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6. Will Material be Handed Out? No Yes

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Cc: Raidl, Robert F
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Janice, as discussed this morning, please accept this email as James Hanson's concurrence.

Thank you...

From: Hanson, James P
Sent: Wednesday, May 16, 2007 9:03 AM
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Cc: Farrell, Lee J
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I have reviewed the document and am satisfied with the modifications and message contained within the document.

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BobR

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Page 1 of 1

DOCUMENT TITLE:

Calendar Year 2006 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations

OWNING ORGANIZATION/FACILITY:

FH

Document Number: DOE/RL-2006-76

Revision/Change Number: 0

DOCUMENT TYPE (Check Applicable)
 Plan
 Report
 Study
 Description Document
 Other
DOCUMENT ACTION
 New
 Revision
 Cancellation
RESPONSIBLE CONTACTS

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373-4447

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373-3807

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 Yes No

Does document contain controlled-use information?

 Yes No

("Yes" requires information clearance review in accordance with HNF-PRO-184)

DOCUMENT REVISION SUMMARY

NOTE: Provide a brief description or summary of the changes for the document listed.

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20

DOE/RL-2006-76
Revision 0

Calendar Year 2006 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and- Treat Operations

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management



**United States
Department of Energy**
P.O. Box 550
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DOE/RL-2006-76
Revision 0

Calendar Year 2006 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations

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May 2007

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Release Approval Date

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LIST OF TERMS

CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
COC	contaminant of concern
CY	calendar year
DO	dissolved oxygen
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
FH	Fluor Hanford, Inc.
FY	fiscal year
gpm	gallons per minute
HEIS	Hanford Environmental Information System
ISRM	In Situ Redox Manipulation
IX	ion exchange
LWDF	Liquid Waste Disposal Facility
MCL	maximum contaminant level
ORP	oxidation-reduction potential
OU	operable unit
PRB	permeable reactive barrier
PSDB	project-specific database
QC	quality control
RAO	remedial action objective
ROD	Record of Decision
RPD	relative percent difference
TPH	total petroleum hydrocarbon
Tri-Party Agreement	<i>Hanford Federal Facility Agreement and Consent Order</i>
WCH	Washington Closure Hanford, LLC

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METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
<i>If You Know</i>	<i>Multiply By</i>	<i>To Get</i>	<i>If You Know</i>	<i>Multiply By</i>	<i>To Get</i>
Length			Length		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			Area		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			Mass (weight)		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			Volume		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			Temperature		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			Radioactivity		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries

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1.0 INTRODUCTION

Fluor Hanford, Inc. (FH) is currently operating six groundwater pump-and-treat systems across the Hanford Site. Four systems address groundwater in the 100 Areas: two systems treat hexavalent chromium in the 100-HR-3 Operable Unit (OU); the 100-KR-4 OU system also treats hexavalent chromium; and the 100-NR-2 system, which treats strontium-90, is in cold-standby status. Two pump-and-treat systems have remediated groundwater in the 200 West Area: the 200-UP-1 OU system, which is going through a rebound investigation after treating technetium-99, uranium, carbon tetrachloride, and nitrate; and the 200-ZP-1 OU system, which is actively treating carbon tetrachloride, chloroform, and trichloroethene.

This annual summary report discusses the groundwater remedial actions in the 100 Areas, including interim remedial actions at the 100-HR-3, 100-KR-4, and 100-NR-2 OUs (Figure 1-1). A detailed description of the progress and performance of the In Situ Redox Manipulation (ISRM) barrier was reported separately in the *Fiscal Year 2006 Annual Summary Report for the In Situ Redox Manipulation Operations* (DOE-RL 2007). The ISRM barrier is located in the southwestern portion of the 100-D Area.

The interim remedial actions chosen for the 100-HR-3 and 100-KR-4 OUs are pump-and-treat systems that use an ion-exchange (IX) medium for contaminant removal. The systems were designed to achieve three remedial action objectives (RAOs), as well as specific operational and aquifer performance criteria described in the interim remedial action Record of Decision (ROD), *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site (Interim Remedial Actions)* (EPA et al. 1996). The three RAOs are identified as follows:

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- **RAO #2:** Protect human health by preventing exposure to contaminants in the groundwater.
- **RAO #3:** Provide information that will lead to a final remedy.

The interim remedial action initially chosen for the 100-NR-2 OU was a pump-and-treat system using an IX medium for removal of strontium-90. The *Interim Remedial Action Record of Decision (ROD) Declaration, USDOE Hanford 100 Area, 100-NR-1, and 100-NR-2 Operable Units, Hanford Site* (EPA et al. 1999) specified this selected remedy. The implementation of the existing pump-and-treat system was authorized in the *Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy Hanford Site, Richland, Washington* (Ecology and EPA 1994). The 100-NR-2 RAOs are summarized as follows:

- **RAO #1:** Maintain beneficial uses of the Columbia River and protect the aquifer by reducing contaminant concentrations in the 100-NR-2 groundwater.
- **RAO #2:** Evaluate commercially available treatment options for strontium-90.
- **RAO #3:** Provide data necessary to set demonstrable strontium-90 cleanup standards.

In 2005, a review of the RAO actions was evaluated, and it was determined that the pump-and-treat system was ineffective and inefficient in reducing the flux of strontium-90 to the Columbia River. As a result of this review and via approval in accordance with the *Hanford Federal*

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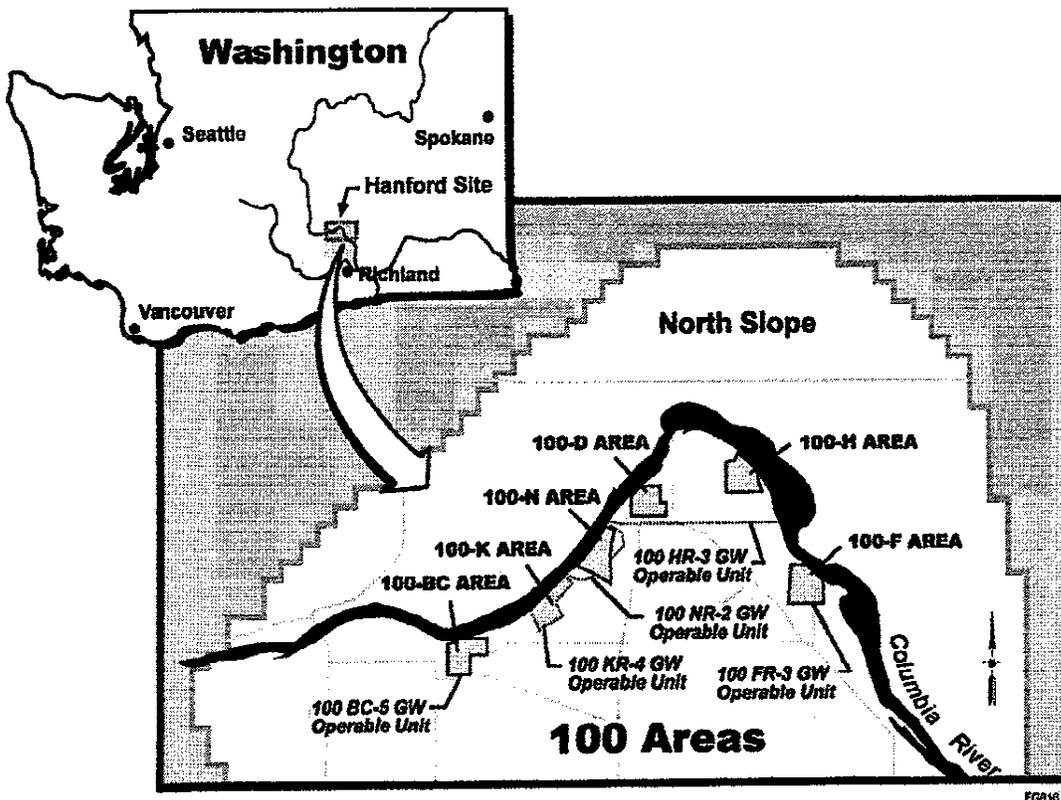
Facility Agreement and Consent Order (Tri-Party Agreement) (Ecology et al. 2003), the 100-NR-2 pump-and-treat system was placed in cold-standby status on March 9, 2006, in support of Tri-Party Agreement Milestone M-16-06-01 (“Complete a Permeable Reactive Barrier [PRB] at 100-N”).

A discussion of the progress toward the RAOs is presented in this annual report in the respective conclusion section for each OU. The 100-NR-2 discussion will be limited to the timeframe prior to placing the system in cold-standby status.

This report is organized into three major sections, each presenting the annual summary and performance evaluation for the three respective OUs. Section 2.0 discusses the 100-HR-3 OU, Section 3.0 discusses the 100-KR-4 OU, and Section 4.0 discusses the 100-NR-2 OU. An evaluation of costs is presented in Section 5.0, and the references cited in this report are included as Section 6.0.

This report provides a summary of major calendar year 2006 (CY06) activities, major trends, and significant differences between 2005 and 2006 for each OU. The “horn” area between 100-D/DR and 100-H is described in the 100-HR-3 discussion. Additional supporting information is included in Appendices A through L. An updated conceptual model is also presented for each OU in Appendix B.

Figure 1-1. Location of 100 Area Groundwater Operable Units.



2.0 100-HR-3 OPERABLE UNIT PUMP-AND-TREAT SYSTEM

The 100-HR-3 pump-and-treat facility is located in the north-central portion of the Hanford Site along the Columbia River. The 100-HR-3 OU represents the groundwater underlying the source OUs that are associated with the D and H Reactor areas and the adjacent 600 Area (Figure 2-1). Groundwater extraction systems were installed at the D and H Reactor areas in June 1997, with a common treatment facility in a surplus building located near H Reactor. A stand-alone pump-and-treat system, DR-5, began testing in July 2004 and became fully operational in December 2004 to treat a new contaminant source located in the central portion of the 100-D Area.

Monitoring and extraction well locations for the 100-D Area are shown in Figure 2-2, and 100-H Area well locations are shown in Figure 2-3. Appendix A provides a history of operations and identifies the supporting documents used in the development of the 100-HR-3 pump-and-treat system. Site conceptual models are presented in Appendix B.

This section provides the CY06 annual summary report for pump-and-treat operations in the 100-HR-3 OU, as required by the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* (DOE-RL 1996). Section 2.1 briefly summarizes activities within the OU that potentially impact activities associated with the pump-and-treat system. Section 2.2 summarizes the treatment system's performance. Sections 2.3 and 2.4 review hydraulic conditions, provide capture zone analysis through numerical modeling, and evaluate the contaminant concentrations for the 100-D and 100-H Areas, as well as the "horn" area between the 100-D and 100-H Areas. Section 2.5 discusses the quality control (QC) results for groundwater samples. Sections 2.6 and 2.7 provide conclusions and recommendations for the pump-and-treat system. Cost information is presented in Section 5.0.

2.1 SUMMARY OF ASSOCIATED ACTIVITIES

A summary of remedial actions for the 100-HR-3 OU is discussed in the following subsections.

2.1.1 100-D/DR Area

Multiple leaks and spills of sodium dichromate stock solution (hexavalent chromium) occurred in the 100-D Area during the reactor's operating years (1944 through 1969). Continuing movement of residual contamination from these sources in the soil is assumed to account for the widely distributed and persistent groundwater contamination beneath much of the 100-D Area. Efforts have been underway since 1997 to reduce releases to the Columbia River using a pump-and-treat system and a PRB, which was completed in 2003.

Groundwater remedial action progress in the 100-D/DR Area during 2006 included the following operational areas:

- The original 100-HR-3 pump-and-treat system (100-D) in the northeastern portion, the DR-5 pump-and-treat system in the central portion of the 100-D Area, and monitoring in the southwestern portion where a 660-m (2,165-ft)-long PRB is in place (i.e., the ISRM barrier).

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Activities during 2006 in these areas included the following:

- **Operation of the initial 100-D pump-and-treat system:** This system continues to contain the chromium plume in the northeastern sector where salmon spawning beds are known to be located off the shoreline.
 - More than 394 million L (104 million gal) of groundwater were extracted from the 100-D and H Areas during 2006 and treated in the 100-H treatment plant. Approximately 28.8 kg of chromium were extracted during 2006 and a total of over 299.9 kg have been removed since startup. The average removal efficiency was 93.6% during 2006, and the system operated 99.3% of the available run-time.
- **Operation of the DR-5 pump-and-treat system:** The DR-5 pump-and-treat system became fully operational in December 2004 and was installed to address chromium-contaminated groundwater that passes north of the ISRM treatment zone and west of the original 100-D pump-and-treat capture zone. The regulatory direction to construct the new pump-and-treat system is specified in *Direction to Implement the Requirements Under the 100-KR-4 Records of Decision (ROD) for the 100-D Area Chromium Plume* (DOE-RL 2004b).
 - The DR-5 pump-and-treat plant consists of a self-contained, modular IX treatment system that receives groundwater from four extraction wells. Three of the wells are located north of the 182-D reservoir (199-D5-20, 199-D5-32, and 199-D5-92), and the fourth well (199-D5-39) is south of the 182-D reservoir (Figure 2-2). One injection well, 199-D5-42, returns treated groundwater to the aquifer. The treatment plant is housed in the 186-D Building and contains four IX vessels (i.e., lead, lag, polish, and standby). Additional tanks are used to store and mix chemicals for onsite regeneration of the IX medium.
 - Over 81.3 million L (21.5 million gal) of water were treated in CY06, removing 64.6 kg of chromium. A total of 106.8 kg of chromium have been removed since startup. The average influent concentration was near 796 µg/L, with a removal efficiency of over 99.9%.
- **Monitoring the ISRM barrier:** The ISRM barrier monitoring is reported annual under separate cover (DOE-RL 2007).

2.1.2 100-H Area

A pump-and-treat system has been operating since 1997 to contain and remove hexavalent chromium in 100-H Area groundwater. Approximately 165 million L (43.6 million gal) of water were processed during CY06. The moderate contaminant concentrations in this area are believed to be related to the following:

- Past leakage from the 183-H solar evaporator basin that was used to concentrate wastewater (it has since been demolished)
- Leakage and disposal of sodium dichromate-laden reactor coolant water during operations from 1949 to 1965
- Movement of a hexavalent chromium plume created by reactor coolant from the 100-D Area.

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In 2005, the extraction and injection well network was reconfigured (1) to accelerate the capture and treatment of a smaller remaining portion of the 100-H plume near the river, which is above the RAO of 22 $\mu\text{g/L}$; and (2) to improve the capture efficiency in areas where gaps were previously identified using groundwater modeling. The following sections present an evaluation of the changes implemented above.

2.2 100-HR-3 OPERABLE UNIT TREATMENT SYSTEM PERFORMANCE

This section describes the 100-HR-3 pump-and-treat system's operation and related sampling activities. Information presented includes system availability, changes to system configuration, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and short-term contaminant comparisons. Additional operational details are found in the associated appendices, as specified in this report.

2.2.1 System Modification/Operation

2.2.1.1 100-H and 100-D Area. The reconfiguration of extraction and injection well network in the 100-H Area started in late December 2004, with additional changes being made during CY05 and 2006. The purposes of these changes were (1) to accelerate the capture and treatment of a small remaining portion of the 100-H chromium plume near the river that is above the RAO of 22 $\mu\text{g/L}$, and (2) to improve the capture in areas that were previously identified using groundwater modeling. The affected wells are displayed in the table below, indicating their uses at the start of 2006 and at the end of 2006. The only well affected in 2006 was 199-H3-2A, which was converted from an injection well to a monitoring well. The dates of changes and injection and extraction volumes are found in the project-specific database (PSDB).

Well	Use on January 1, 2005	Use on January 1, 2006	Use on December 31, 2006
199-H4-11	Extraction	Monitoring	Monitoring
199-H4-12A	Extraction	Extraction	Extraction
199-H4-15A	Extraction	Extraction	Extraction
199-H4-7	Extraction	Injection	Injection
199-H3-2A	Extraction	Injection	Monitoring
199-H4-65	Extraction	Monitoring	Monitoring
199-H4-4	Compliance	Extraction	Extraction
199-H4-5	Compliance	Compliance	Compliance
199-H4-63	Compliance	Extraction	Extraction
199-H4-64	Compliance	Extraction	Extraction
199-H3-3	Injection	Monitoring	Monitoring
199-H3-4	Injection	Monitoring	Monitoring
199-H3-5	Injection	Monitoring	Monitoring
199-H4-3	Monitoring	Extraction	Extraction
199-H4-17	Monitoring	Injection	Injection
199-H4-18	Monitoring	Injection	Injection

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Figures 2-2 and 2-3 present the most recent 2006 well configurations for the 100-D and 100-H Areas. Well symbols represent the use of the well at the end of 2006.

2.2.1.2 DR-5 Pump-and-Treat System. The extraction and injection well network for the DR-5 pump-and-treat system was reconfigured in CY05 to improve the capture efficiency due to deficiencies in some of the extraction wells. The affected wells are displayed in the table below. The dates of previous changes and flow volumes are available in the PSDB. There were no changes made to the system in CY06. Figure 2-4 provides a schematic of the current DR-5 pump-and-treat system.

Well	Use on January 1, 2005	Use on December 31, 2006
199-D5-20	Extraction	Extraction
199-D5-32	Extraction	Extraction
199-D5-37	Extraction	Monitoring
199-D5-39	Monitoring	Extraction
199-D5-92	Monitoring	Extraction
199-D5-42	Injection	Injection

The DR-5 operational and system highlights for CY06 are shown in the table below:

Total DR-5 processed groundwater:	
Total amount of groundwater treated (since December 2004) (million L)	131.7
Total amount of groundwater treated during CY06 (million L)	81.3
Mass of hexavalent chromium removed:	
Total amount of hexavalent chromium removed (since August 2004 startup) (kg)	106.8
Total amount of hexavalent chromium removed in CY06 (kg)	64.6
Summary of operational and system availability:	
Removal efficiency (% by mass)	99.9
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	171.7
Planned operations (hours)	8,588.3
Unscheduled downtime (hours)	307.1
Total time on-line (hours)	8,281.2
Total availability (%)	96.5
Scheduled system availability (%)	94.5

- A total of 81.3 million L (21.5 million gal) of groundwater was processed in CY06. The total volume of water treated since startup of the operational phase of the pump-and-treat system is 131.7 million L (35 million gal). In CY06, 64.6 kg of hexavalent chromium was removed, resulting in a total of 106.8 kg processed since startup.

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- The average removal efficiency for CY06 was 99.9%. The average hexavalent chromium influent concentration was 796 µg/L, while the effluent concentration was 1 µg/L (Figure 2-5).
- Scheduled system availability for CY06 was 96.4%, which was higher than the 85% reported in CY05. The total availability was 94.5%. The higher system availability values can be attributed to increased system efficiencies associated after completing testing and system modification activities (Figure 2-6).

2.2.1.3 100-HR-3 Pump-and-Treat Operations. A summary of operational parameters and total system performance for the 100-HR-3 pump-and-treat system in CY06 are presented in the tables below. The system schematic of the current 100-HR-3 pump-and-treat is presented in Figure 2-7.

Total 100-HR-3 processed groundwater (million L):^a		
	CY06	Since 1997 Startup
100-D Area	229.4	1,618.1
100-H Area	164.6	1,367.5
Total	394.0	2,985.6
Mass of hexavalent chromium removed January 1 to February 5, 2006 (kg), combined stream:		
100-D and 100-H Areas	4.3	
Mass of hexavalent chromium removed February 6 to December 31, 2006 (kg), separated:		
100-D Area	21.9	NA
100-H Area	2.6	NA
	CY06	Since 1997 Startup
Total	28.8	299.9

^a Does not include system parameters for the DR-5 pump-and-treat system.

^b Combined influent streams.

^c Influent streams are separated.

2006 operational parameters:^a	
Removal efficiency (% by mass)	93.6
Waste generation (m ³) ^b	0
Regenerated resin installed (m ³)	61.2
New resin installed (m ³)	11.3
Number of resin vessel changeouts	32 vessels
2006 system availability:^a	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	59.8
Planned operations (hours)	8,700.2
Unscheduled downtime (hours)	16.2
Total time on-line (hours)	8,684
Total availability (%)	99.1
Scheduled system availability (%)	99.3

^a Does not include system parameters for the DR-5 pump-and-treat system.

^b Each IX vessel contains 2.3 m³ of IX resin.

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The operational and system highlights for CY06 discussed below pertain to the original 100-HR-3 (100-D and 100-H) pump-and-treat system:

- A combined total of 394 million L (104.1 million gal) of groundwater were processed in CY06, which was more than the 325.6 million L (86 million gal) processed in CY05. The 28.5 kg of hexavalent chromium removed in CY06 is smaller than the 33.5 kg processed in CY05. This decrease in total mass removed is likely attributed to lower extraction well concentrations from the 100-H Area.
- The average removal efficiency for CY06 was 93.6%, which is similar to 93.5% that was reported in CY05 (Figure 2-8).
- The 100-D Area influent hexavalent chromium concentration average (after separating the process streams) was about 128 µg/L. This was lower than the 220 µg/L reported early in CY05.
- The average 100-H influent hexavalent chromium concentration in CY06 (after separating the process streams) was <22 µg/L. This was same as that reported in early CY05. Trend plots of CY06 influent and effluent concentrations are presented in Figure 2-9.
- Effluent concentrations for the CY06 reporting period were all below 20 µg/L.
- Scheduled system availability for CY06 was 99.3%, which was higher than that reported in CY05. The total availability for CY06 was 99.1%, which was higher than the 99.1% on-line availability reported for CY05. The increase in total availability can be attributed to extended plant operations during cold weather that had previously resulted in shutdowns due to freezing conditions. The monthly on-line percentages and method used to calculate scheduled and on-line availability are presented in Figure 2-10.
- Resin changeouts were performed on 32 vessels in CY06. New resin installed totaled 11.3 m³ (399.1 ft³), while regenerated resin totaled 61.2 m³ (2,161.3 ft³).

Historical presentation of operational parameters, total system performance, and extraction well chromium concentration and extraction rates are included in Appendix C.

2.3 AQUIFER RESPONSE IN THE 100-D AREA

This section describes the general hydrogeologic conditions in the 100-D Area, the numerical modeling conducted to evaluate the extraction well network, and the changes in contaminant concentrations in monitoring wells.

2.3.1 Hydrogeologic Conditions at the 100-D Area

Groundwater flows to the north or northwest in the southern half (near ISRM) and to the north and northeast in the northern and eastern sections of the 100-D Area. During the spring months, the Columbia River's elevation is generally increased by snowmelt run-off. Regulated flow is controlled at the Priest Rapids Dam to provide irrigation water and aid in fish migration.

Appendix D presents hydrographs for the 100-D Area wells. Other conditions at the 100-D Area are summarized below:

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- The average river stage during CY06 was 118.0 m (387.0 ft), which is slightly higher than the 5-year average of 117.8 m (± 0.144 m) (386.4 ft [± 0.472 ft]) and also above the CY05 average of 117.7 m (386.3 ft). Overall, the Columbia River stage has shown slight but consistent rise in average stage elevation over the past 4 years (average stage of 117.7 m [386.45 ft] for fiscal year 2004 [FY04] and 117.6 m [386.0 ft] for FY03).
- The average hydraulic gradient (as measured by the triangle of wells 199-D8-70, 199-D8-55, and 199-D8-69) was 0.0005 in 2006, with a net flow azimuth of 8.8 degrees.
- The estimated average groundwater flow velocity at the 100-D Area was 0.021 m/day (0.068 ft/day) based on hydraulic conductivity of 13.8 m/day (45 ft/day) and porosity of 20% (BHI 1996).
- As shown in Figure 2-11, the northern 100-D chromium plume and the southwest (ISRM) plume are still separated northwest of the 182-D reservoir; however, the separation appears to be decreasing.

2.3.2 Numerical Modeling and Field Validation of Zone of Influence

Numerical modeling was conducted to confirm that the locations and pumping rates of the extraction wells provided the most effective capture of the contaminant plume. Flow lines reaching the Columbia River indicate incomplete capture. Also, one-year time markers in the flow lines provide an indication of actual groundwater flow velocity.

- The hexavalent chromium pump-and-treat plume (from the D and DR Reactors, north to the Columbia River) is within the capture zone of the 100-HR-3 extraction well network, as shown in Figure 2-12 (100-D capture zone). Based on the 100-D chromium plume in 2006 (Figure 2-11), flow lines to the east of the reactor areas that reach the river trend through areas postulated to be < 22 $\mu\text{g/L}$ chromium.
- A portion of the hexavalent chromium plume north of the decommissioned D Pond with concentrations > 22 $\mu\text{g/L}$ is located outside the capture zone of the 100-HR-3 and DR-5 extraction wells. This area extends from well 199-D8-88 to well 199-D8-55 and includes about 8% (2/25 flow lines) of the capture zone created by the 100-D and DR-5 extraction wells shown in Figure 2-12.
- Flow lines that pass between the ISRM treatment zone to the south and the DR-5 capture zone to the north trend through an area that may have been influenced by leakage from the 182-D reservoir. Chromium concentrations in wells 199-D5-36 and 199-D5-44 have been historically low.
- Figure 2-12 shows time markers spaced one year apart on the flow lines, based on the high November steady-state velocities. The fastest velocities are displayed by flow lines running from new injection well 199-D5-42 to near extraction well 199-D5-32.

Table 2-1 presents a comparison of the measured and modeled water table elevations, as well as the average flow rates used in the numerical model. A detailed discussion of the numerical model is presented in Appendix E.

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2.3.3 Contaminant Monitoring in the 100-D Area

This section summarizes and interprets the analytical results obtained from groundwater wells and aquifer sampling tubes included in the interim remedial action and OU monitoring programs in the 100-D Area. The *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1997) and *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1998) define the sampling protocols implemented for CY06. The results presented below compare the fall 2006 concentrations to the fall 2005 concentrations, unless otherwise specified. Chromium results included both hexavalent chromium and total filtered chromium. Where more than one result is available for the time interval represented, the results are averaged in accordance with the protocol described in Appendix F. Data are stored in the Hanford Environmental Information System (HEIS) database. Appendix F contains tables of average annual contaminant concentrations for CY01 through CY06.

The principal contaminant of concern (COC) in the 100-D Area is hexavalent chromium. The RAO is to reduce the chromium concentration to 22 µg/L at the compliance wells. Strontium-90, tritium, and nitrate are co-contaminants that are actively monitored but are present in concentrations that result in low ecological risk (DOE-RL 1994). In addition, sulfate is a contaminant of interest because the secondary drinking water standard (DWS) has been exceeded in the past in a limited number of wells. Institutional controls, implemented to satisfy an RAO, limit human exposure to hexavalent chromium and the co-contaminants.

Section 2.3.3.1 discusses the results of chromium monitoring, and Section 2.3.3.2 discusses the results of co-contaminant monitoring. The discussion of sampling results for the sections presented below exclude the results from those wells within and downgradient of the ISRM barrier. The locations of the monitoring wells and aquifer sampling tubes are shown in Figure 2-2. Appendix G presents trend charts for wells in the 100-D Area.

The CY06 contaminant monitoring highlights are as follows:

- Fall 2006 chromium concentrations were above the 22 µg/L RAO in all of the 100-D and DR-5 extraction wells.
- Average chromium concentrations were stable or decreasing in eight of nine 100-D Area and DR-5 extraction wells.
- Average chromium concentrations were stable in both 100-D Area compliance wells.
- Average chromium concentrations increased 89% in DR-5 extraction well 199-D5-39. The source of this plume will be further investigated in the spring of 2007.
- The maximum chromium concentration in an aquifer sampling tube was 333 µg/L in January 2006 in aquifer tube 36-D, which is down from 518 µg/L in 2005. This tube is located downgradient of DR-5 extraction well 199-D5-92 in which chromium concentrations decreased 43% from fall 2005 to fall 2006.
- The pump-and-treat systems have removed contaminant mass and reduced chromium flux to the river as evidenced by decreases in chromium concentrations in most extraction and compliance wells.
- None of the wells or aquifer sampling tubes had strontium-90 concentrations above the 8 pCi/L maximum contaminant level (MCL) or tritium concentrations above the 20,000 pCi/L MCL.

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- Eight wells had nitrate concentrations above the 45 mg/L MCL. The highest nitrate concentration was 89 mg/L in well 199-D5-13.
- No wells had sulfate concentrations above the 250 mg/L secondary DWS.

2.3.3.1 100-D Area Chromium Monitoring Results. Chromium concentrations are monitored in extraction wells, compliance wells, monitoring wells, and aquifer tubes in the 100-D and DR-5 pump-and-treat operational areas. The 100-D Area chromium plume for fall 2006 and associated historical trends in individual wells are presented in Figure 2-11. Chromium plumes for the period from 1995 through 2006 are displayed in Figure 2-13. Chromium concentrations in wells along the ISRM shoreline are discussed in the FY06 ISRM annual summary report (DOE-RL 2007).

As shown on Figure 2-13, the interpretation of the 100-D chromium plume has varied significantly between 1995 and 1999, and much of the change in the interpretation was a result of additional monitoring wells and aquifer sampling tubes added through the years. Numerous aquifer sampling tubes were installed in 1995 and 1997, and many monitoring wells were drilled in 1999. These data led to the confirmation of an expanded and high-concentration chromium plume located south of the 182-D reservoir and resulted in the construction of the ISRM treatment zone from 2000 to 2002. Since 1999, the major change to the chromium plume north of the 182-D reservoir has been its extension west to the Columbia River. The result of this change was the implementation of the DR-5 pump-and-treat system.

The table below compares the specific conductance and chromium data for fall 2005 versus fall 2006 for all of the pump-and-treat extraction wells and compliance wells. A <20% change in concentration from 2005 to 2006 is interpreted to be stable conditions. Wells not displayed below are included in the tables in Appendix F:

Well	Type (Pump-and-Treat System)	Fall 2005		Fall 2006		Cr Percent Change ^a
		Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
199-D8-53	Extraction (100-D)	NA	115	NA	95	-17%
199-D8-54A	Extraction (100-D)	685	127	617	94	-26%
199-D8-68	Extraction (100-D)	530	122	460	107	-12%
199-D8-72	Extraction (100-D)	515	534	542	491	-8%
199-D5-20	Extraction (DR-5)	351	570	374	434	-24%
199-D5-92	Monitoring/extraction (DR-5)	NA	359	291	205	-43%
199-D5-32	Extraction (DR-5)	447	1,130	470	470	-58%
199-D5-39	Monitoring/extraction (DR-5)	479	870	483	1,640	+89%
199-D5-37	Extraction/monitoring (DR-5)	241	58	256	47	-19%
199-D8-69	Compliance (100-D)	379	62	335	53	-15%

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Well	Type (Pump-and-Treat System)	Fall 2005		Fall 2006		Cr Percent Change ^a
		Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
199-D8-70	Compliance (100-D)	602	117	453	92	-21%

^a Percent change is calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.
NA = data not available

Changes in fall 2005 to 2006 in 100-D and DR-5 extraction wells or 100-D compliance wells can be summarized as follows:

- Fall 2006 chromium concentrations were above the 22 µg/L RAO in all of the 100-D and DR-5 extraction and compliance wells.
- Fall 2006 chromium concentrations increased 89% in DR-5 extraction well 199-D5-39, from 870 to 1,640 µg/L. The source of this plume will be further characterized in the spring of 2007.
- Chromium concentrations decreased more than 20% in one 100-D extraction well (199-D8-54A).
- Chromium concentrations were stable in three of four 100-D extraction wells.
- Chromium concentrations decreased more than 20% in three of four DR-5 extraction wells, with the maximum decrease of 58% in well 199-D5-32.
- Average chromium concentrations decreased more than 20% in 100-D compliance well 199-D8-70.
- Decreases in chromium concentrations did not appear to be the result of river water dilution because specific conductance readings were similar from 2005 to 2006.

In addition to the compliance monitoring wells discussed above, the 100-D interim action requires sampling in other wells to help assess pump-and-treat operational performance. The table below compares the chromium data for fall 2005 versus fall 2006 for monitoring wells, where the fall 2006 chromium is above the RAO, or the change in average concentration from 2005 to 2006 was >20%:

Well	System Monitored	Fall 2005 ^a		Fall 2006 ^a		Cr Percent Change ^a
		Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
199-D5-13	100-D/DR-5	624	471	750	517	+10%
199-D5-14	100-D	649	376	656	480	+28%
199-D5-15	100-D	630	467	619	1,058	+127%
199-D5-16	100-D	681	58.2	620	88	+51%
199-D5-34	DR-5	391	5	457	622	+12,340%
199-D5-37	DR-5	241	58	256	47	-19%
199-D5-41	DR-5	559	402	588	239	-41%

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Well	System Monitored	Fall 2005 ^a		Fall 2006 ^d		Cr Percent Change ^a
		Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
199-D8-4	DR-5/100-D	538	183	534	186	+2%
199-D8-5	100-D	254	57	423	245	+330%
199-D8-55	100-D	170	7.5	220	24	+220%
199-D8-71	100-D	634	180	528	173	-4%
199-D8-73	DR-5	395	170	357	209	+23%
699-96-49 ^{b,c}	100-D	441	24.5	447	27	+10.2%

^a Percent change is calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.

^b Samples collected in fall 2004 and fall 2006.

^c Well located east of D Reactor area, in the "horn" area between the D/DR and H Reactor areas.

^d Data collected November 1 through November 30 in both 2005 and 2006. Values represent data available in the HEIS database on February 1, 2007.

The results of 2006 chromium monitoring in 100-D and DR-5 monitoring wells are summarized as follows:

- Average chromium concentrations increased more than 20% in five wells monitoring the 100-D pump-and-treat system (199-D5-14, 199-D5-15, 199-D5-16, 199-D8-5, and 199-D8-55). Chromium concentrations have fluctuated significantly in these wells over the last 5 years (see trend plots in Figure 2-13 and Appendix G). South of the 182-D reservoir, the reduction of leakage from the reservoir since early 2004 has generally removed the small groundwater mound that separated the chromium plumes east of the reservoir and has contributed to plume dilution west of the reservoir.
- The maximum increase in chromium concentration was 12,340% in well 199-D5-34. This increase is probably because the groundwater mound south of the 182-D reservoir has generally dissipated.
- Average chromium concentrations decreased more than 20% only in DR-5 monitoring well 199-D5-41.

Aquifer tubes were sampled along the 100-D and DR-5 shoreline in January 2006. The table below includes hexavalent chromium, specific conductance, and dissolved oxygen (DO) concentrations for these sampling events. A summary of 2006 results along the 100-D and DR-5 shoreline is as follows:

Aquifer Tube	Jan. 2006 Chromium (µg/L)	Jan. 2006 DO (µg/L)	Jan. 200 Specific Conductance (µS/cm)
36-D	333	7,900	286
36-M	120	5,900	251.9
36-S	37	8,500	275.2
AT-D-1-D	20	8,300	266.8
AT-D-1-M	31	10,300	253.9
AT-D-1-S	10	9,100	131.2
AT-D-2-M	14	8,500	192.9

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Aquifer Tube	Jan. 2006 Chromium ($\mu\text{g/L}$)	Jan. 2006 DO ($\mu\text{g/L}$)	Jan. 200 Specific Conductance ($\mu\text{S/cm}$)
AT-D-2-S	11	4,500	234.1
AT-D-4-D	1	7,000	152.1
AT-D-4-M	3	7,700	150.5
AT-D-4-S	1	8,400	150

D = deep, M = middle, and S = shallow

- The maximum January 2006 hexavalent chromium concentration was 333 $\mu\text{g/L}$ in aquifer tube 36-D. This tube is located downgradient of DR-5 extraction well 199-D5-92 and had a chromium concentration of 518 $\mu\text{g/L}$ in March 2005.
- Four of eleven samples had hexavalent chromium concentrations above the 22 $\mu\text{g/L}$ RAO.
- One of 11 samples had a low DO concentration (4,500 $\mu\text{g/L}$ in aquifer tube AT-D-2-S).
- Aquifer tube samples collected in December 2006 will be discussed in the upcoming 100 Areas semi-annual technical memorandum for 2007.

2.3.3.2 100-D Area Co-Contaminant Monitoring Results. The 100-D Area co-contaminants are strontium-90, tritium, and nitrate (DOE-RL 1997). Sulfate is also a constituent of interest. Gross alpha and gross beta are monitored as a survey tool in lieu of analyzing for numerous potential alpha and beta emitters. The average results for co-contaminants for CY01 through CY06 are listed in Appendix F.

- **Strontium-90:** None of the 100-D extraction wells, monitoring wells, or aquifer sampling tubes had fall 2006 strontium-90 concentrations above the 8 pCi/L MCL. The maximum fall 2006 strontium-90 concentration in a 100-D Area well was 6.4 pCi/L in well 199-D8-68. Numerous wells in the 100-D Area are also analyzed annually for gross beta as a survey tool. It is assumed that about 50% of gross-beta activity can be attributed to strontium-90 alone. The maximum fall 2006 gross-beta reading from wells within the pump-and-treat operational area was 13 pCi/L from wells 199-D5-13 and 199-D8-54B. Well 199-D8-54B is screened in the first producing horizon below the upper unconfined aquifer. If 50% of the gross-beta activity were from strontium-90, the average strontium-90 from wells 199-D5-13 and 199-D8-54B would still fall below the MCL.
- **Tritium:** The maximum 2006 tritium concentration was 15,000 pCi/L in well 199-D5-18. The MCL for tritium is 20,000 pCi/L tritium. Well 199-D5-17 has been above 20,000 pCi/L historically, but it was not sampled during 2006. The table below lists the extraction wells, compliance wells, and well 199-D5-18 (in which the highest fall 2006 concentration was detected):

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Well	Type	Fall 2005 Tritium (pCi/L)	Fall 2006 Tritium (pCi/L)	Percent Change ^a
199-D5-15	Monitoring	7,050 (±450)	3,435 (±545)	-51%
199-D5-17	Monitoring	20,200 (±990)	--	^b
199-D8-53	Extraction	5,900 (±1,000)	5,000 (±1,000)	-18%
199-D8-54A	Extraction	12,200 (±1,400)	7,200 (±1,400)	-41%
199-D8-68	Extraction	3,900 (±820)	3,600 (±760)	-8%
199-D8-69	Compliance	3,490 (±300)	2,300 (±510)	-34%
199-D8-70	Compliance	8,300 (±500)	5,000 (±1,000)	-40%
199-D8-72	Extraction	1,600 (±350)	1,700 (±420)	+6%
199-D5-18	Monitoring	--	15,000 (±3,000)	^b

^a Percent change is calculated by the following equation: [(Fall 2006 - fall 2005) / fall 2005] x 100%.

^b Could not calculate percent change because the well was not sampled in 2005 or 2006.

The changes in average tritium concentration from 2005 to 2006 for wells sampled in the 100-D pump-and-treat operational area are summarized as follows:

- Tritium concentrations were less than the MCL in all wells monitored in 2006.
- Tritium decreased more than 20% in four wells. The maximum decrease was 51% in well 199-D5-15, declining to 3,435 pCi/L.
- **Nitrate:** Nitrate is widespread in the 100-D Area, as shown in the nitrate plume map (Figure 2-14). The source of the nitrate plume is uncertain. The table below lists the 2006 results for wells that had average nitrate concentrations above the 45 mg/L MCL (equivalent to 10 mg/L NO₃-N). It also lists wells characterized by changes in nitrate concentration of >20%:

Well	Type	Fall 2005 Nitrate (mg/L)	Fall 2006 Nitrate (mg/L)	Percent Change ^a
199-D5-13	Monitoring	62	89	+44%
199-D5-14	Monitoring	68.6	68.2	-10%
199-D5-15	Monitoring	69.9	65.1	-7%
199-D5-16	Monitoring	68.6	59.8	-13%
199-D5-17	Monitoring	50.9	--	^b
199-D5-18	Monitoring	--	50.9	^b
199-D8-4	Monitoring	77	71.3	-7%
199-D8-53	Extraction	17.3	29	+68%
199-D8-55	Monitoring	1.0	10.4	+920%
199-D8-72	Extraction	51.8	52.9	+2%
199-D5-19	Monitoring	--	47.8	^b
199-D8-5	Monitoring	11.1	46.5	+319

^a Percent change is calculated by the following equation: [(Fall 2005 - fall 2006) / fall 2005] x 100%.

^b Not calculated because well was not sampled in both years.

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The changes in average nitrate concentration from 2005 to 2006 for wells sampled in the 100-D and DR-5 pump-and-treat operational area are summarized as follows:

- Eight wells had fall 2006 nitrate concentrations above the 45 mg/L MCL.
 - The maximum fall 2006 nitrate concentration was 89 mg/L in well 199-D5-13.
 - The maximum increase in nitrate concentration was 920% (to 10.4 mg/L) in monitoring well 199-D8-55.
 - Four wells were characterized by a >20% increase in nitrate concentration from 2005 to 2006.
 - The maximum decrease in nitrate concentration was 13% (to 59.8 mg/L) in well 199-D5-16.
- **Sulfate:** Sulfate is a contaminant of interest in the 100-D Area and has a secondary DWS of 250 mg/L. None of the wells had 2006 sulfate concentrations above the DWS. The maximum 2006 concentration in the 100-D Area was 125 mg/L in well 199-D5-13. The table below lists wells in which the 2005 versus 2006 average sulfate concentrations changed more than 20%:

Well	Type	Fall 2005 Sulfate (mg/L)	Fall 2006 Sulfate (mg/L)	Percent Change ^a
199-D5-16	Monitoring	144.0	105.0	-27%
199-D8-5	Monitoring	24.3	73.0	+200%
199-D8-55	Monitoring	9.5	21.5	+126%
199-D8-70	Compliance	123.0	94.4	-23%

^a Percent change is calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.

2.4 AQUIFER RESPONSE IN THE 100-H AREA

2.4.1 Hydrogeologic Conditions at the 100-H Area

As shown in Figure 2-15, the most prevalent groundwater flow direction in the 100-H Area is east to northeast. During the spring months, the Columbia River's elevation generally increases flow from snowmelt run-off. Flow is regulated at Priest Rapids Dam to provide irrigation water and to aid in fish migration.

The hydrogeologic conditions in the 100-H Area are summarized below:

- The average river stage during CY06 was 115.65 m (378.43 ft), which is an increase over the CY05 average of 115.44 m (378.74 ft) but within the 5-year average of 115.50 m (±0.26 m) (378.94 ft [±0.85 ft]). Overall, the Columbia River stage and flow regime has shown a slight, but relatively consistent, increase over the past 3 years (average stage 115.34 m [378.41 ft] for FY04).
- The average hydraulic gradient in the 100-H Area between the former 183-H solar evaporation basin and the Columbia River was 0.0023 toward the northeast (58 degrees azimuth).

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- The estimated average groundwater flow velocity at the 100-H Area varied widely from 20.8 m/day (68.2 ft/day) in the area of well 199-H4-10 to 0.25 m/day (0.82 ft/day) in the area of well 199-H4-11 based on hydraulic conductivity measurements of 1,810 m/day (5,940 ft/day) to 21.6 m/day (71 ft/day) and porosity of 20% (BHI 1996). Appendix D presents a detailed discussion of aquifer response in the 100-H Area. Appendix D presents hydrographs for 100-H Area wells.

2.4.2 Numerical Modeling

The numerical modeling results supporting the 100-HR-3 pump-and-treat system in the 100-H Area can be summarized as follows:

- The original 100-H hexavalent chromium pump-and-treat target plume has been greatly reduced in area. Most of the remainder of the shoreline plume (above 20 $\mu\text{g/L}$) is within the capture zones of extraction wells 199-H4-12A, 199-H4-15A, and 199-H4-64, as shown in Figure 2-16.
- The model shows an apparent gap in the capture zone between extraction wells 199-H4-12A and 199-H4-63 (Figure 2-16). However, the chromium plume concentrations in this area were $<20 \mu\text{g/L}$. A detailed discussion of the numerical model is presented in Appendix E. Table 2-1 presents a comparison of the measured and modeled water table elevations and the average flow rates used in the numerical model.
- The southernmost portion of the east "horn" area plume (discussed below), which has reached well 199-H3-5, is not within the capture zone of the existing extraction well network.
- Figure 2-16 shows time markers spaced 90 days apart on the flow lines based on the high November steady-state velocities. The fastest velocities are displayed by flow lines in the high-conductivity region in the southernmost portion of Figure 2-16, where the pore velocities are as high as 6 m/day (19.7 ft/day) from injection well 199-H3-5 to past monitoring well 199-H6-1. The pore velocities are as low as 1.7 m/day (5.6 ft/day) upgradient from well 199-H4-11.

2.4.3 Contaminant Monitoring in the 100-H Area

This section summarizes and interprets the analytical results obtained from groundwater monitoring wells and aquifer sampling tubes supporting the 100-H Area pump-and-treat remedial action and the 100-HR-3 OU monitoring program. The *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE-RL 1997) and *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1998) define the sampling protocols implemented for CY05. The results presented below are the fall 2006 and fall 2005 concentrations, unless otherwise specified. The range of sampling dates and date of table preparation are also noted. Section 2.4.3.1 includes a discussion of chromium monitoring results. The RAO for chromium concentrations is 22 $\mu\text{g/L}$ at the compliance wells. Section 2.4.3.2 includes a discussion of the monitoring results for the remedial action co-contaminants (i.e., strontium-90, tritium, nitrate, technetium-99, and uranium).

A summary of contaminant monitoring in the 100-H Area for CY06 is as follows:

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- The footprint (i.e., areal extent) of the 1997 chromium plume ($>50 \mu\text{g/L}$) has decreased more than 95% since pump-and-treat operations began. The remainder of the original target plume is along the 100-H shoreline and concentrations are $<50 \mu\text{g/L}$.
- Chromium concentrations decreased more than 20% in two of the six 100-H Area extraction wells and one compliance well.
- Chromium concentrations increased by 20% or more in one 100-H extraction well and in five monitoring wells.
- Chromium concentrations in the 600 Area east plume, west of the 100-H Area, were $113 \mu\text{g/L}$ and $83 \mu\text{g/L}$ in wells 699-97-43 and 699-96-43, respectively. It appears that this plume has reached former injection well 199-H3-5, where hexavalent chromium was detected at $45 \mu\text{g/L}$.
- Chromium concentrations in monitoring wells screened below the Ringold Upper Mud Unit are above the RAO and were as high as $102 \mu\text{g/L}$ in well 199-H4-15CS. The chromium concentrations in these three deep completions are all higher than the corresponding well in the same nest screened in the upper aquifer above the Ringold Upper Mud Unit.
- Well 199-H4-63 was characterized with strontium-90 concentrations at 25 pCi/L . It was the only well in the 100-D or 100-H Areas that had strontium-90 concentrations above the 8 pCi/L MCL.
- Tritium concentrations in 2006 were below the $20,000 \text{ pCi/L}$ MCL in all of the 100-H Area wells.
- Technetium-99 concentrations were below the 900 pCi/L MCL in all of the 100-H Area wells.
- Uranium concentrations were below the $30 \mu\text{g/L}$ MCL in all of the 100-H area wells.
- Nitrate concentrations were measured at 46.9 mg/L in the fall of 2006 in well 199-H4-46. The MCL for nitrate is 45 mg/L .

2.4.3.1 100-H Area Chromium Monitoring Results. Chromium concentrations are monitored in extraction wells, compliance wells, monitoring wells, and aquifer tubes in the 100-H pump-and-treat operational area. The 100-H Area fall 2006 chromium plume and associated historical trends in individual wells are presented in Figure 2-15. Chromium plumes for the period from 1995 through 2006 are shown in Figure 2-17.

The hexavalent chromium plume in the H Reactor area decreased significantly since pump-and-treat operations began in 1997 (Figure 2-17). The 2006 plume includes a small area along the shoreline where chromium concentrations remain above $22 \mu\text{g/L}$. In addition, it appears that the plume centered on "horn" area wells 699-97-43 and 699-96-43 is moving into the 100-H Area. The current use of wells in the pump-and-treat network has undergone numerous adjustments in an attempt to reduce shoreline concentrations to below $22 \mu\text{g/L}$.

The table below lists the fall 2006 chromium concentrations in extraction and compliance wells in the 100-H Area, as well as specific conductance readings. The data include both hexavalent chromium concentrations and filtered total chromium. The current use of the wells in the pump-and-treat network and the original design use are also provided:

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Well ^a	Original Use/ Current Use	Fall 2005		Fall 2006		Percent Change ^b
		Specific Conductance ($\mu\text{S}/\text{cm}$)	Cr ($\mu\text{g}/\text{L}$)	Specific Conductance ($\mu\text{S}/\text{cm}$)	Cr ($\mu\text{g}/\text{L}$)	
199-H4-12A	Extraction	731	38	433	23	-39%
199-H4-15A	Extraction	484	32	388	26	-19%
199-H4-4	Compliance/extraction	488	15	404	18	+20%
199-H4-63	Compliance/extraction	417	15	446	16	+7%
199-H4-64	Compliance/extraction	--	28	--	20	-29%
199-H4-5	Compliance	552	13	388	10	-23%
199-H4-3	Monitoring/extraction	629	16	409	14	-12%

^a The following changes were made to the well network during 2005: well 199-H3-2A was converted from an injection well to a monitoring well and well 199-H4-14 was converted from a monitoring well to an injection well.

^b Percent change is calculated by the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$.

Changes in chromium concentrations from 2005 to 2006 in 100-H extraction wells and compliance wells are summarized as follows:

- Fall 2006 chromium concentrations decreased more than 20% in two of six extraction wells.
- The maximum decrease in chromium concentration in an extraction well was 39% (to 23 $\mu\text{g}/\text{L}$) in well 199-H4-12A.
- The average chromium concentration increased 20% (to 18 $\mu\text{g}/\text{L}$) in well 199-H4-4.
- Fall 2006 chromium concentrations were above the 22 $\mu\text{g}/\text{L}$ RAO in two extraction or compliance wells (199-H4-12A and 199-H4-15A).

The table below lists fall 2005 and fall 2006 hexavalent or total chromium concentrations and specific conductance readings in monitoring wells in the 100-H Area. The wells listed had chromium concentrations above the 22 $\mu\text{g}/\text{L}$ RAO or concentrations changed more than 20% from 2005 to 2006. Wells not listed are included in Appendix F:

Well	Original Use/ Current Use	Fall 2005		Fall 2006		Percent Change ^a
		Specific Conductance ($\mu\text{S}/\text{cm}$)	Cr ($\mu\text{g}/\text{L}$)	Specific Conductance ($\mu\text{S}/\text{cm}$)	Cr ($\mu\text{g}/\text{L}$)	
199-H3-2C ^b	Monitoring	357	29.7	395	49.8	+68%
199-H3-3	Injection/ monitoring	--	--	492	20	^c
199-H3-4	Injection/ monitoring	--	--	488	18	^c
199-H3-5	Injection/ monitoring	--	--	491	45	^c

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Well	Original Use/ Current Use	Fall 2005		Fall 2006		Percent Change ^a
		Specific Conductance ($\mu\text{S}/\text{cm}$)	Cr ($\mu\text{g}/\text{L}$)	Specific Conductance ($\mu\text{S}/\text{cm}$)	Cr ($\mu\text{g}/\text{L}$)	
199-H4-11	Extraction/ monitoring	540	11	448	18	+64%
199-H4-12B ^c	Monitoring	799	52	385	34	-35%
199-H4-12C ^b	Monitoring	263	94	267	92	-2%
199-H4-15B ^c	Monitoring	455	54	410	35	-35%
199-H4-15CS ^b	Monitoring	265	95	243	102	+7%
199-H4-6	Monitoring	470	7	446	11	+57%
199-H4-8	Monitoring	551	5	410	9	+80%
199-H4-9	Monitoring	599	7.5	436	9	+20%
699-96-43 ^d	Monitoring	500	82.7	494	85	+3%
699-97-43 ^d	Monitoring	--	--	458	113	^e

^a Percent change is calculated by the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$.

^b Well screen located in Ringold Upper Mud Unit.

^c Well screen located at bottom of unconfined (upper) aquifer (Hanford formation).

^d Well located in the "horn" area west of the 100-H Area.

^e Well not sampled in 2005 and 2006.

Changes in chromium concentrations from CY05 to CY06 in 100-H Area monitoring wells are summarized as follows:

- Chromium concentrations decreased more than 20% in two wells.
- Chromium concentrations increased more than 20% in four wells.
- The maximum decrease in chromium concentration was 35% in wells 199-H4-12B (to 34 $\mu\text{g}/\text{L}$) and 199-H4-15B (to 35 $\mu\text{g}/\text{L}$).
- The maximum increase in chromium concentration was 80% (to 9 $\mu\text{g}/\text{L}$) in well 199-H4-8.
- Monitoring well 199-H3-5, which was formerly an injection well, had a chromium concentration of 45 $\mu\text{g}/\text{L}$ in the fall of 2006. It appears that the plume around "horn" area wells 699-97-43 and 699-96-43 has moved east into the southern 100-H Area.
- The maximum 2006 chromium concentration in a well in the "horn" area between the 100-D and 100-H Areas was 113 $\mu\text{g}/\text{L}$ in well 699-97-43. This well is located approximately 1,000 m (3,280.8 ft) northwest of well 199-H3-2A. Well 699-96-43, located south of well 699-97-43, had a chromium concentration of 85 $\mu\text{g}/\text{L}$.
- The two wells screened at the bottom of the upper aquifer (199-H4-12B and 199-H4-15B) had 2006 chromium concentrations that decreased 35% in 2006, to 34 $\mu\text{g}/\text{L}$ and 35 $\mu\text{g}/\text{L}$, respectively. Chromium concentrations have decreased moderately in these wells since startup of pump-and-treat operations, similar to extraction wells 199-H4-12A and 199-H4-15A.

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- The three wells screened below the top of the Ringold Upper Mud Unit (199-H3-2C, 199-H4-12C, and 199-H4-15CS) had 2006 chromium concentrations of 49.8 µg/L, 92 µg/L, and 102 µg/L, respectively. The chromium concentration in each of these three deep wells is higher than the most recent sample concentration in the corresponding well in the same nest screened in the upper aquifer. The cause of this deep contamination is not clear but may be the result of mounding around the 100-D and 100-H retention basins driving contamination deeper into the aquifer. It is also possible that the deep contamination may be from the 100-D Area and has been slower to clean up because vertical conductivity is less than horizontal conductivity.
- The aquifer sampling tubes in the 100-H Area were not sampled in 2006. The 100-H Area tubes were sampled in November 2005, and all chromium results were <22 µg/L.

2.4.3.2 100-H Area Co-Contaminant Monitoring Results. The 100-H Area co-contaminants are strontium-90, technetium-99, uranium, tritium, and nitrate (DOE-RL 1997). Average results for co-contaminants for the period of CY01 through CY06 are listed in Appendix F, Table F-4. Contaminant trend charts are presented in Appendix G. Further discussion on these co-contaminants is provided below:

- **Strontium-90:** The table below lists those wells in which the fall 2005 or fall 2006 strontium-90 concentrations were above the 8 pCi/L MCL. Strontium-90 concentrations above the MCL are not unexpected in wells 199-H4-11 and 199-H4-63 because they are located downgradient of the former 107-H retention basins and well 199-H4-45 is downgradient of the 116-H-1 Trench.

Well	Type (Current Use)/ Design Use	Fall 2005 Sr-90 (pCi/L)	Fall 2006 Sr-90 (pCi/L)	Percent Change ^a
199-H4-11	Monitoring	23 (±3.4)	--	^b
199-H4-15A	Extraction	32 (±4.8)	4.7	-85%
199-H4-45	Monitoring	--	11.5 (±1.8)	
199-H4-63	Extraction/ Compliance	40 (±8)	25 (±5)	-38%
199-H6-1	Monitoring	8 (±1.3)		^b

^a Percent change is calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.

^b Well not sampled in 2005 and 2006 or data not available.

- **Tritium:** None of the wells monitored in the 100-H Area had tritium concentrations above the 20,000 pCi/L MCL. The maximum 2006 readings were 2,800 pCi/L in well 199-H4-15A and 5,150 pCi/L in well 699-96-43, located approximately 900 m (2,952.7 ft) west of well 199-H3-2A. Tritium concentrations for 2006 are provided in Appendix F, Table F-4.
- **Technetium-99:** Well 199-H4-9 had 8.1(U) pCi/L of technetium in November 2006 after a concentration of 1,510 pCi/L in April 2005. It was the only well with technetium-99 concentrations above the 900 pCi/L MCL in either 2005 or 2006. However, technetium-99 was detected at very low concentrations in downgradient wells 199-H4-3 and 199-H4-4. The maximum fall 2006 technetium concentration was

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57.2 pCi/L in well 199-H4-3. The source of this contaminant is likely the upgradient former 183-H solar evaporation basin. As shown in the table below, technetium concentrations varied significantly in some of the other 100-H Area wells:

Well	Type (Current Use)	Fall 2005 Tc-99 (pCi/L)	Fall 2006 Tc-99 (pCi/L)	Percent Change ^a
199-H4-12A	Extraction	402 (±50)	50 (±9.4)	-88%
199-H4-3	Extraction	108.6 (±18)	57.2 (±10.4)	-47%
199-H4-4	Extraction	40.8 (±9.4)	53.6 (±10.2)	+31%
199-H4-9	Monitoring	81.1 (±10)	8.1(U) (6)	NA

^a Percent change is calculated by the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$.
NA = not available

- Uranium:** None of the 100-H wells had fall 2006 total uranium concentrations above the 30 µg/L MCL. The maximum fall 2006 concentration was 12.8 µg/L in well 199-H4-3. The source of this uranium is likely the former 183-H solar evaporation basin. As shown in the table below, uranium concentrations decreased significantly in some of the other 100-H Area wells located downgradient of the 183-H solar evaporation basin:

Well	Type (Current Use)	Fall 2005 U (µg/L)	Fall 2006 U (µg/L)	Percent Change ^a
199-H4-12A	Extraction	51.4	9.8	-81%
199-H4-3	Extraction	24.4	12.8	-48%
199-H4-4	Extraction	10.2	7.3	-28%
199-H4-9	Monitoring	19.9	3.0	-85%

^a Percent change is calculated by the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$.

- Nitrate:** Nitrate is widespread in the 100-H Area. The source of the nitrate plume is uncertain, but the highest concentrations historically have been in wells downgradient of the former 183-H solar evaporation basin, although concentrations have decreased. The table below lists the fall 2006 results for wells that had fall 2005 or fall 2006 nitrate concentrations above the 45 mg/L MCL (equivalent to 10 mg/L NO₃-N). The table also lists the wells characterized by changes in nitrate concentration of >20%:

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Well	Type (Current Use)	Fall 2005 Nitrate (mg/L)	Fall 2006 Nitrate (mg/L)	Percent Change ^a
199-H3-2C	Monitoring	14.6	21.5	+47%
199-H4-10	Monitoring	15.9	23.2	+46%
199-H4-12A	Extraction	130.5	36.8	-72%
199-H4-16	Monitoring	38.1	23.2	-39%
199-H4-46	Monitoring	47.8	46.9	-2%
199-H4-64	Extraction	35.9	23.2	-35%
199-H4-3	Extraction	65.7	42.9	-35%
199-H4-9	Monitoring	60.9	--	^b
199-H6-1	Monitoring	44.3	42.1	-5%

^a Percent change is calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.

^b Well not sampled in fall 2005 or fall 2006

Nitrate concentrations in 100-H Area wells can be summarized as follows:

- One 100-H Area well (199-H4-46) had a fall 2006 nitrate concentrations above the 45 mg/L MCL.
- The maximum increase in fall nitrate concentration was 47% (to 21.5 mg/L) in well 199-H3-2C, which is screened below the top of the Ringold Upper Mud Unit.
- The maximum decrease in fall nitrate concentration was 72% (to 36.8 mg/L) in well 199-H4-12A. This well had a fall 2005 nitrate concentration of 130.5 mg/L. This well typically shows variability in nitrate concentration.
- The nitrate concentration dropped to 42.9 mg/L in well 199-H4-3, which is the first time it was measured below the MCL since 1975.

2.4.4 Contaminant Monitoring in the “Horn” Area

The “horn” area includes the 600 Area between the D/DR Reactor area and the H Reactor area. This area is important to interim action because the groundwater flow direction is northeast to east from the D/DR Reactor area toward the 100-H Area. The area is monitored with six actively sampled wells and aquifer sampling tubes 40 through 45. Monitoring well and aquifer tube locations are shown in Figure 2-18. The figure also shows the 2006 “horn” area chromium plume and representative well trend plots.

Chromium concentrations across the “horn” area have decreased significantly, as shown in the chromium trend plots included in Figure 2-18. There appear to be at least two plumes remaining with chromium concentrations above the RAO (22 µg/L). It is also possible that other plumes remain that have not been identified because of limited well control or operational knowledge.

- **600 Area plume (west):** This chromium plume is centered around wells 699-97-51A and 699-96-49 and is near the 100-D Area chromium plume. This plume is likely the result of crib discharges and retention basin leakage, as well as the 1967 reactor effluent infiltration test in the 107-DR (116-DR-1) Liquid Waste Disposal Trench. The maximum fall 2006 chromium concentration was 32.7 µg/L in well 699-97-51A.

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- **600 Area plume (east):** This plume is apparently centered on monitoring wells 699-97-43 and 699-96-43. Fall 2006 total chromium concentrations in these wells were 113 µg/L and 83 µg/L, respectively, but have been as high as 180 µg/L in the past (Figure 2-18). This plume is apparently moving northeast and east from wells 699-97-43 and 699-96-43 and has reached well 199-H3-5 in the southern 100-H Area.

Aquifer sampling tubes 43 and 44 (north of wells 699-97-43 and 699-96-43) had chromium concentrations ranging from 20 to 53 µg/L from 1999 through 2005. It is likely that this plume is connected to the plume centered on wells 699-97-43 and 699-96-43. The east "horn" area plume will be further characterized during the summer of 2007.

2.5 QUALITY CONTROL RESULTS FOR 100-D AND 100-H MONITORING DATA

The QC results for 100-HR-3 sampling involved field or offsite laboratory testing for hexavalent chromium or total chromium, nitrate, sulfate, technetium-99, tritium, and uranium. The CY06 highlights of the QC data for 100-D and 100-H Area sampling are summarized below. Tables listing the complete QC results are found in Appendix H.

Type of QC Sample	Number of Pairs	Number of Pairs <20% RPD	Percent of Pairs <20% RPD
Field replicates (hexavalent chromium)	36	34	94.4%
Field/offsite laboratory splits (hexavalent chromium)	65	52	80%
Offsite laboratory replicates (total chromium)	1	1	100%
Offsite laboratory replicates (hexavalent chromium)	3	3	100%
Field/offsite laboratory splits (sulfate)	44	39	88.6%

RPD = relative percent difference

The U.S. Environmental Protection Agency's (EPA's) *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses* (EPA 1988) for field-tested replicates is $\pm 20\%$. Of the 36 field replicates collected, 94.4% were within acceptable limits. There are no functional guidelines for split results or offsite laboratory replicates, but the results correlated well based on the relative percent differences (RPDs).

2.6 CONCLUSIONS

The pump-and-treat system continues to make significant progress toward remediating the contaminant plume along the 100-D and 100-H Area shorelines by extracting groundwater before it reaches the river. In addition, human receptors are protected onsite using institutional controls. Details regarding the operation of the existing pump-and-treat system will be useful in evaluating system upgrades and modifications.

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- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River. The RAO for compliance wells is 22 µg/L based on the 11 µg/L ambient water quality criterion in place at the time of the signing of the ROD and a 1:1 dilution ratio.

Results:**100-D Area:**

- Approximately 310.7 million L (82.1 million gal) of groundwater were treated during CY06.
- Approximately 93.4 kg of hexavalent chromium were removed using the combined HR-3 (100-D and 100-H) pump-and-treat system (28.8 kg) and the DR-5 system (64.6 kg).
- Chromium concentrations decreased or were stable from 2005 to 2006 in seven of eight 100-D and DR-5 extraction wells and decreased in one of two compliance wells. However, chromium concentrations were above the 22 µg/L RAO in all of the extraction and compliance wells.
- Strontium-90 concentrations were less than the MCLs for all of the fall 2006 samples from the 100-D Area.
- Average tritium concentrations were less than MCLs in all of the 100-D Area wells north of the 182-D reservoir.
- The shape and areal extent of the 100-D chromium plume north of the 182-D reservoir has changed over the past few years by extending west to the Columbia River. This change was addressed by adding the DR-5 pump-and-treat system in 2004.
- The maximum chromium concentration in an aquifer tube north of the 182-D reservoir was 333 µg/L in tube 36-D.
- Monitoring well 199-D5-13 was characterized by a fall 2006 nitrate concentration of 89 mg/L, which was the highest 2006 nitrate concentration in the 100-D Area.
- The current IX treatment technology was proposed in 1995 for a smaller chromium plume extending from the D/DR Reactors north to the Columbia River. The RAO was to “protect aquatic receptors in the river bottom from contaminants in groundwater entering the Columbia River.” The current 2006 plume north of the 182-D reservoir is much larger in areal extent than the original target area identified in the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* (DOE-RL 1996). The combined 100-D and DR-5 pump-and-treat systems have removed several hundred kilograms of chromium mass from the chromium plume since 1997. However, the areal extent of the plume north of the 182-D reservoir has not changed significantly for the last few years of operation.

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100-H Area:

- Approximately 164.6 million L (43.5 million gal) of groundwater were treated in CY06. The 100-HR-3 influent streams were combined in 2005; therefore, the 100-H chromium mass and 100-D mass were included in the combined 100-HR-3 mass (28.8 kg).
- The fall 2006 average chromium concentrations were above the RAO of 22 µg/L in two of the extraction wells (199-H4-12A and 199-H4-15A). The maximum fall 2006 chromium concentration in an extraction well was 26 µg/L in well 199-H4-15A.
- The areal extent of the chromium plume has decreased more than 95% since pump-and-treat operations started in 1997.
- Chromium concentrations in wells 199-H4-12C, 199-H4-15(CS), and 199-H3-2C (screened below the top of the Ringold Upper Mud Unit) were all above 22 µg/L. The fall 2006 chromium concentration in well 199-H4-15CS was 102 µg/L, which was the highest 2006 concentration in the 100-H Area.
- Chromium concentrations in wells 199-H4-12B and 199-H4-15B (screened at the bottom of the unconfined aquifer) were 34 µg/L and 35 µg/L, respectively. The chromium concentration trend was down 35% for these two wells.
- Analytical modeling results indicate that the extraction well network generally captures the remaining plume north of the H Reactor.
- Former injection well 199-H3-5 in the southern portion of the H Reactor area had a concentration of 45 µg/L in the fall of 2006. Cessation of injection may have allowed groundwater from the horn area with higher chromium concentrations to flow into the area.

“Horn” area:

- Chromium concentrations across the “horn” area have decreased significantly since 1995.
 - A chromium plume exists around monitoring wells 699-97-43 and 699-96-43. Chromium concentrations in these wells were 113 µg/L and 83 µg/L, respectively, in 2006 but have been >180 µg/L in the recent past. The extent of this plume is not certain because there are only two wells in this area. The groundwater flow direction in this area is east northeast, and the plume may have extended into the area of well 199-H3-5.
 - Chromium concentrations were at or above 50 µg/L in aquifer tube 44 in 2000 and 2004. This plume may be part of the plume around wells 699-97-43 and 699-96-49, or it may be a separate plume.
- **RAO #2:** Protect human health by preventing exposure to contaminants in groundwater.

Results: The interim remedial action ROD (EPA et al. 1996) establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

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- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances in each reactor area)
- Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
- Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls was presented in the *2004 Final Institutional Controls (IC) Assessment Report* (DOE-RL 2004a). The findings of this report indicate that institutional controls were maintained to prevent public access, as required.

- **RAO #3:** Provide information that will lead to a final remedy.

Evaluation of treatment options to date:

- The reduction of the 100-H Area target chromium plume in the uppermost aquifer by over 95% and the removal of significant chromium mass in both 100-H and 100-D have confirmed that the pump-and-treat technology is effective. The existing pump-and-treat network has been less effective in achieving the RAO at compliance wells or at reducing the areal extent of the 100-D plume north of the 182-D reservoir.

2.7 RECOMMENDATIONS

100-D Area:

- Apply a systems approach to 100-D Area chromium plume remediation to include the following components: (1) locate chromium sources and provide data to source remediation contractors integrating groundwater and source remediation efforts; and (2) evaluate an electrocoagulation treatment system and bioremediation as alternatives or supplements to pump-and-treat technology.
- Work at the Hanford Site to minimize leakage from the 182-D reservoir.

100-H/"horn" area:

- Evaluate shallow (upper unconfined aquifer) and deep (upper semi-confined aquifer) contamination across the northern "horn" area, which may extend into the 100-H Area. Additional wells proposed in this area will provide delineation of magnitude and extent of chromium contamination and will help to determine whether the plume should be addressed as an interim action or as part of the remedial investigation/feasibility study process.
- After achieving the RAO, stop extracting groundwater and conduct a rebound study.
- Perform additional characterization of the aquifer in the horn area below the initial aquitard (i.e., the top of the Ringold Upper Mud Unit).
- Actively monitor the chromium plume that has reached well 199-H3-5.

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Figure 2-1. Location of the 100-HR-3 Operable Unit.

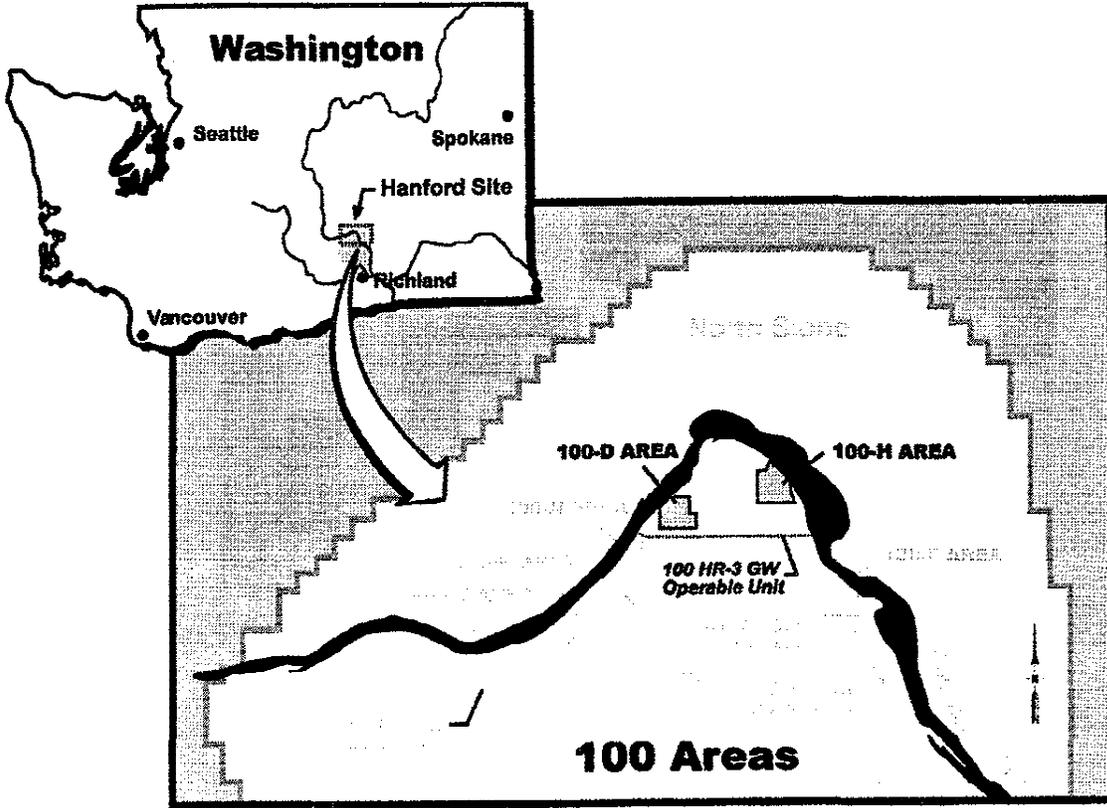


Figure 2-2. 100-HR-3 Operable Unit – 100-D Area Wells and Aquifer Sampling Tubes.

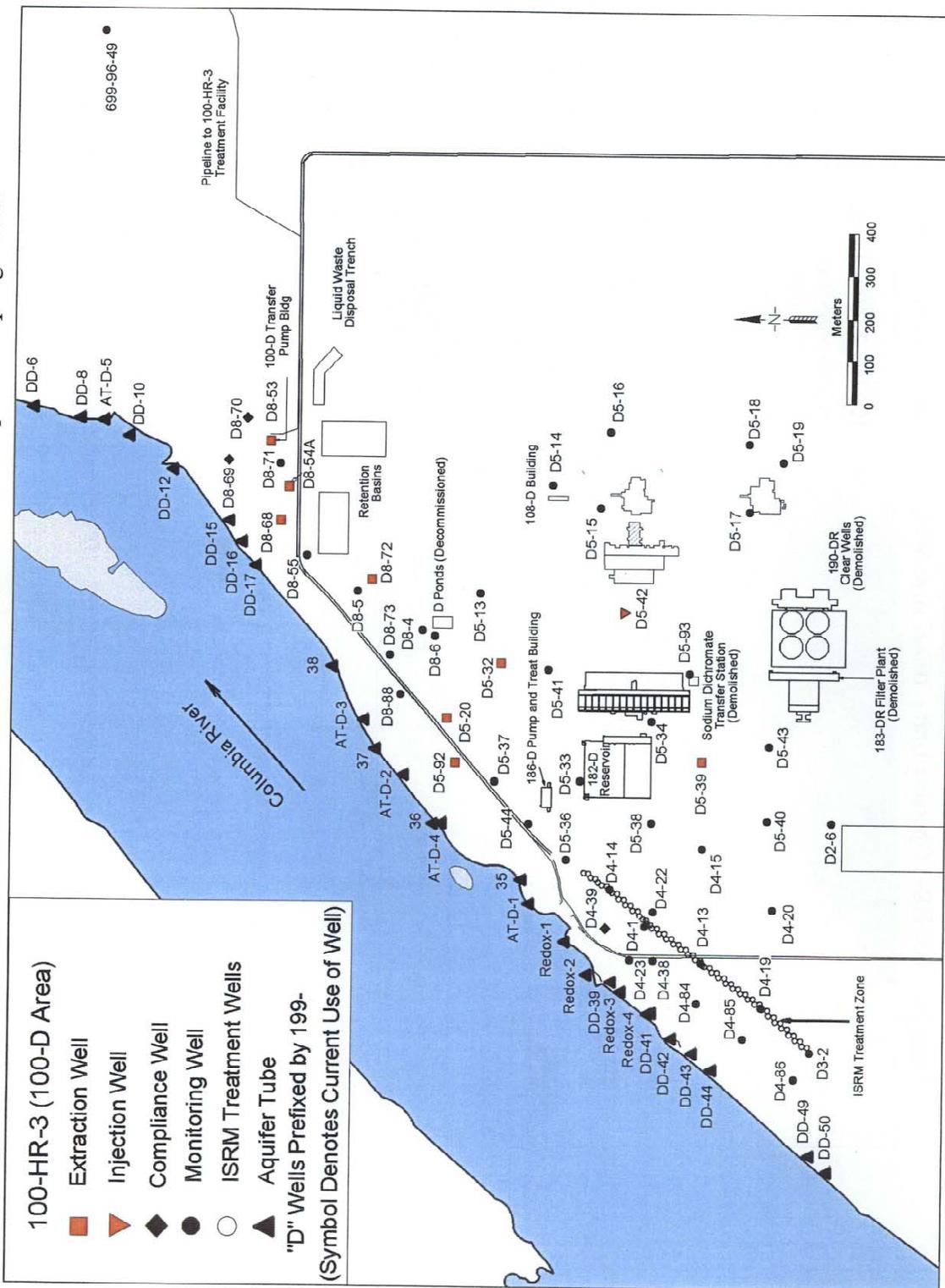
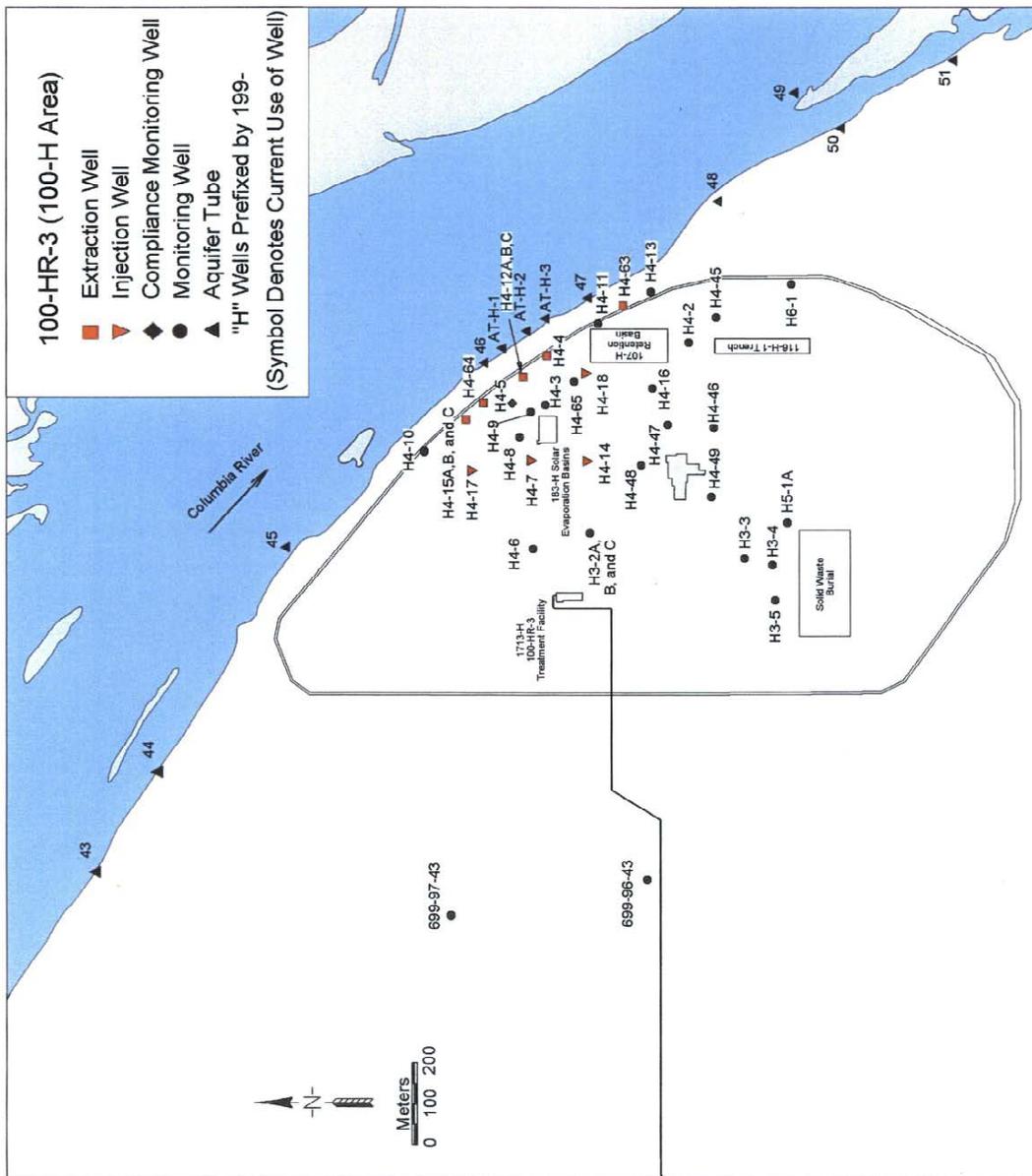
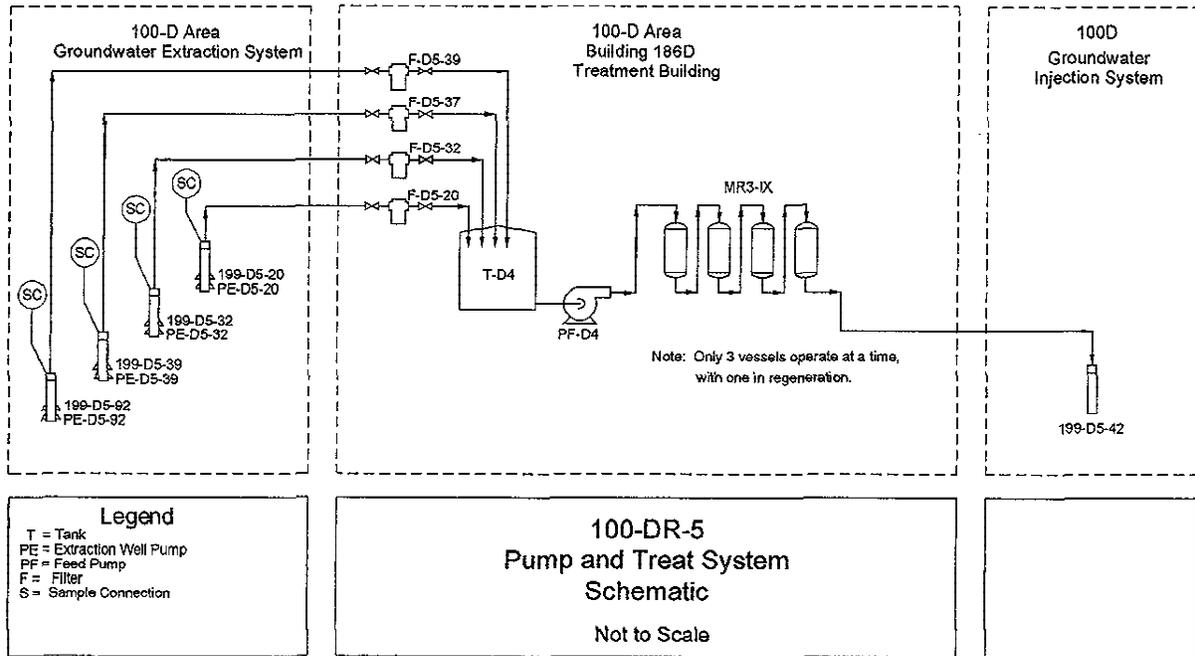


Figure 2-3. 100-HR-3 Operable Unit – 100-H Area Wells and Aquifer Sampling Tubes.



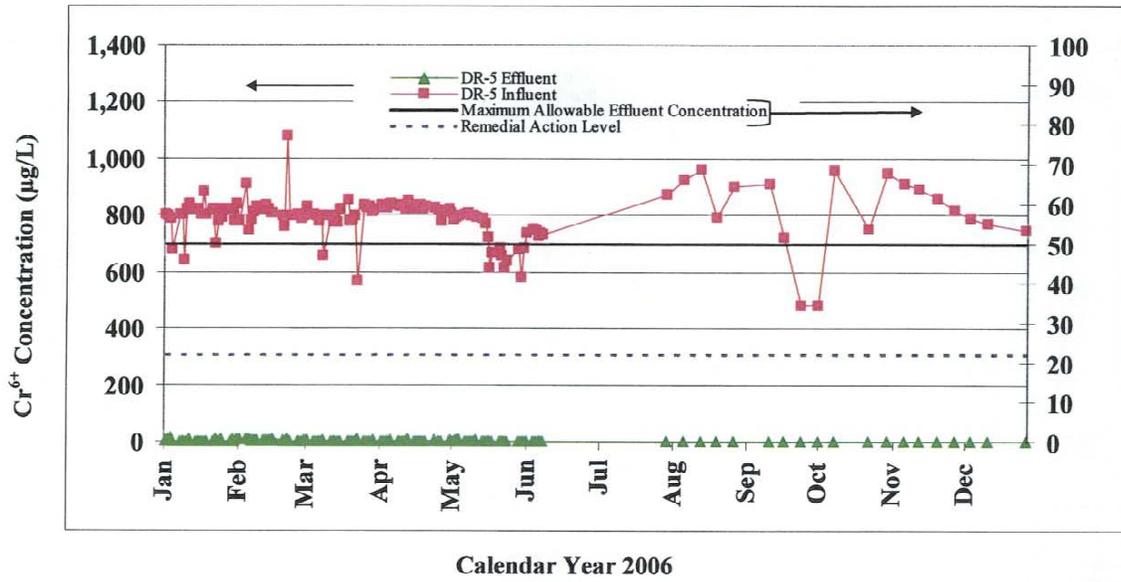
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Figure 2-4. DR-5 Pump-and-Treat System Schematic.



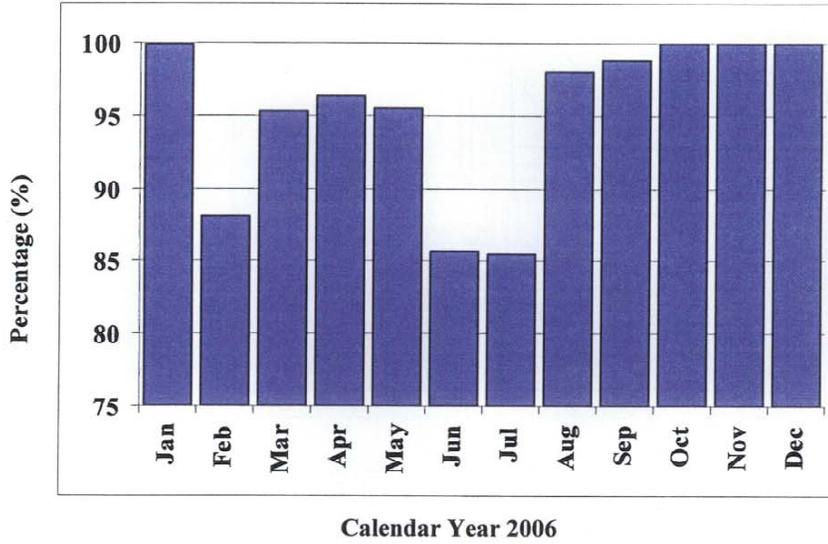
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Figure 2-5. Calendar Year 2006 100-DR-5 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations.



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Figure 2-6. 100-DR-5 System Availability and On-Line Percentages for Calendar Year 2006.

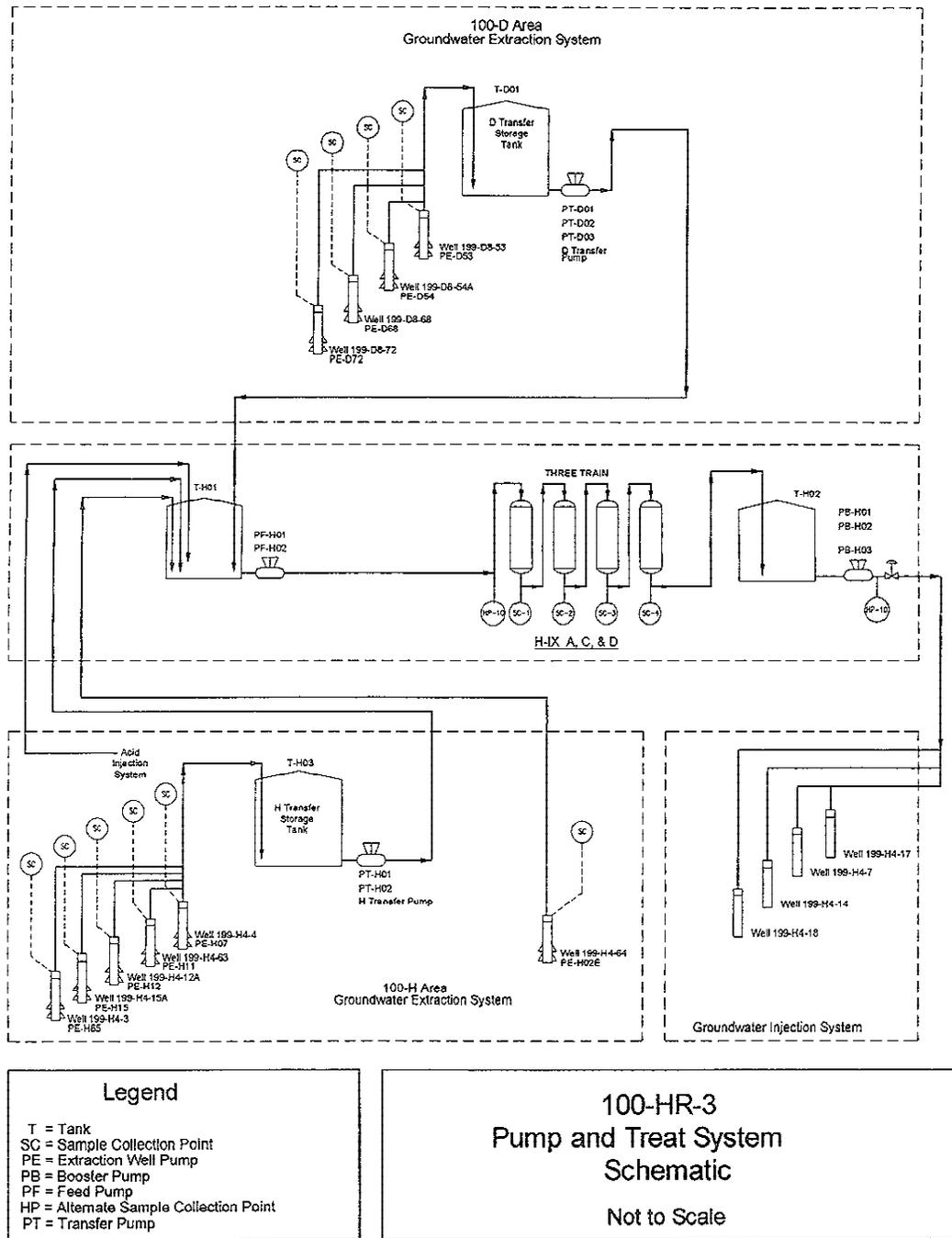


DR-5 system availability for 2006: ^a	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	171.7
Planned operations (hours)	8,588.3
Unscheduled downtime (hours)	307.1
Total time on-line (hours)	8,281.2
Total availability (%)	96.5
Scheduled system availability (%)	94.5

^a Scheduled system availability [(total possible run-time – unscheduled downtime) / total possible run-time].
 Total availability [(total possible run-time – scheduled and unscheduled downtime) / total possible run-time)].

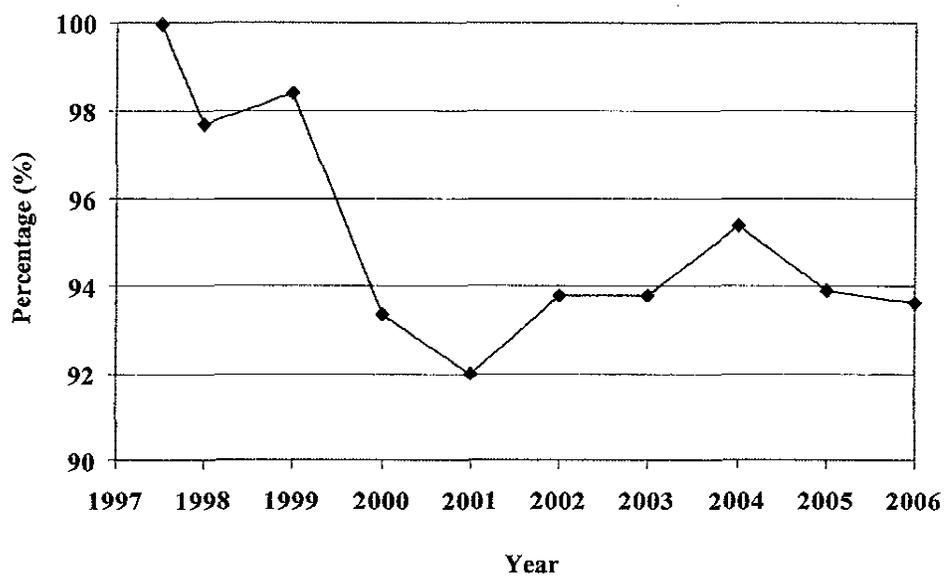
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Figure 2-7. 100-HR-3 Pump-and-Treat System Schematic.



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Figure 2-8. 100-HR-3 Pump-and-Treat Trend of Average Removal Efficiencies.^a

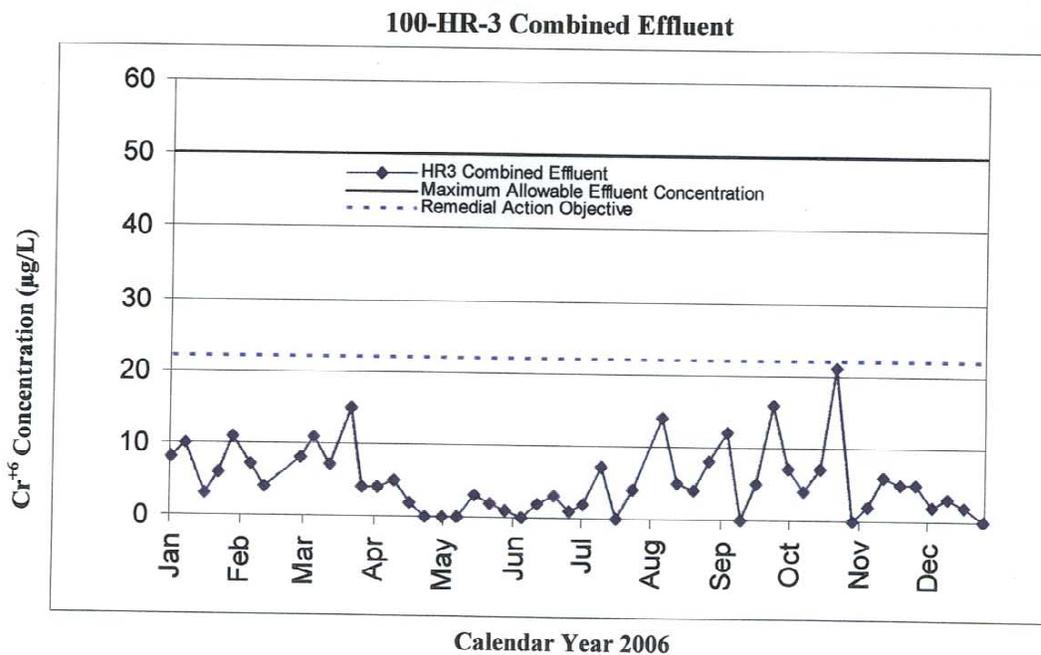
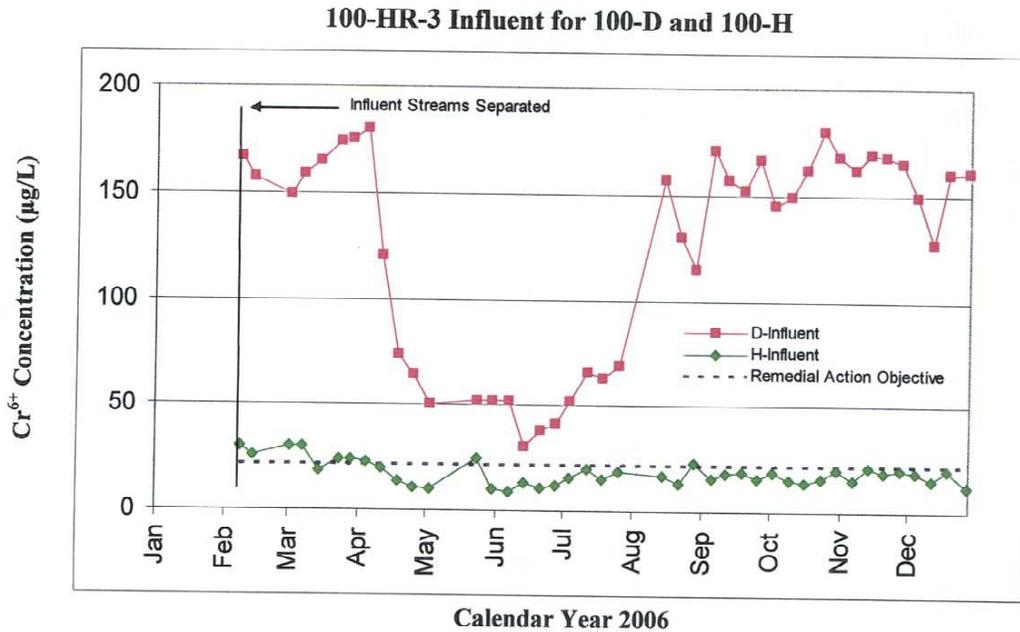


NOTE: The 100-HR-3 pump-and-treat trends of average removal efficiencies do not include the DR-5 pump-and-treat system.

^a Average removal efficiency is calculated as (% by mass) = [(influent – effluent) / influent].

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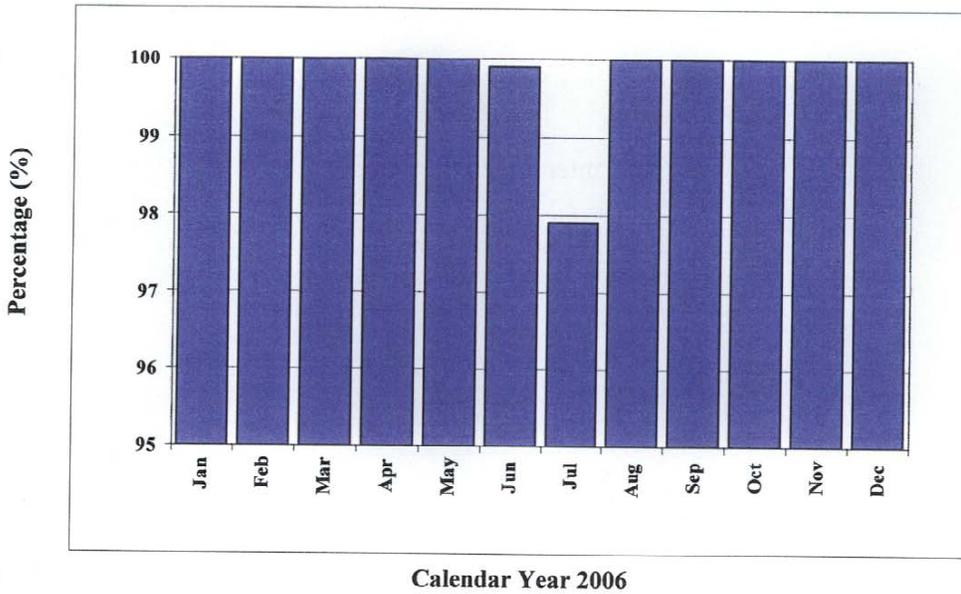
Figure 2-9. Calendar Year 2006 100-HR-3 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations.



NOTE: Calendar year 2006 100-HR-3 pump-and-treat trends of influent and effluent hexavalent chromium concentrations do not include the DR-5 pump-and-treat system.

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Figure 2-10. 100-HR-3 System Availability and On-Line Percentages for Calendar Year 2006.



100-HR-3 pump-and-treat system availability for 2006: ^a	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	59.8
Planned operations (hours)	8,700.2
Unscheduled downtime (hours)	16.0
Total time on-line (hours)	8,984.2
Total availability (%)	99.8
Scheduled system availability (%)	99.1

NOTE: The 100-HR-3 system availability and on-line percentages for calendar year 2006 do not include the DR-5 pump-and-treat system.

^a Scheduled system availability [(total possible run-time – unscheduled downtime) / total possible run-time].
 Total availability [(total possible run-time – scheduled and unscheduled downtime) / total possible run-time].

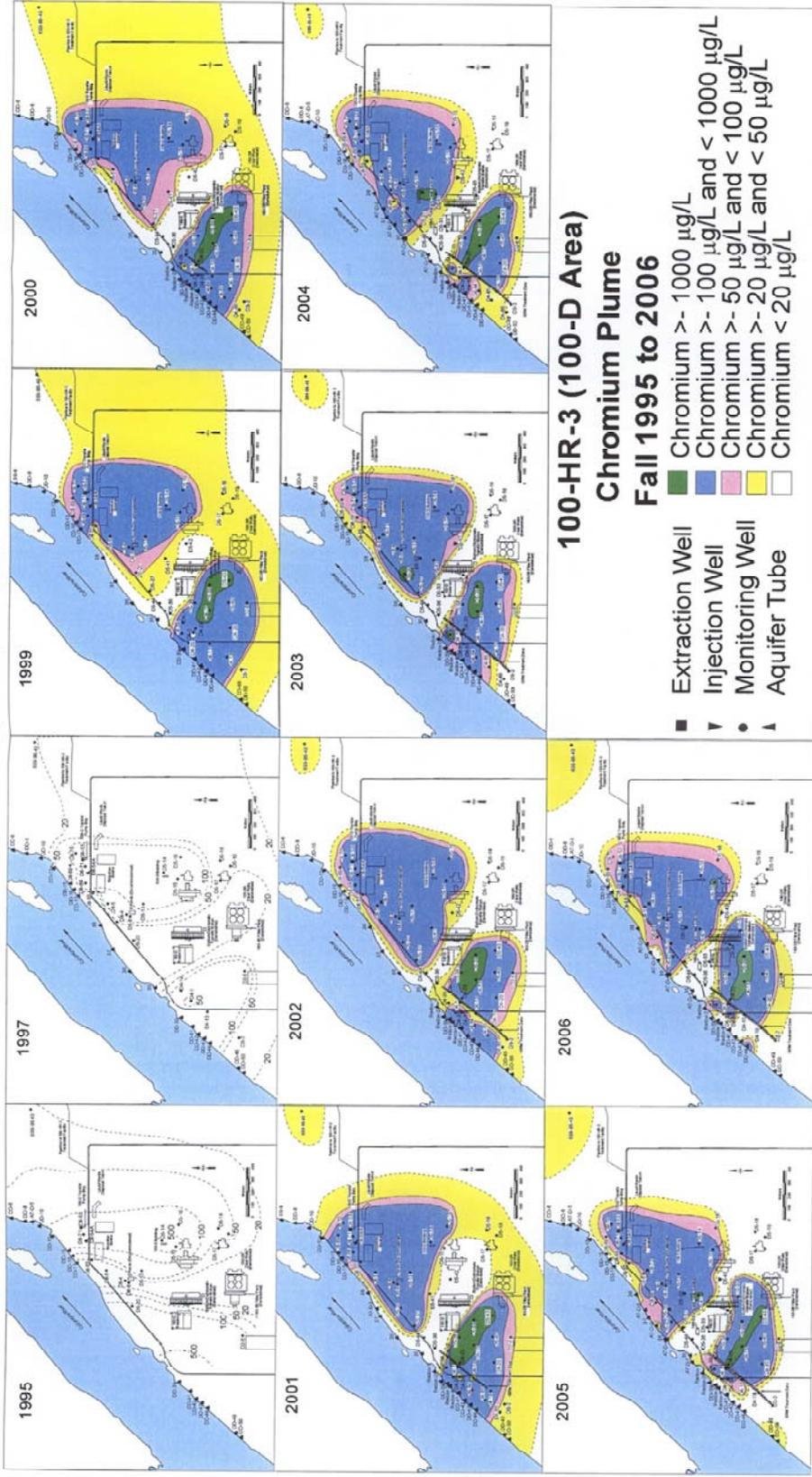
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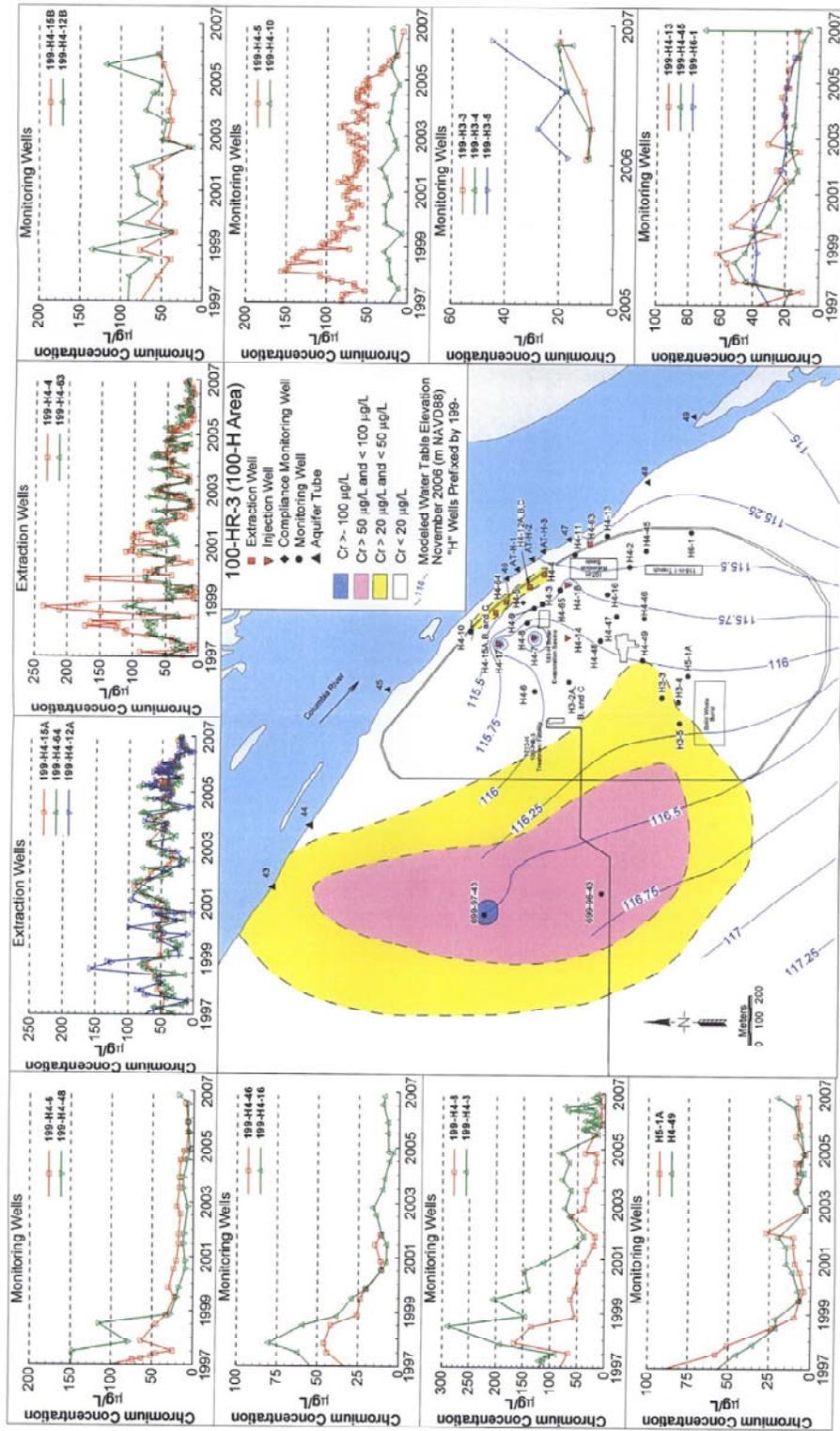
Figure 2-13. 100-D Chromium Plumes, 1995 to 2006.



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Figure 2-15. 100-H Area Chromium Plume, Fall 2006.



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Figure 2-17. 100-H Chromium Plume, 1995 to 2006.

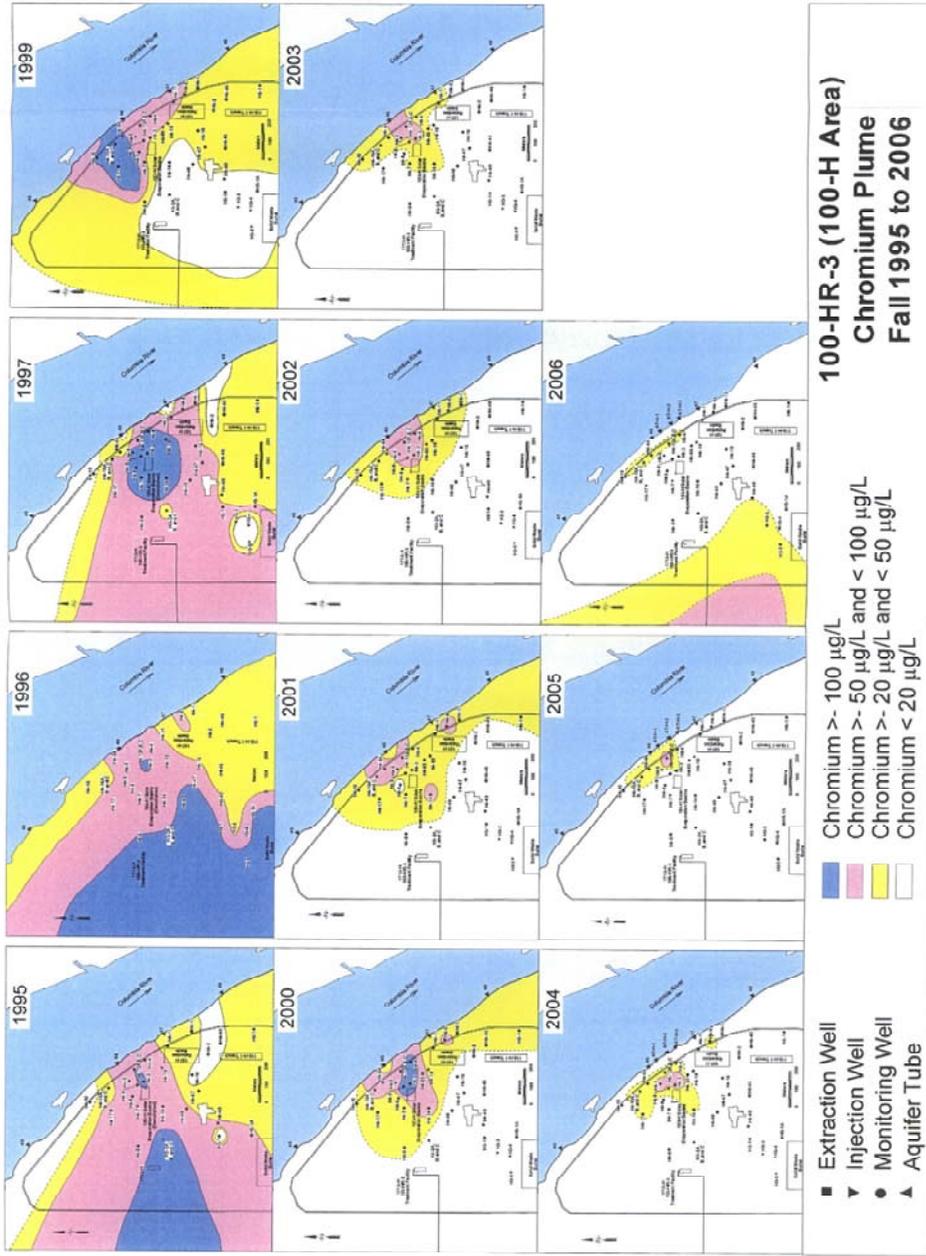
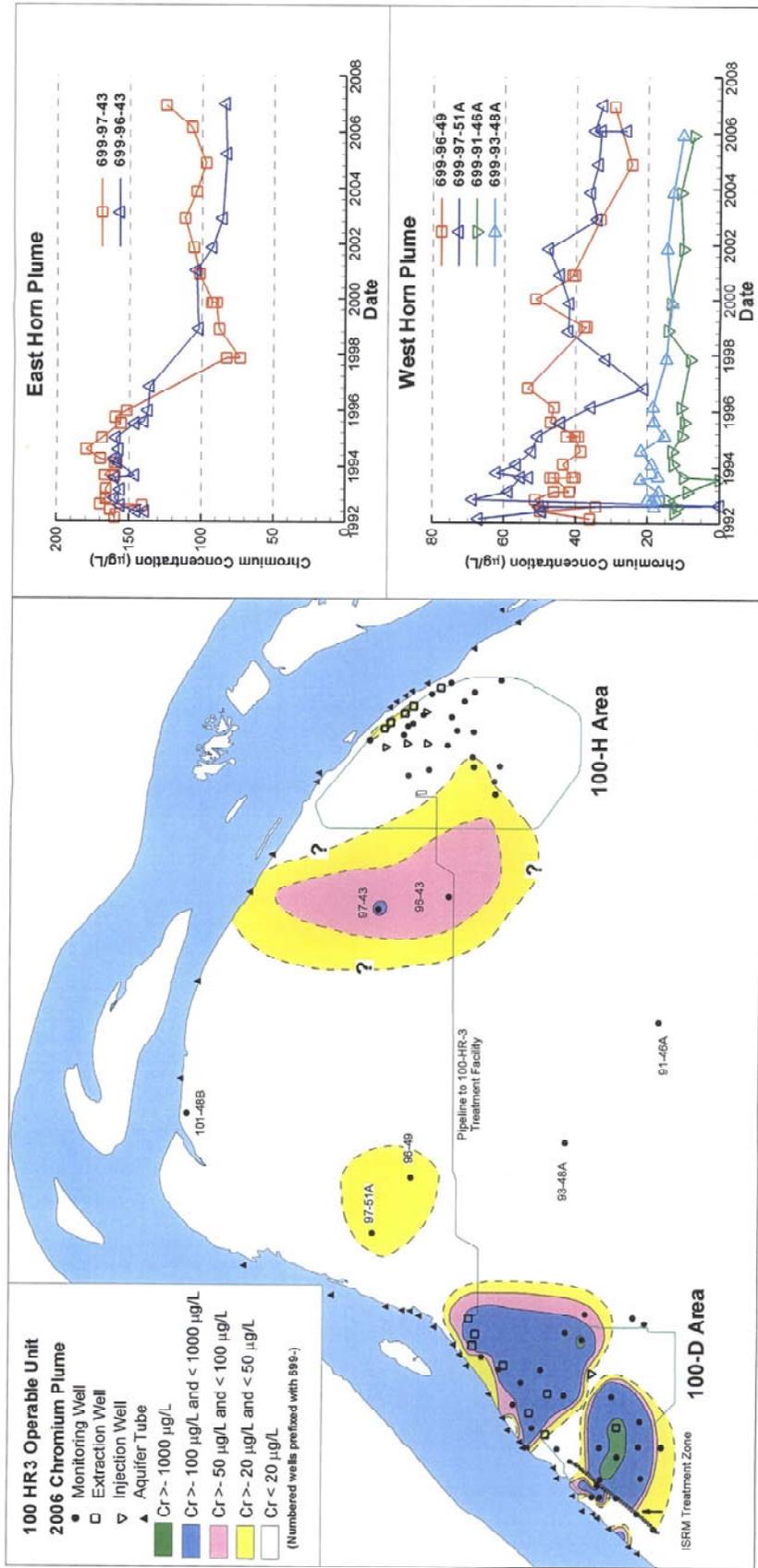


Figure 2-18. "Horn" Area Chromium Plume, 2006.



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Table 2-1. 100-HR-3 (100-H and 100-D Areas) Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis, Nov. 2005		Measured Water-Level Elevation, Nov. 2005 (m NAVD88 ^a)	Modeled Water-Level Elevation, Nov. 2005 (m NAVD88 ^a)
	Extraction Rate (L/min)	Injection Rate (L/min)		
100-H Area				
199-H3-2A	—	168.2	—	115.94
199-H4-7	—	339.1	—	118.16
199-H4-17	—	339.1	—	117.44
199-H4-11	0	—	115.20	115.26
199-H4-18	—	143.2	—	116.11
199-H4-12A	24.6	—	—	115.44
199-H4-15A	75.7	—	—	115.31
199-H4-65	—	—	115.74	115.65
199-H3-3	—	0	115.93	116.08
199-H3-4	—	0	115.93	116.10
199-H3-5	—	0	115.93	116.19
199-H3-2C	—	—	115.81	116.18
199-H4-3	28.1	—	—	115.63
199-H4-4	27.3	—	—	115.43
199-H4-5	—	—	115.10	115.58
199-H4-8	—	—	115.94	116.01
199-H4-10	—	—	114.90	115.20
199-H4-12C	—	—	115.43	115.46
199-H4-15B	—	—	115.24	115.41
199-H4-63	88.6	—	—	115.07
199-H4-64	34.5	—	—	115.42
199-H5-1A	—	—	115.93	116.00
100-H River	—	—	115.24	115.24
100-D Area				
199-D8-53	44.2	—	—	117.33
199-D8-54A	121.9	—	—	117.20
199-D8-68	207.8	—	—	117.11
199-D8-72	72.4	—	—	117.31
199-D5-20	80.3	—	—	115.60
199-D5-32	54.7	—	—	117.59
199-D5-37	0	—	—	117.56
199-D5-39	54.9	—	—	117.95
199-D5-42	—	204.0	—	118.14
199-D5-92	28.3	—	—	116.95
199-D8-69	—	—	117.01	117.20
199-D8-70	—	—	117.02	117.23
199-D8-71	—	—	116.96	117.22
100-D River	—	—	117.52	117.52

^a NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

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3.0 100-KR-4 PUMP-AND-TREAT SYSTEM

The 100-KR-4 OU includes the groundwater underlying the 100-KR-1 and 100-KR-2 source OUs. The 100-KR-4 pump-and-treat facility is located along the Columbia River, several miles southwest of the 100-HR-3 OU (Figure 3-1). The 100-KR-4 treatment system and injection/extraction well field are located adjacent to the 116-K-2 mile-long disposal trench. A map of wells and aquifer tube locations in the 100-K Area is presented in Figure 3-2. Appendix A provides a history of operations and supporting documents used in the development of the 100-KR-4 pump-and-treat system. Appendix B presents an updated conceptual model.

The 100-KR-4 interim action is similar to the 100-HR-3 interim action in that the primary COC is hexavalent chromium. Interim action co-contaminants in the 100-KR-4 OU include tritium and strontium-90. Carbon-14 and nitrate are co-contaminants of interest because they are present above MCLs in some wells.

This section provides the annual performance report for the 100-KR-4 OU. Primary emphasis is on pump-and-treat operations for the reporting period of January 1 through December 31, 2006. Section 3.1 summarizes groundwater conditions for all of the 100-KR-4 OU, as well as source area remedial actions within the groundwater OU. Section 3.2 summarizes the treatment system's performance, system operations, extraction well operations, and operational sampling. An evaluation of the aquifer response (including hydraulic monitoring, analytical modeling, and contaminant monitoring in the area impacted by pump-and-treat operations and in the KW and KE Reactor areas) is discussed in Section 3.3. Section 3.4 presents conclusions on the progress toward achieving each RAO and the performance criteria. Section 3.5 provides recommendations to change/enhance the 100-KR-4 OU pump-and-treat system. Cost information for the 100-KR-4 pump-and-treat system is presented separately in Section 5.0.

3.1 SUMMARY OF SOURCE AND GROUNDWATER OPERABLE UNIT ACTIVITIES

The long-term remedy for groundwater contamination in the 100-K Area requires both source and groundwater remedial actions.

3.1.1 Source Area Activities

Washington Closure Hanford, LLC (WCH) excavated chemically and radioactively contaminated soil and buried materials from the 118-K-1 Burial Ground during 2006. In addition, the WCH Field Remediation Project completed backfilling and revegetating at the 116-K-2 Trench.

3.1.2 Groundwater Operable Unit Activities

The groundwater activities associated with the 100-KR-1 and 100-KR-2 source OUs are discussed in the following subsections.

3.1.2.1 100-KR-1 Operable Unit. Groundwater remedial action in the vicinity of the 100-KR-1 source OU is the ongoing pump-and-treat operation in the vicinity of the 116-K-2 mile-long trench. The 100-KR-4 pump-and-treat system began operation in 1997 as a containment and mass-removal strategy to reduce the release of hexavalent chromium to the Columbia River in the vicinity of the mile-long trench. The primary source of the residual hexavalent chromium in

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the aquifer is attributed to the discharge of large volumes of reactor coolant containing approximately 700 µg/L of hexavalent chromium during operations from 1955 to 1971. A large groundwater mound developed around the mile-long trench, raising the water table to 6 m (19.7 ft) above the present-day water table elevation at a distance of over 1 km (0.6 mi) inland. This mound may have affected the groundwater chemistry to a distance of over 1 km (0.6 mi) from the trench to the vicinity of well 699-78-62, where chromium has been detected at nearly 50 µg/L during recent years.

The highlights associated with operations and improvements in the 100-KR-4 pump-and-treat system for CY06 are discussed in more detail in Section 3.3.3 and are summarized below:

- The operation of the 100-KR-4 pump-and-treat system has decreased chromium concentrations below the 22 µg/L RAO in the center of the plume, downgradient of the 116-K-2 Trench. The highest concentration portion of the plume (>100 µg/L chromium) has been reduced to two small areas around compliance wells 199-K-18 and 199-K-114A.
- Average October 2006 chromium concentrations remain above the 22 µg/L RAO in seven of nine extraction wells. The exceptions are wells 199-K-119A and 199-K-125, which dropped to 16 µg/L and 21 µg/L, respectively.

3.1.2.2 100-KR-2 Operable Unit. Groundwater actions associated with the 100-KR-2 OU consisted primarily of groundwater monitoring in the vicinity of the reactor areas, as reported in *Hanford Site Groundwater Monitoring for Fiscal Year 2006* (PNNL 2007). The primary groundwater issue in this area is the localized chromium plume near the KW Reactor building. The highest total chromium concentration during 2006 was 2,170 µg/L in new well 199-K-137. This high chromium concentration indicates that the source of the contamination was a more highly concentrated solution than reactor coolant water. A stand-alone K West pump-and-treat system was designed and constructed during 2006 and was scheduled to be operational during February 2007.

Other key groundwater issues being tracked in the 100-KR-2 OU include (1) fluctuating tritium concentrations near both reactor areas; (2) the occurrence of low, but measurable, technetium-99 concentrations near the KW Reactor that are of unknown origin; and (3) a possible tritium source near the 118-K-1 Burial Ground (PNNL 2007).

3.2 100-KR-4 TREATMENT SYSTEM PERFORMANCE

This section describes the 100-KR-4 pump-and-treat system's operations and sampling activities for CY06. Specific details include changes to system configuration, system availability, mass of contaminants removed during operation, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and contaminant trends.

In CY06, no major system modifications were implemented for the 100-KR-4 pump-and-treat system. To improve system efficiency for the 100-KR-4 pump-and-treat system, flow rates for select extraction and injection wells were adjusted to prevent over-pumping and associated system shutdown during freezing conditions. This resulted in greater scheduled system availability. Figure 3-3 presents a schematic drawing at the current 100-KR-4 pump-and-treat system.

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A summary of operational parameters and total system performance for CY06 is presented in the table below:

Total processed groundwater:	
Total amount of groundwater treated (since October 1997 startup) (billion L)	3.88
Total amount of groundwater treated during CY06 (million L)	525.9
Mass of hexavalent chromium removed:	
Total amount of hexavalent chromium removed (since October 1997 startup) (kg)	304.2
Total amount of hexavalent chromium removed in CY06 (kg)	21
Summary of operational parameters:	
Removal efficiency (% by mass)	85.1
Waste generation (m ³)	0
Regenerated resin installed (m ³)	56.6
New resin installed (m ³)	11.3
Number of resin vessel changeouts	30 vessels
Summary of system availability:	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	24
Planned operations (hours)	8,736
Unscheduled downtime (hours)	22.8
Total time on-line (hours)	8,713.2
Total availability (%)	99.5
Scheduled system availability (%)	99.7

Key operational and system highlights for CY06 are as follows:

- The 85.1% removal efficiency for CY06 is lower than the 93.6% reported for CY05 (Figure 3-4). The lower reported efficiency for CY06 may be attributed to lower influent concentration.
- The average 100-KR-4 influent hexavalent chromium concentration of 46.5 µg/L was lower than the CY05 average of 51.1 µg/L. The smaller influent concentration reported in CY06 can be attributed to development of a circulation cell between extraction and injection wells.
- The average effluent hexavalent chromium concentration of 5.7 µg/L for CY06 was higher than the 3.2 µg/L in CY05. Trend plots of CY06 influent and effluent concentrations are presented in Figure 3-5.
- The maximum hexavalent chromium concentration in the effluent was 15 µg/L.
- System availability for CY06 (not including scheduled downtime) was 99.7%, which was higher than the 97.3% reported in CY05. The total availability was 99.5%, which was higher than the on-line availability of 95.3% reported for CY05. The higher total system availability values can be attributed to increased operation during freezing conditions and greater efficiency during scheduled maintenance. Figure 3-6 presents the monthly

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on-line percentages and method used to calculate scheduled and on-line for the reporting period.

- Resin changeouts were performed on 30 vessels in CY06. New resin installed totaled 11.3 m³ (399.1 ft³), while regenerated resin totaled 56.6 m³ (1,98.8 ft³).

The following table presents the pumping flow rates and total run-time (total flow hours / total possible run-time) for extraction wells at the 100-KR-4 pump-and-treat system. Except where noted, the recommended flow rates are based upon updated numerical modeling results that were prepared to support the *Comprehensive Environmental Response, Compensation, and Recovery Act of 1980* (CERCLA) 5-year review design modification. The yearly average flow rates are calculated from actual totalized volumes divided by the total hours in a year:

Well	Recommended ^b Flow Rate (L/min)/(gpm)	Yearly Avg. Flow Rate (L/min)/(gpm)	Total Flow Hours in CY06	Total Run-Time (%) ^c	Purpose
K-129 ^a	94.6 (25.0)	79.2 (20.9)	7,906.4	90.3%	Extraction
K-113A	56.8 (15.0)	47.7 (12.6)	8,220.4	93.8%	Extraction
K-114A ^d	94.6 (25.0)	91.4 (24.1)	7,695.8	87.9%	Extraction
K-115A	94.6 (25.0)	141.4 (37.4)	8,167.8	93.2%	Extraction
K-116A	151.4 (40.0)	154.8 (40.9)	8,460.6	96.6%	Extraction
K-119A	113.6 (30.0)	139.9 (37.0)	8,532.4	97.4%	Extraction
K-120A	113.6 (30.0)	139.6 (36.9)	8,589.8	98.1%	Extraction
K-125A	113.6 (30.0)	134.4 (35.5)	7,365.0	84.1%	Extraction
K-127	151.4 (40.0)	138.8 (36.7)	8,592.0	98.1%	Extraction
K-121A	NA	159.1 (42.0)	8,680.6	99.1%	Injection
K-122A	NA	280.6 (74.1)	8,712.4	99.5%	Injection
K-123A	NA	218.2 (57.6)	8,710.8	99.4%	Injection
K-124A	NA	65.1 (17.2)	8,321.2	95.0%	Injection
K-128	NA	271.4 (71.7)	8,712.8	99.5%	Injection

^a Extraction well 199-K-112A was replaced with well 199-K-129, which began operating as an extraction well on July 10, 2003.

^b Recommended flow rate based upon drawdown analysis.

^c Total flow hours in CY06 / total hours in CY06 x 100%.

^d Monitoring well 199-K-114A was converted to an extraction well and began operation in November 2004.

NA = not available

A comparison of the extraction rates shows that wells 199-K-115A, 199-K-116A, 199-K-119A, 199-K-120A, and 199-K-125A were pumped at greater flow rates than recommended. These wells were able to sustain higher yields during the reporting period and were, therefore, used to offset lower rates from wells 199-K-113A and 199-K-127.

The lower-than-recommended flow rates at wells 199-K-113A and 199-K-127 may be attributed to fluctuations in river levels throughout the year, which frequently limited the available drawdown in these wells. Decreased well efficiency due to scaling (calcium carbonate) or biological fouling may also impact pumping rates. During the year, all wells were subject to downtime because of area power-grid outages, equipment failures or maintenance, and

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construction activities. This downtime is reflected in the yearly average flow-rate calculations and the total run-time percentages for each extraction well.

Operational parameters, total system performance, and extraction well chromium concentrations and extraction rates are provided in Appendix C.

3.3 AQUIFER RESPONSE IN THE 100-K AREA

This section describes the general hydrogeologic conditions in the 100-K Area, numerical modeling conducted to evaluate the extraction well network, and changes in contaminant concentrations in monitoring wells.

3.3.1 Hydrogeologic Conditions at the 100-K Area

The hydrogeologic conditions at the 100-K Area are discussed below. As shown in Figure 3-7, the most prevalent groundwater flow direction at 100-K is northwest. During the spring months, the Columbia River's elevation generally increases due to additional flow from snowmelt run-off. Flow is regulated at Priest Rapids Dam to provide irrigation water and to aid in fish migration.

- The average river stage during CY06 increased over CY05 but was within the 5-year average. Overall, the Columbia River stage and flow regime has shown a slight but relatively consistent increase over the past 3 years.
- The average hydraulic gradient in the 100-K Area was 0.0009 toward the northwest.
- Groundwater flow velocity for 2006 over the 100-K Area was 0.03 m/day (0.09 ft/day) based on a hydraulic conductivity of 6.1 m/day (20 ft/day) and porosity of 0.2, with the gradient derived from a three-point solution of hourly data from wells 199-K-37, 199-K-18, and 199-K-117A (BHI 1996). However, there are significant differences in flow velocity in the 100-K Area caused by river flux, mounding around injection wells, and lithologic variations.

Appendix D presents a detailed discussion of the aquifer response in 100-KR-4. Appendix I provides hydrographs for select 100-K Area wells.

3.3.2 Analytical Modeling

A detailed discussion of the analytical model is presented in Appendix E. Table 3-1 presents a comparison of the measured and modeled water table elevations, as well as the average flow rates used in the numerical model.

A summary of the numerical modeling results supporting the 100-KR-4 pump-and-treat operations is as follows:

- The original targeted plume from the 116-K-2 Trench, north to the Columbia River, is within the capture zone of the existing extraction well network (Figure 3-8).
- There is incomplete capture south of well 199-K-120A, where hexavalent chromium concentrations have ranged from 75 to 85 $\mu\text{g/L}$ in aquifer tube AT-K-3-D since May 2005.

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- The plume north of extraction well 199-K-129 is not being captured by the current extraction well network because former extraction well 199-K-126 was removed from the pump-and-treat network in 2005 for the calcium polysulfide treatability test.

3.3.3 Contaminant Monitoring

This section summarizes and interprets the CERCLA analytical results obtained from groundwater monitoring wells supporting the 100-K Area pump-and-treat remedial action and other areas in the 100-KR-4 OU. The *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1997) and *Sampling Changes to the 100-HR-3 and 100-KR-4 Operable Unit* (DOE-RL 1998) define the sampling protocols implemented for CY05. The results presented below include the individual or average fall 2006 concentrations for CY06, unless otherwise specified. The fall time period for 2005 and 2006 sampling is from October 1 through November 12 each year, unless otherwise specified. Section 3.3.3.1 includes a discussion on chromium monitoring results, and Section 3.3.3.2 includes a discussion on the monitoring results for remedial action co-contaminants strontium-90 and tritium. Nitrate and carbon-14 are also constituents of interest.

Complete contaminant monitoring results for CY06 and the historical results for CY01 through CY06 are presented in Appendix F. Contaminant trend charts are presented in Appendix J. A summary and highlights for CY06 are discussed below:

- The operation of the pump-and-treat system has been effective in reducing chromium concentrations below the 22 µg/L RAO in the center of the plume (downgradient from the 116-K-2 Trench). The highest concentration portion of the plume (>100 µg/L chromium) has been reduced to two small areas around compliance wells 199-K-18 and 199-K-114A (Figures 3-7 and 3-8).
- Average fall 2006 chromium concentrations remain above the 22 µg/L RAO in seven of nine extraction wells. The exceptions are wells 199-K-119A and 199-K-125A, where the 2006 concentrations have dropped to 21 µg/L for well 199-K-125A and 16 µg/L for well 199-K-199A.
- Average chromium concentrations were stable in the extraction wells. None of the extraction wells displayed increases or decreases of more than 20% when comparing fall 2005 versus fall 2006.
- Fall 2006 chromium concentrations remain above the RAO in two of four compliance wells. The maximum fall 2006 chromium concentration was 137 µg/L in well 199-K-18 and the lowest was 6 µg/L in well 199-K-117A.
- The farthest northeastern downgradient monitoring well, 199-K-131, had a fall 2006 chromium concentration of 82 µg/L. This was an increase of only 2.4% from fall 2005 and may indicate that the chromium plume movement north toward the 100-N Area has slowed. From fall 2004 through fall 2005, chromium concentration increased from 63 µg/L to 80 µg/L, or 27%. A northeastern migration of the chromium plume is displayed clearly in Figure 3-9, which includes a snapshot of the fall plume for each year since 1997 when the pump-and-treat system became operational.

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- The maximum hexavalent chromium concentration in the KW Reactor area was 2,284 µg/L in monitoring well 199-K-137. This plume will be remediated by the KW pump-and-treat system, which will become operational in February 2007.
- The maximum strontium-90 concentration (31 pCi/L) was detected in pump-and-treat monitoring well 199-K-21.
- Tritium was above the 20,000 pCi/L MCL in two pump-and-treat area wells. The maximum concentration detected was 37,000 pCi/L in extraction well 199-K-120A.
- The maximum fall 2006 strontium-90 concentration in the KW and KE Reactor areas was 26.6 pCi/L in well 199-K-107A, which is located downgradient of KW Reactor.
- The KE Basin remediation activities precluded the sampling of well 199-K-109A, which had 1,269 pCi/L strontium-90 in samples collected in the fall of 2005.
- The maximum tritium concentration in the KW and KE Reactor areas was 190,000 pCi/L in well 199-K-30, located downgradient of KE Reactor.
- Well 199-K-106A, located downgradient of the KW Reactor, showed 1,116,000 pCi/L tritium in samples collected in the fall of 2005. This well was not sampled in the fall of 2006.
- The maximum carbon-14 concentration in 2006 in the KW and KE Reactor areas was 3,340 pCi/L in well 199-K-132, which is downgradient of KW Reactor. Well 199-K-106A, which had 16,300 pCi/L carbon-14 in samples collected in the fall of 2005, was not sampled in the fall of 2006.

3.3.3.1 Chromium Monitoring Results. Chromium concentrations are monitored in extraction wells, compliance wells, monitoring wells, and aquifer tubes in the 100-KR-4 pump-and-treat operational area. Additional CERCLA monitoring wells outside of the area affected by pump-and-treat operations are also sampled for chromium. The chromium plumes downgradient of the KW Reactor and near the KE Reactor are described below.

The 100-K Area's fall 2006 chromium plume and associated historical trends are displayed in Figure 3-7. Chromium plumes for most of the years since pump-and-treat operations began in 1997 are displayed in Figure 3-9.

- **100-KR-4 pump-and-treat chromium plume:** The table below compares the average chromium and specific conductance data for CY05 versus CY06 for pump-and-treat extraction wells, compliance wells, and selected 100-KR-4 pump-and-treat monitoring wells. Most of the wells were sampled in October and, where more than one result was available, the results were averaged. The average results shown include hexavalent chromium and filtered total chromium.

Well	Well Use	Fall 2005		Fall 2006		Percent Change ⁹
		Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
199-K-18	Compliance	538	139	516	137	-2%
199-K-19	Monitoring	451	58	436	54	-7%

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Well	Well Use	Fall 2005		Fall 2006		Percent Change ^a
		Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
199-K-20	Compliance	343	18	347	18	0%
199-K-21	Monitoring	361	15	364	7	-53%
199-K-22	Monitoring	393	125	412	120	-4%
199-K-37	Monitoring	351	80	361	79	-1%
199-K-113A	Extraction	--	76	--	74	-3%
199-K-114A	Compliance/ extraction	--	63	--	75	+16%
199-K-115A	Extraction	--	93	--	96	+3%
199-K-116A	Extraction	--	81	--	81	0%
199-K-117A	Compliance	188	5	210	6	+17%
199-K-119A	Extraction	--	19	--	16	-19%
199-K-120A	Extraction	--	60	--	62	+3%
199-K-125A	Extraction	--	23	--	21	-10%
199-K-127	Extraction	--	37	--	31	-19%
199-K-129	Extraction	--	58	--	51	-14%
199-K-130	Monitoring	393	91	393	94	+3%
199-K-131	Monitoring	395	80	422	82	+2%
699-78-62	Monitoring	--	23.5	--	28	+19%

^a Percent change is calculated by the following equation: $[(CY05 - CY06) / CY05] \times 100\%$.

NOTE: Results for samples collected between October 1 and November 12 in both 2005 and 2006, and averaged if multiple results available. Includes data available in the HEIS database on January 24, 2007.

-- = well not sampled, or analytical results not available for report preparation

The changes in chromium concentrations in extraction wells can be summarized as follows:

- Average fall 2006 chromium concentrations were below the 22 µg/L RAO only in extraction wells 199-K-119A (16 µg/L) and 199-K-125A (21 µg/L).
- Average chromium concentrations remained stable (within 20%) in all extraction wells.

Chromium concentrations in compliance wells can be summarized as follows:

- Average chromium concentrations in the fall of 2006 were below the 22 µg/L RAO only in wells 199-K-117A (7 µg/L) and 199-K-20 (18 µg/L).
- Average chromium concentrations remained stable (within 20%) in all compliance wells, although chromium increased to 75 µg/L in well 199-K-114A, which is being used as an extraction well. The source of elevated chromium concentrations in well 199-K-18 (137 µg/L) is unknown; however, the existing groundwater flow direction indicates that the 116-K-1 Crib may be a possible source. It is also possible that injected water may have caused migration of the plume toward well 199-K-18.

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Changes in chromium concentrations for the seven monitoring wells in the pump-and-treat operational area can be summarized as follows:

- Fall 2006 chromium concentrations were above the 22 µg/L RAO in all monitoring wells, except for well 199-K-21 (7 µg/L).
 - Decreases of more than 20% occurred only in well 199-K-21 (-53%).
 - Fall 2006 chromium concentrations remained stable ($\pm 20\%$) in wells 199-K-19, 199-K-22, 199-K-37, 199-K-130, 199-K-131, and 699-78-62.
 - The average December 2006 chromium concentration was 26 µg/L in well 699-78-62, which is located approximately 1,200 m (3,937 ft) northeast of the 116-K-2 Trench. The source of the hexavalent chromium likely was the mounding of groundwater caused by filling the 116-K-2 Trench with reactor coolant water during reactor operations.
- **Aquifer tube sampling:** The table below compares the CY05 versus CY06 values for the aquifer sampling tubes downgradient of the pump-and-treat operational area, if the results exceeded the 22 µg/L RAO, or if the percent change from 2005 to 2006 was >20%. It is important to note that the 2005 sampling took place in May and the 2006 sampling occurred in February and March.

Aquifer Tube	May 2005		February/March 2006		Percent Change ^{a, b}
	Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
22-D	--	--	198	11	^b
22-M	--	--	130	2	^b
26-D	369	45	410	46	+2%
26-M	220	11	162	4	-64%
AT-K-3-D	306	85	308	80	+6%
AT-K-3-M	321	80	327	77	-4%
AT-K-3-S	403	68	398	63	-7%
AT-K-5-D	301	70	294	70	+0%
AT-K-5-M	303	54	300	49	-9%
AT-K-5-S	302	43	299	51	+19%
AT-K-6-M	--	--	374	57	^b
21-M	--	--	161	6	^b
23-M	135	3	132	2	-33%
25-D	244	2(U)	253	30	^c
AT-K-6-D	--	--	378	43	^b
DK-04-2	333	77	324	69	-12%
DK-04-3	337	42	333	57	+36%

^a Percent change is calculated by the following equation: $[(CY05 - CY06) / CY05] \times 100\%$.

^b Insufficient data to compare.

^c Not calculated because one value characterized by the "U" undetected qualifier.

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A comparison of chromium concentrations in aquifer sampling tubes between May 2005 and February/March 2006 can be summarized as follows:

- Chromium concentrations in aquifer tube AT-K-3, downgradient of well 199-K-18, stabilized at 80 $\mu\text{g/L}$ in 2006 compared to 85 $\mu\text{g/L}$ in 2005.
- February/March 2006 chromium concentrations on the northern end of the pump-and-treat operational area ranged from 70 $\mu\text{g/L}$ in aquifer tube AT-K-5-D to 30 $\mu\text{g/L}$ in aquifer tube 25-D. Chromium concentrations were stable in many of the aquifer tubes in this area but increased in DK-04-3 and 25-D. Specific conductance values at these sites were essentially constant; therefore, the chromium increases appear to reflect the approach of groundwater with higher chromium concentrations.

The aquifer tube sampling results suggest that there are probably gaps in capture south of extraction well 199-K-120A and north of extraction well 199-K-129.

- **KW Reactor chromium plume:** The chromium plume centered in the KW Reactor area has been monitored since the early 1990s when many of the CERCLA monitoring wells were installed. In 1997, when many of the aquifer tubes were installed in the 100-K Area, the plume appeared to be centered on the KW Reactor (well 199-K-107A), with a maximum chromium concentration of 191 $\mu\text{g/L}$. The maximum concentration in near-river well 199-K-33 was 21.7 $\mu\text{g/L}$ of total chromium. The maximum 1997 total chromium concentration in a downgradient aquifer tube was 6 $\mu\text{g/L}$ in tube 17-D.

In 2004, well 199-K-132 replaced well 199-K-33, which was decommissioned to facilitate remediation of the former KW retention basins. In addition, aquifer sampling tubes AT-K-1 through AT-K-6 were installed to fill gaps along the 100-K Area shoreline.

In 2005, chromium concentrations in well 199-K-132 and aquifer tube AT-K-1-D reached 132 $\mu\text{g/L}$ and 42.4 $\mu\text{g/L}$, respectively. These increases in chromium indicated that the KW Reactor plume had reached the Columbia River shoreline. Chromium concentrations decreased to 8 $\mu\text{g/L}$ in 2006 in aquifer tube AT-K-1-D but averaged 175 $\mu\text{g/L}$ in well 199-K-132 (Figure 3-10).

The result of increasing chromium concentrations in near-river well 199-K-132 and a 2005 spike in the chromium concentrations in aquifer tube AT-K-1-D was the design and construction of the KW pump-and-treat system during 2006. The wells making up the KW pump-and-treat network and other nearby wells are listed in the table below:

Well	Type	Fall 2005 Chromium ($\mu\text{g/L}$) ^{a,c,e}	Fall 2006 Chromium ($\mu\text{g/L}$) ^{a,c,e}	Percent Change ^d
199-K-34	Monitoring	10.1	13.7	+26%
199-K-35	Monitoring/ injection	11	7	-57%
199-K-106A	Monitoring	3	--	^b
199-K-107A	Monitoring	502	444	-13%
199-K-108A	Monitoring	69	25	-176%
199-K-31	Monitoring	11.5	10.9	-5%

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Well	Type	Fall 2005 Chromium ($\mu\text{g/L}$) ^{a,c,e}	Fall 2006 Chromium ($\mu\text{g/L}$) ^{a,c,e}	Percent Change ^d
199-K-132 ^f	Monitoring/ extraction	76	175	+57%
199-K-137 ^f	Monitoring	--	1,987	^b
199-K-138 ^f	Extraction	--	67	^b
199-K-139	Extraction	--	155	^b
199-K-140	Extraction	--	155	^b

^a Sampled between October 1 and November 12 in both 2005 and 2006.

^b Insufficient data to compare.

^c Concentration may include hexavalent chromium or total chromium (inductively coupled plasma-filtered) sample. Results are averaged if more than one available for time interval.

^d Percent change is calculated by the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$

^e Includes data available in the HEIS database on January 29, 2007.

^f Vertical profiling results in Table 2-1, DOE/RL-2006-52, Rev. 1.

The maximum 2006 chromium concentration in a well in the KW Reactor area was 2,284 $\mu\text{g/L}$ in well 199-K-137, which averaged 1,987 $\mu\text{g/L}$ in October 2006. This well was originally designed as an injection well for the KW pump-and-treat system but was replaced with well 199-K-158 because of the high chromium concentration detected in well 199-K-137. The high hexavalent chromium concentration suggests a concentrated sodium dichromate source upgradient of the KW Reactor. Details regarding the KW pump-and-treat system are found in the *KW Pump-and-Treat System Remedial Design and Remedial Action Work Plan, Supplement to the 100-KR-4 Groundwater Operable Unit Interim Action* (DOE-RL 2006b).

The following wells were drilled during 2006 for the KW pump-and-treat network: 199-K-137, 199-K-138, 199-K-139, and 199-K-140. In addition, existing monitoring wells 199-K-132 and 199-K-35 were converted to extraction and injection wells, respectively. The drilling of replacement injection well 199-K-158 started in December 2006, with a scheduled date of February 2007 for tie into the network.

- **KE Reactor chromium plume:** The chromium concentrations in monitoring wells around KE Reactor are summarized from the table below:

Well	Type	Fall 2005 Chromium ($\mu\text{g/L}$) ^{a,c}	Fall 2006 Chromium ($\mu\text{g/L}$) ^{a,c}	Percent Change ^d
199-K-32A	Monitoring	19.7	14.3	-38%
199-K-32B ^e	Monitoring	8.6	8.9	+3%
199-K-30	Monitoring	3.3	4.0	+18%
199-K-29	Monitoring	1.9(U)	3.1(U)	NA
199-K-27	Monitoring	2.4	--	^b
199-K-23	Monitoring	58	38.6	-50%
199-K-11	Monitoring	4.4	--	^b

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Well	Type	Fall 2005 Chromium (µg/L) ^{a,c}	Fall 2006 Chromium (µg/L) ^{a,c}	Percent Change ^d
199-K-110A	Monitoring	4.2	4	-5%
199-K-111A	Monitoring	33.8	32	-6%
199-K-36	Monitoring	23.8	26	+8%

- ^a Sampled between October 1 and November 12 in both 2005 and 2006.
- ^b Insufficient data to compare.
- ^c Concentration may include hexavalent chromium or total chromium (inductively coupled plasma-filtered) sample. The results averaged if more than one available for time interval.
- ^d Percent change is calculated by the following equation: [(Fall 2005 - fall 2006) / fall 2005] x 100%.
- ^e This well is screened in deep aquifer.
- (U) = not detected in sample
- NA = not available

- The maximum fall 2006 chromium concentration was 38.6 µg/L in well 199-K-23, which is down 50% from 2005. This well is located west of the KE Reactor.
- The fall 2006 chromium concentration in upgradient well 199-K-36 was 26 µg/L.
- Well 199-K-111A, located east of the KE Reactor, had 32 µg/L chromium in fall 2006.
- All other wells located north of the KE Reactor had October 2006 chromium concentrations <22 µg/L.

The table below compares CY05 versus CY06 chromium values for aquifer sampling tubes located downgradient of the KE and KW Reactors. The data include both hexavalent chromium and specific conductance results. All aquifer tubes downgradient of the KE and KW Reactors were characterized by 2006 hexavalent chromium concentrations <10 µg/L.

Aquifer Tube	Location (Downgradient of)	April/May 2005		February 2006		Percent Change ^a
		Specific Conductance (µS/cm)	Cr (µg/L)	Specific Conductance (µS/cm)	Cr (µg/L)	
AT-K-1	KW Reactor	--	44.0	221	7	-84%
17-D	KW Reactor	372	7	395	3	-57%
18-S	KW/KE Reactors	340	9	187	1	-89%
19-D	KE Reactor/ K-1 Crib	221	3	203	3	0%
AT-K-2	KE Reactor	208	--	197	3.1	^b

- ^a Percent change is calculated by the following equation: [(April/May 2005 - February 2006) / April/May 2005] x 100%.
- ^b Insufficient data to compare.

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In 2005, a treatability test was performed adjacent to well 199-K-126 to test the ability of calcium polysulfide (a strong, liquid reductant) to create a persistent reactive barrier in a portion of the 100-KR-4 aquifer. Over 1.3 million L (approximately 350,000 gal) of 7% calcium polysulfide solution were circulated between four injection wells and one extraction well for 45 days. After the test was concluded on August 11, the wells were sampled monthly through November 2006; quarterly sampling of all five wells will continue at least through 2007. The results of this test are included in *Treatability Test Report for Calcium Polysulfide in the 100-K Area* (DOE-RL 2006c) and summarized in the *Calendar Year 2005 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit Pump-and-Treat Operations* (DOE-RL 2006a).

Oxidation-reduction potential (ORP) measured in injection wells 199-K-133 through 199-K-136 through the end of 2006 (shown in Figure 3-11) indicates that the groundwater remains strongly reduced (ORP <0). Groundwater in the extraction well (199-K-126) remained reduced until September 2006, at which point it began increasing to approximately 120 mV in October and November. Hexavalent chromium in the extraction well also began increasing in mid-2006. The highest value was 51 µg/L in October 2006, which is about half of the concentration in nearby well 199-K-130 (see Figure 3-7).

3.3.3.2 Co-Contaminant Monitoring Results. Strontium-90 and tritium are listed in the 100-KR-4 ROD (EPA et al. 1996) as co-COCs. Nitrate and carbon-14 are contaminants of interest that are also monitored as part of the CERCLA monitoring program because they have been detected above MCLs in certain wells or because of a previous qualitative risk assessment documented in *100-KR-4 Operable Unit Focused Feasibility Study* (DOE-RL 1995). The co-contaminant monitoring results are discussed below by individual contaminant:

- **Strontium-90:** The table below displays the strontium-90 results for extraction wells, fall 2005 compliance wells, and monitoring wells in the pump-and-treat operational area for fall 2006 if the results were greater than the 8 pCi/L MCL, or if the change between 2005 and 2006 was >20%.

The strontium-90 results for wells in the 100-KR-4 pump-and-treat operational area are summarized as follows:

- The maximum strontium-90 concentration in 2006 was 31 pCi/L in monitoring well 199-K-21.
- Four total wells contained strontium-90 above the 8 pCi/L MCL in the fall of 2006.

Strontium-90 also occurs around KW Reactor in low concentrations and in higher concentrations around KE Reactor. The source of this contamination is likely past disposal of KE fuel storage basin effluent to the adjacent drain field/injection well (waste site 116-K-3) (PNNL 2007).

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Well	Type	Fall 2005 ^b Sr-90 (pCi/L)	Fall 2006 ^b Sr-90 (pCi/L)	Percent Change ^a
199-K-21	Monitoring	37.8 (± 6)	31 (±4.7)	-18%
199-K-22	Monitoring	8.65 (±1.4)	8.2 (±1.6)	-5%
199-K-113A	Extraction	9.6 (±1.9)	5.3 (±3.3)	-45%
199-K-114A	Extraction	17 (±3.4)	9.5 (±3.8)	-44%
199-K-115A	Extraction	9.6 (±1.9)	5.5 (±3.2)	-43%

^a Percent change is calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.

^b Includes samples collected between October 1 and November 30 in both 2005 and 2006.

NOTE: “±” values in parentheses represent total analytical error.

The table below displays the fall 2005 and fall 2006 strontium-90 results for monitoring wells in the vicinity of the KE and KW Reactors if the results were greater than the 8 pCi/L MCL, or if the change between the fall 2005 and fall 2006 was >20%. All of the aquifer tube samples were nondetects (U) for strontium-90.

Well/ Aquifer Tube	Location	Fall 2005 ^b Sr-90 (pCi/L)	Fall 2006 ^b Sr-90 (pCi/L)	Percent Change ^a
199-K-109A	DG – KE Reactor	1,269 (±208)	--	^c
199-K-107A	DG – KW Reactor	32.3 (±5)	26.6 (±4)	-18%
199-K-34	DG – KW Reactor	24.1 (±4)	20.7 (±3.2)	-14%

^a Percent change is calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.

^b Includes samples collected between October 1 and November 30 in both 2005 and 2006.

^c Well not sampled in 2006; comparison not possible.

DG = downgradient

The 2005 results for strontium-90 for wells in the KE and KW Reactor areas are summarized as follows:

- The maximum fall 2006 strontium-90 concentration in the KW Reactor area was 26.6 pCi/L in well 199-K-107A. This well is located downgradient of KW Reactor.
 - Well 199-K-34, located approximately 25 m (82 ft) downgradient of KW Reactor, was characterized by 20.7 pCi/L strontium-90 in 2006.
 - The maximum fall 2005 strontium-90 concentration in the KE Reactor area was 1,269 pCi/L in monitoring well 199-K-109A. This well could not be accessed to sample in the fall of 2006 because of KE Basin remediation.
- **Tritium:** The table below displays the tritium results for extraction wells, compliance wells, monitoring wells, and aquifer sampling tubes in the pump-and-treat operational area if tritium was detected above 20,000 pCi/L, or if the change from 2005 to 2006 was >20%. Tritium is also useful as a tracer that shows that treated water has moved from the injection wells to well 199-K-125A, a distance of approximately 750 m (2,460 ft) (Figure 3-10). The timing is generally consistent with the path-line travel times shown in Figure 3-8. The MCL for tritium is 20,000 pCi/L:

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Well	Type	Spring 2005 ^b Tritium (pCi/L)	Fall 2006 Tritium (pCi/L)	Percent Change ^a
199-K-116A	Extraction	1,700 (±420)	2,200 (±480)	+29%
199-K-120A	Extraction	41,000 (±8,200)	37,000 (±7,400)	-10%
199-K-127	Extraction	2,900 (±610)	4,000 (±830)	+38%
199-K-18	Compliance	37,850 (±1,700)	29,000 (±5,800)	+23%
199-K-19	Monitoring	570 (±180)	840 (±250)	+47%

^a Percent change is calculated by the following equation: [(Spring 2005 – fall 2006) / spring 2005] x 100%.

^b Spring 2005 results were used because fall 2005 results were not available.

The 2006 tritium results for wells in the pump-and-treat operational area are summarized as follows:

- Two wells were characterized by tritium above the MCL (199-K-120A [extraction well] at 37,000 pCi/L, and 199-K-18 [compliance well] at 29,000 pCi/L).
- Average tritium concentrations increased more than 20% in three wells. The maximum increase from 2005 to 2006 was 47% (to 840 pCi/L) in monitoring well 199-K-19.
- Average tritium concentrations decreased more than 20% in compliance well 199-K-18 to 29,000 pCi/L.
- The source of this tritium for all of the wells is unknown but may be from past disposal to the 116-K-1 Crib, 116-K-2 Trench, or 118-K-1 Burial Ground.

The table below displays the 2005 tritium results for monitoring wells and aquifer sampling tubes the KE and KW Reactor areas. The results displayed are above the 20,000 pCi/L MCL, or there was a >20% change from 2005 to 2006:

Well	Location	Fall 2005 Tritium (pCi/L) ^{b,c}	Fall 2006 Tritium (pCi/L) ^{b,c}	Percent Change ^a
199-K-29	DG – KE Reactor	38,050 (±1,750)	13,400 (±660)	+65%
199-K-30	DG – KE Reactor	534,000 (±22,000)	190,000 (±38,000)	+64%
199-K-32A	DG – KE Reactor	14,000 (±740)	5,800 (±1,200)	-59%
199-K-106A	DG – KW Reactor	254,000 (±11,000)	155,000 (±30,000)	-39%
199-K-31	DG – KW Reactor	1,350 (±210)	860 (±225)	+24%
199-K-107A	DG – KW Reactor	716 (±195)	500 (±200)	-28%

^a Percent change is calculated by the following equation: [(Fall 2005 - fall 2006) / fall 2005] x 100%.

^b Wells sampled October through November 2005, and from October through December 2006.

^c Results are those available in the HEIS database on February 24, 2007.

DG = downgradient

Treated effluent with about 6,200 pCi/L tritium has been detected in extraction well 199-K-125A. Tritium concentrations of >2,000 pCi/L were detected in well 199-K-116A, approximately 550 m (1,804.5 ft) from injection well 199-K-121A.

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The tritium results for 2006 for wells in the KE and KW Reactor areas can be summarized as follows:

- Wells 199-K-30 (190,000 pCi/L) was characterized by the highest tritium concentration of any wells or aquifer sampling tubes in the fall of 2006. The well is located immediately downgradient of the KE Reactor condensate cribs. It was the only well downgradient of the KE Reactor characterized by tritium concentrations above the 20,000 pCi/L MCL.
 - Average tritium concentrations decreased more than 20% from 2005 to 2006 in six wells (199-K-29, 199-K-30, 199-K-32A, 199-K-31, 199-K-106A, and 199-K-107A).
 - Tritium decreased from 254,000 pCi/L to 155,000 pCi/L in well 199-K-106A, located downgradient of the KW Reactor.
- **Carbon-14:** Carbon-14 is a contaminant of interest that is monitored as part of the CERCLA monitoring program in the KE and KW Reactor areas. The source of the carbon-14 is thought to be gas condensate from the reactors that was discharged to infiltration cribs on the east side of both the KE and KW Reactors (PNNL 2005). The MCL for carbon-14 is 2,000 pCi/L. The following table displays the 2006 carbon-14 concentrations in monitoring wells and aquifer sampling tubes if concentrations were above the 2,000 pCi/L MCL, or if the change from 2005 to 2006 was >20%:

Well/ Aquifer Tube	Location	Fall 2005 C-14 (pCi/L) ^{b,c}	Fall 2006 C-14 (pCi/L) ^{b,c}	Percent Change ^a
199-K-111A	CG – KW Reactor	196 (±12)	98.8 (±18)	-50%
199-K-106A	CG – KW Reactor	16,300 (±710)	12,400 (1,400)	-24%
199-K-108A	UG – KW Reactor	1,545 (±71)	1,050 (±130)	-32%
199-K-34	DG – KW Reactor	2,190 (±99)	2,310 (±270)	+5%
199-K-132	DG – KW Reactor	3,115 (±140)	3,340 (±380)	+7%
199-K-29	DG – KE Reactor	2,030 (±92)	1,850 (±240)	-9%
199-K-30	DG – KE Reactor	5,660 (±250)	7,210 (±820)	+27%
199-K-107A	DG – KW Reactor	209 (13)	162 (±25)	-22%

^a Percent change calculated by the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%.

^b Results from samples collected October through November in both 2005 and 2006.

^c Represent data available in the HEIS database on March 6, 2007.

CG = cross-gradient

DG = downgradient

UG = upgradient

The fall 2006 carbon-14 results for wells and aquifer tubes in the KE and KW Reactor areas are summarized as follows:

- Three wells were characterized by carbon-14 concentrations above the 2,000 pCi/L MCL.

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- The maximum fall 2006 concentration of carbon-14 in the KW Reactor area was 12,400 pCi/L in well 199-K-106A (cross-gradient of KW Reactor). The highest 2006 carbon-14 result downgradient of the KW Reactor was 3,340 pCi/L from KW pump-and-treat extraction well 199-K-132.
- Average carbon-14 concentrations decreased more than 20% in three wells, namely 32% (to 1,050 pCi/L) in well 199-K-108A, located upgradient of the KW Reactor. Carbon-14 also decreased 22% (to 162 pCi/L) in well 199-K-107A and 24% (to 12,400 pCi/L) in well 199-K-106A.
- The maximum 2006 carbon-14 concentration downgradient of the KE Reactor was 7,210 pCi/L in well 199-K-30. This was the only well in which carbon-14 increased more than 20%.
- **Nitrate:** Nitrate is a contaminant of interest that is monitored as part of the pump-and-treat interim action and the CERCLA monitoring program. The MCL for nitrate (analyzed as NO₃) is 45 mg/L (10 mg/L for NO₃-N). Nitrate is widely distributed in 100-K Area groundwater and the source is uncertain; however, the source may be related to operation of septic systems (WHC 1994). The following table displays the 2006 nitrate concentrations in compliance wells, monitoring wells, and aquifer sampling tubes in the pump-and-treat operational area, if concentrations were above the 45 mg/L MCL, or if changes in concentration from 2005 to 2006 were >20%:

Well/ Aquifer Tube	Type	Fall 2005 Nitrate (mg/L)	Fall 2006 Nitrate (mg/L)	Percent Change ^a
199-K-18	Compliance	83.9	73.0	-13%
199-K-19	Monitoring	42.5	33.6	-21%
199-K-117A	Compliance	2.0	9.3	+365%

^a Percent change calculated by the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$.

The 2006 average nitrate results for wells in the pump-and-treat operational area are summarized as follows:

- One well, 199-K-18, was characterized by a fall 2006 nitrate concentrations above the 45 mg/L MCL; the concentration in this well was 73 mg/L.
- Average nitrate concentrations increased more than 20% in one well (365% to 9.3 mg/L in well 199-K-117A).
- Average nitrate concentrations decreased more than 20% (to 33.6 mg/L) in well 199-K-19.

Nitrate is present above the MCL in the KE and KW Reactor areas. The following table displays the fall 2006 nitrate concentrations in monitoring wells and aquifer sampling tubes in the KE and KW Reactor areas:

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Well/ Aquifer Tube	Location	Fall 2005 Avg. Nitrate (mg/L)	Fall 2006 Avg. Nitrate (mg/L)	Percent Change ^a
199-K-106A	DG – KW Reactor	116	124.5	+7%
199-K-108A	UG – KW Reactor	80.4	78.1	-3%
199-K-23	CG – KE Reactor	73.5	61.1	-17%
199-K-30	DG – KE Reactor	112	40.6	-64%
199-K-32A	DG – KG Reactor	24.8	16.6	-33%
199-K-34	DG – KW Reactor	16.4	22.1	+35%
199-K-138	DG – KW Reactor	--	47.4	^b

^a Percent change calculated by the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$.

^b Well not sampled in fall 2005 or fall 2006; therefore, insufficient data to calculate percent change.

CG = cross-gradient

DG = downgradient

UG = upgradient

The 2006 fall nitrate results for monitoring wells in the KE and KW Reactor areas are summarized as follows:

- Four wells were characterized by average nitrate concentrations above the 45 mg/L MCL (10 mg/L NO₃-N).
- The highest fall 2006 nitrate concentrations in each reactor area were 124.5 mg/L in well 199-K-106A (downgradient of KW Reactor) and 61.1 mg/L in well 199-K-23 (cross-gradient of KE Reactor).
- Nitrate concentrations decreased more than 20% in three wells (199-K-132, 199-K-30, and 199-K-32A).
- Nitrate concentrations increased more than 20% in only one well (35% [to 22.1 mg/L] in well 199-K-34).
- **Other constituents:** Technetium-99 and sulfate were also monitored in 2006 as part of CERCLA monitoring. The maximum technetium-99 detected in any sampling event was 76.8 pCi/L in monitoring well 199-K-109A, located downgradient of KE Reactor. The MCL for technetium-99 is 900 pCi/L. The maximum sulfate concentration detected in any sampling event in a well outside the calcium polysulfide treatability test was 228 mg/L in well 199-K-138, downgradient of the KW Reactor. The secondary MCL for sulfate is 250 mg/L.

3.4 QUALITY CONTROL RESULTS FOR 100-K AREA MONITORING DATA

The QC results for the 100-K sampling included field or laboratory testing for hexavalent chromium and total chromium. Additional laboratory tests were run for strontium-90 and tritium. The QC samples represented both laboratory duplicates and splits. The QC replicates are samples collected at the same time and sent to the same laboratory for analysis. The QC splits are samples collected at the same time and sent to different laboratories for analysis.

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The CY06 highlights of the QC data for 100-KR-4 are summarized in the table below. A complete list of QC results is found in Appendix H.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent <20% RPD
Field replicates (hexavalent chromium)	8	7	87.5%
Field/laboratory split (hexavalent chromium)	69	56	81.2%
Laboratory replicates (total chromium)	4	4	100%

The EPA's functional guideline for field-tested replicates is an RPD of <20% (EPA 1988). The majority of the field replicates satisfied this requirement, with only one sample exceeding the 20% RPD. The 20% RPD was exceeded for 13 of 69 field/laboratory split samples for hexavalent chromium. The field analytical results were typically higher than the values reported from laboratory analysis. With the exception of these results, the chromium results were consistent for offsite laboratories. There are no functional guidelines for split results or laboratory duplicates.

3.5 CONCLUSIONS

- **RAO #1:** Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.

The RAO cleanup goal for compliance wells is 22 µg/L based on the 11 µg/L ambient water quality criterion in place at the time of the signing of the ROD (EPA et al. 1996).

Results:

- Approximately 526 million L (139 million gal) of groundwater were treated during 2005 and 21 kg of hexavalent chromium removed.
- Average fall chromium concentrations were above the RAO in seven of nine extraction wells; the exceptions were well 199-K-119A and 199-K-125A. The maximum fall 2006 chromium concentration in an extraction well was 96 µg/L in well 119-K-115A.
- Chromium concentrations were above the RAO in two of four compliance wells. The maximum chromium concentration in a compliance well was 137 µg/L in well 199-K-18. The lowest chromium concentration was 6.0 µg/L in well 199-K-117A.
- The pump-and-treat system has decreased chromium concentrations below 22 µg/L in the center of the plume, downgradient of the 116-K-2 Trench. There are two remaining plume areas above 100 µg/L: one around well 199-K-18, and one around well 199-K-114A.
- The two farthest downstream monitoring wells (199-K-130 and 199-K-131) had fall 2006 chromium concentrations of 94 µg/L and 82 µg/L, respectively, indicating that the plume extends toward the northeast and the 100-N Area.

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- Well 199-K-137, located upgradient of the KW Reactor, had an average of 1,987 µg/L chromium in October 2006 and a maximum concentration of 2,284 pCi/L. This plume appears to extend to the Columbia River and will be the focus of the K West pump-and-treat system that will be operational in February 2007.
- Maximum carbon-14 concentrations downgradient of KE Reactor were 7,210 pCi/L in well 199-K-30. The maximum carbon-14 concentrations downgradient of KW Reactor was 3,340 pCi/L.
- The maximum 2005 strontium-90 concentration in the pump-and-treat area of influence was 31 pCi/L at monitoring well 199-K-21.
- Two pump-and-treat area wells had tritium concentrations above the 20,000 pCi/L MCL (extraction well 199-K-120A and compliance well 199-K-18). The tritium concentrations in these wells were 31,000 pCi/L and 29,000 pCi/L, respectively.
- The maximum tritium concentrations in the KW and KE Reactor areas were 190,000 pCi/L in well 199-K-30 (downgradient of KE Reactor) and 155,000 pCi/L in well 199-K-106A (downgradient of KW Reactor).

- **RAO #2:** Protect human health by preventing exposure to contaminants in groundwater.

Results: The interim remedial action ROD (EPA et al. 1996) establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

- Access control and visitor escorting requirements
- Signs providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
- Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
- Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls was presented in the *2004 Final Institutional Controls (IC) Assessment Report* (DOE-RL 2004a). The findings of the report indicate that institutional controls were maintained to prevent public access, as required.

- **RAO #3:** Provide information that will lead to a final remedy.

Results: Operational data and improvements, as well as special studies and technical reviews, provide information that should contribute to a final remedy. Progress made during 2006 included the following:

- The calcium polysulfide treatability test demonstrated the effectiveness of this technology in reducing hexavalent chromium to trivalent chromium under 100-K Area groundwater conditions. It may be applicable in other locations, especially where the plume is not approaching the Columbia River.
- A recirculation cell has been established in the center of the hexavalent chromium plume. Influent concentrations continue to decline verifying that washout of the chromium is a valid concept.

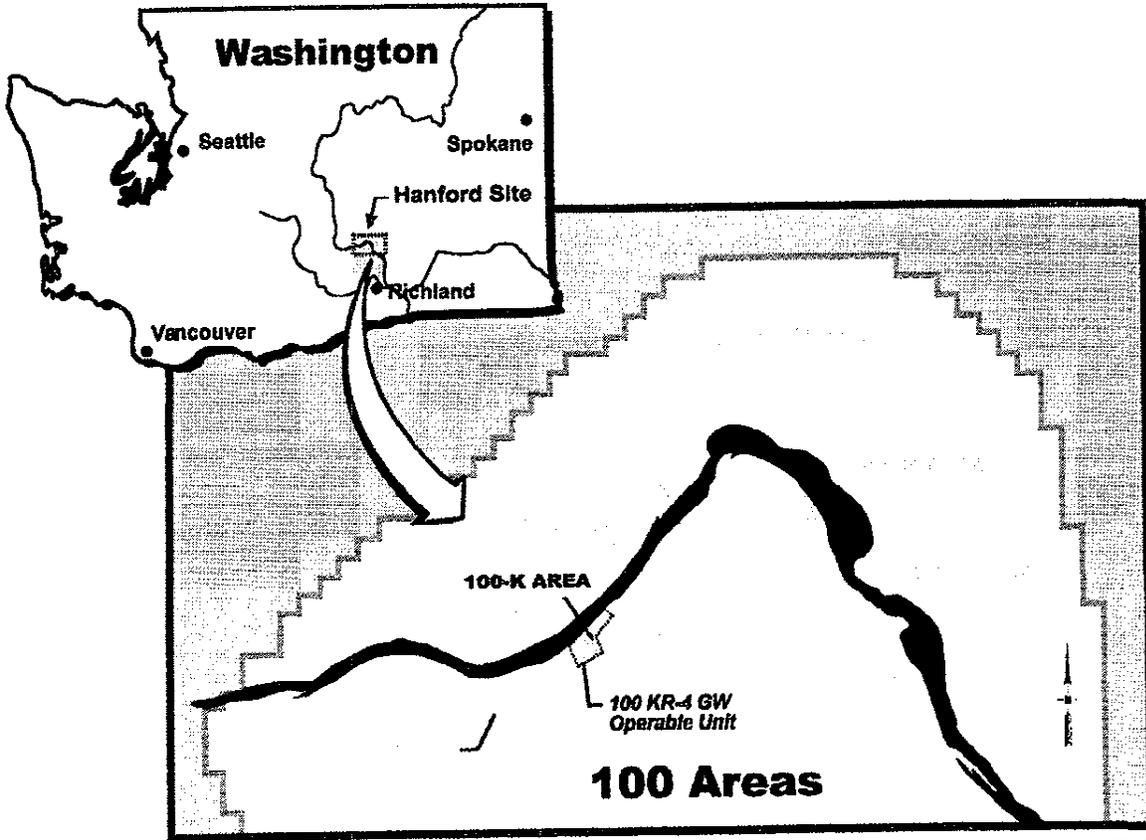
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3.6 RECOMMENDATIONS

- Accelerate remediation of the remaining 116-K-2 chromium plume by adding new extraction wells and/or injection wells at each end. Injection wells located at the north end of the plume should stop the migration of the plume toward the 100-N Area.
- Evaluate whether additional extraction wells are necessary to fill in gaps in capture between existing extraction wells 199-K-113A and 199-K-129.
- Evaluate whether an additional extraction well is necessary west of extraction well 199-K-120A to capture chromium-contaminated groundwater reaching aquifer tube AT-K-3.
- Expand the 100-KR-4 pump-and-treat system by 378.5 L/min (100 gallons per minute [gpm]) to enhance remediation of the chromium plume between the former 116-K-2 Trench and the N Reactor perimeter fence.
- Continue to try to meet the 22 $\mu\text{g/L}$ RAO in extraction and compliance wells.

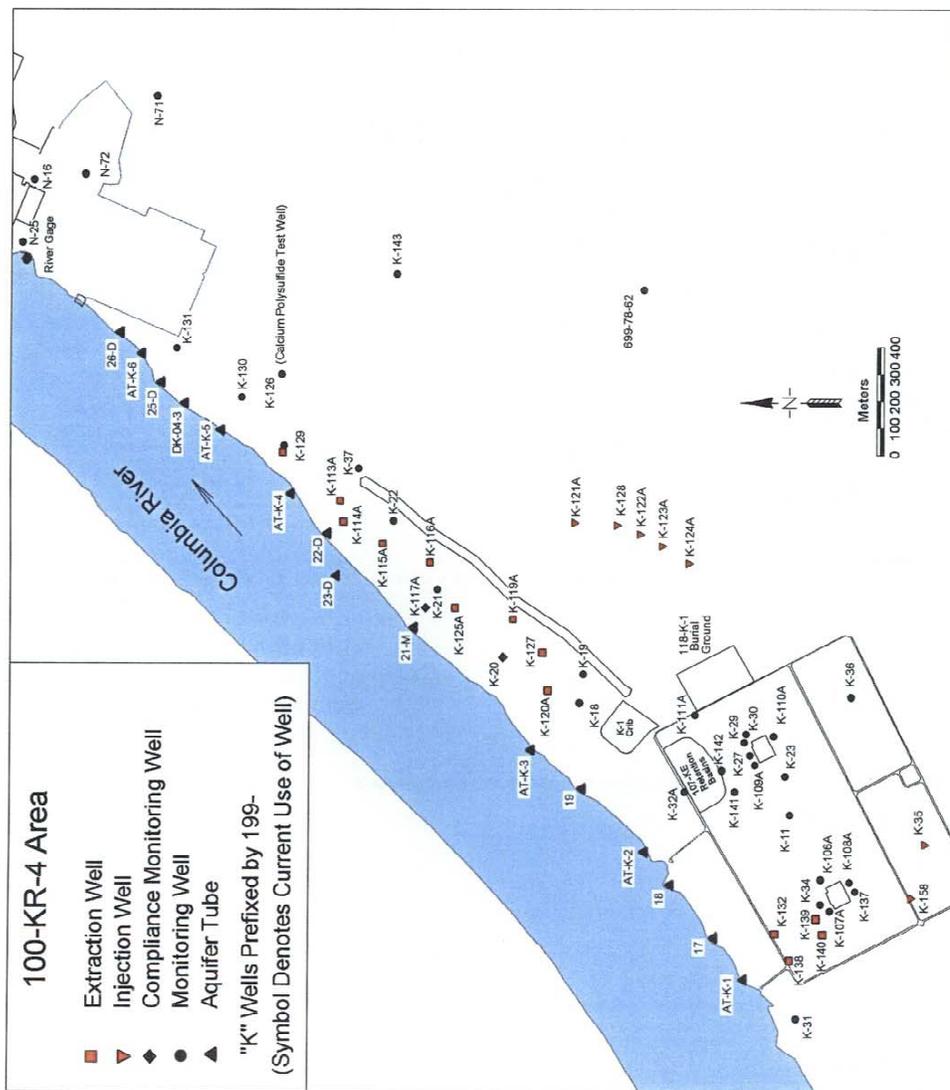
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Figure 3-1. Location of the 100-KR-4 Operable Unit.



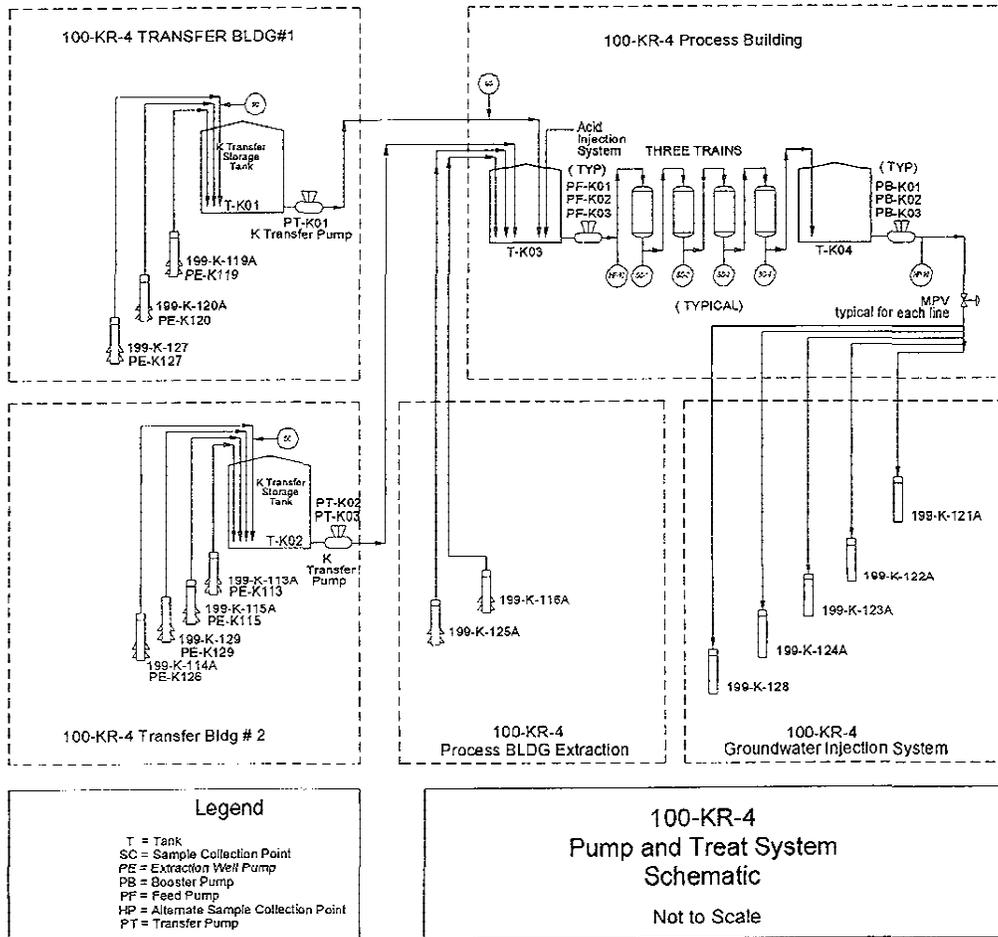
FG16.2

Figure 3-2. 100-KR-4 Operable Unit Wells and Aquifer Sampling Tubes.



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Figure 3-3. 100-KR-4 Operable Unit Pump-and-Treat System Schematic.

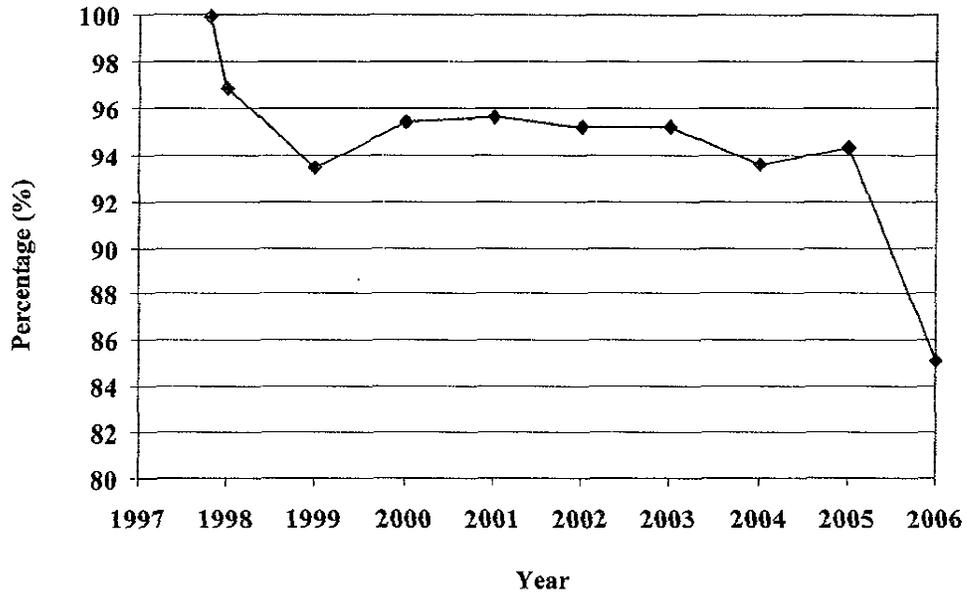


NOTE: Sample collection (SC) is where piping enters each BLDG not at well head.

K Schematic 2006.dwg

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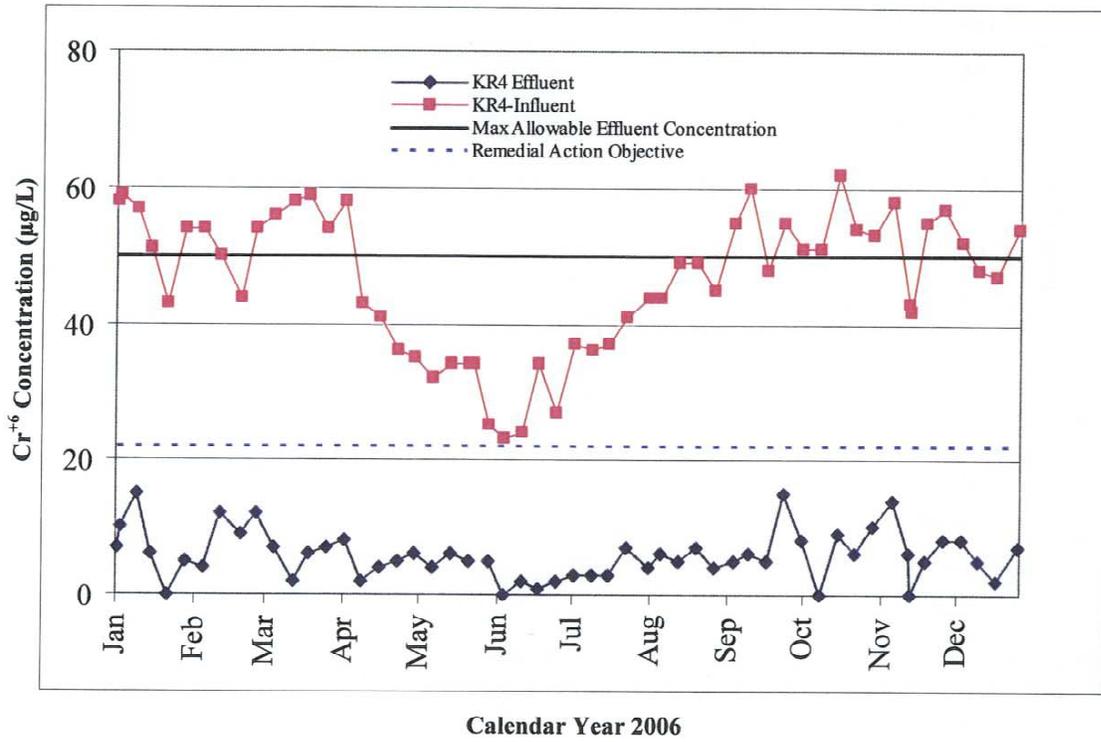
Figure 3-4. 100-KR-4 Pump-and-Treat System Average Removal Efficiencies.



Average removal efficiency (% by mass) = $[(\text{influent} - \text{effluent}) / \text{influent}]$.

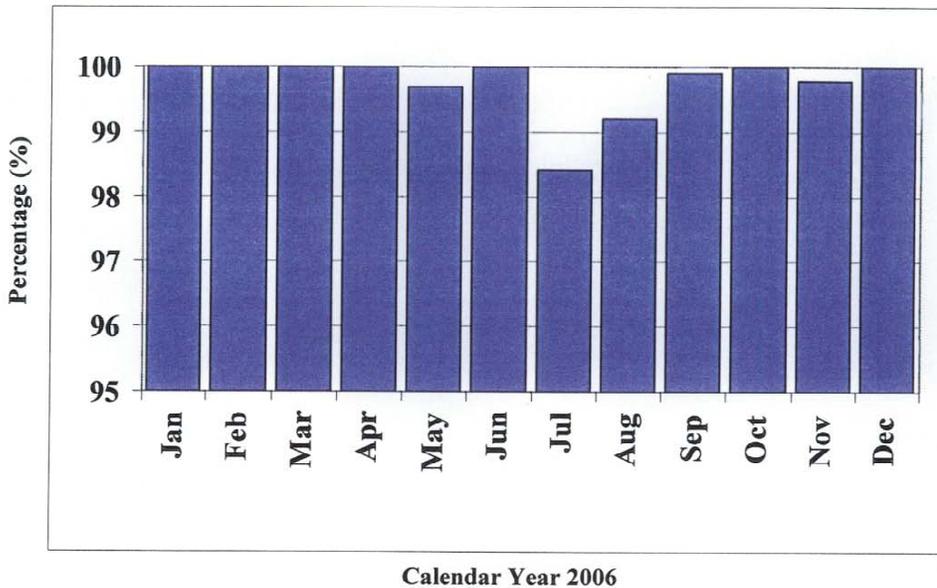
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Figure 3-5. 100-KR-4 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations, Calendar Year 2006.



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Figure 3-6. 100-KR-4 System Availability and On-Line Percentages for Calendar Year 2006.



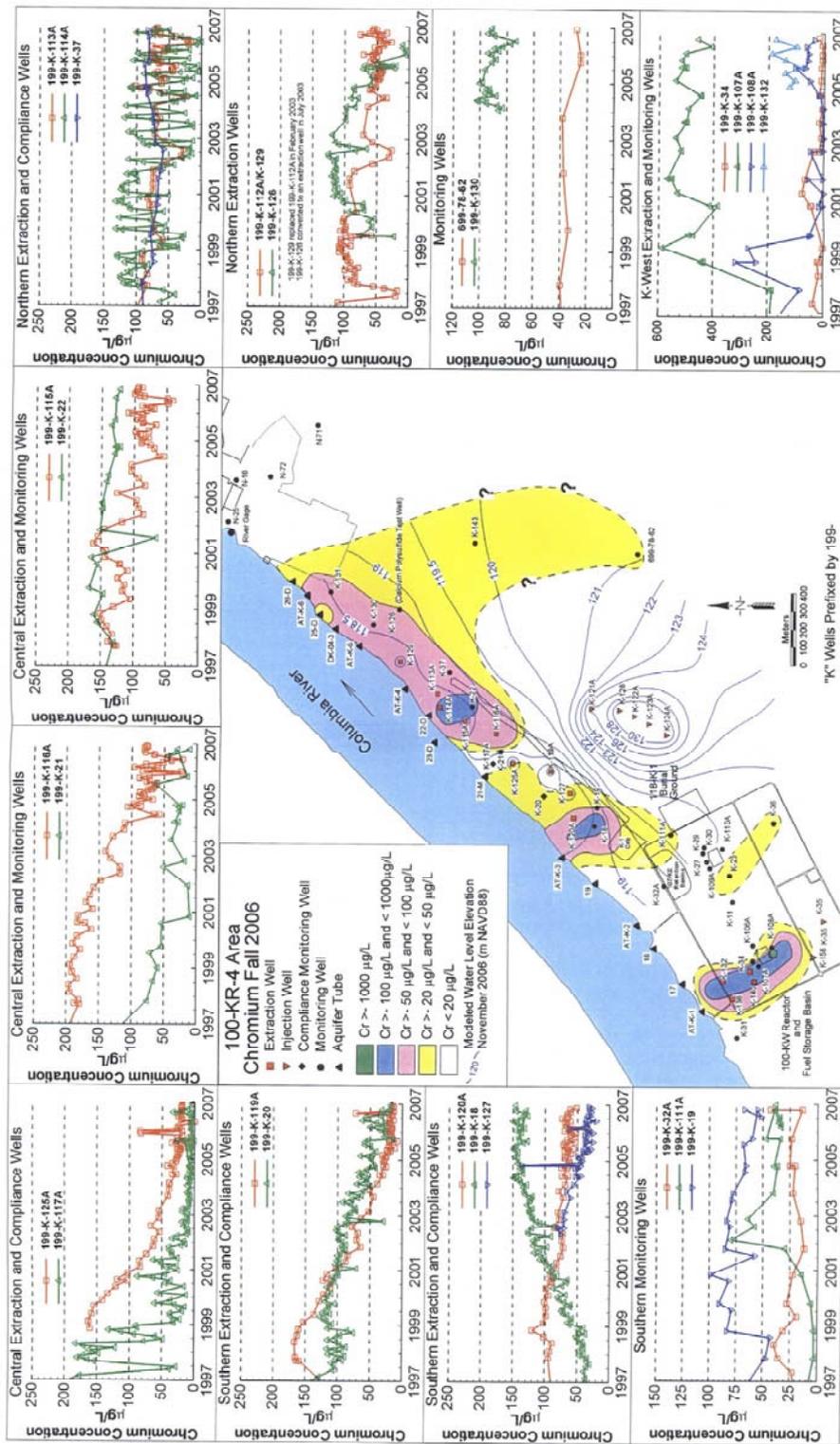
100-KR-4 pump-and-treat system availability for 2006: ^a	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	24.2
Planned operations (hours)	8,735.8
Unscheduled downtime (hours)	22.6
Total time on-line (hours)	8,713.2
Total availability (%)	99.5
Scheduled system availability (%)	99.7

^a Scheduled system availability [(total possible run-time – unscheduled downtime) / total possible run-time].
 Total availability [(total possible run-time – scheduled and unscheduled downtime) / total possible run-time].

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Figure 3-7. 100-KR-4 Chromium Plume, Fall 2006.

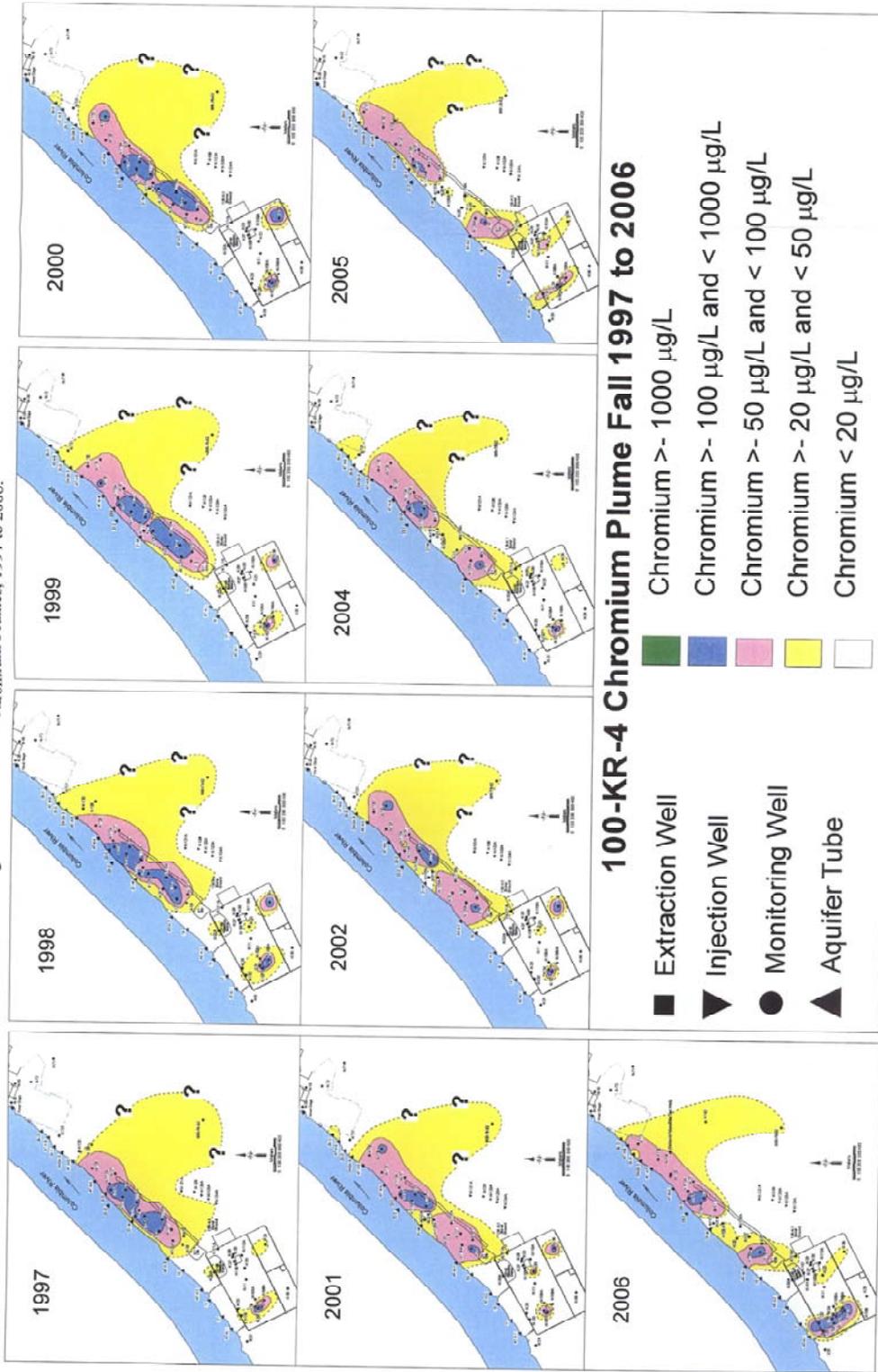


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Figure 3-9. 100-KR-4 Chromium Plumes, 1997 to 2006.



3-33/3-34

Figure 3-10. K West Reactor Chromium Plumes, 1997 and 2006.

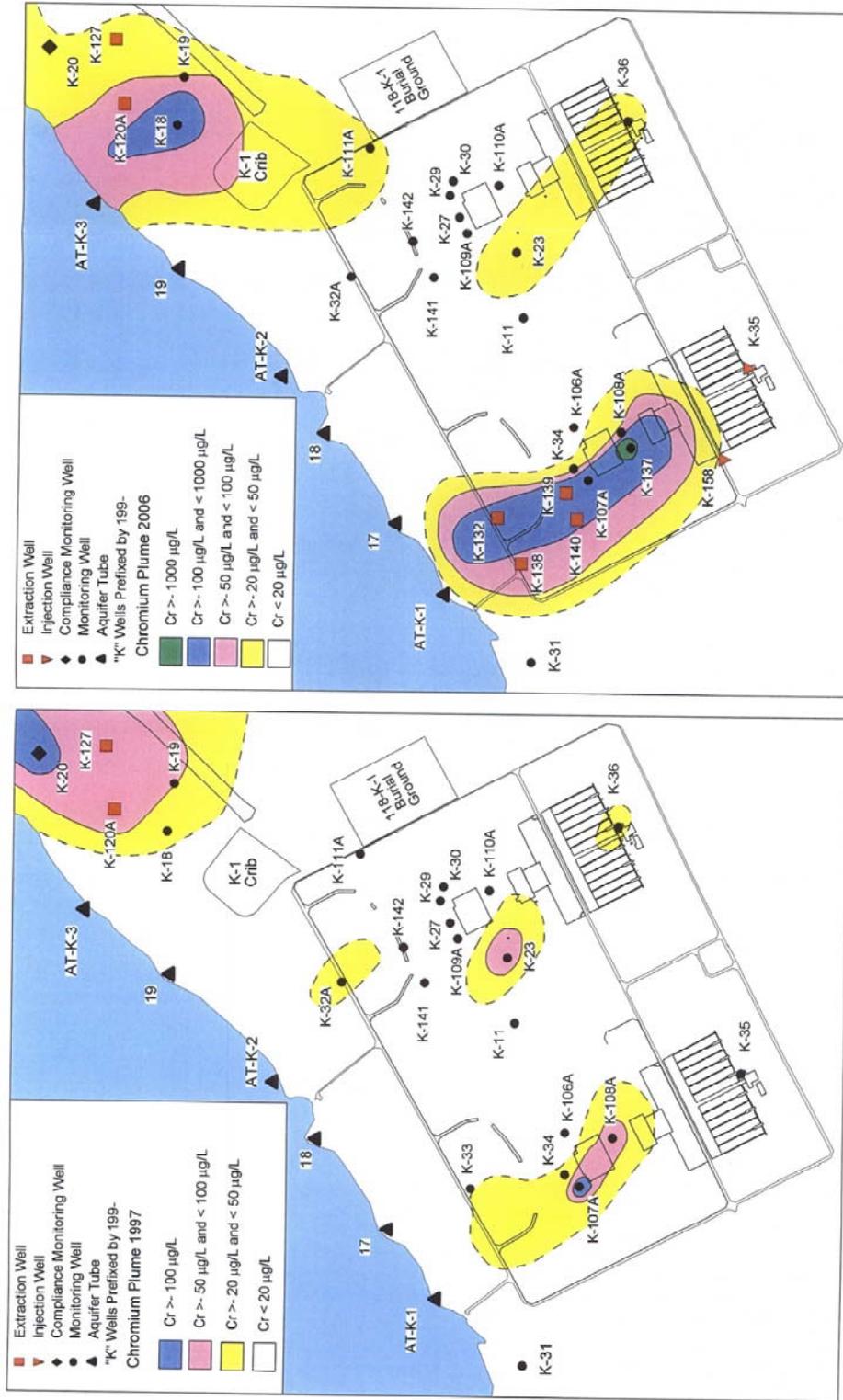
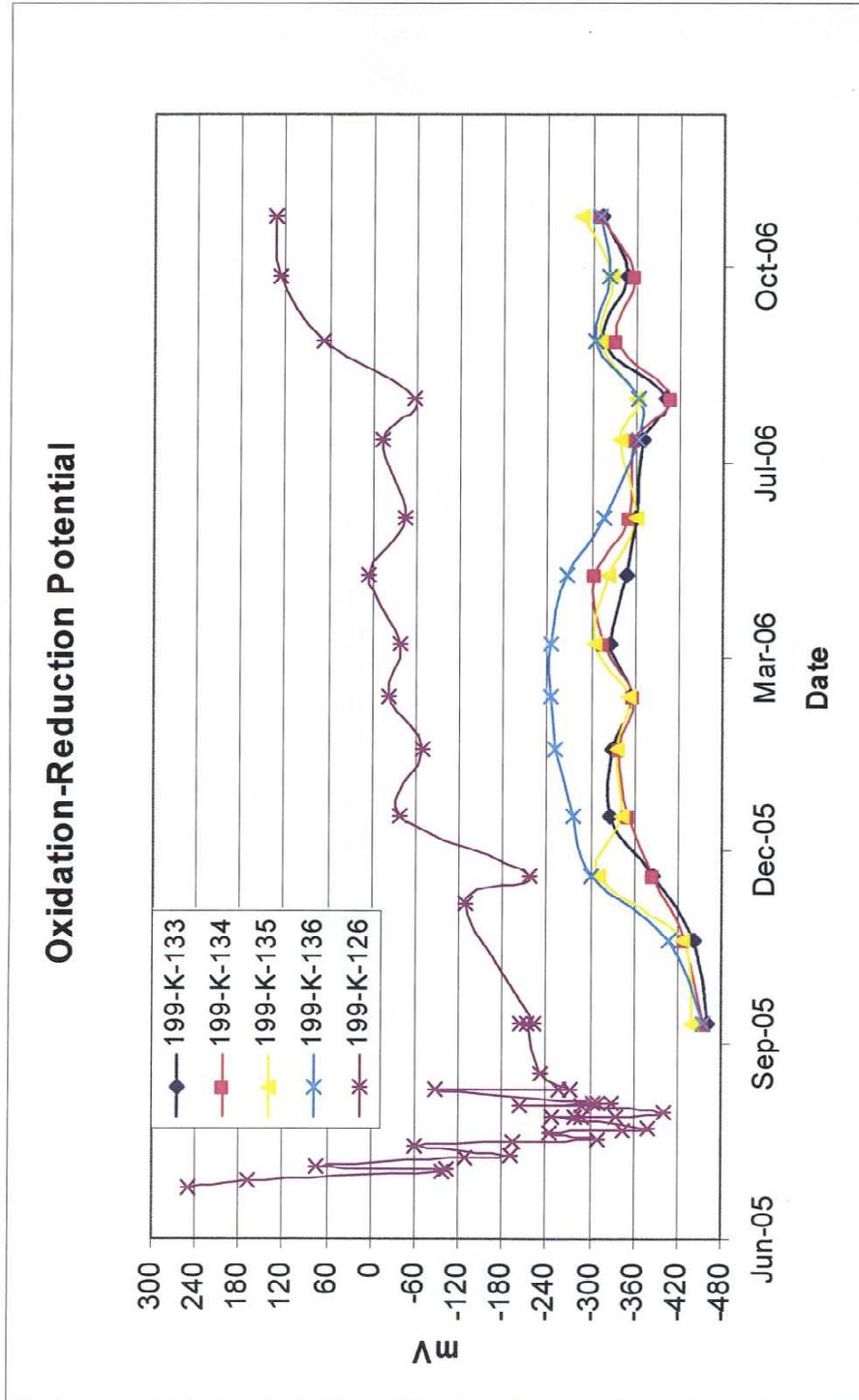


Figure 3-11. Oxidation-Reduction Potential of Wells Included in the Calcium Polysulfide Treatability Test.



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Table 3-1. 100-KR-4 Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis, Nov. 2005		Measured Water-Level Elevation, Nov. 2005 (m NAVD88 ^a)	Modeled Water-Level Elevation, Nov. 2005 (m NAVD88 ^a)
	Extraction Rate L/min	Injection Rate L/min		
199-K-129	87.9	—	—	116.39
199-K-113A	45.7	—	—	116.52
199-K-115A	144.7	—	—	115.62
199-K-116A	152.8	—	—	118.51
199-K-119A	144.9	—	—	115.22
199-K-125A	138.8	—	—	114.97
199-K-126	0	—	—	118.96
199-K-127	139.4	—	—	116.22
199-K-120A	127.8	—	—	117.95
199-K-121A	—	143.0	129.9	129.66
199-K-122A	—	265.6	—	149.21
199-K-123A	—	208.5	—	147.65
199-K-124A	—	98.9	127.09	140.20
199-K-128	—	264.2	—	143.94
199-K-18	—	—	118.67	118.46
199-K-19	—	—	118.17	118.64
199-K-20	—	—	118.18	117.97
199-K-21	—	—	118.25	118.40
199-K-22	—	—	120.63	118.43
199-K-37	—	—	118.68	118.74
199-K-114A	—	—	118.13	118.12
199-K-117A	—	—	116.87	118.27
199-K-118A	—	—	117.82	117.10

^a NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

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4.0 100-NR-2 INTERIM ACTION STATUS

The 100-NR-2 Groundwater OU is located along the Columbia River between the 100-KR-4 OU and the 100-HR-3 OU (Figure 4-1). The 100-NR-2 OU consists of the groundwater underlying and in the vicinity of the source OUs that are associated with the 100-N Area. The 100-NR-2 pump-and-treat system is currently in cold-standby status to facilitate the interpretation of a treatability test for a 91.4-m (300-ft)-long PRB constructed along the 100-N Area shoreline. Figure 4-2 shows the location of the 100-NR-2 extraction and injection wells and the associated monitoring wells in relation to the primary facilities; the figure also shows the location of the proposed PRB. The authorization for this change in the 100-NR-2 interim action is documented in Tri-Party Agreement Change Request #M-16-06-01, dated February 15, 2006. Appendix A provides a history of operations and supporting documents used in the development of the 100-NR-2 pump-and-treat system.

This section provides the annual performance report for the 100-NR-2 pump-and-treat system, as required by the *Interim Remedial Action Record of Decision (ROD) Declaration, USDOE Hanford 100 Area, 100-NR-1 and 100-NR-2 Operable Units, Hanford Site* (EPA et al. 1999). The purpose of this section is to report treatment system and aquifer performance data collected through March 2006 and to describe the observed effects of the cold standby on the aquifer.

The following sections summarize and evaluate the performance of the pump-and-treat system, the response of the aquifer in relation to these goals, and the OU contaminants. Section 4.1 provides a brief overview summary of activities pertaining to the 100-NR-2 pump-and-treat system and the source area remedial actions that have occurred within the OU for CY05. Section 4.2 focuses on treatment system performance. Section 4.3 describes aquifer response, including the baseline conditions, hydraulic effects, numerical modeling, contaminant changes during the pump-and-treat operations, and contaminant distributions and trends throughout the OU. Section 4.4 discusses QC chemical analysis. Conclusions and recommendations are presented in Section 4.5 and 4.6, respectively. Cost information is presented in Section 5.0. The updated conceptual model is discussed in Appendix B.

4.1 SUMMARY

Progress on source removal and groundwater remediation activities for CY06 is summarized in the following subsections.

4.1.1 100-NR-1 Operable Unit

The interim action ROD (EPA et al. 1999) requires that the most significant soil contamination in the 100-NR-1 OU be addressed first. Cleanup of the remaining surface and subsurface sites will occur in the future in order of priority, as established by the regulatory agencies. The status and activities at the most contaminated soil sites include the following:

- Cleanup of the major strontium-90 source areas, the 116-N-1 and 116-N-3 Cribs, was completed during the year. Excavation to a depth of approximately 4.6 m below ground surface was completed at 116-N-3 and 116-N-1 in 2005 and backfilling was completed in 2006.

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4.1.2 100-NR-2 Operable Unit

The activities required for the 100-NR-2 OU by the interim action ROD to address strontium-90 and other contaminants in groundwater near the source areas consist of (1) operating a pump-and-treat system in cold-standby status, (2) maintaining a groundwater monitoring network for tracking changes in contaminant concentrations, (3) investigating alternative treatment technologies, (4) assessing ecological risk of contaminated groundwater, and (5) removing any free product (e.g., diesel) in monitoring wells. The progress for these activities during CY06 is summarized below and is discussed in greater detail in the following sections:

- The system was placed in cold-standby status starting on March 9, 2006.
- Network monitoring well data indicate an increase in strontium-90 concentrations in former extraction wells and in well 199-N-46. This may be caused by a combination of changed groundwater conditions after pump-and-treat shutdown and river stage impacts. Elevated manganese and iron persist in well 199-N-18, which is attributed to biodegradation of residual diesel in the aquifer that creates anoxic (i.e., reducing) conditions.
- An alternative treatment method, in situ apatite sequestration, and a full-scale field test are underway where the highest near-shore strontium-90 concentrations occur.
- Diesel fuel was removed from monitoring well 199-N-18, which is the only well with observable free product.

4.2 100-NR-2 TREATMENT SYSTEM PERFORMANCE

This section summarizes the CY06 treatment system operations and sampling activities for the 100-NR-2 pump-and-treat system. This information includes system availability, mass of contaminants removed during operations, contaminant removal efficiencies, and quantity and quality of extracted and disposed groundwater. Additional operational details are found in the associated appendices, as referenced in this report.

4.2.1 System Operation

The 100-NR-2 pump-and-treat system was placed in cold-standby status on March 9, 2006, in support of Tri-Party Agreement Milestone M-16-06-01 ("Complete a Permeable Reactive Barrier [PRB] at 100-N"). Treatability testing for an apatite PRB was begun in April 2006, beginning with a pilot-scale tracer test, followed by a single well injection of apatite-forming chemicals in June 2006. The system shutdown was required to allow equilibration prior to placement of the PRB. Additional pilot-scale testing was conducted during FY06 to refine the injection protocol prior to injecting 10 wells along the 100-N Area shoreline to form a 91.4-m (300-ft) barrier. Additional information pertaining to the PRB and can be obtained in the *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit* (DOE-RL 2005). A summary of operational parameters for CY06 and for total performance is as follows:

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Total processed groundwater:	
Total since September 1995 startup (million L)	1,155.3
Total for January 1 to March 9, 2006 (million L)	23.3
Mass of strontium-90 removed:	
Total since September 1995 startup (Ci)	1.83
Total for CY06 (Ci)	0.04
Summary of 2006 operational parameters:	
Total possible run-time (hours)	1,632
Scheduled downtime (hours)	16.3
Planned operation (hours)	1,615.7
Unscheduled downtime (hours)	11.8
Total time on-line	1603.9
Total availability (%)	99.3
Scheduled system availability (%)	98.3

^a Average percent removal, based upon the percent average removed each clino-period for CY05.

Key operational and system highlights for CY06 are as follows:

- The scheduled system availability of 98.3% for CY06 was higher than the 90.7% reported in CY05. The total availability was 99.3%, which was also higher than the 85.3% reported for CY05. The higher performance percentages were a result of the shorter operational time in CY06 due to the plant being placed in cold-standby status (i.e., fewer maintenance issues and fewer clinoptilolite changeouts). The monthly on-line percentages and method used to calculate scheduled and on-line availability are presented in Figure 4-3.
- The average percentage removal of strontium-90 during CY06 was 82.6%, compared to 76.3% in CY05. The higher removal efficiency during CY06 is attributed to the resolution of the QC issues associated with the clinoptilolite supplier in CY05.
- The average influent activity during CY06 for strontium-90 was 2,369 pCi/L, while the average effluent activity was 411 pCi/L. A historical presentation of operational parameters, total system performance, and activities for influent and effluent are provided in Appendix C.

4.3 AQUIFER RESPONSE AT THE 100-N AREA

This section describes the general hydrogeologic conditions in the 100-N Area, numerical modeling conducted to evaluate the extraction well network, and changes in contaminant concentrations in monitoring wells.

4.3.1 Hydrogeologic Conditions at the 100-N Area

As shown in Figure 4-4, the most prevalent groundwater flow direction is northwest. During the spring months, the Columbia River elevation generally increases due to additional flow from snowmelt run-off. Flow is regulated at the Priest Rapids Dam to provide irrigation water and to aid in fish migration. Hydrographs for select wells in the 100-NR-2 OU are presented in Appendix K.

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Other hydrogeologic conditions at the 100-N Area are discussed below:

- The average river stage during CY06 increased over that of CY05 but was within the 5-year average. Overall, the Columbia River stage and flow regime has shown a slight but relatively consistent increase over the past 3 years.
- The average hydraulic gradient in the uppermost aquifer at the 100-N Area was 0.0005 toward the northwest based on the average CY06 head measurements.
- Groundwater flow velocity for 2006 over the 100-N Area varied significantly from 0.038 m/day (0.012 ft/day) to 0.23 m/day (0.75 ft/day). This is based on a hydraulic conductivity of 50 ft/day to 300 ft/day and a porosity of 0.2. The gradient is derived from a three-point solution of hourly data from wells 199-N-3, 199-N-14, and 199-N-50.

4.3.2 Contaminant Monitoring

This section summarizes the 100-N Area groundwater monitoring results collected to support the interim remedial action to March 2006 and subsequent OU monitoring during CY06. An engineering change notice, *Modifications to the Groundwater Sampling and Analysis Schedules for the 100-NR-2 Operable Groundwater Sampling Project and 100-N Area RCRA Monitoring Program* (FDH 1996), defines the sampling protocols implemented for CY06. The results presented below are the fall 2005 and fall 2006 concentrations, unless otherwise specified.

The principal groundwater COCs in the 100-N Area are strontium-90, tritium, chromium, manganese, sulfate, and petroleum hydrocarbons. The CERCLA sampling is conducted in March and September. Additional sampling to assess rebound after placing the pump-and-treat system into cold-standby status is conducted in accordance with the *100-N Shoreline Groundwater Monitoring Plan* (PNNL 2006). Analytical results from other programs are also presented where the data are useful for assessing rebound after shutting off the pump-and-treat system.

4.3.2.1 Strontium-90 Monitoring Results. The highest fall 2006 strontium-90 concentration was 11,200 pCi/L in well 199-N-67, which is located downgradient of the 116-N-1 Liquid Waste Disposal Facility (LWDF), and historically has been characterized by the highest strontium-90 concentration in the 100-N Area. Strontium-90 also increased from 2,690 pCi/L to 6,040 pCi/L in well 199-N-46, located downgradient of well 199-N-67 and about 20 m (65.6 ft) from the Columbia River shoreline. The major change in the strontium-90 plume interpretation from 2005 to 2006 is the downgradient extent of the >5,000 pCi/L isopleth, which includes well 199-N-46 for 2006 (Figure 4-5).

The 100-NR-2 interim action pump-and-treat system operated until March 2006 and created a local flow gradient reversal near the shoreline by lowering the water table in the extraction wells. The effect of this gradient reversal and the mixing of river water and groundwater are shown on the 2005 and 2006 diagrams of specific conductance in the area of the 100-NR-2 interim action (Figure 4-5). The only well that displayed significant changes in strontium-90 concentration and specific conductance was well 199-N-46. This well displayed significant changes in specific conductance when the pump-and-treat was operating. The 2006 sample may have been affected by the nearby apatite treatability test.

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As noted in the table below, strontium-90 increased significantly in former 100-NR-2 extraction wells 199-N-75 and 199-N-103A and in monitoring/extraction well 199-N-105A, where strontium-90 increased 434%, 60%, and 95%, respectively. Strontium-90 is bound to soil higher in the saturated zone. The higher 2006 river stage and no pumping in the extraction wells resulted in samples collected from the upper, more contaminated portion of the aquifer. The reason for the 10% decrease in strontium-90 concentration in extraction well 199-N-106A is not clear. Trend plots for these and other wells are provided in Figure 4-5.

Fall 2006 strontium-90 concentrations in aquifer tubes ranged from a low of 33.1 pCi/L in aquifer tube 116m Array 11A to a high of 2,940 pCi/L in tube NVP2-116. Results for the aquifer tubes are summarized in Appendix F. Strontium-90 data for wells or aquifer tubes within the former pump-and-treat operations area (Figures 4-4 and 4-5) are summarized in the table below. The shutdown of the pump-and-treat extraction wells had very little apparent effect on strontium-90 concentrations in aquifer tubes when comparing fall 2005 versus fall 2006 results.

Well/Tube Name	Fall 2005		Fall 2006		Sr-90 Percent Change ^a
	Sr-90 (pCi/L)	Specific Conductance (µS/cm)	Sr-90 (pCi/L)	Specific Conductance (µS/cm)	
199-N-2	81 (+12)	403	726 (+110)	442	+796%
199-N-3	1,310 (+190)	1,258	1,230 (+180)	1504	-6%
199-N-14	1,070 (+170)	291	1,120 (+170)	392	-5%
199-N-75	307 (+47)	310	1,640 (+240)	448	+434%
199-N-76	216 (+33)	412	156 (+23)	388	-27%
199-N-92A	0.92 (+0.38)	271	0.26 (u) (+0.22)	290	^c
199-N-96A	5.7 (+0.99)	764	4.13 (+0.77)	913	-33%
199-N-99A	1,270 (+180)	179	1,090 (+160)	185	-14%
199-N-103A	422 (+62)	479	828 (+120)	480	+95%
199-N-105A	1,360 (+200)	497	2,180 (+320)	458	+60%
199-N-67	9,710 (+1500)	740	11,200 (+1700)	623	+15%
199-N-119	280 (+41)	150	259 (+38)	158	+8%
199-N-46	2,690 (+400)	173	6,040 (+930)	324	+125%
199-N-106A	3,260 (+480)	394	2,940 (+420)	375	-10%
116m Array 1A	63 (+9.2)	203	--	--	^b
116m Array 2A	277 (+40)	499	272 (+39)	507	-2%
116m Array 3A	379 (+55)	172	329 (+47)	194	-13%
116m Array 4A	1,260 (+180)	161	1,270 (+180)	181	+1%
116m Array 6A	477 (+70)	151	415 (+61)	160	-13%
116m Array 7A	330 (+48)	145	287 (+42)	140	-13%
116m Array 8A	0.04(U) (+0.6)	144	47.1 (+6.9)	145	^c
116m Array 9A	127 (+19)	132	120 (+17)	127	-4%
116m Array 10A	--	--	117 (+17)	161	^b
116m Array 11A	--	--	434 (+65)	162	^b
116m Array 12A	--	--	33.1 (+5.1)	140	^b
116m Array 13A	--	--	238 (+35)	157	^b
116m Array 14A	--	--	97 (+14)	173	^b
NS2A-87cm	1,510 (+220)	153	1,550 (+220)	188	+3%
NS3A-87cm	3,460 (+510)	151	--	--	^b

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Well/Tube Name	Fall 2005		Fall 2006		Sr-90 Percent Change ^a
	Sr-90 (pCi/L)	Specific Conductance (μS/cm)	Sr-90 (pCi/L)	Specific Conductance (μS/cm)	
NS3B-40cm	50 (+7.2)	161	--	--	^b
NVP-2-116	3,200 (+470)	157	2,940 (+420)	154	-21%
NVP-1-4	1,610 (+230)	141	--	190	^b
NS4A-138cm	132 (+20)	141	--	--	^b
NS4B-31cm	24 (+3.6)	154	--	--	^b

^a Percent change calculated using the following equation: $[(CY05 - CY06) / CY05] \times 100\%$

^b Not calculated because not sampled in fall 2005 or fall 2006.

^c Not calculated because one value "U" qualified (i.e., nondetect).

4.3.2.2 Contaminants of Concern Monitoring Results. Other COCs in the 100-N Area include tritium, chromium, manganese, nitrate, sulfate, and petroleum hydrocarbons (EPA et al. 1999). The results of the COC monitoring for CY06 are summarized as follows:

- Tritium:** Overall tritium concentrations appear to be decreasing. The highest fall 2006 tritium concentration of 25,300 pCi/L was in well 199-N-32, located north of the 116-N-3 Crib. Average tritium concentrations were above the 20,000 pCi/L MCL in two wells sampled during the fall of 2006 compared to seven wells sampled in the fall of 2005. Tritium data are summarized in the table below for wells within the operational area of the former 100-NR-2 pump-and-treat system. The 2005 and 2006 100-NR-2 tritium plumes are displayed in Figure 4-6. It appears that shutting off the pump-and-treat extraction wells has not resulted in higher tritium concentrations in shoreline wells or aquifer tubes when comparing fall 2005 versus fall 2006 results.

Well/Tube Name	Fall 2005		Fall 2006		Tritium Percent Change ^a
	Tritium (pCi/L)	Specific Conductance (μS/cm)	Tritium (pCi/L)	Specific Conductance (μS/cm)	
199-N-2	21,500 (±1,000)	403	18,400 (+850)	442	-14%
199-N-3	3,745 (+310)	1258	2,360 (+240)	1504	-37%
199-N-14	28,500 (±1300)	291	20,400 (+920)	392	-28%
199-N-32	26,300 (±1,200)	414	25,300 (±1,100)	440	-3.8%
199-N-75	13,900 (+730)	310	14,000 (+710)	448	+1%
199-N-76	22,300 (±1,100)	412	17,400 (+810)	388	-22%
199-N-92A	10,095 (+575)	271	10,600 (+550)	290	+5%
199-N-96A	2,860 (+280)	764	3,320 (±280)	913	+16%
199-N-99A	29.7 (u) (±150)	179	880 (±180)	185	^c
199-N-103A	14,700 (+770)	479	12,000 (±610)	480	-18%
199-N-105A	21,600 (±1,000)	497	18,700 (±860)	458	-13%
199-N-67	28,100 (±1,300)	740	19,900 (+900)	623	-29%
199-N-119	70.7(U) (±160)	150	36.6(U) (±130)	158	+0%
199-N-46	449 (+180)	173	1,780 (+220)	324	+296%
199-N-106A	21,100 (±1,000)	394	18,500 (±850)	375	-12%

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Well/Tube Name	Fall 2005		Fall 2006		Tritium Percent Change ^a
	Tritium (pCi/L)	Specific Conductance (µS/cm)	Tritium (pCi/L)	Specific Conductance (µS/cm)	
116m Array 1A	88.5(U) (±130)	203	--	--	^b
116m Array 2A	2,530 (±290)	499	2,010 (±220)	507	-21%
116m Array 3A	--	172	69.6(U) (±140)	194	^b
116m Array 4A	542 (±200)	161	374 (±150)	181	-31%
116m Array 6A	29.3(U) (±100)	151	87.3(U) (±140)	160	0
116m Array 7A	416 (±130)	145	38.3(U) (±130)	140	^c
116m Array 8A	12(U) (±100)	144	76.7(U) (±140)	145	+0%
116m Array 9A	47.2(U) (±100)	132	205(U) (±150)	127	0
116m Array 10A	--	--	89.1(U) (±140)	161	^b
116m Array 11A	--	--	1,200 (±210)	162	^b
116m Array 12A	--	--	80.7(U) (±170)	140	^b
116m Array 13A	--	--	680 (±190)	157	^b
116m Array 14A	--	--	7,840 (±450)	173	^b
NS2A-87cm	585 (±200)	153	177(U) (±150)	188	^c
NS3A-87cm	75.9(U) (±130)	151	--	--	^b
NS3B-40cm	74.3(U) (±130)	161	--	--	^b
NVP-2-116	64.8(U) (±110)	157	111(U) (±140)	154	+0%
NVP-1-4	127(U) (±110)	141	--	190	^b
NS4A-138cm	264(U) (±170)	141	--	--	^b
NS4B-31cm	630 (±210)	154	--	--	^b

^a Percent change calculated using the following equation: $[(CY05 - CY06) / CY05] \times 100\%$

^b Not calculated because not sampled in fall 2005 or fall 2006.

^c Not calculated because one value "U" qualified (i.e., nondetect).

- Chromium:** Chromium contamination does not appear to be a widespread problem in the 100-N Area, and it was detected above the 100 µg/L DWS only in well 199-N-80. Well 199-N-80, which was completed in the first producing horizon in the confined aquifer, had total chromium of 181 µg/L in the fall of 2005, compared to 163 µg/L in 2006. The source of the chromium contamination is unknown. Aquifer tube and apatite pilot test well samples analyzed for chromium were predominately at detection limits. Chromium concentrations for all wells are included in Appendix F.
- Manganese:** Manganese is elevated above the 50 µg/L secondary DWS in wells 199-N-16 and 199-N-18. The fall 2006 concentrations for these wells were 658 µg/L and 4,640 µg/L, respectively. Wells downgradient of the apatite treatability test also were characterized by elevated manganese. Several aquifer tubes contained manganese above the 50 µg/L secondary DWS but the results were flagged in the HEIS database as suspect. The cause of the elevated manganese in wells 199-N-18 and 199-N-16 may be caused by chemical reduction because of the petroleum.
- Nitrate:** Nitrate concentrations in the fall of 2006 exceeded the 45 mg/L MCL in eight monitoring wells. Nitrate concentrations have varied greatly historically in 100-N Area wells. For example, the average nitrate concentration at well 199-N-67 was 55 mg/L in

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CY02 but increased to 238 mg/L in CY05 and then decreased to 168 mg/L in 2006. The source of the nitrate is unknown at this time.

Nitrate data in the database (reported as NO₃-N) have been normalized to nitrate for consistency. Nitrate data are summarized in the table below for wells in which the fall 2005 to fall 2006 concentration change was more than 20%, or where fall 2006 concentrations were above the 45 mg/L MCL for nitrate, which is equivalent to 10 mg NO₃-N.

Well	Type	Fall 2005. Nitrate (mg/L)	Fall 2006 Nitrate (mg/L)	Percent Change ^a
199-N-2	Monitoring	64.2	70.4	+10%
199-N-3	Monitoring	78.8	94.7	+20%
199-N-21	Monitoring	48.3	76.1	+58%
199-N-32	Monitoring	68.6	85.0	+24%
199-N-67	Monitoring	238	168	-59%
199-N-75	Extraction/ Monitoring	31.9	64.2	+101%
199-N-99A	Monitoring	6.2	10.6	+71%
199-N-105A	Extraction/ monitoring	81.9	74.8	-9%
199-N-119	Monitoring	2.0	7.5	+275%
199-N-120	Monitoring	3.5	5.8	+66%
199-N-121	Monitoring	7.5	12.8	+71%
199-N-14	Monitoring	26.1	38.1	+46%
199-N-16	Monitoring	3.0	11.1	+270%
199-N-76	Monitoring	58.0	47.8	-16%
199-N-96	Monitoring	30.5	23.0	-25%
199-N-64	Monitoring	50.5	67.0	+33%

^a Percent change calculated using the following equation: [(Fall 2005 – fall 2006) / fall 2005] x 100%. >+20% = increasing and <-20% = decreasing. Stable = -20% to +20%.

- Sulfate:** None of the wells or aquifer tubes sampled for sulfate had fall 2006 concentrations above the 250 mg/L secondary DWS. The maximum fall 2006 sulfate concentration was 183 mg/L in well 199-N-3. Sulfate data are summarized in the following table for wells in which fall concentrations changed more than 20% from 2005 to 2006:

Well	Type	Fall 2005 Sulfate (mg/L)	Fall 2006 Sulfate (mg/L)	Percent Change ^a
199-N-16	Monitoring	51.4	78.7	+53 %
199-N-46	Monitoring	13.6	31.3	+130%
199-N-75	Extraction/ monitoring	41.4	70	+69%
199-N-64	Monitoring	70.1	98.3	+40%
199-N-14	Monitoring	37.7	53	+41%

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Well	Type	Fall 2005 Sulfate (mg/L)	Fall 2006 Sulfate (mg/L)	Percent Change ^a
199-N-119	Monitoring	8.2	10.3	+26%
199-N-120	Monitoring	10.6	13.2	+25%
199-N-121	Monitoring	25.0	41.2	+65%

^a Percent change calculated using the following equation: $[(\text{Fall 2005} - \text{fall 2006}) / \text{fall 2005}] \times 100\%$.

- Petroleum hydrocarbons:** Well 199-N-18 monitors the area of 100-N where a 300,000-L petroleum leak occurred during the 1960s. The total petroleum hydrocarbon (TPH)-diesel range fluctuated from 440 mg/L in September 2002, to 630,000 mg/L in March 2003 (with an inch of free product), and to 350 mg/L in September 2003. The fall 2006 concentration for this well was 6.6 mg/L. Similarly, the average annual TPH-gasoline range concentration in this well has declined from 15 mg/L in CY02, to 8.6 mg/L in CY03, to 0.54 mg/L in the fall of 2006.

A passive treatment method to remove diesel from well 199-N-18 was deployed in October 2003. This approach was chosen because the layer of floating petroleum was too thin for removal by active remediation methods. The passive method uses a polymer (Smart Sponge™) with a molecular structure that selectively absorbs petroleum from the surface of the water (i.e., acting as a sponge) while the device floats at the air/hydrocarbon/water interface. A bundle of four, 0.3-m (1-ft)-long cylinders of the material are lowered into the well to soak, after which the cylinders are removed, weighed, and replaced with a new pre-weighed bundle.

The average mass removal rate for CY04 was 0.4 kg/month. The free-product capacity of one absorbent cylinder is about 0.4 kg of fuel, or 1.6 kg for a bundle of four. Accordingly, the soaking time was changed to once every 2 months during 2006.

Monitoring well 199-N-96A, located downgradient from well 199-N-18, had fall 2006 TPH-diesel range and TPH-gasoline range concentrations below the method detection limits. The TPH-diesel range concentration was 0.6 mg/L in March 2005 and then dropped back below the detection limits in September 2005.

Appendix F presents the sample results for CY06, as well as a historical summary of contaminant and co-contaminant monitoring results for wells and the aquifer tubes. Associated contaminant trend charts are presented in Appendix L.

4.4 QUALITY CONTROL

The data used for QC evaluation included offsite laboratory analysis for manganese, strontium-90, tritium, sulfate, nitrate, iron, petroleum hydrocarbons, and oil and grease. The QC samples represented both laboratory replicates and splits. The QC replicates are samples collected at the same time and sent to the same facility for analysis. The QC splits are samples collected at the same time and sent to different laboratories for analysis.

Smart Sponge™ is a trademark of AbTech Industries, Scottsdale, Arizona.

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The highlights of QC data for the CY06 100-N Area sampling are summarized in the table below. Additional tables listing complete QC results are presented in Appendix H.

Analyte	Number of Pairs	Number of Pairs <20% RPD	Percent <20% RPD
<i>Laboratory Replicates and Splits</i>			
Chromium	6	6	100%
Nitrate	6	6	100%
Sulfate	6	6	100%
Manganese	6	6	100%
Tritium	9	9	100%
Sr-90	6	6	100%
Oil and grease	1	1	100%

There are no functional guidelines for offsite laboratory replicate results, but the results correlated well based on the percentage of RPD <20% for both replicate and duplicates samples.

4.5 CONCLUSIONS

- RAO #1:** The 100-NR-2 pump-and-treat interim action was implemented to protect the Columbia River from adverse impacts from the 100-NR-2 groundwater so designated beneficial uses of the Columbia River are maintained. It should protect potential human and ecological receptors using the river from exposure to radiological and nonradiological contaminants present in the unconfined aquifer. It also should protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants. The pump-and-treat system was placed into cold-standby status starting March 9, 2006, when the pumps were shut off. The results of this shutdown are summarized below.

Results:

- Fall 2006 strontium-90 concentrations increased in former pump-and-treat extraction wells compared to fall 2005 concentrations. The reason for this increase is likely because the water level in the wells rose and samples were collected from shallower, more contaminated intervals in the aquifer. The higher water levels may be attributed to higher river stage in 2006 and the cessation of extraction in pump-and-treat wells. However, fall 2006 strontium-90 concentrations in aquifer tubes near the 100-N Area shoreline did not change significantly compared to fall 2005 results.
- It appears that shutting off the pump-and-treat extraction wells has not resulted in higher tritium concentrations in shoreline wells and aquifer tubes when comparing fall 2005 versus fall 2006 results.
- RAO #2:** Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater.

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Results: A field test consisting of a 91.4-m (300-ft)-long PRB along the 100-N Area shoreline is currently underway to evaluate sequestration of strontium-90 in apatite in the saturated zone. This technology and others, including pump-and-treat, will be evaluated and presented to the Washington State Department of Ecology in a proposed plan by March 2008.

- **RAO #3:** Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat in general and prevent adverse impacts to cultural resources and threatened or endangered species.

Results: The interim remedial action ROD (EPA et al. 1999) establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include the following:

- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
- Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
- Regulatory agency notification of any trespassing incidents.

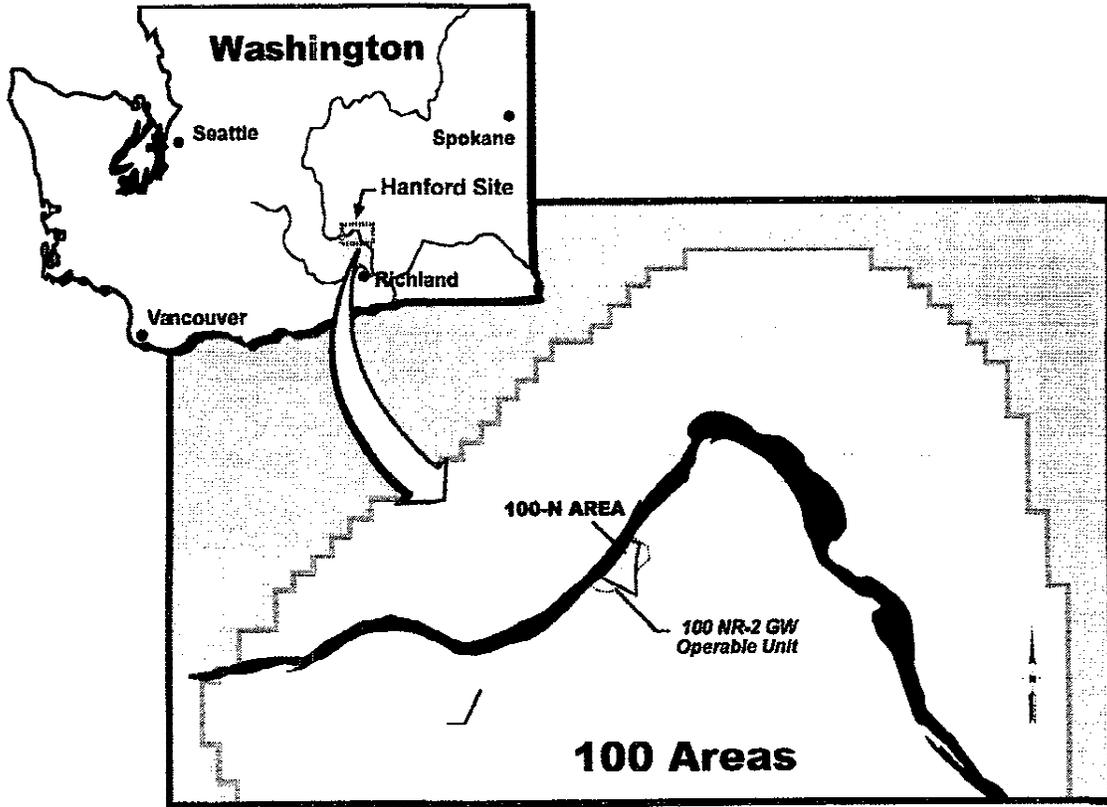
The effectiveness of institutional controls established in the interim action ROD for 100-NR-2 (EPA et al. 1999) was evaluated and summarized for implementation and effectiveness in 2003. The *2004 Final Institutional Controls (IC) Assessment Report* (DOE-RL 2004a) presents the results for the current review. In summary, the report found that institutional controls were maintained to prevent public access, as required.

4.6 RECOMMENDATIONS

- Continue monitoring water-contaminant concentrations in wells and aquifer tubes while the pump-and-treat system is in cold-standby status to assess the effect of shutting down the extraction wells.
- Evaluate the extent of possible shoreline water-quality impacts related to the diesel spill that occurred circa 1963. The evaluation should include placement of additional aquifer tubes and measurement of DO, TPH, dissolved iron, and manganese in near-shore porewater. This activity should be coordinated with the River Corridor sampling effort, which will include toxicity bioassay testing of porewater from aquifer tubes placed along the 100-NR-2 shoreline.

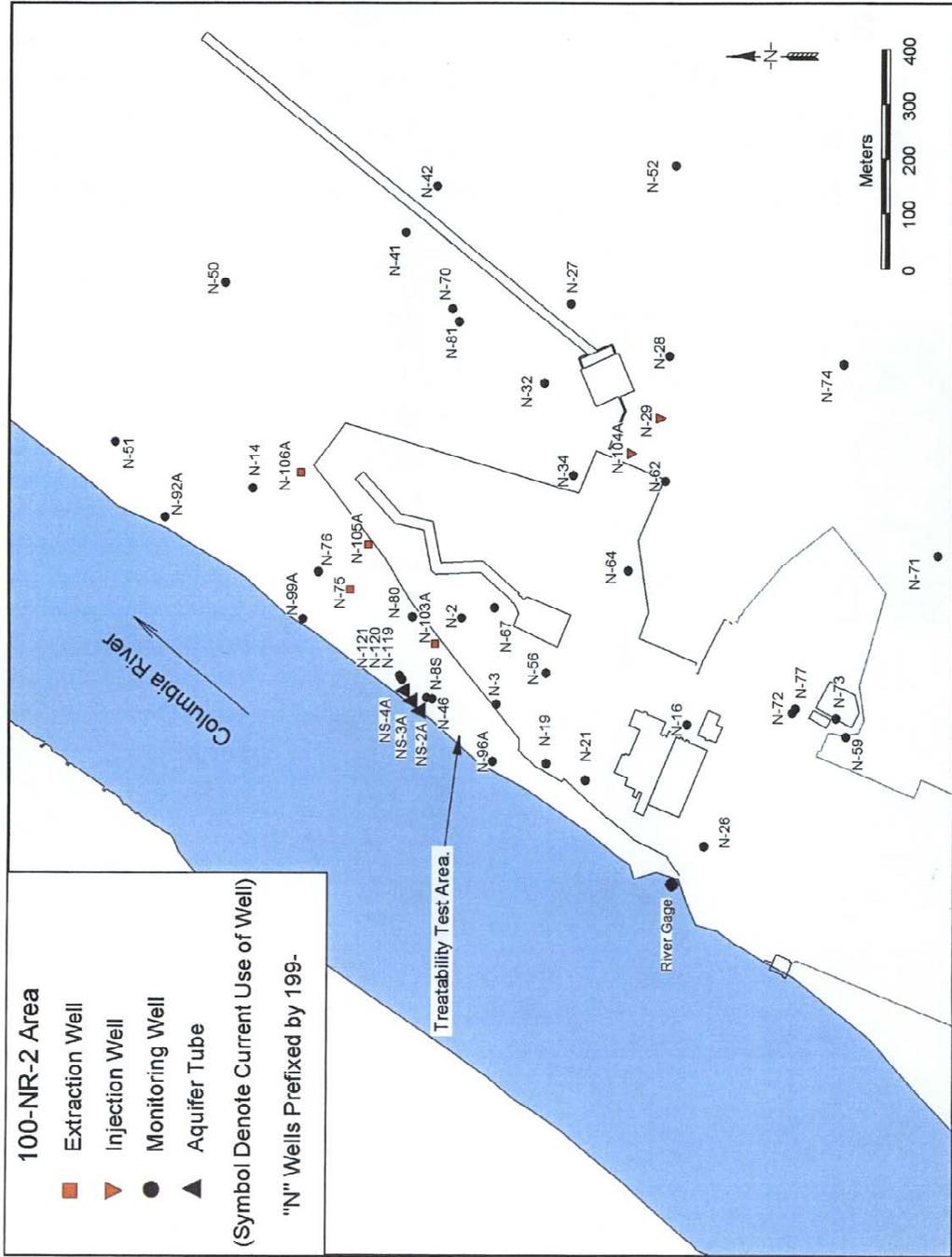
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Figure 4-1. 100-N Area Operable Unit Location.



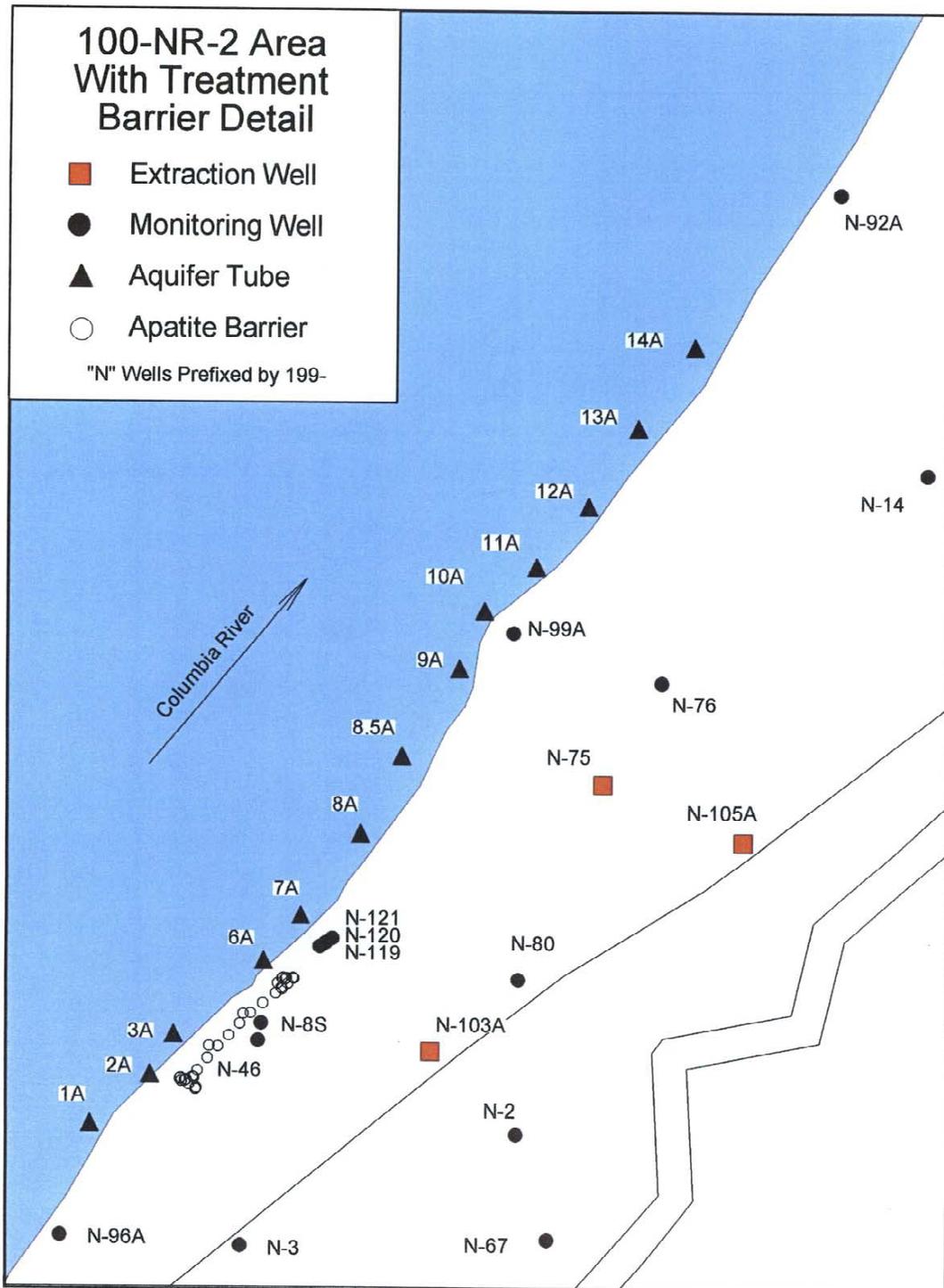
FG010.3

Figure 4-2. 100-NR-2 Operable Unit Wells. (2 sheets)



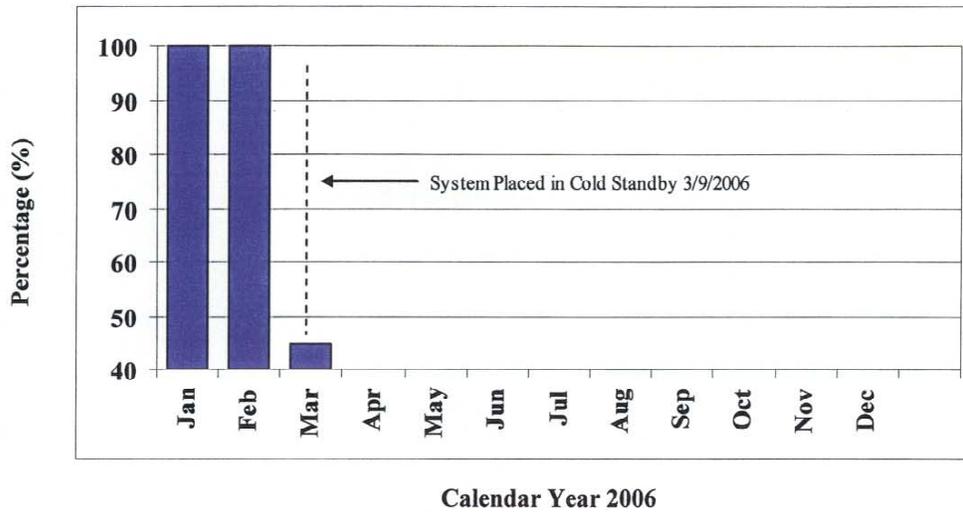
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Figure 4-2. 100 NR 2 Operable Unit Wells. (2 sheets)



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Figure 4-3. 100-NR-2 System Availability and On-Line Percentages for Calendar Year 2006.



100-NR-2 system availability for 2006: ^a	
Total possible run-time (hours)	1,632
Scheduled downtime (hours)	16.3
Planned operations (hours)	1,615.7
Unscheduled downtime (hours)	11.8
Total time on-line (hours)	1,603.9
Total availability (%)	98.3
Scheduled system availability (%)	99.3

^a Scheduled system availability [(total possible run-time – unscheduled downtime) / total possible run-time]. Total availability[(total possible run-time – scheduled and unscheduled downtime) / total possible run-time].

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Figure 4-4. 100-NR-2 Strontium-90 Plume, Fall 2006.

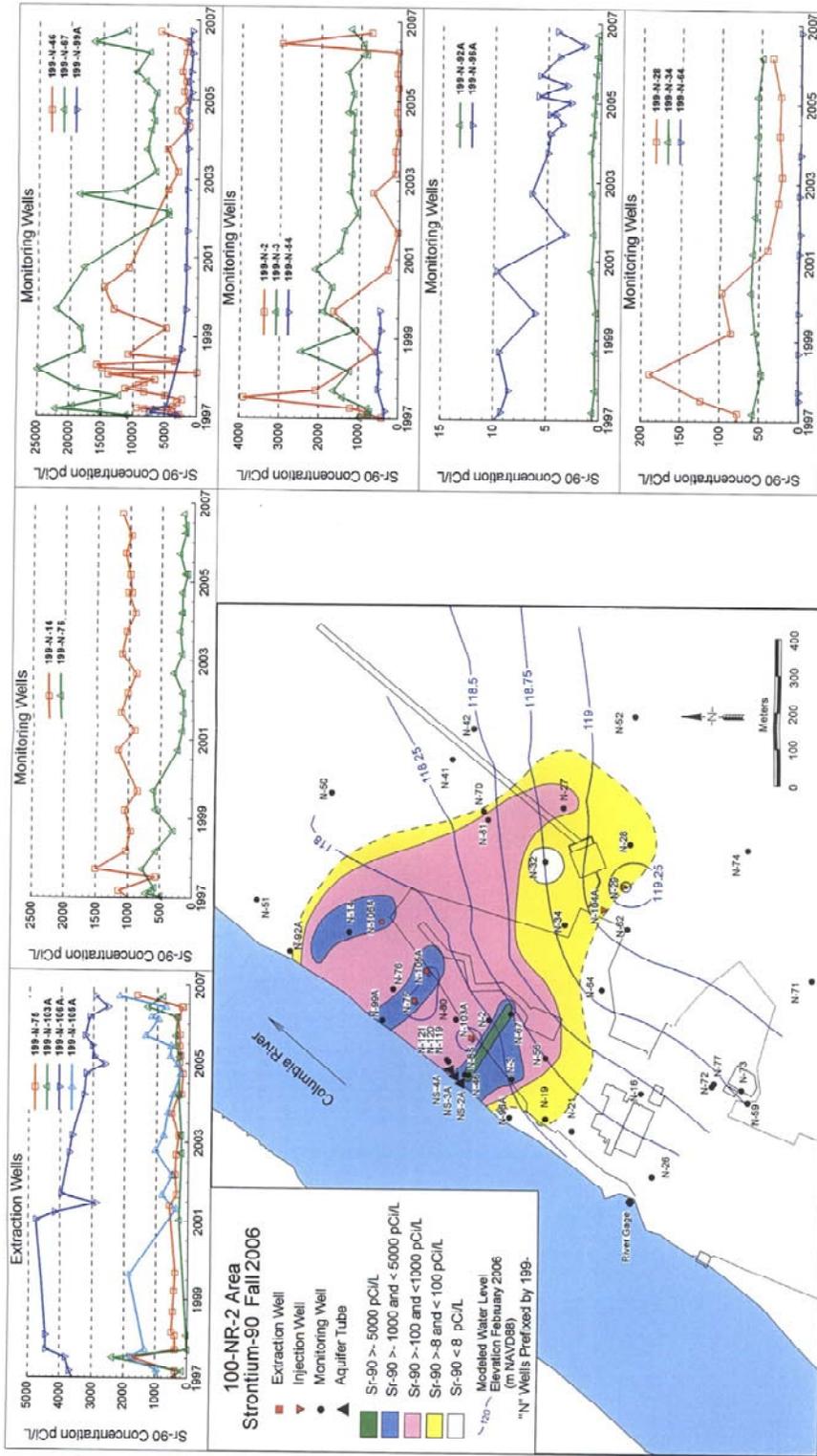


Figure 4-5. 100-NR-2 Strontium-90 and Specific Conductance for 2005 and 2006.

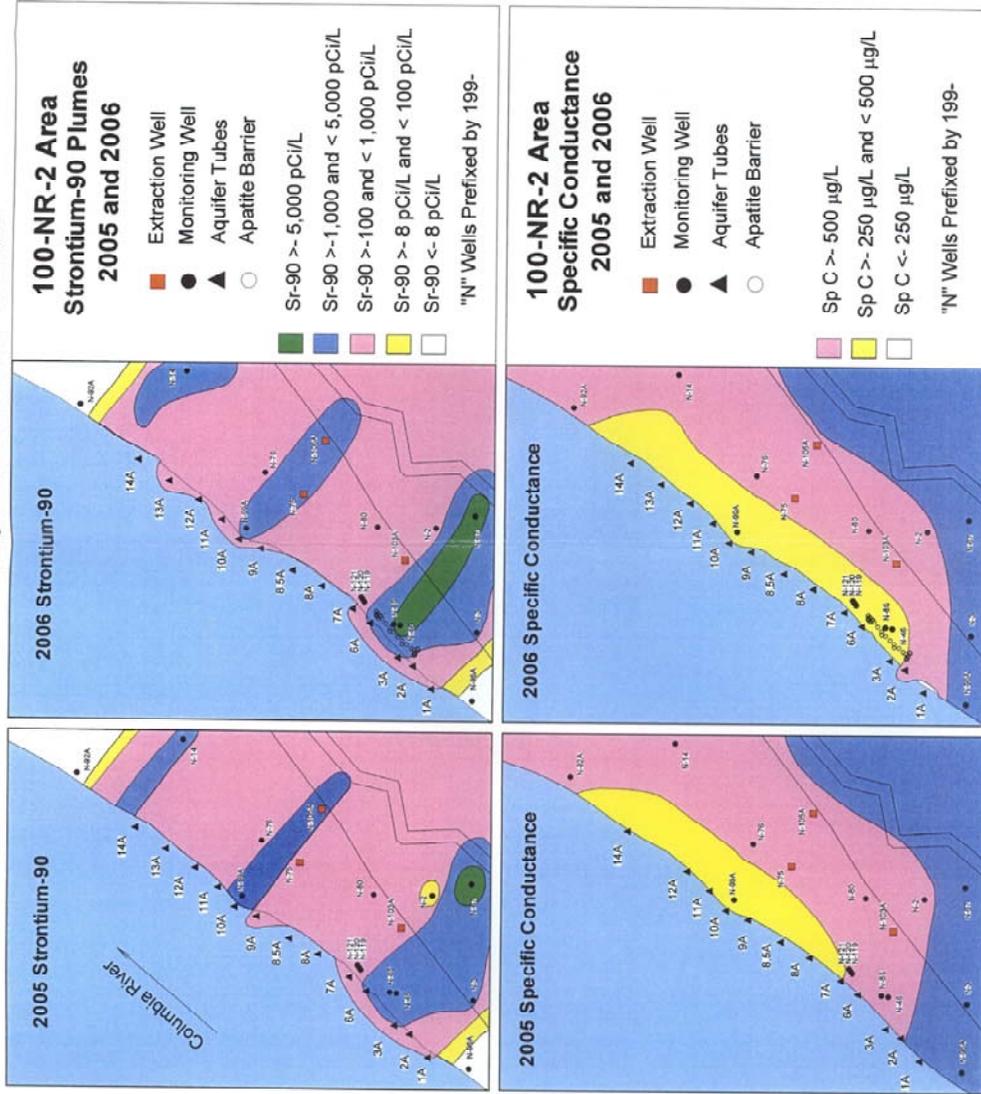
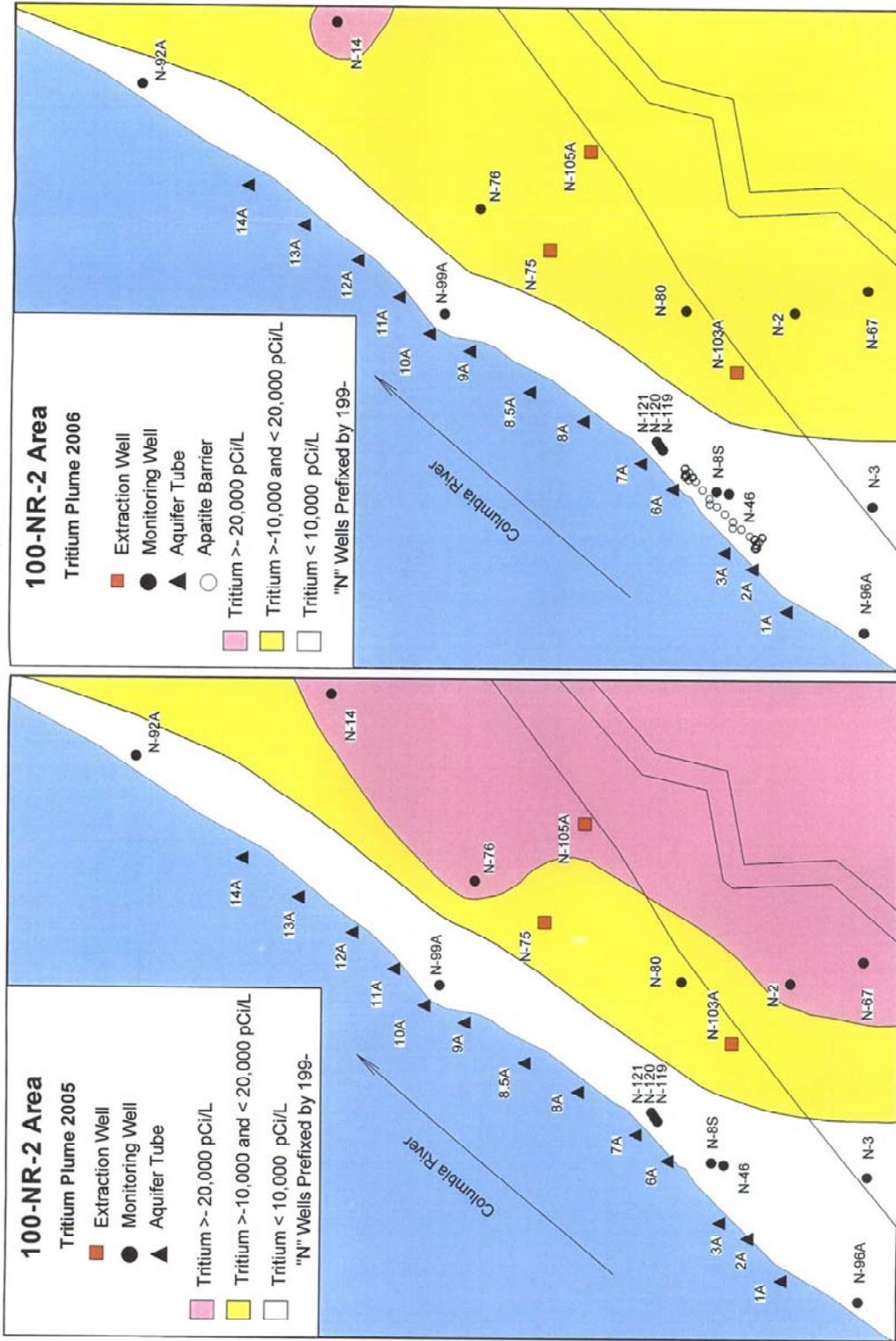


Figure 4-6. 100-NR-2 Tritium Plume, 2005 and 2006.



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5.0 PUMP-AND-TREAT SYSTEM COST DATA

Actual costs for the 100-HR-3, 100-KR-4, and 100-NR-2 pump-and-treat systems were recorded in FH's Hanford Data Integrator. The data are used to determine the actual capital and expense costs associated with a specific activity during the FY. Specific activities are briefly described below:

- **Capital design:** Includes design activities to construct the pump-and-treat systems and designs for major system upgrades and modifications.
- **Capital construction:** Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the pump-and-treat system.
- **Project support:** Includes project coordination-related activities and technical consultation as required during the course of the facility design, construction, acceptance testing, and operation.
- **Operations and maintenance:** Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes costs associated with routine field screening and engineering support as required during the course of pump-and-treat operation and periodic maintenance.
- **Performance monitoring:** Includes system and groundwater sampling and sample analysis as required in accordance with the 100-HR-3 and 100-KR-4 interim action work plan (DOE-RL 1996).
- **Waste management:** Includes the cost for the management of spent resin at 100-HR-3 and 100-KR-4 and spent clinoptilolite in accordance with applicable laws for suspect hazardous, toxic, and regulated wastes. It includes waste designation sampling and analysis. Also included are resin regeneration costs and new resin purchase.

Costs are burdened and are based on actual operating costs incurred during FY06. A comparison between FY05 and FY06 costs is presented in the following sections.

5.1 100-HR-3 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-HR-3 pump-and-treat system is presented in Figure 5-1. Total construction and operation costs for FY06 are higher when compared to FY05. As shown in Figure 5-1, the cost breakdown indicates that the majority of the costs, in decreasing order, are charged to operations (38%), project support (30%), performance monitoring (21%), waste management (9%), and design (2%). Based on the total FY06 cost (\$2,351,000), the yearly production rate of 394 million L (104.1 million gal), and 28.8 kg of hexavalent chromium removed, the annual treatment costs equate to \$0.006/L, or \$81/g of hexavalent chromium removed. These treatment costs are higher than FY05 treatment costs of \$63/g of hexavalent chromium removed.

The cost breakdown for the 100-DR-5 pump-and-treat system is presented in Figure 5-2. The total FY06 construction and operation costs are \$1,351,600, which are similar to \$1,427,400 reported for FY05. The FY06 cost breakdown indicates that the majority of the cost was for operations and maintenance (44.8%), followed, in decreasing order, by project support (27.4%),

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design (14.6%), waste management (11.4%), treatment system capital construction (1.6%), and performance monitoring (0.1%). Based on the total FY06 cost of (\$1,351,600), the yearly production rate of 81.3 million L (21.5 million gal), and 64.2 kg of hexavalent chromium removed, the annual treatment costs equate to \$0.017/L, or \$21.00/g, of hexavalent chromium removed.

5.2 100-KR-4 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-KR-4 pump-and-treat system is shown in Figure 5-3. Compared to FY05, the total construction and operations costs were higher in FY06. As shown in Figure 5-2, the cost breakdown indicates that the majority of the costs, in decreasing order, are charged to treatment system capital construction (36%), operations (32%), performance monitoring (13%), project support (12%), waste management (5%), and design (2%). Based on the FY06 cost (\$4,263,900), the yearly production rate of 525.9 million L (139 million gal), and 21 kg of hexavalent chromium removed, the annual treatment costs equate to \$0.008/L, or \$203/g of hexavalent chromium removed. The treatment costs for FY06 compared to FY05 are higher per liter of groundwater processed and per gram of hexavalent chromium removed.

5.3 100-NR-2 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-NR-2 pump-and-treat system is presented in Figure 5-4. Compared to FY05, total construction and operations costs were significantly higher in FY06. Cost increases are attributed to the activities performed to place the pump-and-treat facility in cold-standby status, the short duration that the plant operated in 2006, and the small amount of water processed and strontium-90 removed. As shown in Figure 5-4, the cost breakdown indicates that the majority of the costs, in decreasing order, are charged to treatment system capital construction (46.3%), operations and maintenance (29.7%), project support (14.3%), performance monitoring (9.1%), and waste management (0.7%). Based on the FY06 cost (\$1,994,790), the production rate of 23.3 million L (6.2 million gal), and 0.004 Ci of strontium-90 removed, the annual treatment costs equate to \$0.86/L, or \$498,697,500/Ci of strontium-90 removed.

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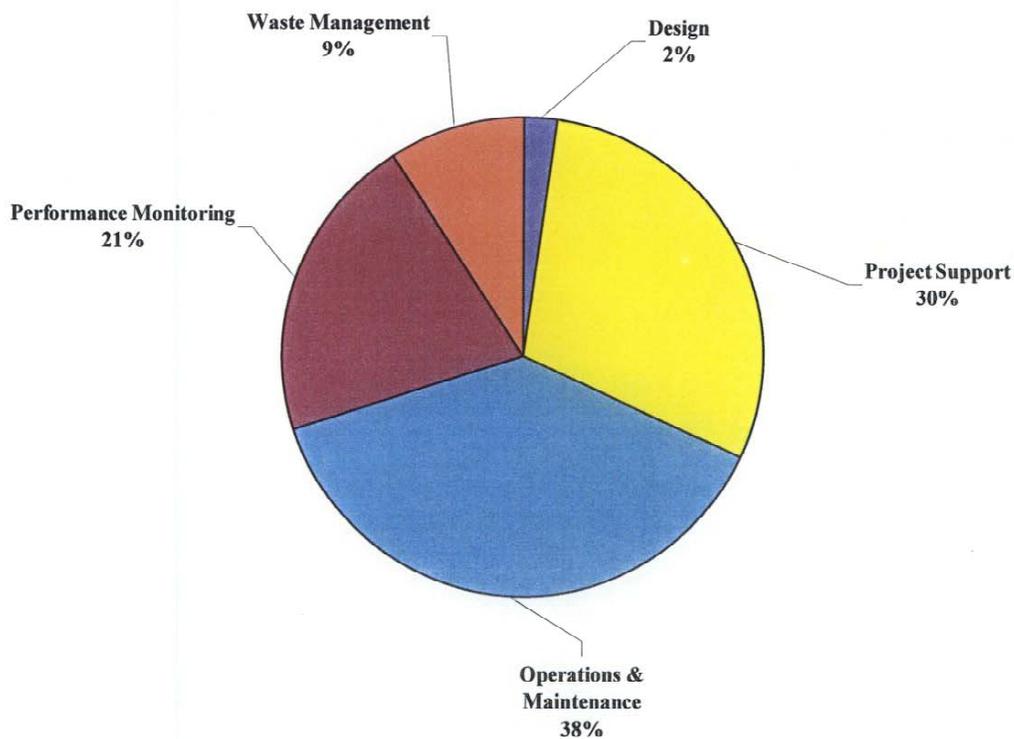
Figure 5-1. 100-HR-3 Pump-and-Treat System Costs. (2 sheets)

Cost Breakdown for 100-HR-3 Pump-and-Treat Construction and Operations										
Description	Actual Costs (Dollars x 1,000)									
	1997	1998	1999	2000	2001 ^a	2002 ^b	2003	2004	2005	2006
Design	--	--	--	--	97.7	15.4	8.1	196.1	196	55.00
Treatment system capital construction	--	--	--	57.7	(36.1)	750.3	--	496.6	10	0.0
Project support	741.0	264.9	265.3	276.7	225.8	309.3	229.8	211.8	722.6	697.6
Operations and maintenance	3,437.0	1,533.3	1,650.8	799.1	739.2	816.6	733.7	1,049.5	618.5	891.2
Performance monitoring	259.0	0.4	--	173.7	219.9	120	163.2	120.3	353	489.6
Waste management	--	--	--	895.3	424.9	720.1	877.2	501.7	202.2	217.6
Totals	\$4,437	\$1,799	\$1,916	\$2,202	\$1,671	\$2,732	\$2,012	\$2,576	\$2,102.4	\$2,351

^a The 2001 costs corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

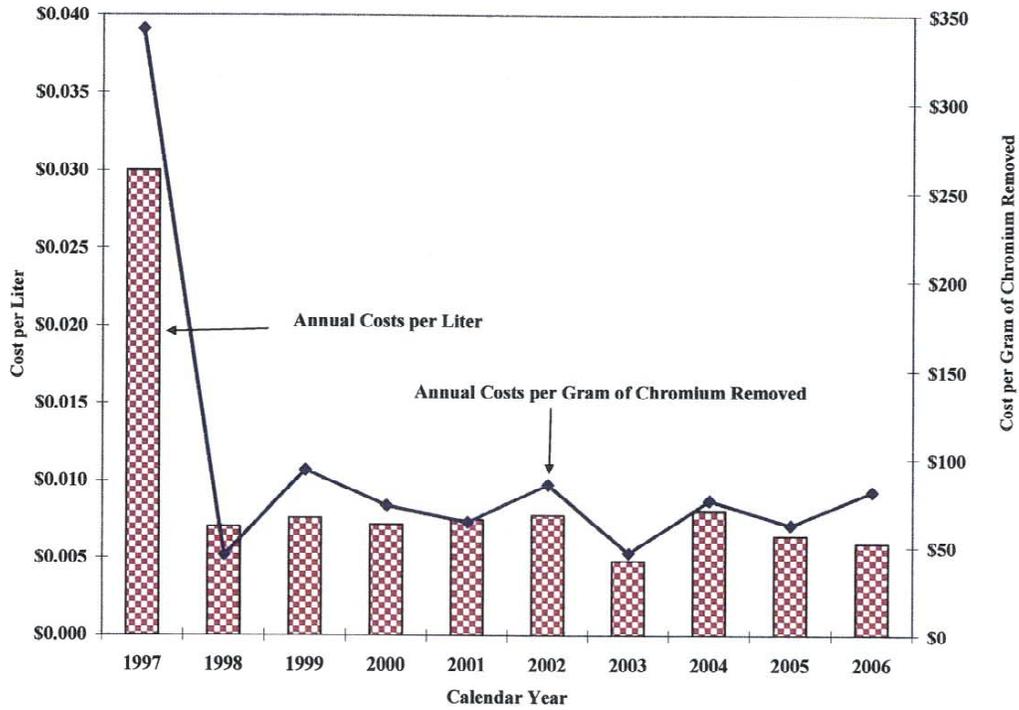
^b The 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.
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100-HR-3 Pump-and-Treat System, Fiscal Year 2006 Cost Breakdown (by Percentage)



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Figure 5-1. 100-IIR-3 Pump-and-Treat System Costs. (2 sheets)



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Figure 5-2. DR-5 Pump-and-Treat System Costs. (2 sheets)

Cost Breakdown for DR-5 Pump-and-Treat Construction and Operations			
Description	Actual Costs (Dollars x 1,000)		
	2004	2005	2006
Design	244	246.9	196.8
Treatment system capital construction	1,620.3		22.2
Project support	175.1	586.4	370.6
Operations and maintenance	48.3	459.6	605.7
Performance monitoring	1.7	106.2	1.6
Waste management	.7	28.3	154.7
Totals	\$2,090.1	\$1,427.4	\$1,351.6

DR-5 Pump-and-Treat System, Fiscal Year 2006 Cost Breakdown (by Percentage)

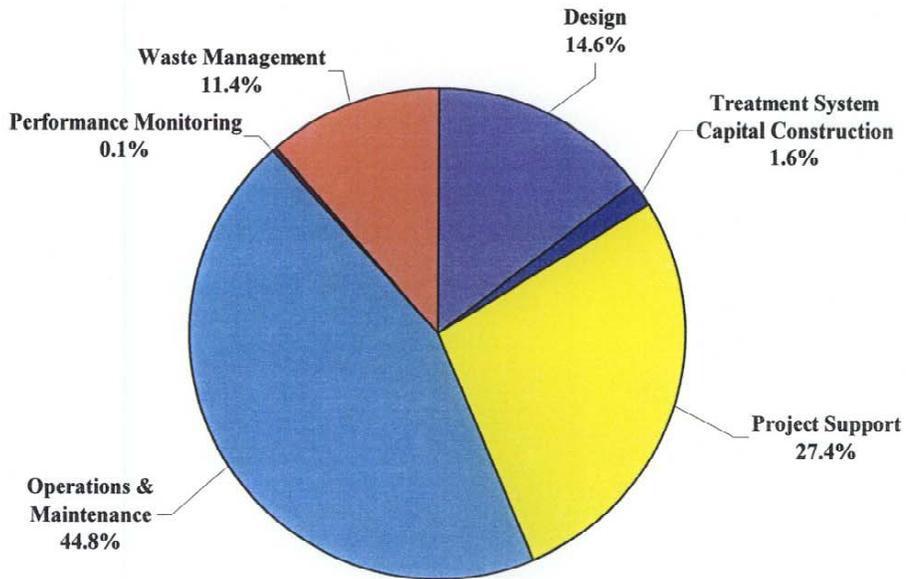
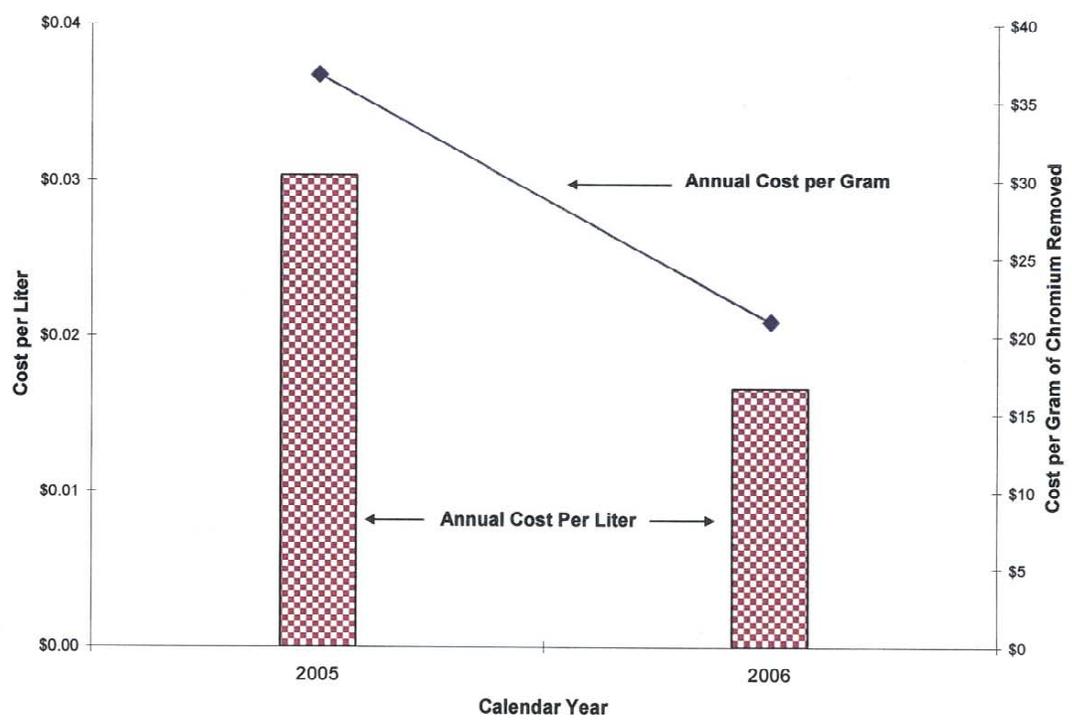


Figure 5-2. DR-5 Pump-and-Treat System Costs. (2 sheets)



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Figure 5-3. 100-KR-4 Pump-and-Treat System Costs. (2 sheets)

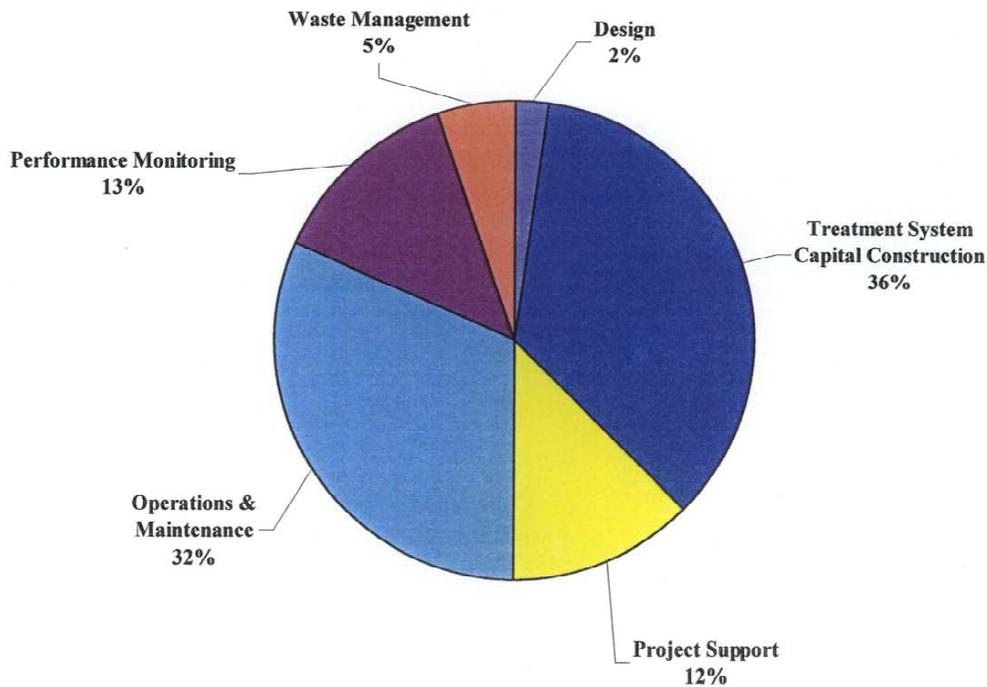
Cost Breakdown for 100-KR-4 Pump-and-Treat Construction and Operations										
Description	Actual Costs(Dollars x 1,000)									
	1997	1998	1999	2000	2001 ^a	2002 ^b	2003	2004	2005	2006
Design	163.0	85.4	0.2	--	96.5	55.2	70.8	163.9	190.8	97.8
Treatment system capital construction	--	--	--	109.1	(0.1)	860.1	379.9	94.2	273.8	1,505.8
Project support	327.0	208.4	157.2	143.0	188.2	257.8	171.0	211.8	851.9	530.5
Operations and maintenance	2,525.0	1,028.9	717.4	538.0	578.6	771.9	789.7	1,118.2	878.6	1,350.8
Performance monitoring	382.0	1.4	--	111.2	122.6	124.6	119.7	83.3	446.3	548.8
Waste management	--	--	--	481.8	367.5	343.3	684.7	475.8	198.3	230.2
Totals	\$3,397	\$1,324	\$875	\$1,383	\$1,353	\$2,413	\$2,216	\$2,147	\$2,839.7	\$4,263.9

^a The 2001 costs corrected for project support and waste management. Initial expense calculations for 2001 were not properly categorized.

^b The 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

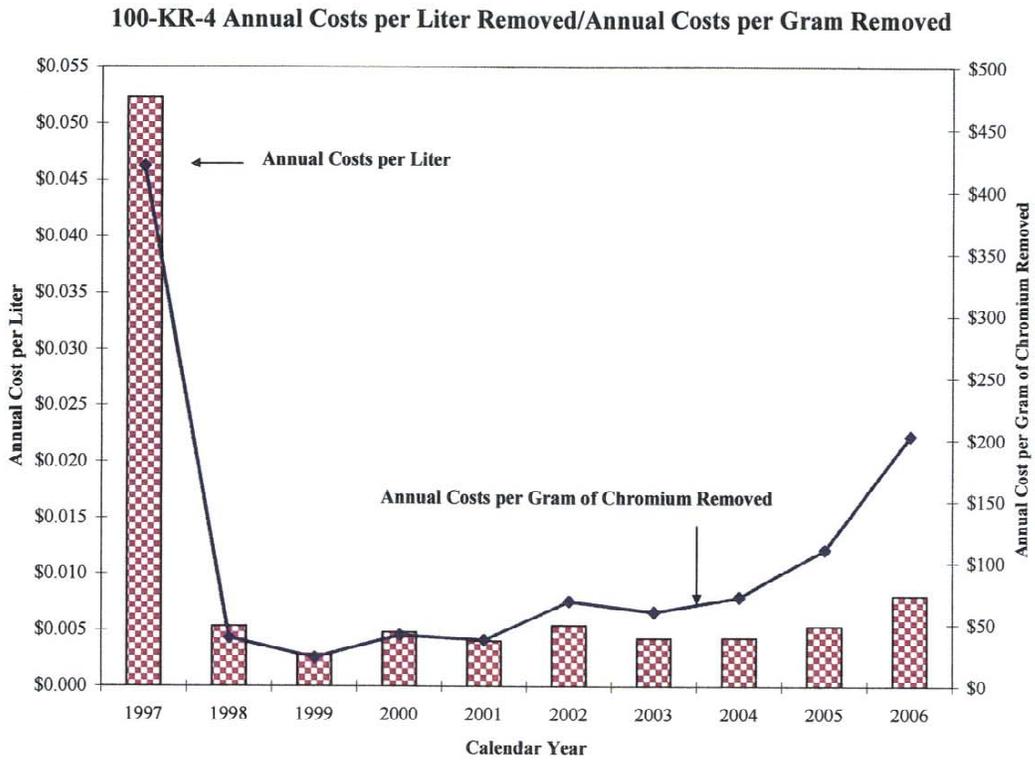
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100-KR-4 Pump-and-Treat System, Fiscal Year 2006 Cost Breakdown (by Percentage)



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Figure 5-3. 100-KR-4 Pump-and Treat System Costs. (2 sheets)



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Figure 5-4. 100-NR-2 Pump-and-Treat System Costs. (2 sheets)

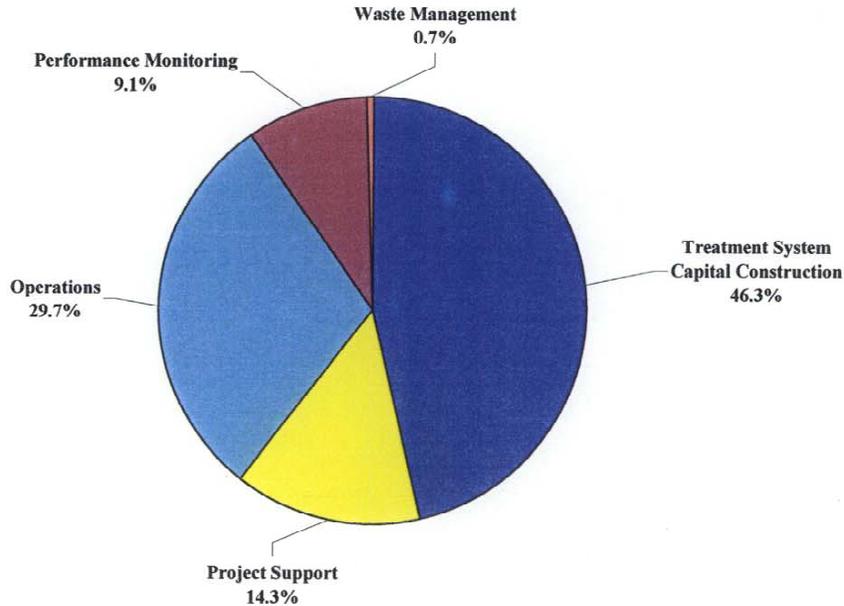
Cost Breakdown for 100-NR-2 Pump-and-Treat Construction and Operations										
Description	Actual Costs (Dollars x 1,000)									
	1997	1998	1999	2000	2001 ^a	2002 ^b	2003	2004	2005	2006
Design	951.8	32.6	0.2	--	--	--	--	--	447.9	--
Treatment system capital construction	--	-	--	--	--	--	--	--	161.9	922.6
Project support	119.4	136.0	113.1	96.3	183.5	219.4	133.0	329.7	416.5	284.4
Operations and maintenance	1,027.8	425.2	657.4	462.2	631.5	631.8	604.3	553.0	650.6	592.6
Performance monitoring	--	--	--	82.6	83.1	72.4	51.6	79.6	408.7	182.2
Waste management	--	--	--	131.6	112.5	100	45.4	27.4	7.6	13.0
Totals	\$2,099	\$594	\$771	\$773	\$1,011	\$1,024	\$834	\$989.7	\$2,093.2	\$1,994.8

^a 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.

^b 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

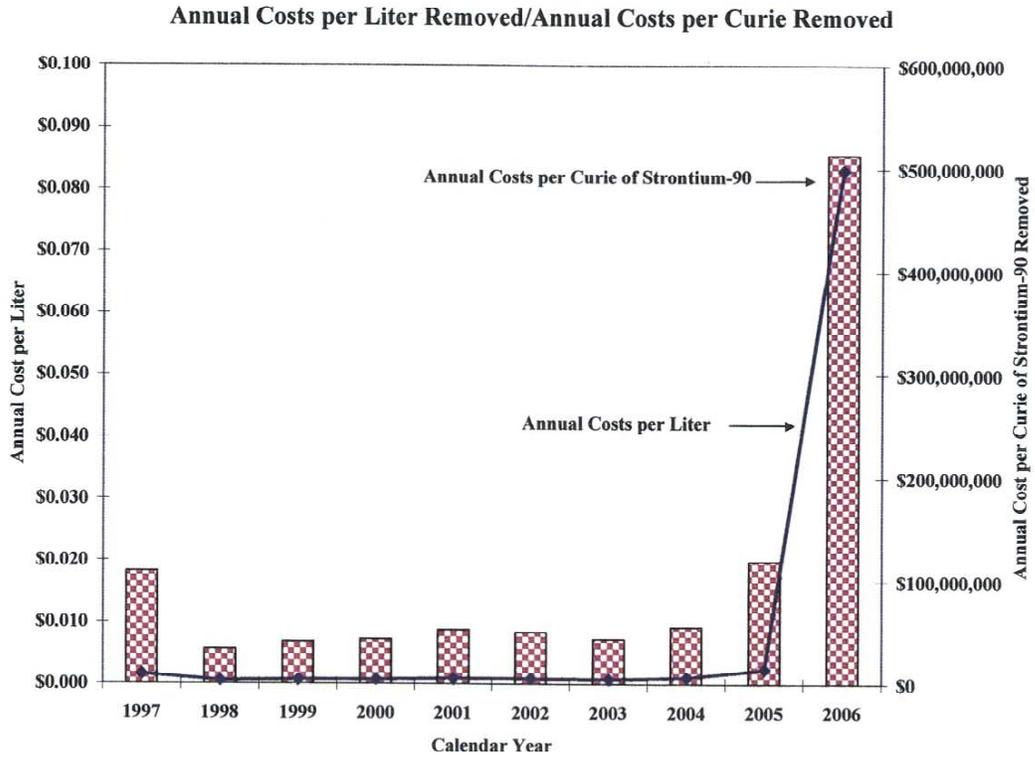
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100-NR-2 Pump-and-Treat System, Fiscal Year 2006 Cost Breakdown (by Percentage)



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Figure 5-4. 100-NR-2 Pump-and Treat System Costs. (2 sheets)



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APPENDIX A
HISTORY

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APPENDIX A

HISTORY

A1.0 100-HR-3 HISTORY

In September 1994, the *Limited Field Investigation Report for the 100-HR-3 Operable Unit* (DOE-RL 1994a), including a qualitative risk assessment, was completed. Hexavalent chromium was identified as a contaminant of concern for ecological receptors in the Columbia River. In August 1995, the *100-HR-3 Operable Unit Focused Feasibility Study* (DOE-RL 1995a) and the *Proposed Plan for Interim Remedial Measure at the 100-HR-3 Operable Unit* (DOE-RL 1995d) were finalized. The proposed plan recommended the use of a pump-and-treat system to mitigate chromium migration into the river. In 1994, a pilot-scale pump-and-treat system was deployed, and in December 1995 the *Pilot-Scale Treatability Test Summary Report for the 100-HR-3 Operable Unit* (DOE-RL 1995c) was issued. The report indicated that removing hexavalent chromium from extracted groundwater in the 100-HR-3 Operable Unit (OU) using a resin treatment (ion-exchange) system was viable.

In April 1996, the *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site (Interim Remedial Actions)* (EPA et al. 1996) was issued for the 100-HR-3 pump-and-treat system. The interim remedial action Record of Decision (ROD) specified installation of a pump-and-treat system in the 100-HR-3 and 100-KR-4 OUs to intercept portions of the hexavalent chromium plumes that impact the Columbia River. Full-time operation of the 100-HR-3 treatment system was initiated July 1, 1997. On August 5, 1998, the pump-and-treat system was modified to permit groundwater from the 100-D Area to be treated separately from 100-H Area groundwater.

In October 1999, the *U.S. Department of Energy Hanford Site – 100 Area Benton County, Washington, Amended Record of Decision Summary and Responsiveness Summary (100-HR-3 Operable Unit)* (EPA et al. 1999) was approved, which modified the selected remedial action by deploying an innovative treatment technology, In Situ Redox Manipulation (ISRM), to address the groundwater chromium plume located southwest of the D/DR Reactors. This plume is not within the established treatment zone for the pump-and-treat system for the interim action. The initial phase of the ISRM remedial action was implemented in 2000. The monitoring results of the ISRM are presented in the various fiscal year (FY) annual summary reports for the ISRM operations.

Additional detailed site characterization and background information on the OU and the pump-and-treat activity are provided in the limited field investigation (LFI) report (DOE-RL 1994a) and focused feasibility study (FFS) (DOE-RL 1995a). Further information on the pump-and-treat system design and operation can be found in the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* (DOE-RL 1996b) and *100-HR-3 and 100-KR-4 Operable Units Interim Action Performance Evaluation Report* (DOE-RL 1998a). Groundwater monitoring requirements are described in *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE-RL 1997a). Additional information regarding the progress of the 100-NR-2 pump-and-treat operations is provided in previous FY summary reports (DOE-RL 1998b, 1999, 2001, etc.).

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Additional background/current information is available in the *Hanford Site Groundwater Monitoring for Fiscal Year 2006* (PNNL 2007).

Although salmon spawning habitat has been identified as potentially being at risk in some river channel areas adjacent to Hanford Site chromium plumes, the segment along the 100-H Area is not a major spawning area (Dauble and Watson 1997).

A2.0 100-KR-4 HISTORY

In July 1994, the LFI report (DOE-RL 1994b), including a qualitative risk assessment, was completed. The report concluded that an interim remedial measure (IRM) was not warranted based on human health risk, but an IRM could be justified for ecological concerns related to chromium. In October 1995, the *100-KR-4 Operable Unit Focused Feasibility Study* (DOE-RL 1995b) and the *Proposed Plan for Interim Remedial Measure at the 100-KR-4 Operable Unit* (DOE-RL 1995e) were completed. The proposed plan recommended a pump-and-treat IRM to mitigate chromium migration into the Columbia River.

In April 1996, an interim remedial action ROD (EPA et al. 1996) was issued for the 100-KR-4 pump-and-treat system. The ROD specified installation of a pump-and-treat system in the 100-HR-3 and 100-KR-4 OUs to intercept portions of the chromium plumes that impact the Columbia River. Full-time operation of the treatment system was initiated on October 1, 1997.

Detailed site characterization and background information on the OU and the pump-and-treat activity are provided in the FFS (DOE-RL 1995b) and the proposed plan (DOE-RL 1995e). Further information on the pump-and-treat system's design and operation can be found in the work plan (DOE-RL 1996b) and interim action performance evaluation report (DOE-RL 1998a). Groundwater monitoring requirements are described in the interim action monitoring plan (DOE-RL 1997a). Additional information regarding the progress of the 100-NR-2 pump-and-treat operations is provided in previous FY summary reports (DOE-RL 1998b, 1999, 2001, etc.). Additional background/current information is available in the *Hanford Site Groundwater Monitoring for Fiscal Year 2006* (PNNL 2007).

A3.0 100-NR-2 HISTORY

On September 23, 1994, the Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) issued an action memorandum to the U.S. Department of Energy, Richland Operations Office (RL) to immediately initiate groundwater remedial actions in the 100-N Area (Ecology and EPA 1994). The requested remedial actions included the design, construction, and operation of a groundwater pump-and-treat system and the construction of a sheet-pile barrier wall at N-Springs. However, in a letter dated March 1995, Ecology and EPA concurred with RL that installation of the sheet-pile wall could not be achieved in the manner specified. This conclusion was based on a construction test conducted in December 1994 (Ecology 1995).

Ecology and EPA subsequently directed RL to proceed with installing a pump-and-treat system as an expedited response action. The N-Springs pump-and-treat system was completed by August 1995 and began full operation by September 1995, meeting *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 2003) Milestone M-16-12D.

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From system startup in September 1995 through November 8, 1996, the N-Springs pump-and-treat system operated at a nominal rate of 189 L/min (50 gallons per minute [gpm]). During this period, the system consisted of four extraction wells (199-N-75, 199-N-103A, 199-N-106A, and 199-N-105A, with three wells operating and one well as a backup) and two injection wells (199-N-29 and 199-N-104A).

Based on recommendations in the *N-Springs Expedited Response Action Performance Evaluation Report* (DOE-RL 1996a) and the *N-Springs Pump-and-Treat Optimization Study* (DOE-RL 1997b), the system was shut down and upgraded to operate at 227 L/min (60 gpm) between November 8 and December 17, 1996. The pump-and-treat system was brought back on-line on December 17, 1996, and has continued to operate in this configuration until being placed in cold-standby mode. Under this configuration, the network consists of three extraction wells (199-N-75, 199-N-103A, and 199-N-106A) and two injection wells (199-N-29 and 199-N-104A), with well 199-N-105A serving as a backup extraction well.

Additional information regarding the progress of the 100-NR-2 pump-and-treat operations is provided in previous FY summary reports (DOE-RL 1998b, 1999, 2001, etc.). Additional background/current information is available in the *Hanford Site Groundwater Monitoring for Fiscal Year 2006* (PNNL 2007).

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APPENDIX B

CONCEPTUAL MODELS

B1.0 100-D CONCEPTUAL MODEL UPDATE

This section describes the sources of the chromium contamination in the 100-D Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate dihydrate, $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$, is a corrosion inhibitor added to Columbia River water used as reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium readily adsorbs to soil particles and is relatively insoluble in groundwater, with a pH of >6.0 . For convenience, hexavalent chromium is simply referred to as "chromium" in this text, unless noted otherwise.

Coolant water containing sodium dichromate in solution leaked from cooling water retention basins and large-diameter underground piping, introducing chromium to the soil column and ultimately to the groundwater. In addition, radiologically contaminated coolant water was disposed in process effluent trenches, french drains, or cribs. Chromic acid, H_2CrO_4 , is a strong oxidizer that was used to decontaminate and clean reactor equipment, and the contaminated solution was then disposed to french drains. Transfer lines leading from the sodium dichromate transfer station to the reactors may have leaked to the vadose zone. These transfer lines are located near and parallel to raw water lines. A summary of waste sites that may be a source of chromium contamination in the D/DR Reactor area is presented in *Conceptual Site Models for Groundwater Contamination at 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units* (BHI 1996).

Known disposal and spill sites have been investigated by boring from the surface and collecting samples to detect near-surface contamination. An investigation was conducted in 2000 around the sodium dichromate transfer station in the 100-D Area (PNNL 2000). This investigation was not successful in locating significant near-surface chromium sources.

Another soil investigation was conducted in November 2003 during the drilling of monitoring well 199-D5-34. Samples were collected at 1.5-m (4.9-ft) intervals from the surface to the water table at a depth of 33.5 m (109.9 ft). Hexavalent chromium was not detected in any of the soil samples. This well was located adjacent to a french drain that was a suspected disposal site for excess sodium dichromate.

In 2004, soil sampling was performed in response to concerns regarding high concentrations of chromium in the groundwater, which pointed to the source area around the sodium dichromate transfer station. Sampling was conducted to locate soil contamination associated with spills and releases of sodium dichromate from tanker cars staged on the tracks and potential pipeline leakage during past operations. Test pit samples and near-surface samples were collected. Results of this investigation are described in *Results of Hexavalent Chromium Sampling Near 100-D Area Sodium Dichromate Transfer Station and Railroad Tracks* (BHI 2004). Of the 116 samples collected, 16 samples were above the reporting limit of 0.35 mg/kg and 2 samples were above the 2.0 mg/kg standard for protection of groundwater and the Columbia River.

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Seven additional wells are planned in 2007 to investigate potential chromium sources in the upgradient ("head") end of the southwest chromium plume in the 100-D Area. These wells will be monitored frequently for about 6 months, and the vadose zone soil collected during drilling operations will also be analyzed if discolored. Chromium contamination in the 100-D Area is believed to be limited to the uppermost unconfined aquifer.

Typical unconfined aquifer hydrostratigraphy in the 100-D Area includes the Hanford formation, the Ringold Unit E, and the Ringold Upper Mud Unit. Well 199-D8-54B, which is screened in the first producing horizon below the top of the Ringold Upper Mud Unit, has shown very low chromium concentrations. The thickness of Ringold Unit E varies significantly from north to south, and it may have been eroded locally in the north so the Hanford formation was deposited directly on the Ringold Upper Mud Unit. Two of the 100-D pump-and-treat extraction wells (199-D8-53 and 199-D8-54A) appear to be located where the Hanford formation is deposited directly on the Ringold Upper Mud Unit. The unconfined aquifer in these wells is located in Hanford formation sand and gravel with locally silty intervals. These wells are characterized by high well efficiency (e.g., significant production per foot of drawdown).

In the southern portion of the 100-D Area, the Hanford formation was deposited on the Ringold Unit E. The unconfined aquifer in this area is within the Ringold Unit E, composed of more consolidated silt, sand, and gravel with locally cemented intervals. The wells associated with the In Situ Redox Manipulation (ISRM) were screened in Ringold Unit E sediments and almost universally are not as efficient (e.g., less production per foot of drawdown) as those wells screened in the Hanford formation. A more detailed description of the 100-D Area stratigraphy is presented in the conceptual site model report (BHI 1996) and the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* (DOE-RL 1996b).

Groundwater flow in the 100-D Area is predominantly to the north in the pump-and-treat area and northwest in the southern portion of the 100-D Area, near the ISRM. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices associated with the 182-D reservoir, and variation in the hydrostratigraphy.

Groundwater flow is generally toward the Columbia River (i.e., gaining stream), except near the river during May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the stage of the river and may reverse the flow direction (i.e., losing stream). The releases are managed to balance summer irrigation demand and power (electricity) production and to maintain safe reservoir elevations.

Facilities that have most recently affected the groundwater flow regimes in the 100-D Area include the 120-D-1 Ponds and the 182-D reservoir. Normal disposal practices and leakage from these facilities may have been responsible for mounding between the reactor buildings and the Columbia River. The 120-D-1 Ponds were closed to disposal in 1995. The 182-D reservoir was emptied from November 2002 to April 2003 and remained empty until mid-July 2003, when it was filled to capacity. Reservoir construction joints were repaired while the reservoir was empty. Operational practices were changed in 2004 to reduce leakage from this reservoir; however, there is enough leakage from the reservoir to separate the 2006 chromium plumes west of the 182-D reservoir into a northern 100-D plume and a southwest ISRM plume. In addition, injection of treated groundwater from the DR-5 pump-and-treat system into well 199-D5-42 may be separating the plumes east of the former 183-D basins.

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The 1967 reactor effluent infiltration test in 107-DR Liquid Waste Disposal Trench #1 also affected groundwater flow in the 100-D Area. From March to June 1967, 1.28×10^8 L (3.4×10^7 gal) of effluent went into the 107-DR-1 Trench, creating an 11 m (36 ft) mound and increasing the groundwater flow gradient from the 100-D Area east, across the "horn" area (see Figure B-1). The reactor effluent also contained hexavalent chromium and, therefore, spread the contaminant radially from the 107-DR-1 Trench.

Additional site characterization since 1995 led to the discovery of the southwest 100-D plume, which was outside of the capture zone of the 100-D pump-and-treat extraction wells. The ISRM barrier was built to control this southwest plume. The southwest 100-D plume was separated from the north plume (i.e., the pump-and-treat plume) by groundwater mounds created by disposal to the 120-D-1 Ponds, leakage from the 182-D reservoir, and possibly by injection into wells south of the DR Reactor in 1994-1995 during the pilot-scale pump-and-treat test. The DR-5 pump-and-treat system was implemented in 2004 to address the spread of the 100-D plume west to the Columbia River.

The highest remaining concentrations are in the southwest plume area, notably in well 199-D5-39, where chromium has been measured above 4,500 $\mu\text{g/L}$. The source of this plume may be the former sodium dichromate/chromic acid transfer station upgradient (east) of well 199-D5-39. Well 199-D5-39 was included in the network of DR-5 extraction wells. Figure B-2 presents an historical comparison of the baseline chromium plume through the 2006 plume.

B2.0 100-H CONCEPTUAL MODEL UPDATE

This section describes the sources of chromium contamination in the 100-H Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate dihydrate, $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$, is a corrosion inhibitor that was added to Columbia River water used as reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium readily adsorbs to soil particles and is relatively insoluble in groundwater, with a pH of >6.0 .

Coolant water containing sodium dichromate in solution leaked from cooling water retention basins and large-diameter underground piping, introducing chromium to the soil column and ultimately to the groundwater. Specific facilities that have leaked include the 183-H solar evaporation basins and the 107-H retention basins. Hydrographs of existing "horn" area wells 699-97-43 and 699-96-49, and decommissioned well 199-H4-1 confirm that the 100-H retention basin leaked during operations, creating a mound up to 4 m (13 ft) above the current groundwater. The water table elevation in former well 199-H4-1, located adjacent to the former 107-H retention basin, was generally higher from 1952 to 1964 than the highest recorded elevation in inland wells 699-97-43 and 699-96-49 (see Figure B-1). It is likely that contaminated groundwater traveled an unknown distance west from the 100-H Area into the "horn" area. A summary of waste sites that may be a source of chromium contamination in the 100-H Reactor area is provided in the conceptual site model report (BHI 1996).

The 100-D Area may have been a contributing source of a chromium plume west of the 100-H Area. Leaking cooling water retention basins (107-DR-1) created a significant mound of sodium dichromate contaminated water that flowed radially (including east) from the 100-D retention

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basin area. The 1967 infiltration test in the 107-DR-1 Trench also contributed to the plume flowing east toward the 100-H Area, as shown in the hydrograph of well 699-96-49, which shows a 3-m (10-ft) spike in head in 1967 during the infiltration test. This well is located approximately 1,000 m (3,281 ft) east of the 107-DR-1 Trench. Two of the 600 Area wells (i.e., wells 699-96-43 and 699-97-43, located upgradient [west] of the 100-H Area) have been characterized by chromium concentrations near 100 $\mu\text{g/L}$ since the start of pump-and-treat operations. Well 699-97-43 was constructed in 1962 and the perforated interval extends across the Hanford formation and Ringold Upper Mud Unit contact. This well may provide a conduit from the upper unconfined aquifer to the deeper aquifer sampled by wells 199-H3-2C, 199-H4-12C, and 199-H4-15CS.

Typical unconfined aquifer hydrostratigraphy in the 100-H Area includes the Hanford formation and the Ringold Upper Mud Unit. The unconfined aquifer is located in the saturated Hanford formation, with the top of the Ringold Upper Mud Unit as its base. The thickness of the unconfined aquifer at the 100-H area varies significantly, as shown in Figure B-3 (isopach map of saturated Hanford formation). Extraction wells located near the Columbia River are characterized by 3 to 4.5 m (9.8 to 14.8 ft) of saturated Hanford formation. As shown in Figure B-3, the saturated thickness of the Hanford formation thins to as little as 0.6 m (2 ft) in the 600 Area, which is west of the 100-H Area (well 699-96-43). Additional details regarding 100-H Area hydrostratigraphy are found in conceptual site model report (BHI 1996) and the remedial design report/remedial action work plan (DOE-RL 1996b).

Groundwater flow in the 100-H Area is predominantly to the northeast. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices (especially injection wells), and hydrostratigraphy.

Groundwater flow generally is toward the Columbia River (i.e., gaining stream), except near the river during May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the stage of the river and may reverse the flow direction (i.e., losing stream). The releases are managed to balance summer irrigation demand and power (electricity) production and to maintain safe reservoir elevations.

Hydrostratigraphy has a strong influence on aquifer conditions in the 100-H Area. The minimal thickness of the saturated Hanford formation west of the 100-H Area (0.6 to 2.1 m [2 to 6.9 ft]) in wells 699-96-43 and 699-97-43 restricts the flow into the 100-H Area. In addition, a thin aquifer along the Columbia River limits drawdown in extraction wells and, therefore, restricts pumping rates.

The original target area of the pump-and-treat system, which came on-line in 1997, was a wedge-shaped, 100 $\mu\text{g/L}$ chromium isopleth that extended to well 199-H3-2A and was bounded along the shoreline by the 50 $\mu\text{g/L}$ chromium isopleth (Figure B-3). Maximum concentrations within this target area were >100 $\mu\text{g/L}$ in well 199-H3-2A. This high-concentration area around well 199-H3-2A moved to the near-river wells in subsequent years. The extraction well and injection well network configuration has been modified several times since 2004 to more effectively complete remediation of the 100-H chromium plume to the remedial action objectives (RAOs). Figure B-4 shows baseline through the 2006 plume configurations for the 100-H Area.

Chromium concentrations are above the 22 $\mu\text{g/L}$ RAO in several wells in the 100-H Area that are completed in the 100-H Area that are completed in the Ringold Upper Mud. The highest 2005 concentration was 96 $\mu\text{g/L}$ in well 199-H4-12C screened in the Ringold Upper Mud at

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approximately 27 m (90 ft) below ground surface. The source of this contamination is not clear, but it may be a combination of unsealed wells in the 600 Area and higher head during operations driving contamination deeper into the Ringold Upper Mud Unit.

B3.0 100-KR-4 CONCEPTUAL MODEL UPDATE

This section describes the sources of chromium contamination in the 100-K Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate dihydrate, $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$ is a corrosion inhibitor that was added to Columbia River water used as reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium is readily adsorbed by soil particles and is relatively insoluble in groundwater, with a pH of >6.0 .

The primary source of chromium contamination in the 100-K Area is thought to be the 116-K-2 Trench. Large volumes of chromium-contaminated reactor coolant water and other reactor effluents were discharged into the trench between 1955 and 1971. The 116-K-2 Trench was approximately 1,250 m (4,101 ft) long, 14 m (46 ft) wide, and 5 m (16 ft) deep in its original configuration. The trench was excavated parallel to and about 250 m (820 ft) from the Columbia River (DOE-RL 1996b). Lists of other potentially significant sources that may have contributed to chromium contamination in the 100-K Area are presented in conceptual site model report (BHI 1996) and in *Summary of Hanford Site Groundwater Monitoring for Fiscal Year 2002* (PNNL 2003).

The reactor coolant water and other liquids discharged to the trench contained an estimated 300,000 kg of sodium dichromate, as well as other chemical wastes and a significant radiological inventory. An estimated 2,100 Ci of radionuclides were disposed to the trench (Dorian and Richards 1978, WHC 1994).

The unconfined aquifer in the 100-K Area is situated in the Ringold Unit E facies of the Ringold Formation. The base of the unconfined aquifer is formed by Ringold Formation paleosols and overbank deposits. The Ringold Unit E facies in the 100-K Area may be more cemented and less eroded than in the surrounding 100 Areas. This is evidenced by Coyote Rapids, located upstream of the 100-K Area, which is made up of very resistant, well-cemented Ringold Unit E sediments. Additional hydrostratigraphic description is presented in the remedial design report and remedial action work plan (DOE-RL 1996b) and in *Geology of the 100-K Area, Hanford Site, South-Central Washington* (WHC 1993).

Groundwater flow in the 100-K Area is predominantly to the northwest. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices, and hydrogeology.

Groundwater flow is generally toward the Columbia River, except near the river during May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the river level and may reverse the groundwater flow direction (inland flow). The releases are managed to balance summer irrigation demand and power (electricity) production and to maintain safe river elevations for fisheries management.

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When the K Reactors were in operation, the full length of the 116-K-2 Trench was filled to capacity with reactor coolant water. A groundwater mound about 6 m (20 ft) higher than the natural water table caused flow inland (southeast) and toward the river (northwest). Mounding has been observed at well 699-78-62, which is located approximately 1.6 km (1 mi) from the 116-K-2 Trench (see Figure B-5). Any mounding should have long since dissipated; however, the contaminated groundwater is moving downgradient and may be draining the lower vadose zone.

Hydrogeology has a strong influence on flow rate in the 100-K Area. The hydraulic conductivities vary greatly from 200 m/day (656 ft/day) in local areas downgradient of the 116-K-2 Trench to 2 m/day (6.6 ft/day) in the injection well area. The range of hydraulic conductivities is likely a function of the degree of cementation of the Ringold Unit E sediments. Slug test results are reported in the conceptual site model report (BHI 1996).

The original 1997 100-K pump-and-treat target area was oblong in shape, on the downstream side of the 116-K-2 Trench, extending the full length of the trench (Figure B-6). The 100 $\mu\text{g/L}$ chromium isopleth extended the full length of the trench. Six extraction wells were constructed to capture the known plume.

The November 2006 100-K chromium plume map is shown in Figure B-6. Monitoring well 199-K-131 was added to the network during 2004 to monitor downstream concentrations of chromium. This well contained an average of 74 $\mu\text{g/L}$ of hexavalent chromium in November 2005. Six wells were sampled for chromium in the Hanford Generating Plant area during May 2005. The analytical results indicate that the chromium plume has not reached this area.

B4.0 100-NR-2 CONCEPTUAL MODEL UPDATE

The conceptual model for strontium-90 contamination at the 100-N Area is discussed in detail in the *N-Springs Expedited Response Action Performance Evaluation Report* (DOE-RL 1996a). Groundwater chemistry data, water-level data, and operational information gathered since 1995 continue to support the original conceptual model. This update will briefly describe the 1995 conceptual model and provide information about source removal from 1995 until cold shutdown in 2006.

The main sources of strontium-90 contamination are the 1301-N Liquid Waste Disposal Facility (LWDF) (also known as the 116-N-1 Facility) and the 1325-N LWDF (also known as the 116-N-3 Facility). The 1301-N Facility operated from 1964 to September 1985 and the 1325-N Facility operated from 1983 to 1991. These facilities received liquid wastes from N Reactor that contained strontium-90, cobalt-60, cesium-137, plutonium, and tritium. Tritium was transported through the soil column with the liquid wastes, reaching and then moving with the groundwater. Cesium-137, cobalt-60, and plutonium were concentrated in the upper portion of the soil column beneath the LWDFs. Strontium-90 was spread throughout the soil column and into the upper aquifer.

The upper aquifer in the 100-N Area is contained in the Ringold Unit E facies of the Ringold Formation. The base of the upper aquifer is the Ringold Upper Mud Unit. The Ringold Unit E sediments at the 100-N Area are composed of sandy gravel to sandy silt. Strontium-90 is adsorbed preferentially onto the silt-sized aquifer solids and is in equilibrium with dissolved-phase strontium-90. Dissolved-phase strontium-90 that was removed by pump-and-treat

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operations will come back into equilibrium with the adsorbed phase when extraction ceases. It should also be noted that adsorbed strontium-90 on aquifer solids from past discharges occurs near the shoreline, based on core samples from well 199-N-95A (DOE-RL 1994). Additional details regarding the strontium-90 adsorption-desorption process can be found in DOE-RL (1996a).

Dissolved-phase strontium-90 likely extends into the riverbed to some extent based on strontium-90 concentrations of 3,340 pCi/L detected in aquifer tube NS-3A-87cm in 2005 and 2,940 pCi/L in aquifer tube NVP2-116m in 2006. This source is beyond the influence of the pump-and-treat capture zone, as discussed below. However, based on sediment core profiles from near the shoreline and near the 1301-N Trench, the expected concentrations of adsorbed strontium-90 in the riverbed should be much lower than in the more central portion of the capture zone in the vicinity of the 1301-N Trench. Dissolved-phase strontium-90 concentrations were 11,200 pCi/L in well 199-N-67, which is located adjacent to the former 1301-N LWDF.

The general historical trends of strontium-90 and tritium results (shown in Figures B-7 and B-8, respectively), the 2005 and 2006 strontium-90 plumes, and the 1995 and 2005 tritium plumes illustrate several important points relevant to a groundwater remedial action conceptual model:

- The areal extent of the strontium-90 plume has not changed significantly since pump-and-treat operations began in 1995, as shown in Figure B-7. This lack of change is a result of the well-known adsorption-desorption kinetics of strontium-90, which cause elevated pore-fluid concentrations to persist in the near-shore aquifer long after crib discharges have ceased and after 10 years of the pump-and-treat system operations.
- The change in the tritium plume between 1995 and 2005 is clearly displayed in Figure B-8. Low concentrations of tritium along the shoreline in 2005 confirm that tritium flux to the river has nearly been nearly eliminated by pump-and-treat operations, which have created a hydraulic barrier along the river shore. Tritium concentrations persist in monitoring wells that lie between the extraction wells and the injection wells, suggesting a continuing recirculation cell. The reduction in tritium concentration in the inland wells is a result of the short half-life of tritium (<13 years). The inverse relationship between strontium-90 and tritium in near-shore monitoring wells is shown in Figure B-9.

These observations suggest that the pump-and-treat system has had little, if any, measurable impact on the near-shore groundwater concentrations of strontium-90, as predicted by previous numerical modeling. Thus, for remedial action purposes, the near-shore aquifer or stream-bank storage zone must be considered as a separate, semi-isolated portion of the aquifer that requires a different approach to control strontium-90 concentrations in the near-shore aquifer and discharge to the river. This near shore environment is currently being studied as part of an ongoing apatite sequestration treatability test.

The January 1995 strontium-90 inventory for the 1301-N and 1325-N LWDF soil column and underlying saturated zone was 1,866 Ci. In this total, 88 Ci were estimated adsorbed to soil particles in the saturated zone and 0.8 Ci were dissolved in groundwater (DOE-RL 1996a). The remaining inventory was assumed to be absorbed to soil particles in the vadose zone beneath the LWDFs. The 2005 estimated inventory of adsorbed saturated zone strontium-90 has decayed to approximately 69 Ci.

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Because the pump-and-treat system has been ineffective in reducing strontium-90 concentrations in groundwater that reaches the river, alternative treatment methods are being evaluated. Laboratory studies of strontium-90 sequestration by apatite continued during the year. Favorable results for one approach led to the decision to prepare a treatability test plan for a pilot-scale field test and installation of a 9-m (29.5-ft) barrier in fiscal year 2006. The barrier will be placed where the highest clam tissue and aquifer tube strontium-90 concentrations have been observed. The goal is to create a permeable reactive barrier near the shoreline that will capture strontium-90 as groundwater flows through a treatment zone created by injection of apatite-forming chemicals.

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Figure B-2. 100-D Area Chromium Plume Map, 1995 and 2006.

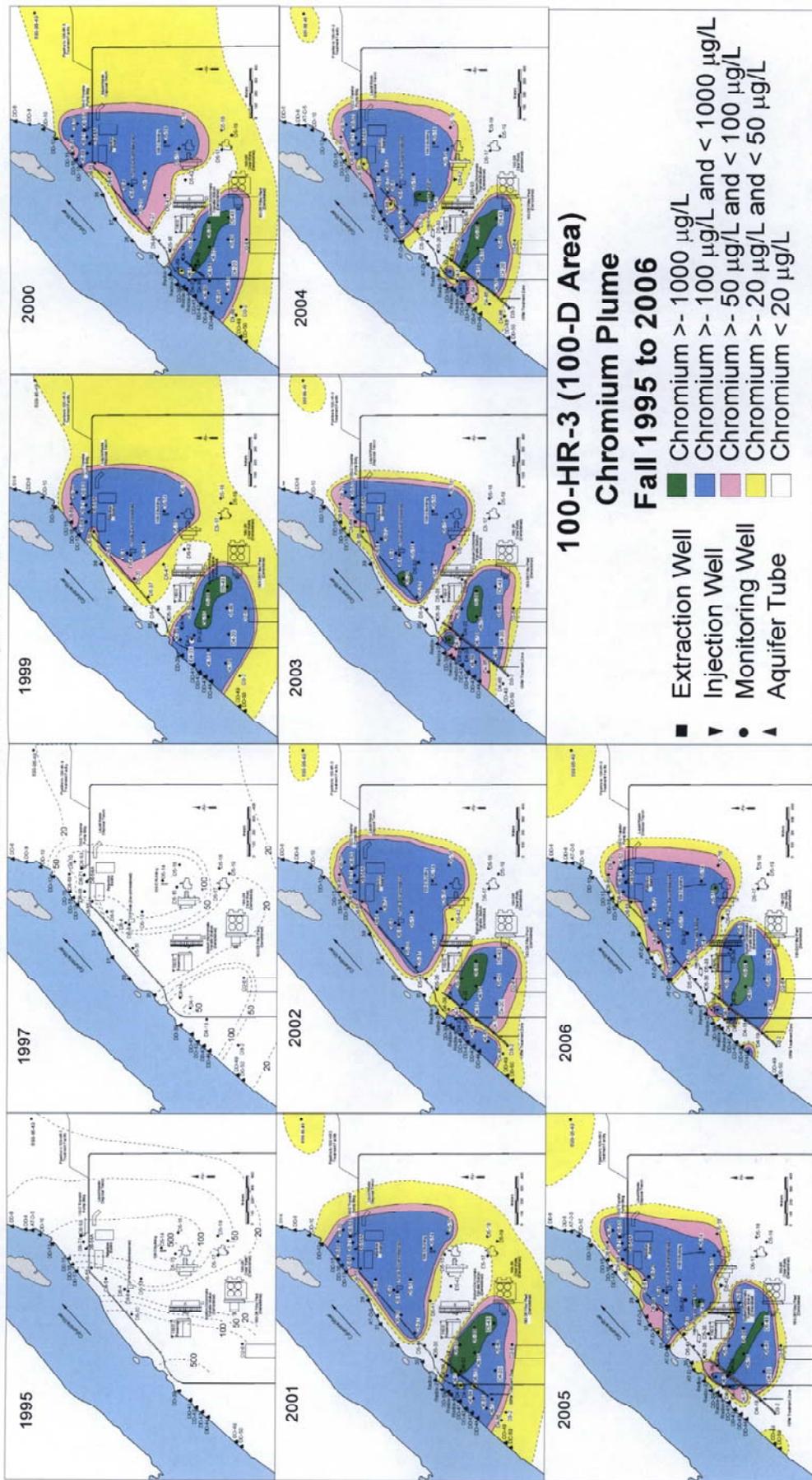
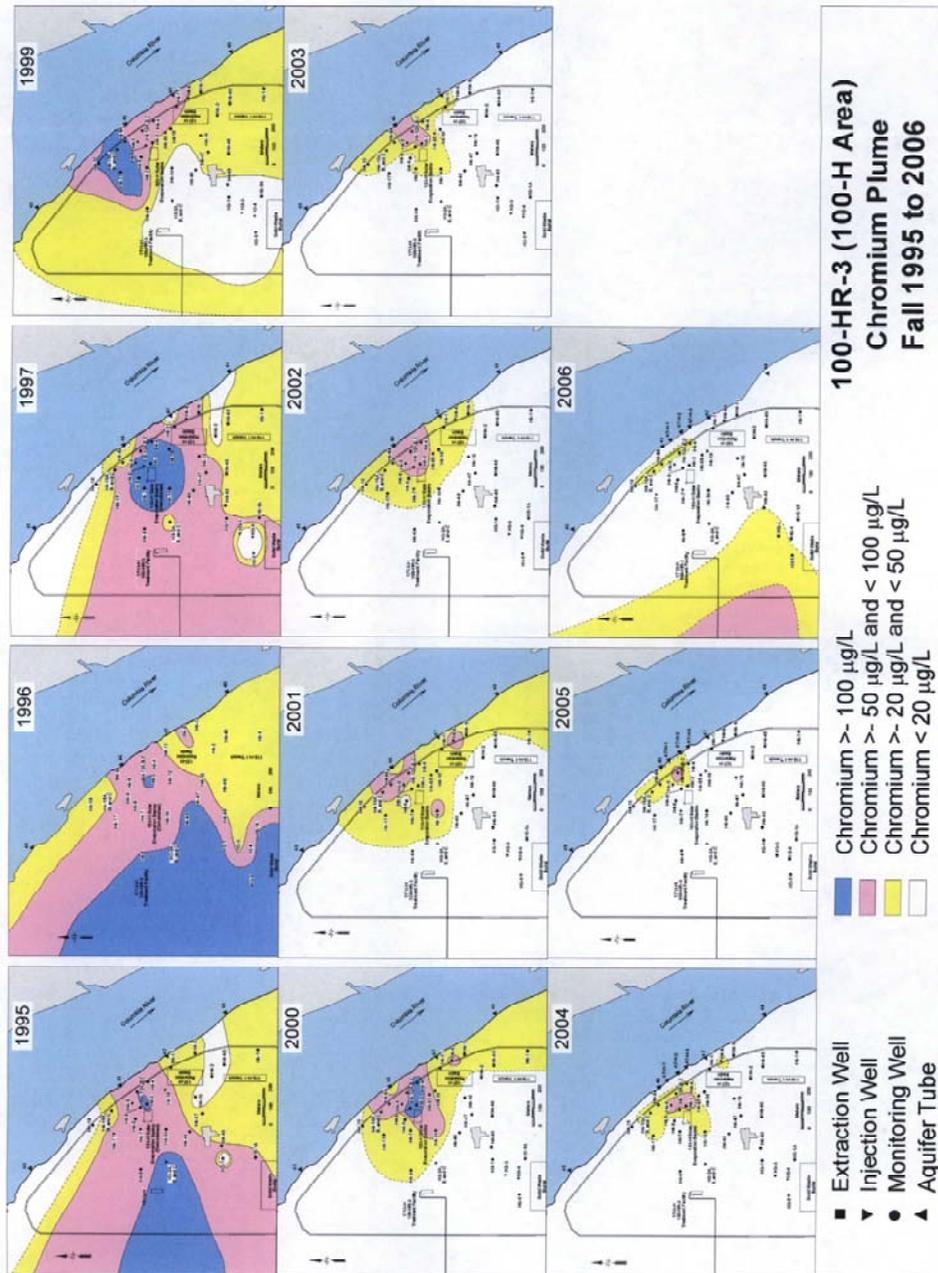


Figure B-4. 100-H Area Chromium Plume Map, 1995 and 2006.

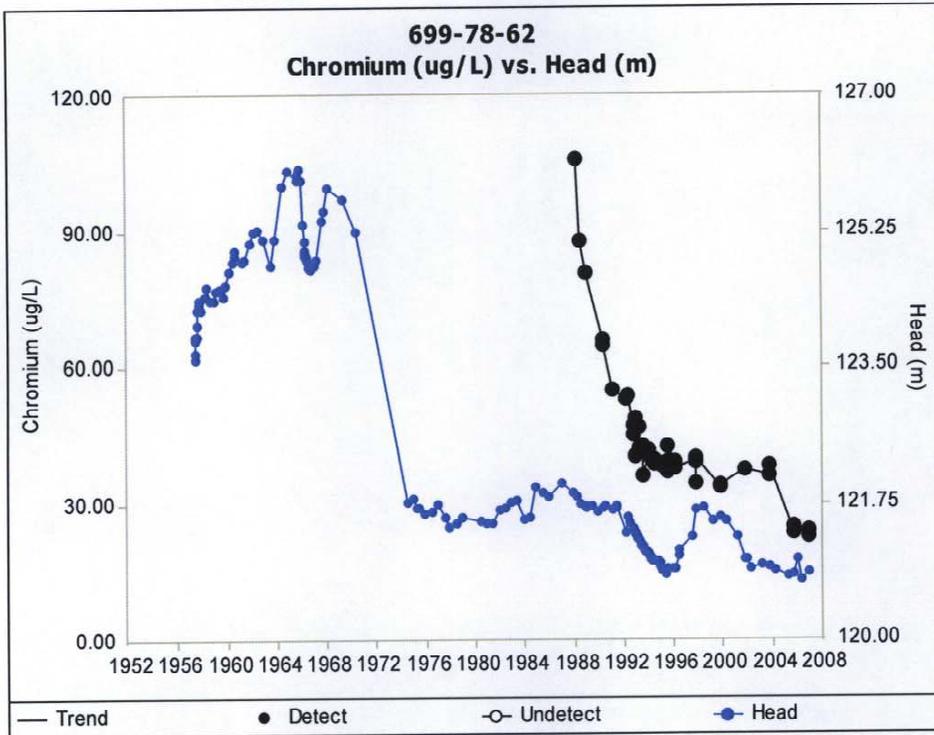


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Figure B-5. Head and Total Chromium in Well 699-78-62, 100-K Area.

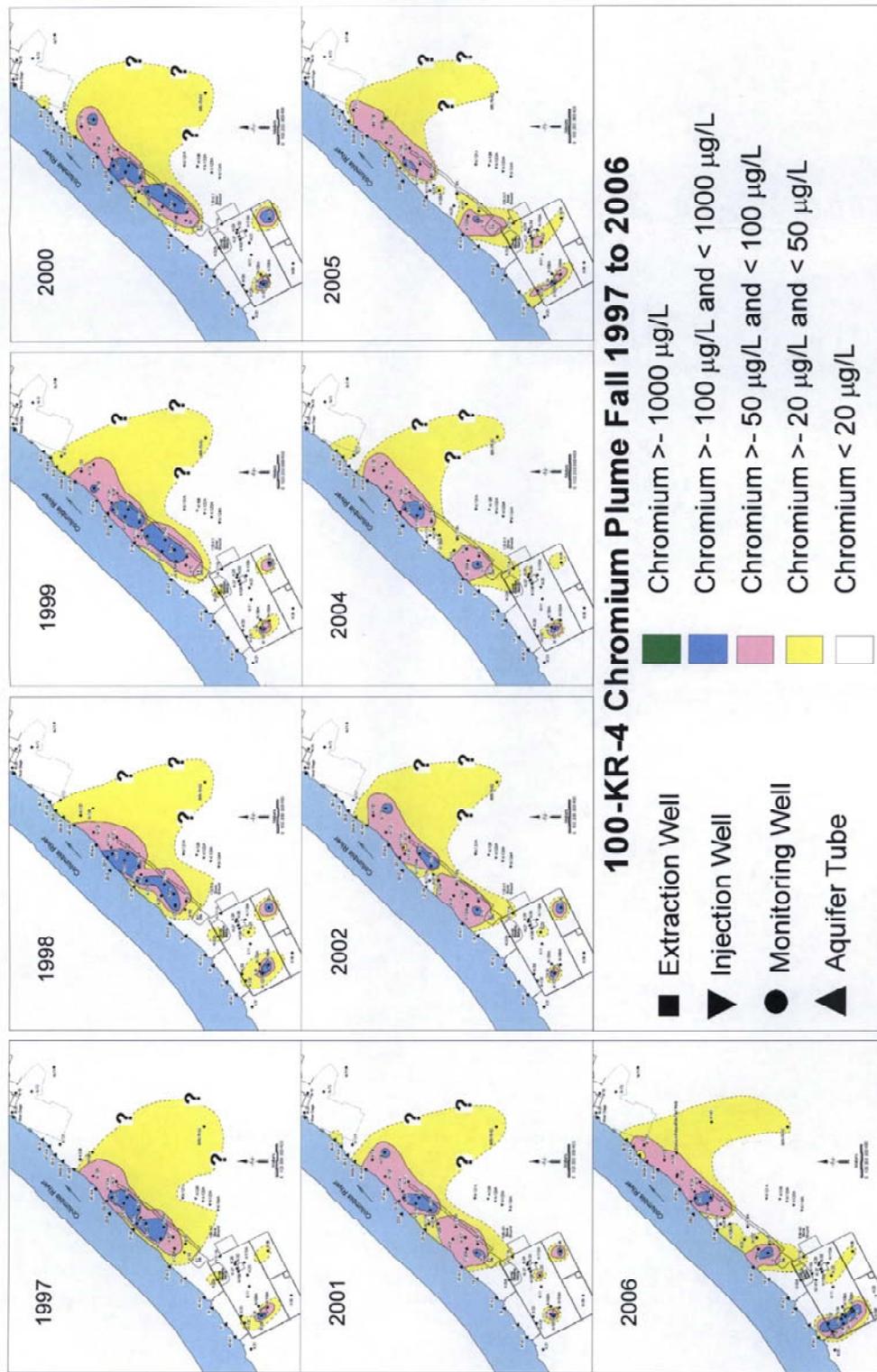


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Figure B-6. 100-K Chromium Plume Map and Baseline, 1995 and 2006.



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Figure B-7. 100-NR-2 Strontium-90 and Specific Conductance for 2005 and 2006.

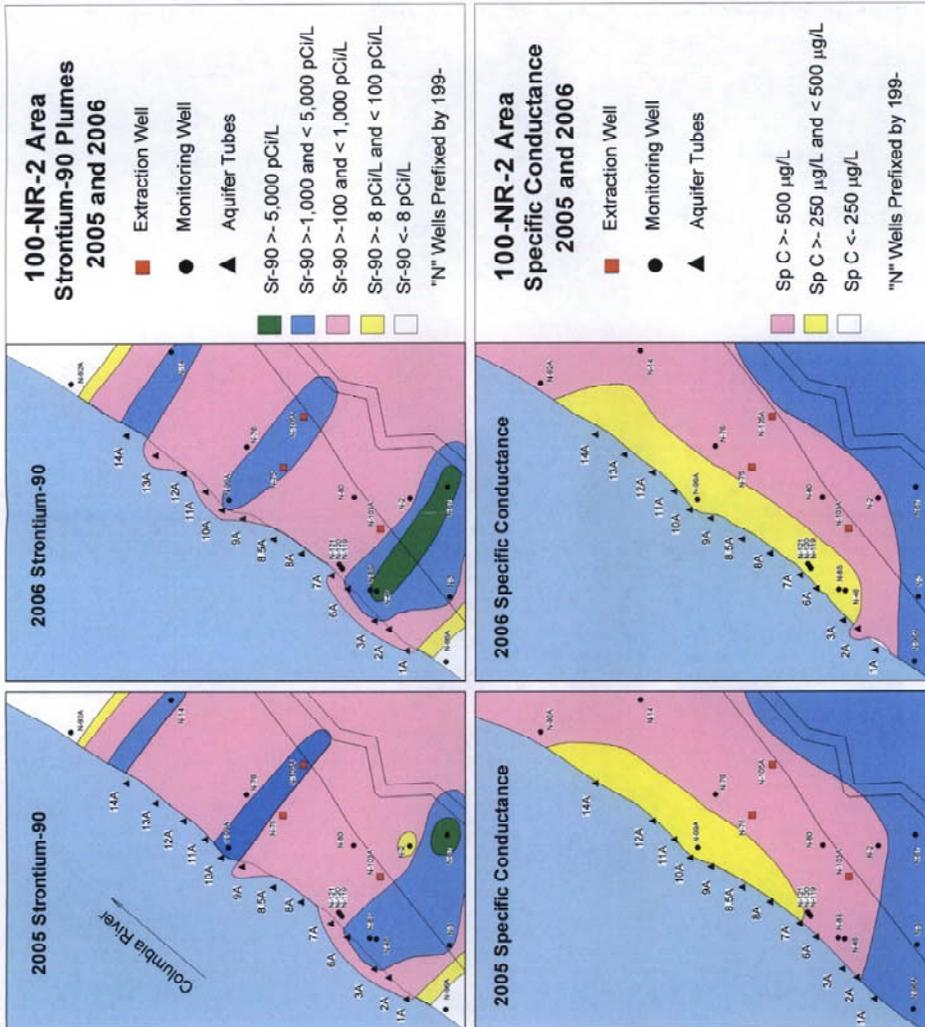
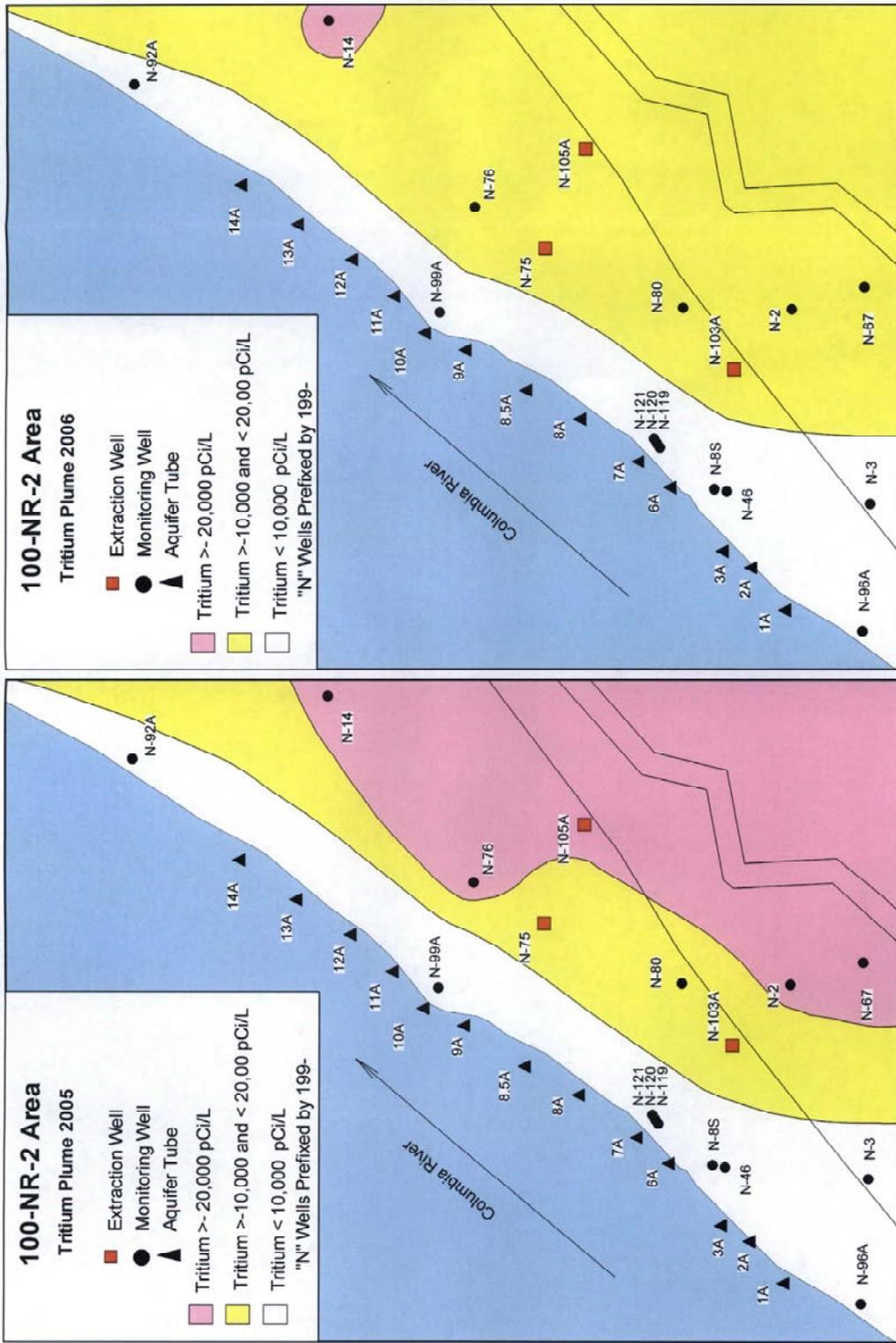


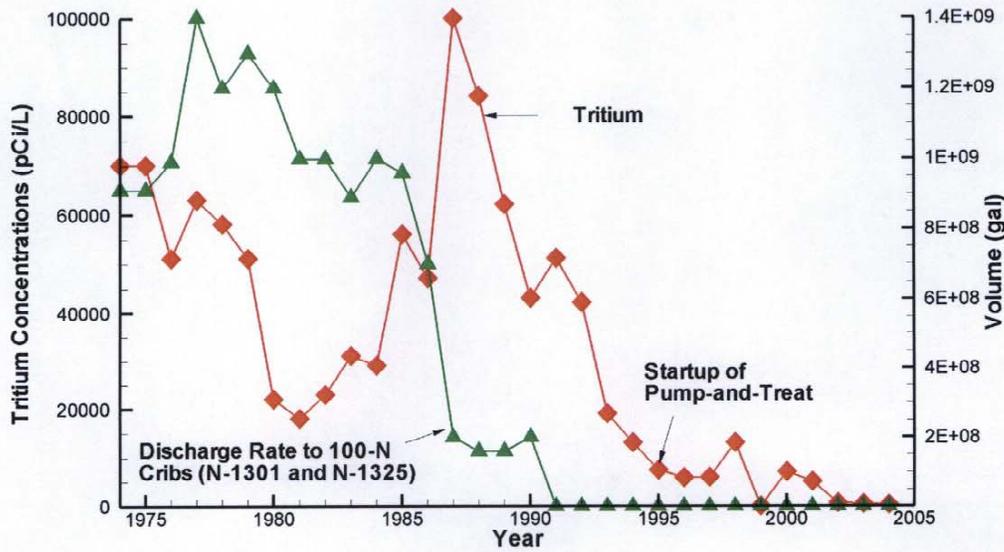
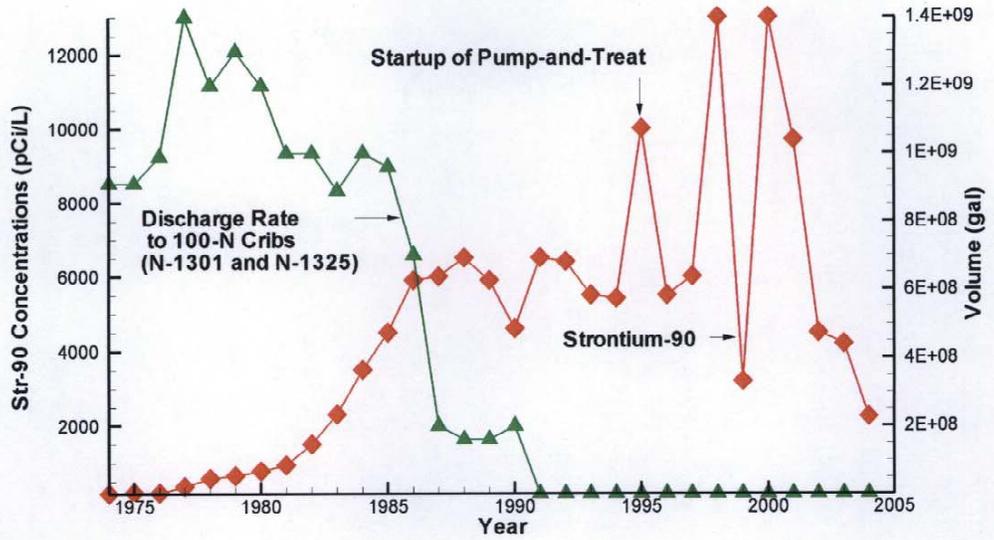
Figure B-8. 100-NR-2 Tritium Plume, 2005 and 2006.



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Figure B-9. Strontium-90 and Tritium in Near-Shore Monitoring Wells 199-N-8 and 199-N-46.



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APPENDIX C
TREATMENT SYSTEM PERFORMANCE

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APPENDIX C

TREATMENT SYSTEM PERFORMANCE

C1.0 100-HR-3 AND DR-5 TREATMENT SYSTEM PERFORMANCE

The following tables present a summary of 100-HR-3 and DR-5 pump-and-treat operational parameters:

- Table C-1 presents the average extraction rates for the DR-5 system for calendar year 2006 (CY06).
- Table C-2 provides the DR-5 extraction well chromium concentrations.
- Table C-3 provides the 100-HR-3 pump-and-treat summary of operations.
- Table C-4 provides the minimum, maximum, and average chromium concentrations for extraction wells in 100-HR-3.
- Table C-5 provides a comprehensive presentation of system availability since system startup.
- Table C-6 presents average extraction rates since system startup and the percentage run-time for extraction wells.

C2.0 100-KR-4 TREATMENT SYSTEM PERFORMANCE

The following tables present a summary of the 100-KR-4 pump-and-treat operational parameters:

- Table C-7 provides the 100-KR-4 pump-and-treat summary of operations.
- Table C-8 provides the minimum, maximum, and average chromium concentrations for extraction wells in 100-KR-4.
- Table C-9 provides a comprehensive presentation of system availability since system startup.
- Table C-10 presents average extraction rates since system startup and the percentage run-time for extraction wells.
- Table C-11 provides the average extraction rates for CY97 to CY06.

C3.0 100-NR-2 TREATMENT SYSTEM PERFORMANCE

The following tables present a summary of the 100-NR-2 pump-and-treat operational parameters:

- Table C-12 provides the volume of groundwater treated and strontium removed since startup of operations at 100-NR-2, presented on a quarterly schedule.

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- Table C-13 provides the average strontium-90 activities for influent and effluent tanks at the 100-NR-2 pump-and-treat system.
- Table C-14 provides the summary of system availability.

Table C-1. DR-5 Average Extraction Rates, Calendar Year 2006.

Well	2006												Total Hours On-Line	Avg Monthly Flow Rate (gpm)	Total Run-Time (%)	
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.				
199-D5-20	7.5	7.5	7.5	7.5	7.5	7.5	7.4	0	0	7.5	7.5	7.5	7.5	6,696.9	7.5	76.4
199-D5-32	14.5	13.5	14.3	14.5	21.0	14.5	14.5	17.5	18.3	14.6	13.9	12.4	12.4	8,277.3	15.3	94.5
199-D5-39	14.5	13.4	14.3	14.5	14.5	14.5	14.5	17.4	15.2	14.5	13.9	12.4	12.4	7,828.5	14.5	89.4
199-D5-92	7.5	7.5	7.5	7.5	8.1	7.5	7.2	8.5	12.1	8.0	7.7	7.5	7.5	1,728.1	8.1	19.7

^a Total hours on-line / total possible run-time.
gpm = gallons per minute

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Table C-2. DR-5 Extraction Well Chromium Concentrations for Calendar Year 2006.

Location/ Well	CY06 Avg. Cr ⁺⁶ (µg/L)	CY06 Min. Cr ⁺⁶ (µg/L)	CY06 Max. Cr ⁺⁶ (µg/L)
199-D5-20	506	404	594
199-D5-32	888	422	1,120
199-D5-39	1,148	136	1,895
199-D5-92	256	136	479
DR-5 influent ^a	790.2	479	1,080
DR-5 effluent	2.7	0	30

CY = calendar year

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Table C-3. 100-HR-3 Pump-and-Treat Summary of Operations.

Activity	CY01	CY02	CY03	CY05	CY06
System availability (%)	99.8	99.8	99.9	94.1	99.1
100-D Area volume treated (L)	184,133,793	237,450,895	164,244,767	189,354,116	229,370,623
100-H Area volume treated (L)	166,434,370	179,197,084	153,462,037	136,173,155	164,648,024
Total volume treated (L)	350,568,163	416,647,979	317,706,804	325,527,272	394,018,647
Combined contaminant mass removed (g) ^a	NA	NA	NA	NA	4,359
100-D Area contaminant mass removed (g) ^b	28,067	38,331	30,145	25,656	21,797
100-H Area contaminant mass removed (g) ^b	3,977	4,660	3,529	7,818	2,511
Total contaminant mass removed (g)	32,044	42,992	33,675	33,474	28,667
Removal efficiency (% by mass)	93.8	93.8	95.2	93.5	93.6
Waste generation (m ³) ^c	66.7	80.5	81.6	11.3	0
Low-level radioactive waste generation (m ³)	13.4	4.5	NA	NA	NA
Regenerated resin installed (m ³)	32.2 m ³	43	40.8	63.4	61.2
New resin installed (m ³)	34.5 m ³	36.2	40.8	4.5	11.3
Number of vessels changed	29	35	36	30	32

^a For the time period January 1 to February 5, 2006.

^b For the time period February 6 to December 31, 2006.

^c Each ion-exchange vessel contains 2.3 m³ of ion-exchange resin.

CY = calendar year

NA = not available

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Table C-4. 100-HR-3 Extraction Well Chromium Concentrations. (2 sheets)

Location/ Well	CY03 Avg. Cr ⁶⁺ (µg/L)	CY03 Min. Cr ⁶⁺ (µg/L)	CY03 Max. Cr ⁶⁺ (µg/L)	CY04 Avg. Cr ⁶⁺ (µg/L)	CY04 Min. Cr ⁶⁺ (µg/L)	CY04 Max. Cr ⁶⁺ (µg/L)	CY05 Avg. Cr ⁶⁺ (µg/L)	CY05 Min. Cr ⁶⁺ (µg/L)	CY05 Max. Cr ⁶⁺ (µg/L)	CY06 Avg. Cr ⁶⁺ (µg/L)	CY06 Min. Cr ⁶⁺ (µg/L)	CY06 Max. Cr ⁶⁺ (µg/L)
199-D8-53	103	23	167	91.4	34	150	79.2	21	120	66.7	9	129
199-D8-54A	106	11	168	119	40	163	109.5	4	145	79	19	168
199-H3-2A	11	4	30	6.8	4	10	5.0	5	5			
199-H4-3	—	—	—	—	—	—	25.1	11	39	25.9	6	73
199-H4-4	—	—	—	—	—	—	23.1	10	46	15.1	2	52
199-H4-7	27	14	51	15	9	21	16.0	16	16	—	—	—
199-H4-11	27	18	42	21.6	17	27	17.7	10	41	—	—	—
199-H4-12A	53	16	125	39	6	70	48.5	23	78	22.5	3	68
199-H4-15A	50	35	74	40.8	27	50	41.5	21	58	23.5	7	55
199-D8-68	87	8	192	99.2	16	150	60.5	12	108	65.9	88	126
199-D8-72	490	291	626	486.6	408	540	428.7	38	530	422.6	3	556
199-H4-63	—	—	—	—	—	—	19.1	11	35	16.3	7	27
199-H4-64	—	—	—	—	—	—	36.2	20	84	20	2	40
199-H4-65	23.5	15	38	—	—	—	8.6	0	23	8	1	8
100-D Area influent ^a	176.1	70	292	194.1	98	302	155.3	70	248	155.7	115	180

Table C-4. 100-HR-3 Extraction Well Chromium Concentrations. (2 sheets)

Location/ Well	CY03		CY04		CY05		CY06		CY07		CY08	
	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)
100-H Area influent ^a	28	16	23	102	63.2	16	138	91.2	76	105		
Effluent tank	7.3	0(U)	5.4	99	NA	0(U)	NA	5.7	0	21		

NOTE: Data presented herein are stored in the project-specific database. The chromium data are also stored in the Hanford Environmental Information System database. The data are collected in support of operations.

^a Before the system modification on August 5, 1998, the influent for the 100-D and 100-H Areas was combined.

- CY = calendar year
- U = undetected
- = not applicable
- NA = not available at time of report preparation

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Table C-5. 100-HR-3 Summary of System Availability
(July 1, 1997, to December 31, 2006).

Year	Total Time On-Line (hours)	Total Possible Run-Time (hours)	Scheduled Downtime (hours)	Unscheduled Downtime (hours)	Total Availability (%) ^a	Scheduled Availability (%) ^b
1997	3,866	4,416	2	548	87.5	87.6
1998	7,038	8,760	368	1,355	80.3	84.5
1999	7,782	8,760	290	689	88.8	92.1
2000	8,397	8,784	157	230	95.6	97.4
2001	8,411	8,760	92	258	96.0	97.1
2002	8,525	8,760	218	17	97.3	99.8
2003	8,570.5	8,760	173	16.5	97.8	99.8
2004	8,710	8,784	73	1	99.1	99.9
2005	8,036.2	8,760	209.1	514.7	91.7	94.1
2006	8,684	8,760	59.8	16.2	99.1	99.3

^a Total availability = (total possible run-time - scheduled and unscheduled downtime) / total possible run-time.

^b Scheduled availability = (total possible run-time - unscheduled downtime) / total possible run-time.

Table C-6. 100-HR-3 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (6 sheets)

Well	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Design Flow Rate (gpm)	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
1997															
199-D8-53						39.6	25.3	28.0	33.3	39.3	31.8	24.6	40.0	31.7	78.3
199-D8-54A						39.8	25.4	28.2	32.4	38.6	31.8	24.8	40.0	31.6	78.3
199-H3-2A						40.2	42.1	26.9	32.1	32.9	17.6	30.1	40.0	31.7	88.0
199-H4-11						15.1	16.3	12.5	11.6	16.8	16.5	19.2	20.0	15.4	87.0
199-H4-12A						14.7	16.1	12.3	9.4	15.2	16.7	19.4	10.0	14.8	86.4
199-H4-15A						14.8	16.1	12.5	10.2	15.7	16.5	19.4	10.0	15.0	87.0
199-H4-65						—	—	—	—	—	—	—	20.0	—	—
199-H4-7						27.7	27.8	25.0	21.0	13.4	—	—	20.0	23.0	50.5
1998															
199-D8-53	23.7	39.3	35.7	37.0	41.7	34.4	18.2	35.3	40.3	37.7	37.7	24.2	40.0	33.8	84.4
199-D8-54A	23.8	39.1	35.7	37.0	41.7	34.3	18.7	35.2	40.1	41.0	40.7	29.9	40.0	34.8	86.0
199-H3-2A	21.4	18.6	18.5	18.4	20.1	18.4	8.4	19.4	17.7	17.1	16.5	16.4	40.0	17.6	87.9
199-H4-11	10.1	10.3	11.8	16.2	19.9	14.4	4.6	10.4	13.6	17.4	16.7	19.4	20.0	13.7	81.6
199-H4-12A	10.2	9.9	8.1	9.5	10.9	11.3	4.8	10.6	8.2	9.8	9.4	10.9	10.0	9.5	82.7
199-H4-15A	10.5	12.9	8.0	9.4	11.1	11.3	4.6	10.2	7.8	9.1	8.7	10.2	10.0	9.5	82.7
199-H4-65	—	—	—	—	—	—	—	—	—	—	—	—	20.0	—	—
199-H4-7	3.7	19.5	15.7	15.0	4.1	2.0	9.0	18.6	11.5	5.8	9.6	11.2	20.0	10.5	66.3

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Table C-6. 100-HR-3 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (6 sheets)

Well	1999												Design Flow Rate (gpm)	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.			
199-D8-53	23.5	33.8	33.7	33.6	33.7	33.8	30.5	22.9	17.4	33.0	23.2	26.2	40.0	28.8	84.7
199-D8-54A	28.1	41.5	41.4	41.3	41.3	41.3	37.3	27.9	20.8	39.6	29.8	34.2	40.0	35.4	84.7
199-H3-2A	13.3	17.5	19.2	19.3	19.5	19.7	17.6	14.8	13.0	12.1	20.4	10.5	40.0	16.4	83.8
199-H4-11	16.0	18.1	19.5	21.4	23.7	23.9	21.7	17.6	15.5	14.2	23.9	10.3	20.0	18.8	82.5
199-H4-12A	10.7	13.6	11.9	12.2	13.7	13.8	12.4	10.2	8.7	8.0	13.4	5.9	10.0	11.2	82.5
199-H4-15A	10.6	13.5	11.7	7.9	5.1	13.4	12.1	9.5	8.4	7.8	13.2	5.8	10.0	9.9	75.1
199-H4-65	—	—	—	—	—	—	—	0.4	—	—	—	—	20.0	0.4	0.4
199-H4-7	9.7	12.0	11.0	10.8	12.2	12.4	11.3	9.5	7.8	7.1	11.9	5.2	20.0	10.1	82.5
2000															
199-D8-53	28.5	29.3	34.5	39.8	39.9	39.9	40.2	40.1	39.9	36.5	34.3	32.4	40.0	36.3	95.8
199-D8-54A	33.9	37.8	38.3	40.1	40.1	40.0	40.0	40.0	39.9	39.7	36.4	32.8	40.0	38.2	94.0
199-H3-2A	27.7	23.2	17.2	19.8	20.2	20.1	20.1	19.9	19.2	19.6	21.5	18.4	40.0	20.6	84.5
199-H4-11	13.3	11.2	13.2	20.0	20.1	20.0	20.0	20.0	19.8	19.9	20.0	20.4	20.0	18.2	84.5
199-H4-12A	11.2	9.3	10.2	15.0	14.9	14.9	14.9	14.9	14.7	13.8	13.4	14.5	10.0	13.5	84.5
199-H4-15A	10.9	9.5	7.6	15.1	15.1	15.0	15.0	15.0	15.0	15.0	15.0	15.0	10.0	13.6	81.5
199-H4-65	3.5	9.9	2.7	6.4	12.9	12.6	11.9	9.4	—	—	—	—	20.0	8.7	58.9
199-H4-7	10.6	9.9	16.7	19.9	20.2	20.2	20.3	20.3	18.6	14.3	13.6	15.6	20.0	16.7	88.7

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Table C-6. 100-HR-3 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (6 sheets)

Well	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Design Flow Rate (gpm)	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
199-D8-53	32.4	32.3	32.2	31.8	28.8	32.6	23.8	20.2	18.6	18.2	19.5	23.1	40.0	26.1	91.2
199-D8-54A	32.3	32.2	32.1	32.1	24.6	32.2	24.0	20.0	19.7	20.5	20.7	33.1	40.0	27.0	92.5
199-H3-2A	17.6	17.6	18.5	20.0	18.5	19.8	18.7	20.3	18.5	18.4	18.5	20.2	40.0	18.9	95.1
199-H4-11	19.9	19.9	19.8	19.7	18.4	19.6	18.2	17.0	17.0	17.8	19.1	23.2	20.0	19.1	95.2
199-H4-12A	14.6	10.7	11.1	7.0	6.3	9.2	6.8	6.2	6.1	6.0	6.5	8.5	10.0	8.3	88.3
199-H4-15A	15.0	15.0	14.9	14.8	13.0	16.2	14.7	10.4	10.2	10.2	10.3	10.4	10.0	12.9	95.7
199-H4-65	—	—	—	—	—	—	—	—	—	—	—	—	20.0	—	—
199-H4-7	15.0	12.5	11.4	8.1	6.6	6.8	6.2	5.5	5.5	5.3	5.3	5.4	20.0	7.8	94.2
2002															
199-D8-53	27.4	32.4	25	19.4	31.3	40.5	43.2	44	23.9	18.2	21.7	20.9	40.0	29.0	89.3
199-D8-54A	34.1	32.3	29.5	23.5	31.1	40.2	40.1	40.9	34.1	22.4	34.3	34.3	40.0	33.1	91.9
199-H3-2A	20.1	20.2	21.7	23.1	17.3	20.1	20.5	20.2	20	24.9	36.2	36.2	40.0	23.4	95.6
199-H4-11	21.4	21.4	21.1	18.6	19.8	22	21.7	21.4	21.2	21.6	22.9	23.6	20.0	21.4	96.6
199-H4-12A	8.9	10.3	8.2	13.9	15.8	14.8	14.7	13.7	8.5	8.1	8.3	8.2	10.0	11.1	91.1
199-H4-15A	12.8	15.4	15.3	14.2	16.9	19.2	19.3	19	18.5	18.5	18.6	18.5	10.0	17.2	96.3
199-H4-65	—	—	—	—	—	—	—	—	—	—	—	—	20.0	—	—
199-H4-7	6.4	8.8	7.3	7.3	11.7	20.3	21.6	21.1	18.4	15.5	15.1	14.9	20.0	14.0	93.6

Table C-6. 100-HR-3 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (6 sheets)

Well	2003												Total Hours On-Line	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.			
199-D8-53	16.6	12.2	12.6	28.5	35.6	41	33.3	22.7	11.8	11.6	18.9	23.9	7,826.5	22.4	89.3
199-D8-54A	29.8	22.7	22.5	40.3	42.7	45.8	38.8	31.8	20.4	18.9	29.5	23.7	8,052	30.5	91.9
199-D8-68	—	—	—	—	—	—	—	—	—	—	—	—	5,346.5	49.1	61.0
199-D8-72	—	—	—	—	—	—	—	—	—	—	—	—	5,323	25.1	60.7
199-H3-2A	36.2	36.2	36.1	36.2	33.2	23.5	20.1	22.9	24.3	24.2	24.2	24.2	8,374	28.4	95.5
199-H4-11	24	25.6	25.7	25.7	23.6	21.2	20.4	24	24.6	25.2	23	24.7	8,464.5	23.9	96.6
199-H4-12A	7.3	5.6	6.3	8.4	11.3	11.5	11.1	9.1	6.3	6.4	8.7	9	7,976.5	8.4	91
199-H4-15A	18.5	18.6	18.6	19.8	19.1	19	19.2	20	18.7	16.5	19.6	19.8	8,432	18.9	96.2
199-H4-65	—	—	—	—	11.9	11.7	11.2	—	—	—	5.3	4.5	260	8.9	2.9
199-H4-7	12	10.5	9.8	11.7	12.5	12.8	17.5	18.6	15.9	11	14.8	13.5	8,195	13.3	93.5
2004															
199-D8-53	26.1	17.4	11.7	13.2	16.3	17	16	16.2	14.5	12.5	15.2	18.2	7,786.00	16.2	88.6
199-D8-54A	22.6	24.3	24.9	23.3	25.8	25.1	22.4	—	—	21.9	23.6	24.2	5,571	24	63.4
199-D8-68	50.2	50.3	21.8	24.9	31.1	29.4	25.9	29.6	30.7	30.5	29	29.7	8,161.00	31.9	92.9
199-D8-72	27.9	24.8	21.4	21.9	22.2	22.2	21.7	21.6	21.4	21.3	21.3	22	8,169	22.5	93
199-H3-2A	24.2	24.2	24.1	24.1	24.2	24.4	24.4	24.3	24.2	24.1	23.9	24	8,377	24.2	95.4
199-H4-11	24.3	24.4	21.9	22.8	24.7	24.7	24.7	24.6	24.6	24.6	—	13.6	6,578.00	23.5	74.9
199-H4-12A	9.6	8	6.2	6.6	7.4	7.2	6.7	7.3	7.5	7.9	7.9	8.2	7,742.00	7.5	88.1
199-H4-15A	19.7	19.7	19	19.3	20	19.9	19.7	19.7	19.7	19.6	19.4	19.5	8,092	19.6	92.1
199-H4-65	—	—	—	—	—	11.9	11.7	—	—	—	—	—	744.5	11.8	8.5
199-H4-7	14.7	13	10.6	8.8	9.4	9.8	10.2	10	10.2	10.3	10.5	10.6	7,646	10.5	87

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Table C-6. 100-HR-3 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (6 sheets)

Well	2005												Total Hours On-Line	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)			
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec						
199-D8-53	23.4	21.9	20.3	15.2	23.5	26.5	25.8	22.8	12.6	11.1	11.7	11.9	6,938	19.0	79.2			
199-D8-54A	25.5	27.1	26.6	21.1	10.0	27.6	29.5	36.1	30.6	30.2	32.2	28.3	5,579	28.2	63.7			
199-D8-68	35.0	34.9	35.9	53.5	56.1	55.6	55.8	55.0	55.1	55.1	54.9	38.0	7,456	50.4	85.1			
199-D8-72	24.5	25.4	25.8	24.0	23.3	23.4	23.8	24.5	21.4	19.2	19.1	14.7	7,438	22.6	84.9			
199-H3-2A	24.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--			
199-H4-3	--	--	--	--	--	--	--	--	6.6	7.6	7.4	6.8	2,676	7.1	30.5			
199-H4-4	8.5	7.6	7.8	6.9	8.6	8.6	8.5	--	6.4	7.1	7.2	8.1	6,415	7.7	73.2			
199-H4-7	10.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--			
199-H4-11	21.4	22.5	23.6	25.9	26.2	25.2	25.1	--	25.9	--	--	--	--	--	--			
199-H4-12A	--	--	--	--	--	--	--	--	--	--	--	--	7,196	8.7	82.2			
199-H4-15A	--	--	--	--	--	--	--	--	--	--	--	--	7,338	20	83.7			
199-H4-63	--	--	--	--	--	--	--	--	22.8	23.2	23.4	24.3	2,595	23.4	29.6			
199-H4-64	14.7	16.3	14.0	11.0	13.3	11.6	17.3	13.5	9.6	8.3	9.1	10.3	6,870	12.0	78.4			
199-H4-65	13.6	14.3	15.3	17.7	17.9	18.0	18.1	--	--	--	--	--	--	--	--			
2006													Total Hours On-Line	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)			
199-D8-53	14.9	15.7	13.2	22.2	32.7	26.9	32.2	24.0	10.8	6.1	7.1	10.0				18.1	89.6	14.9
199-D8-54A	37.9	42.4	32.2	41.4	53.9	46.9	44.5	35.8	18.4	13.5	16.4	18.1				33.7	92.7	37.9
199-D8-68	55.7	55.8	55.8	55.9	49.8	34.9	42.7	55.6	56.0	56.1	56.2	55.8				52.5	96.9	55.7
199-D8-72	18.7	20.4	18.0	18.2	22.8	24.3	22.7	19.0	13.4	10.3	10.6	10.5				17.4	96.3	18.7

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Table C-6. 100-HR-3 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (6 sheets)

Well	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Hours On-Line	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
199-H3-2A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
199-H4-3	8.2	9.9	5.1	5.3	8.9	7.4	5.6	5.1	4.9	5.8	6.3	7.5	6.6	98.7	8.2
199-H4-4	7.6	8.1	8.3	8.1	8.9	10.6	10.5	9.4	6.6	5.7	5.9	6.8	8.1	88.6	7.6
199-H4-7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
199-H4-11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
199-H4-12A	7.4	8.4	7.2	10.4	14.0	18.1	17.5	9.1	6.2	5.4	6.2	6.3	9.7	97.8	7.4
199-H4-15A	20.0	20.0	20.0	19.9	19.8	19.9	20.0	20.0	20.0	20.0	20.0	18.9	19.9	98.9	20.0
199-H4-63	24.6	23.6	24.3	24.5	24.9	25.0	25.0	24.9	24.7	24.6	24.6	24.5	24.6	96.6	24.6
199-H4-64	12.9	10.1	10.3	17.5	25.5	41.8	22.4	13.3	12.1	9.5	11.6	12.1	16.6	97.1	12.9
199-H4-65	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

^a Total hours on-line / total possible run-time.

gpm = gallons per minute

-- = not applicable

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Table C-7. 100-KR-4 Pump-and-Treat Summary of Operations for Calendar Year 2006.

Activity	CY02	CY03	CY04	CY05	CY06
System availability (%)	98.3	99.3	99.1	97.3	99.7
Total volume treated (L)	445,740,587	517,640,068	500,016,928	529,515,373	525,895,008
Total contaminant mass removed (g)	35,291	36,657	29,603	25,631	21,005
Removal efficiency (% by mass)	95	95.2	93.6	94.3	85.1
Waste generation (m ³) ^a	58	96.6	80.5	13.6	0
Regenerated resin installed (m ³)	25.3	52.1	39	49.8	56.6
New resin installed (m ³)	55.2	43	41.5	13.6	11.3
Number of vessels changed	35	42	35	28	30

^a Each ion-exchange vessel contains 2.3 m³ of ion-exchange resin.
CY = calendar year

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Table C-8. 100-KR-4 Extraction Well Chromium Concentrations.

Location/ Well	2002		2003		2003		2003		2004		2004		2004		2005		2005		2005		2006		2006		2006	
	Avg. Cr ⁶⁺ (µg/L)	—	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)	Avg. Cr ⁶⁺ (µg/L)	Min. Cr ⁶⁺ (µg/L)	Max. Cr ⁶⁺ (µg/L)
199-K-112A	75	—	72	60	81	NA																				
199-K-113A	51	—	63	41	77	66.1	23	102	61.5	40	78	49.8	15	78	49.8	15	78	49.8	15	78	49.8	15	78	49.8	15	78
199-K-114A	—	—	—	—	—	—	—	—	43.4	6	105	45.5	0	100	45.5	0	100	45.5	0	100	45.5	0	100	45.5	0	100
199-K-115A	94	—	95	52	126	84.4	54	138	86.5	67	98	79.0	41	109	79.0	41	109	79.0	41	109	79.0	41	109	79.0	41	109
199-K-116A	126	—	113	61	146	84.1	57	110	71.5	22	89	63.9	22	96	63.9	22	96	63.9	22	96	63.9	22	96	63.9	22	96
199-K-118A	N/A	—	NA																							
199-K-119A	75	—	54	38	89	30.2	25	39	21.1	8	31	19.5	9	73	19.5	9	73	19.5	9	73	19.5	9	73	19.5	9	73
199-K-120A	69	—	76	63	86	69.4	62	80	64.8	54	72	61.6	35	74	61.6	35	74	61.6	35	74	61.6	35	74	61.6	35	74
199-K-125A	67	—	50	30	149	34.1	28	42	27.9	14	83	23.1	0	84	23.1	0	84	23.1	0	84	23.1	0	84	23.1	0	84
199-K-126	—	—	102	76	132	83.3	60	97	NA	NA	NA	13.3	2	51	13.3	2	51	13.3	2	51	13.3	2	51	13.3	2	51
199-K-127	—	—	61	31	75	60.8	45	136	38.5	26	50	32.6	21	62	32.6	21	62	32.6	21	62	32.6	21	62	32.6	21	62
199-K-129	—	—	67	51	87	52	35	64	48.5	41	60	48.9	28	76	48.9	28	76	48.9	28	76	48.9	28	76	48.9	28	76
100-K Area influent	85	—	75	55	93	62.9	45	84	51	33	64	45.6	23	62	45.6	23	62	45.6	23	62	45.6	23	62	45.6	23	62
Effluent tank	4	—	3.1	1	11	3.8	1	16	3	0	16	5.3	0	15	5.3	0	15	5.3	0	15	5.3	0	15	5.3	0	15

NOTE: Data presented herein are stored in the project-specific database.

N/A = not available

— = not applicable

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Table C-9. 100-KR-4 Summary of System Availability
(July 1, 1997, to December 31, 2006).

Year	Total Time On-Line (hours)	Total Possible Run-Time (hours)	Scheduled Downtime (hours)	Unscheduled Downtime (hours)	Total Availability (%) ^a	Scheduled Availability (%) ^b
1997	2,374	4,416	0	2,042	53.8	53.8
1998	7,742	8,760	10	1,009	88.4	88.5
1999	8,629	8,760	61	70	98.5	99.2
2000	8,387	8,784	292	105	95.5	98.8
2001	8,466	8,760	29	266	96.6	97.0
2002	8,255	8,760	359	145	94.3	98.3
2003	8,563	8,760	142	55	96.7	99.3
2004	8,431	8,784	277.5	75.5	95.9	99.1
2005	8,345.9	8,760	178.3	235.8	95.3	97.3
2006	8713.2	8,760	24.2	22.8	99.5	99.7

^a Total availability = (total possible run-time - scheduled and unscheduled downtime) / total possible run-time.

^b Scheduled availability = (total possible run-time - unscheduled downtime) / total possible run-time.

Table C-10. 100-KR-4 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (4 sheets)

Well	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Design Flow Rate (gpm)	Ave. Monthly Flow Rate (gpm)	Total Run-Time (%)
1997															
199-K-113A										24.0	21.1	23.0	25.0	22.7	91.7
199-K-115A										24.6	21.3	22.3	25.0	22.7	89.9
199-K-116A										16.3	19.3	22.8	25.0	19.5	78.9
199-K-119A										24.4	21.5	22.1	25.0	22.6	89.9
199-K-120A										24.3	21.4	23.0	25.0	22.9	79.8
No data available.															
1998															
199-K-113A	26.1	25.7	25.6	17.5	—	—	17.8	24.4	25.5	25.0	12.9	12.4	25.0	21.3	74.8
199-K-115A	25.5	25.6	24.9	18.0	3.0	30.5	26.6	25.5	25.2	24.9	29.1	29.3	25.0	24.0	89.3
199-K-116A	25.7	25.7	25.0	27.0	12.0	45.5	43.3	46.4	46.3	38.9	25.9	24.2	25.0	32.1	90.4
199-K-119A	25.1	25.5	25.3	18.0	5.6	29.4	25.8	24.2	25.0	24.7	25.2	25.1	25.0	23.2	89.6
199-K-120A	25.1	25.3	25.8	18.2	5.4	26.9	26.8	26.5	25.2	24.9	25.5	25.6	25.0	23.4	90.4
199-K-125A										9.9	25.8	24.9	25.0	20.2	71.3
No data available.															
1999															
199-K-113A	25.1	25.4	25.1	25.1	25.4	25.8	25.6	30.2	28.1	25.3	23.9	23.9	25.0	25.7	97.3
199-K-115A	25.8	26.0	25.8	25.9	25.4	25.9	25.7	29.6	33.8	34.0	34.2	29.4	25.0	28.5	97.3
199-K-116A	25.9	26.2	25.7	25.8	25.7	25.8	25.8	30.1	35.3	33.8	29.7	14.9	25.0	27.1	92.3
199-K-119A	25.0	24.7	25.5	25.6	25.6	25.5	23.0	—	—	9.0	34.7	25.0	25.0	24.4	74.2
199-K-120A	25.7	25.5	25.6	25.6	25.6	26.0	25.9	30.1	34.9	34.7	34.2	24.7	25.0	28.2	96.2
199-K-125A	28.2	27.1	25.8	26.2	19.4	26.6	26.0	30.0	34.3	32.6	34.5	30.5	25.0	28.4	95.3

Table C-10. 100-KR-4 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (4 sheets)

Well	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Design Flow Rate (gpm)	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
2000															
199-K-113A	15.3	23.5	22.2	20.7	5.5	9.6	24.7	24.2	22.6	22.7	23.1	23.6	25.0	19.8	67.6
199-K-115A	16.0	24.8	23.6	22.6	35.4	39.4	36.9	25.2	25.1	25.0	25.4	25.6	25.0	27.1	91.8
199-K-116A	20.8	25.0	26.7	22.9	23.3	22.3	24.9	34.9	45.1	45.2	45.7	45.8	25.0	31.9	96.5
199-K-119A	17.0	25.0	24.8	22.9	23.3	22.3	25.0	25.0	27.3	29.7	25.5	25.6	25.0	24.5	92.9
199-K-120A	17.1	24.8	24.6	22.9	23.3	22.4	24.8	25.2	26.6	28.0	25.5	25.7	25.0	24.2	92.9
199-K-125A	17.7	25.1	24.2	22.0	22.2	17.8	—	25.1	24.8	24.8	24.7	25.5	25.0	23.1	92.4
2001															
199-K-112A	--	27.8	20.1	22.2	22.1	23.2	24.1	20.8	20.2	21.2	22.2	22.1	25.0	22.4	75.8
199-K-113A	22.4	20.5	17.8	14.3	14.8	17.9	15.0	15.1	13.9	13.8	14.5	15.6	25.0	16.3	92.8
199-K-115A	25.3	26.3	23.5	24.0	25.3	25.5	25.0	25.2	23.9	25.2	25.7	31.0	25.0	25.5	95.9
199-K-116A	45.7	45.0	41.4	40.8	45.0	45.3	45.3	45.2	43.5	42.7	39.9	41.2	25.0	43.4	95.5
199-K-119A	26.6	25.5	24.3	23.9	25.1	25.3	25.2	25.3	24.5	25.2	25.2	25.2	25.0	25.1	95.6
199-K-120A	25.6	25.3	24.2	24.1	25.2	25.5	25.2	25.5	24.5	25.2	25.2	25.3	25.0	25.1	95.6
199-K-125A	25.4	25.6	24.2	24.2	25.3	25.2	25.4	25.3	24.4	25.5	25.2	25.4	25.0	25.1	95.8
2002															
199-K-112A	25.1	23.5	24.1	15.4	16.8	20.8	20.7	20.2	26.4	26.6	25.4	25.0	25.0	22.5	86.8
199-K-113A	15.6	15.7	14.0	0.0	20.1	22.1	21.4	18.2	15.1	13.4	17.1	17.6	25.0	15.9	79.7
199-K-115A	35.3	35.7	35.4	24.1	38.0	43.2	42.9	40.3	44.2	44.1	44.1	44.1	25.0	39.3	94.1
199-K-116A	44.5	44.1	44.0	30.1	43.3	44.9	44.7	41.9	44.4	44.4	44.5	44.6	25.0	43.0	93.4
199-K-119A	25.6	27.3	26.8	23.7	28.7	28.9	29.9	29.1	29.5	29.2	29.2	29.2	25.0	28.1	93.2
199-K-120A	27.0	28.6	28.3	24.2	29.8	30.6	30.4	28.8	29.9	29.7	29.5	29.4	25.0	28.9	93.2
199-K-125A	25.4	26.3	25.6	24.5	36.0	38.5	39.8	37.5	41.0	40.7	40.5	40.6	25.0	34.7	93.4

Table C-10. 100-KR-4 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (4 sheets)

Well	2003												Total Flow Hours	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.			
199-K-112A/199-K-129	24.9	24.1	23.8	24.8	25.2	—	24.3	20.8	20.5	20.4	22.8	24.7	7,328.5	23.3	83.6
199-K-113A	14.9	11.3	12	13.1	15.2	20.6	17.9	14.9	13	12.2	13.6	14.5	8,378.5	14.4	95.6
199-K-115A	43.9	43.7	43.7	44	44.5	44.8	43.7	42.7	44	43.9	44.1	44.2	8,522	43.9	97.2
199-K-116A	40.3	22.9	38.6	42.9	44.4	44.6	43.7	43.2	44.7	44.9	45.1	45.4	8,420	41.7	96.1
199-K-119A	29	29.2	29.7	29.8	30.4	35.8	35.4	30.5	30.4	30.1	30.1	30.5	8,521.5	30.9	97.2
199-K-120A	29.3	29.4	30	30.1	30.5	30.7	30.3	30.6	33.2	33.4	37.5	40.3	8,522.5	32.1	97.2
199-K-125A	37.3	26.7	37.6	29.2	29.7	35.1	33.6	32.9	35.3	37.9	39.3	40.7	8,483.5	34.6	96.8
199-K-126	11.8	12.7	13.0	13.3	14.8	15.1	16.8	15.5	14.7	15.0	14.2	13.9	8,154.5	14.2	93.0
199-K-127	36.9	26.5	39.9	40.1	40.4	40.7	40.0	34.7	35.1	34.9	35.1	35.5	8,523.5	36.7	97.3
2004															
199-K-112A/199-K-129	26.5	24.9	24.6	23.7	24.9	24.6	25.2	27.1	25.9	26.6	25.4	24.6	8,037.0	25.3	91.5
199-K-113A	13.5	13.5	12.2	12.5	15.2	16.3	15.5	14.2	13.2	13.5	15.1	15.2	8,074.0	14.2	91.9
199-K-115A	43.2	44.1	43.8	43.8	44.4	44.7	44.6	39.5	39.8	39.9	38.4	40.2	6,158.0	42.8	70.1
199-K-116A	45.5	45	45.2	45.4	44.9	44.8	44.8	45	44.7	44.7	42.1	40.4	7,897.5	44.4	89.9
199-K-119A	31	30	30.2	30.7	29.7	29.9	29.9	30	30.1	30.2	28.4	30.2	7,714.5	30	87.8
199-K-120A	39.7	38.8	39.6	41	40.8	40.4	39.9	40.1	39.9	39.9	37.7	40.4	7,731.5	39.9	88
199-K-125A	41.8	40.9	40.7	40.3	40	39.8	39.9	40.3	40.2	40.1	36.7	40	7,897.0	40.1	89.9
199-K-126	15.2	15.1	17.1	18	19.9	19.2	18.2	17.8	18.7	18.1	14.4	0	6,449.0	17.8	73.4
199-K-127	35	34	34.7	35.2	34.6	34.7	34.6	34.9	34.8	34.8	33.1	34.9	7,691.5	34.6	87.6

Table C-10. 100-KR-4 Average Extraction Rates, Calendar Year 1997 to Calendar Year 2006. (4 sheets)

Well	2005												Total Flow Hours	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%) ^a
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec			
199-K-112A/ 199-K-129	24.5	24.6	24.8	24.5	26.5	28.0	29.8	29.0	24.4	22.3	23.2	16.0	7,090	24.8	80.9
199-K-113A	14.9	14.7	13.1	12.1	14.4	15.9	16.7	15.7	11.8	11.6	12.1	11.7	7,368	13.7	84
199-K-115A	39.9	38.6	38.2	39.5	39.5	--	34.8	34.7	40.1	40.1	37.2	38.2	6,512	38.3	74.3
199-K-114A	26.6	36.8	37.3	30.9	41.4	49.7	21.2	23.2	25.1	19.0	12.9	21.6	7,368	28.2	83.8
199-K-116A	40.8	45.7	45.6	45.5	44.8	45.3	46.1	45.9	45.6	44.5	40.4	37.0	8,204	43.9	93.7
199-K-119A	30.4	35.0	35.0	36.2	38.2	39.9	40.1	40.8	42.8	40.0	38.3	36.1	8,063	37.6	92.1
199-K-120A	40.4	41.1	41.0	40.9	38.9	36.7	36.9	36.8	36.4	36.5	33.8	28.6	8,127	37.3	92.8
199-K-125A	40.1	40.5	40.5	41.8	42.2	43.0	42.7	42.3	41.6	40.3	36.7	32.8	8,191	40.4	93.5
199-K-126	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
199-K-127	35.0	36.1	36.0	36.8	37.7	37.9	38.1	37.8	37.5	36.3	36.8	33.6	8,156	36.6	93.1
2006															
199-K-112A/ 199-K-129	9.8	12.4	23.4	24.2	25.5	28.6	29.2	26.7	21.6	18.9	14.3	17.1	7906.4	20.9	90.3
199-K-113A	9.8	10.0	9.2	11.5	16.1	19.5	16.2	13.1	10.4	10.1	12.9	13.0	8220.4	12.6	93.8
199-K-114A	25.4	25.1	25.6	21.4	20.8	25.8	23.2	24.1	24.1	18.8	34.4	24.1	7695.8	24.1	87.9
199-K-115A	41.7	42.8	42.4	42.7	36.0	31.4	29.2	29.2	31.8	37.9	39.2	41.7	8167.8	37.3	93.2
199-K-116A	45.3	45.2	42.4	42.0	36.6	34.3	36.8	37.9	40.2	45.0	41.3	44.5	8460.6	40.9	96.6
199-K-119A	39.9	39.9	41.2	37.5	36.8	40.8	41.4	36.8	34.9	37.1	26.0	31.2	8532.4	37.0	97.4
199-K-120A	33.2	33.3	33.2	34.3	25.8	34.9	35.4	35.2	34.9	36.1	49.0	47.0	8589.8	36.9	98.1
199-K-125A	43.2	43.3	43.3	0	24.7	22.9	25.0	34.0	39.2	42.7	35.1	42.0	7365.0	35.5	84.1
199-K-127	41.8	41.3	41.2	41.3	39.7	33.7	31.8	34.9	34.5	36.9	31.4	31.5	8592.0	36.7	98.1

NOTE: Well 199-K-112A was not in service as an extraction well until 2001.

^a Total hours on-line / total possible run-time.

-- = well out of operation

gpm = gallons per minute

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Table C-11. Volume of Groundwater Treated and Strontium Removed Since Startup of Operations at 100-NR-2. (2 sheets)

Reporting Period	Liters Treated	Strontium Removed (Ci)
September 1995 – December 1996	114,627,001	0.13113
January 1997 – March 1997	27,323,363	0.04482
April 1997 – June 1997	31,035,673	0.07458
July 1997 – September 1997	28,848,891	0.05394
October 1997 – December 1997	27,959,680	0.04294
January 1998 – March 1998	22,129,512	0.03940
April 1998 – June 1998	28,336,727	0.06093
July 1998 – September 1998	28,029,708	0.04816
October 1998 - December 1998	25,219,497	0.04873
January 1999 – March 1999	29,723,159	0.05532
April 1999 – June 1999	29,715,000	0.05193
July 1999 – September 1999	29,278,950	0.05005
October 1999 - December 1999	23,614,586	0.03255
January 2000 - March 2000	27,370,448	0.04793
April 2000 - June 2000	25,148,800	0.03809
July 2000 - September 2000	25,696,052	0.04419
October 2000 - December 2000	27,798,844	0.04655
January 2001 - March 2001	28,992,043	0.05472
April 2001 - June 2001	26,424,003	0.03651
July 2001 - September 2001	29,298,351	0.04715
October 2001 - December 2001	29,946,018	0.04667
October 2002 - December 2002	29,946,018	0.04667
January 2002 - March 2002	30,665,715	0.04719
April 2002 - June 2002	29,506,579	0.04333
July 2002 - September 2002	30,160,865	0.05248
October 2002 - December 2002	31,339,176	0.05168
January 2003 – March 2003	31,006,631	0.05143
April 2003 – June 2003	30,730,999	0.04869
July 2003 – September 2003	21,170,307	0.03546
October 2003 – December 2003	31,198,431	0.04976

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Table C-11. Volume of Groundwater Treated and Strontium Removed Since Startup of Operations at 100-NR-2. (2 sheets)

Reporting Period	Liters Treated	Strontium Removed (Ci)
January 2004 – March 2004	30,676,503	0.04875
April 2004 – June 2004	27,285,703	0.04983
July 2004 – September 2004	19,745,742	0.02544
October 2004 – December 2004	29,489,895	0.03216
January 2005 – March 2005	24,298,503	0.02882
April 2005 – June 2005	29,207,722	0.03609
July 2005 – September 2005	25,538,687	0.03687
October 2005 – December 2005	26,088,851	0.04401
January 2006 – March 2006 ^a	23,376,108	0.04577
Totals	1,167,948,741	1.87072

^a 100-NR-2 pump-and-treat placed in cold-standby mode on March 9, 2006.

Table C- 12. Average Strontium-90 Activities for Influent and Effluent Tanks at the 100-NR-2 Pump-and-Treat System.

Tank	Average Strontium-90 Activity (pCi/L)										Annual Comparison ^a
	CY97 ^b	CY98	CY99	CY00	CY01	CY02	CY03	CY04	CY05	CY06	
System influent (TK-1)	2,143	2,393	2,046	1,972	1,761	1,914	1,878	1,970	1,833	2,369	Increasing
System effluent (T-400)	349	450	355	377	265	327	264	499	303	411	Increasing

^a Annual comparison is the percent difference between CY02 and CY01 (or two most recent years) and is calculated by the following equation:

$$\frac{(CY06 - CY05) / CY05 \times 100\%}{(CY02 - CY01) / CY01 \times 100\%}$$
Wells are considered stable if there is less than a 20% change in concentration from CY05 to CY06.

^b CY95 and CY96 influent and effluent dropped from table for space considerations.

CY = calendar year

Table C-13. 100-NR-2 Average Extraction Rates, Calendar Year 1995 to Calendar Year 2006. (3 sheets)

Well	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Design Flow Rate (gpm)	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
1995															
199-N-75									12.4	12.7	10.5	10.7	15.0	11.5	81.8
199-N-103A									12.2	11.8	12.6	—	15.0	12.2	56.5
199-N-105A									18.3	14.4	13.9	13.5	15.0	—	88.9
199-N-106A									14.9	14.6	14.8	14.2	25.0	14.6	93.0
1996															
199-N-75	10.2	9.5	11.2	10.9	8.8	12.6	12.1	11.1	11.5	9.6	9.5	13.9	15.0	10.9	93.5
199-N-103A	—	—	—	13.3	—	12.3	14.1	14.3	13.0	13.9	14.2	14.0	15.0	13.7	84.0
199-N-105A	12.4	15.3	14.8	16.1	17.0	16.1	15.9	15.1	18.9	30.6	—	—	15.0	—	86.7
199-N-106A	15.9	16.0	16.2	17.2	17.5	14.6	14.8	15.1	15.7	17.6	18.0	56.6	25.0	19.6	94.9
1997															
199-N-75	14.4	16.7	17.0	17.3	17.0	16.3	16.5	16.2	16.0	15.8	16.0	16.3	15.0	16.3	100.0
199-N-103A	14.5	12.4	13.1	13.3	13.7	14.8	97.9	20.4	16.1	15.4	16.0	16.0	15.0	22.0	99.3
199-N-105A	—	—	—	—	—	—	—	—	—	—	—	—	15.0	—	16.7
199-N-106A	54.1	33.7	33.6	33.8	34.1	30.8	30.3	30.8	30.7	30.8	31.1	31.2	25.0	33.7	100.0
1998															
199-N-75	16.2	15.6	16.4	14.0	14.8	13.4	14.9	15.2	14.3	9.1	10.7	11.9	15.0	13.9	91.8
199-N-103A	16.4	15.6	16.2	14.9	16.5	15.1	15.6	15.6	14.4	10.8	17.2	18.3	15.0	15.6	92.7
199-N-105A	—	—	—	—	—	0.1	—	—	0.0	0.0	0.0	0.0	15.0	0.0	0.1
199-N-106A	30.2	27.3	29.0	26.4	30.3	28.0	28.6	30.1	27.9	21.7	30.7	31.5	25.0	28.5	92.6

No data available.

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Table C-13. 100-NR-2 Average Extraction Rates, Calendar Year 1995 to Calendar Year 2006. (3 sheets)

Well	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Design Flow Rate (gpm)	Avg. Monthly Flow Rate (gpm)	Total Run-Time (%)
1999															
199-N-75	12.0	12.2	14.3	15.4	14.0	14.5	15.0	14.9	14.1	14.6	12.5	8.8	15.0	13.5	90.2
199-N-103A	18.7	18.9	18.5	17.3	17.4	17.2	17.6	17.4	17.2	17.4	14.5	11.4	15.0	17.0	90.4
199-N-105A	—	—	0.2	—	0.6	—	0.2	0.4	—	0.4	—	—	15.0	0.4	0.1
199-N-106A	31.8	32.0	30.9	28.3	29.6	29.1	29.5	26.7	27.6	28.9	23.9	18.2	25.0	28.1	90.2
2000															
199-N-75	12.7	13.6	13.5	12.0	13.8	12.7	11.6	5.8	12.8	11.8	10.8	9.2	15.0	11.7	79.0
199-N-103A	15.6	16.7	16.5	14.7	16.2	15.2	14.2	15.5	10.9	11.5	14.0	14.6	15.0	14.6	88.4
199-N-105A	—	—	0.0	—	0.0	0.0	0.6	11.5	17.5	14.9	19.4	0.0	15.0	7.1	5.3
199-N-106A	25.5	28.6	29.2	24.7	26.3	24.6	22.0	31.0	36.0	36.3	36.6	36.3	25.0	29.8	88.1
2001															
199-N-75	10.6	10.5	10.1	10.0	11.2	—	8.2	7.7	8.0	8.9	8.7	9.2	15.0	9.4	76.4
199-N-103A	14.3	13.6	13.6	15.3	13.7	13.4	14.2	16.0	16.3	16.8	17.1	17.3	15.0	15.1	93.9
199-N-105A	—	—	—	24.3	10.8	11.0	13.0	15.3	17.8	24.2	23.0	14.1	15.0	17.0	19.9
199-N-106A	34.8	36.8	36.5	36.7	36.4	36.5	37.3	37.3	37.2	37.6	37.3	37.5	25.0	36.8	90.6
2002															
199-N-75	8.7	9.1	9.3	8.1	11.1	12.5	10.1	11.1	11.4	10.7	11.0	11.0	15.0	10.3	88.4
199-N-103A	17.4	17.3	17.2	17.0	17.1	15.6	16.9	16.5	16.6	16.7	16.8	16.7	15.0	16.8	94.7
199-N-105A	—	—	22.1	19.7	18.2	—	28.0	—	—	—	—	—	15.0	22.0	6.3
199-N-106A	37.8	37.5	37.4	32.7	34.0	36.0	35.8	35.9	36.9	37.5	37.3	37.3	25.0	36.3	94.7

Table C-13. 100-NR-2 Average Extraction Rates, Calendar Year 1995 to Calendar Year 2006. (3 sheets)

Well	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Hours On-Line	Average Monthly Flow Rate (gpm)	Total Run-Time (%)
2003															
199-N-75	11.1	10.2	10.1	10.5	10.5	10.6	10.7	10.6	10.5	11	11	11	7,779	10.6	88.8
199-N-103A	16.1	16.1	15.9	16.2	16.4	16.4	16.4	16.3	10.5	15	15.1	15	7,622	15.5	87.0
199-N-105A	20.5	--	17.3	--	--	--	--	--	10.5	--	--	--	101	16.1	1.2
199-N-106A	36.9	38.1	38.1	38.4	38.2	38.2	38.4	38.5	10.5	37.1	38	38	7,778.5	35.7	88.8
2004															
199-N-75	11	11	11	10.4	10.6	10.5	10.6	12.8	12.1	12.4	11.1	10	7,617.0	11.1	86.7
199-N-103A	15	14.5	13.7	13	13.7	13.5	0	5.9	0	0	0	0	3,691.5	13.9	42
199-N-105A	0	0	27.2	0	0	21.1	20.1	21.4	21	21.1	21.4	20.4	3,911.0	21.1	44.5
199-N-106A	38.3	38.1	38.4	38.5	38.6	33.3	30.9	27.6	28.8	28.3	28.5	30.3	7,593.5	33.5	86.4
2005															
199-N-75	11.3	10.9	11.7	11.3	12.4	13.5	11.3	11.5	11.6	11.6	11.4	12.6	7,768	11.8	88.7
199-N-103A	14.7	13.4	13.0	13.0	14.4	14.3	12.9	13.3	12.5	12.5	12.9	12.6	7,215	13.2	82.4
199-N-105A	24.7	27.4	27.5	17.3	27.2	26.9	--	17.0	14.0	--	13.9	--	1,080	25.1	12.3
199-N-106A	29.8	36.5	36.3	37.2	37.5	33.7	36.8	33.5	36.4	36.7	36.8	37.1	6,865	36.0	78.4
2006															
199-N-75	12.7	13.5	13.5	--	--	--	--	--	--	--	--	--	1,598.4	13.1	97.9
199-N-103A	12.4	12.8	13.2	--	--	--	--	--	--	--	--	--	1,599.4	12.7	98.0
199-N-105A	0	20.8	15.1	--	--	--	--	--	--	--	--	--	1.8	12.0	0.01
199-N-106A	38.8	38.9	38.8	--	--	--	--	--	--	--	--	--	1,599.8	38.9	98.0

^a Total hours on-line / total possible run-time.
 -- = well out of operation
 gpm = gallons per minute

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Table C-14. 100-NR-2 Summary of System Availability
(September 1, 1995, to December 31, 2006).

Year	Total Time On-Line (hours)	Total Possible Run Time (hours)	Scheduled Downtime (hours)	Unscheduled Downtime (hours)	Total Availability (%) ^a	Scheduled Availability (%) ^b
1995	2,244	2,928	0	684	76.6	76.6
1996	7,202	8,784	0	1,582	82.0	82.0
1997	6,768	8,760	96	1,896	77.3	78.4
1998	7,401	8,760	0	1,359	84.5	84.5
1999	7,841	8,760	376	544	89.5	93.8
2000	7,573	8,784	946	265	86.2	97.0
2001	8,266	8,760	344	151	94.4	98.3
2002	8,323	8,760	328	109	95	98
2003	7,776.5	8,760	789.5	194	88.8	97.7
2004	7,616.5	8,784	337	830.5	86.7	90.2
2005	7,470.9	8,760	473.2	815.9	85.3	90.7
2006	1,603	1,632	16.3	11.8	99.3	98.3

^a Total availability = (total possible run-time - scheduled and unscheduled downtime) / total possible run-time.

^b Scheduled availability = (total possible run-time - unscheduled downtime) / total possible run-time.

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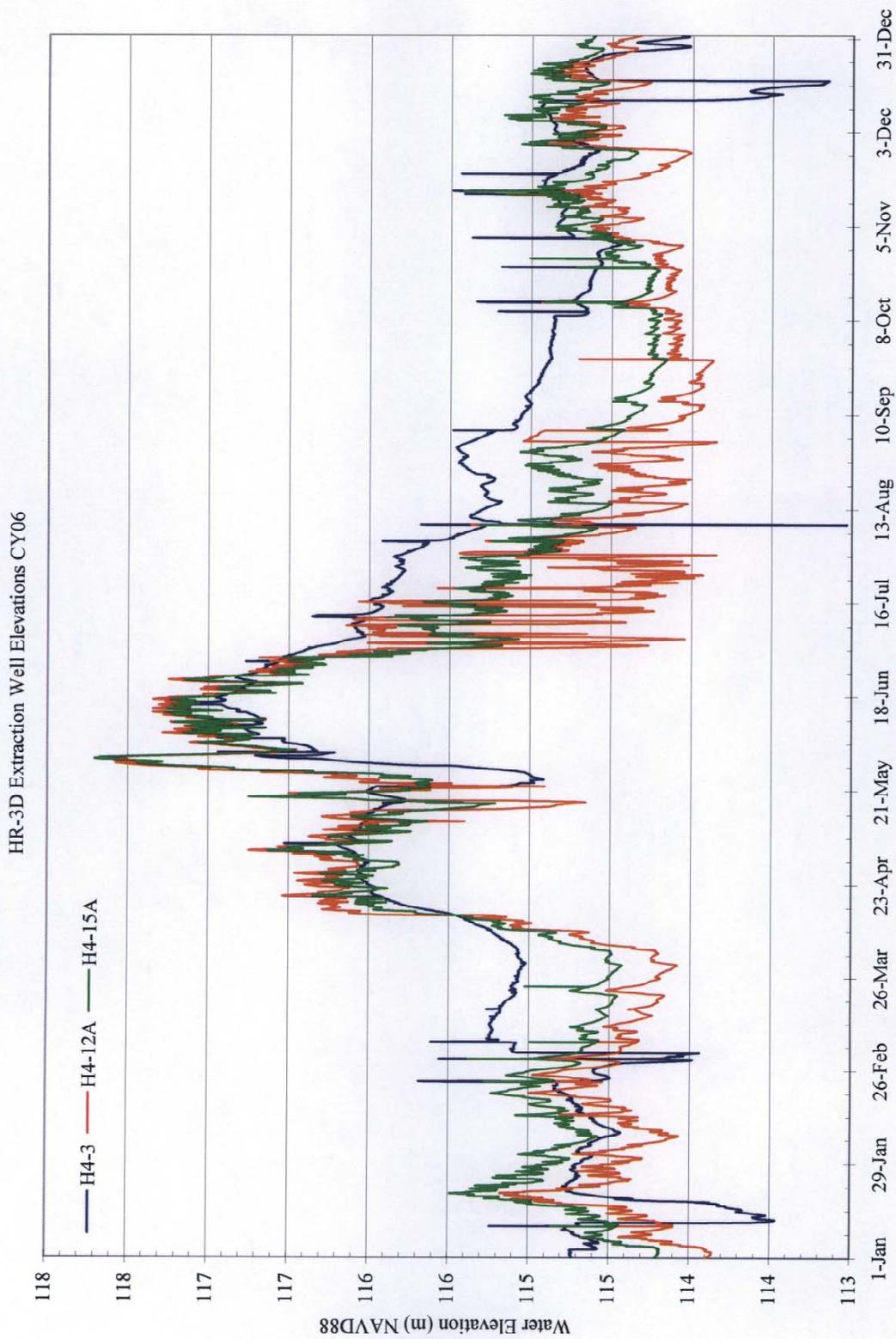
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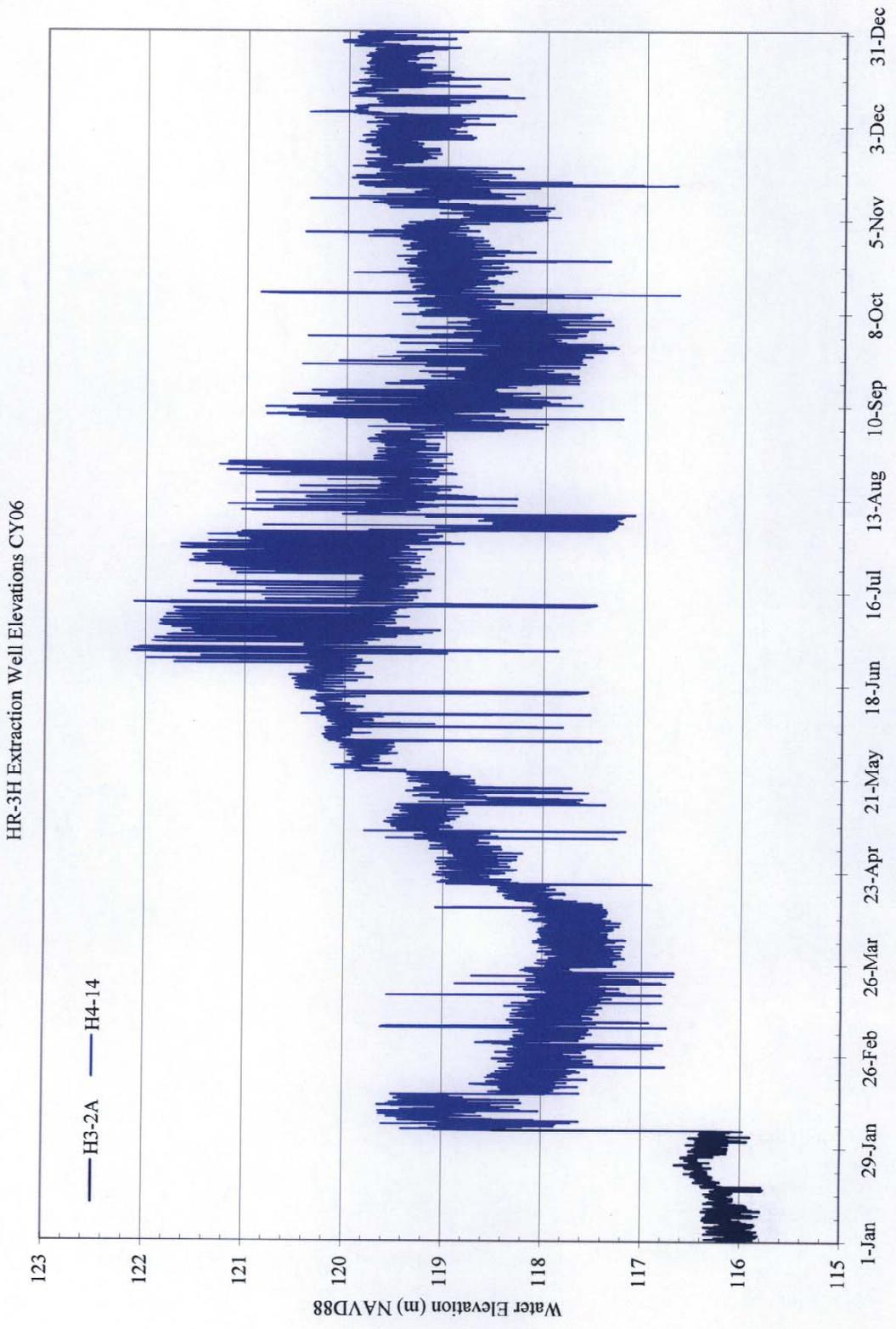
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APPENDIX D
HYDROGRAPHS FOR THE 100-HR-3 OPERABLE UNIT

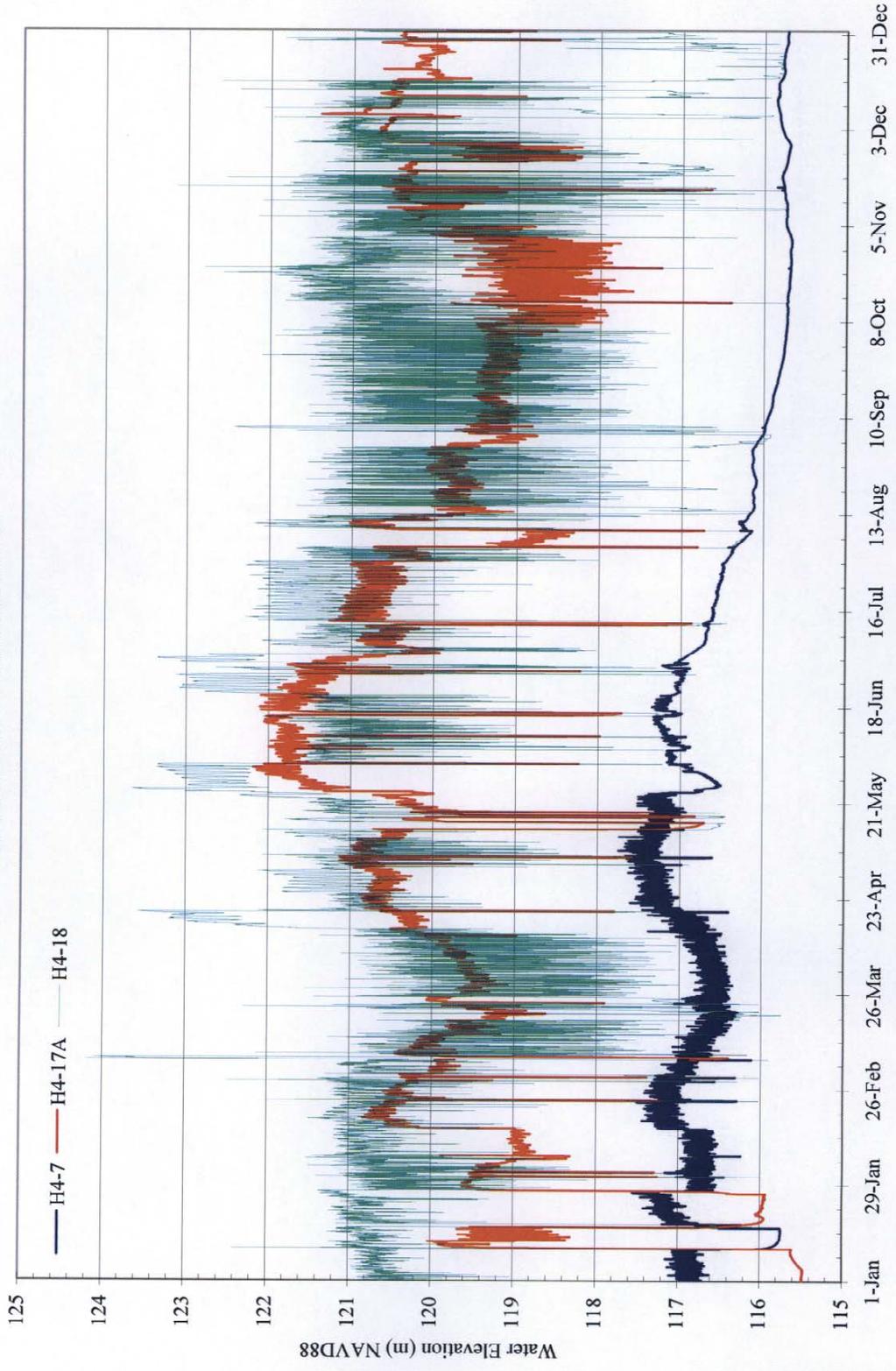
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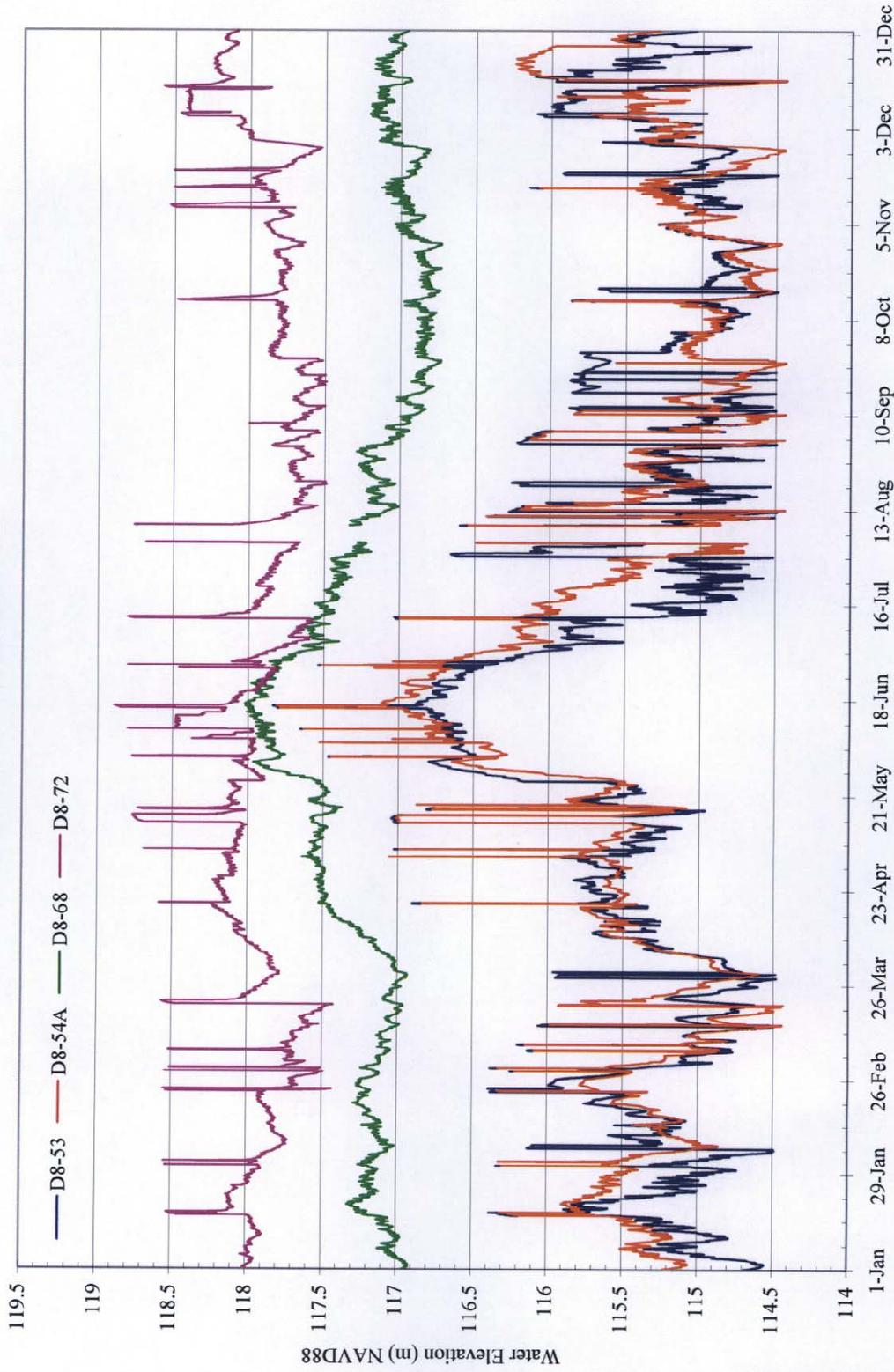




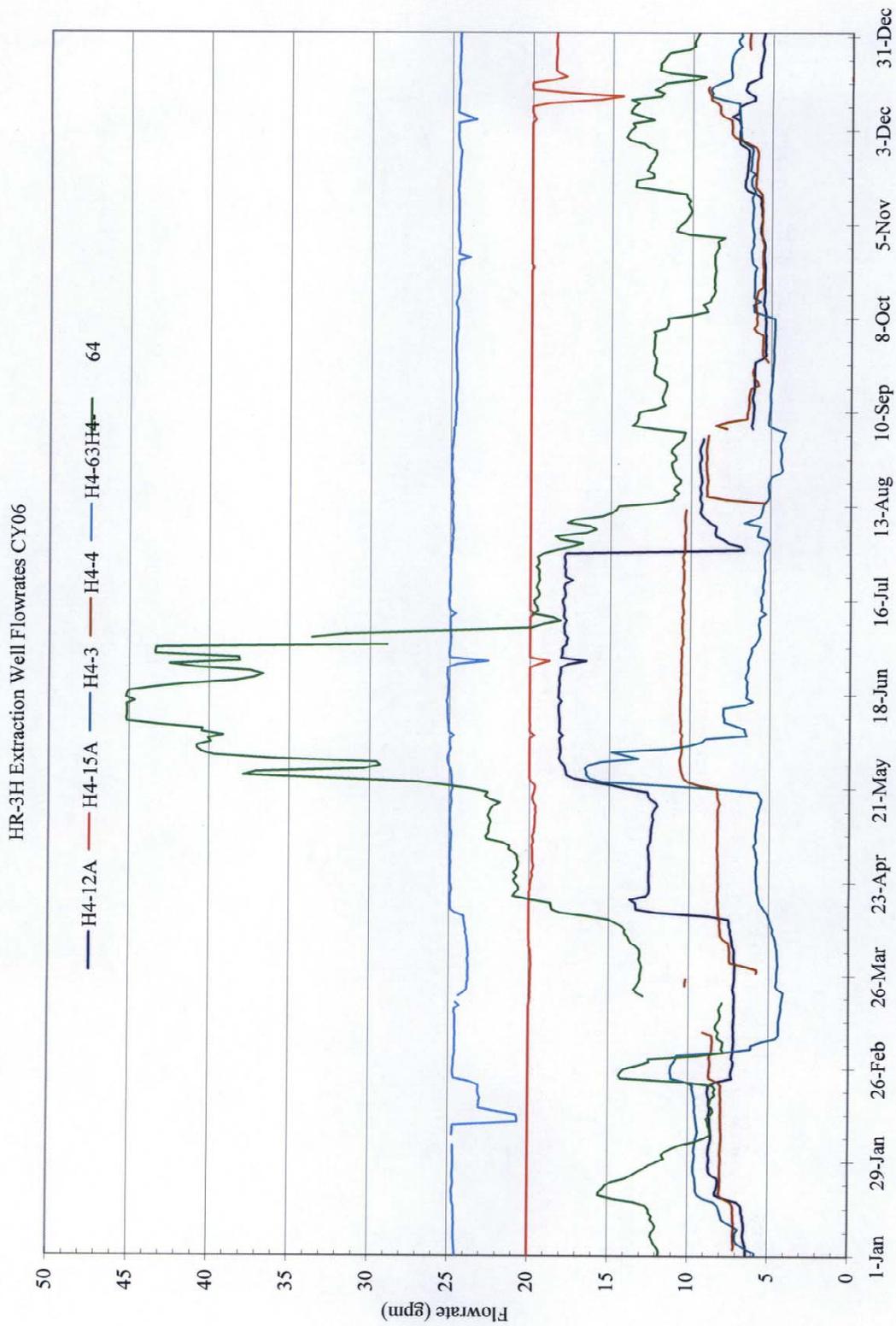
HR-3H Extraction Well Elevations CY06

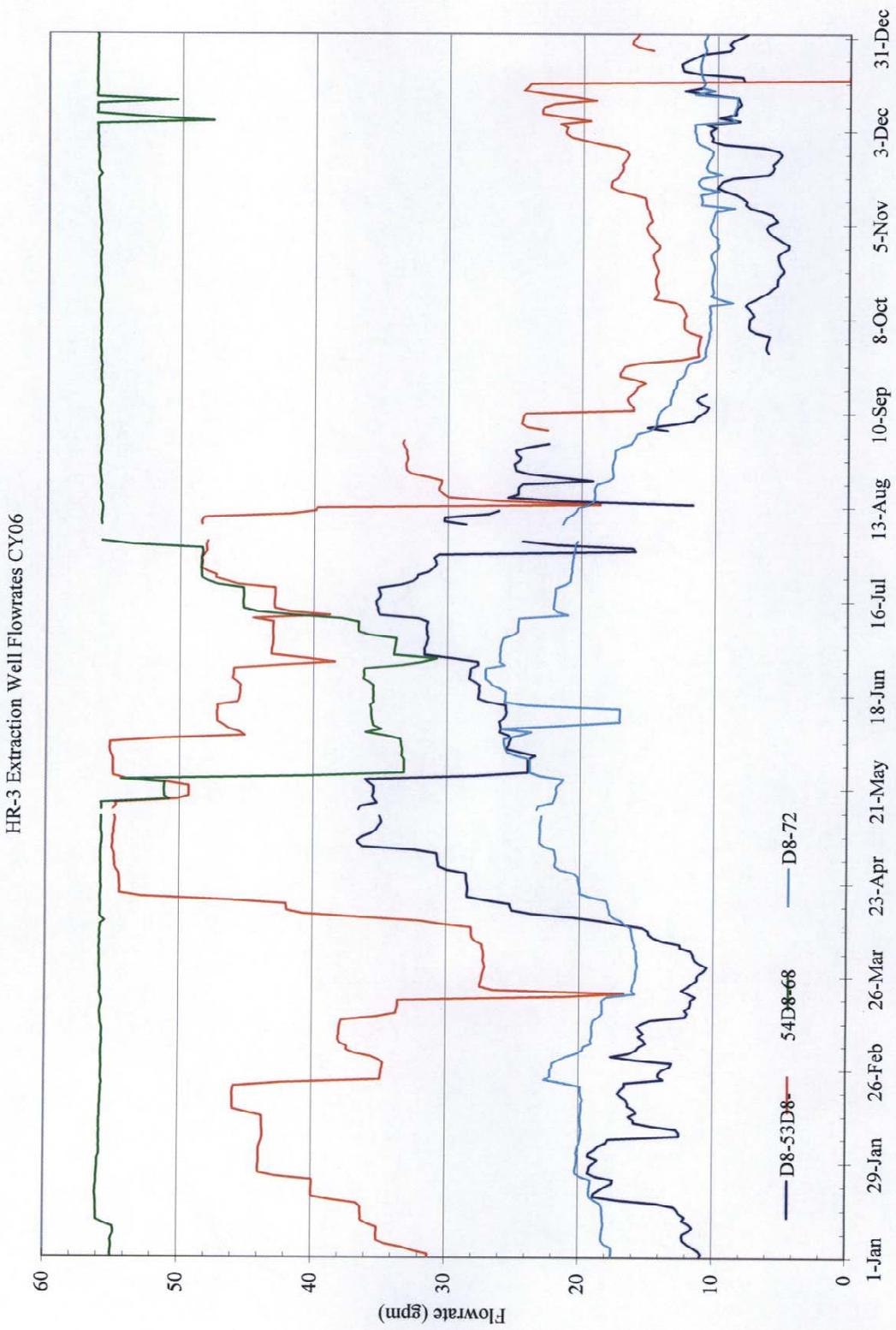


HR-3D Extraction Well Elevations CY06

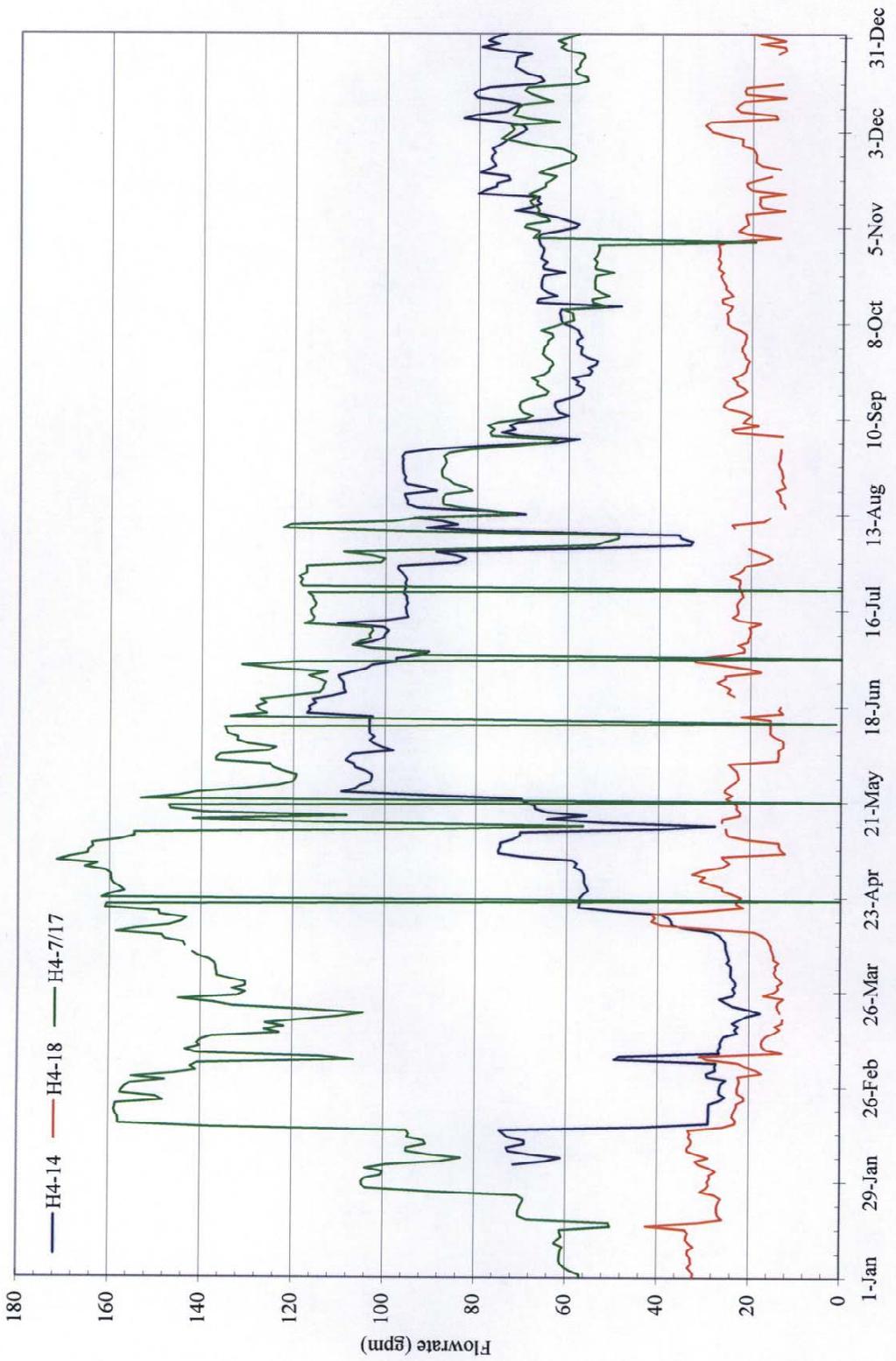


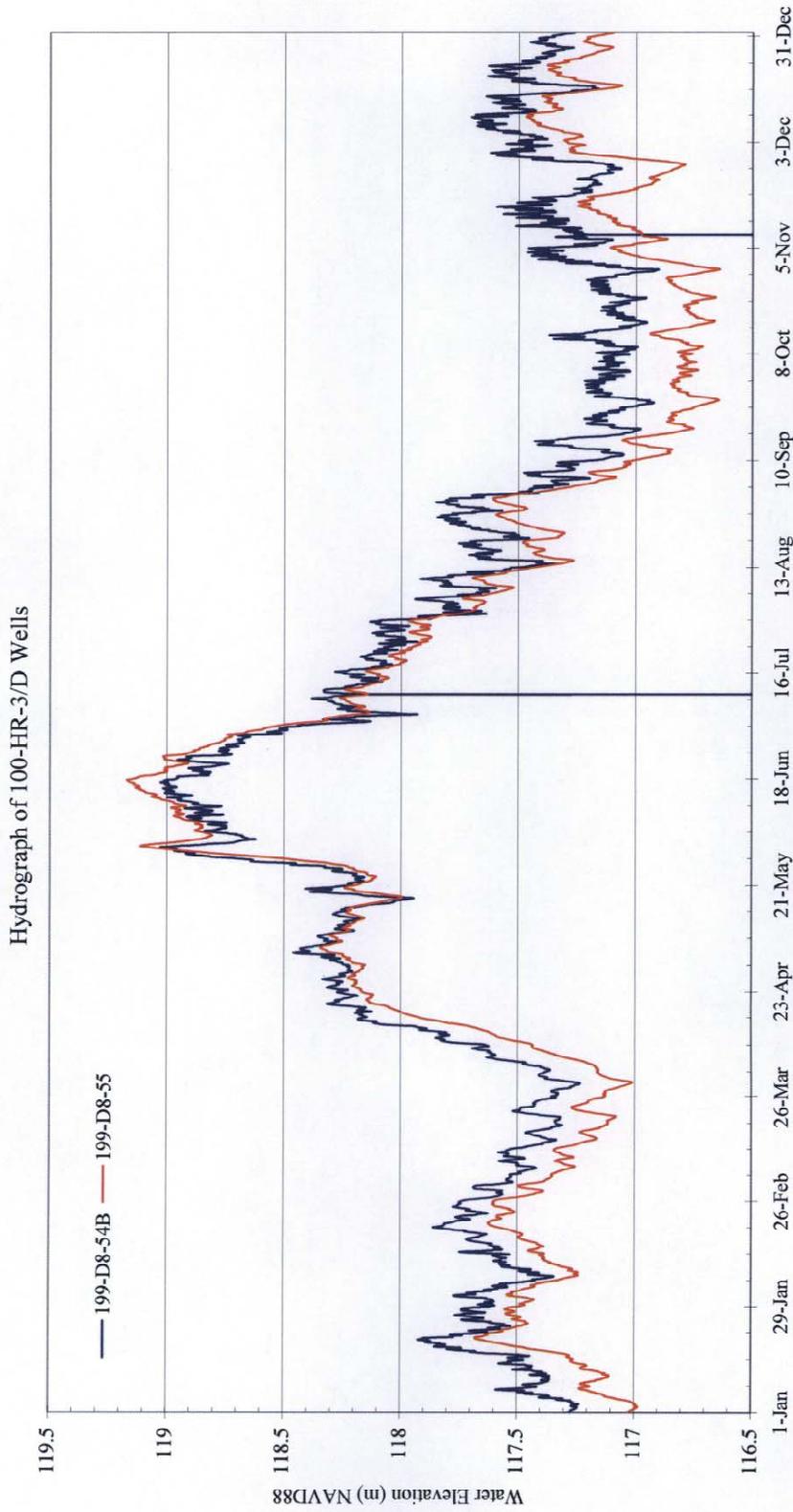
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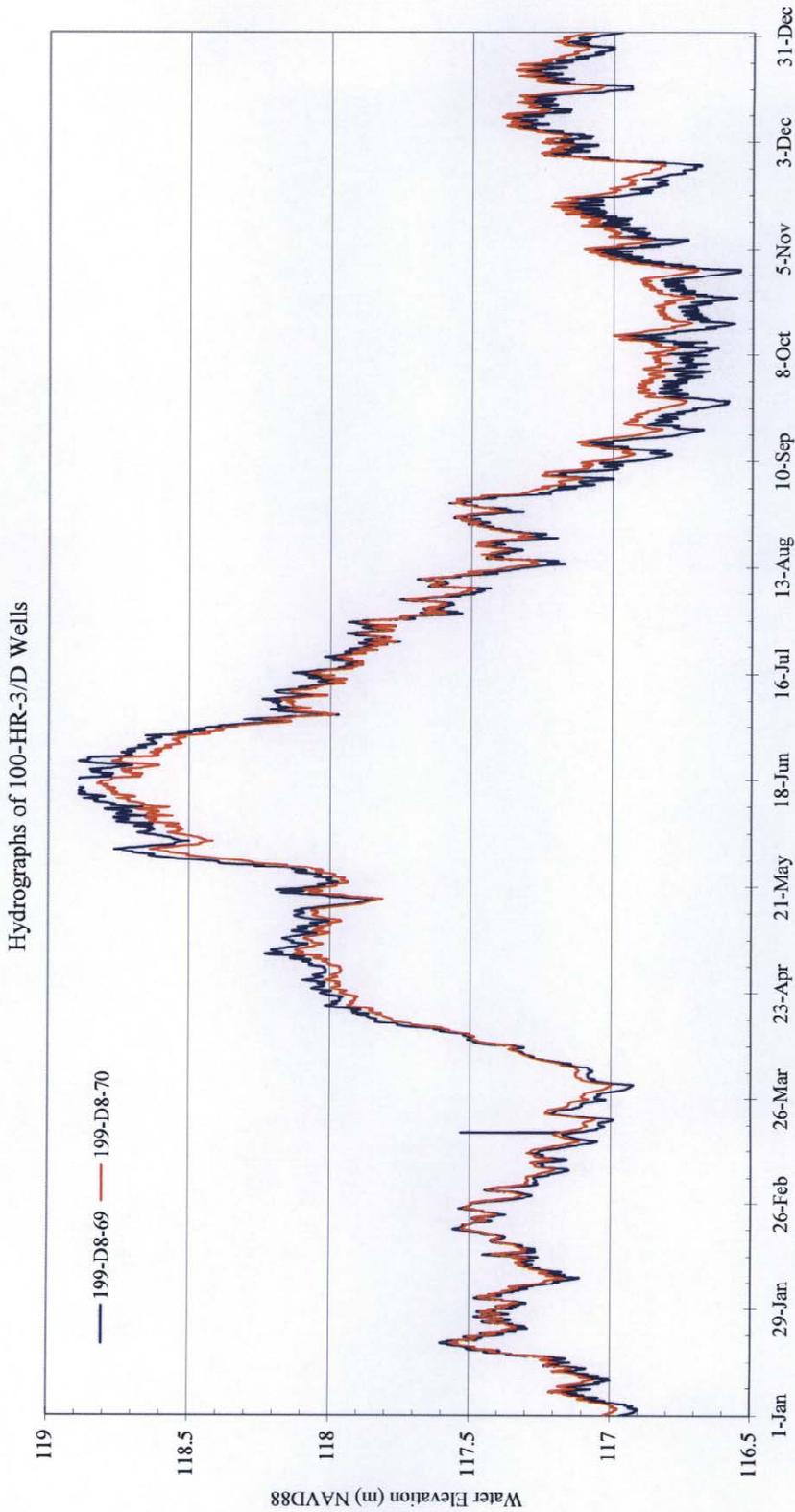


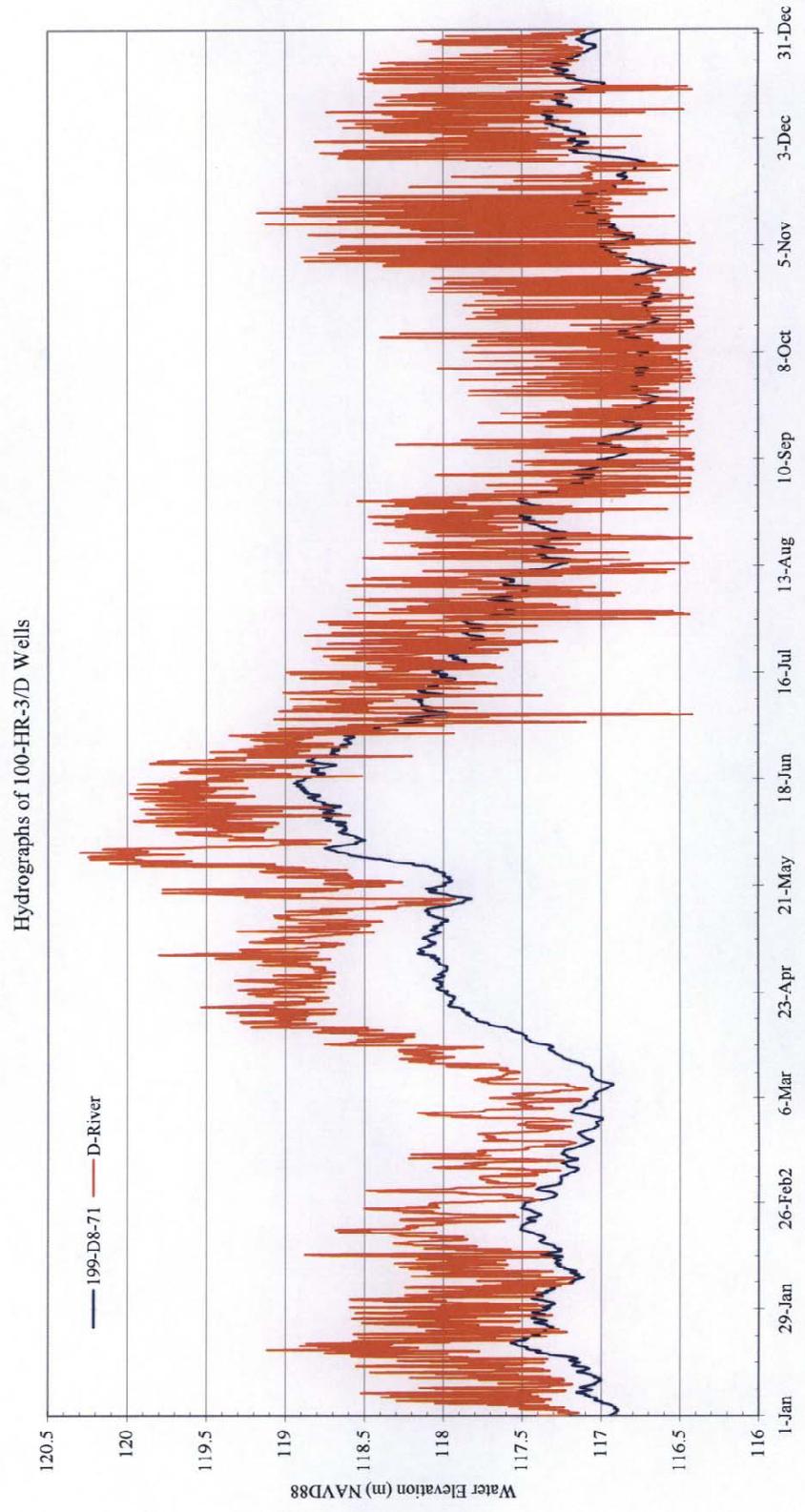


HR-3 Injection Well Flowrates CY06

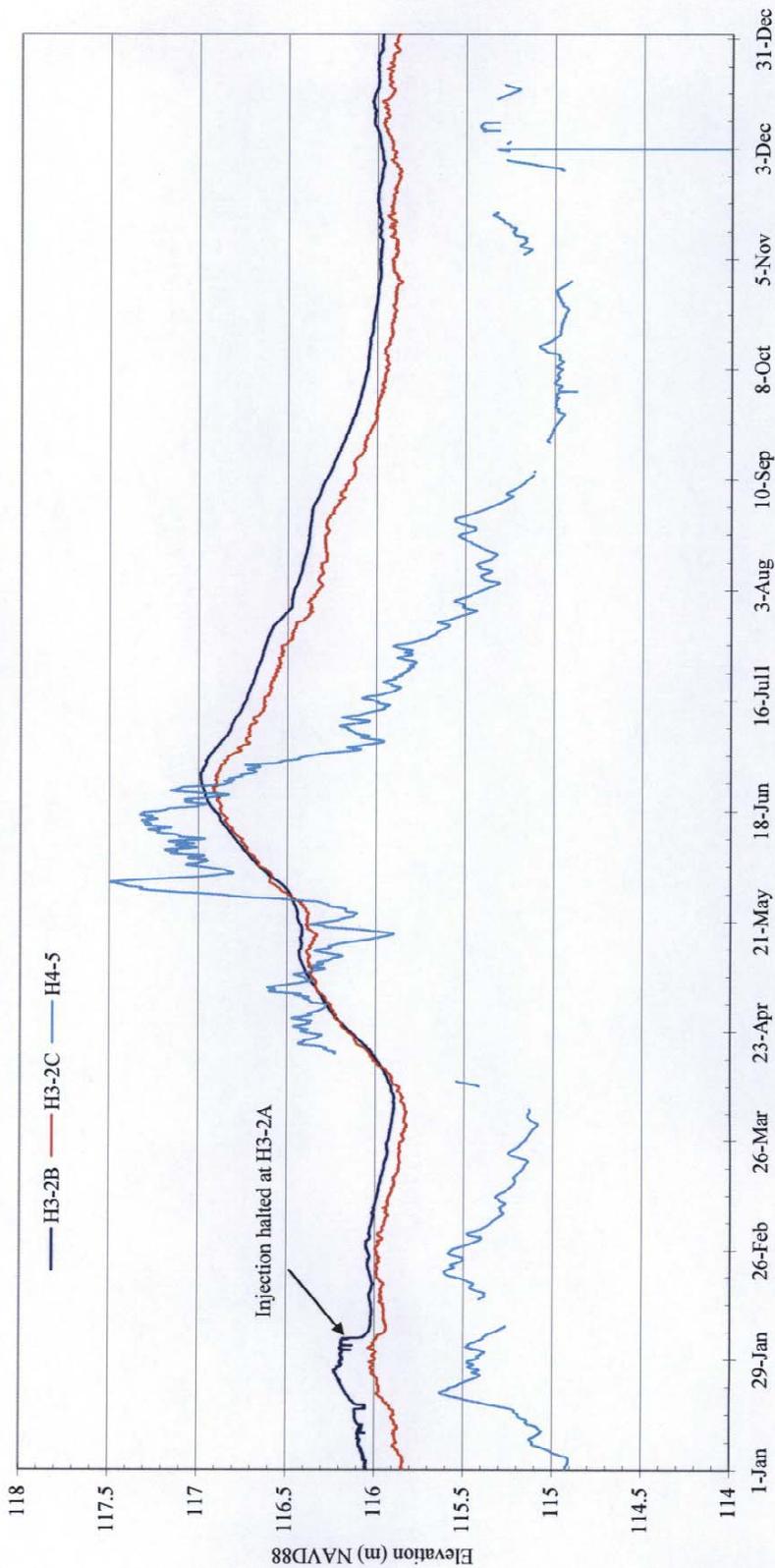


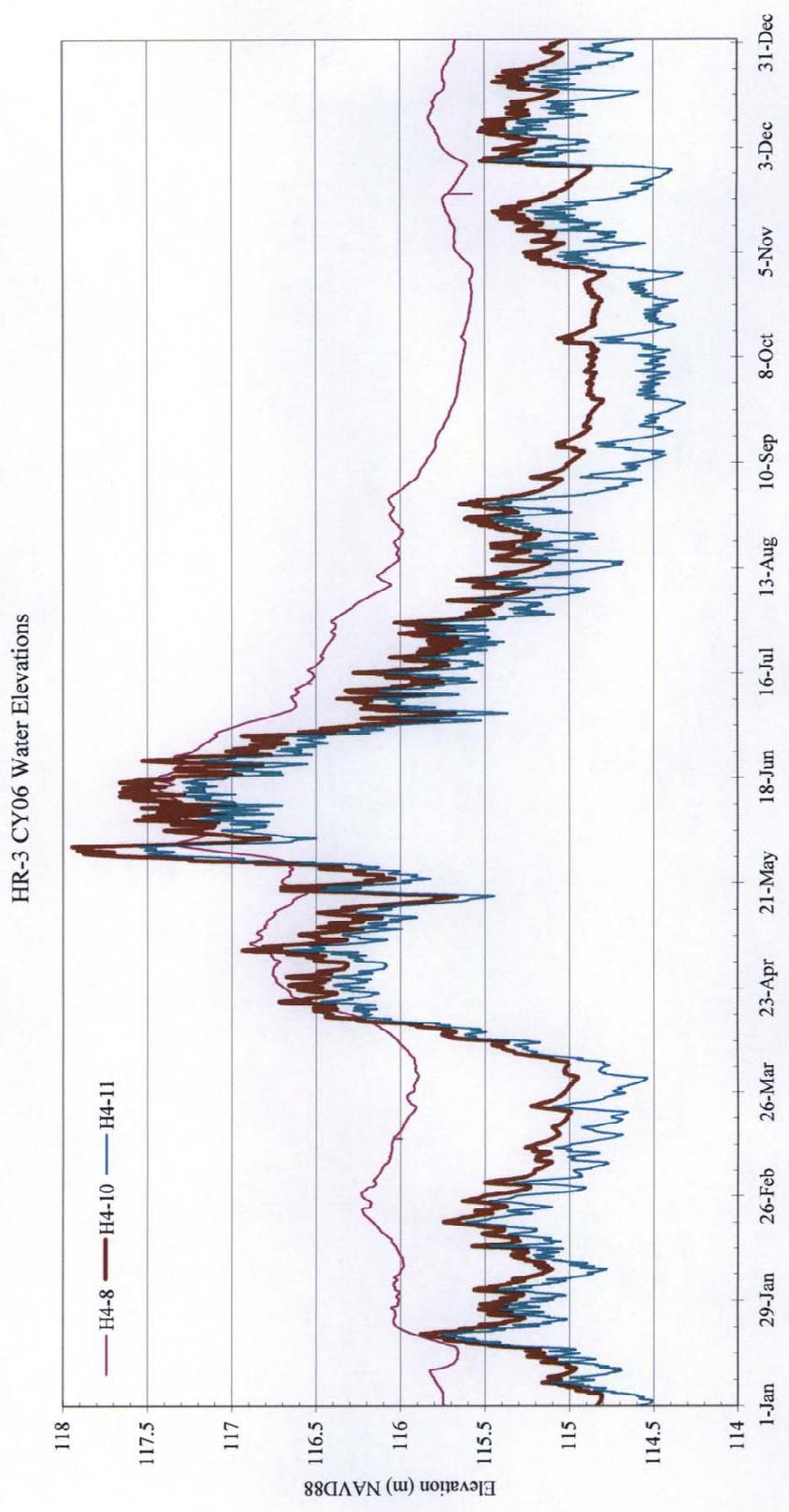


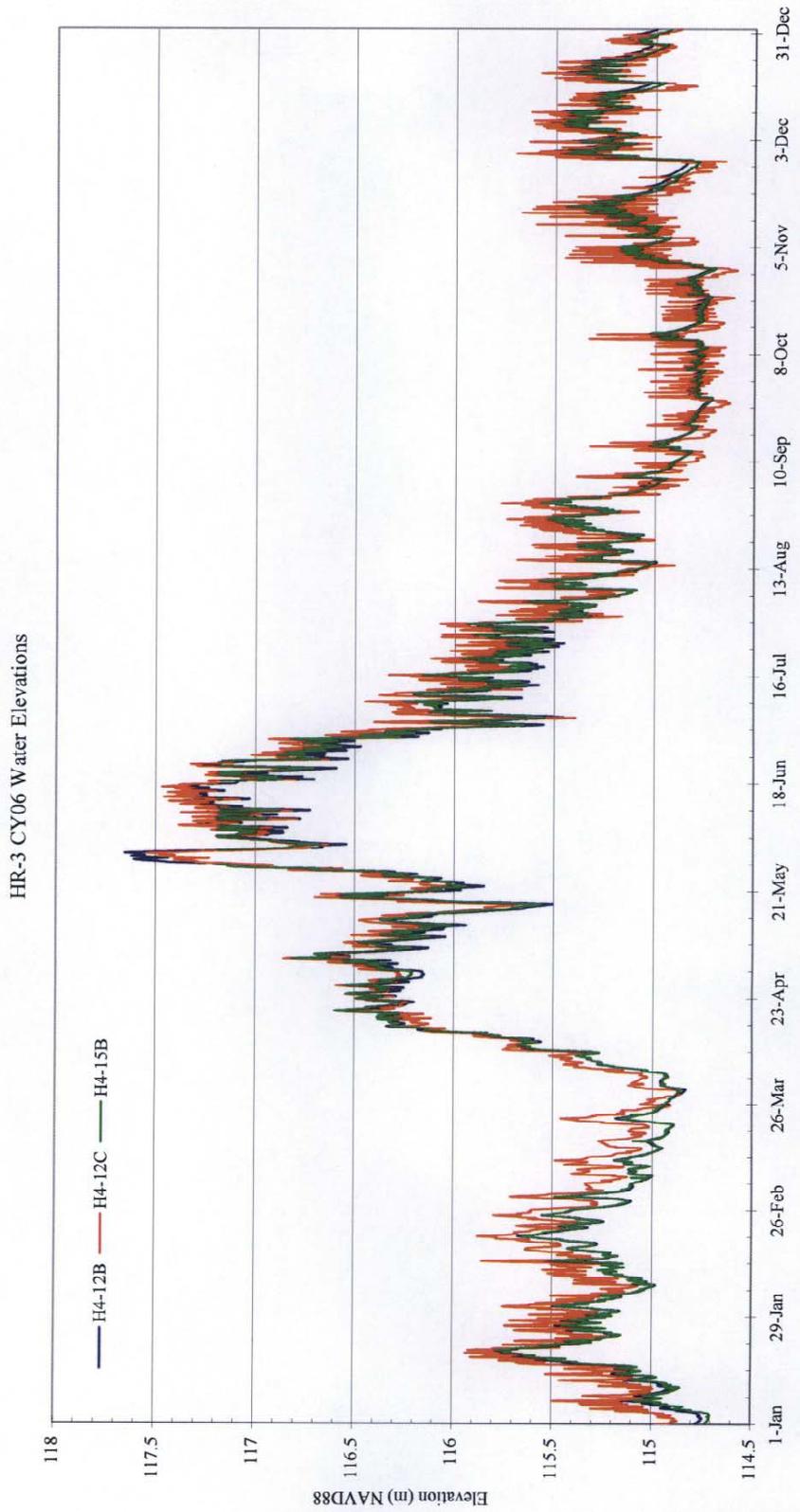




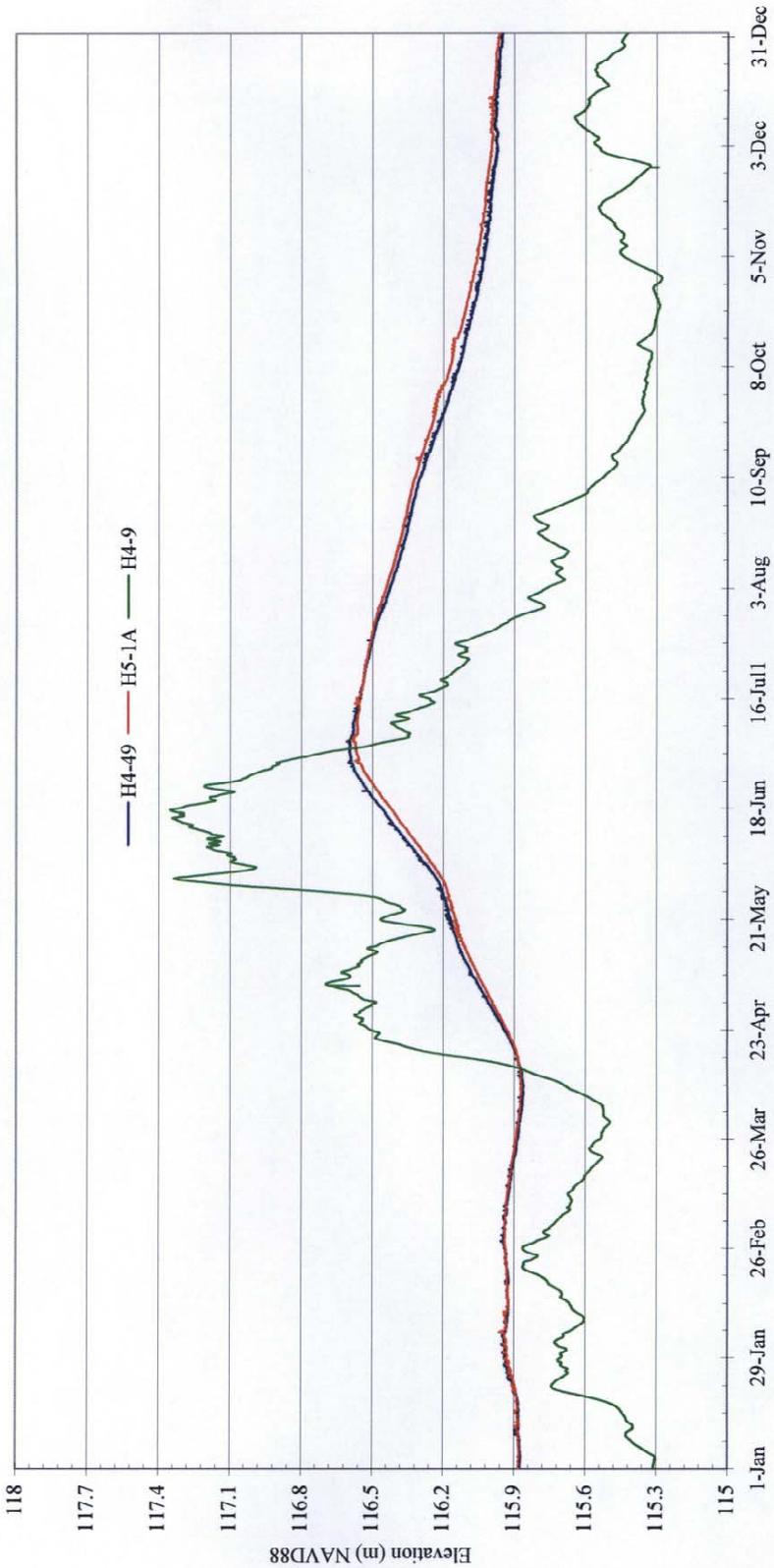
HR-3 CY06 Water Elevations

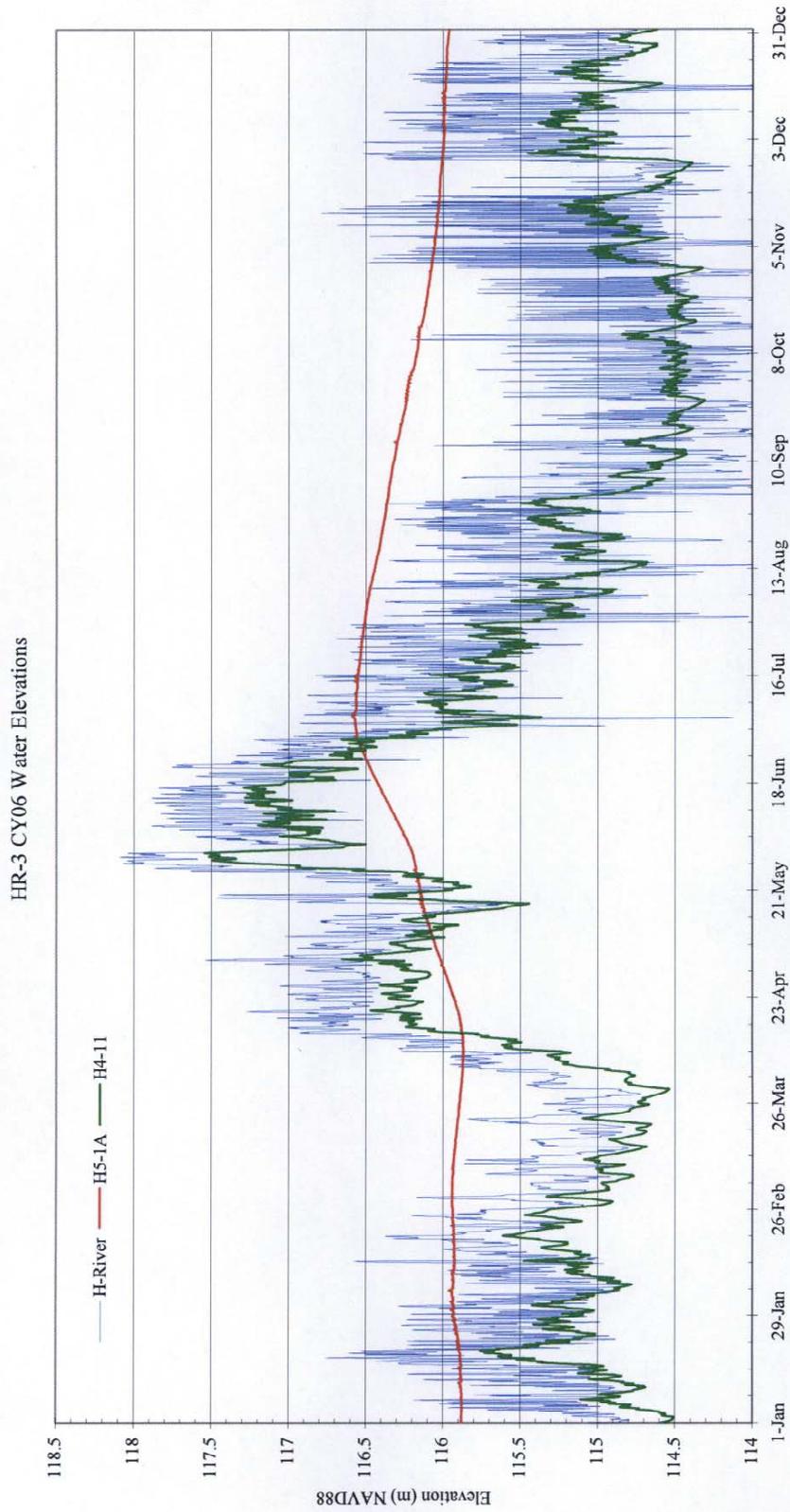






HR-3 CY06 Water Elevations





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APPENDIX E
NUMERICAL MODELING

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APPENDIX E

NUMERICAL MODELING

E1.0 100-HR-3, 100-KR-4, AND 100-NR-2 NUMERICAL MODELING CONSTRAINTS

This section details the constraints that are applicable for the 100-D, 100-H, and 100-K pump and treat numerical modeling effort. The 100-NR-2 pump-and-treat system was placed in cold-standby mode in March 2006, so no numerical modeling was performed.

Groundwater numerical modeling is used to evaluate the effectiveness of the extraction wells in preventing the discharge of contaminated groundwater (and by inference, chromium) into the Columbia River. By lowering the water table during pumping, the extraction wells develop a hydraulic sink that reduces the net flow through the target area into the river. The modeling evaluations were performed using November hydraulic boundary conditions (average river levels) to calculate the steady-state heads and flow lines. Flow lines shown on the figures are steady-state approximations; the actual flow lines vary in time and space because of the highly variable nature of the water table near the river where the stage elevation fluctuates daily. The modeling does not include the transient effects of the changing river stage on the water table, bank storage, or actual contaminant transport, nor is any attempt made to estimate the actual area of hydraulic capture during the year. The difficulty and level of complexity involved in incorporating those transient effects greatly exceed the intended scope and purpose of the modeling. For example, the river water level usually varies by about 2 m (6.6 ft) every day, so a time-average value was used in the model for each spatial grid cell. The river level declines in the downstream direction with a hydraulic gradient of 0.00023.

To ensure a conservative evaluation of the extraction well hydraulic capture that is consistent with the steady-state boundary conditions, the modeling used November 2006 water-level data to establish water-level boundary conditions. November water-level data corresponded with the period of sustained low flow in the Columbia River, when the water table acquired the steepest gradient toward the river. The groundwater gradient and flow through the target area (and contaminant discharge) to the Columbia River appeared to be greatest during this time. Evaluating the performance of the extraction wells against November water-level and river-stage boundary conditions provides a conservative and relevant evaluation of the effectiveness of the pump-and-treat system in accomplishing the goal of protecting the aquatic receptors in the river bottom substrate from the groundwater contaminants. During other times of the year when the river stage is higher, the hydraulic capture may appear more effective, as the flow lines extend more laterally and farther toward the river from the extraction wells. However, capture during these times may include river and bank storage water, which does not appear to contain elevated levels of contaminants, namely chromium.

The transport mechanism of contaminants across the river/aquifer interface is not well understood, but certain observations have been made. River water entering the aquifer during times of high or increasing river stage appears to displace groundwater back from the river, with little actual dilution occurring between the river and the wells. This phenomenon is evidenced by the decrease in chromium concentrations observed in the monitoring wells near the river during the months of spring run-off, followed by the rebound in concentration when the river stage recedes in the fall. If the concentrations had become diluted, then they would not rebound

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as there is no concentrating mechanism present in the aquifer. The bank storage water discharging back into the Columbia River does not appear to contain elevated levels of chromium and, thus, does not add to the contaminant transport to the river.

E2.0 100-D AREA GROUNDWATER NUMERICAL MODELING

The 100-D numerical model was developed initially to support design of the pump-and-treat systems. The transmissivity distributions in the model were developed from a limited set of hydraulic properties (e.g., *Limited Field Investigation Report for the 100-HR-3 Operable Unit* [DOE-RL 1993], *Limited Field Investigation Report for the 100-KR-4 Operable Unit* [DOE-RL 1994], and *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* [DOE-RL 1996]) and were then updated in *100-HR-3 and 100-KR-4 Operable Units Interim Action Performance Evaluation Report* (DOE-RL 1998) to include aquifer property analyses based on data collected by the hydraulic monitoring network and pump-and-treat operations. Refinements to the 100-D transmissivity distribution have been made as additional data have become available, including geologic layering and hydraulic conductivity distributions from Pacific Northwest National Laboratory's Sitewide model. A comparison of the modeled water levels to the current year's water levels measured in November 2006 is presented in Table E-1. The model has never included any leaking from the 182-D reservoir, located in between monitoring wells 199-D5-38, 199-D5-34, and 199-D5-33, because it has been difficult to characterize or quantify. However, leaks in this area would act like another injection well or several injections wells in a small area. In order to incorporate the leaking into the model, the modeled heads were coupled to the measured heads in the area around the 182-D reservoir, especially to the south and west. As a result, the modeled heads match the measured heads in this area. The main evidence of previous leaking is shown in the measured heads, which show a higher head contour to the west of the 182-D reservoir.

Flow lines terminating at the extraction wells (Figure E-1) show the approximate area of the aquifer through which each extraction well removes groundwater. The total area encompassed by the flow lines terminating at each extraction well represents the capture zone of that extraction well. Wells 199-D8-53, 199-D8-54A, 199-D8-68, and 199-D8-72 fully penetrate the unconfined aquifer, so the flow lines represent the groundwater travel occurring throughout the depth of the aquifer. The flow-line calculations are independent of the travel time, and as stated previously, the actual flow paths vary throughout the year. Because the purpose of the pump-and-treat system is to reduce discharge of contaminated groundwater to the Columbia River, the flow lines shown on the figures are only representative of the conditions during the time when groundwater flow toward the river would be greatest.

Figure E-1 also shows time markers spaced 180 days apart on the flow lines, based on the high November steady-state velocities. The fastest flow lines run from the injection well 199-D5-42 to near the extraction well 199-D8-68, which takes slightly more than 1 year for a pore velocity of about 2.2 m/day (7.2 ft/day) (800 m/365 days [2,625 ft/365 days]). The slower velocities are less than 1 m/day (3.3 ft/day) and are located before extraction well 199-D5-32, assuming the high November values. However, this time-velocity snapshot in November produces the largest velocities, as explained previously. In reality, the time markers would be closer together, indicating slower yearly average velocities. The effective porosity was set to a low value of 0.1, which also increases the calculated pore velocities.

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Contaminated groundwater is contained and prevented from discharging into the Columbia River along the river and downgradient of the capture zones. The conversion in October 2005 of monitoring well 199-D5-39 to an extraction well has helped to extend the capture zone to part of the southwest chromium plume and remove contaminant mass from groundwater. Flow lines terminating at the river in Figure E-1 indicate areas where the groundwater may bypass the extraction wells (north of well 199-D8-53 and south of well 199-D5-37) and discharge into the river. Some groundwater flow lines circumvent the pump-and-treat system to the north, but the contaminant monitoring data indicate that the extraction wells are containing the original high-concentration area of the plume.

E3.0 100-H AREA GROUNDWATER NUMERICAL MODELING

The 100-H numerical model was developed initially to support design of the pump-and-treat systems. The transmissivity distributions in the model were developed from hydraulic properties contained in DOE-RL (1993, 1994, 1996) and then were updated in DOE-RL (1998, 1999) to include aquifer property analyses based on data collected by the hydraulic monitoring network and pump-and-treat operations. A comparison of the modeled water levels to the current year's water levels measured in November 2006 is presented in Table E-2.

Flow lines terminating at the extraction wells (Figure E-2) show the approximate area of the aquifer through which each extraction well removes groundwater. The total area encompassed by the flow lines terminating at each extraction well represents the capture zone of that extraction well. All of the extraction wells fully penetrate the unconfined aquifer, to the top of the Ringold Upper Mud, so the flow lines represent the groundwater travel occurring throughout the depth of the aquifer. The flow-line calculations are independent of the travel time, and as stated previously, the actual flow paths vary throughout the year. Because the purpose of the pump-and-treat system is to reduce discharge of contaminated groundwater to the Columbia River, the flow lines shown on the figures are only representative of the conditions during the time when groundwater flow toward the river would be greatest.

Figure E-2 also shows time markers spaced 90 days apart on the flow lines, based on the high November steady-state velocities. The fastest flow lines are the high conductivity region in the southernmost part of Figure E-2, where the pore velocities are as high as 6 m/day (20 ft/day) (1,100 m/180 days [3,609 ft/180 days]) from former injection well 199-H3-5 to past monitoring well 199-H6-1. The effective porosity was set to a low value of 0.1, which also increases the calculated pore velocities. The pore velocities are as low as 1.7 m/day (5.6 ft/day) (approximately 300 m/180 days [984 ft/180 days]) upgradient from well 199-H4-11.

Contaminated groundwater is contained and prevented from discharging into the Columbia River and downgradient of the capture zones. Flow lines terminating at the river in Figure E-2 indicate areas where the groundwater may bypass the extraction wells and discharge into the river. Although a flow line reaches the river near aquifer tube AT-H-1, chromium concentrations in this tube have historically been very low. The capture zone extends from well 199-H4-15A downward to well 199-H4-63. Former extraction well 199-H4-11 was turned off, and former injection wells 199-H3-3, 199-H3-4, and 199-H3-5 were also turned off. Extraction well 199-H4-7 was converted into an injection well, and monitoring wells 199-H4-14 and 199-H4-17 were turned into injection wells in 2005. The contaminant monitoring data indicate that the extraction wells are containing the remaining high-concentration area of the plume, whereas the

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concentrations observed in the areas where the flow lines bypass the extraction wells are below or close to the compliance level.

Overall, the pump-and-treat system appears to have improved conditions in the aquifer. The extraction of the contaminated groundwater and the arrival of the treated injection water appear to be reducing the hexavalent chromium concentration throughout the original targeted plume area. The chromium plume west of the H Reactor (which had been controlled by injection in wells 199-H3-3, 199-H3-4, and 199-H3-5) apparently has moved back into the former injection well area and is actively being monitored.

E4.0 100-K AREA NUMERICAL MODEL

The 100-K numerical model was developed initially to support design of the pump-and-treat systems. The transmissivity distributions in the model were developed from hydraulic properties contained in DOE-RL (1993, 1994, 1996) and then were updated in DOE-RL (1998, 1999) to include aquifer property analyses based on data collected by the hydraulic monitoring network and pump-and-treat operations. A comparison of the modeled water levels to the current year's water levels measured in November 2006 is presented in Table E-3.

Flow lines terminating at the extraction wells in Figure E-3 show the approximate area of the aquifer through which each extraction well removes groundwater. The flow lines indicate where a particle of water travels in the aquifer and whether the water is captured by the extraction wells or discharged into the river. Because the extraction wells fully penetrate the unconfined aquifer, the flow lines represent groundwater travel throughout the depth of the aquifer. The total area encompassed by the flow lines terminating at each extraction well represents the capture zone of that extraction well. The flow-line calculations are independent of the travel time, and as stated previously, the actual flow paths vary throughout the year. Because the purpose of the pump-and-treat system is to reduce discharge of contaminated groundwater to the Columbia River, the flow lines shown on the figures are only representative of the conditions during the time when groundwater flow toward the river would be greatest.

Figure E-3 also shows time markers spaced one year apart on the flow lines, based on the high November steady-state velocities. The slowest flow lines, which have pore velocities of around 0.3 m/day (1 ft/day) (approximately 110 m/365 days [361 ft/365 days]) for most of the distance, are located northeast and southwest of the extraction wells in the center. The pore velocities upgradient and between extraction wells 199-K-119A and 199-K-125A are the largest, with values around 1.5 m/day (4.9 ft/day) (approximately 540 m/365 days [17,772 ft/365 days]), which are enhanced by injection wells 199-K-121A and 199-K-122A. There is high hydraulic conductivity in this region, and the effective porosity is set to a low value of 0.1, which also increases the calculated pore velocities. The high velocities are the main reason that the chromium levels are so low for extraction wells 199-K-119A and 199-K-125A. The low velocities and the high chromium plume up-gradient from extraction well 199-K-120A in the southwest indicate that the concentration levels there will remain above 50 $\mu\text{g/L}$ for 2 years or more. Compliance well 199-K-18, located near well 199-K-120A, is actually in the peak contaminant plume and should show reduced levels in 1 or 2 years.

An exponential decay model is developed in Section E4-1 for the removal rate of contaminants from extraction wells. The model indicates that the travel time from an injection well to an extraction well can be used to predict the concentrations in the future. Such predictions can

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indicate the presence of new vadose zone contaminant input. For extraction wells 199-K-119A and 199-K-125A, no new contaminant input from the vadose zone is indicated.

Apparent hydraulic capture extends almost entirely the length of the extraction wells between wells 199-K-129 in the north and 199-K-120A in the south; however, up to 80 µg/L chromium have been detected in aquifer tube AT-K-3 since 2005. The locations of all 100-K Area extraction wells resulted from discussions with cultural resources representatives and the Tribes, and the wells were placed to minimize impacts to cultural resource sites (DOE-RL 1996). The locations of wells 199-K-119A, 199-K-127, and 199-K-120A were particularly difficult because of their proximity to a highly sensitive area. Because of the high transmissivity around well 199-K-116A, the capture zone resulting from pumping in that well is very small compared to the capture zones surrounding the other extraction wells; however, all of the groundwater appears to be captured by the extraction wells. North of the extraction wells, groundwater bypasses the system in the vicinity of well 199-K-126, which is no longer an extraction well.

E4.1 Evaluation of Aquifer Cleanup Dynamics

Using the travel times between injection and extraction wells (time markers shown in Figures E-1 through E-3), some inferences can be made about the nature and extent of mobile contaminants (e.g., hexavalent chromium) removal from the aquifer. For example, a semi-log plot of chromium concentration versus time should approximate a straight line if only washout or purging of a contaminant from the aquifer is occurring. If additional contaminant input occurs over the period of observations, the observed concentrations will depart significantly from the expected linear model.

The expected rate of decline can be estimated from a simple exponential washout model (Graham and Johnson 1991) of the form:

$$C(t) = C_0 [\exp(-Q/V)*t] \quad (\text{Equation E-1})$$

where:

- $C(t)$ = chromium (µg/L) in the extracted water at time t , (yr)
- C_0 = initial concentration at some starting time,
- Q = extraction rate in volume per unit time
- V = pore fluid volume in the portion of the aquifer being treated.

The “ Q/V ” term is a rate constant and requires knowing the aquifer volume. Where the pore volume is unknown, an equivalent expression for the “ Q/V ” term can be derived by assuming that one aquifer volume is removed during the average travel time along particle flow paths between injection and extraction well pairs. A macro-scale “ Q ” and “ V ” can be computed in terms of travel time (T) for a particle to travel between injection and extraction well, average groundwater velocity (v), distance or length of the aquifer(x), and cross-sectional area (A), as follows:

$$Q = A * v \quad (\text{Equation E-2})$$

$$V = A * x \quad (\text{Equation E-3})$$

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The length (x) of the aquifer is related to velocity by the product of travel time (T) and velocity, or $x = v * T$; substituting for “x” in Equation (E-3) above:

$$V = A * v * T \quad \text{(Equation E-4)}$$

Then dividing Equation (E-2) by Equation (E-4), the cross-sectional area (A) and groundwater velocity (v) cancel and the macro-scale “Q/V” term reduces to the following:

$$Q/V = 1/T \quad \text{(Equation E-5)}$$

Thus, using the average travel time (T) in years between injection and extraction wells (e.g., average of particle path time markers in Figure E-3 for the 100-K Area), the derived rate constant (1/T) can be substituted in Equation (E-1) above to provide an approximation of chromium concentration versus pumping time.

A basic assumption in applying the above to the 100-KR-4 OU pump-and-treat conditions is that the initial concentration, C_0 , is uniform in the aquifer being treated. This is a reasonable assumption for at least a qualitative evaluation of pump-and-treat cleanup dynamics for some of the extraction wells. In reality, there are some higher concentrated regions in the aquifer, which could increase the concentration at an extraction well, but such an increase would not be due to new contaminant input from the vadose zone.

Application of Equations (E-1) to (E-5) is illustrated in Figures E-4 and E-5 up until the end of year 2005. The predicted concentration over time shown in the figures uses an average travel time of 3 years (i.e., from time markers on particle path lines) and a time decay constant (T) from best-fit of the data. For well 199-K-119A, the best-fit determined value of “T” is 3.308 years and 3.37 years for well 199-K-125A, which slightly higher than 3 years, and the two predicted curves with different time decay constants are shown in each figure. The observed data for the two extraction wells (119-K-119A and 119-K-125A) are in reasonable agreement with the predicted concentration (the R^2 value of fitted curves is around 0.96 for both best fits). This suggests that washout of cleanup of the aquifer treated by the theoretical capture zone for the two wells is occurring in an expected manner. Also, new contaminant input from vadose zone drainage or other sources must be minimal, or a significant departure from the linear model would exist. The efficacy of many of the other extraction well pairs can be analyzed in a similar manner. Qualitatively, the time concentration patterns of the more northeasterly pairs suggest much slower decline in chromium concentration because the travel times are much longer.

In conclusion, it appears that the sluggish pump-and-treat response for the northeastern end of the network is more related to simple aquifer turnover dynamics than to additional new input. The significance of this hypothesis is that it may mean that efforts should be focused more on changing network dynamics than on chasing a more elusive vadose zone source.

In November 2006, hexavalent chromium measured values were 0.014 mg/L for well 199-K-119A and 0.020 mg/L for well 199-K-125A. These values are lower than shown in Figures E-4 and E-5, which indicates that the curves are still declining, but more slowly than previous years.

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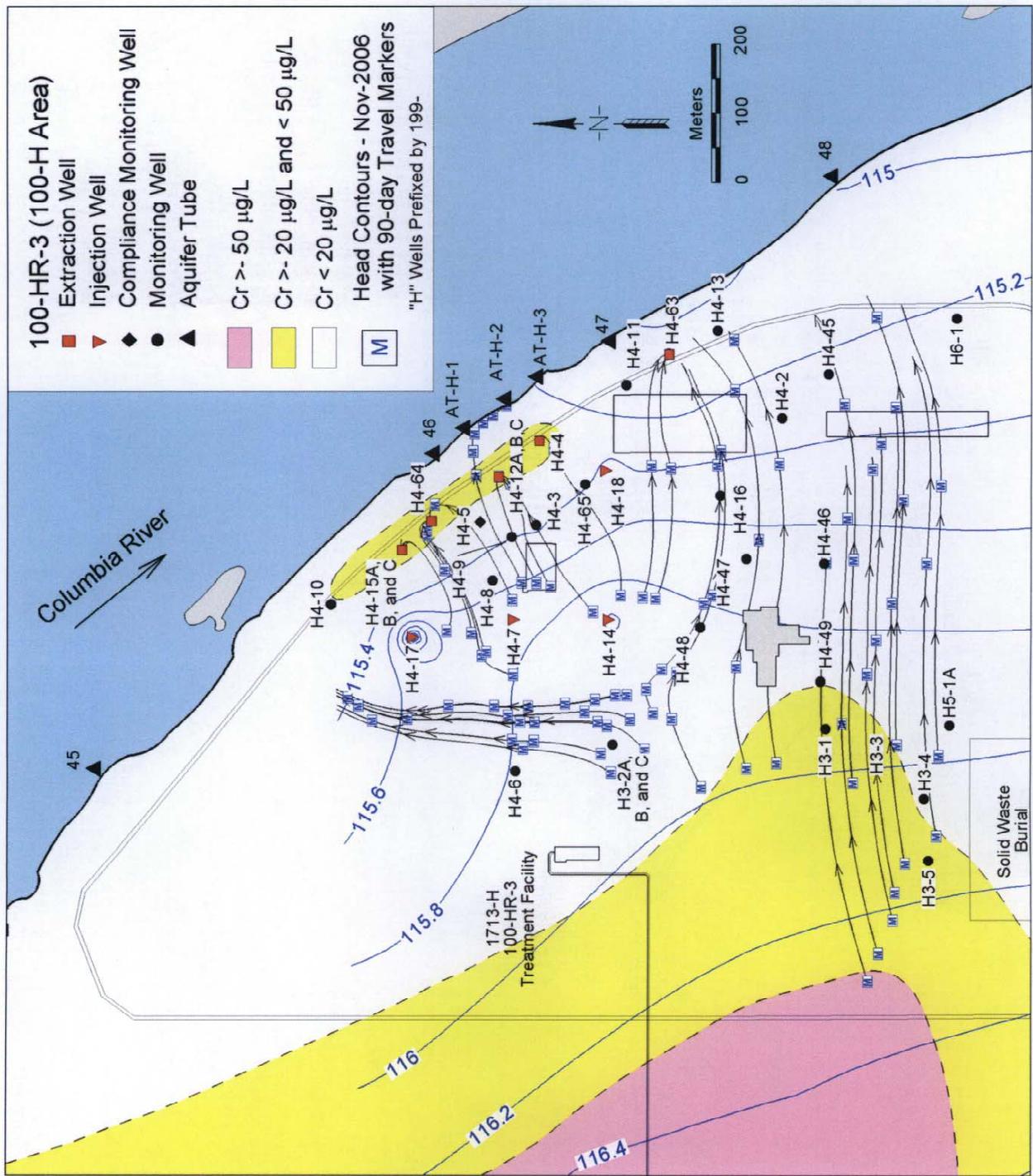
E5.0 100-N AREA GROUNDWATER NUMERICAL MODELING

Numerical modeling was not performed in the 100-N Area during calendar year 2006. The water heads for selected wells that were measured in November 2006 are presented in Table E-4.

E6.0 REFERENCES

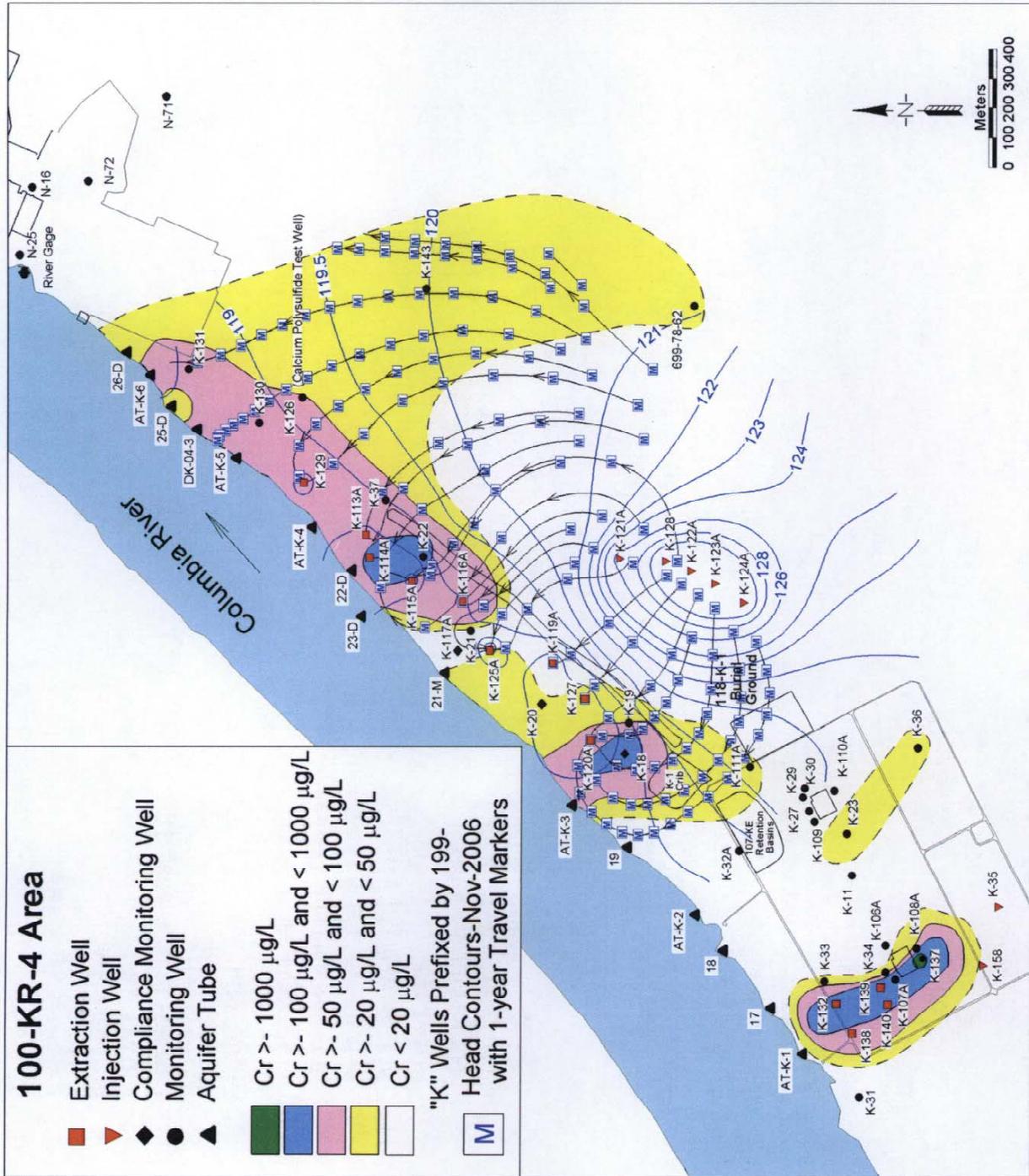
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Figure E-2. Estimated Steady-State Hydraulic Capture Zone Developed by 100-HR-3 Operable Unit 100-H Area Extraction Wells and Nearby Flow Field.



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Figure E-3. Estimated Steady-State Hydraulic Capture Zone Developed by 100-KR-4 Operable Unit Extraction Wells and Nearby Flow Field.



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Figure E-4. Observed and Predicted Chromium Levels in Extraction Well 199-K-119A.

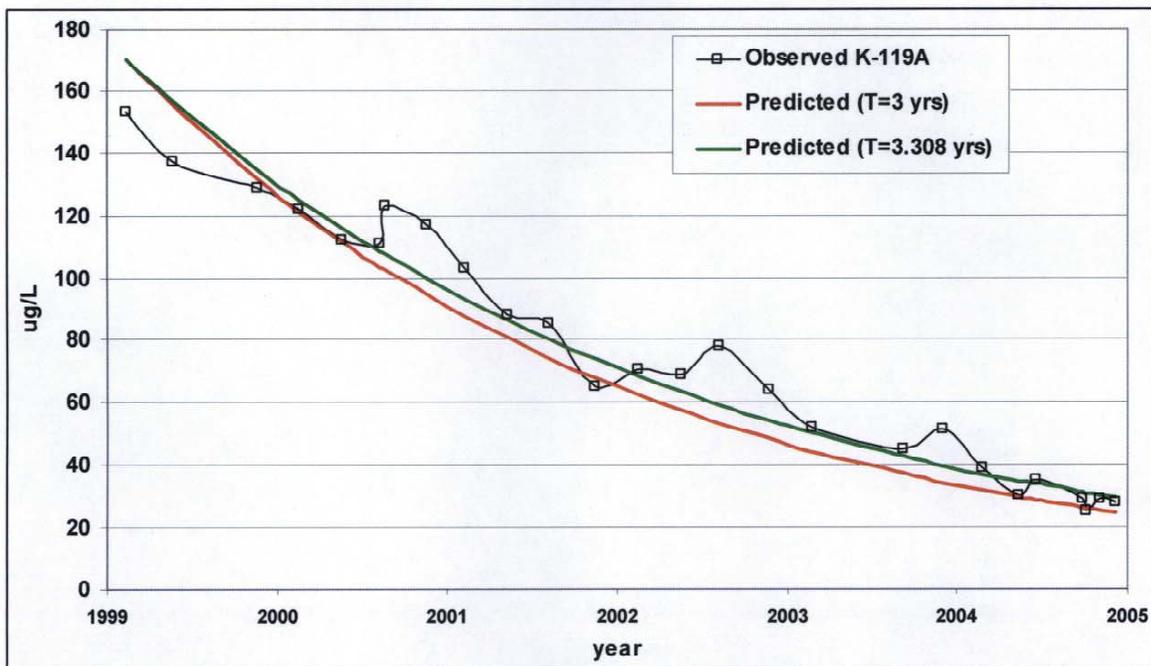
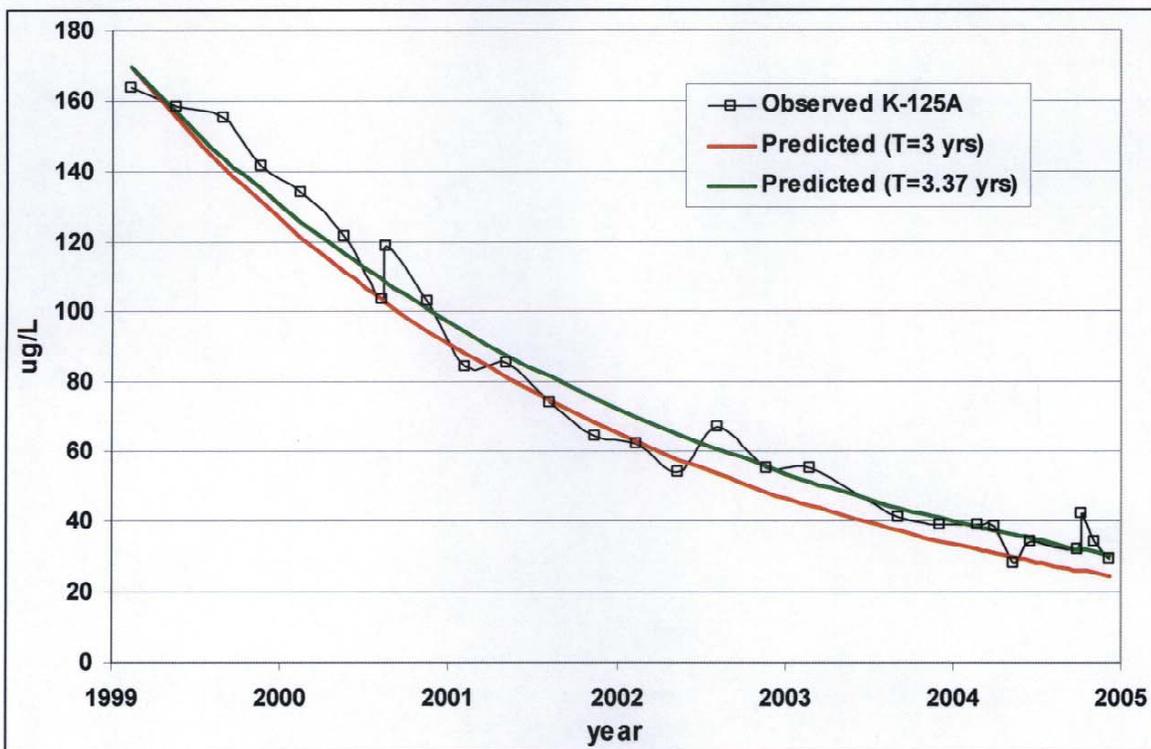


Figure E-5. Observed and Predicted Chromium Levels in Extraction Well 199-K-125A.



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Table E-1. 100-HR-3 (100-D Areas Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis. Nov. 2006		Measured Water-Level Elevation, Nov. 2006 (m NAVD88 ^a)	Modeled Water-Level Elevation, Nov. 2006 (m NAVD88 ^a)
	Extraction Rate L/min	Injection Rate L/min		
100-D Area				
199-D5-13	—	—	117.70	117.71
199-D5-14	—	—	117.99	117.83
199-D5-15	—	—	118.10	118.10
199-D5-16	—	—	118.06	117.93
199-D5-17	—	—	118.30	118.19
199-D5-18	—	—	118.23	118.18
199-D5-19	—	—	118.35	118.24
199-D5-41	—	—	117.94	117.89
199-D5-43	—	—	118.19	118.14
199-D5-44	—	—	117.76	117.77
199-D8-5	—	—	117.12	117.27
199-D8-6	—	—	117.90	117.56
199-D8-55	—	—	117.06	117.14
199-D8-53	30.6	—	—	117.16
199-D8-54A	58.3	—	—	117.07
199-D8-68	212.9	—	—	116.85
199-D8-72	42.2	—	—	117.24
199-D5-20	28.4	—	—	115.62
199-D5-32	54.9	—	—	117.60
199-D5-37	—	—	—	117.58
199-D5-39	54.9	—	—	117.95
199-D5-42	—	166.6	—	118.19
199-D5-92	28.3	—	—	117.00
199-D8-69	—	—	117.07	117.15
199-D8-70	—	—	117.04	117.22
199-D8-71	—	—	116.99	117.17
100-D River	—	—	117.55	117.55

^a NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

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Table E-2. 100-HR-3 (100-H Area) Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis. Nov. 2006		Measured Water-Level Elevation, Nov. 2006 (m NAVD88 ^a)	Modeled Water-Level Elevation, Nov. 2006 (m NAVD88 ^a)
	Extraction Rate L/min	Injection Rate L/min		
100-H Area				
199-H3-2A	—	—	115.95	115.90
199-H4-7	—	26.1	115.80	115.87
199-H4-17	—	234.5	120.18	117.01
199-H4-11	—	—	114.90	115.14
199-H4-14	—	254.2	118.50	116.16
199-H4-18	—	69.4	118.49	115.58
199-H4-12A	21.5	—	—	115.22
199-H4-15A	75.7	—	114.76	115.21
199-H4-65	—	—	115.61	115.39
199-H3-3	—	0	116.04	116.02
199-H3-4	—	0	116.04	116.05
199-H3-5	—	0	116.10	116.14
199-H3-2C	—	—	115.95	115.90
199-H4-3	23.7	—	114.80	115.34
199-H4-4	21.3	—	114.73	115.21
199-H4-5	—	—	115.23	115.32
199-H4-8	—	—	115.68	115.52
199-H4-10	—	—	115.22	115.20
199-H4-63	93.1	—	115.10	114.91
199-H4-64	39.2	—	115.49	115.17
199-H5-1A	—	—	116.04	115.95
100-H River	—	—	115.29	115.29

^a NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

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Table E-3. 100-KR-4 Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis, Nov. 2006		Measured Water-Level Elevation, Nov. 2006 (m NAVD88 ^a)	Modeled Water-Level Elevation, Nov. 2006 (m NAVD88 ^a)
	Extraction Rate L/min	Injection Rate L/min		
199-K-129	55.7	—	—	117.59
199-K-113A	50.2	—	—	116.59
199-K-114A	146.2	—	118.69	118.24
199-K-115A	152.3	—	—	115.78
199-K-116A	142.8	—	118.15	118.90
199-K-119A	94.3	—	—	116.83
199-K-120A	188.8	—	117.63	117.99
199-K-125A	134.7	—	—	115.54
199-K-126	—	—	119.34	119.16
199-K-127	119.3	—	116.94	116.90
199-K-121A	—	162.2	128.12	131.13
199-K-122A	—	297.3	—	152.65
199-K-123A	—	234.9	—	150.85
199-K-124A	—	92.1	128.51	140.19
199-K-128	—	295.6	—	146.88
199-K-18	—	—	118.44	118.69
199-K-19	—	—	118.53	118.92
199-K-20	—	—	118.26	118.43
199-K-21	—	—	118.14	118.82
199-K-22	—	—	118.08	118.72
199-K-37	—	—	118.68	119.00
199-K-114A	—	—	118.69	118.24
199-K-117A	—	—	116.27	118.73

^a NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

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Table E-4. 100-NR-2 Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Extraction Rate L/min	Injection Rate L/min	Measured Elevation, Nov. 2006 (m NAVD88a)	Modeled Elevation, Nov. 2006 (m NAVD88a)
199-N-75	—	—	—	NC
199-N-103A	—	—	—	NC
199-N-105A	—	—	—	NC
199-N-106A	—	—	—	NC
199-N-104A	—	—	—	NC
199-N-29	—	—	—	NC
199-N-2	—	—	118.17	NC
199-N-3	—	—	118.11	NC
199-N-8S	—	—	118.31	NC
199-N-14	—	—	118.04	NC
199-N-16	—	—	118.37	NC
199-N-34	—	—	118.78	NC
199-N-50	—	—	118.00	NC
199-N-72	—	—	118.70	NC
199-N-76	—	—	118.02	NC
199-N-92A	—	—	118.19	NC
N-River	—	—	118.44	NC

^a NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

NC = not calculated because of no pumping

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APPENDIX F
CONTAMINANT MONITORING

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APPENDIX F

CONTAMINANT MONITORING

The annual averages for contaminant monitoring discussed below were developed using data from the Hanford Environmental Information System database and were calculated using software performing the algorithm logic specified below. Where data was not available from the previous year, results were added.

F1.0 SAMPLE RECOGNITION

ARTDAT, v2.1.1 Logic: result recognition:

[A] Metal - A result is recognized as a metal:

- (1) If (STD_CON_LONG_NAME is Uranium) and (METHOD_NAME is in (RADIOISOTOPES_ICPMS, TCLP_200.8_MET_ICP, UTOT_KPA, UTOT_KPA_FLD) and (STD_ANAL_UNITS_RPTD is not pCi/L)).
- (2) If (STD_CON_LONG_NAME is not Uranium) and (CLASS is METALSING or METALMULT) and (STD_ANAL_UNITS_RPTD is not pCi/L).

[B] Non-metal - A result is recognized as a non-metal:

- (1) If (STD_CON_LONG_NAME is Uranium) and (METHOD_NAME is not in (RADIOISOTOPES_ICPMS, TCLP_200.8_MET_ICP, UTOT_KPA, UTOT_KPA_FLD)) and (STD_ANAL_UNITS_RPTD is not pCi/L).
- (2) If (STD_CON_LONG_NAME is not Uranium) and (CLASS is not METALSING and not METALMULT) and (STD_ANAL_UNITS_RPTD is not pCi/L).

[C] Radiological - A result is recognized as radiological:

- (1) If (STD_ANAL_UNITS_RPTD is pCi/L).

[D] Duplicate - Results are recognized as a duplicate pair by:

- (1) Two results with the same WELL_NAME, STD_CON_ID, SAMP_DATE_TIME, FILTERED_FLAG, LAB_CODE.

[E] Split - Results are recognized as a split pair by:

- (1) Two results with the same WELL_NAME, STD_CON_ID, SAMP_DATE_TIME and different LAB_CODE.

F2.0 AVERAGE CONCENTRATIONS METHODOLOGY

F2.1 METALS (CHROMIUM AND HEXAVALENT CHROMIUM)

The average concentration reported (AVG_CONC column of output table) is rounded to the least number of digits after the decimal place.

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The average concentration (AVG_CONC_SD column of the output table) is reported in scientific notation to the correct number of significant figures.

(Example: For the STD_VALUE_RPTD set of 9, 16.9, 21;
the AVG_CONC = 15.6 and AVG_CONC_SD = 2E+1.)

[A] Results are used for the average concentration calculation:

- (1) If (STD_CON_LONG_NAME is Chromium) and (FILTERED_FLAG is Y).
- (2) If (STD_CON_LONG_NAME is Hexavalent Chromium).
- (3) If (LAB_QUALIFIER is like *U*), then use 1/2 of the STD_VALUE_RPTD.

[B] Duplicate - Results used in the average concentration calculation:

- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_VALUE_RPTD.
- (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_VALUE_RPTD.
- (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_VALUE_RPTD for result with (LAB_QUALIFIER is not like *U*).

[C] Split - Results used in the average concentration calculation:

- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_VALUE_RPTD.
- (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_VALUE_RPTD.
- (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_VALUE_RPTD for result with (LAB_QUALIFIER is not like *U*).

F2.2 NON-METALS

The average concentration reported (AVG_CONC column of output table) is rounded to the least number of digits after the decimal place.

The average concentration (AVG_CONC_SD column of the output table) is reported in scientific notation to the correct number of significant figures.

(Example: For the STD_VALUE_RPTD data set of 9, 16.9, 21;
the AVG_CONC = 15.6 and AVG_CONC_SD = 2E+1.)

[A] Results used for the average concentration calculation:

- (1) All non-metal samples (see SECTION 1[B]).
- (2) If LAB_QUALIFIER is like *U*, then use 1/2 of the STD_VALUE_RPTD result value.

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[B] Duplicate - Results used in the average concentration calculation:

- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_VALUE_RPTD.
- (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_VALUE_RPTD.
- (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_VALUE_RPTD for result with (LAB_QUALIFIER is not like *U*).

[C] Split - Results used in the average concentration calculation:

- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_VALUE_RPTD.
- (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_VALUE_RPTD.
- (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_VALUE_RPTD for result with (LAB_QUALIFIER is not like *U*).

F2.3 RADIOLOGICAL

The average concentration reported (AVG_CONC column of output table) is rounded to the least number of digits after the decimal place.

The average concentration (AVG_CONC_SD column of the output table) is reported in scientific notation to the correct number of significant figures.

(Example: For the STD_VALUE_RPTD data set of 9, 16.9, 21;
the AVG_CONC = 15.6 and AVG_CONC_SD = 2E+1.)

The average TOTAL_ANALYTICAL_ERROR reported (AVG_ANAL_ERROR) is rounded to the least number of digits after the decimal place.

If STD_VALUE_RPTD result value is negative, then use the absolute value.

[A] Results used for the average concentration calculation:

- (1) If (LAB_QUALIFIER is not like *U*), then use the STD_VALUE_RPTD.
- (2) If (LAB_QUALIFIER is like *U*), then use 1/2 of the STD_VALUE_RPTD.

[B] Results used for the average total analytical error calculation:

- (1) If (LAB_QUALIFIER is not like *U*), then use the STD_TOTAL_ANALYTICAL_ERROR.
- (2) If (LAB_QUALIFIER is like *U*), then use 1/2 of the STD_TOTAL_ANALYTICAL_ERROR.

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- [C] Duplicate - Results used in the average concentration calculation:
- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_VALUE_RPTD.
 - (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_VALUE_RPTD.
 - (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_VALUE_RPTD for result with (LAB_QUALIFIER is not like *U*).
- [D] Duplicate - Results used in the average total analytical error calculation:
- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_TOTAL_ANALYTICAL_ERROR.
 - (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_TOTAL_ANALYTICAL_ERROR.
 - (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_TOTAL_ANALYTICAL_ERROR for result with (LAB_QUALIFIER is not like *U*).
- [E] Split - Results used in the average concentration calculation:
- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_VALUE_RPTD.
 - (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_VALUE_RPTD.
 - (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_VALUE_RPTD for result with (LAB_QUALIFIER is not like *U*).
- [F] Split - Results used in the average total analytical error calculation:
- (1) If both (LAB_QUALIFIERS are not like *U*), then use the average of STD_TOTAL_ANALYTICAL_ERROR.
 - (2) If both (LAB_QUALIFIERS are like *U*), then use 1/2 of the average STD_TOTAL_ANALYTICAL_ERROR.
 - (3) If (LAB_QUALIFIER is not like *U*) and (LAB_QUALIFIER is like *U*), then use the STD_TOTAL_ANALYTICAL_ERROR for result with (LAB_QUALIFIER is not like *U*).

F2.4 LABORATORY DUPLICATES

- [A] Two results with the same SAMP_DATE_TIME, STD_CON_ID, WELL_NAME, FILTERED_FLAG, LAB_CODE and LAB_CODE is not like FIELD
- [B] Relative percent difference (RPD) calculation:
- (1) If both (LAB_QUALIFIERS are not like *U*), then $RPD = [(Abs(dupOne - dupTwo) * 100) / ((dupOne + dupTwo) / 2)]$.
 - (2) If one (LAB_QUALIFIER is like *U*), then RPD = " " (i.e., blank).

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- (3) If METHOD_NAME for the duplicate pair are not the same, then RPD = " " (i.e., blank).
- (4) If both (STD_VALUE_RPTD are NULL), then RPD = " " (i.e., blank).

F2.5 FIELD DUPLICATES

[A] Two results with the same SAMP_DATE_TIME, STD_CON_ID, WELL_NAME, FILTERED_FLAG, LAB_CODE and LAB_CODE is like FIELD

[B] RPD calculation:

- (1) If both (LAB_QUALIFIERS are not like *U*), then $RPD = [(Abs(dupOne - dupTwo) * 100) / ((dupOne + dupTwo) / 2)]$.
- (2) If one (LAB_QUALIFIER is like *U*), then RPD = " " (i.e., blank).
- (3) If METHOD_NAME for the duplicate pair are not the same, then RPD = " " (i.e., blank).
- (4) If both (STD_VALUE_RPTD are NULL), then RPD = " " (i.e., blank).

F2.6 LABORATORY SPLITS

[A] Two results with the same SAMP_DATE_TIME, STD_CON_ID, WELL_NAME and LAB_CODE is different

[B] RPD calculation:

- (1) If both (LAB_QUALIFIERS are not like *U*), then $RPD = [(Abs(dupOne - dupTwo) * 100) / ((dupOne + dupTwo) / 2)]$.
- (2) If one (LAB_QUALIFIER is like *U*), then RPD = " " (i.e., blank).
- (3) If METHOD_NAME for the duplicate pair are not the same, then RPD = " " (i.e., blank).
- (4) If both (STD_VALUE_RPTD are NULL), then RPD = " " (i.e., blank).

F3.0 100-HR-3 CONTAMINANT MONITORING

The historical trend plot of contaminants and co-contaminants for the 100-D and 100-H Areas is presented in Appendix J.

- **100-D chromium monitoring results:** Chromium is monitored in the 100-D Area in extraction wells, compliance wells, monitoring wells, and aquifer tubes. The average annual chromium concentrations for 1997 through 2006 are presented in Table F-1.
- **100-D co-contaminant monitoring results:** The 100-D Area co-contaminants are strontium-90 and tritium (*Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* [DOE-RL 1997]). Other contaminants of concern (COCs) include nitrate and sulfate. Table F-2 presents the average annual co-contaminant concentrations and short-term concentration trends (where they could be developed).

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- **100-H chromium monitoring results:** Chromium is monitored in the 100-H Area in extraction wells, compliance wells, monitoring wells, and aquifer tubes. Average annual chromium concentrations for 1997 through 2006 are presented in Table F-3.
- **100-H co-contaminant monitoring results:** The 100-H Area co-contaminants are strontium-90, technetium-99, tritium, uranium, and nitrate (DOE-RL 1997). A summary of 100-H Area co-contaminant results is provided in Table F-4.

F4.0 100-KR-4 CONTAMINANT MONITORING

The principal COC addressed by pump-and-treat operations in the 100-K Area is chromium. Co-contaminants relevant to pump-and-treat operations are tritium and strontium-90 (DOE-RL 1997). Nitrate and carbon-14 are contaminants of interest. The historical summary of 100-K Area contaminants and co-contaminants is presented in Appendix J.

- **100-K chromium monitoring results:** Chromium is monitored throughout the 100-K pump-and-treat area in extraction wells, compliance wells, monitoring wells, and aquifer tubes. Additional *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) monitoring wells outside of the area influenced by pump-and-treat operations are also monitored for chromium. The average annual chromium concentrations for 1997 through 2006 are presented in Table F-5.
- **100-K co-contaminant monitoring results:** Strontium-90 and tritium are 100-K Area pump-and-treat co-contaminants. Nitrate and carbon-14 are 100-K contaminants of interest that are also monitored as part of the CERCLA sampling. A summary of 100-K co-contaminant results is presented in Table F-6.

F5.0 100-NR-2 CONTAMINANT MONITORING

The principal groundwater COCs in the 100-N Area are strontium-90, tritium, chromium, manganese, sulfate, and petroleum hydrocarbons. The major annual sampling event is in September and March. The governing document for sampling is the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 2003) Change Control Form, Control Number M-15-96-08, dated October 9, 1996.

The historical summary of 100-NR-2 contaminants and co-contaminants is presented in Appendix L.

- **100-NR-2 strontium-90 monitoring results:** Strontium-90 was monitored in extraction wells, monitoring wells, and aquifer tubes during calendar year 2006 (CY06). A summary of average strontium-90 concentrations since 1997 is presented in Table F-7.
- **100-NR-2 co-contaminant monitoring results:** Other COCs in the 100-N Area include tritium, chromium, manganese, nitrate, sulfate, and petroleum hydrocarbons (EPA et al. 1999). Table F-8 provides the average annual COC concentrations discussed below and the short-term concentration trends (where they could be developed) from 1997 to 2006.

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F6.0 AQUIFER SAMPLING TUBE RESULTS

Samples for principal groundwater COCs and associated co-contaminants were collected in the various operable units from aquifer sampling tubes at 100-NR-2, 100-KR-4, the 100-D Area, and at the 100-H Area for the 100-HR-3 Operable Unit in CY04. The results are presented in Tables F-9, F-10, and F-11.

F7.0 REFERENCES

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, 42 U.S.C. 9601, et seq.

DOE-RL, 1997, *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units*, DOE/RL-96-90, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 2003, *Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement)*, 2 vols., as amended, 89-10, Rev. 6, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

EPA, Ecology, and DOE, 1999, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington*, U.S. Environmental Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Olympia, Washington.

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Table F-1. Selected Chromium Data for 100-D Area Wells. (3 sheets)

Well Name	Well ID	CY99 Average (µg/L)	CY00 Average (µg/L)	CY01 Average (µg/L)	CY02 Average (µg/L)	CY03 Average (µg/L)	CY04 Average (µg/L)	CY05 Average (µg/L)	CY06 Average (µg/L)	Annual Comparison	Well Use
Hexavalent Chromium (µg/L)											
199-D2-6	A4568	—	—	—	—	—	36.2	31 [3.1 E+1]	25 [3E+1] (D)	Stable	M
199-D2-8	C3040	—	—	—	—	—	156.5	144 [1.4 E+2]	—	c	M
199-D3-2	B8074	—	—	—	—	—	9.7	14 [1 E+1]	—	c	M
199-D4-15	B8073	—	—	—	—	—	—	1,381 [1.4E+3]	1,460 [1.5E+3]	Stable	M
199-D4-20	B8750	—	—	—	—	—	—	148 [1E+2]	180 [1.8E+2]	Increasing	M
199-D4-22	B8778	—	—	—	—	—	—	926 [9.3E+2]	837 [8.4E+2]	Stable	M
199-D5-13	A4570	379.2	436.8	641	717	759.5	701	554 [5.54 E+2]	537 [5.37E+2]	Stable	M
199-D5-14	A4571	839	—	602	395	281	303	384 [3.84 E+2]	430 [4.3E+2] (D)	Stable	M
199-D5-15	A4572	150.2	72	193	244	281.5	559	731 [7.3 E+2]	1,231 [1.23E+3]	Increasing	M
199-D5-16	A4573	313	251.5	204	136	120.8	98.6	70 [7 E+1]	70 [7.0E+1] (D)	Stable	M
199-D5-17	A4574	28	—	20.0	12	15.2	15.2 ^c	15.1 [1.51 E+1]	c	Stable	M
199-D5-18	A4575	—	—	20.9	13	—	12.2 ^c	—	—	c	M
199-D5-19	A4576	21.1	—	24.3	—	11.1	12.5 ^c	—	—	c	M
199-D5-20	A4577	49	140.3	201	487	845.8	1,380	645 [6.45 E+2]	513 [5.1E+2] (D)	Decreasing	E
199-D5-32	C4185	—	—	—	—	—	843	1,191 [1.19 E+3]	902 [9.0E+2] (U)	Decreasing	E
199-D5-33	C4186	—	—	—	—	—	5.0	5 (U) [5 E+0]	3 [3E+0]	Stable	M
199-D5-34	C4187	—	—	—	—	—	6.5	5 (U) [5 E+0]	415 [4.1E+2] (U)	Increasing	M
199-D5-36	B8744	—	—	—	—	—	6.6	3 [3 E+0]	2 [2E+0]	Stable	M