

START

9513381.2780

0041968 42

PNL-8654

UC-603

50

**Columbia River Monitoring:
Summary of Chemical Monitoring
Along Cross Sections at Vernita
Bridge and Richland**

R. L. Dirkes
G. W. Patton
B. L. Tiller

May 1993

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute



PNL-8654

START

**THIS PAGE INTENTIONALLY
LEFT BLANK**



DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

9513381.2782

PNL-8654
UC-603

**Columbia River Monitoring:
Summary of Chemical Monitoring
Along Cross Sections at
Vernita Bridge and Richland**

R.L. Dirkes
G.W. Patton
B.L. Tiller

May 1993

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Summary

This report presents the results of the chemical monitoring performed by the Surface Environmental Surveillance Project (SESP) along cross sections of the Columbia River established at Vernita Bridge and the Richland Pumphouse. Potential Hanford-origin chemical constituents of interest were selected based on their presence in ground water near the river, past surveillance efforts that have documented their entry into the river, and reviews of special study reports, CERCLA remedial investigation/feasibility study (RI/FS) documentation, RCRA facility investigation/corrective measure (FI/CM) study plans, and preliminary risk assessments. Results presented in this report include volatile organic compounds, metals, and anions. The data were generated as part of the routine Columbia River monitoring program currently conducted as part of the SESP.

Volatile organic compounds were not routinely detected during the course of this surveillance effort. Several metals were detected both upstream and downstream of the Hanford Site at levels comparable to those reported by the U.S. Geological Survey (USGS) as part of their ongoing national water quality monitoring network. Similarly, some anions were detected upstream and downstream of the Site at levels consistent with those reported by the USGS. There was no measurable difference between the concentrations of metals and anions detected in river water along the cross sections at Vernita Bridge and the Richland Pumphouse.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Acknowledgments

The authors wish to express their appreciation to L. E. Bisping and J. L. Julya for sample scheduling, bottle preparation, and data management; to the Environmental Monitoring Group for sample collection; to T. M. Poston and R. K. Woodruff for technical review; to the Sigma V Text Processing Team for word processing support; and to R. E. Schrempf for editing and report production.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

Contents

Summary	iii
Acknowledgments	v
1.0 Introduction	1.1
2.0 Background Information	2.1
2.1 Columbia River	2.1
2.2 Hanford Site	2.1
2.3 Environmental Surveillance	2.3
3.0 Study Description	3.1
3.1 Objectives	3.1
3.2 Constituents of Interest	3.1
3.3 Sample Locations	3.6
3.4 Sample Frequency	3.6
3.5 Sample Collection	3.7
3.5.1 Equipment	3.7
3.5.2 Procedure	3.7
3.5.3 Field Measurements	3.9
3.5.4 Quality Control	3.10
4.0 Results and Discussion	4.1
4.1 Volatile Organic Compounds	4.1
4.2 Metals	4.3
4.3 Anions	4.3
4.4 Conductivity, pH, and Temperature	4.6
5.0 References	5.1

Figures

2.1 U.S. Department of Energy's Hanford Site	2.2
3.1 Sample Vessel and Equipment	3.8

Tables

3.1 Limits of Detection for Volatile Organic Compounds Analyzed by Gas Chromatography - Mass Spectrometry	3.4
3.2 Limits of Detection and Analytical Method for Metals	3.5
3.3 Limits of Detection and Analytical Method for Anions	3.5
4.1 Average Transect Concentrations for Volatile Organic Compounds	4.2
4.2 Average Transect Concentrations for Metals	4.4
4.3 Average Transect Concentrations for Anions	4.5
4.4 Average Transect Measurements for pH, Conductivity, and Temperature	4.7

1.0 Introduction

The Hanford Site Surface Environmental Surveillance Project (SESP) is conducted by the Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE). The routine Columbia River monitoring program, conducted as part of the SESP, provides an historical record of contaminant concentrations in the river attributable to natural causes, worldwide fallout resulting from past atmospheric testing of nuclear weapons, and from operations conducted at the Hanford Site. Historically, this program has focused on monitoring radionuclide concentrations in the Columbia River for use in evaluating the potential dose to those persons living near and using the river.

Operations at the Hanford Site have included the use of a wide variety of chemicals, many of which were released to the environment through effluent discharges. Recent hazardous wastes regulatory requirements and a changing mission at the Hanford Site, from operations to waste management and environmental restoration, have increased the awareness of, and concerns about, chemical contaminants in the environment. Additional information on the type, concentrations, fate, transport, and environmental significance of chemical contaminants in the Columbia River is needed.

To this end, the chemical monitoring portion of the routine Columbia River Monitoring program was expanded to include metals, anions, and volatile organic compounds (VOCs). The additional analyses were added to samples collected along cross sections upstream and downstream of the Hanford Site. The expanded list of analytes focused on chemical contaminants of potential Hanford-origin that had been detected in the ground water near the river or identified as contaminants of concern in other investigations and preliminary risk assessments. The initial set of sample results provides baseline concentration data on which to base a routine monitoring program for those constituents proven to be of concern.

This report summarizes the results obtained during the first year of operation of the expanded chemical monitoring program. The report includes a brief section of background information about past Site operations, a description of the Columbia River hydrology along the Hanford Site, and a history of river monitoring activities. The introductory material is followed by a description of the study and sampling methodology, and a presentation and discussion of the results observed during the initial year of sampling.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

2.0 Background Information

2.1 Columbia River

The Columbia River, which originates in the mountains of eastern British Columbia, Canada, flows through the northern edge of the Hanford Site and forms part of the Site's eastern boundary (Figure 2.1). The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (created by McNary Dam) near Richland. This stretch of the Columbia River is the last above Bonneville Dam within the United States that remains unimpounded.

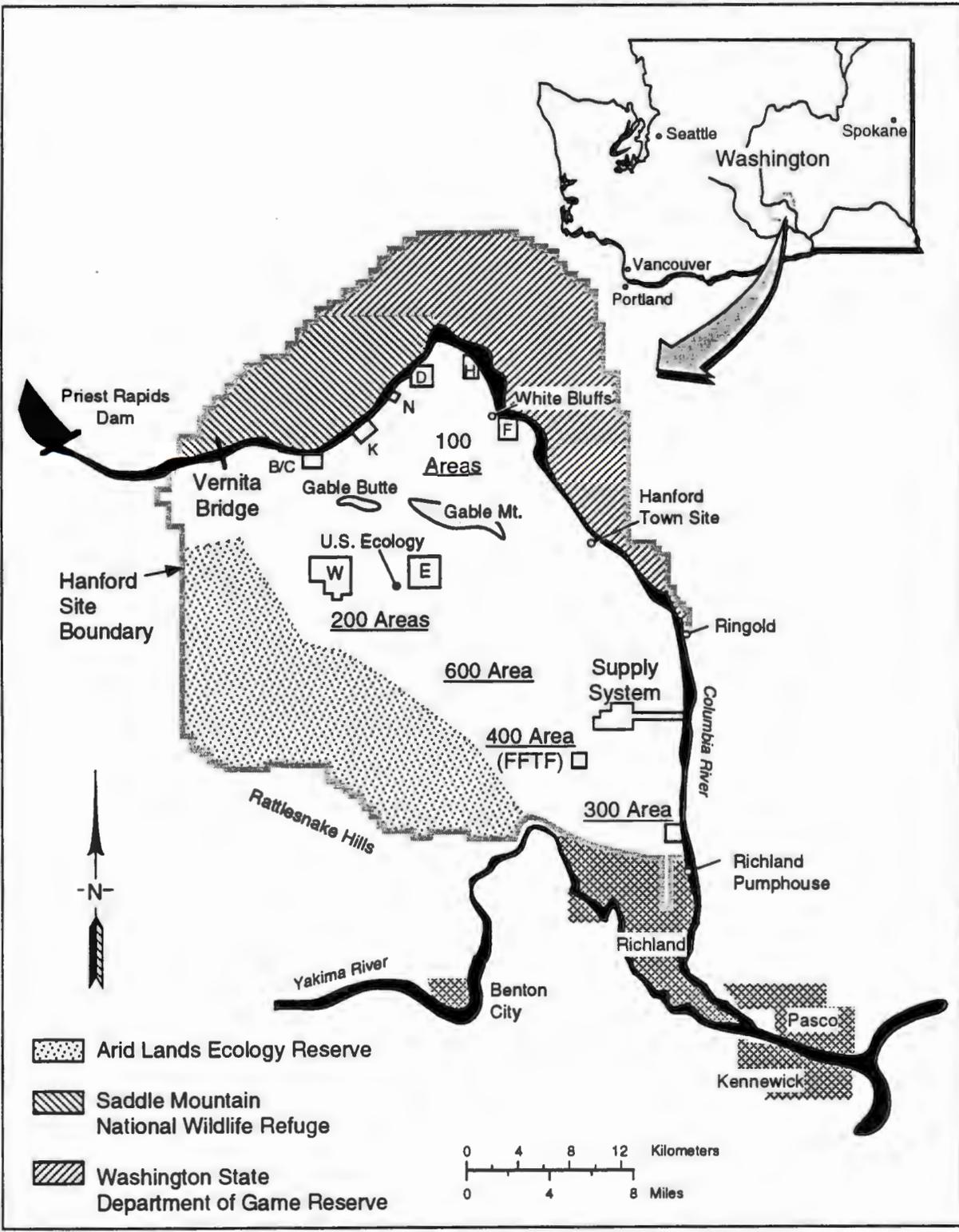
Flows through the Reach fluctuate significantly and are dictated primarily by operations at Priest Rapids Dam. Annual average flows at Priest Rapids Dam over the last 68 years have averaged nearly 120,000 cubic feet per second (cfs) (McGavock et al. 1988). Daily average flows range from 36,000 cfs to 250,000 cfs. Monthly mean flows typically peak from April through June and are lowest from September through October.

The Washington State Department of Ecology has designated the Columbia River along this stretch as Class A, Excellent (WDOE 1982; WDOE 1992). Water use guidelines are provided and water quality standards established for this class designation. Class A waters are to be suitable for essentially all uses, including raw drinking water, recreation, and wildlife habitat. Recent revisions to the water quality standards included the addition of concentration limits for several toxic substances (WDOE 1992).

2.2 Hanford Site

The Hanford Site, established in 1943, is located in southeastern Washington, occupying an area of approximately 560 square miles. The Site lies approximately 170 miles southeast of Seattle, Washington; 125 miles southwest of Spokane, Washington; and 200 miles northeast of Portland, Oregon (Figure 2.1). The Hanford Site was established to design, build, and operate nuclear reactors and chemical separations facilities for the production of special nuclear materials.

Nine production reactors have operated along the banks of the Columbia River since the Hanford Site was established. Eight of these reactors used once-through cooling systems, which resulted in the release of heated water, corrosion inhibiting chemicals, and radionuclides (primarily activation products) directly into the river. The N Reactor used a closed-loop cooling system, which resulted in the discharge of a significant amount of heat



S9304026.2

Figure 2.1. U.S. Department of Energy's Hanford Site

directly into the Columbia River, although very little radioactivity was associated with it. With the shutdown of the once-through cooling system reactors from 1965 to 1971, direct discharges of contaminants into the Columbia River were virtually eliminated, resulting in a tremendous decrease in the amount of radioactivity released to the river (Cushing et al. 1980; Becker 1990).

In addition to liquid discharges directly to the river, large volumes of wastewater were generated and discharged to the ground as a result of operations at the Hanford Site. The disposal of this liquid effluent to the ground has had a considerable impact on the unconfined aquifer beneath the Site. The movement of ground water and the associated radiological and nonradiological contaminants has changed over time as a result of the variation in both the volumes and composition of the wastewater. In general, the predominant flow pattern of Hanford Site ground water is from the recharge areas in the west to the discharge areas (primarily the Columbia River) in the east (Freshley and Graham 1988; Woodruff et al. 1992).

2.3 Environmental Surveillance

The Ground-Water Protection and Monitoring Project (GWMP), operated by PNL for the DOE, is responsible for monitoring the ground water beneath the Hanford Site. Monitoring is performed via a network of sampling wells located throughout the Site (Evans et al. 1992; Woodruff et al. 1992). Monitoring data indicate several contaminants are present in the ground water beneath waste disposal sites. The data also indicate that several of these contaminants are mobile in the ground-water system and travel at various rates through the unconfined aquifer, eventually discharging to the Columbia River. While this program has historically focused on radioactive pollutants in the ground water, monitoring for nonradiological contaminants has increased during the past few years.

The SESP is responsible for the routine monitoring of the Hanford Site surface waters, including the Columbia River and the riverbank springs entering the river along the Hanford Reach (Woodruff et al. 1992). Routine monitoring has shown that radiological and nonradiological contaminants are entering the river via riverbank springs (ground-water seepage) along the Hanford Reach (Dirkes 1990; McCormack and Carlile 1984; Manley 1992). Contaminant concentrations found during these efforts were indicative of those observed in ground water near the riverbank spring sampling sites.

Columbia River monitoring has been performed at Hanford since 1945, shortly after the start-up of the original plutonium production reactors. The primary emphasis of the Columbia River monitoring program has been the evaluation of the potential radiation dose to those

persons living near to and using the river. Therefore, the river monitoring program has focused on radiological constituents.

A limited number of chemical constituents are currently monitored through the SESP by the United States Geological Survey (USGS) in conjunction with their national water quality network (McGavock et al. 1988). In addition, a study conducted during 1988 included analysis of a few river water samples for an extensive list of nonradiological parameters (Dirkes 1990). While there is an extensive database for radionuclides in the Columbia River, the extent of chemical data is relatively limited.

In addition to the routine sitewide environmental surveillance projects, several hazardous wastes ground-water monitoring compliance projects are ongoing in conjunction with the Resource Conservation and Recovery Act (RCRA). These projects provide an extensive amount of information relative to the contaminants present in the ground water that is entering the river along the Hanford Site (Liikala et al. 1988; Schalla et al. 1988).

Several Comprehensive Environmental Response, Compensation, and Liability Act- (CERCLA) related activities are also ongoing at the Hanford Site. Remedial investigation/feasibility study (RI/FS) work plans, prepared in conjunction with the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (WDOE et al. 1990) have identified contaminants of concern that are, or may be, discharging to the river (DOE-RL 1990; DOE-RL 1992b). Recent investigations conducted under the RI/FS work plans have documented contaminants presently entering the river through the discharge of contaminated ground water from the Site (DOE-RL 1992a; Peterson and Johnson 1992).

3.0 Study Description

Routine environmental surveillance programs identified that Hanford-origin contaminants, both radiological and nonradiological, have been discharged to the river in the past and are continuing to enter the river along the Hanford Site. Various RCRA and CERCLA investigations have identified several additional potential contaminants of concern that may be entering the river. Preliminary and conservative risk evaluations have shown that the type and amounts of nonradiological contaminants entering the river may be of potential concern. The need to better characterize the types and concentrations of nonradiological constituents in the river was evident.

The number of nonradiological constituents analyzed for under the SESP was increased significantly during 1991. The nonradiological surveillance activities discussed in this report were initiated as part of the SESP under a long-term plan to enhance the river monitoring program at the Hanford Site, and to better understand the types, concentrations, transport, and fate of contaminants entering the river along the Hanford Reach. The plan identified the need to characterize the current levels of nonradiological contaminants present in the river that are attributable to the Hanford Site.

3.1 Objectives

The objectives of this report are to document the expansion of the chemical surveillance activities in the Columbia River monitoring program, and to present and discuss the results from samples collected during the first year of monitoring. Data presented in this report will provide a basis on which to further modify the Columbia River surveillance plan to obtain the amount and type of information needed to accurately characterize the contaminants of potential Hanford-origin, and to assess the potential impacts on the river. Results generated during future monitoring efforts will be included in the annual Hanford Site environmental reports.

3.2 Constituents of Interest

A large body of information has been generated for nonradiological contaminants in Hanford Site ground water; however, information on chemicals in Hanford Site surface water is relatively limited (Dirkes 1990; Poston et al. 1991; DOE-RL 1992a; Peterson and Johnson 1992). Chemical constituents of interest for this study were selected by reviewing summary results from the ground water monitoring program issued in the annual Hanford Site Environmental Report, special study reports, and both CERCLA remedial investigation/feasibility

study (RI/FS) documentation and RCRA facility investigation/corrective measure (FI/CM) study plans for the 300 and 100 Areas of the Hanford Site.

The chemical contaminants reported above the drinking water standard (DWS) by the ground-water program (Jaquish and Bryce 1990) were nitrate (in all operational areas except the 400 Area), chromium (in the 100-D, 100-H, 100-K, 200-E, and 200-W Areas), carbon tetrachloride (200-W Area), and trichloroethylene (Solid Waste Landfill, 100-F, and 300 Areas) with some of its partial degradation product cis-dichloroethylene. Cyanide was detected in ground water north of the 200-E Area; however, no DWS had been established for cyanide. Fluoride was detected above the DWS in the ground water directly beneath the 200-W Area, but all wells sampled outside the 200-W Area were below the DWS.

Dirkes (1990) characterized both radiological and nonradiological contaminants associated with Hanford Site ground-water seepage along the Columbia River. Water from riverbank springs was analyzed for a wide variety of nonradiological contaminants including metals, anions, thioureas, volatile organic compounds (VOCs), semivolatile organic compounds, pesticides, and polychlorinated biphenyls (PCBs). This study confirmed that the types and concentrations of contaminants in riverbank springs were similar to ground water (well samples) near the river. Nitrate concentrations in spring water were well above typical river water concentrations, but below the DWS in all cases. Other nonradiological contaminants were generally undetectable in spring water; however, samples collected near the 300 Area indicated that concentrations of chloroform, copper, and zinc were elevated relative to river water.

A scoping study was conducted by the SESP in 1988 to identify chemical contaminants to consider for monitoring. This study reviewed effluent release reports generated by the operating contractors for calendar years 1985, 1986, and 1987; a 1986 Rockwell report (RHO-RE-SA-133 P) on 200 Area effluents of hazardous constituents; a 1987 Westinghouse characterization report (WHC-SP-1093) for the 300 Area process trenches; the PA/SI report for inactive waste sites at Hanford; 1986 CERCLA characterization reports on 300 Area process ponds; and the Hanford Site ground-water data base. The scoping study analyzed data with the Multimedia Environmental Pollutants Exposure Assessment System (MEPAS) to generate cancer risk estimates for various human exposure scenarios (Droppo et al. 1989). The scoping study recommended the addition of chromium, nitrate, and VOCs (particularly methylene chloride near the 300 Area) as contaminants to be considered in river monitoring.

Both CERCLA RI/FS (100-BC-5 and 300-FF-1) and RCRA FI/CM (100-HR-3 and 100-DR-1) study plans for Hanford operable units were reviewed to identify constituents of interest for river water sampling. An interim characterization report for the 300 Area Process Trench was also reviewed. For the 100 Area, this review process identified nitrates, nitrite,

sulfate, fluoride, potassium, chromium, barium, copper, iron, lead, mercury, oxalic and sulfuric acids, 1,1,1-trichloroethane, tetrachloroethylene, chloroform, methylene chloride, and various radioisotopes as possible contaminants. PCBs and solvents were listed as likely 100 Area pollutants, although there was no documented evidence of their presence. Chemical contaminants of concern that were detected above background levels in soil from the 300 Area were fluoride, silver, cadmium, chromium, mercury, nickel, lead, antimony, zinc, barium, vanadium, trichloroethylene, and trans-1,2-dichloroethylene. Chemicals routinely discharged to the 300 Process Trench included copper, detergents, ethylene glycol, hydrofluoric acid, nitrates, nitric acid, sodium hydroxide, paint solvents, photography chemicals, sodium chloride, and uranium. Intermittent discharges to the 300 Area Process Trench included a wide variety of laboratory reagents and solvents.

As a result of the review of past monitoring results and various RI/FS (FI/CM) work plans and preliminary risk assessments, the Columbia River monitoring program was expanded to include numerous nonradiological constituents including VOCs, metals, and anions. Table 3.1 provides a list of VOCs that were included in the expanded monitoring program and shows their detection limits. The water samples were analyzed for all VOCs that were identified as contaminants of interest during the reviews.

Samples were also submitted for metals analysis as part of this monitoring enhancement. The specific metals included in the analysis and their detection limits are provided in Table 3.2. Water samples were analyzed for all metals that were identified during the review as contaminants of interest.

In addition to VOCs and metals, the program was expanded to include several anions, listed in Table 3.3 with their detection limits. Water samples were analyzed for all anions of interest except for cyanide. Cyanide in Hanford Site ground water was only detected near the 200-E Area and was unlikely to have any significant Columbia River input (Jaquish and Bryce 1990). Dirkes (1990) monitored for cyanide in a limited number of riverbank spring and river water samples. Cyanide concentrations reported in that study were below the detection level ($10 \mu\text{g/L}$) in all river water samples and all but one spring sample, where it was measured just above the detection level ($10.5 \mu\text{g/L}$).

Other constituents of interest that were identified during the review of potential nonradiological constituents of interest, but were not added to the routine monitoring program at this time, were oxalic acid, detergents, ethylene glycol, lead, and PCBs. Ethylene glycol, lead, and PCBs were not detected ($10 \mu\text{g/L}$, $5 \mu\text{g/L}$, and $4 \mu\text{g/L}$, respectively) in previous investigations of the riverbank springs and river water, and were not added to the routine monitoring program (Dirkes 1990). Oxalic acid and detergents were not monitored because of their relatively low risk to human health.

Table 3.1. Limits of Detection for Volatile Organic Compounds Analyzed by Gas Chromatography - Mass Spectrometry

Compound	Limit of Detection ^(a)
Volatile Organic Compounds ($\mu\text{g/L}$)	
acetone	4.3 (100)
benzene	1.6 (5.0)
carbon tetrachloride	1.5
chloroform	1.8
p-dichlorobenzene	5.0
1,1-dichloroethane	2.1
1,2-dichloroethane	2.4
total 1,2-dichloroethene	1.2
methylene chloride	1.6 (5.0)
methyl ethyl ketone	3.8
4-methyl-2-propanone	3.5
tetrachloroethylene	1.5
tetrahydrofuran	10 (10)
toluene	1.5 (5.0)
1,1,1-trichloroethane	1.6
1,1,2-trichloroethane	1.1
trichloroethylene	1.3 (5.0)
vinyl chloride	1.7
total xylene	1.0 (5.0)
1-butanol	1000

(a) Values in () indicative of laboratory used during August, September, and October 1991

Table 3.2. Limits of Detection and Analytical Method for Metals

<u>Compound</u>	<u>Limit of Detection</u>	<u>Method</u>
<u>Metals ($\mu\text{g/L}$)</u>		
antimony	200	Atomic Emission Spectroscopy
barium	20	
beryllium	3	
cadmium	10	
calcium	100	
chromium	20	
cobalt	20	
copper	20	
iron	20	
magnesium	100	
manganese	10	
mercury	0.2	Atomic Absorption
nickel	30	Atomic Emission Spectroscopy
potassium	300	
silver	20	
sodium	300	
tin	100	
vanadium	30	
zinc	10	

Table 3.3. Limits of Detection and Analytical Method for Anions

<u>Compound</u>	<u>Limit of Detection</u>	<u>Method</u>
<u>Anions ($\mu\text{g/L}$)</u>		
bromide	500	Ion Chromatography
chloride	200	
fluoride	100	
nitrate	200	
nitrite	200	
phosphate	400	
sulfate	500	

3.3 Sample Locations

Sample locations were established directly downstream of Vernita Bridge, upstream of all Hanford Site facilities, and at the Richland Pumphouse downstream of the Site (see Figure 2.1). Samples obtained from Vernita Bridge represent background conditions in the river as the water quality at this location is not influenced by operations at the Hanford Site. Samples were collected at the Richland Pumphouse to identify any increase in contaminant concentrations that may be attributable to Hanford Site operations. Because the Richland Pumphouse is the first downstream point of river water withdrawal for a public drinking water supply, this location provides an upper estimate of the contaminants present in river water that is used by the public at, and downstream of, this point (DOE 1991).

Sampling was conducted along cross sections at these locations to accurately characterize the average contaminant concentrations in the river. Past sampling along a cross section at the Richland Pumphouse revealed that concentration gradients exist for tritium under certain river flow conditions (Dirkes 1993). Multiple sample stations were established along each cross section. Four stations, equidistant across the river, were deemed adequate at the Vernita Bridge location. Initially, four stations were also sampled along the Richland Pumphouse cross section. Sampling was expanded to ten stations during 1992, again at equal distances across the river, to avoid the potential for biasing the results due to the concentration gradients that may exist near the Benton County shoreline at this location.

Samples were withdrawn from the river at a depth of 0.6 times the depth of the river at each station along the cross sections. Sampling at approximately mid-depth avoided the potential influence of bottom seepage and eliminated the potential for contamination associated with surface debris.

3.4 Sample Frequency

The cross-sectional sampling and subsequent chemical analysis was initially performed monthly to establish a database to characterize contaminant concentrations in the river. Monthly samples were obtained for August 1991 through December 1991. The sample frequency was reduced to quarterly during calendar year 1992, consistent with the Site Environmental Monitoring Plan (DOE-RL 1991). Sampling continues to be conducted quarterly at the present time.

3.5 Sample Collection

3.5.1 Equipment

Samples were collected using a 24-ft Thunder Jet boat equipped with various auxiliary sampling equipment as shown in Figure 3.1. A bow-mounted electric winch was used to deploy the anchor (approximately 250 pounds), which was needed in the swift current to hold the vessel stationary at the desired location. Special equipment required to sample water at 0.6 times river depth included a davit and wire-line depressor controlled by a battery-operated winch coiled with stainless steel cable that attached to the wire-line depressor. River depth was determined at each sample location using a Lowrance Model X25 depth finder.

Sampling locations along the cross sections were initially identified visually by evenly spacing four locations across the river with reference to a particular landmark. A Garmin GPS-100 global positioning system (GPS) was used for documentation and relocation of the sampling sites. In this manner, the vessel was repositioned relatively close to the desired location, within the limitations (120 ft) of the GPS, during subsequent sampling events.

Initially, a MasterFlex model 7570-10 peristaltic pump was used to pump water through MasterFlex 6411-15 silicon and MasterFlex 6409-15 tygon tubing into the sample containers at a flowrate of approximately 0.4 liter per minute (L/min). A TEEL Flow-Jet 2100-12 Type IV pump, which operated at a flowrate of approximately 7.5 L/min, was subsequently chosen to replace the MasterFlex pump to reduce the sampling time associated with the relatively large volume of water collected at each station. Water temperature was measured with a FLUKE 51 thermometer. Conductivity and pH were measured with a MYRON "L" model DCH4 meter.

3.5.2 Procedure

The GPS was used to locate the desired location within the river along the cross section. Once located, the vessel was maneuvered directly upstream of the sample station where the anchor was dropped. Once stabilized, the vessel was gradually moved downstream on the anchor line back into the desired position indicated by the GPS. In this manner, the sample stations remained constant within the limitations of the GPS. The engines were shut down before sampling activities began, to avoid the potential for sample contamination.

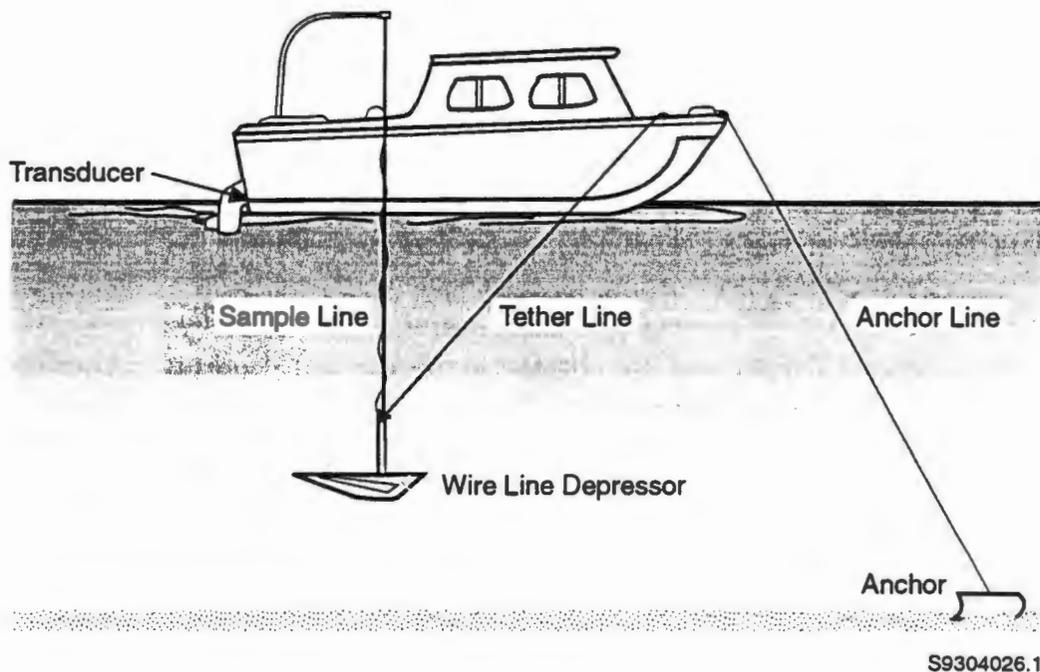


Figure 3.1. Sample Vessel and Equipment

The depth of the river was measured and recorded at each station along the cross sections prior to sample collection. Once the depth of the river at the sample location was determined, the desired sample collection depth (0.6 times the river depth) was calculated and the equipment was lowered at known increments to the desired depth. Under some flow conditions, proper positioning of the sample intake in the water column was maintained by using a nylon tether line secured to the wire-line depressor and the bow of the boat (Figure 3.1).

The sample pump was activated when the sample intake was positioned at the desired depth to purge the sample line for several minutes prior to sampling. This ensured that water from the desired depth was being collected and avoided potential cross-contamination of the samples. In addition, all silicon and tygon tubing was conditioned prior to use by purging with river water for at least 24 hours. Surgical gloves were worn during sample collection to further minimize the potential for sample contamination.

Water samples analyzed for ICP metals were collected in 500-mL plastic bottles containing 1 mL of nitric acid preservative. Water samples analyzed for various VOCs were collected in

40-mL dark glass bottles containing 0.1 mL of hydrochloric acid preservative. Samples analyzed for selected radionuclides were collected in 9.4-L collapsible plastic containers. All samples were placed on ice in an ice chest immediately after collection.

A unique sample identification number was provided for every sample collected. Sample collection and chain-of-custody were documented on trip sheets or field records used routinely in environmental surveillance programs. Data received from the laboratory were identified by the unique sample number established prior to sample collection. All samples were delivered to the appropriate laboratory as soon as possible following sample collection, well within sample transport/storage restrictions (NUS 1987).

3.5.3 Field Measurements

Temperature, specific conductance, and pH measurements were performed prior to and immediately after the collection of each water sample. Field measurements were made at the outlet of the sample collection tubing, on water collected from the desired sampling depth. These measurements are performed routinely as part of ongoing environmental monitoring programs, in accordance with established procedures (PNL 1989). In addition to these water quality-related measurements, the water depth was determined at each cross-section station prior to and immediately after each sampling event using the manufacturer's (Lowrance) recommended operating procedures. The field measurements performed during the cross-sectional sampling are discussed briefly below.

3.5.3.1 Temperature

The temperature of the river water was determined at each sample location at the sample line outlet prior to and after each sample collection. The water temperature as measured at the outlet may indicate some artificial warming due to travel time through the sample line and exposure of the line to sunlight and warmer air temperatures. However, the temperature at this point best represents the sample collected for chemical analysis. The Fluke thermometer was calibrated in accordance with standard environmental surveillance procedures (PNL 1989).

3.5.3.2 pH and Specific Conductance

The pH and conductivity of the river water was determined at each sample location prior to and after sample collection. The instrument used was calibrated prior to use each day during the investigation in accordance with standard environmental surveillance procedures (PNL 1989). Calibrations consisted of both internal standards, which served primarily as a

battery check, and external standard solutions. The standard solutions used in the routine calibrations were within the range typically observed in Columbia River water.

3.5.4 Quality Control

All samples were collected and handled according to approved sample collection procedures. Adhesive labels were placed on the sample bottles, completed in ink, and covered with clear plastic tape. Chain-of-custody, which was maintained throughout the sample collection and transport process, was documented on appropriate forms with custodian transfer and sign-off upon relinquishing the samples to the laboratory. Samples were delivered to the laboratory as soon after collection as practical, well within recommended sample storage/transport time limitations for the desired analyses. Field measurements were documented in field record books and are maintained in SESP study files.

4.0 Results and Discussion

Water samples were collected from the Columbia River along cross sections established at Vernita Bridge and the Richland Pumphouse, monthly during the last 4 months of 1991 and quarterly throughout 1992. Samples were collected from multiple stations along the cross sections as described earlier (see Section 3.0, Study Description). The following sections summarize and discuss the chemical sample results.

The data summaries present average contaminant concentrations for each cross section for those constituents that were reported above the analytical detection level during the report period. The average concentrations were calculated using the detection limit value when individual sample results were less than the detection level (e.g., the average of 0.20, 0.40, 0.50, and ≤ 0.10 would be reported as 0.30). In this manner the averages are biased high, providing a conservative estimate of contaminant concentrations in the river.

4.1 Volatile Organic Compounds (VOCs)

Water samples were analyzed for the following VOCs; acetone; benzene; carbon tetrachloride (tetrachloromethane); chloroform (trichloromethane); p-dichlorobenzene; 1,1-dichloroethane; 1,2-dichloroethane; total 1,2-dichloroethylene; methylene chloride (dichloromethane); methyl ethyl ketone; 4-methyl-2-pentanone (hexone); tetrachloroethylene (perchloroethylene); tetrahydrofuran; toluene; 1,1,1-trichloroethane; trichloroethylene; vinyl chloride (chloroethylene); total xylene; and 1-butanol. Two contract analytical laboratories were involved in the VOC determinations. Samples collected during August, September, and October 1991 were analyzed by the first laboratory while contract negotiations were finalized with the second laboratory, which analyzed the samples collected during the rest of the study period. In general, detection levels were improved with the second laboratory.

No VOCs were routinely detected in the water samples (Table 3.1). Table 4.1 provides average concentrations of those constituents that were identified above the detection level at any time during the report period. The November 1991 samples had elevated concentrations of toluene; tetrahydrofuran; xylene; benzene; 1,1,1-trichloroethane; and methylene chloride. All compound concentrations were higher at Vernita Bridge with the exception of toluene, which was elevated at the Richland Pumphouse. This one set of samples represented the majority of VOC results above the detection limits and may be the result of sample contamination during collection or analysis because all of the compounds detected are common laboratory and industrial solvents. The average acetone concentration was elevated at the Richland Pumphouse, compared to Vernita Bridge, on one occasion (December 1992); however, it was detected in only 2 of the 10 cross-section samples collected.

Table 4.1. Mean Transect Concentrations for Volatile Organic Compounds ($\mu\text{g/L}$)

<u>Location & Date^(a)</u>	<u>Number of Samples</u>	<u>Toluene</u>	<u>THF^(b)</u>	<u>Xylene</u>	<u>Ace^(c)</u>	<u>Benzene</u>	<u>TCE^(d)</u>	<u>Methylene chloride</u>
<u>8 Aug 91/7 Aug 91</u>								
Vernita Bridge	4	<5.0	<10	<5.0	<100	<5.0	<5.0	<5.0
Richland Pumphouse	4	<5.0	<10	<5.0	<100	<5.0	<5.0	<5.0
<u>24 Sept 91/25 Sept 91</u>								
Vernita Bridge	4	<5.0	<10	<5.0	<100	<5.0	<5.0	<5.0
Richland Pumphouse	4	<5.0	<10	<5.0	<100	<5.0	<5.0	<5.0
<u>17 Oct 91/18 Oct 91</u>								
Vernita Bridge	4	<5.0	<10	<5.0	<100	<5.0	<5.0	<5.0
Richland Pumphouse	4	<5.0	<10	<5.0	<100	<5.0	<5.0	<5.0
<u>25 Nov 91/27 Nov 91</u>								
Vernita Bridge	4	<1.5	580	4.8	<4.3	29	1900	68
Richland Pumphouse	4	4.7	<10	4.0	<4.3	<1.6	<1.6	<1.6
<u>17 Dec 91/18 Dec 91</u>								
Vernita Bridge	4	1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
Richland Pumphouse	4	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
<u>25 Mar 92/30 Mar 92</u>								
Vernita Bridge	4	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
Richland Pumphouse	10	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
<u>11 Jun 92/12 Jun 92</u>								
Vernita Bridge	4	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
Richland Pumphouse	10	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
<u>30 Sep 92/6 Oct 92</u>								
Vernita Bridge	4	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
Richland Pumphouse	10	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
<u>10 Dec 92/11 Dec 92</u>								
Vernita Bridge	4	<1.5	<10	<1.0	<4.3	<1.6	<1.6	<1.6
Richland Pumphouse	10	<1.5	<10	<1.0	11	<1.6	<1.6	<1.6

(a) The Vernita Bridge sampling date is provided first in all cases

(b) THF = tetrahydrofuran

(c) Ace = acetone

(d) TCE = 1,1,1-trichloroethane

4.2 Metals

Water samples were analyzed for the following metals: antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, mercury, nickel, potassium, silver, sodium, tin, vanadium, and zinc. Table 4.2 lists average concentrations of metals for the Vernita Bridge and Richland Pumphouse transects, except for antimony, beryllium, cadmium, cobalt, mercury, silver, tin, and vanadium, which were below detection limits for all samples (Table 3.2). The USGS monitoring also reports these metals at less than detectable concentrations in the Columbia River (McGavock et al. 1988).

Barium, calcium, iron, potassium, magnesium, and sodium were detected in all water samples, with no consistent difference between Vernita Bridge and Richland Pumphouse samples. Potassium results were generally slightly elevated at Vernita Bridge compared to the Richland Pumphouse. Low concentrations of zinc were detected in 23% of the 106 samples collected during the study period; however, no upriver/downriver trend was observed. Chromium, copper, manganese, and nickel were detected in very few samples, with all these results being near the limit of detection. In all cases, the concentrations of metals were similar to those reported by the USGS (McGavock et al. 1988; Woodruff et al. 1992).

4.3 Anions

Water samples were analyzed for the following anions; fluoride (F), chloride (Cl), bromide (Br), nitrate (NO₃), nitrite (NO₂), phosphate (PO₄³⁻), and sulfate (SO₄²⁻). Table 4.3 lists average concentrations of anions for the Vernita Bridge and Richland Pumphouse transects, except for bromide, nitrite, and phosphate, which were below detection limits for all samples (Table 3.3). Measurements performed by the USGS confirmed the less-than-detectable levels of these anions in Columbia River water along the Hanford Reach (McGavock et al. 1988)

Mean fluoride concentrations ranged between 100 - 300 µg/L, with no consistent pattern between concentrations at Vernita Bridge and the Richland Pumphouse. Average chloride concentrations were 800 - 1100 µg/L, with little difference between locations. Mean nitrate concentrations ranged from <200 to 1100 µg/L, with the the Richland Pumphouse generally exhibiting slightly higher concentrations than Vernita Bridge. Average sulfate concentrations range from 8300 - 10,000 µg/L and were similar at both locations. The concentrations of fluoride, chloride, nitrate, and sulfate were similar to those measured by the USGS (McGavock et al. 1988; Woodruff et al. 1992).

Table 4.2. Average Transect Concentrations for Metals ($\mu\text{g/L}$)

<u>Location & Date^(a)</u>	<u>Number of Samples</u>	<u>Ba</u>	<u>Ca</u>	<u>Cr</u>	<u>Cu</u>	<u>Fe</u>	<u>K</u>	<u>Mg</u>	<u>Mn</u>	<u>Na</u>	<u>Ni</u>	<u>Zn</u>
<u>8 Aug 91/7 Aug 91</u>												
Vernita Bridge	4	33	18,000	<20	<20	160	820	4100	<10	2300	<30	<10
Richland Pumphouse	4	32	18,000	<20	<20	150	500	3900	11	2200	<30	<10
<u>24 Sep 91/25 Sep 91</u>												
Vernita Bridge	4	24	17,000	<20	<20	72	1900	3800	<10	1800	<30	12
Richland Pumphouse	4	28	18,000	<20	<20	130	490	3900	10	2100	<30	<10
<u>17 Oct 91/18 Oct 91</u>												
Vernita Bridge	4	25	18,000	<20	<20	99	930	4100	11	2100	<30	<10
Richland Pumphouse	4	26	19,000	22	22	180	850	4100	<10	2100	<30	<10
<u>25 Nov 91/27 Nov 91</u>												
Vernita Bridge	4	29	18,000	<20	<20	68	720	4000	<10	1900	<30	<10
Richland Pumphouse	4	30	19,000	<20	<20	45	650	4200	<10	2000	<30	<10
<u>17 Dec 91/18 Dec 91</u>												
Vernita Bridge	4	28	19,000	<20	20	52	1500	4300	<10	2000	<30	15
Richland Pumphouse	4	30	19,000	<20	<20	79	500	4400	<10	2100	31	15
<u>25 Mar 92/30 Mar 92</u>												
Vernita Bridge	4	22	19,000	<20	<20	33	800	4400	<10	1800	<30	<10
Richland Pumphouse	10	26	20,000	<20	<20	36	690	4800	<10	2400	<30	17
<u>11 Jun 92/12 Jun 92</u>												
Vernita Bridge	4	32	18,000	<20	<20	82	560	4000	<10	2200	<30	19
Richland Pumphouse	10	28	17,000	<20	<20	99	820	4000	<10	2200	<30	10
<u>30 Sep 92/2 Oct 92</u>												
Vernita Bridge	4	25	18,000	<20	<20	40	1100	4200	<10	2000	<30	<10
Richland Pumphouse	10	29	19,000	<20	<20	50	1000	4400	<10	2300	<30	<10
<u>11 Dec 92/12 Dec 92</u>												
Vernita Bridge	4	30	20,000	<20	<20	43	880	4600	<10	2100	<30	<10
Richland Pumphouse	10	30	20,000	<20	<20	60	740	4600	<10	2200	<30	11
<u>Overall Average of Mean Concentrations</u>												
Vernita Bridge	36	28	18,000	NC ^(b)	NC	72	1000	4600	NC	2000	NC	12
± 1 std deviation		3.8	870			39	420	240		170		3.4
Richland Pumphouse	60	29	19,000	NC	NC	92	690	4200	NC	2200	NC	11
± 1 std deviation		2.0	970			51	180	320		120		2.6

(a) The Vernita Bridge sampling date is provided first in all cases
(b) Not calculated because this element was not routinely detected

Table 4.3. Average Transect Concentrations for Anions ($\mu\text{g/L}$)

<u>Location & Date^(a)</u>	<u>Number of Samples</u>	<u>F⁻</u>	<u>Cl⁻</u>	<u>NO₃</u>	<u>SO₄²⁻</u>
<u>08 Aug91/07 Aug91</u>					
Vernita Bridge	4	150	980	NA ^b	7400
Richland Pumphouse	4	150	1000	NA	7500
<u>24 Sept91/25 Sept91</u>					
Vernita Bridge	4	110	680	NA	8400
Richland Pumphouse	4	110	740	NA	8700
<u>17 Oct91/18 Oct91</u>					
Vernita Bridge	4	150	900	NA	9050
Richland Pumphouse	4	130	740	NA	7050
<u>25 Nov91/27 Nov91</u>					
Vernita Bridge	4	300	800	300	8700
Richland Pumphouse	4	300	850	265	8800
<u>17 Dec91/18 Dec91</u>					
Vernita Bridge	4	150	920	180	8700
Richland Pumphouse	4	180	880	220	8800
<u>25 Mar92/30 Mar92</u>					
Vernita Bridge	4	100	920	450	9900
Richland Pumphouse	10	170	1100	1100	10,000
<u>11 Jun92/12 Jun92</u>					
Vernita Bridge	4	100	900	< 200	8300
Richland Pumphouse	10	100	910	340	8300
<u>30 Sep92/02 Oct92</u>					
Vernita Bridge	4	150	650	280	9500
Richland Pumphouse	10	< 100	680	380	9800
<u>11 Dec92/10 Dec92</u>					
Vernita Bridge	4	200	1000	450	9500
Richland Pumphouse	10	< 100	890	560	8900
<u>Overall Average of Mean Concentrations</u>					
Vernita Bridge	36	160	860	310 ^(c)	8800
± 1 std deviation		62	120	120	760
Richland Pumphouse	60	150	870	480 ^(d)	8600
± 1 std deviation		64	130	330	950

(a) The Vernita Bridge sampling date is provided first in all cases

(b) Not Analyzed

(c) 28 Samples

(d) 52 Samples

4.4 Conductivity, pH, and Temperature

Temperature, pH, and conductivity were measured at the pump outlet for all samples, with the average transect results given in Table 4.4. The average pH values ranged from 7.3 to 8.6 for all samples with no apparent difference between locations. Mean conductivity values, which varied from 112 - 191 uS, were similar at both locations. The March 1992 samples had the largest upriver/downriver difference for both pH and conductivity; however, the Richland Pumphouse samples were collected 5 days after the Vernita Bridge samples. Water temperature measured at the pump outlet ranged from 6.6 to 22.8°C for all locations with little difference between sampling locations. Water temperature, pH, and conductivity were within the range observed by the USGS during the course of their national water quality investigations (McGavock et al. 1988; Woodruff et al. 1992).

Table 4.4. Average Transect Measurements for pH, Conductivity, and Temperature

<u>Location and Date^(a)</u>	<u>Number of Locations</u>	<u>pH</u>	<u>Conductivity (uS)</u>	<u>Temperature (°C)</u>
<u>08 Aug91/07 Aug91</u>				
Vernita Bridge	4	8.6	126	21.4
Richland	4	8.3	128	22.8
<u>24 Sept91/25 Sept91</u>				
Vernita Bridge	4	8.4	119	19.9
Richland Pumphouse	4	8.5	121	19.8
<u>17 Oct91/18 Oct91</u>				
Vernita Bridge	4	8.3	122	15.9
Richland Pumphouse	4	7.7	112	15.0
<u>25 Nov91/27 Nov91</u>				
Vernita Bridge	4	7.3	121	12.0
Richland Pumphouse	4	7.8	122	10.6
<u>17 Dec91/18 Dec91</u>				
Vernita Bridge	4	7.4	142 ^(b)	7.2
Richland Pumphouse	4	7.9	134	6.6
<u>25 Mar92/30 Mar92</u>				
Vernita Bridge	4	7.5	191	9.0
Richland Pumphouse	10	8.5	145	10.2
<u>11 Jun92/12 Jun92</u>				
Vernita Bridge	4	8.6	121 ^(c)	16.1
Richland Pumphouse	10	8.3	123	15.8
<u>30 Sep92/02 Oct92</u>				
Vernita Bridge	4	8.2	133	19.4
Richland Pumphouse	10	8.0	130	18.7
<u>11 Dec92/10 Dec92</u>				
Vernita Bridge	4	8.0	154	7.8
Richland Pumphouse	10	8.0	146	7.8
<u>Overall Average of Mean Measurements</u>				
Vernita Bridge	36	8.0	136	14.3
± 1 std deviation		NA ^(d)	24	5.5
Richland Pumphouse	60	8.1	129	14.1
± 1 std deviation		NA	11	5.7

(a) The Vernita Bridge sampling date is provided first in all cases

(b) The result includes one value of 197 uS, by excluding this point the average becomes 134 uS

(c) One measurement of 382 uS was excluded from the average

(d) Not Applicable

**THIS PAGE INTENTIONALLY
LEFT BLANK**

5.0 References

Becker, C. D. 1990. *Aquatic Bioenvironmental Studies: The Hanford Experience, 1944-84*. Elsevier Science Publishing Company, Inc., New York.

Cushing, C. E., D. G. Watson, A. J. Scott, and J. M. Gurtisen. 1980. *Decrease of Radionuclides in Columbia River Biota Following Closure of Hanford Reactors*. PNL-SA-8407, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L. 1990. *1988 Hanford Riverbank Springs Characterization Report*. PNL-7500, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L. 1993. *Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pumphouse*. PNL-8531, Pacific Northwest Laboratory, Richland, Washington.

Droppo, J. G., Jr., D. L. Streng, J. W. Buck, B. L. Hoopes, R. D. Brockhans, M. B. Walter, and G. Whelan. 1989. *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance*. PNL-7216, Volume 1, Pacific Northwest Laboratory, Richland, Washington.

Evans, J. C., R. W. Bryce, and D. J. Bates. 1992. *Hanford Site Ground-Water Monitoring for 1991*. PNL-8284, Pacific Northwest Laboratory, Richland, Washington.

Freshley, M. D., and M. J. Graham. 1988. *Estimation of Ground-Water Travel Time at the Hanford Site: Description, Past Work, and Future Needs*. PNL-6328, Pacific Northwest Laboratory, Richland, Washington.

Jaquish, R. E. and R. W. Bryce. 1990. *Hanford Site Environmental Report for Calendar Year 1989*. PNL-7346, Pacific Northwest Laboratory, Richland, Washington.

Liikala, T. L., R. L. Aaberg, N. J. Aimo, D. J. Bates, T. J. Gilmore, E. J. Jensen, G. V. Last, P. L. Oberlander, K. B. Olsen, K. R. Oster, L. R. Roome, J. C. Simpson, S. S. Teel, and E. J. Westergard. 1988. *Geohydrologic Characterization of the Area Surrounding the 183-H Solar Evaporation Basins*. PNL-6728, Pacific Northwest Laboratory, Richland, Washington.

- Manley, C. L. 1992. *Environmental Releases for Calendar Year 1991*. WHC-EP-0527-1, Westinghouse Hanford Company, Richland, Washington.
- McCormack, W. D., and J. M. V. Carlile. 1984. *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River*. PNL-5289, Pacific Northwest Laboratory, Richland, Washington.
- McGavock, E. H., W. D. Wiggins, R. L. Blazs, P. R. Boucher, L. L. Reed, and M. L. Smith. 1988. *Water Resources Data Washington Water Year 1986*. U.S. Geological Survey, Tacoma, Washington.
- NUS Corporation. 1987. *Analytical Laboratory Guidebook for Environmental Professionals*. NUS Corporation, Pittsburgh, Pennsylvania.
- Pacific Northwest Laboratory (PNL). 1989. *Procedures for Ground-Water Investigations*. PNL-6894, Pacific Northwest Laboratory, Richland, Washington.
- Peterson, R. E., and V. G. Johnson. 1992. *Riverbank Seepage of Groundwater Along the 100 Areas Shoreline, Hanford Site*. WHC-EP-0609, Westinghouse Hanford Company, Richland, Washington.
- Poston, T. M., K. R. Price, and D. R. Newcomer. 1991. *An Evaluation of the Chemical, Radiological, and Ecological Conditions of West Lake on the Hanford Site*. PNL-7662, Pacific Northwest Laboratory, Richland, Washington.
- Schalla, R., R. W. Wallace, R. L. Aaberg, S. P. Airhart, D. J. Bates, J. M. Carlile, C. S. Cline, D. I. Dennison, M. D. Freshly, T. R. Heller, E. J. Jensen, K. B. Olsen, R. G. Parkhurst, J. T. Rieger, and E. J. Westergard. 1988. *Interim Characterization Report for the 300 Area Process Trenches*. PNL-6716, Pacific Northwest Laboratory, Richland, Washington.
- U.S. Department of Energy, Richland Field Office (DOE-RL). 1990. *Remedial Investigation/Feasibility Study Work Plan for the 300-FF-5 Operable Unit, Hanford Site, Richland, Washington*. DOE/RL-89-14, U.S. Department of Energy, Richland, Washington.
- U.S. Department of Energy (DOE). 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. DOE/EH-0173T, U.S. Department of Energy, Washington, D. C.

U.S. Department of Energy, Richland Field Office (DOE-RL). 1991. *Environmental Monitoring Plan United States Department of Energy Richland Field Office*. DOE/RL 91-50, U.S. Department of Energy, Richland, Washington.

U.S. Department of Energy, Richland Field Office (DOE-RL). 1992a. *Sampling and Analysis of 100 Area Springs*. DOE/RL-92-12, Revision 1, Department of Energy, Richland, Washington.

U.S. Department of Energy, Richland Field Office (DOE-RL). 1992b. *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-5 Operable Unit, Hanford Site, Richland, Washington*. DOE/RL-90-08, Revision 0, U.S. Department of Energy, Richland, Washington.

Washington State Department of Ecology (WDOE). 1982. *Water Quality Standards for Waters of the State of Washington*. Washington Administrative Code, Chapter 173-201, Olympia, Washington.

Washington State Department of Ecology (WDOE), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE). 1990. *Hanford Federal Facility Agreement and Consent Order*. Two volumes, as amended, Washington State Department of Ecology, Olympia, Washington.

Washington State Department of Ecology (WDOE). 1992. *Water Quality Standards for Waters of the State of Washington*. Washington Administrative Code, Chapter 173-201a, Olympia, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren. 1992. *Hanford Site Environmental Report for Calendar Year 1991*. PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

**THIS PAGE INTENTIONALLY
LEFT BLANK**

DistributionNo. of
CopiesNo. of
CopiesOFFSITE

- 2 DOE/Office of Scientific and
Technical Information

J. Erickson
Washington State Department
of Health
Division of Radiation
Protection
Airdustrial Center
Building 5, M.S. C-13
Olympia, WA 98503

ONSITE

- 5 DOE Richland Operations Office

R. F. Brich
B. L. Foley
E. D. Goller
M. W. Tiernan
K. M. Thompson

- 9 Westinghouse Hanford Company

L. P. Diediker
J. J. Dorian
E. M. Greager
L. C. Hulstrom
C. J. Perkins
J. W. Schmidt
S. E. Vukelich
S. G. Weiss
Public Reading Room

- 57 Pacific Northwest Laboratory

E. J. Antonio
R. W. Bryce
T. A. Cooper
R. L. Dirkes (25)
S. L. Friant
R. H. Gray
R. W. Hanf, Jr.
P. M. Irving
R. E. Jaquish
E. W. Lusty
G. W. Patton (5)
T. M. Poston
R. E. Schrempf
B. L. Tiller (5)
H. E. Westerdahl
R. K. Woodruff
Publishing Coordination
SESP Historical Files/
R. K. Woodruff (2)
Technical Report Files (5)

Routing

R. M. Ecker
M. J. Graham
C. J. Hostetler
R. L. Skaggs
C. S. Sloane
P. C. Hays (last)

**THIS PAGE INTENTIONALLY
LEFT BLANK**