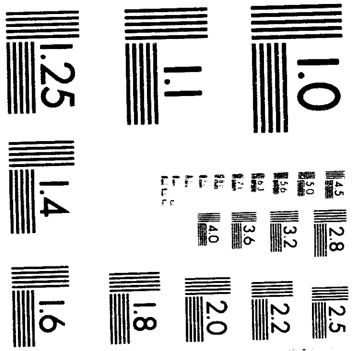
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Revision 0

Phase I and II Feasibility Study Report for the 300-FF-5 Operable Unit

United States
Department of Energy
Richland, Washington

Approved for Public Release

EXECUTIVE SUMMARY

The purpose of this Phase I/II FS is to assemble and screen a list of alternatives for remediation of the 300-FF-5 operable unit. This screening is based on information gathered in the Phase I RI and on currently available information on remediation technologies. The alternatives remaining after screening provide a range of response actions for remediation. In addition, key data needs are identified for collection during a Phase II RI (if necessary). This Phase I/II FS represents a primary document as defined by the Tri-Party Agreement, but will be followed by a Phase III FS that will further develop the alternatives and provide a detailed evaluation of them. The signatories of the Tri-Party Agreement will use the Phase III FS as the basis for selecting a remedy for the 300-FF-5 operable unit to mitigate potential risk to human health and the environment.

The following remedial action objectives were identified for the 300-FF-5 operable unit:

1) **Limit current human exposure to contaminated groundwater in the 300-FF-5 operable unit.**

2) **Limit discharge of contaminated groundwater to the Columbia River.**

3) **Reduce contaminant concentrations in groundwater below acceptable levels by the year 2018.**

Potential ARARs for determining remediation goals (cleanup levels) include MTCA Method B, MTCA Method C, and drinking water MCLs. The selection of a remedy will depend on the applicability of these regulations to remediation of the 300-FF-5 operable unit. If MTCA is applicable, an ARAR waiver should be considered in accordance with Section 121 of CERCLA. The MTCA Method B level for uranium (4.3 pCi/L) is currently the 300-FF-5 background concentration. However, because of the small number of background samples and apparent analytical variability, the background level for uranium at the 300-FF-5 operable unit is uncertain. If the site-specific background proves lower with the acquisition of additional data, compliance with MTCA Method B standards will require significantly greater effort and cost than compliance with either MTCA Method C or drinking water MCLs.

Remedial action objectives for the 300-FF-5 operable unit do not include remediation of contaminants migrating from sources outside the 300 Area. Two upgradient contaminant plumes are approaching the operable unit: a tritium plume from the northwest and a plume from the southwest that contains technetium-99 and nitrate. The technetium-99 and nitrate plumes were described in the 1100-EM-1 operable unit RI/FS (DOE-RL 1993d); groundwater monitoring is continuing in part to identify the sources of these plumes. Remediation of these plumes will be covered under feasibility studies for other operable units at the Hanford Site. In addition, monitoring (without active remediation) is the proposed remedy for the 1100-EM-1 operable unit (DOE-RL 1992e), which includes the technetium and nitrate plumes. Therefore, these plumes are addressed only to the extent that they affect remediation of target contaminants from the 300 Area.

Tritium represents a special case because it is technically infeasible to limit discharges of tritium to the Columbia River. Most of the tritium plume currently entering the river is in the 600 Area to the north of the 300-FF-5 operable unit. Tritium discharges to the Columbia River along the 300 Area are below MCLs, but above MTCA Method B and C cleanup standard. It may be advisable to waive ARARs pertaining to tritium as allowed by Section 121 of CERCLA.

To assemble remediation alternatives, a list of potentially applicable technologies was developed and screened. These technologies were screened (considering site conditions and contaminants of concern) based on effectiveness, implementability, and cost. The retained technologies were then assembled into a wide range of alternatives for remediation of the 300-FF-5 operable unit.

A range of alternatives was developed that includes no action (required under the NCP), limited action (e.g., institutional controls), containment, and treatment to remove contaminants from the site for offsite landfill disposal. In order to address various degrees of active remediation, two categories of active remedial alternatives were developed: "extensive" alternatives and "selective" alternatives.

- "Extensive" remediation refers to the greatest extent of active remediation that would be performed.
- "Selective" remediation refers to active remediation of the most contaminated areas, allowing natural aquifer flushing of remaining contaminated areas.

The following initial list of alternatives was assembled for the 300-FF-5 operable unit:

Alternative 1:	No Action
Alternative 2:	Institutional Controls
Alternative 3:	Selective Hydraulic Containment
Alternative 4:	Selective Hydraulic Containment with In-Situ Flushing
Alternative 5:	Extensive Hydraulic Containment
Alternative 6:	Extensive Hydraulic Containment with Selective In-Situ Flushing
Alternative 7:	Selective Slurry Wall Containment
Alternative 8:	Selective Slurry Wall Containment with Minimal Extraction
Alternative 9:	Selective Slurry Wall Containment with In-Situ Flushing
Alternative 10:	Extensive Slurry Wall Containment
Alternative 11:	Extensive Slurry Wall Containment with Minimal Extraction
Alternative 12:	Extensive Slurry Wall Containment with Selective In-Situ Flushing
Alternative 13:	Selective Hydraulic Containment with a River Cutoff Wall
Alternative 14:	Selective In-Situ Flushing with a River Cutoff Wall
Alternative 15:	Selective Aquifer Dredging
Alternative 16:	Extensive Aquifer Dredging

Estimated costs for these alternatives range from less than 10 million to more than 150 million.

The alternatives were screened based on effectiveness, implementability, and cost to derive a reduced list for detailed evaluation in the Phase III FS. The following alternatives remained after screening:

Alternative 1:	No Action
Alternative 2:	Institutional Controls
Alternative 3:	Selective Hydraulic Containment

Alternative 4:	Selective Hydraulic Containment with In-Situ Flushing
Alternative 5:	Extensive Hydraulic Containment
Alternative 8:	Selective Slurry Wall Containment with Minimal Extraction
Alternative 9:	Selective Slurry Wall Containment with In-Situ Flushing
Alternative 11:	Extensive Slurry Wall Containment with Minimal Extraction

The current incremental cancer risk due to 300 Area groundwater is estimated to be approximately $2x10^{-5}$, based on exposure to the existing industrial well. However, there is no unacceptable risk to human health or the environment provided direct exposure to contaminated groundwater is prevented. In addition, groundwater contamination due to 300 Area operations is expected to decrease below levels of concern by the year 2018. Therefore, it appears that the Institutional Controls alternative deserves strong consideration. Unlike many sites, where institutional controls would be required indefinitely, they would only be required at this site for a relatively short time. Institutional controls can be considered highly reliable as long as the Hanford Site remains under DOE jurisdiction (presumably until at least the year 2018).

The primary purpose of active remedial actions would be to accelerate remediation of the 300-FF-5 operable unit. However, active remediation of groundwater could not begin until after completion of (1) necessary treatability studies (discussed in Section 6.5.2), (2) the alternative selection process, (3) remedial design of the selected alternative, (4) selection of remediation contractors, and (5) construction of groundwater extraction and treatment systems. Because of the time required to complete all of these activities, active remediation would likely begin in the next two to five years. Given the modelling results indicating that natural flushing may achieve remediation goals within 10 years, the benefits of installing and operating an active remediation system may be minimal.

In addition, the impact of the upgradient plumes must be considered. If these plumes will require institutional controls, beyond the time when 300 Area contaminants are below levels of concern, then the desirability of active remediation for the 300-FF-5 operable unit is greatly diminished. Furthermore, incentives for remedial action must be balanced against NEPA and NRDA issues. Any construction activity associated with remedial action will increase adverse ecological effects, such as habitat destruction and disturbance of wildlife.

The extent of remedial action (i.e., the remediation area) will significantly affect the implementability and cost of remediation alternatives. The adverse effects of remedial action would be less with a smaller remediation area. Before detailed evaluation of a number of active remediation alternatives is warranted, the need for active remediation should be determined. The required extent of active remediation should be part of this determination. Final determinations on ARARs, particularly the applicability of MTCA Method B, will also affect the need for remedial action. Given these factors, it is recommended that the Phase III FS focus on the need for remedial action and the appropriateness of institutional controls as the primary method of ensuring protection of human health and the environment.

LIST OF ACRONYMS

ACL	alternative concentration limit
ALARA	as low as reasonably achievable
AMSL	above mean sea level
ARAR	applicable or relevant and appropriate requirement
BARCT	best available radionuclide control technology
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR	Code of Federal Regulations
DCE	dichloroethene (dichloroethylene)
DCG	derived concentration guide
DNAPL	dense non-aqueous phase liquid
DOE	United States Department of Energy
Ecology	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
ERA	expedited response action
ERDA	United States Energy Research and Development Administration
ERSDF	Environmental Restoration Storage and Disposal Facility
FS	feasibility study
HMS	Hanford Meteorological Station
HRA-EIS	Hanford Remedial Action Environmental Impact Statement
ICR	lifetime incremental cancer risk
LDR	land disposal restriction
MCL	maximum contaminant level
MCLG	maximum contaminant level goals
MTCA	Model Toxics Control Act
NCP	National Oil and Hazardous Substances Contingency Plan
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NRDA	Natural Resources Damage Assessment
OSHA	Occupational Safety and Health Act
PQL	practical quantification limits
RAO	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington (State)
RI	remedial investigation
RL	Richland field office (of DOE)
RO	reverse osmosis
ROD	record of decision
SARA	Superfund Amendments and Reauthorization Act of 1986
SDWA	Safe Drinking Water Act
SITE	Superfund Innovative Technology Evaluation
SLM	supported liquid membrane
SMCL	secondary maximum contaminant level

LIST OF ACRONYMS (Cont.)

SPCC	spill prevention control and countermeasures
TBC	to be considered
TCE	trichloroethene (trichloroethylene)
UIC	Underground Injection Control
USGS	United States Geological Survey
UST	underground storage tank
UV	ultra violet
VOC	volatile organic compound
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company

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1.0 INTRODUCTION

The U.S. Department of Energy (DOE) Hanford Site, in Washington State, is organized into numerically-designated operational areas that include the 100, 200, 300, 400, 600, and 1100 Areas. In November 1989, the U.S. Environmental Protection Agency (EPA) placed the 300 Area on the National Priorities List (NPL) pursuant to the *Comprehensive Environmental Response, Compensation and Liability Act of 1980* (CERCLA), as amended by the *Superfund Amendments and Reauthorization Act of 1986* (SARA). The 300-FF-5 operable unit addresses contamination of groundwater, saturated soils (i.e., soils beneath the water table), surface water, and river sediments emanating from the 300 Area.

As required for NPL sites, a remedial investigation (RI) and feasibility study (FS) is being performed for this operable unit to characterize the nature and extent of contamination, assess risks to human health and the environment, and develop and evaluate remediation alternatives. These efforts are covered by the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1992), which was negotiated and approved by the DOE, the EPA, and the State of Washington, Department of Ecology (Ecology) in May 1989. This agreement, known as the Tri-Party Agreement, governs all CERCLA efforts at the Hanford Site.

In June 1990, a RI/FS work plan for the 300-FF-5 operable unit was issued pursuant to the Tri-Party Agreement (DOE-RL 1990a). The decisional draft of the Phase I RI report (DOE-RL-1993a) was issued in May 1993 and is currently under review. This document is the combined Phase I/Phase II FS report for the 300-FF-5 operable unit.

1.1 BACKGROUND

The Hanford Site is a 1,450 km^2 (560 mi^2) tract of land located along the Columbia River in southeastern Washington State that covers portions of Benton, Grant, Franklin, and Adams Counties (Figure 1-1). Operated by the Federal Government since 1943, the primary mission of the Hanford Site has been plutonium production for military use and nuclear energy research and development.

Initial construction at the 300 Area fuels fabrication complex was completed in 1943. Most of the facilities in the area were involved in the fabrication of nuclear reactor fuel elements. In addition to the fuel manufacturing processes, many technical support, service support, and research and development activities related to fuels fabrication were carried out within the 300 Area. In the early 1950's, construction began in the 300 Area on the research and development facilities known as the Hanford Laboratories. As the Hanford Site production reactors have been shut down, fuel fabrication activities in the 300 Area have decreased and research and development activities have increased. Current research and development activities focus on peaceful uses of plutonium, reactor fuels development, liquid metal technology, fast-flux test facility support, gas-cooled reactor development, life science research, and environmental restoration technologies.

The 300 Area is located along the Columbia River at the southeast corner of the Hanford Site, approximately 1.6 km (1 mi) north of the City of Richland. The 300 Area NPL site has been divided into four operable units: 300-FF-1, 300-FF-2, 300-FF-3, and 300-FF-5. The 300-FF-1, 300-FF-2, 300-FF-3, and 300-FF-5 operable units are shown in Figures 1-2 and 1-3. The first three "source" operable units address wastes and contaminated soils from source areas. The 300-FF-5 operable unit addresses contamination of groundwater and saturated sediments caused by waste management activities conducted in the 300-FF-1, 300-FF-2, and 300-FF-3 source operable units. The 300-FF-5 operable unit also includes surface water and river sediments contaminated by 300 Area activities.

1.2 PURPOSE AND SCOPE

The purpose of this Phase I/Phase II FS report is to assemble and screen a list of alternatives for remediation of the 300-FF-5 operable unit, based on information gathered in the Phase I RI (DOE-RL 1993a). (All references to "RI" refer to the Phase I Remedial Investigation Report prepared for the 300-FF-5 operable unit, unless specifically identified otherwise.) These alternatives will, to the degree feasible, provide a range of response actions for remediation (e.g., no action, removal, and treatment). In addition, any key data needs will be identified for a Phase II RI (if necessary). This report will be followed by a Phase III FS that will further develop the alternatives and provide a detailed evaluation. The signatories of the Tri-Party Agreement will use the Phase III FS as the basis for selecting a remedy to mitigate potential risk to human health or the environment presented by the 300-FF-5 operable unit (i.e., groundwater beneath the 300 Area).

1.3 OVERVIEW OF THE FEASIBILITY STUDY PROCESS

In accordance with EPA guidance (*Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, Interim Final, EPA 1988a), a FS is generally conducted in the following steps:

1. Establishment of remedial action objectives (cleanup goals) for contaminants and media of interest. These objectives are developed based on the findings of the baseline risk assessment and chemical-specific applicable or relevant and appropriate requirements (ARARs).

2. Identification of the applicable general response actions (e.g., containment, removal, and treatment).

3. Estimation of the areas and volumes of contaminated media that exceed remedial action objectives based on information developed during the RI.

4. Identification and screening of potentially applicable technologies for each contaminated medium to obtain a set of technologies feasible for use in achieving remedial action objectives.

5. Assembly of retained technologies into remediation alternatives that cover the full range of possible response actions. The alternatives are then screened based on effectiveness, implementability, and cost to eliminate alternatives that are impractical or infeasible relative to the other alternatives.

6. Further development and detailed evaluation of the alternatives to support selection of a remedy for the operable unit.

A FS can be conducted in a phased manner. A Phase I FS consists of steps 1 through 4: establishing remedial action objectives, identifying general response actions, estimating areas and volumes of contamination, and identifying and screening remediation technologies. A Phase II FS uses the results of the Phase I FS to assemble technologies retained after screening into alternatives for remediating the operable unit and screens these alternatives to produce a manageable list of alternatives for detailed consideration (i.e., step 5). The final Phase III FS combines the results of the first two phases with step 6, development and detailed evaluation of alternatives. In the Phase III FS, the alternatives are evaluated using criteria established in the National Oil & Hazardous Substances Contingency Plan (NCP, 40 CFR 300.430):

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness
- Reduction in toxicity, mobility, and volume
- Short-term effectiveness
- Implementability
- Cost

The first two criteria are considered "threshold" criteria that an alternative must meet to be acceptable. The next five criteria are the primary criteria used in the evaluation. The results of the evaluation of alternatives are used by the decision makers to select a preferred remedy for the operable unit. The proposed remedy and basis for its selection are presented in the proposed plan. Two additional selection criteria, state acceptance and community acceptance, are determined based on comments received on the proposed plan. The final remedy selection is then made and promulgated in the final Record of Decision (ROD).

CERCLA provides that natural resource trustees (e.g., the United States Fish and Wildlife Service and DOE) shall identify the need for natural resource damage assessments (NRDA) at NPL sites. The trustees may assess damages to natural resources resulting from a discharge or release of a hazardous substance and may seek to recover those damages. According to the NCP, the lead agency shall make available information and documentation that can assist the respective trustees in the determination of actual or potential natural resource injuries. To that end, for groundwater units potentially impacting the Columbia River from a discharge or release, potential injury from these releases will need to be identified. Potential future injuries as a result of remedial actions will also need to be considered in the context of NRDA. The NRDA considerations are important prior to establishing the ecological remedial action objectives. Because NRDA methodology for the Hanford Site is currently under development, it was not possible to fully address NRDA considerations in this report. Once the methodology is complete, NRDA determinations will be provided in a separate document and incorporated into the Phase III FS.

1.4 REPORT ORGANIZATION

This FS report is organized into the following sections:

- **Chapter 1, Introduction** - This chapter.

- **Chapter 2, Summary of the Remedial Investigation** - This section includes a description and brief history of the operable unit and summarizes the information obtained during the remedial investigation.

- **Chapter 3, Remedial Action Objectives** - This section includes a summary of the baseline risk assessment for the operable unit and uses it as a basis for developing the remedial action objectives used to develop alternatives for site remediation. Laws and regulations that are potentially applicable or relevant and appropriate (ARARs) are also identified and considered in the development of the remedial action objectives.

- **Chapter 4, Identification and Screening of Remediation Technologies and Process Options** - This section identifies and screens remediation technologies that are potentially applicable to the site to produce a list of technologies to be used in developing the remediation alternatives for this operable unit.

- **Chapter 5, Assembly and Screening of Remediation Alternatives** - This section assembles the technologies retained after screening into alternatives for site remediation. The initial list of alternatives is screened to produce a reduced list for development and detailed evaluation using CERCLA criteria.

- **Chapter 6, Summary and Conclusions** - This section summarizes the results of the screening of alternatives, discusses potential issues and data needs, and provides recommendations for use in preparing the Phase III FS.

- **Chapter 7, References** - This section cites the documentation referenced in the body of this report.

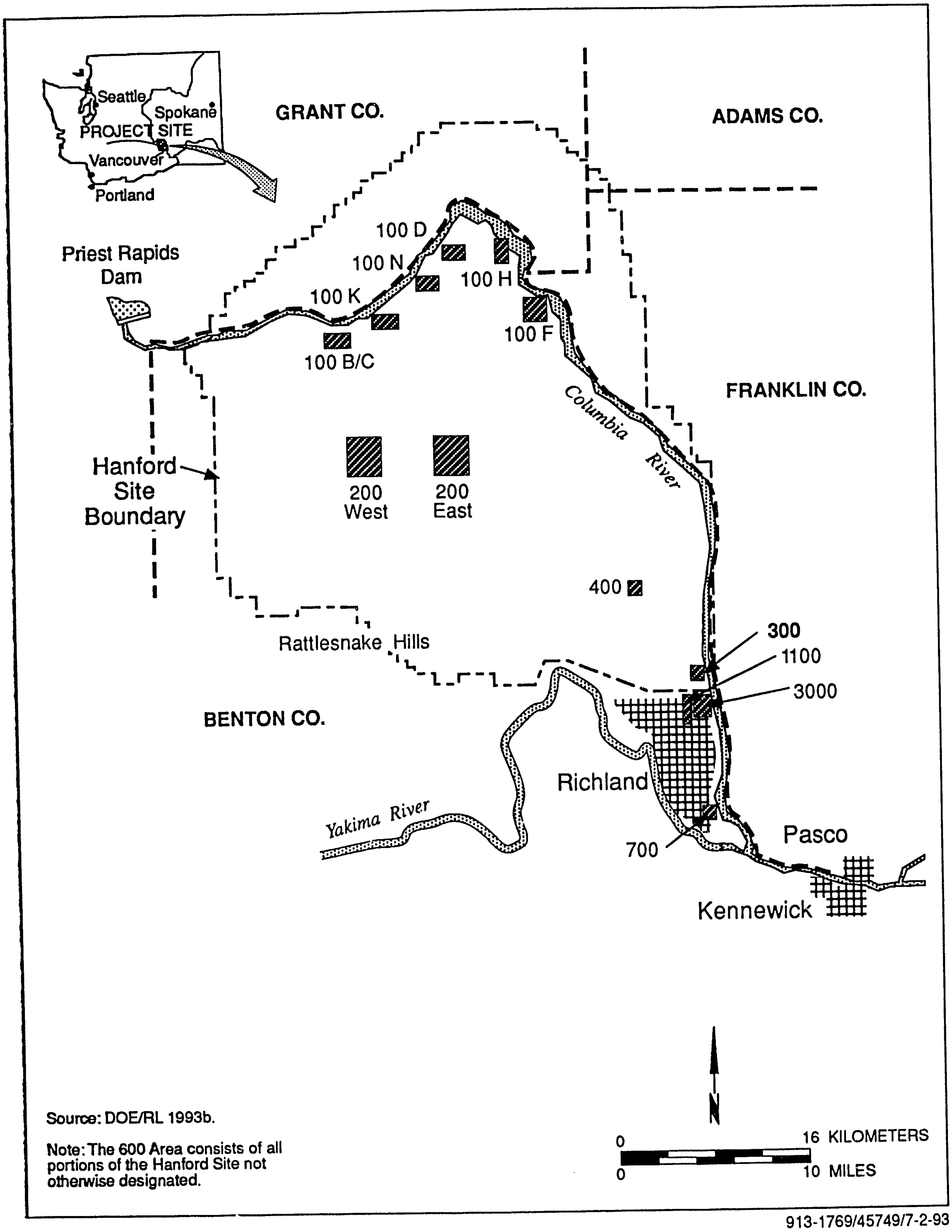

Figure 1-1. Hanford Site Operational Areas.

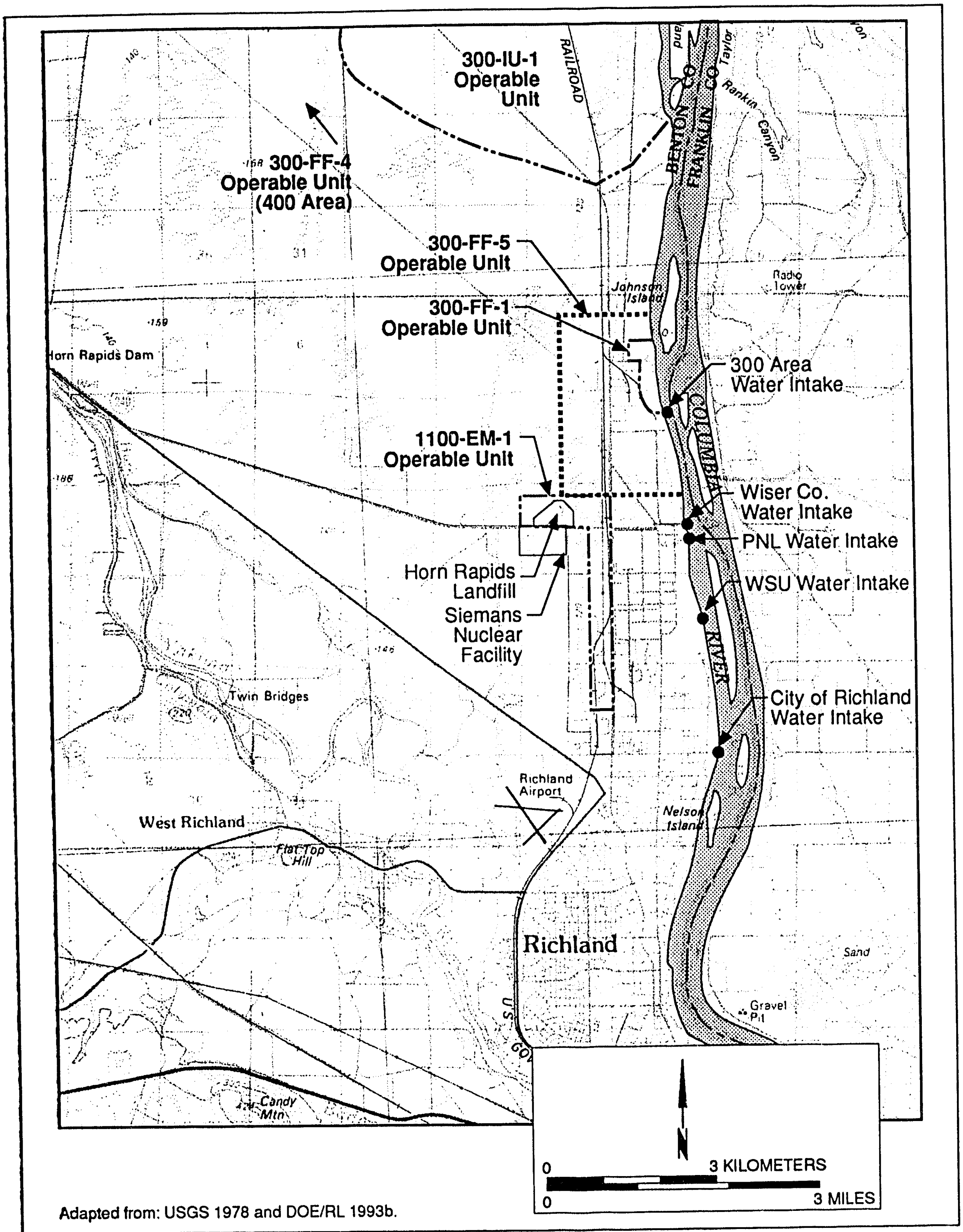

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Figure 1-2. Other Operable Units and Columbia River Water Intakes in Vicinity of 300-FF-5.

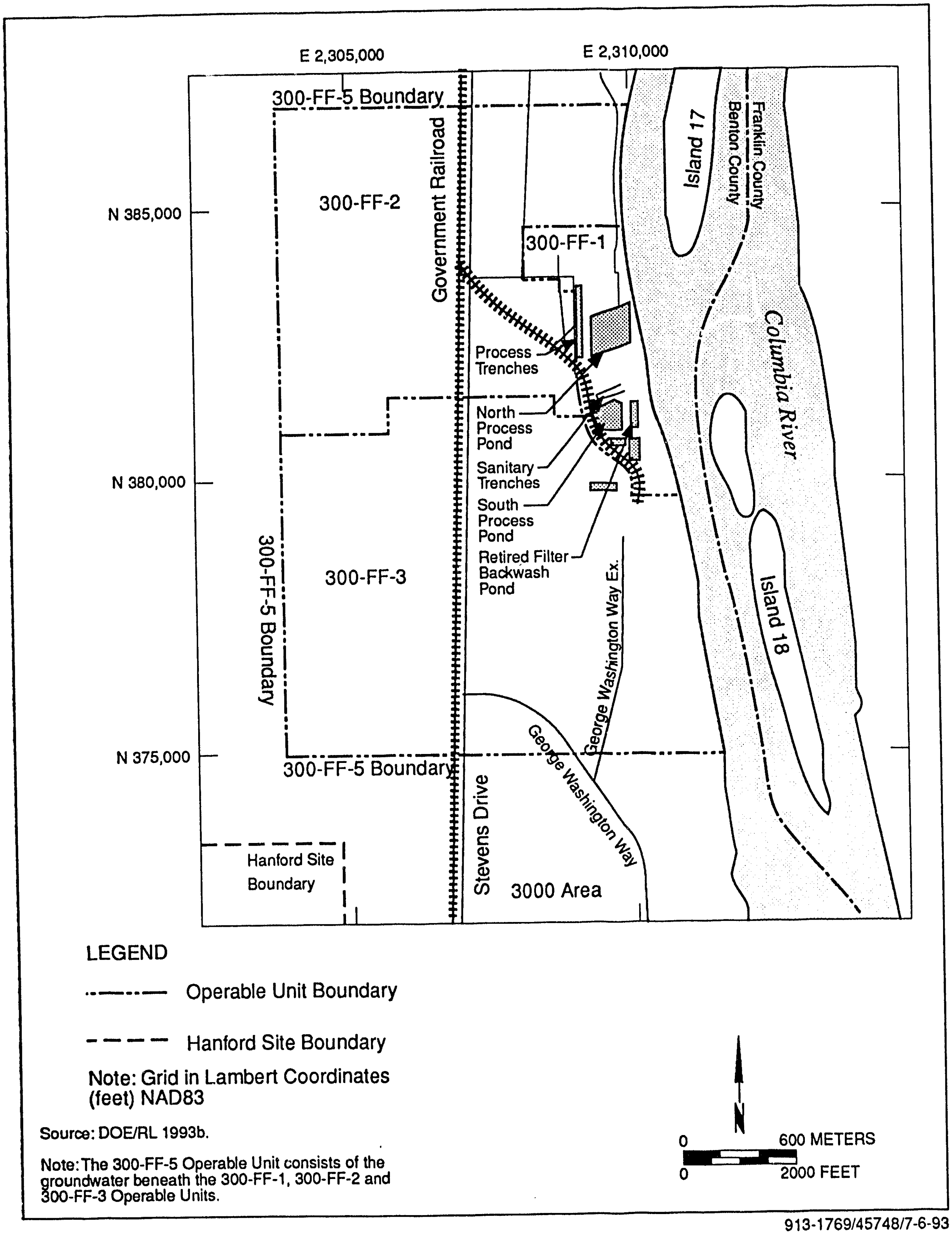


Figure 1-3. Location of Operable Units Within the 300 Area on the Hanford Site.

2.0 SUMMARY OF THE REMEDIAL INVESTIGATION

This chapter summarizes relevant characteristics of the 300-FF-5 operable unit, including waste source characteristics, meteorology, surface water hydrology, geology, hydrogeology, and ecology. Also provided is a synopsis of the nature and extent of contamination, contaminant fate and transport, and the baseline risk assessment for the 300-FF-5 operable unit.

2.1 OPERABLE UNIT DESCRIPTION

2.1.1 Location

The 300-FF-5 operable unit is located in the 300 Area within the southeastern section of the Hanford Site in Benton County, Washington (Figure 1-1). The Columbia River forms the eastern boundary of the operable unit and the northern, western, and southern boundaries have been located to represent the potential extent of groundwater contamination migrating from the three (300-FF-1, 300-FF-2, and 300-FF-3) source operable units (Figure 1-3).

2.1.2 300 Area Waste Generating Processes and Waste Management Units

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

The largest volume of waste generated in the 300 Area is from the fuel fabrication operations. The majority of this waste was disposed of in the 300-FF-1 operable unit. Details regarding waste disposal in the 300-FF-1 operable unit are presented in DOE-RL (1993b). Some of this waste, however, was disposed of in the other 300 Area source operable units.

In addition to the fuel fabrication activities, other waste generation activities in the 300 Area include support operations (e.g., convertible coal/oil powerhouse), research operations, water treatment, and sanitary waste disposal (DOE-RL 1993a). Many of the waste management units potentially affecting the 300-FF-5 operable unit received waste from these activities.

Tables 3-1 and 3-2 in the Phase I RI report for the 300-FF-5 operable unit (DOE-RL 1993a) list the individual waste management units and summarize the waste types, dates of operation, size, and approximate waste amounts for the 300-FF-2 and 300-FF-3 operable units, respectively. These units include liquid waste disposal units, solid waste burial grounds, hazardous waste storage facilities, waste treatment facilities, and unplanned releases. The locations of the individual waste management units assigned to the 300-FF-2 and 300-FF-3 operable units are shown in DOE-RL (1992a).

The fuel fabrication operations generated both liquid and solid wastes. Most of the liquid waste was disposed of in the 300-FF-1 waste management units. Solid wastes were disposed of in solid waste burial grounds, most of which are located in the 300-FF-2 operable unit, although one is in the 300-FF-3 operable unit. These burial grounds were open, unlined pits or trenches into which dry solids or drummed liquids were placed. The solid waste burial grounds contain mixed waste of mostly unknown composition, but are known to contain various fission products and isotopes of uranium and plutonium. When filled, the burial grounds were backfilled to grade with local sediments.

In addition to the waste management units, a number of unplanned releases are assigned to the 300-FF-2 and 300-FF-3 operable units. With the exception of two petroleum leaks from underground storage tanks (USTs), located at the 300 Area fire station, all other unplanned releases were generally associated with fuel fabrication operations (Stenner et al. 1988). An unrecorded quantity of contaminated soil and associated equipment was removed during remediation of the unplanned petroleum releases. Two downgradient monitoring wells are planned to be installed and monitored in accordance with the Department of Ecology guidance documents to determine the effect of the UST release on the unconfined aquifer (DOE-RL 1992b).

2.1.3 Interactions with Other Operable Units

The 300-FF-5 groundwater operable unit is potentially affected by inflowing groundwater migrating from several source areas in addition to the 300-FF-1, 300-FF-2, and 300-FF-3 operable units (Figure 1-2) (DOE-RL 1990a). The 300-IU-1 operable unit (shown on Figure 1-2), located approximately 4.8 km (3 mi) northwest of the 300 Area, consists of various waste management units that received waste from fuel fabrication operations and miscellaneous construction debris from various construction sites (DOE-RL 1992a; Stenner et al. 1988). Because of the southeasterly flow of groundwater, contaminants entering the groundwater beneath the 300-IU-1 operable unit could impact the 300-FF-5 operable unit.

The 300-FF-4 operable unit is composed of the waste management units located at the Fast Flux Test Facility, also known as the 400 Area (WHC 1989). This operable unit is located approximately 10 km (6 mi) to the northwest of the 300 Area. Because of the southeasterly flow of groundwater, contaminants entering the groundwater beneath the 300-FF-4 operable unit could potentially impact the 300-FF-5 operable unit.

A tritium plume (Figure 2-1), believed to be associated with the 200-PO-2 operable unit in the 200 East Area (WHC 1989), is present in an area primarily to the north of the 300 Area and is currently migrating south and east, discharging to the Columbia River. This tritium plume is extensive, covering approximately 100 km^2 (38.6 mi^2), and extends into the 300-FF-5 operable unit. The current extent of tritium contamination in groundwater of the 300-FF-5 operable unit is presented in Section 4.3 of the RI (DOE-RL 1993a).

The Horn Rapids Landfill, a waste management unit assigned to the 1100-EM-1 operable unit, is located in the 600 Area approximately 1.6 km (1 mi) to the south and west of the southern portion of the 300-FF-5 operable unit (WHC 1989). This closed landfill is roughly 20 ha (50 ac) in size and was used primarily for the disposal of office and construction wastes. The disposal of drummed waste solvents at the facility has been alleged (DOE-RL 1990b). A plume of trichloroethene, technetium-99, and nitrate emanates from the general vicinity of the landfill and apparently is migrating to the northeast, towards the 300 Area (DOE-RL 1993d and 1993a). The source(s) for this plume are currently uncertain.

2.2 PHYSICAL SETTING

2.2.1 Meteorological Characteristics

This section summarizes meteorological data compiled and presented in Hulstrom (1992). The regional meteorology is based primarily on data collected at the Hanford Meteorological Station (HMS), which provides a long-term and comprehensive base of information. The HMS is located between the 200 East and 200 West Areas of the Hanford Site, approximately 32 km (20 mi) to the northwest of the 300 Area, at an elevation of 223 m (733 ft) above mean sea level (AMSL). A 300 Area meteorologic station monitors evapotranspiration, wind speed, and wind direction.

2.2.1.1 Precipitation. The Cascade Range, located approximately 130 km (80 mi) west of the Hanford Site, creates a rain shadow that limits total annual precipitation to about 16 cm (6.3 in) at the HMS. Rain is the usual form of precipitation at the HMS, but snowfall regularly occurs during winter. Hail storms, although unusual, may occur during the summer thunderstorm season. The average annual snowfall is 33 cm (13.0 in.). The largest volume of precipitation occurs in the winter. January is the wettest month, with average precipitation of 0.23 cm (0.91 in.), and July is the driest month with average precipitation of only 0.38 cm (0.15 in.). Precipitation intensity is greatest in the summer months and coincides with the thunderstorm season.

2.2.1.2 Temperature. The summer months at the Hanford Site are typically hot and dry, and winters are moderately cold. July is the warmest month of the year with an average temperature of 24.7°C (76.4°F), and January is the coolest month with an average temperature of -1.5°C (29.3°F). During summer months, when the average relative humidity is 30 to 40%, the diurnal temperature range is greatest, on the order of 15°C (27°F) (DOE-RL 1990a and Hulstrom 1992). In winter, with relative humidity ranging from 60 to 80%, the diurnal temperature range is reduced to about 8°C (14°F) (DOE-RL 1990a and Hulstrom 1992).

2.2.1.3 Evapotranspiration. A local monitoring site has been operated near the 300 Area since 1979 as part of a monitoring program to study groundwater recharge at Hanford and measure parameters that affect recharge rates.

Using measurements of changes in water storage, drainage, and precipitation during the period from July 1988 to June 1989, evaporation and transpiration were measured to be about 14.3 cm (5.6 in) for a bare surface and 19.9 cm (7.9 in) for a vegetated surface. Precipitation during this period was about 18.0 cm (7.1 in). Drainage was about 4.0 cm (1.6 in) from the bare surface and 1 cm (0.4 in) from the vegetated surface. The excess of evapotranspiration and drainage over precipitation is compensated by a reduction in soil moisture (Hulstrom 1992).

2.2.1.4 Wind Direction and Speed. Local wind speed and direction data for the 300-FF-5 operable unit were obtained from the 300 Area monitoring station operated by Pacific Northwest Laboratory (PNL). Wind direction at the 300 Area varies over 360 degrees, with a prevailing wind direction from the southwest (11% of the time); winds from the north, southeast, south-southwest, and north-northwest occur almost as frequently (>8% of the time from each direction). Wind direction generally becomes southerly from the fall to winter and northerly from the spring to summer (DOE-RL 1990a).

Daily average wind speed at the 300 Area ranges from 8 km/h (5 mph) to 16 km/h (10 mph). The range of daily average wind speeds for the 300 Area station is calm to 40 km/h (25 mph). Median daily average wind speed at the 300 Area is about 11 km/h (7 mph). The upper, one-sided 95% confidence limit of the daily average is 23 km/h (14 mph) for the 300 Area (DOE-RL 1990a).

2.2.2 Surface Water Hydrological Characteristics

2.2.2.1 Regional.

2.2.2.1.1 Major Rivers. The major surface water body in the Pasco Basin is the Columbia River, which crosses the northern portion of the Hanford Site, then turns southward to form the Hanford Site's eastern boundary (Figure 2-2). The Snake River and Yakima River are the second and third largest rivers, respectively, in the Pasco Basin and enter the Columbia River downstream of the Hanford Site. These rivers are important sources of water for domestic agricultural, industrial, and recreational users in the Pasco Basin (DOE 1987; Jaquish and Bryce 1990).

The Columbia River above Priest Rapids Dam drains an area of approximately 250,000 km^2 (95,500 mi^2) in Washington, Idaho, Montana, and British Columbia. Priest Rapids Dam, located approximately at river mile 397, is the nearest impoundment upstream of the Hanford Site. McNary Dam is the nearest dam downstream, at river mile 292. No perennial or ephemeral tributaries enter the Columbia River between Priest Rapids Dam and the Yakima River confluence just south of the City of Richland. Irrigation return flow enters the Columbia River on the Franklin County side in the form of distributed seeps and constructed wasteways.

The Hanford Reach of the Columbia River extends approximately 8.5 km (5.3 mi) above the northwestern Hanford Site boundary, to the head of Lake Wallula (approximately at the southeastern Hanford Site boundary). The Hanford Reach, which is approximately 100 km (60 mi) in length, is the only substantial remaining stretch of the Columbia River within the United States that is not impounded by a dam (Jaquish and Bryce 1990).

Regional flooding within the Columbia and Yakima rivers is controlled by hydroelectric power dams and irrigation structures (Skaggs and Walters 1981). Except for extreme flooding scenarios, flooding in either river is not anticipated to inundate the 300 Area source operable units.

2.2.2.1.2 Other Naturally-Occurring Surface Waters. There are no perennial streams in the Pasco Basin. Cold Creek and its main tributary, Dry Creek, are two major ephemeral streams located along the southwestern boundary of the Hanford Site. The Cold Creek drainage ultimately connects to the Yakima River (Figure 2-2). Flow in these creeks resulting from precipitation is not well documented.

West Lake, located about 3.2 km (2 mi) north of the 200 East Area, is a pond on the Hanford Site. The pond is shallow, with an average depth of about 1 m (3 ft) and a surface area of about 4 ha (10 ac) (Fuchs et al. 1985). The source of recharge to the pond is groundwater, which is locally mounded because of infiltration resulting from 200 Area operations (Graham et al. 1981). The pond's size fluctuates with the height of the groundwater mound.

2.2.2.1.3 Manmade Ditches and Ponds. On the Hanford Site, waste water discharge into ponds and ditches occurs in the 200 and 300 Areas. At these locations, several ponds, ditches, and trenches exist to hold waste waters, which eventually evaporate and/or infiltrate (e.g., 300 Area process trench and sanitary leach trench). Near the Hanford Site, manmade ponds exist at the

Siemans Nuclear Facility and at the City of Richland well field (USGS 1978; CWC-HDR, Inc. 1988).

2.2.2.2 Local. Two types of surface water exist on the 300-FF-5 operable unit: the Columbia River and groundwater seeps along the river bank. Major groundwater seeps along the west bank of the Columbia River in the vicinity of the 300-FF-5 operable unit have been identified, mapped, and sampled.

The river in the vicinity of the 300-FF-5 operable unit is influenced by the operational practices of the Priest Rapids Dam (upstream) and the McNary Dam (downstream) with respect to flowrate volumes, velocity, and depth.

The wetted width of the river near the operable unit ranges from approximately 550 m (1,800 ft) to 920 m (3000 ft). The range is due primarily to the presence of islands that occur throughout the Hanford Reach. Throughout this reach, the river is characterized by a narrow modern flood plain, one or two terrace levels, numerous point bars, and extensive islands. Typical maximum river depths in the vicinity of the 300-FF-5 operable unit range from 3.1 m (10 ft) to 12 m (40 ft) at normal flow rates. Channel sediments consist predominantly of sand and gravel with cobbles up to 20 cm (8 in) in diameter. Silt and clay occur in areas of low-energy flow, such as pools and channel margins.

Volumetric flow rates in the Columbia River along the Hanford Reach vary due to operation of the Priest Rapids Dam by Public Utility District No. 2 of Grant County. Daily flow rates may range from 1,000 to 4,500 m^3/s (36,000 to 160,000 ft^3/s) and are accompanied by fluctuations in river stage of about 1.5 m (5 ft) (ERDA 1975). The flow velocity, which also varies along the reach, may range from 1 to greater than 3 m/s (3 to >10 ft/s).

The pressure transducer data collected at the river stage recorder showed that the operational practices at Priest Rapids and McNary Dams resulted in daily river stage (elevation) changes of as much as 2.4 m/d (8 ft/d), but more typically less than or equal to 0.8 m/d (2.5 ft/d) (Campbell et al. 1993). Groundwater elevation data collected by Campbell et al. (1993) indicate that the river gradient is not uniform along the 300-FF-5 operable unit boundary because of the influence of the McNary pool, but is approximately 0.19 m/km (1 ft/mi) based on March 1992 data.

2.2.3 Geological Characteristics

This section describes local geologic characteristics of the 300-FF-5 operable unit. The information in this section has been summarized from Gaylord and Poeter (1991), Delaney et al. (1991), and Swanson et al. (1992), unless otherwise noted. These references may be consulted for details regarding regional geologic characteristics or additional information on the 300-FF-5 operable unit.

2.2.3.1 Geomorphology. The physiography of the Hanford Site is dominated by the low-relief plains of the Central Plains physiographic region and the anticlinal ridges of the Yakima Folds physiographic region. The surface topography at the Hanford Site is the result of (1) uplift of anticlinal ridges, (2) Pleistocene cataclysmic flooding, (3) Holocene eolian activity, and (4) landsliding. Uplift of the ridges began in the Miocene Epoch and continues to the present. Cataclysmic flooding occurred when ice dams in western Montana and northern Idaho were breached, allowing large volumes of water to spill across eastern and central Washington. The last major flood occurred about 13,000 years ago during the late Pleistocene Epoch. Anastomosing flood channels, giant current ripples, bergmounds, and giant flood bars are among the landforms created by these major floods. Since the end of the Pleistocene Epoch, winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and loess (windblown silt) around the margins of the Pasco Basin. Generally, sand dunes have been stabilized by anchoring vegetation except where vegetation is disturbed or absent.

The Pasco Basin is bounded on the north by the Saddle Mountains anticline, on the west by the Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills anticlines, and on the south by the Rattlesnake Mountain anticline. The Palouse slope, a west-dipping monocline, bounds the Pasco Basin on the east. The Pasco Basin is divided into the Wahluke and Cold Creek synclines separated by the Gable Mountain anticline, the eastern extension of the Umtanum Ridge anticline.

The Cold Creek syncline lies between the Umtanum Ridge-Gable Mountain uplift and the Yakima Ridge uplift and is an asymmetric and relatively flat-bottomed structure. The bedrock of the northern limb dips gently (approximately 5 degrees) to the south. The 300 Area lies at the southern end of the Cold Creek syncline where it merges with the Pasco syncline.

2.2.3.2 Regional Geology.

2.2.3.2.1 Regional Stratigraphy. The Hanford Site is situated within the Pasco Basin, a regional structural and topographic, sediment-filled basin within the Columbia Plateau. The sediments within the Pasco Basin are underlain by the Miocene-age Columbia River Basalt Group, a thick sequence of flood basalts that covers a large area in eastern Washington, western Idaho, and northeastern Oregon. The Columbia River Basalts are underlain by Early Neogene sediments and eventually crystalline bedrock. The sediments overlying the basalts, from oldest to youngest, include: the Miocene-Pliocene Ringold Formation, local alluvial deposits of possible late Pliocene or probable early Pleistocene age, local early "Palouse" soil of mostly eolian origin derived from either the reworked Plio-Pleistocene unit or upper Ringold material, glaciofluvial deposits of the Pleistocene Hanford formation, and surficial Holocene eolian and fluvial sediments. Figure 2-3 illustrates the stratigraphy in the Pasco Basin.

The Columbia River Basalt Group comprises an assemblage of tholeiitic, continental flood basalts of Miocene age with accumulated thickness within the downwarped Pasco Basin in excess of 3,000 m (10,000 ft). The Columbia River Basalt Group is formally divided into five formations (from oldest to youngest): Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt.

The Ellensburg Formation consists of all sedimentary units that occur between the basalt flows of the Columbia River Basalt Group in the central Columbia Basin. The Ellensburg Formation generally displays two main lithologies, volcaniclastics and siliciclastics.

The suprabasalt sedimentary sequence at the Hanford Site is up to approximately 230 m (750 ft) thick in the west-central Cold Creek syncline, while it pinches out against the anticlinal ridges that bound or are present within the Pasco Basin. The suprabasalt sediments are subdivided into (in ascending order) the Ringold Formation, Hanford formation, and unnamed alluvial and eolian sediments.

Ringold Formation. Overlying the Columbia River Basalt Group is the late Miocene to Pliocene-aged Ringold Formation, which consists of interstratified deposits of sand, silt, clay, and gravel. This formation is up to 185 m (600 ft) thick in the deepest part of the Cold Creek syncline and pinches out against the anticlinal ridges that bound or are present within the Pasco Basin.

The Ringold Formation consists of semi-indurated clay, silt, pedified mud, fine- to coarse-grained sand, and granule-to-cobble gravel that usually are divided into the (1) gravel, sand, and paleosols of the basal unit, (2) clay and silt of the lower unit, (3) gravel of the middle unit, (4) mud and lesser sand of the upper unit, and (5) basaltic detritus of the fanglomerate unit.

Post-Ringold Pre-Hanford Deposits. Thin alluvial deposits situated stratigraphically between the Ringold Formation and Hanford formation are found within the Pasco Basin, but not within the 300 Area. Therefore, they are only briefly discussed. These deposits are referred to informally as (1) Plio-Pleistocene unit, (2) pre-Missoula gravels, and (3) early "Palouse" soil.

Hanford Formation. The Hanford formation consists of unconsolidated, glaciofluvial sediments that were deposited during several episodes of cataclysmic flooding during the Pleistocene Epoch. The sediments are composed of pebble-to-boulder gravel, fine- to coarse-grained sand, and silt and are divided into gravel-dominated deposits and deposits dominated by sand and silt. The Hanford formation is commonly divided into two informal members, the Pasco gravels and Touchet Beds (DOE 1988).

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

2.2.3.3 Local Geology. The 300 Area is situated at the south end of the Cold Creek syncline. The geologic units found in the 300 Area are, from the oldest to the youngest, (1) Saddle Mountains Basalt, (2) Ringold Formation, (3) Hanford formation, and (4) Holocene surficial deposits. The distribution of these units is shown in Figures 2-4 to 2-9. The information in this section has been summarized from Swanson et al. (1992), which may be consulted for additional details regarding local geologic characteristics in the operable unit. Additional information on the geologic variability within the 300-FF-5 operable unit and, in particular, information on the Holocene soil horizon and the Hanford/Ringold contact is provided in Kunk et al. (1993).

2.2.3.3.1 Local Stratigraphy

Saddle Mountains Basalt. The Ice Harbor Member of the Saddle Mountains Basalt is the uppermost basalt unit in the 300 Area. The Ice Harbor Member is of limited lateral extent, being found only in the eastern Pasco Basin.

Ringold Formation. The Ringold Formation consists of semi-indurated clay, silt, pedified mud, fine- to coarse-grained sand, and granule-to-cobble gravel. Characteristics typical of the three observed Ringold Formation facies associations (defined on the basis of lithology, petrology, stratification, and pedogenic alteration) found in the 300 Area are as follows:

> **Fluvial gravel** -- Clast-supported granule-to-cobble gravel with a sandy matrix dominates the association. Intercalated lenses of sand and mud are also found. Compaction and cementation are highly variable, with most cementation consisting of calcium carbonate and iron oxides. The association was deposited in a gravelly fluvial braidplain characterized by wide, shallow, shifting channels.
>
> **Overbank deposits** -- Laminated-to-massive silt, silty fine-grained sand, and paleosols containing variable amounts of pedogenic calcium carbonate dominate this association. Overbank deposits occur as thin (<0.5 to 2 m [1.6 to 6.5 ft]) lenticular interbeds in the fluvial gravel

and fluvial sand associations and as thick (up to 10 m [33 ft]) laterally continuous sequences. These sediments record deposition in proximal levee to more distal floodplain conditions.

Lacustrine deposits -- Plane laminated-to-massive clay with thin silt and silty sand interbeds displaying some soft-sediment deformation dominate this association. Coarsening upwards sequences less than 1 m (3.3 ft) to 10 m (33 ft) thick are common. Strata comprising the association were deposited in a lake under standing water to deltaic conditions.

Ringold strata in the 300 Area are generally divided into a lower, mud-dominated sequence and an upper, gravelly sequence (Figures 2-5 through 2-8). The lower mud sequence, previously known as the M-3 mud unit (DOE-RL 1990a), is correlated to the lower mud sequence that is found throughout the Pasco Basin near the bottom of the Ringold Formation (Delaney et al. 1991, Lindsey 1991). All wells in the 300 Area drilled to the depth of the lower mud sequence have encountered it. Therefore, it appears that erosional windows through the lower mud sequence are not present in the vicinity of the 300-FF-5 operable unit. However, the rapid thinning of the unit observed to the north and west suggests that the unit may be absent at locations adjacent to the 300 Area. This stratigraphic interval, which ranges from 2.5 to 24 m (8 to 80 ft) in thickness, thins to the north and west and thickens to the south. The lower mud sequence generally appears to be dominated by massive-to-crudely laminated clay and silt (Swanson et al. 1993).

Throughout the 300 Area, the lower mud sequence is overlain by deposits dominated by the clast-supported gravels typical of the fluvial gravel facies association. The gravelly strata overlying the lower mud sequence in the 300 Area can be correlated with the Ringold gravel units B, C, and E (Delaney et al. 1991, Lindsey 1991). Neither the fluvial gravels of units A and D nor the fluvial sands and overbank deposits of the upper Ringold are found in the 300 Area (Swanson et al. 1993). These deposits are similar to sediments designated Ringold lithofacies G by Gaylord and Poeter (1991). Two mud-dominated intervals are locally found in the upper gravel sequence in the 300 Area. The lowest of these, designated mud A, is found only in the southern and western part of the area (Figures 2-5 through 2-8), where it is up to 4 m (13 ft) thick. The uppermost mud-dominated interval consists of a series of laterally discontinuous muds that lie at approximately the same stratigraphic horizon. These muds are designated B, C1, and C2. Mud intervals B, C1, and C2 consist dominantly of paleosols such as those comprising the overbank facies association (Lindsey 1991) and Gaylord and Poeter's (1991) Ringold lithofacies M and MS. Mud B is 0 to 11 m (0 to 37 ft) thick and forms a broad tract through the west-central part of the 300 Area. Units C1 and C2 form thin lenses 0 to 6 m (0 to 20 ft) thick that are only found in the east-central part of the 300 Area. Muds B, C1, and C2 roughly correspond to Gaylord and Poeter's (1991) accessory No. 2 mud/silt hydrofacies (Swanson et al. 1993).

There is evidence from borehole logs of erosion and channelization of the top of the Ringold Formation throughout the 300 Area (Figure 2-9). This erosion has produced several lows in the top of the Ringold Formation that generally extend from west to east across the area.

Hanford Formation. The Hanford formation in the 300 Area consists of two main facies discussed in Delaney et al. (1991). It is dominated by pebble-to-boulder gravels typical of the gravel-dominated facies. Sandy horizons typical of the sand-dominated facies are present locally. Slackwater fines or graded rhythmites (interbedded silts and sands) are absent. Typical characteristics of the two Hanford formation facies associations found in the 300 Area are as follows:

- The gravel-dominated facies generally consists of granule-to-boulder gravel with a dominantly sand matrix. These deposits typically display massive bedding, planer-to-low-angle bedding, and large-scale scour cut-and-fill structures and forest bedding in outcrops. The gravel-dominated facies usually display an open-framework texture because of their lack of matrix. Lenticular sand and silt beds are intercalated throughout the facies. Gravel clasts in the facies generally are dominated by basalt (50 to 80%). The gravel-dominated facies was deposited by high-energy flood waters in or immediately adjacent to the main cataclysmic flood channelways.

- The sand-dominated facies is characterized by fine- to coarse-grained sand and granular gravel displaying plane lamination and bedding and, less commonly, plane bedding and channel-fill sequences in outcrop. These sands may contain small pebbles and rip-up clasts in addition to pebble-gravel interbeds and silty interbeds less than 1 m (3.3 ft) thick. The silt content of these sands is variable, but where it is low, an open framework texture is common. These sands typically are basaltic, commonly referred to as black, gray, or salt-and-pepper sands. The laminated sand facies was deposited adjacent to main flood channelways during the waning stages of flooding and as water spilled out of channelways.

The gravel-dominated facies is divided into two sediment types, pebble-cobble gravel, which is the most common in the 300 Area, and boulder-rich gravel. The pebble-cobble gravel generally consists of open-framework pebble-to-cobble gravels that contain single boulders up to 1 m (3.3 ft) in diameter. The matrix of these gravels is dominated by coarse-grained sand and granules. Interbedded strata consisting of boulder-rich deposits and sand-rich horizons are encountered locally. Mud is relatively rare in the matrix. The boulder-rich gravels are distinguished from the pebble-cobble gravels on the basis of increased boulder content (greater than 25% boulder-sized material). The matrix of these gravels is dominated by coarse-grained sand and granules. Except for elevated boulder content, the boulder-rich gravels display textures and structures similar to the pebble-cobble gravels. The thickest occurrence of boulder-rich gravels is found in the central eastern part of the 300 Area, where up to 18 m (60 ft) of such strata is encountered (Figures 2-5 through 2-8).

The sand-dominated facies consists largely of basaltic coarse-grained sand and granules, although the pebble content can range from <5% to as much as 50%. Pore-filling matrix is relatively rare, giving these sands an open-framework texture similar to that seen in the gravel-dominated facies. Laminated sand facies consist of fine- to coarse-grained sand that may contain small pebbles or pebble-gravel interbeds <20 cm (8 in.) thick. Thick occurrences of the sand-dominated facies are relatively rare, although it can be locally abundant.

Holocene Deposits. Holocene surficial deposits in the 300 Area consist dominantly of eolian silts and fine-grained sands. These deposits are found in thin (0 to 2m [0 to 6.6 ft]) sheets and thicker (0 to 4.5 m [0 to 15 ft]) dunes north, west, and south of the main developed part of the 300 Area. Inside the 300 Area fence, and locally elsewhere, the eolian deposits are absent largely as a result of human activity. Minor occurrences of overbank silt and sand alluvial deposits may also be found in the area immediately adjacent to the Columbia River (Swanson et al. 1993). Additional information on the Holocene soil horizons is discussed in Kunk et al. (1993).

2.2.3.3.2 Local Structure. The 300 Area is situated at the north end of the Pasco syncline. The Pasco syncline in this area is generally a northwest-southeast trending structure that is essentially continuous with the Cold Creek syncline, which underlies the south-central Hanford Site. The amplitude of folding within the Pasco Sycline in the vicinity of the 300 Area is relatively small. The basalts and overlying suprabasalt sediments are essentially flat lying beneath the 300 Area. No evidence of faulting was observed in the basalts or sediments beneath the 300 Area (Swanson et al. 1993).

2.2.4 Hydrogeological Characteristics

The discussion on regional hydrogeology summarizes groundwater conditions in the Pasco Basin, detailing the primary aquifers and providing the regional context to understand the local hydrogeology. The local hydrogeology is focused at the 300-FF-5 operable unit scale and relies primarily on data presented in Gaylord and Poeter (1991), Graham et al. (1981), and Swanson et al. (1992).

2.2.4.1 Regional Hydrogeology. The hydrogeology of the Pasco Basin has been broadly characterized as consisting of four primary hydrogeologic units (DOE 1988). These units correspond to the upper three formations of the Columbia River Basalt Group (Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt) and the sedimentary overburden. The basalt aquifers consist of the flood basalts of the Columbia River Basalt Group and relatively minor amounts of intercalated fluvial and volcaniclastic sediments of the Ellensburg Formation. Confined aquifers are present in the sedimentary interbeds and/or interflow zones that occur between dense basalt flows. The suprabasalt sediment, or uppermost aquifer system, consists of fluvial, lacustrine, and glaciofluvial sediments. This aquifer is regionally unconfined and is contained mainly within the Ringold Formation and Hanford formation.

2.2.4.1.1 Unconfined Aquifer. The unconfined aquifer lies within the boundaries of the Pasco Basin, where it is contained within the Hanford formation sands and gravels and the Ringold Formation sands, silts, and gravels. The aquifer is over 70 m (230 ft) thick in the southern areas of the Hanford Site and thins to zero thickness along the flanks of the bordering anticlinal structures to the north and west. Some local basalt highs within the basin protrude above the water table, the most notable of which are Gable Mountain and Gable Butte on the Hanford Site (Graham et al. 1981). The base of the unconfined aquifer is generally defined as the top of the lower mud unit of the Ringold Formation or the uppermost basalt flow.

Recharge. Sources of natural recharge to the unconfined aquifer are rainfall and runoff from the bordering higher elevations, water infiltrating from small ephemeral streams, and river water along influent reaches of the Yakima and Columbia rivers. The Yakima River recharges the unconfined aquifer along its reach from Horn Rapids Dam to Richland. During high stages of the Columbia River, river water moves into the unconfined aquifer, a phenomenon known as bank storage. Within the basin, upward leakage from the lower basalt aquifers may enter the unconfined aquifer.

Artificial recharge to the groundwater occurs in the basin from two sources: agricultural irrigation and waste disposal operations at the Hanford Site. Recharge from Hanford waste disposal practices has occurred at many locations over the site from effluent discharges to ponds, cribs, trenches, and drywells. Recharge through ponds and cribs in the 200 Area is the largest single artificial recharge source, beginning in the late 1940's and continuing to the present. Other artificial recharge sources include infiltration ponds at the Siemans Nuclear Facility and infiltration ponds at the City of Richland well field (DOE 1988).

Groundwater Movement. From the recharge areas, the groundwater flows from topographic highs to the discharge areas, primarily the Columbia River. Before operations at the Hanford Site began in 1944, regional groundwater flow was generally toward the east-southeast, although flow north of Gable Mountain was more northward. The regional groundwater flow for the Hanford Site now trends in a more northeasterly direction. Currently at the Hanford Site south of Gable Mountain, flow is interrupted locally by the groundwater mounds in the 200 Area. Regional groundwater flow for the Hanford Site is shown in Figure 2-10.

Discharge. Groundwater discharge from the unconfined aquifer under the Hanford Site is almost exclusively to the Columbia River north of Richland, Washington. Localized downward leakage to the lower confined aquifers may occur in effluent discharge areas where the water table elevation is above the potentiometric level of the confined aquifer (DOE/RL 1993a).

West Lake (Figure 2-2) is hydraulically connected to the unconfined aquifer and represents a topographic depression that intersects the water table. Because of high surface water evaporation rates and low surface overland flow, even during storms, the lake is expected to show a net loss of groundwater and thus be a local discharge zone.

Hydraulic Properties. The geologic and hydraulic properties of the Pasco Basin sediments are highly variable. Results of studies on the hydraulic properties of the suprabasalt sediments are presented in Swanson et al. (1992). Generally, saturated hydraulic conductivity is greater in the Hanford formation, where values from 10^{-1} to 10^{1} cm/s (10^{2} to 10^{4} ft/d) are typical, than in the Ringold Formation, where hydraulic conductivities are generally from about 10^{-5} to 10^{-1} cm/s (10^{-2} to 10^{2} ft/d).

2.2.4.1.2 Confined Aquifers. A multiple confined aquifer system occurs within the Columbia River Basalt Group underlying the Pasco Basin (Deju and Fecht 1979; Gephart et al. 1979; DOE 1988). The confined aquifers consist primarily of interbeds within the basalt (DOE 1988). Interbed aquifers of the Saddle Mountains Basalt range in thickness from 6 to 35 m (20 to 100 ft) and are likely localized to the Pasco Basin by geologic structures along the basin margin (Gephart et al. 1979; DOE 1988). Confined aquifers occur within the lower portion of the Ringold Formation below the lower mud unit (M-3), but are generally more limited in areal extent than the unconfined aquifer.

Recharge. Recharge to the Saddle Mountains Basalt is primarily from infiltration of meteoric water and stream runoff where the basalt formations are at or near ground level. Artificial recharge could be occurring from the unconfined aquifer, as evidenced by present-day water levels that show the unconfined aquifer water table lies above the potentiometric surface of the Rattlesnake Ridge interbed under major disposal ponds, creating the potential for aquifer leakage from the unconfined to the confined aquifers in these areas (Graham et al. 1981).

Movement. The potentiometric surface is influenced by the areas of recharge and discharge for the confined aquifer. In the southern portion of the Hanford Site, this movement is assumed to generally conform closely with the regional dip of the basalts along the axis of the Cold Creek syncline (southeast trending). However, in the northern portion of the Hanford Site, flow is toward the Gable Mountain-Gable Butte area (Graham et al. 1981).

Discharge. The major discharge area for the southern portion of the Saddle Mountains Basalt aquifers is assumed to be to the unconfined aquifer and to the Columbia River near Richland (Gephart et al. 1979; Delaney et al. 1991). In this area, the potentiometric surface lies above the mean stage of the river.

Hydraulic Properties. Hydraulic conductivities within the basalt interbeds are generally orders of magnitude lower than those observed in the unconfined aquifer. Hydraulic transmissivity values for the confined aquifers were obtained primarily from aquifer tests conducted at wells within the Hanford Site (Graham et al. 1981).

2.2.4.2 Local Hydrogeology. The hydrogeologic system in the 300-FF-5 operable unit is generally congruent with the regional hydrogeologic model of the Hanford Site. The vadose zone consists predominantly of sandy gravel, gravelly sand, and silty, sandy gravel of the Hanford formation. The unconfined (water table) aquifer occurs within both the Hanford and Ringold Formations and is contiguous with the regionally extensive unconfined aquifer observed below most of the Hanford Site. The local hydrogeologic model discussed in this section was developed from data acquired in previous investigations, data collected during the installation and monitoring of the observation wells, and data acquired through aquifer tests (DOE-RL 1993a).

In general, the unconfined aquifer consists of the relatively permeable, silty, sandy gravels of the Ringold Formation. In addition to the unconfined aquifer, at least three distinct hydrogeologic units (semi-confined to confined aquifers) separated by mud units of the Ringold Formation may be present at well cluster sites 699-S22-E9X and 699-S27-E9X, above the Saddle Mountains Basalt (see Figure 2-4 for well locations). The presence of semi-confining conditions was determined from the lack of drawdown response in the lower aquifers during a constant-discharge test. In the deep confined wells (C wells) below the lower mud unit (M-3) at each well cluster, the potentiometric level rises to near ground surface at well cluster 699-S27-E9C and is above ground at well cluster 699-S22-E9C. There is an upward hydraulic gradient in this area (which is the general case for the 300 Area), indicating that this is a discharge region for the semi-confined and confined aquifers (Swanson et al. 1993).

2.2.4.2.1 Vadose Zone. The vadose zone is the region above the water table in which the fluid pressures of the sediments are negative with respect to local atmospheric pressure. The vadose zone occurs between the ground surface and the water table and is the zone through which natural meteoric infiltration and manmade discharge effluent waters may flow to the water table. The vadose zone consists predominantly of unsaturated interlayered sandy gravel, gravelly sand, and silty, sandy gravel of the Hanford formation. The thickness of the vadose zone in the 300-FF-5 operable unit ranges from approximately 6 m (20 ft) at wellsite 699-S22-E9X to 12 m (40 ft) at wellsite 699-S27-E9X (both on the western boundary of the operable unit) (Swanson et al. 1993) to zero at the edge of the Columbia River.

2.2.4.2.2 Unconfined Aquifer. The unconfined aquifer in the 300-FF-5 operable unit occurs between the water table and the lower mud (LM) unit of the Ringold Formation. This aquifer is approximately 6 to 12 m (20 to 40 ft) below the surface at the western boundary of the operable unit and zero to 0.5 m (0 to 1.5 ft) below the surface at the edge of the Columbia River. The thickness of the unconfined aquifer is relatively constant at approximately 12 m (40 ft) in the 300-FF-5 operable unit (Swanson et al. 1993). Locations of completed wells in the 300-FF-5 operable unit are shown in Figure 2-11. The "A" wells are completed near the upper surface of the unconfined aquifer, "B" wells are completed in the semi-confined aquifers, and "C" wells are completed in the confined basalt aquifer.

Recharge. Sources of recharge to the unconfined aquifer in the 300-FF-5 operable unit are precipitation and infiltration of runoff to the water table, principally around the periphery of the Pasco Basin. Little natural recharge to the groundwater occurs in the 300 Area because of the high rates of evapotranspiration. Artificial recharge to the groundwater is occurring in the study area primarily from effluent discharges to the 300 Area process trenches and sanitary trenches. During high stages of the Columbia River temporary inflow of river water to the aquifer occurs. An additional source of recharge is upward leakage from the lower confined basalt aquifers to the semi-confined aquifer and unconfined aquifer.

Groundwater Movement. As shown in Figure 2-12, groundwater flow in the 300-FF-5 operable unit is generally from west to east, similar to the regional system. However, surrounding groundwater converges on the 300-FF-5 area as it discharges into the Columbia River. Groundwater flow from the northwest to the southeast in the north part of the operable unit is due to discharge in the 200 Area and inflows from Cold and Dry Creeks. Groundwater flow is from the southwest to the northeast for the southern portion of the operable unit because of inflows from the high surface water elevations of the Yakima River. Groundwater movement is very dynamic close to the Columbia River and is dependant on the transient stage of the river. Some reversal or reduction of the water table gradient occurs during high river stages of the unconfined aquifer when inflow (bank storage) from the river into the unconfined aquifer occurs.

Vertical Gradients. Data from clustered monitoring well groups in the 300-FF-5 operable unit were evaluated to determine the presence, magnitude, and direction of vertical gradients between the basalt (confined) aquifer and the suprabasalt (semi-confined and unconfined) aquifers (Campbell et al. 1993). Hydraulic heads in the confined aquifer are generally about 10 m (33 ft) higher than in the unconfined and semi-confined aquifers. An upward gradient also exists between the semi-confined and unconfined aquifers; head differences of approximately 1.0 m (3.3 ft) to 0.09 m (0.3 ft) existed between the semi-confined and unconfined aquifers for the clustered monitoring well groups that had upward gradients. Clustered well group 699-S29-E16, located in the southeastern portion of the operable unit near the Columbia River, had a slight downward gradient of 0.05 m (0.16 ft) between the upper (A well) and the lower (B well) portions of the unconfined aquifer.

Discharge. Discharge of groundwater from the unconfined aquifer occurs to the Columbia River. However, the Columbia River has a variable stage of several feet over a period of days to weeks, significantly affecting the local water table in the area. At high- river level stages, the surface water from the Columbia River recharges the aquifer (bank storage) and reduces water table gradients in the vicinity of the river. During low-river level stages, the groundwater discharges into the Columbia River with steeper water table gradients across the site. The inherent heterogeneity of the subsurface geology results in higher conductivity zones that exhibit a faster response than surrounding sediments to the variable river stages (DOE-RL, 1993a).

The groundwater elevation data indicated that groundwater flows toward the river in the 300-FF-5 operable unit, where it enters a zone of higher transmissivity that apparently runs parallel to the river. Lower transmissive zones (possibly remnant protrusions of the upper Ringold Formation units) exist along the river and impede groundwater discharge to the river (and bank storage to the aquifer). Groundwater flow in the unconfined aquifer is dominantly directed around these lower transmissive protrusions and through the higher transmissive areas where it eventually discharges to the Columbia River (Campbell et al. 1993).

Hydraulic Properties. Estimated conductivities for well 699-S22-E9X and 699-S27-E9X were 36 m/day (120 ft/day) and 50 m/day (160 ft/day) for the horizontal direction (Swanson et al.

1992). These hydraulic conductivity estimates are lower than previous studies conducted in the 300 Area (Schalla et al., 1988). Since these wells are located in the eastern portion of the 300 Area, their conductivities probably reflect a different dispositional environment than in the western margin of the 300-FF-5 operable unit adjacent to the Columbia River. As discussed in the RI (DOE-RL 1993a), a more likely range for hydraulic conductivity along the Columbia River is 3,000 m/day (10,000 ft/day) to 15,000 m/day (50,000 ft/day). The differences in hydraulic conductivity indicate that the aquifer is very heterogeneous (DOE-RL 1993a).

2.2.5 Ecological Characteristics

2.2.5.1 Human Ecology.

2.2.5.1.1 Land Use.

Regional Land Use. The region consists of the incorporated cities of Richland, West Richland, Kennewick, and Pasco, and of the surrounding communities within Benton and Franklin Counties. Land use in the region is primarily agricultural, residential, industrial, and recreational.

Most agricultural lands are located north and east of the Columbia River and south of the Yakima River. The land is used primarily for dryland and irrigated crop production and for livestock grazing. Principal agricultural products include hay, wheat, vegetables, apples, grapes, other fruits, and hops.

Residential land use is concentrated around the incorporated areas. Industrial lands are concentrated east of Kennewick along the Columbia River. Most industrial activities in the region are associated with either agriculture or energy production.

That portion of the Hanford Site located north of the Columbia River consists of two wildlife reserves: the Wahluke Slope Wildlife Area, a Washington State Department of Wildlife management area, and the Saddle Mountain National Wildlife Refuge, managed by the U.S. Fish and Wildlife Service. The northeast slope of the Rattlesnake Hills, along the southwestern boundary of the Hanford Site, is designated as the Arid Lands Ecology Reserve and it is used for ecological research. The Arid Lands Ecology Reserve and the entire Hanford Site are designated a National Environmental Research Park (DOE-RL 1990a).

The majority of private land located within a 1.6 km (1 mi) radius of the 300-FF-5 operable unit (across the Columbia River to the east) is zoned Agricultural Production (AG) by the Franklin County Planning Department. Hay production, grapes, and orchards comprise the primary agricultural activities in this area.

Based on 1980 census data, 53,000 people live within 16 km (10 mi) of the 300 Area. Approximately 10 residences are within a 1.6 km (1 mi) radius of the 300-FF-5 operable unit, approximately 1.4 km (0.9 mi) east across the Columbia River. The nearest of these is located along the east bank of the Columbia River, approximately 0.8 km (0.5 mi) east of the 300-FF-5 operable unit. The City of Richland corporate boundary is about 0.5 km (0.3 mi) to the south, and the nearest Richland residences are about 3.3 km (2 mi) from the 300-FF-5 operable unit (DOE-RL, 1990a). The estimated population of the region in 1991 was 153,400, with 114,800 residents in Benton County and 38,600 residents in Franklin County.

Local Land Use. For reasons of national security, as well as to ensure public health and safety, access to the entire Hanford Site is administratively controlled and is expected to remain controlled for the foreseeable future. Current land use activities associated with the 300 Area are all industrial in nature. Specific uses include active laboratories, project research, miscellaneous operations related to the Hanford Site, and waste management facilities.

2.2.5.1.2 Water Use. The Columbia River is the most significant surface water body in the region. It is used as a source of drinking water, industrial process water, crop irrigation, and for a variety of recreational activities, including fishing, hunting, boating, water skiing, and swimming. Water intakes in the vicinity of the 300-FF-5 operable unit (Figure 1-2) include the 300 Area intake located just downstream of the south process pond (316-1) and the City of Richland intake located approximately 3.25 km (2.75 mi) south of the 300-FF-5 operable unit. Additional intakes, used for irrigation, include the Washington State University and PNL intakes. A farm irrigation intake (the Wiser Company water intake) supplies farmland west of the 1100-EM-1 operable unit.

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

Swimming and water skiing are also popular recreational activities. In the region, both of these activities are centered downstream in McNary Reservoir. However, a public swimming area has been established at Leslie R. Groves Park, which is approximately 0.8 km (0.5 mi) downstream from the city water intake (DOE-RL 1990a).

2.2.5.1.3 Cultural Resources. Late prehistoric material is prevalent throughout the 300 Area, especially adjacent to the Columbia River. Refer to Section 3.7.1.3 of the Phase I RI (DOE-RL 1993a) for more detailed discussion.

2.2.5.2 Wildlife Ecology. The Hanford Site is located in the big sagebrush/bluegrass/ wheatgrass plant community. The dominant shoreline (riparian) flora species in the 300-FF-5 operable unit consist of white mulberry, peachleaf willow, reed canary grass, bulbous bluegrass, and a large variety of forbs. The non-riparian flora species include cheatgrass, russian thistle, and rabbit brush species. One protected species, persistentsepal yellowcress, was found in the riparian environment.

Fauna observed in the 300-FF-5 operable include several reptiles, such as the western yellow-bellied racer, gopher snake, and several species of lizards. Fifty-three species of birds were documented during winter and summer surveys, including ring-billed and California gulls, bank swallows, a variety of ducks, and Canada geese. Approximately 40 species of mammals have been identified on the Hanford Site. The most abundant small mammals captured in the 300-FF-5 operable unit were the house mouse and the Great Basin pocket mouse. A total of 44 fish species have been identified in the Hanford Reach portion of the Columbia River. Refer to Section 3.7.2 of the RI (DOE-RL 1993a) for a more detailed discussion.

2.2.5.3 Sensitive Environments. Sensitive environments in the 300-FF-5 operable unit include the Columbia River, the riparian zone along the river shore, and the terrestrial mature sagebrush and bitterbrush habitat of the northern boundary of the site. Refer to Section 3.7.3 of the Phase I RI for a more detailed discussion (DOE-RL 1993a). Because groundwater remedial alternatives generally do not involve extensive disturbance of natural environments, detailed delineation of habitat extent is generally not necessary.

2.3 NATURE AND EXTENT OF CONTAMINATION

In Chapter 4 of the Phase I RI report (DOE-RL 1993a), compounds that potentially pose a chemical or radiological risk to human health and the environment are defined. Each of these contaminants of potential concern were identified through a step-wise screening process, which compared the chemical constituents detected in each of the media against laboratory and field blank data, background concentrations, appropriate regulatory criteria, and media-specific risk-based benchmark screening concentrations. This section summarizes the contaminants of potential concern that were preserved through the screening process and were carried forward into the baseline risk assessment, as well as their extent within each medium of concern: groundwater, river sediment, surface water, and riparian biota. Table 2-1 lists the contaminants of potential concern for each of the exposure scenarios and the maximum concentration detected in each medium. The constituents listed in Table 2-1 were further screened in the risk assessment to arrive at the list of constituents of concern (Section 2.5).

2.3.1 Sources of Contaminants

As discussed in Chapter 1, sources of groundwater contaminants in the 300-FF-5 groundwater operable unit are not addressed in this FS. Sources of contamination include the three source area operable units above the water table (300-FF-1, 300-FF-2, and 300-FF-3) and groundwater contamination upgradient (to the north and west) of the 300 Area. Figure 1-3 identifies significant facilities in the 300-FF-1 operable unit which contributed to groundwater contamination.

2.3.2 Groundwater

Figure 2-11 shows the groundwater monitoring well network in the 300 Areas. For groundwater, the identified contaminants of potential concern are:

- Total coliform bacteria, 1,2-dichloroethene (DCE) (total and trans), trichloroethene (TCE), chloroform, nitrate, Sr-90, Tc-99, tritium, total uranium, U-234, U-235, U-238, nickel, and copper.

As explained in the RI (DOE-RL 1993a), three background screening scenarios were performed for groundwater:

- results from all wells
- results from the existing production well (399-4-12)
- results from wells in the tritium plume

Compounds which were detected above background were further screened using risk-based and regulatory screening criteria. All of these contaminants of potential concern are associated only with the unconfined aquifer. The contaminants of potential concern that were identified for the confined aquifer were eliminated because of low frequency of detection, inconsistent detection, and/or suspected problems with poor well construction at well 399-1-16C.

Although there are not toxicity values available for which to calculate risk-based screening concentrations, total coliform bacteria was retained as a potential contaminant of concern based on regulatory standards. It is important to note that total coliform standards are not based on concentration. The total coliform standard is based on the number of samples collected from a drinking water supply and the percentage of these which are positive for coliform bacteria. Since compliance is based on samples collected from a drinking water supply, the results obtained from the 300-FF-5 RI are not necessarily applicable in determining compliance. In order to be conservative, the approach taken in the screening for total coliform bacteria has been to retain the parameter as a contaminant of potential concern (DOE-RL 1993a).

Groundwater contamination at the 300-FF-5 operable unit generally consists of three main plumes (Figure 2-13). The primary plume, and the only one of the three that is derived from 300 Area operations, is centered beneath the 300-FF-1 operable unit. Section 2.1 describes the source facilities, waste management units, and chemical processes in the 300 Area that have impacted the unconfined aquifer. Contaminants associated with this plume are total coliform bacteria, chloroform, DCE, TCE, nickel, copper, Sr-90, and the uranium isotopes. Concentrations of U-234, U-238, chloroform, and TCE are shown in Figures 2-14 through 2-18 to demonstrate the extent of contamination in this plume. Contour intervals shown on these figures generally represent Hanford Site background or potential regulatory cleanup levels, although in several instances (e.g., the chloroform contours) they were intended to best illustrate contaminant distribution. While the distribution of each of these contaminants varies somewhat because of differing transport properties and sources, maximum concentrations occur primarily in the vicinity of the process trenches and the north and south process ponds (see Figure 1-3 for locations of these facilities).

A second plume, consisting of tritium, is present throughout the north and eastern portions of the 300-FF-5 operable unit (Figure 2-19). This plume is derived from operations in the 200 Area and is migrating into the 300-FF-5 operable unit from the north (Figure 2-1). Maximum tritium concentrations (approximately 12,000 pCi/L) occurred in the northern portions of the operable unit and lower concentrations (approximately 1,000 pCi/L) occurred approximately 400 m (1300 ft) south of the 300-FF-1 operable unit (DOE-RL 1993a).

The third plume, consisting of technetium-99 and nitrate, is migrating from the vicinity of the 1100-EM-1 operable unit located approximately 1.6 km (1 mi) to the west of the southern portion of the 300-FF-5 operable unit (Figure 2-20). Figure 2-12 presents groundwater gradients and flow in the 300 Area operable unit and illustrates how groundwater moves from the 1100 Area towards the 300 Area. TCE is also present in groundwater at the 1100-EM-1 operable unit (DOE-RL 1990b and 1992c).

The current extent of groundwater contamination in the unconfined aquifer is presented in a series of plume maps prepared for compounds that display well-defined plume areas (i.e., compounds that were consistently detected throughout the operable unit). The plume maps are presented in Appendix K of the Phase I RI (DOE-RL 1993a) and are available for:

gross alpha	U-235
gross beta	U-238
Sr-90	chloroform
Tc-99	trichloroethene
total U	nickel
tritium	copper
U-234	

Constituent concentrations in seeps were screened as groundwater instead of surface water. This is because background concentrations in groundwater are more representative of seep concentrations than surface water background. In addition, the surface water exposure pathways would not be appropriate for seeps since it is unlikely that seeps would be used for drinking water, bathing, or swimming.

2.3.3 Sediment

Sediment samples were collected at four spring sites during low river stage levels. Hanford Site-specific background concentrations in river sediments (Weiss 1993) are available and were compared to detected compounds in 300 Area sediments. Compounds in the sediment detected above background concentrations were used during the risk-based and regulatory screening performed in the Phase I RI report (DOE-RL 1993a). No compounds were identified in sediments at concentrations that exceeded risk-based or regulatory screening. Thus, there were no contaminants of potential concern in the Columbia River sediments that were retained for use in the risk assessment (DOE-RL 1993a) and the sediment pathway was eliminated as a human exposure pathway in the risk assessment.

2.3.4 Surface Water

Contaminants of potential concern in surface water for the 300-FF-5 operable unit are: TCE, Tc-99, tritium, U-234, U-235, and U-238. Concentrations generally were observed to be highest close to the riverbank and lowest away from the riverbank. The maximum concentrations were all associated with the sample collected 1 m (3 ft) from the bank. It was also noted that concentrations generally increased toward the downstream end of the 300-FF-5 operable unit. The maximum river concentrations of the uranium isotopes, tritium, TCE, and Tc-99 all occurred at the SP11 sampling location (Figure 2-21).

The maximum value for fecal coliform bacteria was observed at the SP9 location, which is the closest sampling point to the sanitary trenches. Fecal coliform bacteria concentrations at sampling location SP9 were screened against regulatory standards because no toxicity values are available for which to calculate risk-based screening concentrations. Regulatory criteria for fecal coliform bacteria in surface water are based on organism density (counts per unit volume of water). Surface water fecal coliform densities were well below the regulatory standards, and therefore were eliminated as potential contaminants of concern for surface water.

2.3.5 Biota

A biotic uptake assessment was performed to determine if constituents of concern could be transported from contaminated groundwater and soil into the foodchain. Brandt et al. (1993) looked at several biological components, including riparian vegetation and small mammals. For vegetation, elevated concentrations of certain metals were noted in operable unit samples of reed canarygrass.

For small mammals (house mice and Great Basin pocket mice), Brandt et al. (1993) reported little difference between operable unit and control sample contaminant concentrations, except for higher manganese in pocket mice from the operable unit.

For aquatic vegetation, contaminants were analyzed in periphytic communities above and below the operable unit. Although the highest concentrations of most contaminants were found at the furthest downstream station, there was apparently little evidence of any tendency toward a downstream increase in contaminant concentrations. An evaluation of data collected from macrophytes, however, did show a general downriver increase in concentrations of aluminum, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. The implication of this trend was not addressed, however.

With regard to aquatic organisms, samples of whitefish and carp have been collected routinely from the Columbia River and analyzed for radionuclides. The results of the analyses are reported in the yearly Hanford Site Environmental Reports (Jaquish and Bryce 1990). There are no data from fish adjacent to the 300 Area; however, no difference in fish tissue constitent concentrations is apparent upgradient and downgradient of the Hanford Site.

2.4 CONTAMINANT FATE AND TRANSPORT

Section 5.1 of the Phase I RI (DOE-RL 1993a) provides an environmental fate analysis of each of the contaminants of potential concern defined for the 300-FF-5 operable unit. Contaminant fate is discussed as it relates to the environmental media of groundwater, surface water, and biota. The results of the fate analysis are used in the baseline risk assessment to determine human and ecological receptor exposure scenarios and pathways. Because coliform bacteria are organisms, and not a chemical compound, no risk quantification of this 300-FF-5 operable unit contaminant of potential concern was attempted.

The purpose of the transport analyses conducted in Chapter 5 of the Phase I RI (DOE-RL 1993a) is to provide reasonably conservative estimates of future contaminant concentrations at points of potential receptor exposure. These concentrations serve as input to the future exposure scenarios in the baseline risk assessment. The remainder of this section is a summary of the transport analysis.

A variety of techniques were used to predict future contaminant concentrations, including numerical and analytical simulation of groundwater transport and observed proportionality factors for future river concentrations. Trend analysis using historical data was not used because the process trench expedited response action (ERA) conducted in 1991 changed the contaminant flux to the aquifer. Insufficient historical data has been collected since the ERA to conduct trend analysis under the new conditions.

2.4.1 Groundwater Transport

The 300-FF-5 operable unit subsurface water transport pathway includes only the saturated zone. Transport in the 300 Area unsaturated zone is addressed in the source operable units 300-FF-1 through 300-FF-3. The purpose of the saturated transport pathway analysis was to calculate maximum future concentrations of the 300-FF-5 operable unit contaminants of potential concern in operable unit groundwater. Maximum concentrations were calculated for the year 2018 (Table 2-2) because this represents the first year that institutional control may be relaxed for groundwater use. Groundwater concentrations were assumed not to increase in the future. This assumption is valid for those contaminants whose surface or vadose zone source either is declining in strength, is removed, or is contained by source control measures (DOE-RL 1993a).

No transport analysis was performed for coliform bacteria, nitrate, technetium-99, or tritium. Transport analysis of coliform bacteria was not performed because future concentrations were assumed equal to those currently measured. Coliform bacteria are associated with sewage disposal, which is assumed to continue into the future. Nitrate, technetium-99, and tritium migrate as plumes into the 300-FF-5 operable unit from sources outside of the 300 Area. Transport modeling of nitrate, technetium-99 and TCE from the 1100-EM-1 operable unit are addressed in the 1100-EM-1 operable unit Phase I and II RI reports (DOE-RL 1990b and 1992c). Modeling of the tritium plume emanating from the 200 East Area is beyond the scope of this document, so future concentrations were assumed equal to present concentrations (DOE-RL 1993a).

Numerical modeling of uranium in the saturated pathway was performed by Westinghouse Hanford Company (WHC). Uranium was the only 300-FF-5 operable unit contaminant detected at high enough concentrations to warrant the resources required to run the numerical model. All other 300-FF-5 operable unit contaminants of potential concern were modeled analytically by solving an analytical solution to the equation describing groundwater flow and contaminant transport in saturated porous media. The analytical model was benchmarked by comparing uranium modeling results with the numerical model. Both models predicted similar maximum uranium concentrations at the year 2018.

Predictions of future uranium concentration in groundwater are uncertain. Uranium migration and fate in the aquifer is dependent on uranium's partitioning coefficient (K_d) between the aquifer water and soil matrix. Published uranium K_d values are generally between 1 and 10 mL/g (see Appendix I of the RI [DOE-RL 1993a]). Observations of uranium concentrations in aquifer soils and adjacent groundwater in the 300 Area indicate K_d's could be as high as 25 mL/g (Tyler 1992). Both numeric and analytic modeling were conducted for uranium using K_d's between 1 and 25 mL/g. Assuming a K_d of 1 mL/g, uranium contaminants will be flushed out of the unconfined aquifer by the year 2018. Assuming a K_d of 25 mL/g, remaining concentrations of total uranium will range from about 10 to 20 pCi/L in the aquifer by the year 2018.

The fate and migration of uranium in the aquifer may also be dependent on kinetic or equilibrium solubility constraints. The possibility exists that uranium floc that was discharged to the 300 Area process trenches and possibly other waste management units in the 300 Area could have migrated as a floc to the water table. This is possible because of the open gravels in the area and because of the high flux of percolating waste effluents to the water table after discharge. Another possibility is that uranium became oversaturated in the aquifer and precipitated as a solid floc. Measured soil concentrations, used to calculate K_d's as high as 25 mL/g, may actually represent secondary sources of uranium floc in the aquifer matrix that is slowly dissolving and that is not associated with soil sorption processes. Given the potential mass of uranium floc (based on aquifer soil samples), the estimated flux of groundwater in the impacted area, and the observed groundwater concentrations of uranium, modeling of uranium as a dissolving floc indicated that this secondary source could be dissipated by the year 2000. Uranium would then migrate through the aquifer into the Columbia River subject to retardation due to soil/water partitioning. Therefore, if secondary sources of uranium exist in the aquifer, they are predicted to add only about 10 years to the K_d-modeled results.

Results of the modeling demonstrate that the maximum concentrations of 1,2-dichloroethene (total) (150 μg/L or 1.3×10^{-6} lb/gal), dichloroethene (trans) (130 μg/L or 1.1×10^{-6} lb/gal), and trichloroethene (14 μg/L or 1.2×10^{-7} lb/gal) remained unchanged through the year 2018. This resulted because the hypothesized dissolving dense non-aqueous phase liquid (DNAPL) source was assumed to provide mass at a constant rate into the foreseeable future. The results also indicated that chloroform will flush out of the unconfined aquifer and into the Columbia River several years after disposal of discharge effluent to the process trenches has hypothetically ceased. The maximum concentration of copper was predicted to decrease from 11.6

μg/L ($9.68x10^{-8}$ lb/gal) to 1.5 μg/L ($1.3x10^{-8}$ lb/gal) between the years 1992 and 2018, while nickel was predicted to decrease from 118 to 50 μg/L ($9.85x10^{-7}$ to $4.2x10^{-7}$ lb/gal) during the same period. The predicted reduction in maximum concentration for strontium-90 between the years 1992 and 2018 was from 4.57 to 0.24 pCi/L, respectively.

2.4.2 Surface Water Transport

Columbia River transport of contaminated groundwater that discharges to the river along the boundary of the 300-FF-5 operable unit is the only surface water pathway for the operable unit. The purpose of the surface water transport analysis is to estimate future concentrations of the 300-FF-5 operable unit contaminants of potential concern in the Columbia River resulting from discharge of contaminated groundwater from the operable unit. Contaminant concentrations in the Columbia River were estimated at two potential receptor locations. The first location is near the southern boundary of the 300-FF-5 operable unit, where contaminant concentrations in the Columbia River adjacent to the 300 Area are generally greatest. The second receptor location is downstream of the 300 Area at the City of Richland river intake/pumphouse.

Future Columbia River concentrations were not estimated at either receptor location for total coliform bacteria, nitrate, technetium-99, and tritium. Sewage disposal in the 300 Area is a major source of total coliform bacteria, and is assumed to continue indefinitely. The maximum future concentration of total coliform bacteria in the Columbia River was therefore assumed equal to the maximum river concentration measured during the year 1992 (30 c/100 mL). Future concentrations of nitrate, technetium-99, and tritium were not estimated because the contamination originates outside of the 300 Area. Impacts to the Columbia River from the nitrate and technetium-99 plumes were modeled for the 1100-EM-1 operable unit Phase I and II RI reports (DOE-RL 1990b and 1992c). Much uncertainty exists with regard to future tritium concentrations. Although concentrations may rise or fall, it was assumed that concentrations of this contaminant would remain constant until the year 2018 (DOE-RL 1993a).

Calculating future contaminant concentrations in the Columbia River adjacent to the 300 Area was accomplished by first calculating an average and maximum "proportionality factor" representing the current flux of groundwater contaminants entering the river to observed average and maximum river concentrations. These proportionality factors were then multiplied by the contaminant mass flux estimated to enter the river in the future. At low river stages (maximum observed concentrations in river water), 1,2-DCE was not detected in river water, which prevented calculating a proportionality factor for this contaminant. The maximum future Columbia River concentrations of 1,2-DCE (total and trans) were therefore assumed to be at or near zero. Using the aforementioned method, the average and maximum future Columbia River concentrations were calculated and are presented in Table 2-3.

With the possible exception of copper and nickel, the maximum future mass flux into the Columbia River for all the 300-FF-5 operable unit contaminants of potential concern is expected to be equal to or less than the current mass flux into the river. Concentrations of the 300-FF-5 operable unit contaminants of potential concern are, therefore, generally not expected to increase at the City of Richland pumphouse due to discharge of contaminated groundwater from the operable unit into the Columbia River. It is possible that at the City of Richland pumphouse could experience a rise in the concentration of copper and nickel derived from the 300-FF-5 operable unit in the future. However, the calculated maximum future Columbia River concentrations of these two contaminants along the near shore in the 300 Area are still below risk-based standards, and these concentrations would be further diluted by the river water prior to reaching the City of Richland pumphouse approximately 1 mile downstream of the operable unit.

2.4.3 Biotic Transport

The 300-FF-5 operable unit includes both the riparian zone along the Columbia River shoreline and the terrestrial mature sagebrush and bitterbrush habitat along the north boundary of the operable unit. Contaminant transport in the riparian and terrestrial pathways begins at the primary producers, and continues through the herbivores, primarily carnivores, and secondary carnivores. The riparian zone includes wetlands protected under the Clean Water Act, and the terrestrial habitat is used by a number of rare and protected species. Twenty-one birds listed as threatened, endangered, or as candidates for listing by the State of Washington or the federal government have been observed near the 300-FF-5 operable unit. These birds include the loggerhead shrike, burrowing owl, common loon, and sage sparrow. No listed mammals have been observed or documented in the vicinity of the 300-FF-5 operable unit.

The Columbia River was also included as part of the biotic transport analysis because of the potential impact of the 300-FF-5 operable unit on river biota. Contaminant transport in the aquatic pathway begins with groundwater transport into the river via springs, and enters the aquatic food web through the primary producers, herbivores, consumers, primary carnivores, and secondary carnivores. Two species of mollusk found in the Columbia River are listed as candidates for protection under the Endangered Species Act. These are the shortfaced lanx, *Fisherola nuttalli*, a Washington State candidate species, and the Columbia pebblesnail, *Fluminicolla colombiana*, which is both a federal and state candidate species. Although not threatened or endangered, species of economic importance in the Columbia River are chinook salmon, sockeye salmon, coho salmon, and steelhead trout.

2.5 SUMMARY OF BASELINE RISK ASSESSMENT

The baseline risk assessment is presented in Chapter 6 of the Phase I RI (DOE-RL 1993a) and contains both human health and ecological components. The Phase I RI performed two separate human health risk assessments: (1) the impact of current and future 300-FF-5 operable unit contaminants, and (2) the impact of 300-FF-1 operable unit soils on groundwater. The human health evaluation of the 300-FF-1 operable unit impact on groundwater is not presented here because those results will be addressed in the FS for the 300-FF-1 operable unit. Human health evaluations are provided for both current and future (year 2018) conditions. The ecological risk assessment is based on current contaminant conditions.

2.5.1 Human Health Assessment - 300-FF-5 Contaminants

To assess human health impacts, the 300-FF-5 operable unit contaminants of potential concern were evaluated under four exposure scenarios (industrial, residential, recreational, and agricultural), three locations (300 Area, on-Hanford-Site, and off-Hanford-Site), and for current and future conditions. Exposure pathways evaluated in the baseline human health risk assessment were associated with water use. Exposure pathways evaluated under the industrial scenario for exposure to groundwater were dermal contact and inhalation of volatiles. Exposure pathways evaluated for off-Hanford-Site scenarios were evaluated for water ingestion, dermal contact, and inhalation of volatiles.

The off-Hanford-Site recreational scenario did not include evaluation of inhalation of volatiles because this exposure pathway is based on the accumulation of volatile contaminants due to indoor water use, and the recreational scenario generally consists of outdoor activities. Table 2-4 indicates the locations and time frames for each of the exposure scenarios. Tables 2-5 (current conditions) and 2-6 (future conditions) indicate the media and exposure points through which receptors may become exposed to contaminants.

Non-radioactive contaminants were evaluated for both non-carcinogenic and carcinogenic effects, as appropriate. Radioactive contaminants were evaluated only for their carcinogenic potential. Although uranium is known to cause toxic effects associated with its chemical characteristics, the carcinogenic potential of uranium is considered the primary health effect of concern because carcinogenesis remains a concern at concentrations that are below the threshold for toxic effects of uranium. The threshold concentration associated with toxic effects is roughly equivalent with concentrations associated with a 10^{-4} cancer risk; lower uranium concentrations are therefore only a concern for carcinogenesis, not chemical toxicity.

The largest hazard quotient (an indicator of non-carcinogenic human health impacts) for any constituent is 0.2 (associated with 1,2-DCE). A hazard quotient is a unitless number calculated by dividing a contaminant intake value by the reference dose for that contaminant. The reference dose is the threshold dose above which adverse effects could occur. Thus, a hazard quotient less than one indicates the reference dose is not exceeded for a given concentration. Since the hazard quotient of 1-2-DCE is nearly an order of magnitude less than 1, no systemic toxic effects are expected to occur as a result of exposure to contaminants at the operable unit.

The lifetime incremental cancer risk (ICR) associated with the current groundwater use scenario (water from Well 300-4-12) is provided in Table 2-7. The total risk associated with this scenario is 2×10^{-5}. However, this risk is primarily due to chloroform in groundwater, which is likely due to water chlorination. By excluding chloroform from the assessment, the groundwater risk drops to 1×10^{-6}. The surface water risk for industrial receptors (based on actual average contaminant concentrations in the 300 Area water intake) is 9×10^{-8}. Therefore, the total risk to industrial receptors on the 300 Area is 1×10^{-6} (excluding the contribution from chloroform).

A current major downstream user of Columbia River water is the City of Richland, which supplies the municipality with river water. This water supply is routinely analyzed. Based on evaluation of available data, the ICR from the water supply system currently and in the future for all uses is below 10^{-6}.

Contaminants in the 300-FF-5 groundwater operable unit are predicted to either remain the same or decrease in the future (except for the Tc-99 and nitrate plume emanating from the vicinity of the 1100-EM-1 operable unit and the tritium plume originating in the 200 Area). This prediction assumes that source control measures will be implemented in the 300-FF-1, 300-FF-2, and 300-FF-3 operable unit sources if potential groundwater impacts are unacceptable. A summary of ICRs associated with future groundwater use scenarios is provided in Table 2-8. Based on predicted groundwater contaminant concentrations, the only future scenario that exceeds a 10^{-6} risk is the industrial scenario with receptors on the 300 Area (7×10^{-6}). Approximately half of this risk is associated with the tritium plume from the 200 Area. The remaining risk driver (TCE) has an ICR of 3×10^{-6}, which is based on the conservative assumption that current TCE groundwater concentrations will remain constant beyond the year 2018. If the source of TCE is depleted before the year 2018, then the total industrial scenario risk (on the 300 Area) becomes 1×10^{-6} (excluding the contribution from tritium).

Because of the lack of current data during moderate and high river stages, and the uncertainty in predicting future contaminant concentrations in the Columbia River, future predictions of risk were analyzed for average and maximum potential future impacts to the river. A summary of average and maximum ICRs associated with contaminants of potential concern under future river conditions is provided in Table 2-8. Based on the use of predicted average river contaminant concentrations, ICRs are all less than 10^{-6}. If the predicted maximum river concentrations are used to represent surface water in the 300 Area, then the risk to industrial receptors on the 300 Area becomes $2x10^{-5}$. In addition, the risks to industrial, residential, and agricultural receptors on the Hanford Site will exceed 10^{-6} [$8x10^{-6}$ (industrial), $2x10^{-5}$ (residential and agricultural)]. However, these risk estimates include chloroform (associated with process water chlorination) and tritium (which does not originate on the operable unit). When these constituents are excluded, the risk is $5x10^{-6}$. In addition, many other conservative assumptions are built into these risk estimates such that they are considered bounding estimates and do not represent actual risks.

Table 2-9 presents risk-based concentrations for contaminants of concern evaluated under the industrial scenario and identifies contaminant concentrations that result in an HQ equal to 1 or an ICR of 10^{-6}. The minimum risk-based concentration values for each contaminant are used in Chapter 3 to assist development of remediation goals.

Although neither a HQ nor an ICR could be calculated for coliform bacteria, portions of the aquifer (mainly between the sanitary trenches and the Columbia River) currently contain coliform bacteria. Since the future land use is not anticipated to change from industrial, sanitary discharges were assumed to continue into the future; thus, impacts to local portions of the aquifer by coliform bacteria are also assumed to continue. Coliform bacteria is a relatively common problem in natural water supply systems, and the usual abatement is chlorination of the water before distribution and use. Unacceptable health risks may result from future potable use of groundwater impacted by coliform bacteria if used without routine chlorination.

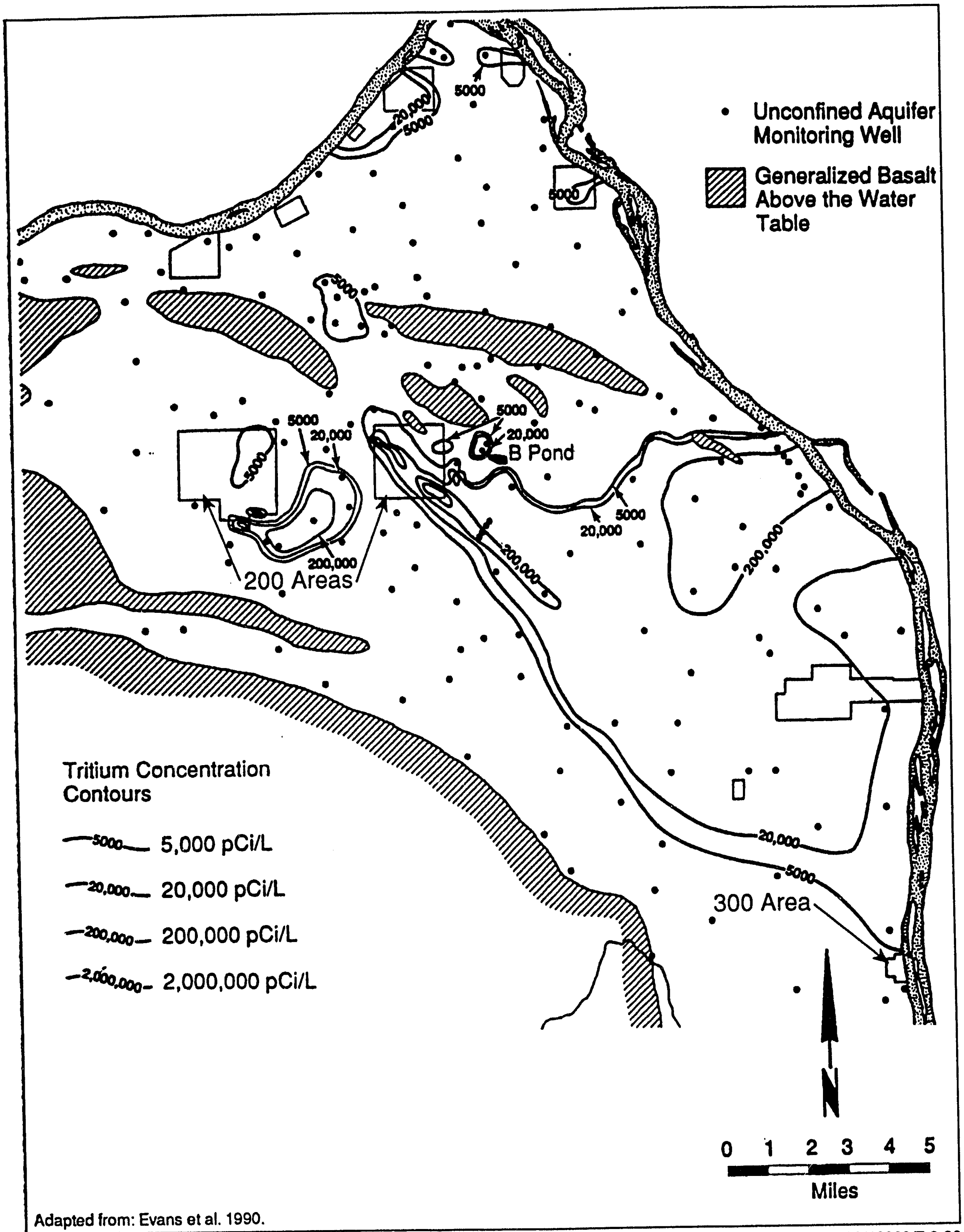
2.5.2 Ecological Risk Assessment

The 300-FF-5 operable unit includes riparian and aquatic ecosystems, although the emphasis of the risk assessment was on the aquatic system. Ecological or environmental risk was characterized by using groundwater concentrations as the source terms.

Risk to aquatic organisms from radionuclides and hazardous chemicals was estimated by computer modeling. Receptors were identified as generic organisms: crustacean, fish, plant-eating duck, fish-eating duck, and heron. Radiological dose was not found to exceed the DOE Order 5400.5 limit of 1 rad/day. Chemicals with groundwater concentrations that exceeded ambient water quality standards for protection of aquatic life (lowest observable effect level) were copper and nickel.

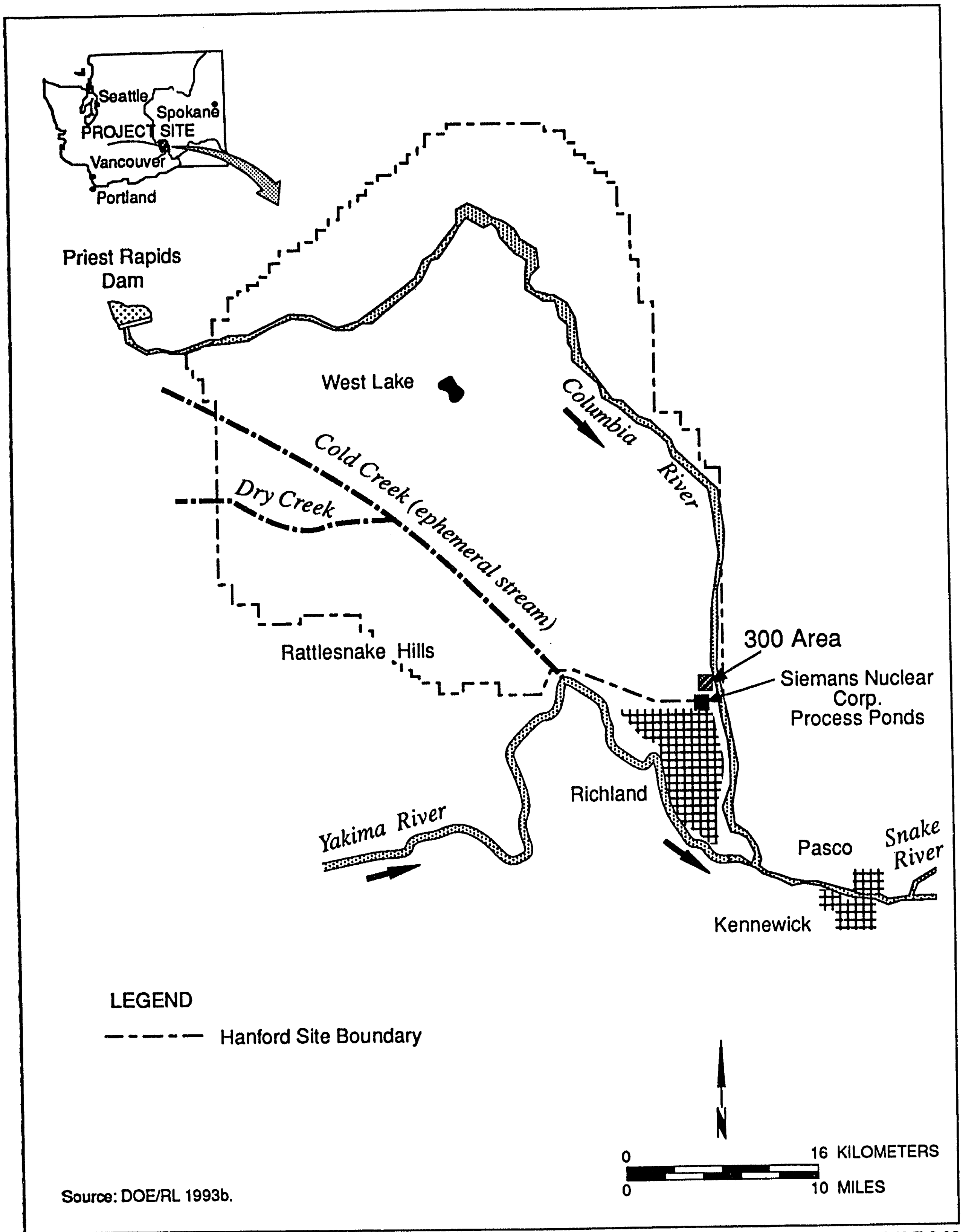
Although the ecological risk assessment indicated that groundwater concentrations of copper and nickel exceeded lowest observable effect levels, there is large uncertainty in the source term, rate of contaminant uptake by organisms, size and weight of receptor organisms, frequency of the site use, etc. For the river, no dilution of the groundwater source terms was considered, when in fact the groundwater entering the river will undergo almost instantaneous dilution, and the river concentrations are not expected to approach source term concentrations (which was confirmed in spring studies conducted during September 1992).

None of the chemicals that exceeded ambient water quality standards for protection of aquatic life and/or risk-based lowest observable effect levels are considered to be significantly elevated in groundwater. Although these chemicals occasionally exceeded background levels, these occurrences were sporadic and did not suggest sources or groundwater plumes that could be remediated. Therefore, they were not considered contaminations of concern.



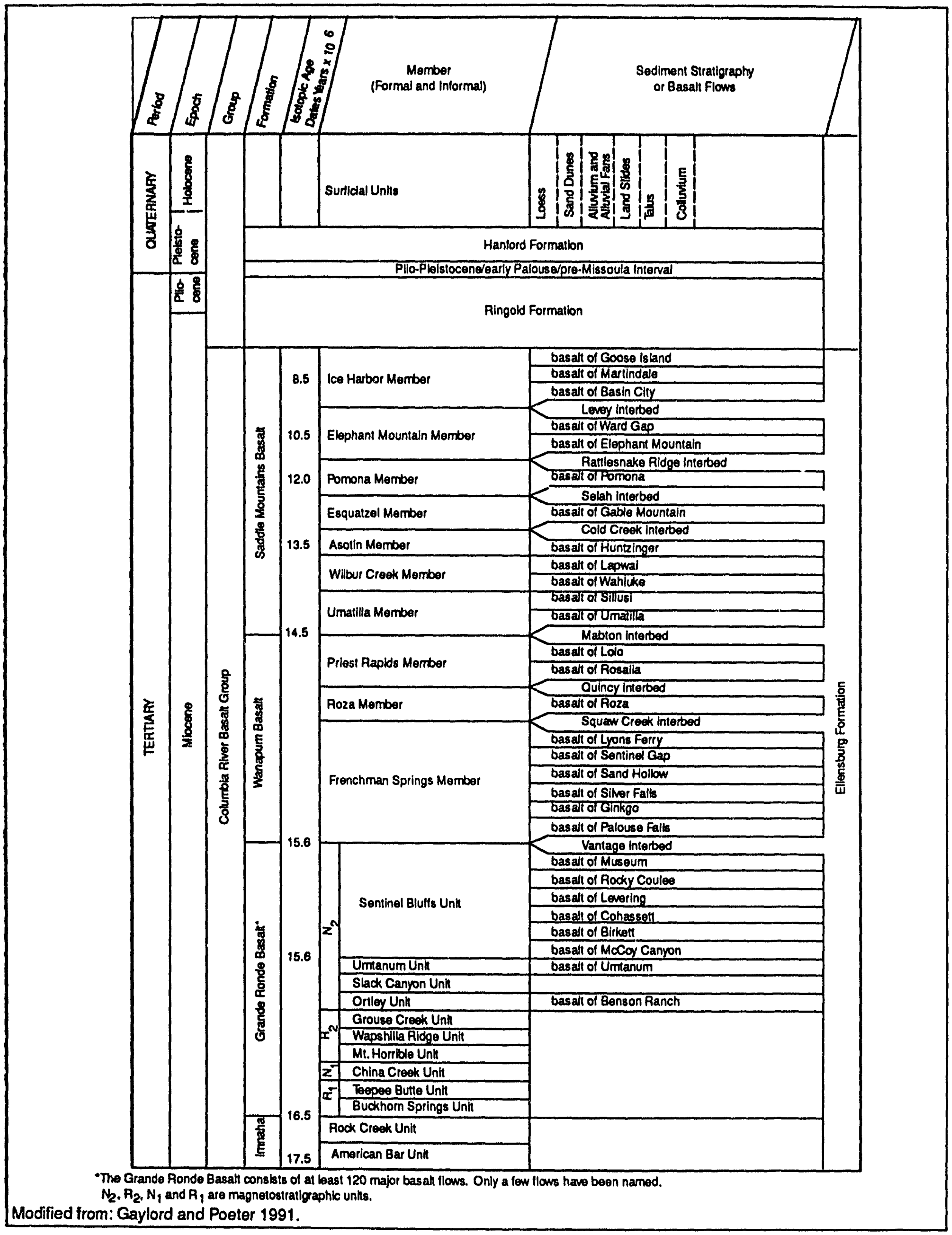
913-1769/46609/7-2-93

Figure 2-1. Hanford Site Tritium Plume.



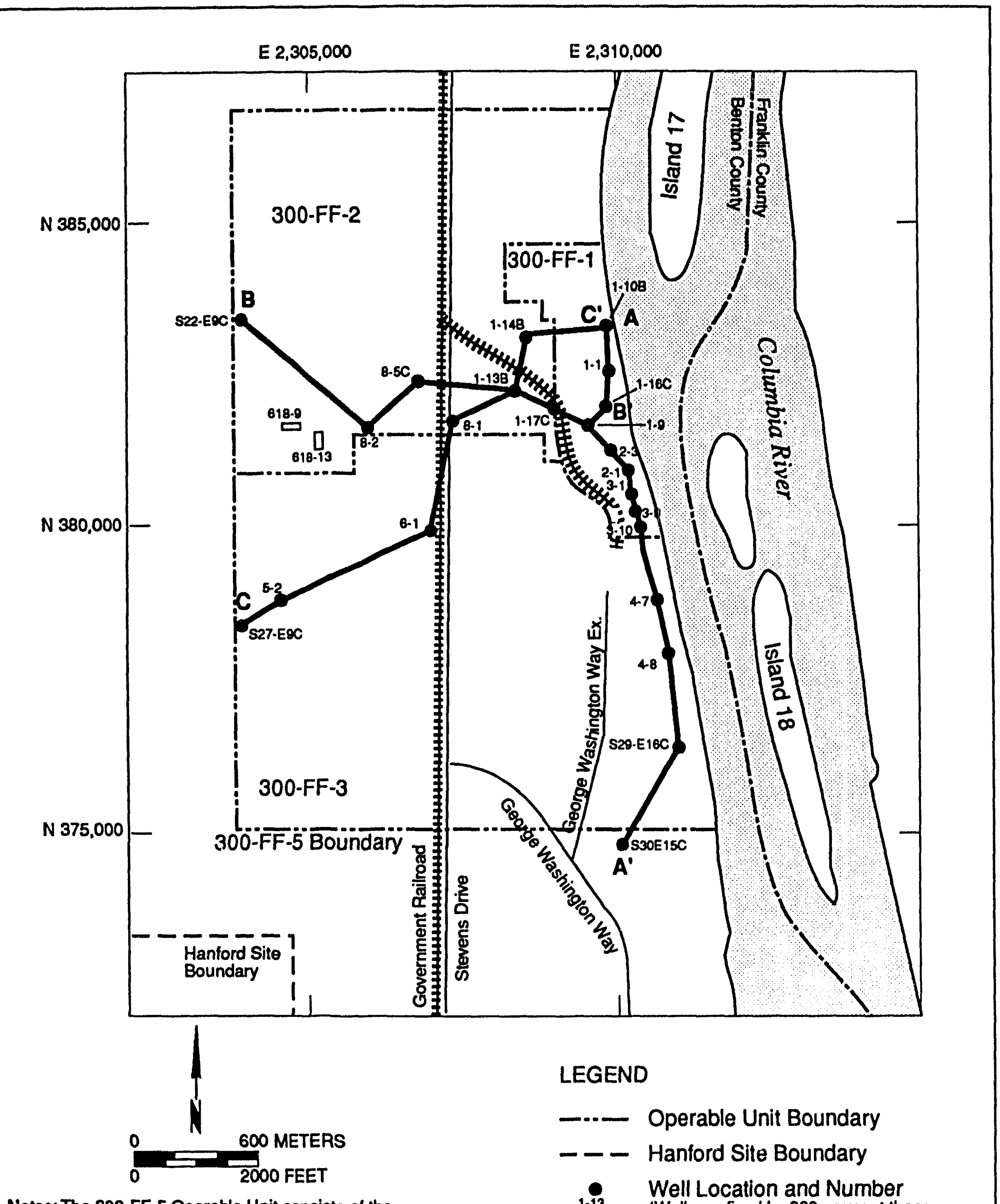
913-1769/45740/7-6-93

Figure 2-2. Major Surface Water Features of the Hanford Site.



913-1769/4574/7-1-93

Figure 2-3. Basalt and Suprabasalt Stratigraphy at the Hanford Site, Washington.



Notes: The 300-FF-5 Operable Unit consists of the groundwater beneath the 300-FF-1, 300-FF-2 and 300-FF-3 Operable Units.

Grid in Lambert Coordinates (feet) NAD83

Source: Swanson et al. 1992.

913 1769/46647/1-26-94

Figure 2-4. Location Map for Geologic Cross Sections.

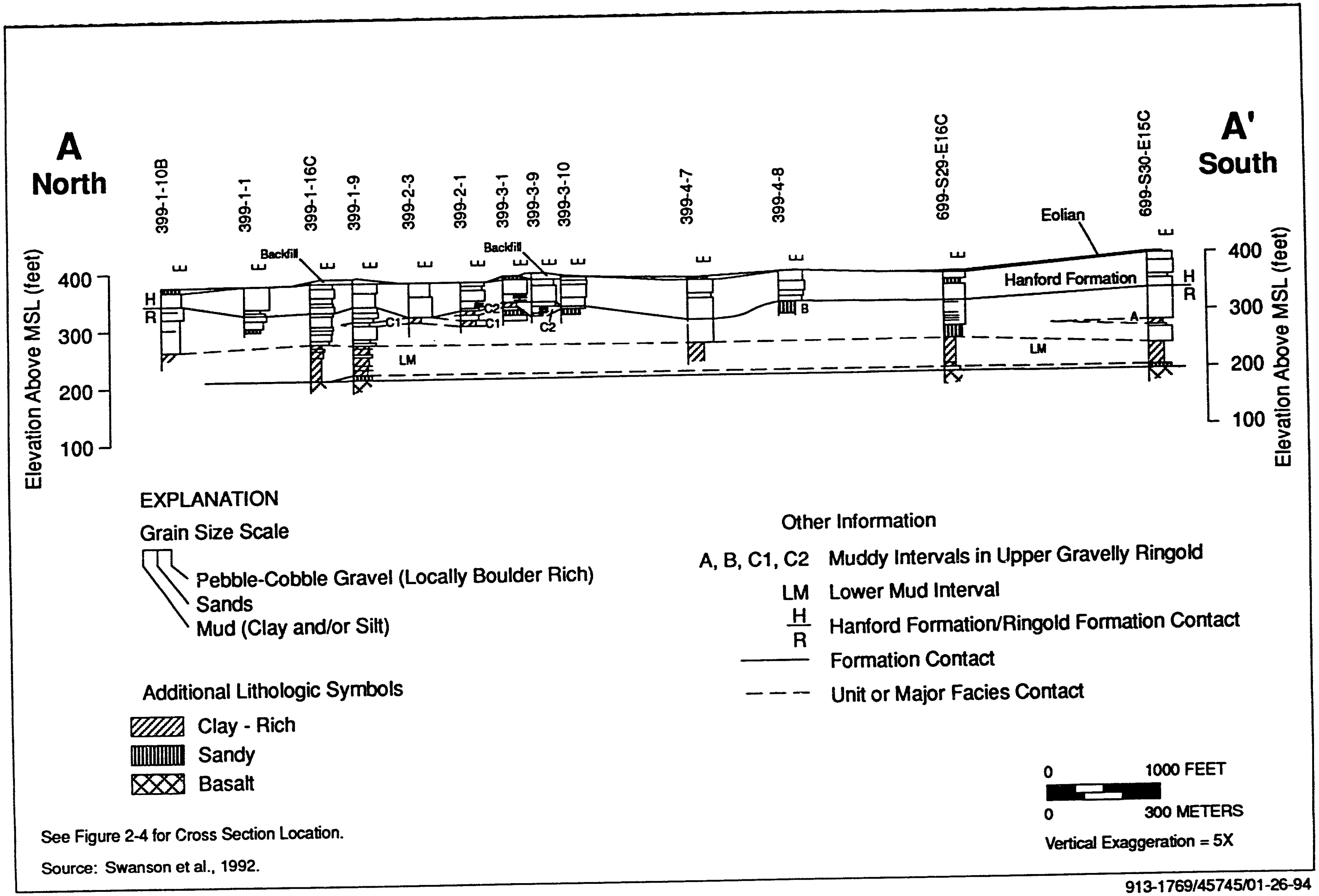


Figure 2-5. Geologic Cross Section A-A'.

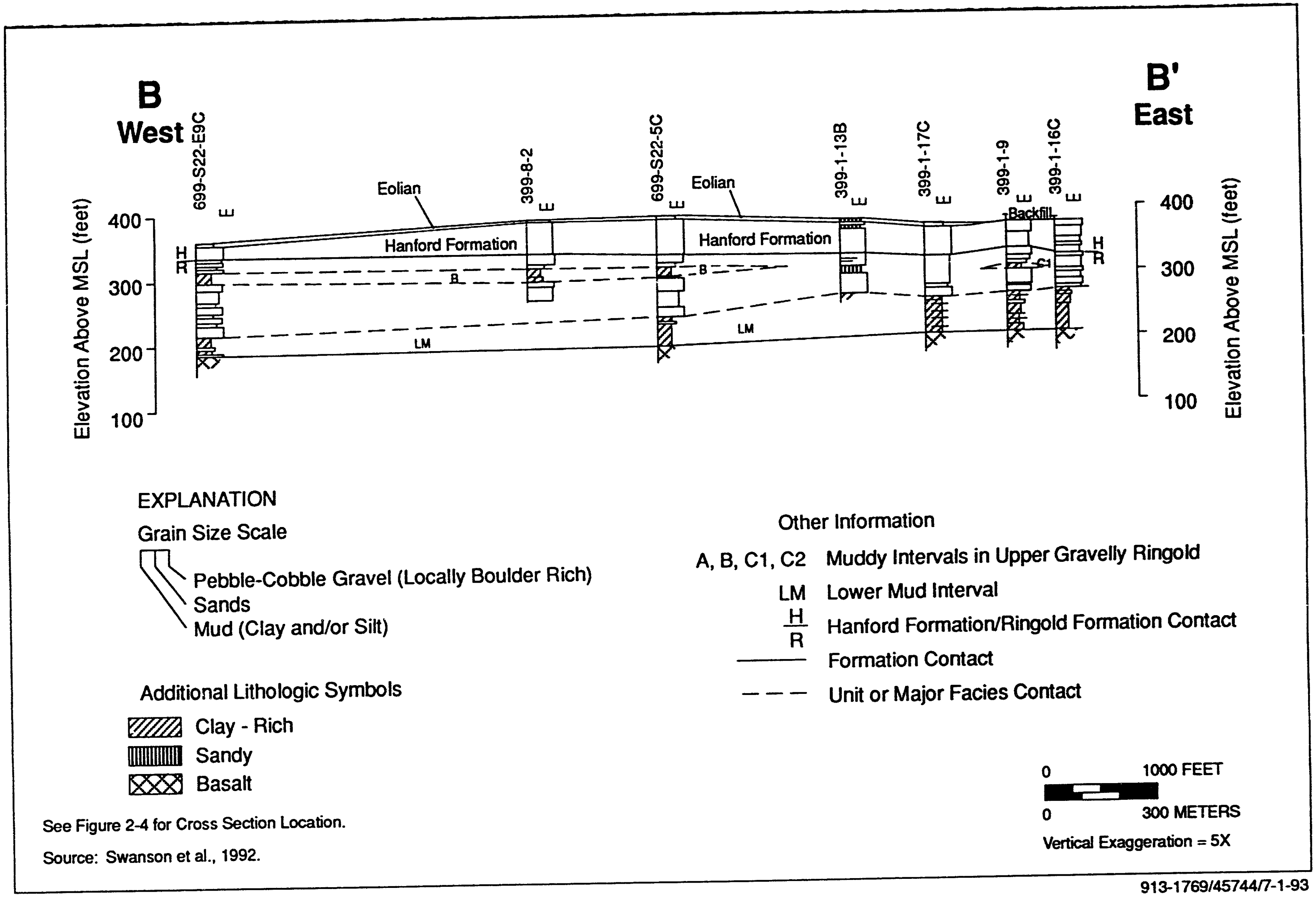
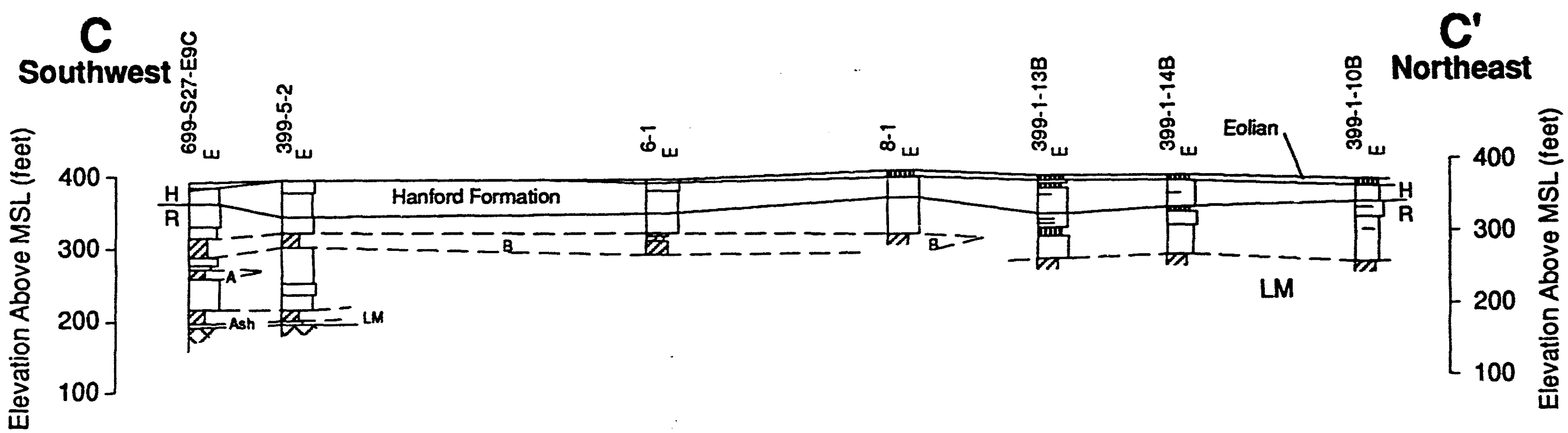


Figure 2-6. Geologic Cross Section B-B'.



EXPLANATION

Grain Size Scale

- Pebble-Cobble Gravel (Locally Boulder Rich)
- Sands
- Mud (Clay and/or Silt)

Additional Lithologic Symbols

- Clay - Rich
- Sandy
- Basalt

Other Information

A, B, C1, C2	Muddy Intervals in Upper Gravelly Ringold
LM	Lower Mud Interval
H/R	Hanford Formation/Ringold Formation Contact
———	Formation Contact
— — —	Unit or Major Facies Contact

0 1000 FEET

0 300 METERS

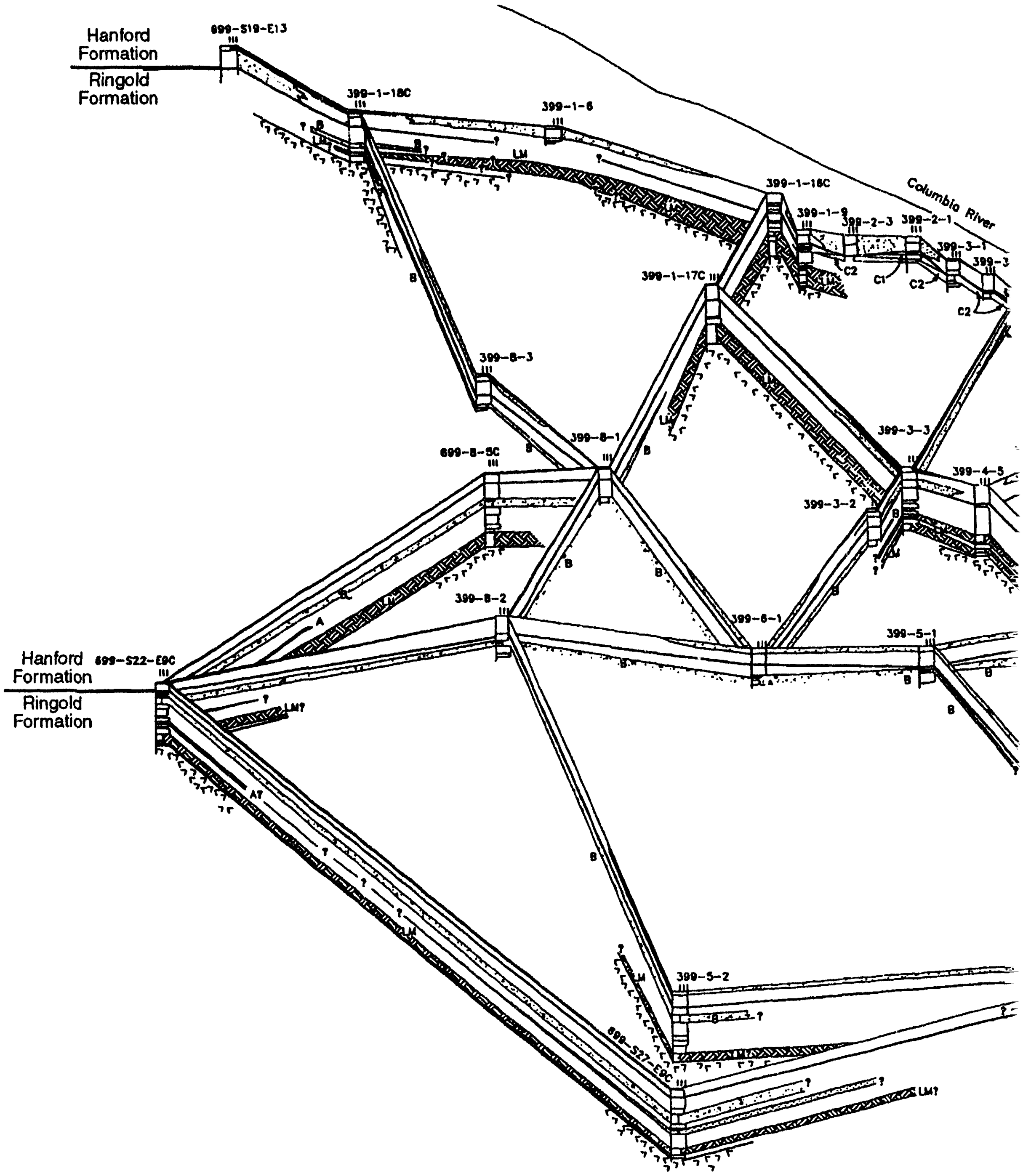
Vertical Exaggeration = 5X

See Figure 2-4 for Cross Section Location.

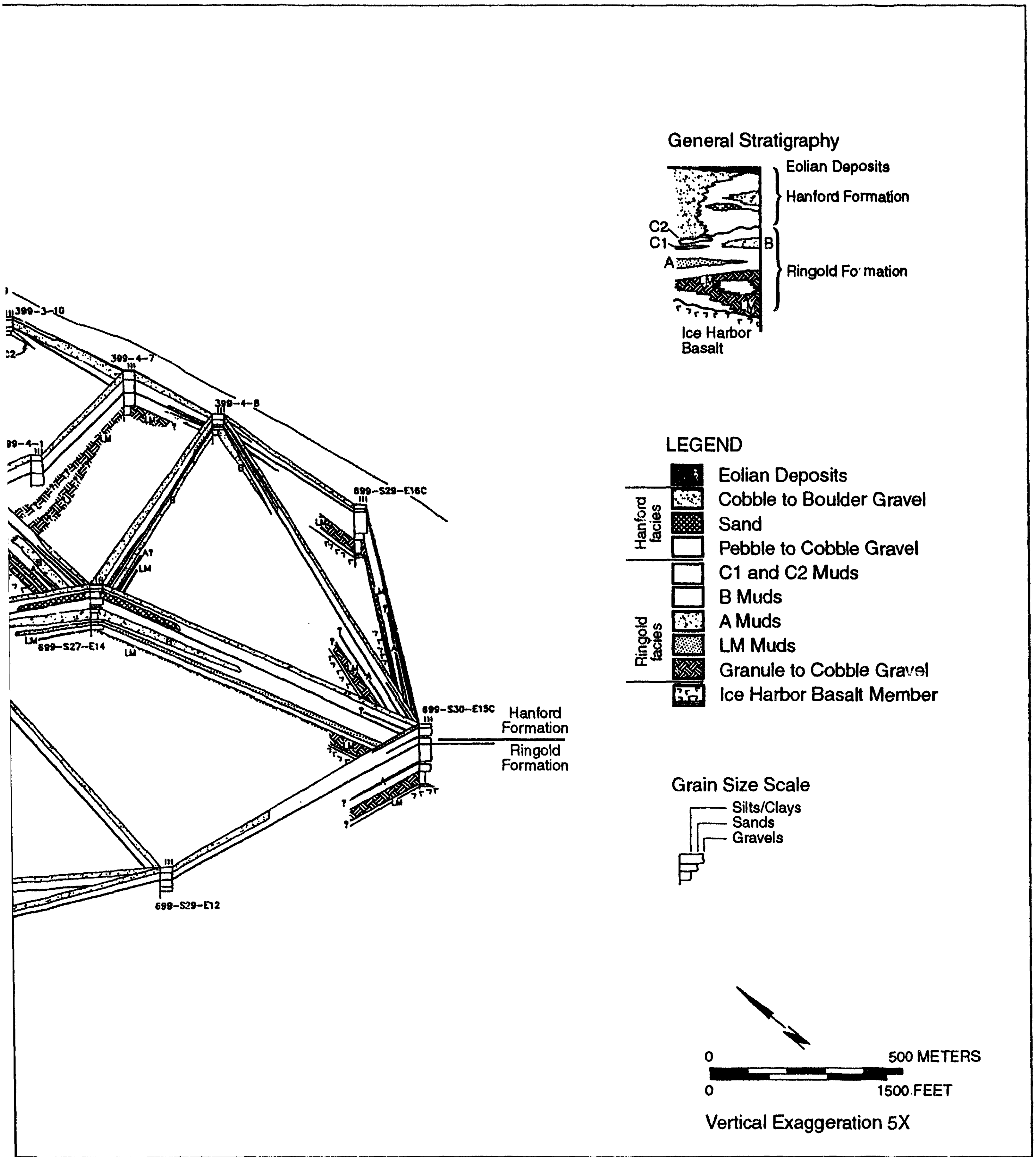
Source: Swanson et al., 1992.

913-1769/45743/7-1-93

Figure 2-7. Geologic Cross Section C-C'.

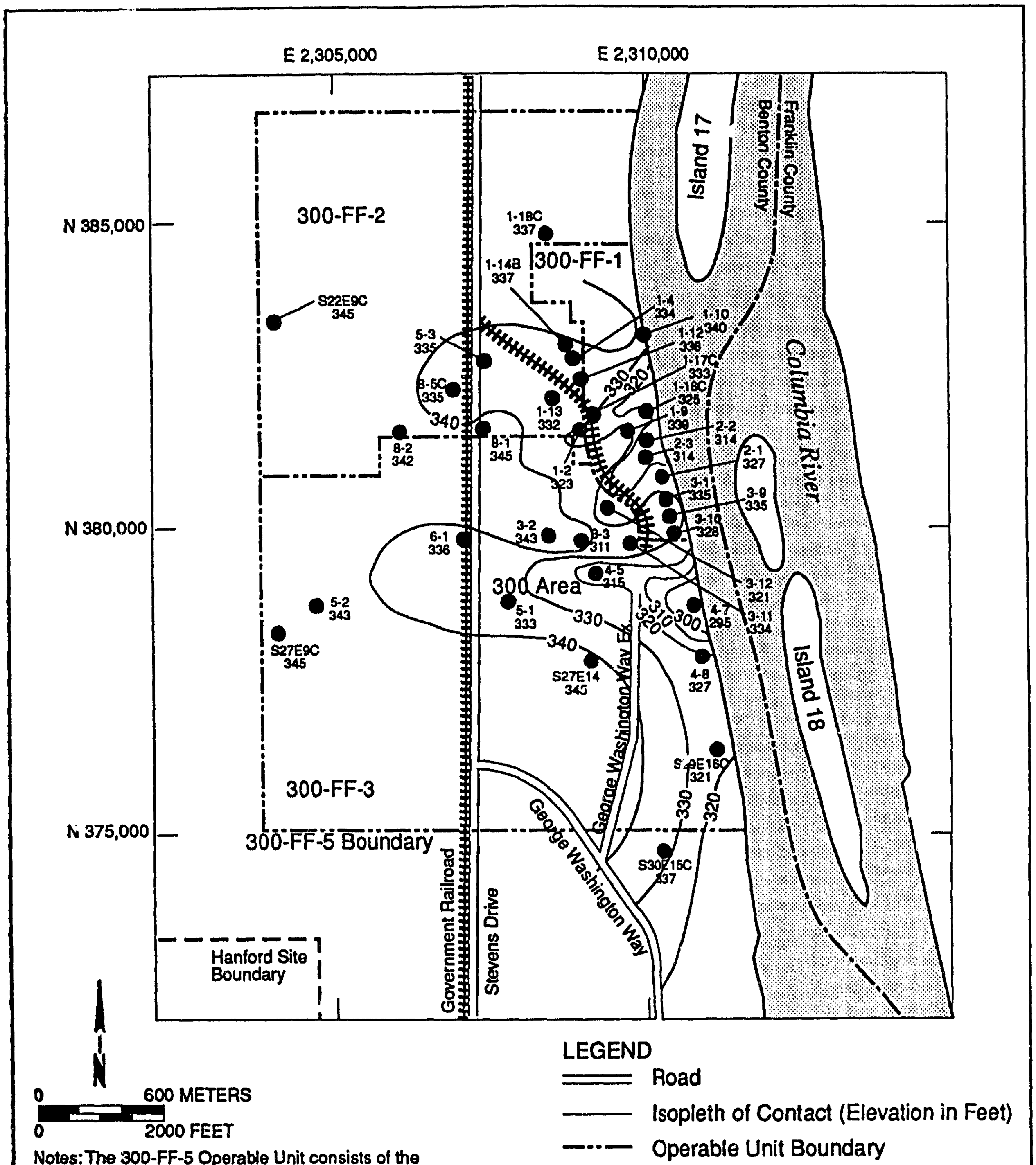


Source: Swanson et al.1992.



913 1769/45750/7-1-93

Figure 2-8. Geologic Fence Diagram of the 300 Area.



Notes: The 300-FF-5 Operable Unit consists of the groundwater beneath the 300-FF-1, 300-FF-2 and 300-FF-3 Operable Units.

Grid in Lambert Coordinates (feet) NAD83

Source: Swanson et al. 1992.

Contour Interval = 10 ft
1m = 3.28 ft

913 1769/46646/1-26-94

Figure 2-9. Structure Contour Map of the Hanford/Ringold Contact.

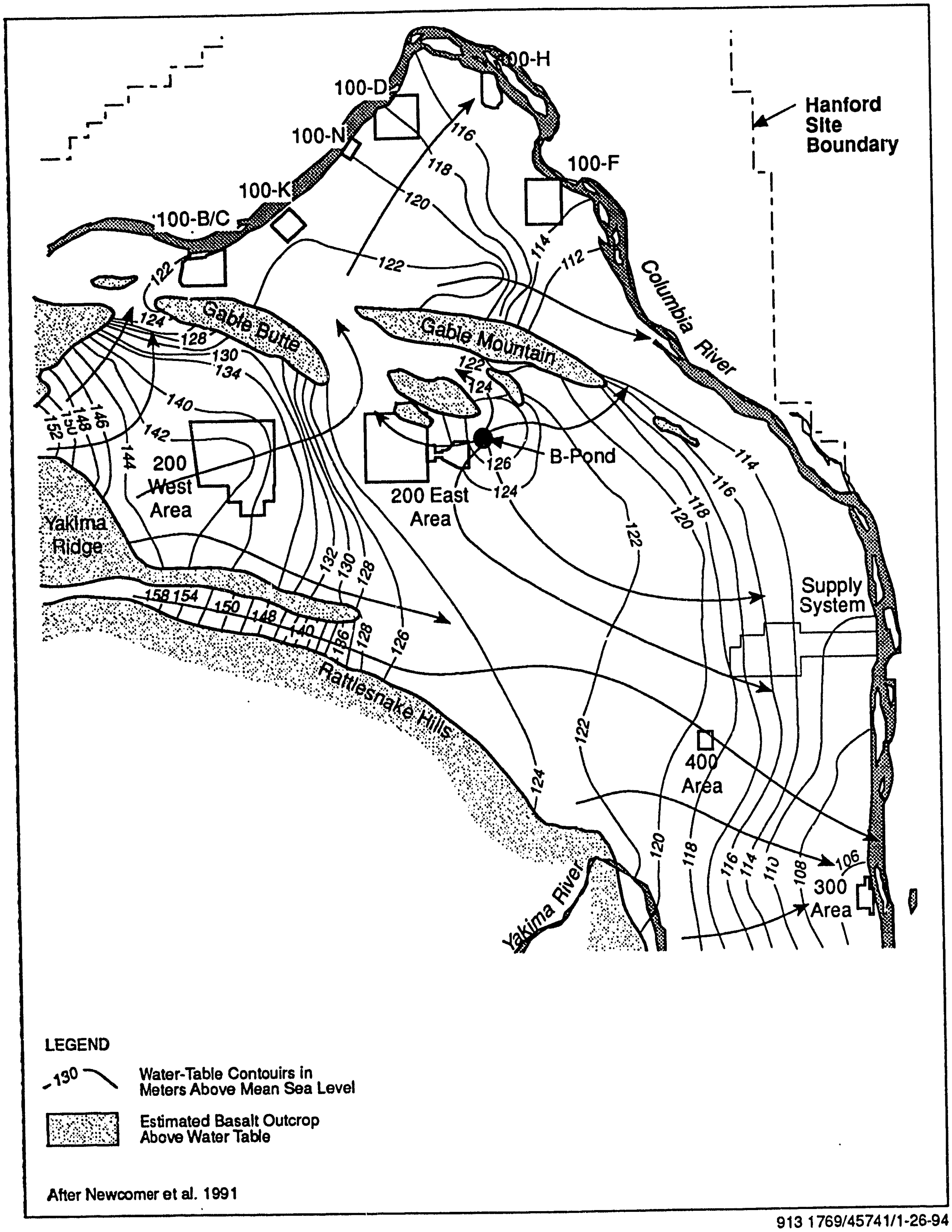
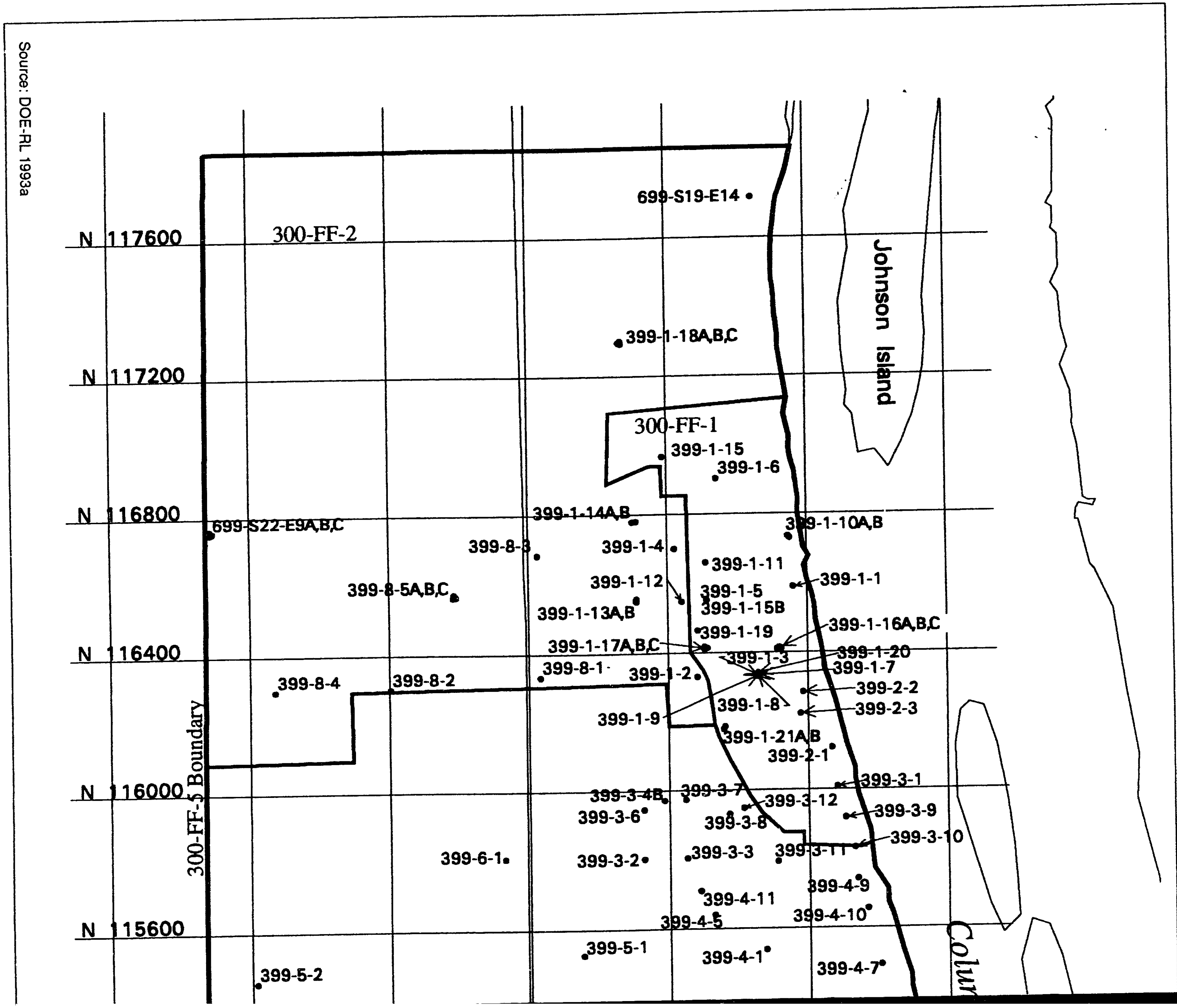
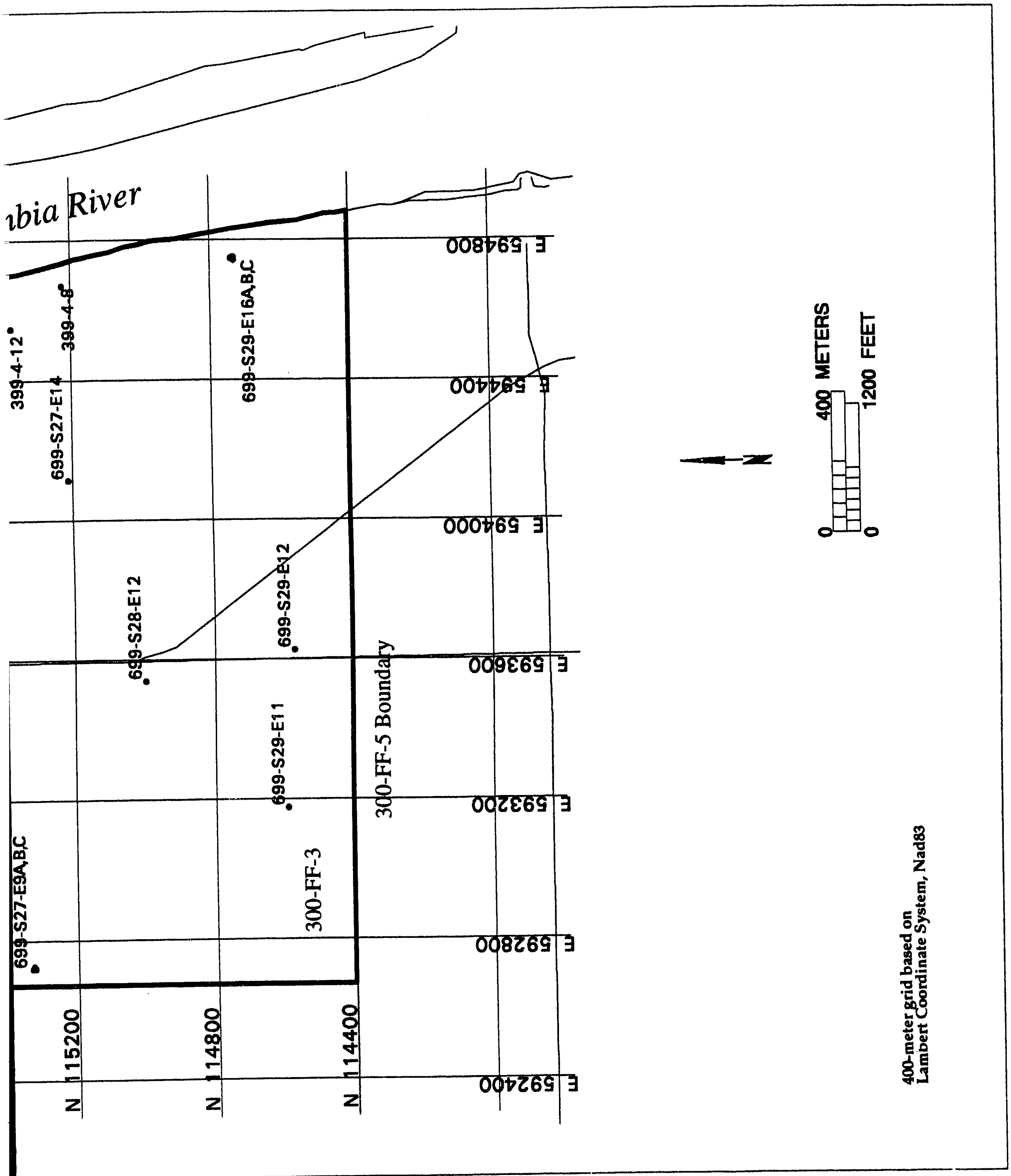


Figure 2-10. Water-Table Elevations for the Hanford Site Unconfined Aquifer in 1990.



Source: DOE-RL 1993a
N 117600
N 117200
N 116800
N 116400
N 116000
N 115600
300-FF-2
300-FF-1
300-FF-5 Boundary
Johnson Island
699-S19-E14
399-1-18A,B,C
399-1-15
399-1-6
399-1-14A,B
699-S22-E9A,B,C
399-1-10A,B
399-8-3
399-1-4
399-1-11
399-1-1
399-8-5A,B,C
399-1-12
399-1-5
399-1-15B
399-1-13A,B
399-1-16A,B,C
399-1-19
399-1-17A,B,C
399-1-3
399-1-20
399-1-7
399-8-1
399-1-2
399-8-4
399-8-2
399-2-2
399-1-8
399-2-3
399-1-9
399-1-21A,B
399-2-1
399-3-1
399-3-4B
399-3-7
399-3-12
399-3-6
399-3-8
399-3-9
399-3-10
399-6-1
399-3-2
399-3-3
399-3-11
399-4-9
399-4-11
399-4-10
399-4-5
399-5-1
399-4-1
399-4-7
399-5-2



913 1769/45617/5-6-93

Figure 2-11. Location of Monitoring Wells in the 300-FF-5 Operable Unit.

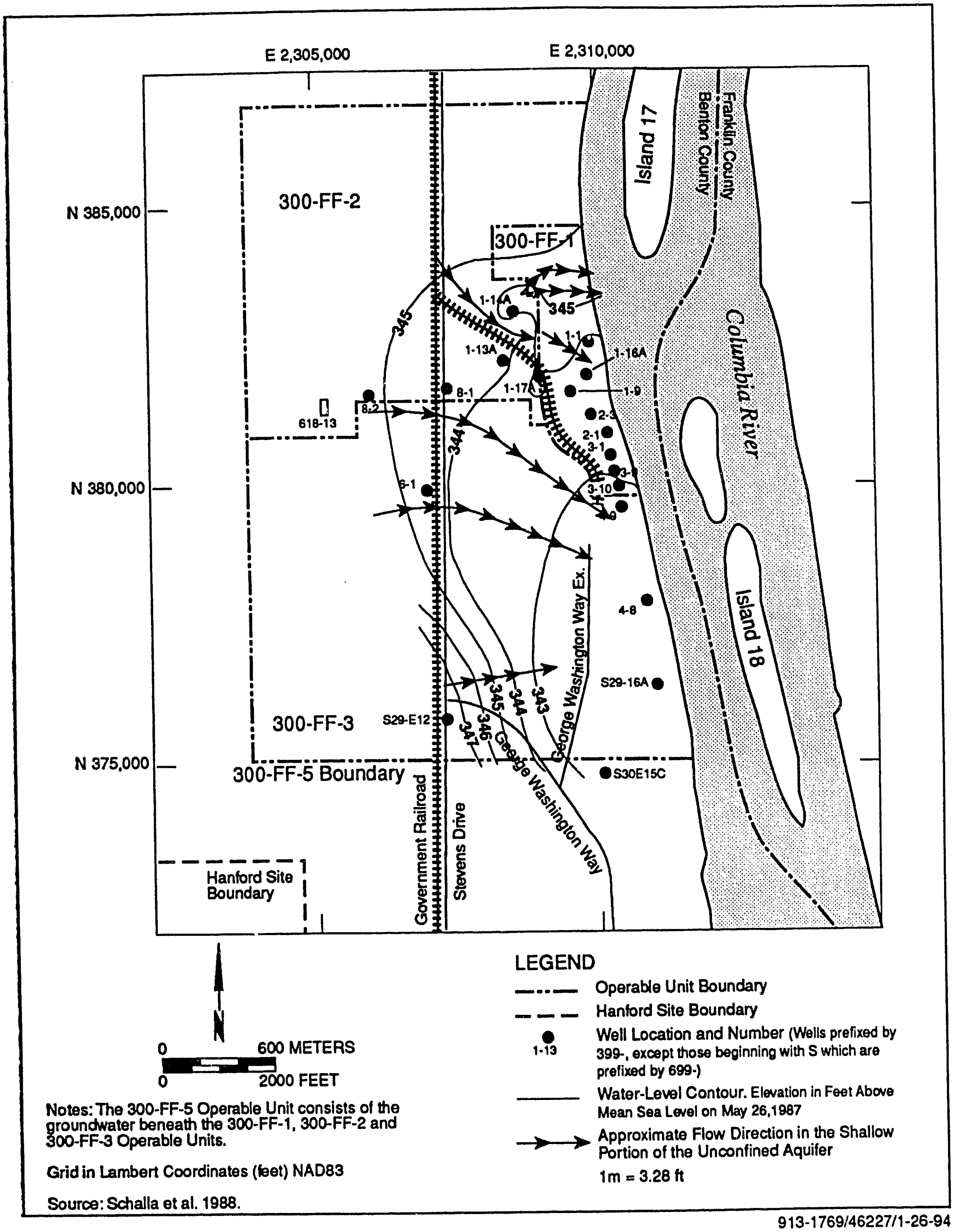


Figure 2-12. Generic Water-Level Contour Map of the Unconfined Aquifer.

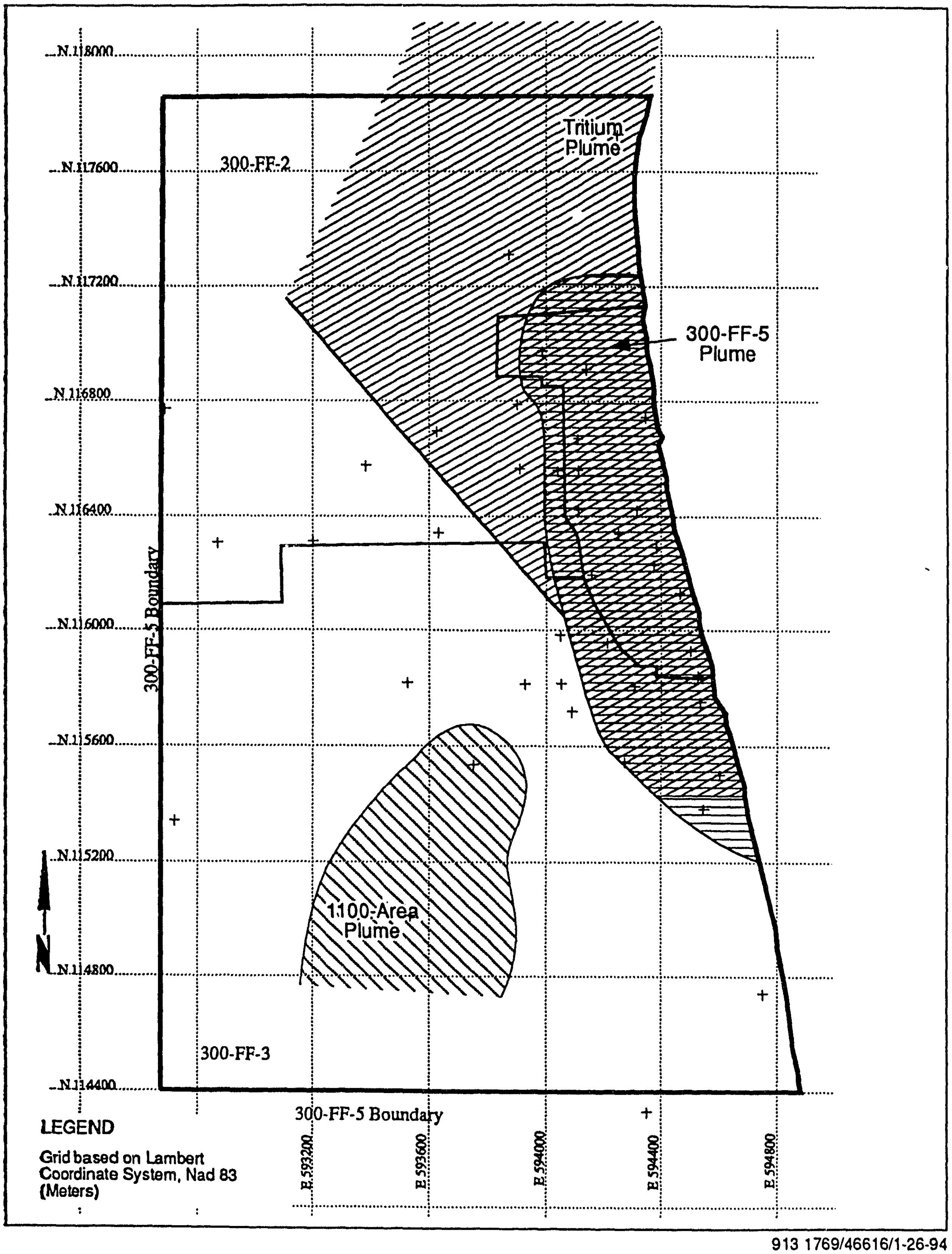
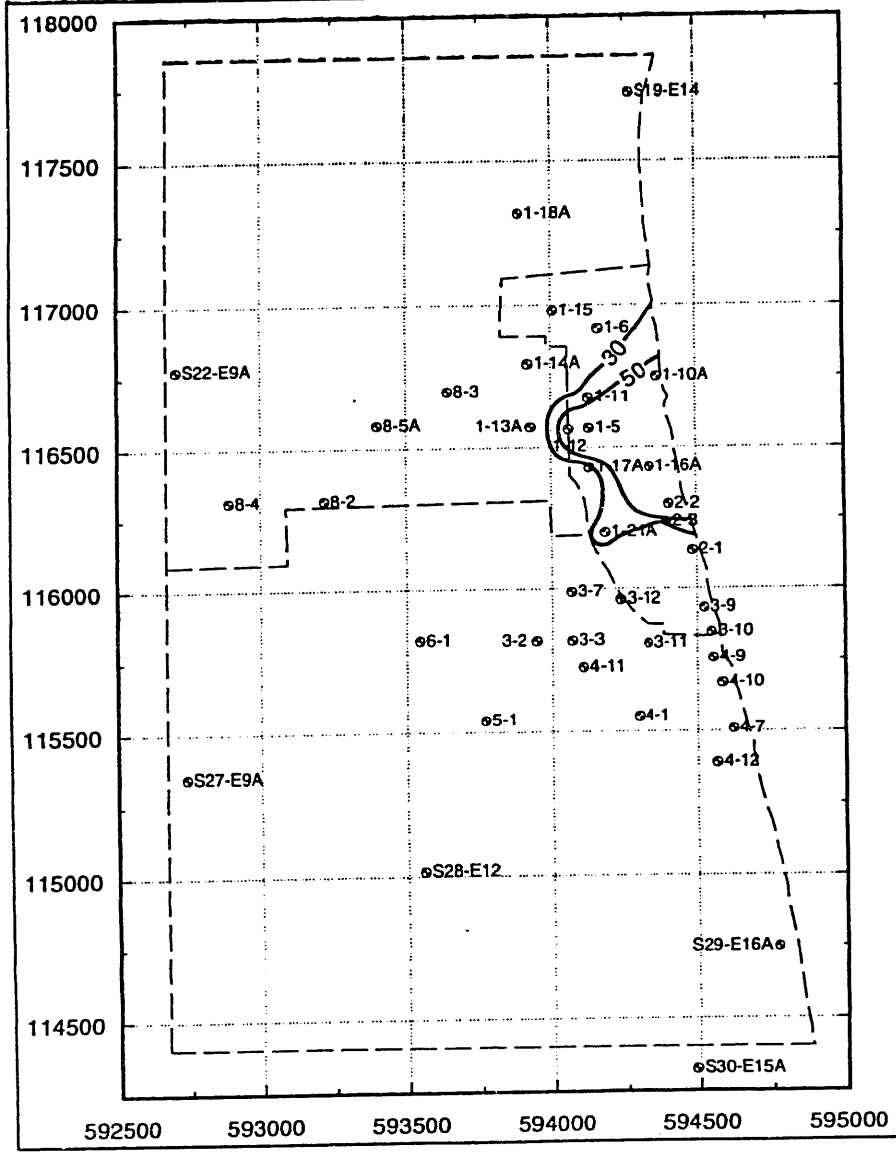


Figure 2-13. General Shape and Extent of 300 Area Plumes.

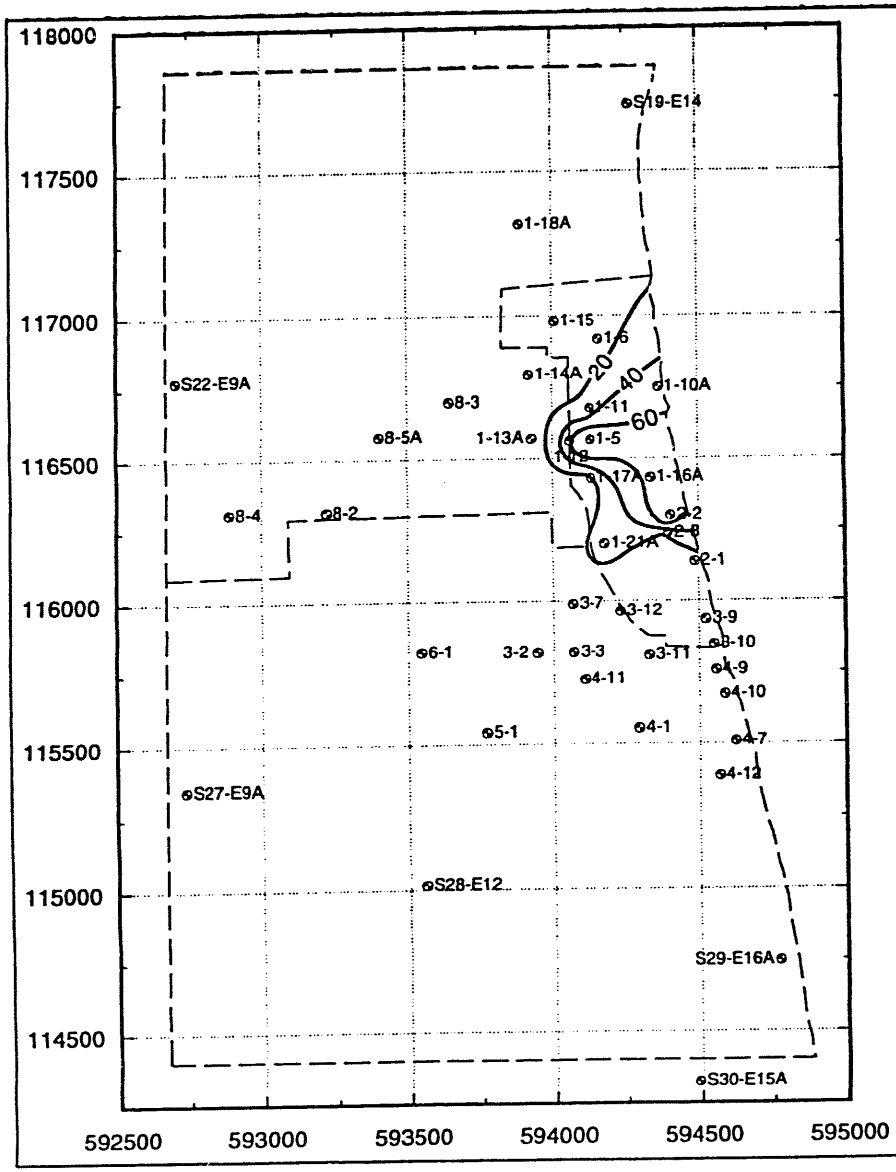


Well	Value	Well	Value
1-10A	60.00	4-12	8.10 J
1-11	37.00	4-7	16.00
1-12	58.00	4-9	18.00 J
1-13A	0.05 U	5-1	2.70 U
1-14A	4.00 B	6-1	3.10 J
1-15	2.30	8-2	1.10
1-16A	74.00	8-3	2.10 B
1-17A	5.40	8-4	1.30 U
1-18A	2.30 J	8-5A	5.00 U
1-21A	35.00 J	S19-E14	2.70 U
1-5	120.00	S22-E9A	1.30 J
1-6	11.00 J	S27-E9A	2.20 J
2-1	9.10	S28-E12	2.30 J
2-2	94.00	S29-E16A	2.30 U
2-3	14.00 J	S30-E15A	1.10 B
3-10	6.40		
3-11	12.00		
3-12	11.00 J		
3-2	4.30 U		
3-3	2.70		
3-7	5.10		
3-9	6.00		
4-1	5.00		
4-10	13.00		
4-11	4.60 B		

Notes:
1. Non-detects were contoured using one-tenth of the reported detection limit shown above.
2. Well labels begining with a "S" are prefixed with "699-". All other well labels are prefixed with "399-".
3. Coordinates are in meters and conform to the Lambert Coordinate System (NAD83).

913 1769/45472/1-26-94 pu

Figure 2-14. U-234 Concentration Contours for the Unconfined Aquifer (Round 2).



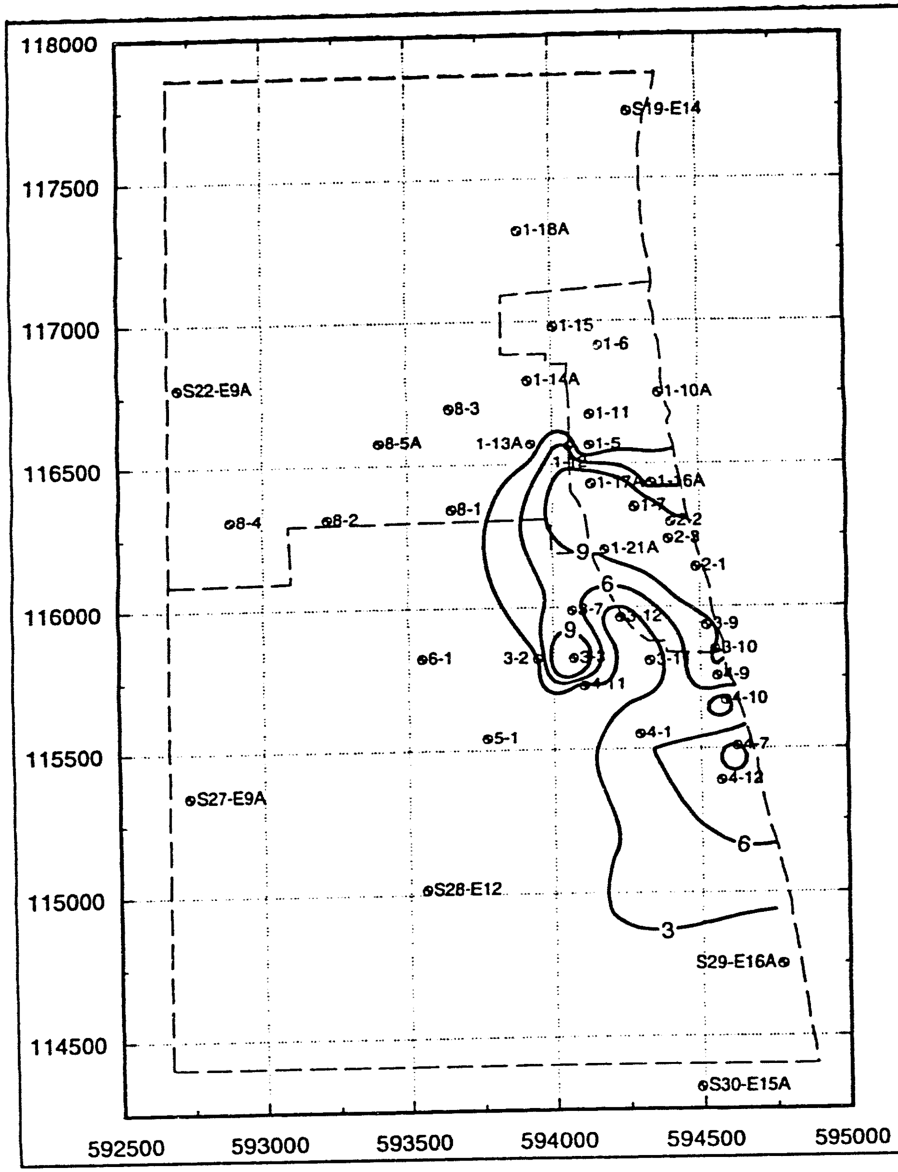
Well	Value	Well	Value
1-10A	52.00	4-12	8.40 J
1-11	27.00	4-7	14.00
1-12	46.00	4-9	17.00 J
1-13A	0.05 U	5-1	2.30 U
1-14A	3.20	6-1	3.20 U
1-15	1.80	8-2	0.92
1-16A	61.00	8-3	2.10
1-17A	3.90	8-4	1.20 U
1-18A	1.60 J	8-5A	4.20 U
1-21A	27.00 J	S19-E14	2.20 U
1-5	93.00	S22-E9A	0.99 J
1-6	9.60 J	S27-E9A	2.10 J
2-1	8.00	S28-E12	1.90 J
2-2	76.00	S29-E16A	2.00 U
2-3	11.00 J	S30-E15A	0.86
3-10	5.90		
3-11	11.00		
3-12	9.80 J		
3-2	3.80 U		
3-3	2.60		
3-7	4.80		
3-9	6.30		
4-1	4.90		
4-10	13.00		
4-11	4.50		

Notes:

1. Non-detects were contoured using one-tenth of the reported detection limit shown above.
2. Well labels begining with a "S" are prefixed with "699-". All other well labels are prefixed with "399-".
3. Coordinates are in meters and conform to the Lambert Coordinate System (NAD83).

913 1769/45469/1-26-94 pu

Figure 2-15. U-238 Concentration Contours for the Unconfined Aquifer (Round 2).



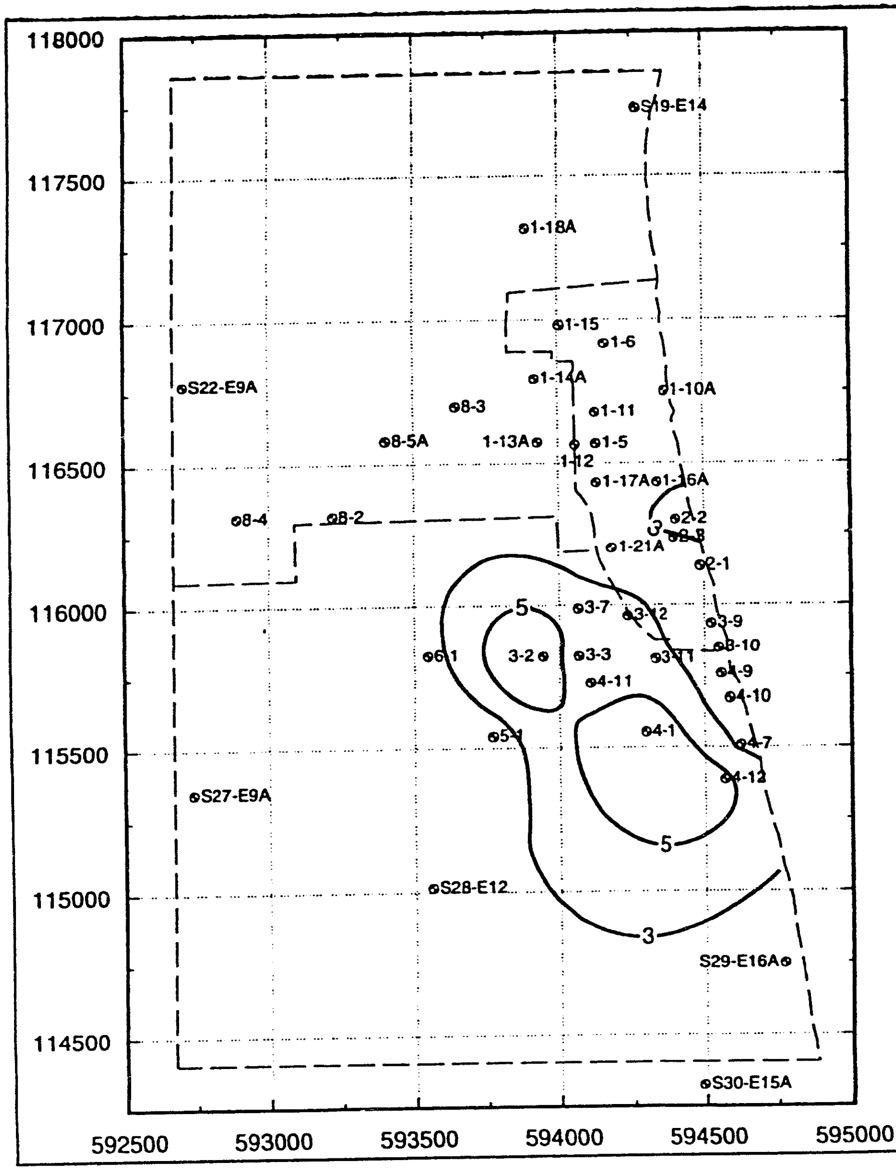
Well	Value
1-10A	2.00 U
1-11	1.00 U
1-12	8.00
1-13A	1.00 U
1-14A	10.00 U
1-15	5.00 U
1-16A	6.00 B
1-17A	15.00
1-18A	5.00 U
1-21A	9.00
1-5	4.00 U
1-6	1.00 U
1-7	17.00 B
2-1	13.00 B
2-2	10.00
2-3	11.00
3-10	9.00 B
3-11	4.00 U
3-12	4.00 U
3-2	1.00 U
3-3	18.00
3-7	7.00 B
3-9	8.00
4-1	6.00
4-10	7.00 U
4-11	4.00 U
4-12	8.00 B
4-7	10.00
4-9	9.00
5-1	5.00 U
6-1	5.00 U
8-1	5.00 U
8-2	5.00 U
8-3	5.00 U
8-4	5.00 U
8-5A	5.00 U
S19-E14	5.00 U
S22-E9A	5.00 U
S27-E9A	5.00 U
S28-E12	5.00 U
S29-E16A	5.00 U
S30-E15A	5.00 U

Notes:

1. Non-detects were contoured using one-tenth of the reported detection limit shown above.
2. Well labels begining with a "S" are prefixed with "699-". All other well labels are prefixed with "399-".
3. Coordinates are in meters and conform to the Lambert Coordinate System (NAD83).

913 1769/45471/01-26-94 pu

Figure 2-16. Chloroform Concentration Contours for the Unconfined Aquifer (Round 1).



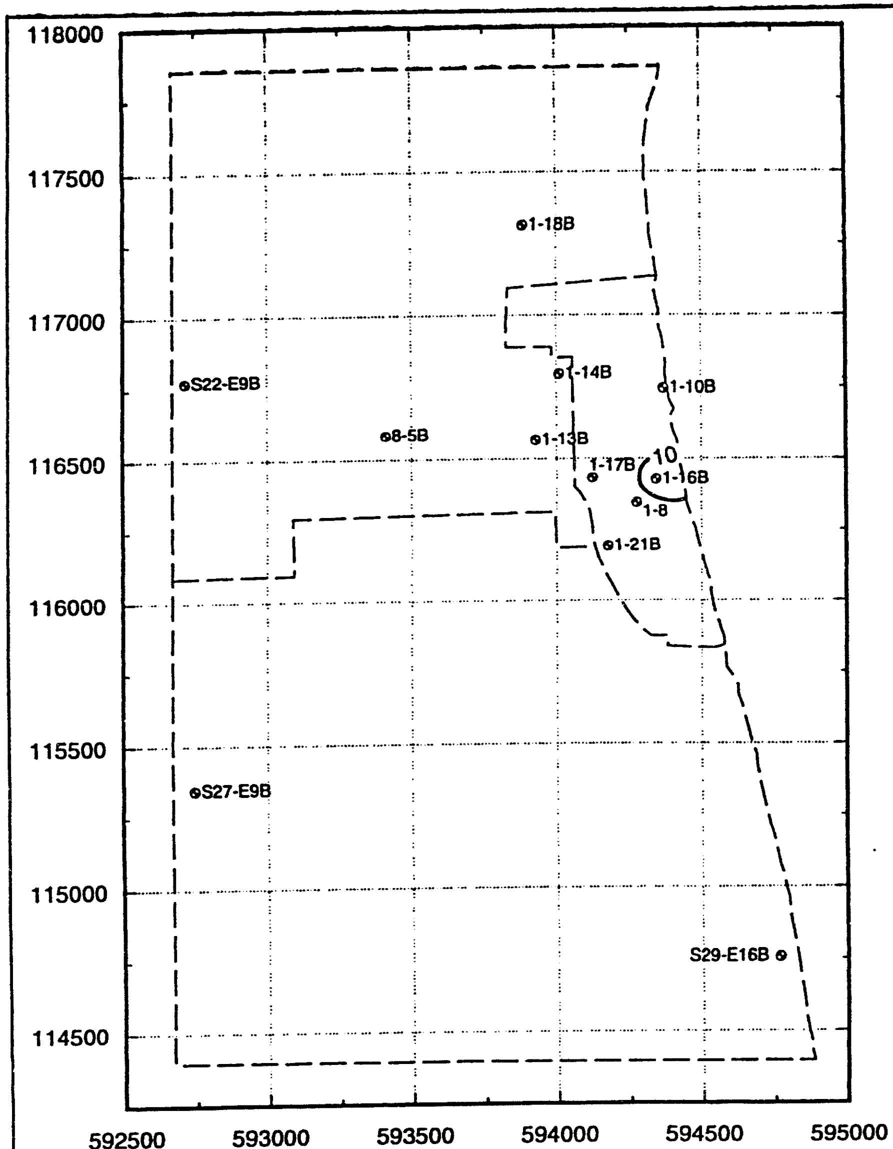
Well	Value	Well	Value
1-10A	10.00 U	4-12	6.00 J
1-11	10.00 U	4-7	3.00 J
1-12	10.00 U	4-9	2.00 J
1-13A	10.00 U	5-1	10.00 U
1-14A	10.00 U	6-1	2.00 J
1-15	10.00 U	8-2	10.00 U
1-16A	2.00 J	8-3	10.00 U
1-17A	10.00 U	8-4	10.00 U
1-18A	10.00 U	8-5A	10.00 U
1-21A	2.00 J	S19-E14	10.00 U
1-5	10.00 U	S22-E9A	10.00 U
1-6	10.00 U	S27-E9A	10.00 U
2-1	3.00 J	S28-E12	10.00 U
2-2	5.00 J	S29-E16A	10.00 U
2-3	10.00 U	S30-E15A	10.00 U
3-10	2.00 J		
3-11	4.00 J		
3-12	4.00 J		
3-2	9.00 J		
3-3	3.00 J		
3-7	4.00 J		
3-9	1.00 J		
4-1	7.00 J		
4-10	2.00 J		
4-11	4.00 J		

Notes:

1. Non-detects were contoured using one-tenth of the reported detection limit shown above.
2. Well labels begining with a "S" are prefixed with "699-". All other well labels are prefixed with "399-".
3. Coordinates are in meters and conform to the Lambert Coordinate System (NAD83).

913 1769/45562/1-26-94 pu

Figure 2-17 TCE Concentration Contours for the Unconfined Aquifer (Round 2).



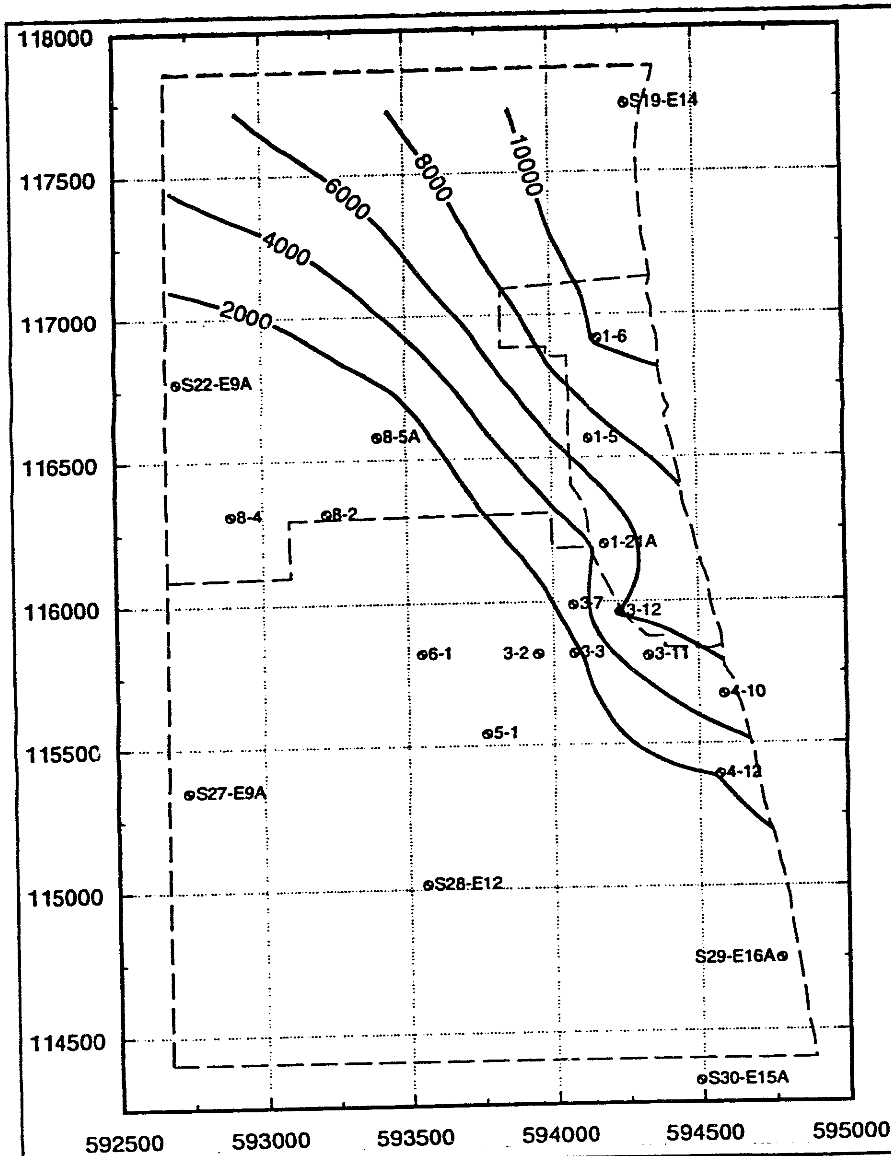
Well	Value
1-10B	10.00 U
1-13B	10.00 U
1-14B	10.00 U
1-16B	14.00
1-17B	10.00 U
1-18B	10.00 U
1-21B	10.00 U
1-8	10.00 U
8-5B	10.00 U
S22-E9B	10.00 U
S27-E9B	10.00 U
S29-E16B	10.00 U

Notes:

1. Non-detects were contoured using one-tenth of the reported detection limit shown above.
2. Well labels begining with a "S" are prefixed with "699-". All other well labels are prefixed with "399-".
3. Coordinates are in meters and conform to the Lambert Coordinate System (NAD83).

913 1769/48970/1-28-94 pu

Figure 2-18. TCE Concentration Contours for the Unconfined Aquifer (Round 2)(B-Zone Wells).



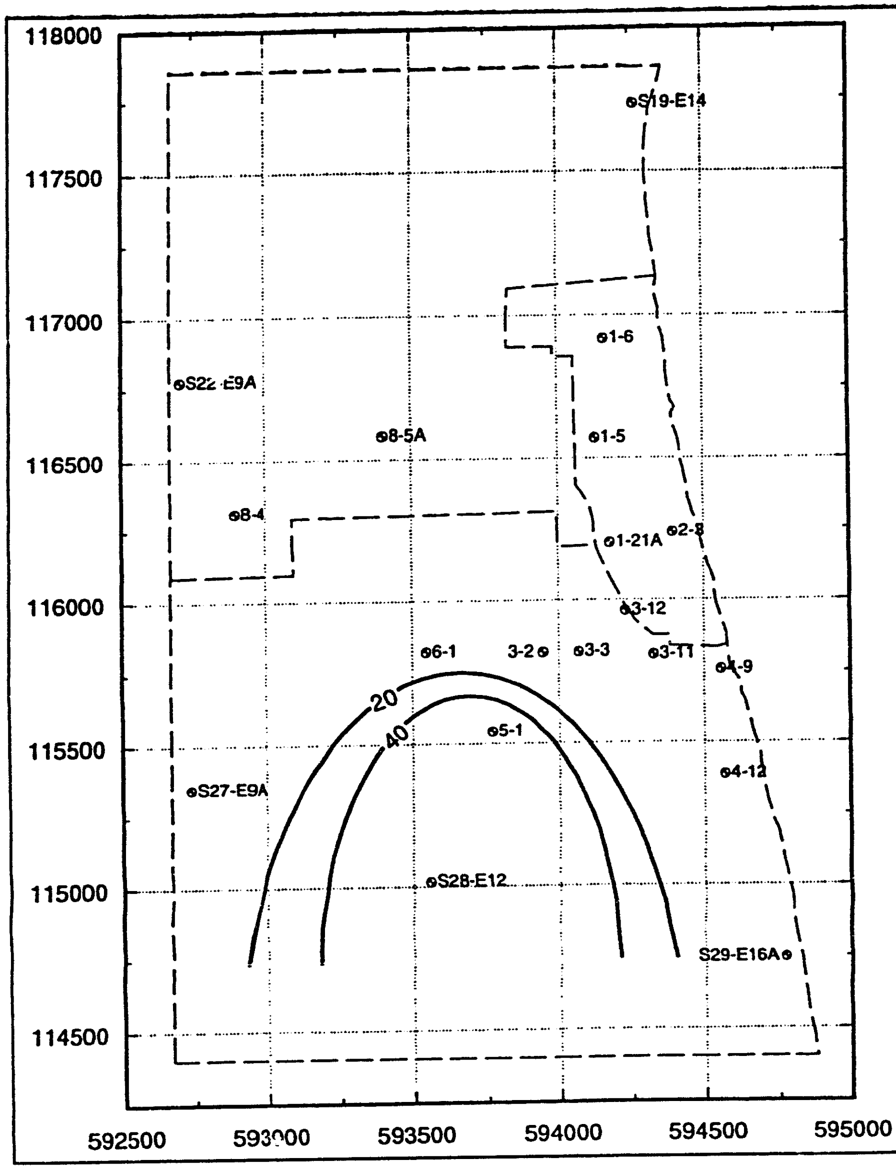
Well	Value
1-21A	4130.00 J
1-5	6904.00
1-6	9989.00
3-11	4634.00
3-12	6010.00 J
3-2	300.00 U
3-3	1075.00
3-7	2480.00 J
4-10	5030.00 J
4-12	1887.00
5-1	31.00 UJ
6-1	19.80 UJ
8-2	99.15 U
8-4	59.74 U
8-5A	0.00 UJ
S19-E14	11770.00
S22-E9A	0.00 UJ
S27-E9A	12.70 UJ
S28-E12	0.00 UJ
S29-E16A	59.90 UJ
S30-E15A	143.00 U

Notes:

1. Non-detects were contoured using one-tenth of the reported detection limit shown above.
2. Well labels begining with a "S" are prefixed with "699-". All other well labels are prefixed with "399-".
3. Coordinates are in meters and conform to the Lambert Coordinate System (NAD83).

913 1769/45559/1-26-94 pu

Figure 2-19. Tritium Concentration Contours for the Unconfined Aquifer (Round 1).

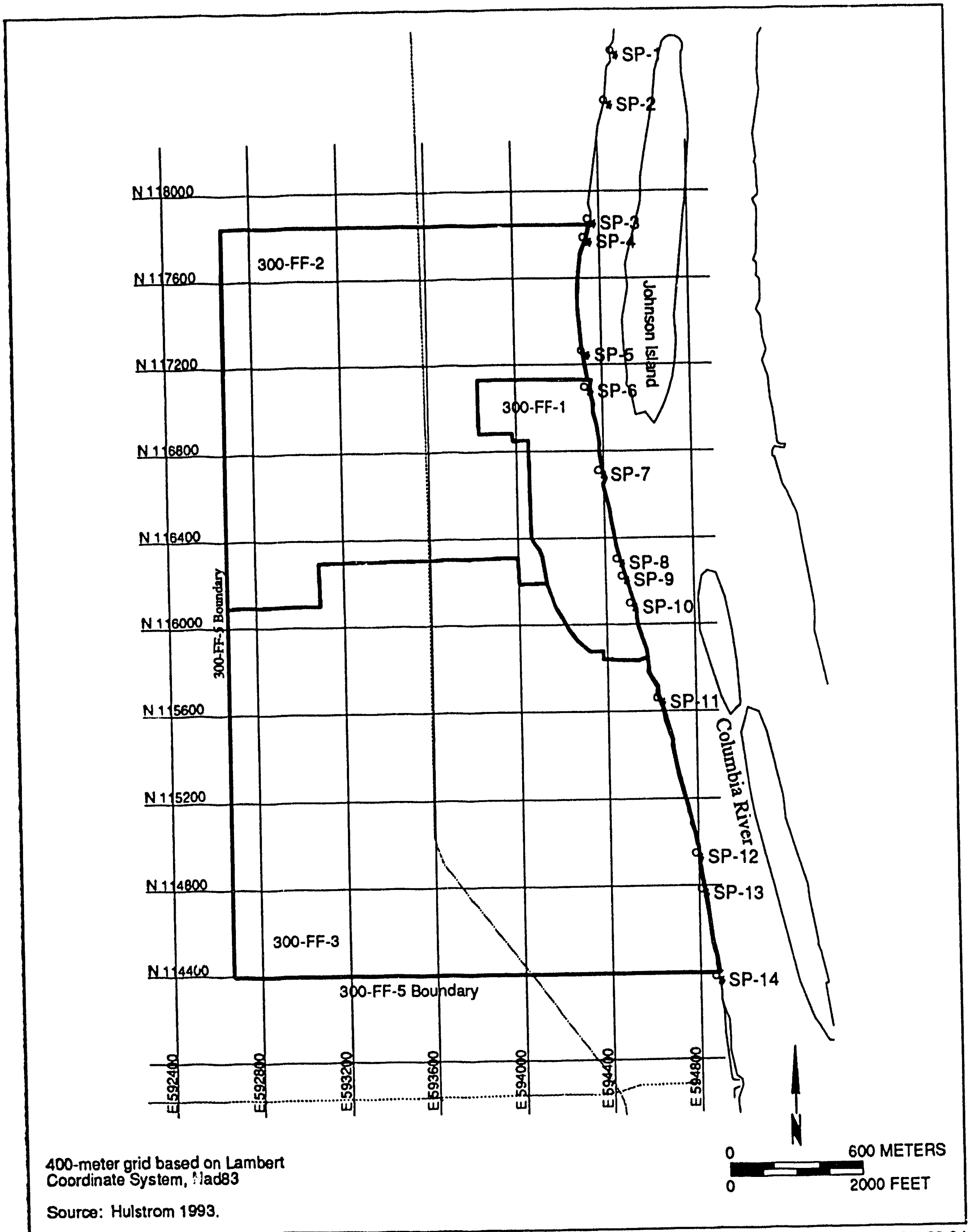


Well	Value
1-21A	5.70 UJ
1-5	15.00
1-6	9.40 J
2-3	2.00 UJ
3-11	8.20
3-12	5.60 J
3-2	6.20 J
3-3	0.42 U
4-12	2.10 UJ
4-9	7.70 J
5-1	65.00 J
6-1	4.80 J
8-4	1.90 UJ
8-5A	0.95 UJ
S19-E14	11.00 J
S22-E9A	3.10 UJ
S27-E9A	5.00 UJ
S28-E12	64.00 J
S29-E16A	8.30 J

Notes:
1. Non-detects were contoured using one-tenth of the reported detection limit shown above.
2. Well labels begining with a "S" are prefixed with "699-". All other well labels are prefixed with "399-".
3. Coordinates are in meters and conform to the Lambert Coordinate System (NAD83).

913 1769/45558/1-27-94 pu

Figure 2-20. Tc-99 Concentration Contours for the Unconfined Aquifer (Round 2).



913-1769/45616/1-26-94

Figure 2-21. Location of Springs and Seeps Along the West Bank of 300-FF-5 Operable Unit.

Table 2-1. Summary of Contaminants of Potential Concern Carried Forward to the Risk Assessment for Groundwater, Sediment and Surface Water. (Sheet 1 of 3)

MEDIUM/Parameter	Maximum Detected Concentration
GROUNDWATER	
ALL WELLS SCREENING SCENARIO	
Unconfined Aquifer	
Organics	(mg/L)
Chloroform	1.80E-02
1,2-Dichloroethene (total)	1.50E-01
Trans-Dichloroethene	1.30E-01
Trichloroethene	1.40E-02
Total coliform (c/100 ml)	280
Inorganics	(mg/L)
Copper	1.16E-02
Nickel	1.18E-01
Nitrate	1.56E+01
Radionuclides	(pCi/L)
Strontium-90	4.57E+00
Technetium-99	6.50E+01
Tritium	1.18E+04
Uranium-234	1.20E+02
Uranium-235	1.70E+01
Uranium-238	9.30E+01
Total Uranium	1.89E+02
Confined Aquifer	
Inorganics	(mg/L)
none	

Table 2-1. Summary of Contaminants of Potential Concern Carried Forward to the Risk Assessment for Groundwater, Sediment and Surface Water. (Sheet 2 of 3)

MEDIUM/Parameter	Maximum Detected Concentration
Organics	
none	
Radionuclides	(pCi/L)
none	
ON-SITE WELL SCREENING SCENARIO	
Inorganics	(mg/L)
none	
Organics	(mg/L)
Chloroform	8.00E-03
Trichloroethene	7.00E-03
Radionuclides	(pCi/L)
Tritium	1.89E+03
Uranium-234	8.10E+00
Uranium-235	5.1E-01
Uranium-238	8.40E+00
Total Uranium	1.75E+01
TRITIUM PLUME SCREENING SCENARIO	
Organics	(mg/L)
None	
Inorganics	
None	
Radionuclides	(pCi/L)
Tritium	1.18E+04

Table 2-1. Summary of Contaminants of Potential Concern Carried Forward to the Risk Assessment for Groundwater, Sediment and Surface Water. (Sheet 3 of 3)

MEDIUM/Parameter	Maximum Detected Concentration
SEDIMENT	
Inorganics	
none	
Organics	
none	
Radioisotopes	
none	
SURFACE WATER	
Hanford Site Background	
Organics	(mg/L)
Trichloroethene	2.00E-03J
Radionuclides	(pCi/L)
Technetium-99	5.40E+00J
Tritium	3.10E+03
Uranium-234	1.8E+01
Uranium-235	1.10E+00J
Uranium-238	1.90E+01
Inorganics	(mg/L)
none	
Operable-Unit Specific Background	
Inorganics	(mg/L)
none	
Organics	(mg/L)
Trichloroethene	2.00E-03J
Radionuclides	(pCi/L)
Technetium-99	5.40E+00J
Uranium-234	1.80E+01
Uranium-235	1.10E+00J
Uranium-238	1.90E+01

Table 2-2. Maximum Contaminant Concentrations in Groundwater Measured in 1992 and Predicted in 2018. (Sheet 1 of 2)

Parameter	Units	Maximum Groundwater Concentration	
		Measured in 1992	Predicted in 2018
ORGANICS			
1,2-Dichloroethene (total)[a]	μg/L	150	150
Trans-1,2-Dichloroethene[a]	μg/L	130	130
Chloroform	μg/L	18	0
Total Coliform[b]	c/100 ml	280	280
Trichloroethene[a]	μg/L	14	14
METALS			
Copper	μg/L	11.6	1.5
Nickel[c]	μg/L	118	50
ANIONS			
Nitrate[c]	mg/L	15.6	NA
RADIONUCLIDES			
Strontium-90	pCi/L	4.57	0.24
Technetium-99[c]	pCi/L	65	NA
Tritium[d]	pCi/L	11,800	11,800
Uranium-234	pCi/L	120	5
Uranium-235	pCi/L	17	1
Uranium-238	pCi/L	93	4
Uranium Total[e]	μg/L	270	12

Table 2-2. Maximum Contaminant Concentrations in Groundwater Measured in 1992 and Predicted in 2018. (Sheet 2 of 2)

NA = Not Applicable
Source: DOE-RL 1993a

[a] There appears to be a steadily dissolving source for these dense nonaqueous phase liquids (DNAPL). It was assumed that the mass of the source is large enough to insure steady dissolution and hence steady concentrations beyond 2018.

[b] Discharge of coliform bacteria is expected to continue indefinitely. The maximum future concentration of total coliform in 300-FF-5 operable unit groundwater was therefore assumed equal to the maximum measured in 1992.

[c] Impacts of the nitrate and technetium-99 plumes on 300-FF-5 operable unit groundwater were modeled for the 1100-EM-1 operable unit phase I and II remedial investigation reports (DOE-RL 1990b and 1992d). The reader is referred to these reports for future concentrations of nitrate and technetium-99 in 300-FF-5 operable unit groundwater.

[d] Rather than modeling the 200 Area tritium plume, future concentrations of tritium in 300-FF-5 operable unit groundwater were instead assumed identical to those currently measured.

[e] The half-life and distribution coefficient for total uranium were assumed identical to that of uranium-238.

Table 2-3. Maximum Future Mass Flux into the Columbia River and the Resulting Future River Concentration. (Sheet 1 of 2)

Parameter	Maximum Future Mass Flux Value	Maximum Future Mass Flux Units	Predicted Maximum River Concentration[a]	Predicted Average River Concentration
ORGANICS				
1,2-Dichloroethene (total)	NZ	µg/d	NZ	NZ
1,2-Dichloroethene (trans)	NZ	µg/d	NZ	NZ
Chloroform	$4.5x10^7$	µg/d	2.2 µg/L	0.028 µg/L
Total Coliform[b]	NA	c/100 ml	30 c/100 ml	30 c/100 ml
Trichloroethene	$3.6x10^7$	µg/d	1.8 µg/L	0.022 µg/L
METALS				
Copper	$3.2x10^7$	µg/d	1.6 µg/L	0.020 µg/L
Nickel	$1.4x10^8$	µg/d	7.1 µg/L	0.088 µg/L
ANIONS				
Nitrate[c]	NA	NA	NA	NA
RADIONUCLIDES				
Strontium-90	$6.3x10^5$	pCi/d	0.03 pCi/L	$3.9x10^{-4}$ pCi/L
Technetium-99[c]	NA	NA	NA	NA
Tritium[d]	NA	NA	5,800 pCi/L	130[e] pCi/L
Uranium-234	$2.0x10^7$	pCi/d	1.0 pCi/L	0.013 pCi/L
Uranium-235	$1.3x10^6$	pCi/d	0.06 pCi/L	0.0008 pCi/L
Uranium-238	$1.6x10^7$	pCi/d	0.81 pCi/L	0.010 pCi/L
Uranium Total	$4.2x10^7$	µg/d	2.1 µg/L	0.03 pCi/L

Table 2-3. Maximum Future Mass Flux into the Columbia River and the Resulting Future River Concentration. (Sheet 2 of 2)

NA = Not Applicable.

NZ = Near Zero. Frequency of detection is so small that calculation of the future maximum mass flux is not possible, but is expected to be near zero.

[a] Calculated as the average proportionality factor from Table 5-3 multiplied by the predicted maximum mass flux.

[b] Discharge of total coliform bacteria is expected to continue indefinitely. The maximum future Columbia River concentration of total coliform was therefore assumed equal to the maximum measured in 1992.

[c] Impacts of the nitrate and technetium-99 plumes on the Columbia River were modeled for the 1100-EM-1 operable unit phase I and II remedial investigation reports (DOE-RL 1990b and 1992d). The reader is referred to the aforementioned reports for future concentrations of nitrate and technetium-99 in the Columbia River.

[d] Rather than modeling the 200 Area tritium plume, future concentrations of tritium in the Columbia River were instead assumed identical to those currently measured. See discussion in Section 5.2.1.2.

[e] Represents the average concentration of tritium measured in water obtained from the 300 Area intake structure for 1991 (Bispring and Woodruff 1992a).

Table 2-4. Matrix of Locations, Times, and Exposure Scenarios Evaluated for the 300-FF-5 Operable Unit.

Scenario	300 Area	On Hanford Site	Off Hanford Site
Current			
Industrial	yes	no	yes
Residential	no	no	yes
Recreational	no	no	yes
Agricultural	no	no	yes
Future			
Industrial	yes	yes	yes
Residential	no	yes	yes
Recreational	no	yes	yes
Agricultural	no	yes	yes
Source: DOE-RL 1993a			

Table 2-5. Matrix of Current Exposure Scenarios and Exposure Points Evaluated for the 300-F-5 Operable Unit.

Media[a]	Exposure Point	Current Scenario				
		Industrial on 300 Area	Off Hanford Site			
			Industrial	Residential	Recreational	Agricultural
Groundwater[b]	Well 399-4-12[c]	yes	no	no	no	no
Surface[d] Water	Columbia River at 300 Area	yes	no	no	yes	no
Surface[d] Water	Columbia River at Richland	no	yes	yes	yes	yes

[a] Current exposure to sediment and biota was not assessed.
[b] Exposure to groundwater from well 399-4-12 was evaluated only for dermal and inhalation pathways. Well water is not used for drinking purposes.
[c] Onsite = well screening scenario.
[d] Exposure to surface water was evaluated for ingestion, dermal, and inhalation pathways. However, the inhalation pathway was not evaluated for recreational receptors.

Source: DOE-RL 1993a

Table 2-6. Matrix of Future Exposure Scenarios and Exposure Points Evaluated for the 300-FF-5 Operable Unit.

Media	Exposure Point	Future Scenario								
		Industrial on 300 Area	On Hanford Site				Off Hanford Site			
			Industrial	Residential	Recreational	Agricultural	Industrial	Residential	Recreational	Agricultural
Groundwater[a]	Any Well[a]	yes	no	no	no	no	no	no	no	no
Surface Water	Columbia River at 300 Area[a]	yes	yes	yes	yes	yes	no	no	no	no
Surface Water	Columbia River at Richland[a,b]	no	no	no	no	no	yes	yes	yes	yes
Biota	Fish	no	no	yes	yes	yes	no	yes	yes	yes

[a]Exposure to groundwater and surface water was evaluated for ingestion, dermal, and inhalation pathways. However, the inhalation pathway was not evaluated for recreational receptors.
[b]Qualitatively evaluated.

Source: DOE-RL 1993a

Table 2-7. Summary of Lifetime Incremental Cancer Risks for Current Exposure Scenarios for the 300-FF-5 Operable Unit.

Media	Exposure Point	Current Scenario				
		Industrial on 300 Area	Off Hanford Site			
			Industrial	Residential	Recreational	Agricultural
Groundwater[c]	Well 399-4-12	2E-05[a]	-	-	-	-
Surface Water	Columbia River at 300 Area	9E-08[b] (5E-06[c])	-	-	4E-07	-
Surface Water	Columbia River at Richland	-	1E-07	4E-07	8E-09	3E-07
Total ICR		2E-05	1E-07	4E-07	5E-07	4E-07

[a]Includes contribution from chloroform attributable to water chlorination (2E-05).
[b]Data from 300 Area water intake (represents average river concentrations).
[c]Data from spring locations 9 and 11 (represents maximum river concentrations). Includes contribution from Uranium-238 (3E-06) and Uranium-234 (1E-06).
- = Not evaluated.
ICR = Lifetime Incremental Cancer Risk.

Source: DOE-RL 1993a

Table 2-8. Summary of Lifetime Incremental Cancer Risks for Future Exposure Scenarios for the 300-FF-5 Operable Unit.

Media	Exposure Point	Future Scenario								
		Industrial on 300 Area	On Hanford Site				Off Hanford Site			
			Industrial	Residential	Recreational	Agricultural	Industrial	Residential	Recreational	Agricultural
Groundwater[e]	Any Well	7E-06[a]	-	-	-	-	-	-	-	-
Surface Water[b]	Columbia River at 300 Area	1E-07 (8E-06[c])	1E-07 (8E-06[c])	3E-07 (2E-05[d])	3E-09 (2E-07[e])	3E-07 (2E-05[d])	-	-	-	-
Surface Water	Columbia River at Richland	-	-	-	-	-	<1E-06[f]	<1E-06[f]	<1E-06[f]	<1E-06[f]
Biota	Fish	-	-	2E-07	2E-07	2E-07	-	2E-07	2E-07	2E-07
Total ICR[b]		7E-06 (2E-05)	1E-07 (8E-06)	5E-07 (2E-05)	2E-07 (4E-07)	5E-07 (2E-05)	<1E-06	<1E-06	<1E-06	<1E-06

[a]Includes contribution from tritium plume from 200 Area (3E-06) and trichloroethene (3E-06).
[b]Risk values associated with exposure to surface water from the 300 Area are based on predicted average river concentrations (300 Area water intake); risk values in parentheses are based on predicted maximum river concentrations (spring locations 9 and 11).
[c]Includes contribution from tritium plume from 200 Area (2E-06) and chloroform attributable to water chlorination (5E-06).
[d]Includes contribution from tritium plume from 200 Area (7E-06) and chloroform attributable to water chlorination (8E-06).
[e]Includes contribution from tritium plume from 200 Area (1E-07).
[f]Qualitatively evaluated.
- = Not evaluated.
ICR = Lifetime Incremental Cancer Risk.

Source: DOE-RL 1993a

Table 2-9. Risk-Based Concentrations at the 300-FF-5 Operable Unit for the Industrial Scenario.

Contaminant	Noncarcinogenic		Carcinogenic		
	Water Ingestion	Dermal	Water Ingestion	Inhalation of Volatiles	Dermal
INORGANIC (mg/L)					
copper	4.1	1,200	-[a]	-[a]	-[a]
nickel	2.0	300	-[a]	-[a]	-[a]
nitrate	-[a]	-[a]	-[a]	-[a]	-[a]
ORGANIC (mg/L)					
chloroform	1.0	3.0	0.059	0.00045	0.17
1,2-dichloroethene (cis)	1.0	30	-[a]	-[a]	-[a]
1,2-dichloroethene (trans)	2.0	61	-[a]	-[a]	-[a]
trichloroethene	-[a]	-[a]	0.032	0.0060	0.048
RADIOACTIVE (pCi/L)					
strontium-90	-[b]	-[b]	5.6	-[b]	-[b]
technetium-99	-[b]	-[b]	150	-[b]	-[b]
tritium (H-3)	-[b]	-[b]	3,700	-[b]	-[b]
uranium-234	-[b]	-[b]	13	-[b]	-[b]
uranium-235	-[b]	-[b]	13	-[b]	-[b]
uranium-238	-[b]	-[b]	7.1	-[b]	-[b]

[a]No toxicity factor available for this pathway.
[b]Applies to non-radioactive contaminants only.
Note: Risk-based concentrations were calculated using a target hazard quotient of 1 and a target incremental cancer risk of 1E-06. Shading identifies risk-based concentrations used in Chapter 3 for comparison to regulatory based cleanup standards.

3.0 REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) are developed to establish site-specific remediation goals, taking into account specific contaminants, contaminated environmental media, and potential contaminant exposure pathways [40 CFR 300.430(e)(i)]. Remedial action objectives and remediation goals, which are subject to refinement in the FS process, focus the development, screening, and evaluation of remedial alternatives to ensure that they are protective of human health and the environment.

The 300-FF-5 operable unit is a groundwater operable unit. Surface and vadose zone sources in the 300 Area are included in separate source operable units: 300-FF-1, 300-FF-2, and 300-FF-3. The existence of separate operable units for groundwater and sources in the 300 Area leads to questions regarding allocation (separation) and potential overlap of remedial action objectives between groundwater and source operable units. These questions are related primarily to whether, in spite of the fact that sources are not included as part of the groundwater operable unit, remedial action objectives for groundwater units should address potential future impacts from source operable units. There is the opportunity, in the separation of groundwater from the source operable units, to establish a framework that allows for the efficient coordination of remedial actions between source and groundwater operable units. This framework is described below.

Numerous sources of contamination impact groundwater in the 300 Area. Impacts from these sources will need to be considered in the evaluation of remedial alternatives in each source operable unit RI/FS. Impacts from these sources can be addressed in one of the following two ways:

- Groundwater operable unit studies could include evaluations of impacts to groundwater for each source operable unit, with the ultimate remedial solution for groundwater dependent on the completion and integration of these individual source studies.

- The individual source operable unit remedial actions will address source migration to groundwater. Given this approach, the remedial objectives of the groundwater operable unit RI/FS can be focused on addressing the existing groundwater contamination only, thereby decoupling the groundwater operable unit study from the individual source operable unit evaluations.

The second of these two options, by eliminating the dependency of the groundwater FS on the source studies, will allow the groundwater operable unit RI/FS to proceed more quickly and efficiently because of the limited and clearly defined scope. In fact, the latter alternative is the only means to complete the RI/FS process and reach a ROD for the 300-FF-5 operable unit when the RI/FS process has not been initiated for source units.

Evaluation of groundwater impacts from 300-FF-1 operable unit sources was conducted in the 300-FF-5 operable unit RI. Remedial action objectives related to groundwater impacts from source units need to be incorporated into the 300-FF-1 operable unit FS because they involve source control measures. To evaluate the 300-FF-1 operable unit source control measures in the 300-FF-5 FS would duplicate much of the work conducted in the 300-FF-1 operable unit FS.

It is recommended that RI for the other source operable units, 300-FF-2 and 300-FF-3, include predictive modeling of future impacts to the 300-FF-5 groundwater operable unit. Feasibility studies should develop remedial action objectives for source control measures if future impacts to groundwater are unacceptable. In this manner, the 300-FF-5 groundwater operable unit can proceed to a ROD before the RI/FS for the 300-FF-2 and 300-FF-3 operable units are completed.

The general remedial action objectives for the 300-FF-5 operable unit are to:

- comply with all regulatory-based numerical concentration standards for hazardous and radioactive constituents
- ensure that the human incremental cancer risk is less than a goal between 10^{-4} to 10^{-6} and that constituent concentrations are less than their corresponding reference dose concentrations (i.e., the concentration above which a toxic effect could reasonably be anticipated)
- minimize impacts on the environment.

In order to translate these general objectives into site- and constituent-specific objectives, it is necessary to consider in detail the 300-FF-5 operable unit constituents of concern, the types of affected media, the potential applicable or relevant and appropriate requirements (ARARs), areas and volumes of affected media, the potential exposure pathways, and the point of compliance. The point of compliance, which is based on land use, is discussed in Section 3.1.4.

The constituents of concern were determined in the RI and are summarized in Section 2.5 of the RI report (DOE-RL 1993a). Descriptions of constituent distribution within the affected media are provided in the 300-FF-5 RI for groundwater, surface water, sediments, and biota. Since the 300-FF-5 is a groundwater operable unit, the on[illegible]ys addressed are those related to water use, including ingestion, dermal exposure, and i[illegible]of volatiles. The source operable units address the direct exposure and air pathways.

3.1 POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This section presents potential applicable or relevant and appropriate requirements (ARARs) for the 300-FF-5 operable unit. This section identifies and evaluates federal and state requirements that are applicable or relevant and appropriate chemical, location, and action-specific requirements to the 300-FF-5 operable unit. The ARAR identification process is based on CERCLA guidance (EPA 1988a, EPA 1988b). Determination of final ARARs will be made by negotiation among DOE, EPA and Ecology, as agreed to by the three parties under the Tri-Party Agreement (Ecology et al. 1992).

Section 121 of the CERCLA, as amended, establishes cleanup standards for remedial actions at NPL sites. Section 121 requires in part that any applicable or relevant and appropriate standard, requirement, criteria, or limitation under any federal environmental law, or any more stringent state requirement promulgated pursuant to a state environmental statute, be met for any hazardous substance, pollutant, or contaminant that will remain onsite after completion of remedial action.

A requirement for Superfund compliance at a hazardous substance cleanup site may be either "applicable" or "relevant and appropriate," but not both. Identification of ARARs must be made on a site-specific basis and involves a two-part analysis: first, a determination is made whether a given requirement is applicable; then, if it is not applicable, a determination is made whether it is both relevant and appropriate. EPA guidance also includes To-Be-Considered (TBC) standards, which are advisories and non-promulgated guidance issued by federal or state governments that are non-statutory requirements. TBCs may be considered in setting cleanup standards, or may note regulations that, while not currently ARAR, may become ARAR prior to remedial action.

The EPA may waive ARARs and select a remedial action that does not attain the same level of cleanup as identified by ARARs. Section 121 of the Superfund Amendments and Reauthorization Act identifies six circumstances in which EPA may waive ARARs for on-site remedial actions. The six circumstances are:

- The remedial action selected is only a part of a total remedial action (such as an interim action), and the final remedy will attain the ARAR upon its completion.
- Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options.
- Compliance with the ARAR is technically impracticable from an engineering perspective.
- An alternative remedial action will attain an equivalent standard of performance through the use of another method or approach.
- The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.
- In the case of Section 104, Superfund-financed remedial actions, compliance with the ARAR will not provide a balance between protecting human health and the environment and the availability of Superfund money for response at other facilities.

Different types of requirements that CERCLA actions may have to comply with are generally identified as chemical-specific, location-specific and action-specific ARARs. The following definitions are excerpts from EPA guidance in *CERCLA Compliance with Other Laws Manual: Interim Final* (EPA 1988b). However, some requirements may not fall neatly into EPA's classification system.

> Chemical-specific requirements are health- or risk-based numerical values, or methodologies that, when applied to site-specific conditions, result in numerical values. These numbers establish the acceptable amount or concentration of a chemical that can be found in, or discharged to, the ambient environment.
>
> Location-specific requirements are restrictions placed on the concentration of hazardous substances or the conduct of activities because they occur in special or sensitive locations or environments.

Action-specific requirements are those that place either technology-based or activity-based requirements on remedial actions at CERCLA sites.

The following discussion of ARARs focuses on the most significant potential ARARs. The associated tables (Tables 3-1, 3-2, 3-5 and 3-6) present the full list of ARARs that were evaluated.

3.1.1 Chemical-Specific ARARs

Potential federal and state chemical-specific requirements, criteria, or guidance for the contaminants of concern at the 300-FF-5 operable unit are listed in Tables 3-1 and 3-2, respectively.

3.1.1.1 Federal Chemical-Specific ARARs. Federal chemical-specific requirements, criteria, or guidance for the contaminants of concern at the 300-FF-5 operable unit are listed in Table 3-1.

National Primary Drinking Water Regulations - 40 CFR 141

Requirements of the National Primary Drinking Water Regulations (40 CFR 141) promulgated under the Safe Drinking Water Act (SDWA) are not applicable to the 300-FF-5 operable unit because they address contamination in community water systems and groundwater at the site is not used for drinking water. However, they are relevant and appropriate requirements to the 300-FF-5 operable unit because contaminated groundwater discharges to the Columbia River, which is used for drinking water. The regulations establish maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs). MCLs and MCLGs have been established for both non-radioactive contaminants and radionuclides. Remedial alternatives must consider protection of potential drinking water supplies as required by Section 300.430 (e)(B) of the National Oil and Hazardous Substances Contingency Plan (NCP). Section 121 (d)(2)(A)(ii) of CERCLA requires that remedial actions for ground or surface water that are current or potential sources of drinking water attain standards established under the SDWA. However, if the MCLG equals zero then the MCL is used instead. Drinking water MCLGs and MCLs for contaminants of concern at the 300-FF-5 operable unit are listed in Tables 3-3 and 3-4.

MCL's for gross alpha (15 pCi/L) and gross beta (50 pCi/L) are not included on Table 3-3, even though they are exceeded in 300-FF-5 operable unit groundwater. The gross alpha MCL is not relevant to the 300-FF-5 operable unit because it excludes gross alpha due to uranium. When gross alpha due to uranium is subtracted out, the remaining gross alpha concentrations are less than 15 pCi/L. The gross beta MCL is not a health-based standard, but rather a threshold concentration that requires analysis for specific beta-emitters. These analysis were already conducted for 300-FF-5 operable unit samples, and no beta-emitters were found to exceed isotope-specific MCLs. Note that the beta emissions are due to uranium-238 and its daughters (e.g. protactinium-238m).

National Secondary Drinking Water Regulations - 40 CFR 143

The National Secondary Drinking Water Regulations control contaminants in drinking water that primarily affect aesthetic qualities of the water related to public acceptance. These regulations are neither applicable nor relevant and appropriate as federal requirements to the 300-FF-5 operable unit because they are not legally enforceable. However, under the Washington State Model Toxics Control Act Cleanup Regulation [173-340-720 (2) (a) (ii)] these standards are defined as applicable requirements for cleanup of groundwater that is a current or potential source of drinking water. Secondary maximum contaminant levels (SMCLs) established for operable unit contaminants of concern are presented in Table 3-4.

Environmental Radiation Protection Standards for Nuclear Power Operations - 40 CFR 190

Environmental Radiation Protection Standards for Nuclear Power Operations (40 CFR 190) are not applicable to the operable unit because the regulation addresses operations that directly support the production of electrical power for public use and excludes operations at disposal sites. However, the standard is relevant and appropriate because it addresses acceptable dose to the public as a result of planned discharges which occurred from past activities conducted at source operable units within 300-FF-5. The standard sets dose equivalents that any member of the public may receive as a result of planned discharges (radon and its daughter products excluded) at levels that shall not exceed 25 mrem/yr to the whole body, 75 mrem/yr to the thyroid, or 25 mrem/yr to any other organ. In addition, release limits are established for the total quantity of radioactive material that may enter the environment from the entire uranium fuel cycle, per giga-watt year of electrical energy produced.

Standards for Protection Against Radiation - 10 CFR 20

Nuclear Regulatory Commission Standards for Protection Against Radiation found in 10 CFR 20 are relevant and appropriate to the operable unit because the regulation establishes standards for protection against radiation hazards that may result from occupational exposure or discharges to air and water. The standard is not applicable because it only applies to operations licensed by the Nuclear Regulatory Commission. The concentration limits for radionuclides in liquid effluent discharged to unrestricted areas established under the standard are summarized in Table 3-3.

Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings - 40 CFR 192

Requirements of 40 CFR 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, are potentially relevant and appropriate requirements to the operable unit because they provide guidance for implementing remedial actions if contaminants have been released to groundwater. The regulation establishes concentration limits for Ra-226, 228, and gross alpha radioactivity in groundwater. Limits for gross alpha activity, excluding radon and uranium, are set at 15 pCi/L. The requirements are not applicable because the 300-FF-5 operable unit is not associated with uranium or thorium milling.

DOE Order 5400.5 Radiation Protection of the Public and Environment

Radiation protection and radioactive waste management requirements issued under the Atomic Energy Act are implemented at DOE facilities as DOE orders. Under CERCLA, these standards are TBC for activities conducted at the 300-FF-5 operable unit because they are not formally promulgated regulations. However, compliance with DOE orders is required at Hanford. DOE Order 5400.5, Radiation Protection of the Public and Environment, includes derived concentration guides (DCGs) for radioactively-contaminated liquid discharges to surface waters, aquifers, soil, and sanitary sewage systems. These limits are based on the 4 mrem/year effective dose equivalent for drinking water ingestion and are provided in Table 3-3. The order incorporates most of the same control and cleanup provisions of EPA's 40 CFR 192 and provides factors used to estimate external and internal doses received from exposure to radiation, as well as expanded requirements and guidance on environmental monitoring.

The DOE order applies the "As Low As is Reasonably Achievable" (ALARA) process to radiation protection. The ALARA process is not a dose-based limit, but a feasibility limit, in that exposures should be as far below applicable limits as practical. The feasibility limit should account for social, economic, technical, and public policy considerations. The ALARA process includes procedures for evaluating alternative operations and other factors to reduce radiation exposures.

Radiological protection requirements are established for residual radioactive material and cleanup of residual materials. The basic public dose limit is 100 mrem effective dose equivalent per year in excess of naturally occurring background. Additional guidelines for residual radioactive material in soils for radium and thorium are set at the levels issued under 40 CFR 192. The level of gamma radiation in any habitable structure shall not exceed 20 μR/h above background and residual concentrations of radionuclides in air and water are set at the DCGs or as required by applicable state and federal law. Long-term management guidelines for uranium, thorium and their decay products include:

- Control and stabilization features designed to provide to the extent possible an effective life of 1,000 yr, but no less than 200 yr.
- Rn-222 emanation limited to less than 20 pCi/m^2/s and prevent increase in Rn-22 concentrations at any point at or outside the boundary by more than 0.5 pCi/l.
- Groundwater protection in accordance with legally applicable federal and state standards.

DOE Order 5400.5 identifies circumstances where supplemental limits or exceptions to the standards may be implemented. Situations identified by DOE that may warrant use of a supplemental standard include situations where remedial action would pose a clear and present risk to workers or members of the public using reasonable measures to reduce or avoid the risk. Supplemental standards may also be issued where the cost for remedial actions for contaminated soils is unreasonably high relative to the long-term benefits and where residual material does not pose a clear present risk after taking necessary control measures. The likelihood that persons will not erect buildings or spend long periods on the property should be evaluated in considering the site risk.

The proposed DOE rule, Radiation Protection of the Public and the Environment (10 CFR 834), in the March 23, 1993 Federal Register (58 FR 16268), promulgates the standards presently found in DOE order 5400.5. The proposed rule retains the substantive portions of the DOE order and differs from the existing order in format, enhanced emphasis on the ALARA process, and changes in the usage of DCGs. The proposed rule identifies DCGs not as "acceptable" discharge limits, but to be used as reference values for estimating potential dose and determining compliance with the requirements of the proposed rule. Where residual radioactive materials remain, the proposed rule states that various disposal modes should address impacts beyond the 1,000 year time period identified in the existing DOE Order.

3.1.1.2 State of Washington Chemical-Specific ARARs. CERCLA 121(d) requires that, in addition to satisfying Federal ARARs, any state standard, requirement, criterion, or limitation that is more stringent must also be met. State requirements must be legally enforceable regulations or statutes, identified in a timely manner, and be of general applicability to all circumstances covered by the requirement. Table 3-2 identifies preliminary chemical-specific Washington State ARARs for the 300-FF-5 operable unit. Tables 3-3 and 3-4 present regulatory limits for operable contaminants of concern.

Model Toxics Control Act Cleanup Regulations - WAC 173-340

Regulations under chapter 173-340 WAC, which implement requirements of the Model Toxics Control Act (MTCA, Ch. 70.105D RCW), are potentially applicable to the 300-FF-5 operable unit. Signatories of the Tri-Party Agreement, DOE, Ecology, and EPA (Ecology et al. 1992), are currently negotiating the applicability of MTCA to the Hanford Site. These regulations establish administrative processes and standards to identify, investigate, and clean up facilities where hazardous substances have been released. The state regulations have the potential to be stricter than federal standards. For example, MTCA specifies secondary MCLs as applicable requirements for groundwater that is a current or potential source of drinking water. Secondary MCLs are non-enforceable standards under 40 CFR 143 and are based on non-human health-based goals relating to qualities such as taste and odor.

The MTCA regulations establish three basic methods for determining cleanup levels for groundwater, as set forth in WAC 173-340-700. These include Method A (Tables), Method B (Standard), and Method C (Conditional).

Method A is generally used for routine cleanups with relatively few contaminants. Standards for Method A cleanups are based on other federal or state ARARs, are established in Table 1 in WAC 173-340-720, or are based on natural background concentrations or practical quantification limits (PQLs). Because the cleanup at the 300-FF-5 operable unit cannot be considered routine and most of the contaminants are not included in Table 1, Method A cleanup standards are not appropriate for use at the 300-FF-5 operable unit.

Under WAC 173-340-705, Method B is generally used unless one or more of the reasons for using Method A or Method C are demonstrated. Under Method B, cleanup levels are determined using federal or state ARARs or risk-based equations specified in WAC 173-340-720. For individual carcinogens, the cleanup levels are based on the upper bound of the excess lifetime cancer risk of one in one million (1×10^{-6}). Total excess cancer risk under Method B for multiple substances and pathways cannot exceed one in one hundred thousand (1×10^{-5}). However, concentrations of individual contaminants established under Method B are at least as stringent as concentrations established under federal, state, or local laws. The Department of Ecology may also establish more stringent concentrations for individual contaminants to take into account exposure to multiple contaminants and/or exposure resulting from more than one pathway. Adjustments to cleanup levels are made according to the procedure set forth in WAC 173-340-708.

Method C cleanup levels are used where Method A or B cleanup levels are below area background concentrations, cleanup to Method A or B levels has the potential for creating greater overall threat to human health and the environment than Method C, or cleanup to Method A or B is not technically possible. Method C cleanups must comply with other federal or state ARARs, must use all practical levels of treatment, and must incorporate institutional controls (WAC 173-340-440). Risk-based equations for Method C cleanup levels for groundwater are specified in WAC 173-340-720. Total incremental cancer risk for Method C cannot exceed 1×10^{-5}. However, concentrations of individual contaminants established under Method C are at least as stringent as concentrations established under federal, state, or local laws. The Department of Ecology may also establish more stringent concentrations for individual contaminants to take into account exposure to multiple contaminants and/or exposure resulting from more than one pathway. Adjustments to cleanup levels are made according to the procedure set forth in WAC 173-340-708.

Under WAC 173-340-700(4)(d), the cleanup level cannot be established at less than the background level. MTCA Method B risk-based standards for U-234 (2.9 pCi/L) and U-238 (1.6 pCi/L) are below their respective site-specific background concentrations calculated in the RI (DOE-RL 1993a). Therefore, background concentrations for these constituents are shown in Table 3-3 for the Method B standards. As described in the RI, the high site-specific background may reflect the small number of background samples and analytical variability. In short, actual uranium background concentration in the 300 Area is uncertain.

All three MTCA methods for determining cleanup levels require minimum compliance with other federal or state ARARs and should not result in contamination of another medium (air, water, or soil). Cleanup actions must use appropriate measures to reduce impacts to other media. Groundwater cleanup levels based on WAC 173-340-720 Methods B and C are shown in Tables 3-3 and 3-4.

The point of compliance is defined in the regulations as the point or points throughout the site where cleanup levels must be met, as specified in Section 173-340-720. The regulations state the point of compliance for groundwater must be attained throughout the site from the uppermost level of the saturated zone vertically to the lowest depth that could be potentially affected. For alternatives that involve containment of hazardous substances, cleanup levels typically will not meet these points of compliance. In these cases, compliance monitoring and other requirements identified in 173-340-360 (8) may be required to ensure long term integrity of the containment system. Conditional points of compliance may be established at sites where cleanup levels are based on protection of surface waters. At these sites, the conditional point of compliance must be set as close as technically possible to the points where groundwater flows into the surface water.

Department of Health Standards for Public Water Supplies - WAC 246-290

The rules established under WAC 246-290 defines the regulatory requirements necessary to protect consumers using public drinking water supplies. The rules are intended to conform with the federal Safe Drinking Water Act (SDWA), as amended.

WAC 246-290-310 establishes maximum contaminant levels (MCLs) which define the water quality requirements for public water supplies. The requirements of WAC 246-290-310 are not applicable to the 300-FF-5 operable unit since they address public drinking water supplies and groundwater at the site is not used for drinking water. However, these standards may be relevant and appropriate since groundwater discharges to the Columbia River, which is used for drinking water.

WAC 246-390-310 establishes both primary and secondary MCLs and identifies that enforcement of the primary standards is the Department of Health's first priority. Since the standards set under WAC 246-290-310 are set at the levels established under the federal SDWA, refer to Tables 3-3 and 3-4 for federal drinking water MCLs and MCLGs.

Surface Water Quality Standards - WAC 173-201A

Under MTCA [WAC 173-340-720 (1)(c)(iii)], groundwater quality must meet surface water quality criteria at the point of discharge. Groundwater from the 300-FF-5 operable unit discharges to the Columbia River; therefore these criteria are applicable. The chapter defines water quality criteria for surface waters of the state that are protective of public health, fish, and wildlife. Surface waters of the state are classified by characteristics and categorized into classes and quality criteria are specified for each class. The Columbia River in the Hanford Reach is classified as Class A Excellent. Tables 3-3 and 3-4 list water quality criteria for operable unit contaminants of concern.

Sediment Management Standards - WAC 173-204

Sediment Management Standards were developed pursuant to the Water Pollution Control Act (Ch. 90.48 RCW) and MTCA. WAC 173-204 sets surface sediment quality standards and provides a management and decision process for reduction of pollutant discharges and the cleanup of contaminated sediments. This chapter is applicable to all existing or proposed actions at the 300-FF-5 operable unit that may affect sediment quality. The Department of Ecology determines fresh water surface sediment quality on a case-by-case basis. Numeric criteria for freshwater sediments have not been promulgated. The Department of Ecology may apply the most restrictive standard if the beneficial uses of more than one resource are affected, such as at the interface between surface sediments, groundwater, or surface water. No degradation of existing sediment quality is allowed in waters constituting an outstanding national resource and existing beneficial uses must be maintained and protected. Whenever sediments are of a higher quality than criteria assigned to the sediment, the existing surface sediment quality shall be protected and waste and other materials shall not be allowed to contaminate the surface sediments or reduce existing sediment quality.

State Radiation Protection Standards - CH. 70.98 RCW

Washington State Radiation Standards (Ch. 70.98 RCW) were developed pursuant to the Atomic Energy Act of 1954 and are implemented in WAC 246-220 through WAC 246-255. Not all the standards in the referenced chapters are specifically applicable to the operable unit and only the following standards are considered as chemical-specific ARARs. WAC 246-221, Radiation Protection Standards, is applicable because it establishes the maximum allowable radiation dose to individuals in restricted areas, exposure to minors and permissible levels of radiation from external sources in unrestricted areas. Radiation dose limits to individuals in restricted areas are not to exceed 1.25 rem per quarter to the whole body, head and trunk, active blood forming tissues, lens of the eyes or gonads; 18.75 rem per quarter to hands and forearms or feet and ankles; or a dose of 7.5 rem per quarter to the skin of the whole body. Chapter 246-221 also establishes concentration limits in effluent released to unrestricted areas. WAC 246-247, Radiation Protection-Air Emissions, promulgates air emission limits for airborne radionuclide emissions at the same levels as defined in WAC 173-480 which are consistent with federal NESHAPs. The ambient standard requires that emission of radionuclides to the air must not cause a dose equivalent of 25 mrem per year to the whole body or 75 mrem per year to any critical organ. Radiation protection standards for uranium and thorium milling sites are presented in WAC 246-252 and are not applicable to the 300-FF-5 operable unit because it was not used for uranium or thorium milling. However, the regulation is considered relevant and appropriate because it presents specific radiation protection standards for groundwater.

3.1.2 Location-Specific ARARs

Location-specific ARARs at the 300-FF-5 operable unit are restrictions placed on the concentration of hazardous substances or the conduct of activities at the site based solely on location characteristics of the 300-FF-5 operable unit.

3.1.2.1 Federal Location-Specific ARARs. Federal location-specific requirements that were evaluated are summarized in Table 3-1.

The Archeological and Historic Preservation Act - 16 USC 469a

The Archeological and Historic Preservation Act is applicable because archaeologic sites have been identified at the 300-FF-5 operable unit. This act is similar to the National Historic Preservation Act, but differs in that it mandates only protection of historic or archaeologic data and not the actual archaeologic or historic site. If new archeological sites are discovered during remediation activities, the lead agency must preserve the data or request the Department of Interior to do so.

The Endangered Species Act - 16 USC 1531

The Endangered Species Act of 1973 is applicable because a protected vegetation species, persistentsepal yellowcress, was identified in the riparian zone of the 300-FF-5 operable unit during ecological surveys (DOE-RL 1993a). A number of candidate species of vegetation and animals reside in the 300 Areas, but the only endangered or threatened animal species observed along the riparian zone of the 300 Area are infrequent visitors. Regulation implementing this act have been promulgated in 50 CFR 17, Endangered and Threatened Wildlife and Plants.

The Wild and Scenic River Act - 16 USC 1271

The Wild and Scenic River Act is TBC because the Hanford Reach of the Columbia River has been nominated for inclusion on the national list of wild and scenic rivers. Therefore, remediation alternatives should consider potential impacts to the Columbia River.

Requirements of this act specify that projects that affect the free-flow characteristics of the river should be undertaken in such manner as to minimize adverse impacts. The Act identifies dredging, rip-rap, shoreline development, and direct and indirect discharges as activities that may affect free-flowing characteristics. Remedial alternatives should be developed in coordination with the Departments of Interior and Agriculture and should be designed to reduce impacts to the river. The ROD should specify how the selected remedy will meet these requirements.

Hanford Reach Comprehensive River Protection Study and Interim Protection - P.L. 100-605

This law requires that the Secretary of Interior prepare a comprehensive river conservation study for the segment of the Columbia River from a point one mile below the Priest Rapids Dam approximately 51 miles downstream to the McNary Pool, north of Richland. This stretch of the river is commonly referred to as the Hanford Reach. This law is applicable to remedial actions performed at 300-FF-5 that may impact the river. Pursuant to this law, *The Hanford Reach of the Columbia River, Draft Comprehensive River Conservation Study and Environmental Impact Statement* has been prepared (NPS, 1992). This environmental impact statement documents the resources of the Hanford Reach and develops alternatives for their protection as required by PL

100-605. One alternative included in the study is designation of the Hanford Reach into the National Wild and Scenic Rivers System.

Enactment of this law also provides for interim protection of the Hanford Reach for a period of eight years. During the period of interim protection, construction of dams is prohibited and so are dredging and channelization projects. Interim protection also requires all other existing or planned federal and non-federal projects to minimize adverse impacts to the river and whenever possible, to make use of existing structures and facilities. Agencies planning projects within the area of the Hanford Reach are to coordinate with the Secretary of the Interior in order to minimize and mitigate potential adverse impacts.

Compliance With Floodplain/Wetlands Environmental Review Requirements - 10 CFR 1022

This regulation is applicable to remedial actions at the 300-FF-5 operable unit because a portion of the 300-FF-5 operable unit is in the Columbia River floodplain, and because wetlands exist along the shoreline. This regulation requires DOE and other federal agencies to comply with the requirements of Executive Order 11990 - Protection of Wetlands, and Executive Order 11988 - Floodplain Management. Executive Order 11988 requires that DOE procedures ensure that actions conducted in a floodplain consider flood hazards. Executive Order 11990 requires the protection of wetlands from destruction and specifies that construction activities in the area of wetlands be minimized. The Executive Orders specify that federal agencies implement these considerations through existing federal requirements, such as the National Environmental Policy Act. The Army Corp of Engineers has established a nationwide permitting program for actions that may impact wetlands. Under CERCLA, onsite cleanup actions are not required to comply with administrative permit requirements of federal, state, and local regulations, however; CERCLA actions must comply with the substantive portions of the regulations.

3.1.2.2 State Location-Specific ARARs. State location-specific requirements that were evaluated are summarized in Table 3-2.

3.1.3 Action-Specific ARARs

Preliminary federal and state action-specific requirements are identified in Tables 3-5 and 3-6, respectively. Action-specific requirements will be re-considered for those remedial alternatives that pass preliminary screening.

3.1.3.1 Federal Action-Specific ARARs. Federal action-specific requirements that were evaluated are summarized in Table 3-5.

Resource Conservation and Recovery Act Regulations (RCRA) - 40 CFR 260-268

Requirements under RCRA are applicable to remedial alternatives that may be conducted at the site if any hazardous waste is generated. RCRA provides requirements that address the generation, transport, storage, treatment, and disposal of hazardous waste. Hazardous wastes may be subject to land disposal restrictions (LDRs) (40 CFR 268).

The Corrective Action for Solid Waste Management Units regulation (40 CFR 264.552) presents provisions for the use of corrective action management units (CAMUs) and temporary units as remediation waste management units and is considered applicable. Previous EPA experience found that implementing RCRA Subtitle C rules to remediation wastes provided disincentives to the implementation of more protective remedies and remediation was negatively impacted by RCRA regulatory controls. Specific areas where increased flexibility in the management of remediation wastes provided by this regulation include; placement of remediation waste into a CAMU is not considered land disposal of waste and is not subject to LDRs; CAMUs do not have to meet minimum technology requirements for landfills; and finally, CAMUs are only subject to closure requirements as deemed necessary by the EPA Regional Administer and as appropriate to the waste management unit. The creation of CAMUs allows decision makers and facility operators increased flexibility in order to expedite remediation of environmental releases from operating hazardous waste TSD facilities.

Licensing Requirements for Land Disposal of Radioactive Waste - 10 CFR 61

Licensing Requirements for Land Disposal of Radioactive Waste under 10 CFR 61 are relevant and appropriate to remedial actions that include land disposal of radioactive material or release of radioactive effluent. The standard is not applicable because it only applies to disposal of radioactive waste received from other persons. The standard sets limits for the annual dose allowed beyond the facility boundary, performance standards for protection of individuals during operation, and protection of inadvertent intruders after cessation of institutional controls.

Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings - 40 CFR 192

Standards for cleanup set by 40 CFR 192, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, are relevant and appropriate requirements to the operable unit because the standard establishes groundwater protection strategies if contaminants have been released to groundwater. The standard is not applicable because the site is not associated with uranium or thorium milling.

National Pollutant Discharge Elimination System (NPDES) - 40 CFR 122 to 125

The NPDES program controls release of toxic pollutants through monitoring requirements and implementation of a best management practices program. The administrative (e.g., permitting) requirements of the NPDES program are not applicable for on site discharge at CERCLA sites (in accordance with CERCLA Section 121(c)). The substantive requirements would still be applicable. A NPDES permit would be required if discharge of treated groundwater to the Columbia River is considered an offsite activity.

Underground Injection Control Program - 40 CFR 144 to 148

These regulations address permitting for Underground Injection Control (UIC) to prevent contamination of underground sources of drinking water. These requirements concern siting, construction, operating, monitoring, and closure of injection wells. NPL sites that construct underground injection wells onsite are not required to comply with the administrative requirement, (e.g, permitting), but must meet the substantive requirements of the program.

Radiation Protection for Occupational Workers - DOE Order 5480.11

DOE Order 5480.11 implements radiation protection standards and program requirements for worker protection at DOE and DOE-contractor operations. These standards were developed to be consistent with EPA standards and are based on recommendations by organizations recognized as authorities in the area of radiation protection. These standards are TBC under CERCLA because they are not federally-promulgated regulations. However, compliance with DOE orders is required at the Hanford Site.

National Environmental Policy Act (NEPA) Regulations - 40 CFR 1500

The purpose of NEPA requirements is to ensure that potential impacts of cleanup activities are assessed. NEPA requires either an Environmental Assessment or Environmental Impact Statement for major federal projects. With the exception of the no action and institutional controls alternatives, NEPA requirements will likely be applicable. Therefore, either an Environmental Assessment or Environmental Impact Statement would be required for identifying and evaluating the impacts associated with the selected remedial alternative.

3.1.3.2 State Action-Specific ARARs. Table 3-6 lists the preliminary state action-specific ARARs for the 300-FF-5 groundwater operable unit.

Model Toxics Control Act Cleanup Regulations - WAC 173-340

The Model Toxics Control Act (MTCA) Cleanup Regulations implemented under WAC 173-340 are potentially applicable to remediation of the 300-FF-5 operable unit. This regulation establishes cleanup requirements that are protective of human health and the environment and the methods necessary to achieve compliance. The MTCA has a statutory preference for permanent solutions that minimize the amount of untreated hazardous substances remaining onsite. The hierarchy of preference described in WAC 173-340-360 favors destruction and treatment over disposal, containment, or institutional controls. Specific requirements that ensure cleanup actions are designed, constructed and implemented in a manner consistent with acceptable engineering practices are outlined in WAC 173-340-400. Section 173-340-410 of the WAC specifies compliance monitoring requirements for remedial actions and WAC 173-340-440 defines the requirements for institutional controls applicable to cleanup actions where residual concentrations of contaminants exceed levels specified under WAC 173-340-700 through 760 at conditional points of compliance established under the regulation.

Dangerous Waste Regulations - WAC 173-303

Washington State Dangerous Waste Regulations (WAC 173-303) contain requirements that are applicable to remedial alternatives at the 300-FF-5 operable unit if dangerous waste is generated, treated, stored or disposed on- or offsite during remedial actions. Washington state regulations are at least as stringent as federal regulations.

State Waste Discharge Program - WAC 173-216

The requirements of the State Waste Discharge Program (WAC 173-216) are applicable to remedial actions that discharge waste materials into groundwater or surface water and municipal sewerage systems. This chapter controls waste discharge by implementing a permit system that requires pretreatment or any other methods necessary to meet regulatory standards established under other laws, including the dangerous waste program and surface water quality criteria of the Federal Water Pollution Control Act. The Waste Discharge Program also specifies that all known, available, and reasonable prevention, control and treatment methods be applied to the waste prior to discharge. The requirements of this chapter are not applicable to discharges subject to NPDES permits.

CERCLA Section 121 (e) exempts remedial response actions conducted entirely on-site from having to obtain federal, state or local permits. In general, on-site actions must meet only the substantive requirements of WAC 173-216. However, off-site response actions must comply with all legally applicable requirements, both substantive and administrative. Off-site discharge of groundwater resulting from remedial actions would require a permit under the Waste Discharge Program, whereas only the substantive requirements of the program would be applicable to on-site discharges.

Underground Injection Control Program (UIC) - WAC 173-218

These regulations address permitting for Underground Injection Control (UIC) to prevent contamination of underground sources of drinking water. These requirements concern siting, construction, operating, monitoring, and closure of injection wells. NPL sites that construct underground injection wells onsite are not required to comply with the administrative requirement, (e.g, permitting), but must meet the substantive requirements of the program.

3.1.4 Point of Compliance

Important to the evaluation of ARARs is determination of the point of compliance. EPA guidance (EPA 1988a) notes that ARARs should be attained at all points throughout the contaminant plume at the completion of remedial action, or if wastes are left in place, ARARs should be met at all points of potential exposure or at points specified by individual ARARs. For groundwater, CERCLA cleanup goals should be attained throughout the contaminated plume, or at the point or points where groundwater enters surface waters. Integral to defining the point or points of compliance are decisions regarding future groundwater and land use in the 300 Area of the Hanford Site. Currently the 300 Area groundwater is not a source of drinking water, however, contaminated groundwater does discharge into the Columbia, which is used by the City of Richland as a source of drinking water.

The Safe Drinking Water Act provides the most stringent point of compliance identified in a potential federal ARAR, if groundwater contaminated by the 300-FF-5 operable unit is used for drinking water. The EPA interim guidance on compliance with ARARs states MCLs "are generally applicable where the water will be supplied to 15 or more service connections. If the MCLs are applicable, they are applied at the tap." EPA interim guidance notes that MCLs are "relevant and appropriate" as in-situ cleanup standards where groundwater is or may be used for drinking water.

Washington State requirements for point of compliance are contained in the Model Toxics Control Act Cleanup Regulations (WAC 173-340-700). The point of compliance is defined as the point or points throughout the site where cleanup levels are established in accordance with sections WAC 173-340-720 through 750, which address groundwater, surface water, soil and air quality cleanup standards. The regulation states that the point of compliance for groundwater is throughout the site, from the uppermost level of the saturated zone vertically to the lowest depth that could potentially be affected. Conditional points of compliance may be set at sites where cleanup levels are based on the protection of surface waters. At these sites, the conditional point of compliance must be set as close as technically possible to the points where groundwater flows into the surface water. The cleanup standards for this conditional point of compliance are water quality standards established under WAC 173-201A, Surface Water Quality Standards.

3.2 REMEDIAL ACTION OBJECTIVES

Important conclusions of the 300-FF-5 operable unit RI (DOE-RL 1993a) for development of remedial action objectives include the following:

- Currently, groundwater in the 300-FF-5 operable unit is contaminated above potential ARARs. Constituents that exceed potential ARARs are strontium-90, uranium, tritium, technetium-99, copper, nickel, 1,2-DCE, chloroform, TCE, and coliform. Contaminants that are predicted to exceed potential ARARs in the year 2018 include uranium, 1,2-DCE, TCE, and tritium although these predictions rely on conservative assumptions and concentrations may decrease below ARARs by this time.

- Two upgradient plumes, a tritium plume originating in the 200 East Area, and a technetium-99 and nitrate plume migrating from the vicinity of the 1100 Area, are being addressed by other operable units. Remediation of these plumes is therefore not a remedial action objective for the 300-FF-5 operable unit. These plumes are addressed only to the extent that they affect remediation of target contaminants from the 300 Area.

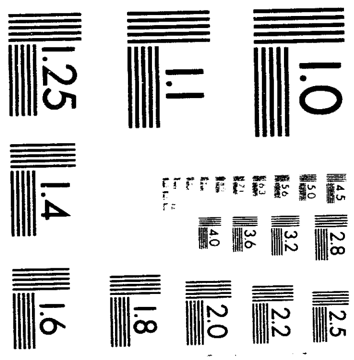
- Future TCE and DCE groundwater concentrations were predicted to be similar to current concentrations beyond the year 2018, because the mass and nature of a potential DNAPL source is unknown and was conservatively estimated to exist for decades. Additional data on the location and mass of the source, or continued monitoring of groundwater concentrations, may provide an indication on the fate and transport of these contaminants.

- Additional data on the K_d and solubility of uranium are necessary for more accurate predictions of its fate and migration.

- Current cancer risk associated with industrial use of groundwater from Well 399-4-12 is estimated to equal $2x10^{-5}$. The risk is from the inhalation of chloroform at concentrations comparable to municipal water supply systems. If chloroform is not included in the risk assessment, the risk associated with industrial use of this groundwater is reduced to $1x10^{-6}$.

- The only future exposure pathway that exceeds 10^{-6} is industrial use of groundwater beneath the 300 Area (risk equals $7x10^{-6}$). Tritium and TCE are the major risk drivers for this pathway.

- Contaminants at concentrations above potential ARARs within the 300-FF-5 operable unit are discharging into the Columbia River. Based on river sampling at low-river stage, constituent concentrations in near-shore river water are approximately half of the concentrations observed in nearby groundwaters. There is much uncertainty with regard to the average



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concentration of the 300-FF-5 operable unit contaminants in the river. Based on uranium sampling of the 300 Area river intake, the average river water concentrations may be two orders of magnitude less than the maximum river water concentrations. The river water contaminant concentrations at the 300 Area intake do not exceed ARARs.

Three remedial action objectives have been developed based on these conclusions:

1) Limit current human exposure to contaminated groundwater in the 300-FF-5 operable unit.

This remedial action objective is to limit current human exposure to groundwater beneath the 300 Area and includes: (1) eliminating current use of groundwater from Well 399-4-12, and (2) preventing future use of groundwater beneath the 300 Area until constituent concentrations are below acceptable levels.

2) Limit discharge of contaminated groundwater to the Columbia River.

The Hanford Reach of the Columbia River is classified as a Class A Excellent river, has been nominated for wild and scenic river status, is used for drinking water supplies, and is an important natural resource for the entire Pacific Northwest. Therefore, a remedial action objective for the 300-FF-5 operable unit is to protect this valuable resource by limiting discharges to the river of groundwater with unacceptable contaminant concentrations. The major issue in evaluating remedial actions required to meet this objective is determining acceptable concentrations of contaminants. Although the baseline risk assessment indicated that apparent average risk from the surface water exposure pathways is less than 10^{-6} [see Phase I RI Tables 6-36 and 6-37 (DOE-RL 1993a)], some of the potential contaminant-specific ARARs (see Section 3.1.2) were exceeded in groundwater, including MTCA Method B, MTCA Method C, and drinking water MCLs. It has not been decided if MTCA is applicable at the Hanford Site.

Based on contaminant fate and transport modeling conducted in the RI, groundwater impacts on the Columbia River are anticipated to decline with time. It is possible that by the year 2000 most groundwater contaminants of concern (except tritium from 200 Area sources) could be flushed from the aquifer (DOE-RL 1993a). Considering that the 300 Area groundwater has been discharging contaminated groundwater to the Columbia River for many years (Tyler 1992), only marginal benefits will be gained by undertaking remedial actions that may not be necessary in 7 years or less. However, additional data are needed to more accurately predict the fate and transport of contaminants of concern.

Tritium represents a special case because it is technically infeasible to limit discharges of tritium to the Columbia River. Most of the tritium plume currently entering the river is in the 600 Area to the north of the 300-FF-5 operable unit. Tritium discharges to the Columbia River along the 300 Area are below MCLs, but above MTCA Methods B and C criteria concentrations. It may be advisable to waive ARARs pertaining to tritium as allowed by Section 121 of SARA.

3) **Reduce contaminant concentrations in groundwater below acceptable levels by the year 2018.**

This objective is based on the intended goal of the Tri-Party Agreement to complete remediation of the Hanford site by 2018. The risk assessment predicted that risk associated with unlimited industrial use of groundwater after the year 2018 would exceed 10^{-6} ICR, primarily due to tritium and TCE. The 10^{-6} ICR concentrations for the constituents of concern are provided in Tables 3-3 and 3-4. At this time, it is unclear whether active remediation is necessary to achieve these concentrations by the year 2018.

Based on these remedial action objectives, preliminary remediation goals or clean-up levels are identified in Table 3-7. These goals are constituent-specific numerical values that correspond to the minimum applicable ARAR or risk-based standard. The ARARs and risk-based standards are listed in Tables 3-3 and 3-4. Clean-up standards for constituents associated with upgradient plumes (tritium and technetium-99) are not considered applicable since these plumes will be addressed in other RI/FS investigations.

3.3 AREAS AND VOLUMES OF AFFECTED MEDIA

The areas and volumes of contaminated media are described in this section. Based on the results of the RI, groundwater and surface water are the two types of media that contain contaminant concentrations above ARARs. Sediments obtained in the riparian zone during the Phase I RI for the 300-FF-5 operable unit were not considered to be contaminated (DOE-RL 1993a). Estimated areas and volumes of contaminated media are presented in Table 3-8. Volumes and areas of affected media were calculated based on concentration contours representative of background concentrations, risk-based or regulatory based cleanup concentrations. The volume of impacted aquifer soils for the radionuclides Sr-90 and uranium (total) represents only the upper 5 m (16 ft) of the aquifer because these contaminants have only been detected in the upper portions of the aquifer. The volume of impacted soils associated with trichloroethene contamination represents only the lower 5 m (16 ft) of the aquifer because trichloroethene has been found primarily in the lower portions of the aquifer. Using the volume of impacted soils, the volume of groundwater representing one pore volume was then calculated using an assumed soil porosity of 0.3.

3.3.1 Groundwater

Contaminants that currently exceed potential ARARs are strontium-90, uranium, tritium, technetium-99, copper, nickel, 1,2-DCE, total coliform bacteria, chloroform, and TCE. Current maximum concentrations of these constituents are shown in Tables 3-3 and 3-4, along with the potential chemical-specific ARARs and the 10^{-6} risk based standards.

Areas and volumes were not determined for a number of constituents for the following reasons:

- Technetium-99 and tritium are entering the 300-FF-5 operable unit from upgradient sources. Consequently, remediation of these plumes will not be addressed in this document except in terms of meeting effluent discharge limitations.

- Copper was only detected in one well during the last two sampling rounds, and the detected value (0.005 mg/L) was below all the cleanup standards. The maximum detected value of 0.012 mg/L was detected only during the first sampling period.

- Nickel was only detected in one well (399-1-16A) above ARARs, and the maximum nickel concentration detected in all three sampling rounds was 0.118 mg/L (compared to a minimum ARAR of 0.1 mg/L). The maximum concentration during the third sampling round (0.074 mg/L) was below ARARs. Therefore, nickel is not considered a contaminant of concern.

- Chloroform concentrations exceed the 10^{-6} risk level for the inhalation pathway and exceed chemical-specific ARARs (MCTA Method B). However, because groundwater concentrations are similar to those considered acceptable in drinking water, chloroform is not considered a contaminant of concern.

- 1,2-DCE was only detected in one well (399-1-16B) and was not considered significantly widespread to warrant area and volume determination. Since TCE was found in the same well, the areas and volumes for TCE will be considered representative.

- Although total coliform bacteria was detected in the wells immediately downgradient of the sanitation trenches, they were not detected consistently enough to warrant area and volume determination.

The maximum strontium-90 concentrations in each well from the first three sampling rounds are shown in Figure 3-1. Figure 3-1 shows the 1.3 pCi/L contour (corresponding to the MTCA Method B cleanup standard). The estimated areas and volumes inside this contour are provided in Table 3-8. No strontium-90 concentrations exceeded the MTCA Method C standard (13 pCi/L) or the MCL (8 pCi/L).

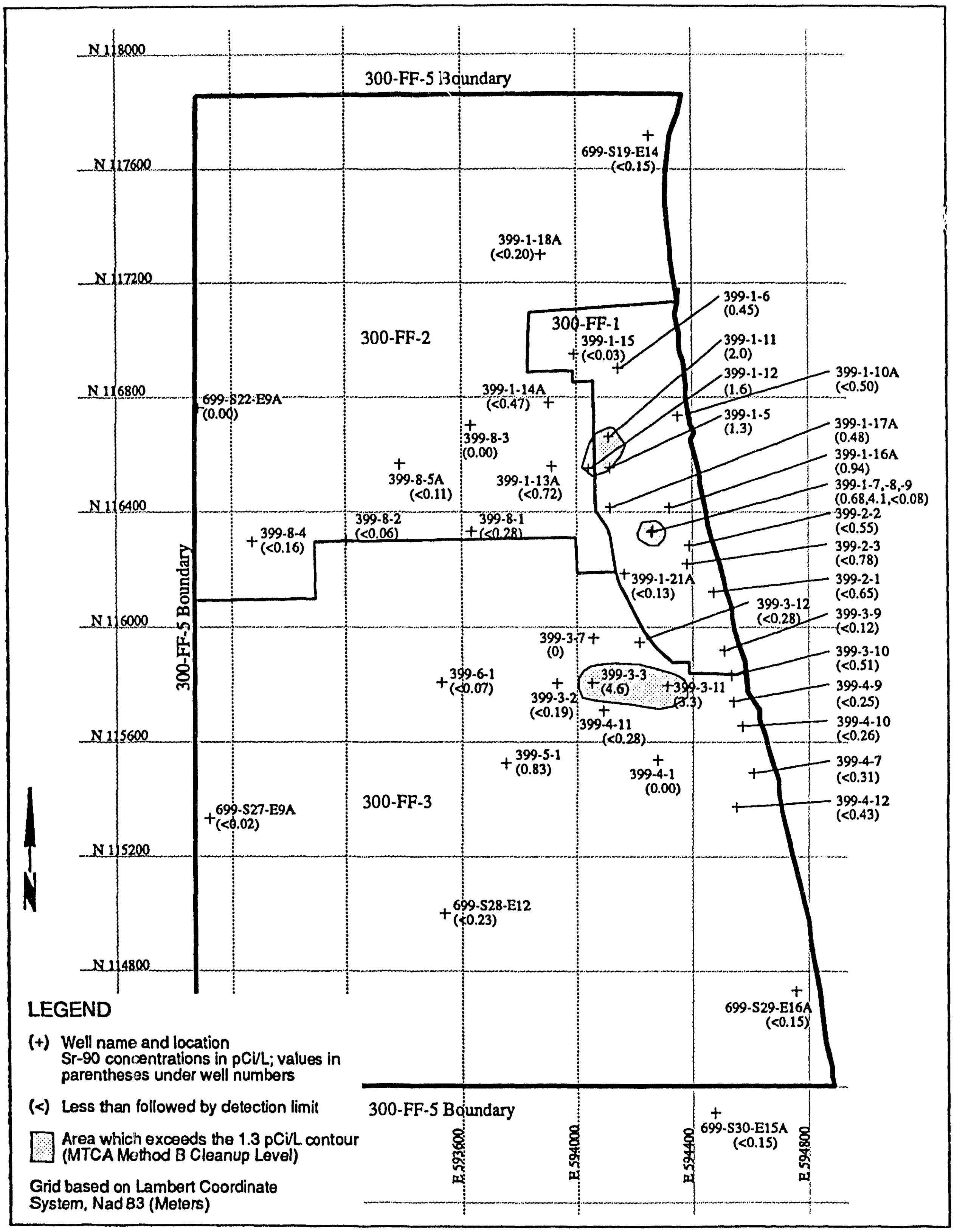
Maximum uranium-238 concentrations in each well from all four sampling rounds are shown in Figure 3-2, along with concentration contours corresponding to the MTCA cleanup standards and the 10^{-6} incremental cancer risk (7.1 pCi/L). The MTCA Method B standard is based upon the site-specific background concentration of 4.3 pCi/L. The estimated areas and volumes inside these contours are provided in Table 3-8. Although the MCL is for total uranium, not uranium-238, the equivalent uranium-238 concentration of 6.7 pCi/L can be calculated using the conversion factor of 0.335 pCi/μg (provided in Chapter 4 of DOE-RL 1993a). The contour for 6.7 pCi/L, (and the area inside the contour) would appear very similar to the 7.1 pCi/L contour.

Areas and volumes for the other uranium isotopes are not provided because given the relative abundances of the isotopes in groundwater from the 300-FF-5 operable unit, the risk associated with uranium-238 exceeds that of the other isotopes. This is clearly true in terms of chemical toxicity (which is relative to mass percent), because uranium-238 is usually about 97-99 percent of the total uranium mass. The dominance of uranium-238 regarding cancer risk is also apparent when the equivalent cancer risk activities are compared to the relative activities in groundwater samples from 300-FF-5 operable unit. As evident from the risk screening concentrations provided in Table 3-3, the activity ratio of equivalent risk for uranium-234/uranium-238 and uranium-235/uranium-238 is 1.8. Inspection of data provided in the RI (DOE-RL 1993a) indicates that the relative activities of the isotopes in groundwater samples from the 300-FF-5 operable unit are between 1.1 and 1.4 for uranium-234/uranium-238 and 0.05 to 0.2 for uranium-235/ uranium-238. As a result, any remedial actions that fulfill the remedial action objectives for uranium-238 will also fulfill these objectives for the other uranium isotopes.

The maximum TCE concentrations in each well from all three sampling rounds are shown in Figure 3-3. The concentration contours corresponding to the MCL for TCE (0.005 mg/L) and the MTCA Method B standard (0.004 mg/L) are shown in Figures 3-3. The estimated area and volume inside these contours are provided in Table 3-8.

3.3.2 Surface Water

Surface water data collected during low-river stage indicate that constituents showing elevated concentrations in groundwater were also detected above background in the Columbia River. Data available from the 300 Area water intake indicate that river concentrations are diluted by two orders of magnitude during normal and high river stages. Because of this apparent temporal variability, areas and volumes of affected surface water would be expected to fluctuate greatly and would not be meaningful. For this reason, and because of the lack of detailed data, areas and volumes of affected surface water were not determined. Because sediment samples obtained during the 300-FF-5 operable unit Phase I RI were not considered to be contaminated, the remedial action objectives focus on reducing discharge of contaminated groundwater to the Columbia River, not remediation of the river.



913-1769/46610/1-28-94

Figure 3-1. The Maximum Strontium-90 Concentrations in Each Well From All Three Sampling Rounds.

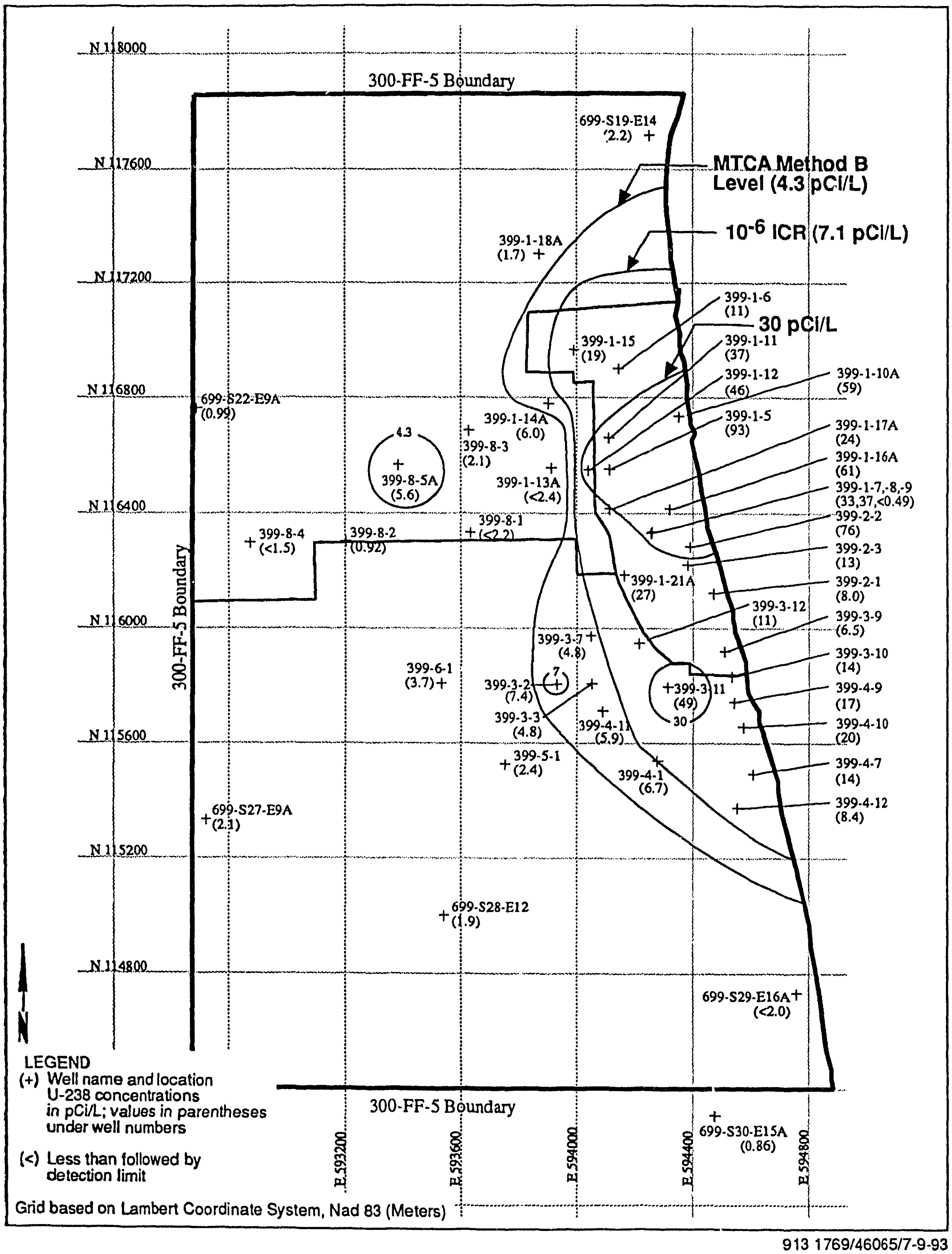


Figure 3-2. The Maximum U-238 Concentrations in Each Well From All Three Sampling Rounds.

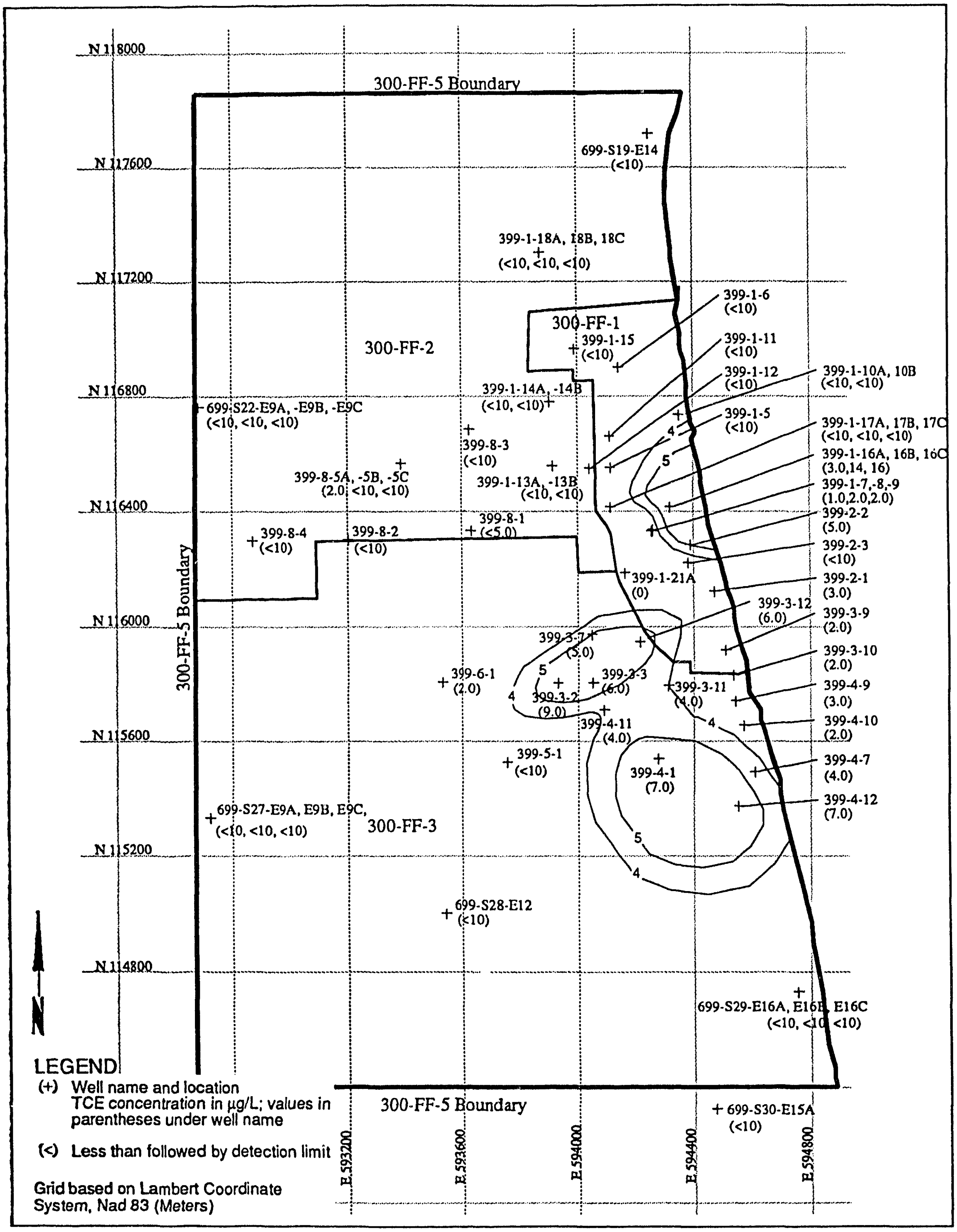


Figure 3-3. The Maximum TCE Concentrations in Each Well From All Three Sampling Rounds.

Table 3-1. Identification of Potential Federal Chemical- and Location-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 1 of 5)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
CHEMICAL-SPECIFIC		
Safe Drinking Water Act of 1974 Title 42 USC 300, et seq.		
National Primary Drinking Water Standards 40 CFR 141	Relevant & Appropriate[a]	The NCP requires that maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) established under the Safe Drinking Water Act be attained by remedial actions for groundwater and surface waters that are current or future sources of drinking water where the MCLG or MCL are relevant and appropriate to the situation. Groundwater is currently not used for drinking; however, it could be used in the future, if the site is released from institutional controls. In addition, there is discharge of contaminated groundwater to the Columbia River, which is used for drinking water. MCLs and MCLGs for public drinking water are presented in Tables 3-3 and 3-4 for contaminants of concern.
National Secondary Drinking Water Standards 40 CFR 143	Not ARAR[a]	Federal secondary standards are not federally enforceable standards and are not typically applicable or relevant and appropriate requirements. (See Footnote a.) These requirements are not ARAR because secondary maximum contaminant levels have not been established for operable unit contaminants of concern.
Clean Water Act of 1977 Title 33 USC 1251, as amended		
Water Quality Standards 40 CFR 131	Applicable	The Water Quality Standards under 40 CFR 131 were promulgated persuant to the Clean Water Act and are applicable to the 300-FF-5 operable unit. 40 CFR 131 establishes the requirements and procedures for states to develop and adopt water quality standards based on federal water quality criteria that are at least as stringent as the federal standards. 40 CFR 131 provides EPA the authority to review and approve state water quality standards. Washington State has received EPA approval and has adopted more stringent water quality criteria under WAC 173-201A. These criteria are presented in detail as state chemical-specific ARARs.
Atomic Energy Act of 1954, as amended Title 42 USC 2011 et seq.		
Environmental Radiation Protection Standards for Nuclear Power Operations 40 CFR 190	Relevant & Appropriate	The regulation specifies the levels below which normal operations of the uranium fuel cycle are determined to be environmentally acceptable. These standards are not applicable because the standard excludes operations at disposal sites, and the definition of the uranium fuel cycle focuses on those processes that result in generation of electrical power. However, the standards are relevant and appropriate because they address acceptable dose to the public as a result of planned discharges which occurred as a result of past activities conducted at source operable units with 300-FF-5. The standard sets dose equivalents from the facility that are not to exceed 25 mrems/yr to whole body, 75 mrems/yr to thyroid, or 25 mrems/yr to any other organ.

Footnotes [a] WAC 173-340-720 (2)(a)(ii) specifies that MCLs, MCLGs, and SMCLs are applicable requirements for groundwater cleanup, where groundwater has a current or potential future use as drinking water.

Table 3-1. Identification of Potential Federal Chemical- and Location-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 2 of 5)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level Waste, and Transuranic Radioactive Waste 40 CFR Part 191	Not ARAR	Standards under this regulation are not applicable and not relevant and appropriate because they contain environmental protection requirements for management and disposal of spent nuclear fuel, high-level waste, and transuranic wastes at facilities operated by the Department of Energy. Wastes meeting this definition are not known to have been disposed in the 300 Area.
Nuclear Regulatory Standards for Protection Against Radiation 10 CFR 20	Relevant & Appropriate	The regulation establishes standards for protection of the public against radiation arising from the use of regulated materials and as such are relevant and appropriate. Radioactive material from sources not licensed by the NRC are not subject to these regulations, therefore this standard is not applicable because the operable unit is not NRC-licensed. Remedial alternatives need to limit external and internal exposure from releases to levels that do not exceed 100 mrem/yr or 2 mrem/ hr from external exposure in unrestricted areas. Specific concentration limits of contaminants of concern in liquid effluent allowed in unrestricted areas are listed in Table 3-3. These limits are based on annual effective dose equivalent from internal exposure for adults of 50 mrem.
Uranium Mill Tailings Radiation Control Act of 1978 Title 42 USC 2022		
Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings 40 CFR 192	Relevant & Appropriate	The standard is not applicable because the operable unit is not a milling site for uranium or thorium. However, the standard is relevant and appropriate because it provides guidance for implementing remedial actions if contaminants have been released to groundwater. Subpart B sets groundwater protection requirements for concentrations of Ra-226, Ra-228, and gross alpha particle activity at EPA-established levels for drinking water, 5 pCi/L for Ra-226 and Ra-228, and 15 pCi/L for gross alpha activity excluding radon and uranium. Concentration limits for Ra-226 in soils for land cleanup actions are set at 5 pCi/g averaged over the upper 15 cm and 15 pCi/g averaged over any 15 cm thick layer more than 15 cm from the surface. The level of gamma radiation in any occupiable building is not to exceed 20 microroentgens/hr above background.
DOE Order 5400.5 - Radiation Protection of the Public and the Environment	To Be Considered	This DOE Order sets radiation standards for protection of the public in the vicinity of DOE facilities. The order sets limits for the annual effective dose equivalent of 100 mrem, but allows temporary limits of 500 mrem if avoidance of higher exposures is impractical. The standards sets annual dose limits for any organ at 5 mrem. An annual dose equivalent from drinking water supplies operated by DOE is set at 4 mrem and states that liquid effluent from DOE activities will not cause public drinking water systems to exceed EPA MCLs. Specific concentration limits in water for contaminants of concern are listed in Table 3-3.

Table 3-1. Identification of Potential Federal Chemical- and Location-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 3 of 5)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
		The DOE published proposed rule, Radiation Protection of the Public and the Environment (10 CFR 834), in the March 23, 1993 Federal Register (58 FR 16268), promulgates the standards presently found in DOE Order 5400.5. The proposed rule retains the substantive portions of the DOE Order, but differs from the existing Order in format, enhanced emphasis on the ALARA process, and changes the usage of derived concentration guides (DCGs). The proposed rule identifies DCGs not as "acceptable" discharge limits, but to be used as reference values for estimating potential dose and determining compliance with the requirements of the proposed rule. Where residual radioactive materials remain, the proposed rule states that various disposal modes should address impacts beyond the 1,000 year time period identified in the existing DOE Order.
Resource Conservation and Recovery Act Title 42 USC 6901 et seq		
Criteria for Classification of Solid Waste Disposal Facilities and Practices 40 CFR 257	Applicable	Groundwater protection requirements for solid waste disposal facilities are established at the same levels as MCLs published under 40 CFR 141.
Groundwater Protection Standards 40 CFR 264.92	Applicable	Groundwater restoration goals established by this section are applicable because hazardous waste management units (i.e., 300-Area process trenches) are located in source operable units above the 300-FF-5 operable unit. Restoration goals under CERCLA are to restore the groundwater to their beneficial use within the appropriate time frame established for each specific site. Three remediation levels of groundwater protection established by this section are background, MCL and alternate concentration levels (ACLs). MCLs are set at the same levels as SDWA MCLs and where no SDWA MCL has been set, health based ACLs may be established that are protective of human health and environment.
Toxic Substance Control Act Title 15 USC 2601 et seq.		
Regulation of PCBs 40 CFR 761	Not ARAR	Toxic Substance Control Act requirements are neither applicable nor relevant and appropriate because PCBs have not been detected in groundwater or in source operable unit soils at levels above 50 ppm. Handling, storage, and disposal requirements are applicable if PCBs are detected above 50 ppm.

Table 3-1. Identification of Potential Federal Chemical- and Location-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 4 of 5)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
LOCATION-SPECIFIC		
National Historic Preservation Act of 1966 Title 16 USC 470 et seq.	Not ARAR	Requirements established under this act are neither applicable nor relevant and appropriate to the operable unit because no facilities located on the operable unit are currently listed on or proposed for inclusion on, the National Register of Historic Places. A nomination was previously prepared by the U.S. Army Corp. of Engineers, but was later withdrawn.
Archeological and Historic Preservation Act Title 16 USC 469a	Applicable	This act requires that actions conducted at the site must not cause the loss of any archeological and historic data. This act varies from the National Historic Preservation Act in that it mandates only preservation of the data and not the actual facility. Archeological or historic sites have been identified within the operable unit and therefore these requirements are applicable.
Endangered Species Act of 1973 Title 16 USC 1531 et seq		
Endangered and Threatened Wildlife and Plants 50 CFR 17	Applicable	The regulations in this part implement the Endangered Species Act which includes requirements to protect species threatened by extinction and habitats critical to their survival. These requirements are applicable to remedial alternatives performed on the site. Endangered species and critical habitats have been evaluated at the Hanford Site, and persistantsepal yellowcress has been identified in the operable unit.
Wild and Scenic Rivers Act Title 16 USC 1271 et seq	To Be Considered	Requirements of this act are TBC because the Hanford Reach of the Columbia River has been proposed for inclusion on the national list of wild and scenic rivers. Remediation alternatives need to consider impacts to the Columbia River.
Hanford Reach Comprehensive River Protection Study and Interim Protection P.L. 100-605	Applicable	This law requires that the Secretary of Interior prepare a comprehensive river conservation study for the segment of the Columbia River from a point one mile below the Priest Rapids Dam approximately 51 miles downstream to the McNary Pool, north of Richland. This stretch of the river is commonly referred to as the Hanford Reach. This law is applicable to remedial actions performed at 300-FF-5 that may impact the river. Pursuant to this law, *The Hanford Reach of the Columbia River, Draft Comprehensive River Conservation Study and Environmental Impact Statement* has been prepared (NPS, 1992). This environmental impact statement documents the resources of the Hanford Reach and develops alternatives for their protection as required by PL 100-605. One alternative included in the study is designation of the Hanford Reach into the National Wild and Scenic Rivers System.

Table 3-1. Identification of Potential Federal Chemical- and Location-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 5 of 5)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
		Enactment of this law also provides for interim protection of the Hanford Reach for a period of eight years. During the period of interim protection, construction of dams is prohibited and so are dredging and channelization projects. Interim protection also requires all other existing or planned federal and non-federal projects to minimize adverse impacts to the river and whenever possible, to make use of existing structures and facilities. Agencies planning projects within the area of the Hanford Reach are to coordinate with the Secretary of the Interior in order to minimize and mitigate potential adverse impacts.
Fish and Wildlife Conservation Act Title 16 USC 2901	Not ARAR	Fish and Wildlife Conservation Act is administrative in nature and is not considered applicable or relevant and appropriate. The act requires states to prepare conservation plans that include inventories and identification of for nongame fish and wildlife. The act also includes statements encouraging federal agencies and programs to use all available statutory resources to conserve and promote protection of nongame fish and wildlife. Previous to this law, conservation measures were addressed for only game species.
Compliance With Floodplain/Wetlands Environmental Review Requirements 10 CFR 1022	Applicable	This regulation is applicable to remedial actions at 300-FF-5 because a portion of the 300-FF-5 operable unit is in the Columbia River floodplain, and because wetlands exist along the shoreline. This regulation requires DOE and other federal agencies to comply with the requirements of Executive Order 11990 - Protection of Wetlands, and Executive Order 11988 -Floodplain Management. Executive Order 11988 requires DOE procedures to ensure that any actions conducted in a floodplain consider flood hazards. Executive Order 11990 requires the protection of wetlands from destruction. The Executive Orders require that federal agencies implement these considerations through existing federal requirements, such as the National Environmental Policy Act. The U.S. Army Corp of Engineers has established a nationwide permitting program for actions that may impact wetlands. Under CERCLA, onsite cleanup actions are not required to comply with administrative permit requirements of federal, state, and local regulations; however, CERCLA actions must comply with the substantive portions of the regulations.

Table 3-2. Identification of Potential State Chemical and Location-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 1 of 3)

Requirements	Applicable, Relevant & Appropriate, To Be Considered	Comment
CHEMICAL-SPECIFIC		
Hazardous Waste Cleanup-Model Toxics Control Act Ch. 70.105D RCW		
Model Toxics Control Act Cleanup Regulations WAC 173-340	Potentially Applicable	Requirements under this standard are applicable to the operable unit. Specific cleanup goals established in the standard require implementation of the strictest federal or state cleanup criteria. For groundwater remediation, MCLs, MCLGs, and secondary drinking water standards are identified as cleanup criteria. MTCA also establishes requirements for cleanup of soils based on protection of groundwater. Standards are set at 100 times the most stringent federal or state standard or calculated using methods in the regulation, unless it can be demonstrated this is not appropriate for the site. MTCA surface and groundwater cleanup levels for contaminants of concern are listed in Tables 3-3 and 3-4.
Hazardous Waste Management Act Ch. 70.105 RCW		
Dangerous Waste Regulations WAC 173-303	Applicable	Requirements found in the dangerous waste regulations are applicable because source operable units above the 300-FF-5 groundwater operable unit contain permitted dangerous waste management facilities.
Regulation of Public Ground Water Ch. 90.44 RCW		
Water Quality Standards for Groundwater WAC 173-200	Not ARAR	This standard specifically exempts CERCLA and MTCA cleanup actions and therefore is neither applicable nor relevant and appropriate to the operable unit.
Water Pollution Control/Water Resource Act of 1971 Ch. 90.48 RCW/ Ch.90.54 RCW		
Surface Water Quality Standards WAC 173-201A	Applicable	Under MTCA [WAC 173-340-720(1)(c)(iii)], groundwater quality must meet surface water quality criteria at the point of discharge. Groundwater from the 300-FF-5 operable unit discharges to the Columbia River; therefore these criteria are applicable. Water quality standards are set at levels protective of aquatic life. Tables 3-3 and 3-4 list criteria for operable unit contaminants of concern.
Sediment Management Standards WAC 173-204	Applicable	The chapter sets surface sediment quality standards and provides a management and decision process for reduction of pollutant discharges and the cleanup of contaminated sediments. This chapter is applicable to all existing or proposed actions at the 300-FF-5 operable unit that may affect surface sediment quality. The Department of Ecology determines fresh water surface sediment quality on a case-by-case basis. Numeric criteria for freshwater sediments have not been promulgated. The Department of Ecology may apply the most restrictive standard if the beneficial uses of more than one resource are affected, such as at the interface between surface sediments, groundwater, or surface water.

Table 3-2. Identification of Potential State Chemical- and Location-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 2 of 3)

Requirements	Applicable, Relevant & Appropriate, To Be Considered	Comment
Solid Waste Management, Recovery and Recycling Act Ch. 70.95 RCW		
Minimum Functional Standards for Solid Waste Handling WAC 173-304	Relevant & Appropriate	The standard is not applicable to the 300-FF-5 groundwater operable unit, but may be considered relevant and appropriate because waste management facilities are present in source operable units above the 300-FF-5 groundwater operable unit. The standard sets groundwater maximum contaminant levels (MCLs) at the same levels as the drinking water standards under 40 CFR 141.
Health Standards for Public Drinking Water Supplies WAC 246-290	Relevant & Appropriate	The rules established under WAC 246-290 define the regulatory requirements necessary to protect consumers using public drinking water supplies. The rules are intended to conform with the federal Safe Drinking Water Act (SDWA), as amended. WAC 246-290-310 establishes maximum contaminant levels (MCLs) which define the water quality requirements for public water supplies. The requirements of WAC 246-290-310 are not applicable to the 300-FF-5 operable unit since they address public drinking water supplies and groundwater at the site is not used for drinking water. However, these standards may be relevant and appropriate since groundwater discharges to the Columbia River, which is used for drinking water. WAC 246-390-310 establishes both primary and secondary MCLs and identifies that enforcement of the primary standards is the Department of Health's first priority. Since the standards set under WAC 246-290-310 are set at the levels established under the federal SDWA, refer to Tables 3-3 and 3-4 for federal drinking water MCLs and MCLGs.

Table 3-2. Identification of Potential State Chemical- and Location-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 3 of 3)

Requirements	Applicable, Relevant & Appropriate, To Be Considered	Comment
State Radiation Protection Requirements CH. 70.98 RCW		Washington State Radiation Protection Requirements are implemented under specific sections of WAC 246
Radiation Protection Standards WAC 246-221	Applicable	This regulation is applicable because it establishes the maximum allowable radiation dose to individuals in restricted areas, exposure to minors and permissible levels of radiation from external sources in unrestricted areas. Radiation dose limits to individuals in restricted areas are not to exceed 1.25 rem per quarter to the whole body, head and trunk, active blood forming tissues, lens of the eyes or gonads; 18.75 rem per quarter to hands and forearms or feet and ankles; or a dose of 7.5 rem per quarter to the skin of the whole body. Chapter 246-221 also establishes concentration limits in effluent released to unrestricted areas
Radiation Protection- Air Emissions WAC 246-247	Applicable	This regulation promulgates air emission limits for airborne radionuclide emissions as defined in WAC 173-480 and consistent with federal NESHAPs. The ambient standard requires that emission of radionuclides to the air must not cause a dose equivalent of 25 mrem per year to the whole body or 75 mrem per year to any critical organ.
Radiation Protection at Uranium and Thorium Milling Operations, WAC 246-252	Relevant & Appropriate	The regulation, Radiation Protection at Uranium and Thorium Milling Operations is not applicable to 300-FF-5 because the site was not a uranium or thorium milling operation, however, the regulation is relevant and appropriate because it contains specific concentration limits for protection of groundwater: gross alpha excluding radon and uranium not to exceed 15 pCi/L, and combined radium-226 and radium-228 not to exceed 5 pCi/L.
LOCATION-SPECIFIC		
Department of Game SEPA Procedures WAC 232-012	Not ARAR	Requirements which define actions the Department of Game must take to protect endangered, threatened or sensitive wildlife. These requirements are not applicable since no endangered or threatened wildlife species were identified at the operable unit during wildlife surveys performed within the area of the operable unit.
Shoreline Management Act RCW 90.58		
Shoreline Management Act Guidelines WAC 173-16	Applicable	Regulations and restrictions of the Shoreline Management Act implemented under WAC 173-16 are applicable to remedial alternatives at the 300-FF-5 operable unit. These chapters establish standards that restrict certain activities near shorelines and limit contaminant concentrations along shorelines that may result from certain activities.

Table 3-3. Chemical-Specific ARARS for the 300-FF-5 Operable Unit (Radionuclides).

Contaminant (Maximum Concentration)	Drinking Water 40 CFR 141[a]	Washington State Model Toxics Control Act Cleanup Regulation[b]		NRC Standards 10 CFR 20[c,d]	Protection of the Public and Environment, DOE Order 5400.5	Risk-based Concentrations that Equal an ICR of 10^{-6}
	MCL (pCi/L)	Method B Groundwater (pCi/L)	Method C Groundwater (pCi/L)	Water (pCi/L)	Water (pCi/L)	(pCi/L)
Sr-90 (4.6 pCi/L)	8[e]/42[g]	1.3	13	300/40000	40	5.6[h]
U-234 (120 pCi/L)	-	5.2[i]	29	30000/ 30000	20	13[h]
U-235 (17 pCi/L)	-	2.9	29	30000/ 30000	24	13[h]
U-238 (93 pCi/L)	-	4.3[i]	16	40000/ 40000	24	7.1[h]
Total U (270 μg/L)	-/20μg/L[g,h]	-	-	40000/40000	24	-
Tritium (H-3) (11,800 pCi/L)	20,000[e]/ 61,000[g]	850	8500	3000000/ 3000000	80,000	3,700[h]
Tc-99 (65 pCi/L)	900[e]/3,800[g]	35	354	300000/ 200000	400	150[h]

Note: Shading indicates the minimum ARAR or risk-based concentration.

[a] State Drinking Water Standards, WAC 246-290, are as stringent as current federal MCLs, unless otherwise noted

[b] Calculated using the formula in WAC 173-340.

[c] 10 CFR 20, Appendix B, Table II, Column 2, Concentration Limits for Radionuclides in Liquid Effluent Released to Unrestricted Areas (soluble/insoluble)

[d] Washington State Water Quality standards for radionuclides are established under WAC 173-201A at 1/100TH the value listed in WAC 246-221, Appendix A, Table II, Column 2. WAC 246-221, Appendix A, Table II, Column 2 is equivalent to 10 CFR 20, Appendix B, Table II, Column 2.

[e] Current MCL

[f] Represents a 4 mrem/year effective dose equivalent for drinking water.

[g] Proposed MCL as reported in the Advanced Notice of Proposed Rule published in 56 FR 33050, July 18, 1991. The notice also published a proposed MCLG of 0 for radionuclides.

[h] Industrial screening water ingestion pathway

[i] Site-specific background concentration as discussed in Appendix E of the RI (DOE-RL 1993a)

\- Criteria not listed

Table 3-4. Chemical-Specific ARARs for the 300-FF-5 Operable Unit (Non-Radioactive Contaminants).

Contaminant (Maximum Concentration)		Drinking Water Standards 40 CFR 141[a] and 40 CFR 143[b]		Washington State Model Toxics Cleanup Act WAC 173-340		Washington State Surface Water Quality Standards WAC 173-201A (WSR 92-24-037)		Risk-Based Concentrations that Equal an ICR of 10^{-6} or HQ of 1
		MCLs (current/proposed)	MCLGs (current/proposed)	Groundwater, 173-340-720		Freshwater		
				Method B	Method C	Acute	Chronic	
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Copper (0.012 mg/L)		1.3[c]	-	0.59[e]	1[e]	0.01[d]	0.007[d]	4.1[g]
Nickel (0.118 mg/L)		0.1	0.1	0.32[e]	0.7[f]	0.901[d]	0.1[d]	2.0[g]
Nitrate (15.6 mg/L)		44	44	44[f]	44[f]	-	-	-[i]
1,2-dichloroethene (0.15 mg/L)	cis	0.07	0.07	0.07[f]	0.07[f]	12[g]	-	1[g]
	trans (0.13 mg/L)	0.1	0.1	0.16[e]	0.1[f]	12[g]	-	2.0[g]
Chloroform (0.018 mg/L)		0.1	-	0.007[e]	0.07[e]	29[g]	1.2[g]	0.00045[j]
Trichloroethene (0.014 mg/L)		0.005	0	0.004[e]	0.005[f]	45[g]	22[g]	0.006[j]
coliform bacteria (c/100 ml)		k	-	-	-	1	-	-

Note: Shading indicates the minimum ARAR or risk-based concentration.
[a] - State MCLs and MCLGs are based on federal standards, as amended
[b] - Secondary Drinking Water Standard under 40 CFR 143
[c] - Treatment Standard effective December 7, 1992
[d] - Calculated using hardness of 62.5 mg/L or pH of 7.95 (Miles et al. 1992)
[e] - Reference doses and carcinogenic slope factors taken from IRIS, EPA 1993
[f] - MTCA requires cleanup concentrations to be as stringent as applicable state or federal standards. MCLs are reported because MTCA Method B and C calculated cleanup concentrations exceed state and federal drinking water MCLs
[g] - Industrial scenario, water ingestion, noncarcinogenic HQ = 1
[h] - Criteria not developed, value presented is the LOEL - Lowest Observed Effect Level, per EPA Water Quality Criteria (EPA 1986)
[i] - No toxicity criteria have been developed.
[j] - Industrial scenario, inhalation of volatiles, carcinogenic ICR = 10^{-6}
[k] - Total coliform MCL compliance criteria is based on the presence or absence of total coliform in a sample, rather than coliform density. Refer to Section 3.3.2 for further discussion.
[l] - Fecal coliform organism levels for a Class A surface water shall not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/mL.
\- Criteria not listed

Table 3-5. Identification of Potential Federal Action-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 1 of 7)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Action-Specific		
Resource Conservation and Recovery Act, as amended Title 42 USC 6901		
Criteria for Municipal Solid Waste Landfills 40 CFR 258	Not ARAR	This rule establishes the minimum national criteria for the location, design, operation, cleanup and closure of municipal solid waste landfills. This rule applies only to municipal solid waste landfills as defined under the standard and that received waste on or after October 9, 1993. The standard defines a municipal solid waste landfill as a discrete area of land that receives household waste and is not a land application unit, surface impoundment or waste pile as defined under 40 CFR 257. This standard is not applicable or relevant and appropriate since the solid waste management facilities located in the source operable units which overlie the 300-FF-5 groundwater operable unit do not meet this definition. The standard also does not apply since solid waste facilities in source operable units which overlie 300-FF-5 stopped receiving waste prior to October 1991.
Identification and Listing of Wastes 40 CFR 261	Applicable	These requirements are applicable because this section establishes the framework for determining whether or not a waste is hazardous. Treatment wastes should be tested using methods established under this section.
Generator Standards 40 CFR 262	Applicable	Regulatory requirements for facilities that generate hazardous waste are applicable to the operable unit if hazardous wastes are generated. Requirements limit waste accumulation to 90 days, and specify packaging, training, emergency preparedness planning, and record-keeping procedures. Generators may accumulate hazardous waste onsite for less than 90 days without a RCRA Part B permit, providing waste is placed in containers or tanks in compliance with Subparts I and J of 40 CFR 264.
Standards Applicable to Transporters of Hazardous Waste 40 CFR 263	Applicable	This section of the regulation establishes standards applicable to transporters of hazardous wastes. Transporters must maintain records concerning generator's delivery to treatment, storage, and disposal facilities, proper labeling of transported waste, and compliance with manifest system.
Standards for Owners and Operators of TSD Facilities 40 CFR 264	Applicable	Regulatory requirements for owners and operators of hazardous waste storage, treatment, or disposal facilities are applicable if wastes are stored longer than 90 days, treated, or disposed onsite.
General Facility Standards 40 CFR 264.10-264.18	Applicable	General facility requirements are specified that address facility identification, employee training, emergency preparedness, contingency planning, closure, and post-closure requirements. Additional requirements for hazardous waste landfills, surface impoundments, and incineration facilities are also specified.
Preparedness and Prevention 40 CFR 264.30-264.37	Applicable	Facilities must be maintained and operated to minimize the possibility of fire, explosion, and unplanned release of hazardous waste to air, soil, and water. These requirements are applicable to the management of any hazardous waste generated as a result of remediation activity.

Table 3-5. Identification of Potential Federal Action-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 2 of 7)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Closure and Post-Closure 40 CFR 264.110-264.178	Applicable	Describes performance standards for controls to minimize or eliminate the escape of hazardous waste constituents from landfills or tanks to the ground and surface waters. Applicable if sludges containing hazardous waste from groundwater remedial actions are disposed in landfills or tanks.
Use and Management of Containers 40 CFR 264.170-264.178	Applicable	Requirements of this section are applicable if hazardous waste is held onsite prior to treatment or disposal. Subpart I provides standards and management practices for containers that include inspection, segregation, contaminant, and closure.
Air Emission Standards for Process Vents 40 CFR 264.170 subparts AA	Applicable	This section will be applicable if organics in the treatment system have concentrations greater than 10 ppm. Subpart AA applies to process vents associated with distillation, fractionation, thin-film evaporation, solvent extraction, and air or steam stripping operations.
Corrective Action Management Units 40 CFR 264.552	Applicable	This rule presents provisions for the use of corrective action management units (CAMUs) and temporary units as remediation waste management units. Previous EPA experience found that implementing RCRA Subtitle C rules to remediation wastes provided disincentives to the implementation of more protective remedies and remediation was negatively impacted by RCRA regulatory controls. Specific areas where increased flexibility in the management of remediation wastes provided by this regulation include; placement of remediation waste into a CAMU is not considered land disposal of waste and is not subject to LDRs; CAMUs do not have to meet minimum technology requirements for landfills; and finally, CAMUs are only subject to closure requirements as deemed necessary by the EPA Regional Administer and as appropriate to the waste management unit
Corrective Action and Groundwater Monitoring at Hazardous Waste Facilities 40 CFR 264 and 270	Applicable	Groundwater protection standards are established to protect upper aquifers that underlay the 300 Waste Management Area. These requirements are applicable to 300-FF-5 as a result of releases from the 300 Area Process Trenches, which are regulated units under RCRA. The concentration limits in the underlying aquifer cannot exceed the levels established beyond the point of compliance. Maximum concentration limits are provided in Table 1 of 40 CFR 264.94.
Land Disposal Restrictions 40 CFR 268	Applicable	These requirements are applicable if restricted waste is generated during remediation and disposed offsite. Specific treatment standards and prohibitions on storage are included in the requirements.

Table 3-5. Identification of Potential Federal [illegible]ion-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 3 of 7)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Clean Water Act of 1977, Title 33 USC 1251, as amended		The Clean Water Act establishes the guidelines and standards to control discharge of pollutants to waters of the U.S., in this case the Columbia River.
National Pollutant Discharge Elimination System (NPDES) 40 CFR 122 to 125	Applicable	The NPDES program controls release of toxic pollutants through monitoring requirements and implementation of a best management practices program. The administrative (e.g., permitting) requirements of the NPDES program are not applicable for on site discharge at CERCLA sites (in accordance with CERCLA Section 121(c)). The substantive requirements would still be applicable. A NPDES permit would be required if discharge of treated groundwater to the Columbia River is considered an offsite activity.
EPA Pretreatment Standards 40 CFR 403	Applicable	This regulation establishes the national pretreatment standards for waste discharge to publically owned and operated wastewater treatment plants. This regulation is potentially applicable to remedial alternatives that require discharge of wastewater to a publically owned treatment plant.
Federal Water Quality Criteria 55FR 14350	To Be Considered	Federal water quality criteria are non-enforceable guidelines that are TBC for remedial actions at 300-FF-5. Ambient water quality criteria provide protection for propagation of fish, shellfish, wild life, and recreation in and on the water. Such criteria serving a dual purpose of establishing the water quality goals for a specific water body and serving as the regulatory basis for the establishment of state water quality-based treatment controls beyond the technology-based levels required in Sections 301(b) and 306 of the Act.
Safe Drinking Water Act (SDWA) as amended, Title 42 USC 300f		The Safe Drinking Water Act mandates regulations to protect human health from contaminants in drinking water. There are no wells in the 300 Area used for drinking water purposes, but the groundwater aquifer does reach the Columbia River, which is used for drinking water.
Underground Injection Control Regulations 40 CFR 144-148	Applicable	These regulations address permitting for Underground Injection Control (UIC) to prevent contamination of underground sources of drinking water. These requirements concern siting, construction, operating, monitoring, and closure of injection wells. NPL sites that construct underground injection wells onsite are not required to comply with the administrative requirements (e.g., permitting), but must meet the substantive requirements of the program.
Clean Air Act of 1977, as amended Title 42 USC 7401 et seq.		The Clean Air Act (CAA) regulates emission of hazardous pollutants to the air. Controls for emissions are implemented through federal, state, and local programs. Pursuant to the CAA, EPA has promulgated National Ambient Air Quality Standards, National Emission Standards for Hazardous Air Pollutants, and New Source Performance Standards. Treatment actions that may be performed and are subject to air standards, include air stripping and thermal destruction.
National Ambient Air Quality Standards 40 CFR 50	Applicable	Requirements of these regulations are applicable to airborne releases of radionuclides and criteria pollutants specified under the statue. Specific release limits for particulates are set at 50 ugm/m^3 annually or 150 ugm/m^3 per 24-hour period. Standards for airborne lead measured as elemental lead are set at 1.5 ugm/m^3, maximum arithmetic mean averaged over a calendar quarter.

Table 3-5. Identification of Potential Federal Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 4 of 7)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Ambient Air Quality Monitoring 40 CFR 58	Relevant & Appropriate	This regulation presents the criteria and requirements for ambient air quality monitoring and reporting for local air pollution control agencies and operators of new sources of air pollutants. This regulation is not applicable to 300-FF-5 because remedial actions do not meet the regulatory definition of a new source. However, these requirements may be considered relevant and appropriate to remedial actions that nave the potential to emit air contaminants. This regulation defines the requirements for a national ambient air quality monitoring network of state and local air monitoring stations.
New Source Performance Standards (NSPS) 40 CFR 60	Not ARAR	Standards of performance for new stationary sources would not be applicable to remedial actions proposed at the 300-FF-5 operable unit because none of the proposed actions include any of the sources identified in the standard.
National Emission Standard for Hazardous Air Pollutants (NESHAP), Subpart H - National Emission Standards for Emissions of Radionuclides Other than Radon From Department of Energy Facilities 40 CFR 61	Applicable	These requirements are applicable to the site and remedial alternatives because the potential to release air emissions to unrestricted areas exists. Subpart H sets emissions limits to ambient air from the entire facility not to exceed an amount that would cause any member of the public to receive an effective dose equivalent of 10 mrem/yr. The definition of facility includes all buildings, structures, and operations on one contiguous site. Radionuclide emission from stacks shall be monitored and effective dose equivalent values to members of the public calculated.
Occupational Safety and Health Act of 1970 (OSHA), as amended Title 20 USC 333		
General Standards 29 CFR 1910	Applicable	Health and safety requirements established under OSHA are applicable to all activities at the site, including Section 1910.120, Hazardous Waste Operations and Emergency Response.
Radioactive Waste Management DOE Order 5820.2A	To Be Considered	Policies nd guidelines established for the management of radioactive waste and contaminated facilities should be considered during selection of remedial alternatives. These standards are TBC under CERCLA because they are not federally promulgated regulations. However, compliance with DOE orders is required at the Hanford Site. These guidelines set performance objectives to limit the annual effective dose equivalent beyond the facility boundary to 25 mrems. Disposal methods selected must be sufficient to limit the annual effective dose equivalent to 100 mrem for continuous exposure or 500 mrem for acute exposures when institutional controls are removed.

Table 3-5. Identification of Potential Federal [illegible]on-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 5 of 7)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Chapter III-Management of Low-Level Waste		
Waste treatment [Paragraph 3(f)(1)(2)(3)]	To Be Considered	This section states that waste treatment techniques such as incineration, shredding, and compaction shall be implemented to meet performance requirements. These requirements are TBC and should be considered during selection of remedial alternatives.
Disposal [Paragraph 3(i)]	To Be Considered	Proposed remedial actions related to disposal of low-level waste should be selected and designed considering the criteria in this section. The section includes engineered modifications, disposal site selection, disposal facility and site design, and disposal facility operations.
Chapter VI - Waste Management Plan Outline		
Radioactive and Mixed Waste Management [Paragraph 3(c)]	To Be Considered	This section is TBC during selection of remedial alternatives because the section includes system and facility descriptions, current and future plans, and implementation requirements.
Hazardous Waste Management[Paragraph 3(d)]	To Be Considered	This section is TBC and includes system and facility descriptions that should be considered during selection of remedial alternatives.
Radiation Protection for Occupational Workers, DOE Order 5480.011	To Be Considered	DOE Order 5480.11 implements radiation protection standards and program requirements for worker protection at DOE and DOE-contractor operations. These standards were developed to be consistent with EPA standards and are based on recommendations by organizations recognized as authorities in the area of radiation protection. These standards are TBC under CERCLA because they are not federally-promulgated regulations. However, compliance with DOE orders is required at the Hanford Site. DOE policy is to maintain radiation exposure as low as reasonably achievable (ALARA) and as low as possible where limiting values have been established. Limiting values for an annual effective dose equivalent to a worker from both internal and external sources received in any year is 5 rem. The limiting value to specific organs and tissues is 15 rem to the lens of the eye or 50 rem to any other organ or extremity of the body. Additional limiting values are established for the unborn (0.5 rem/yr) and children and minors (0.1 rem/yr). Radiation protection standards for the public entering controlled areas are set at 0.1 rem/yr from the committed effective dose equivalent from any external radiation. In addition, exposure shall not cause a dose equivalent to any tissue to exceed 5 rem/yr.

Table 3-5. Identification of Potential Federal Action-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 6 of 7)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Atomic Energy Act of 1954, as amended, Title 42 USC 2011 et seq.		
Licensing Requirements for the Land Disposal of Radioactive Waste 10 CFR 61	Relevant and Appropriate	Requirements that disposal systems must be designed to limit the annual dose equivalent beyond the facility boundary below 25 mrems to the whole body, 75 mrems to the thyroid, or 25 mrem to any other organ are relevant and appropriate to remedial actions that include land disposal or release radioactive effluent. The regulation is not applicable because it applies to land disposal of radioactive wastes containing by-product, source, and special nuclear material received from other persons. Requirements to define protection to inadvertent intruders at any time after institutional controls have been removed may also be relevant and appropriate to actions implemented at the site.
Packaging and Transportation of Radioactive Material 10 CFR 71	Relevant and Appropriate	These requirements apply to the packaging, preparation for shipment, and transportation of licensed radioactive material. The regulations are applicable for NRC licensed plants and facilities where material is transported outside the confines of the plant. The Hanford Site is not an NRC-licensed plant; however, potentially radioactive waste will be generated by the remedial treatment of the groundwater. Subparts of this regulation are relevant and appropriate for packaging, testing, and preparation of packages containing radioactive material.
Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes 40 CFR Part 191	Not ARAR	Containment requirements established by this standard are neither applicable nor relevant and appropriate because these wastes are not present in 300-FF-5. The standard states that radionuclide release to the environment for a period of 10,000 yr after disposal shall have a likelihood of less than one chance in ten of exceeding the level specified in Appendix A, Table 1 of the regulation, or a likelihood of less than one in 1,000 chance of exceeding 10 times the limit specified in Appendix A, Table 1.
Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings 40 CFR 192	Relevant and Appropriate	Standards for cleanup set under this program are relevant and appropriate to remedial actions conducted at the site, including groundwater protection requirements for Ra-226, Ra-228, and gross alpha particle activity, which are set at levels established under state and federal water quality criteria programs. The standard is not applicable because the operable unit is not a uranium or thorium milling site.
Hazardous Materials Transportation Act 49 USC 1801, et seq		
Hazardous Materials Regulation 49 CFR 171	Applicable	No person may offer to accept hazardous material for transportation in commerce unless the material is properly classed, described, packaged, marked, labeled, and in condition for shipment. These requirements are applicable to hazardous material generated during treatment of groundwater that would be sent offsite for disposal. Items could include ion exchange resins, reverse osmosis brine, filters, and sludge from processing equipment.

Table 3-5. Identification of Potential Federal [illegible]n-Specific ARARs at the 300-FF-5 Operable Unit.
(Sheet 7 of 7)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Hazardous Materials Tables, Hazardous Materials Communications Requirements, and Emergency Response Information Requirements 49 CFR 172	Applicable	These requirements are only applicable if hazardous waste generated by remedial actions is transported off the Hanford Site. The class of each hazardous material is identified in tables with requirements pertaining to its packaging, labeling, and transportation. Small quantities of radioactive materials are not subject to any other requirements of the chapter if the activity level does not exceed that specified in §§173.421, 173.422, or 173.424. Packages used for shipping the hazardous materials shall be designed and constructed, and contents so limited, that under conditions normally incident to transportation there is no significant release of hazardous materials to the environment.
Purpose and Use of Hazardous Materials Table 49 CFR 172.101	Applicable	This table identifies the class of each hazardous material and specifies or references requirements pertaining to its packaging, labeling, and transportation. These requirements are applicable if hazardous materials generated by remedial actions are transported off the Hanford Site.
Packaging and Exceptions 49 CFR 173.3	Applicable	Packaging of hazardous material for transport is specified in this part. These specifications are only applicable if hazardous materials generated by remedial actions performed at the site are transported off the Hanford Site.
Exceptions for Small Quantities 49 CFR 173.4	Applicable	This section is applicable to small quantities of radioactive materials that are not subject to any other requirements of this subchapter if the activity level does not exceed that specified in §§173.421, 173.422, or 173.424, as appropriate.
Exception of Shipment of Waste Material 49 CFR 173.12	Applicable	The waste material meeting the hazard class definition of a flammable liquid, flammable solid, oxidizer, or corrosive material is exempt from the specification packaging requirements of this subchapter if packaged in combination packages in accordance with this section and transported for disposal or recovery by private or contract motor carrier offsite over highways.
Standard Requirements for All Packages 49 CFR 173.24	Applicable	Packages used for shipping the hazardous materials under this subchapter shall be so designed and constructed, and contents so limited, that under conditions normally incident to transportation, there is no significant release of the hazardous materials to the environment. This section is applicable if the waste generated by the remedial actions is transported offsite over highways.
Hazardous Waste Discharges 40 CFR 263.30	Applicable	In the event of a discharge of hazardous waste during transportation from the treatment facility to the disposal facility, this section is applicable.
National Environmental Policy Act (NEPA) Regulations 40 CFR 1500	Applicable	The purpose of NEPA requirements is to ensure that potential impacts of cleanup activities are assessed. NEPA requires either an Environmental Assessment or Environmental Impact Statement for major federal projects. With the exception of the no action and institutional controls alternatives, NEPA requirements will likely be applicable. Therefore, either an Environmental Assessment or Environmental Impact Statement would be required for identifying and evaluating the impacts associated with the selected remedial alternative for cleanup.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 1 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Hazardous Waste Cleanup-Model Toxics Control Act Ch. 70.105D RCW		
Model Toxics Control Act Cleanup Regulations WAC 173-340		
Selection of Cleanup Actions WAC 173-340-360	Potentially Applicable	This chapter is potentially applicable to the operable unit because it describes the requirements for selecting cleanup actions, preferred technologies, policies for use of permanent solutions, the time frame for cleanup, and the process for making decisions. DOE, Ecology and EPA are currently negotiating the applicability of MTCA to the Hanford Site. The regulations specifies that all cleanup, actions be protective of human health, comply with all applicable state and federal regulations, and provide for compliance monitoring. Specific criteria for the various cleanup methods are presented in the regulation. The chapter specifies permanent solutions using cleanup technologies that minimize the amount of untreated hazardous substances remaining onsite. Technologies that recycle or re-use materials, followed by methods that destroy or detoxify hazardous substances, are preferred over those cleanup methods that may leave contaminants onsite.
Cleanup Actions WAC 173-340-400	Potentially Applicable	Potentially applicable to remedial actions at the site because it establishes specific requirements that ensure cleanup actions are designed, constructed, and implemented in a manner consistent with acceptable engineering practices, site cleanup plan, and other requirements of 173-340-360.
Compliance Monitoring WAC 173-340-410	Potentially Applicable	This section of the regulation specifies requirements for compliance monitoring applicable to remedial actions.
Institutional Controls WAC 173-340-440	Potentially Applicable	Requirements of this section are applicable to cleanup actions where residual concentrations exceed levels specified under 173-340-700 through 760 at conditional points of compliance established in the regulation or as determined by the Department of Ecology. Institutional controls may include physical, administrative/legal, or financial measures.
Hazardous Waste Management Act 70.105 RCW		
Dangerous Waste Regulations WAC 173-303		
Designation of Dangerous Waste 173-303-070	Applicable	The requirements of this section are applicable to dangerous wastes generated during remedial activities. The section defines the procedures to determine if the solid waste is a dangerous waste.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 2 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Dangerous Waste Characteristics WAC 173-303-90	Applicable	This section sets forth the methods to classify wastes as dangerous or extremely hazardous based on characteristics of ignitability, corrosivity, reactivity, and toxicity. Classification of wastes from treatment processes is applicable to remedial activities conducted at 300-FF-5.
Land Disposal Restrictions WAC 173-303-140	Applicable	This section of the regulation is applicable to remedial actions at the site because it identifies dangerous wastes (that may result from remedial processes) that are restricted from land disposal, describes requirements for restricted wastes, and defines the circumstances under which a prohibited waste may continue to be landfilled.
Spills and Discharges into the Environment WAC 173-303-145	Applicable	Applicable to remedial actions at the site because it sets forth the requirements that apply when any dangerous waste or hazardous substance is intentionally or accidentally spilled or discharged into the environment, regardless of the quantity of dangerous waste or hazardous substance.
Division, Dilution, and Accumulation WAC 173-303-150	Applicable	This section of the regulation is applicable to management of dangerous wastes, and states that any actions that divide or dilute wastes to change their designation is prohibited, except for the purposes of treating, neutralizing, or detoxifying such wastes. Subpart (2)(b) requires designation of each phase of the heterogeneous waste, in accordance with the dangerous waste designation requirements of WAC 173-303, and handles each phase accordingly.
Containers WAC 173-303-160	Applicable	This section is applicable to remedial actions at the site because it specifies that containers and inner liners shall not be considered as a part of the waste when measuring or calculating the quantity of a dangerous waste. Additionally, requirements for rinsing or vacuum cleaning the containers are specified.
Overpacked Containers WAC 173-303-161	Applicable	The requirements of this section are applicable to the remedial actions performed at the site if dangerous waste is generated. The section specifies the conditions that must be met to place small containers of dangerous waste in overpacked drums (40 CFR 178 and 179).
Requirements for Generators of Dangerous Waste WAC 173-303-170	Applicable	Requirements for generators of dangerous waste established under this chapter are applicable to remedial actions performed at the site if dangerous waste is generated. Requirements defined under this section include: a 90-day waste accumulation period, specific levels of training, emergency preparedness, and record-keeping.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 3 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Accumulating Dangerous Waste Onsite WAC 173-303-200	Applicable	Requirements of this section are applicable to remedial actions at the site that generate dangerous waste. Dangerous waste may be accumulated onsite without a permit for 90 days or less after the date of generation. Requirements are included for labeling, marking, and inspection of the dangerous waste while it is being accumulated.
Special Accumulation Standards WAC 173-303-201	Applicable	The requirements of this section apply to persons who generate less than 2,200 pounds (1,000 kg) per month and do not accumulate onsite more than 2,200 pounds(1,000 kg) of dangerous waste. Requirements of this section may apply to the remedial actions at the site if more than 200 pounds, but less than 2,200 pounds, of dangerous waste is generated. It is not anticipated that wastes will be accumulated in tanks.
General Requirements for Dangerous Waste Management Facilities 173-303-280	Applicable	General requirements for dangerous waste management facilities are applicable to remedial actions that include treatment, storage, or disposal of designated dangerous waste. General requirements include siting standards and procedures for permitting, training, emergency preparedness, contingency planning, and management of containers. Standards defining additional requirements for incinerators, landfills, and surface impoundments are also included in the regulation.
General Waste Analysis WAC 173-303-300	Applicable	Analysis of a waste is required to determine the presence of dangerous waste before it is stored, treated, or disposed of. These requirements are applicable if wastes are generated by remedial actions.
Security WAC 173-303-310	Applicable	Security procedures will be taken to ensure that the remedial actions at the site do not injure persons and that access to the site is controlled. These requirements are applicable if dangerous wastes are generated by remedial actions at the site.
General Inspection WAC 173-303-320	Applicable	Requirements to inspect facilities to prevent malfunctions and deterioration, operator errors, and discharges that may cause or lead to the release of dangerous waste constituents to the environment, or a threat to human health, are applicable if dangerous wastes are generated by remedial activities conducted at 300-FF-5.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 4 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Personnel Training WAC 173-303-330	Applicable	A program of classroom instruction or on-the-job training for facility personnel is applicable if a dangerous waste is generated as a result of remedial actions at the site.
Preparedness and Prevention WAC 173-303-340	Applicable	This section describes preparations and preventive measures, which help avoid or mitigate fire, explosion, or unplanned sudden or nonsudden releases of dangerous waste or dangerous waste constituents. This section is applicable if a dangerous waste is generated as a result of remedial actions at the site.
Contingency Plan and Emergency Procedures WAC 173-303-350	Applicable	Spill prevention, control and countermeasures (SPCC) plans required for remedial actions performed at the site to lessen the potential impact on public health and the environment in the event of an emergency circumstance. Substantive sections of this section are applicable if a dangerous waste is generated as a result of remedial actions at the site.
Other General Requirements WAC 173-303-395	Applicable	The regulations in this section define specific precautions for ignitable, reactive, or incompatible wastes. This section is applicable if dangerous waste is generated as a result of remedial actions at the site.
Use and Management of Containers WAC 173-303-630	Applicable	This section discusses procedures for management of containers used to store dangerous waste and is applicable if a dangerous waste is generated as a result of remedial actions at the site.
Groundwater Protection 173-303-645	Applicable	Groundwater protection requirements are applicable because source operable units within the area of the 300-FF-5 groundwater operable unit contain dangerous waste management units that disposed of waste-to-surface impoundments. Contaminant concentrations based on protection of groundwater may be established at background concentrations, at MCLs established under the SDWA, or at health-based alternate concentration levels (ACLs) that do not pose present or future risk to human health or environment.
Solid Waste Management, Recovery, and Recycling Act Ch. 70.95 RCW		
Minimum Functional Standards for Solid Waste Handling WAC 173-304	Applicable	These regulations are applicable to onsite management and disposal of solid waste.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 5 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Onsite Containerized Storage, Collection, and Transportation Standards for Solid Waste WAC 173-304-200	Applicable	Requirements of this section are applicable to the containerized storage, collection, and transportation of solid waste. Treatment processes that generate waste that is not designated as hazardous waste would need to comply with these solid waste standards.
General Facility Requirements WAC 173-304-405	Applicable	This section is applicable to remedial actions that include onsite disposal of solid waste. The section sets the minimum standards for handling all solid waste, including siting, operational, monitoring, and closure requirements. Groundwater maximum contaminant levels (MCLs) are set at the same levels as 40 CFR 141.
Water Well Construction Ch. 18.104 RCW		
Minimum Standards for Construction and Maintenance of Water Wells WAC 173-160	Applicable	Requirements are applicable to remedial actions that include construction of wells used for groundwater extraction, monitoring, or injection of treated groundwater or wastes.
Water Pollution Control/Water Resources Act Ch. 90.48 RCW/ Ch. 90.54 RCW		
Protection of Upper Aquifer Zones WAC 173-154	Relevant & Appropriate	This regulation directs Ecology to provide for protection of upper aquifers and upper aquifer zones to avoid depletions, excessive water level declines, or reductions in water quality. This regulation is not applicable to remedial actions at 300-FF-5 because the regulation establishes the policy and program for Ecology. However, the regulation may be considered relevant and applicable to remedial alternatives that involve removal or re-injection of groundwater from upper aquifers.
State Waste Discharge Program WAC 173-216	Applicable	Requirements of this program are applicable to remedial actions that include discharges to the ground. The chapter implements a permit system applicable to industrial and commercial operations that discharge to the groundwater, surface waters, or sewerage systems. Specific discharges prohibited under the program are identified. Application for a permit will not be required for on-site remedial actions; however, onsite CERCLA remedial actions must meet substantive requirements of the regulations. The intent of the law is to maintain the highest possible standards, and the law requires the use of all known available and reasonable methods to prevent and control the discharge of wastes into the waters of the state.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 6 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Underground Injection Control Program WAC 173-218	Relevant & Appropriate	Not applicable because groundwater is not used as a drinking water source. However, it is relevant and appropriate to remedial actions that involve underground injection of treated water or wastes. The regulation sets procedures and practices designed to meet SDWA requirements under 40 CFR 124, 141, 144 and 146. Onsite remedial actions need only meet the substantive requirements of the standard.
National Pollution Discharge Elimination System Permit Program WAC 173-220	Applicable	Establishes a state permit program pursuant to the national NPDES system. Substantive sections of the regulation are applicable to alternatives that discharge to the Columbia River, however, under CERCLA Section 121, on-site response actions do not require a permit. Discharges may include plant site run-off, spillage, leaks, sludge, or other waste disposal.
Washington Clean Air Act Ch. 70.94 RCW and Ch. 43.21A RCW		
General Regulations for Air Pollution WAC 173-400	Applicable	Substantive standards established for the control and prevention of air pollution under this regulation are applicable to remedial actions proposed for the operable unit. The regulation requires that all sources of air contaminants meet emission standards for visible, particulate, fugitive, odors, and hazardous air emissions.
General Standards for Maximum Emissions WAC 173-400-040	Applicable	This section requires that all emission units use reasonably available control technology, which may be determined for some source categories to be more stringent than the emission limitations listed in this chapter.
Emission Standards for Sources Emitting Hazardous Air Pollutants WAC 173-400-075	Applicable	Requirements of this standard are applicable to remedial actions performed at the site that could result in the emission of hazardous air pollutants. The regulation requires that source testing and monitoring be performed.
Implementations of Regulations for Air Contaminant Sources WAC 173-403	Applicable	Substantive requirements of this section may be applicable to remedial actions performed at 300-FF-5. A new source would include any process or source that may increase emissions or ambient air concentration of any contaminant for which federal or state ambient or emission standards have been established. Remedial actions under CERCLA need to meet the substantive requirement of best available control technology for emission control, however, under CERCLA Section 121, on-site remedial actions are exempt from administrative requirements and do not require a permit.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 7 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
Controls for New Sources of Air Pollution WAC 173-460	Not ARAR	This chapter establishes controls for new sources emitting toxic air pollutants; however, the standard specifically exempts sites subject to MTCA actions. The standard establishes three major requirements for new sources of air pollutants: use of best available control technology, quantification of toxic emissions, and demonstration that human health is protected.
Ambient Air Quality Standards for Particulate Matter WAC 173-470	Applicable	Requirements for maximum acceptable levels for particulate matter in the ambient air at 150 ug/m^3 over a 24-hour period, or 60 ug/m^3 annual geometric mean, are applicable requirements. Also applicable is the 24-hour ambient air concentration standard for particles less than 10um in diameter (PM_{10}), which are set at 105 ug/m^3 and 50 ug/m^3 geometric mean. The section defines standards for particle fallout not to exceed 10 g/m^2 per month in an industrial area or 5 g/m^2 per month in residential or commercial areas. Alternate levels for areas where natural dust levels exceed 3.5 g/m^2 per month are set at 6.5 g/m^2 per month, plus background levels for industrial areas, and 1.5 g/m^2 per month plus background in residential and commercial areas.
Ambient Air Quality Standards and Emission Limits for Radionuclides WAC 173-480	Applicable	Requirements of this standard are applicable to remedial actions performed at the site. The standard defines the maximum allowable level for radionuclides in the ambient air, which shall not cause a maximum accumulated dose equivalent of 25 mrems/yr to the whole body or 75 mrems/yr to any critical organ. Emission standards for new and modified emission units shall utilize best available radionuclide control technology (BARCT). The standard requires all sources of emissions to meet levels set in 246-220, including determination of compliance using methods established by the Department of Social and Health Services.
Emission Standards and Controls for Sources Emitting Volatile Organic Compounds (VOC) WAC 173-490	Relevant & Appropriate	This chapter establishes technically feasible and attainable standards for sources emitting volatile organic compounds. This regulation is not applicable to remedial actions conducted at the 300-FF-5 operable unit because the source of potential volatile organic compound emissions generated by remedial actions does not meet the definition of emission sources specified under WAC 173-490-03. However, this regulation may be considered relevant and appropriate if remedial actions have the potential to emit volatile organic compounds into the air.

Table 3-6. Identification of Potential State Action-Specific ARARs at the 300-FF-5 Operable Unit. (Sheet 8 of 8)

Requirements	Applicable, Relevant & Appropriate, or To Be Considered	Comment
State Radiation Protection Requirements CH. 70.98 RCW		Washington State Radiation Protection Requirements are implemented under specific sections of WAC 246 and only specific sections that may be considered ARAR for remedial actions at the 300-FF-5 operable unit are presented.
Radioactive Waste-Licensing Land Disposal WAC 246-250	Relevant & Appropriate	WAC 246-250, establishes the procedures, criteria and conditions for licensing of low-level radioactive waste land disposal facilities. This section presents specific levels of radiation protection and technical requirements for land disposal of radioactive waste and that may be considered relevant and appropriate requirements if remedial alternatives allow radioactive waste to remain on-site
Washington Industrial Safety and Health Act Ch. 49.17 RCW		
Worker Safety and Health WAC 173-340-810	Applicable	Regulations under the Washington Industrial Safety and Health Act are applicable to all remedial actions.
General Safety and Health Standards WAC 296-24	Applicable	This regulation covers worker safety requirements for all workplaces and is applicable during remedial actions at 300-FF-5. The standard covers personnel protective equipment, general safety procedures, and materials handling and storage.
Occupational Health Standards - Safety Standards for Carcinogens WAC 296-62	Applicable	This regulation establishes the requirements for the prevention of unsafe work conditions and specifically addresses working environments where carcinogens may be present. State safety and health regulation are applicable to all non-DOE or offsite remedial actions involving potential human exposure to hazardous materials, including carcinogens.
Richland Pretreatment Ordinance City of Richland Ordinance No. 35-84	To Be Considered	This city ordinance establishes a set of uniform requirements for discharges to the City of Richland waste water collection and treament system. This ordinance is TBC to remedial alternatives that include discharge of wastes to the city wastewater treatment system.

Table 3-7. Preliminary Remediation Goals.

Constituent	Concentration	Explanation
Strontium-90	1.3 pCi/L	MTCA Method B
Uranium-234	5.2 pCi/L	Background
Uranium-235	2.9 pCi/L	MTCA Method B
Uranium-238	4.3 pCi/L	Background
Tritium	N/A	Associated with an upgradient plume
Technetium-99	N/A	Associated with an upgradient plume
Copper	0.001 mg/L	Surface water quality standards for acute toxicity
Nickel	0.1 mg/L	MCL
1,2-dichloroethene	0.07 mg/L	MCL
Chloroform	0.00045 mg/L	Risk based
Trichloroethene	0.004 mg/L	MTCA Method B
Coliform bacteria	No detects	MCL
Explanation: N/A - Not applicable See Tables 3-3 and 3-4 for further explanation.		

Table 3-8. Estimated Areas and Volumes Within Selected Contours.

Contaminant	Area (m^2)	Volume of Groundwater Representing One Pore Volume (m^3)[a]	Volume of Impacted Aquifer Soils (m^3)
Strontium-90			
1.3 pCi/L contour (MTCA Method B Cleanup Level)	69,000	100,000[b]	345,000[b]
Uranium (U-238)			
4.3 pCi/L contour (MTCA Method B Cleanup Level)	1,200,000	1,800,000[b]	6,000,000[b]
7.1 pCi/L contour (10^{-6} Incremental Cancer Risk)	830,000	1,200,000[b]	4,150,000[b]
30 pCi/L contour	170,000	255,000[b]	850,000[b]
Trichloroethene			
0.005 mg/L (current MCL)	300,000	450,000[c]	1,500,000[c]
0.004 mg/L (MCTA Method B Cleanup Level)	540,000	810,000[c]	2,700,000[c]

[a] Assumes porosity of 0.3
[b] Assumes contamination is limited to the upper 5 m (16 ft) of the aquifer
[c] Assumes contamination is limited to the lower 5 m (16 ft) of the aquifer

4.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

In this chapter, technologies are identified that are potentially applicable for remediation of contaminated groundwater at the 300-FF-5 operable unit. A comprehensive list of technologies and process options that are potentially applicable to this operable unit was developed to cover all the applicable general response actions. The list of technologies was then screened to develop a refined list of potentially feasible technologies that can then be used to develop remediation alternatives for the operable unit. These remediation technologies were screened using the following criteria:

- **Effectiveness** - The potential effectiveness of the technology to (1) address site-specific conditions, including applicability to the media and contaminants of concern for this operable unit, (2) meet remedial action objectives, (3) minimize human health and environmental impacts during implementation, and (4) provide proven and reliable remediation under site conditions.

- **Implementability** - The technical and administrative feasibility of implementing a technology. Technical considerations cover site-specific factors that could prevent successful use of a technology, such as physical interferences or constraints, practical limitations of a technology, and soil properties. Administrative considerations include the ability to obtain permits and the availability of qualified contractors, equipment, and disposal services.

- **Cost** - The capital and operation and maintenance costs associated with the technology. At the screening stage, cost is used to reject a technology only if another technology is retained within the same general response action that is at least as effective in meeting remedial action objectives. Because of this limited role, the cost evaluation is based primarily on engineering judgment of relative costs.

The technologies and process options were screened against the criteria in the priority order listed above using the "fatal flaw" approach. This approach was adopted for efficiency and is based on ranking criteria in order of importance, as listed above. The ranking is in turn based on CERCLA guidance (EPA 1988a). Once a technology is rejected, based on effectiveness, it is not further evaluated based on implementability or cost. For example, a technology that is ineffective for site contaminants or other site conditions is not evaluated against implementability or cost, as further evaluation is unnecessary. Similarly, if a technology is effective, but not implementable, the technology is rejected; evaluation of cost is not undertaken. This approach streamlined the evaluation of technologies while maintaining the screening methodology required under CERCLA.

Screening of technologies and process options has been performed in a single step. The key criterion in selecting the screening level (technology class, individual technology, or process option) is whether there is a significant difference between the technologies or process options when evaluated against the screening criteria (effectiveness, implementability, and cost). Technologies and process options that are judged to have significant differences are screened separately, and the retained technologies or process options will be developed into separate remediation alternatives to allow full evaluation and comparison.

Process options retained for any given technology that are screened together (i.e., not evaluated separately) are considered equally suitable (at the screening level of evaluation). Selection of representative process options is performed during the detailed development of alternatives, so that best engineering judgment may be used to select and combine appropriate technologies and process options into cohesive, integrated remediation alternatives.

The general response actions and potentially applicable technologies and process options considered for remediation of groundwater at Hanford's 300-FF-5 operable unit are presented in Table 4-1. The technology screening is also summarized in this table. Brief descriptions of the listed technologies and discussions of the screening evaluations are provided below. Technologies retained through this screening process were then incorporated into remediation alternatives (Chapter 5).

4.1 GENERAL RESPONSE ACTIONS

General response actions are broad categories of remedial actions that can be combined to meet remedial actions at a site. The following general response actions are generally applicable to most sites, including the 300-FF-5 operable unit:

- No action
- Institutional controls (including monitoring)
- Containment
- Removal
- Disposal
- Ex-Situ Treatment
- In-Situ Treatment

Except for "no action," each of these response actions represents a category of technologies. The applicable technologies will vary depending on the media (e.g., soil or groundwater) and contaminants of concern (e.g., organic compounds or metals). The discussion of technologies is organized below by general response actions for groundwater and aquifer soils (the applicable media). "No action" is not discussed further because it is not associated with any technologies.

4.2 INSTITUTIONAL CONTROLS AND MONITORING

Institutional controls for groundwater prevent withdrawal of contaminated groundwater. Risk is eliminated to the extent that exposure is prevented. Groundwater use restrictions are an example of institutional controls for groundwater. They do not prevent offsite transport of contaminants via surface water or groundwater flow. Institutional controls are effective within their limitations, are easily implemented, and are low in cost. Institutional controls are typically included in any remedy where contaminants will remain after completion of remediation, and are retained for further consideration. Institutional controls can include the following measures:

- Restrictions on groundwater withdrawal and use

- Alternate water supplies
- Site security patrols
- Fencing
- Deed restrictions
- Warning signs

Under CERCLA, site monitoring is a required component of any site remedy (including "no action"). Short-term monitoring is conducted to ensure that potential risks to human health and the environment are controlled while a site remedy is being implemented. Long-term monitoring is conducted to measure the effectiveness of the remedy. A monitoring plan will be developed for the selected remedial action. Monitoring would include surface water and groundwater as appropriate.

4.3 CONTAINMENT

4.3.1 Horizontal Barriers

Horizontal barriers are intended to minimize the vertical migration of contaminated groundwater deeper into an aquifer, into deeper aquifers, or under vertical barriers. In general, horizontal barriers are difficult to implement. Because of difficulties in construction and verification (quality control), they have questionable effectiveness and reliability. At the 300-FF-5 operable unit, the Ringold Lower Mud unit forms an aquitard approximately 12 m (40 ft) below the water table that prevents the downward migration of contaminated groundwater. Horizontal barriers are therefore not necessary and this technology is not retained.

4.3.2 Vertical Barriers

Vertical barriers are designed to prevent or minimize horizontal migration of contaminants by minimizing the lateral flow of groundwater and confining the contamination to a limited area. Vertical barriers are used to reduce or contain groundwater flow and also can be used to isolate contaminated soils from offsite groundwater. For reliable containment, vertical barriers should be keyed into a continuous low-permeability stratum or artificial horizontal barrier to prevent migration underneath the vertical barrier. For the 300-FF-5 operable unit, a vertical barrier would be keyed into the Ringold Lower Mud unit. Groundwater extraction within the contained area is typically used to maintain inward hydraulic gradients.

Slurry Walls. Slurry walls are constructed by excavation of a vertical trench and adding admix in a slurry to construct a low-permeability vertical wall. The slurry mixture is used to shore the trench to prevent collapse during construction and serves as part of the impermeable soil mixture backfill. Bentonite and cement/bentonite are common admixes. Cement admixes are used where structural strength is required in addition to low permeability. Slurry walls are widely used in site remediation. One advantage of using a bentonite-based admix is that the slurry wall may absorb metals from groundwater passing through the wall.

The highly permeable, coarse-grained soils present at the 300-FF-5 operable unit will increase the quantity of slurry necessary to complete the wall, because of losses to surrounding soils. The aquifer in the 300 Area has a continuous confining layer (the Ringold Lower Mud unit) into which a slurry wall would be keyed. Slurry walls have been constructed to depths greater than those needed for the 300-FF-5 operable unit. The effectiveness of this alternative would depend upon complete continuity of the cutoff wall with no high permeability zones. Any side-wall sloughing during construction of the wall could result in high permeability gaps in the wall. Monitoring wells could be installed inside and outside the wall to help demonstrate the continuity of the wall. This technology is implementable and effective for containing contaminated groundwater, and is retained for further consideration.

Grout Wall. One method of grout wall construction is grout injection. Another method of constructing a grout wall is "deep soil mixing." A combination of these methods is also possible (e.g., grout injection in places where deep soil mixing is unsuccessful).

Grout Injection. The grout injection method requires drilling boreholes and pressure-injecting grout into the boreholes and outward into the surrounding soil. The boreholes are spaced closely enough to obtain overlapping grout zones, forming a continuous wall. As with slurry walls, a grout wall constructed using soil injection must be keyed into a horizontal confining layer to provide complete containment.

The coarse-grained and non-uniform materials found in the Hanford Formation soils decrease the reliability of achieving uniform grout application and increase the uncertainty of constructing an effective grout wall. Grout injection is more difficult to control than slurry wall construction and therefore is less reliable. For this reason, grout injection is not retained. However, should additional site information indicate that slurry wall technology is not suitable, grout injection technology may be re-evaluated.

Deep Soil Mixing. Deep soil mixing technology uses a hollow-shaft auger to mix soil and grout. As the augers are advanced vertically, grout is injected into the soils and blended. Grout walls constructed using deep soil mixing technology must be keyed into a horizontal confining layer to prevent contaminant migration and to provide complete containment.

The boulders and cobbles within the Hanford Formation in the 300-FF-5 operable unit will substantially increase the difficulty in forming a grout wall using soil mixing because of the difficulty in penetrating the soils with the auger. Deep soil mixing technology for grout wall construction has enhanced capability to provide uniform grout application compared to grout injection techniques. Deep soil mixing is more expensive to implement than slurry wall technology and its overall effectiveness may be less. Therefore, deep soil mixing is not retained. However, should additional site information indicate that slurry wall technology is not suitable, deep soil mixing technology may be re-evaluated.

Sheet Pilings. Sheet piling is another type of vertical barrier used to limit lateral flow of groundwater. Interlocking steel sheets are driven into the ground and keyed into a confining layer. Grout can be injected into the joints created by the interlocking sheets to minimize leakage. Sheet piling would be difficult to install at the 300-FF-5 operable unit to the required depth (> 50 ft), and boulders and cobbles within the Hanford Formation would hinder or prevent penetration of the piles (Canter and Knox 1985). In addition, sheet piling is often more permeable than slurry walls (because of seam leakage). For these reasons, sheet piling is not considered implementable at the 300-FF-5 operable unit and is not retained.

Cryogenic Walls. Cryogenic walls (freeze walls) are an established technology for short-term containment during dam construction and deep excavation, where technical difficulties make this expensive technology cost effective. A cryogenic wall is constructed by freezing interstitial water within soil around the contaminated zone, forming a barrier to contaminant migration. Frozen soil is substantially less permeable than unfrozen soil. A cryogenic wall is formed by installing steel pipes using drilling techniques and circulating refrigerant to freeze the water in the surrounding soil. Freeze walls may be installed vertically or, using slant drilling, at an angle. A freeze wall can thus be used to prevent both vertical and horizontal migration.

Application of freeze wall technology to waste sites is only in the developmental stage. Freeze walls for long-term containment are an unproven technology (Freeman 1989). An above-ground cryogenic plant is required to operate indefinitely to maintain the barrier, making it an active barrier, in contrast to more permanent and proven passive barriers (e.g., a slurry wall). The technology is not retained because it is unproven for long-term containment, requires active control to maintain integrity, and is more expensive than other more established technologies.

4.3.3 Hydraulic Containment

Hydraulic containment consists of active manipulation of groundwater heads to prevent offsite migration of contaminated groundwater. Groundwater heads are most commonly changed by pumping to lower the head in the contaminated area, so that groundwater flows into (and not out of) the contaminated area. Once the groundwater is extracted, it must be treated to comply with effluent discharge standards. Groundwater infiltration may be used in conjunction with pumping to aid containment, and could also serve to divert upgradient plumes from the contaminated area. Groundwater infiltration is usually performed on the periphery of the contaminated area, using effluent from treatment of the contaminated groundwater.

Groundwater extraction is performed using wells or interceptor trenches (see Section 4.4.1). Groundwater infiltration is essentially extraction in reverse and usually involves infiltration trenches that allow treated groundwater to percolate down to the aquifer. Hydraulic containment is feasible for the 300-FF-5 operable unit and is retained for further consideration.

4.4 REMOVAL

Removal consists of extraction for groundwater and dredging/excavation for aquifer soils. Unlike institutional controls, containment, or in-situ treatment, removal by itself cannot be a complete remedial action. For groundwater, extraction would be followed by treatment to meet applicable standards, followed by reinjection, infiltration, or surface water discharge. Excavated aquifer soil would require dewatering (at a minimum), possibly other treatment, and disposal. Because treatment cannot destroy metals or radionuclides, removal at the 300-FF-5 operable unit would always be followed by some form of disposal.

4.4.1 Groundwater Extraction

Wells. The use of extraction wells for the removal of groundwater is a proven technology. Wells are most often used to remove contaminated groundwater for ex-situ treatment and to control groundwater flow (i.e., hydraulic containment). Well systems have a high degree of design and operational flexibility. They can be operated singly with high extraction rates to provide capture over an entire site or in groups strategically located to allow fine-tuning of the hydraulic control.

The Hanford Formation and the coarse-grained units of the Ringold Formation have sufficient permeability and saturated thickness to readily yield groundwater to wells. Groundwater removal using extraction wells is retained as a feasible remediation technology.

Interceptor Trenches. The use of an interceptor trench for collection of groundwater is a proven technology under the appropriate conditions. Typically, the trench is installed in a trench below the water table and possibly to the top of the first continuous confining layer. A collection pipe is sometimes placed at the bottom and the trench is then backfilled with gravel. The groundwater is collected by pumping from the trench or collection pipe.

Trench systems are used for directly removing groundwater plumes. Advantages to trenches are that the area of influence is large compared with wells, they are an effective horizontal barrier when properly designed and installed, and their operation and maintenance costs are relatively low. They are especially effective when contaminants exist in the near surface of the water table and when the water table is close to the ground surface. Interceptor trenches are retained as a potential technology for groundwater extraction at the 300-FF-5 operable unit.

4.4.3 Aquifer Soil Dredging/Excavation

Dredging/excavation would be used to remove contaminated aquifer soils. Commonly used methods are described below. A combination of the retained methods would be used for aquifer excavation. Any removed soil would require dewatering and/or other treatment, followed by landfill disposal.

Excavation with Dewatering. Soil excavation technology is widely used for the removal of contaminated soils. Conventional equipment, such as backhoes, bulldozers, draglines, and similar equipment may be used. However, aquifer soils would first require dewatering (groundwater removal) prior to excavation. This would also require treatment and disposal of the contaminated groundwater. Excavation is a proven technology and is retained for consideration.

Mechanical Dredging. Mechanical dredging includes use of clamshells, draglines, or similar equipment to excavate saturated soils or sediments. Mechanical dredging is a well-developed technology that is regularly used in harbors and river channels. Mechanical dredging has been used to remove contaminated sediments at numerous sites and is effective for a wide range of soil types. The equipment required for mechanical dredging is readily available from commercial sources. Mechanical dredging would be an effective and implementable method for excavation of contaminated saturated soils, and is retained.

Hydraulic Dredging. Hydraulic dredging is used to remove sediments (or saturated soil) by sucking material from beneath a water surface and pumping the slurry to a treatment facility where the solids and liquids are separated. Hydraulic dredging is regularly used in harbors and river channels and has been used to remove contaminated sediments. Hydraulic dredging equipment is readily available.

The range of particle sizes that can be removed by hydraulic dredging is limited. Depending on the equipment, hydraulic dredges typically accommodate a maximum particle size of 4 to 6 inches. Thus, hydraulic dredging would have difficulty removing the large cobbles and boulders that are found in aquifer soils at the 300-FF-5 operable unit. Mechanical dredging does not have this limitation. In addition, hydraulic dredging results in a low-solids slurry (typically around 10% solids). The solids content from mechanical dredging is much higher (typically greater than 50%), and thus is much easier to store and dewater or otherwise treat prior to disposal. For these reasons, hydraulic dredging of aquifer soils is rejected in favor of mechanical dredging or excavation.

4.5 DISPOSAL

Disposal is a general response action for final disposition of treated groundwater, solid waste generated by treatment processes, and contaminated soils. Disposal relocates contaminants from one place to another for long-term containment. Solid wastes or contaminated soils may require additional treatment (e.g., fixation) prior to disposal.

4.5.1 Treated Groundwater

Treated groundwater that meets effluent discharge standards may be discharged either to surface water or subsurface land disposal.

Surface Water Discharge. Surface disposal of treated water would consist of direct discharge into the Columbia River. Discharge to the river would be require to meet the substantive requirements of federal and state discharge regulations. Surface water disposal is commonly used in commercial and government groundwater remediation projects, is effective and easy to implement, and therefore is retained.

Subsurface Discharge. Subsurface discharge of treated water following removal of contaminants involves injection or infiltration of the groundwater into the subsurface. Injection/infiltration can be used as an aid in maintaining gradients to the groundwater extraction wells, as a flushing aid to improve extraction of contaminants, and as an aid to prevent migration of contaminants in the groundwater. Onsite subsurface discharge of treated water will require approval by government agencies and must meet substantive requirements of chemical-specific ARARs. Subsurface disposal would be effective and relatively easy to implement at the 300-FF-5 operable unit, therefore the technology is retained.

4.5.2 Sludge and Soils

Disposal of soils and sludges is a general response action for final disposition of waste from other technologies. This general response action also includes soils that may require disposal as a result of aquifer excavation. Disposal relocates contaminants from one location to another; it is not treatment to destroy or detoxify contaminants. However, if needed, treatment can be used prior to disposal. For example, sludge is commonly treated by chemical fixation (stabilization/solidification) prior to disposal. Fixation involves the addition of binding agents to the sludge to create a solid matrix that reduces contaminant mobility, thus reducing risk.

Onsite Disposal. An engineered landfill, the Environmental Restoration Storage and Disposal Facility (ERSDF), is currently planned for construction on the Hanford Site. This landfill will be designed for low-level radioactive waste, mixed waste, and hazardous waste from remediation activities throughout the Hanford Site. The final design of the ERSDF has not been completed, but compliance with applicable regulations and DOE policies for disposal of the wastes will be required under the ERSDF operating permit. Appropriate monitoring will be provided during operation and following closure of the facility. Compliance with all applicable regulations and DOE policies regarding closure and post-closure care will also be required.

In contrast to offsite landfills, transportation of contaminated soil from the 300-FF-5 operable unit to the ERSDF would not be a major concern. The hauling distance would be short and the contaminated material would not leave the Hanford reservation. Standard Hanford safety and environmental controls, including packaging standards and personnel protection, would be used. Additional controls would be used if appropriate.

The permitting process should provide review to ensure the effectiveness and reliability of the facility. Conventional, well-developed technologies and methods will be used to construct and operate the facility. Therefore, the ERSDF is considered readily implementable. Onsite disposal, including disposal of sludges, contaminated soil, and other solid wastes at the ERSDF, is retained for further consideration.

Offsite Disposal. Use of an offsite landfill for permanent disposal is similar in concept to the other landfill options discussed above. The offsite facility would probably be a general low-level mixed waste facility serving a state or regional area. The disadvantages of using an offsite disposal facility are that (1) there are few facilities prepared to accept soil contaminated with low levels of radioactivity (and none in the Pacific Northwest), (2) transportation distances would be large, with the associated potential risk of contaminant release, and (3) public opposition to offsite disposal of Hanford waste is likely to be high. For these reasons, offsite disposal is not retained.

4.6 EX-SITU TREATMENT OF GROUNDWATER

Treatment of groundwater following withdrawal is a widely used remedial technology. Treatment technologies may destroy contaminants, remove them from the influent and concentrate them in a secondary waste stream, or immobilize them. Disposal of untreated and contaminated groundwater is not permitted by any method under existing regulations; therefore, treatment of withdrawn and contaminated groundwater is mandatory.

4.6.1 Gravity Separation

Gravity separation is a common, well-established technology for removal of suspended solids from water. It is effective only on larger particle sizes; very small particles must be removed by filtration. Sedimentation or clarification are common gravity separation processes. The low concentrations of suspended solids in groundwater at this site would not be amenable to gravity separation (EPA 1987). However, gravity separation would be usable as an ancillary technology. Gravity separation would probably be a component of a treatment subsystem for precipitation of metals or for removal of concentrated solids in filter backwash. This technology is therefore retained for further consideration.

4.6.2 Filtration

Filtration is a method for removing suspended solids from a liquid using a porous medium. Filtration cannot directly remove chemicals that are dissolved in water. However, filtration is very effective at removing solids created by precipitation technology (James M. Montgomery 1985). Filtration is typically used at the beginning of many treatment systems to remove particulates that may affect later treatment operations. Because uranium is adsorbed to soil particles, filtration of turbid groundwater should remove some of the uranium. Filtration is retained for further consideration.

4.6.3 Ion Exchange

Ion exchange has been widely applied to the treatment of high flows of wastewaters with dilute concentrations of metals. The contaminant ions are exchanged with ions on the resin (e.g., Na^+). When the exchange capacity for a bed is reached, the resin is regenerated with a brine solution. The regenerant exchanges the original resin ion with the contaminant ion, using an acidic, basic, or brine solution (depending on the specific resin). The regenerant stream then contains the contaminants in a more concentrated form. Cation resins can be weak acid, strong acid, and chelating-type resins. Anion resins are weak or strong base types. The resin is chosen to selectively remove the target contaminant. A mixture of resins may be used to remove multiple contaminants.

Ion exchange resins are easily fouled by suspended solids and organic compounds (EPA 1987). The ion exchange influent is usually treated to remove high levels of organic compounds (if present) and filtered to remove suspended solids (EPA 1981). The regenerant solution is treated to remove the metals for disposal, generally by precipitation. The sludge from precipitation is then dewatered and disposed in a landfill.

Ion exchange is a proven technology and can be applied to a range of contaminants. It has been used for treatment of leachate and groundwater containing uranium from in-situ uranium mining. This technology is an attractive choice for removal of uranium and other contaminants from groundwater at the 300-FF-5 operable unit, and is therefore retained for further consideration.

4.6.4 Reverse Osmosis

Reverse osmosis (RO) can be used to remove the inorganic and some organic compounds from water. RO separates dissolved materials in solution by diffusion through a semi-permeable membrane. Pressure is used to overcome the osmotic pressure caused by the dissolved compounds. Treatment by RO results in a permeate stream with low concentrations of ions and organic compounds, and a low-volume reject stream that contains the concentrated dissolved compounds. RO is effective for a wide range of metals. Removal efficiency is dependent on membrane type, operating pressure, and the specific compounds.

A large number of equipment vendors is available commercially. RO has been used to concentrate metals from dilute solutions and also has been used to remove uranium from solution. Membranes are easily fouled by suspended solids and some organic compounds and are expensive to replace (EPA 1987). Pre-treatment by filtration is usually required. RO is a proven technology for removal of inorganic contaminants in wastewater (EPA 1981), and is retained for further consideration.

4.6.5 Ultrafiltration

Ultrafiltration is a membrane process used for separation of impurities from water (e.g., suspended solids, oil and grease, large organic molecules, and complexed heavy metals). However, the predominant mechanism for separation is selective sieving through pores, as opposed to RO and electrodialysis, in which the transport process is diffusivity. Because of the difference in transport mechanisms involved, ultrafiltration is limited to the removal of compounds with molecular weights greater than about 500 (James M. Montgomery 1985). Slightly soluble components can foul ultrafiltration membranes unless wastewater flow is of a sufficient velocity to create enough turbulence to minimize the problem. Pre-treatment may be necessary for removal of large solids that can pierce the membrane (EPA 1981). Ion exchange and reverse osmosis would be more effective for site contaminants (e.g., uranium) for equivalent cost. Ultrafiltration is therefore not retained.

4.6.6 Membrane-Based Coupled Transport

Inorganic ions can be removed from contaminated groundwater with membrane-based coupled transport utilizing a supported liquid membrane (SLM). Selected ions are transported from the bulk solution on one side of the SLM into a strip solution on the other side of the SLM. The SLM is a micro-porous membrane with an organic extractant held in the pores by capillary forces. The strip solution is chemically formulated to disassociate the ions from the extractant complex, in effect "stripping" the ion off the membrane. In contrast to reverse osmosis, which is a non-selective process, membrane-based coupled transport allows extraction of specific ions, thereby reducing the volume of waste produced. The membrane-based coupled transport process results in a "clean" effluent stream and a concentrate stream that will require further treatment prior to disposal.

Membrane-based coupled transport is a developing technology and is not yet in common use. Further development will be required before this technology can be used in full-scale applications (Hodgeson 1989). This technology is eliminated from further consideration because its effectiveness and implementability are unproven, and because more established technologies are available. However, SLM could be reconsidered if further development of the technology indicates that it would offer the best effectiveness in removing uranium from groundwater and would be available for full-scale use at the 300-FF-5 operable unit site.

4.6.7 Electrodialysis

Electrodialysis uses a direct current electrical field and ion-exchange membranes to separate ionic species from solution. The electrodialysis process consists of an electrolytic cell containing an anode and a cathode separated by cation-selective and anion-selective membranes. The feed material enters the cell between the two selective membranes. When a direct current charge is applied to the cell, cations are attracted to the cathode and anions to the anode. Ions pass through the appropriate membrane and are concentrated in two brine solutions.

Operational systems consist of multiple stacks of cells in vertical or horizontal configurations. A selective membrane is typically 0.5 mm thick and the flow path between membranes is 1 mm thick. Electrodialysis is well suited for the removal and concentration of ionic species. The process has limited waste treatment applications because of the sensitivity of the membranes to fouling (EPA 1981). A reversible electrodialysis process has been developed that may reduce membrane fouling. Based on its sensitivity to membrane fouling and cost, this technology is not retained.

4.6.8 Freeze Crystallization

Freeze crystallization is a separation process in which the wastewater is cooled until ice crystals begin to form. The crystals are separated from the remaining liquid and washed to remove the coating layer and its impurities. The inorganic and organic constituents are concentrated in the remaining liquid. The washed crystals are then remelted and removed as treated effluent for discharge. This method has been successfully used to treat metal finishing wastewaters, to purify water, and to concentrate volatile and non-volatile impurities.

Freeze crystallization is still in the developmental stages for waste remediation. Pilot-scale tests indicate good process stability and the capability to treat a wide variety of wastes. However, the process has rather high capital costs with unproven long-term operation and maintenance costs (Freeman 1989).

Because reverse osmosis and ion exchange have proven effectiveness and implementability for the contaminants and concentrations in 300-FF-5 operable unit groundwater, freeze crystallization is eliminated from further consideration because it is an unproven technology.

4.6.9 Evaporation/Distillation

Evaporation is the physical separation of a liquid from a dissolved or suspended solid by the application of energy to volatilize the liquid. Evaporation results in a condensate effluent stream and a more concentrated secondary waste stream that may require further treatment. Evaporation can be accomplished by heating a liquid consisting of non-volatile solutes (heavy metals, radionuclides, and nitrates) in a volatile solvent (water). The evaporation process can utilize equipment and facilities such as heaters and condensers or evaporation ponds. The use of evaporation ponds is not preferred because of the large amount of land that would be required.

The level of hardness in the groundwater should be considered in the use of evaporators for the groundwater treatment. Elevated carbonate hardness may necessitate frequent cleaning of the evaporator because of scale formation. The concentrated impurities may require additional treatment prior to final disposal. Evaporation/distillation is more expensive than other effective technologies and is therefore not retained.

4.6.10 Electrolysis

Electrolysis is a process in which there is electrochemical reduction of metal ions at the cathode. These ions are reduced to elemental metal. Electrolytic recovery is used primarily to remove metal ions from concentrated solutions such as metal plating and etching solutions. Treatment of dilute solutions using conventional electrolysis is not practical because of high power consumption. The process is not feasible for the 300-FF-5 operable unit because of the low concentrations of metals, and the technology is therefore not retained.

4.6.11 Precipitation

Dissolved metals in wastewaters are typically found as metal cations. The addition of specific chemicals to the solution causes the metal cations to react and precipitate out of solution as insoluble compounds. The most common chemical precipitation technology uses lime ($Ca(OH)_2$) to produce insoluble hydroxides. Other common precipitation chemicals are caustic soda (NaOH), sulfides, and carbonates. Selection of precipitation chemicals is based on a number of site-specific parameters. Precipitates are then removed from solution by flocculation and sedimentation or filtration. Sludge from precipitation is then dewatered for landfill disposal. Additional treatment (e.g., chemical fixation) may be required or desired.

Iron co-precipitation has been successfully used to remove uranium and radium in surface runoff water from uranium mill tailings, and to remove uranium from nitrate-containing wastes at the Oak Ridge Y-12 Plant (EPA 1989). In these processes, iron compounds are added to the waste stream, and precipitation is induced by raising the pH of the solution with lime or sodium hydroxide.

Precipitation is generally more effective for wastewater with influent metals concentrations in the mg/L (ppm) range rather than the μg/L (ppb) range (Corbitt 1990). Low influent concentrations may not provide enough driving force for the precipitation reactions to occur quickly, and overdosing of treatment chemicals would be required. Over-dosing will result in a larger amount of solids for final disposal. Precipitation is better suited to treatment of a concentrated secondary stream (e.g., regenerant from ion exchange). Chemical precipitation is retained for further consideration.

4.6.12 Air Stripping

Air stripping is a process that transfers a contaminant from the liquid phase to the vapor phase. Air stripping is an effective process for removing volatile and slightly soluble organic compounds from water. The effectiveness of air stripping is related to the air/water partitioning of the contaminant determined by Henry's Constant. The stripping takes place in a column where the groundwater flows downward over trays or packing, and air flows upward from the bottom of the column, countercurrent to the water flow. The air stripping process results in an effluent stripped of volatile compounds, and an air stream containing the stripped volatile compounds.

The stripping air will contain the contaminants removed from the groundwater and may require treatment prior to release to the atmosphere, typically by vapor-phase activated carbon adsorption or thermal oxidation. Permitting will likely be required for discharge of the treated or untreated air stream. Air stripping is retained as a potential treatment for volatile organic compounds in groundwater.

4.6.13 Carbon Adsorption

The carbon adsorption process utilizes activated carbon to provide a solid surface where organic compounds can be removed by adsorption. Carbon adsorption may used in liquid- phase or vapor-phase media. For treatment, the medium is passed through beds containing activated carbon where the contaminants are adsorbed. When the adsorptive capacity for the contaminants has been exceeded, the activated carbon must be replaced. The adsorptive capacity of activated carbon depends on the target compound and the individual characteristics of the carbon. Performance characteristics of activated carbon vary by source and manufacturing methods.

In general, most organic compounds are readily adsorbed by activated carbon. However, removal efficiencies are generally poor for organic compounds that are very soluble in water (e.g., methanol or methyl ethyl ketone) or have very low molecular weight (e.g., methane). Activated carbon is not generally considered applicable for metals or radionuclides, as it has poor removal efficiencies for metals.

Vapor-phase carbon adsorption is effective for low concentrations of organic compounds found in air streams following application of air stripping technology. This combination of technologies may be applicable to 300-FF-5 operable unit groundwater as a method to remove organic contaminants with minimal radiological contamination of the activated carbon.

Spent carbon generated by either vapor-phase or liquid-phase carbon adsorption requires disposal or regeneration. Carbon that has adsorbed heavy metals or received radiological contamination may not be suitable for regeneration and require disposal. Because some organic compounds are contaminants of concern for the 300-FF-5 operable unit, activated carbon adsorption is retained for further consideration.

4.6.14 Enhanced Oxidation

This technology includes processes in which the oxidation state of a substance is increased with subsequent destruction or conversion of undesirable organic chemicals to CO_2 and H_2O or other less harmful materials. This technology is not applicable to metals. UV photo-oxidation utilizes strong oxidants, such as hydrogen peroxide or ozone, combined with ultraviolet (UV) radiation to oxidize organic contaminants. A range of treatment techniques using advanced oxidation processes, including UV-ozone, UV-hydrogen peroxide, UV-ozone-hydrogen peroxide, and ozone-hydrogen peroxide, have been demonstrated for the EPA Superfund Innovative Technology Evaluation (SITE) program to clean up groundwater containing organic compounds (EPA 1987).

UV photo-oxidation systems are available commercially. Influent conditioning is required in order to prevent fouling. Water containing high concentrations of dissolved or suspended solids may create a coat of film over the UV lamp when the solids are oxidized, reducing the effectiveness of the UV lamp (Nyer 1992). Because of potential problems with inorganic compounds present in the groundwater, and the availability of other treatment processes that are effective for organic compounds, enhanced oxidation is not retained.

4.6.15 Chemical Oxidation/Reduction

Chemical oxidation-reduction reactions are used to reduce toxicity or to transform a substance to one more easily handled. For example oxidation-reduction reactions between waste components and added chemicals in which the oxidation state of one reactant is raised while that of another is lowered. An example of chemical reduction is the conversion of hexavalent chromium to trivalent chromium, which is less toxic and more easily removed from solution than hexavalent chromium.

Chemical oxidation or reduction generally requires the addition of relatively large quantities of chemical oxidizing or reducing agents (Nyer 1992) and is therefore generally expensive. Other effective and less costly technologies are available for treatment of 300-FF-5 operable unit contaminants. This technology is therefore not retained.

4.6.16 Biological Treatment

Biological treatment primarily consists of degradation of organic compounds to less complex compounds by microorganisms. Under aerobic conditions, biological treatment will oxidize compounds. The products of complete aerobic biotreatment are carbon dioxide and water. Biotreatment can also occur under anaerobic conditions, in which case reducing reactions usually occur. Biological dechlorination is often an anaerobic process. Anaerobic treatment is typically much slower than aerobic treatment; therefore, aerobic biotreatment is much more common. Biotreatment products are usually less toxic than the unmetabolized contaminants, but can be more toxic (e.g., anaerobic transformation of TCE to vinyl chloride).

Recent research is investigating use of microorganisms for removal of metals (Lovley et al. 1991); however, biotreatment is currently considered not applicable for metals (Nyer 1992). Biological treatment is not considered feasible for treatment of groundwater from the 300-FF-5 operable unit because (1) biological degradation of chlorinated compounds is difficult, (2) biotreatment works poorly with low contaminant concentrations, and (3) other, more effective treatment methods (i.e., air stripping and carbon adsorption) are available. Biological treatment is therefore not retained.

4.6.17 Thermal Treatment

Thermal treatment technologies for contaminated groundwater are not applicable to metals. Furthermore, the low concentrations of organic contaminants in the 300-FF-5 operable unit may be treated more effectively and at lower costs using air stripping or carbon adsorption. Based on these considerations, thermal treatment technology is not retained.

4.7 EX-SITU TREATMENT OF AQUIFER SOILS

Identification and screening of ex-situ treatment technologies for soils is presented in the 300-FF-1 Feasibility Study (DOE-RL 1992d). Treatment technologies for ex-situ treatment of aquifer soils would be limited to those technologies that were retained in the 300-FF-1 FS. Those technologies are:

- Thermal desorption
- Incineration
- Cement-based stabilization/solidification
- Vitrification
- Physical soil washing
- Chemical soil washing
- Bioreactors

4.8 IN-SITU TREATMENT

This section considers a wide range of technologies for treatment in-place (in-situ). As with ex-situ treatment, the purpose is to reduce the toxicity, mobility, or volume of contaminated material. Metals and radionuclides cannot be destroyed by treatment, but can be removed or immobilized. For in-situ treatment of groundwater, mobility reduction is accomplished by changing the physical and/or chemical characteristics of the aquifer and groundwater to decrease contaminant transport. Removal is accomplished by extracting contaminants from the groundwater and/or aquifer soils. Extracted contaminants still require treatment and disposal.

In many cases, removal of contaminated groundwater is either not feasible (e.g., because of very large volumes) or not advisable (e.g., because the short-term risks created by extraction exceed the benefits of treatment). The key disadvantage to in-situ treatment is that the treatment process cannot be controlled nearly as well as the same treatment method performed ex-situ. The lack of process control results from the inability to achieve desired process conditions and the inherent heterogeneity of the subsurface. Therefore, an in-situ treatment process is, in general, less effective at achieving treatment objectives and less reliable in achieving uniform treatment than the corresponding ex-situ treatment process.

4.8.1 Vapor Extraction

Vapor extraction is an in-situ treatment process frequently applied to vadose-zone (unsaturated) soils for removal of volatile organic compounds (VOCs). It has also been used for removal of VOCs from groundwater, generally in conjunction with remediation of unsaturated soils. Vapor extraction works by applying a vacuum to the subsurface and collecting the VOC-rich air in vapor extraction wells. In some cases the extracted air is vented to the atmosphere. However, more often the VOC-rich air is treated by thermal oxidation or vapor-phase carbon adsorption to allow discharge of clean air. Vapor sparging is a means of enhancing vapor extraction by pumping air through contaminated groundwater in addition to vacuum withdrawal of contaminated vapors.

At the 300-FF-5 operable unit, VOC contamination is only significant in the deeper portion of the unconfined aquifer. Vapor extraction generally applies only to the shallow zone of an aquifer because it is the only groundwater in contact with soil vapor. Air sparging is potentially feasible for deeper groundwater, although this is not well-established technology. Vapor extraction is not applicable to metals, and groundwater treatment for metals would involve an above-grade treatment system. VOC removal, if required, would be performed as part of an ex-situ groundwater treatment system. Vapor extraction is, therefore, rejected in favor of proven ex-situ treatment technologies for VOCs that are more compatible with ex-situ treatment for metals.

4.8.2 In-Situ Flushing

Soil flushing is an in-situ washing process in which the soil is flooded with a flushing solution to extract contaminants, and is primarily applicable for sorbed contaminants. Although groundwater remediation focuses on dissolved contaminants, aquifer soils in the 300-FF-5 operable unit contain sorbed contaminants that could serve as a continuing source of groundwater contamination. The flushing solution is extracted and treated above-ground to remove the contaminants. Flushing solutions may be allowed to passively percolate into the groundwater or may be actively injected. Soil flushing solutions may be enhanced with agents such as surfactants, solvents, detergents, or oxidizers. Bubbling air through groundwaters or adding a chemical oxidant (e.g., hydrogen peroxide) can oxidize uranium to increase its solubility. Carbon dioxide or carbonate can also be added to aid in forming more soluble compounds. Adjustments of pH for optimum solubility would also be considered. The soil flushing process is similar to leaching operations in the uranium mining industry (in-situ solution mining) (Merritt 1971). Uniform application of the flushing solution, and hence uniform and reliable treatment, is difficult. Adequate collection of the flushing solution would require reliable containment of the contaminated area to avoid spreading contamination.

Soil flushing could be used in conjunction with "pump-and-treat" options to improve the recovery of contaminants and shorten the remediation period. It would serve as a remedial action for both soil and groundwater. A disadvantage of soil flushing is the potential to release additional contaminants adsorbed to the saturated soil matrix at unacceptable concentrations that require capture and treatment. Treatability studies are important to determine the viability of the technology for the specific site conditions. This technology is retained for further evaluation.

4.8.3 In-Situ Precipitation/Fixation

This technology involves injection of chemical agents into the contaminated groundwater to precipitate dissolved contaminants and bind them to aquifer soils. It would also serve to immobilize contaminants on soil particles. Risk is reduced by immobilizing the contaminants. Chemical precipitation of the contaminants may be accomplished by the addition of chemical agents that react with the contaminant and create non-soluble compounds that cannot be transported by groundwater flow. In-situ precipitation technology for groundwater contamination is still in the developmental stage and is therefore not retained.

4.8.4 In-Situ Biological Treatment

Biological treatment is a class of technologies commonly applied for destruction of organic contaminants. Biological treatment can be performed in-situ with varying effectiveness under either aerobic or anaerobic conditions. In-situ biological treatment, while potentially effective for treatment of organic constituents, is unproven for the chlorinated organic compounds present in the groundwater at the 300-FF-5 operable unit (Nyer 1992). It is also generally ineffective for the low concentrations of organic compounds found at this site. Biological treatment is not currently applicable to radionuclides (Nyer 1992), although this may change in the future based on research activities (Lovley et al. 1991). This technology is therefore not retained.

Table 4-1. Summary of Screening Results for Groundwater Remediation Technologies and Process Options. (Sheet 1 of 3)

Technology/Process Option	Screening Comments	Retained (Yes/No)
Institutional Controls and Monitoring	Effective and feasible. May be used in conjunction with treatment technologies. Groundwater monitoring is a necessary component of all alternatives.	Yes
Containment		
Horizontal Barriers	Not necessary because existing aquitard serves as a horizontal barrier.	No
Vertical Barriers		
Slurry Walls	Proven and feasible technology.	Yes
Grout Walls		
Grout Injection	Less effective and more costly than slurry walls.	No
Deep Soil Mixing	No more effective than slurry walls but more expensive.	No
Sheet Pilings	Not implementable under site conditions; less effective than slurry walls.	No
Cryogenic Walls	Less established and more expensive than slurry walls.	No
Hydraulic Containment	Feasible.	Yes
Removal		
Groundwater Extraction		
Wells	Established and feasible technology.	Yes
Interceptor Trenches	Established and feasible technology.	Yes
Aquifer Soil Dredging/Excavation		
Excavation with Dewatering	Well-developed, effective technology; widely used in conventional construction.	Yes
Mechanical Dredging	Established, effective technology; widely used in conventional construction.	Yes
Hydraulic Dredging	May not be effective for the large cobbles present in aquifer soils.	No
Disposal		
Treated Groundwater		
Surface Water Discharge	Feasible.	Yes
Subsurface Discharge	Feasible.	Yes
Sludge and Soils		
Onsite Disposal	Disposal facility in 200 Area is planned.	Yes
Offsite Disposal	Less preferred under CERCLA guidance than onsite disposal; no regional offsite facility available for low-level radioactive waste.	No

Table 4-1. Summary of Screening Results for Groundwater Remediation Technologies and Process Options. (Sheet 2 of 3)

Technology/Process Option	Screening Comments	Retained (Yes/No)
Ex-Situ Treatment of Groundwater		
Gravity Separation	Well-established and commonly used technology.	Yes
Filtration	Well-established and commonly used technology.	Yes
Ion Exchange	Established technology; effective for low concentrations of metals and uranium.	Yes
Reverse Osmosis	Effective for concentrating metals in wastewater.	Yes
Ultrafiltration	Limited to removal of compounds with very high molecular weights.	No
Membrane-Based Coupled Transport	Technology still in development phase.	No
Electrodialysis	More expensive and less established than ion exchange and reverse osmosis.	No
Freeze Crystallization	More expensive and less established than ion exchange and reverse osmosis.	No
Evaporation/Distillation	More expensive and less established than ion exchange and reverse osmosis.	No
Electrolysis	More expensive and less established than ion exchange and reverse osmosis.	No
Precipitation	Effective treatment method for secondary waste streams.	Yes
Air Stripping	Effective for removal of volatile organic compounds.	Yes
Carbon Adsorption	Effective for removal of organic compounds.	Yes
Enhanced Oxidation	Concentrations of organic compounds too low to be effective; not applicable to metals and radionuclides.	No
Chemical Oxidation/Reduction	More expensive than other effective technologies.	No
Biological Treatment	Not established for treatment of chlorinated organic compounds; not effective for metals.	No
Thermal Treatment	Only removes organic compounds; too expensive for low concentrations.	No

Table 4-1. Summary of Screening Results for Groundwater Remediation Technologies and Process Options. (Sheet 3 of 3)

Technology/Process Option	Screening Comments	Retained (Yes/No)
Ex-Situ Treatment of Aquifer Soils	Ex-situ treatment technologies for aquifer soils are presented in the 300-FF-1 FS. Treatment technologies for ex-situ treatment of aquifer soils would be limited to those retained in the 300-FF-1 FS (DOE-RL 1992d).	
In-Situ Treatment		
Vapor Extraction	Not feasible for volatile organic compounds found at the base of the aquifer.	No
In-situ Flushing	Potentially effective and feasible.	Yes
In-situ Precipitation/Fixation	Unproven technology for in-situ application.	No
In-situ Biological Treatment	Potentially effective for organic constituents; however, effectiveness is unproven for in-situ treatment of chlorinated compounds and not effective for metals or radionuclides.	No

5.0 ASSEMBLY AND SCREENING OF REMEDIATION ALTERNATIVES

In this chapter, Remediation technologies retained following the screening process presented in Chapter 4 are assembled into remediation alternatives for the 300-FF-5 operable unit. The technologies are combined to create a wide range of alternatives that represent various approaches to achieving remediation goals. Factors considered in assembling the alternatives are discussed in Section 5.1. Remedial action components common to several alternatives (slurry wall containment, hydraulic containment, in-situ flushing, and groundwater treatment) are discussed in Section 5.2 for clarity and to avoid repetition. The initial alternatives are then described and discussed in Section 5.3. Finally, these alternatives are screened in Section 5.4 based on effectiveness, implementability, and cost.

5.1 ASSEMBLY OF ALTERNATIVES

Factors considered in assembling remediation alternatives for the 300-FF-5 operable unit are discussed in this section.

5.1.1 General

Based on CERCLA guidance and the NCP, remediation alternatives are developed to achieve the following goals:

- Protection of human health and the environment
- Attainment of ARARs, to the maximum extent feasible
- Cost-effectiveness
- Utilization of permanent solutions and alternate treatment or resource recovery technologies, to the maximum extent practicable
- Satisfaction of the statutory preference for treatment

These remediation goals must be weighed against NEPA and NRDA considerations (e.g., habitat destruction, extirpation of endangered or threatened species, irreversible and irretrievable commitment of resources). These considerations are most relevant to alternatives that involve considerable excavation and/or construction activities.

To meet these goals, a range of alternatives was developed that employs the following strategies:

1) No action (required by the NCP)

2) Limited action (e.g., institutional controls)

3) Reduction of potential site risks primarily through containment

4) Reduction of potential site risks primarily through removal, treatment, and disposal. In the case of radionuclides in groundwater at the 300-FF-5 operable unit, treatment to destroy contaminants is not available.

5.1.2 Extent of Active Remediation

As discussed in Chapter 2, fate and transport modeling results indicate that, with the possible exception of tritium and TCE, natural flushing will likely reduce contaminant concentrations below remediation goals by 2018. Although these results are uncertain, they suggest that active remediation may not be necessary. Alternatively, active remediation may be implemented for all groundwater not meeting remediation goals, or the portion of the plume with the highest concentrations. Natural flushing may be relied upon for remediation of any remaining contamination. To address these various degrees of active remediation, two categories of active remedial alternatives were developed: "extensive" alternatives and "selective" alternatives.

"Extensive" remediation refers to the greatest extent of active remediation that would be performed. For alternatives involving extensive remediation, the intent would be to actively remediate all groundwater with contaminant concentrations above remediation goals. It was assumed that the remediation goals for extensive remediation would be based on MTCA Method B. The area of remediation for this level would be the 4.3 pCi/L contour for U-238 on Figure 3-2.

"Selective" remediation refers to an active remediation of the most contaminated regions, allowing natural aquifer flushing of remaining contaminated areas. For the purposes of the FS, it was assumed that the selective remediation area would be defined by the 30 pCi/L contour for U-238 on Figure 3-2.

NRDA and NEPA considerations are expected to be more significant for extensive remediation alternatives than selective alternatives. As illustrated on Figure 3-2, the extensive remediation area is approximately seven times greater than the selective remediation area. In addition, the length of impacted river bank area for the extensive remediation area is approximately 2,500 meters (8,200 feet), compared with 650 meters (2,100 feet) for the selective area. The differing impacts of remediation, and the corresponding NRDA and NEPA considerations, need to be weighed when considering which remediation area is most appropriate.

5.1.3 Upgradient Contaminant Plumes

The purpose of this FS is to develop and evaluate alternatives for remediation of contamination in the 300-FF-5 operable unit that result from 300 Area operations. As discussed in Section 3.2, remediation goals for this operable unit do not include remediation of contaminants migrating into the operable unit from sources outside the 300 Area. Two upgradient contaminant plumes are approaching the operable unit: a tritium plume from the northwest and a technetium and nitrate plume from the southwest. Remediation of these plumes will be covered under other operable units at the Hanford Site. Therefore, these plumes are addressed only to the extent that they affect remediation of target contaminants in the 300-FF-5 operable unit. Coordination between remediation efforts involving the 300-FF-5 operable unit and upgradient plumes will be necessary. The proposed remedy for the 1100-EM-1 operable unit, which is considered the source of the technetium-nitrate plume, is monitoring without active remediation (DOE-RL 1992e).

5.1.4 Chlorinated Organic Constituents

TCE and/or 1,2-DCE have been detected in several wells at low concentrations (TCE as high as 0.014 mg/L and total 1,2-DCE as high as 0.15 mg/L). Unless these areas are specifically targeted for selective extraction, concentrations of these compounds in extracted groundwater would be diluted to well below significant risk levels. Therefore, treatment for these contaminants may not be necessary. However, continued monitoring of TCE and other chlorinated VOCs is suggested to determine the need for future remediation.

The descriptions of the alternatives in this section do not explicitly discuss remedial actions targeting TCE or other chlorinated compounds. Targeted remediation of chlorinated compounds is a potential part of any of the alternatives. For "selective" remediation alternatives, this would be accomplished either by addition of extraction wells in those portions of the water-table aquifer having the highest TCE concentrations or by extension of slurry wall containment to include these areas. For "extensive" remediation alternatives, the proposed remediation area already includes areas contaminated by chlorinated compounds. The groundwater treatment system includes a sub-system for removal of TCE and 1,2-DCE (and other VOCs), should such treatment be required.

5.2 COMMON REMEDIAL ACTION COMPONENTS

Remedial action elements common to several alternatives are discussed in this section (to avoid repetitious discussions for each alternative) and are included by reference in each of the alternatives involving these components.

5.2.1 Slurry Wall Containment

A slurry wall is used in several alternatives to provide containment of contaminated groundwater (Figures 5-1 and 5-2). The slurry wall would key into the Ringold Lower Mud unit, at a depth of approximately 33 m (100 ft), which would provide a bottom for the contained region. The upward gradient of the underlying, semi-confined aquifer would ensure that no contamination could migrate downward (e.g., groundwater flow would be up into the confined region). Used in conjunction with groundwater extraction, a slurry wall would reduce the rate of groundwater extraction and treatment by preventing capture of river water and groundwater outside the remediation area. In addition, as discussed in Section 5.2.2, a slurry wall should simplify operation of a hydraulic containment system by minimizing interaction between upgradient plumes and 300-FF-5 operable unit groundwater extraction and treatment.

Because clay soils (including bentonite) have an ion-exchange capacity for adsorption of metals (API 1984), a slurry wall may have some capacity for removal and/or retardation of radionuclides in groundwater passing through the wall. A treatability study would be necessary to determine the concentration of uranium and other metals exiting a slurry wall, and the removal capacity of the wall (mass of uranium removed per unit volume of wall).

Unlike hydraulic containment, slurry wall containment (by itself) does not provide removal of contaminants from the subsurface. By interfering with natural flushing of the aquifer, a slurry wall could increase the time required to achieve remediation goals in some alternatives. In addition, slurry wall construction could have difficulties. Although slurry walls have been installed to greater depths, 33 m (100 ft) is deep for a slurry wall and would require special excavation equipment. In addition, the coarse-grained soils in the Hanford Formation would probably cause greater than normal slurry loss into the soils. Slurry losses, in combination with low side-wall stability often found in coarse soils, could lead to problems with side-wall sloughing (i.e., collapse into the excavation). It is expected that these construction difficulties could be overcome. Core samples from the slurry wall and water level measurements in piezometers on both sides of the wall could be used to demonstrate continuity (i.e., no high-permeability gaps).

In the event a slurry wall is not constructable, a grout wall could be used; however, a grout wall would be much more expensive. Cost is expected to be a key factor in comparing slurry wall containment to hydraulic containment in the Phase III FS. A slurry wall has high capital cost, but would decrease the capital and operating costs of a groundwater treatment system. Constructing a pilot slurry trench to ensure constructability and better define construction cost would be advisable prior to detailed evaluation of alternatives in the Phase III FS.

5.2.2 Hydraulic Containment

Groundwater extraction (pumping) and infiltration are used in several alternatives to provide hydraulic containment of contaminated groundwater (Figures 5-3 and 5-4). Groundwater extraction would be accomplished using either interceptor trenches or wells (or both). The extracted groundwater would be treated (see Section 5.2.4) to remove contaminants to levels acceptable for infiltration. Infiltration of treated groundwater would be accomplished using trenches to allow percolation into the aquifer through the unsaturated zone. Groundwater extraction and infiltration are well-established technologies.

Design and operation of a hydraulic containment system at the 300-FF-5 operable unit would require addressing a number of site-specific difficulties. Two upgradient contaminant plumes are approaching the operable unit: a tritium plume from the northwest, and a technetium and nitrate plume from the southwest. Nitrate is currently detected at concentrations less than action levels, and technetium can be removed from extracted groundwater. However, tritium currently exceeds action levels and cannot be removed from extracted groundwater. Due to likely discharge limitations on treated groundwater, it is therefore desirable to minimize capture of groundwater contaminated by tritium. This may be accomplished using groundwater injection to divert the tritium plume away from the 300 Area, or using a slurry wall to minimize groundwater extraction rates. Alternatively, it may be possible to receive permission for discharge of tritium to the subsurface.

There are additional design and operation considerations because of the proximity of the Columbia River. Because groundwater pumping would not draw down the river level, the river would serve as an "infinite source" of unwanted water flowing to the groundwater extraction system. Thus, part of the cost of the groundwater treatment system would be for unnecessary treatment of clean river water. In addition, the elevation (stage) of the river varies up to 2.4 m (8 ft) on a daily basis (Campbell et al. 1993), so that the rate of groundwater extraction would need to be varied to account for changes in river elevation.

The design and operation of a hydraulic containment system needs to account for dynamic interactions between the 300-FF-5 system and the river, while at the same time minimizing capture of upgradient plumes. A careful balance would be required between containment of contaminated groundwater, minimizing onsite migration of contaminants from upgradient plumes, and minimizing capture of river water. Infiltration of treated groundwater upgradient of the extraction area would create hydraulic resistance (i.e., localized high groundwater elevations) to minimize migration of the upgradient plumes into the 300 Area. Infiltration of treated groundwater would not be expected to adversely affect the upgradient plumes or the City of Richland wells. Detailed remedial design and monitoring will insure that the existing plumes will not impact the City of Richland well field.

Potential difficulties associated with hydraulic containment become more significant as the extent of groundwater extraction (active remediation) increases. These difficulties are believed to be relatively minor for selective remediation, but could be significant concerns for extensive remediation. The cost of hydraulic control alternatives is dependent on the extent of remediation: a larger capture zone requires a higher extraction rate, meaning higher capital and operating costs for groundwater treatment. Additional investigation (e.g., pump testing) of aquifer characteristics is necessary for detailed evaluation of hydraulic containment alternatives in the Phase III FS, including placement of extraction trenches or wells, placement of infiltration trenches, and accurate estimation of groundwater extraction rates.

5.2.3 In-Situ Flushing

In comparison with groundwater extraction alone, in-situ flushing (also referred to as in-situ leaching and lixiviation) of uranium could increase the rate of uranium removal and decrease the duration of groundwater remediation. This would be accomplished by increasing the solubility of any precipitated uranium (discussed in Sections 2.4.1 and 4.8.2) that may provide a continuing source of groundwater contamination. Leaching solution (e.g., highly oxygenated water with elevated carbonate) would be injected into the aquifer using injection wells or trenches, recovered in extraction wells/trenches, and treated to remove contaminants (Figure 5-5). The rate of injection would be less than the rate of extraction, to maintain an overall inward gradient. Therefore, some of the extracted groundwater would not be used as the leaching solution and would be discharged outside the area of active remediation.

In-situ flushing has been used for mining of uranium. However, the uranium concentrations at the 300-FF-5 operable unit are significantly lower than those typical of uranium mining (generally in the mg/L or 1000 pCi/L range) and uranium mining is usually conducted in reducing environments with significant concentrations of precipitated uranium minerals (Merritt 1971).

A potential problem with in-situ flushing is that contaminants not now present in groundwater at levels of concern could be mobilized from the soil. As a result, an important objective of treatability testing is to determine the potential for mobilizing sorbed or precipitated contaminants. In addition, careful monitoring of the extracted leaching solution for changes in contaminant concentrations during operation of the system will be necessary.

In-situ flushing may be able to achieve remediation goals in less time than extraction and treatment without leaching, because uranium would be removed at a faster rate. The amount of time saved is unknown and would require laboratory and field treatability testing to establish. Although the technology is used for uranium mining, it is considered a promising, but unproven, remediation technology. Use of in-situ flushing at the 300-FF-5 operable unit would require development and testing of the technology for site-specific conditions, such as soil types, stratigraphy and hydrogeology, groundwater chemistry, low uranium concentrations in groundwater and aquifer soils, and subsurface variability of these parameters (heterogeneity). Implementation of in-situ flushing would be more difficult than implementation of hydraulic control measures alone because of the design and operational complexity of the leach solution injection/extraction systems. The cost impacts will depend on the tradeoff between additional costs for the in-situ leaching system and cost savings from the reduced duration of remediation.

5.2.4 Groundwater Treatment

Many of the remediation alternatives involve extraction and treatment of groundwater. The capacity (size) of the system will vary between alternatives. Groundwater extraction rates (required treatment capacities) for the varied alternatives are estimated to range between approximately 50 and 1,000 gpm.

A process flow diagram for a groundwater treatment system is shown in Figure 5-6. This system is described primarily for purposes of illustration (to help the reader understand what would be involved in treating groundwater extracted from this operable unit); it is not intended as a final or definitive treatment system. Other treatment processes or system configurations could be used, provided they are capable of cost-effectively achieving the required effluent concentrations.

The system described here shows representative process options that should be effective for removal of uranium, TCE (if required), and other 300-FF-5 operable unit contaminants (except tritium). The proposed system should be suitable for treating groundwater recovered either by groundwater extraction or by in-situ flushing. Conceptual design of the groundwater treatment system will be refined in the Phase III FS. If the selected remedy includes groundwater treatment, the final design of a groundwater treatment system will be determined in the remedial design phase, following treatability studies.

If discharged to a surface water (i.e., the Columbia River), the treated water may be required to meet federal and state effluent standards. If infiltrated into the subsurface onsite (via percolation through the vadose zone), discharge permitting may not be necessary under the CERCLA exclusion, but the substantive requirements of the Washington State Waste Discharge Program (WAC 173-216) would be applicable. Effluent quality requirements for constituents that are particularly toxic to aquatic organisms (such as copper) may be lower for discharge to the subsurface than to the Columbia River. In addition, tritium is not removed by any available water treatment technology. Tritium concentrations in the 300-FF-5 aquifer are currently below the MCL (20,000 pCi/L) but above the MTCA Method B standard (850 pCi/L). However, continued migration of the tritium plume into the 300-FF-5 aquifer could result in tritium concentrations exceeding the MCL, and could thus prevent surface discharge of treated groundwater. In contrast, since groundwater is already contaminated with tritium, subsurface infiltration may be more feasible. Finally, as discussed in Section 5.2.2, infiltration of treated groundwater will improve the effectiveness of hydraulic containment. In particular, infiltration would help minimize the impact of upgradient plumes (see Section 5.1.3) on the 300 Area. For these reasons, treated groundwater would likely be discharged to the subsurface in all of the remediation alternatives that include groundwater extraction.

As discussed in Section 5.1.4, the need for treatment of TCE and other VOCs is uncertain. If required, VOCs would be removed by air stripping followed by vapor-phase carbon adsorption. Spent carbon, which would probably be contaminated by radionuclides, would be disposed in the ERSDF.

Extracted groundwater would be sent to a feed tank. This tank would provide equalization of influent, to dampen variations in flow and groundwater quality between the extraction wells. The tank would also receive recycled water from dewatering (i.e., the clarifier and filter press). A treatment system that does not have to deal with rapid and massive changes in feed is more efficient in its task, as well as considerably less expensive to design and build.

Multi-media filtration would be used to remove suspended solids from the influent. Solids filtration will remove some of the uranium and other metals, which tend to adsorb to soil particles. Filtration is also needed to prevent fouling or plugging of the ion exchange resin. Two columns in parallel would be used. One column would be online while the other column was being backwashed. The columns would be backwashed with treated groundwater.

The effluent from the multi-media filter would then pass through two ion exchange columns in series. The system would include a third column, allowing two-column operation while one column is regenerated. Contaminant-specific resins would be used for preferential removal of uranium. The ion exchange columns would be regenerated with acidic, basic, or salt solutions (depending on the resin used). For example, a solution of sodium chloride and soda ash is used for regeneration of ion exchange systems used in mining uranium.

Reverse osmosis could be used for concentration of uranium in place of ion exchange. In general, ion exchange offers simpler, and therefore more reliable, operations than reverse osmosis. In addition, the membranes used in reverse osmosis are susceptible to fouling, and their replacement can be a large part of maintenance costs. Reverse osmosis tends to concentrate all inorganic ions in the feed, whereas ion exchange can use resins selective for uranium (and other contaminants, if necessary). Therefore, ion exchange usually produces a more concentrated, lower-volume secondary waste (the spent regenerant) than the concentrate from reverse osmosis and results in less sludge for disposal. These technologies (and others, if deemed appropriate) will be compared in more detail during the Phase III FS.

Series operation of the ion exchange columns would allow maximum resin loading and provide a safety factor against off-specification effluent. Water quality would be monitored after the first column, as well as after the second. When breakthrough (rapidly rising contaminant concentrations) was observed in the first column, the third (fresh) column would be placed online (third in series). This allows the first column to run to exhaustion without any danger of exceeding effluent specifications. When the first column was exhausted, it would be taken offline and regenerated. After regeneration, it would become the new third column. This operation allows more efficient regeneration, which lowers chemical costs. The third column also provides a backup in the event one column requires maintenance.

Clean effluent from the ion exchange units would be discharged to the groundwater infiltration system. Effluent pH adjustment would probably not be necessary, although it could easily be added to the system if required. A portion of the treated water would be collected in a storage tank for backwashing the filters and for making fresh ion exchange regenerant.

Precipitation would be used to remove uranium and other metals from the ion exchange regenerant. Several precipitation additives would be considered in a treatability study. Lime is the most common precipitant in general use, primarily because of its low cost. However, lime tends to be inefficient in terms of the volume of sludge produced. An additive (or combination of additives) would be selected based on cost and on the volume of sludge (which would require landfill disposal).

Used ion exchange regenerant would go to a mixing tank, where the precipitation chemicals would be added. Flocculants could be added to the mixing tank if required for improved solid/liquid separation. The liquid would then go to a clarifier, where the sludge would be collected and thickened.

Filter backwash would be collected in a storage tank and then treated via flocculation and clarification to remove solids. With proper sizing, the same mix tank and clarifier can be used for treating both spent ion exchange regenerant and filter backwash.

Clarifiers are generally sufficient for the removal of suspended solids. However, solids from precipitation or filter backwash sometimes coagulate and settle poorly, so that a clarifier might provide insufficient removal for discharge of the liquid supernatant (the clarifier overflow). However, the clarifier overflow in this system is recycled to the feed tank and then passes through the multi-media filters. If the solids from precipitation or filter backwash coagulate and settle poorly, the filter columns would be sized to handle the additional solids loading. Therefore, this system addresses this potential problem.

Sludge from the clarifier, containing the solids and precipitated uranium and other metals, would be dewatered using a recessed plate (plate-and-frame) filter press. This type of filter press can usually achieve greater than 50% solids in the filter cake. The dewatered sludge would be sent to the ERSDF for disposal. Presumably, the sludge would be treated by chemical fixation (stabilization/solidification) prior to disposal; this treatment would be performed at the ERSDF. Most of the solids in the sludge will be normal (non-contaminant) dissolved solids, such as calcium carbonates and hydroxides. Radioactive contaminants will be present in relatively low concentrations.

Treatability studies would be necessary to determine the site-specific effectiveness of filtration, ion exchange, reverse osmosis, precipitation, clarification, and filter pressing. This information will be used for detailed alternative evaluation in the Phase III FS, and final design.

5.3 DESCRIPTION OF ALTERNATIVES

Each of the alternatives are described below, along with a discussion of key advantages and disadvantages. Table 5-1 shows which system components are included in each alternative. Table 5-2 provides a summary of the alternatives and the screening evaluation.

Alternative 1: No Action

Description

A no-action alternative is required under the NCP to provide a baseline for comparison to the other alternatives. In accordance with EPA's definition, this alternative assumes that the institutional controls currently in place would be removed and that no remedial actions would be performed. As required under CERCLA, groundwater monitoring would be performed to verify the effectiveness of the remedy.

Discussion

Under this alternative, use of contaminated groundwater would not be prevented. Groundwater contamination currently exceeds remediation goals in portions of the water-table aquifer. Contaminants in groundwater would continue to discharge to the Columbia River, where they would be greatly diluted. Although groundwater modeling indicates that groundwater concentrations of some contaminants from 300 Area operations will not naturally decrease below remediation goals before the year 2018, these results relied on conservative assumptions and may not accurately reflect reality. It is possible that concentrations may decrease below ARARs by this time. Groundwater impacts from upgradient sources (i.e., the tritium and technetium/nitrate plumes) could still occur.

Alternative 2: Institutional Controls

Description

The objective of this alternative is to minimize risk by controlling exposure. Institutional control would consist of legal and physical measures to prevent use of contaminated groundwater. These controls would include restrictions to groundwater extraction or use within the area of contaminated groundwater in the 300-FF-5 operable unit. Extensive site controls are currently in place. Institutional controls and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

Under this alternative, prevention of human exposure to groundwater contamination would minimize potential risks. Groundwater contamination currently exceeds remediation goals in portions of the water table aquifer. Contaminants in groundwater would continue to discharge to the Columbia River, where they would be greatly diluted. Groundwater modeling indicates a good probability that the groundwater concentrations of contaminants from 300 Area operations will naturally decrease below remediation goals before the year 2018. Groundwater impacts from upgradient sources (i.e., the tritium, technetium, and nitrate plumes) could still occur.

Alternative 3: Selective Hydraulic Containment

Description

The objective of this alternative is to provide selective remediation that reduces discharge of the highest concentrations of contaminants to the Columbia River, accelerates the natural recovery process, and removes contaminants for disposal. Natural recovery would reduce concentrations outside the selective remediation area. This alternative would involve installation of groundwater extraction wells/trenches, above-ground treatment of extracted groundwater, and infiltration of treated groundwater. Groundwater extraction and infiltration systems would be designed to provide hydraulic containment for the selective remediation area (see Figure 5-3 and Section 5.2.2). Treatment would remove contaminants to levels suitable for groundwater infiltration. The treatment system would generate radioactive sludge requiring landfill disposal.

Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit met remediation goals.

Discussion

This alternative is more effective than institutional controls alone because it decreases the time required to achieve remediation goals. Groundwater extraction could, however, increase the rate of aquifer contamination from offsite sources (although to a lesser extent than Alternative 5, which consists of extensive hydraulic containment). Because it relies on well-developed technology, this alternative is easily implemented.

Considerably less groundwater extraction and treatment are required for this alternative than for alternatives with extensive hydraulic containment (e.g., Alternatives 5 and 6); this alternative would therefore be less expensive than those alternatives. Although the capital cost of selective hydraulic containment would likely be less than the capital cost of selective slurry wall containment (Alternative 7), the operating costs would be greater.

Alternative 4: Selective Hydraulic Containment with In-Situ Flushing

Description

The objectives and design of this alternative are similar to those for Alternative 3 (Selective Hydraulic Containment), except that some of the extracted groundwater would be amended to increase the solubility of uranium and then reinjected into the regions with highest uranium concentrations. The remaining extracted groundwater would be infiltrated to divert upgradient plumes (Figure 5-5). Hydraulic containment is discussed in Section 5.2.2, and in-situ flushing is discussed in Section 5.2.3. The treatment system would generate radioactive sludge requiring landfill disposal.

Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction and flushing, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

This alternative should remediate the aquifer in less time than Alternative 3. Because of the need for treatability testing to determine the effectiveness of in-situ uranium flushing, and the added complexity of the injection system, this alternative would be more difficult to implement than Alternative 3. The capital and annual operating costs of this alternative would be greater than for Alternative 3 because of the in-situ flushing system. However, total costs could be less if in-situ flushing reduced the time needed to complete remediation.

Alternative 5: Extensive Hydraulic Containment

Description

The objective of this alternative is to provide extensive remediation that minimizes contaminant discharges to the Columbia River, accelerates the natural recovery process, and removes contaminants for disposal. This alternative involves installation of groundwater extraction wells/trenches, above-ground treatment of extracted groundwater, and infiltration of treated groundwater. Groundwater extraction and infiltration systems would be designed to provide hydraulic containment for the extensive remediation area, (see Figure 5-4 and Section 5.2.2). Treatment would remove contaminants to levels suitable for groundwater infiltration. The treatment system would generate radioactive sludge requiring landfill disposal.

The groundwater extraction rate would be reduced with time because the size of the capture zone could be reduced as the plume size is reduced. Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

This alternative provides a more aggressive approach to groundwater remediation than the preceding alternatives. However, the effectiveness would be decreased to the extent that contamination were drawn into the 300-FF-5 operable unit from upgradient plumes. Because of the larger region of groundwater extraction, and the associated difficulties with river stage interactions and upgradient plumes, this alternative would be more difficult to implement than selective hydraulic control alternatives (e.g., Alternative 3). In addition, costs for this alternative would be considerably higher because of the increased extraction rates and the larger treatment facility.

Alternative 6: Extensive Hydraulic Containment with Selective In-Situ Flushing

Description

The objectives and design of this alternative are similar to Alternative 5, except in-situ flushing would be used for the most contaminated region, and hydraulic containment for the remainder of the extensive remediation area (see Figures 5-4 and 5-5). Hydraulic containment is discussed in Section 5.2.2, and in-situ flushing is discussed in Section 5.2.3. The groundwater extraction rate would be reduced as the contaminant plume decreased in area. Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction and flushing, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

This alternative should remediate the aquifer in less time than Alternative 5. Because of the need for treatability testing to determine the effectiveness of in-situ uranium flushing, and the added complexity of the injection system, this alternative would be more difficult to implement than Alternative 5. The capital and annual operating costs of this alternative would be greater than for Alternative 5 because of the in-situ flushing system. However, total costs could be less if in-situ flushing reduced the time needed to complete remediation.

Alternative 7: Selective Slurry Wall Containment

Description

The objectives of this alternative are to contain contaminated groundwater within the selective remediation area, and to allow natural recovery of remaining contamination. A slurry wall would be constructed to provide passive contaminant (Figure 5-1). No groundwater extraction, and thus no treatment and disposal, would be included in this alternative. Thus, the groundwater concentrations of contaminants within the slurry wall would exceed remediation goals indefinitely.

Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Institutional controls and groundwater monitoring would continue indefinitely, provided groundwater contamination remained above remediation goals.

Because of meteoric infiltration, seepage through the slurry wall, and groundwater leakage from the underlying semi-confined aquifer, a groundwater mound would probably develop within the confined area. In this case, a very slow outflow of groundwater would occur. However, contaminant migration would be mitigated in two ways. First, the slurry wall would adsorb uranium and other contaminants (except tritium) until its capacity was exceeded. Second, the mass flux of groundwater through the slurry wall would be very low. The slurry wall would not necessarily require remediation since presumably the associated groundwater concentrations would be below clean-up levels.

Discussion

This alternative is protective of human health and the environment, (as long as groundwater institutional controls remain in place), but relies on containment onsite rather than removal and disposal. One advantage of this approach over hydraulic containment is that it would not be vulnerable to mechanical failure. In addition, this alternative would prevent contamination of the contained area from upgradient plumes and would not accelerate migration of these plumes.

Groundwater contamination outside the containment area that is present because of 300 Area operations would be expected to naturally decrease below remediation goals before the year 2018. Groundwater impacts from offsite sources (i.e., the tritium, technetium, and nitrate plumes) could still occur outside the containment area. Slurry wall construction is well-established technology and is likely to be readily implemented (see Section 5.2.1). The capital cost of selective slurry wall containment would be greater than the capital cost of selective hydraulic containment (Alternative 3), but the annual operating costs would be minimal.

Alternative 8: Selective Slurry Wall Containment with Minimal Extraction

Description

The objectives of this alternative are the same as Alternative 3 (Selective Hydraulic Contaminant). However, the selective remediation area would be surrounded by a slurry wall (Figure 5-1) to provide containment, thereby minimizing the treatment rate. Natural recovery would reduce concentrations outside this area.

This alternative is nearly the same as Alternative 7 (Selective Slurry Wall Containment), but adds a small groundwater treatment system. Above-ground treatment would remove contaminants to levels suitable for groundwater infiltration. The treatment system would generate radioactive sludge requiring landfill disposal.

The treated groundwater would be infiltrated outside the slurry wall. Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction and treatment, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

In contrast with Alternative 7, this alternative prevents escape of contaminants through the slurry wall and provides active remediation of groundwater. The rate of remediation depends on the rate of groundwater extraction inside the slurry wall. Slurry wall containment with minimal extraction would require more time to meet remediation goals than hydraulic containment alternatives or more aggressive treatment (e.g., Alternative 9). Groundwater contamination outside the containment area that is present because of 300 Area operations would be expected to naturally decrease below remediation goals before the year 2018. Groundwater impacts from offsite sources (i.e., the tritium, technetium, and nitrate plumes) could still occur outside the containment area.

This alternative is somewhat more complex than Alternative 7, and therefore more difficult to implement, because it includes groundwater treatment and infiltration. Although the slurry wall increases the difficulty of initial implementation, this alternative would be easier to operate than hydraulic containment without a slurry wall (Alternative 3). In addition, the extraction and treatment systems would be much smaller, and thus less expensive, than those for Alternative 3. The cost of this alternative would be slightly more than for a slurry wall alone (Alternative 7).

Alternative 9: Selective Slurry Wall Containment with In-Situ Flushing

Description

The objective of this alternative is to provide selective remediation that reduces discharge of contaminants to the Columbia River and maximizes the rate of removal of contaminants in the selective remediation area. Natural recovery would reduce concentrations outside this area. In-situ flushing would be used within slurry wall containment (Figures 5-1 and 5-5). The primary purposes of the slurry wall are to minimize migration of upgradient plumes into the 300 Area and to provide better control of in-situ flushing. The treatment system would be larger for this alternative than for Alternative 8 because it would treat the recirculated leaching solution as well as meteoric infiltration, leakage across the slurry wall, and leakage from the underlying, semi-confined aquifer.

Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction and flushing, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

Because the flushing solution could be circulated through the region inside the slurry wall at a much greater rate than the rate of inward leakage, this alternative should remediate the aquifer in less time than Alternative 8 (Selective Slurry Wall Containment with Minimal Extraction). The rate of remediation compared with Alternative 4 (Selective Hydraulic Containment with In-Situ Flushing) is not clear.

Because of the need for treatability testing to determine the effectiveness of in-situ uranium flushing and the added complexity of the injection system, this alternative would be more difficult to implement than Alternative 8. Although construction of the slurry wall increases the difficulty of initial implementation compared with Alternative 4, this alternative would be easier to operate than in-situ flushing without a slurry wall.

The total costs for this alternative are probably similar to those for Alternatives 4 and 8. The tradeoffs depend on the benefits of in-situ flushing versus the benefits of a slurry wall.

Alternative 10: Extensive Slurry Wall Containment

Description

The objective of this alternative is to contain contaminated groundwater within the extensive remediation area. A slurry wall (Figure 5-2) would be constructed to completely isolate these portions of the unconfined aquifer. No groundwater extraction, and thus no treatment and disposal, would be included in this alternative. Thus, the groundwater concentrations of contaminants would exceed remediation goals indefinitely. This alternative is similar to Alternative 7, except in the size of the region contained by the cutoff wall. Human exposure to contaminated groundwater would be prevented by institutional controls. Institutional controls and groundwater monitoring would continue indefinitely, provided groundwater contamination remains above remediation goals.

Because of meteoric infiltration and groundwater leakage across the slurry wall and from the underlying semi-confined aquifer, a groundwater mound would probably develop within the confined area. In this case, a very slow outflow of groundwater would occur. However, contaminant migration would be mitigated in two ways. First, the slurry wall would adsorb uranium and other contaminants (except tritium) until its capacity was exceeded. Second, the mass flux of groundwater through the slurry wall would be very low.

Discussion

This alternative is protective of human health and the environment (as long as institutional controls remain in place), but relies on containment onsite rather than removal and offsite disposal. One advantage of this approach, not shared by hydraulic containment, is that it would not be vulnerable to mechanical failure. In addition, this alternative would prevent contamination of the contained area from upgradient plumes, and would not accelerate migration of these plumes. Slurry wall construction is well-established technology and is expected to be readily implemented (see Section 5.2.1). The capital cost of this alternative would be greater than the capital cost of extensive hydraulic containment (Alternative 5), but the annual operating costs would be minimal.

Alternative 11: Extensive Slurry Wall Containment with Minimal Extraction

Description

The objectives of this alternative are the same as Alternative 5 (Extensive Hydraulic Containment). However, the selective remediation area would be surrounded by a slurry wall (Figure 5-2) to provide containment, thereby minimizing the treatment rate.

This alternative takes the same approach as Alternative 8 (Selective Slurry Wall Containment with Minimal Extraction), but includes a larger area inside the slurry wall. This alternative is nearly the same as Alternative 10 (Extensive Slurry Wall Containment), but adds a groundwater extraction and treatment system. Above-ground treatment would remove contaminants to levels suitable for groundwater infiltration. The treatment system would generate radioactive sludge requiring landfill disposal.

The treated groundwater would be infiltrated outside the slurry wall. Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction and treatment, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

In contrast with Alternative 10, this alternative prevents escape of contaminants through the slurry wall and provides active remediation of groundwater. The rate of remediation depends on the rate of groundwater extraction inside the slurry wall. Slurry wall containment with minimal extraction would require more time to meet remediation goals than hydraulic containment alternatives or more aggressive treatment (e.g., Alternative 12). Groundwater impacts from offsite sources (i.e., the tritium, technetium, and nitrate plumes) could still occur outside the containment area.

This alternative is somewhat more complex than Alternative 10, and therefore more difficult to implement, because it includes groundwater treatment and infiltration. Although the slurry wall increases the difficulty of initial implementation, this alternative would be easier to operate than hydraulic containment without a slurry wall (Alternative 5). In addition, the extraction and treatment systems would be much smaller, and thus less expensive, than those for Alternative 5. The cost of this alternative would be slightly more than for extensive slurry wall containment alone (Alternative 10).

Alternative 12: Extensive Slurry Wall Containment with Selective In-Situ Flushing

Description

The objective of this alternative is to provide extensive remediation that minimizes contaminant discharges to the Columbia River and maximizes the rate of removal of contaminants. In-situ flushing would be used within slurry wall containment (Figures 5-2 and 5-5). The primary purposes of the slurry wall are to minimize migration of upgradient plumes into the 300 Area and to provide better control of in-situ flushing. The treatment system would be larger for this alternative than for Alternative 10 because it would treat the recirculated leaching solution as well as meteoric infiltration, leakage across the slurry wall, and leakage from the underlying, semi-confined aquifer.

Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction and flushing, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

Because the flushing solution could be circulated through the region inside the slurry wall at a much greater rate than the rate of inward leakage, this alternative should remediate the aquifer in less time than Alternative 10 (Complete Slurry Wall Containment with Minimal Extraction). The rate of remediation compared with Alternative 6 (Complete Hydraulic Containment with Selected In-Situ Flushing) is not clear.

Because of the need for treatability testing to determine the effectiveness of in-situ uranium flushing and the added complexity of the injection system, this alternative would be more difficult to implement than Alternative 10. Although construction of the slurry wall increases the difficulty of initial implementation compared with in-situ flushing without a slurry wall (Alternative 6), this alternative would be easier to operate.

The total costs for this alternative are probably similar to those for Alternatives 6 and 10. The tradeoffs between these alternatives depend on the benefits of in-situ flushing versus the benefits of a slurry wall.

Alternative 13: Selective Hydraulic Containment with a River Cutoff Wall

Description

The objectives of this alternative are the same as for Alternative 3 (Selective Hydraulic Containment). Natural recovery would reduce concentrations outside the selective remediation area. This alternative adds a river cutoff wall to decrease the influx of water from the Columbia River. A slurry wall would be installed parallel to the Columbia River, between the river and the extraction system (Figure 5-7). The other components of this alternative are the same as Alternative 3 (Selective Hydraulic Containment and Treatment). The required volume of extracted groundwater and the treatment system size would be less than for hydraulic containment without a wall, but of the same order of magnitude.

Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

This alternative would have approximately the same effectiveness as Alternative 3 (Selective Hydraulic Containment and Treatment). Construction of the slurry wall would increase the difficulty of initial implementation. However, the slurry wall would decrease the difficulty of operation by decreasing the river influx. Reduction in the rate of groundwater extraction compared with Alternative 3 is unknown. However, it is unlikely that the savings due to reduced flow rates would justify the cost of the slurry wall.

Alternative 14: Selective In-Situ Flushing with a River Cutoff Wall

Description

The objectives of this alternative are the same as Alternative 4 (Selective Hydraulic Containment with In-situ Flushing). Natural recovery would reduce concentrations outside the selective remediation area. The design and implementation of this alternative are similar to those for Alternative 13 (Selective Hydraulic Containment with a River Cutoff Wall), except that some of the extracted groundwater would be amended to increase the solubility of uranium and then reinjected into the regions with highest uranium concentrations (Figures 5-5 and 5-7). The remaining extracted groundwater would upgradient to minimize onsite migration of the upgradient plumes.

Human exposure to contaminated groundwater would be prevented by institutional controls (see Alternative 2 discussion). Groundwater extraction and flushing, institutional controls, and groundwater monitoring would be maintained until groundwater quality in the 300-FF-5 operable unit achieved remediation goals.

Discussion

This alternative should remediate the aquifer in less time than Alternative 13. Because of the need for treatability testing to determine the effectiveness of in-situ uranium flushing and the added complexity of the injection system, this alternative would be more difficult to implement than would Alternative 13. The capital and annual operating costs of this alternative would be greater than for Alternative 13 because of the in-situ flushing system. However, total costs could be less if the in-situ flushing reduced the time needed to achieve remediation goals.

Alternative 15: Selective Aquifer Excavation

Description

The objective of this alternative is to remove contaminated groundwater and aquifer soils in the selective remediation area. Natural recovery would reduce concentrations outside this area. This alternative would only be possible if the selected remedial actions for the 300-FF-1 operable unit included excavation and disposal of the overlying contaminated soil. Remediation alternatives for the 300-FF-1 operable unit that involve containment or in-situ treatment would be incompatible with this alternative. Institutional controls and groundwater monitoring would continue until groundwater concentrations met remediation goals.

Implementation of this alternative could not begin until remediation of the 300-Area soils operable units were completed, including demolition of all surface structures and excavation of unsaturated soils. A slurry wall would then be installed to prevent groundwater flow into the operable unit during excavation (see Figures 5-8 and 5-9). This wall would be set back from the excavation area so that the excavation could take place without damage to the slurry wall, which would not provide structural support. A structural cutoff wall could be used, enclosing a smaller area, but would be more expensive.

Following completion of the slurry wall, the aquifer would be dewatered. The contaminated groundwater would be treated and discharged using a treatment system that removes contaminants to levels suitable for groundwater infiltration (outside the slurry wall). Because of groundwater inflow from infiltration of meteoric water, leakage through the slurry wall, and leakage from the underlying, semi-confined aquifer, groundwater extraction and treatment would operate continuously during aquifer soil removal.

Following dewatering, aquifer soils would be removed by dredging and/or standard excavation techniques. Because of the large quantity of soil with relatively low contamination, soil washing may be used to separate contaminated and relatively clean soil particles, provided it were feasible. If soil washing were infeasible, ex-situ chemical extraction of contaminants would be considered, but would likely prove prohibitively expensive because of low contaminant concentrations. The contaminated soil or treatment residue would be disposed in a secure landfill (i.e., the ERSDF).

Discussion

This alternative would increase the potential for exposure of humans and wildlife to contaminated groundwater and aquifer soil during excavation/dredging and dewatering and would therefore increase the short-term risk to human health and the environment. Removal, treatment, and disposal would be required for a very large volume of soil (see Table 3-7) with relatively low concentrations of contaminants. This alternative would be implementable, as it relies on proven technologies: slurry wall construction, groundwater treatment, and soil excavation/dredging. However, it would be prohibitively expensive and would not provide significant benefits compared with the other alternatives. It would also result in destruction of wildlife habitat that might not recover after completion of remediation. This would include habitat in both the excavated region and the additional landfill space.

Alternative 16: Complete Aquifer Excavation

Description

The objectives of this alternative are to remove contaminated aquifer soils in the extensive remediation area. This alternative is the same as Alternative 15, except that the area and volume of excavated soils would be much greater (Figures 5-8 and 5-9).

Discussion

This alternative would increase the potential for exposure of humans and wildlife to contaminated groundwater and aquifer soil during excavation/dredging and dewatering and would therefore increase the short-term risk to human health and the environment. Removal, treatment, and disposal would be required for a very large volume of soil (see Table 3-7) with relatively low concentrations of contaminants. This alternative would be implementable, as it relies on proven technologies: slurry wall construction, groundwater treatment, and soil excavation/dredging.

The benefit of this alternative compared with all the other alternatives is that it would accomplish extensive remediation of groundwater in the shortest period of time. However, it would not provide significantly more benefits. Costs for this alternative would be even more prohibitive than for Alternative 15. It would also result in destruction of wildlife habitat that might not recover after completion of remediation. This would include habitat in both the excavated region and the additional landfill space.

5.4 SCREENING OF ALTERNATIVES

In this section, the remediation alternatives are screened based on effectiveness (protection of human health and the environment, and reliability), implementability, and cost (see Chapter 4 for criteria definitions) to derive a reduced list for detailed evaluation in the Phase III FS. Alternatives may be rejected because they are not sufficiently effective or because they are not feasible to implement, but not solely on the basis of cost. Alternatives can also be rejected by comparison to a retained alternative that is at least as effective for less cost. Alternatives may also be rejected where incremental benefit compared to another alternative (i.e., increased effectiveness or implementability) is not justified by the increased cost or increased implementation difficulty, provided the retained alternative is protective of human health and the environment. This screening is only a preliminary evaluation; alternatives are retained unless a clear basis for rejection can be documented. The following alternatives are not retained for the reasons stated:

- Alternative 6 (Extensive Hydraulic Containment with Selective In-Situ Flushing) is not retained because of the difficulties of implementation associated with effectively and reliably operating hydraulic containment and in-situ flushing for the extensive remediation area. Alternative 5 (Extensive Hydraulic Containment) would eventually achieve the same remediation goals and would be simpler to operate.

- The slurry wall alternatives with no groundwater extraction (Alternatives 7 and 10) are not retained because they do not provide treatment to remove contaminants and because elevated contaminant concentrations inside the slurry wall will remain indefinitely.

- Alternative 12 (Extensive Slurry Wall Containment with Selective In-Situ Flushing) is not retained because Alternative 11 (Extensive Slurry Wall Containment with Minimal Extraction) provides similar effectiveness and is easier to implement for less cost.

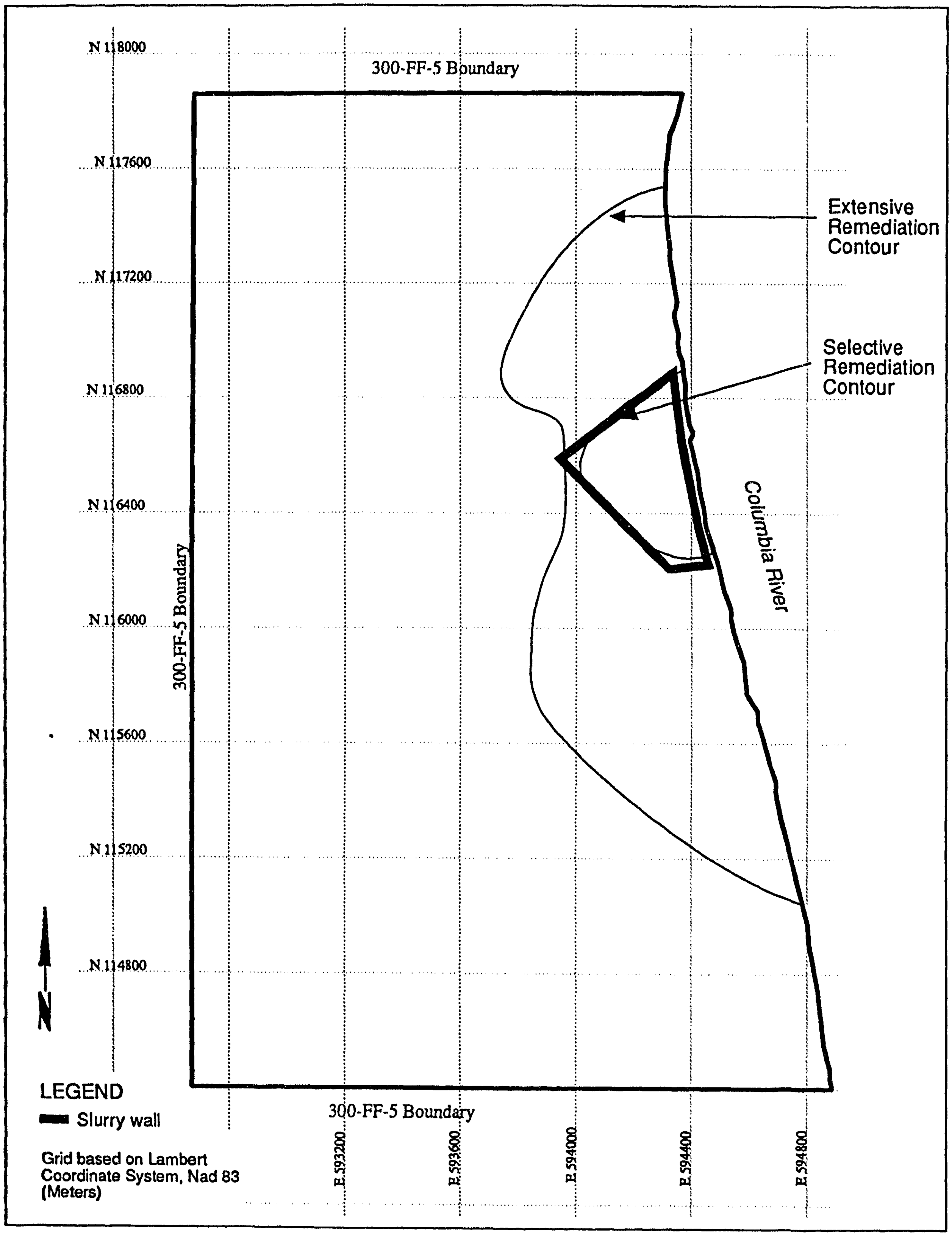
- The two river cutoff wall alternatives (Alternatives 13 and 14) are not retained because Alternative 3 (Selective Hydraulic Containment) and Alternative 4 (Selective Hydraulic Containment with In-situ Flushing) would be equally effective and easier to implement for less cost. The decrease in the rate of groundwater extraction (and corresponding decrease in cost) afforded by a river cutoff wall is not expected to be large enough to justify the significant cost of the wall.

- The two excavation alternatives (Alternatives 15 and 16) are not retained because other retained alternatives have equal or better long-term effectiveness, have less short-term risks, and are less disruptive to the environment. In addition, the effectiveness of Alternatives 15 and 16 does not justify their poor implementability and very high cost.

With the exception of Alternative 1 (No Action), the remaining alternatives are all considered protective of human health and the environment and implementable, although they vary significantly in cost and cost-effectiveness. Although its effectiveness is poor, Alternative 1 is retained in accordance with the NCP to provide a baseline for comparison with other alternatives. The following alternatives therefore remain after screening:

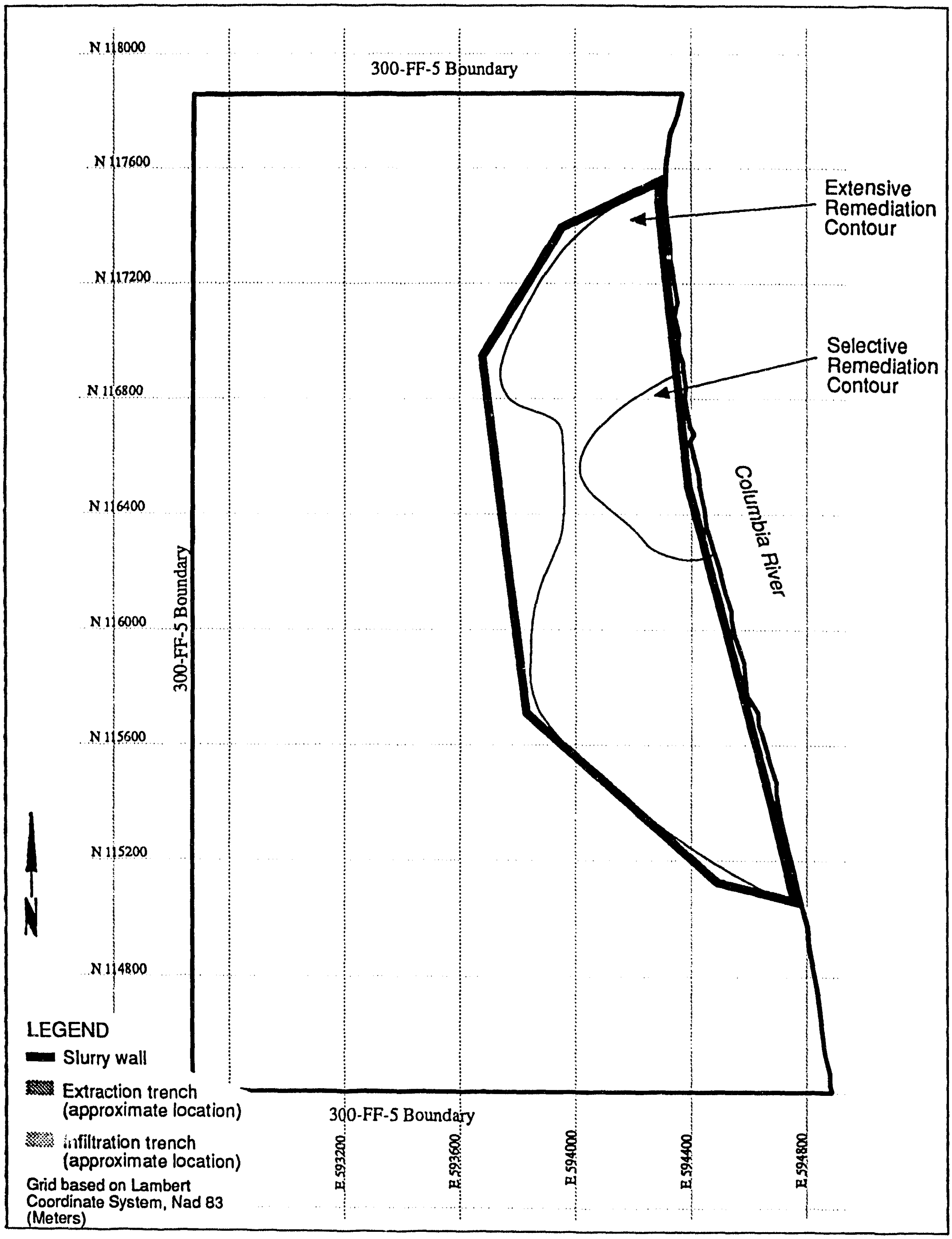
Alternative 1:	No Action
Alternative 2:	Institutional Controls
Alternative 3:	Selective Hydraulic Containment
Alternative 4:	Selective Hydraulic Containment with In-Situ Flushing
Alternative 5:	Extensive Hydraulic Containment
Alternative 8:	Selective Slurry Wall Containment with Minimal Extraction
Alternative 9:	Selective Slurry Wall Containment with In-Situ Flushing
Alternative 11:	Extensive Slurry Wall Containment with Minimal Extraction

These alternatives will be further developed and evaluated in the Phase III FS.



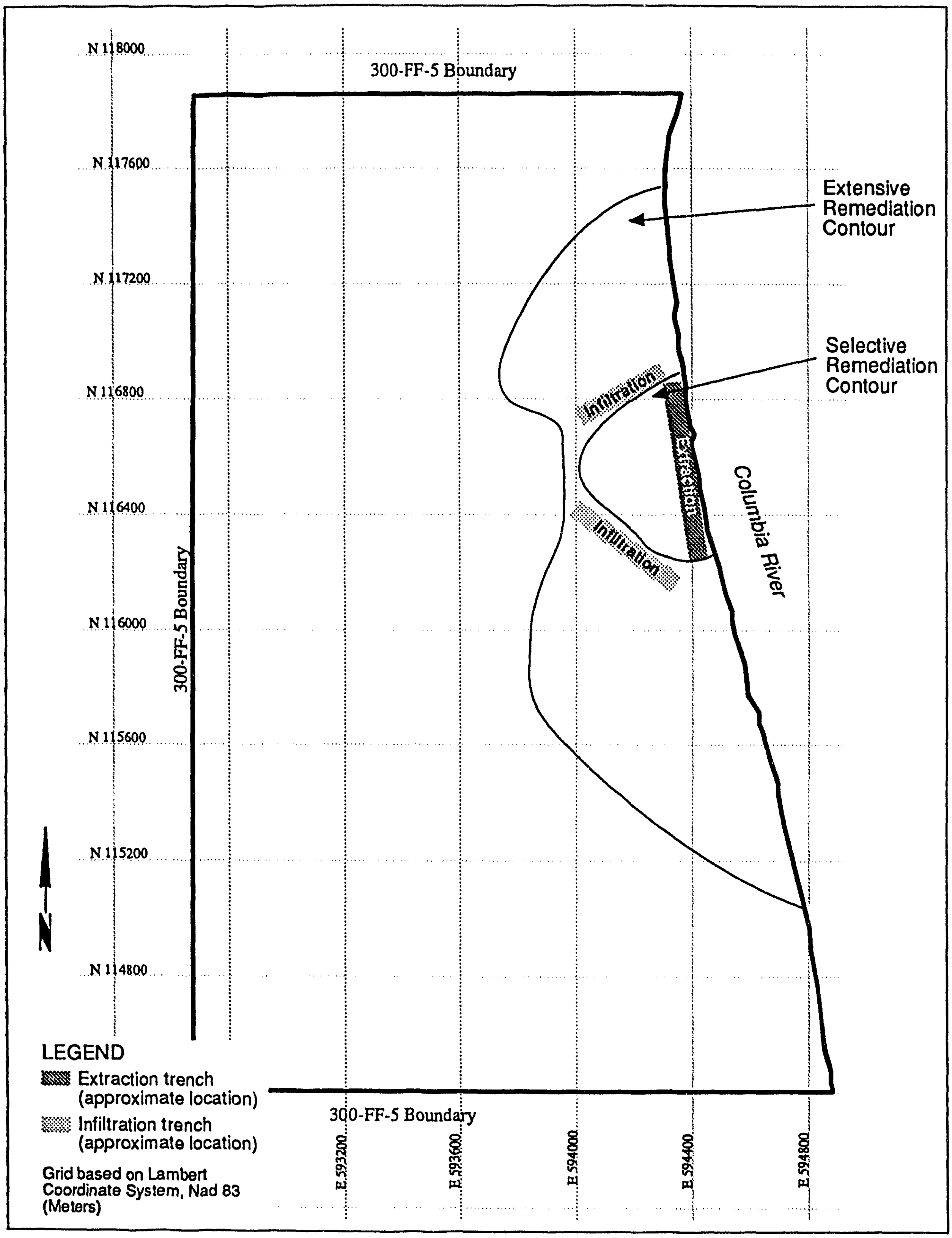
913 1769/45672/7-6-93

Figure 5-1. Layout for Selective Slurry Wall Containment.



913 1769/45665/7-6-93

Figure 5-2. Layout for Extensive Slurry Wall Containment.



913 1769/45663/7-6-93

Figure 5-3. Layout for Selective Hydraulic Containment.

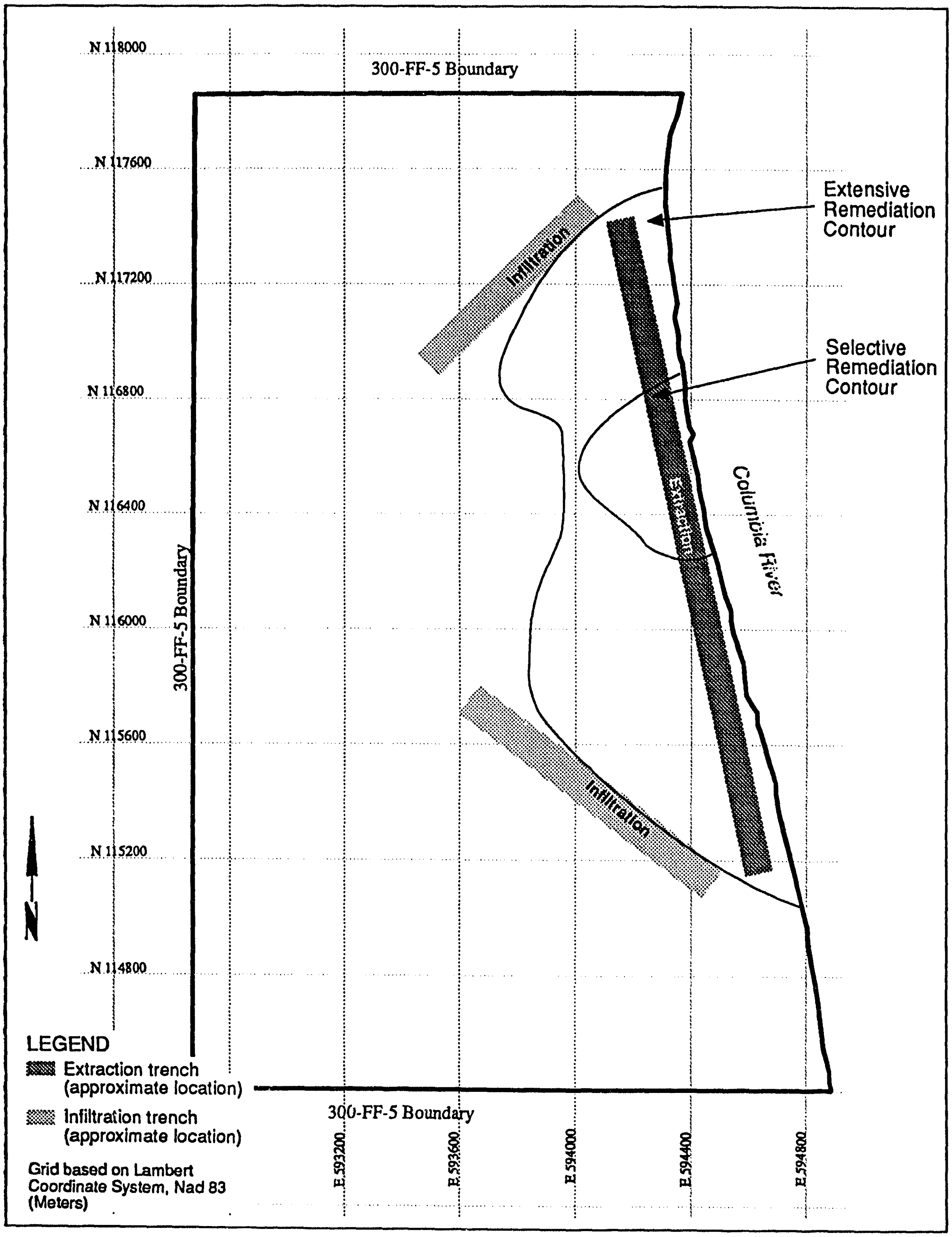


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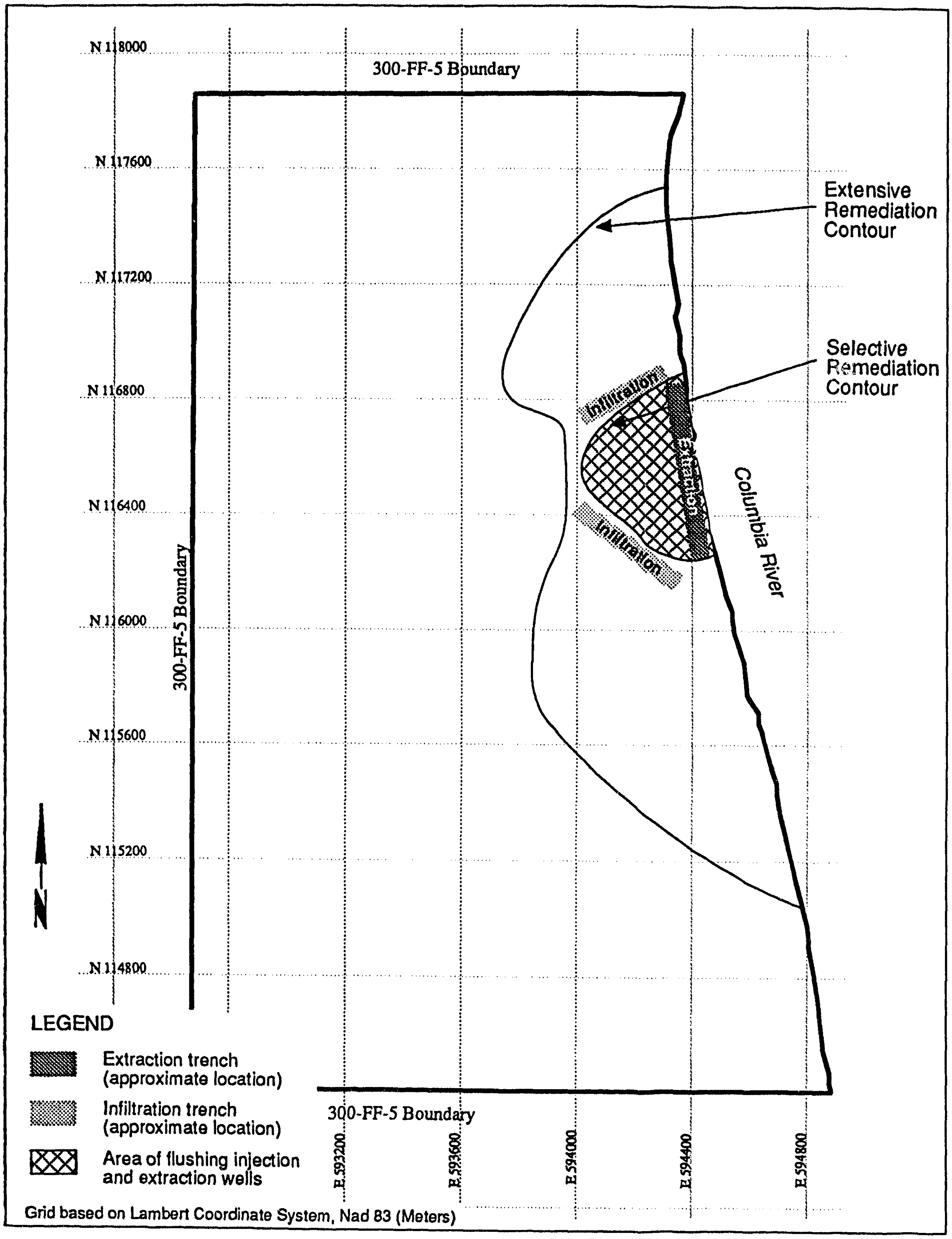
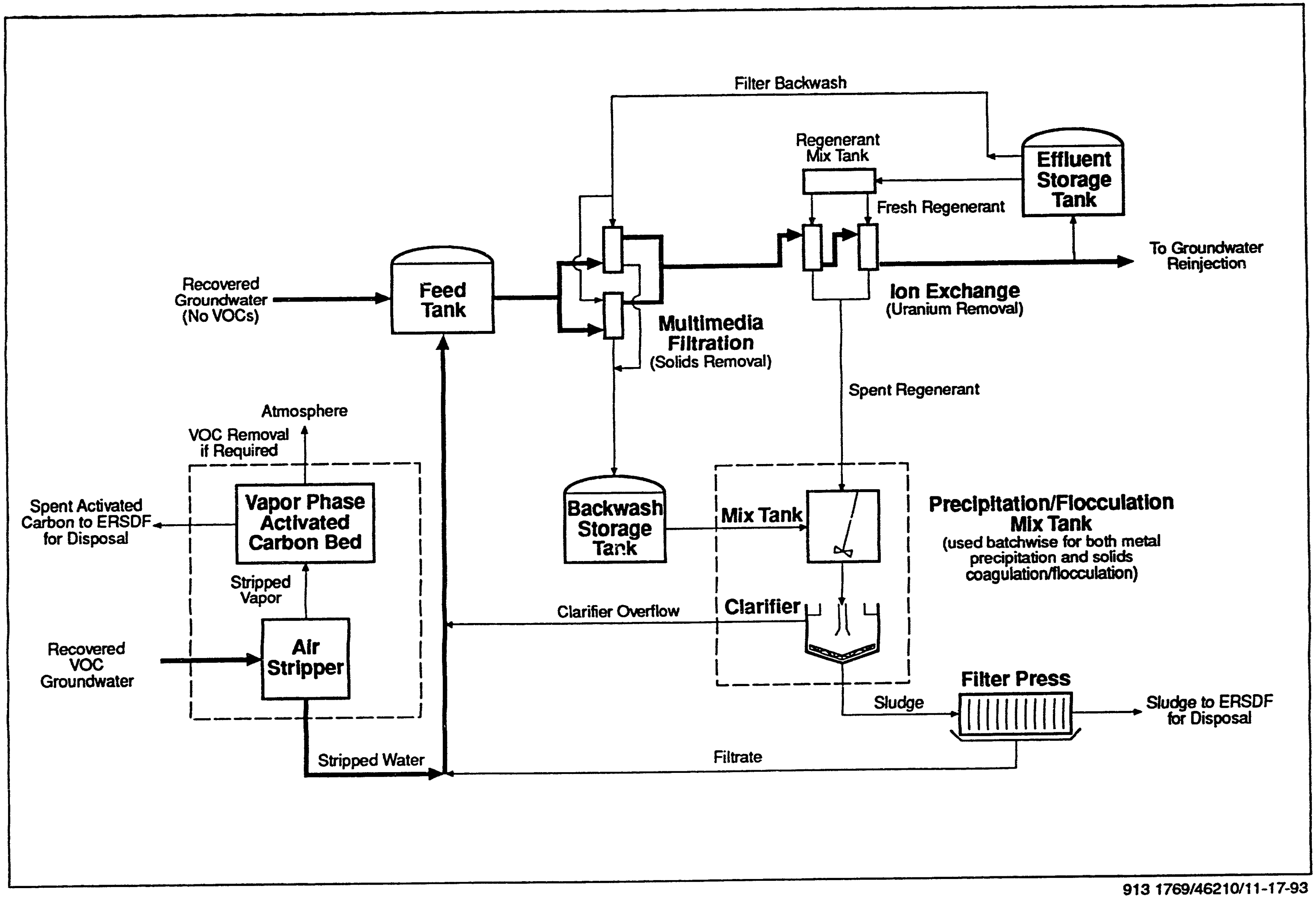
Figure 5-4. Layout for Extensive Hydraulic Containment.



913 1769/46607/7-6-93

Figure 5-5. Layout for In-Situ Flushing.



913 1769/46210/11-17-93

Figure 5-6. Process Flow Diagram for Groundwater Treatment.

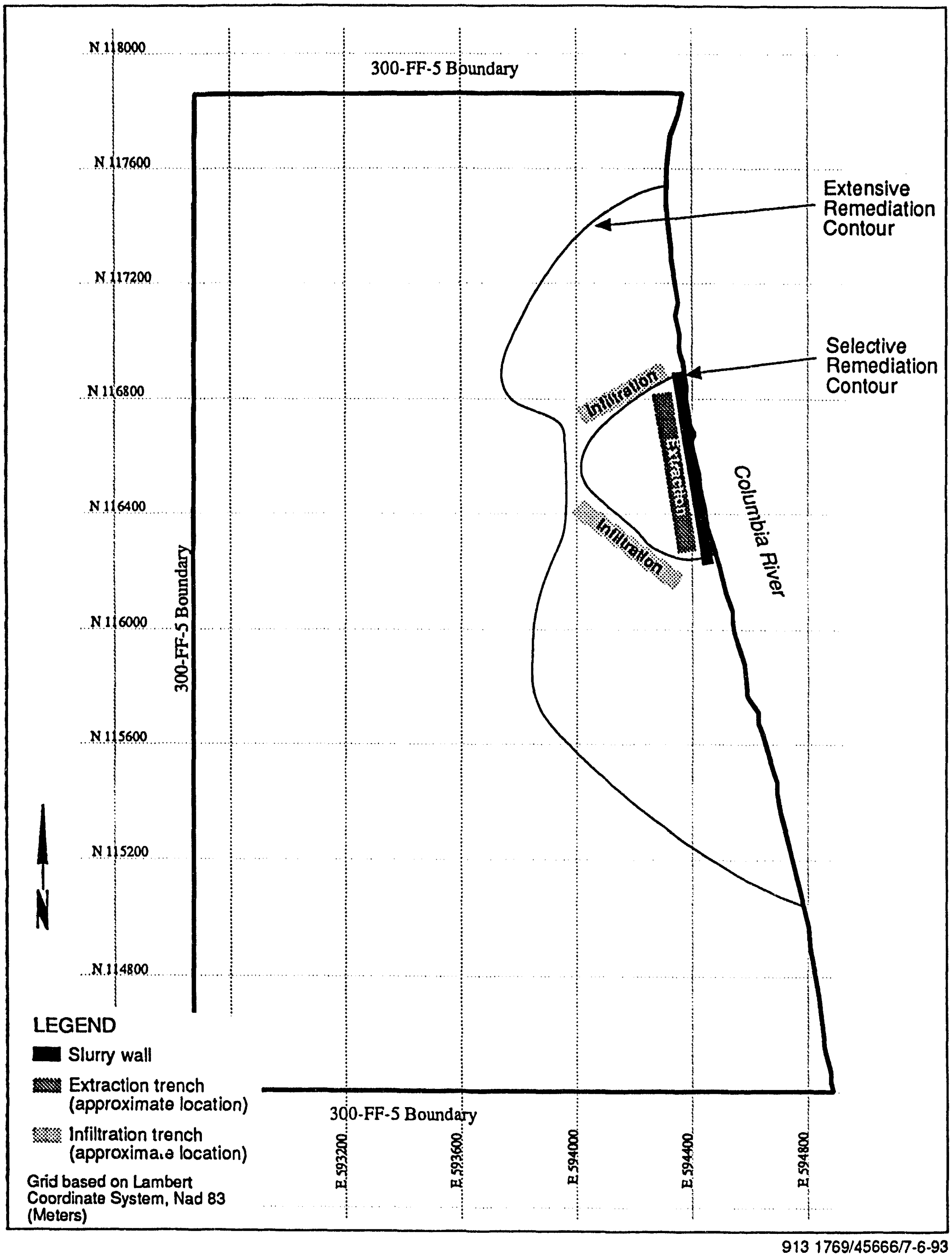


Figure 5-7. Layout of River Cutoff Wall.

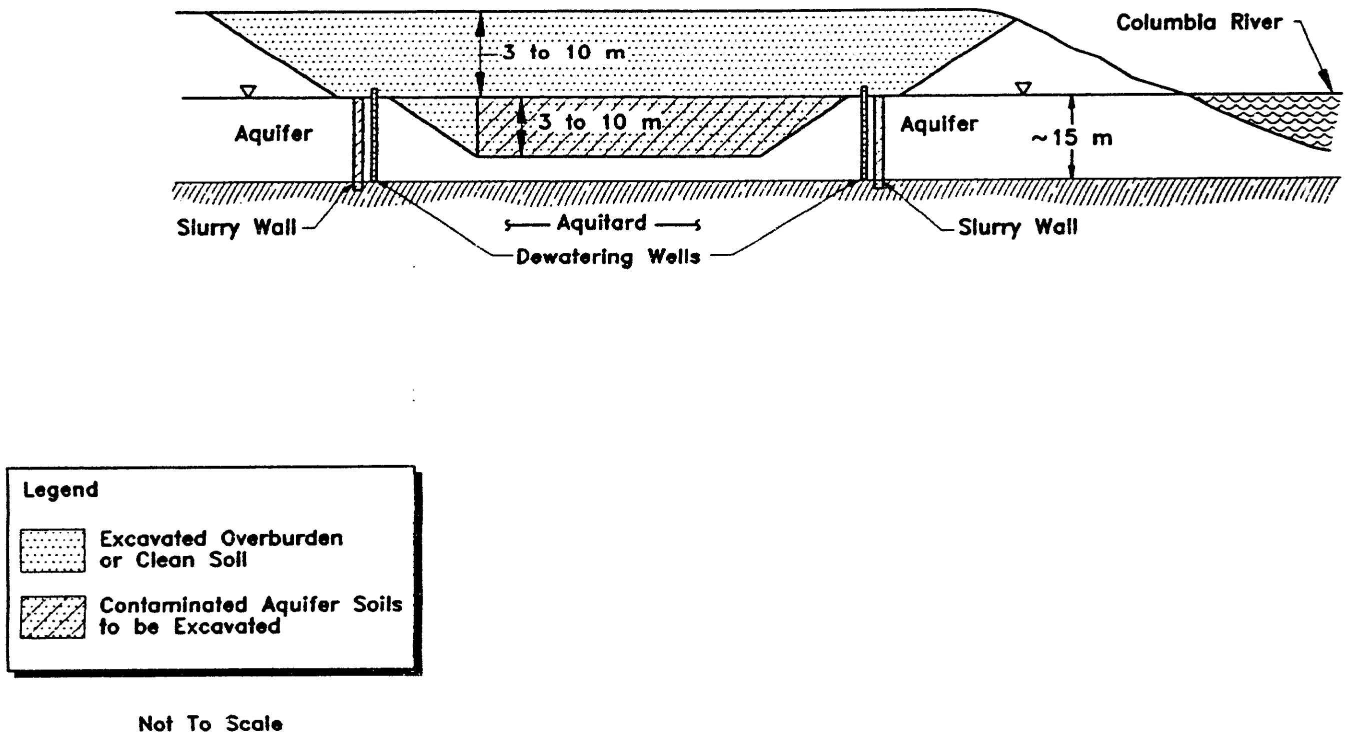


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Figure 5-8. Conceptual Cross Section of Aquifer Excavation.

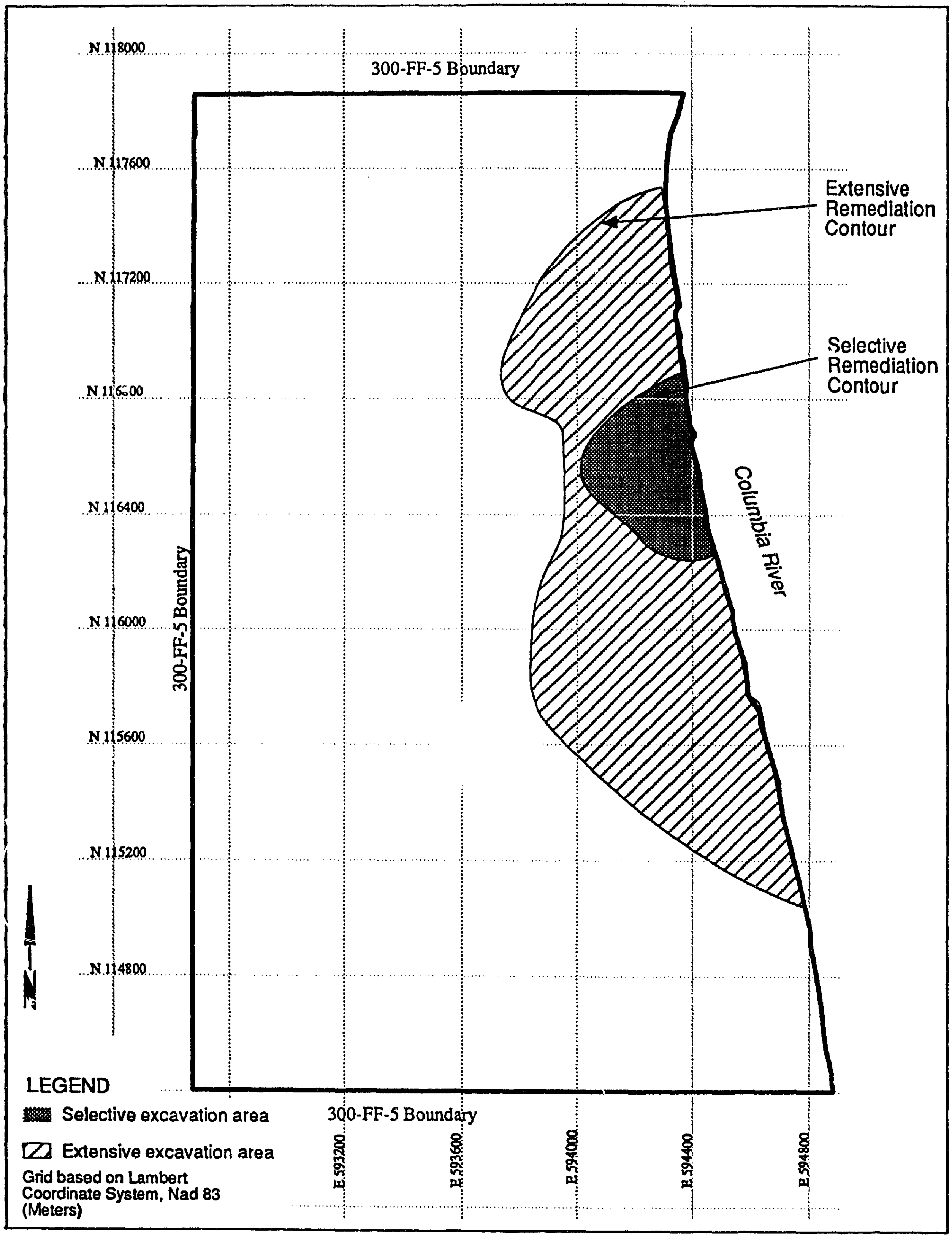

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Figure 5-9. Layouts for Aquifer Excavation.

Table 5-1. Summary of Remedial Action Components for Remediation Alternatives.

Alternative Number	Extent of Active Remediation	Institutional Controls	Hydraulic Containment	Slurry Wall	In-Situ Flushing	Groundwater Treatment	Aquifer Excavation
1	None						
2	None	Yes					
3	Selective	Yes	Yes			Yes	
4	Selective	Yes	Yes		Yes	Yes	
5	Extensive	Yes	Yes			Yes	
6	Extensive	Yes	Yes		Yes	Yes	
7	Selective	Yes		Yes			
8	Selective	Yes	Yes	Yes		Yes	
9	Selective	Yes	Yes	Yes	Yes	Yes	
10	Extensive	Yes		Yes			
11	Extensive	Yes	Yes	Yes		Yes	
12	Extensive	Yes	Yes	Yes	Yes	Yes	
13	Selective	Yes	Yes	River cutoff		Yes	
14	Selective	Yes	Yes	River cutoff	Yes	Yes	
15	Proposed MCL	Yes	No	Yes		Yes	Yes
16	Extensive	No	No	Yes		Yes	Yes

Alternative Names:

Alternative 1:	No Action
Alternative 2:	Institutional Controls
Alternative 3:	Selective Hydraulic Containment
Alternative 4:	Selective Hydraulic Containment with In-Situ Flushing
Alternative 5:	Extensive Hydraulic Containment
Alternative 6:	Extensive Hydraulic Containment with Selective In-Situ Flushing
Alternative 7:	Selective Slurry Wall Containment
Alternative 8:	Selective Slurry Wall Containment with Minimal Extraction
Alternative 9:	Selective Slurry Wall Containment with In-Situ Flushing
Alternative 10:	Extensive Slurry Wall Containment
Alternative 11:	Extensive Slurry Wall Containment with Minimal Extraction
Alternative 12:	Extensive Slurry Wall Containment with Selective In-Situ Flushing
Alternative 13:	Selective Hydraulic Containment with a River Cutoff Wall
Alternative 14:	Selective In-Situ Flushing with a River Cutoff Wall
Alternative 15:	Selective Aquifer Excavation
Alternative 16:	Extensive Aquifer Excavation

Table 5-2. Summary of Screening of Remediation Alternatives. (Sheet 1 of 4)

Alternative No.	Name	Description	Effectiveness	Implementability	Cost[a]	Retained (Yes/No)
1	No Action	1. Perform long-term performance monitoring as required by CERCLA. 2. Discontinue monitoring when groundwater quality meets remediation goals.	Low: Exposure not prevented; natural recovery expected to result in attainment of remediation goals in a reasonable timeframe.	Good: No action required	Low (monitoring costs only)	Yes
2	Institutional Controls	1. Implement institutional controls and monitoring for groundwater. 2. Continue institutional controls and monitoring until groundwater quality meets remediation goals.	Moderate: Exposure prevented; natural recovery expected to result in attainment of remediation goals in a reasonable timeframe.	Good: Most controls already in place.	Low	Yes
3	Selective Hydraulic Containment	1. Extract groundwater from the selective remediation area. 2. Treat recovered groundwater to achieve an effluent quality suitable for reinjection. 3. Reinject treated groundwater to decrease onsite migration of contaminants from other areas (e.g., tritium and technetium). 4. Implement institutional controls and monitoring for groundwater. 5. Continue groundwater extraction, institutional controls, and monitoring until groundwater quality meets remediation goals.	Moderate: Removes and treats highly-contaminated groundwater (accelerates natural recovery process).	Good: Common technology.	Moderate	Yes
4	Selective Hydraulic Containment with In-Situ Flushing	1. Inject a solution to leach uranium from the aquifer soils in selective remediation area. 2. Extract groundwater to recover the leaching solution and provide hydraulic isolation (containment) of groundwater. 3. Treat the recovered groundwater to achieve an effluent quality suitable for reinjection. 4. Implement institutional controls and monitoring for groundwater. 5. Continue leaching, extraction and treatment, institutional control, and monitoring until groundwater quality meets remediation goals.	Moderate: Removes and treats highly-contaminated groundwater (accelerates natural recovery); benefits of in-situ flushing are uncertain.	Moderate: Uranium flushing technology is untested and may be relatively complex to operate.	Moderate	Yes
5	Extensive Hydraulic Containment	1. Extract and reinject groundwater to hydraulically contain contaminant migration into the Columbia River where the groundwater concentration of uranium exceeds the MTCA Method B cleanup level. 2. Treat recovered groundwater to achieve an effluent quality suitable for reinjection. 3. Reinject treated groundwater to decrease onsite migration of contaminants from other areas (e.g., tritium and technetium). 4. Implement institutional controls and monitoring for groundwater. 5. Continue groundwater extraction and treatment, institutional controls, and monitoring until groundwater quality meets remediation goals.	High: Prevents release of contaminants above MTCA Method B standards to Columbia River. May accelerate contaminant migration from off-site.	Moderate: Difficult to implement and operate reliably because of river stage interactions.	High	Yes

Table 5-2. Summary of Screening of Remediation Alternatives. (Sheet 2 of 4)

Alternative No.	Name	Description	Effectiveness	Implementability	Cost(a)	Retained (Yes/No)
6	Extensive Hydraulic Containment with Selective In-Situ Flushing	1. Extract and reinject groundwater in the extensive remediation area. 2. Extract groundwater to recover the leaching solution and provide hydraulic isolation (containment) of groundwater. 3. Treat the recovered groundwater to achieve an effluent quality suitable for reinjection. 4. Implement institutional controls and monitoring for groundwater. 5. Continue leaching, extraction and treatment, institutional control, and monitoring until groundwater quality meets remediation goals.	High: Prevents release of contaminants above remediation goals. May accelerate contaminant migration from off-site. Faster remediation than Alternative 5.	Difficult: Difficult to implement and operate reliably because of river stage interactions and complexities associated with the in-situ flushing system.	High	No
7	Selective Slurry Wall Containment	1. Install a slurry wall around the selective remediation area. 2. Implement institutional controls and monitoring for groundwater. 3. Continue institutional controls and monitoring indefinitely.	Low: Reduces mass flux rate into the river but does not actively remove contamination.	Moderate: Some construction difficulties for slurry wall.	Moderate	No
8	Selective Slurry Wall Containment with Minimal Extraction	1. Install a slurry wall around the selective remediation area. 2. Extract sufficient groundwater to ensure no outward leakage through containment (i.e., to provide an inward gradient). 3. Treat extracted groundwater to achieve an effluent quality suitable for reinjection. 4. Reinject treated groundwater outside the slurry wall. 5. Implement institutional controls and monitoring for groundwater. 6. Continue groundwater extraction and treatment, institutional controls, and monitoring until groundwater quality meets remediation goals.	High: Removes and treats highly-contaminated groundwater (accelerates natural recovery process).	Moderate: Some construction difficulties for slurry wall; more complex than slurry wall alone	Moderate	Yes
9	Selective Slurry Wall Containment with In-Situ Flushing	1. Install a slurry wall around the selective remediation area. 2. Inject a solution to leach uranium from the contained aquifer soils. 3. Extract groundwater to recover the leaching solution and provide hydraulic isolation (containment) of groundwater. 4. Treat recovered groundwater to achieve an effluent quality suitable for reinjection. 5. Implement institutional controls and monitoring for groundwater. 6. Continue leaching, extraction and treatment, institutional control, and monitoring until groundwater quality meets remediation goals.	High: Removes and treats highly-contaminated groundwater (accelerates natural recovery); benefits of in-situ flushing are uncertain.	Difficult: Some construction difficulties for slurry wall; uranium flushing technology is untested and may be relatively complex to operate.	Moderate	Yes
10	Extensive Slurry Wall Containment	1. Install a slurry wall to around the extensive remediation area. 2. Implement institutional controls and monitoring for groundwater. 3. Continue institutional controls and monitoring indefinitely.	Low: Reduces mass flux rate into the river but does not actively remove contamination.	Moderate: Some construction difficulties for slurry wall.	High	No

Table 5-2. Summary of Screening of Remediation Alternatives. (Sheet 3 of 4)

Alternative No.	Alternative Name	Description	Effectiveness	Implementability	Cost[a]	Retained (Yes/No)
11	Extensive Slurry Wall Containment with Minimal Extraction	1. Install a slurry wall to around the extensive remediation area. 2. Extract sufficient groundwater to ensure no outward leakage through containment (i.e., to provide an inward gradient). 3. Treat extracted groundwater to achieve an effluent quality suitable for reinjection. 4. Reinject treated groundwater outside the slurry wall. 5. Implement institutional controls and monitoring for groundwater. 6. Continue groundwater extraction and treatment, institutional controls, and monitoring until groundwater quality meets remediation goals.	Very High: Removes and treats groundwater with contaminant levels above remediation goals (accelerates natural recovery process).	Moderate: Some construction difficulties for slurry wall; more complex than slurry wall alone.	High	Yes
12	Extensive Slurry Wall Containment with Selective In-Situ Flushing	1. Install a slurry wall around the extensive remediation area. 2. Inject a solution to leach uranium from the contained aquifer soils. 3. Extract groundwater to recover the leaching solution and provide hydraulic isolation (containment) of groundwater. 4. Treat recovered groundwater to achieve an effluent quality suitable for reinjection. 5. Implement institutional controls and monitoring for groundwater. 6. Continue leaching, extraction and treatment, institutional control, and monitoring until groundwater quality meets remediation goals.	Very High: Removes and treats groundwater with contaminant levels above MTCA Method B (accelerates natural recovery process); benefits of in-situ flushing are uncertain.	Difficult: Slurry wall construction may not be feasible; uranium flushing technology is untested and may be relatively complex to operate.	High	No
13	Selective Hydraulic Containment with a River Cutoff Wall	1. Install a slurry wall parallel to the Columbia River to decrease river flow to the groundwater extraction system. 2. Extract and reinject groundwater from the selective remediation area. 3. Treat recovered groundwater to achieve an effluent quality suitable for reinjection. 4. Implement institutional controls and monitoring for groundwater. 5. Continue groundwater extraction, institutional controls, and monitoring until groundwater quality meets remediation goals.	Moderate: Removes and treats highly-contaminated groundwater (accelerates natural recovery process).	Difficult: Construction difficulties for slurry wall; difficult to implement and operate reliably because of river stage interactions.	Moderate	No
14	Selective In-Situ Flushing with a River Cutoff Wall	1. Install a slurry wall parallel to the Columbia River to decrease river flow to the groundwater extraction system. 2. Inject a solution to leach uranium from the aquifer soils in the selective remediation area. 3. Extract groundwater to recover the leaching solution and provide hydraulic isolation (containment) of groundwater. 4. Treat the recovered groundwater to achieve an effluent quality suitable for reinjection. 5. Implement institutional controls and monitoring for groundwater. 6. Continue leaching, extraction and treatment, institutional control, and monitoring until groundwater quality meets remediation goals.	Moderate: Removes and treats highly-contaminated groundwater (accelerates natural recovery process); benefits of in-situ flushing are uncertain.	Difficult: Construction difficulties for slurry wall; difficult to implement and operate reliably because of river stage interactions; uranium flushing technology is untested and may be relatively complex to operate.	Moderate	No

Table 5-2. Summary of Screening of Remediation Alternatives. (Sheet 4 of 4)

Alternative No.	Name	Description	Effectiveness	Implementability	Cost[a]	Retained (Yes/No)
15	Selective Aquifer Excavation	1. Demolish surface structures. 2. Extensive remediation of 300-Area soils operable units (300-FF-1, 300-FF-2, and 300-FF-3). Remedial actions for these units cannot include capping or other containment and should consist of unsaturated soil excavation and treatment to be compatible with this 300-FF-5 alternative. 3. Install a slurry wall at the outermost extremity of soil removal (including excavation laybacks). 4. Install a groundwater extraction and treatment system and dewater the excavation. 5. Excavate or dredge aquifer soils in the selective remediation area. Because of upward groundwater flow from the underlying semi-confined aquifer, groundwater treatment would operate continuously during soil removal. 6. Reinject treated groundwater upgradient of the site. 7. Reduce the volume of contaminated soil by soil washing, if feasible. 8. Dispose of contaminated soil in the ERSDF. 9. Backfill the excavation with clean soil.	Moderate: Removes and treats highly-contaminated groundwater (accelerates natural recovery process); provides the quickest remediation; increases short-term risk to human health and the environment by increasing the potential for exposure.	Difficult: Requires excavation of source operable units; generally low implementability.	Very high	No
16	Extensive Aquifer Excavation	1. Demolish surface structures. 2. Extensive remediation of 300-Area soils operable units (300-FF-1, 300-FF-2, and 300-FF-3). Remedial actions for these units cannot include capping or other containment and should consist of unsaturated soil excavation and treatment to be compatible with this 300-FF-5 alternative. 3. Install a slurry wall at the outermost extremity of soil removal (including excavation laybacks. 4. Install a groundwater extraction and treatment system and dewater the excavation. 5. Excavate or dredge aquifer soils in the extensive remediation area. Because of upward groundwater flow from the underlying semi-confined aquifer, groundwater treatment would operate continuously during soil removal. 6. Reinject treated groundwater upgradient of the site. 7. Reduce the volume of contaminated soil by soil washing, if feasible. 8. Dispose of contaminated soil in the ERSDF. 9. Backfill the excavation with clean soil.	Moderate: Removes and treats highly-contaminated groundwater (accelerates natural recovery process); provides the quickest remediation; increases short-term risk to human health and the environment by increasing the potential for exposure.	Difficult: Requires excavation of source operable units; generally low implementability.	Very high	No

Notes: (a) Low Cost: < $10 Million
Moderate Cost: $10 - $40 Million
High Cost: $40 - $150 Million
Very High Cost: > $150 Million

6.0 SUMMARY AND CONCLUSIONS

The purpose of this Phase I/II FS is to assemble and screen a list of alternatives for remediation of the 300-FF-5 operable unit. This screening is based on information gathered in the Phase I RI and on currently available information on remediation technologies. The alternatives remaining after screening provide a range of response actions for remediation. In addition, key data needs are identified for collection during a Phase II RI (if necessary). This Phase I/II FS represents a primary document as defined by the Tri-Party Agreement, but will be followed by a Phase III FS that will further develop the alternatives and provide a detailed evaluation of them. The signatories of the Tri-Party Agreement will use the Phase III FS as the basis for selecting a remedy for the 300-FF-5 operable unit to mitigate potential risk to human health and the environment.

6.1 NATURE AND EXTENT OF CONTAMINATION

Groundwater

Groundwater contamination at the 300-FF-5 operable unit generally consists of three main plumes (shown in Figure 2-13). The primary plume, and the only one of the three that is derived from 300 Area operations, is centered beneath the 300-FF-1 operable unit, primarily in the vicinity of the process trenches and the north and south process ponds. Contaminants associated with this plume are total coliform bacteria, chloroform, DCE, TCE, nickel, copper, Sr-90, and the uranium isotopes. A second plume, consisting of tritium contamination migrating into the 300-FF-5 operable unit from the north, is present throughout much of the 300-FF-5 operable unit. This plume is derived from operations in the 200 East Area (Figure 2-1). Currently, tritium concentrations are highest (approximately 12,000 pCi/L) in the northern portions of the operable unit and decline to the south. The third plume is comprised of Tc-99 and nitrate contamination and is migrating from the vicinity of the 1100-EM-1 operable unit, located approximately 1.6 km (1 mi) to the west of the southern portion of the 300-FF-5 operable unit. This plume is centered in the southern portion of the 300-FF-5 operable unit. TCE is also known to be present in groundwater at the 1100-EM-1 operable unit; however, TCE contamination was not detected with the Tc-99 and nitrate in the 300 Area during the 300-FF-5 operable unit RI.

Current cancer risk associated with industrial use of groundwater from Well 399-4-12 is estimated to equal $2x10^{-5}$. The risk is from the inhalation of chloroform at concentrations comparable to municipal water supply systems. If chloroform is not included in the risk assessment, the estimated risk associated with industrial use of this groundwater is reduced to $1x10^{-6}$.

Sediment

There were no contaminants of potential concern associated with the 300-FF-5 operable unit identified in shoreline sediments along the Columbia River. Therefore, the sediment pathway was eliminated as a human exposure pathway in the risk assessment.

Surface Water

Contaminants of potential concern in surface water for the 300-FF-5 operable unit are: TCE, Tc-99, tritium, U-234, U-235, and U-238. Concentrations were generally observed to be highest close to the riverbank and lowest away from the riverbank. The maximum concentrations were all associated with the sample collected 1 m (3 ft) from the bank. It was also noted that concentrations generally increased toward the downstream end of the 300-FF-5 operable unit. The maximum river concentrations of the uranium isotopes, tritium, TCE, and Tc-99 all occurred at the SP11 sampling location (Figure 2-20).

The river sampling event for the Phase I RI took place at extreme low-river stage (338.5 ft. AMSL) and represents the maximum river impacts from 300-FF-5 groundwater. Available data on uranium concentrations in water from the 300-Area intake average about two orders of magnitude less than uranium concentrations found in river samples. Uncertainty exists about actual average concentrations of 300-FF-5 operable unit contaminants in near-shore Columbia River water.

Biota

A biotic uptake assessment was performed to determine if constituents of concern could be transported from contaminated groundwater and soil into the foodchain.

Brandt et al., (1993) looked at several biological components, including vegetation and small mammals. For vegetation, elevated concentration of certain metals were noted in 300-FF-5 operable unit samples of reed canarygrass. For small mammals (house mice and Great Basin pocket mice(, Brandt et al. (1993) reported little difference between 300-FF-5 operable unit and control sample contaminant concentrations, except for higher manganese in pocket mice from the operable unit.

For aquatic vegetation, contaminants were analyzed in periphytic communities above and below the 300-FF-5 operable unit. Although the highest concentrations of most contaminants were found at the further downstream station, there was apparently little evidence of any tendency toward a downstream increase in contaminant concentrations. An evaluation of data collected from macrophytes, however, did show a general downriver increase in concentrations of aluminum, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. The implication of this trend was not addressed.

6.2 REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAO's) are developed to establish site-specific remediation goals, taking into account specific contaminants, contaminated environmental media, and potential contaminant exposure pathways [40 CFR 300.430(e)(i)]. Remedial action objectives and remediation goals, which are subject to refinement throughout the FS, focus the development, screening, and analysis of remedial alternatives to ensure that they are protective of human health and the environment.

Remedial action objectives for groundwater impacts from source operable units will be addressed in feasibility studies for the source operable units. Only existing groundwater impacts are addressed in this FS. In this manner, the 300-FF-5 groundwater operable unit can proceed to a ROD without being delayed by the RI/FS process for 300 Area source operable units. The following remedial action objectives were identified for the 300-FF-5 operable unit:

1) **Limit current human exposure to contaminated groundwater in the 300-FF-5 operable unit.**

2) **Limit discharge of contaminated groundwater to the Columbia River.**

3) **Reduce contaminant concentrations in groundwater below acceptable levels by the year 2018.**

Potential ARARs for determining remediation goals (cleanup levels) include MTCA Method B, MTCA Method C, and drinking water MCLs. The selection of a remedy will depend on the applicability of these regulations to remediation of the 300-FF-5 operable unit. If MTCA is applicable, an ARAR waiver should be considered in accordance with Section 121 of CERCLA. The MTCA Method B level for uranium (4.3 pCi/L) is currently the 300-FF-5 background concentration. However, because of the small number of background samples and apparent analytical variability, the background level for uranium at the 300-FF-5 operable unit is uncertain. If the site-specific background proves lower with the acquisition of additional data, compliance with MTCA Method B standards will require significantly greater effort and cost than compliance with either MTCA Method C or drinking water MCLs. Preliminary remediation goals are identified in Table 3-7.

Most groundwater contaminants of concern (except tritium from 200 Area sources) may be flushed from the aquifer within about 10 years (based on groundwater modeling). Thus, natural recovery could met remediation goals by 2018, the year targeted by the Tri-Party Agreement for completion of Hanford site remediation, and the earliest year possible for release of existing institutional controls. Considering that the 300 Area has been discharging contaminated groundwater to the Columbia River for many years (Tyler 1992), marginal benefits would be gained by instituting active remedial actions that may not be necessary in the near future.

Remedial action objectives for the 300-FF-5 operable unit do not include remediation of contaminants migrating from sources outside the 300 Area. Two upgradient contaminant plumes are approaching the operable unit: a tritium plume from the northwest and a plume from the southwest that contains technetium and nitrate. Remediation of these plumes will be covered under feasibility studies for other operable units at the Hanford site. In addition, monitoring (without active remediation) is the proposed remedy for the 1100-EM-1 operable unit (DOE-RL 1992e), which is considered the source of the technetium-nitrate plume. Therefore, these plumes are addressed only to the extent that they affect remediation of target contaminants from the 300 Area.

Tritium represents a special case because it is technically infeasible to limit discharges of tritium to the Columbia River. Most of the tritium plume currently entering the river is in the 600 Area to the north of the 300-FF-5 operable unit. Tritium discharges to the Columbia River along the 300 Area are below MCLs, but above MTCA Method B and C cleanup standards. It may be advisable to waive ARARs pertaining to tritium as allowed by Section 121 of CERCLA.

6.3 ASSEMBLY AND SCREENING OF REMEDIATION ALTERNATIVES

To assemble remediation alternatives, a list of potentially applicable technologies was developed and screened. These technologies were screened (considering site conditions and contaminants of concern) based on effectiveness, implementability, and cost (see Chapter 4 for definitions of these terms). The screening of technologies is summarized in Table 4-1. The retained technologies were then assembled into a wide range of alternatives for remediation of the 300-FF-5 operable unit. These alternatives will be further developed and evaluated in detail in the Phase III FS.

6.3.1 Assembly of Alternatives

Based on CERCLA guidance and the NCP, remediation alternatives are developed to achieve the following goals:

- Protection of human health and the environment
- Attainment of ARARs, to the maximum extent feasible
- Cost-effectiveness
- Utilization of permanent solutions and alternate treatment or resource recovery technologies, to the maximum extent practicable
- Satisfaction of the statutory preference for treatment

These remediation goals must be weighed against NEPA and NRDA considerations (e.g., habitat destruction, extirpation of endangered or threatened species, irreversible and irretrievable commitment of resources). These considerations are most relevant to alternatives that involve considerable excavation and/or construction activities.

To meet these goals, a range of alternatives was developed that includes no action (required under the NCP), limited action (e.g., institutional controls), containment, and treatment to remove contaminants from the site for offsite landfill disposal. The treatment alternatives also provide for destruction of organic contaminants, should it be determined that treatment for TCE and other chlorinated VOCs is required. However, the primary constituents of concern are metal radionuclides, which cannot be destroyed by treatment.

In order to address various degrees of active remediation, two categories of active remedial alternatives were developed: "extensive" alternatives and "selective" alternatives.

- "Extensive" remediation refers to the greatest extent of active remediation that would be performed. For alternatives involving extensive remediation, the intent would be to actively remediate all groundwater with contaminant concentrations above remediation goals.
- "Selective" remediation refers to active remediation of the most contaminated regions, allowing natural aquifer flushing of remaining contaminated areas.

Based on the foregoing considerations, the following initial list of alternatives was assembled for the 300-FF-5 operable unit:

Alternative 1:	No Action
Alternative 2:	Institutional Controls
Alternative 3:	Selective Hydraulic Containment
Alternative 4:	Selective Hydraulic Containment with In-Situ Flushing
Alternative 5:	Extensive Hydraulic Containment
Alternative 6:	Extensive Hydraulic Containment with Selective In-Situ Flushing
Alternative 7:	Selective Slurry Wall Containment
Alternative 8:	Selective Slurry Wall Containment with Minimal Extraction
Alternative 9:	Selective Slurry Wall Containment with In-Situ Flushing
Alternative 10:	Extensive Slurry Wall Containment
Alternative 11:	Extensive Slurry Wall Containment with Minimal Extraction
Alternative 12:	Extensive Slurry Wall Containment with Selective In-Situ Flushing
Alternative 13:	Selective Hydraulic Containment with a River Cutoff Wall
Alternative 14:	Selective In-Situ Flushing with a River Cutoff Wall
Alternative 15:	Selective Aquifer Dredging
Alternative 16:	Extensive Aquifer Dredging

Estimated costs for these alternatives (provided in Table 5-2) range from less than 10 million to more than 150 million.

6.3.2 Screening of Alternatives

A summary of the remediation alternatives and the screening evaluation is found in Table 5-2. The alternatives were screened based on effectiveness, implementability, and cost to derive a reduced list for detailed evaluation in the Phase III FS. The following alternatives were eliminated from further evaluation:

- Alternative 6 (Extensive Hydraulic Containment with Selective In-Situ Flushing) is not retained because of the difficulties of implementation associated with operating a complete hydraulic containment system and an in-situ flushing system at the same time. Alternative 5 (Extensive Hydraulic Containment) eventually achieves the same remediation goals and will be a simpler system to operate.

- The passive slurry wall alternatives with no groundwater extraction (Alternatives 7 and 10) are not retained because they do not provide treatment to remove contaminants and because elevated contaminant concentrations inside the slurry wall will remain indefinitely.

- Alternative 12 (Extensive Slurry Wall Containment with Selective In-Situ Flushing) is not retained because Alternative 11 (Extensive Slurry Wall Containment with Minimal Extraction) provides similar effectiveness and is easier to implement.

- The two river cutoff wall alternatives, (Alternatives 13 and 14) are not retained because Alternative 3 (Selective Hydraulic Containment) and Alternative 4 (Selective Hydraulic Containment with In-situ Flushing) would be equally effective and easier to implement for less cost. The decrease in the rate of groundwater extraction (and corresponding decrease in cost) afforded by a river cutoff wall is not expected to be large enough to justify the significant cost of the wall.

- The two excavation alternatives (Alternative 15 and 16) are not retained because other retained alternatives with equal or better long-term effectiveness have less short-term risk and are less disruptive to the environment. In addition, the effectiveness of Alternatives 15 and 16 does not justify their poor implementability and very high cost.

The following alternatives remain after screening:

Alternative 1:	No Action
Alternative 2:	Institutional Controls
Alternative 3:	Selective Hydraulic Containment
Alternative 4:	Selective Hydraulic Containment with In-Situ Flushing
Alternative 5:	Extensive Hydraulic Containment
Alternative 8:	Selective Slurry Wall Containment with Minimal Extraction
Alternative 9:	Selective Slurry Wall Containment with In-Situ Flushing
Alternative 11:	Extensive Slurry Wall Containment with Minimal Extraction

These alternatives will be further developed and evaluated in the Phase III FS.

6.4 POTENTIAL DATA NEEDS

A number of data needs were identified in the Phase I RI; these data would be useful to better define the rate of natural flushing and the need for active remediation. In addition, several studies are recommended for better development and evaluation of alternatives in the Phase III FS. However, the need for additional FS-related data is dependent on the need for active remediation (see Section 6.5).

6.4.1 Phase II RI Data Needs

The following data needs were identified in the RI and are repeated here for completeness:

- **Additional river sampling to determine the average concentrations of constituents of concern in the Columbia River.** The Phase I RI chemical data for the Columbia River were collected during a very low river stage to determine the maximum possible risk associated with the surface water pathways. Chemical data collected during high and average river stages would allow better assessment of the average risk associated with the surface water pathway.

- **Continued monitoring of the TCE and DCE plumes in the 300-FF-5 operable unit.** Because of the potential for DNAPL forms of these constituents, it is not possible to estimate future concentrations of these constituents. Continued monitoring of these constituents will allow predictions of future concentrations based on empirical trend analyses, and allow a better assessment of the need for remedial action for these contaminants.

- **Filtered and unfiltered uranium analyses.** Uranium analyses reported in the RI were performed on unfiltered groundwater samples. Because uranium tends to sorb onto soil particles, a significant portion of the uranium may be associated with suspended solids (colloids) that may be filtered out during extended pumping (such as would be conducted in a production well as opposed to a monitoring well). Initially, chemical analysis should be performed on filtered and unfiltered split samples (using a variety of filter sizes) to determine the partitioning of uranium between dissolved phase and suspended solids (colloids) in groundwater. Similar split sampling should be conducted during any long-term pump test. This information will be useful not only for refinement of the risk assessment in the Phase II RI, but also to support detailed evaluation of alternatives in the Phase III FS.

- **Batch uranium solubility testing.** It is not now known whether concentrations of uranium in groundwater are controlled by equilibrium or kinetics. Information on the equilibrium concentration of uranium and the time to reach equilibrium is useful for predicting future uranium concentrations. This information would also be useful for the Phase III FS, allowing better evaluation of the remedial alternatives. Additional information on groundwater chemistry (such as Eh) is needed to aid in predicting uranium solubility under changing conditions.

- **Batch testing to determine soil/water partitioning of uranium.** Data on the soil/water partitioning coefficient (K_d), the linearity of the Freundlich isotherm, and the reversibility of adsorption are needed to better estimate the transport of uranium out of the aquifer into the Columbia River and to predict future risk. This information would also be useful for the Phase III FS to predict the duration of pumping necessary to achieve remedial action objectives.

- **Site-specific background determination for uranium.** If MTCA Method B cleanup standards are used for remediation of the 300-FF-5 operable unit groundwater, the site-specific background concentration of uranium is important. As stated in MTCA, cleanup standards shall not be lower than background concentrations. Area-specific background and Hanford Site background levels for uranium in groundwater appear higher than MTCA Method B standards. Unfortunately, the Hanford Site background may not adequately represent the 300 Area background. In addition, high uncertainty exists about the area-specific background because of the location of wells, the small number of samples obtained for analysis, and the high variability in analytical results. To delineate the area and volume of contaminated media to satisfy MTCA Method B cleanup standards, area-specific background concentrations of uranium in groundwater need to be refined. High analytical precision and accuracy, with lower detection limits, are necessary. Filtered and unfiltered samples should also be taken to better understand this variability. Additional background monitoring wells may be necessary for better areal representation, particularly in the northwest portion of the 300-FF-5 operable unit.

All of these data would also be useful for better development and evaluation of the remediation alternatives for the 300-FF-5 operable unit in the Phase III FS.

6.4.2 Phase III FS Data Needs

Treatability studies are not recommended until the need for active remediation has been determined. If it is determined that active remediation will be required, then the following studies are recommended to allow more accurate, reliable and efficient development and detailed evaluation of remedial action alternatives:

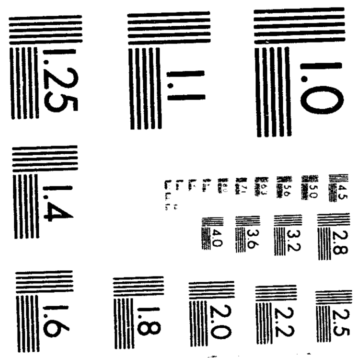
- **Bench-scale testing of ion exchange and reverse osmosis.** In all likelihood, the primary groundwater treatment technology will be either ion exchange or reverse osmosis. While general considerations favor ion exchange, the uncertainties are such that the choice could be affected by site-specific factors. Therefore, bench-scale testing of these technologies should be performed to determine site-specific values for (1) removal efficiencies and (2) the degree of concentration of the contaminants in the secondary liquid wastes from these processes.

- **Uranium sorption by a soil/bentonite slurry wall.** General considerations of metal adsorption by clays suggest that a soil/bentonite slurry wall may remove uranium from groundwater as it passes through the wall. This could affect the evaluation of the effectiveness of alternatives with slurry walls.

- **Pilot slurry wall construction.** Although it is expected that a slurry wall could be constructed for the 300-FF-5 operable unit, the feasibility of slurry wall construction is uncertain. Major difficulties are possible with sidewall collapse, considering the coarse soils and the required depth of the wall (33 m, or 100 ft). Even if construction is feasible, the cost of installation could vary significantly, which would affect the comparison of slurry wall and hydraulic containment. Therefore, construction of a pilot slurry wall in the 300 Area is advisable for accurate evaluation of the implementability and cost of slurry wall alternatives.

- **Pump testing.** Groundwater flow data specific to the 300 Area are needed for accurate conceptual design and evaluation in the Phase III FS. Chemical analyses should be performed on groundwater samples after sustained pumping to provide data on actual contaminant removal requirements (i.e., what a groundwater treatment system would actually receive from an extraction system). It is likely that the concentrations of uranium and other contaminants will be much lower under extraction conditions than static well concentrations.

- **In-situ flushing treatability study.** This study would determine the effectiveness of enhancing uranium solubility under site conditions, and would include (1)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laboratory determination of the most effective and the most cost-effective leaching solutions, and (2) laboratory determination of the variation in leaching effectiveness across the range of uranium soil concentrations found in 300-FF-5 aquifer soils. If in-situ leaching appears promising, a pilot (field) study would be necessary to determine its effectiveness under the heterogeneous site conditions.

All of these data would be useful for better development and evaluation of active remediation alternatives for the 300-FF-5 operable unit in the Phase 3 FS.

6.5 CONCLUSIONS

Sixteen alternatives were identified for meeting remedial action objectives at the 300-FF-5 operable unit, including: alternatives that rely on natural recovery (No Action and Institutional Controls), alternatives that provide active remediation of the highest contaminant concentrations and natural recovery of remaining contamination, and alternatives that provide extensive active remediation. Eight of these alternatives remain after screening based on effectiveness, implementability, and cost.

As discussed in Section 2.5, the current incremental cancer risk due to 300 Area groundwater is estimated to be approximately $2x10^{-5}$, based on exposure to the existing industrial well. However, there is no unacceptable risk to human health or the environment provided direct exposure to contaminated groundwater is prevented. In addition, groundwater contamination due to 300 Area operations may decrease below levels of concern by the year 2018. Therefore, it appears that the Institutional Controls alternative deserves strong consideration. Unlike many sites, where institutional controls would be required indefinitely, they would only be required at this site for a relatively short time. Institutional controls can be considered highly reliable as long as the Hanford Site remains under DOE jurisdiction (presumably until at least the year 2018).

The primary purpose of remedial action would be to accelerate remediation of the 300-FF-5 operable unit. However, active remediation of groundwater could not begin until after completion of (1) necessary treatability studies (discussed in Section 6.5.2), (2) the alternative selection process, (3) remedial design of the selected alternative, (4) selection of remediation contractors, and (5) construction of groundwater extraction and treatment systems. Because of the time required to complete all of these activities, active remediation would likely begin in the next two to five years. Given the modelling results indicating that natural flushing may achieve remediation goals within 10 years, the benefits of installing and operating an active remediation system may be minimal.

In addition, the impact of the upgradient plumes must be considered. If these plumes will require institutional controls, beyond the time when 300 Area contaminants are below levels of concern, then the desirability of active remediation for the 300-FF-5 operable unit is greatly diminished. Furthermore, incentives for remedial action must be balanced against NEPA and NRDA issues. Any construction activity associated with remedial action will increase adverse ecological effects, such as habitat destruction and disturbance of wildlife.

The extent of remedial action (i.e., the remediation area) will significantly affect the implementability and cost of remediation alternatives. The adverse effects of remedial action would be less with a smaller remediation area (i.e., "selective" remediation, discussed in

Section 5.1.2). Before detailed evaluation of a number of active remediation alternatives is warranted, the need for active remediation should be determined. The required extent of active remediation should be part of this determination. Final determinations on ARARs, particularly the applicability of MTCA Method B, will also affect the need for remedial action. Given these factors, it is recommended that the Phase III FS focus on the need for remedial action and the appropriateness of institutional controls as the primary method of ensuring protection of human health and the environment.

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