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100 AREA FEASIBILITY STUDY PHASES 1 AND 2
PAGE CHANGES TO DRAFT B
November 5, 1993

For Draft B documents issued with Appendix F:

- Replace old pages ES-5 through ES-10 of the Executive Summary with new pages ES-5 through ES-10
- Replace old pages v through xi of the Table of Contents with new pages v through x
- Replace old pages 1-5 through 1-37 of Section 1.0 with new pages 1-5 through 1-37
- Replace old Section 7.0 with new Section 7.0
- Replace old Appendix F with new Appendix F

For Draft B documents issued without Appendix F:

- Replace old pages ES-5 through ES-10 of the Executive Summary with new pages ES-5 through ES-10
- Replace old pages v through x of the Table of Contents with new pages v through x
- Replace old pages 1-5 through 1-37 of Section 1.0 with new pages 1-5 through 1-37
- Replace old Section 7.0 with new Section 7.0
- Add Appendix F

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Decision logic diagrams were developed to determine the regulatory contaminants of concern. (Figures 1 and 2 of Appendix A) Contaminants which the data showed were below background were included on a suspect contaminant list, i.e., future characterization data may warrant their inclusion as contaminants of concern. The qualitative toxicity assessment further refined the contaminants of concern determination by evaluating the toxicological significance of each regulatory contaminant of concern. The end product of this effort was a list of potential contaminants of concern and suspect contaminants for sources, groundwater, and the 100-N Area (presented in Section 2.0 and in Appendix A). A composite list, including the potential contaminants of concern only, is provided in Table 1.

Section 3.0 documents the results of the effort to identify potential ARARs. Three categories of ARARs are defined in the U.S. Environmental Protection Agency document titled *CERCLA Compliance with Other Laws Manual* (EPA, 1988c): chemical-specific, location-specific, and action-specific ARARs. Table 2 lists some of the more prominent potential ARARs for the 100 Area. Determination of ARARs is an iterative process and thus the list of potential ARARs will be refined with additional data from future 100 Area investigations and studies.

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Section 4.0 documents the Phase I effort to identify and screen remedial technologies and process options. This section also identifies remedial action objectives (RAOs), remedial action goals and general response actions (GRAs), and provides estimates of areas and volumes of contaminated materials.

The media of interest for the RAOs include soils, groundwater, riverbank sediments, solid wastes generated during site remediation activities. The same media and RAOs apply to the 100 N Area as well. In addition, this FS includes the identification of technologies and process options which may be used to address potentially-contaminated river bottom sediments and outfall pipelines. Descriptions of these technologies and process options are provided in Appendix F.

Remedial action goals are the target cleanup levels which satisfy the RAOs, and as such, are considered a subset of RAOs. These cleanup levels are driven by risk assessments and/or ARARs. In lieu of site-specific investigation and risk assessment data, assumptions were made to develop remedial goals. While the use of assumptions instead of site-specific data provides for a greater level of uncertainty, preliminary RAOs and remedial action goals can still be developed to a degree adequate for the Phase I/II alternatives development. However, site-specific data and definitive risk assessments will be necessary for future detailed analysis of alternatives. For purposes of this Phase I/II FS, the preliminary remedial action goals are based primarily on state and federal regulatory limits (potential ARARs) along with selected assumptions regarding cleanup levels as developed in the *Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991c). These assumptions are as follows:

- Performance of the tasks described for this FS is based on existing site data, primarily as documented in the eleven draft 100 Area OU RI/FS work plans issued previously (DOE 1990a-e; 1991a-f), and supplemented by existing data given in other documents for sites not covered by draft work plans. New

sampling or monitoring data produced as a result of current site investigations were unavailable to meet the FS schedule and are therefore, not incorporated.

- All sites in the 100 Area are categorized within one of the four types of sites identified for this project (solid wastes, soils/riverbank sediments, groundwater, and the 100-N Area.

- Sampling and monitoring data reported in source documents are assumed to be of adequate quality to support the FS.

Estimates of volumes of contaminated media were based primarily upon values presented in the *100 Area Hanford Past Practice Site Cleanup and Restoration Conceptual Study* (WHC 1991e).

General response actions were identified as follows:

- No Action
- Institutional Actions
- Containment Actions
- Removal/Disposal Actions
- In situ Treatment Actions
- Removal/Treatment/Disposal Actions.

The identification and screening of technologies considered the universe of technology types that would be potentially applicable to the identified general response actions. Technologies include general categories such as chemical treatment, thermal treatment, stabilization/solidification, or capping. Within each technology category are process options. Examples of process options within the chemical treatment technology category include precipitation, ion exchange, and oxidation/reduction.

Potentially-feasible, media-specific technologies and process options were identified for each of the GRAs by compiling information obtained from EPA documents, reference program sources, personal interviews, and other relevant technical references.

Technologies and process options were initially screened in the Phase I FS to eliminate those that are not technically implementable for the site conditions or contaminants encountered in the 100 Area. This first screening step only considered whether a technology and/or process option can be effectively implemented at the site, based on an assessment of existing site data on both contaminant types/concentrations and site characteristics.

A second screening step was performed on technologies/process options which considered effectiveness as a primary criterion with implementability (now including administrative implementability) and cost considered as secondary criteria.

Technologies and process options were identified for three media: solid wastes, groundwater, and soils/riverbank sediments. While the 100-N Area has been set apart as a separate medium in this FS, analysis of the applicability of technologies and process options

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indicated that there are no unique features of the 100-N Area which would present technologies or options differing from the three basic media which have been considered.

Section 5.0 documents the Phase II effort to 1) assemble screened technologies and process options into area-wide alternatives and 2) screen the alternatives with respect to implementability, effectiveness, and cost to arrive at a list for advancement to future focused feasibility studies.

In Phase II of the FS, the list of technologies and process options which passed the Phase I screening steps was used to assemble 27 alternatives representing the entire range of general response actions as well as treatment and containment combinations. Tables 3, 4 and 5 below list the component technologies and process options for each of the 27 alternatives for the solid waste, groundwater, and soils media, respectively.

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The Phase II FS also included an alternatives evaluation and screening step. The goal of the alternatives screening step was to limit the number of alternatives that must undergo detailed analysis while still preserving the range of response actions and technologies to be considered. Each of the 27 alternatives was described in sufficient detail such that they could be evaluated in the alternatives screening step. Descriptions were based upon the general process information developed for each technology/process option in Phase I. In addition, each alternative was described in view of known site conditions, contaminant ranges, volumes of contaminated media, and other factors.

In accordance with the CERCLA FS process (EPA 1988a), each alternative was evaluated against established criteria. The criteria are essentially the same as used for technology screening, i.e., implementability, effectiveness, and cost. However, in the alternatives evaluation stage, the criteria were now viewed in more detail, considering more site-specific conditions, and as applied to the integrated remedial solution rather than to just a portion of the solution. The CERCLA evaluation criteria are listed as follows:

Effectiveness:

- Short-term protection of human health
- Short-term protection of the environment
- Long-term protection of human health
- Long-term protection of the environment
- Reduction of mobility, toxicity, or volume reduction.

Implementability - technical feasibility:

- Constructability
- Operational reliability
- Maintenance.

Implementability - administrative feasibility:

- Agency approvals

- Availability of services
- Specialized equipment and personnel.

Cost - relative cost:

The alternative evaluation step culminated in a formal scoring process to provide a numerical qualification of how each alternative met the evaluation criteria. An alternative's rating against a specific criterion was not a pass/fail situation but an indication of the degree to which the alternative meets the criterion. This degree, which considers the balance of pros and cons for each factor, is represented by a simple 1 to 5 scale, where "1" (poor) suggests that the criterion is not met at all while "5" (excellent) suggests that the criteria is met very well.

The scoring was performed independently by nine individuals who made up the FS project team. Multiple scoring was done to reduce the influence of personal bias in the final results. The individual scores were then averaged to form an initial composite alternative ranking score. The guidance document (EPA 1988a) directs that the effectiveness criterion should be weighted more heavily than implementability and cost criterion.

The development of alternatives is based on the classes of contaminants (i.e., organics, metals, and radionuclides) and generalized conditions of all 100 Area operable units. Because protection of human health and the environment is the principal goal of remedial actions, the major focus of the screening is on the effectiveness of an alternative to meet RAOs. Therefore, effectiveness is given a high weighting factor in comparison to implementability and cost. After effectiveness, implementability is the next most important consideration and is given the second highest weighting factor. At this phase of the FS process, site-specific cost information is limited. Costs are relative and serve as comparisons between alternatives which are similar in effectiveness and implementability. Costs will be more fully defined during detailed analysis (focused feasibility studies), when individual sites are considered along with their specific conditions, waste volumes and types, and contaminants.

For the purposes of this feasibility study, this was accomplished by first normalizing the sum of individual factors for each criterion to 100 (for example, a total of "25" was possible for the five factors considered for evaluating effectiveness; the effectiveness score was normalized by multiplying the new score by 4), and then by weighting (multiplying by a weighting factor).

The evaluation criteria were weighted as follows:

	Weight
• Effectiveness	0.6
• Implementability	0.3
• Cost	0.1
Total	1.0

The decision to discard alternatives at this point was made on the basis of retaining a broad range of general response actions for detailed analysis. This is deemed necessary for this particular feasibility study due to an incomplete set of input parameters that are specified in the guidance document for traditional feasibility studies. Alternatives recommended for consideration at the detailed analysis/focused feasibility study levels cover the spectrum of all potential remedial actions from "no action" (which would be applicable only if a risk assessment indicates acceptability of such an approach) to removal, treatment, and disposal actions, which reduce uncertainty and risk but at a high cost.

Based on composite scores, alternatives were selected which are considered representative of the range of general response actions for future FS evaluations. These are listed in Table 6 below.

The retained alternatives may serve as a baseline from which to evaluate the future impact of site characterization data and risk assessment results. Note that alternatives (and technologies) that were not retained may be revisited at any time as new information warrants, in accordance with FS guidance.

While the CERCLA Phase I/II FS process provides a rational process for developing and screening remedial alternatives, it is important to note that all this is done in the absence of a baseline risk assessment to comprehensively evaluate the inherent risks posed by the contamination. The baseline risk assessment will be a part of future studies. The Phase I/II process also does not allow much consideration of cost. The NCP states "Each remedial action selected shall be cost effective..." (40 CFR 300.430 (f)(1)(ii)(D)). The cost effectiveness of each alternative has not yet been evaluated. This is an essential element in the ultimate decision-making process. While protection of human health and the environment is of utmost importance, the final remedial solutions must be cost effective.

Section 6.0 of this report discusses development of a Treatability Study Program Plan for conducting treatability studies needed to support further analysis of remedial technologies. This section also provides an outline of the RI/FS program steps needed to advance the feasibility study process through future detailed analysis efforts to be conducted as part of FSs for OUs and/or IRMs.

In general, treatability studies are conducted for two purposes:

- To gather sufficient data to allow treatment alternatives to be fully developed and evaluated during the detailed analysis and to support detailed design of a selected alternative

- To reduce cost and performance uncertainties for treatment alternatives to acceptable levels so that a remedy can be selected.

The data collected from the treatability studies may provide information to help determine the following:

- Potential effectiveness in achieving target cleanup levels

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- Contaminant removal (or destruction) efficiencies
- Achievable processing rates
- Selection of process reagents or additives, and formulations
- Pretreatment or post-treatment requirements for waste streams
- Treated-waste disposal requirements.

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1.3 BACKGROUND/SUMMARY OF EXISTING DATA

1.3.1 100 Area Description

1.3.1.1 Location. The Hanford Site is a 560 mi^2 (1,434 km^2) tract of land located in the south-central portion of the State of Washington in Adams, Benton, Franklin, and Grant Counties. The 100 Area lies along the southern shoreline of the Columbia River at the north end of the Hanford Site (see Figure 1-1).

Identifying numbers were given to the buildings and facilities in the 100 Area. These are summarized as follows (Adams et al., 1984):

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FACILITY CATEGORIES

CATEGORY	FACILITY DESIGNATION	FACILITY FUNCTION
Reactor Buildings	105	Housed reactor and fuel storage basin (irradiated)
Ground Disposal Facilities	116 (liquid) 118 (solid)	Inground disposal of liquid and solid wastes
Effluent Systems	107 1904/1908 1608	Retention basins Outfall structures Pumping stations
Ancillary Facilities	103	Fuel element storage building (unirradiated)
	108	Laboratory
	115	Gas recirculation buildings
	116	Reactor stacks
	117	Exhaust filter buildings
	119	Exhaust sample buildings
	1706	Reactor loop testing facility

1.3.1.2 History of Operations. 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 are under evaluation for decommissioning. The ninth reactor, N, was recently taken out of standby status and will be retired. Table 1-1 lists the construction date, period of operation, and status of each reactor. 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. Post-production activities are listed in Table 1-2.

1.3.1.2.1 Reactor Components (Excluding 100-N). The principal components of the original eight reactors consist of the reactor, the reactor cooling water loop, the reactor gas and ventilation system, and the irradiated fuel handling system. Each of these systems is briefly described below.

Reactor. Each reactor was graphite moderated and cooled with water pumped through on a single-pass basis. The reactor moderator stack consisted of graphite blocks, some of which were cored to provide channels for process tubes, control and safety rods, and other equipment. Aluminum process tubes held the aluminum-clad, uranium-metal fuel elements and provided channels for cooling water flow (Irradiation Processing Department 1963). Boron was the primary neutron absorber used in control and safety rods. The initial reactor design included a third safety system which used a tank filled with a boron solution suspended above the reactor. Aluminum sleeves, called thimbles, were inserted into the channels to protect the graphite from the boron.

After a few years of operation, the boron system was redesigned to utilize hoppers containing 3/8-inch (0.95 cm) nickel-plated boron balls instead of the liquid boron system (Irradiation Processing Department 1963). The balls emptied into the vertical safety rod channels when reactor shutdown was required. A vacuum system removed the balls when the reactor went back on-line.

Reactor Cooling Water Loop. Figure 1-2 presents a simplified process flow diagram for the original eight reactors. Cooling water for the reactor was pumped from the Columbia River to a water treatment facility either directly or via a reservoir. Additives, listed in Table 1-3, were introduced to the river water which then passed through flocculators to settling basins where an organic polyelectrolyte was added as a filter aid. The water was filtered through beds of gravel, sand, and crushed anthracite coal and stored in clearwells.

The treated water was pumped to large-capacity storage tanks where about 2 ppm sodium dichromate was added as a corrosion inhibitor (Richards 1953). The water from the storage tanks was then pumped via electric pumps to the reactor. The water at that point contained residues of alum, sulfate, chlorine, calcium, sodium dichromate, electrolyte, and other impurities.

The heated water passed from the reactor to a retention basin by gravity flow. The water was retained in the basin for a time sufficient to permit partial thermal cooling and radioactive decay of short-lived radionuclides. The water then flowed from the retention basin via the outfall structure and river pipelines where it was discharged to the middle of the river. The outfall structure contained a concrete or rip-rap spillway to divert the water to the river in case of an overflow.

A backup cooling system was provided by river water which was kept in a holding reservoir. This water was normally used to supply the powerhouse; however the water could be pumped to the water treatment facility or, in cases of emergencies, directly to the reactor. Steam was generated in the coal-fired powerhouse where the water was treated (to reduce formation of boiler scale) with sodium sulfite and trisodium phosphate and was subsequently passed through an ion exchange system[1].

Reactor Inert Gas and Ventilation Systems. The inert gas system was used to remove moisture and foreign gases, to serve as a heat transfer media between the graphite and process tubes, and to detect water leaks within the reactor. The reactor atmosphere was a mixture of helium with carbon dioxide or nitrogen. The composition of the gas mixture was varied to control the graphite temperature which in turn influenced reactivity conditions (Chattin and Powers 1985).

Irradiated Fuel Handling. Refueling occurred about once a month for about 10 percent of the process tubes in the reactor. Irradiated fuel elements removed from the reactor were sorted in a pickup chute area and transferred to the fuel storage basin for radioactive decay. Following the storage decay period, the fuel elements were placed in

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[1] Sodium chloride was used as the regeneration solution for the ion exchange system (Irradiation Processing Department 1963).

railroad cask cars for transport to the chemical reprocessing facilities in the 200 Areas (Miller and Steffes 1987).

1.3.1.2.2 100-N Reactor Components. 100-N Reactor. The 100-N reactor was a graphite moderated, light-water-cooled reactor and the newest of the 100 Area reactors. Its design and operation differ substantially from the other plutonium production reactors. Unlike the other eight single-pass reactors, the 100-N reactor was a dual purpose reactor which produced steam for electricity generation as well as plutonium. The 100-N reactor did not use once-through cooling as did the other eight production reactors. Instead water was recirculated through the reactor and steam generators.

The reactor core was a structure of interlocking graphite bars containing zirconium alloy pressure tubes which held the zirconium alloy-clad, uranium-metal fuel elements. Reactivity was controlled by horizontal control rods and the vertical ball system. Boron was the primary neutron absorber used in the rods and balls.

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100-N Reactor Cooling Water Loop. Figure 1-3 presents a simplified process flow diagram for the 100-N reactor cooling water loop. Untreated water from the Columbia River was supplied to the emergency coolant pumps, dump condensers, and the water treatment facility. The water treatment system produced raw, sanitary, and demineralized water. Raw water received no treatment other than straining; all other water was passed through a filtration plant where coagulant chemicals and small amounts of chlorine were added. A filter aid was added and the water passed through gravity filters which consisted of layers of gravel, sand, and granulated anthracite.

Treated water from the demineralizer plant was stored in a holding tank. Its uses included the reactor (graphite and shield), and rod coolant systems as well as the secondary water system.

The secondary steam system removed the reactor heat from the primary cooling water. During operation solely for production of special nuclear materials, the major portion of this steam was routed to dump condensers. During dual purpose operation, the major portion of the generated steam was routed to the Washington Public Power Supply System (WPPSS) Hanford Generating Project for production of electricity, through steam turbines and condensers. The secondary steam system was closed-loop, i.e., the condensed steam was returned to the steam generator.

Reactor Inert Gas and Ventilation Systems. The inert gas system in the N reactor was similar to the systems used in the other production reactors.

Irradiated Fuel Handling. Irradiated fuel elements removed from the reactor were moved to the storage basins for short term radioactive decay then placed in rail-mounted shipping casks for transport to reprocessing or storage facilities.

1.3.1.2.3 Decontamination and Decommissioning. To reduce the potential spread of radioactive contamination from the reactors and associated facilities, DOE began a program of decontamination and decommissioning (D&D) of buildings and facilities after the

reactor facilities were retired. Most of the contaminated buildings and facilities have been demolished and were buried in place, in the clearwells, or taken to the 200 Areas for burial. Clean wooden buildings and equipment were salvaged and uncontaminated buildings were converted for new programs or storage. In some instances, new buildings were constructed over the demolished building locations.

A photographic summary of D&D activities is presented in *Summary of the Hanford Site Decontamination, Decommissioning, and Cleanup FY 1974 Through FY 1990* (Wahlen 1991). The decommissioning plans for the 100 Area are presented in the *Hanford 100 Area Long-Range Decommissioning Plan* (Adams, et al., 1984).

1.3.1.3 100 Area Facility Characteristics and Contamination (excluding N Reactor). Waste units included in this FS are listed in the tables in Appendix E.

1.3.1.3.1 Effluent Handling. Facilities used in the handling of cooling water effluent included retention basins, pipelines, and outfall structures.

Retention Basins. The 100 Area retention basins were rectangular concrete or circular steel structures used to retain cooling water effluent from the reactor for radioactive decay and thermal cooling prior to discharge to the river. The basins ranged in capacity from 16 to 24 million gallons (DOE-RL 1991a). Some of the basins were baffled to provide separate compartments. In initial operations, effluent was directed to only one side of the basin at a time which allowed effluent contaminated by ruptured fuel elements to be diverted to other disposal facilities such as cribs and trenches. However, temperature differentials between the basin halves resulted in cracks and subsequent leakage. This leakage, coupled with increased production rates, forced simultaneous use of the retention basin compartments. This in turn precluded routing the more highly contaminated effluent to alternate disposal sites. Therefore all effluent was discharged directly to the river. Some of the retention basins were partially demolished and the rubble buried in-place after the Dorian and Richards study. The basins have also been used for disposal of contaminated piping and other demolition materials.

Some of the retention basins leaked, in some cases enough to produce surface ponds and streams that flowed to the river. This leakage resulted in contamination of soils adjacent to the basins. In addition, contaminated sludge was deposited on the basin floors and represents a significant source of contamination. The following summarizes the nature and extent of radionuclide contamination at the retention basins (Dorian and Richards 1978):

- Each retention basin contains from 1/4 inch to 3 inches of sludge covered by two to four feet of soil fill.

- Total radionuclide inventories for the B, C, D, DR, F, H, KE, and KW retention basins range from less than 10 curies for each of the K Area basins to over 400 curies for the B Area basin.

- For the B and C retention basins, approximately 90% of the contamination is located outside the basin in the soils beneath and adjacent to them.

- For all the reactors, Cesium-137, Cobalt-60, Europium-152, Europium-154, and Europium-155 account for approximately 97% of the radionuclide inventory located outside the retention basins.

- For the D, DR, F, and H basins, approximately 75% of the contamination is contained inside the basins in the sludge, the soil fill, and the concrete.

- For all the reactors, Cobalt-60, Europium-152, Europium-154, and Nickel-63 account for approximately 94% of the radionuclide inventory located within the retention basins.

- The KE and KW retention basins are much less contaminated than the others and have total inventories less than 10 curies each; approximately 85% of this contamination is located in soils adjacent to the basins.

Table 1-4 provides typical inventories for the areas of contamination related to the retention basins: basin sludge, basin fill, concrete, and surrounding areas.

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. Table 1-5 lists contaminant concentration ranges for the basins.

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 discharge point in the middle of the Columbia River. The 100 Area contained approximately 62,000 feet of effluent pipeline ranging in size from 12 to 84 inches in diameter (Adams, et al., 1984). The pipelines were constructed of carbon steel, reinforced concrete, or sometimes vitreous tile. The pipelines included manholes, junction boxes, tie-lines between parallel legs, and valves. Most of the on-land pipelines were buried although a portion of the effluent line in the 100-F Area was above-ground. This above-ground portion has been removed and placed in the 116-F-14, 107-F retention basin. The remaining land portions of the 100 Area effluent lines are still in place. Junction boxes have been sealed or filled with gravel and the effluent lines were sealed to prevent entry. The river pipelines are still in place except at F Area; approximately 50 feet of pipe has been dislodged and washed downstream.

Leaks occurred along the pipelines, mainly at the junction boxes of all the steel and concrete lines and the rubber joints of the tile lines. Contamination associated with the effluent lines is primarily in these leakage areas and in the accumulated sludge in the pipes. Radionuclide and chemical contaminants in the effluent lines and leakage areas are presumed to be the same as shown for the retention basins in Table 1-5.

Outfall Structure. Outfall structures were compartmentalized boxes used to direct the liquid effluent from the retention basin to the river pipelines for discharge to the middle of the Columbia River. The structures were constructed of reinforced concrete with concrete or rip-rap spillways (spillways were used only in case of overflow). With the exception of the structure at the 100-K Area, all the outfalls were 27 feet long by 14 feet wide with walls

one foot above grade and 25 feet below grade. The 100-K Area outfall was 30 feet long by 40 wide with 30 foot walls above and below grade (DOE-RL 1991a). Most of the outfalls have been demolished to near-grade level and backfilled. An outfall structure in the F Area, the PNL outfall, was used by the Pacific Northwest Laboratory (PNL) for disposal of wash wastewater from the animal pens. Contaminants include strontium-90 and small amounts of cesium-137 and plutonium-239 (DOE 1991d).

Effluent was normally discharged via the outfall and river pipelines; however effluent discharges sometimes overflowed the outfall structure and exceeded the capacity of the spillways resulting in contamination of surrounding soils down to the river's edge. The residual radionuclides and chemical contaminants associated with the outfalls are presumed to be the same as those listed in Table 1-5 for the retention basins.

1.3.1.3.2 Liquid Waste Disposal. Liquid waste was disposed to the soil column through cribs, trenches, and French drains. Cooling water was routinely discharged to the river; however, during fuel cladding rupture events, the water was diverted to cribs and trenches for disposal to the soil column. This practice avoided direct disposal of transuranics to the river.

Site characterization activities were conducted in the 1970s by Dorian and Richards (1978). The characterization effort was aimed primarily at the liquid waste disposal facilities with lesser efforts expended on the solid waste disposal facilities. Samples were taken from the surface and at depths varying from 5 to 25 feet. Sample analysis was conducted primarily for radionuclides. Contamination information pertinent to liquid waste disposal facilities is summarized in Table 1-6. Based on the information obtained during this effort, the following generalizations can be made concerning the 100 Area liquid waste disposal facilities:

- The principal radionuclides in these facilities are generally:
  - Cobalt-60
  - Cesium-137
  - Strontium-90
  - Europium-152
  - Europium-154
  - Europium-155

- The radioactive waste is generally confined to within five to twenty feet below the facility.

- Plutonium-239/240 concentrations are generally less than 1 pCi/g but range as high as 1500 pCi/g at the 116-C-2C pluto crib sand filter. Plutonium-238 concentration at the sand filter is as high as 1600 pCi/g.

Cribs. Cribs were buried, generally rock-filled, structures. Early cribs were typically open-bottomed, buried boxes, constructed from timbers, which ranged in area from 100 to 200 square feet. Some of these timbered cribs had associated tile fields for overflow. Some were provided with a secondary cavity to handle overflow. The 116-C-2 crib was

much larger than the other cribs, 140 feet by 100 feet at the bottom, and were provided with a sand filter. Figure 1-4 shows a typical crib with a tile drainage field (Adams et al. 1984). Interviews with operations personnel suggest that this schematic may not accurately represent certain cribs. Some of the 100 Area cribs may have been excavated pits which received waste through fire hoses.

Often a crib was dedicated to a specific building or process, and thus received a relatively uniform flow. Cribs can generally be categorized by the type of service provided. All data were obtained from Dorian and Richards 1978 or DOE-RL 1991a. Radionuclide quantities have not been decayed to current time. (Decay of radionuclides will be conducted in the LFI and incorporated into the FFS for each OU.) Crib types are listed as follows:

- Pluto cribs

  Except for the 116-C-2 (105-C) pluto crib, these cribs were generally small, approximately 10x10x10 feet (Dorian and Richards 1978), and were operated for short time periods only (less than two years). The pluto cribs received effluent from individual process tubes following fuel cladding failures.

  The 116-C-2A crib was the last crib to be constructed and was approximately 14,000 square feet in area. Associated facilities included a sand filter and pump station.

  Pluto cribs contained radionuclide inventories ranging from less than 0.1 curie to 3 curies. The 105-C pluto crib, 116-C-2A, had an associated sand filter and pump station. The sand filter contained contamination two orders of magnitude higher than that of the crib and plutonium concentrations up to 1600 pCi/g. Chromium and other cooling water additives are potential contaminants in the pluto cribs.

- Dummy/Perf Decontamination Cribs/Drains

  The dummy/perf decontamination cribs/drains received radioactive liquid wastes from the decontamination of dummy fuel element spacers in the 105-F, 105-H, and 111-B buildings. The cribs ranged in size from 4x8x8 feet to 12x8x15 feet and the drains were 3 to 4 foot diameter pipes 15 to 20 feet deep (DOE-RL 1991a).

  Acids, including nitric, sulfuric, oxalic, hydrofluoric, were used extensively in decontamination processes. Therefore, in addition to the radionuclides listed in Table 1-6, nitrate and other acid residues are likely contaminants in soils and groundwater beneath these cribs.

- 108 Building Cribs/Drains

  These cribs or underground drains received contaminated liquid effluents from the 108 laboratory building operations. The 116-B-5 crib was 84 feet long by

15 feet wide by 10 feet deep. The 116-D-3 crib was 3 foot diameter by 5 feet deep (DOE-RL 1991a). The 116-B-5 crib had 300 curies of tritium; the other 108 crib contained less than 0.1 curie of contamination.

- 115 Building Cribs

  The 115 building cribs were underground drains which received condensate and liquid waste from reactor gas purification systems. The cribs measured 40x40x26 feet. Each crib consisted of a four inch pipe leading into an 8-inch corrugated, perforated pipe 10.5 feet long. Two 5.4-ft sections branched off at 45 degrees (DOE-RL 1991a). Tritium and carbon-14 were the principal radionuclides disposed to these cribs. In 1978, the 116-KW-1 crib contained a total of 240 curies (Dorian and Richards 1978).

- 117 Building Cribs

  The 117 building cribs received drainage from the confinement system 117 building seal pits. The crib structures ranged from 125 to 1000 cubic feet (DOE-RL 1991a). Radioactive effluents disposed to these cribs generally contained only short-lived radionuclides. These cribs were released from radiological control prior to 1967.

Several special use cribs are described as follows:

- 116-F-5, 100-F Ball Washer Crib

  This crib received liquid wastes from the decontamination of the boron-steel balls used in the ball 3X system. The crib was 10 x 10 x 10 feet (DOE-RL 1991a). The crib contained 0.00092 curies; the principal radionuclides present included

  Strontium-90, Europium-154, Europium-155, and Cesium-137. No plutonium was detected.

- 116-KE-2, 1706-KER Crib

  This crib received radioactive liquid from the cleanup columns in the 1706-KER loop. The crib was 16 feet long by 16 feet wide by 32 feet deep. A wooden crib structure rests within the excavation 3 feet above the bottom. The bottom 10 feet are filled with crushed stone and backfilled with soil (DOE-RL 1991a). The crib contained 38 curies of Strontium-90 and Cobalt-60 with a 2.1 pCi/g maximum concentration of Plutonium-239/240.

- 116-DR-7, 105-DR Inkwell Crib

  This crib received liquid potassium borate solution from the 3X system prior to the ball 3X system upgrade. The crib was 5 feet long, 5 feet wide, and 10

feet deep (DOE-RL 1991a). The radiological contamination was found to be less than 0.1 curie.

French Drains. French drains were generally gravel-filled, concrete or vitreous clay pipe. These were 3 to 4 feet in diameter and ranged from 3 to 20 feet deep. French drains in the K Area received sulfuric acid sludge from the acid storage tanks. The 120-KE-1 French drain contains approximately 200 kilograms of mercury. French drains in the other areas received liquid wastes from decontamination processes. Drains in the F Area received effluent water from botany experiments (DOE-RL 1991a). Like cribs, they were usually dedicated to a specific building or process. Inventories for these French drains are unavailable (DOE-RL 1991a).

Trenches. Trenches were generally open excavations with sloped sides. The trenches ranged in length from 150 feet to 4000 feet, in width from 10 feet to 400 feet, and in depth from 6 feet to 25 feet. Each reactor area used a trench as backup to the retention basin when the effluent was too highly contaminated to be released to the river. Most of the trenches contain inventories of less than 10 curies. The liquid waste disposal trench at the K Area contained a total of 2100 curies with a maximum Plutonium-239/240 concentration of 130 pCi/g. Types of trenches are described as follows:

- Liquid Waste Disposal Trenches

  The liquid waste disposal trenches received effluent from the retention basins during fuel element cladding failures. The trenches ranged in size from 10 by 150 feet to 50 by 500 feet and in depth from 15 to 25 feet (DOE-RL 1991a). The trenches were used in early reactor operations until increased flow and leakage forced the parallel use of both sides of the retention basins. With the exception of the K Trench, the total contamination ranged from 3 to 79 curies with a maximum Plutonium-239/240 concentration of 5.3 pCi/g. Sodium dichromate was used extensively as a corrosion inhibitor; therefore chromium contamination is expected in these trenches (DOE-RL 1991a).

- K Trench

  The K trench (116-K-2) serviced both K Area reactors. The trench was 4000 feet long by 45 feet wide by 15 feet deep with a 4 foot bottom width (DOE-RL 1991a). The trench received wastes from all contaminated floor drains in the 105 buildings, approximately 500 gallons per minute of overflow from each metal storage basin, and an undetermined amount of 107 effluent basin leakage from valves in the tank bottoms. Periodic sources of contaminated flow to the trench included:

  - Low volume neutralized dummy decontamination waste;
  - Process cooling water during charge-discharge via metal storage basin and cross-under line;
  - Approximately 700 gpm metal storage basin flow during charge-recharge;

15 feet wide by 10 feet deep. The 116-D-3 crib was 3 foot diameter by 5 feet deep (DOE-RL 1991a). The 116-B-5 crib had 300 curies of tritium; the other 108 crib contained less than 0.1 curie of contamination.

- 115 Building Cribs

  The 115 building cribs were underground drains which received condensate and liquid waste from reactor gas purification systems. The cribs measured 40x40x26 feet. Each crib consisted of a four inch pipe leading into an 8-inch corrugated, perforated pipe 10.5 feet long. Two 5.4-ft sections branched off at 45 degrees (DOE-RL 1991a). Tritium and carbon-14 were the principal radionuclides disposed to these cribs. In 1978, the 116-KW-1 crib contained a total of 240 curies (Dorian and Richards 1978).

- 117 Building Cribs

  The 117 building cribs received drainage from the confinement system 117 building seal pits. The crib structures ranged from 125 to 1000 cubic feet (DOE-RL 1991a). Radioactive effluents disposed to these cribs generally contained only short-lived radionuclides. These cribs were released from radiological control prior to 1967.

Several special use cribs are described as follows:

- 116-F-5, 100-F Ball Washer Crib

  This crib received liquid wastes from the decontamination of the boron-steel balls used in the ball 3X system. The crib was 10 x 10 x 10 feet (DOE-RL 1991a). The crib contained 0.00092 curies; the principal radionuclides present included

  Strontium-90, Europium-154, Europium-155, and Cesium-137. No plutonium was detected.

- 116-KE-2, 1706-KER Crib

  This crib received radioactive liquid from the cleanup columns in the 1706-KER loop. The crib was 16 feet long by 16 feet wide by 32 feet deep. A wooden crib structure rests within the excavation 3 feet above the bottom. The bottom 10 feet are filled with crushed stone and backfilled with soil (DOE-RL 1991a). The crib contained 38 curies of Strontium-90 and Cobalt-60 with a 2.1 pCi/g maximum concentration of Plutonium-239/240.

- 116-DR-7, 105-DR Inkwell Crib

  This crib received liquid potassium borate solution from the 3X system prior to the ball 3X system upgrade. The crib was 5 feet long, 5 feet wide, and 10

feet deep (DOE-RL 1991a). The radiological contamination was found to be less than 0.1 curie.

French Drains. French drains were generally gravel-filled, concrete or vitreous clay pipe. These were 3 to 4 feet in diameter and ranged from 3 to 20 feet deep. French drains in the K Area received sulfuric acid sludge from the acid storage tanks. The 120-KE-1 French drain contains approximately 200 kilograms of mercury. French drains in the other areas received liquid wastes from decontamination processes. Drains in the F Area received effluent water from botany experiments (DOE-RL 1991a). Like cribs, they were usually dedicated to a specific building or process. Inventories for these French drains are unavailable (DOE-RL 1991a).

Trenches. Trenches were generally open excavations with sloped sides. The trenches ranged in length from 150 feet to 4000 feet, in width from 10 feet to 400 feet, and in depth from 6 feet to 25 feet. Each reactor area used a trench as backup to the retention basin when the effluent was too highly contaminated to be released to the river. Most of the trenches contain inventories of less than 10 curies. The liquid waste disposal trench at the K Area contained a total of 2100 curies with a maximum Plutonium-239/240 concentration of 130 pCi/g. Types of trenches are described as follows:

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- Liquid Waste Disposal Trenches

  The liquid waste disposal trenches received effluent from the retention basins during fuel element cladding failures. The trenches ranged in size from 10 by 150 feet to 50 by 500 feet and in depth from 15 to 25 feet (DOE-RL 1991a). The trenches were used in early reactor operations until increased flow and leakage forced the parallel use of both sides of the retention basins. With the exception of the K Trench, the total contamination ranged from 3 to 79 curies with a maximum Plutonium-239/240 concentration of 5.3 pCi/g. Sodium dichromate was used extensively as a corrosion inhibitor; therefore chromium contamination is expected in these trenches (DOE-RL 1991a).

- K Trench

  The K trench (116-K-2) serviced both K Area reactors. The trench was 4000 feet long by 45 feet wide by 15 feet deep with a 4 foot bottom width (DOE-RL 1991a). The trench received wastes from all contaminated floor drains in the 105 buildings, approximately 500 gallons per minute of overflow from each metal storage basin, and an undetermined amount of 107 effluent basin leakage from valves in the tank bottoms. Periodic sources of contaminated flow to the trench included:

  - Low volume neutralized dummy decontamination waste;
  - Process cooling water during charge-discharge via metal storage basin and cross-under line;
  - Approximately 700 gpm metal storage basin flow during charge-recharge;

- Occasional rear face decontamination wastes diluted with metal storage basin flow;
- Occasional "special" disposal such as waste from a single cross header through-reactor decontamination experiment; and
- An occasional tank-full of process cooling water collected after a fuel cladding failure.

The trench received large volumes of contaminated water and contained over 2000 curies of remaining activity. Maximum plutonium concentration was 130 pCi/g. Sodium dichromate, sulfamic acid, sulfuric acid, and copper sulfate were disposed to the trench (Dorian and Richards 1978).

- 1608 Trenches

The 1608 trenches were located in the F and H Areas and were used to receive effluent during the Ball 3X Project. Both trenches have overflowed in the past and contaminated nearby soils. The trenches have been backfilled with soil. The 1608-H trench is 275 feet by 100 feet by 6 feet deep and the 1608-F trench is 300 X 100 X 10 feet (DOE-RL 1991a). Total radioactivity ranges from 0.0021 curies to 1.4 curies. The major radionuclides include Strontium-90, tritium, Europium-152 and -154, Cobalt-60, and Cesium-137 with a maximum plutonium concentration less than 1 pCi/g (Dorian and Richards 1978).

- Sludge Trenches

The B Area contained two trenches, one 50 by 50 by 10 feet and one 120 by 10 by 10 feet that were used to bury low level sludge waste from the B Area retention basin (DOE-RL 1991a). Sampling data and contaminant inventories are not available for these trenches, although the contaminants and concentrations should be similar to those measured by Dorian and Richards 1978 for the B Area retention basin.

- 116-F-1, Lewis Canal

The Lewis Canal, located in the 100-F Area, received miscellaneous wastes from the 105-F and 190-F buildings, as well as decontamination wastes from the 189-F building. On occasion, contaminated coolant from the reactor front and rear faces was also routed to the Lewis Canal. Effluent water from the 1953 ball 3X outage was channeled to the river through this trench. The trench was originally several thousand feet long, however, all but 1500 feet at the inlet end have been released from radiological control. Dorian and Richards 1978 estimated a total inventory of 3 curies and Plutonium-239/240 concentrations of 1 pCi/g. The major radionuclides include Europium-152 and -154, Cobalt-60, and Cesium-137. Sodium dichromate and sulfamic acid are known to have been disposed to the Lewis Canal (DOE-RL 1991a).

1.3.1.3.3 Solid Waste Disposal. Solid waste disposal units consisted of burial grounds, landfills, ash/burn pits, and storage caves/vaults. For the early operational years of the nuclear reactors at Hanford, few if any records are available on the materials sent to solid waste disposal facilities. Also, characterization efforts for these facilities are limited. Dorian and Richards 1978 sampled the 118-B-1 burial ground and developed the following generalizations:

- No measurable migration of radionuclides was found.
- Plutonium-239/240 was generally not detected.
- The primary radionuclide was Cobalt-60, comprising approximately 90 percent of the inventory; other radionuclides in significant concentrations included Europium-152, -154, -155, Cesium-134, -137, Strontium-90, and Nickel-63.

A total of 28 radioactive solid waste 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 separations project at B reactor area. The remaining burial grounds were used for reactor upgrade projects, major maintenance projects, and special irradiation programs (Miller and Wahlen 1987). These special burial grounds generally contained low levels of radioactivity. Nonradioactive solid waste burial grounds in the 100 Area include ash and burn pits, demolition sites, and landfills. Estimated contamination inventories for the burial grounds are presented below and in Table 1-7.

Solid Waste Burial Grounds. Solid waste burial grounds which served the reactor facilities consisted of a series of trenches, pits, vertical pipes, and/or vault-like structures. The burial grounds ranged in size with the smallest being only a few feet wide and a few feet long to the largest being about 20 feet deep, 300 feet long, and 8 feet wide (at the bottom). The deep, narrow trenches contained high-dose large equipment; the pits and pipes were used for small, high-dose reactor hardware such as thermocouple stringers and horizontal control rod tips. A typical burial trench consisted of layers of hard waste (metal components such as irradiated process tubes and fuel charge spacers) and soft waste (such as contaminated paper, plastic, and clothing). Hard waste was usually placed in the bottom of the trench. Figure 1-5 is a schematic of a typical burial trench as presented in Adams et al., 1984. Interviews with operations personnel indicate that the layering of waste shown in the schematic may not accurately portray conditions in the burial trenches. Soft waste may have been disposed in different part of the trench than hard waste, or in some cases, hard waste was placed on top of the soft waste. Soft waste makes up more than 75% of the volume in the trenches but contains less than 1% of the radioactive inventory (Adams et al. 1984).

Each reactor had an associated burial ground. Miller and Wahlen 1987 estimated the total radionuclide inventory from reactor operations for these burial grounds to be about 4,000 curies, 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 an estimated 37.5 tons of wastes associated with the glass process lines used in the tritium

separations program, including lithium-aluminum alloy. This waste contained a tritium inventory of about 3,800 curies and approximately 2,000 pounds 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 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 40 by 20 by 10 foot trenches. The F Area burial ground was 175 feet by 50 feet by 15 feet deep, the B Area burial ground was 50 feet by 50 feet by 20 feet deep, and the H Area burial ground was 150 feet by 30 feet by 10 feet deep (DOE-RL 1991a).

Tritium Separations Project Burial Ground. Wastes associated with the metal lines used in the tritium separations project were disposed to this burial ground. An estimated 562 tons of waste, including 18 tons of lead and 25 tons of aluminum, were disposed. This included 11,000 curies of tritium.

Biological Burial Grounds. Two burial grounds in the F Area were used for the disposal of biological wastes. Each burial ground contained an estimated 15 curies of Strontium-90 and 0.30 curies of Plutonium-239/240.

Ash Pits. The ash pits received coal ash sluiced with water from the powerhouse. 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 and no hazardous materials were found (DOE-RL 1991a).

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 to the burn pits include scrap metal, glass, and asbestos. Sizes of the burn pits range from 9,600 to 224,000 square feet.

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 40 foot by 25 foot concrete tunnels covered with mounds of dirt. The vault in the F Area was a 16x8x8 foot concrete box with a wooden cover (DOE-RL 1991a). Exposure rates vary from 1 mR/hr up to 50 mR/hr at the tunnel entrances. 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.

1.3.1.3.4 Reactor Building. The reactor building housed the reactor core and a fuel storage basin which consisted of a water filled concrete structure used to temporarily hold spent fuel elements for decay of short-lived radionuclides. Some basins presently contain highly radioactive sludge. The reactor buildings are not included within the past practice operable units and thus are not within the scope of this FS; they are subject to actions as part of the Surplus Reactors Decommissioning Program.

1.3.1.3.5 Miscellaneous Facilities and Waste Sites. Storage Tanks. Tanks were used in the 100 Area for storing hydrocarbon products, acids, and chemical wastes. The tanks range in size from approximately 30 gallons for an evaporation unit to 1,650,000 gallons for oil storage tanks. Many of the tanks are currently either empty or water-filled, although some contain small amounts of residual waste. A few of the tanks have been moved to the 200 Area. Contamination associated with the tanks includes leaks and spills (DOE-RL 1991a).

Unplanned Releases. Unplanned releases occurred in the 100-F, 100-K, and 100-N Area. The 100-N unplanned releases are discussed in further detail in Section 1.3.3.2.5. 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 an estimated 4.0E-5 Ci of Strontium-90 and 1.06E-6 Ci of Plutonium-239. The area was stabilized with clean gravel (DOE-RL 1991a).

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 450 gallons per hour of fuel storage basin effluent and debris for an unknown period of time. Total activity was estimated at 2,530 curies including 1.3 Ci of Plutonium-239/240. The release was completely below ground with no associated surface contamination (DOE-RL 1991a).

Undocumented releases of hydrocarbon products and chemicals may have resulted in contamination of the soils in the 100 Area. In addition, unplanned releases to the air occurred in the 100 Area but are outside the scope of this report.

100-K Area Brine Pits. The pits were concrete structures, either underground or partially underground, ranging in area from 160 to 390 square feet. Salt was unloaded to the pits and water was circulated through the salt to create a brine for use in the power house. The salt was also used in water softeners. Contamination includes salt brine and residue (DOE-RL 1991a).

White Bluffs Pickling Acid Crib. This crib is located in the 100-IU-5 operable unit and was used to treat (pickle) piping for the reactors during the construction phase. This process used several thousand gallons of nitric and hydrofluoric acid. Vent pipes protrude every 18 inches and the surface is covered with large cobbles (DOE-RL 1991b).

Septic Systems. Thirty septic systems serviced the first eight reactor areas. The systems received sanitary sewage from buildings and possible contamination could include mercury from manometers, thermometers, and electrical equipment or wastes from laboratories which may have been disposed in sinks and floor drains. In addition, waste water from change rooms and the decontamination of face masks may have contributed to radiological contamination of the septic systems. No sampling data are available for the septic systems (DOE-RL 1991a).

1.3.1.4 100-N Area Facility Characteristics and Contamination.

1.3.1.4.1 Liquid Waste Disposal Facilities. The liquid waste disposal facilities in the 100-N Area consist of cribs, French drains, ponds, emergency dump tank and basin, and miscellaneous liquid waste facilities. Available data on the nature and extent of liquid waste disposal facility contamination are given in Table 1-8.

Cribs. The 116-N-1 crib consisted of a rectangular basin 290x125x12 feet with a 50x1600 foot extension trench. The 116-N-3 crib consisted of a concrete diversion box with an associated 250x240 foot concrete header box and a 3,000x10x7 foot extension trench. A 36 inch diameter, 1,200 foot long pipeline connected the box to the header. The cribs received radioactive water containing both activation and fission products. Small quantities of corrosives and laboratory chemicals were also disposed of in these cribs.

Chemical wastes disposed to the cribs include:

- Hydrazine test solution
- Ammonia test solution
- Chloride test solution
- Fluoride test solution
- Lead-acetate battery fluid
- Nickel-cadmium battery fluid
- Hydrazine
- Sodium dichromate (DOE 1990d).

French Drains. The 100-N Area French drains were constructed of 2 to 8 foot diameter clay pipe packed with lime. One of the drains had an associated 8x25 foot concrete vault/neutralization pit. The drains received either spent sulfuric acid or sodium hydroxide wastes (DOE-RL 1991a).

Ponds. Ponds were used in the 100-N Area to treat corrosive regeneration effluent, to settle out solids from filter backwash, and to dispose of backwash effluent. The ponds were generally unlined sloped-sided trenches ranging in area from 5,500 square feet to 29,000 square feet. Exceptions are the 130-N-1 filter backwash discharge pond, which is a natural, marshlike basin, and the 120-N-2 surface impoundment, which was double lined. The 130-N-1 pond also received aluminum sulfate and polyacrylamide solutions. Flow rates to the ponds were as high as 430,000 gallons per day.

Miscellaneous Liquid Waste Facilities. The 116-N-2 (1310-N) radioactive chemical waste treatment and storage facility was a waste management unit consisting of a complex system of piping, pumps, a transfer tank, and a large treatment and storage tank. This facility was used to neutralize the pH of and temporarily store radioactive waste acid solution used in internal reactor decontamination. The transfer tank is a spherical metal structure with a 900,000 gallon capacity; it is partially buried and surrounded by a 25 foot high compacted soil radiation barrier on three sides. Decontamination wastes from the primary water loop of the reactor were transferred by a 6 inch diameter underground pipe to the transfer tank and then to the storage tank for neutralization.

The decontamination wastes included 70% phosphoric acid and diethylthiourea. Decontamination of the primary loop occurred once every three to five years and resulted in approximately 600,000 gallons of waste solution per decontamination event (DOE 1990d).

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1.3.1.4.2 Solid Waste Disposal Facilities. The 128-N-1 burning pit is the only solid waste disposal facility listed in the Waste Information Data System (WIDS) for the 100-N Area. The burning pit was used to burn nonhazardous waste such as paper, wood, trash, etc. generated at 100-N Area. The dimensions and exact location of the unit are unknown (DOE-RL 1991a). No characterization data are available in WIDS or DOE 1990d.

1.3.1.4.3 Miscellaneous Waste Facilities. Miscellaneous waste facilities include the three 118-N-1 spacer storage silos, the 116-N-8 mixed waste storage area, and the 120-N-4 nonhazardous and nonradioactive storage area. Information on types and amounts of contamination in these facilities is unavailable.

- 118-N-1

  The three 118-N-1 spacer storage silos were used for temporary storage of irradiated fuel spacers which came in direct contact with the fuel elements in the reactor. The silos were each 16 feet in diameter and 20 feet deep. Two of the silos were open-bottomed; the other had a concrete floor. All three were covered with concrete caps. The silos currently contain dry irradiated spacers (DOE 1990d).

- 116-N-8

  The 116-N-8 mixed waste storage area is a concrete-paved, mixed waste container storage pad. The pad is walled on two sides, covered by a roof, and surrounded by a curb and a mesh fence. The pad measured 60 feet by 152 feet. Drums and containers of radioactively contaminated oil and miscellaneous hazardous process chemicals are stored on the pad (DOE 1990d).

- 120-N-4

  The 120-N-4 nonhazardous and nonradioactive storage area is a 100 foot by 75 foot curbed concrete pad. The pad is used to store nonradioactive and

nonhazardous oils and aqueous liquids. Prior to 1985, the unit was unpaved and used as a laydown yard for radioactively-contaminated equipment. Information on types and amounts of wastes for this time period are unavailable (DOE 1990d).

1.3.1.4.4 Sanitary Sewer Systems. The 100-N Area contains ten sanitary septic systems: one cesspool, one lagoon, one septic tank with an associated tile field, two septic tanks with seepage pits, and five septic tanks with associated drain fields. Flow rates to the septic systems ranged from 45 to 50,000 gallons per day.

The 124-N-4 sanitary sewer system has detectable surface contamination. No other characterization data are available for these facilities in WIDS or the 100-N Area work plans.

1.3.1.4.5 Unplanned Releases. The 100-N Area had 33 unplanned releases consisting primarily of line leaks and spills during transfers (DOE 1990d). One release resulted when a contaminated piece of equipment fell off a truck; the other releases involved spills/leaks of low level radioactive water, petroleum fuels, or nonradioactive chemicals. Unplanned releases are tabulated in Appendix E.

Radioactive Liquids. Releases of radioactive liquids ranged from less than 100 gallons to over 500,000 gallons. Contamination ranged from less than 1μCi to 35 curies. Many of the releases were remediated by removal of contaminated soil and/or covering with clean soil.

Petroleum Fuels. Diesel and/or fuel oil leaked from pipelines or overflowed from storage tanks. The fuels were nonradioactive and ranged from 200 gallons up to 80,000 gallons. The extent of remediation on these releases is generally unknown.

Nonradioactive Chemical Liquids. Spills during the transfer of chemicals ranged from approximately 500 gallons to 3,500 gallons. The chemicals included phosphoric acid and diethylthiourea mixture, sulfuric acid, and sodium hydroxide. Acid spills were neutralized with soda ash. Cleanup included removal of contaminated soils and backfill in some spill areas. The extent of residual contamination is unknown (DOE-RL 1991a).

1.3.1.5 Soils. Most of the wastes generated during the operations of the 100 Area reactors were disposed to the soils, either intentionally or through leakage. Groundwater mounds existed in the 100 Area because of the volumes of liquids disposed to the soils. Available data on nature and extent of soil contamination are summarized in the subsections below. The 100-N Area soils are discussed in Section 1.3.1.5.4.

1.3.1.5.1 Background Soil Quality (excluding 100-N Area). Background soil quality data specific to the 100 Area are generally unavailable. Samples are collected periodically as part of the Hanford Environmental Management Program from locations both on and off the Hanford Site. These samples are limited in applicability for several reasons:

- No subsurface samples are collected.

- Those samples which are routinely obtained are analyzed for a limited range of radionuclides.

- Samples are generally collected near sources and are therefore influenced by past operations.

Data from the 1989 onsite and offsite sampling are presented in Table 1-9. No data have been developed for nonradioactive inorganic contaminants such as nitrate and chromium.

A characterization effort is currently underway at Hanford to determine background concentrations for soils. Available data from this effort are presented in Table 1-10.

1.3.1.5.2 Soil Contamination (excluding N Area). Soil contamination in the 100 Area has resulted from the following potential operational sources:

- Fallout from stack emissions
- Planned releases from waste handling and disposal facilities
- Unplanned releases (Jaquish and Mitchell 1988).

Table 1-11 contains surface soil data collected in 1987 as part of the Hanford Environmental Management Program. The environmental samples of surface soil collected in 1985 by United Nuclear Corporation (UNC) near the retired 100 Area reactor facilities indicated no release or biotransport of radionuclides to the immediate environment. Table 1-12 presents the range of contaminants found in the 100 Area soils in the 1985 sample collection (Jacques 1986).

Sampling for vadose zone contaminants was performed in the 1970s by Dorian and Richards (1978). Their investigation focused on the retention basins and liquid waste disposal facilities. Contaminant information given in Section 1.3.3.1, Section 1.3.3.2, and Tables 1-5, 1-6, and 1-8 represents the available data for the 100 Area soils. Sampling data for nonradioactive contaminants are unavailable.

1.3.1.5.3 100-N Area Background Soil Quality. Background soil samples were collected at the 120-N-1 Surface Impoundment, the 120-N-2 Percolation Pond, and the north and south settling ponds. The analyses of these samples can be generalized as follows:

- Background radionuclide concentrations were low; the radionuclides present included:
  - Uranium
  - Potassium-40
  - Lead-212
  - Lead-214
  - Gross beta.

- Background soils contained metals, with low concentrations of volatile organics and no semi-volatiles (DOE 1990d).

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Background values for other sites in the 100-N Area are unavailable.

1.3.1.5.4 100-N Area Soil Contamination. The findings from UNC's 1985 sampling campaign (Jacques 1986) are presented in Tables 1-11 and 1-12 and can be generalized as follows:

- Environmental samples of surface soil and direct radiation measurements collected near 100-N Area indicated no significant releases to the immediate environment.

- Radionuclides released to 116-N-1, the 1301-N liquid waste disposal facility, were detected in the surface soil adjacent to the facility.

- Sediment samples collected from the 1301-N liquid waste disposal facility and 116-N-3, the 1325-N crib, contained activation and fission products discharged from N Reactor.

Table 1-13 presents average radionuclide concentrations in the 100-N Area surface soil from 1981 to 1985.

Subsurface soils near the 116-N-1 crib and trench were sampled in 1982 (Robertson et. al., 1984) as part of a research project. Data from gamma logs of the boreholes indicate that very low concentrations of radionuclides such as Cobalt-60, Cesium-137, Antimony-125, and Ruthenium-106 were present above the water table in the borehole nearest the facility. Concentrations of the radionuclides in the unsaturated zone decreased in the other two boreholes which are farther from the crib and trench. Concentrations increased markedly in the soils at the water table in all three wells. Organics found in the samples include alkenes, alkanes, alkynes, elemental sulfur, and three cyclic sulfur species.

Studies conducted on 100-N Area soils indicate that radionuclide-specific sorption will occur and that sorption is dependent upon ionic species; 100-N Area soils have no capacity to retain iodine and phosphorous and very low capacity to retain tritium. Strontium, cesium, and other radionuclides will be preferentially sorbed to varying degrees (DOE 1990d).

1.3.1.6 Groundwater. Groundwater contamination in the 100 Area is primarily a result of direct disposal of liquid wastes to the soil. The groundwater beneath the 100-N Area contains higher concentrations of a greater number of radionuclides because of its more recent operations.

1.3.1.6.1 Background Groundwater Quality. Groundwater in the unconfined aquifer on the Hanford Site is characterized as calcium bicarbonate dominant; primary inorganic constituents include calcium, bicarbonate, sulfate, silica, sodium, chloride, magnesium, and potassium. Secondary natural constituents occurring in trace amounts (< 1 ppm) include ammonia, barium, fluoride, manganese, and strontium. The natural Hanford groundwater contains moderate total hardness, approximately 120 ppm, and total dissolved solids, approximately 250 ppm. Background levels for Hanford groundwater are presented in Table 1-14. Background concentrations have been estimated from groundwater samples

collected as part of the Hanford Sitewide Groundwater Monitoring Project from areas judged to be unaffected by Hanford operations (Evans et al. 1990).

An effort is currently underway to determine sitewide groundwater background levels. The initial results from this study are presented in Table 1-15. The information in the table was taken from *Hanford Site Groundwater Background* (DOE-RL 1992b) and represents a compilation of data from the following sources:

- Basalt Waste Isolation Project Hydrochemistry Database
- The Hanford Groundwater Database
- U.S. Geological Survey Data
- Pacific Northwest Laboratories Summary (Evans et. al., 1990).

Background concentrations specific to the 100 Area are not available and use of the general Hanford Site groundwater data may not be appropriate for all comparisons. Because of the close proximity to the Columbia River, the river water influx may dominate the flow system in the vicinity of the reactors, such that background groundwater quality may be closer to river water quality.

1.3.1.6.2 Groundwater Contamination. Contamination in the groundwater of the 100 Area is a result of past waste disposal practices. Groundwater is monitored routinely for radioactive and inorganic contaminants. Tritium and nitrate are mobile contaminants found in the Hanford area groundwater and serve as indicators of the extent of contamination. Tritium was one of the major radionuclides found in the 100 Area waste streams and nitrate results from the nitric acid used in reactor decontamination. Hexavalent chromium is another mobile contaminant which can be used to estimate the extent of contamination. Sodium dichromate, used to control oxidation of aluminum parts, and chromic acid, used to decontaminate dummy fuel elements, account for the hexavalent chromium concentrations in the Hanford groundwater.

Groundwater monitoring efforts for 1989 included analyses of samples taken from 91 wells, 43 of which were in the 100-N Area. Contaminants found in the groundwater which exceeded (for comparison) the Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCL) (40 CFR 141) are presented below (Evans et al. 1990). Tables 1-16 through 1-18 present contaminant ranges for key inorganic constituents, radiological constituents, nitrate, and volatile organic compounds found the 100 Area groundwater (Evans, et al., 1990). Table 1-19 presents a list of constituents detected in the 100-N Area which exceeded drinking water standards (SDWA MCLs) for the period April 1987 to November 1989.

Hexavalent Chromium. Hexavalent chromium was detected in wells in the 100-B/C, -D/DR, -H, -F, and -K Areas. The maximum concentration, 692 μg/L, was found in a monitoring well in the 100-D Area. This concentration was lower by a factor of two from 1987. Chromium plumes are centered near the D reactor and south of 116-H-6, the 183-H solar evaporation basins.

Nitrate. Nitrate was measured at concentrations greater than the 45 mg/L MCL in all areas.

Tritium. Tritium concentrations greater than the 20,000 pCi/L MCL were detected in 100-B/C, -D/DR, and -K Areas with the maximum concentration of 882,000 pCi/L found in the 199-K-30 well.

Gross Alpha. The gross alpha MCL of 15 pCi/L was exceeded in the F and H Areas. The wells in the F Area with elevated gross alpha contained uranium at levels which would account for the gross alpha levels detected.

Gross Beta. The 50 pCi/L MCL for gross beta activity was exceeded throughout the Hanford Site. Gross beta levels in the 100 Area can be attributed mainly to a combination of uranium and technetium-99 activity. Strontium-90 also contributes to the gross beta activity in the 100-N Area.

Cobalt-60. Cobalt-60 concentrations were consistently at or below detection limits except in the 100-N Area.

Strontium-90. Strontium-90 concentrations in the 100-B/C, -D/DR, -F, -K, and -N Areas exceeded the MCL of 8 pCi/L. The highest concentration of 23,400 pCi/L was found at 116-N-1, the 1301-N liquid waste disposal facility.

Technetium-99. 100-H Area wells showed technetium-99 concentrations greater than the 900 pCi/L SDWA MCL.

Ruthenium-106. Ruthenium-106 has a short half-life (367 days) and is generally associated with operating reactors. Ruthenium-106 has been detected in the past at the N Area but could not be detected by routine methods in 1989. The SDWA MCL for ruthenium-106 is 200 pCi/L.

Antimony-125. Antimony-125 was measured in the 100-N Area near 116-N-3, the 1325-N liquid waste disposal facility, with a maximum concentration of 93.6 pCi/L. The SDWA MCL for this radionuclide is 300 pCi/L.

Iodine-131. Iodine-131 has a half-life of just over 8 days. This radionuclide has been detected in the 100-N Area during operating periods but was not measured in 1989 due to the cold standby status of the 100-N reactor.

Uranium. Uranium levels in two F Area wells increased sharply in 1987 to a maximum of 414 pCi/L in January 1988. The levels have decreased since that time and a low of 91 pCi/L was measured in October of 1989. A uranium plume exists in the 100-H Area near 116-H-6, the 183-H solar evaporation basins. The maximum concentration measured in 1989 was 89 pCi/L.

Cesium-137, Plutonium. Concentrations for these contaminants were below detection limits in the 100 Area.

1.3.1.7 Surface Water and Sediments. Routine monitoring of the Columbia River water and sediments was initiated during 1945, shortly after the startup of the original plutonium

production reactors, and continues today as part of the Hanford Environmental Monitoring Program (Jacquish and Bryce 1989). Throughout the years, sample locations upstream of the Hanford Site, outside the influence of site operations, and downstream of all site facilities have been maintained to provide information on the background conditions in the Columbia River and to identify influences from Hanford operations. The monitoring programs are not, however, designed to differentiate contributions of contaminants from individual operating facilities or areas.

1.3.1.7.1 Background Surface-Water Quality. Columbia River water samples were collected upstream of Hanford facilities at Priest Rapids Dam and near the Vernita Bridge to provide background data from locations unaffected by site operations (Jacquish and Bryce 1989). Samples collected at Priest Rapids Dam were analyzed for radiological constituents, while nonradiological analyses were performed on those samples collected near the Vernita Bridge as part of the Surface Environmental Monitoring Project. In addition to the Columbia River monitoring performed by Pacific Northwest Laboratories (PNL), the river-water quality is monitored by the U.S. Geological Survey as part of the national Stream Quality Accounting Network (McGavock et al. 1987), which provides primarily hydrologic and nonradiological water-quality data.

Results of the radiological analysis of Columbia River water samples collected at Priest Rapids Dam during 1988 are summarized in Table 1-20. This table shows that radionuclide concentrations in the river water are extremely low; several of the radionuclides identified are undetectable without the use of special sampling techniques and/or analytical procedures. The 1988 average radionuclide concentrations shown in Table 1-20 are more than an order of magnitude lower than the applicable drinking water standards in all cases.

Nonradiological water-quality data for the Columbia River upstream of the Hanford Site are summarized in Table 1-21. Some listed parameters have no regulatory limit but are useful as indicators of water quality. The results, where duplicated, were in general agreement and were comparable to levels observed in recent years. In all cases, applicable standards for Class A designated water were met.

Groundwater seeps are located along the riverbank throughout the 100 Area (McCormack and Carlile 1984). Because these seep areas reflect groundwater discharge to the river, background contaminant concentrations are best defined through the analysis of groundwater samples.

1.3.1.7.2 Surface-Water Contamination. Radiological and nonradiological pollutants are known to enter the Columbia River from the Hanford Site. In addition to direct discharges from Hanford facilities, contaminants in the groundwater from past effluent discharges are known to be transported into the river.

Columbia River water samples were collected at two locations downstream of Hanford, the 300 Area water intake and the Richland Pumphouse, to identify possible influence on contaminant concentrations from Hanford operations (Jacquish and Bryce 1989). Samples collected from the 300 Area water intake were analyzed for radiological constituents, while the Richland Pumphouse samples were analyzed for radiological and

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nonradiological parameters. The U.S. Geological Survey monitors the Columbia River water quality at the Richland Pumphouse and several locations farther downstream of the Hanford Site. Results of the radiological analyses of the Columbia River water samples collected from the Richland Pumphouse during 1988 are summarized in Table 1-22 (Jacquish and Bryce 1989). All radionuclide concentrations observed were well below applicable drinking water standards. Tritium, Strontium-90, and Iodine-129 concentrations were identified as statistically elevated at the Richland Pumphouse relative to Priest Rapids Dam, thus indicating an influence from Hanford operations. Concentrations of other constituents observed at the Richland Pumphouse were similar to those observed at Priest Rapids Dam (Jacquish and Bryce 1989).

Nonradiological river water quality data at the Richland Pumphouse for 1988 are summarized in Table 1-23. In general, concentrations of nonradiological water quality parameters were similar at Priest Rapids Dam and the Richland Pumphouse. No indication of any significant nonradiological deterioration of water quality along the Hanford Reach as a result of Hanford Site operations exists. As was the case at Priest Rapids Dam, applicable standards for Class A waters were met at the Richland Pumphouse.

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1.3.1.7.3 Background Sediment Quality. Sediments in the Hanford Reach are typically sand intermixed with gravel and rock (ERDA 1975). The stream bed in deep channels is generally sand and gravel, while shallow areas have a bed consisting of sand, silt, and some clay. Stream beds in the eddying areas of this fast-water stretch are mostly composed of sand. Slack-water area sediments are made up of sand, silt, and some clay.

Columbia River sediment was sampled routinely from 1945 through 1960 at several locations along the Hanford Reach. Special studies of the river sediments have continued through the years and the State of Oregon and PNL have published reports (Beasley et al. 1981, Sula 1980) about radionuclide concentrations in the Columbia River sediments.

Background sediment samples were collected from behind Priest Rapids Dam in 1976 (Robertson and Fix 1977). Cesium-137 was the most abundant fallout radionuclide detected, with trace amounts of Plutonium-238, Plutonium-239/240, and Americium-241 also present.

Sediment sampling above Priest Rapids and McNary dams was recently reinitiated as part of the Surface Environmental Monitoring Project. Results of analyses of samples collected during 1988 were published in Jacquish and Bryce (1989). Concentrations observed above Priest Rapids Dam provide background information on sediment contamination for the 100 Area. Analyses of the sediment samples included gamma scans, Strontium-90, Uranium-235, Plutonium-238, and Plutonium-239/240. Table 1-24 summarizes radionuclide concentrations detected in sediments collected at Priest Rapids Dam. Background information for chemical constituents in sediment is not available.

1.3.1.7.4 Sediment Contamination. Radionuclides, including neutron activation products, fission products, and trace amounts of transuranics, were discharged into the Columbia River as a result of plutonium production reactor operations in the 100 Area (Robertson and Fix 1977). The radioactive material was dispersed in the river water and sorbed onto detritus and inorganic particles, incorporated into the aquatic biota or, for larger

particles of insoluble material, deposited on the riverbed. Some of this material has been deposited along the shoreline areas above the low river level (riverbank sediments). Radiation surveys of the exposed shorelines from the 100-B/C Area to the confluence of the Snake River during 1978 and 1979 revealed several areas with elevated ($>25\mu R/hr$) exposure rates (Sula 1980). The predominant radionuclides present in the riverbank sediments were Cobalt-60, Cesium-137, and Europium-152 (Sula 1980).

Results from recent sediment-sampling activities at McNary Dam are available for calendar year 1988 (Jacquish and Bryce 1989) and are summarized in Table 1-24. Surface sediments behind McNary Dam are known to contain low levels of Hanford-origin radionuclides (Robertson and Fix 1977, and Beasley et al. 1981) in addition to radionuclides from atmospheric fallout. As expected, concentrations of Cobalt-60, Strontium-90, Cesium-134, Cesium-137, Plutonium-238, and Plutonium-239/240 were higher in sediments from behind McNary Dam than from behind Priest Rapids Dam (Jacquish and Bryce 1989). Data on chemical characterization of sediments are not available.

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1.3.1.8 Air.

1.3.1.8.1 Background Air Quality. Background concentrations of airborne radionuclides have been measured at several distant communities in Eastern Washington at locations shown in Figure 1-6 (Jacquish and Mitchell 1988). The average values for these distant communities for 1987 are shown in Table 1-25.

1.3.1.8.2 Air Contamination. Concentrations of airborne radionuclides have been extensively monitored on the Hanford Site and in nearby offsite communities. Data for the 100 Area are available from four monitoring stations: one each in the 100-K, 100-N, and 100-D Area, and one at the 100 Area fire station. These monitoring locations are shown in Figure 1-6. The 1987 monitoring data for the 100 Area and nearby communities are included in Table 1-25.

1.3.1.9 Biota. Very little site-specific data concerning radiological or chemical contamination of biota in the 100 Area exists. However, the Hanford Environmental Monitoring Program provides data on radionuclide contamination in biota throughout the Hanford Site.

1.3.1.9.1 Terrestrial Biota. Strontium-90 concentrations in deer bones collected on the Hanford Site ranged from 0.7 to 58 pCi/g and were comparable to those concentrations measured in 1985. Cesium-137 concentrations were very low or nondetectable and were in the range attributable to worldwide fallout. Strontium-90 levels in cottontail rabbits collected near the 100-N Area indicated that the animals had at some time consumed food or water contaminated with the radionuclide. Cesium-137 levels in the muscle and Plutonium-239/240 levels in the liver were below detection limits. Mean concentrations of Strontium-90 and Cesium-137 were similar to levels in previous years (Woodruff, et al., 1991).

Tritium was measured in leaf water extracted from six locust trees growing near the 100-K Area. The maximum tritium concentration was 12,000 pCi/L and concentrations

generally exceeded the concentrations from well water samples taken near the trees (Rickard and Price 1989).

Deep-rooted plants in the riparian zone may have some usefulness as biological indicators of radioactive materials in groundwater. These plants have roots deep enough to contact groundwater. However, uptake quantities depend on plant species, age of growth, and other factors.

1.3.1.9.2 Aquatic Biota. An extensive survey of the radionuclide concentrations in aquatic biota at the 100-F Area was done in 1966-1967 (Watson et al. 1970) while the reactors were still operating. The reported concentrations resulted from bioaccumulation of reactor generated radionuclides rather than from atmospheric fallout. These radionuclides would not be expected in samples collected above the Hanford Site.

Whitefish, carp, and bass were collected by Woodruff, et. al., (1991) from locations along the Columbia River. Whitefish were collected near the 100-D and -N Areas; bass were collected from the 100-F Area; and carp were collected near 100-N. Strontium-90 concentrations were detected in all the fish carcasses analyzed during 1990. Levels in whitefish samples collected near the 100-D Area were similar to those collected downstream of the Priest Rapids Dam. Bass and carp collected near the 100-N Area had higher concentrations of Strontium-90 than the whitefish. Cobalt-60, Strontium-90, and Cesium-137 concentrations in the fish muscle samples collected from the 100-F and 100-N Areas were typically below detection limit. Mean combined concentrations of Cobalt-60 and Cesium-137 in the fish muscle samples from the 100-D Area were similar to those collected above the Vernita Bridge (Woodruff, et. al., 1991).

Clams collected near 100-N had Cobalt-60 and Strontium-90 levels close to detection limits; Cesium-137 concentrations were below detection limits (Woodruff, et. al., 1991).

Tables 1-26 and 1-27 present radionuclide concentrations found in fish carcasses collected in 1988 from locations upstream and downstream of the Hanford Site. Table 1-28 presents research conducted on radionuclide contamination of aquatic biota.

1.3.1.9.3 Riparian Biota. The shoreline of the Columbia River adjacent to the 100 Area includes a narrow band of riparian vegetation dominated by reed canary grass and other grasses, sedges, and rushes. Strontium-90 was measured in the leaves and stems of reed canary grass in this zone at locations downstream from the 100-K Area. The highest concentrations were measured in samples collected near the 100-N Area and the lowest in those samples collected near Richland (Rickard and Price 1989).

Strontium-90 was measured in the eggshells of Canada geese nesting on islands, including Plow Island near Ringold, in the Columbia River. These data show that Strontium-90 of Hanford Site origin is available to geese. However, the concentrations are too low to observe health or reproductive defects in wild geese (Rickard and Price 1989).

The great blue herons that nest on the Hanford Site feed mostly on Columbia River fish and can serve as biological indicators of chemical contamination in the riparian

environment (Rickard et al. 1978; Fitzner et al. 1981, 1988; Blus et al. 1985; Riley et al. 1986). Toxic metals, such as lead, cadmium, and mercury, have been measured in the nest debris (feces and food scraps) at one Hanford Site heron rookery. However, the levels of these metals found in herons on the Hanford Site are lower than these reported elsewhere in the Northwest (Fitzner et al. 1982). Heavy metal concentrations have also been examined in eggs and in young herons from Hanford (Blus et al. 1985). Although no elevated levels were detected for lead, copper, zinc, or mercury, these data provide a useful baseline for comparison in future studies.

Birds of prey, particularly owls, have been implicated in the spread of radionuclides near the 100-D, 100-F, and 100-H reactors (Caldwell and Fitzner 1984). Pellets and regurgitated undigestible prey remains were found that contained Manganese-54, Cobalt-60, Cesium-137, Europium-152,-154,-155, and two natural occurring radionuclides, Potassium-40 and Radium-226. The mean Cesium-137 concentration for barn owl pellets collected near the 100-D, 100-F and 100-H Areas was 3.1 ($\pm$1.1) pCi/g dry weight. Pellet analysis show these owls were feeding mostly on small mammals.

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1.3.2 Physical Setting

1.3.2.1 Topography. The 100 Areas lie on a relatively flat bench between the Columbia River and Gable Mountain and Gable Butte. Gable Mountain and Gable Butte separate the 100 Area from the rest of the Hanford Site. Gable Mountain in an elongated anticline rising 1086 ft above mean sea level. The average elevation of the 100 Area is approximately 400 feet. The land surface slopes gently to the north from the bases of Gable Mountain and Gable Butte toward the Columbia River.

The Columbia River defines the northern boundary of past activities at the Hanford Site. However, contamination may extend beyond the riverbank to include sediments and surface water affected by releases from Hanford operations.

1.3.2.2 Geology of the Hanford Site. Hanford Site geology has been studied extensively as part of site characterization activities for the Basalt Waste Isolation Project. Other geologic studies have been completed to support facility siting and groundwater studies. The following provides a summary of previous geologic studies compiled in Liikala et al. 1988.

The Hanford Site lies within the Columbia Plateau physiographic province. The province is underlain by the Miocene age Columbia River Basalt Group (CRBG). The geologic units beneath the Hanford Site are, in ascending order: the CRBG, the Ringold Formation, a Plio-Pleistocene unit, and the Hanford Formation. Locally, Pleistocene and Holocene alluvium, colluvium, and eolian deposits veneer the surface. The stratigraphy is shown in Figure 1-7.

1.3.2.2.1 Columbia River Basalt Group. The CRBG forms the bedrock of the Pasco Basin. The CRBG was emplaced between 6 and 17 million years before present (Ma) from fissures in southeastern Washington and adjacent parts of Idaho and Oregon. Five formations make up the Columbia River Basalt Group (Ledgerwood et al. 1978; Swanson et

al. 1979). Beneath the Pasco Basin, the CRBG may be as thick as 14,000 ft (4,267 m). The upper flows of the CRBG may be interbedded with Miocene sediments of the Ellensburg Formation (Swanson et al. 1979).

1.3.2.2.2 Ringold Formation. The Ringold Formation was deposited over the CRBG between 8.5 and 3.7 Ma in a fluvial/flood plain environment (Myers et al. 1979). The maximum thickness is estimated at more that 1,200 ft (366 m).

Within the Pasco Basin, the Ringold Formation is divided into three stratigraphic section types as shown in Figure 1-8 (Tallman et al. 1981).

Section Type I, located throughout the central Pasco Basin, is subdivided into four textural units (Tallman et al. 1981):

- Basal Ringold unit, sand and gravel
- Lower Ringold unit, clay silt, and fine sand with minor gravel lenses
- Middle Ringold unit, occasionally cemented sand and gravel
- Upper Ringold unit, fine sand and silt.

Section Type II consists of predominantly silt, sand, and clay with minor gravel lenses, and is found north and east of Gable Mountain. Section Type III is composed of talus, slope wash, and side-stream deposits that occur along the flanks of anticlinal ridges and interfinger with the central basin deposits.

1.3.2.2.3 Plio-Pleistocene Unit. The Plio-Pleistocene unit overlies the Ringold Formation in the western part of the Hanford Site near the 200 West Area. This eolian silt and fine sand unit was deposited as reworked Ringold sediments. Relatively high caliche contents are found in much of this unit. This unit does not occur within the 100 Area.

1.3.2.2.4 Hanford Formation. The Hanford Formation lies unconformably on the eroded surface of the Ringold Formation, the Plio-Pleistocene unit, and locally, the basalt bedrock. The Hanford Formation consists of cataclysmic flood sediments. These sediments originated when ice dams in western Montana and northern Idaho broke resulting in massive volumes of water flooding across eastern and central Washington. The floods scoured the land surface, locally eroding the Ringold Formation, upper basalt flows, and interbeds.

Cataclysmic flood deposits are locally divided into two main facies, the Pasco Gravels and the Touchet Beds. The Pasco Gravels are composed of poorly sorted gravels and coarse sands. The Touchet Beds consist of rhythmically bedded sequences of graded silt, sand, and minor gravel units (Myers et al. 1979).

1.3.2.2.5 Surficial Deposits. Eolian sediments, consisting of loess, active and inactive sand dunes, alluvium, and colluvium, locally veneer the surface of the Hanford Site.

1.3.2.2.6 Geologic Structure. The major structural feature of the region is a series of sub-parallel, west-to-northwest-tending folds known as the Yakima Fold Belt. Umtanum

Ridge and Cold Creek Valley, west of the 100 Area, are examples of structurally controlled anticlinal ridges and synclinal valleys. Gable Butte and Gable Mountain on the Hanford Site represent an eastward extension of the Umtanum Ridge structure (Fecht 1978). The 100 Areas lie in the Wahluke syncline of the Yakima Fold Belt. This syncline is a down-warped valley between the Gable Mountain and the Saddle Mountain anticlines.

1.3.2.3 Hydrogeology of Hanford Site. The Hanford Site lies near the center of the Pasco Basin. Groundwater at the Site occurs under both unconfined and confined conditions. The unconfined aquifer is within sedimentary deposits of the Ringold and Hanford Formations.

The depth to groundwater beneath the 200 Area plateau of the Hanford Site is generally 200 to 300 ft (61 to 91 m) below land surface. However, north and east of Gable Butte in the 100 Area, the water table is shallower and lies within the Hanford Formation at depths of less than 200 ft (30 m) (Liikala et al. 1988).

The confined aquifers of the regional groundwater flow system are mostly contained in the rubbley interflow zones and in sedimentary interbeds of the CRBG. Intermediate or local confined systems also may occur in the Ringold Formation, where clay units act as aquitards.

A regional water table contour map is presented in Figure 1-9. Groundwater moves eastward across the Site and north to northeast beneath the 100 Area toward the Columbia River. The river serves as the regional discharge for both the unconfined and confined aquifers. The general eastward groundwater flow is interrupted by artificial recharge mounds near the 200 Areas. Precipitation and runoff provide natural recharge to the unconfined aquifer.

1.3.2.3.1 Hydrogeology of the 100 Area. Hydrostratigraphy. Six hydrostratigraphic units are identified beneath the 100 Area. They are: lower confined aquifer system, lower aquitard, upper confined aquifer system, upper aquitard, unconfined aquifer, and the vadose zone. Figure 1-7 shows the hydrostratigraphy for the 100 Area. The four upper hydrostratigraphic units are of importance to the 100 Area.

- Upper Confined Aquifer

  The upper confined aquifer is contained in the basal Ringold Formation and consists primarily of clays, sand, and gravel. The hydraulic conductivity of the basal Ringold Formation has not been measured in the 100 Area; however, since it contains significant quantities of clay and silts, conductivity is expected to be low.

- Upper Aquitard

  The upper aquitard is comprised of the clays, silts, and fine sands of the lower Ringold unit. The estimated vertical hydraulic conductivity of this zone from test results at 100-H Area is 10^{-4} ft/day (Liikala et al. 1988).

- Unconfined Aquifer

  The unconfined aquifer is primarily found within the Ringold Formation above the lower Ringold unit. Portions of the Hanford formation may be locally included. An important hydrostratigraphic zone in the unconfined aquifer is a silty sand zone that separates the relatively coarse upper and lower sand and gravel zones. This zone may act as an aquitard and restrict groundwater flow between the upper and lower portions of the unconfined aquifer. 100-H Area aquifer tests results provide a hydraulic conductivity range of 10 to 100 ft/day for the silty sand and gravelly silt sand units of the Ringold Formation (Liikala et al. 1988).

- Vadose Zone

  Vadose zone sediments range in particle size from boulders to silt. Field water contents of these sediments range up to 11 percent at the 100-H Area (Liikala et al. 1988).

Groundwater Flow. In general, groundwater flows toward the river. Studies at some 100 Area facilities show that gradient reversals occur near the river due to fluctuations in river stage. Depth to groundwater in the 100 Area ranges from about 40 ft (12 m) near the river to 200 ft (61 m) at the southern margin. The hydraulic gradient ranges from 0.001 to 0.0001 ft/ft (m/m).

1.3.2.4 Surface Water Hydrology.

1.3.2.4.1 Drainage Patterns and Surface Run-off. No well-defined drainage channels exist within the 100 Area. The surficial deposits of the area are highly permeable and consist primarily of coarse sands, pebbles, cobbles, and boulders. Direct precipitation over the unit is mostly lost through evaporation, transpiration, and infiltration (ERDA 1975). Normal precipitation, 6.25 in. (15.9 cm) per year (Stone et al. 1983), and extreme precipitation events in combination with high evaporation and soil infiltration capacities, does not generate significant surface runoff. Any surface runoff, however, would flow toward the Columbia River.

1.3.2.4.2 Seeps and Springs. Small groundwater seeps have been seen during low river stage near many of the reactor areas (McCormack and Carlile 1984). Seepage is partly from bank storage and is affected by changes in river stage. During periods of high river stage, the flow of groundwater may be temporarily reversed. The volume of the seep discharges has not been quantified. No other naturally occurring surface water exists in the 100 Area.

1.3.2.4.3 Streamflow Characteristics. The Columbia River is the largest river in the Pacific Northwest and the fifth largest river (by volume) in North America. Eleven dams regulate its flow within the United States: seven upstream and four downstream of the Hanford Site. Priest Rapids Dam, located at approximate river mile 397, is the nearest

impoundment upstream of the Hanford Site. McNary Dam in the nearest dam downstream, at river mile 292.

The Hanford Reach extends from Priest Rapids Dam to the head of Lake Wallula, the impoundment behind McNary Dam, at approximate river mile 351. The Hanford Reach is not impounded; however, it is regulated by Priest Rapids Dam. River discharge peaks in June and is lowest in September and October. Table 1-29 describes the major characteristics of the Columbia River.

1.3.2.4.4 Flooding Potential. Maximum Columbia River floods of historical record occurred in June 1894 and June 1948. Maximum flows during these floods were about 740,000 and 690,000 ft^3/s (20,900 to 19,500 m^3/s), respectively (McGavock et al. 1987). Construction of several dams upstream of the Hanford Site since 1948 has significantly reduced the likelihood of recurring floods of this magnitude (DOE 1987). The probable maximum flood has been calculated to be about 1.4 million ft^3/s (39,600 m^3/s) and would be expected to inundate the northern and eastern portions of the 100 Area (DOE-RL 1982, DOE 1987, Cushing 1988). The flooded area for a flood of this magnitude is shown in Figure 1-10. The 100-year and 500-year floods, which would be of lower flow volume than the probable maximum flow, are not expected to significantly affect the area.

1.3.2.5 Meteorology. Climatological data are available from the Hanford Meteorological Station (HMS), located between the 200 East and 200 West Areas in the central portion of the Hanford Site. Data have been collected at the HMS since 1945, and precipitation and temperature data from nearby locations are also available for the time period 1912 through 1943. Data from the HMS are assumed to represent the general climatic conditions for the entire site. The summaries presented in the following sections were extracted from DOE 1987. Data from the Vernita Bridge climatological station were not included.

1.3.2.5.1 Precipitation. The Hanford Site is located within a rain shadow formed by the Cascade Mountains to the west. The average annual precipitation at the site is 6.3 in. (16 cm). Most of the precipitation takes place during the winter, with nearly half of the annual amount occurring from November through February. Average winter monthly snowfall ranges from 0.3 in. (0.8 cm) in March to 5.3 in. (13.5 cm) in January.

Days with precipitation greater than 0.5 in. (1.3 cm) occur with a frequency of less than 1 percent during the year. The average annual relative humidity is 54 percent. Humidity is higher in winter than in summer, averaging about 75 and 35 percent, respectively.

1.3.2.5.2 Temperature. Average monthly temperatures at the Hanford Site range from 29°F (-1.5°C) in January to 76°F (24.7°C) in July.

1.3.2.5.3 Wind. In general, prevailing wind directions are from the northwest throughout the year. Monthly average wind speeds are lowest during the winter, averaging 6.2 to 6.8 mi/h (10 to 11 km/h). Monthly average wind speeds peak in the summer, averaging 8.7 to 9.9 mi/h (14 to 16 km/h). Wind speeds well above average are usually associated with southwesterly winds. In the summer, high-speed winds from the southwest

are responsible for most of the dust storms in the region. High-speed winds are also associated with afternoon winds and thunderstorms. The summertime drainage winds are usually northwesterly and frequently reach 31 mi/h (50 km/h). An average of 10 thunderstorms occur each year, usually during the summer.

1.3.2.5.4 Evapotranspiration. Mean annual evapotranspiration for the Hanford area is about 60 in. (74 cm). The actual annual evapotranspiration rate under normal conditions for a 6-in. (15-cm) assumed available water capacity is estimated to be about 7 in. (18 cm) (USWB/USDOA 1962).

1.3.2.6 Environmental Resources.

1.3.2.6.1 Flora. The natural vegetation consists mostly of a sparse covering of desert shrubs and drought-resistant grasses, predominantly from the sagebrush/cheatgrass/ bluegrass community. Bitterbrush and rabbitbrush are also common shrubs (DOE 1987; PNL 1988). A narrow riparian zone, consisting of grasses and herbs interspersed with a few deciduous shrubs and trees, exists along the banks of the Columbia River.

Endangered and threatened flora that could exist at the Hanford Site are listed in Table 1-30. Persistentsepal yellowcress is found along the Hanford Reach and has recently been located in the 100-B and -D Areas (Sackschewsky 1992).

1.3.2.6.2 Fauna. Predominant fauna of the sagebrush/grass community that may reside in or near the 100 Area are the cottontail rabbit, jackrabbit, Great Basin pocket mouse, horned lark, and western meadowlark. Mule deer, coyotes, and assorted species of raptors forage in this habitat type, and grasshoppers are the most conspicuous insects in the community (DOE 1987). Shade trees provide nesting sites for hawks, owls, and great blue herons as well as perches for wintering bald eagles (Rickard et al. 1980, Rickard and Watson 1985).

Dominant riparian fauna along the Columbia River include swallows, gulls, and waterfowl (ducks and geese). The long-billed curlew is also known to nest within the cheatgrass habitat in the 100 Area (Allen 1980).

The Columbia River is the dominant aquatic ecosystem on the Hanford Site and supports a large and diverse community of plankton, benthic invertebrates, fish, and other communities. Phytoplankton (free-floating algae) and periphyton (sessile algae) are abundant in the Columbia River and provide food for herbivores such as immature insects, that are consumed by carnivorous species. Game species in the Columbia River include salmon, bass, sturgeon, steelhead, and whitefish.

Table 1-30 lists endangered and threatened fauna that potentially occur at the Hanford Site. Of the threatened species that could be found at the Hanford Site, only the bald eagle is known to frequent the 100 Area. Endangered animal species likely to occur on and along the Columbia River in or near the 100 Areas are the American white pelican, the peregrine falcon, and the sandhill crane.

1.3.2.6.3 Critical Habitats. Bald eagle roost trees, and nesting and foraging areas are regarded as critical habitats for this species (Washington State Department of Wildlife 1987). No other critical animal habitats exist in the 100 Area due to the transient use of the 100 Area by other endangered and threatened animal species.

1.3.2.6.4 Land Use. Access to the entire Hanford Site is administratively controlled by the DOE (DOE 1987). The site is zoned as an unclassified use district by Benton County and, under the county's comprehensive land-use plan, the Hanford Site may be used for nuclear-related activities. Nuclear and non-nuclear activities are authorized only on approval from DOE.

Land use in the area surrounding the Hanford Site consists primarily of irrigated and dry-land farming, livestock grazing, and urban and industrial development. (DOE 1987) Immediately north and across the river from the 100 Area are the 32,100-acre Saddle Mountain National Wildlife Refuge and the 55,600-acre State of Washington Department of Wildlife Reserve (Figure 1-1). These lands provide a buffer zone around the reactor complexes (DOE 1987).

1.3.2.6.5 Surface Water. The Hanford Reach of the Columbia River, near the 100 Area, is used for boating, fishing, hunting, and swimming (EPA 1988b). The 181-B pumphouse supplies portable and process water to the 100-B/C, 100-D, 100-N, 100-K, and 200 Areas. The nearest downstream water intake is the 181-D pumphouse; the next downstream water intake is the Ringold Fish Hatchery. The Richland pumphouse, the first point of withdrawal for public use, is located 12.5 miles downstream of the 100-F Area.

1.3.2.6.6 Groundwater. The nearest known non-Hanford groundwater well is located about 4 mi (6 km) upstream at the Vernita Bridge rest area. Because of the buffer zone and the surrounding land use, private wells would be located at a minimum of 5 mi (8 km) from the 100 Area to the northwest.

1.3.2.6.7 Sensitive Environments. The Hanford Reach is the only significant stretch of the Columbia River within the United States above Bonneville Dam that is not impounded by a dam (PNL 1988). The reach has also been designated as a Class A (excellent) surface water by the State of Washington (WAC 173-201). This designation requires that water quality be maintained for the following uses:

- Domestic, industrial, and agricultural water supply
- Stock watering
- Fish and shellfish migration, rearing, spawning, and harvesting
- Wildlife habitat
- Recreation (including primary contact recreation)
- Commerce and navigation.

1.3.2.7 Human Resources. The Hanford Reach is under consideration for designation as a Wild and Scenic River. This designation could have impacts on removal actions at Hanford.

1.3.2.7.1 Demography. No one resides on the Hanford Site. The working population for the entire 100 Area is about 760 persons (EPA 1988b).

1.3.2.7.2 Archaeological Resources. Archaeological sites are found in several locations on the Hanford Site including locations along the Hanford Reach. Both the Ryegrass and the proposed Coyote Rapids Archaeological Districts are located on or near the 100 Area. Site 45BN153, lying partially within the 100-B/C Area, consists of house pits and an open campsite but is not considered eligible for the National Register of Historic Places. The other two sites lie on the opposite bank of the Columbia River across from the 100-B/C Area. The K Area includes two campsites and one cemetery, all three contained in the Ryegrass Archaeological District. The N Area has 8 sites, three of which are located north of the river. No information is available for sites in the D Area, but several sites are located in the vicinity of the 100-H Area. Archaeological sites at the Hanford and White Bluffs townsites, as well as old ferry crossings, are the only sites associated with the F Area.

1.3.2.7.3 Historical Resources. The 100-B reactor is listed on the Historic American Engineering Record and may be nominated to the National Register of Historic Places by DOE. Gable Butte is a part of the Gable Mountain/Gable Butte Cultural District. The district is being nominated to the National Register of Historic Places on the basis of its archaeological and Native American cultural/religious significance. (Chatters 1989).

1.3.2.7.4 Community Involvement. The involvement of the potentially affected community with respect to the RI/FS for the 100 Area is described in the Community Relations Plan (CRP) that has been developed for the Hanford Site Environmental Restoration Program. The CRP includes a discussion and analysis of key community concerns and perceptions about the project, with a list of all interested parties.

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APPENDIX F
DESCRIPTIONS OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS FOR RIVER PIPELINES AND SEDIMENTS

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1.0 INTRODUCTION

The purpose of the 100 Area Feasibility Study Phases 1 and 2 is to develop a baseline of remedial alternatives which can be used in focused feasibility studies for individual sites or OUs. The purpose of this appendix is to identify technologies which potentially apply to remediation of river sediments and outfall pipelines for use in future feasibility studies. A joint assessment of the Columbia River involving DOE-RL, EPA, and Ecology was initiated in FY93. This comprehensive assessment will evaluate human health and environmental risks from the cumulative impacts of Hanford-derived contaminants. The resulting information will be used to determine the need for any appropriate remedial actions.

2.0 SUMMARY OF DISCHARGES TO THE RIVER

At each of the reactor areas, except 100 N Area, pipelines were used to carry cooling water from the Columbia River to the reactor and ultimately back to the river. The cooling water, contaminated with fission products and additives, was released from the reactor and discharged to the retention basins. After a brief hold-time in the basins, the water was diverted to the outfall structure, through the river pipelines, then discharged to the river in an area of high flow. Overflow from the basins was diverted through concrete overflow spillway(s) (DOE 1991a).[1] These practices may have impacted sediments in the river. In addition, cooling water contaminated as the result of a fuel cladding failure was discharged directly to the ground in the 100 Area through liquid waste disposal facilities such as cribs. Some of these contaminants have migrated to groundwater. Flow of this contaminated groundwater to the river may be affecting sediments along the shoreline. Contaminants in cooling water have been sorbed onto the interior of the river discharge pipelines. In addition, the river pipelines may present physical hazards in the river should the pipelines become dislodged.

3.0 TECHNOLOGY AND PROCESS OPTION DESCRIPTIONS

The following technologies and process options may apply to remediation of river sediments. Only those options specific to the river media have been identified. Once the sediments or pipelines are removed, they would be treated the same as riverbank sediments and pipelines identified in the main body of the FS and in Appendix C. For instance, the solidification/stabilization options identified for soils and riverbank sediments in Appendix C, Section 3.15 would also apply to river sediments. Likewise, treatment technologies for outfall pipelines would be the same as those identified for the land-based pipelines in Section 1.0 of Appendix C. Water removed by dewatering processes would be treated by technologies identified in Section 2.0 of Appendix C.

[1]The cooling water system is explained more fully in Section 1.0 of the main body of this FS.

3.1 ACCESS RESTRICTIONS

3.1.1 Use Restrictions

Because the Columbia river is a public resource, deed restrictions cannot be applied; however, use restrictions may be applied to control commercial and recreational use of the river. Use restrictions prevent entry to areas where exposure to contamination could result and prevent activities that could mobilize contaminants.

Use restrictions require only administrative resources and visual monitoring to ensure they are obeyed. Use restrictions may be effective in preventing short-term human contact with contaminated areas; however, the long-term effectiveness of use restrictions is uncertain.

3.2 MONITORING

Monitoring is performed by continuously or periodically sampling environmental media and analyzing for contaminants of interest. Surface water can be monitored by continuous reading and recording probes or meters installed in the river flow path; sediment and ecologic samples can be periodically collected. Sampling can be performed easily with little preparation and minimal specialized equipment.

Environmental monitoring along the river, including background monitoring, is routinely performed at the Hanford Site. Monitoring programs aid in assessing the existence of contamination in the river environment and can be used to gauge the success of remedial activities. Monitoring alone is not effective in protecting human health and environment; however, monitoring can be an effective tool to evaluate the natural attenuation of contaminants. Any remedial actions taken on the river will likely include a monitoring program, such as the environmental monitoring programs currently in place.

3.3 COVERS/REVETMENTS

The following covers/revetments for contaminated river sediments and outfall pipelines are discussed below:

- silt/clay/sand
- grout
- riprap
- mattresses.

3.3.1 Silt/Clay/Sand Covers

Silt/clay/sand covers are constructed by spreading clean sand, clay, silt, or uncontaminated, dredged river bottom sediments over an area of contamination. The cover helps minimize the leaching of contaminants and erosive transport of the contaminated sediments. Cover materials have application for temporary or permanent containment of hazardous waste constituents. Their use is generally limited to protected open waters where bottom currents and flow velocity are not sufficient to erode the cover (EPA 1985). Silt/clay/sand covers may be used as interim measures for short-term control of contaminant mobility due to erosion.

The materials necessary to construct the cover can be obtained by dredging other areas of the river or by excavating uncontaminated surface soils from the Hanford Site. General construction equipment can be used to excavate surface soils; dredges can be used to remove the sediments and to place the cover material. Placement methods include point dumping, pumpdown, or submerged diffuser systems (EPA 1985).

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In the point dumping method, the cover material is dumped from barges, scows, or hopper dredges. This method results in a high degree of turbidity and dispersion of both the cover material and the contaminated sediments. The barges or hopper dredges require deep drafts; application of cover materials may be very difficult in shallow waters (EPA 1985).

The pumpdown method uses a pumpdown barge to pump the cover material from a scow, barge, or land-based storage area down a discharge pipe whose termination point is set close to the bottom of the river. This method is limited to relatively calm waters and is not feasible in shallow waters due to the deep draft required by the barges. This method is much slower than the point dump method (EPA 1985).

The submerged diffuser system is similar to the pumpdown method in that the cover material is pumped through a pipe from a barge, scow, hydraulic dredge, or land-based storage area to the river bottom where it is spread over the contaminated area by a submerged sediment diffuser. Like the pumpdown method, this method is not feasible in shallow water and is much slower than the point dump method. The diffuser system provides the most controlled placement of cover material and results in the least amount of turbidity and resuspension of contaminated sediments (EPA 1985).

Silt/clay/sand covers may be used as interim measures for short-term control of contaminant mobility due to erosion. The high flow velocities of the Columbia River, especially during peak runoffs (DOE 1991c), could lead to rapid erosion and ineffectiveness of the cover. The effectiveness and durability of the silt/clay/sand covers can be increased if used in conjunction with isolation process options such as dikes or berms so that the river flow velocity is reduced in the area of the cover. While cover materials are readily available and inexpensive, continual maintenance of the cover would likely be necessary. Placement of the covers may result in remobilization of contaminants resulting in further contaminant spread and potentially impacting salmon spawning grounds.

3.3.2 Grout

Cement or other grouting materials are applied to the surface of or mixed with bottom sediments to create a cover or seal which minimizes erosive transport of contaminated sediments. A grout cover may be emplaced with or without river diversion away from the area (i.e., using cofferdams or diversion channels).

Two emplacement methods are available for use with river diversion techniques (EPA 1985). The first is pneumatic application of a layer of concrete (shotcrete) or grout to form a surface seal. The second is in situ mixing of concrete, quicklime, or a grout material with the top layer of the contaminated sediments (similar to shallow soil mixing; see Section 3.10.3 of Appendix C). These two methods for placing grout covers are largely dependent on the implementability and effectiveness of the river diversion techniques (see Sections 3.4.1 and 3.4.3). Grout materials and the equipment necessary for placement of the grout or shotcrete are readily available. Soil mixing of the top layer of the contaminated sediments has been performed in very soft sediments using a soft ground crawler vehicle called the Soil Limer (Yamanouchi et al. 1978; Nissan Hodo, Co. Ltd. undated).

If the river is not diverted, grout can be applied underwater with concrete pumps or aggregates can be grouted in place. Mobile concrete pumps, which may be barge-mounted or used on shore, are widely used for placing concrete underwater (EPA 1985). Grouting of preplaced aggregate is a method that has been used in flowing streams and rivers. A course aggregate or combination of several types of aggregate are preplaced in forms. Grout made of cement, sand, and water can then be forced through pipes to fill the voids in the aggregate (Portland Cement Association 1979). Following the emplacement of the grout cover/seal, the sediment bottom can be restored to an acceptable grade and composition with clean sediment to reestablish the river bottom habitat (EPA 1985).

Grout covers may be used as interim measures for short-term control of contaminant mobility due to erosion. Grout covers are not as susceptible to erosion as silt/clay/sand covers but may require periodic maintenance. The effectiveness and durability of the grout covers can be increased if used in conjunction with isolation process options, such as dikes or berms, so that the river flow velocity is reduced in the area of the cover. High velocity flow over grout covers can create a lifting effect which may result in cracks and undermining of the cover. Grout covers, like silt/clay/sand covers may resuspend contaminants during implementation and have a similar potential to affect spawning grounds.

3.3.3 Riprap

Riprap is a protective stone cover placed on river sediments to prevent erosion. Riprap generally consists of quarry stones that are well graded from large to small. The small size stones are required to ensure that large voids do not exist in the cover after placement. The angularity of quarry stones result in a well-packed, stable cover (Petersen 1986). The largest stone size required is generally a function of the river velocity, i.e., the

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stone size should be selected so the cover remains stable against river flow velocities. Less expensive cobbles can be used in place of expensive quarry stones in situations where the grade of the river bank is relatively flat (Petersen 1986).

Riprap as a cover for erosion control in rivers is a well developed technology. Riprap blankets are currently in use for erosion control in the Arkansas and Red Rivers. Riprap covers can be mass produced; construction is fast and economical (Petersen 1986). However, placement of the riprap cover will likely cause resuspension of some contaminated sediments (EPA 1985) and may impact fish spawning beds.

3.3.4 Mattresses

Mattresses are protective covers placed on river sediments to prevent erosion. These mattresses are generally placed on underwater banks extending from the water's edge at low water out onto the river bed (Petersen 1986). Mattresses can be constructed of lumber, reinforced asphalt, or articulated concrete (Petersen 1986). Large sections of mattresses are generally constructed directly above the area of the river sediments to be covered then sunk into place.

The use of mattresses for erosion prevention on riverbanks is a well developed technology. Articulated concrete mattresses are currently in use along the Mississippi River (Petersen 1986). Mattresses help prevent resuspension and/or erosion of contaminated sediments. However, the longevity of such mattresses is unknown; mattresses would likely require periodic maintenance and replacement. Resuspension of contaminants and potential impacts to spawning grounds may result from mattress placement.

3.4 ISOLATION

The following methods of isolating contaminated river sediments and outfall pipelines are discussed below:

- cofferdams
- silt curtains
- diversion
- dikes/berms.

3.4.1 Cofferdams

A cofferdam is used to isolate a contaminated area in a waterbody from the stream flow. The water held within the confines of the cofferdam is removed to allow access to the river bottom. Cofferdams are comprised of a physical obstruction that diverts the flow of water and may be constructed of such materials as soil, sheet piling, earth-filled sheet pile cells, and sand bags (EPA 1985).

Cofferdams are most effectively constructed in shallow ports, streams, rivers, or waters with low flow velocities. Construction of a pile driven cofferdam is difficult when flow velocities exceed 2 ft/s, when water depths exceed 10 ft (EPA 1985), or when driving sheet piles in areas where cobbles are typically present in the river bottom sediments. Surface water velocities in the Hanford Reach sometimes exceed 11 ft/s (DOE 1991c) and may make installation of cofferdams very difficult. The high permeability of the underlying river sediments may allow high water flow rates under the cofferdams. Cofferdams constructed by the Corps of Engineers along the Snake River in similar river sediments were found to be ineffective in preventing the inflow of water into the isolated area (Willard 1993).

3.4.2 Silt Curtains

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Silt curtains are low permeability floating barriers that extend vertically from the surface of the water to a specified depth. Silt curtains are used to control the surface turbidity in the vicinity of a small dredging or capping operation (EPA 1985). Silt curtains are generally constructed of a flexible skirt material, such as polyester or nylon reinforced PVC. The skirt is anchored at the base with a ballast chain and at the top with a tension line. The skirt is held in the desired configuration by anchored lines (EPA 1985).

Silt curtains are most easily deployed in calm waters with low flow velocities (i.e., less than 2 ft/s) and minimal wave influences (EPA 1985). In higher flow velocity waters, silt curtains are difficult to deploy and maintain.

3.4.3 Diversion

Diversion requires a complete rechanneling of a river reach to isolate the contaminated area from flow, greatly reducing the mobility of the contamination. Diversion would also facilitate access by land-based excavation equipment or in situ remedial or containment options. The diversion may be instituted by a combination of cofferdams, pipes, and channels (EPA 1985). The contaminated sediment area is isolated by rechanneling the course of the river from an upstream point through a secondary channel or conduit and reuniting the secondary channel with the primary channel at a downstream location. However, it should be noted that changing the course of the river would have a major effect on the groundwater movement in the area. Any changes to groundwater movement would likely affect groundwater remedial alternatives that are planned or being implemented.

The flow volume in the Hanford Reach ranges from 36,000 to 450,000 ft^3/s (DOE 1991c) and makes diversion difficult. An alternate channel for the river's flow could possibly cross the Hanford Site, potentially affecting waste sites. The alternate channel would require extremely large scale excavation.

3.4.4 Dikes/Berms

Retaining dikes and berms are physical barriers placed downstream of a remedial action to minimize the transport distance of resuspended contaminated sediments. These include earthen embankments, earth-filled sheet pile walls, water inflated dams, or other materials designed to minimize sediment transport (EPA 1985).

Earthen dikes can be constructed quickly and easily using earth moving equipment (i.e., bulldozers or mechanical dredging equipment) (EPA 1985). Alternatives using sheet piling or securely-anchored, water-inflated dams are extremely difficult to install due to high flow velocities. A large number of dikes or berms would be required to control the flow velocity in the area of contamination. Construction of such a large number of dikes would probably adversely affect the salmon spawning grounds and could result in resuspension of contaminated sediments. Dikes/berms may also cover part of the contaminated media, complicating removal options.

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3.5 IN SITU STABILIZATION/SOLIDIFICATION

The following in situ stabilization/solidification techniques are discussed below:

- pipeline anchoring
- soil mixing
- grout injection
- ground freezing.

3.5.1 Pipeline Anchoring

Several measures may be taken to anchor outfall pipelines into the substrate to preclude inadvertent transport. The outfall pipelines could be grouted in place by filling them with cement or other grouting material. This would increase the bulk density of the pipe, reducing the tendency for suspended transport. Other methods may include driving large U-shaped brackets over the pipe and into the substrate or securing the outfall pipelines with cable. The brackets would secure the pipe in place, even if the pipe were to be breached. The cable could be placed through the length of the pipe and secured at either end. If any section of the pipe were to become dislodged, it would still be secured by the cable.

The grouting method would require that some type of material be pumped into the pipe under pressure. Care must be taken to minimize differential filling as a result of blockages or existing breaches in the outfall pipeline. The U-shaped brackets would require a means to drive them into the substrate, such as pile driving equipment. Installing a cable through the existing outfall pipelines would require a means to breach the pipe for entry and exit as well as the need to effectively string the cable through the pipe. Any of the methods would be relatively easy to perform. Anchoring of underwater pipelines and telecommunication cables is an established technology.

Cables or anchors may degrade over time making the long-term reliability of these methods uncertain. Pipeline anchoring by cable or U-shaped anchors does not stabilize the contaminated scale inside the outfall pipelines. Filling the pipeline with grout does reduce the mobility of the scale contaminants in the short term but rusting of the pipe from the outer surface could expose the scale to the water in the long term.

In situ remedial actions performed on the outfall pipeline may affect any future removal actions of the pipelines, should this become necessary. The grout-filled pipe sections may result in prohibitively heavy sections which would be difficult to cut into manageable sections. The U-shaped brackets and cable would be easier to remove.

3.5.2 Soil Mixing

Refer to discussion on "Shallow Soil Mixing," Appendix C, Section 3.10.3, under "In Situ Stabilization/Solidification" technologies in the "Soils and Riverbank Sediments Technology Descriptions."

3.5.3 Grout Injection

Refer to discussion on "Grout Injection," Appendix C, Section 1.10.1, under "In Situ Stabilization/Solidification" technologies in the "Solid Waste Technology Descriptions."

3.5.4 Ground Freezing

Refer to discussion on "Ground Freezing," Appendix C, Section 3.10.6, under "In Situ Stabilization/ Solidification" technologies in the "Soils and Riverbank Sediments Technology Descriptions."

Ground freezing of the river sediments is not practical because of the infinite heat sink provided by the flowing Columbia river.

3.6 IN SITU CHEMICAL TREATMENT

The following methods of in situ chemical treatment of contaminated river sediments are discussed below:

- detoxification
- immobilization.

3.6.1 Detoxification

In situ detoxification destroys, degrades, or otherwise reduces the toxicity of contaminants through neutralization and oxidation/reduction (EPA 1985).

Neutralization involves injecting dilute acids or bases into the contaminated sediments to adjust the pH. This pH adjustment can serve as pretreatment prior to in situ oxidation or reduction to optimize the pH range (EPA 1985).

Oxidation and reduction reactions serve to alter the oxidation state of a compound. Such reactions can detoxify, precipitate, or solubilize metals. Oxidation/reduction techniques are standard wastewater treatment approaches, but their application as in situ treatment technologies is largely conceptual. Oxidation of inorganics in soils, is for all practical purposes, limited to oxidation of arsenic and possibly some lead compounds (EPA 1985).

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3.6.2 Immobilization

Immobilization methods are designed to render contaminants insoluble and prevent leaching of the contaminants from the soil matrix and their movement from the area of contamination. Little is currently known about the effectiveness and reliability of immobilization techniques (EPA 1985). An immobilization method which may be potentially applicable to the river sediments is chelation.

The use of chelating agents may be very effective in immobilizing metals although additional research is needed. Depending on the chelating agent, some stable metal chelates may become highly mobile while others may become strongly sorbed to the soil or sediments (EPA 1985). This method may not apply to radionuclides.

3.7 RIVER-BASED REMOVAL

The following methods of river-based removal of contaminated river sediments and outfall pipelines are discussed below:

- mechanical dredging
- hydraulic dredging
- demolition.

3.7.1 Mechanical Dredging

Mechanical dredging involves the use of vessel-mounted draglines, clamshells, or bucket ladders. These are standard excavation equipment that have been barge-mounted for the purpose of underwater sediment removal. Mechanical dredging techniques remove sediments at nearly in situ densities and thereby maximize solids content (EPA 1985). However, these techniques typically operate at low process rates and tend to resuspend

sediments. Mechanical dredging is applicable to relatively shallow streams and rivers that have low flow velocities (EPA 1985).

Mechanical dredging equipment is readily available and commonly used for river sediment removal. The U.S. Army Corps of Engineers frequently uses mechanical dredging along the Columbia River to keep shipping channels open and to excavate dock areas (Willard 1993). There are two primary limitations to the use of mechanical dredging for removing sediments from the Columbia river: resuspension of contaminated sediments (especially radioactive contaminants) and shallow water application (EPA 1985). However, resuspension of sediments has not been a problem encountered by the U.S. Army Corps of Engineers during their dredging operations along the Columbia (Willard 1993). Small, shallow water dredges may be required in some areas. Additionally, dredging in the upper Columbia River near the Hanford Site is limited to two months of the year (January and February) due to spawning habits of the salmon and spring runoffs (Willard 1993).

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3.7.2 Hydraulic Dredging

Hydraulic dredging involves removal of sediments by pumping in a liquid slurry form. Sediments are dislodged from river bottoms by plain suction, cutterhead, dustpan, or hopper methods (EPA 1985). Once dislodged, the sediments are pumped to the surface with centrifugal pumps. Slurries of 10 to 20 percent solids by wet weight are typical for standard hydraulic dredging operations (Petersen 1986). The suction end of the dredge is mounted on a movable ladder to enable variable dredging depths.

Hydraulic dredges are applicable to streams and rivers with appreciable flow velocities (EPA 1985). This technique can be operated at process rates greater than mechanical dredges and can minimize resuspension of sediments by surrounding the suction end of the dredge with a hood. The primary disadvantage of hydraulic dredging is the large volumes of water that are removed with the sediments.

Hydraulic dredging equipment is readily available and commonly used for river sediment removal. The high water content of the slurry makes handling of the dredged material more difficult. A dewatering system would be required (see Section 3.8). Dredging in the upper Columbia River near the Hanford Site is limited to two months of the year (January and February) due to spawning habits of the salmon and spring runoffs (Willard 1993).

3.7.3 Demolition

Demolition is the initial operation in removal of the outfall pipeline. The existing outfall pipeline would be cut into smaller, more manageable sections to facilitate removal. A crane or other hoisting device would be used to remove the pipe segments.

Standard barge-mounted hoisting equipment could be employed. Underwater rigging would be completed remotely from the barge or if necessary, by divers. Some sediment

dredging may be required to expose buried lengths of pipeline. Cutting with underwater torches is required for sizing pipelines into manageable lengths.

The physical removal of the submerged pipelines would result in the most effective long term solution by removing a potential source of contaminants. Limitations to pipeline demolition include resuspension of contaminated sediments during removal and difficulties inherent in underwater diving. Remedies, such as sealing the end of each section of pipeline prior to removal, may be required.

3.8 LAND-BASED REMOVAL

3.8.1 Excavation

Refer to discussion on "Excavation," Appendix C, Section 1.7.1, under "Removal" technologies in the "Solid Waste Technology Descriptions."

Land-based excavation of river bottom sediments along the riverbank is difficult because of the long reach required. Typical excavation equipment will not perform well on saturated and submerged sediments and tends to sink. Special equipment designed to "float" on saturated sediments could be used. Land-based removal of the river bottom sediments also shares some of the same limitations as mechanical dredging (i.e., resuspension of contaminated sediments and a narrow two month window to perform the excavation).

3.9 DEWATERING

The following methods of dewatering contaminated river sediments are discussed below:

- mechanical dewatering
- thermal drying.

3.9.1 Mechanical Dewatering

Mechanical dewatering is a mineral processing technology involving either sedimentation or gravity and centrifugal forces to obtain water separation (Cummins and Given 1973). These processes are typically used in the mining industry for solid-liquid separation of slurries and can achieve capacities in the tons per hour range. Mechanical dewatering processes require laboratory testing to determine capacity and operating requirements for full-scale processes.

Screens are filtering processes that use gravity and centrifugal forces to dewater by removing suspended solids from a slurry, thereby leaving a liquid effluent. Selection for particular applications depends on the particle sizes to be removed from the slurry. Shaking-

or vibrating-type screens are applicable for larger particle sizes whereas centrifugal or sieve screens are applicable for smaller particle sizes. Centrifugal screens enhance dewatering by increasing the applied forces on moisture adhering to particles (Cummins and Given 1973).

Sedimentation involves establishing flow velocities that will cause particles to fall out of suspension. This settling velocity is a function of Stokes law; however, it can also be influenced by conditions that hinder settling (Cummins and Given 1973). The sedimentation process can be enhanced by the addition of coagulants or flocculants. Some type of filtration typically follows sedimentation as a polishing step to remove particles remaining in suspension.

Mechanical dewatering is a well established technology that is commonly used in the mining industry. However, application of this technology to radiologically contaminated river sediments is unknown.

The effectiveness of mechanical dewatering is dependent on the properties of the slurry influent as well as the degree of dewatering desired. River sediment removal by methods other than hydraulic dredging would not form a slurry without the addition of water. Therefore, mechanical dewatering is only feasible for hydraulically dredged river sediments.

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3.9.2 Thermal Drying

Thermal drying is a mineral processing technology involving the application of heat to separate water from solids. These processes are used in the mining industry for drying minerals. Thermal dewatering typically involves vaporizing moisture by direct contact of particles with hot air. Thermal drying processes include rotary dryers, flash dryers, tray dryers, and fluidized beds (Cummins and Given 1973).

Thermal drying differs from mechanical dewatering in that thermal drying removes moisture from wet solids whereas mechanical dewatering removes suspended solids from slurries.

Thermal drying is a well established technology. However, application of this technology to radiologically contaminated river sediments is unknown. Radionuclides removed with vaporized moisture may require extensive offgas collection and treatment.