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Chromium in River Substrate Pore Water and Adjacent Groundwater: 100-D/DR Area, Hanford Site, Washington

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Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Bechtel Hanford, Inc.
Richland, Washington

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Author(s): S. J. Hope
R. E. Peterson

Approval: J. D. Isaacs, Groundwater Project Engineer

R. P. Schroeder FOR J. D. ISAACS — 9-26-96
Signature — Date

G. C. Henckel, Manager
Groundwater Project

[signature] — 9/26/96
Signature — Date

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Authors

S. J. Hope
R. E. Peterson

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EXECUTIVE SUMMARY

Groundwater underlying the 100-D/DR Reactor Area discharges into the Columbia River in the vicinity of fall chinook salmon (*Onchorynchus tshawytscha*) spawning habitat within the Hanford Reach. This groundwater is contaminated with hexavalent chromium at concentrations that exceed the U.S. Environmental Protection Agency's chronic ambient water quality criterion of 11 μg/L (EPA, 1986). At concentrations above 11 μg/L, hexavalent chromium is considered toxic to aquatic ecological receptors.

The methodology designed and implemented to obtain pore-water samples from salmon spawning habitat located near the 100-H Area in early 1995 was successfully employed at the 100-D/DR Area. Divers obtained pore water from a depth of 46 cm (18 in.) in the substrate, which is deeper than the 10 to 40 cm (4 to 16 in.) substrate depth typically excavated by fall chinook salmon during spawning. Hexavalent chromium was detected at levels above acute (16 μg/L) and chronic (11 μg/L) ambient water quality criteria at 19 of 100 pore-water sample sites.

Hexavalent chromium in pore water was detected at concentrations exceeding chronic ambient water quality criteria in two portions of the river substrate study area. The area where hexavalent chromium is elevated represents approximately one-third of the total study area. Suitable spawning habitat, as assessed by grain size, concretion, and embeddedness of the substrate, is present in approximately one-tenth of the study area, and only a small portion of that suitable spawning habitat coincides with the area contaminated by hexavalent chromium. This common area is adjacent to the extraction well network that is part of the interim remedial action.

A new methodology to obtain groundwater samples from the aquifer along the Columbia River shoreline was successfully implemented. Samples were collected at multiple depths in the aquifer to characterize the vertical distribution of hexavalent chromium. Samples obtained from shoreline sampling tubes have confirmed the presence of chromium in the aquifer that discharges to the river. Two areas have been identified: One area has already been incorporated into an interim remedial action that is currently being implemented, while the second area is a newly identified area in the southwest corner of the 100-D/DR Area.

ACKNOWLEDGEMENTS

This field investigation was made possible with the support of the U.S. Department of Energy (DOE) and the Environmental Restoration Contractor (ERC) Team, which is comprised of Bechtel Hanford, Inc, CH2M HILL Hanford, Inc., IT Hanford, Inc., and Thermo Hanford, Inc. The authors thank the DOE River Sites Restoration Division, the U.S. Environmental Protection Agency, and the Washington State Department of Ecology, which supported this innovative groundwater contaminant pathway investigation. Appreciation is also expressed to Doug Bowers, Rick McCain, Chris Kramer, Rich Mahood, Monty Mehlhorn, and Clay Smith of the ERC field team, and Khris Olsen and Sergey Kucheryavyy of Battelle Pacific Northwest National Laboratory who met the schedule demands of a rigorous field effort. The beneficial consultations of the National Oceanic and Atmospheric Administration Diving Center's Director, Cliff Newell, and National Marine Fisheries Service's Unit Diving Supervisor, George Swan are appreciated.

The success of this field investigation would not have been realized without the expertise of subcontractors Frank Cobb and Bud Massengale for designing and rigging the dive-sled, tow-boat, and underwater equipment necessary to meets the special conditions required to conduct Hanford Reach riverbed sampling and survey activities.

The ERC gratefully acknowledges the cooperation and assistance of the Grant County PUD Power Dispatching Department and the operators at the Priest Rapids Dam facility. The efforts of the dam operations organizations greatly assisted the ERC project team by controlling river flows, which made the in-river sampling and hydrological analysis aspects of this project possible.

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LIST OF TERMS

AA	atomic absorption
AdSV	adsorptive stripping voltammetry
~	approximately
AWQC	ambient water quality criteria
BHI	Bechtel Hanford, Inc.
cm	centimeter
CPVC	chlorinated polyvinyl chloride
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
ERC	Environmental Restoration Contractor
ft^3/s	cubic feet per second
ft	feet
HEIS	Hanford Environmental Information System
ICP	inductively coupled plasma
in.	inch
kg	kilogram
m	meter
m^3/s	cubic meter per second
MDL	method detection limit
mg/L	milligram per liter (= ppm)
mL	milliliter
NTU	nephelometric turbidity unit
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion (= μg/L)
QC	quality control
QES	Quanterra Environmental Services
redds	chinook salmon egg nests
SCUBA	self contained underwater breathing apparatus
SDM	sample and data management
SSA	syringe sampling apparatus
μg/L	microgram per liter (= ppb)

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1.0 INTRODUCTION

This report describes a field investigation of groundwater discharging from the 100-D/DR Reactor Area into the Hanford Reach of the Columbia River. This section of the Hanford Reach is used by fall chinook salmon (*Onchorynchus tshawytscha*) as spawning habitat. The field investigation focused on hexavalent chromium in river substrate pore water, river water, riverbank seepage, and the Hanford Site aquifer at the shoreline. The data are used to establish a baseline for chromium concentrations in river substrate pore water and in the aquifer near the river. This baseline will help assess the potential for exposure of ecological receptors to contaminated groundwater discharges and support groundwater remediation activities. The Hanford Reach is the portion of the Columbia River adjacent to the Hanford Site (Figure 1-1).

Hexavalent chromium is present in the groundwater underlying several reactor areas along the Columbia River in the northern portion of the Hanford Site. The chromium contamination is a result of former reactor operations, which generally ended in the mid-1960s. Groundwater underlying the reactor areas discharges into the Columbia River primarily through the riverbed substrate and secondarily via riverbank seepage that is exposed during low river stage.

Based on the success of the initial pore-water investigation conducted at the 100-H Area (Hope and Peterson, 1996), the project to characterize groundwater movement into the Columbia River was expanded to conduct comprehensive investigative efforts at 100-D/DR, 100-K, and 100-H Areas during fiscal year 1996. However, Columbia River Basin flooding, which began in late November 1995 and continued throughout the winter and spring of 1996, interrupted field sampling. Sampling was completed only at the 100-D/DR Reactor Area. Planned sampling at 100-K and 100-H Areas has been postponed.

The ecological receptor of concern in the Columbia River, with respect to contaminant exposure for this report, is the embryonic life stage of the fall chinook salmon. This receptor was selected because the developing salmon are non-motile and could be chronically exposed to chromium from groundwater discharge through the Columbia River substrate. The early life stages (i.e., egg, alevin, and fry) of locally spawned fall chinook salmon may be particularly susceptible to the toxic effects of contaminant exposure. Salmon in these life stages spend a significant portion of their life cycles within or near the substrate of the river. Of particular concern are spawning areas adjacent to known groundwater contamination associated with the retired production reactors.

The zone in the riverbed substrate where the groundwater meets the Columbia River may vary in depth with the seasons and with daily river stage cycles. The current hypothesis is that the greatest potential for flow from the unconfined aquifer into the Columbia River occurs when the water table gradient towards the river is the steepest (e.g., when river discharge is low). This typically occurs in late summer and early fall after the spring runoff and before winter precipitation. During that period, the groundwater/river water mixing zone should occur at the shallowest depth in the riverbed substrate. Because fall chinook salmon use this substrate to a depth of 10 to 40 cm (4 to 16 in.) to deposit their eggs in late October/early November

(Chapman, et al., 1986), the eggs are susceptible to potential groundwater contaminant exposure for the 90-day period between fertilization and "swim-up". As the seasonal water cycle continues and the river levels rise, the mixing zone is expected to occur at greater depths in the substrate. This would be advantageous for the contaminant-sensitive alevin, which hatch about 60 days after the eggs are fertilized and swim up out of the gravel as fry. The fry begin their migration to the Pacific Ocean approximately 30 days after hatching.

A summary of groundwater contamination in the 100-D/DR Reactor Area and a review of the principal aspects of the interaction between Hanford Site groundwater and the Columbia River are included as background information. The report concludes with a discussion of pore-water and shoreline aquifer sampling results and preliminary data interpretations.

1.1 EPA'S DATA QUALITY OBJECTIVES PROCESS

The U.S. Environmental Protection Agency's (EPA) Data Quality Objectives (DQO) Process was followed in designing a field sampling program to acquire new environmental data for characterizing the presence of hexavalent chromium contamination at ecologically sensitive locations in the river. The DQO established for the sampling program was achieved for the 100-D/DR segment of the planned study but not for the 100-K and 100-H Areas. Data for these areas were not collected because of unanticipated Columbia River flooding.

1.2 INVESTIGATION OBJECTIVES

The objectives of the sampling program derived from the DQO process follow:

- Establish a baseline for chromium concentrations in river substrate pore water in areas that are presumed to be influenced by the groundwater contaminated by chromium that is discharging from the 100-HR-3 and 100-KR-4 Operable Units.

- Provide observational information on the distribution of habitat suitable for salmon spawning adjacent to the 100-D/DR, 100-K, and 100-H Areas.

- Obtain field measurements of selected water quality indicators in river substrate pore water. These measurements will be used for comparison with groundwater data from nearshore wells, riverbank seepage, and aquifer sampling tubes at the shoreline.

- Enhance the conceptual site models for the 100-Area groundwater plume(s) and their interaction(s) with the Columbia River.

The Columbia River substrate pore-water sampling program provides basic information on groundwater quality from the river substrate, riverbank seepage, and the aquifer at the shoreline to characterize contamination in the river environment. This information serves as a baseline to

assess the performance of the 100-Area groundwater remediation activities (e.g., pump-and-treat systems), and to support selection of a final remediation alternative for each operable unit.

1.3 CONCEPTUAL SITE MODEL FOR CHROMIUM CONTAMINATION IN THE 100-D/DR AREA

Contamination of soils and groundwater by chromium is the result of past practices involving liquid effluent disposal and spills/leakage associated with reactor operations. Nearly all of these operations became inactive by the mid- to late-1960s, with the exception of disposal of chromium-bearing solutions at 100-N, which continued into the early 1970s. Chromium currently observed in groundwater is presumed to reflect residual amounts from more extensive contamination that existed during Hanford's operating years.

The following sections describe in more detail the present distribution of chromium in groundwater, suspected chromium sources, and how chromium moves with groundwater into the Columbia River environment.

1.3.1 Chromium in 100-D/DR Area Groundwater

The distribution of chromium in 100-D/DR Area groundwater is shown in Figure 1-2. This map illustrates the average chromium concentration in filtered water samples that were collected primarily in February and August 1995. Contour lines indicate the geographic extent of the chromium plume. These lines are dashed where boundaries are inferred because of limited monitoring well coverage.

Water table contour lines are included on the map (Figure 1-2) to illustrate the general direction of groundwater movement. Groundwater flow is oriented perpendicular to the contour lines and is typically toward or subparallel to the Columbia River. Direction of movement has been considered when drawing the chromium plume contours.

There is greater confidence in the chromium plume portrayal for the northeastern portion of the 100-D/DR Area than for the southwestern portion. This results from more extensive monitoring well coverage and better information on potential sources for chromium. The dashed plume boundaries shown in the southwest portion are inferred largely on the basis of river substrate pore-water and aquifer samples at the shoreline. The distribution and concentrations do not change appreciably from year to year as indicated by previous sampling conducted for the remedial investigation.

Little information is available to describe the vertical distribution of contamination in the aquifer. The saturated thickness of the unconfined aquifer that is potentially contaminated ranges from 1.5 to 6 m (5 to 20 ft). For groundwater flow modeling purposes, a thickness of 5 m (16 ft) is assumed for the unconfined aquifer (DOE-RL, 1996). It is uncertain whether chromium contamination extends throughout this entire thickness because no observational data are available to accurately define the thickness of the contaminated layer.

Most monitoring wells have a screened opening that extends approximately 3 m (10 ft) below the water table and monitors the unconfined aquifer. An exception is well 199-D8-54B, which has a screened interval approximately 24 m (80 ft) below the water table and monitors the unconfined aquifer. While unfiltered water samples from 199-D8-54B show occasional detections of total chromium at concentrations up to 100 μg/L, filtered sample results are generally below typical quantitation limits (approximately 12 to 16 μg/L). The unfiltered chromium results are not considered to indicate a chromium plume beneath the uppermost unconfined aquifer since there is no known waste disposal activity that would have contaminated this deep zone. Anomalously high chromium in unfiltered samples has been observed sporadically in other 100-Area wells, especially those constructed with stainless steel, which contain chromium.

1.3.2 Suspected Sources for Chromium Contamination

Chromium in groundwater is attributed to leakage from coolant water retention basins soil column disposal of liquid wastes associated with decontamination activities and leakage/spillage of concentrated sodium dichromate stock solution. General locations for these various source facilities are shown in Figure 1-2. A tabular summary of waste sites that are potential sources for chromium is in Appendix A. Reactor operations and associated liquid effluent-generating activities are described in the *100-D Area Technical Baseline Report* (Carpenter, 1993). The following summary is derived from that report.

The 107-D/DR coolant water retention basins received enormous volumes of reactor coolant on a routine basis. Daily reactor use ranged from 148 to 204 million gallons (561 to 773 million liters). The coolant contained sodium dichromate, which was added as a corrosion inhibitor, at a concentration of approximately 2 milligrams per liter (mg/L). When sodium dichromate is fully dissociated in water, the resulting chromium concentration is approximately 700 μg/L. The valence state for this dissolved chromium is hexavalent, which is the soluble form of chromium that is most toxic to aquatic life. The other common form is trivalent chromium, which is relatively insoluble and found in solid materials (e.g., suspended particulate matter or coatings). It is much less toxic to aquatic life (Eisler, 1985).

Leakage from coolant water piping and retention basins, which may have been up to several million liters per day at times, created artificial mounds on the natural water table. These mounds altered the pattern of groundwater movement and caused widespread dispersal of chromium throughout the reactor area. Some of the contaminated water probably moved upgradient relative to the natural flow direction. When operations ceased, the mounds dissipated and groundwater flow resumed its natural flow direction carrying with it contamination that had been forced upgradient by the mounding. Current plume maps may reflect some of this contamination.

Acid solutions, which included chromic acid, were used to decontaminate equipment associated with reactor operations. Used decontamination solutions contained metals and radionuclides, and were typically disposed to soil column facilities located near the reactor buildings (i.e., cribs, french drains, and trenches). Compared to coolant water from retention basins, decontamination solutions represent relatively low-volume, high-concentration sources for chromium disposed to

the soil column and subsequent migration downward to groundwater. For example, the 105-D storage basin trenches located near the 105-D reactor building received millions of liters of liquid wastes that included 1,700 kilograms (kg) of sodium dichromate.

Concentrated sodium dichromate stock material used in reactor coolant water was stored in liquid and solid form in tanks at several locations near the 105-D reactor building. Piping carried stock solutions to the 190-D building where it was added to freshly prepared coolant water. The storage tanks, transferring equipment, and piping frequently leaked sodium dichromate, thus contaminating the underlying soil column.

Process sewers were used to carry away a variety of nonradioactive liquid effluents from reactor operations such as backwash from the water treatment plant filters and floor drains. They also received overflow from coolant water makeup and storage facilities. Chromium is presumed to have been frequently present in process sewer effluent, which was discharged directly to the Columbia River via outfall structures. Therefore, the 1904-D, 1904-DR, and 1907-DR outfalls may represent historic, and possibly current, point sources for introducing chromium to the river environment.

Chromium concentrations currently observed in the 100-D/DR Area are thought to be the result of slow, downward diffusion of contaminated moisture from the overlying soil column and possibly by the influx of contaminated water from upgradient regions. An additional potential source is sodium dichromate that continues to migrate from contaminated soil near the 105-D Reactor Building.

1.3.3 Chromium Movement into the River Environment

Because the elevation of the water table under the Hanford Site is higher than the average elevation of the river, groundwater from the uppermost part of the unconfined aquifer underlying the reactor areas discharges into the Columbia River. The rate at which groundwater enters the river is uncertain but presumed to be considerably less than the discharge of the river, which falls in a normal range of 2,266 to 5,664 m^3/s (80,000 to 200,000 ft^3/s). A very simplistic estimate, which is based on aquifer thickness and rate of groundwater flow, suggests that 0.0054 m^3/s (0.19 ft^3/s) of chromium-contaminated groundwater discharges into the river from the 100-D/DR-Area aquifer.

One objective of the river substrate and shoreline aquifer sampling project is to enhance the conceptual site model for chromium contamination. An understanding of how groundwater and river water interact is important when assessing potential risks to human and ecological receptors. The interaction occurs in two zones: A bank storage zone and a riverbed substrate zone. These zones are illustrated in Figure 1-3.

The bank storage zone is formed by river water moving into the riverbank during high-river stage. A high-river stage also forms a dam that retards the natural flow of groundwater toward the river. The combined effect is called bank storage (Newcomb and Brown, 1961). Groundwater and river water may be mixed and/or layered within bank storage. During low

river stage, bank storage drains back to the river often revealing itself as riverbank seepage. This seepage varies in composition from river characteristics to a mixture of groundwater and river water. Existing observations of bank seepage water quality rarely indicate that it is pure groundwater (Peterson and Johnson, 1992).

Groundwater also meets river water in the riverbed substrate. There is uncertainty about depth and dimensions of the zone of interaction within the substrate where this occurs. Adding to the complexity of interaction in this zone, is the flow of river water through the pore spaces of the riverbed sediments. This pore-water flow is probably highly variable and dependent on sediment texture, daily river stage fluctuations, and seasonal discharge conditions. Where the river substrate consists of unconsolidated gravelly sediment, it is likely that groundwater and river water become mixed before discharging into the free-flowing stream of the river.

Pathways of concern for dispersion of chromium by groundwater flow include human and ecological exposure to riverbank seepage; uptake by aquatic plants and animals in the riparian zone (the riverbank environment); and ecological exposure in continuously submerged habitat such as salmon redds. The interaction involves multiple physical, chemical, and biological processes. Awareness and understanding of these processes help to reduce uncertainty in risk assessments.

Figure 1-1. 100-D/DR Reactor Area

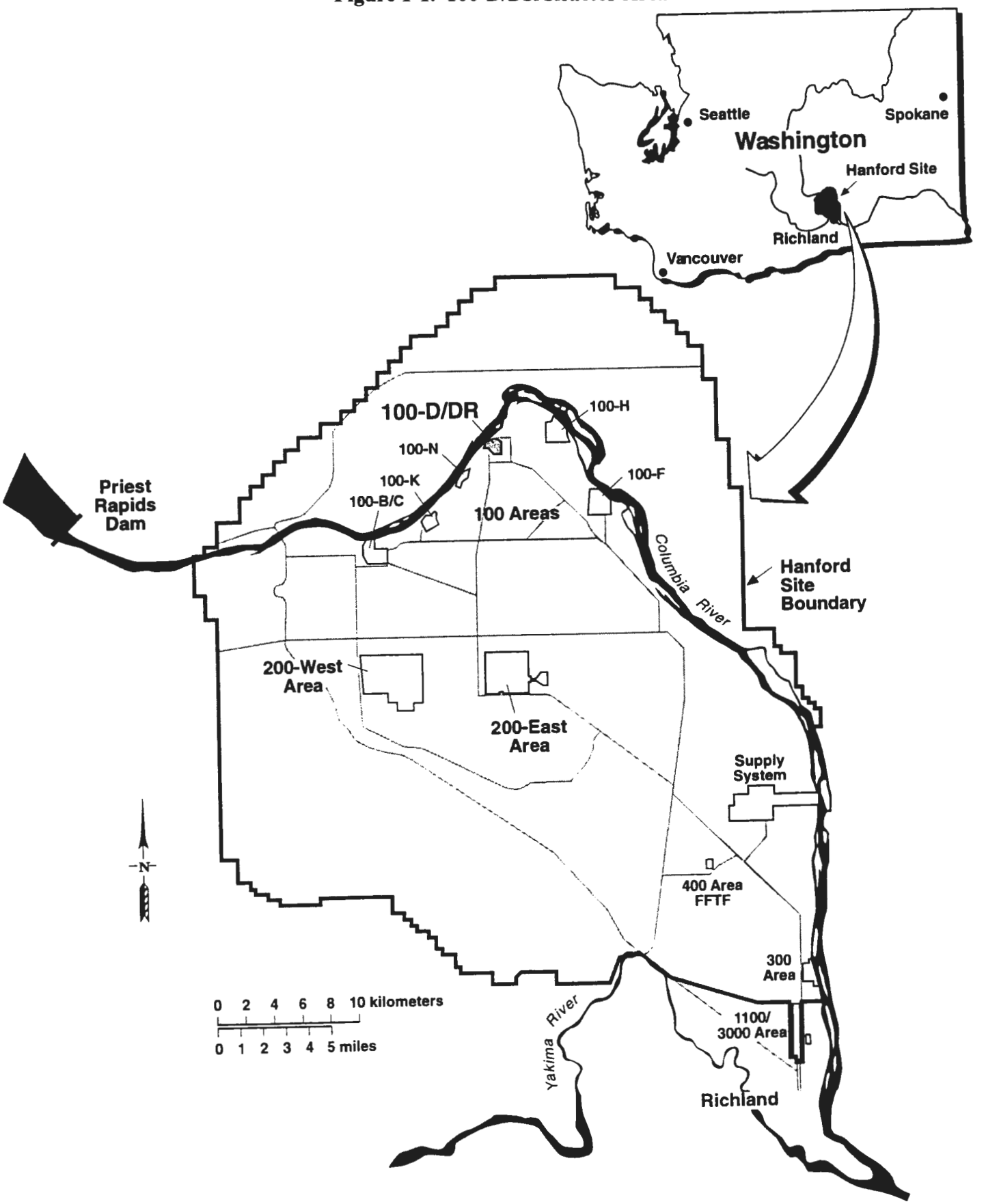

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Figure 1-2. Chromium in 100-D/DR Area Groundwater.

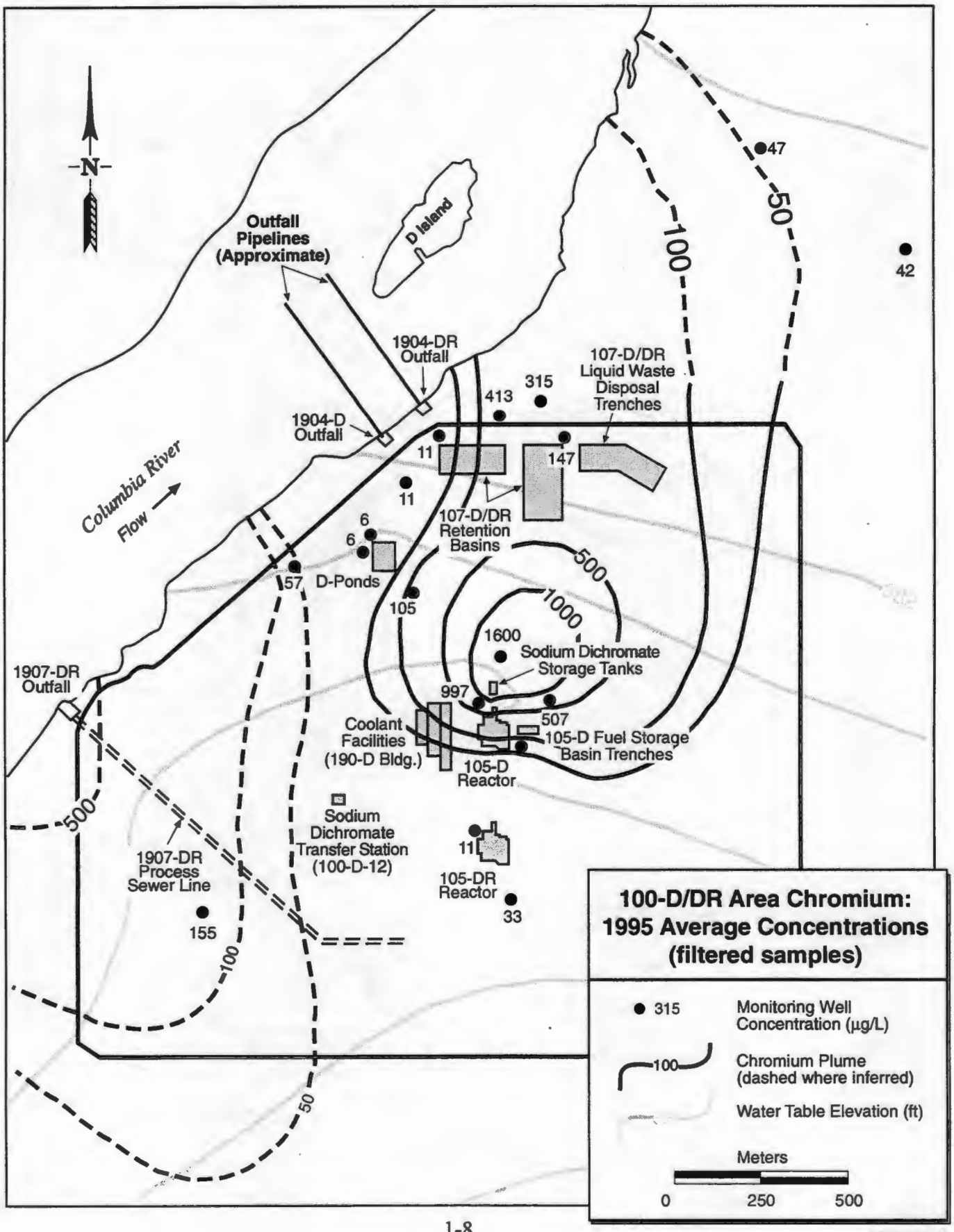

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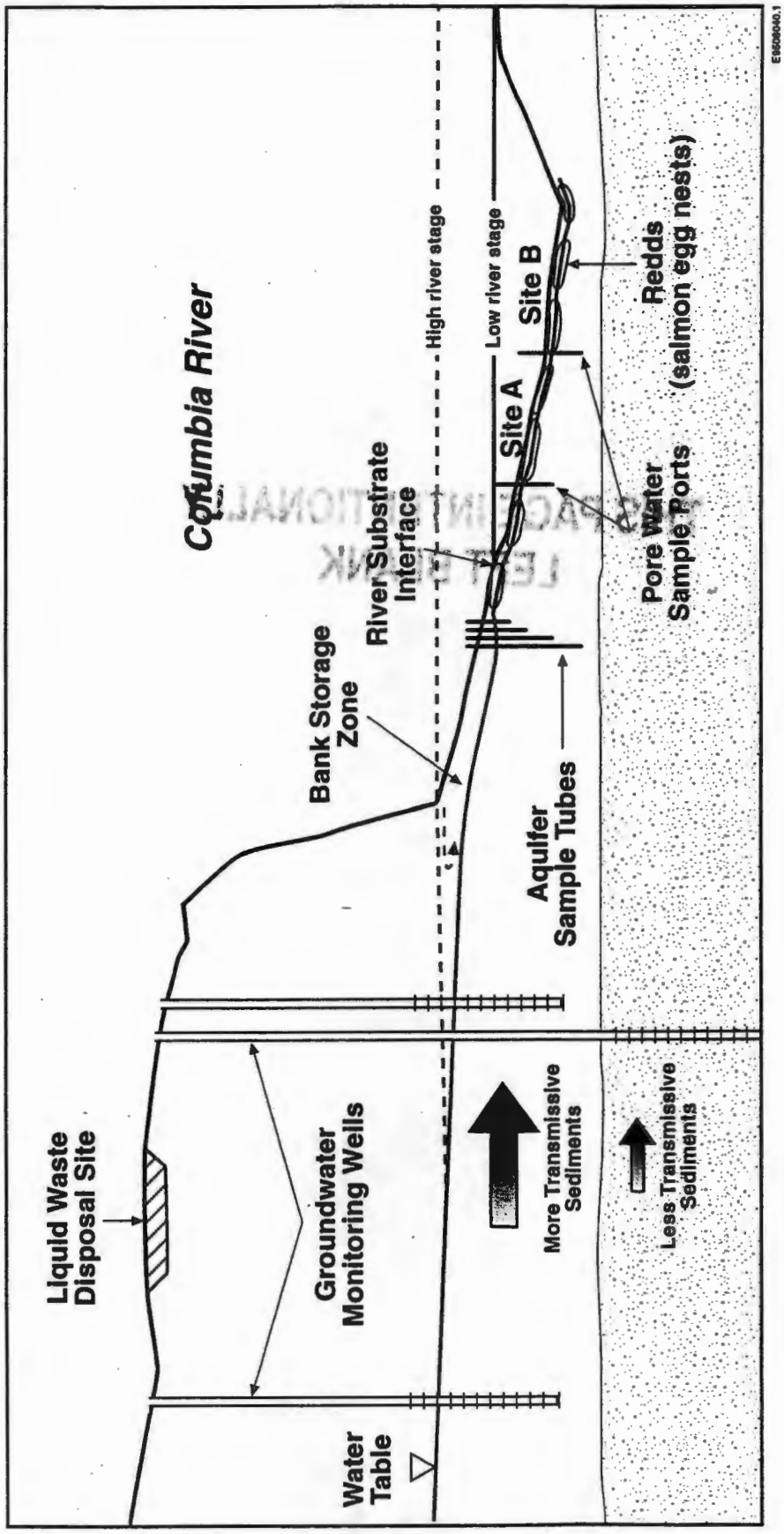
Figure 1-3. Conceptual Model for Groundwater/River Interaction



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2.0 RIVER SUBSTRATE AND SHORELINE SAMPLING METHODS

This section describes the sampling locations and methods for river substrate pore-water sampling, including associated sampling of the river water column, riverbank seepage, and aquifer sampling along the shoreline. Also included are discussions of sample site locations, substrate characterization, the sampling schedule, and project safety and health.

2.1 INTRODUCTION

The general methodology for river substrate pore-water sampling and aquifer sampling from near the shoreline are presented in the following discussion.

2.1.1 Pore Water

River substrate pore-water samples were collected by Environmental Restoration Contractor (ERC) team divers. The divers used an anchored boat with a dive sled in tow that functioned as an underwater work platform in the strong river currents (Figure 2-1). An underwater pneumatic air hammer was used to penetrate the river bottom to install a sampling port at depths up to 46 cm (18 in.) into the river sediment. A syringe sampling apparatus (SSA) was inserted into the sampling port and used to extract the pore-water samples (Figure 2-2). A detailed description of the pore-water sampling equipment and methods is presented in Section 2.3.1 and in Hope and Peterson (1996).

The data collected represent an approximate worst-case scenario for embryonic fall chinook salmon exposure to contaminated groundwater. The developing salmon are potentially exposed to chromium-bearing groundwater discharge during the late-autumn/early-spring incubation period when a seasonally low river stage flow regime typically exists. During this time after adult salmon have completed spawning the sensitive embryonic life stages (i.e., alevin and fry) are present in redd-egg pockets within the river substrate.

The Grant County PUD Power Dispatching Department controlled Columbia River flows at the Priest Rapids Dam to accommodate the ERC field team's pore-water sampling activities. The lowered river flows served to limit the variability of the analytical data by: (1) compensating for the variance in the flow regime of the river and (2) facilitating river sample collection by holding flows low so that the groundwater/river interface is at its shallowest in the riverbed sediments. River flows were maintained between 991 and 2,124 m^3/s (35,000 and 75,000 ft^3/s), with an average of 1,756 m^3/s (62,000 ft^3/s), during days that diving operations and sampling were conducted (Table 2-1). When Hanford Reach flows were lowered below approximately 2,265 m^3/s (80,000 ft^3/s), the groundwater discharge was considered representative of the low-river/high-groundwater discharge pattern that could potentially result in a worst-case scenario chromium exposure for the embryonic salmon.

2.1.2 Aquifer Samples Near the Shoreline

Sampling tubes were installed in the aquifer near the shoreline at selected pore-water transect locations. The objectives for these installations follow:

- Test the methodology for obtaining samples from multiple depths in the aquifer, using simple, inexpensive technology
- Obtain hexavalent chromium measurements from the aquifer for comparison with pore-water results
- Obtain additional field observations to help delineate the horizontal and vertical extent of chromium contamination.

2.2 STUDY AREA AND SAMPLING LOCATIONS

Pore-water sampling sites and shoreline aquifer sampling sites were developed along the 100-D/DR riverbed substrate and adjacent shoreline, respectively. The shoreline aquifer sampling sites were sited to correspond with pore-water sampling sites where potentially significant hexavalent chromium concentrations were detected in the riverbed sediments. Ecological and cultural resource clearances to work along the riverbank of the 100-D/DR Reactor Area were obtained before field mobilization.

2.2.1 Pore-Water Sample Sites

The pore-water sampling study area encompassed 3,109 linear m (10,200 linear ft) of the riverbed offshore of the 100-D/DR reactor area (Figure 2-3). The upstream and downstream ends of the study area correspond to the mapped extent of chromium contamination in the 100-D/DR Area. Sample transects labeled TDP-01 through TDP-51 were set at 61 m (200 ft) intervals (Figure 2-3). Sample sites were established on the transects at 1.5 m (5 ft) and 3 m (10 ft) river depths. Sample sites designated "A" (i.e., 1.5 m [5 ft] depth) ranged from 2.7 m (9 ft) to 50 m (164 ft) from the shoreline (at ~ 991 and 2,124 m^3/s) (~ 35,000 and 75,000 ft^3/s), and sample sites designated "B" (i.e., 3 m [10 ft] depths) ranged from 11.3 m (37 ft) to 52 m (170 ft) from the shoreline at the lowered flows (Figure 2-3 and Table 2-1). Diving and sampling activities were planned to occur as precisely as possible at the 1.5 m (5 ft) and 3 m (10 ft) depths along the submerged and sloping riverbank. However, because of navigational factors associated with anchoring the tow-boat along a curving riverbank, and wind and river current influences on the tow-boat and dive-sled, the range of diving/sampling depths varied from 1 m (3 ft) to 4 m (13 ft).

Maintaining 1.5 m (5 ft) and 3 m (10 ft) water depths for pore-water sites "A" and "B" was done to provide a common basis for comparing pore-water results with shoreline aquifer sampling tube results. The objective was to obtain samples from several horizons in the aquifer at the

shoreline locations and at offshore pore-water sites "A" and "B." This results in a data set that has the greatest potential for identifying a consistent groundwater/surface water dilution factor.

Co-located pore-water samples, which were intended to evaluate the sample spacing design were collected and submitted to the laboratory at a frequency of one co-locate per ten samples. The distance of the co-locate sample was the approximate diameter of a redd (i.e., 3 to 4.6 m [10 to 15 ft]) and was centered on a pore-water sampling point.

Originally 45 transects were planned at the 100-D/DR Area. However, the unexpected discovery of hexavalent chromium above ambient water quality criteria (AWQC) between transects TDP-39 and -45 (see Figure 2-3) indicated that further sampling upstream be conducted in an effort to better characterize the boundary of contamination. Although chromium was still present at sample transect TDP-51 (at decreasing concentrations), sampling was suspended, so that the ERC field team could begin pore-water sampling activities at the 100-K Area.

2.2.2 River Water Column Sample Sites

River-water column samples were collected 2.54 cm (1 in.) above the substrate at each pore-water sample site. Results were compared to associated pore-water samples collected from a 46 cm (18 in.) depth in the substrate.

2.2.3 Riverbank Seepage Sample Sites

Riverbank seepage samples were collected from sites located in the vicinity of pore-water sampling transects (Figure 2-3). These water samples represent bank storage (see Section 1.3.3) that drains back to the river during periods of low river stage. Previous investigations of riverbank seepage (Peterson and Johnson, 1992) indicated that the characteristics of bank seepage, when exposed, vary widely with location and the timing of sample collection relative to river stage conditions prior to sampling. In general, the greater the length of time the river is at low stage, the more representative seepage becomes of groundwater. Because of the differing processes that are active in each zone of groundwater/river interaction, riverbank seepage concentrations are indirectly related to concentrations observed in pore water from offshore sites.

2.2.4 Aquifer Sampling Locations Along the Shoreline

During the initial stage of the project, aquifer sampling tubes were installed along the shoreline only where chromium was detected in river substrate pore water. This strategy was adopted because success of the experimental drive-point method to install aquifer sampling tubes was initially believed to be less certain than subsequent experience revealed. As the project progressed, additional aquifer sampling tubes were installed at some pore-water transects where hexavalent chromium was not detected in pore-water samples. This was done to provide a more comprehensive coverage of chromium contamination. Four depths were targeted for aquifer sampling ports at selected transect locations along the shoreline.

2.3 SAMPLING METHODOLOGY

The following sections describe the sampling methodologies for pore water, river water column, riverbank seepage, and the aquifer along the shoreline. A numbering scheme was adopted that identifies the location and type of sample collected. For pore-water and river water samples, an example location identifier is: "TDP-17A." The first letter "T" indicates a pore-water transect; the second letter "D" identifies the reactor area ("D" = 100-D/DR); and the third letter "P" indicates a pore-water sample. An "R" indicates a river water sample. The next group identifies the transect as number 17, pore-water site "A." A suffix "c" is added to the pore-water site letter if it is a co-located sample site (e.g., "-17Ac").

Riverbank seepage locations are numbered slightly differently: "SD-110-1" indicates riverbank seepage at 100-D/DR Area, located at Hanford River Mile 11.0, and "-1" indicates the first of several seepage sites at that general location. For aquifer samples, an example location identifier is: "DD-17-2." The first letter indicates a driven sampling tube; the second identifies the reactor area; the number "17" indicates the transect; and the number "2" indicates the depth horizon ("1" indicating the shallowest and "4" indicating the deepest sampling port).

2.3.1 Pore-Water Sampling

A 6.7 m (22 ft) inboard-outboard fiberglass boat was used to tow/hold-at-anchor a two-man dive sled. The sled was connected to the tow-boat with a 46 m (150 ft) combination tow-line/compressed gas supply line/hardwire underwater communications cable (Figure 2-1). The dive-sled has a clear plastic shield to protect the divers from the force of the river current, which was estimated up to 2.44 meters per second (8 ft per second). Nitrogen-gas cylinders on the tow-boat supplied gas pressure for the pneumatic power tools on the dive-sled via a gas supply line secured to the tow-line. A 6 m (20 ft) support jet boat was used by the divers to enter the river upstream of the dive sled, so they could drift back and mount the dive sled. The support boat was then maneuvered downstream of the dive-sled to retrieve the divers after sampling.

Pore-water sampling was accomplished by driving a stainless steel pipe and rod up to 46 cm (18 in.) into the riverbed substrate with a pneumatic air hammer then inserting a 61-cm (24-in.) chlorinated poly vinyl chloride (CPVC) sampling port through the pipe into the substrate. A SSA (i.e., 140 milliliter [mL] syringe(s) with nylon/Tygon® tubing with "O" rings, nylon hose barbs, and tubing clamps) was then inserted into the sampling port and used to extract the pore-water sample (Figure 2-2). The syringe(s) were filled slowly (i.e., ~ 140 mL/15 seconds) to prevent clogging of the sampling port inlet screen and/or SSA with silt/sand. A purge syringe was used before sample extraction to withdraw five volumes of water to remove the residual film of river water that accumulated in the sampling port during installation in the substrate and in the SSA tubing during insertion into the sampling port.

At some locations, a hardpan layer (i.e., clay-caliche) would impede penetration to the desired 46 cm (18 in.) sample port installation depth. As a result, at twenty-three of the 100 sample sites, samples were collected from 20 to 41 cm (8 to 16 in.) deep in the river substrate (Table 2-1).

Sample volumes varied according to requirements of sampling design, quality control (QC), and analytical methods, and ranged from 140 mL to 2,100 mL (i.e., 1 to 15 syringes). The infrequent requirement for a 2,100 mL (15-syringe) sample volume was necessary to accommodate combinations of QC samples (i.e., sample splits and samples duplicates) to meet sample design requirements. Samples requiring multiple syringes were homogenized in a single clean container before being submitted to the laboratories.

2.3.2 River Water Column Sampling

For comparison to pore-water samples collected 46 cm (18 in.) deep in the substrate, samples of river water were collected by the divers with a 140 mL syringe from 2.54 cm (1 in.) above the substrate at each pore-water sample location.

2.3.3 Riverbank Seepage Sampling

Riverbank seepage samples were collected using a peristaltic pump following procedures previously established for riverbank seepage sampling (DOE-RL, 1992). Samples were analyzed by the ERC Mobile Field Laboratory for the same constituents as pore-water samples. Measurements for specific conductance gave an indication of whether site groundwater or bank storage was the primary discharge to the river shoreline during pore-water sampling activities.

2.3.4 Aquifer Sampling Along the Shoreline

Aquifer sampling tubes were installed at multiple depths in the aquifer along the shoreline. Depending on site access, either the GeoProbe™ vehicle or a hand-held air hammer was used for the sampling tube installation. To install the sampling tubes, a temporary steel casing was initially driven as deeply as conditions permitted and to a depth where the formation yielded water. Sampling tubes were then sequentially installed as the temporary casing was backpulled. Ideally, a sampling port, the end of which has a two-inch long screen that acts as the sample intake, could be implanted at the following four horizons: (1) as deep as the equipment could drive the casing, (2) a horizon equivalent to pore-water Site B, (3) a horizon equivalent to pore-water Site A, and 4) immediately below the water table (see Figure 1-3). Due to substrate variability and equipment limitations, it was not possible to install sampling ports at all four target depths in all areas.

The depth-below-ground surface for each sampling port was recorded in the field. Because it was not possible to accurately survey the sampling locations during the 1995 field season, there is uncertainty in the elevation estimates for the sampling ports. A Global Positioning System (GPS) survey of acquifer sampling tube sites was completed in September 1996. The results provide accurate elevations for the sampling ports, which will be useful in future analysis of shoreline data.

Samples were withdrawn from the aquifer sampling tubes using a peristaltic pump and were analyzed using the same methods used for river substrate pore-water sample analysis. Specific conductance was monitored to provide an indication of whether the sample intake was located

within or below the bank storage zone. Each location was marked with an identifying stake and the ends of the plastic sampling tubes were labeled and secured.

The ability of the plastic tubes to survive the dynamic environment along the shoreline, given the strong river currents and fluctuating stage, was uncertain during project planning. Whether or not the screened sampling ports would remain open for long-term monitoring of the aquifer along the shoreline was also questionable. However, periodic field observations during the months following installation suggests an excellent survival rate for the plastic sampling tubes. How long the screened ports remain open and unclogged by fine sediment remains to be demonstrated by repeat sampling.

2.4 SUBSTRATE CHARACTERIZATION

An assessment of the suitability of the river bottom substrate to support salmon spawning activity (i.e., redd-egg pocket development) and egg incubation was conducted by the fisheries scientist divers during pore-water sampling activities. The relative proportions of substrate particles (i.e., boulder, cobble, gravel, pea gravel, and sand-silt) were recorded that included a qualitative evaluation of embeddedness and concretion of the riverbed sediments.

"Embeddedness" is the degree to which boulders, cobble, and gravel are surrounded (embedded) by fine sediment. The degree of substrate embeddedness provides an indication of the suitability of the river substrate as habitat for benthic macroinvertebrates, fish spawning, and egg incubation. Concretion of the cobble and gravel relates to the cementing characteristic of the fine sediments on larger sediment particles. Loose, non-concreted sediment particles, or slightly concreted fines between the gravels and cobble which could be dislodged and excavated by a nest-building salmon, were generally assessed as potentially suitable to support salmon spawning and egg incubation. Hard concretions, typically in undisturbed riverbed sediments where clay particles were interspersed with sand-silt fines that probably could not be dislodged or loosened by a nest-building salmon, were assessed as not suitable to support salmon spawning or egg incubation.

The physical characterization of the substrate was based on habitat assessment criteria discussed in the EPA's *Rapid Bioassessment Protocols* (EPA, 1989), a review of the effects of fines in salmon redds (Chapman, 1988), and the lead diver's previous experiences with Pacific Northwest salmon habitat assessment.

To conduct substrate characterization, the diver surveyed the substrate type by hand manipulation of the river sediments and visual observation of a 6+ m (20+ ft) radius of the river bottom at each pore-water sampling site. The particle/grain-size assessment information was then communicated to the tow-boat tender via underwater radio equipment. If hardpan was present, the depth of a hardpan layer (i.e., caliche-clay $\leq$ 46 cm [18 in.] deep) was also recorded when the pore-water sampling port was installed.

2.5 PORE-WATER SAMPLING SCHEDULE

Sampling occurred during 17 suitable diving days (i.e., steady winds ≤ 20 miles per hour [mph], river flows ≤ 2,265 m^3/s [≤ 80,000 ft^3/s]) from October 17, 1995, through November 19, 1995. The schedule was driven primarily by the following factors:

- River flow regime and water levels controlled by power generating demands and other water users from upstream hydroelectric generating stations (e.g., Priest Rapids Dam).
- Morning fog that sometimes delayed the daily boat launching activities and field team mobilization on the riverbank.
- Steady winds exceeding 20 mph and/or wind gusts above 25 mph which could move the boat off its anchorage.

Pore-water sampling activities were suspended in late November 1995 because of high-river discharge conditions. Precipitation events in the Columbia River drainage basin precluded Priest Rapids Dam operations' ability to continue lowering river flows to levels appropriate for pore water, riverbank seepage, and shoreline aquifer sampling.

2.6 SAFETY AND HEALTH

Diving work was performed in accordance with the "Occupational Safety and Health Administration Standards for Commercial Diving," 29 CFR 1910, Subpart T. A copy of the standards was maintained at the dive location.

Divers were certified in the use of self contained underwater breathing apparatus (SCUBA) by nationally recognized organizations and have had experience with river dives in turbulent flow regimes. Following standard buddy-system diving protocols, two divers were in the water for each sampling event. Each diver wore appropriate dive gear (e.g., drysuits with thermal liners) for cold-water diving, and each diver had buoyancy compensation control to assist in adjusting buoyancy and to maintain floatation if an emergency situation occurred. Each diver wore U. S. Navy approved full-face SCUBA masks with hard-wire voice communications to the boat-tender, pilot, and each other, to coordinate surface and subsurface activities and transfer of information. Dives did not exceed 4 m (13 ft) in depth, and dive-times ranged from 8 to 29 minutes. The divers' log, which provides dive times, depths, and underwater visibility, is shown in Appendix B.

The tow-boat was anchored and was under power to maintain position, as appropriate, for the area being sampled. The boat displayed a large diver's flag at all times to indicate to other boat traffic that divers were in the water.

The safety and health representative set up emergency response procedures with the Hanford Fire Department, maintained first-aid equipment at the field site, and supervised the rigging of

boat-to-dive-sled connections. The field person-in-charge supervised overall operations and maintained two-way radio communications with the boats. The boat tender maintained underwater communications with the divers.

Hanford Reach, Columbia River

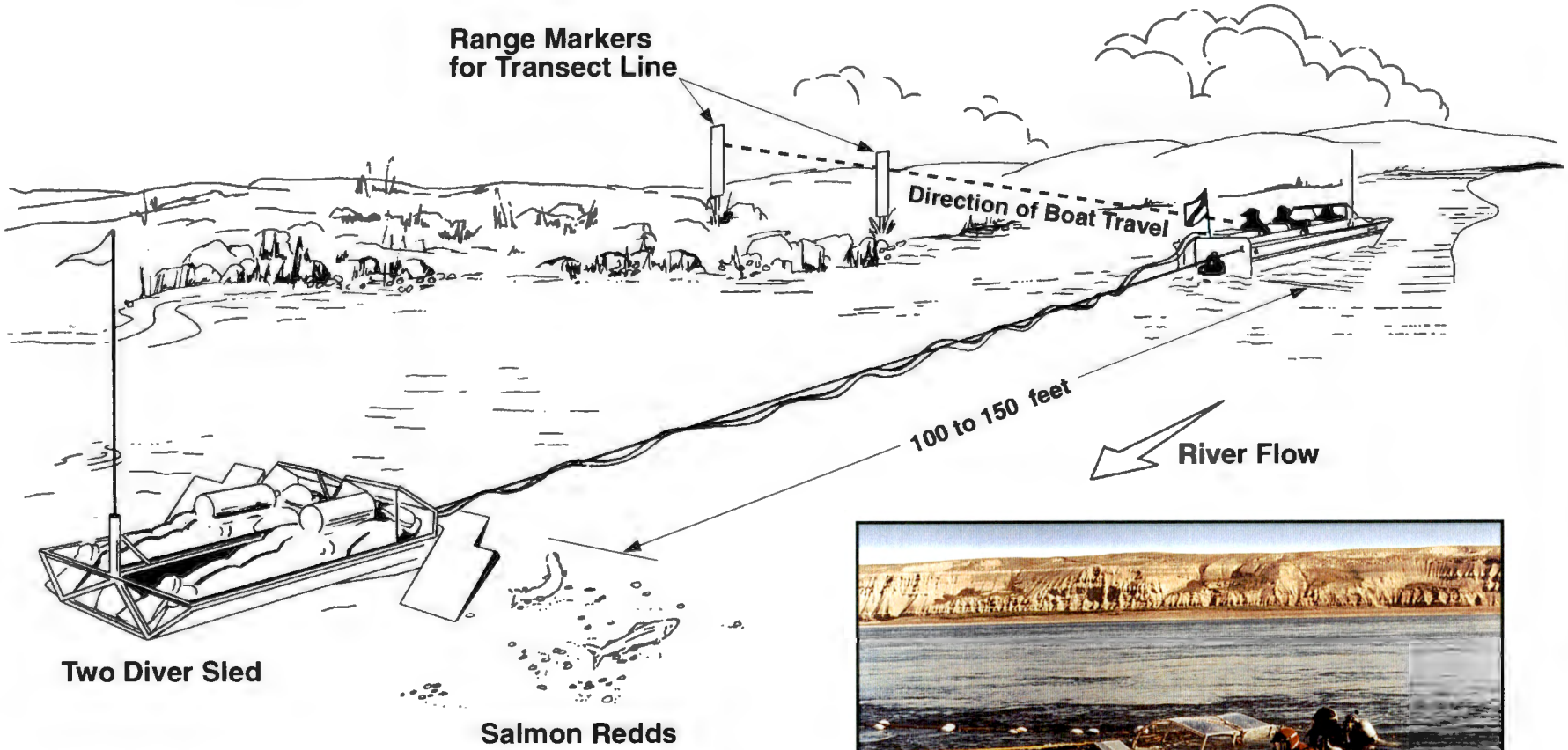

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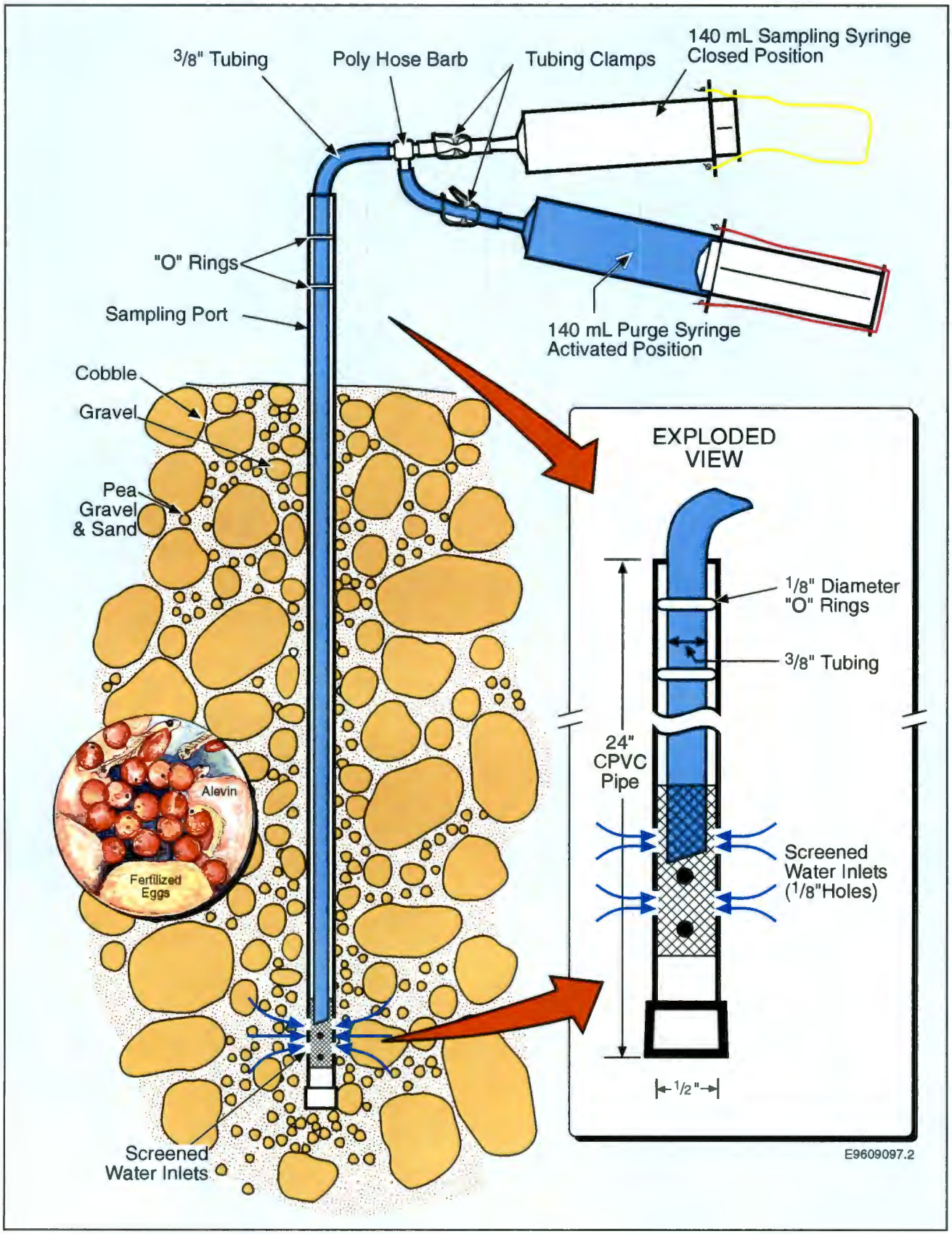
Figure 2.1. Dive Sled with Tow Boat.

Figure 2-2. Sampling Port Set 18 in. into Substrate with Syringe Sampling Apparatus.



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100-D/DR Study Area

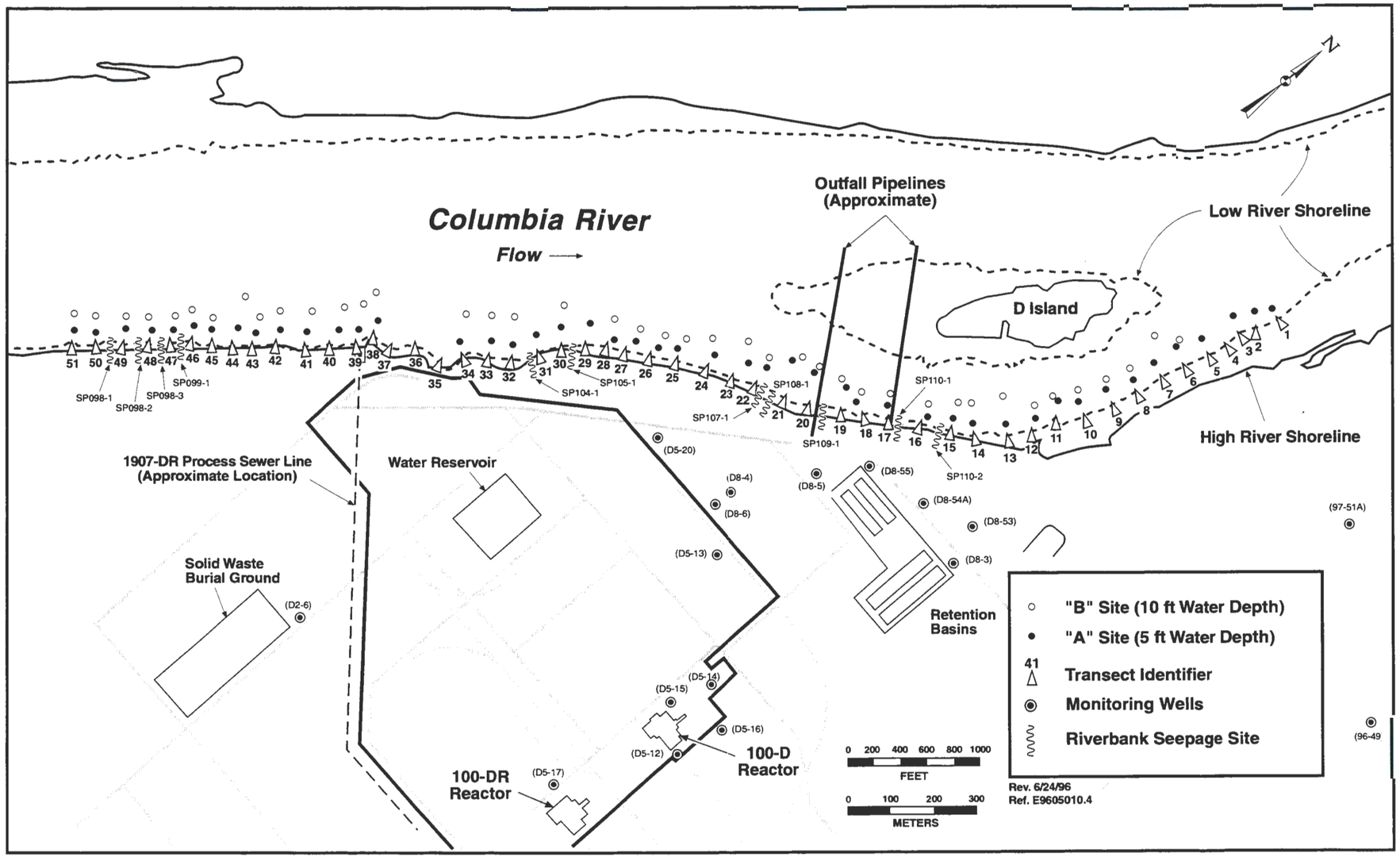

Figure 2-3. Pore-Water Sample Sites at 100-D/DR Study Area

Table 2-1. Physical Parameters at Pore-Water Sample Sites: 100-D/DR Area (Page 1 of 4)

Date	Transect/ Sample Site Number	Water Depth (ft)	Sample Port Depth (in.)	Distance from Shoreline (ft)	Priest Rapids Discharge x1000 (ft^3/s)	Elevation at River Level (ft)	Washington State Plane Coordinates		Transect Azimuth (degrees)
							Easting (m)	Northing (m)	
10/17/95	TDP-01A	7	18	40	50	377.1	574015	153260	nr
10/17/95	TDP-02A	6	18	70	50	376.8	574000	153215	nr
10/17/95	TDP-03A	7	18	68	50	376.5	573980	153175	nr
10/19/95	TDP-05A	6	18	84	65	378.1	573940	153070	287
10/19/95	TDP-06A	6	18	93	65	378.0	573920	153025	293
11/18/95	TDP-06B	11	10	65	67	378.6	573905	153040	280
10/19/95	TDP-07A	7	18	164	65	377.9	573910	152975	309
11/18/95	TDP-07B	9	18	55	67	378.7	573895	152990	284
10/19/95	TDP-08A	5	18	39	65	377.9	573900	152920	295
11/18/95	TDP-08B	13	12	85	67	378.8	573885	152935	288
10/19/95	TDP-09A	6	18	20	65	377.9	573880	152850	290
11/18/95	TDP-09B	12	16	80	67	378.9	573865	152865	291
11/18/95	TDP-09Bc	12	10	80	67	378.9	573865	152865	291
10/22/95	TDP-10A	6	18	46	35	375.7	573860	152790	291
11/18/95	TDP-10B	11	18	110	67	379.3	573845	152805	292
10/22/95	TDP-11A	7	18	64	35	375.7	573830	157760	304
11/17/95	TDP-11B	10	18	72	66.9	377.8	573815	157775	294
10/22/95	TDP-12A	5	18	54	40	375.7	573820	152700	312
11/17/95	TDP-12B	9	18	82	66.9	377.9	573805	152715	301
10/22/95	TDP-13A	5	18	52	45	376.2	573800	152635	313
10/22/95	TDP-13Ac	5	18	52	45	376.8	573800	152635	312
11/17/95	TDP-13B	6	18	165	66.9	377.9	573785	152640	308
10/22/95	TDP-14A	3	18	37	50	376.2	573750	152595	315
11/17/95	TDP-14B	6	18	120	66.9	378.1	573735	152610	308
10/27/95	TDP-15A	5	18	27	66	378.2	573700	152555	334
11/17/95	TDP-15B	6	18	100	66.9	378.1	573685	152570	330
11/17/95	TDP-15Bc	6	18	110	66.9	378.1	573685	152570	330
10/27/95	TDP-16A	6	18	32	66	378.0	573645	152520	327
11/17/95	TDP-16B	9	18	89	66.9	378.3	573630	152535	328
10/27/95	TDP-17A	6	18	22	66	377.9	573600	152470	317

Table 2-1. Physical Parameters at Pore-Water Sample Sites: 100-D/DR Area (Page 2 of 4)

Date	Transect/ Sample Site Number	Water Depth (ft)	Sample Port Depth (in.)	Distance from Shoreline (ft)	Priest Rapids Discharge x1000 (ft^3/s)	Elevation at River Level (ft)	Washington State Plane Coordinates		Transect Azimuth (degrees)
							Easting (m)	Northing (m)	
11/15/95	TDP-17B	9	18	78	68	377.8	573585	152485	319
10/27/95	TDP-18A	6	18	78	66	377.9	573535	152420	330
10/27/95	TDP-18Ac	5	18	74	66	377.9	573535	152420	330
11/15/95	TDP-18B	8	16	110	68	377.8	573520	152435	319
10/28/95	TDP-19A	6	18	117	66	377.8	573490	152380	315
11/15/95	TDP-19B	7	16	98	68	378.0	573475	152395	321
11/15/95	TDP-19Bc	7	10	95	68	378.0	573475	152395	319
10/28/95	TDP-20A	5	18	114	66	377.8	573445	152340	317
11/15/95	TDP-20B	6	18	132	68	378.2	573430	152355	321
10/28/95	TDP-21A	6	18	119	66	377.8	573380	152300	338
11/12/95	TDP-21B	7	18	105	67	377.8	573365	152315	325
10/28/95	TDP-22A	5	18	62	66	377.8	573310	152270	342
11/12/95	TDP-22B	6	16	88	67	377.8	573295	152285	328
10/28/95	TDP-23A	6	15	69	66	377.8	573255	152235	349
11/06/95	TDP-23B	10	14	150	66	377.9	573240	152250	329
10/28/95	TDP-24A	6	18	62	66	377.8	573205	152205	341
11/06/95	TDP-24B	9	18	132	66	377.9	573190	152220	334
10/29/95	TDP-25A	5	18	15	50	376.5	573155	152170	329
11/06/95	TDP-25B	9	14	76	66	378.0	573140	152185	335
10/29/95	TDP-26A	6	18	36	50	376.5	573100	152135	317
11/06/95	TDP-26B	9	18	77	66	378.0	573085	152150	331
10/29/95	TDP-27A	6	18	35.5	50	376.5	573055	152100	325
11/06/95	TDP-27B	10	18	83	66	378.0	573040	152115	328
11/06/95	TDP-27Bc	10	18	83	66	378.0	573040	152115	328
10/29/95	TDP-28A	4	10	12	50	376.4	573035	152065	332
11/06/95	TDP-28B	10	14	60	66	378.0	573020	152080	315
10/29/95	TDP-29A	7	18	60	50	376.6	572975	152025	335
10/29/95	TDP-30A	8	10	70	50	376.9	572940	151985	322
11/06/95	TDP-30B	10	18	150	66	378.1	572925	152000	330
11/05/95	TDP-31A	5	18	19	65	377.6	572930	151955	319

Table 2-1. Physical Parameters at Pore-Water Sample Sites: 100-D/DR Area (Page 3 of 4)

Date	Transect/ Sample Site Number	Water Depth (ft)	Sample Port Depth (in.)	Distance from Shoreline (ft)	Priest Rapids Discharge x1000 (ft^3/s)	Elevation at River Level (ft)	Washington State Plane Coordinates		Transect Azimuth (degrees)
							Easting (m)	Northing (m)	
10/31/95	TDP-31B	11	18	37	75	379.5	572915	151970	320
10/31/95	TDP-32A	5	18	33	75	379.2	572910	151910	298
11/05/95	TDP-32B	10	18	152	65	377.7	572895	151925	308
10/31/95	TDP-33A	5	18	30	75	378.8	572875	151870	317
10/31/95	TDP-33Ac	5	18	29	75	378.8	572875	151870	317
11/05/95	TDP-33B	10	14	170	65	377.7	572860	151885	317
10/31/95	TDP-34A	5	18	35	75	378.4	572800	151800	313
11/05/95	TDP-34B	10	18	160	65	377.7	572785	151815	325
11/01/95	TDP-38A	4	18	30	66	378.8	572630	151675	313
11/05/95	TDP-38B	10	18	125	65	377.7	572615	151680	304
11/01/95	TDP-39A	6	18	28	66	378.5	572610	151615	305
11/01/95	TDP-39Ac	6	18	29	66	378.5	572610	151615	311
11/03/95	TDP-39B	10	18	130	65	378.0	572595	151630	324
11/01/95	TDP-40A	5	18	51	66	378.3	572570	151580	319
11/03/95	TDP-40B	11	14	110	65	378.4	572555	151595	317
11/01/95	TDP-41A	5	18	34	66	378.2	572520	151530	307
11/02/95	TDP-41B	11	18	120	68.5	378.2	572505	151545	315
11/01/95	TDP-42A	5	18	37	66	378.2	572485	151495	318
11/02/95	TDP-42B	11	18	91	68.5	378.0	572470	151510	318
11/01/95	TDP-43A	5	18	46	66	378.2	572450	151440	311
11/02/95	TDP-43B	11	18	91	68.5	378.2	572435	151455	321
11/02/95	TDP-44A	6	18	26	68.5	378.8	572415	151395	310
11/02/95	TDP-44Ac	6	18	30	68.5	378.8	572415	151395	316
11/02/95	TDP-44B	11	18	148	68.5	378.3	572400	151410	322
11/02/95	TDP-45A	4	18	38	68.5	378.5	572365	151355	314
11/02/95	TDP-45B	8	15	55	68.5	378.5	572350	151370	318
11/03/95	TDP-46A	5	18	42	65	377.8	572325	151305	310
11/12/95	TDP-46B	9	14	92	67	378.1	572310	151320	306
11/03/95	TDP-47A	5	18	55	65	377.8	572290	151260	317
11/12/95	TDP-47B	9	16	68	67	378.0	572275	151275	312

Table 2-1. Physical Parameters at Pore-Water Sample Sites: 100-D/DR Area (Page 4 of 4)

Date	Transect/ Sample Site Number	Water Depth (ft)	Sample Port Depth (in.)	Distance from Shoreline (ft)	Priest Rapids Discharge x1000 (ft^3/s)	Elevation at River Level (ft)	Washington State Plane Coordinates		Transect Azimuth (degrees)
							Easting (m)	Northing (m)	
11/03/95	TDP-48A	4	18	72	65	377.8	572260	151223	317
11/12/95	TDP-48B	11	16	105	67	377.9	572245	151238	308
11/19/95	TDP-49A	5	18	70	50	378.3	572220	151175	309
11/19/95	TDP-49B	10	18	90	50	377.0	572205	151190	308
11/19/95	TDP-50A	4	18	35	50	377.7	572185	151124	316
11/19/95	TDP-50Ac	4	16	35	50	377.7	572185	151124	316
11/19/95	TDP-50B	10	18	85	50	377.0	572170	151139	310
11/19/95	TDP-51A	6	18	65	50	377.4	572135	151075	311
11/19/95	TDP-51B	10	10	77	50	377.2	572120	151090	311
11/19/95	TDP-51Bc	10	18	87	50	377.2	572120	151090	311

Notes:
Columbia River discharge from Priest Rapids Dam during sampling in thousands of cubic feet per second (ft^3/s)
Columbia River elevation is calculated using data from river stage recorders and gradient of river
Transect Azimuth is compass direction from transect marker to dive sled in degrees from true north.
nr = not recorded

3.0 SAMPLE ANALYSES, DATA MANAGEMENT, AND QUALITY ASSURANCE/QUALITY CONTROL

This section describes the laboratory analyses, data management, and quality assurance/quality control procedures applied to the river-sampling program at the 100-D/DR Area. The results of the analytical methods discussed in this section are presented in Section 4.0.

3.1 SAMPLE ANALYSES

Water samples from riverbed sediment (pore-water), river water column, shoreline aquifer, and riverbank seepage were analyzed for hexavalent chromium using two independent analytical methods. The first utilized Adsorptive Stripping Voltammetry (AdSV), and the second diphenylcarbohydrazide reaction with photometric determination (HACH method). The immediate availability of these two laboratory services permitted rapid determinations within hours of sample collection and did not require the use of preservatives. Split samples for quality control were sent to a contract lab and analyzed for hexavalent chromium using SW-846 test methods (method 7196). Information on specific methods, detection limits, minimum volume requirements, sample preservation, and analytical holding times are provided in Table 3-1. The laboratory prepared and analyzed internal QC samples including method blanks, matrix spikes, and duplicates as indicators of contamination, accuracy, and precision. Internal laboratory QC samples were prepared and analyzed at a frequency consistent with the requirements of the applicable referenced method.

Water samples were normally filtered at 0.45 microns before analysis for hexavalent chromium. At the request of the Washington State Department of Ecology, several samples of pore water and shoreline aquifer water were analyzed using filtered and unfiltered samples to test for comparability.

Table 3-1. Methods, Detection Limits, Minimum Volume Requirements, Sample Preservation, and Analytical Holding Times

Water Matrix (Filtered Sample)						
Analyte	**Method**	**Methodology**	**Preservative**	**Holding Time**	**Sample Volume**	**MDL**
Chromium (Hexavalent)	AdSV	Adsorptive Stripping Voltammetry	Cool 4°C	24 hours	10 mL	0.2[a] μg/L
Chromium (Hexavalent)	HACH 8023	Diphenyl-carbohydrazide Colorimetric	Cool 4°C	24 hours	50 mL	10[b] μg/L
Chromium (Hexavalent)	7196	AA	Cool 4°C	24 hours	400 mL	1.2[c] μg/L
Chromium (Total)	6010	ICP	HNO_3 to pH <2 Cool 4°C	6 months	400 mL	20[d] μg/L

AA - atomic absorption.
AdSV- adsorptive stripping voltammetry
ICP - inductively coupled plasma.
MDL - method detection limit.

[a] PNNL detection limit using AdSV analytical method.

[b] Mobile Field Laboratory detection limit using enhanced HACH method.

[c] The Quanterra Environmental Services, Inc., (QES) laboratory optimized the analysis system to attain the lowest detection limit below the MDL of 6 μg/L. Laboratory calculations indicate that a detection level of 1.2 μg/L was achievable. The quantitation limit is estimated at 12 μg/L.

[d] Information provided is the SW-846 estimated quantitation limit. Instrument detection limits for 1995 RCRA monitoring are 5 μg/L, and the quantitation limit is 16 μg/L.

3.1.1 Offsite Laboratories

The Pacific Northwest National Laboratory (PNNL) measured hexavalent chromium in all pore-water, river water column, shoreline aquifer, and riverbank seepage samples. Hexavalent chromium concentrations were determined using the AdSV method (Olsen and Kucheryavyy, 1995). Samples were analyzed by PNNL on the day of sampling usually within 6 hours.

Split samples were sent to the Quanterra Environmental Services (QES) Laboratory, which analyzed approximately five percent of the total number of pore-water samples for hexavalent chromium and a subset of the same samples for total chromium. All QES samples were analyzed using SW-846 standard methods.

3.1.2 ERC Mobile Field Laboratory

The ERC Mobile Field Laboratory provided quick turnaround (i.e., ≤ 30 min) field analyses for hexavalent chromium in pore-water samples using HACH methodology. The results were used for field decisions on candidate sites for shoreline aquifer sampling. Interpretation of HACH results were enhanced to provide greater resolution at the lower range of hexavalent chromium concentrations. Quantitation became unreliable at concentrations of less than approximately 10 μg/L. Correspondence between Mobile Field Laboratory results and PNNL AdSV results was excellent in the range of 10 to 50 μg/L. At higher concentrations, the HACH method tended to produce slightly lower values than the AdSV method.

In addition, the mobile field laboratory analyzed all water samples (i.e., pore water, river water column, shoreline aquifer, and seep water) for hexavalent chromium, nitrate (as NO_3-), pH, dissolved oxygen (DO), specific conductance (μS/cm), turbidity (nephelometric turbidity unit), and hardness using field analysis techniques and methods. Water samples were analyzed for nitrate because it was used in past reactor decontamination activities, is present in the groundwater, and has the potential to react with chromium (Geist et al., 1994). Water quality parameters were measured (e.g., pH, DO, temperature, hardness) because of the potential for these parameters to influence the toxicity of hexavalent chromium on aquatic life (Eisler, 1985). In future assessments of risk to developing salmon and other aquatic life, these additional parameters should be considered in addition to hexavalent chromium concentrations.

3.2 DATA MANAGEMENT

The ERC's sample and data management section (SDM) was responsible for coordinating all communications associated with sample scheduling, shipment, receipt, analysis, disposal, and/or return to the ERC. Analytical laboratories and the field sampling team provided SDM with copies of the chain-of-custody forms. Chain-of-custody information was entered into the sample management database and the receipt of results was tracked. Chain-of-custody forms were used for sample transfers. The SSA was labeled before sampling to prevent errors in sample handling and storage. When anomalies were identified, SDM worked with the project lead to establish resolution. Upon receipt, analytical results were entered into the Hanford Environmental Information System (HEIS) database for future reference.

3.2.1 Field Documentation

Standard Hanford Site procedures were followed for labeling samples, documenting collected samples and sample transfer to and from the laboratories. A field logbook was used to document field activities associated with boat anchoring, diving, and personnel activities, and to log in samples that were collected before transfer to the laboratory for analyses.

3.3 QUALITY ASSURANCE/QUALITY CONTROL SAMPLES

Pursuant to the requirements of DOE/RL (1995), quality assurance/quality control criteria were selected for this activity using a graded approach. The criteria are controls described in BHI-QA-01, *ERC Quality Program*.

BHI-QA-01 was prepared and implemented in compliance with the DOE/BHI Contract DE-AC06-93RL12367 and DOE/RL, 1995. Commensurate with the program/policies promulgated by BHI-QA-01, the ERC managed it's work to ensure that Hanford Federal Facility Agreement and Consent Order requirements and other commitment documents and laws were satisfied in a timely manner. The controls were implemented by qualified personnel as described in the statement of work. They were then implemented by EPA-reviewed environmental investigation procedures contained in BHI-EE-01, *Environmental Investigations Procedures*.

4.0 RESULTS AND DISCUSSION

This section describes the results from field and laboratory analyses of river and shoreline water samples (i.e., pore water, river water column, riverbank seepage, and shoreline aquifer), and the divers' characterization of the suitability of the river substrate to support salmon spawning and egg incubation. Tables 4-1 through 4-5 provide analytical results of pore-water, river water column, seep water, shoreline aquifer, and quality control water samples respectively.

4.1 PORE-WATER RESULTS

The analytical results for pore-water samples are tabulated in Table 4-1. The table contains analytical results for hexavalent chromium along with measurements of additional physical and chemical parameters. Figure 4-1 shows pore-water sampling analytical results and Figure 4-3 illustrates areas of hexavalent chromium contamination in relation to suitable spawning habitat and locations of actual redds.

Chromium concentrations in pore water were detected at 41 of the 100 pore-water sample sites in the 100-D/DR study area. Hexavalent chromium was detected above the chronic (11 μg/L) and acute (16 μg/L) AWQC at 19 of the sites (Figure 4-1). The highest concentrations of hexavalent chromium at 100-D/DR were detected in two areas: sample sites TDP-12 to TDP-16 across from D Island (i.e., up to 84.7 μg/L), and TDP-38 to TDP-51 upstream of the 100-D/DR intake structure (i.e., up to 632 μg/L) (Figure 4-1). Hexavalent chromium was detected in the range of 0.5 to 1.6 μg/L at 3 of the 23 sample sites between transects TDP-1 and TDP-11. Between sample transects TDP-17 and TDP-34 hexavalent chromium was detected in the range of 0.4 to 3 μg/L at 5 of the 39 sample sites. The highest concentration of hexavalent chromium detected was 632 μg/L collected upstream of the 100-D/DR intake structure. Hexavalent chromium was detected from 25 sample sites between transects TDP-38 and TDP-51 in the range of 0.3 to 632 μg/L.

Twenty co-located samples were planned to statistically evaluate sample spacing (i.e., 1 co-located sample every 5th sample site). The statistical evaluation was not conducted because the frequent occurrence of hardpan at some planned co-located sample sites reduced co-locate sampling by one-half (i.e., 1 co-locate sample every 10th sample site). Analytical results from ten of the eleven co-locate samples closely matched the results for corresponding pore-water sample sites (e.g., TDP-39A @ 632 μg/L and TDP-39Ac @ 629 μg/L) (Figure 4-1 and Table 4-1).

Filtered water samples yielded hexavalent chromium results comparable to unfiltered water samples. The analytical results from unfiltered pore-water samples indicated a range of concentrations from 8 percent lower to 15 percent higher than results from filtered pore-water samples (Table 4-1). Analyses of unfiltered water samples were discontinued when the close comparability between filtered and unfiltered analyses was observed.

Nitrate concentrations ranged from 0.02 to 6.67 mg/L in pore water with the highest value at sample site TDP-39A, which is also the site of the highest chromium concentrations. The pH ranged from 6.9 to 8.3; turbidity of the samples ranged from 104 to >1,000 nephelometric turbidity units (NTUs); specific conductance ranged from 122 to 338 micro Siemens per centimeter (μS/cm); dissolved oxygen ranged from 3.5 to 10.6 mg/L, and hardness ranged from 60 to 200 mg/L.

Twenty-three pore-water samples were collected at depths shallower than the planned 46 cm (18 in.) depth in the river substrate. This occurred in areas where the river sediment (i.e., cobble and gravel) was less than 46 cm (18 in.) deep and the pneumatically driven steel rod could not penetrate the underlying hardpan layer. In some instances, a thick paste-like layer of clay-caliche (i.e., hardpan) enveloped the sampling port inlet orifices and severely restricted the passage of water into the sampling port and SSA[1]. In these instances, the sampling port was pulled out of the river sediment in 2.54 cm (1 in.) increments until it was possible to extract a pore-water sample. When a pore-water sample was collected from a sample site where the hardpan was slightly penetrated, the sample exhibited a light-tan color from the clay-fines dislodged during substrate penetration.

While developing a sampling port insertion point in the substrate using the pneumatic air hammer and steel rod at sample site TDP-16B, the diver felt the resistance of the hardpan layer inhibiting penetration at about the 36 cm (14 in.) depth. At about the 41 cm (16 in.) depth, the steel rod penetrated through a 5 cm (2 in.) thick layer of hardpan into the more typical sediment substrate. After inserting the sampling port to the 46 cm (18 in.) depth, the diver observed a significant upwelling of light-colored fines from the top of the sampling port in the form of a smoke-like plume, apparently under pressure from Hanford site groundwater discharging to the riverbed. Upon extraction of the pore-water sample with the SSA, the color of the sample was observed to be uncharacteristically clear (i.e., 270 NTUs) in comparison to the majority of other samples obtained from samples collected above the hardpan (i.e., > 1,000 NTUs). The results of laboratory analysis indicated that hexavalent chromium was detected at a concentration of 84.7 μg/L at TDP-16B, one of the highest hexavalent chromium concentrations observed along the 100-D/DR Area.

Seven 100-D/DR Area pore-water sample sites were not sampled (i.e., TDP-1B through 5B, TDP-4A, and TDP-29-B) because of the absence of gravelly substrate and the presence of hardpan that generally could not be penetrated by the diver's power-tool for sampling port insertion. Transects TDP-35 through TDP-37 were not sampled because the embayment in front of the 100-D/DR intake structure was filled with very large boulders (i.e., up to 1.5 m [5 ft] in diameter). Voids between the boulders could not be penetrated with a pore-water sampling port, and dense stands of milfoil (*Myriophyllum spp*) growing from the bottom sediment (up to 9 m [30 ft] deep) were considered a potential fouling hazard for the dive-sled and tow-line connection to the tow-boat. Planned background pore-water samples were not collected from Vernita Bar

[1]The resistance (vacuum) experienced when attempting to pull the syringe plunger out to fill the syringe confirmed that the experimental SSA operated as intended by drawing water only through the screened inlet orifices, and it restricted the passage of surface water downward into the top of the sampling port.

because unanticipated flooding of the Columbia River caused river study field operations to cease before the samples could be collected.

Underwater visibility during pore-water sampling ranged from 2.4 m (8 ft) to 6+ m (20+ ft). Surface water temperatures (i.e., top 2 to 10 cm [1 to 4 in.]) ranged from 12°C to 21.9°C (54°F to 71°F) during the study period.

4.2 RIVER WATER COLUMN RESULTS

Hexavalent chromium was not detected in the river water column samples taken 2.54 cm (1 in.) above the substrate at the pore-water sample sites (Table 4-2). Water column samples were analyzed for hexavalent chromium only by the ERC Mobile Field Laboratory, and its method detection limit (MDL) is approximately 10 μg/L. Nitrate ranged from 0.02 to 0.14 mg/L; pH ranged from 7.6 to 8.3; turbidity ranged from 0.1 to 21.5 NTUs; specific conductance ranged from 117 to 150 μS/cm; dissolved oxygen ranged from 7.1 to 10.5 mg/L, and hardness ranged from 60 to 200 mg/L. Analytical results for samples collected from the river water column are presented in Table 4-2.

4.3 RIVERBANK SEEPAGE RESULTS

Hexavalent chromium was detected at concentrations up to 28 μg/L (highest at SD-099-1) in samples taken from groundwater seep discharges on the riverbank (Table 4-3). Nitrate ranged from 0.2 to 2.3 mg/L; pH ranged from 7.1 to 7.9; turbidity ranged from 0.5 to 138 NTUs; specific conductance ranged from 140 to 283 μS/cm; dissolved oxygen ranged from 7.1 to 9.1 mg/L, and hardness ranged from 70 to 110 mg/L. Analytical results for samples collected from seeps are presented in Table 4-3.

4.4 SHORELINE AQUIFER RESULTS

Hexavalent chromium was detected at concentrations up to 869 μg/L (i.e., DD-39-3 at Transect 39) in the shoreline aquifer (Figure 4-2 and Table 4-4). Analytical results for hexavalent chromium are included on Figure 4-2 along with an average chromium concentration for groundwater monitoring wells. Nitrate ranged from 0.02 to 16.1 mg/L; pH ranged from 6.9 to 8.1; specific conductance ranged from 135 to 539 μS/cm; dissolved oxygen ranged from 5.1 to 11.7 mg/L, and hardness ranged from 60 to 280 mg/L. All analytical results for samples collected from shoreline aquifer sampling tubes are presented in Table 4-4.

4.4.1 Chromium in the Aquifer Along the Shoreline

The highest hexavalent chromium concentrations observed in the aquifer along the shoreline occurred at pore-water Transect 39 (Figure 4-2). Concentrations as high as 869 μg/L, which occur at aquifer depth horizons presumed to be roughly equivalent to the pore-water sites "A"

and "B", were measured. Repeat sampling of the sampling ports confirmed concentrations in the 700 to 800 μg/L range. The specific conductance measured for all of these samples (approximately 450 μS/cm) indicates that essentially undiluted groundwater is being collected from the sampling tubes that show high hexavalent chromium concentrations.

On November 22, 1995, the Transect 39 aquifer sampling tube for depth horizon three was used to collect approximately 10 liters of water to be analyzed for strontium-90. None was detected above an estimated detection limit of 18 picocuries per liter. Hexavalent chromium and specific conductance were monitored during the four-hour period required to pump 10 liters from the sampling tube. Both parameters remained essentially constant at approximately 780 μg/L and 450 μS/cm respectively.

The three different sampling tube horizons at Transect 39 were resampled during a brief period of low-river stage in April 1996. Hexavalent chromium was measured using the HACH method (enhanced resolution) and specific conductance was recorded. Hexavalent chromium concentrations were approximately one half those observed in November 1995, and specific conductance values were correspondingly lower, thus suggesting a greater component of river water in the aquifer. These results appear to reflect increased penetration of river water into the aquifer brought on by the unusually high discharge of the Columbia River during the winter of 1995-1996.

One result from the aquifer at Transect 39 was anomalously low (158 μg/L from DD-39-3 on November 12, 1995). Previous samples indicated concentrations in the 700 to 800 μg/L range. A review of field and lab records for the sample revealed no obvious explanation, and the result is being treated as an outlier (i.e., not representative of conditions at that depth in the aquifer).

Immediately upriver from Transect 39, hexavalent chromium was detected at concentrations in the 200 to 450 μg/L range in aquifer samples at Transects 40 through 44. Much lower concentrations in the aquifer were observed further upriver at Transects 49 and 50 where concentrations ranged from 2 μg/L up to 50 μg/L.

The presence of hexavalent chromium at multiple depths in the aquifer along this stretch of shoreline suggests relatively widespread contamination. However, the horizontal extent of contamination along the shoreline is uncertain, since there are no sampling tubes in place that would help delineate the downstream limits. The horizontal extent in an inland direction is also uncertain, since only a single monitoring well (199-D2-6) is available in the area to confirm this and that well is located 640 m (2,100 ft) inland (Figure 4-2). Currently, groundwater flow paths leading to this stretch of shoreline originate in areas east and southeast and do not connect well-known sources for chromium to the shoreline observations. Although a solid-waste burial ground (waste site 118-D-2) is located immediately upgradient near well 199-D2-6, there is no historical evidence to indicate chromium disposal at that burial ground.

During reactor operations from 1944 to 1967, an extensive mound was present under the coolant water retention basins. The mound may have created flow paths that might have connected known chromium sources at the (1) retention basins, (2) disposal sites near the reactor buildings,

and (3) spillage/leakage from sodium dichromate transfer facilities to the currently observed area of contamination (Connelly, 1996).

Another possible source for this contamination is liquid waste disposal, which included chromium solutions, at the 1301-N Crib during the late 1960s and early 1970s. During these operations, a mound existed that would have driven groundwater flow northeastward parallel to the river. This flow would ultimately end up discharging into the river along the shoreline between 100-N and 100-D/DR Areas. Field evidence to support this idea is lacking due to the scarcity of monitoring wells.

Soils associated with the 1907-DR process sewer outfall (Figure 4-2), which is adjacent to Transect 39, might have been contaminated with chromium. To test whether residual contamination in soils is still present, soil pits were excavated in April 1996. Chromium was not detected in any of the soil samples (Hope, 1996). Even if residual contamination from the process sewer were detected in these soils, it would be difficult to connect this source with the underlying aquifer and chromium contamination further upstream since the soil column is separated from the underlying aquifer by the bank storage zone. This zone of dynamic interchange with the river creates a barrier to downward migration from the soil column to the aquifer.

Aquifer samples from the shoreline at Transects 12, 15, 16, and 17 also revealed hexavalent chromium detections at concentrations ranging from 4 μg/L up to 172 μg/L with the highest value at Transect 16. This contamination is presumed to be associated with the chromium plume (see Figure 1-2) that is the target of an interim remedial measure involving a pump-and-treat system (DOE-RL, 1996). Potential sources for this contamination include liquid effluent waste sites and possible spill locations near the 105-D Reactor Building, and also the 107-D/DR Coolant Water Retention Basins.

Backfilled excavations associated with the six-foot diameter coolant water piping system and associated river outfalls may provide preferential pathways from the above-mentioned sources for contamination to reach the river. The backfill material is generally more transmissive to groundwater flow than the natural sediments. The coolant water piping system leads from the reactor buildings to the retention basins then into the river via outfall pipes that are buried in the riverbed. If the backfilled excavations are funnelling contaminated groundwater to the shoreline region, they may be implicated in the occurrence of chromium at Transects 12 through 17, which are located immediately downstream of the two shoreline outfall structures and pipes buried in the river (see Figure 4-3).

4.4.2 Correlation Between Aquifer and River Substrate Sampling Results

Groundwater flowing through the aquifer along the shoreline is assumed to discharge into the river through the riverbed sediments. (An insignificant amount of groundwater also discharges to the river via riverbank seepage). It is logistically easier to monitor groundwater quality inland from the river than to monitor at the actual receptor locations that remediation is intended to protect. Therefore, a means to predict contaminant concentrations at ecologically sensitive river

bottom environments using data from wells and sampling tubes near the shoreline is being investigated.

As part of this investigation, two questions were asked: (1) Does the data set for the 100-D/DR project contain evidence that samples from the aquifer at the shoreline and from the river substrate sites represent a simple mixture of groundwater and river water? and (2) If such evidence exists, can a mixing ratio be defined?

The first question was addressed by graphing chromium concentration as a function of specific conductance for all data associated with a transect (i.e., pore water, shoreline sampling tubes, riverbank seepage, and nearshore wells as shown on Figure 4-4). Specific conductance is an indicator of two water types: nearshore river water (125 to 150 μS/cm) and groundwater (400 to 500 μS/cm or higher if contaminated). If a chromium plume of constant concentration meets and mixes with river water, samples collected at various points along the flow path should plot on a straight line on this graph. The slope of the line is related to the concentration of the plume in groundwater.

The graph shown in Figure 4-4 suggests that mixing may exist at transects associated with the "hot spot" identified near Transect 39 and also the groundwater plume targeted for an interim remedial measure near Transects 12 through 17. A roughly linear relationship is present for the two areas, thus indicating that a mixture of river water and groundwater is present in the samples collected. The different line slopes reflect the different chromium concentrations in the groundwater at the two locations.

Attempts to answer the second question (i.e., identify a characteristic mixing ratio) have been less successful at this stage in the data evaluation process. Comparing concentrations from shoreline monitoring wells and shoreline sampling tubes with concentrations observed in river substrate pore-water samples results in a variety of dilution factors that do not reveal a consistent pattern. It is generally observed that where chromium is detected in pore-water samples, the concentration is lower than in adjacent shoreline sampling tubes and/or monitoring wells, thus suggesting that dilution of groundwater by river water is occurring.

The correlation between chromium concentrations in riverbank seepage and river substrate pore-water results offers less promise for identifying a useful predictor of conditions in the riverbed environment. Processes occurring in the bank storage zone from which bank seepage discharges are different and separate from those at the groundwater/river interface near the river bottom. Thus, a good correlation is not expected. However, a previous compilation of shoreline water quality data from wells, river bank seepage, and nearshore river water (Peterson and Johnson, 1992) demonstrated that river bank seepage water quality is generally intermediate between groundwater and river water. This does suggest some degree of mixing of groundwater and river water in the bank storage zone and is useful information with regard to river water quality issues.

4.5 SUBSTRATE CHARACTERIZATION

The river bed offshore of the 100-D/DR area is free of any man-made structures or debris fields with the exception of small charcoal particles (≤ 0.2 cm diameter) observed between gravel and cobble particles at pore-water sample sites TDP-38 and -39. The history of 100-D/DR operations indicates that the source of the charcoal particles is filter backwash material that was discharged from the 1907-DR Process Sewer Outfall, which was in operation from 1949 to 1968.

Substrate in the study area is generally comprised of an inorganic matrix of rock particles (i.e., boulder, cobble, gravel, pea gravel, sand), and about 20 percent exposed hardpan as a result of localized scouring. Scouring of the riverbed down to the hardpan layer is most evident along the 427-m (1,400-ft) study area segment between sample sites TDP-1 and TDP-7, which is located between the downstream end of D Island and the Hanford Site shoreline. It appears that the high flow velocity discharge through the channel between D Island and the Hanford Site shoreline is the cause of the localized scouring. Aquatic vegetation (i.e., milfoil) was only observed in the low flow region of the 100-D/DR intake embayment area.

Embeddedness of the substrate in the study area between the Hanford Site and D Island appeared to be between 5 percent and 25 percent (i.e., percentage of gravel, cobble, boulder particles surrounded by fine sediment), which is physically representative of habitat considered suitable for spawning and egg incubation. The gravels and cobble have a loose texture indicating minimal concretion of the surface layer of riverbed substrate. Sample sites upstream of D Island, where the river flow velocity was observed to be lower than next to D Island, exhibit embeddedness that appears to exceed 50 percent with significant concretion of sediment fines. This condition is not considered suitable for salmon spawning or egg incubation.

The areas assessed as suitable for spawning are substrates dominated by gravel and cobble particles, have low silt content, have current velocities sufficient to flush away detritus and debris, and are not embedded or concreted by silt sand or clay. The substrates assessed as non-suitable to support salmon spawning activity are generally dominated by boulders (i.e., ≥ 0.4 m [15 in.]) and/or silt sand, and/or hardpan that appears a few inches below the riverbed surface or as outcrops, and/or are in low current velocity areas with hard silt-sand concretions between the substrate particles.

A summary of the relationship between Hanford Site groundwater and salmon spawning habitat is presented in Figure 4-3. Hexavalent chromium concentrations in riverbed sediments are shown along with known spawning areas and with areas where substrate is suitable for salmon spawning. Substrate characterized as suitable for spawning, and verified by aerial photograph locations of salmon redds (Luttrell et al., 1995), indicate use of spawning substrate adjacent to the upstream end of D Island.

The relative percentages of substrate particle sizes, the depth of substrate over the underlying hardpan, and the characterization of the substrate as suitable or non suitable to support salmon spawning and egg incubation are found in Table 4-6. Data about water depth and sampling distances from the shoreline are included in the table.

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100-D Area River Substrate Pore Water Results (October / November, 1995)

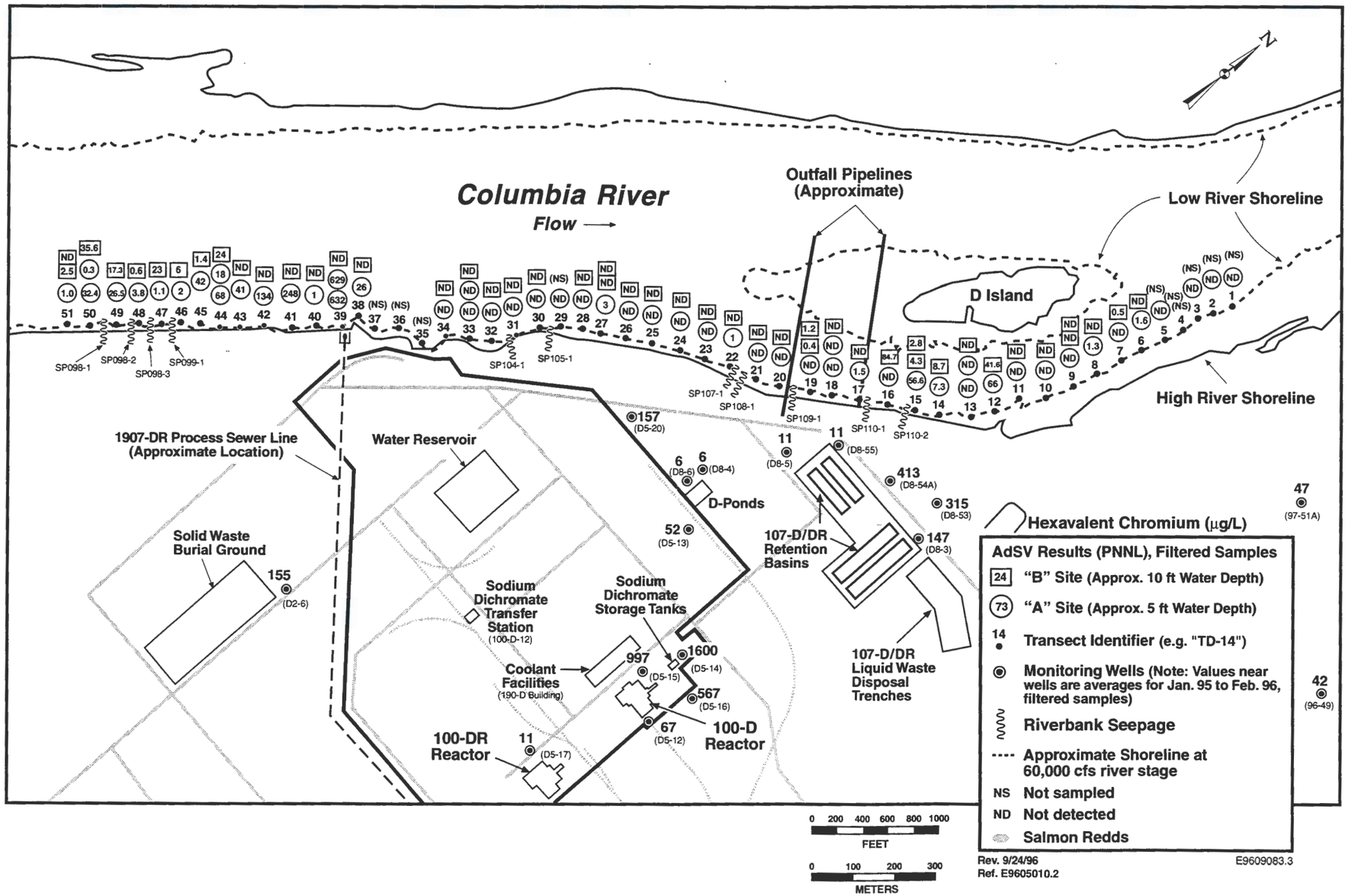

Figure 4-1. Pore Water Sampling Results.

9713540.2745

100-D Area Aquifer Sampling Tube Results (October / November, 1995)

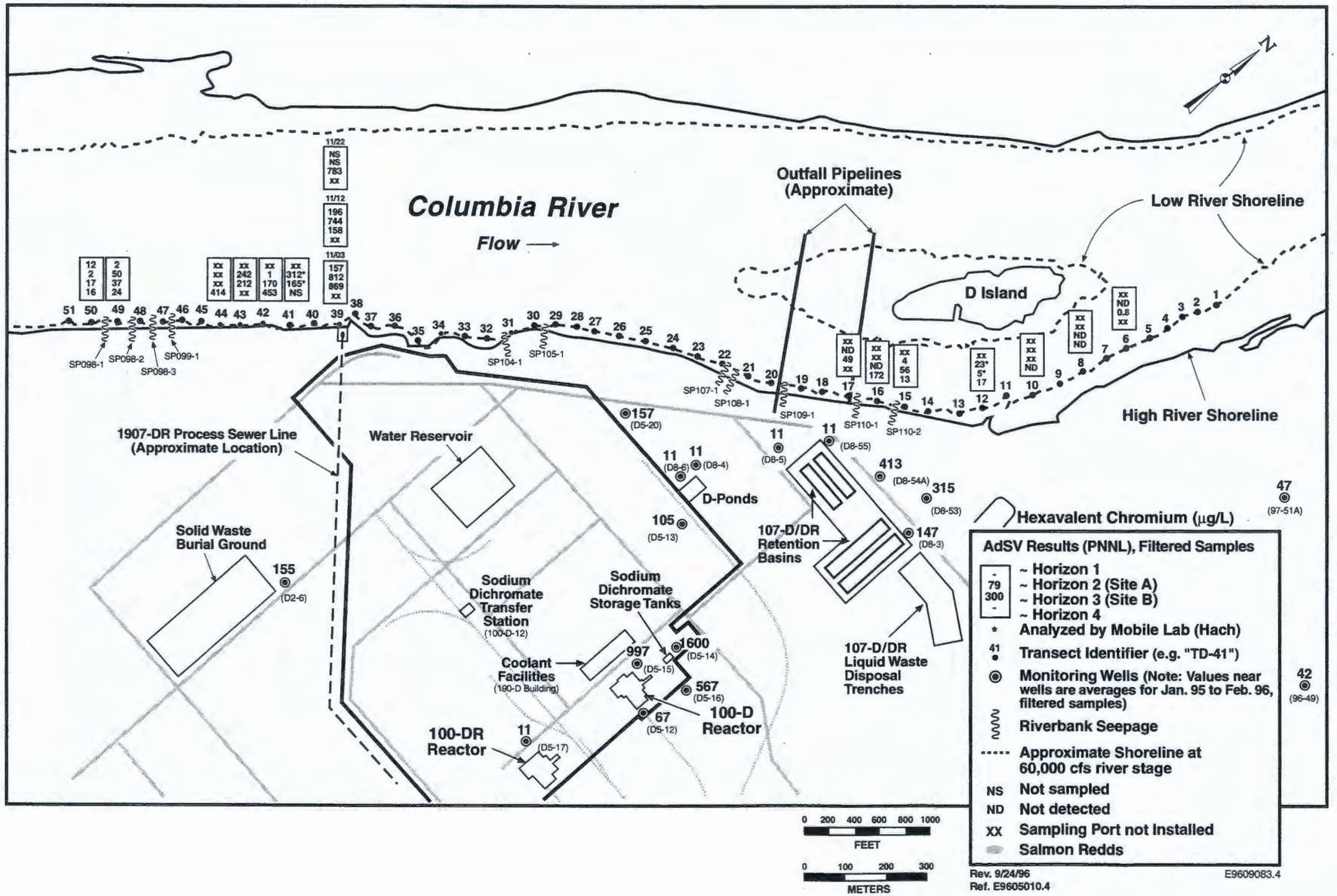

Figure 4-2. Groundwater Discharge Monitoring Results, Shoreline Sampling Tubes Along Shoreline.

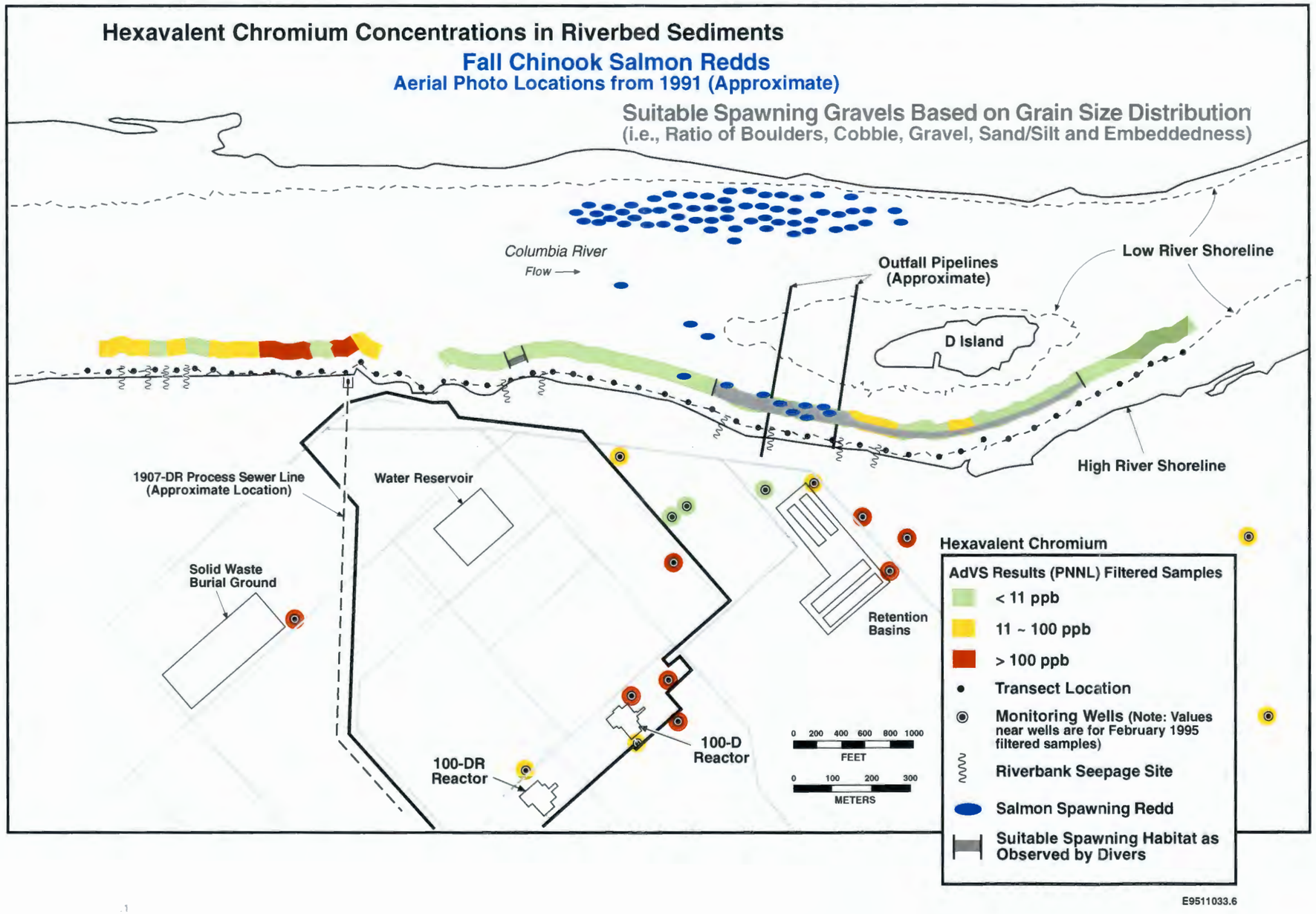

Figure 4-3. Hexavalent Chromium Concentrations in Riverbed Sediments.

9713540.2747

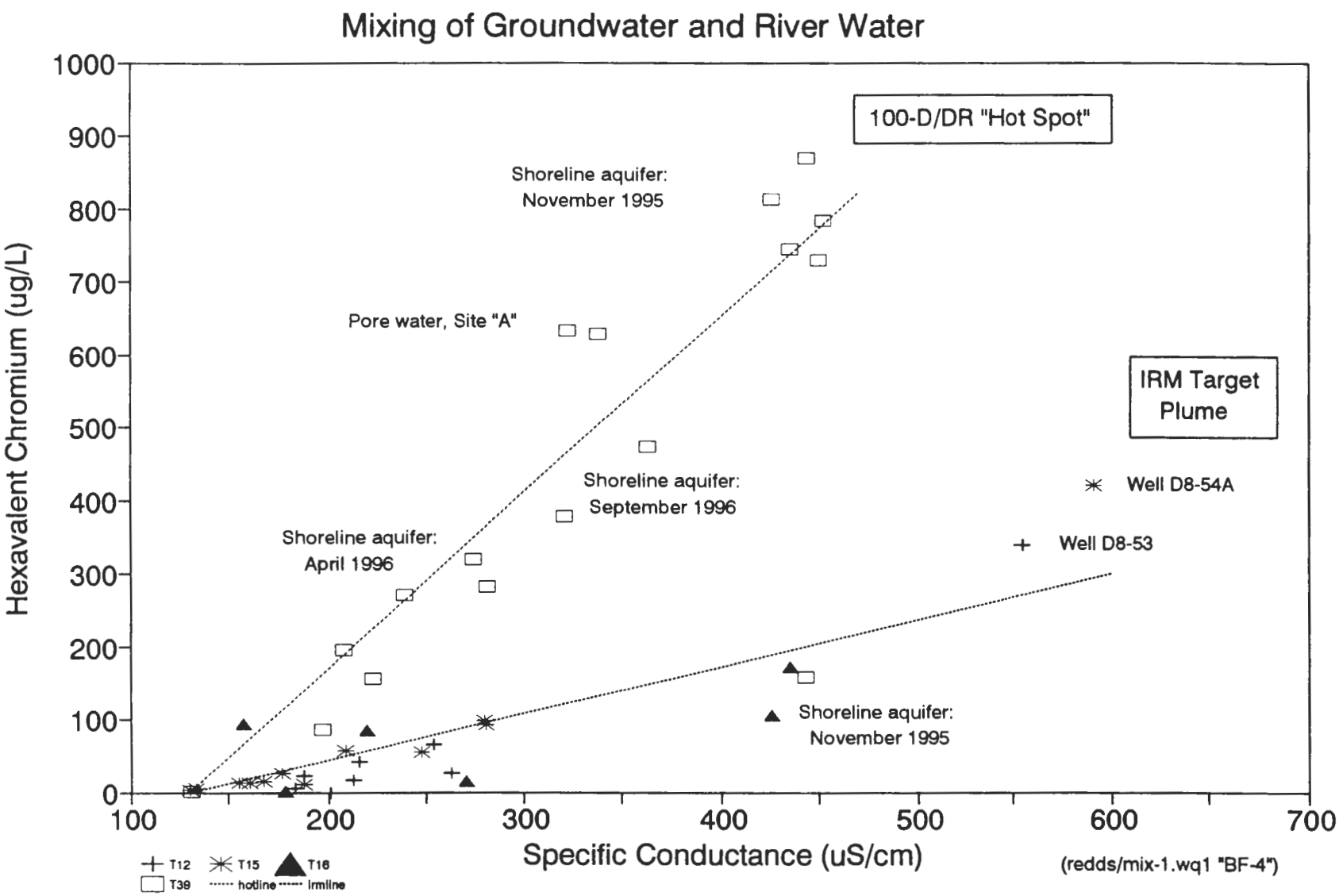

Figure 4-4. Graph of Chromium Concentrations in Relation to Specific Conductance

Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 1 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium µg/L					NO_3 mg/L	Spec Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								
B0GQJ9	10/17/95	TDP-01A	7	ND	ND	< 1	na	na	0.04	160	> 1000	7.7	6.4	100	15.8	
B0GQK1	10/17/95	TDP-02A	6	ND	ND	< 1	na	na	0.04	186.3	> 1000	7.7	3.5	140	16.4	
B0GQK3	10/17/95	TDP-03A	7	0	ND	< 1	na	na	0.04	144.9	1000	7.9	6.5	100	20.6	
B0GQK4	10/17/95	TDP-03A	7	na	na	< 1	na	na	na	na	na	na	na	na	na	Duplicate of B0GQK3
B0GQK6	10/19/95	TDP-05A	6	0	ND	< 1	na	na	0.09	150.9	1000	7.8	8.0	80	16.7	
B0GQK9	10/19/95	TDP-06A	6	ND	ND	1.6	na	na	0.17	171.6	1000	7.4	8.4	90	18.5	
B0GQL1	10/19/95	TDP-07A	7	ND	ND	1	na	na	0.12	154.8	1000	8.0	na	100	18.6	
B0GQL3	10/19/95	TDP-08A	5	0	ND	1.3	na	na	0.04	154.8	1000	7.5	8.5	90	18.7	
B0GQL6	10/19/95	TDP-09A	6	0	ND	< 1	na	na	0.05	177.1	1000	7.5	8.3	80	19.7	
B0GQL8	10/22/95	TDP-10A	6	0	ND	< 0.5	na	na	0.04	209	1000	7.7	9.0	120	17.3	
B0GQM0	10/22/95	TDP-11A	7	0	ND	< 0.5	na	na	0.15	138	1000	7.3	7.8	90	18.2	
B0GQM2	10/22/95	TDP-12A	5	50	43	66	na	na	0.18	254	1000	7.3	8.0	130	17.6	
B0GQM4	10/22/95	TDP-13A	5	ND	ND	< 0.5	na	na	0.06	144.6	1000	7.8	8.0	100	18.1	
B0GQM5	10/22/95	TDP-13A	5	na	na	< 0.5	na	na	na	na	na	na	na	na	na	Duplicate of B0GQM4
B0GQM7	10/22/95	TDP-13Ac	5	ND	ND	< 0.5	na	na	0.07	146.2	1000	7.6	7.8	75	19.7	Co-locate to B0GQM4
B0GQM9	10/22/95	TDP-14A	3	ND	ND	7.3	na	na	0.36	151	1000	7.8	9.2	95	17.8	
B0GQN1	10/27/95	TDP-15A	5	50	59	56.6	na	na	0.74	209	1000	7.9	9.0	90	17.7	
B0GQN2	10/27/95	TDP-15A	5	na	na	na	43	na	na	na	na	na	na	na	na	Split of B0GQN1
B0GQN4	10/27/95	TDP-16A	6	ND	ND	< 0.5	na	na	0.2	178.6	1000	7.6	8.7	70	18.1	

Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 2 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium µg/L					NO_3 mg/L	Spec Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								
B0GQN6	10/27/95	TDP-17A	6	0.01	ND	1.5	na	na	0.07	142.6	1000	7.4	7.6	70	19.1	
B0GQN8	10/27/95	TDP-18A	6	0.01	ND	< 0.5	na	na	0.12	132.8	990	7.9	9.1	60	17.2	
B0GQP0	10/27/95	TDP-18Ac	5	0	ND	< 0.5	na	na	0.06	131.6	831	7.9	8.4	85	17.8	Co-locate to B0GQN8
B0GQP2	10/28/95	TDP-19A	6	ND	ND	< 0.5	na	na	0.13	175.7	1000	7.7	8.1	65	13.3	
B0GQP5	10/28/95	TDP-20A	5	0	ND	< 0.5	na	na	0.19	154.3	1000	7.5	8.6	70	15.7	
B0GQP7	10/28/95	TDP-21A	6	0	ND	< 0.5	na	na	0.04	142.5	959	8.0	8.3	80	16.8	
B0GQP9	10/28/95	TDP-22A	5	ND	ND	1	na	na	0.02	141.8	857	8.0	9.1	70	17.3	
B0GQQ1	10/28/95	TDP-23A	7	0	ND	< 0.5	na	na	0.03	134.4	1000	7.9	9.2	70	17.1	
B0GQQ7	10/28/95	TDP-24A	6	ND	ND	< 0.5	na	na	0.05	136.7	503	7.9	9.5	80	16.7	
B0GQQ9	10/29/95	TDP-25A	5	0	ND	< 0.5	na	na	0.1	169	1000	7.8	8.2	80	19.1	
B0GQR1	10/29/95	TDP-26A	6	0	ND	< 0.5	na	na	0.17	140	1000	7.9	9.1	80	17.7	
B0GQR3	10/29/95	TDP-27A	6	nr	ND	3	na	na	0.01	174	1000	7.5	7.0	90	17.7	
B0GQR5	10/29/95	TDP-28A	4	0	ND	< 0.5	na	na	0.14	141	1000	8.3	9.8	70	15.9	
B0GQR8	10/29/95	TDP-29A	7	ND	ND	< 0.5	na	na	0.06	137	803	7.9	9.3	70	15.1	
B0GQS0	10/29/95	TDP-30A	8	0	ND	< 0.5	na	na	0.1	136	1000	8.2	9.8	80	15.3	
B0GQS2	10/31/95	TDP-31B	11	20	ND	na	na	na	na	140.3	1000	7.4	8.3	70	15.7	
B0GQS4	10/31/95	TDP-32A	5	ND	ND	< 0.5	na	na	na	134.6	1000	7.9	8.7	70	19.1	
B0GQS5	10/31/95	TDP-32A	5	na	na	< 0.5	< 1.2	na	na	na	na	na	na	na	na	Split of B0GQS4
B0GQS7	10/31/95	TDP-33A	5	ND	ND	< 0.5	na	na	na	235	1000	7.7	8.6	110	16.6	

Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 3 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium µg/L					NO_3 mg/L	Spec Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								
B0GQS8	10/31/95	TDP-33A	5	na	na	< 0.5	na	na	na	na	na	na	na	na	na	Duplicate of B0GQS7
B0GQT0	10/31/95	TDP-33Ac	5	ND	ND	< 0.5	na	na	na	144.5	1000	8.1	8.8	75	18.2	Co-locate of B0GQS7
B0GQT1	10/31/95	TDP-33A	5	na	na	< 0.5	na	na	na	na	na	na	na	na	na	Duplicate of B0GQT0
B0GQT3	10/31/95	TDP-34A	5	10	15	< 0.5	na	na	na	137.5	1000	7.8	6.1	85	17.1	
B0GQT5	11/01/95	TDP-38A	4	20	20	26	na	na	0.52	153.4	471	7.5	7.7	80	12.8	
B0GQT7	11/01/95	TDP-39A	6	540	562	632	na	na	6.67	323	1000	7.9	9.7	200	14.6	
B0GQT9	11/01/95	TDP-39Ac	7	560	580	629	na	na	6.23	338	104	7.9	8.9	200	17.8	Co-locate to B0GQT7
B0GQV1	11/01/95	TDP-40A	5	0	ND	1	na	na	0.08	129.5	1000	7.9	9.8	80	16.2	
B0GQV3	11/01/95	TDP-41A	5	200	210	248	na	na	2.88	224	190	8.0	7.3	140	15.8	
B0GQV6	11/01/95	TDP-42A	5	100	112	134	na	na	2.01	189.6	1000	8.1	6.4	90	17.1	
B0GQV8	11/01/95	TDP-43A	5	30	36	41	na	na	0.65	146.8	1000	7.9	8.2	80	15.4	
B0GQV9	11/01/95	TDP-43A	5	na	na	40	na	na	na	na	na	na	na	na	na	Duplicate of B0GQV8
B0GQW1	11/02/95	TDP-44A	5	20	23	18	na	na	0.66	150.7	361	8.2	10.4	110	13.5	
B0GQW3	11/02/95	TDP-44Ac	6	40	47	68	na	na	1.31	177.4	276	7.9	10.1	100	14.8	Co-locate of B0GQW1
B0GQW5	11/02/95	TDP-45A	4	40	43	42	na	na	2.14	202	1000	8.0	10.0	100	15.6	
B0GQW7	11/02/95	TDP-45B	8	0	ND	1.4	na	na	0.11	132.5	602	8.1	10.6	na	12.9	
B0GQW9	11/02/95	TDP-44B	11	20	21	24	na	na	0.94	155.6	1000	8.1	9.3	na	17.1	

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Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 4 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium µg/L					NO_3 mg/L	Spec Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								
B0GQX1	11/02/95	TDP-43B	11	0	ND	< 0.5	na	na	0.02	127.7	1000	7.9	na	na	17.5	
B0GQX4	11/02/95	TDP-42B	11	ND	ND	< 0.5	na	na	0.14	129	1000	7.5	9.3	80	17.1	
B0GQX6	11/02/95	TDP-41B	11	0	ND	< 0.5	na	na	0.04	125.5	1000	7.9	10.0	80	15.1	
B0GQX7	11/02/95	TDP-41B	11	na	na	na	< 1.2	na	na	na	na	na	na	na	na	Split of B0GQX6
B0GQX9	11/03/95	TDP-40B	11	0	ND	< 0.5	na	na	0.08	131.2	1000	7.9	9.2	80	18.6	
B0GQY1	11/03/95	TDP-39B	10	ND	ND	< 0.5	na	na	0.09	131.6	1000	7.9	9.2	80	19.2	
B0GQY4	11/03/95	TDP-46A	5	ND	ND	2	na	na	0.19	136.3	1000	7.5	8.3	na	20.2	
B0GQY6	11/03/95	TDP-47A	5	ND	ND	1.1	na	na	0.19	135.6	1000	7.9	8.9	80	18.4	
B0GQY8	11/03/95	TDP-48A	4	ND	ND	3.8	na	na	0.31	145.8	1000	8.0	9.4	85	19.2	
B0GRW9	11/05/95	TDP-38B	10	0	ND	0.5	na	na	0.11	138.2	1000	7.4	7.6	100	15.9	
B0GRX1	11/05/95	TDP-34B	10	0	ND	0.5	na	na	0.06	133.4	1000	8.0	7.8	80	15.5	
B0GRX3	11/05/95	TDP-33B	10	0	ND	0.5	na	na	0.07	134.1	1000	7.7	8.5	80	16.7	
B0GQZ0	11/05/95	TDP-32B	10	0	ND	< 0.5	na	na	0.13	137.7	1000	8.1	8.8	140	17.2	
B0GQZ3	11/05/95	TDP-31A	5	ND	ND	< 0.5	na	na	0.12	136.5	1000	7.8	9.2	140	15.7	
B0GQZ5	11/06/95	TDP-30B	10	0	ND	< 0.5	na	na	0.1	135.3	1000	7.5	9.2	100	14.5	
B0GQZ7	11/06/95	TDP-28B	10	0	ND	< 0.5	na	na	0.08	132.1	528	7.8	9.3	80	16.5	
B0GQZ9	11/06/95	TDP-27B	10	0	ND	< 0.5	na	na	0.09	131.9	1000	7.7	9.0	90	17.4	
B0GRV8	11/06/95	TDP-27Bc	10	0	ND	< 0.5	na	na	0.2	155.6	1000	7.7	8.3	90	17.8	Co-locate to B0GQZ9
B0GRW0	11/06/95	TDP-26B	9	0	ND	0.5	na	na	0.19	138.6	1000	7.7	8.0	110	17.5	

Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 5 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium µg/L					NO_3 mg/L	Spec Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								
B0GRW1	11/06/95	TDP-26B	9	na	na	0.5	na	na	na	na	na	na	na	na	na	Duplicate of B0GRW0
B0GRW3	11/06/95	TDP-25B	9	0	ND	0.5	na	na	0.07	133	1000	7.8	9.2	90	17.1	
B0GRW5	11/06/95	TDP-24B	9	0	ND	0.5	na	na	0.06	135.4	1000	7.6	8.7	100	17.6	
B0GRW7	11/06/95	TDP-23B	10	20	15	0.5	na	na	0.07	134.2	1000	7.8	9.0	170	15.9	
B0GRX5	11/12/95	TDP-46B	9	ND	ND	6	na	na	0.7	181	1000	7.8	7.6	80	14.8	
B0GRX7	11/12/95	TDP-47B	9	20	28	23	na	na	2.7	261	1000	8.0	8.7	110	15.3	
B0GRX9	11/12/95	TDP-48B	11	0	ND	0.6	na	na	0.16	143	1000	7.7	8.7	70	16.2	
B0GRY1	11/12/95	TDP-22B	6	0	ND	0.5	na	na	0.17	142.9	1000	7.9	8.3	85	17.6	
B0GRY3	11/12/95	TDP-21B	7	0	ND	0.5	na	na	0.02	154.2	1000	7.9	5.7	80	17.2	
B0GRY5	11/15/95	TDP-20B	6	0	ND	< 0.2	na	na	0.17	133.3	1000	7.5	8.4	80	20.2	
B0GRY7	11/15/95	TDP-19B	7	0	ND	1.2	na	na	0.11	146	1000	7.5	7.3	70	18.3	
B0GRY9	11/15/95	TDP-19Bc	7	0	ND	0.4	na	na	0	141.1	1000	7.5	8.3	75	18.4	Co-locate of B0GRY7
B0GRZ1	11/15/95	TDP-18B	8	0	ND	< 0.2	na	na	0.09	122.4	1000	7.6	10.0	80	18.2	
B0GRZ2	11/15/95	TDP-18B	8	na	na	na	<1.2	173	na	na	na	na	na	na	na	Split of B0GRZ1
B0GRZ3	11/15/95	TDP-18B	8	na	na	na	1.2	150	na	na	na	na	na	na	na	Duplicate of B0GRZ2
B0GRZ7	11/15/95	TDP-17B	9	0	ND	< 0.2	na	na	0.24	129	1000	7.8	8.9	60	18.5	

Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 6 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium µg/L					NO_3 mg/L	Spec Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								
B0GRZ8	11/15/95	TDP-17B	9	na	na	< 0.2	na	na	na	na	na	na	na	na	na	Duplicate of B0GRZ7
B0GS02	11/17/95	TDP-16B	9	70	75	84.7	na	na	2.6	220	270	8.3	4.2	100	15.5	Sampled beneath hardpan. 87.4µg/L Unfiltered (AdSV)
B0GS04	11/17/95	TDP-15B	6	0	ND	4.3	na	na	0.27	134	1000	7.9	7.3	70	16.3	4.9 µg/L Unfiltered (AdSV)
B0GS06	11/17/95	TDP-15Bc	6	0	ND	2.8	na	na	0.19	130.7	1000	7.9	9.5	80	17.6	Co-locate of B0GS04
B0GS08	11/17/95	TDP-14B	6	ND	ND	8.7	na	na	0.46	143.7	960	7.7	9.4	70	17.5	10.0 µg/L Unfiltered (AdSV)
B0GS10	11/17/95	TDP-13B	6	0	ND	< 0.2	na	na	0.19	130.3	1000	7.5	8.3	80	17.9	
B0GS12	11/17/95	TDP-12B	9	30	36	41.6	na	na	2	216	1000	7.5	8.0	100	17.1	38.3 µg/L Unfiltered (AdSV)
B0GS14	11/17/95	TDP-11B	10	0	ND	< 0.2	na	na	0.08	123.5	708	7.7	9.6	140	17.9	
B0GS16	11/18/95	TDP-10B	11	0	ND	< 0.2	na	na	na	127	1000	7.2	9.3	70	13.8	
B0GSL2	11/18/95	TDP-09B	12	0	ND	< 0.2	na	na	na	135.8	1000	8.2	9.7	80	17.2	
B0GSL4	11/18/95	TDP-09Bc	12	0	ND	< 0.2	na	na	na	130.4	613	7.8	9.7	70	17.2	Co-locate of B0GSL2
B0GSL6	11/18/95	TDP-08B	13	0	ND	< 0.2	na	na	0.07	126.8	1000	7.8	9.4	60	18	

Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 7 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium µg/L					NO_3 mg/L	Spec Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								
					ND	< 0.2	na	na	0.07	126.8	1000	7.8	9.4	60	18	
B0GSL8	11/18/95	TDP-07B	9	0	ND	0.5	na	na	0.16	151	1000	7.9	9.0	70	18	
B0GSL9	11/18/95	TDP-07B	9	na	na	0.5	na	na	na	na	na	na	na	na	na	Duplicate of B0GSL8
B0GSM1	11/18/95	TDP-06B	11	0	ND	< 0.2	na	na	0.05	na	na	na	na	na	na	
B0GSM3	11/19/95	TDP-49A	5	30	33	26.5	na	na	1.8	264	1000	7.9	7.8	125	12	31.3 µg/L Unfiltered (AdSV)
B0GSM5	11/19/95	TDP-50A	4	20	29	32.4	na	na	1.9	225	1000	7.9	8.8	100	16	34.4 µg/L Unfiltered (AdSV)
B0GSM7	11/19/95	TDP-50Ac	5	0	ND	0.3	na	na	0.09	125	1000	8.0	10.1	75	16.9	Co-locate of B0GSM5
B0GSM9	11/19/95	TDP-51A	6	0	ND	1	na	na	0.14	132	1000	8.1	10.0	70	16.6	
B0GSN1	11/19/95	TDP-51B	10	0	ND	< 0.2	na	na	0.03	127	184	8.1	10.4	75	16.8	
B0GSN3	11/19/95	TDP-51Bc	10	0	ND	2.5	na	na	0.18	137.8	1000	8.2	10.1	80	17.2	Co-locate of B0GSN1
B0GSN5	11/19/95	TDP-50B	10	30	35	35.6	na	na	2.3	206	1000	8.0	9.6	90	16.7	34.5 µg/L Unfiltered (AdSV)
B0GSN7	11/19/95	TDP-49B	10	0.01	21	17.3	na	na	1.4	183.4	675	8.1	10.1	90	16.2	16.7 µg/L Unfiltered (AdSV)

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Table 4-1. Analytical Results for Pore-Water Samples: 100-D/DR Area (Page 8 of 8)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Chromium μg/L					NO_3 mg/L	Spec Cond μS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				Hexavalent				Total								
				HS	HE	AdSV	Q	QT								

Depth - Water depth at sample site
HS - Hexavalent chromium concentration in micrograms per liter (μg/L) by HACH DR2000 Accuvac Chromaver3 method (Mobile Field Lab)
HE - Hexavalent chromium concentration by HACH DR2000 Accuvac Chromaver3 method, modified for enhanced resolution (μg/L) at low concentration ranges (5-100 (μg/L) (Mobile Field Lab)
AdSV - Hexavalent chromium concentration by Adsorption Stripping Voltammetry (AdSV) method (PNNL)
Q - Hexavalent chromium concentration by EPA Method SW-846 7196
QT - Total chromium concentration by EPA Method 6010 (QES)
Turb- Turbidity of sample in Nephelometric Turbidity Units (NTU)
Cond - Specific conductance of sample in micro Siemens per cm (μS/cm)
DO - Dissolved oxygen concentration in sample in miligrams per liter (mg/L)
Hard - Hardness of sample as concentration of calcium carbonate
NO_3 - Nitrate concentration in sample
Temp - Temperature of sample
ND - Measured value less than 10 μg/L, reported as non-detect
na - Not analyzed for this constituent or parameter

Table 4-2. Analytical Results for River Water Column Samples: 100-D/DR Areas (Page 1 of 5)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Hexavalent Chromium µg/L		NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE								
B0GQK0	10/17/1995	TDR-01A	7	0	na	0.04	148.1	0.94	8.08	8.21	80	14.5	
B0GQK2	10/17/1995	TDR-02A	6	0	ND	0.02	148.2	0.72	8.03	8.28	90	16.6	
B0GQK5	10/17/1995	TDR-03A	7	0	ND	0.04	137.2	0.55	8.02	8.30	100	17.3	
B0GQK7	10/19/1995	TDR-05A	6	ND	ND	0.04	135.2	1.63	7.80	9.23	90	17.8	
B0GQL0	10/19/1995	TDR-06A	6	0	ND	0.02	136.5	1.49	7.94	9.24	100	19.5	
B0GQL2	10/19/1995	TDR-07A	7	0	ND	0.04	134.3	0.68	8.06	9.43	90	20.8	
B0GQL4	10/19/1995	TDR-08A	5	ND	ND	0.07	149.8	0.75	8.10	9.52	90	21.9	
B0GQL7	10/19/1995	TDR-09A	6	ND	ND	0.06	137.2	0.69	8.23	9.77	80	20.5	
B0GQL9	10/22/1995	TDR-10A	6	0	ND	0.09	133	1.95	7.88	9.01	90	18.5	
B0GQM1	10/22/1995	TDR-11A	7	ND	ND	0.09	131	3.48	7.77	9.42	90	17.4	
B0GQM3	10/22/1995	TDR-12A	5	0	ND	0.08	131	0.77	8.19	9.63	90	18.1	
B0GQM6	10/22/1995	TDR-13A	5	0	ND	0.07	132.3	0.88	8.29	9.83	100	19.2	
B0GQM8	10/22/1995	TDR-13Ac	5	0	ND	0.09	132.7	0.77	8.26	9.82	70	19.4	Co-locate to B0GQM6
B0GQN0	10/22/1995	TDR-14A	3	0	ND	0.08	134.2	0.85	8.24	9.86	90	17.9	
B0GQN3	10/27/1995	TDR-15A	5	ND	ND	0.03	141	1.01	8.15	9.51	70	18.4	
B0GQN5	10/27/1995	TDR-16A	6	ND	ND	0.07	138.4	1.39	8.17	9.31	70	19.2	
B0GQN7	10/27/1995	TDR-17A	6	0	ND	0.07	139.3	1.02	8.23	9.21	na	19.6	
B0GQN9	10/27/1995	TDR-18A	6	ND	ND	0.02	135.4	1.12	8.26	9.01	60	18	
B0GQP1	10/27/1995	TDR-18Ac	5	0	ND	0.07	134.8	0.73	8.31	8.68	80	17.7	Co-locate to B0GQN8
B0GQP4	10/28/1995	TDR-19A	6	0	ND	0.06	130.8	1.39	8.01	9.71	60	14.2	
B0GQP6	10/28/1995	TDR-20A	5	0	ND	0.04	131.5	0.58	8.02	9.31	80	17	

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Table 4-2. Analytical Results for River Water Column Samples: 100-D/DR Areas (Page 2 of 5)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Hexavalent Chromium µg/L		NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE								
B0GQP8	10/28/1995	TDR-21A	6	0	ND	0.07	129	0.89	8.08	9.29	90	17.7	
B0GQQ0	10/28/1995	TDR-22A	5	0	ND	0.06	132.5	0.61	8.19	8.92	65	17.6	
B0GQQ2	10/28/1995	TDR-23A	7	ND	na	0.02	134.4	0.99	8.17	9.30	70	17.8	
B0GQQ8	10/28/1995	TDR-24A	6	ND	ND	0.11	134	0.8	8.14	9.94	80	17.6	
B0GQR0	10/29/1995	TDR-25A	5	0	ND	na	na	na	na	na	80	na	
B0GQR2	10/29/1995	TDR-26A	6	ND	ND	0.30	142	2.1	7.50	9.29	80	17.7	
B0GQR4	10/29/1995	TDR-27A	6	0	ND	0.03	136	2.6	8.10	9.65	65	16.9	
B0GQR7	10/29/1995	TDR-28A	4	0	ND	0.09	136	1.31	8.20	9.45	80	16.3	
B0GQR9	10/29/1995	TDR-29A	7	0	ND	0.07	136	0.83	na	9.63	80	15.7	
B0GQS1	10/29/1995	TDR-30A	8	0	ND	0.07	136	4.3	8.10	9.69	80	16.4	
B0GQS3	10/31/1995	TDR-31B	11	ND	ND	na	132.6	0.84	7.85	8.73	80	18.4	
B0GQS6	10/31/1995	TDR-33A	5	ND	ND	na	129	1.73	7.84	8.52	75	19.6	
B0GQS9	10/31/1995	TDR-33A	5	0	ND	0.10	134.5	1.32	7.79	8.75	80	18.8	Duplicate of B0GQS6
B0GQT2	10/31/1995	TDR-33Ac?	5	0	ND	na	129.2	0.84	7.92	8.97	70	18.8	Co-locate of B0GQS6
B0GQT4	10/31/1995	TDR-34A	5	na	ND	na	134	1.4	8.00	8.24	70	18.6	
B0GQT6	11/01/1995	TDR-38A	4	ND	ND	0.04	128.2	0.91	7.91	10.01	85	14.9	
B0GQT8	11/01/1995	TDR-39A	6	0	ND	0.04	127.8	1	8.06	9.65	70	15.7	
B0GQV0	11/01/1995	TDR-39Ac	7	0	ND	0.04	127.2	0.84	8.10	9.29	75	18.6	Co-locate to B0GQT7
B0GQV2	11/01/1995	TDR-40A	5	ND	ND	0.07	127.2	2.91	8.03	9.37	70	18.7	
B0GQV5	11/01/1995	TDR-41A	5	0	ND	0.02	127.2	0.64	8.25	7.18	70	17.2	
B0GQV7	11/01/1995	TDR-42A	5	0	ND	0.14	134.3	1.09	7.95	7.34	60	17.8	

Table 4-2. Analytical Results for River Water Column Samples: 100-D/DR Areas (Page 3 of 5)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Hexavalent Chromium µg/L		NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE								
B0GQW0	11/01/1995	TDR-43A	5	0	ND	0.08	134.1	0.06	8.22	7.69	80	16	
B0GQW2	11/02/1995	TDR-44A	5	0	ND	0.05	133.5	0.65	7.93	9.28	100	18	
B0GQW4	11/02/1995	TDR-44Ac	6	0	ND	0.10	126.5	0.72	8.10	9.30	90	17.7	Co-locate of B0GQW2
B0GQW6	11/02/1995	TDR-45A	4	0	ND	0.02	126.3	0.06	8.06	9.66	100	17.6	
B0GQW8	11/02/1995	TDR-45B	8	ND	ND	0.05	125.8	0.68	8.13	9.62	NR	17.7	
B0GQX0	11/02/1995	TDR-44B	11	0	ND	0.12	125.9	0.71	8.13	9.69	90	16.8	
B0GQX3	11/02/1995	TDR-43B	11	ND	ND	0.00	125.2	1.24	8.22	9.70	85	17	
B0GQX5	11/02/1995	TDR-42B	11	0	ND	0.03	124.8	1.98	8.04	10.26	80	15.5	
B0GQX8	11/02/1995	TDR-41B	11	ND	ND	0.09	126.9	0.85	8.14	10.44	80	14.9	
B0GQY0	11/03/1995	TDR-40B	11	ND	ND	0.07	126.7	0.79	7.87	8.39	65	20.5	
B0GQY2	11/03/1995	TDR-39B	10	ND	ND	0.07	126.8	0.75	7.87	8.48	80	20.4	
B0GQY5	11/03/1995	TDR-46A	5	ND	ND	0.13	127.8	0.7	7.84	8.91	80	19.6	
B0GQY7	11/03/1995	TDR-47A	5	0	ND	0.10	129.6	1.26	8.11	8.95	75	19.5	
B0GQY9	11/03/1995	TDR-48A	4	0	ND	0.07	116.5	2.24	8.08		75	21.4	
B0GQZ1	11/05/1995	TDR-32B	10	0	ND	0.09	131.6	0.7	7.92	8.78	120	17.9	
B0GQZ4	11/05/1995	TDR-31A	5	ND	ND	0.10	130.6	1.17	7.99	9.65	200	16	
B0GQZ6	11/06/1995	TDR-30B	10	0	ND	0.07	130.1	1.87	7.54	9.44	80	16.2	
B0GQZ8	11/06/1995	TDR-28B	10	0	ND	0.09	130.5	1.06	7.96	9.19	100	17	
B0GRV7	11/06/1995	TDR-27B	10	0	ND	0.09	131.2	0.91	7.73	8.72	80	18.2	
B0GRV9	11/06/1995	TDR-27Bc	10	0	ND	0.05	131.3	1.49	7.59	8.95	100	18.3	Co-locate to B0GQZ9
B0GRW2	11/06/1995	TDR-26B	9	0	ND	0.07	130	0.71	7.70	8.84	120	18.7	

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Table 4-2. Analytical Results for River Water Column Samples: 100-D/DR Areas (Page 4 of 5)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Hexavalent Chromium µg/L		NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE								
B0GRW6	11/06/1995	TDR-24B	9	0	ND	0.08	132.1	1.11	7.68	8.85	80	18.8	
B0GRW8	11/06/1995	TDR-23B	10	0	ND	0.08	132.2	1.45	7.73	9.00	70	18.1	
B0GRX0	11/05/1995	TDR-38B	10	0	ND	0.07	130.2	1.06	7.99	9.22	75	16.4	
B0GRX2	11/05/1995	TDR-34B	10	ND	ND	0.14	134.2	0.81	7.83	9.55	80	16.4	
B0GRX4	11/05/1995	TDR-33B	10	0	ND	0.13	130.9	1.24	7.67	9.63	90	16.1	
B0GRX6	11/12/1995	TDR-46B	9	0	ND	na	131	1.42	7.87	10.45	75	14	
B0GRX8	11/12/1995	TDR-47B	9	0	ND	0.10	130	1.01	8.00	10.53	65	15	
B0GRY0	11/12/1995	TDR-48B	11	0	ND	0.09	129.8	1.61	7.92	9.66	70	17.9	
B0GRY2	11/12/1995	TDR-22B	6	0	ND	0.04	131.5	21.5	7.94	na	70	18.5	
B0GRY4	11/12/1995	TDR-21B	7	0	ND	0.06	129.4	1.4	7.88	9.66	70	17.9	
B0GRY6	11/15/1995	TDR-20B	6	0	ND	0.05	123.3	3.98	7.63	9.86	65	19.9	
B0GRY8	11/15/1995	TDR-19B	7	0	ND	0.05	120.3	2.85	7.59	10.05	65	19	
B0GRZ0	11/15/1995	TDR-19Bc	7	0	ND	0.05	122.3	1.59	7.75	10.21	60	18.1	Co-locate of B0GRY8
B0GRZ6	11/15/1995	TDR-18B	8	0	ND	0.10	121.4	1.35	7.83	9.75	85	17.9	
B0GRZ9	11/15/1995	TDR-17B	9	0	ND	0.07	123	0.9	7.74	9.64	70	19.2	
B0GS03	11/17/1995	TDR-16B	9	0	ND	0.12	122	1.1	7.81	9.93		16.5	
B0GS05	11/17/1995	TDR-15B	6	na	na	na	123.5	0.88	7.82	9.50	70	18.4	
B0GS07	11/17/1995	TDR-15Bc	6	na	na	na	126	1.38	7.79	9.06	60	18.2	Co-locate of B0GS05
B0GS09	11/17/1995	TDR-14B	6	na	na	na	123.9	1.16	7.86	9.67	60	18.5	
B0GS11	11/17/1995	TDR-13B	6	na	na	na	122.2	1.03	7.88	9.40	65	18.2	
B0GS13	11/17/1995	TDR-12B	9	0	ND	na	124	1.29	7.87	9.72	70	18.5	

Table 4-2. Analytical Results for River Water Column Samples: 100-D/DR Areas (Page 5 of 5)

HEIS No.	Date	Sample Site Identifier	Water Depth (ft)	Hexavalent Chromium μg/L		NO_3 mg/L	Cond μS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE								
B0GS15	11/17/1995	TDR-11B	10	na	na	na	124.2	0.08	7.92	9.62	65	18	
B0GSL1	11/18/1995	TDR-10B	11	0	ND	na	127.5	1.02	7.78	10.04	75	15.4	
B0GSL3	11/18/1995	TDR-09B	12	na	na	na	126.9	0.95	8.01	9.81	60	16.6	
B0GSL5	11/18/1995	TDR-09Bc	12	na	na	na	125.4	0.88	7.89	9.82	65	17	Co-locate of B0GSL3
B0GSL7	11/18/1995	TDR-08B	13	na	na	na	124.9	1.27	8.02	9.58	65	17.8	
B0GSM0	11/18/1995	TDR-07B	9	0	ND	0.08	127.6	0.83	8.12	9.39	75	19	
B0GSM2	11/18/1995	TDR-06B	11	na	na	na	123.3	1.2	8.14	10.33	65	15.2	
B0GSM4	11/19/1995	TDR-49A	5	na	na	na	123	0.83	7.78	10.31	65	13.4	
B0GSM6	11/19/1995	TDR-50A	4	na	na	na	123	0.92	8.05	10.46	80	16	
B0GSM8	11/19/1995	TDR-50Ac	5	na	na	na	126.8	0.8	8.03	10.26	65	17.6	Co-locate of B0GSM6
B0GSN0	11/19/1995	TDR-51A	6	na	na	na	127	2.66	7.90	10.30	70	16.9	
B0GSN2	11/19/1995	TDR-51B	10	0	ND	0.07	126.9	1.79	8.18	10.52		16.7	
B0GSN4	11/19/1995	TDR-51Bc	10	na	na	na	126.2	1.01	8.09	10.21	65	17.8	Co-locate of B0GSN2
B0GSN6	11/19/1995	TDR-50B	10	na	na	na	125.9	2.33	8.14	10.34	65	16.7	
B0GSN8	11/19/1995	TDR-49B	10	na	na	na	126.1	1.03	8.10	10.50	60	16.5	
BOGRW4	11/06/1995	TDR-25B	9	na	ND	0.01	131	1.47	7.70	8.49	80	18.3	

Notes:
Depth - Sample depth below Columbia River surface
HS - Hexavalent chromium concentration in micrograms per liter (μg/L) by HACH DR2000 Accuvac Chromaver3 method (Mobile Field Lab)
HE - Hexavalent chromium concentration by HACH DR2000 Accuvac Chromaver3 method, modified for enhanced resolution (μg/L) at low concentration ranges (5-100 μg/L) Mobile Field Lab)
Turb- Turbidity of sample in Nephelometric Turbidity Units (NTU) Cond - Specific conductance of sample in micro Siemens per cm (μS/cm)
DO - Dissolved oxygen concentration in miligrams per liter (mg/L) Hard - Hardness of sample as concentration of calcium carbonate NO_3 - Nitrate concentration in sample
Temp - Temperature of sample ND - Measured value less than 10 μg/L, reported as non-detect na - Not analyzed for this constituent or parameter

Table 4-3. Analytical Results for Riverbank Seepage Water Samples: 100-D/DR Area (Page 1 of 2)

HEIS No.	Date	Sample Site Identifier	Hexavalent Chromium µg/L			NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C
			HS	HE	AdSV							
B0GR00	10/22/95	SD-110-2	20	26	26	0.54	177.1	3.06	7.47	8.21	110	19.7
B0GR01	10/23/95	SD-110-1	40	35	na	0.5	189	2.08	7.78	8.62	90	14.4
B0GR02	10/23/95	SDW-110-1	9	40	45	na	0.7	180	1.58	7.76	8.87	100
B0GR03	10/23/95	SD-110-1	130	117	na	2.3	283	14	7.60	8.92	100	17.3
B0GR04	10/23/95	SDW-110-1	9	140	136	na	2	290	11.2	7.67	8.60	140
B0GR14	10/27/95	SD-110-2	130	117	na	0.13	188	31	7.53	8.62	70	17.2
B0GR15	10/27/95	SD-110-2	na	na	22.6	na	na	na	na	na	na	na
B0GR18	10/27/95	SD-110-1	30	31	na	0.3	162.5	3.78	7.78	8.23	80	17.9
B0GR19	10/27/95	SD-110-1	30	31	27	na	na	na	na	na	na	na
B0GR20	10/27/95	SD-110-2	10	14	na	0.07	167.9	6.58	7.57	8.19	70	17.4
B0GR21	10/27/95	SD-110-2	10	14	11	na	na	na	na	na	na	na
B0GR24	10/28/95	SD-108-1	0	ND	na	0.02	139.8	3.44	7.22	7.42	80	18.1
B0GR25	10/28/95	SD-108-1	na	na	< 0.5	na	na	na	na	na	na	na
B0GR26	10/28/95	SD-109-1	20	18	na	0.07	160.2	36.2	7.43	7.14	90	18.0
B0GR27	10/28/95	SD-109-1	20	18	9.3	na	na	na	na	na	na	na
B0GR28	10/28/95	SD-109-1	20	18	na	0.09	172.1	7.27	7.49	7.25	95	17.0
B0GR29	10/28/95	SD-109-1	20	18	13.4	na	na	na	na	na	na	na
B0GR30	10/28/95	SD-108-1	ND	ND	na	0.02	143.2	0.52	7.20	7.44	80	16.7
B0GR31	10/29/95	SD-107-1	0	ND	< 1.0	0.02	172	1.4	7.30	8.46	100	16.7
B0GR32	10/29/95	SD-105-1	0	ND	< 1.0	0.02	178	1.81	7.10	7.31	100	16.5
B0GR35	10/31/95	SD-104-1	ND	ND	< 0.5	0.02	143	4.6	7.60	8.58	70	17.2
B0GR36	11/1/95	SD-098-1	ND	ND	1.6	0.234	144.3	138	7.63	7.24	100	15.8
B0GR37	11/1/95	SD-098-2	ND	ND	3.4	0.579	155.2	3.57	7.41	6.78	100	16.1
B0GR38	11/3/95	SD-098-3	ND	ND	6.5	0.61	178	0.71	7.93	NR	110	19.1
B0GR52	11/12/95	SD-099-1	20	22	28	1.3	190.8	0.65	7.43	9.14	85	17.5
B0GS23	11/19/95	SD-098-1	10	17	16	1	175.6	2.25	7.74	9.08	90	17.9

Table 4-3. Analytical Results for Riverbank Seepage Water Samples: 100-D/DR Area (Page 2 of 2)

HEIS No.	Date	Sample Site Identifier	Hexavalent Chromium µg/L			NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C
			HS	HE	AdSV							

Notes:
Seeps discharge at ground surface along the Columbia River shoreline
HS - Hexavalent chromium concentration in micrograms per liter (µg/L) by HACH DR2000 Accuvac Chromaver3 method (Mobile Field Lab)
HE - Hexavalent chromium concentration by HACH DR2000 Accuvac Chromaver3 method, modified for enhanced resolution (µg/L) at low concentration ranges (5-100 µg/L) (Mobile Field Lab)
AdSV - Hexavalent chromium concentration by Adsorption Stripping Voltammetry (AdSV) method (PNNL)
Turb- Turbidity of sample in Nephelometric Turbidity Units (NTU)
Cond - Specific conductance of sample in micro Siemens per cm (µS/cm)
DO - Dissolved oxygen concentration in miligrams per liter (mg/L)
Hard - Hardness of sample as concentration of calcium carbonate
NO_3 - Nitrate concentration in sample
Temp - Temperature of sample
ND - Measured value less than 10 µg/L, reported as non-detect
na - Not analyzed for this constituent or parameter

Table 4-4. Analytical Results for Shoreline Aquifer Water Samples: 100-D/DR Area (Page 1 of 3)

HEIS No.	Date	Sample Site Identifier	Depth Below Ground (ft)	Hexavalent Chromium µg/L			NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE	AdSV								
B0GR05	10/24/95	DD-12-2	11	0	ND	na	0.06	201	> 1000	6.90	5.62	100	17.9	
B0GR06	10/25/95	DD-17-2	10.5	na	42	< 1.0	0.07	na	na	na	na	na	na	
B0GR07	10/24/95	DD-17-3	15	40	46	na	0.35	222	449	7.80	6.86	90	19.2	
B0GR08	10/26/95	DD-12-4	21	na	31	na	0.44	na	na	na	na	na	na	Filtered
B0GR09	10/26/95	DD-12-4	21	na	26	na	0.12	263	8.82	7.10	7.95	na	19.2	Unfiltered
B0GR10	10/26/95	DD-12-3	15	na	ND	na	0.09	na	na	na	na	na	na	Filtered
B0GR11	10/26/95	DD-12-3	15	na	ND	na	0.13	183	50.9	7.30	7.36	na	19.2	Unfiltered
B0GR12	10/26/95	DD-12-2	10	na	ND	na	0.02	na	na	na	na	na	na	Filtered
B0GR13	10/26/95	DD-12-2	10	na	23	na	0.11	188	280	7.00	7.24	na	19.2	Unfiltered
B0GR16	10/27/95	DD-16-3	17.5	10	94	na	0.06	157.8	> 1000	7.95	7.06	60	19.1	
B0GR17	10/27/95	DD-16-3	17.5	na	na	< 0.5	na	na	na	na	na	na	na	
B0GR22	10/27/95	DD-15-2	15	10	13	na	0.03	155.8	> 1000	7.63	7.90	70	18.4	
B0GR23	10/27/95	DD-15-2	15	na	na	4.3	na	na	na	na	na	na	na	
B0GR33	10/30/95	DD-15-3	21	90	92	na	na	281.3	4.77	7.90	9.70	150	13	
B0GR34	10/31/95	DD-15-3	21	0	98	na	na	280	5.8	7.90	5.87	200	17.2	
B0GR39	11/03/95	DD-39-2	10.5	610	590	812	6.7	426	106	7.87	8.27	200	16.3	
B0GR40	11/03/95	DD-39-3	15	700	703	869	7.1	444	34.3	7.83	8.50	200	16.2	
B0GR41	11/03/95	DD-39-1	5.5	150	151	157	1.92	223	150	7.68	8.98	na	16	
B0GR42	11/06/95	DD-16-4	25.5	140	143	172	11.2	435	3.89	7.73	7.71	170	18.9	
B0GR43	11/06/95	DD-15-4	25.5	10	13	13	0.22	161	16.3	7.92	8.23	110	18.9	
B0GR44	11/07/95	DD-41-2	13.6	320	312	305	7.6	296	40	7.63	8.94	200	14	

Table 4-4. Analytical Results for Shoreline Aquifer Water Samples: 100-D/DR Area (Page 2 of 3)

HEIS No.	Date	Sample Site Identifier	Depth Below Ground (ft)	Hexavalent Chromium µg/L			NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE	AdSV								
B0GR45	11/07/95	DD-41-3	18.6	170	165	187	1.64	236	12.2	7.78	9.50	180	14.6	
B0GR46	11/08/95	DD-42-3	15.2	200	196	na	3.5	268	20.9	7.91	9.59	140	13	
B0GR47	11/08/95	DD-42-2	10.5	0	0	na	0.2	140	454	7.91	9.05	70	12.8	
B0GR48	11/09/95	DD-42-3	18.2	440	424	na	12.6	412	6.77	8.00	8.76	200	16.5	
B0GR49	11/09/95	DD-43-3	13.9	350	340	na	9.7	477	277	8.12	8.31	200	16.4	
B0GR50	11/10/95	DD-43-3	13.9	370	363	212	14.3	457	4.39	8.10	8.99	240	14.1	
B0GR51	11/10/95	DD-43-2	10	70	79	242	1.6	195.7	10.1	7.94	9.32	100	15.1	
B0GR53	11/12/95	DD-42-2	10.2	0	ND	1	0.18	135.9	900	7.70	8.68	60	18.2	
B0GR54	11/12/95	DD-42-3	15.5	140	138	170	2.4	237	7.42	7.88	9.30	100	17.4	
B0GR55	11/12/95	DD-42-4	18.2	420	406	453	12.6	363	71	7.79	8.70	160	17.6	
B0GR56	11/12/95	DD-39-1	5.5	180	175	196	2.4	208	80.9	7.58	8.25	100	20.2	
B0GR57	11/12/95	DD-39-2	10.5	700	na	744	16.1	435	85.2	7.76	8.53	190	17.6	
B0GS17	11/12/1995	DD-39-3	15.5	780	na	158	14.1	443	2.41	7.75	8.97	160	17.9	AdSV suspected outlier
B0GS18	11/13/95	DD-44-4	18	320	312	235	10.2	544	489	7.94	7.32	260	20.3	
B0GS19	11/15/95	DD-17-2	10.5	40	45	49	1.3	189.4	120	7.56	7.23	100	18.2	
B0GS20	11/17/95	DD-12-4	21	10	13	17	0.6	213	0.12	7.19	7.73	100	18.4	
B0GS21	11/17/95	DD-15-3	21	40	45	56	2.4	248	28.8	8.04	7.27	140	18.1	
B0GS22	11/18/95	DD-16-4	25.5	110	110	106	9.8	426	77.5	8.12	6.19	160	16.4	
B0GS24	11/20/95	DD-10-4	22	10	ND	< 0.2	0.27	222	17.9	7.33	5.25	90	16	
B0GS25	11/21/95	DD-44-4	18	400	391	388	12.3	539	23.9	7.65	8.98	240	14.9	Composite from 10:50 to 13:10

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Table 4-4. Analytical Results for Shoreline Aquifer Water Samples: 100-D/DR Area (Page 3 of 3)

HEIS No.	Date	Sample Site Identifier	Depth Below Ground (ft)	Hexavalent Chromium µg/L			NO_3 mg/L	Cond µS/cm	Turb NTU	pH	DO mg/L	Hard mg/L	Temp °C	Comments
				HS	HE	AdSV								
B0GS26	11/21/95	DD-44-4	18	410	410	414	13.5	539	14.2	7.87	8.92	280	15.2	
B0GS27	11/21/95	DD-08-4	22.3	0	ND	< 0.2	0.6	218	306	7.98	6.37	120	15	Req'd 2nd filtration
B0GS28	11/21/95	DD-08-3	17.2	0	ND	< 0.2	0.34	175	15.6	7.90	6.96	100	15.5	
B0GS29	11/22/95	DD-39-3	15	na	720	730	12.9	450	3.28	7.80	8.96	240	18.6	Composite from 10:30 to 12:15
B0GS30	11/22/95	DD-39-3	15	760	760	783	12.6	452	38	7.80	8.13	280	17.8	
B0GS31	11/22/95	DD-06-3	16	0	ND	0.8	1.7	235	46.8	7.70	5.08	140	16.9	
B0GSQ1	11/22/95	DD-06-2	12	0	ND	< 0.2	1.2	193	43.7	7.30	6.90	110	17	
B0GSQ4	12/04/95	DD-49-4	31	na	na	24	24	260	24.7	7.20	9.20	120	13.9	
B0GSQ5	12/08/95	DD-49-2	22	na	na	50	na	262	55.8	7.70	11.57	140	7.4	
B0GSQ6	12/08/95	DD-49-1	16	na	na	1.8	na	135	66.8	7.50	11.76	70	7.5	
B0GSQ7	12/12/95	DD-49-1	12	na	na	1.9	na	143	165	7.40	9.36	70	14.5	
B0GSQ8	12/12/95	DD-49-3	25	na	na	36.5	na	259	22.3	7.90	9.01	130	15.7	
B0GSQ9	12/13/95	DD-50-4	31	na	na	16	na	245	196	8.10	7.95	110	17.6	
B0GSR0	12/15/95	DD-50-2	20	na	na	1.6	na	243	1000	7.80	7.70	140	15.4	
B0GSR1	12/15/95	DD-50-3	25	na	na	16.7	na	242	313	7.80	8.61	150	15.6	
B0GSR2	12/15/95	DD-50-1	15	na	na	12	na	199	820	7.80	8.54	90	16.2	

Table 4-5. Analytical Results for Quality Control Samples: 100-D/DR

HEIS No.	Date	Sample Site	Hexavalent Chromium µg/L		Comments
			AdSV	Q	
B0GQK8	10/19/1995	TDX-05A	< 1.0	na	Field blank
B0GQL5	10/19/1995	TDX-08A	< 1.0	na	Spike @ 1 ppb
B0GQP3	10/28/1995	TDX-19A	2	na	Spike @ 2 ppb
B0GQR6	10/29/1995	TDX-28A	24	na	Spike @ 22 ppb
B0GQV4	11/01/1995	TDX-41A	< 0.5	na	Field blank
B0GQX2	11/02/1995	TDX-43B	24	na	Spike @ 17 ppb
B0GQY3	11/03/1995	TDX-39A	14.5	na	Spike @ 12 ppb
B0GQZ2	11/05/1995	TDX-32B	< 0.5	na	Field blank
B0GS00	11/16/1995	TDX-N/A	na	301	Spike @ 300 ppb Lab QC
B0GS01	11/16/1995	TDX-N/A	315	na	Spike @ 300 ppb Lab QC
B0GTM3	11/20/1995	TDX-N/A	na	76	Spike @ 75 ppb Lab QC

Notes:
AdSV - Hexavalent chromium concentration by Adsorption Stripping Voltammetry (AdSV) method (PNNL)
Q - Hexavalent chromium concentration by EPA Method SW846 7196 (QES)
na - Not analyzed for this constituent or parameter

Table 4-6. Sample Site Substrate Characterization Data: 100-D/DR Area (Page 1 of 4)

Transect/ Sample Site Number	Distance from Shoreline (ft)	Water Depth (ft)	% Boulder	% Cobble	% Gravel	% Pea Gravel	% Sand-Silt	Habitat Suitable to Support Salmon Spawning and Egg Incubation? (Yes or No)
TDP-01A	40	7	50	30	10	0	10	No
TDP-02A	70	6	40	40	15	0	5	No
TDP-03A	68	7	40	40	15	5	0	No
TDP-05A	84	6	30	50	15	0	5	No
TDP-06A	93	6	10	80	10	0	0	Yes
TDP-06B	65	11	20	50	15	10	5	No
TDP-07A	164	7	5	75	15	5	0	Yes
TDP-07B	55	9	30	40	15	10	5	No
TDP-08A	39	5	10	70	15	5	0	Yes
TDP-08B	85	13	0	70	10	10	10	No
TDP-09A	20	6	10	70	10	5	5	Yes
TDP-09B	80	12	0	40	40	10	10	No
TDP-09Bc	80	12	0	40	40	10	10	No
TDP-10A	46	6	5	70	20	5	0	Yes
TDP-10B	110	11	0	60	20	10	10	No
TDP-11A	64	7	0	70	20	10	0	Yes
TDP-11B	72	10	20	60	10	5	5	No
TDP-12A	54	5	0	70	25	5	0	Yes
TDP-12B	82	9	10	50	20	10	10	No
TDP-13A	52	5	0	50	35	10	5	Yes
TDP-13Ac	52	5	0	75	20	5	0	Yes
TDP-13B	165	6	0	60	20	15	5	No
TDP-14A	37	3	0	75	15	5	5	Yes
TDP-14B	120	6	5	70	15	5	5	No
TDP-15A	27	5	10	50	35	5	0	Yes
TDP-15B	100	6	10	60	20	5	5	No

Table 4-6. Sample Site Substrate Characterization Data: 100-D/DR Area (Page 2 of 4)

Transect/ Sample Site Number	Distance from Shoreline (ft)	Water Depth (ft)	% Boulder	% Cobble	% Gravel	% Pea Gravel	% Sand-Silt	Habitat Suitable to Support Salmon Spawning and Egg Incubation? (Yes or No)
TDP-15Bc	110	6	10	60	20	5	5	No
TDP-16A	32	6	10	50	30	10	0	Yes
TDP-16B	89	9	20	50	20	5	5	No
TDP-17A	22	6	0	60	30	5	5	Yes
TDP-17B	78	9	10	70	10	5	5	Yes
TDP-18A	78	5	10	50	30	5	5	Yes
TDP-18Ac	74	5	10	50	30	5	5	Yes
TDP-18B	110	8	0	70	20	5	5	Yes
TDP-19A	117	6	0	70	20	5	5	Yes
TDP-19B	98	7	0	70	20	5	5	Yes
TDP-19Bc	95	7	0	70	20	5	5	Yes
TDP-20A	114	5	0	60	30	5	5	Yes
TDP-20B	132	6	0	70	20	5	5	Yes
TDP-21A	119	6	0	60	30	5	5	Yes
TDP-21B	105	7	5	70	20	5	0	Yes
TDP-22A	62	5	0	70	20	5	5	Yes
TDP-22B	88	6	20	60	10	10	0	No
TDP-23A	69	6	10	60	20	5	5	No
TDP-23B	150	10	80	10	10	0	0	No
TDP-24A	62	6	10	70	15	5	0	No
TDP-24B	132	9	80	10	10	0	0	No
TDP-25A	15	5	0	60	25	5	5	Yes
TDP-25B	76	9	70	10	10	10	0	No
TDP-26A	36	6	10	70	10	5	5	No
TDP-26B	77	9	70	10	10	5	5	No
TDP-27A	35.5	6	20	60	10	5	5	No

Table 4-6. Sample Site Substrate Characterization Data: 100-D/DR Area (Page 3 of 4)

Transect/ Sample Site Number	Distance from Shoreline (ft)	Water Depth (ft)	% Boulder	% Cobble	% Gravel	% Pea Gravel	% Sand-Silt	Habitat Suitable to Support Salmon Spawning and Egg Incubation? (Yes or No)
TDP-27B	83	10	70	10	10	5	5	No
TDP-27Bc	83	10	70	10	10	5	5	No
TDP-28A	12	4	30	50	10	5	5	No
TDP-28B	60	10	70	10	0	10	10	No
TDP-29A	60	7	20	60	10	5	5	No
TDP-30A	70	8	50	30	10	5	5	No
TDP-30B	150	10	70	10	0	10	10	No
TDP-31A	19	5	0	70	20	10	0	No
TDP-31B	37	11	10	20	60	5	5	Yes
TDP-32A	33	5	20	30	30	10	10	No
TDP-32B	152	10	70	20	10	0	0	No
TDP-33A	30	5	0	20	50	0	30	No
TDP-33Ac	29	5	20	30	30	10	10	No
TDP-33B	170	10	70	20	5	5	0	No
TDP-34A	35	5	10	50	20	10	10	No
TDP-34B	160	10	70	10	10	0	10	No
TDP-38A	30	4	40	40	15	5	0	No
TDP-38B	125	10	40	20	20	10	10	No
TDP-39A	28	6	10	30	40	5	15	No
TDP-39Ac	29	6	10	40	30	5	15	No
TDP-39B	130	10	60	20	10	5	5	No
TDP-40A	51	5	20	20	40	10	10	No
TDP-40B	110	11	50	20	20	10	0	No
TDP-41A	34	5	0	50	30	10	10	No
TDP-41B	120	11	25	25	25	20	5	No
TDP-42A	37	5	10	50	20	10	10	No

Table 4-6. Sample Site Substrate Characterization Data: 100-D/DR Area (Page 4 of 4)

Transect/ Sample Site Number	Distance from Shoreline (ft)	Water Depth (ft)	% Boulder	% Cobble	% Gravel	% Pea Gravel	% Sand-Silt	Habitat Suitable to Support Salmon Spawning and Egg Incubation? (Yes or No)
TDP-42B	91	11	50	20	10	15	5	No
TDP-43A	46	5	20	30	30	10	10	No
TDP-43B	91	11	50	20	5	15	10	No
TDP-44A	26	6	20	40	20	10	10	No
TDP-44Ac	30	6	20	40	20	10	10	No
TDP-44B	148	11	50	30	5	5	10	No
TDP-45A	38	4	50	20	15	5	10	No
TDP-45B	55	8	30	30	20	10	10	No
TDP-46A	42	5	20	20	30	15	15	No
TDP-46B	92	9	60	20	10	5	5	No
TDP-47A	55	5	25	50	15	5	5	No
TDP-47B	68	9	60	20	10	5	5	No
TDP-48A	72	4	30	40	15	10	5	No
TDP-48B	105	11	70	20	5	5	0	No
TDP-49A	70	5	20	40	20	10	10	No
TDP-49B	90	10	30	40	15	5	10	No
TDP-50A	35	4	30	40	15	5	10	No
TDP-50Ac	35	4	50	20	20	0	10	No
TDP-50B	85	10	40	30	20	0	10	No
TDP-51A	65	6	40	30	20	0	10	No
TDP-51B	77	10	70	10	10	0	10	No
TDP-51Bc	87	10	70	10	10	0	10	No

c Co-locate sample site

5.0 SUMMARY AND CONCLUSIONS

5.1 PORE-WATER SAMPLING PROGRAM

Hexavalent chromium in pore water was detected above AWQC along two segments of the 100-D/DR study area. The study area encompassed 3,109 linear m (10,200 linear ft) of the riverbed. Hexavalent chromium was found between pore-water sample sites TDP-12 and TDP-16, representing 244 linear m (800 linear ft) of riverbed substrate, and between sample sites TDP-38 and TDP-51, representing 792 linear m (2,600 linear ft). Approximately one-third of the riverbed segment along which the samples were collected, was found to be affected by contaminated groundwater discharge. However, the only suitable salmon spawning habitat found to be affected by the chromium discharge was between sample sites TDP-12A and TDP-16A, which represent about one-tenth of the riverbed in the study area.

Installation of a sampling port at pore-water sampling site TDP-16B resulted in penetration through the hardpan layer and subsequent visual observance of a smoke-like silt plume. The visible silt plume may have been the result of a discharge from groundwater pressure. The sampling event at TDP-16B indicates that the hardpan layer of the riverbed may function as a natural cap to contain groundwater discharge. This suggests the potential for localized release points in the riverbed rather than a uniform and widespread release of groundwater through the riverbed.

Hexavalent chromium was detected in pore-water samples between sample sites TDP-12 and -19, which are located immediately downstream of the 100-D/DR coolant outfall piping system (see Figure 4-3). The backfill materials in the excavations for this system are likely to be more transmissive to groundwater flow than the surrounding natural sediments and may provide a preferred pathway for contaminant movement. The outfall structures may be implicated in the occurrence of chromium in river substrate pore water at Transects 12 through 19.

Nitrate, a potential co-contaminant with hexavalent chromium, was detected as high as 6.67 mg/L in pore water at TDP-39A. The drinking water standard is 45 mg/L, but no criteria exist for the protection of aquatic life. Concentrations of nitrate that would exhibit toxic effects on cold-water fish rarely occur in nature; hence, restrictive criteria are not provided by the EPA (Geist et al., 1994). Other pore-water quality parameter values (i.e., pH, DO, temperature, and hardness) were found to be within normally expected ranges, thus the toxicity of hexavalent chromium in 100-D/DR pore-water does not appear to be exacerbated. Specific conductance varies among pore-water, seep water, and shoreline aquifer water samples. As expected, the specific conductance measured in seeps and the shoreline aquifer were observed to be significantly higher than the measurements observed in pore water. This is the result of a greater proportion of groundwater in samples from riverbed seepage and the shoreline aquifer.

River water specific conductance (from river water column samples) ranged from 117 to 150 μS/cm with an average of 130 μS/cm. Based on the results of specific conductance measurements, pore-water samples above 150 μS/cm (in the absence or presence of chromium)

are considered to be indicative of groundwater influence. Of 37 pore-water samples (out of 100) with specific conductances that exceed 150 μS/cm, 25 samples had detectable levels of hexavalent chromium, and 12 samples were non-detects (Table 4-1).

Hexavalent chromium was not detected in river water column samples above the MDL of 10 μg/L even at pore-water samples sites TDP-39A and -39Ac where hexavalent chromium in pore water was measured respectively at 632 and 629 μg/L. The absence of detectable chromium in the water column one inch above the substrate indicates that rapid mixing and dilution of contaminated groundwater occurs at the riverbed sediment/surface water interface. However, a larger sample set that is distributed over a broader riverbed area and analyzed at the AdSV MDL of 0.5 μg/L is necessary to better quantify mixing zone characteristics where pore water emerges from the sediments into relatively high-river flow velocity.

Based on a visual observation of the physical attributes of the river sediments (i.e., particle size, embeddedness, and concretion), a majority of the river substrate between D Island and the Hanford Site appeared to be suitable for salmon spawning and egg incubation. However, although the surface appearance of the substrate indicated that it was potentially suitable for salmon spawning, hardpan was observed to be as shallow as 7-10 cm (3-4 in). The near-surface hardpan indicates that the substrate may not be deep enough for viable egg pocket development. Also, in-gravel flow of the oxygenated water necessary during egg incubation may be impeded by the near-surface layer of hardpan beneath the aggregate layer. Chinook salmon prefer spawning areas with high subgravel flow, which may explain their tendency to aggregate in particular locations for spawning and to ignore other superficially similar areas (Vronsky, 1972, as reported in Groot and Margolis, 1991).

5.2 AQUIFER SAMPLING ALONG THE SHORELINE

A new methodology to obtain groundwater samples from the aquifer along the Columbia River shoreline was successfully implemented. Samples were obtained from multiple depths in the aquifer to characterize the vertical distribution of chromium at fourteen locations. At several locations, the vertical distribution of specific conductance is sufficient to demonstrate that some of the sampling tube ports are fully below the bank storage zone; therefore, they provided representative samples from the aquifer close to the river channel. The plastic sampling tubes have demonstrated good resistance to damage by river currents and river stage fluctuations. Based on observations during the winter of 1995-96, the potential for repeated future sampling appears good. Resampling the tubes is scheduled for late 1996. At that time, it will be known whether the sampling ports at the ends of the tube can remain unclogged by sediment for extended periods.

Samples from sampling tubes along the shoreline have confirmed the presence of chromium in the unconfined aquifer that discharges to the Columbia River. Two shoreline segments of concern are (1) the chromium plume in the northern portion of the 100-D/DR Area that is the target of an interim remedial measure, and (2) a newly identified area in the southwest corner of the 100-D/DR Area, for which a chromium source is not obvious. Results for hexavalent

chromium and specific conductance from all samples collected in the vicinity of a river substrate pore-water sampling transect (e.g., pore water, riverbank seepage, aquifer sampling tubes, and near-river monitoring wells) indicate that mixing between river water and groundwater explains some of the variability observed for chromium concentrations.

The 100-D/DR study area covered by pore-water sampling transects was not entirely covered by aquifer sampling tube installations. Shoreline sampling tubes were intended to supplement pore water sampling whenever hexavalent chromium was detected in the river substrate. However, several installations were made at pore-water transects where hexavalent chromium was not detected (or at very low concentrations), thus confirming the absence of significant contamination in the shoreline aquifer at those transects. Additional sampling tube installations will be required to reduce the uncertainty in the distribution of chromium in the aquifer along other portions of the 100-D/DR shoreline.

5.3 AQUATIC LIFE AT THE 100-D/DR STUDY AREA

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Fall chinook salmon were observed by the divers and boat crews congregating on the spawning beds along the upstream end of D Island adjacent to pore-water transects TDP-17 through -22. Carp *(Cyprinus carpio)*, suckers *(Catostomus spp)*, and crayfish *(Oronectes spp)* were observed intermittently upstream of pore-water sample site TDP-30 (Figure 4-1).

The pore-water, river water column, seep, and shoreline aquifer water quality data presented in this report provide a reliable indication of the 100-D/DR groundwater contaminant pathways to the Columbia River. The data are being used in the design of pump-and-treat remediation systems. This information will optimize the placement of the groundwater extraction wells in the aquifer to intercept chromium before contaminated groundwater reaches the riverbed sediments and discharges into the river.

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6.0 REFERENCES

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APPENDIX A

SUMMARY OF WASTE SITES

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Table A-1. Summary of Known Facility Sources for Chromium in the 100-D/DR Area (Page 1 of 2)

Waste Site Number	Facility Name	Operating Period	Liquid Effluent Summary
116-D-1A	105-D Fuel Storage Basin Trench #1	1947-52	200,000 liters of contaminated water from fuel storage basin, 1,000 kg of sodium dichromate
116-D-1B	105-D Fuel Storage Basin Trench #2	1953-67	8 million liters of liquid waste, fuel storage basin water and decontamination solutions, 700 kg sodium dichromate
116-D-2	105-D Pluto Cribs	1950-52	4,000 liters of liquid wastes, 0.004 kg sodium dichromate
116-D-5	1904-D Outfall Structure	1944-75	Reactor coolant and process sewer effluent, possible leakage and release to shoreline via concrete spillway
116-D-7	107-D Retention Basin	1944-67	Temporary storage of reactor coolant, prior to discharge into river, significant leakage created mound on underlying water table
116-DR-1	107-DR Liquid Waste Disposal Trench #1 (used for infiltration test in 1967)	1950-67	40 million liters of highly contaminated reactor coolant from fuel element ruptures, 40 kg sodium dichromate
116-DR-2	107-DR Liquid Waste Disposal Trench #2	1952-67	Received overflow from Trench #1, 40 kg sodium dichromate
116-DR-5	1904-DR Outfall Structure	1956-65	Reactor coolant, possible leakage and release to shoreline via concrete spillway
116-DR-9	107-DR Retention Basin	1950-65	Temporary storage of coolant prior to discharge into river, possible significant leakage contributing to groundwater mound
126-D-2	184-D Coal Pit	1970s-86	Original coal pit subsequently used as burial ground, possible sodium dichromate crystals
(Unlisted)	1907-DR Outfall Structure	1950-65	Received effluent via 105-DR process sewer lines, contained overflow from coolant storage basins and other process wastes possibly containing chromium
(Unlisted)	Sodium dichromate storage tanks near 108-D building (north of 105-D reactor)		Leakage of sodium dichromate stock solution from tanks and supply pipelines to 190-D building

Table A-1. Summary of Known Facility Sources for Chromium in the 100-D/DR Area (Page 2 of 2)

Waste Site Number	Facility Name	Operating Period	Liquid Effluent Summary
100-D-12	Transfer Station; sodium dichromate unloading and transfer; northwest of 105-DR reactor		Leakage of sodium dichromate stock solution during transfer from railcars and from associated piping
(Unlisted)	"Sodium" trench associated with 190-D building		Leakage/spillage of sodium dichromate stock solution at point of introduction to unused coolant

Sources: Listed waste sites: *100-D Technical Baseline Report*, WHC-SD-TI-181, Rev. 0, August 1993 (Carpenter 1993). Unlisted sites: project information described in internal technical memorandum (Connelly, 1996)

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APPENDIX B

PORE WATER DIVE STUDY: DIVERS LOG FOR 100-D/DR AREA

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Table B-1. Pore-Water Dive Study: Divers Log for 100-D/DR Area (Page 1 of 2)

Date	Dive In	Time Out	Total Time (Min)	Depth (ft)	Visibility (ft)	Divers Names	Temperature(F) Water	Air	Comments
10/17/95	10:40	11:04	24	7	10	Frank Cobb/Steve Hope	60.2	59.4	TD-01A
10/17/95	11:50	12:12	22	6	10	Frank Cobb/Steve Hope	60.2	59.4	TD-02A
10/17/95	13:51	14:15	24	7	10	Frank Cobb/Steve Hope	60.2	55	TD-03A
10/17/95	14:45	14:55	10	6	10	Frank Cobb/Steve Hope	60.2	55	TD-04A Hardpan, no sample.
10/19/95	10:34	10:58	24	6	15	Frank Cobb/Steve Hope	59.1	54.4	TD-05A
10/19/95	11:38	11:56	18	6	15	Frank Cobb/Steve Hope	59.3	58.8	TD-06A
10/19/95	13:14	13:38	24	10	15	Frank Cobb/Steve Hope	59.5	63.8	TD-07A
10/19/95	14:07	14:22	15	5	15	Frank Cobb/Steve Hope	59.6	65.1	TD-08A
10/19/95	15:09	15:29	20	6	15	Frank Cobb/Steve Hope	59.8	67	TD-09A
10/22/95	11:52	12:04	12	6	20+	Frank Cobb/Steve Hope	58.3	59	TD-10A
10/22/95	12:26	12:43	17	7	20+	Frank Cobb/Steve Hope	58.3	57.6	TD-11A
10/22/95	13:16	13:25	9	5	20+	Frank Cobb/Steve Hope	58.6	61.4	TD-12A
10/22/95	13:54	14:03	9	3	20+	Frank Cobb/Steve Hope	58.8	61.5	TD-14A
10/22/95	14:31	14:54	23	5	20+	Frank Cobb/Steve Hope	58.8	63.8	TD-13A and TD-13A co-locate
10/27/95	12:17	12:32	15	5	20+	Frank Cobb/Steve Hope	57.4	59.4	TD-15A
10/27/95	13:07	13:25	18	6	20+	Frank Cobb/Steve Hope	57.6	60.8	TD-16A
10/27/95	13:52	14:09	17	6	20+	Frank Cobb/Steve Hope	57.7	61.9	TD-17A
10/27/95	14:54	15:23	29	6	20+	Frank Cobb/Steve Hope	57.8	65	TD-18A and TD-18A co-locate
10/28/95	10:18	10:31	13	6	20+	Frank Cobb/Steve Hope	56	44.2	TD-19A
10/28/95	11:11	11:22	11	5	20+	Frank Cobb/Steve Hope	56.7	52.2	TD-20A
10/28/95	12:15	12:32	17	6	20+	Frank Cobb/Steve Hope	56.7	52.8	TD-21A
10/28/95	13:12	13:28	16	5	20+	Frank Cobb/Steve Hope	56.8	54.6	TD-22A
10/28/95	14:27	14:56	19	6	20+	Frank Cobb/Steve Hope	56.9	53.5	TD-23A and TD-23A co-locate
10/28/95	15:24	15:40	16	6	20+	Frank Cobb/Steve Hope	57	55	TD-24A
10/29/95	10:24	10:40	16	5	20+	Frank Cobb/Steve Hope	56.2	50.8	TD-25A
10/29/95	11:16	11:29	13	6	20+	Frank Cobb/Steve Hope	56.3	52.8	TD-26A
10/29/95	12:09	12:21	12	6	20+	Frank Cobb/Steve Hope	56.4	54.5	TD-27A
10/29/95	12:59	13:15	16	4	20+	Frank Cobb/Steve Hope	56.7	55.4	TD-28A
10/29/95	14:00	14:14	14	7	20+	Frank Cobb/Steve Hope	56.8	54	TD-29A
10/29/95	14:52	15:06	14	8	20+	Frank Cobb/Steve Hope	56.8	53.3	TD-30A
10/31/95	11:03	11:27	24	11	20+	Frank Cobb/Steve Hope	56.1	45	TD-31B
10/31/95	12:06	12:22	16	5	20+	Frank Cobb/Steve Hope	56.3	49.5	TD-32A
10/31/95	13:09	13:36	27	5	20+	Frank Cobb/Steve Hope	56.5	49.9	TD-33A and TD-33A co-locate
10/31/95	14:27	14:36	9	5	20+	Frank Cobb/Steve Hope	56.5	50	TD-34A
10/31/95	14:47	14:58	11	5	20+	Frank Cobb/Steve Hope	56.5	50.3	TD-34A
11/1/95	10:39	10:51	12	4	20+	Frank Cobb/Steve Hope	55.4	44	TD-38A
11/1/95	11:25	11:47	22	7	20+	Frank Cobb/Steve Hope	55.6	48.1	TD-39A and TD-39A co-locate
11/1/95	12:29	12:45	16	5	20+	Frank Cobb/Steve Hope	55.7	50.7	TD-40A
11/1/95	13:19	13:34	15	5	20+	Frank Cobb/Steve Hope	55.8	52.3	TD-41A
11/1/95	14:27	14:37	10	5	20+	Frank Cobb/Steve Hope	55.9	48.8	TD-42A
11/1/95	15:05	15:16	11	5	20+	Frank Cobb/Steve Hope	55.9	48.9	TD-43A
11/2/95	10:28	10:54	26	6	20+	Frank Cobb/Steve Hope	54.6	37.5	TD-44A and TD-44A co-locate
11/2/95	11:37	11:59	22	8	20+	Frank Cobb/Steve Hope	54.9	42.6	TD-45A and TD-45B
11/2/95	12:47	13:00	13	11	20+	Frank Cobb/Steve Hope	55	49.2	TD-44B
11/2/95	13:40	13:55	15	11	20+	Frank Cobb/Steve Hope	55.1	49	TD-43B
11/2/95	14:35	14:47	12	11	20+	Frank Cobb/Steve Hope	55.1	46.8	TD-42B
11/2/95	15:10	15:22	12	11	20+	Frank Cobb/Steve Hope	55.2	48	TD-41B
11/3/95	11:16	11:32	16	11	20+	Frank Cobb/Steve Hope	54.5	40.9	TD-40B
11/3/95	12:16	12:29	13	10	20+	Frank Cobb/Steve Hope	54.6	43.5	TD-39B
11/3/95	13:41	14:04	23	5	20+	Bud Massengale/Steve Hope	54.7	46.8	TD-46A
11/3/95	14:40	14:57	17	5	20+	Bud Massengale/Steve Hope	54.8	48.5	TD-47A
11/3/95	15:18	15:30	12	4	20+	Bud Massengale/Steve Hope	54.8	47.6	TD-48A
11/5/95	10:45	10:59	14	10	20+	Frank Cobb/Clay Smith	53.9	43.7	TD-38B
11/5/95	11:52	12:07	15	10	20+	Frank Cobb/Clay Smith	53.9	50.2	TD-34B
11/5/95	12:52	13:13	21	10	20+	Frank Cobb/Clay Smith	54	53.5	TD-33B
11/5/95	13:38	13:54	16	10	20+	Frank Cobb/Clay Smith	54	53	TD-32B
11/5/95	14:26	14:47	21	5	20+	Frank Cobb/Clay Smith	54	52	TD-31A

Table B-1. Pore-Water Dive Study: Divers Log for 100-D/DR Area (Page 2 of 2)

Date	Dive In	Time Out	Total Time (Min)	Depth (ft)	Visibility (ft)	Divers Names	Temperature(F) Water	Air	Comments
11/6/95	9:53	10:15	22	10	8 to 10	Frank Cobb/Clay Smith	53.7	50.4	TD-30B
11/6/95	10:44	10:59	15	9	10	Frank Cobb/Clay Smith	53.4	52.8	TD-29B
11/6/95	11:27	11:38	11	10	10	Frank Cobb/Clay Smith	53.5	54.2	TD-28B
11/6/95	12:05	12:23	18	10	10	Frank Cobb/Clay Smith	53.5	53.3	TD-27B and TD-27B co-locate
11/6/95	13:00	13:11	11	9	10	Frank Cobb/Clay Smith	53.6	53.3	TD-26B
11/6/95	13:41	13:51	10	9	10	Frank Cobb/Clay Smith	53.7	52.2	TD-25B
11/6/95	14:45	14:58	13	9	10	Frank Cobb/Clay Smith	53.8	53	TD-24B
11/6/95	15:28	15:39	11	10	10	Frank Cobb/Clay Smith	53.8	51.5	TD-23B
11/12/95	10:01	10:15	14	9	10	Frank Cobb/Clay Smith	52.1	47.1	TD-46B
11/12/95	11:01	11:14	13	9	10	Frank Cobb/Clay Smith	52.1	46.9	TD-47B
11/12/95	11:55	12:08	13	11	10	Frank Cobb/Clay Smith	52.2	52.5	TD-48B
11/12/95	13:32	13:46	14	6	10	Frank Cobb/Clay Smith	52.4	50.8	TD-22B
11/12/95	14:51	15:03	12	7	10	Frank Cobb/Clay Smith	52.5	51.3	TD-21B
11/15/95	10:58	11:08	10	6	12	Frank Cobb/Clay Smith	51.5	52.1	TD-20B
11/15/95	11:57	12:20	23	6	12	Frank Cobb/Clay Smith	51.6	54.4	TD-19B and TD-19B co-locate
11/15/95	13:24	13:44	20	8	12	Frank Cobb/Clay Smith	51.7	52.5	TD-18B
11/15/95	14:35	14:50	15	9	12	Frank Cobb/Clay Smith	51.8	52	TD-17B
11/17/95	10:45	11:07	22	9	15	Frank Cobb/Steve Hope	51.4	49.2	TD-16B
11/17/95	11:45	12:05	20	6	15	Frank Cobb/Steve Hope	51.4	51.2	TD-15B and TD-15B co-locate
11/17/95	12:46	13:00	14	6	12 to 15	Frank Cobb/Steve Hope	51.5	53.1	TD-14B
11/17/95	13:49	14:01	12	6	12	Frank Cobb/Steve Hope	51.5	50.9	TD-13B
11/17/95	14:54	15:06	12	9	12 to 15	Frank Cobb/Steve Hope	51.5	49.1	TD-12B
11/17/95	15:30	15:41	11	10	12	Frank Cobb/Steve Hope	51.5	49.9	TD-11B
11/18/95	10:16	10:28	12	11	10 to 12	Frank Cobb/Steve Hope	51.6	55.2	TD-10B
11/18/95	11:09	11:31	22	12	10	Frank Cobb/Steve Hope	51.7	56.4	TD-09B and TD-09B co-locate
11/18/95	12:20	12:32	12	13	10	Frank Cobb/Steve Hope	51.9	57.9	TD-08B
11/18/95	13:14	13:25	11	9	15	Frank Cobb/Steve Hope	51.9	56.7	TD-07B
11/18/95	14:01	14:18	17	11	15	Frank Cobb/Steve Hope	52	55.2	TD-06B
11/19/95	10:18	10:31	13	5	15	Frank Cobb/Steve Hope	51.4	44.8	TD-49A
11/19/95	11:02	11:23	21	5	15	Frank Cobb/Steve Hope	51.5	50.2	TD-50A and TD-50A co-locate
11/19/95	12:08	12:23	15	6	15	Frank Cobb/Steve Hope	51.7	54.8	TD-51A
11/19/95	12:55	13:24	29	10	15	Frank Cobb/Steve Hope	51.7	53.3	TD-51B and TD-51B co-locate
11/19/95	14:12	14:23	11	10	15	Frank Cobb/Steve Hope	51.8	53.4	TD-50B
11/19/95	14:43	14:51	8	10	15	Frank Cobb/Steve Hope	51.8	53.8	TD-49B

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