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0.	84
81	0.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	85
81	0.	0.02	0.	0.	0.	0.	0.0	0.	0.	0.	86
81	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	87
81	0.	0.	0.	0.05	0.	0.0	0.02	0.13	0.05	0.	88
81	0.	0.	0.	0.0	0.74	0.	0.	0.	0.	0.	89
81	0.	0.	0.02	0.0	0.0	0.14	0.	0.06	0.21	0.	90
81	0.	0.	0.0	0.	0.	0.	0.0	0.	0.0	0.	91
81	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	92
81	0.	0.	0.	0.	0.	0.19	0.	0.	0.	0.	93
81	0.	0.	0.0	0.0	0.	0.	0.	0.	0.	0.	94
81	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	95
81	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	96

81	0.	0.	0.	0.	0.	0.0	0.	0.	0.	0.	97
81	0.02	0.01	0.	0.	0.	0.	0.	0.	0.	0.	98
81	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	99
81	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100
81	0.0	0.0	0.0	0.	0.	0.	0.	0.0	0.22	0.38	101
81	0.	0.	0.	0.0	0.0	0.	0.	0.0	0.12	0.	102
81	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	103
81	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0.02	104
81	0.09	0.16	0.0	0.	0.	0.	0.	0.	0.	0.	105
81	0.	0.	0.	0.	0.01	0.0	0.47	0.10	0.13	0.31	106
81	0.03	0.	0.	0.0	0.03	0.0	0.	0.	0.	0.	107
81	0.	0.	0.	0.0	0.	0.	0.0	0.	0.02	0.08	108
81	0.	0.	0.04	0.	0.	0.	0.17	0.23	0.22	0.0	109
81	0.	0.22	0.16	0.	0.	0.	0.0	0.14	0.	0.08	110
81	0.0	0.04	0.	0.	0.05	0.	0.	0.	0.	0.	111
82	0.05	0.10	0.0	0.04	0.	0.	0.	0.	0.	0.	112
82	0.	0.	0.0	0.0	0.0	0.05	0.	0.	0.	0.	113
82	0.0	0.08	0.01	0.	0.0	0.	0.0	0.05	0.	0.0	114
82	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	115
82	0.	0.0	0.	0.08	0.	0.20	0.	0.01	0.04	0.09	116
82	0.05	0.	0.	0.	0.	0.	0.01	0.	0.09	0.09	117
82	0.	0.	0.0	0.	0.	0.	0.0	0.	0.02	0.0	118
82	0.	0.	0.0	0.	0.	0.0	0.	0.	0.	0.	119
82	0.	0.	0.	0.	0.	0.	0.13	0.01	0.02	0.03	120
82	0.01	0.06	0.	0.	0.03	0.36	0.02	0.	0.	0.0	121
82	0.23	0.	0.0	0.	0.	0.	0.	0.	0.	0.	122
82	0.	0.	0.	0.	0.	0.	0.0	0.04	0.	0.	123
82	0.	0.	0.	0.	0.	0.	0.	0.0	0.0	0.	124
82	0.	0.	0.	0.0	0.	0.	0.13	0.	0.	0.	125
82	0.	0.0	0.	0.	0.	0.0	0.05	0.10	0.	0.	126
82	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	127
82	0.	0.	0.0	0.05	0.	0.	0.	0.	0.	0.	128
82	0.	0.	0.	0.	0.	0.01	0.27	0.31	0.09	0.02	129
82	0.	0.	0.0	0.0	0.	0.	0.	0.22	0.	0.	130
82	0.	0.0	0.0	0.0	0.	0.	0.	0.	0.	0.	131
82	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	132
82	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	133
82	0.10	0.	0.	0.	0.04	0.	0.	0.	0.	0.	134
82	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	135
82	0.06	0.	0.	0.	0.	0.02	0.	0.	0.	0.	136
82	0.	0.03	0.	0.05	0.	0.	0.	0.	0.	0.	137
82	0.	0.17	0.0	0.	0.	0.	0.01	0.25	0.	0.	138
82	0.02	0.	0.	0.	0.03	0.	0.	0.	0.0	0.	139
82	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	140
82	0.	0.	0.	0.16	0.15	0.	0.	0.01	0.01	0.	141
82	0.93	0.08	0.	0.	0.	0.	0.	0.	0.	0.	142
82	0.	0.	0.	0.	0.	0.0	0.	0.	0.02	0.02	143
82	0.11	0.46	0.0	0.	0.	0.	0.	0.	0.	0.04	144
82	0.05	0.07	0.14	0.	0.	0.18	0.	0.	0.21	0.10	145
82	0.	0.0	0.	0.	0.	0.29	0.0	0.17	0.11	0.09	146

82	0.	0.0	0.04	0.33	0.27	0.	0.	0.	0.	0.	147
82	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	148
83	0.	0.17	0.08	0.0	0.	0.50	0.	0.0	0.	0.	149
83	0.	0.	0.	0.	0.	0.05	0.0	0.11	0.12	0.	150
83	0.	0.0	0.	0.13	0.02	0.20	0.06	0.	0.0	0.	151
83	0.	0.	0.	0.	0.	0.	0.16	0.	0.0	0.14	152
83	0.09	0.01	0.01	0.02	0.07	0.11	0.	0.07	0.34	0.	153
83	0.	0.07	0.	0.01	0.01	0.22	0.	0.03	0.	0.0	154
83	0.0	0.	0.01	0.02	0.02	0.0	0.10	0.26	0.02	0.	155
83	0.02	0.35	0.	0.	0.	0.	0.	0.	0.	0.	156
83	0.0	0.	0.	0.	0.0	0.05	0.	0.15	0.	0.	157
83	0.18	0.09	0.0	0.0	0.	0.	0.	0.	0.	0.	158
83	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.0	159
83	0.	0.	0.13	0.0	0.	0.0	0.	0.	0.	0.02	160
83	0.0	0.	0.	0.	0.03	0.0	0.39	0.10	0.	0.	161
83	0.	0.	0.	0.0	0.	0.	0.0	0.	0.	0.	162
83	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	163
83	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	164
83	0.08	0.	0.	0.	0.04	0.	0.	0.	0.07	0.01	165
83	0.	0.	0.02	0.01	0.	0.	0.0	0.37	0.0	0.08	166
83	0.0	0.03	0.0	0.	0.	0.	0.0	0.	0.0	0.	167
83	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.0	168
83	0.0	0.	0.	0.02	0.01	0.23	0.	0.02	0.	0.	169
83	0.	0.0	0.	0.	0.	0.	0.	0.	0.0	0.0	170
83	0.0	0.0	0.01	0.	0.	0.	0.	0.	0.	0.	171
83	0.	0.	0.	0.	0.	0.	0.	0.02	0.02	0.03	172
83	0.04	0.	0.0	0.24	0.	0.	0.	0.	0.	0.	173
83	0.0	0.	0.0	0.	0.	0.	0.	0.	0.	0.	174
83	0.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	175
83	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	176
83	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.08	177
83	0.	0.0	0.	0.0	0.20	0.	0.	0.	0.	0.	178
83	0.	0.	0.23	0.01	0.15	0.05	0.04	0.	0.04	0.01	179
83	0.	0.	0.07	0.66	0.	0.01	0.02	0.08	0.01	0.08	180
83	0.09	0.	0.08	0.	0.05	0.0	0.42	0.20	0.	0.0	181
83	0.	0.06	0.	0.	0.	0.03	0.	0.05	0.32	0.0	182
83	0.32	0.	0.41	0.06	0.	0.03	0.	0.01	0.0	0.01	183
83	0.	0.02	0.04	0.0	0.	0.	0.	0.06	0.12	0.0	184
83	0.09	0.0	0.55	0.	0.	0.	0.	0.	0.	0.	185
84	0.0	0.02	0.04	0.	0.0	0.	0.0	0.	0.	0.02	186
84	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	187
84	0.15	0.0	0.	0.	0.	0.	0.	0.	0.	0.	188
84	0.	0.	0.	0.	0.	0.01	0.0	0.0	0.06	0.04	189
84	0.	0.01	0.03	0.18	0.	0.13	0.	0.	0.	0.02	190
84	0.18	0.02	0.	0.08	0.08	0.06	0.	0.	0.	0.04	191
84	0.03	0.0	0.	0.	0.	0.	0.	0.	0.	0.01	192
84	0.	0.	0.14	0.0	0.03	0.03	0.	0.02	0.11	0.43	193
84	0.10	0.	0.0	0.	0.03	0.01	0.	0.07	0.	0.	194
84	0.	0.	0.	0.0	0.13	0.	0.	0.22	0.	0.0	195
84	0.0	0.0	0.01	0.	0.	0.	0.0	0.	0.12	0.0	196

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84	0.	0.0	0.	0.	0.	0.	0.	0.	0.	0.	197
84	0.12	0.19	0.0	0.	0.	0.0	0.0	0.	0.0	0.	198
84	0.0	0.04	0.	0.05	0.07	0.	0.	0.	0.	0.03	199
84	0.	0.	0.12	0.0	0.	0.05	0.	0.	0.	0.	200
84	0.	0.	0.	0.0	0.0	0.25	0.0	0.	0.07	0.	201
84	0.	0.	0.	0.01	0.0	0.	0.	0.	0.	0.	202
84	0.	0.24	0.03	0.	0.	0.	0.	0.0	0.	0.23	203
84	0.16	0.	0.	0.	0.	0.	0.	0.	0.	0.	204
84	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	205
84	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.06	206
84	0.	0.	0.	0.	0.	0.	0.	0.0	0.	0.	207
84	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	208
84	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	209
84	0.	0.	0.	0.	0.	0.	0.	0.	0.03	0.01	210
84	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	211
84	0.	0.	0.0	0.11	0.	0.20	0.07	0.	0.	0.	212
84	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	213
84	0.	0.	0.	0.0	0.0	0.03	0.	0.	0.	0.	214
84	0.	0.	0.	0.	0.	0.	0.02	0.0	0.	0.02	215
84	0.	0.	0.	0.	0.	0.03	0.25	0.01	0.	0.	216
84	0.0	0.	0.0	0.0	0.12	0.14	0.06	0.05	0.	0.	217
84	0.0	0.10	0.05	0.01	0.26	0.	0.	0.20	0.03	0.	218
84	0.	0.49	0.01	0.02	0.	0.	0.	0.	0.	0.	219
84	0.	0.	0.	0.14	0.	0.05	0.05	0.0	0.	0.	220
84	0.0	0.18	0.	0.0	0.02	0.0	0.	0.	0.	0.0	221
84	0.	0.0	0.0	0.13	0.	0.0	0.	0.	0.	0.	222
85	0.	0.	0.	0.0	0.	0.0	0.	0.0	0.0	0.0	223
85	0.0	0.0	0.	0.	0.	0.0	0.0	0.0	0.07	0.26	224
85	0.	0.01	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	225
85	0.0	0.26	0.	0.	0.0	0.01	0.03	0.27	0.12	0.07	226
85	0.	0.06	0.	0.	0.	0.	0.	0.	0.	0.0	227
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	228
85	0.	0.	0.16	0.	0.	0.	0.	0.	0.	0.	229
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	230
85	0.0	0.08	0.	0.	0.09	0.	0.	0.02	0.01	0.	231
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	232
85	0.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	233
85	0.	0.01	0.	0.0	0.	0.	0.	0.	0.	0.	234
85	0.	0.	0.	0.01	0.	0.	0.	0.	0.	0.	235
85	0.	0.	0.11	0.0	0.	0.	0.	0.	0.	0.	236
85	0.	0.	0.0	0.	0.	0.	0.	0.	0.0	0.	237
85	0.	0.	0.	0.0	0.	0.0	0.14	0.01	0.	0.	238
85	0.	0.	0.	0.0	0.	0.	0.	0.	0.	0.	239
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	240
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	241
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	242
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	243
85	0.	0.12	0.	0.	0.	0.01	0.	0.	0.	0.	244
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	245
85	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	246

85	0.	0.	0.	0.02	0.	0.	0.	0.	0.	0.	247
85	0.10	0.07	0.06	0.04	0.	0.11	0.04	0.	0.03	0.16	248
85	0.	0.	0.0	0.	0.	0.	0.	0.	0.	0.	249
85	0.	0.	0.	0.0	0.	0.	0.	0.	0.12	0.25	250
85	0.	0.	0.09	0.	0.	0.	0.	0.	0.	0.	251
85	0.	0.	0.	0.	0.0	0.	0.0	0.	0.	0.0	252
85	0.	0.	0.	0.0	0.	0.	0.	0.04	0.	0.	253
85	0.0	0.03	0.0	0.04	0.	0.	0.	0.	0.17	0.	254
85	0.11	0.	0.13	0.05	0.50	0.02	0.	0.	0.01	0.0	255
85	0.08	0.0	0.04	0.02	0.05	0.34	0.	0.	0.0	0.18	256
85	0.28	0.	0.	0.	0.	0.	0.	0.0	0.	0.0	257
85	0.0	0.	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	258
85	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	0.	0.	259
86	0.01	0.04	0.	0.01	0.19	0.	0.	0.0	0.11	0.	260
86	0.	0.	0.	0.	0.06	0.20	0.10	0.06	0.	0.	261
86	0.	0.36	0.01	0.	0.	0.	0.08	0.19	0.21	0.12	262
86	0.01	0.02	0.05	0.01	0.21	0.0	0.	0.	0.	0.	263
86	0.0	0.01	0.20	0.0	0.39	0.12	0.0	0.	0.	0.	264
86	0.	0.20	0.0	0.	0.	0.	0.	0.	0.	0.	265
86	0.	0.	0.	0.	0.	0.21	0.13	0.0	0.02	0.0	266
86	0.09	0.03	0.	0.0	0.0	0.	0.01	0.	0.	0.	267
86	0.	0.26	0.	0.01	0.0	0.	0.	0.	0.0	0.	268
86	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	269
86	0.0	0.0	0.	0.	0.0	0.	0.0	0.	0.0	0.	270
86	0.	0.0	0.	0.0	0.	0.0	0.	0.	0.	0.	271
86	0.0	0.01	0.01	0.	0.01	0.20	0.	0.	0.	0.0	272
86	0.	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.	273
86	0.04	0.	0.	0.	0.	0.03	0.	0.	0.	0.	274
86	0.	0.	0.	0.	0.	0.	0.	0.0	0.	0.	275
86	0.	0.	0.	0.	0.	0.	0.	0.0	0.	0.	276
86	0.	0.	0.	0.	0.	0.	0.	0.	0.0	0.	277
86	0.	0.	0.07	0.03	0.10	0.	0.	0.	0.01	0.	278
86	0.0	0.	0.	0.	0.	0.	0.0	0.	0.	0.	279
86	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	280
86	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	281
86	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	282
86	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	283
86	0.02	0.	0.	0.	0.	0.	0.	0.	0.	0.	284
86	0.	0.	0.0	0.	0.	0.03	0.	0.54	0.0	0.06	285
86	0.	0.04	0.	0.	0.	0.21	0.	0.0	0.	0.01	286
86	0.0	0.07	0.	0.0	0.	0.	0.	0.	0.	0.	287
86	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	288
86	0.	0.	0.	0.	0.	0.	0.	0.03	0.08	0.	289
86	0.	0.18	0.0	0.	0.	0.	0.	0.	0.02	0.	290
86	0.05	0.	0.	0.	0.0	0.	0.0	0.	0.	0.	291
86	0.	0.	0.	0.0	0.	0.0	0.0	0.17	0.	0.11	292
86	0.11	0.19	0.	0.	0.	0.	0.	0.11	0.19	0.0	293
86	0.	0.	0.	0.0	0.0	0.0	0.12	0.	0.	0.0	294
86	0.01	0.08	0.04	0.	0.0	0.03	0.	0.03	0.08	0.04	295
86	0.01	0.03	0.0	0.	0.0	0.	0.	0.	0.	0.	296

87	0.20	0.0	0.0	0.	0.	0.	0.	0.	0.	0.	297
87	0.	0.	0.12	0.02	0.	0.	0.0	0.0	0.	0.0	298
87	0.	0.0	0.01	0.06	0.16	0.08	0.02	0.	0.	0.	299
87	0.13	0.	0.0	0.	0.	0.	0.	0.	0.	0.	300
87	0.	0.03	0.01	0.11	0.0	0.0	0.0	0.	0.	0.	301
87	0.	0.	0.4	0.	0.	0.	0.	0.	0.	0.	302
87	0.0	0.08	0.0	0.02	0.02	0.	0.04	0.0	0.01	0.05	303
87	0.42	0.0	0.11	0.18	0.0	0.0	0.0	0.12	0.	0.	304
87	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	305
87	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	306
87	0.0	0.	0.	0.	0.	0.	0.12	0.	0.	0.	307
87	0.	0.	0.	0.	0.	0.	0.0	0.0	0.0	0.02	308
87	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	309
87	0.	0.0	0.22	0.	0.	0.	0.	0.	0.	0.03	310
87	0.	0.	0.	0.	0.	0.0	0.	0.	0.0	0.14	311
87	0.0	0.	0.	0.	0.	0.	0.	0.	0.01	0.	312
87	0.	0.	0.	0.	0.01	0.03	0.	0.	0.	0.	313
87	0.03	0.	0.	0.	0.	0.	0.	0.	0.	0.	314
87	0.	0.	0.06	0.	0.0	0.	0.	0.	0.	0.27	315
87	0.	0.	0.	0.	0.	0.	0.	0.05	0.12	0.	316
87	0.	0.	0.0	0.	0.0	0.0	0.	0.	0.	0.	317
87	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	318
87	0.	0.	0.	0.	0.04	0.01	0.	0.	0.	0.	319
87	0.	0.	0.	0.	0.	0.02	0.	0.	0.	0.	320
87	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	321
87	0.	0.	0.	0.	0.	0.	0.	0.0	0.	0.	322
87	0.	0.	0.	0.	0.	0.	0.	0.	0.01	0.	323
87	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	324
87	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	325
87	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	326
87	0.	0.	0.0	0.0	0.18	0.	0.	0.	0.	0.	327
87	0.	0.	0.0	0.	0.02	0.02	0.10	0.	0.	0.	328
87	0.	0.	0.	0.	0.	0.0	0.	0.0	0.	0.	329
87	0.	0.	0.	0.08	0.11	0.26	0.12	0.01	0.07	0.15	330
87	0.	0.0	0.55	0.	0.	0.	0.	0.0	0.09	0.19	331
87	0.	0.	0.0	0.0	0.	0.0	0.	0.	0.0	0.	332
87	0.0	0.08	0.0	0.0	0.	0.	0.	0.	0.	0.	333
88	0.	0.0	0.0	0.02	0.0	0.	0.02	0.13	0.07	0.16	334
88	0.0	0.0	0.0	0.07	0.	0.	0.	0.	0.	0.01	335
88	0.	0.	0.	0.	0.	0.	0.0	0.0	0.	0.0	336
88	0.0	0.	0.	0.	0.	0.	0.	0.0	0.0	0.	337
88	0.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	338
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.0	339
88	0.	0.0	0.	0.06	0.0	0.01	0.21	0.19	0.	0.	340
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	341
88	0.	0.03	0.	0.	0.	0.0	0.	0.09	0.01	0.	342
88	0.	0.0	0.01	0.02	0.	0.0	0.0	0.	0.	0.	343
88	0.	0.	0.	0.	0.	0.	0.	0.36	0.0	0.03	344
88	0.08	0.0	0.07	0.0	0.	0.	0.	0.01	0.48	0.	345
88	0.06	0.	0.01	0.0	0.	0.	0.	0.	0.01	0.	346

88	0.	0.	0.0	0.	0.	0.	0.0	0.	0.02	0.	347
88	0.	0.	0.	0.	0.	0.	0.	0.01	0.28	0.	348
88	0.	0.	0.02	0.01	0.0	0.01	0.07	0.	0.0	0.0	349
88	0.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	350
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	351
88	0.	0.	0.	0.	0.0	0.	0.	0.	0.	0.	352
88	0.	0.	0.	0.	0.13	0.	0.	0.	0.	0.	353
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	354
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	355
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	356
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	357
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	358
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	359
88	0.	0.01	0.25	0.13	0.	0.	0.	0.	0.0	0.0	360
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	361
88	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	362
88	0.	0.01	0.	0.	0.	0.	0.	0.	0.	0.	363
88	0.	0.	0.0	0.	0.	0.	0.10	0.	0.02	0.09	364
88	0.01	0.	0.09	0.03	0.18	0.02	0.	0.	0.	0.10	365
88	0.01	0.02	0.	0.0	0.	0.01	0.10	0.	0.04	0.	366
88	0.	0.0	0.	0.	0.	0.	0.	0.0	0.0	0.02	367
88	0.04	0.	0.02	0.0	0.0	0.0	0.	0.	0.	0.	368
88	0.	0.	0.05	0.01	0.13	0.07	0.06	0.0	0.0	0.	369
88	0.	0.	0.0	0.	0.	0.0	0.	0.	0.	0.	370

Attachment B-8. HELP Model Data File: DATA7 - Temperature Data for Hanford, Washington.

79	29.7	26.5	25.7	21.6	26.5	34.6	28.1	28.7	30.6	22.9	1
79	26.7	22.7	23.2	18.7	15.2	19.6	25.7	28.2	39.7	44.3	2
79	48.9	40.6	44.6	45.3	40.4	36.0	36.1	35.8	34.2	37.6	3
79	37.2	34.8	32.8	37.9	29.9	30.2	34.3	44.2	45.1	42.9	4
79	49.4	44.3	44.8	51.0	46.6	45.8	42.0	44.8	44.7	39.5	5
79	42.5	39.3	36.5	33.8	38.9	32.7	36.6	42.2	43.4	39.1	6
79	29.3	23.0	35.6	39.7	32.2	31.6	43.2	33.1	36.0	31.9	7
79	30.1	28.0	33.8	39.4	46.8	42.0	36.4	46.3	57.4	47.2	8
79	44.9	42.4	42.7	52.1	55.0	54.6	48.4	50.9	55.8	56.4	9
79	47.0	56.7	55.6	41.6	40.4	33.6	34.8	37.8	30.0	50.7	10
79	37.8	37.6	45.0	51.9	46.7	50.5	58.8	64.0	68.9	66.3	11
79	68.0	54.0	50.9	47.8	50.9	48.7	53.3	46.0	46.3	50.5	12
79	47.3	52.6	52.6	58.2	57.0	62.1	57.6	55.2	61.4	51.7	13
79	55.0	59.8	60.1	55.3	64.0	58.3	54.6	57.0	58.9	56.0	14
79	48.7	57.7	58.3	47.0	53.1	48.8	58.2	61.6	60.7	69.2	15
79	66.8	67.3	79.2	68.7	59.8	62.9	70.1	70.0	69.2	68.7	16
79	68.5	71.5	72.1	61.2	56.8	57.7	62.0	71.3	76.8	64.7	17
79	68.9	70.3	71.4	69.2	70.8	70.8	73.7	68.2	66.2	69.6	18
79	69.7	66.9	66.7	65.6	66.7	72.6	73.5	74.3	75.5	78.6	19
79	74.0	71.9	72.6	79.9	82.7	84.1	81.1	77.7	79.9	77.5	20
79	81.3	79.9	81.8	80.8	74.4	72.1	72.2	68.3	62.8	61.6	21
79	58.8	62.2	63.7	64.5	60.5	58.6	58.8	64.0	69.7	72.3	22
79	75.2	79.9	74.0	76.5	64.1	57.6	58.9	53.0	57.9	68.4	23
79	61.4	54.6	66.3	67.9	69.1	69.1	68.7	65.1	64.3	61.3	24
79	55.9	55.7	55.3	51.2	53.7	55.3	64.0	50.7	50.7	49.7	25
79	50.6	50.6	51.7	53.5	55.1	44.5	48.4	54.5	51.4	64.2	26
79	61.6	62.0	60.6	61.3	59.7	57.8	62.5	60.0	54.6	64.2	27
79	61.9	66.7	60.4	58.8	55.5	54.9	64.4	54.3	61.8	65.9	28
79	60.3	65.3	65.3	63.8	63.9	53.8	49.8	52.9	55.0	46.5	29
79	48.4	46.1	42.6	52.2	42.9	40.6	38.5	40.2	52.1	51.8	30
79	49.7	51.1	48.1	53.2	53.5	44.9	48.3	51.0	47.4	50.6	31
79	49.1	51.8	53.9	56.5	57.5	55.0	51.5	46.6	55.4	51.7	32
79	48.7	38.4	45.4	44.9	34.7	32.6	29.6	30.0	38.3	41.5	33
79	33.9	34.0	45.0	34.4	39.6	32.6	36.1	30.9	30.5	39.3	34
79	34.4	35.9	39.9	30.5	23.0	19.9	14.0	12.4	24.7	37.0	35
79	39.4	29.0	26.2	15.5	17.0	29.2	35.9	42.1	40.7	41.0	36
79	40.7	45.0	41.5	43.0	35.0	0.0	0.0	0.0	0.0	0.0	37
80	34.8	30.9	29.6	26.1	32.4	36.5	35.1	27.7	18.6	20.3	38
80	11.9	19.4	10.7	11.5	15.6	18.8	25.2	28.8	31.3	27.4	39
80	31.3	25.7	28.3	22.4	22.3	17.2	27.0	29.7	23.9	21.1	40
80	25.6	34.3	29.7	29.2	34.0	31.1	30.9	37.2	39.1	46.3	41
80	43.2	40.6	42.0	30.8	24.5	31.7	36.3	26.3	27.2	32.6	42
80	34.2	35.8	30.4	34.7	36.7	31.1	30.6	36.2	31.0	30.5	43
80	31.6	26.0	26.4	24.4	35.6	47.4	46.7	45.4	41.3	37.0	44
80	45.9	50.6	50.4	40.7	46.1	51.4	44.2	35.5	32.5	30.4	45
80	38.6	39.6	53.0	59.0	57.2	59.1	48.6	52.0	48.7	54.9	46
80	51.4	50.1	53.6	50.5	40.9	41.5	41.7	46.9	49.3	43.2	47

80	53.4	66.2	60.6	64.3	55.1	49.3	42.0	50.1	53.6	41.7	48
80	51.8	57.0	62.8	68.2	60.6	49.5	49.0	41.7	54.7	55.6	49
80	53.2	57.7	45.9	57.1	64.1	52.4	53.8	60.2	61.0	56.0	50
80	57.0	56.8	50.9	45.1	39.3	37.4	40.4	45.6	46.6	56.5	51
80	56.8	61.8	59.4	56.0	56.1	55.9	56.0	57.9	47.4	54.9	52
80	58.6	58.2	53.7	49.4	48.5	62.9	64.2	66.3	66.7	73.3	53
80	71.0	69.0	69.3	61.7	59.5	57.5	56.1	51.8	53.1	61.1	54
80	65.0	65.9	73.0	67.4	72.0	65.5	59.6	60.9	66.8	72.2	55
80	78.4	69.4	75.7	73.0	72.9	76.6	76.1	71.3	76.5	79.5	56
80	80.4	85.1	77.8	80.1	70.8	70.5	69.5	67.8	73.2	70.2	57
80	67.6	69.2	70.8	76.2	74.4	78.1	75.6	75.4	69.1	75.7	58
80	74.6	70.7	72.5	68.7	70.4	72.6	70.5	67.5	64.7	70.8	59
80	77.3	78.8	68.3	71.6	68.0	73.1	64.9	67.0	62.4	69.2	60
80	67.2	68.5	61.8	67.7	72.8	69.4	65.0	63.0	63.0	67.0	61
80	63.9	61.5	69.7	74.3	74.5	74.1	71.9	69.8	68.9	65.6	62
80	61.9	63.7	65.6	64.2	72.0	77.2	66.0	55.3	56.5	60.0	63
80	56.6	55.8	55.8	56.7	51.5	60.3	62.3	62.4	52.1	56.6	64
80	56.1	51.8	50.7	46.3	45.4	53.9	45.7	49.3	47.7	51.1	65
80	51.4	49.7	49.2	44.5	48.6	53.1	59.7	66.2	61.7	62.8	66
80	59.2	62.5	60.3	58.7	53.5	45.6	42.8	42.4	47.3	51.1	67
80	46.9	40.5	38.8	41.0	43.3	35.2	39.1	45.6	46.6	46.8	68
80	41.6	45.1	31.4	42.5	44.3	39.8	30.9	37.2	40.2	45.3	69
80	39.6	39.1	43.5	42.4	41.4	40.8	30.7	24.1	38.3	34.3	70
80	41.7	45.2	49.1	42.2	46.5	48.2	52.0	38.9	31.1	37.9	71
80	37.2	26.2	19.0	15.6	21.0	16.3	17.3	23.6	19.1	23.2	72
80	32.1	24.6	18.0	23.7	23.8	29.2	34.6	32.2	27.2	22.0	73
80	18.4	13.4	21.7	31.9	34.3	33.9	0.0	0.0	0.0	0.0	74
81	37.3	34.6	35.5	29.6	32.6	32.0	23.6	17.0	23.3	32.7	75
81	32.7	30.4	34.9	32.8	34.7	33.6	29.4	29.6	34.9	33.5	76
81	31.9	28.0	34.3	26.9	23.5	21.1	28.0	24.1	34.7	41.7	77
81	41.4	44.0	36.7	37.8	35.9	43.6	37.7	40.7	33.5	42.5	78
81	39.7	44.1	48.8	37.9	44.5	33.1	32.6	37.3	30.1	30.2	79
81	34.1	40.3	34.7	31.6	30.6	39.0	40.1	43.9	40.3	35.0	80
81	29.3	43.5	35.8	32.7	42.1	39.1	38.5	48.6	39.0	31.1	81
81	20.7	35.2	31.6	37.2	31.7	38.0	40.5	38.3	42.4	37.0	82
81	43.1	39.2	47.5	43.0	37.9	36.8	31.1	43.6	41.6	43.7	83
81	42.8	41.5	41.1	41.7	37.0	42.8	37.5	44.0	46.5	52.2	84
81	47.6	43.8	50.5	48.0	50.2	52.2	59.4	54.2	58.2	57.6	85
81	60.0	54.9	61.1	58.5	66.4	59.0	65.2	60.1	55.9	57.3	86
81	48.2	50.5	48.2	44.4	57.4	55.6	53.4	54.1	55.2	60.1	87
81	50.1	52.9	54.1	53.9	56.4	52.3	53.9	49.2	45.5	49.4	88
81	57.4	59.5	59.8	59.3	54.6	58.8	58.2	63.0	62.3	66.8	89
81	72.0	71.4	69.5	71.7	75.1	70.3	67.5	59.7	54.9	56.8	90
81	51.9	51.4	50.4	52.1	52.6	63.4	60.4	57.9	60.6	61.9	91
81	62.0	67.6	67.7	63.0	61.1	71.3	70.4	60.5	59.3	60.1	92
81	58.2	66.0	59.3	59.8	64.1	69.9	70.0	67.4	78.1	77.8	93
81	66.5	61.8	65.5	68.2	73.7	72.5	75.9	71.7	77.1	81.6	94
81	80.3	78.1	77.3	68.5	71.6	68.4	69.1	66.8	69.5	71.5	95
81	73.1	67.5	66.8	64.0	71.6	69.3	70.1	66.9	70.4	68.1	96
81	61.7	62.2	61.7	63.7	63.6	66.8	65.2	60.6	62.8	64.9	97

81	71.3	59.7	63.4	68.7	65.2	65.4	53.9	55.2	58.9	57.1	98
81	50.7	56.8	51.7	54.6	53.7	53.4	58.3	68.8	68.5	63.6	99
81	54.6	57.1	58.8	56.7	54.2	60.1	55.5	50.4	53.4	52.4	100
81	56.6	52.8	53.6	51.2	54.9	49.6	46.2	45.5	52.1	49.2	101
81	53.2	50.5	56.6	54.2	54.4	56.0	62.1	61.4	49.4	60.6	102
81	54.5	56.2	61.3	64.3	56.8	60.2	64.7	48.7	53.9	59.7	103
81	43.3	34.1	31.9	24.8	21.3	30.7	39.2	44.2	44.8	45.2	104
81	45.3	41.7	46.2	51.7	44.6	43.9	36.3	45.9	50.4	61.4	105
81	44.9	33.8	33.6	36.8	41.8	47.2	35.3	40.2	42.1	50.4	106
81	43.2	42.0	41.1	39.5	27.8	34.5	29.8	38.0	43.6	42.0	107
81	29.7	17.7	29.3	28.9	33.3	33.0	28.3	24.3	11.7	11.1	108
81	17.2	16.3	24.9	31.3	34.1	27.5	29.5	27.0	31.2	25.7	109
81	23.7	21.0	23.6	30.5	30.7	33.1	36.5	35.5	39.7	20.4	110
81	21.7	19.1	21.6	21.2	28.0	33.9	0.0	0.0	0.0	0.0	111
82	26.8	20.4	29.6	24.7	36.1	33.9	38.7	30.8	33.7	29.8	112
82	23.4	20.1	26.2	23.1	17.2	13.4	10.8	18.8	20.9	21.8	113
82	16.2	19.3	22.2	32.5	34.5	39.6	33.9	37.4	46.4	36.7	114
82	36.3	38.3	39.7	36.0	37.8	30.7	33.9	22.1	26.9	24.8	115
82	39.0	42.9	46.3	48.3	37.9	37.9	44.4	38.4	41.4	39.8	116
82	42.1	50.6	44.2	39.6	42.1	40.3	38.4	39.6	35.4	32.8	117
82	28.7	26.8	25.2	32.1	38.6	34.8	34.6	43.0	32.8	35.6	118
82	39.6	34.3	37.0	27.7	32.7	28.7	41.1	45.5	44.7	48.2	119
82	35.8	48.3	38.6	34.3	29.4	40.7	43.4	47.2	47.2	38.0	120
82	30.3	35.5	43.5	37.2	48.5	47.3	49.1	51.0	51.8	48.3	121
82	43.8	46.6	45.0	41.4	36.1	36.8	45.1	44.0	55.9	64.5	122
82	55.1	49.3	49.2	57.9	59.2	53.2	51.1	47.8	52.7	54.2	123
82	55.1	62.3	68.4	66.3	57.5	57.3	56.1	58.8	64.4	64.6	124
82	70.8	71.0	63.0	58.2	68.9	65.9	60.4	55.9	53.0	52.8	125
82	55.9	61.9	64.2	56.7	53.9	45.6	40.3	45.9	46.7	52.7	126
82	55.0	51.5	54.6	62.6	64.5	65.1	62.2	58.2	60.3	58.5	127
82	56.5	61.0	62.4	61.7	66.1	64.2	65.0	67.2	65.6	68.1	128
82	66.9	57.7	66.9	71.4	66.2	67.2	68.8	66.6	65.4	66.9	129
82	74.5	76.6	76.6	75.4	69.9	73.0	69.1	66.1	67.4	72.7	130
82	73.5	75.8	75.2	80.5	78.9	75.5	76.0	72.0	76.5	69.2	131
82	70.2	66.3	75.8	72.5	71.1	71.2	68.6	68.1	74.2	73.0	132
82	68.2	68.2	69.3	64.0	71.8	72.0	76.8	76.2	75.8	63.4	133
82	59.6	67.6	66.9	64.8	66.0	74.5	70.7	65.7	64.6	65.5	134
82	64.8	58.9	65.0	63.3	62.1	75.1	72.6	73.9	67.9	62.3	135
82	59.8	62.6	71.5	69.8	69.8	64.4	63.7	52.8	59.5	62.6	136
82	50.2	42.4	44.9	47.4	49.9	54.3	60.6	60.4	66.7	64.4	137
82	71.0	64.2	71.0	63.9	64.4	65.8	67.5	62.5	65.8	58.8	138
82	60.7	69.8	75.8	59.5	58.3	61.5	58.5	54.3	42.5	43.9	139
82	49.3	56.5	57.3	59.8	55.8	53.5	59.1	64.3	60.3	56.4	140
82	54.2	45.3	37.2	42.8	50.5	53.7	48.4	35.7	36.8	44.7	141
82	38.1	44.4	37.9	34.6	33.4	39.1	52.9	46.2	52.6	47.4	142
82	52.2	56.0	60.1	51.7	51.1	54.7	51.6	42.0	36.7	28.6	143
82	24.6	32.1	33.4	35.8	45.1	39.3	37.5	29.9	39.7	40.6	144
82	36.1	27.0	26.1	35.5	30.8	30.2	35.4	27.1	31.5	27.8	145
82	30.8	25.9	22.9	21.8	26.7	31.2	28.2	31.5	24.8	19.5	146
82	22.1	22.7	17.6	19.5	27.2	43.4	43.6	42.2	41.0	34.5	147

82	39.3	32.8	32.3	26.4	28.6	33.9	0.0	0.0	0.0	0.0	148
83	32.1	34.3	30.5	22.5	18.9	26.8	35.2	39.4	40.3	25.9	149
83	32.1	21.7	18.9	26.6	21.9	11.3	18.7	17.5	15.4	12.8	150
83	15.3	20.1	30.4	27.7	29.2	34.1	40.7	41.6	36.6	39.3	151
83	39.7	46.3	46.8	43.3	35.0	32.2	28.9	31.1	32.0	19.8	152
83	21.4	22.5	24.3	24.0	23.7	24.3	24.6	32.3	37.2	38.9	153
83	46.4	38.6	44.1	42.6	48.8	35.6	39.0	39.3	37.0	32.6	154
83	32.4	38.9	35.5	39.5	27.1	35.1	38.7	53.8	56.5	63.1	155
83	55.1	46.7	50.9	53.3	58.8	64.9	49.8	50.1	48.8	45.7	156
83	42.0	37.1	37.6	37.9	41.7	38.8	46.3	38.2	40.5	41.5	157
83	36.4	32.0	30.7	43.3	37.2	34.0	37.6	40.4	35.6	40.8	158
83	33.5	31.4	44.4	37.0	37.0	40.5	40.2	42.3	42.8	50.6	159
83	51.7	56.3	57.7	59.4	45.4	45.2	52.6	51.1	55.9	56.3	160
83	65.3	49.7	39.5	49.6	47.5	51.7	55.8	54.6	62.3	55.0	161
83	47.9	48.7	56.7	60.1	59.8	67.2	67.0	58.5	49.4	56.6	162
83	60.8	58.2	60.8	62.8	68.6	69.1	59.9	67.2	63.5	67.1	163
83	61.5	55.3	56.8	61.8	58.7	55.5	58.3	58.7	61.5	64.1	164
83	71.9	73.0	77.3	68.4	58.2	63.3	65.0	62.5	65.1	59.1	165
83	60.9	59.3	59.1	63.4	64.4	60.5	55.9	57.4	64.8	65.7	166
83	69.2	60.9	64.0	64.5	62.4	67.7	70.4	74.3	75.7	68.4	167
83	72.6	64.2	67.7	75.0	75.5	74.9	75.3	75.3	77.8	81.4	168
83	69.5	70.4	68.2	70.3	71.9	73.2	79.8	76.0	69.8	70.7	169
83	72.0	72.3	80.1	82.2	71.6	68.8	71.2	66.8	63.6	70.7	170
83	68.0	67.8	68.6	67.6	68.5	74.4	79.4	73.4	78.0	71.5	171
83	70.5	72.7	72.0	66.7	63.9	59.9	54.2	51.9	53.4	51.8	172
83	58.7	58.3	59.7	66.8	71.9	67.5	59.7	52.3	47.2	45.2	173
83	52.2	60.4	66.4	59.9	60.9	50.8	52.0	46.9	55.7	65.2	174
83	63.1	60.6	58.3	54.1	52.1	45.2	46.4	55.9	51.6	47.6	175
83	54.1	57.0	57.2	61.0	72.4	73.3	63.9	67.5	70.8	56.7	176
83	52.2	61.2	52.0	48.7	52.6	57.6	55.8	57.9	48.4	46.9	177
83	43.8	34.5	39.4	41.2	28.1	33.7	35.7	36.5	44.6	38.7	178
83	43.5	41.1	38.6	44.6	43.1	44.4	50.1	52.2	46.1	33.8	179
83	35.3	34.8	34.9	35.5	35.2	34.2	37.3	42.4	41.6	42.1	180
83	45.2	53.3	44.8	53.8	48.8	44.2	41.7	46.2	49.3	49.0	181
83	49.1	45.3	58.5	54.1	38.2	31.4	31.8	25.6	35.7	35.5	182
83	39.7	33.6	35.0	35.3	42.4	31.7	43.7	47.8	44.8	31.8	183
83	30.6	37.3	30.2	28.6	29.4	20.8	24.8	25.0	24.5	31.4	184
83	24.4	29.6	36.9	31.7	36.6	33.9	0.0	0.0	0.0	0.0	185
84	34.4	27.9	32.3	27.6	17.8	20.0	15.9	27.2	25.0	23.6	186
84	31.4	28.6	31.1	33.2	23.8	23.9	23.9	22.7	16.7	13.3	187
84	24.1	25.5	26.4	20.4	21.0	16.7	19.4	19.3	30.4	34.8	188
84	34.7	40.6	37.8	36.0	28.7	24.3	34.8	45.8	36.2	36.8	189
84	40.0	39.0	31.7	35.2	35.2	36.3	38.9	31.4	38.5	37.7	190
84	35.6	35.0	42.5	46.3	44.7	41.6	48.9	42.6	47.3	40.6	191
84	41.7	40.2	31.2	43.2	38.6	32.9	35.2	28.1	27.8	38.1	192
84	47.7	44.3	37.5	44.5	44.1	37.6	40.3	39.4	46.7	46.1	193
84	40.7	54.5	51.1	48.5	52.4	52.6	48.8	44.5	43.9	45.4	194
84	38.6	37.8	43.4	50.9	61.2	64.3	59.8	55.4	53.0	49.5	195
84	63.5	57.8	51.4	45.7	51.1	51.9	45.6	52.0	54.7	48.3	196
84	56.1	55.4	44.3	39.8	42.1	39.6	42.6	49.5	48.1	52.2	197

84	49.1	48.4	60.1	57.8	53.9	61.8	54.1	52.3	54.8	52.0	198
84	43.1	53.1	64.4	65.1	64.8	67.0	59.2	63.9	64.6	68.8	199
84	69.4	60.6	54.9	58.7	64.2	58.4	62.0	60.7	68.3	64.4	200
84	65.0	69.2	68.5	64.4	58.3	54.9	53.8	60.9	65.3	65.7	201
84	62.7	62.0	55.6	57.0	59.2	62.7	64.8	65.3	63.1	63.5	202
84	70.8	61.9	64.2	62.3	67.8	66.2	67.9	68.2	67.3	69.7	203
84	66.4	67.3	65.1	63.8	68.3	73.5	78.1	76.5	75.9	74.4	204
84	67.2	68.9	68.5	68.7	68.9	71.4	72.0	64.5	64.4	61.1	205
84	68.4	75.7	74.1	72.3	77.2	75.0	77.4	79.4	80.8	71.1	206
84	71.6	74.1	72.4	76.2	71.9	79.2	68.2	70.1	76.1	76.2	207
84	70.4	65.9	72.5	59.4	64.4	66.3	68.5	67.5	70.2	70.4	208
84	67.3	67.4	63.0	65.0	65.8	58.7	66.5	68.2	69.5	69.0	209
84	64.1	67.9	70.7	69.4	66.7	69.4	59.5	56.1	57.9	54.3	210
84	60.1	61.6	68.6	56.4	65.4	59.4	57.8	57.1	60.5	61.6	211
84	64.0	72.3	62.8	69.2	62.5	58.7	50.9	56.7	49.1	44.3	212
84	49.8	57.6	57.3	52.7	60.3	49.3	44.4	49.1	51.1	45.6	213
84	55.6	49.4	45.5	53.7	49.1	52.1	51.7	45.5	46.2	46.2	214
84	43.9	40.6	33.2	38.8	39.4	44.8	48.4	50.4	44.2	33.6	215
84	33.7	34.0	42.1	34.6	41.9	42.6	45.5	42.8	47.3	55.4	216
84	49.5	50.6	51.6	45.4	42.5	38.5	37.9	42.8	47.7	42.4	217
84	53.2	43.6	42.0	41.3	36.9	39.5	29.3	30.1	22.3	29.2	218
84	27.7	28.5	31.8	34.4	33.4	36.3	35.4	35.8	32.8	32.9	219
84	34.1	31.7	27.7	35.3	37.2	26.2	29.2	28.3	30.6	28.4	220
84	29.0	24.3	28.7	23.7	31.2	26.1	24.9	21.7	23.3	31.7	221
84	32.0	30.2	33.6	30.7	27.6	33.7	0.0	0.0	0.0	0.0	222
85	32.2	38.8	33.8	38.4	38.8	34.4	30.8	22.9	25.2	22.4	223
85	22.2	25.2	22.1	27.2	16.9	17.7	24.9	32.1	32.4	33.8	224
85	32.2	37.6	44.6	29.5	28.4	20.9	26.6	28.7	27.4	24.3	225
85	17.8	32.7	30.5	37.8	35.9	43.8	49.9	44.3	36.6	33.4	226
85	31.6	30.9	25.0	29.7	38.7	34.7	27.3	26.0	25.4	23.2	227
85	26.6	27.0	30.9	35.3	43.0	45.8	51.6	51.3	56.6	56.0	228
85	46.0	51.6	48.8	49.6	49.9	44.4	48.3	45.2	45.3	46.2	229
85	54.6	43.7	48.4	34.3	43.9	39.0	25.6	36.7	30.8	32.8	230
85	38.4	35.8	46.0	42.6	36.7	36.3	41.6	35.2	29.8	47.8	231
85	51.7	46.2	49.2	50.6	50.7	41.8	37.2	36.0	44.0	41.1	232
85	44.1	37.5	47.9	57.3	61.3	72.1	57.1	50.9	49.4	46.0	233
85	54.5	47.3	41.9	49.9	49.7	56.2	61.3	57.1	52.7	57.8	234
85	51.5	56.8	56.5	51.8	49.4	55.3	56.9	52.0	50.6	54.8	235
85	57.2	55.6	52.2	44.6	52.1	46.9	54.4	60.3	63.8	57.6	236
85	59.7	56.3	55.6	49.2	46.2	52.3	53.4	64.6	71.3	71.8	237
85	71.2	64.9	62.8	59.9	56.3	56.1	58.6	66.8	70.2	65.8	238
85	69.7	64.2	63.4	58.3	61.0	59.6	64.3	68.6	67.0	67.2	239
85	66.8	65.4	67.0	66.1	69.0	74.1	68.8	70.1	75.9	68.3	240
85	70.6	71.4	70.2	68.8	68.4	68.3	68.4	70.3	68.8	76.5	241
85	77.0	75.5	78.7	79.6	74.9	70.9	65.9	64.6	71.3	70.6	242
85	64.7	70.2	70.8	74.0	69.5	66.1	68.8	64.6	65.4	68.0	243
85	75.2	76.0	70.7	73.7	67.6	70.1	73.0	72.9	73.7	65.0	244
85	67.6	67.6	74.8	65.6	65.3	66.4	64.6	67.9	67.9	73.1	245
85	75.6	70.6	76.6	70.9	69.6	66.5	71.0	69.9	75.4	79.2	246
85	75.5	69.1	69.5	68.2	67.0	61.1	63.6	62.9	60.3	59.7	247

85	65.4	59.9	57.1	59.3	57.7	55.5	53.2	63.1	58.9	64.3	248
85	59.9	62.4	58.1	56.9	68.9	63.5	58.2	54.8	51.6	52.2	249
85	56.7	51.5	53.3	54.4	56.8	55.6	56.2	54.5	54.0	51.2	250
85	56.5	53.6	52.8	47.2	60.0	45.0	42.9	43.9	43.0	42.7	251
85	56.0	51.9	51.7	51.4	35.1	47.0	53.6	44.0	37.2	30.4	252
85	26.5	29.7	28.8	32.3	31.2	33.3	36.2	31.9	36.4	30.7	253
85	37.7	33.2	36.7	29.9	38.1	49.0	45.3	48.5	42.6	36.7	254
85	31.3	38.3	36.4	41.5	39.2	36.5	49.5	44.5	44.9	40.2	255
85	33.1	38.4	43.6	48.0	46.1	47.0	43.4	32.9	28.2	23.0	256
85	27.6	27.7	20.9	22.5	23.8	31.8	29.2	36.4	36.7	30.5	257
85	32.6	37.7	44.1	33.6	33.7	33.4	34.4	34.9	39.9	38.6	258
85	28.7	25.0	23.9	34.5	33.9	33.7	0.0	0.0	0.0	0.0	259
86	25.9	33.0	36.0	32.7	35.0	38.9	42.1	42.7	34.5	29.6	260
86	31.1	38.1	37.8	37.6	31.8	25.4	19.5	23.1	29.3	31.4	261
86	38.0	34.4	32.6	29.8	29.0	33.4	34.0	39.4	38.1	47.8	262
86	35.1	39.4	32.5	29.5	38.1	40.2	23.1	35.3	38.2	36.2	263
86	32.5	22.2	28.5	37.9	43.2	41.2	44.7	46.9	49.1	41.5	264
86	43.0	42.3	40.3	39.0	44.2	48.3	42.3	49.7	43.3	37.1	265
86	40.3	40.8	40.2	34.0	34.3	34.8	43.2	36.5	35.1	41.9	266
86	49.9	39.9	34.4	27.6	41.7	46.4	48.5	54.8	51.7	55.2	267
86	52.6	42.5	34.8	36.1	34.9	34.7	40.2	48.9	49.3	51.2	268
86	47.0	49.3	33.0	40.9	34.9	43.7	51.5	40.8	44.0	48.5	269
86	47.6	49.5	60.2	59.9	55.8	57.5	48.4	52.4	58.0	61.3	270
86	55.6	58.4	46.3	50.7	47.1	50.8	52.7	59.0	64.5	59.2	271
86	56.0	53.4	53.8	52.1	59.6	60.8	66.3	70.4	62.7	68.1	272
86	68.7	58.6	48.1	47.2	53.8	56.1	66.2	64.7	57.2	53.2	273
86	42.2	43.9	50.3	50.3	51.7	55.6	49.2	46.1	57.9	61.7	274
86	62.6	61.0	64.2	59.3	63.8	62.7	67.2	70.1	71.5	64.4	275
86	62.5	57.9	61.7	54.5	55.1	58.8	68.7	75.0	75.7	72.1	276
86	69.4	70.6	68.3	76.6	73.6	71.0	70.4	70.9	65.0	62.1	277
86	65.7	71.7	67.6	65.8	68.4	78.3	72.6	72.9	70.9	75.0	278
86	75.4	71.7	71.0	66.5	66.9	67.1	63.6	67.5	72.1	75.1	279
86	72.9	67.1	65.2	72.1	70.6	69.8	68.8	72.6	72.3	72.9	280
86	74.5	74.5	72.1	75.3	71.3	66.6	62.6	66.1	68.0	68.6	281
86	63.6	63.8	63.5	60.4	64.3	63.9	67.5	71.4	67.4	74.0	282
86	78.5	79.2	81.7	75.9	74.7	71.3	71.9	69.4	66.1	61.4	283
86	60.1	58.5	60.1	62.6	56.8	60.8	64.0	59.7	59.4	62.3	284
86	65.7	70.9	64.9	68.7	63.1	49.3	53.9	56.1	54.4	50.3	285
86	53.1	52.4	52.0	55.6	60.6	54.8	53.8	50.6	54.5	53.2	286
86	53.7	44.4	40.5	37.7	44.4	50.8	48.0	46.8	49.8	65.7	287
86	61.4	58.2	55.0	54.8	55.5	56.2	54.2	58.1	61.7	61.4	288
86	63.4	75.5	71.5	70.8	72.9	58.5	50.8	53.6	39.7	37.4	289
86	40.9	28.3	38.7	40.4	40.4	33.4	24.4	39.9	34.1	41.9	290
86	47.1	41.4	37.6	48.5	39.5	43.3	45.6	50.3	50.1	41.7	291
86	32.2	32.9	37.6	36.3	44.0	47.9	42.3	35.9	42.1	36.9	292
86	29.3	32.1	35.0	34.8	22.7	19.3	30.2	26.3	30.6	36.0	293
86	40.5	38.5	31.5	25.3	23.9	31.3	21.1	26.4	31.2	19.4	294
86	14.5	14.5	7.1	12.1	28.4	20.1	23.3	21.1	21.4	26.4	295
86	31.5	31.3	33.2	35.8	36.1	33.7	0.0	0.0	0.0	0.0	296
87	37.7	34.8	27.5	39.1	28.9	29.0	33.0	35.2	30.9	34.7	297

87	22.7	21.5	25.3	22.6	25.7	26.3	26.8	25.2	29.8	29.2	298
87	34.0	32.7	32.1	31.3	37.0	33.5	32.8	28.5	24.6	24.5	299
87	20.9	23.1	26.9	31.9	32.4	32.0	39.7	38.7	34.5	34.0	300
87	31.4	31.2	37.9	35.5	32.7	36.2	44.4	35.6	30.9	24.6	301
87	32.5	35.3	40.0	40.0	40.0	31.1	27.2	23.4	26.5	17.4	302
87	22.9	34.3	34.6	28.8	27.0	33.4	32.1	41.7	40.0	36.9	303
87	35.6	32.3	41.3	42.2	40.0	42.9	43.9	42.3	43.9	51.3	304
87	49.1	39.6	40.2	50.5	49.8	49.7	46.8	53.7	48.0	53.1	305
87	44.0	34.7	37.5	48.4	46.2	48.7	49.8	42.9	46.2	54.9	306
87	60.9	65.3	56.7	58.1	51.3	59.6	51.5	51.1	54.7	55.2	307
87	57.6	50.7	51.7	44.0	45.2	49.9	63.1	54.5	50.3	49.4	308
87	51.3	51.2	48.9	54.0	57.6	58.9	52.2	54.1	58.0	52.2	309
87	57.9	48.1	45.7	53.4	53.5	56.4	54.8	57.0	55.3	49.0	310
87	55.0	56.5	63.8	63.0	63.9	55.8	61.4	59.0	60.1	60.9	311
87	69.3	68.1	76.4	73.1	75.2	71.1	71.8	77.2	64.5	69.5	312
87	64.6	56.1	50.6	58.9	69.1	68.5	71.3	63.7	72.0	72.8	313
87	63.0	59.3	62.2	61.6	65.0	61.1	60.5	67.1	65.5	64.0	314
87	69.4	79.9	78.5	83.8	75.6	78.9	73.2	74.4	70.1	71.1	315
87	71.2	65.7	65.1	68.7	79.9	76.4	73.6	68.1	68.5	70.4	316
87	62.5	67.3	74.2	74.3	70.6	73.2	74.2	67.3	69.5	72.7	317
87	70.3	75.1	76.7	74.9	73.0	74.0	72.1	66.8	60.3	59.8	318
87	65.2	64.2	63.1	65.9	60.6	61.2	63.8	61.3	61.4	58.3	319
87	67.8	68.1	76.4	80.7	70.7	70.9	69.2	68.9	75.1	63.4	320
87	62.2	68.5	69.1	70.3	80.7	80.5	76.6	75.0	69.3	63.7	321
87	65.0	57.0	56.7	58.4	63.7	56.8	57.2	71.8	67.4	62.8	322
87	64.3	55.5	49.5	50.3	58.6	64.1	57.3	51.8	50.2	52.9	323
87	55.7	62.2	54.2	57.4	47.8	46.4	57.8	46.0	40.1	40.4	324
87	42.1	51.5	60.2	58.2	55.8	50.9	51.5	61.1	58.0	60.9	325
87	52.9	53.3	57.2	52.2	49.7	54.7	49.9	54.1	49.5	54.0	326
87	44.5	49.4	51.8	55.7	53.1	40.4	42.0	41.5	33.4	30.6	327
87	37.2	43.7	42.3	37.2	34.2	28.8	34.1	35.1	38.1	49.4	328
87	41.6	40.4	39.3	35.8	41.8	43.1	39.2	44.2	54.5	45.3	329
87	37.9	29.1	24.0	23.4	35.8	29.3	24.0	28.5	25.5	30.0	330
87	25.7	26.5	23.3	29.3	26.7	32.8	41.1	30.4	27.5	24.2	331
87	34.7	29.7	26.2	31.7	40.1	32.9	31.7	28.2	18.8	18.3	332
87	11.3	10.6	12.1	18.8	28.6	33.7	0.0	0.0	0.0	0.0	333
88	29.8	23.9	20.3	21.3	19.1	24.7	30.2	39.9	33.1	33.2	334
88	45.4	37.6	35.4	22.3	23.0	27.6	35.1	37.7	26.4	11.3	335
88	25.0	26.8	31.4	28.6	28.9	39.5	39.7	49.2	40.7	36.2	336
88	32.3	40.7	48.0	41.4	33.5	35.3	45.0	33.5	32.0	28.0	337
88	35.8	27.9	32.7	36.5	33.1	29.5	32.3	37.0	44.3	39.1	338
88	32.9	29.4	33.5	30.2	41.7	44.4	51.2	54.5	41.4	39.5	339
88	36.6	38.7	32.0	38.6	42.4	45.7	43.6	41.2	44.2	43.5	340
88	45.1	49.8	48.9	54.3	49.8	46.1	56.8	47.9	55.0	53.0	341
88	47.2	46.6	53.9	42.3	42.5	47.8	45.5	39.0	33.9	44.3	342
88	51.1	38.1	37.9	34.0	36.8	35.7	41.3	45.7	48.5	41.8	343
88	38.2	46.2	51.3	45.8	51.1	55.0	53.1	52.7	56.2	56.5	344
88	57.7	61.5	62.5	61.2	53.3	49.4	49.3	40.3	44.6	52.4	345
88	49.5	55.3	49.6	51.6	57.0	53.0	58.0	64.9	53.3	54.4	346
88	58.8	55.4	55.0	60.5	52.8	54.9	58.9	61.9	59.6	63.9	347

88	56.1	50.1	54.0	62.7	57.7	61.4	61.2	53.9	58.9	63.9	348
88	60.9	61.5	54.2	61.4	63.3	66.3	65.5	65.2	67.2	69.6	349
88	73.3	69.3	68.2	70.9	68.1	73.7	69.8	73.6	76.8	73.7	350
88	75.7	74.1	76.9	77.0	65.3	69.8	72.6	73.8	70.6	67.0	351
88	66.6	68.9	73.6	69.0	57.8	70.4	65.7	68.6	65.0	62.7	352
88	64.7	65.0	67.0	69.0	68.8	65.2	69.0	66.0	65.8	65.9	353
88	64.1	65.3	67.8	71.1	67.2	64.4	68.1	67.8	64.4	72.1	354
88	75.3	74.9	74.1	77.5	69.1	65.0	73.2	64.5	64.6	64.3	355
88	60.0	64.2	60.4	64.1	67.6	66.6	66.2	65.0	63.9	67.3	356
88	68.4	73.1	73.6	64.8	67.7	76.4	79.1	78.1	69.9	68.2	357
88	72.5	71.7	66.4	71.5	69.3	60.9	56.7	55.2	54.6	58.6	358
88	57.1	64.1	66.3	69.3	72.9	69.3	63.8	75.3	69.5	65.9	359
88	68.3	63.4	58.9	54.5	64.6	55.4	53.6	52.0	54.1	69.0	360
88	69.9	59.3	43.5	45.5	49.1	58.6	63.4	63.8	58.5	59.9	361
88	60.4	49.0	49.7	51.7	45.3	50.0	54.9	52.6	63.9	63.8	362
88	53.9	40.7	45.8	45.9	40.9	37.5	45.5	50.1	47.2	36.6	363
88	30.5	35.8	41.6	43.6	45.8	38.6	34.0	40.3	45.4	44.0	364
88	45.6	39.5	29.8	27.1	35.0	31.8	29.0	23.2	29.9	29.5	365
88	40.6	33.6	29.8	36.4	34.8	33.9	37.6	47.6	44.1	28.9	366
88	30.5	35.3	38.8	40.3	35.0	34.6	34.1	26.3	24.8	32.0	367
88	28.8	27.5	25.5	26.5	32.1	19.2	27.2	32.9	36.9	29.0	368
88	33.6	30.9	26.1	29.3	25.3	20.1	22.1	25.9	20.1	22.3	369
88	17.4	23.1	23.7	31.7	36.9	26.6	0.0	0.0	0.0	0.0	370

Attachment B-9. HELP Model Data File: DATA10 - Soils Data for Hanford Barrier.

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SAIC/ERDF EIS/RC/FS/ WA. 923-E412
CASE 4 - HANFORD BARRIER
3/10/94  YEARS 100-110  CAS4JV11.OUT
 8  1.000000  77.000000    4
   19.37   59.37    5.91   11.81   59.00   11.80    5
    5.91    3.95  000.00    0.00    0.00    0.00    6
  0.4603  0.3702  0.3509  0.3178  0.4170  0.4170    7
  0.0220  0.4170  0.0000  0.0000  0.0000  0.0000    8
  0.2272  0.2109  0.0705  0.0391  0.0210  0.0454    9
  0.0210  0.0450  0.0000  0.0000  0.0000  0.0000   10
  0.0632  0.0500  0.0326  0.0200  0.0200  0.0200   11
  0.0200  0.0200  0.0000  0.0000  0.0000  0.0000   12
   0.000992999994   0.000001600000   0.000154999987   0.000500000024 13
   0.100000001490   1.000000000000   0.000000010000   0.010000000024 14
   0.000000000000   0.000000000000   0.000000000000   0.000000000000 15
  0.0954  0.0556  0.0714  0.0367  0.0697  0.0454   16
  0.0210  0.0261  0.0000  0.0000  0.0000  0.0000   17
   43560.    18
 1  1  1  1  1  2  3  1  0  0  0  0   19
   0.00    0.00    0.00    0.00    0.00    2.00    20
   0.00    0.00    0.00    0.00    0.00    0.00    21
   0.0     0.0     0.0     0.0     0.0   760.0    22
   0.0     0.0     0.0     0.0     0.0     0.0    23
1.00000000 1.00000000 1.00000000 1.00000000 1.00000000 1.00000000    24
1.00000000 1.00000000 1.00000000 1.00000000 1.00000000 1.00000000    25
 0.0000    26
8  0  0
```

Attachment B-10. HELP Model Data File: DATA11 - Climate Data for Hanford, Washington.

```
  2
HANFORD          WASHINGTON
  36.00
1.60 1.60   113  288  16  32  48
  46.57  65.222 59.619 42.627 26.066 18.157 0.154 -0.088  0.204 -0.129
 380.628 246.837 284.041
 0.439 0.516 0.388 0.317 0.301 0.252 0.294 0.258 0.337 0.319 0.444 0.484
 0.195 0.166 0.163 0.121 0.122 0.123 0.055 0.059 0.085 0.094 0.198 0.256
 29.3 36.3 45.1 53.1 61.5 69.3 76.4 74.3 65.2 53.0 39.8 32.7
```

Attachment B-11. HELP Model Data File: DATA11 - Climate Data for Spokane, Washington.

```
   3
SPOKANE              WASHINGTON
  36.00
1.60  2.50    138  267   16   32   48
  46.50  58.00  53.00  37.00  26.60  16.50  0.166  -0.090  0.270  -0.180
 396.00 258.00 297.00
0.648 0.600 0.542 0.409 0.469 0.400 0.240 0.388 0.395 0.479 0.584 0.621
0.361 0.269 0.239 0.225 0.202 0.200 0.099 0.121 0.154 0.184 0.278 0.386
25.7 32.4 37.6 45.8 54.3 61.7 69.7 68.1 59.4 47.6 34.9 29.0
```

Attachment B-12. HELP Model Data File: DATA13 - Solar Radiation Data for Hanford, Washington.

79	102.7	107.4	148.8	63.3	91.1	89.1	114.1	103.0	124.1	40.1	1
79	40.5	99.1	45.8	41.7	124.7	93.5	65.3	80.9	102.3	153.2	2
79	145.6	110.1	46.3	46.9	166.2	165.8	204.7	214.5	187.1	50.7	3
79	94.9	146.4	169.4	161.5	130.9	163.0	209.9	256.8	185.6	133.9	4
79	201.9	123.2	95.1	204.9	263.8	245.3	64.4	201.4	223.2	258.4	5
79	68.2	170.6	165.8	214.8	121.2	73.1	219.8	275.8	214.1	260.0	6
79	280.2	204.7	80.3	384.1	82.4	240.5	422.9	360.3	355.7	309.2	7
79	253.3	141.6	420.3	363.0	306.7	97.2	258.3	443.8	281.8	185.5	8
79	442.3	504.7	495.1	371.7	407.9	105.3	407.7	508.3	442.7	392.8	9
79	318.0	165.3	412.7	492.6	522.7	285.5	366.4	117.9	376.3	461.0	10
79	442.9	275.2	545.8	364.7	380.4	323.4	449.2	373.0	496.4	602.1	11
79	602.3	524.1	470.1	531.7	471.6	667.6	643.3	635.6	686.3	213.1	12
79	138.8	451.0	483.1	429.9	221.0	664.3	716.3	588.1	723.2	725.7	13
79	540.7	726.3	735.9	596.0	720.1	632.7	589.0	539.6	752.8	575.8	14
79	663.0	760.2	762.5	655.0	719.4	536.3	639.5	552.0	632.2	776.5	15
79	610.2	725.7	708.7	657.6	582.0	525.6	590.6	425.5	682.6	596.1	16
79	476.4	486.1	646.7	792.2	688.6	773.4	629.4	681.4	599.4	613.8	17
79	539.9	793.7	793.5	694.0	792.8	773.2	775.1	785.5	790.5	620.3	18
79	788.9	787.9	765.5	612.2	671.5	540.5	731.7	687.0	342.1	638.2	19
79	582.3	712.4	772.1	751.9	759.5	712.9	763.9	707.9	456.5	587.3	20
79	650.7	509.5	697.4	608.4	630.7	741.0	665.6	489.7	555.4	709.3	21
79	599.2	722.4	719.1	649.6	656.9	617.8	553.2	458.9	529.4	540.2	22
79	451.8	426.0	424.7	456.5	210.9	220.2	636.8	574.5	657.0	652.6	23
79	473.4	262.4	473.5	521.6	630.0	525.4	392.5	615.8	585.9	439.4	24
79	502.0	552.3	549.8	329.1	434.7	391.1	559.1	558.2	516.2	493.3	25
79	360.4	408.8	462.3	419.4	435.4	487.8	326.4	513.5	420.1	226.8	26
79	411.9	421.0	353.9	455.4	462.3	408.1	358.8	459.7	454.3	449.0	27
79	384.0	426.8	330.0	178.0	266.0	212.5	304.1	285.9	363.1	366.4	28
79	391.1	318.6	180.2	140.9	230.2	278.9	311.0	320.4	188.2	203.1	29
79	122.4	67.4	155.7	295.3	279.8	227.0	91.3	89.5	89.5	60.2	30
79	188.8	112.0	196.1	144.9	196.0	55.4	169.8	53.8	53.1	68.3	31
79	258.4	248.3	135.3	214.4	160.4	203.3	226.2	208.0	159.3	46.0	32
79	109.2	164.0	44.3	139.7	103.6	42.9	185.1	42.0	57.0	41.1	33
79	101.0	121.3	44.5	68.9	39.3	39.0	38.7	161.8	38.2	81.6	34
79	75.2	167.6	148.7	139.2	122.6	117.7	100.2	80.5	36.5	112.5	35
79	36.3	36.3	109.5	128.4	141.3	96.2	36.3	36.4	36.5	146.4	36
79	112.4	36.8	37.0	37.1	37.3	0.0	0.0	0.0	0.0	0.0	37
80	37.6	77.7	79.4	38.3	69.8	53.6	39.1	39.5	39.8	168.0	38
80	40.5	40.9	41.3	41.7	169.6	42.6	134.5	129.0	153.5	151.9	39
80	153.1	160.5	148.1	187.9	82.5	157.5	208.2	118.3	234.0	134.2	40
80	51.4	52.1	52.8	162.0	233.5	178.1	55.9	231.4	256.7	214.0	41
80	129.3	78.1	168.8	111.7	62.6	85.7	114.4	129.9	72.9	92.6	42
80	83.5	307.7	323.0	355.5	249.0	104.6	155.9	142.9	76.2	385.9	43
80	270.4	204.9	307.4	300.7	150.4	378.0	256.1	238.7	172.0	257.5	44
80	189.9	204.7	98.2	282.4	245.7	274.5	285.8	202.1	443.3	231.7	45
80	495.0	307.5	198.5	312.1	417.2	465.1	416.4	331.9	179.7	447.1	46
80	290.4	505.4	563.8	569.1	385.5	487.7	181.3	333.9	511.3	448.6	47

80	346.6	609.8	562.6	453.3	544.9	629.2	471.5	421.8	537.6	472.6	48
80	468.0	656.7	540.7	539.1	357.8	597.0	591.0	682.3	323.8	524.6	49
80	564.7	528.9	701.9	484.3	581.3	604.2	454.6	719.8	546.3	370.2	50
80	426.8	515.8	524.3	621.2	148.4	386.6	668.0	708.3	752.8	735.5	51
80	705.8	529.9	334.7	672.8	683.0	605.1	573.5	566.4	669.3	608.5	52
80	495.5	632.3	655.5	681.1	755.9	765.2	777.3	656.5	690.5	789.4	53
80	743.9	592.4	738.8	575.7	339.3	793.0	713.7	287.9	678.1	694.0	54
80	645.8	403.1	640.3	711.9	561.7	364.8	242.8	207.4	669.5	789.8	55
80	570.7	622.7	786.9	785.8	776.1	783.3	782.0	412.6	582.0	648.1	56
80	652.6	773.9	582.9	652.6	569.6	627.5	638.4	761.6	655.9	704.5	57
80	698.5	751.9	749.3	746.6	666.2	663.4	626.7	735.1	681.0	640.3	58
80	683.0	555.9	641.4	715.7	633.2	637.1	705.1	701.4	567.1	693.9	59
80	605.5	568.6	438.9	451.9	407.4	659.8	627.5	605.4	624.5	354.5	60
80	239.9	426.9	541.3	575.7	511.5	625.3	585.2	615.8	518.8	606.2	61
80	434.6	580.7	591.4	586.4	398.6	466.3	571.2	566.1	560.9	359.8	62
80	526.4	482.5	315.1	451.0	488.3	425.4	465.2	140.8	309.7	280.3	63
80	421.9	422.1	446.1	293.7	393.0	364.9	465.1	402.1	334.3	343.3	64
80	305.0	438.3	429.9	135.0	228.7	177.5	374.6	406.6	382.8	333.1	65
80	206.8	305.8	251.9	302.1	354.4	145.7	175.7	193.5	113.0	258.4	66
80	321.9	303.2	213.1	205.4	137.5	128.8	229.0	95.5	82.6	155.1	67
80	185.6	287.3	223.5	167.0	219.8	55.4	163.2	66.0	132.0	118.3	68
80	52.1	51.0	115.9	122.4	173.2	160.2	182.0	129.3	46.5	83.3	69
80	152.4	185.1	151.6	182.8	156.7	42.9	69.4	104.0	139.0	132.3	70
80	126.0	40.3	120.5	39.6	60.3	39.4	38.7	38.4	38.2	81.0	71
80	37.7	144.8	103.4	39.6	84.8	142.5	140.7	74.2	79.7	63.9	72
80	61.9	102.2	113.8	87.3	36.3	36.3	117.7	90.6	36.5	36.6	73
80	110.6	117.3	97.0	37.1	37.3	37.5	0.0	0.0	0.0	0.0	74
81	37.6	95.5	121.2	81.0	115.1	151.4	94.2	46.0	119.2	109.5	75
81	96.9	53.2	88.9	83.2	107.9	95.4	43.1	151.1	44.1	101.1	76
81	45.2	45.7	228.2	137.6	150.6	48.1	48.7	49.4	50.0	151.8	77
81	172.2	155.5	134.1	145.7	262.4	245.2	190.4	192.3	179.9	167.2	78
81	137.7	174.0	249.6	61.7	160.0	63.5	322.2	326.8	130.7	132.5	79
81	260.1	345.8	305.7	355.5	169.5	258.5	105.7	266.3	208.6	349.7	80
81	302.2	320.2	308.3	396.7	382.8	417.5	289.6	240.1	178.2	311.0	81
81	335.8	298.0	394.9	440.6	214.5	274.9	338.0	329.9	386.5	425.7	82
81	356.6	483.1	326.3	276.7	340.3	526.4	403.4	327.9	317.8	321.2	83
81	317.9	403.9	465.7	480.4	426.6	521.5	490.8	456.1	496.9	503.3	84
81	570.4	453.1	524.7	376.1	558.8	487.8	575.5	528.6	599.1	647.7	85
81	560.8	252.7	633.2	665.5	455.0	674.0	610.2	682.3	535.8	690.3	86
81	694.2	675.8	623.3	673.5	564.4	658.8	682.0	571.6	717.4	603.4	87
81	526.8	435.9	531.7	445.0	741.9	678.9	712.6	584.7	697.6	669.7	88
81	757.8	660.7	762.5	758.6	766.9	701.1	623.6	772.9	631.6	773.6	89
81	701.6	779.7	746.3	782.6	766.5	554.7	786.4	552.4	375.5	704.5	90
81	684.0	697.6	697.9	792.2	730.0	678.1	616.9	793.6	701.7	709.8	91
81	641.9	775.5	741.6	676.0	601.5	792.4	680.1	572.0	640.8	515.5	92
81	615.7	451.7	673.6	706.5	674.3	429.4	685.6	676.8	596.6	710.5	93
81	753.3	773.9	772.1	770.1	768.1	751.1	763.9	761.6	759.3	737.7	94
81	667.7	751.9	660.7	731.1	708.9	741.0	622.7	735.1	540.5	443.0	95
81	585.7	722.4	616.8	667.7	594.7	474.3	625.6	643.1	697.7	548.8	96
81	570.7	668.8	682.1	575.6	534.1	519.4	395.2	577.6	555.6	626.4	97

81	563.5	522.7	639.2	570.9	630.0	625.3	501.8	346.7	611.0	589.9	98
81	454.1	591.6	523.9	373.6	334.5	493.8	445.0	467.5	560.9	555.7	99
81	255.5	353.4	540.0	421.1	429.2	499.6	462.3	407.7	243.5	439.7	100
81	398.8	421.7	411.4	235.3	421.4	467.3	379.7	345.0	269.9	324.0	101
81	342.1	209.1	311.4	427.6	387.4	417.1	345.7	382.6	161.5	348.7	102
81	378.0	353.2	309.9	256.8	185.4	269.4	360.9	342.6	270.3	220.8	103
81	169.4	155.7	332.3	310.8	306.0	216.0	222.6	208.1	305.4	151.8	104
81	168.2	155.6	163.0	245.0	271.0	276.8	199.9	192.2	142.6	129.5	105
81	134.7	190.0	179.3	190.8	49.0	191.3	47.7	47.1	46.5	46.0	106
81	45.4	163.3	147.9	165.3	43.3	172.1	147.7	120.8	161.4	124.9	107
81	107.8	127.2	95.8	79.6	129.0	104.4	133.0	162.6	38.2	37.9	108
81	102.0	101.6	37.3	90.0	105.8	84.6	36.7	36.6	36.5	84.1	109
81	147.3	36.3	36.3	68.1	66.9	91.4	119.7	36.4	115.9	36.6	110
81	140.6	36.8	155.8	185.5	37.3	37.5	0.0	0.0	0.0	0.0	111
82	37.6	37.8	97.0	38.3	110.1	134.5	105.2	148.3	160.8	92.1	112
82	151.6	158.0	88.5	107.6	165.1	42.6	124.0	139.4	122.1	216.7	113
82	184.0	45.7	46.3	131.1	72.4	76.3	147.6	49.4	199.7	253.6	114
82	203.3	190.6	179.7	188.7	79.8	241.4	279.5	283.5	271.7	214.7	115
82	206.1	128.5	219.7	79.2	155.0	63.5	204.1	65.4	66.3	84.2	116
82	68.2	198.2	99.0	332.0	278.0	195.0	74.1	243.6	146.5	227.2	117
82	312.6	396.3	340.3	230.5	270.5	290.1	304.6	310.9	162.0	439.1	118
82	357.1	370.1	392.4	353.6	361.4	459.4	344.0	257.6	286.5	493.7	119
82	450.5	342.6	323.1	369.9	354.5	428.9	280.6	285.0	108.5	109.6	120
82	186.5	150.0	530.7	327.3	271.5	115.9	250.1	484.9	591.5	538.6	121
82	367.6	609.8	614.7	619.6	471.3	474.6	388.2	574.4	532.5	534.0	122
82	607.6	552.6	582.4	533.5	454.0	483.0	678.2	682.3	686.3	474.0	123
82	694.2	698.1	701.9	705.6	611.2	552.9	644.4	719.8	607.3	619.9	124
82	688.6	682.6	735.9	738.9	685.5	597.2	543.7	750.2	752.8	612.9	125
82	666.0	695.0	762.5	737.7	766.9	769.0	443.3	523.8	722.6	723.1	126
82	686.2	524.5	762.7	524.8	712.1	710.6	720.8	787.5	587.1	425.3	127
82	668.8	746.9	729.6	553.1	673.2	662.9	765.1	784.8	713.0	775.6	128
82	609.7	793.7	659.1	733.2	590.6	584.4	613.0	264.0	534.5	789.8	129
82	723.6	670.4	639.8	759.0	784.6	754.6	673.7	680.7	779.0	658.7	130
82	775.7	719.5	513.2	619.8	688.1	589.0	735.1	698.1	618.3	585.1	131
82	689.5	751.9	715.8	588.8	589.3	741.0	651.9	735.1	675.1	611.9	132
82	695.6	718.3	719.1	665.5	544.9	507.4	681.3	621.0	546.9	602.2	133
82	327.8	634.3	682.1	678.1	594.3	609.8	665.6	661.3	558.2	470.4	134
82	648.2	606.6	516.6	475.7	365.1	498.7	569.7	615.8	570.6	551.3	135
82	199.9	315.7	429.6	504.9	569.8	115.3	390.2	438.1	456.0	493.7	136
82	488.3	473.9	382.5	298.0	529.4	472.4	471.3	494.6	346.5	502.7	137
82	410.0	163.0	228.1	246.7	342.4	248.0	231.6	91.9	422.8	325.3	138
82	205.3	273.3	234.9	236.8	136.2	154.4	288.2	265.9	235.8	237.6	139
82	193.1	264.2	336.4	354.4	363.6	365.9	360.9	356.0	219.7	329.8	140
82	319.0	169.9	192.3	88.6	103.2	234.0	218.5	62.0	118.8	233.1	141
82	59.4	58.6	115.3	284.7	183.8	138.0	134.3	139.8	222.5	206.0	142
82	180.5	173.8	123.8	81.1	210.0	177.1	191.0	200.7	46.5	46.0	143
82	45.4	44.9	171.5	124.9	109.1	135.9	97.7	115.5	201.0	41.1	144
82	40.7	40.3	40.0	131.9	141.5	39.0	77.5	109.3	38.2	37.9	145
82	134.1	163.5	160.9	149.0	114.0	36.8	152.6	36.6	36.5	36.4	146
82	107.5	79.4	36.3	36.3	36.3	115.2	128.7	131.7	76.7	61.3	147

82	61.5	109.3	134.1	65.3	116.3	37.5	0.0	0.0	0.0	0.0	148
83	61.4	37.8	38.0	41.0	66.3	38.8	156.5	157.4	125.0	98.3	149
83	97.1	112.8	150.4	126.6	170.9	42.6	129.8	43.6	44.1	88.5	150
83	113.1	199.7	231.4	46.9	47.5	48.1	48.7	180.7	175.5	195.2	151
83	224.1	203.9	196.3	151.0	118.1	216.6	57.1	283.5	189.3	127.6	152
83	59.2	120.9	121.4	131.9	69.3	89.6	306.1	132.8	114.0	183.9	153
83	193.2	69.2	207.2	189.4	103.9	73.1	273.4	146.2	373.4	237.9	154
83	223.3	247.0	130.3	141.9	142.3	161.0	107.4	159.8	278.0	367.8	155
83	88.9	95.7	213.8	344.0	323.7	471.8	269.3	400.1	200.7	462.5	156
83	334.4	378.9	270.8	271.2	313.7	105.3	424.8	116.3	542.6	444.3	157
83	449.4	292.7	457.3	480.7	427.8	482.1	456.6	536.5	470.1	599.8	158
83	437.2	495.1	379.1	582.8	624.4	629.2	478.7	439.2	415.6	620.3	159
83	480.4	563.2	269.6	559.9	496.6	590.4	586.0	483.8	686.3	360.3	160
83	599.7	456.1	620.5	376.0	154.3	523.3	317.9	662.3	723.2	669.3	161
83	520.3	642.2	674.3	738.9	660.1	579.3	564.2	516.4	500.6	602.4	162
83	629.5	545.1	547.8	654.3	766.9	557.8	568.6	590.4	654.1	509.5	163
83	748.0	477.5	781.2	757.7	765.3	634.0	615.5	668.2	768.3	789.4	164
83	342.6	446.4	655.8	761.9	420.2	714.3	663.3	681.1	519.4	793.8	165
83	656.9	641.6	793.5	643.6	570.2	482.9	672.7	791.2	790.5	581.8	166
83	682.0	787.9	685.3	526.0	661.4	699.8	772.5	566.7	597.9	575.1	167
83	775.7	773.9	634.2	753.0	620.1	764.7	763.9	761.6	759.3	756.9	168
83	724.2	631.5	749.3	568.3	417.3	628.7	738.1	572.4	677.1	578.3	169
83	648.5	722.4	587.0	490.1	504.3	673.6	628.6	609.8	565.6	693.9	170
83	431.3	464.6	461.4	523.0	404.7	669.8	634.5	661.3	496.5	623.3	171
83	469.8	638.3	620.9	434.9	482.6	605.1	442.1	360.7	541.3	366.5	172
83	429.3	550.0	481.0	545.5	521.2	474.8	433.4	463.0	449.7	352.6	173
83	370.2	375.9	394.3	352.9	446.1	524.1	418.5	416.1	353.6	395.9	174
83	122.4	253.0	349.2	323.0	475.8	339.4	436.3	459.7	454.3	449.0	175
83	430.2	438.3	433.0	374.6	422.4	363.4	342.6	292.6	306.4	307.7	176
83	189.3	348.7	305.0	375.9	219.0	176.7	269.9	203.8	75.9	113.2	177
83	192.1	336.9	332.3	197.6	85.4	164.1	224.0	219.0	177.9	269.7	178
83	159.5	79.3	57.7	56.9	66.1	55.4	54.6	209.7	55.0	52.4	179
83	103.2	174.3	59.1	49.6	72.2	48.4	47.7	47.1	46.5	46.0	180
83	45.4	165.7	44.3	73.7	43.3	105.8	42.4	42.0	157.5	126.5	181
83	115.3	40.3	70.6	56.5	93.6	39.0	93.8	38.4	38.2	116.0	182
83	37.7	60.0	37.3	37.1	100.1	36.8	80.0	36.6	117.0	36.4	183
83	111.0	36.3	36.3	112.7	80.0	71.8	66.4	36.4	36.5	113.4	184
83	36.7	96.6	37.0	37.1	66.4	37.5	0.0	0.0	0.0	0.0	185
84	103.2	37.8	38.0	124.2	86.9	115.9	66.9	168.8	116.3	40.1	186
84	125.4	104.7	104.8	92.1	126.3	42.6	110.9	83.7	102.0	146.0	187
84	45.2	135.1	231.4	225.5	237.4	111.7	198.3	238.8	156.5	217.1	188
84	135.8	175.4	249.7	267.9	271.7	55.1	133.5	279.3	72.5	74.9	189
84	216.0	80.5	109.4	61.7	101.6	63.5	246.7	229.1	294.2	67.2	190
84	113.5	153.9	350.6	153.7	188.2	73.1	368.9	253.1	227.3	85.1	191
84	121.6	396.3	335.7	270.7	412.2	356.7	347.4	342.3	367.5	319.5	192
84	376.8	386.9	241.7	315.4	93.3	208.1	269.7	335.1	381.1	270.0	193
84	204.7	441.2	262.7	370.1	257.5	184.0	482.0	377.8	423.4	453.0	194
84	442.1	327.0	493.4	476.6	192.5	573.8	584.6	390.1	379.2	572.2	195
84	543.5	533.2	122.9	420.6	557.1	629.2	575.0	602.8	567.2	575.4	196
84	422.4	542.2	545.0	581.1	669.8	674.0	678.2	682.3	686.3	581.6	197

84	493.6	652.9	588.3	638.2	528.3	712.8	689.8	719.8	723.2	714.5	198
84	675.4	650.9	735.9	383.6	678.2	744.7	709.5	601.0	731.8	368.1	199
84	626.3	446.4	750.7	653.4	668.3	676.3	771.0	662.3	754.6	716.3	200
84	625.9	588.4	781.2	680.4	661.8	435.0	479.5	723.6	387.3	707.8	201
84	665.4	742.3	652.1	228.1	704.8	653.7	627.3	648.5	549.4	793.8	202
84	793.8	635.8	596.8	430.0	538.7	464.8	791.9	749.8	790.5	789.8	203
84	495.4	651.7	549.0	772.5	784.6	655.3	728.4	687.0	552.1	694.1	204
84	775.7	596.1	772.1	745.7	766.5	571.0	707.3	409.0	586.2	756.9	205
84	667.4	636.2	536.3	516.6	546.5	703.0	666.8	593.4	531.0	304.8	206
84	534.0	575.6	568.6	715.7	605.5	708.7	602.5	673.0	685.1	673.0	207
84	564.5	517.9	620.8	610.2	674.0	619.4	648.9	594.6	615.0	531.7	208
84	448.9	643.7	354.9	455.5	524.1	502.0	620.6	533.4	354.9	606.2	209
84	586.3	596.4	513.0	586.4	581.4	551.6	544.7	400.7	159.6	248.1	210
84	534.4	375.1	364.8	534.7	529.4	417.1	422.5	365.1	330.1	415.2	211
84	468.3	275.2	343.8	256.9	407.4	291.2	93.0	293.6	444.6	318.4	212
84	353.4	438.3	344.7	394.2	142.4	258.6	152.7	293.5	199.5	328.1	213
84	211.6	359.6	188.6	328.1	317.4	142.7	274.8	277.9	308.3	252.7	214
84	334.1	336.9	227.8	215.7	162.4	218.5	95.4	175.4	118.9	123.0	215
84	296.9	112.3	125.7	208.3	187.5	78.6	111.6	73.4	235.9	197.1	216
84	225.8	175.6	152.3	203.5	49.0	48.4	47.7	47.1	120.3	118.0	217
84	162.8	44.9	44.3	43.8	43.3	198.8	186.2	42.0	41.5	121.8	218
84	152.6	40.3	40.0	39.6	132.9	171.6	170.5	111.8	86.5	108.6	219
84	37.7	37.5	48.1	37.1	86.4	36.8	36.7	78.2	79.6	113.5	220
84	78.3	36.3	140.5	102.4	36.3	107.8	105.8	83.1	129.2	121.5	221
84	175.5	108.9	56.2	37.1	112.1	98.0	0.0	0.0	0.0	0.0	222
85	37.6	115.9	90.7	100.1	121.8	138.1	62.8	137.4	179.1	139.0	223
85	101.7	68.3	154.4	134.5	105.6	120.7	99.8	142.3	44.1	44.6	224
85	178.2	45.7	183.4	191.3	193.4	216.7	209.3	207.6	114.0	100.3	225
85	152.8	52.1	209.2	136.5	113.8	55.1	55.9	56.7	57.5	58.3	226
85	212.0	106.3	235.8	147.3	133.4	145.8	106.9	189.8	266.2	336.2	227
85	213.6	251.0	350.6	327.2	332.4	308.4	271.1	182.1	183.0	270.1	228
85	220.7	257.5	196.0	406.9	276.7	371.4	278.1	340.2	309.0	301.5	229
85	336.9	380.1	410.2	305.9	355.6	471.8	477.3	445.7	480.5	493.7	230
85	499.2	416.0	341.7	248.4	344.6	393.1	531.8	107.4	108.5	351.6	231
85	346.0	265.4	383.8	355.6	540.8	539.4	572.9	477.6	407.9	424.0	232
85	425.7	586.9	411.5	567.1	518.1	608.3	615.8	413.9	421.5	337.8	233
85	554.5	234.6	439.6	665.5	592.8	538.9	661.3	620.8	565.7	529.3	234
85	683.0	643.1	617.5	705.6	613.0	712.8	716.3	693.9	636.1	726.5	235
85	729.7	626.7	147.2	535.9	551.6	744.7	549.5	666.3	740.4	713.2	236
85	663.8	760.2	660.1	764.8	616.7	769.0	656.2	629.4	611.8	646.8	237
85	661.3	691.9	621.4	782.6	708.9	785.2	289.6	752.4	512.4	757.7	238
85	544.6	567.7	791.6	554.4	573.8	620.9	793.4	774.8	724.0	623.3	239
85	677.6	483.2	763.1	604.0	558.8	666.1	791.9	671.2	645.2	679.8	240
85	754.6	718.0	770.1	692.1	617.5	642.2	718.9	641.7	549.0	687.1	241
85	718.1	565.6	606.7	677.0	768.1	766.1	763.9	610.5	630.3	584.9	242
85	520.2	751.9	706.4	426.2	640.7	583.8	738.1	527.4	694.6	728.9	243
85	602.3	610.6	719.1	715.7	551.3	473.7	648.6	557.2	697.7	520.3	244
85	319.4	351.1	565.3	407.7	411.8	669.8	665.6	657.1	657.0	547.8	245
85	627.4	643.7	602.1	511.9	420.4	621.3	568.0	462.8	524.4	606.2	246
85	601.3	491.1	552.5	122.3	324.4	283.3	379.7	410.3	495.7	555.7	247

85	405.8	375.2	446.5	136.5	346.5	244.8	174.8	437.4	344.0	276.2	248
85	323.8	492.0	349.1	481.2	447.3	337.2	366.5	227.8	324.0	412.5	249
85	364.9	287.2	433.0	194.3	354.0	377.2	316.4	372.4	216.9	183.2	250
85	288.9	386.0	266.6	252.6	265.8	197.9	253.0	259.0	193.4	219.1	251
85	314.1	216.1	289.3	264.2	187.6	261.0	214.4	176.6	214.7	301.1	252
85	199.6	197.6	177.2	222.6	279.2	128.6	166.7	53.8	110.7	190.2	253
85	152.2	54.4	156.0	49.6	190.4	207.4	200.4	139.9	46.5	176.2	254
85	45.4	97.0	44.3	43.8	43.3	42.9	148.8	91.0	41.5	151.0	255
85	40.7	126.8	40.0	39.6	39.3	39.0	111.3	136.8	113.6	37.9	256
85	37.7	125.7	148.0	118.7	157.8	122.2	84.6	84.4	96.1	117.6	257
85	109.2	129.9	128.7	164.2	108.2	57.8	65.2	36.4	95.5	142.4	258
85	130.1	99.8	103.9	150.8	105.6	98.0	0.0	0.0	0.0	0.0	259
86	37.6	37.8	91.5	38.3	38.5	82.1	106.8	102.1	39.8	91.4	260
86	102.9	92.7	85.4	150.4	42.2	42.6	43.1	43.6	131.5	155.1	261
86	55.9	45.7	46.3	95.0	133.2	101.6	48.7	49.4	50.0	50.7	262
86	51.4	70.3	61.6	70.7	54.3	106.7	263.7	244.0	240.7	198.5	263
86	168.2	86.6	106.4	308.7	143.6	82.7	235.8	260.5	187.6	174.0	264
86	303.1	101.6	235.0	185.5	212.5	287.5	329.4	352.5	368.3	259.6	265
86	142.9	174.2	320.0	379.6	390.9	148.0	187.0	265.2	261.4	348.6	266
86	158.9	183.6	338.5	305.1	394.7	273.5	217.8	419.2	365.2	482.1	267
86	393.1	277.1	382.8	179.4	427.2	428.4	337.3	347.0	542.6	484.5	268
86	523.8	540.5	363.4	472.5	574.3	528.9	470.3	391.0	382.2	310.0	269
86	509.3	609.8	508.3	467.1	380.4	524.9	586.7	638.6	573.4	535.1	270
86	423.3	656.7	351.8	609.8	669.8	674.0	484.8	682.3	578.0	688.7	271
86	676.0	228.7	566.5	555.0	709.2	700.2	573.2	475.9	528.0	644.3	272
86	601.4	355.5	418.0	505.8	660.7	633.6	678.2	699.8	646.6	439.0	273
86	429.7	760.2	740.9	687.5	736.9	387.3	637.5	693.1	751.2	776.5	274
86	626.0	719.9	723.6	635.7	602.6	781.0	786.4	787.5	788.4	789.4	275
86	790.2	790.9	787.6	718.4	593.3	560.7	576.1	630.4	686.7	493.7	276
86	616.8	585.5	680.4	768.3	792.8	707.5	622.9	791.2	606.8	687.8	277
86	713.4	511.3	218.4	403.6	476.4	637.6	782.0	700.9	486.2	777.4	278
86	658.1	722.6	751.3	736.5	671.6	706.7	763.9	761.6	759.3	756.9	279
86	415.7	503.9	438.7	575.7	505.1	580.2	738.1	735.1	695.6	670.0	280
86	725.7	613.1	703.6	715.7	712.2	386.5	584.5	664.7	542.6	492.3	281
86	513.5	686.1	662.1	678.1	674.0	615.9	521.3	576.3	324.4	355.3	282
86	349.7	488.2	527.0	423.3	497.4	566.2	620.6	534.0	496.0	606.2	283
86	601.3	596.4	557.9	404.2	581.4	488.1	540.9	370.7	369.2	521.7	284
86	440.5	545.3	540.0	491.7	529.4	376.4	518.8	418.0	508.1	438.2	285
86	268.6	357.8	291.8	348.7	278.0	244.3	321.7	398.6	293.5	130.0	286
86	329.6	259.5	412.1	338.2	261.5	240.0	244.6	293.5	301.4	293.7	287
86	189.9	145.1	131.8	96.0	294.5	267.2	247.5	183.6	277.2	315.3	288
86	210.3	172.2	196.3	201.3	151.9	216.5	175.8	77.4	61.1	166.9	289
86	296.9	58.6	231.8	189.5	236.2	268.7	253.6	233.5	67.9	198.8	290
86	51.7	254.9	231.1	210.4	85.6	77.1	159.8	230.7	227.3	173.2	291
86	206.7	115.0	116.8	148.4	75.1	133.6	172.0	42.0	155.6	41.1	292
86	40.7	40.3	108.6	102.3	192.7	96.1	153.9	38.4	38.2	88.9	293
86	44.9	122.3	125.4	110.6	73.2	88.5	36.7	102.7	49.0	66.1	294
86	36.3	36.3	36.3	118.4	123.7	36.3	108.3	36.4	36.5	36.6	295
86	36.7	36.8	92.7	110.2	133.8	98.0	0.0	0.0	0.0	0.0	296
87	37.6	128.4	68.8	153.3	155.4	84.0	121.6	137.4	132.9	116.9	297

87	153.3	111.8	41.3	41.7	101.5	122.8	121.4	63.3	140.8	211.6	298
87	199.4	228.6	46.3	46.9	47.5	48.1	48.7	79.5	136.6	79.8	299
87	51.4	260.6	165.3	180.3	247.5	261.5	173.8	262.0	193.9	208.5	300
87	270.1	122.1	125.0	171.7	226.4	317.7	224.3	217.7	331.5	299.0	301
87	341.0	240.8	139.3	219.6	331.7	274.4	335.0	375.6	281.2	235.6	302
87	321.0	213.1	345.8	240.4	315.6	200.6	225.4	428.2	181.8	87.8	303
87	204.2	196.2	217.5	208.1	214.8	276.4	373.7	283.5	488.3	493.7	304
87	499.2	385.7	510.1	416.6	346.1	526.4	402.8	537.2	417.7	408.9	305
87	458.5	405.4	532.9	396.0	563.4	420.5	411.9	439.9	574.3	522.7	306
87	604.8	569.4	529.8	601.3	589.0	519.5	235.3	528.1	643.2	647.7	307
87	598.6	521.3	327.9	568.5	623.1	537.0	387.9	658.6	454.7	151.0	308
87	596.9	597.4	574.2	705.6	612.5	584.6	445.5	693.5	504.7	706.0	309
87	680.5	732.8	411.7	642.0	741.9	744.7	711.3	713.3	752.8	641.2	310
87	597.0	498.5	499.1	664.3	766.9	688.2	720.8	680.2	645.6	225.1	311
87	647.3	574.0	753.0	644.9	597.6	660.8	577.5	582.5	788.4	686.3	312
87	605.9	635.4	612.6	743.6	727.9	312.6	476.1	650.2	569.3	735.6	313
87	504.4	793.7	763.9	495.4	792.8	535.9	617.6	784.2	674.0	676.0	314
87	543.2	765.9	786.9	537.5	497.5	580.5	782.0	650.2	421.9	777.4	315
87	727.7	685.6	726.3	723.5	567.1	658.7	649.3	235.7	513.1	557.4	316
87	451.0	463.7	497.9	711.9	669.2	668.7	545.2	652.6	550.8	601.5	317
87	374.0	674.0	719.1	637.6	459.6	586.1	598.1	701.4	697.7	622.8	318
87	378.2	639.4	682.1	678.1	666.0	470.6	665.6	661.3	624.2	366.3	319
87	432.2	545.3	561.6	613.4	406.6	487.7	568.7	469.6	325.9	393.0	320
87	391.7	568.2	520.5	486.8	471.7	568.6	434.7	436.5	560.9	555.7	321
87	550.5	421.3	359.0	521.8	348.2	411.0	492.7	423.2	404.5	402.9	322
87	249.4	166.7	343.6	351.2	475.8	404.8	465.1	459.7	232.1	388.4	323
87	409.5	412.8	433.0	427.6	378.4	417.1	411.8	289.6	401.4	391.6	324
87	239.7	237.9	303.9	370.0	328.6	290.5	327.4	294.0	249.0	226.0	325
87	341.6	223.2	332.3	327.7	303.8	207.2	278.5	309.8	288.9	208.4	326
87	173.8	254.0	288.7	139.4	85.6	193.7	144.8	121.8	139.6	113.2	327
87	182.2	170.2	159.4	236.7	49.0	48.4	47.7	182.3	209.5	194.8	328
87	149.1	108.6	48.5	107.0	142.1	154.6	181.5	133.5	151.9	115.2	329
87	40.7	116.0	125.1	39.6	39.3	39.0	38.7	38.4	38.2	37.9	330
87	71.6	125.4	37.3	87.8	87.4	59.8	92.3	73.8	36.5	36.4	331
87	102.6	73.5	123.4	167.6	142.1	96.2	114.0	123.0	79.2	145.5	332
87	121.8	36.8	65.3	99.9	98.7	98.0	0.0	0.0	0.0	0.0	333
88	82.4	99.8	120.8	38.3	67.8	116.1	39.1	39.5	39.8	40.1	334
88	146.4	72.8	125.5	41.7	103.2	148.9	146.1	144.5	84.9	44.6	335
88	179.2	205.5	194.7	222.2	180.5	130.2	234.6	225.6	161.7	167.7	336
88	67.7	63.9	125.7	224.8	183.7	265.7	154.3	192.0	183.9	77.1	337
88	247.4	192.4	228.6	308.7	313.2	317.7	198.1	227.0	299.3	257.7	338
88	341.0	240.3	350.6	355.5	330.4	345.2	112.6	359.5	303.9	281.5	339
88	201.8	392.8	274.1	186.9	141.9	83.5	106.4	119.4	385.9	362.6	340
88	415.8	216.4	192.5	280.3	294.3	399.8	392.0	351.3	386.0	370.5	341
88	499.2	456.8	434.3	405.0	383.5	466.5	423.5	329.0	253.7	434.4	342
88	497.8	465.5	440.9	402.0	528.3	346.5	335.8	493.6	594.8	523.6	343
88	604.8	563.4	614.7	619.6	450.3	445.0	423.2	127.7	523.6	387.2	344
88	484.9	587.4	364.3	523.3	469.7	601.6	639.8	370.3	355.0	537.2	345
88	694.2	590.9	303.8	590.9	489.9	483.1	446.7	617.5	319.3	518.4	346
88	670.0	532.2	622.5	499.0	741.9	744.7	747.5	713.7	379.2	755.4	347

88	511.4	550.0	762.5	764.8	676.9	737.8	727.6	651.5	470.9	649.1	348
88	676.7	682.7	307.2	536.7	687.1	510.0	721.5	642.7	751.6	753.7	349
88	738.0	666.0	791.6	732.8	581.1	668.6	667.0	661.2	765.4	779.6	350
88	613.3	565.5	793.5	793.2	792.8	685.9	761.8	791.2	776.9	789.8	351
88	542.4	725.8	479.2	747.9	784.6	710.0	612.7	780.5	779.0	618.5	352
88	710.1	593.9	571.4	619.3	298.4	766.1	687.7	761.6	759.3	740.5	353
88	655.5	693.8	706.0	545.8	638.8	648.4	696.8	657.6	397.8	616.6	354
88	658.1	695.0	652.9	715.7	711.2	708.7	559.6	526.0	625.7	448.4	355
88	547.7	394.0	618.6	517.8	653.8	652.2	665.6	573.8	520.7	537.1	356
88	608.3	563.5	639.2	603.3	490.1	475.4	475.4	534.4	474.7	441.3	357
88	601.3	376.9	380.1	378.4	523.6	305.3	301.4	413.1	380.4	380.7	358
88	345.3	539.6	514.3	512.2	483.1	365.4	355.2	513.5	387.3	502.7	359
88	324.3	98.4	97.3	197.1	463.3	418.1	401.7	459.7	454.3	308.2	360
88	368.0	304.0	342.3	420.8	339.6	371.4	219.2	379.0	401.4	355.0	361
88	314.9	159.9	338.2	248.2	182.9	290.9	197.5	199.3	308.6	310.5	362
88	269.2	141.5	261.8	204.0	323.1	123.8	228.1	173.8	293.3	233.3	363
88	158.5	150.8	212.1	222.5	209.5	161.5	54.6	106.5	53.1	52.4	364
88	51.7	254.9	57.2	49.6	49.0	48.4	190.4	235.6	230.0	46.0	365
88	45.4	44.9	118.6	128.6	150.4	42.9	42.4	175.5	41.5	118.8	366
88	80.1	153.5	122.5	143.1	77.7	110.0	175.3	144.1	118.3	37.9	367
88	37.7	115.5	37.3	115.6	105.6	158.3	89.5	81.7	141.8	93.6	368
88	92.0	62.1	36.3	36.3	36.3	36.3	36.3	91.9	103.9	136.1	369
88	106.5	118.7	104.9	67.6	57.5	59.9	0.0	0.0	0.0	0.0	370

APPENDIX C

ACCEPTABLE SOIL AND LEACHATE CONCENTRATION LIMITS

REFERENCE

DOE-RL, 1993, *Hanford Site Baseline Risk Assessment Methodology*, DOE/RL 91-45, Rev. 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOE-RL, 1992, *Hanford Site Groundwater Background*, DOE/RL-92-23, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

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C.0 INTRODUCTION

This appendix provides soil and leachate concentration limits for waste accepted at the ERDF. These limits may be used to ensure that predicted human and ecological risks associated with the ERDF design alternatives will be acceptable. The soil concentration limits ensure that inadvertent intrusion into the waste will not result in unacceptable risks to humans or ecological receptors. The leachate limits ensure that groundwater contaminant concentrations below the ERDF do not exceed acceptable concentrations and are used in Appendix A and Chapter 9 to evaluate impacts to groundwater for the different alternatives. These soil and leachate limits may be used to assist development of waste acceptance criteria for the ERDF. The development of risk-based soil concentration limits is presented in Section C.1 and the development of acceptable leachate concentration limits is presented in Section C.2.

C.1 SOIL CONCENTRATION LIMITS

Acceptable soil limits are calculated assuming that active controls prevent intrusion for 100 years, passive controls prevent intrusion for 500 years, and a barrier thickness of at least 15 feet prevents intrusion due to excavation for at least 10,000 years. Therefore, the acceptable soil concentrations are based on the drilling scenario in 500 years (described in Section 6.3). The drilling scenario assumes that waste is brought to the surface in the form of drill cuttings and eventually spread over an area of 100 m (328 ft) by 50 m (164 ft) to a depth of 15 cm (5.9 in.) for a total volume of 750 m^3 (26,000 ft^3). Assuming a drill bit diameter of 20 cm (7.9 in.) and a waste thickness of 20 m (66 ft) the total volume of waste brought to the surface is 0.63 m^3 (22 ft^3). Dividing the volume of surface soil by the amount of waste results in a dilution factor of 1,190, which is rounded down to 1,000.

The parameters, pathways, and equations used to calculate acceptable soil exposure concentration limits in surface soils are described in Chapter 6. Exposure limits for human health are provided for all the contaminants detected in waste that might be received at the ERDF (Tables 3-8, 3-9, and 3-10) and are based on an ICR of $1x10^{-5}$ and a HQ of 1. Exposure limits for ecological protection are only provided for the potential contaminants of concern in soils (Table 5-8) and are based on NOAELs for the pocket mouse (see Chapter 6). The exposure concentration limits are summarized in Table C-1. The limiting exposure concentration for each contaminant is highlighted. In most cases, protection of human health is the driving factor.

Acceptable soil concentration limits for ERDF waste are calculated from the limiting acceptable exposure concentration assuming 500 years of decay and a 1,000-fold dilution and are provided in Table C-1. The decay coefficients for the constituents are provided in Chapter 4. Comparison with the maximum detected concentrations in the 100, 200, and 300 Area wastes are also provided for reference. For all constituents except copper, the maximum detected concentration is less than the acceptable soil concentration. The acceptable soil concentration for copper (8,200 mg/kg) is approximately one order of magnitude less than the maximum detected concentration.

C.2 LEACHATE CONCENTRATION LIMITS

Leachate concentration limits were calculated assuming the base-conditions groundwater exposure scenario described in Section 6.1 and the fate and transport parameters presented in Chapter 4. This scenario assumed no liner and an infiltration rate of 0.5 cm/yr (0.2 in./yr). To begin with, any constituent with a travel time greater than 10,000 years or a half-life less than 12 years would not present a risk to groundwater and was assumed to have an unlimited leachate concentration limit. (Assuming a vadose zone travel time of at least 520 years, any constituent with a half-life less than 12 years would decay to less than $1x10^{-13}$ of its original concentration before it reached groundwater). This screening step eliminated all the organics, the short-lived radionuclides, and the moderately to strongly sorbing metals and radionuclides.

Risk-Based and ARAR-Based Groundwater Standards. Risk-based and ARAR-based target groundwater concentrations were determined for the constituents that were not eliminated in the screening step. The risk-based standards were determined using a target ICR of $1x10^{-5}$ and a HQ of 1, and were calculated for the groundwater ingestion and volatile inhalation pathways, assuming HSBRAM (DOE-RL 1993) residential exposure parameters. The ARAR-based standards are the minimum ARAR from Table 7-5.

Risk-based groundwater concentrations for non-radioactive constituents are presented in Table C-2. Minimum ARAR groundwater concentrations for non-radioactive constituents are presented in Table C-3. Risk-based and minimum ARAR groundwater concentrations for radionuclides are presented in Table C-4.

Acceptable Leachate Limits. Many contaminant concentrations will decrease during transport through the vadose zone due to radiological decay, biological or chemical degradation, or volatilization. In addition, contaminant concentrations are diluted when the contaminant reaches the groundwater. These processes were accounted for using a modified version of the fate and transport model presented in Appendix A. Whereas the original spreadsheet model calculates leachate and groundwater concentrations based on bulk soil concentrations in waste, the modified spreadsheet model performs the reverse calculation; that is, it calculates leachate concentrations based on target groundwater concentrations. Soil concentration limits for the waste that result in protection of groundwater were not calculated because of the large uncertainties in waste release calculations.

The results are presented in Table C-5. In addition to presenting risk-based and ARAR-based acceptable leachate concentrations, the table also indicates whether the constituent travel time is greater than 10,000 years, whether the constituent decays in the vadose zone, and the Hanford Site groundwater background value. An unlimited acceptable leachate concentration indicates that no matter how high the initial leachate concentration, it would not result in an unacceptable impact on groundwater. The acceptable leachate concentration may be identified as unlimited because its vadose zone travel time is greater than 10,000 years and/or the constituent decays in the vadose zone. As discussed above, any constituent with a half-life less than 12 years would decay in the vadose zone and was identified in the screening step as having an unlimited acceptable leachate concentration. In addition, if the calculated leachate concentration exceeds $1x10^6$ mg/L, the acceptable leachate concentration was presented as unlimited. This is because a pure substance has a density equal to its specific gravity times $1x10^6$ mg/L (the density of water), and it is theoretically impossible for the concentration of a substance to exceed its density. Although some contaminants have densities greater than

$1x10^6$ mg/L, it is unlikely that they would be mobile in their pure form. In reality, leachate concentrations cannot exceed solubilities, which are generally less than $1x10^3$ mg/L.

Most of the organic compounds in Table C-5 decay completely in the vadose zone because of their relatively short half-lives. The remaining contaminants have travel times that are greater 10,000 years. Thus, acceptable leachate concentrations are unlimited for all organic compounds. This analysis assumed that organics would only migrate in the dissolved state; migration of free product was not addressed.

As shown in Table C-5, the non-radionuclide inorganic constituents do not decay in the vadose zone. However, several have travel times greater than 10,000 years. Acceptable leachate limits were also compared to Hanford Site groundwater background for the inorganic constituents. If the calculated limit is less than the background concentration, then the acceptable leachate limit was set equal to the background concentration. Arsenic was the only constituent with a calculated acceptable leachate limit that was less than the Hanford Site groundwater background value.

As shown in Table C-5, most of the radionuclides decay completely in the vadose zone. Generally, only those radionuclides with long half-lives reach groundwater at significant concentrations. These include carbon-14, neptunium-237, potassium-40, technetium-99, and all the uranium isotopes. However, the travel times for neptunium-237 and potassium-40 are greater than 10,000 years and the acceptable leachate concentrations for these radionuclides are therefore unlimited.

Table C-1. Acceptable Soil Concentration. (Sheet 1 of 7)

CONSTITUENT	Acceptable Exposure Concentrations[a]				Acceptable Waste Concentration[b]	Maximum Detected Concentration
	Human Health		Ecological			
	Non-Carcinogen	Carcinogen	Ingestion	External		
ORGANIC	(mg/kg)	(mg/kg)	(mg/kg)	NA	(mg/kg)	(mg/kg)
Acenaphthene	4.6E+03	NT			Unlimited	8.5E-01
Acetone	6.6E+03	NT			Unlimited	2.8E+00
Anthracene	2.3E+04	NT			Unlimited	6.3E+00
Aroclor-1248	NT	7.2E-01	8.1E+01		Unlimited	1.0E+01
Aroclor-1254	NT	7.2E-01	2.6E+02		7.4E+02	6.4E+00
Aroclor-1260	NT	7.2E-01	1.6E+02		7.4E+02	2.3E+00
Benz(a)anthracene	NT	7.8E-01			Unlimited	1.8E+00
Benzene	NT	7.0E+00	3.0E+01		Unlimited	1.9E-01
Benzo(a)pyrene	NT	7.8E-01	9.5E+00		2.5E+04	2.7E+01
Benzo(b)fluoranthene	NT	7.8E-01			Unlimited	2.4E+00
Benzo(g,h,i)perylene	NT	NT				3.7E+00
Benzo(k)fluoranthene	NT	7.8E-01			2.5E+04	7.6E-01
Benzoic acid	3.1E+05	NT			Unlimited	1.3E+00
BHC, beta-	NT	3.2E+00			3.3E+03	7.8E-03
Bis(2-ethylhexyl)phthalate	1.5E+03	4.1E+02	4.0E+02		Unlimited	3.3E+01
Butanone, 2-(MEK)	4.6E+02	NT			Unlimited	3.9E-01
Butylbenzylphthalate	1.5E+04	NT			Unlimited	2.6E+00
Carbazole	NT	2.9E+02			Unlimited	5.4E-02
Carbon Disulfide	4.8E+00	NT			Unlimited	2.0E-01
Carbon Tetrachloride	4.6E+01	4.0E+00			Unlimited	8.0E-03

Table C-1. Acceptable Soil Concentration. (Sheet 2 of 7)

CONSTITUENT	Acceptable Exposure Concentrations[a]				Acceptable Waste Concentration[b]	Maximum Detected Concentration
	Human Health		Ecological			
	Non-Carcinogen	Carcinogen	Ingestion	External		
Chlordane (gamma)	4.6E+00	4.4E+00			Unlimited	1.8E-02
Chloro-3-methyphenol, 4-	NT	NT			Unlimited	3.8E-02
Chloroaniline, 4-	3.1E+02	NT			Unlimited	6.3E+00
Chloroform	6.6E+02	1.0E+00	8.8E+01		Unlimited	8.0E-02
Chrysene	NT	7.8E-01			Unlimited	4.3E+01
DDD, 4,4-	NT	2.4E+01			7.6E+05	1.1E-01
DDE, 4,4'-	NT	1.7E+01			5.4E+05	1.7E-01
Di-n-butylphthalate	7.7E+03	NT			Unlimited	5.5E+00
Dibenz(a,h)anthracene	NT	7.8E-01			Unlimited	1.7E+00
Dibenzofuran	NT	NT				5.0E-01
Dichlorobenzene, 1,3-	NT	NT				4.8E-02
Dichlorobenzene, 1,4-	9.7E+06	2.4E+02			Unlimited	5.1E-02
Dichloroethene, 1,2- (total)	6.0E+02	NT			Unlimited	1.0E+00
Dieldrin	3.9E+00	3.6E-01	1.4E-01		Unlimited	2.1E-02
Diethylphthalate	6.2E+04	NT			Unlimited	1.0E+00
Ethylbenzene	2.3E+03	NT			Unlimited	3.3E-01
Fluoranthene	3.1E+03	NT			Unlimited	2.9E+00
Fluorene	3.1E+03	NT			Unlimited	1.7E+00
Hexanone, 2-	4.6E+02	NT			Unlimited	9.0E-03
Indeno(1,2,3-cd)pyrene	NT	7.8E-01			Unlimited	1.6E+00
Methoxychlor	3.9E+02	NT			Unlimited	8.3E-02

Table C-1. Acceptable Soil Concentration. (Sheet 3 of 7)

CONSTITUENT	Acceptable Exposure Concentrations[a]				Acceptable Waste Concentration[b]	Maximum Detected Concentration
	Human Health		Ecological			
	Non-Carcinogen	Carcinogen	Ingestion	External		
Methyl-2-pentanone, 4-	3.2E+01	NT			Unlimited	1.1E-02
Methylene Chloride	1.1E+03	4.6E+01	2.2E+01		Unlimited	4.5E+00
Methylnaphthalene, 2-	3.1E+02	NT			Unlimited	1.3E+01
Methylphenol, 4-	NT	NT			Unlimited	1.0E+00
Naphthalene	3.1E+02	NT			Unlimited	4.1E+00
Nitrosodiphenylamine, n-	NT	1.2E+03			Unlimited	1.8E+00
Pentachlorophenol	2.3E+03	4.8E+01	1.8E+03		Unlimited	1.5E+00
Phenanthrene	2.3E+03	NT			Unlimited	3.9E+00
Phenol	4.6E+04	NT			Unlimited	2.4E-01
Pyrene	2.3E+03	NT			Unlimited	1.2E+01
Tetrachloroethane, 1,1,2,2-	NT	4.0E-01			Unlimited	3.0E-03
Tetrachloroethene	7.7E+02	6.7E+01			Unlimited	1.1E+00
Toluene	3.4E+02	NT			Unlimited	1.5E-01
Trichloroethane, 1,1,1-	4.8E+02	NT			Unlimited	6.0E-03
Trichloroethene	4.0E+02	1.6E+01	1.1E+03		Unlimited	3.9E-01
Vinyl Chloride	NT	1.5E-01			Unlimited	2.4E-02
Xylenes (total)	1.3E+05	NT			Unlimited	1.1E+00
INORGANIC	(mg/kg)	(mg/kg)	(mg/kg)	NA		
Aluminum	4.7E+04	NT	1.8E+03		Unlimited	7.8E+04
Ammonia	4.6E+01	NT			4.6E+04	1.4E+02
Antimony	1.9E+01	NT	3.2E+01		1.9E+04	1.9E+01

Table C-1. Acceptable Soil Concentration. (Sheet 4 of 7)

CONSTITUENT	Acceptable Exposure Concentrations[a]				Acceptable Waste Concentration[b]	Maximum Detected Concentration
	Human Health		Ecological			
	Non-Carcinogen	Carcinogen	Ingestion	External		
Arsenic	2.4E+01	3.0E+00	2.0E+02		3.0E+03	6.2E+01
Barium	2.5E+03	NT	9.4E+02		9.4E+05	4.3E+03
Beryllium	1.7E+02	2.6E-01	9.9E+03		2.6E+02	4.7E+00
Cadmium	7.0E+01	3.9E+02	3.9E+01		3.9E+04	2.9E+01
Calcium	NT	NT				9.5E+04
Chloride	NT	NT				1.9E+02
Chromium (VI)	3.7E+02	5.9E+01	1.5E+04		5.9E+04	2.5E+03
Cobalt	4.2E+03	NT			Unlimited	9.0E+01
Copper	3.2E+03	NT	8.2E+00		8.2E+03	9.5E+04
Fluoride	4.8E+03	NT			Unlimited	4.0E+01
Iron	NT	NT				1.8E+05
Lead	NT	NT	2.4E+03			7.5E+02
Magnesium	NT	NT				5.0E+04
Manganese	1.1E+04	NT	4.4E+02		4.4E+05	3.1E+03
Mercury	1.8E+01	NT	3.3E+00		3.3E+03	3.7E+01
Nickel	1.4E+03	NT	1.1E+03		Unlimited	1.8E+03
Nitrate	7.9E+03	NT			Unlimited	1.3E+02
Nitrite (NO2 as N)	7.9E+03	NT			Unlimited	2.9E+00
Potassium	NT	NT				1.3E+04
Selenium	4.0E+02	NT			4.0E+05	1.1E+01
Silver	3.5E+02	NT	2.4E+03		3.5E+05	3.6E+02

Table C-1. Acceptable Soil Concentration. (Sheet 5 of 7)

CONSTITUENT	Acceptable Exposure Concentrations[a]				Acceptable Waste Concentration[b]	Maximum Detected Concentration
	Human Health		Ecological			
	Non-Carcinogen	Carcinogen	Ingestion	External		
Sodium	NT	NT				2.6E+03
Strontium	4.7E+04	NT			Unlimited	3.1E+01
Sulfate	NT	NT				7.1E+03
Thallium	5.6E+00	NT			5.6E+03	5.4E+00
Vanadium	3.3E+02	NT	1.6E+03		3.3E+05	3.9E+02
Zinc	2.4E+04	NT	3.0E+02		3.0E+05	6.2E+03
RADIONUCLIDES	NA	(pCi/g)	(pCi/g)	(pCi/g)	(pCi/g)	(pCi/g)
Americium-241		1.5E+01	3.4E+08	1.3E+08	3.4E+04	3.4E+01
Barium-140		7.7E-01	2.3E+07	5.9E+06	Unlimited	4.0E+02
Beryllium-7		2.8E+00	7.9E+10	2.1E+07	Unlimited	9.0E+01
Carbon-14		8.5E+03	4.3E+04	4.4E+11	9.0E+06	6.4E+02
Cerium-141		3.2E+00	1.9E+10	1.9E+07	Unlimited	3.0E+00
Cerium-144		1.6E+01	5.4E+08	8.3E+07	Unlimited	5.0E-01
Cesium-134		8.0E-02	1.7E+05	6.4E+05	Unlimited	5.6E+01
Cesium-137		2.1E-01	1.5E+05	1.7E+06	2.0E+07	1.1E+05
Chromium-51		4.5E+00	3.6E+09	3.5E+07	Unlimited	3.5E+00
Cobalt-58		1.3E-01	7.5E+07	1.0E+06	Unlimited	1.4E+01
Cobalt-60		4.8E-02	2.5E+07	3.8E+05	Unlimited	1.1E+04
Europium-152		1.2E-01	1.2E+09	8.7E+05	1.3E+13	2.9E+04
Europium-154		1.0E-01	4.7E+08	7.9E+05	Unlimited	9.2E+03
Europium-155		7.1E+00	2.4E+09	3.3E+07	Unlimited	9.6E+03

Table C-1. Acceptable Soil Concentration. (Sheet 6 of 7)

CONSTITUENT	Acceptable Exposure Concentrations[a]				Acceptable Waste Concentration[b]	Maximum Detected Concentration
	Human Health		Ecological			
	Non-Carcinogen	Carcinogen	Ingestion	External		
Hydrogen-3		1.4E+05	4.3E+05	NT	Unlimited	2.9E+04
Iron-59		1.0E-01	1.5E+08	8.0E+05	Unlimited	1.0E+00
Manganese-54		1.4E-01	2.9E+07	1.2E+06	Unlimited	7.0E-02
Neptunium-237		9.2E-01			9.2E+02	6.9E-03
Nickel-63		3.1E+04	1.1E+07	NT	9.7E+08	6.2E+04
Plutonium-238		1.8E+01	1.9E+07	3.8E+10	9.1E+05	1.4E+02
Plutonium-239/240		1.7E+01	2.0E+07	3.9E+10	1.8E+04	2.8E+03
Potassium-40		7.7E-01			7.7E+02	3.3E+01
Radium-226+D		6.9E-02	1.4E+05	5.4E+05	8.6E+01	4.3E+01
Radium-228		1.4E-01			1.4E+02	
Ruthenium-103		2.8E-01	1.5E+08	2.2E+06	Unlimited	1.0E+00
Ruthenium-106		2.3E+03	1.5E+08	2.2E+06	Unlimited	8.0E-01
Sodium-22		5.8E-02	6.1E+05	4.5E+05	Unlimited	9.9E+00
Strontium-90+D		2.1E+02	5.7E+03	2.5E+08	3.8E+10	2.0E+03
Technetium-99		5.6E+03			5.6E+06	1.1E+00
Thorium-228+D		7.4E-02	5.9E+07	6.0E+05	7.4E+01	1.7E+01
Thorium-232		4.6E+01	6.8E+07	1.1E+10	4.6E+04	3.6E+00
Thorium-234		1.1E+02			Unlimited	1.0E+00
Uranium-233/234		4.6E+00			4.6E+04	2.1E+03
Uranium-235		1.7E+00			1.7E+03	6.4E+02
Uranium-238+D (total)		7.8E+00	1.5E+06	5.3E+05	7.8E+03	9.1E+00

Table C-1. Acceptable Soil Concentration. (Sheet 7 of 7)

CONSTITUENT	Acceptable Exposure Concentrations[a]				Acceptable Waste Concentration[b]	Maximum Detected Concentration
	Human Health		Ecological			
	Non-Carcinogen	Carcinogen	Ingestion	External		
Zinc-65		2.1E-01	4.8E+04	1.7E+06	Unlimited	3.0E-01
Zirconium-95		1.7E-01	8.4E+09	1.4E+06	Unlimited	5.6E-01

[a] Acceptable exposure concentrations do not account for decay or dilution.
[b] Acceptable waste concentrations are derived from the smallest acceptable exposure concentration, and account for a 1,000-fold dilution and 500-year decay. "Unlimited" means that, for organic or inorganic wastes, the acceptable waste concentration exceeds 1E+06 mg/kg. For radioactive wastes, "Unlimited" means that the acceptable waste concentration exceeds the specific activity for the associated radionuclide.
NT = No toxicity information.
NA = Not applicable.

Table C-2. Risk-Based Groundwater Concentrations for Inorganic Constituents

Constituent	Limiting Groundwater Concentration (mg/L)	Groundwater Ingestion				Groundwater Inhalation (volatiles)				
		Oral RfD (mg/kg-d)	RBC (mg/L)	Oral SF (mg/kg-d)-1	RBC (mg/L)	volatile?	Inhal. RfD (mg/kg-d)	RBC (mg/L)	Inhal. SF (mg/kg-d)-1	RBC (mg/L)
antimony	6.4E-03	4.0E-04	6.4E-03	no tox	no tox	no	not vol	not vol	not vol	not vol
arsenic	4.1E-04	3.0E-04	4.8E-03	2.0E+00	4.1E-04	no	not vol	not vol	not vol	not vol
chromium (VI)	8.0E-02	5.0E-03	8.0E-02	no tox	no tox	no	not vol	not vol	not vol	not vol
fluoride	9.6E-01	6.0E-02	9.6E-01	no tox	no tox	no	not vol	not vol	not vol	not vol
nitrate (as N)	2.6E+01	1.6E+00	2.6E+01	no tox	no tox	no	not vol	not vol	not vol	not vol
nitrite (as N)	1.6E+00	1.0E-01	1.6E+00	no tox	no tox	no	not vol	not vol	not vol	not vol
selenium	8.0E-02	5.0E-03	8.0E-02	no tox	no tox	no	not vol	not vol	not vol	not vol

NOTES:
Target ICR = 1E-05; Target HQ = 0.1
no tox = no toxicity factor available for this contaminant pathway.
not vol = not a volatile compound.
RBC = risk-based concentration
RfD = reference dose
SF = slope factor

Table C-3. Minimum Groundwater ARARs for Inorganic Constituents

Constituent	Minimum ARAR (a) (mg/L)
antimony	6.0E-03
arsenic	5.2E-05
chromium (VI)	1.8E-02
fluoride	9.6E-01
nitrate (as N)	1.0E+01
nitrite (as N)	1.0E+00
selenium	5.0E-02

NOTES:
(a) Based on Table 7-5.

Table C-4. Risk-Based and Minimum ARAR Groundwater Concentrations for Radionuclides

RADIONUCLIDES	Risk Based Conc. (a) (pCi/L)	Minimum ARAR (b) (pCi/L)
carbon-14	5.1E+02	2.0E+03
technetium-99	3.5E+02	9.0E+02
tritium	8.5E+03	2.0E+04
uranium-233/234	2.9E+01	3.0E+02
uranium-235 + D	2.9E+01	3.0E+02
uranium-238	1.6E+01	3.0E+02

NOTES:
(a) Target ICR = 1E-05.
(b) From Table 7-5.
Only the groundwater ingestion pathway is evaluated. The inhalation pathway is not considered for radionuclides since they are not volatile. Only carcinogenic risk is considered.

Table C-5. Acceptable Leachate Concentration Limits

CONSTITUENT	Risk-Based Leachate Concentration (mg/L)	ARAR-Based Leachate Concentration (mg/L)	Travel Time > 10,000 yrs ?	Decays in Vadose Zone?	Hanford Site Groundwater Background (mg/L)
ORGANIC					
Acenaphthene	unlimited	unlimited	yes	yes	-
Acetone	unlimited	unlimited	no	yes	-
Anthracene	unlimited	unlimited	yes	yes	-
Aroclor-1248	unlimited	unlimited	yes	yes	-
Aroclor-1254	unlimited	unlimited	yes	yes	-
Aroclor-1260	unlimited	unlimited	yes	yes	-
Benz(a)anthracene	unlimited	unlimited	yes	yes	-
Benzene	unlimited	unlimited	no	yes	-
Benzo(a)pyrene	unlimited	unlimited	yes	yes	-
Benzo(b)fluoranthene	unlimited	unlimited	yes	yes	-
Benzo(g,h,i)perylene	unlimited	unlimited	yes	yes	-
Benzo(k)fluoranthene	unlimited	unlimited	yes	yes	-
Benzoic acid	unlimited	unlimited	no	yes	-
BHC, beta-	unlimited	unlimited	yes	no	-
Bis(2-ethylhexyl)phthalate	unlimited	unlimited	yes	yes	-
Butanone, 2- (MEK)	unlimited	unlimited	no	yes	-
Butylbenzylphthalate	unlimited	unlimited	no	yes	-
Carbazole	unlimited	unlimited	yes	yes	-
Carbon disulfide	unlimited	unlimited	no	yes	-
Carbon Tetrachloride	unlimited	unlimited	no	yes	-
Chlordane (gamma)	unlimited	unlimited	yes	yes	-
Chloro-3-methyphenol, 4-	unlimited	unlimited	no	yes	-
Chloroaniline, 4-	unlimited	unlimited	yes	yes	-
Chloroform	unlimited	unlimited	no	yes	-
Chrysene	unlimited	unlimited	yes	yes	-
DDD, 4,4-	unlimited	unlimited	yes	yes	-
DDE, 4,4'-	unlimited	unlimited	yes	yes	-
Di-n-butylphthalate	unlimited	unlimited	yes	yes	-
Dibenz(a,h)anthracene	unlimited	unlimited	yes	yes	-
Dibenzofuran	unlimited	unlimited	yes	yes	-
Dichlorobenzene, 1,3-	unlimited	unlimited	no	yes	-
Dichlorobenzene, 1,4-	unlimited	unlimited	no	yes	-
Dichloroethene, 1,2- (total)	unlimited	unlimited	no	yes	-
Dieldrin	unlimited	unlimited	yes	yes	-
Diethylphthalate	unlimited	unlimited	no	yes	-
Ethylbenzene	unlimited	unlimited	no	yes	-
Fluoranthene	unlimited	unlimited	yes	yes	-
Fluorene	unlimited	unlimited	yes	yes	-
Hexanone, 2-	unlimited	unlimited	no	yes	-
Indeno(1,2,3-cd)pyrene	unlimited	unlimited	yes	yes	-

Table C-5. Acceptable Leachate Concentration Limits

CONSTITUENT	Risk-Based Leachate Concentration (mg/L)	ARAR-Based Leachate Concentration (mg/L)	Travel Time > 10,000 yrs ?	Decays in Vadose Zone?	Hanford Site Groundwater Background (mg/L)
Methoxychlor	unlimited	unlimited	yes	yes	-
Methyl-2-pentanone, 4-	unlimited	unlimited	no	yes	-
Methylene Chloride	unlimited	unlimited	no	yes	-
Methylnaphthalene, 2-	unlimited	unlimited	yes	yes	-
Methylphenol, 4-	unlimited	unlimited	no	yes	-
Naphthalene	unlimited	unlimited	yes	yes	-
Nitrosodiphenylamine, n-	unlimited	unlimited	yes	yes	-
Pentachlorophenol	unlimited	unlimited	yes	yes	-
Phenanthrene	unlimited	unlimited	yes	yes	-
Phenol	unlimited	unlimited	no	yes	-
Pyrene	unlimited	unlimited	yes	yes	-
Tetrachloroethane, 1,1,2,2-	unlimited	unlimited	no	yes	-
Tetrachloroethene	unlimited	unlimited	no	yes	-
Toluene	unlimited	unlimited	no	yes	-
Trichloroethane, 1,1,1-	unlimited	unlimited	no	yes	-
Trichloroethene	unlimited	unlimited	no	yes	-
Vinyl Chloride	unlimited	unlimited	no	yes	-
Xylenes (total)	unlimited	unlimited	no	yes	-
INORGANIC					
Aluminum	unlimited	unlimited	yes	no	ND
Ammonia	unlimited	unlimited	yes	no	1.20E-01
Antimony	1.1E-01	1.0E-01	no	no	-
Arsenic	1.0E-02 (a)	1.0E-02 (a)	no	no	1.00E-02
Barium	unlimited	unlimited	yes	no	6.85E-02
Beryllium	unlimited	unlimited	yes	no	ND
Cadmium	unlimited	unlimited	yes	no	ND
Calcium	unlimited	unlimited	yes	no	6.36E+01
Chromium (VI)	1.3E+00	3.0E-01	no	no	ND
Cobalt	unlimited	unlimited	yes	no	-
Copper	unlimited	unlimited	yes	no	ND
Fluoride	1.6E+01	1.6E+01	no	no	7.75E-01
Iron	unlimited	unlimited	yes	no	8.60E-02
Lead	unlimited	unlimited	yes	no	ND
Magnesium	unlimited	unlimited	yes	no	1.65E+01
Manganese	unlimited	unlimited	yes	no	2.45E-02
Mercury	unlimited	unlimited	yes	no	ND
Nickel	unlimited	unlimited	yes	no	ND
Nitrate	4.3E+02	1.7E+02	no	no	1.24E+01
Nitrite (NO2 as N)	2.7E+01	1.7E+01	no	no	-
Potassium	unlimited	unlimited	yes	no	7.98E+00
Selenium	1.3E+00	8.4E-01	no	no	ND

Table C-5. Acceptable Leachate Concentration Limits

CONSTITUENT	Risk-Based Leachate Concentration (mg/L)	ARAR-Based Leachate Concentration (mg/L)	Travel Time > 10,000 yrs ?	Decays in Vadose Zone?	Hanford Site Groundwater Background (mg/L)
Silver	unlimited	unlimited	yes	no	ND
Sodium	unlimited	unlimited	yes	no	3.35E+01
Strontium	unlimited	unlimited	yes	no	2.64E-01
Thallium	unlimited	unlimited	yes	no	-
Vanadium	unlimited	unlimited	yes	no	1.50E-02
Zinc	unlimited	unlimited	yes	no	ND
RADIONUCLIDES	(pCi/L)				
Americium-241	unlimited	unlimited	yes	yes	-
Barium-140	unlimited	unlimited	yes	yes	-
Beryllium-7	unlimited	unlimited	yes	yes	-
Carbon-14	9.1E+03	3.6E+04	no	no	-
Cerium-141	unlimited	unlimited	yes	yes	-
Cerium-144	unlimited	unlimited	yes	yes	-
Cesium-134	unlimited	unlimited	yes	yes	-
Cesium-137	unlimited	unlimited	yes	yes	-
Chromium-51	unlimited	unlimited	no	yes	-
Cobalt-58	unlimited	unlimited	yes	yes	-
Cobalt-60	unlimited	unlimited	yes	yes	-
Europium-152	unlimited	unlimited	yes	yes	-
Europium-154	unlimited	unlimited	yes	yes	-
Europium-155	unlimited	unlimited	yes	yes	-
Iron-59	unlimited	unlimited	yes	yes	-
Manganese-54	unlimited	unlimited	yes	yes	-
Neptunium-237	unlimited	unlimited	yes	no	
Nickel-63	unlimited	unlimited	yes	yes	-
Plutonium-238	unlimited	unlimited	yes	yes	-
Plutonium-239/240	unlimited	unlimited	yes	yes	-
Potassium-40	unlimited	unlimited	yes	no	-
Radium-226	unlimited	unlimited	yes	yes	-
Ruthenium-103	unlimited	unlimited	yes	yes	-
Ruthenium-106	unlimited	unlimited	yes	yes	-
Sodium-22	unlimited	unlimited	yes	yes	-
Strontium-90	unlimited	unlimited	yes	yes	-
Technetium-99	6.0E+03	1.5E+04	no	no	-
Thorium-228	unlimited	unlimited	yes	yes	-
Thorium-232	unlimited	unlimited	yes	yes	-
Thorium-234	unlimited	unlimited	yes	yes	-
Tritium	unlimited	unlimited	no	yes	-
Uranium-233/234	4.8E+02	5.1E+03	no	no	-
Uranium-235	4.8E+02	5.0E+03	no	no	-
Uranium-238	2.8E+02	5.0E+03	no	no	-

Table C-5. Acceptable Leachate Concentration Limits

CONSTITUENT	Risk-Based Leachate Concentration (mg/L)	ARAR-Based Leachate Concentration (mg/L)	Travel Time > 10,000 yrs ?	Decays in Vadose Zone?	Hanford Site Groundwater Background (mg/L)
Zinc-65	unlimited	unlimited	yes	yes	-
Zirconium-95	unlimited	unlimited	yes	yes	-

NOTES:
(a) Limiting concentration based on Hanford Site Background (DOE/RL 1992)
ND = Not detected.

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APPENDIX D

LEACHATE GENERATION MEMO

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MEMORANDUM

TO: Kevin Kelly, MW Richland
Larry Bennett, MW Boise
Project File

December 15, 1993

FR: Frank Shuri, GAI Redmond FS

RE: ERDF LEACHATE VOLUME ESTIMATES, Job No. 923-A024

Two estimates of leachate production at the ERDF have been performed for different purposes. This memo will discuss those estimates, including background, assumptions, results, and applications.

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1. LEACHATE PRODUCTION AFTER INTERIM CLOSURE

This study was performed as part of the Trench Operations Sequence Engineering Study, WHC-SD-W296-ES-01, 1993 (TOS Study). The objective of the analysis was to determine whether a low-permeability layer would be required in addition to the 2-foot-thick interim soil cover that will be placed over the waste once a particular portion of the ERDF trench has been filled. The purpose of this interim cover is to provide containment against dispersion of contaminated soil due to wind, traffic, animals, etc. prior to construction of the Hanford Barrier. This cover will consist of soils excavated from the ERDF trench, probably silty fine sands, and consequently is not expected to have a low permeability. As a result, some precipitation could infiltrate the waste and form leachate which would be collected by the liner system and removed by pumping. There is no regulatory requirement for RCRA Subtitle C facilities to have a low-permeability interim cover prior to installation of the final closure cover (the Hanford Barrier). However, it may be desirable to install such a cover to limit the amount of leachate that must be treated and thus reduce ERDF operational costs. Hence, the analysis for the TOS Study consisted of a comparative analysis of the costs of installing a low-permeability liner vs. treating leachate. The cost for treating leachate is of course strongly dependant on the volume of leachate.

To estimate the average annual volume of leachate, the Hydrologic Evaluation of Landfill Performance (HELP) model Version 2.05 was used. The HELP model is accepted by EPA and is probably the most widely-used tool for determining the performance of landfill covers. It is intended primarily as a screening tool for comparing the performance of several potential cover designs, and the authors of the model caution against using it as an absolute predictive tool. Nevertheless, it incorporates many of the physical processes that govern water balance in landfill covers, and it has been verified against field data. Consequently it is considered useful for conceptual level estimates such as the TOS Study.

For the modelling done as part of the TOS Study, the following assumptions were used:

1. The interim soil cover is 2 feet thick.

2. The interim soil cover was modelled with permeabilities of 10^{-3}, 10^{-4}, and 10^{-5} cm/sec. This is considered to represent the range of permeabilities that can be

expected from the fine-grained ERDF soils. For comparison purposes, a permeability of 10^{-5} cm/sec is characteristic of a fairly clean silt, which is finer grained than any material identified to date at the ERDF site. A value of 10^{-3} cm/sec represents a clean sand. To place this value in perspective, the Minimum Technology Requirement for the drainage layer in a RCRA Subtitle C landfill is 10^{-2} cm/sec, only 1 order of magnitude higher.

3. Porosity, field capacity, and wilting point for the interim cover were HELP default values for sand.

4. The waste layer is 70 feet thick.

5. The waste has a permeability of 1.6×10^{-1} cm/sec. This material is modelled as a gravelly sand; the permeability value was determined by Westinghouse Hanford Company in The Results of Laboratory Tests to Determine the Physical Properties of Various Barrier Construction Materials, WHC-SD-ER-DP-006, Rev. 0, 1993. This value was also used by the U.S. Army Corps of Engineers (USACE) for HELP modelling of long-term leachate generation as described in the Engineering Study for the Trench and Engineered Barrier Configuration for the Environmental Restoration Storage and Disposal Facility, DOE/RL/12074--13 Rev. 0, 1993 (TEB Study). This relatively high permeability value allows any water that passes through the interim cover to reach the liner system relatively rapidly, and is thus considered conservative.

6. Porosity, field capacity, and wilting point for the waste were HELP default values for gravelly sand.

7. The initial moisture content of the waste was set equal to the field capacity of 0.045. In other words, it is assumed that the waste contains the maximum amount of water that it can hold and has no additional capacity to store infiltration. This is considered a conservative assumption.

8. The initial water content of the interim cover was determined by the HELP model at 81% of the field capacity.

9. An SCS runoff number of 77 was assigned to the interim cover. This corresponds to bare soil, and is the most conservative condition.

10. The maximum leaf area index was assumed to be zero, i.e., no vegetation. This is a lower bound condition that does not allow for moisture removal by plant transpiration. If grasses were planted on the interim cover, this assumption would be very conservative.

11. The evaporative zone was assumed to be 18 inches deep, based on previous HELP modelling for the Hanford site (DOE/RL 88-20 Low-Level Burial Grounds Dangerous Waste Permit Application, 1989).

12. Daily temperature and precipitation data for the Hanford site for the years 1979 through 1988 were used in the modelling. The average annual precipitation during this time was 7.08 inches, compared with the long-term average of 6.25

inches (Permanent Isolation Surface Barrier: Functional Performance, WHC-EP-0650, 1993). Hence, the modelling represents a realistic to slightly conservative moisture input.

13. Solar radiation data for Yakima, Washington, were used. These values were provided by the HELP program.

The results of the modelling showed that annual leachate production at the bottom of the waste layer ranged from 1.1 inches for the 10^{-3} cm/sec interim cover down to 0.7 inches for the 10^{-5} cm/sec interim cover. These results are equivalent to 30,000 gallons/acre/year and 19,000 g/ac/yr, respectively.

Another approach for estimating leachate is actual experience at commercial hazardous waste sites. As described in the TOS Study, leachate volumes at the Arlington, Oregon, facility from a landfill comparable to the proposed ERDF have ranged from about 3,000 g/ac/yr to 5,000 g/ac/yr. It should be noted that the Arlington site receives an annual rainfall of about 10.6 inches, 70% higher than Hanford. The difference between the Arlington results and the HELP modelling results is attributed to the many conservative assumptions used in the HELP modelling, particularly with respect to storage capacity of the waste. Assuming the upper limit of the Arlington data (5,000 g/ac/yr) and a lined trench area of 88 acres at the end of Project W296, the maximum annual leachate production is estimated to be 440,000 gallons.

Comparative cost analyses indicated that even the least expensive low-permeability layer in the interim cover (a geomembrane) was economically justified only if both leachate volumes and leachate treatment costs were at the high end of reasonably expected ranges. Based on engineering judgement and the Arlington data, it is possible that actual leachate volumes will be much lower than those predicted by the HELP modelling. This will depend to a large extent on the grain-size and moisture content of the waste placed in the ERDF, which is not well defined at the present time. Because a geomembrane can be installed after the interim cover is in place with no significant economic penalty, there is no requirement to install it at the same time as the interim cover. Hence, a "wait and see" approach was recommended, where actual leachate volumes would be monitored during the first few years of ERDF operation and a decision on a low-permeability interim cover would be made at that time.

2. LEACHATE PRODUCTION DURING ACTIVE LANDFILL OPERATIONS

Leachate production during the active phase of landfill operations, i.e., prior to placement of the upper interim cover, was also estimated. This estimate was required for sizing the storage and treatment facilities that would be required at the ERDF site. In contrast to the approach used above where long-term average values for leachate generation are important, the operational phase estimate considered the 25-year, 24-hour storm as a maximum design event that would dictate storage and treatment capacity. A single large storm event is expected to produce the most severe requirements for timely removal of leachate from the landfill (see 60% ERDF CDR, Conceptual Design Report for the Environmental Restoration Disposal Facility, 60% Draft, DOE/RL/12074--28 Rev. 0, 1993). This approach is consistent with RCRA Subtitle C requirements which specify use of this storm for design of runon and runoff facilities. This approach has also been used - and accepted - for the one existing RCRA Subtitle C landfill on the Hanford site, the Project W-025 landfill (see Design Report, Project W-025, Radioactive Mixed Waste (RMW) Land Disposal Facility, Non-Drag-Off, WHC-SD-W025-FDR-001, Rev. 1, 1992).

The 25-year, 24-hour storm depth at the Hanford site is 1.56 inches (see W-025 Design Report). Water from any area that collects this rainfall event must be treated if it comes in contact with waste. For sizing the ERDF leachate storage and treatment system, it was assumed that precipitation falling on interim cover did not form leachate, but was entirely removed through evapotranspiration. It was also assumed that any precipitation falling on uncovered waste or on the liner system was converted entirely into leachate. It is recognized that both of these assumptions are simplifications of the actual processes, but such an approach is considered adequate at this stage of design.

As described in the 60% CDR, the ERDF landfill will be developed as a number of hydraulically isolated cells to limit the amount of leachate that is produced. The amount of leachate therefore depends on the number of cells which are open and contain waste at any given time. A proposed filling sequence is presented in the TOS study. Based on this approach, a reasonable "worst-case" scenario for leachate generation is to have two corner cells and one side cell approximately half full of waste, as shown on the attached Figure 3-6. Earlier in the operation, fewer cells will be developed, and later in the operation, more interim cover will be in place. The calculated volume of leachate from the design storm falling on this configuration is approximately 800,000 gallons, as shown on the attached calculation sheet.

As described in the CDR, leachate will be stored in two tanks (plus a third backup tank) with 400,000 gallons capacity each. For illustrative purposes, each tank would be 150 feet in diameter and 3 feet deep. This is not considered a particularly large or costly tank, and consequently additional tanks could be added at a later date with little impact to the project if the need arises. The system is designed so that the full contents of both tanks can be pumped to the leachate treatment facility in 120 days at 6 hours per day. This provides substantial excess capacity.

3. SUMMARY

Two types of leachate production estimates for the ERDF have been performed to date. Each has a different purpose. Long-term average leachate generation rates were evaluated using the HELP model. This study indicated that a low-permeability interim cover was not economically justified unless both the volume and unit cost of leachate treatment were relatively high.

Leachate generation rates during active landfill operations were estimated in order to size the leachate storage and treatment system. For this purpose, a single large storm event, rather than average long-term rates, will control facility requirements. This approach is consistent with regulatory requirements and previous work at the Hanford site. The design in the 60% CDR is based on this approach.

It is recognized that a number of uncertainties exist that can significantly influence leachate generation estimates. However, many of these uncertainties will not be resolved until waste is actually received at the ERDF, well beyond the end of the design process. To allow design to proceed, reasonably conservative values have been used as leachate estimates. However, it is considered desirable to avoid incurring excessive capital costs in the initial phases of the project by constructing facilities large enough to accommodate all conceivable contingencies. Consequently, there is some risk that additional leachate system capacity may need to be added in the future. Such capacity would consist of additional storage tanks, treatment units, or other facilities that could be added with little impact to the existing plant. The net consequences of such future additions are considered relatively minor.

The analyses described here are simple approaches suitable for conceptual-level scoping calculations. Issues related to the leachate storage and treatment system will be reviewed in a greater level of detail during the Definitive Design phase of the ERDF. More comprehensive modelling is planned to better define expected leachate volumes and required treatment plant capacity.

leachate.w51

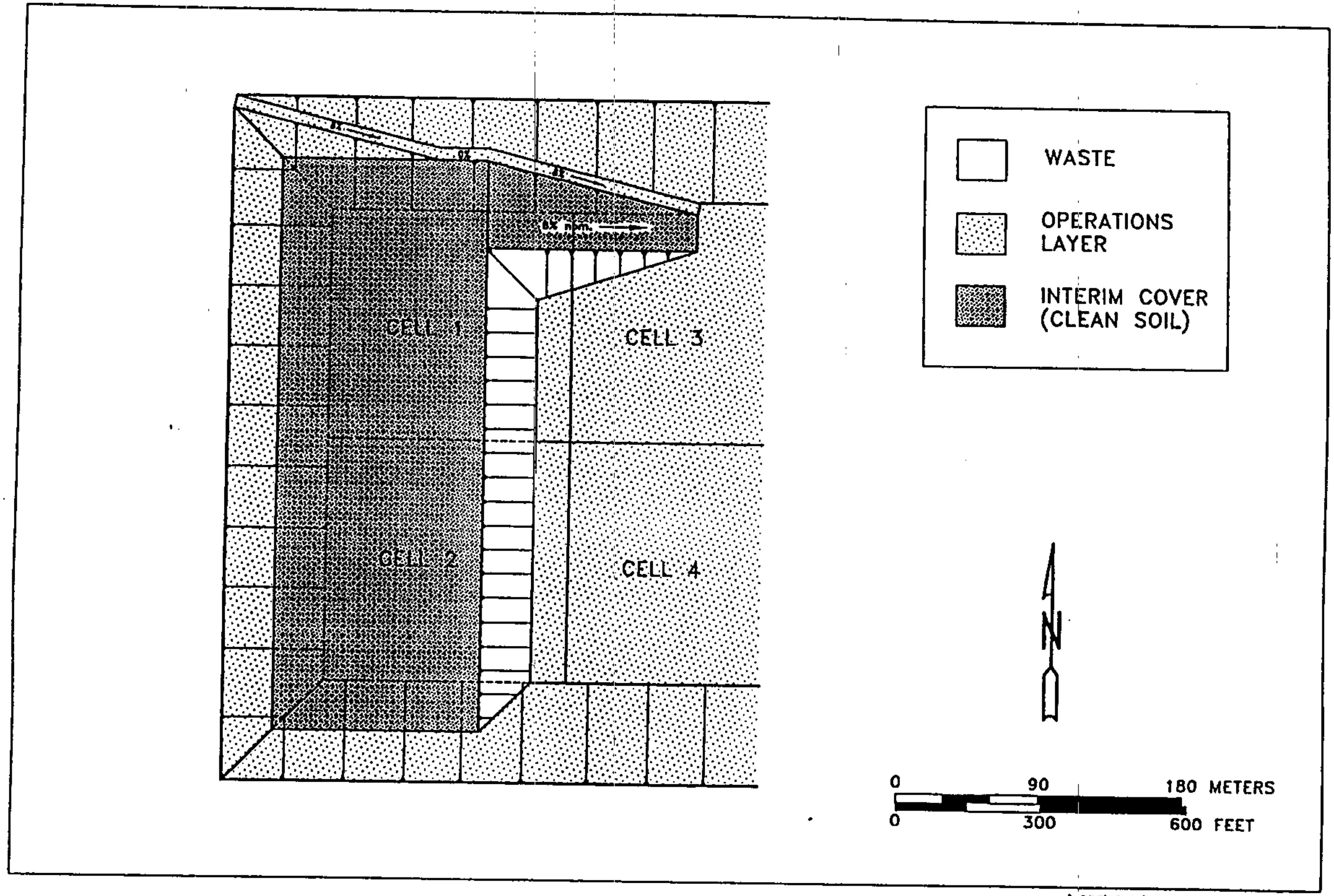

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Figure 3-6. Trench Filling Sequence, Stage 5

Golder Associates	SUBJECT Sizing of Lechate Storage Tanks	
Job No. 923-A024	Made by FSS	Date 11-12-93
Ref. CDR-ELDF	Checked	Sheet 1 of 1
	Reviewed	

25 year storm: 1.56 inches

Area of corner cell: $(210+500)^2 = 504,100 \text{ ft}^2$

Area of side cell: $500(210+500) = 355,000 \text{ ft}^2$

Rainfall volume in corner cell: $504,100 \text{ ft}^2 \times 1.56 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} \times 7.48 \text{ gal/ft}^3$

$= 490,000 \text{ gal}$

Rainfall volume in side cell: $355,000 \times 1.56 \times \frac{1}{12} \times 7.48$

$= 345,000 \text{ gal}$

Amount of contact water depends on filling sequence, but conservatively assume ½ corner cell + ½ corner cell + 1 side cell

$\frac{1}{2}\, 490,000 + \frac{1}{2}\, 490,000 + 345,000 = 835,000 \text{ gal}$

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