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Revision 1

Supplement to the 100-HR-3 and 100-KR-4 Remedial Design Report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System

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

United States Department of Energy
P.O. Box 550
Richland, Washington 99352

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CONCURRENCE PAGE

Title: Supplement to the 100-HR-3 and 100-KR-4 Remedial Design report and Remedial Action Workplan for the Expansion of the 100-KR-4 Pump and Treat System

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LIST OF TERMS

Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
gpm	gallons per minute
GTS	groundwater treatment system
HEIS	Hanford Environmental Information System
HMI	human/machine interface
IX	ion exchange
OIC	operator interface control
OU	operable unit
PLC	programmable logic controller
QAPjP	quality assurance project plan
QC	quality control
ROD	Record of Decision
RAO	remedial action objective
WAC	*Washington Administrative Code*
WSCF	Waste Sampling and Characterization Facility

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METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
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	millibecquerels	millibecquerels	0.027	picocuries

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1.0 INTRODUCTION

1.1 PURPOSE OF EXPANSION

The purpose of the 2008 100-KR-4 pump-and-treat system expansion is to increase the areal extent of hexavalent plume capture and the capacity of the system to aid in meeting the remedial objectives of 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). Implementation of this expansion will aid in satisfying the 100-KR-4 action items listed in *The Second CERCLA Five-Year Review Report for the Hanford Site* (DOE/RL-2006-20). Action 5-1 requires additional wells between the 116-K-2 Trench and the N Reactor perimeter fence; Action 5-2 requires that the wells stipulated in Action 5-1 increase the capacity of the 100-KR-4 pump-and-treat system by 378.5 L/min (100 gallons per min [gpm]). The 600 gpm expansion design described in this document exceeds the CERCLA 5 Year Review Recommendation and may require optimization, subject to U.S. Environmental Protection Agency (EPA) approval, if actual field conditions (particularly hexavalent chromium plume extent, co-contaminant concentrations, and aquifer parameters) are significantly different than the conditions used for the current design.

This supplement to the *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Operable Units Interim Action* (DOE/RL-96-84) supports the expansion of the pump-and-treat system actively remediating the hexavalent chromium plume associated with the former 116-K-2 Trench. The 100-HR-3 and 100-KR-4 Operable Units (OUs) interim Record of Decision (ROD) (EPA et al. 1996) defines the regulatory performance criteria for cleanup of the hexavalent chromium plume in the 100-KR-4 OU. The supplement includes an updated quality assurance project plan (QAPjP) (Appendix A) and a numerical modeling discussion (Appendix B).

The goals of the 100-KR-4 pump-and-treat expansion are as follows:

- Control the northward migration of the hexavalent chromium plume before it reaches the 100-NR-2 OU.
- Protect the Columbia River by removing high concentration areas and eliminate gaps in coverage between extraction wells.
- Remediate the remainder of the hexavalent chromium plume around the former 116-K-1 Trench to less than the remedial action objective (RAO) of 20 µg/L.

1.2 BACKGROUND

The hexavalent chromium plume in the 100-KR-4 OU has been divided into three smaller plume areas based on contaminant source: (1) the plume associated with the former 116-K-1 Trench, which is the subject of this interim remedial action; (2) the plume around the KW Reactor and the Columbia River, which is being remediated by the KW Reactor pump-and treat-system; and (3) the plume around the KE Reactor, which is currently being monitored but not actively remediated. These three plume areas are shown in Figure 1-1 for the fall 2007 hexavalent chromium plume in the 100-KR-4 OU.

The original 100-KR-4 pump-and-treat system was designed to remediate the hexavalent chromium plume between the former 116-K-2 Trench (also known as the Mile-Long Trench)

and the Columbia River. This original design included seven extraction wells and four injection wells. As additional monitoring wells and aquifer tubes were added since 1997 the interpretation of the plume boundaries also changed and the pump-and-treat well network was modified as well. Figure 1-2 depicts the annual fall hexavalent chromium plumes in the 100-KR-4 OU since the start of operations in 1997.

1.3 MODIFICATIONS TO THE 100-KR-4 PUMP-AND-TREAT NETWORK SINCE 1997

The 100-KR-4 pump-and-treat network of wells has been modified as follows since the start of operations in 1997:

- 1997: Started operations with extraction wells 199-K-112A, 199-K-113A, 199-K-115A, 199-K-116A, 199-K-118A, 199-K-119A, and 199-K-120A; and injection wells 199-K-121A, 199-K-122A, 199-K-123A, and 199-K-124A. Well 199-K-118A was not used operationally because of sanding.
- 1998: Replaced extraction well 199-K-118A with 199-K-125A. Well 199-K-118A had been plagued with heavy sand inflow during operation.
- 1999: Added compliance well 199-K-126 to monitor movement of the hexavalent chromium plume toward the 100-N Area.
- 2002: Added extraction well 199-K-127 to improve capture between existing extraction wells 199-K-119A and 199-K-120A.
- 2003: Converted compliance well 199-K-126 to an extraction well, added well 199-K-130 to monitor hexavalent chromium nearer the 100-N Area, and replaced extraction well 199-K-112A with extraction well 199-K-129.
- 2004: Converted compliance well 199-K-114A to an extraction well to improve capture where hexavalent chromium concentrations were high in aquifer tubes 22 and 23. Added well 199-K-131 to monitor the plume nearer the 100-N Area. Added aquifer tubes AT-K-1 through AT-K-6.
- 2005: Used extraction well 199-K-126 in a test of calcium polysulfide as an alternative treatment technology. Drilled four monitoring wells around well 199-K-126 (199-K-133 through 199-K-136)
- 2007: Installed monitoring well 199-K-143 to provide an inland sampling point to assess the hexavalent chromium concentration between the former 116-K-2 Trench and monitoring well 699-78-62.
- Late 2007 and early 2008: Installed nineteen new wells and converted three existing wells for the 100-KR-4 pump-and-treat expansion. The expansion wells are listed below by operational purpose:

Extraction Wells	Injection Wells	Monitoring (Performance)Wells
199-K-130	199-K-143	199-K-151
199-K-131	199-K-159	199-K-152
199-K-144	199-K-160	199-K-153
199-K-145	199-K-164	199-K-154
199-K-146	199-K-156	199-K-157
199-K-147		199-K-163
199-K-148		
199-K-149		
199-K-150		
199-K-161		
199-K-162		

- Mid- to late 2008: Added four injection wells (199-K-169, 199-K-170, 199-K-171, and 199-K-172) to replace expansion wells that could not be used for injection purposes because sampling confirmed that the sites were located within the hexavalent chromium plume and that concentrations were above 30 μg/L.

Figure 1-1. 2007 Hexavalent Chromium Plume at the 100-KR-4 Operable Unit.

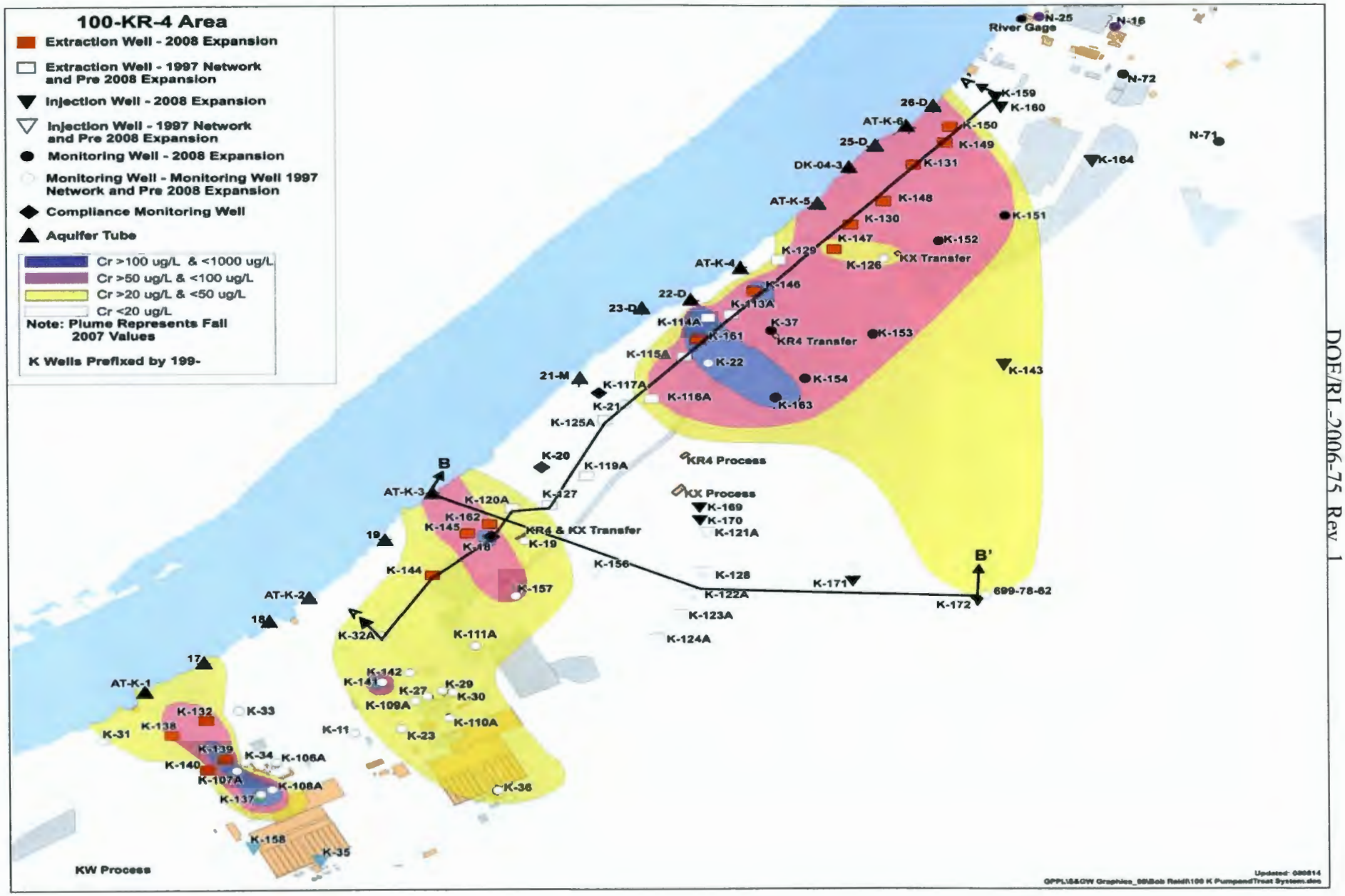
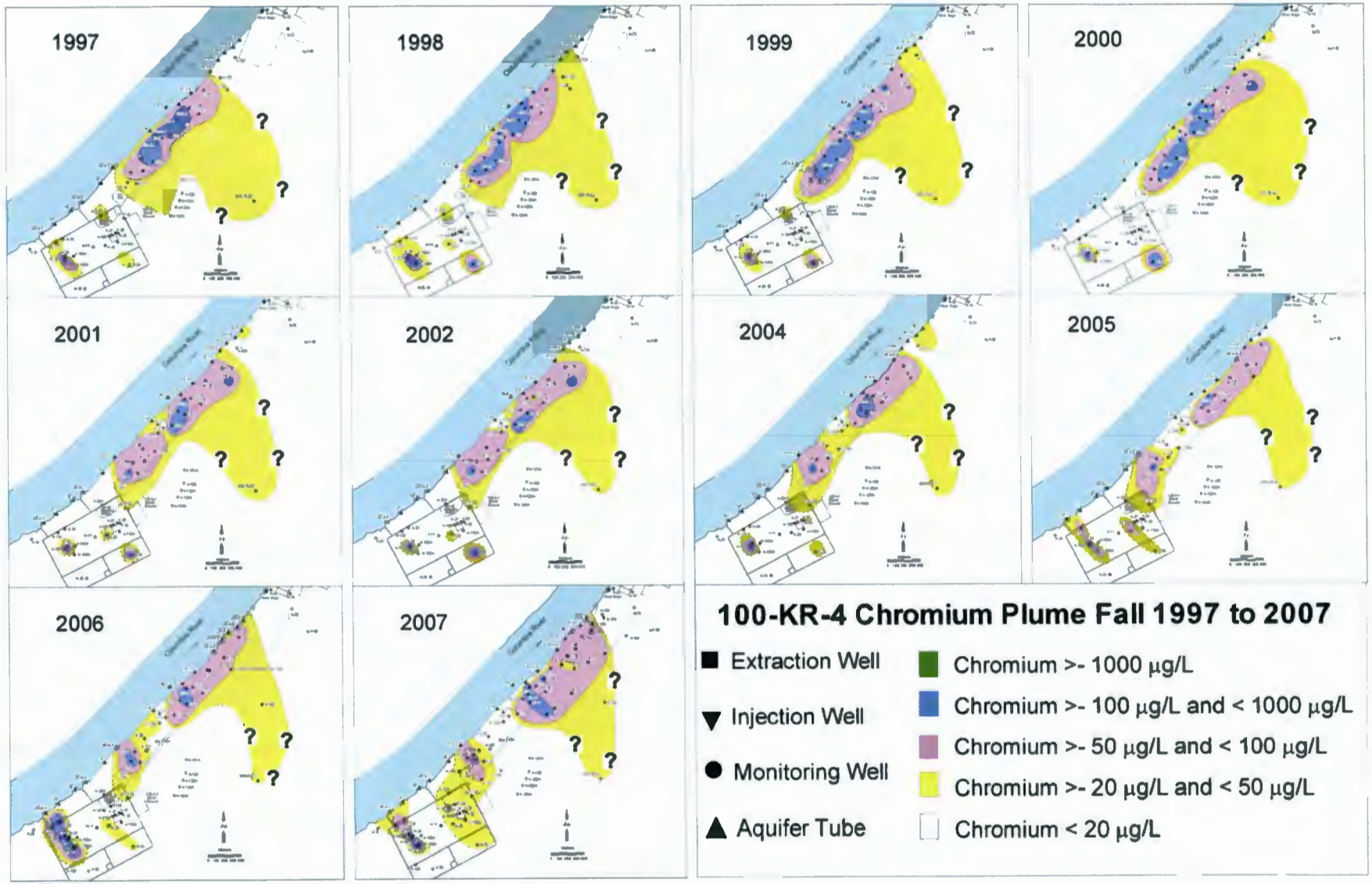

100-KR-4 Area
Extraction Well - 2008 Expansion
Extraction Well - 1997 Network and Pre 2008 Expansion
Injection Well - 2008 Expansion
Injection Well - 1997 Network and Pre 2008 Expansion
Monitoring Well - 2008 Expansion
Monitoring Well - Monitoring Well 1997 Network and Pre 2008 Expansion
Compliance Monitoring Well
Aquifer Tube
Cr >100 ug/L & <1000 ug/L
Cr >50 ug/L & <100 ug/L
Cr >20 ug/L & <50 ug/L
Cr <20 ug/L
Note: Plume Represents Fall 2007 Values
K Wells Prefixed by 199-
River Gage
N-25
N-16
N-72
N-71
K-159
K-160
K-164
26-D
AT-K-6
25-D
DK-04-3
AT-K-5
AT-K-4
22-D
23-D
21-M
AT-K-3
19
18
AT-K-2
17
AT-K-1
K-150
K-149
K-131
K-148
K-130
K-147
K-129
K-126
K-146
K-113A
K-114A
K-161
K-115A
K-117A
K-116A
K-21
K-125A
K-20
K-119A
K-127
K-120A
K-162
K-145
K-18
K-19
K-144
K-157
K-32A
K-111A
K-142
K-141
K-27
K-29
K-30
K-109A
K-110A
K-23
K-11
K-36
K-132
K-33
K-138
K-31
K-139
K-34
K-106A
K-140
K-107A
K-108A
K-137
K-158
K-35
KW Process
KR4 & KX Transfer
KR4 Process
KX Process
KX Transfer
KR4 Transfer
K-151
K-152
K-37
K-153
K-154
K-163
K-143
K-169
K-170
K-121A
K-156
K-128
K-122A
K-123A
K-124A
K-171
K-172
699-78-62
A
A'
B
B'
Updated: 080814

Figure 1-2. Annual Fall Hexavalent Chromium Plumes in the 100-KR-4 Operable Unit Since Start of Operations in 1997.



2.0 UPDATED CONCEPTUAL MODEL FOR 100-KR-4 HEXAVALENT CHROMIUM PLUME

This section discusses the updated conceptual model for the chromium plume targeted by the expanded 100-KR-4 pump-and-treat system.

2.1 SOURCES OF HEXAVALENT CHROMIUM IN GROUNDWATER

Raw Columbia River water was treated extensively with flocculants to remove parent elements so they would not form radioisotopes when the treated water passed through the reactors and was irradiated. However, sodium dichromate dihydrate, $Na_2Cr_2O_7 \cdot 2H_2O$, was added to reactor coolant water as a rust inhibitor starting at a concentration of approximately 1.8 mg/L. When the chromium was irradiated, the radioisotope chromium-51 was formed. This isotope has a half-life of about 27.7 days, and concentrations were not reduced when the coolant water was moved to retention basins for an hour or less before disposal to the Columbia River. To reduce the amount of chromium-51 in effluent, the amount of sodium dichromate added during raw water processing was decreased from 1.8 mg/L to 1.0 mg/L in 1961 and to 0.5 mg/L in 1968 for selected reactors (*Quarterly Report Contamination Control – Columbia River April – June 1968* [DUN-1968]). In 1968, the 12-month daily release average of chromium-51 was approximately 750 Ci/day in the 100-K Area.

The 116-K-2 Trench received about 300 billion L (79 billion gal) of contaminated water from the KE and KW Reactor floor drains and from the KE and KW retention basins from 1955 through 1971 (*Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford* [PNL-6456]). The liquid effluent included about 300,000 kg of dissolved sodium dichromate; therefore, the dissolved dichromate concentration is equivalent to an average of about 1 mg/L. The trench is oriented parallel to and approximately 250 m (820 ft) from the Columbia River.

2.2 100-K AREA HYDROGEOLOGY

The uppermost aquifer in the 100-K Area is located mostly within Unit E of the Ringold Formation; however, the contact between the Ringold Unit E and the overlying Hanford formation is an irregular, erosional surface and the unconfined aquifer locally extends into the lower Hanford formation. The current average depth to groundwater ranges from less than 7.3 m (25 ft) in well 199-K-18, located near the Columbia River to about 23 m (76 ft) inland at well 699-78-62 (Table 2-1).

The Ringold Unit E is underlain by the fine-grained paloesols and overbank deposits of the Ringold Upper Mud Unit (*Vadose Zone Modeling of Carbon Tetrachloride in 200 West Area at the Hanford Site* [WHC-SD-EN-TI-112]). Below the top of the Ringold Upper Mud, the aquifer appears to be at least semi-confined, based on water levels measured in adjacent wells 199-K-32A (screened in the unconfined aquifer) and 199-K-32B (screened in and below the Ringold Upper Mud Unit) located downgradient of the KE Reactor (Figure 2-1). Groundwater flow is toward the river during low river stage and reverses to inland during high river stage.

Table 2-1. Construction Details, Depth to Water, and Average Aquifer Thickness in 100-KR-4 Pump-and-Treat System Wells. (2 sheets)

Well Name	Date Completed	Depth To Bottom/ Ringold Upper Mud (ft)	Screened Interval (ft/type)	Depth to Water (ft)	Avg. Aquifer Thickness (ft)	Well Use Original/ Current/ Planned
199-K-18	Oct. 1954	39/NR	18 to ND/8-in. PCS	23.6	-	C
199-K-19	Apr. 1955	47/NR	26 to 46/est 7-in GS	35.7	-	M
199-K-20	May 1955	47/NR	10 to 50/ 8-in. PCS	36.2	-	C
199-K-21	May 1955	49/NR	10 to 50/8-in. PCS	37.4	-	M
199-K-22	May 1955	49/NR	29 to 49/6-in TS	39.8	-	M
199-K-32A	July 1992	65/NR	45 to 65/4-in. SS-0.010	55.8	-	M
199-K-32B	Aug. 1992	176/136	157 to 167/4-in. SS-0.010	48.5	87.5	M
199-K-37	June 1992	63/NR	43 to 63/4-in. SS-0.010	55.8	-	M
199-K-111A	July 1994	185/155	65 to 85/4-in. SS-0.040	70.6	84.4	M
199-K-112A	Sept. 1996	48/48	21 to 46/6-in. SS-0.040	23.9	24	E
199-K-113A	Sept. 1996	43/41	20 to 40/6-in. SS-0.040	21.8	19	E
199-K-114A	Sept. 1996	51/41	21 to 36/6-in. SS-0.060	22.9	18	C/E
199-K-115A	Oct. 1996	61/54	21 to 41/6-in. SS-0.030	23.7	30	E
199-K-116A	Oct. 1996	92/87	31 to 86/6-in. SS-0.040	34	52	E
199-K-117A	Oct. 1996	73/68	28 to 68/6-in. SS-0.040	27.7	40	C
199-K-118A	Sept. 1996	81//76	33 to 73/6-in. SS-0.040	40.2	3	E
199-K-119A	Oct. 1996	92/89	36 to 86/6-in. SS-0.040	40.8	48	E
199-K-120A	Oct. 1996	101/96	19 to 94/6-in. SS-0.040	17.2	79	E
199-K-121A	Sept. 1996	98/96	60 to 90/6-in. SS-0.030	70.3	26	I
199-K-122A	Sept. 1996	101/100	65 to 95/6-in. SS-0.040	68.8	31	I
199-K-123A	Sept. 1996	98/NR	60 to 90/6-in. SS-0.030	68.9	-	I
199-K-124A	Sept. 1996	100/NR	57 to 77;82 to 92/6-in. SS-0.030	67.8	-	I
199-K-125A	Aug. 1998	78/75	32 to 72/6-in. SS-0.020	32.9	42	E
199-K-126	July 1999	90/NR	64 to 84/6-in. SS-	67.6	-	C/E/treatability test well
199-K-127	Feb. 2002	115/NR	50 to 100/6-in. SS-0.020	43.3	-	E
199-K-128	Jan. 2002	98/NR	55 to 90/6-in. SS-0.030	73	-	I
199-K-129	Feb. 2003	51/48	21 to 46/6-in. SS-0.020	28.2	20	E
199-K-130	Feb. 2003	80/NR	46 to 76/6-in. SS-0.020	48.7	-	M
199-K-131	Sept. 2004	100/94	52 to 82/6-in. SS-0.020	51.4	47	M
199-K-143	Feb. 2007	95/NR	53 to 88/6-in. SS-0.020	53.8	-	M
199-K-144	Mar. 2008	107/97	19 to 94/6-in. SS-0.020	23.7	73	E
199-K-145	Apr. 2008	124/118	18 to 118/6-in. SS-0.020	22.5	96	E
199-K-146	Dec. 2007	58/53	28 to 53/6-in. SS-0.020	31.6	21	E
199-K-147	Nov. 2007	84/79	58 to 78/6-in. SS-0.020	53.2	26	E
199-K-148	Nov. 2007	109/100	60 to 100/6-in. SS-0.020	63.2	37	E
199-K-149	Oct. 2007	113/106	65 to 105/6-in. SS-0.020	70.2	36	E

Table 2-1. Construction Details, Depth to Water, and Average Aquifer Thickness in 100-KR-4 Pump-and-Treat System Wells. (2 sheets)

Well Name	Date Completed	Depth To Bottom/ Ringold Upper Mud (ft)	Screened Interval (ft/type)	Depth to Water (ft)	Avg. Aquifer Thickness (ft)	Well Use Original/ Current/ Planned
199-K-150	Jan. 2008	118/112	62 to 112/6-in. SS-0.020	68.2	44	E
199-K-151	Dec. 2007	119/115	44 to 114/6-in. SS-0.020	68.8	46	M
199-K-152	Jan. 2008	119/116	40 to 114/6-in. SS-0.020	69.7	47	M
199-K-153	Oct. 2007	105/100	30 to 100/6-in. SS-0.020	58.8	41	M
199-K-154	Nov. 2007	108/102	42 to 102/6-in. SS-0.020	58.8	43	M
199-K-156	Feb. 2007	172/166	34 to 164/6-in. SS-0.020	66.3	100	I
199-K-157	Jan. 2008	143/139	38 to 138/6-in. SS-0.020	61.7	77	M
199-K-159	Oct. 2007	117/110	40 to 110/6-in. SS-0.020	68.6	42	I
199-K-160	Oct. 2007	118/113	43 to 113/6-in. SS-0.020	68.8	44	I
199-K-161	Dec. 2007	56/51	24 to 48/6-in. SS-0.020	26.1	23	E
199-K-162	Feb. 2008	134/128	17 to 127/6-in. SS-0.020	22.1	106	E
199-K-163	Nov. 2007	114/109	37 to 107/6-in. SS-0.020	61.2	48	M
199-K-164	Apr. 2008	119/112	42 to 112/6-in. SS-0.020	72	48	I
699-78-62	May 1957	150/120	67 to 107/6-in. TS-0.015	76	44	M

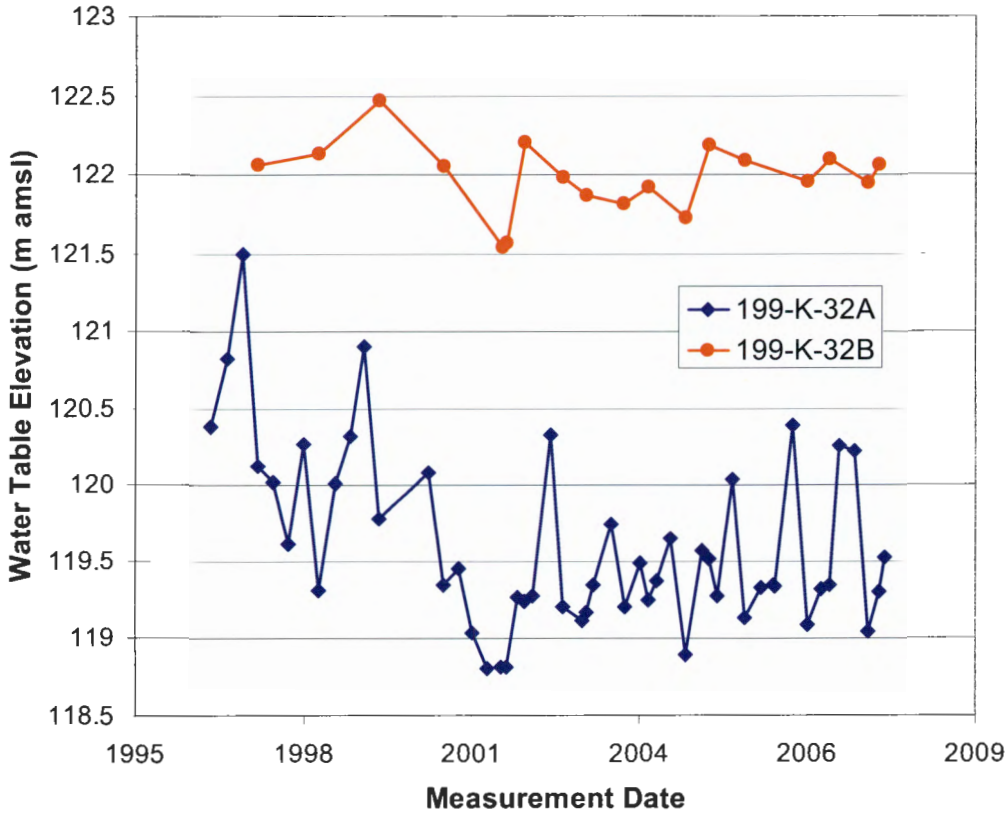
NOTES:

1. Aquifer thickness in extraction and injections wells is based on depth to water in the well before well became operational.
2. Depth to water based on recorded measurements in Hanford Environmental Information System database for the period 1997 through 2007. New wells depth to water based on available data at time of report preparation.
3. Well screen slot-size measurements = (inches x 10^{-3}); for example, 0.020 – 20 x 10^{-3} inches). This is commonly referred to as "20-slot" screen.

C = compliance well
E = extraction well
est = estimated
I = injection well
M = monitoring well
NR = formation not reached in well
PCS = perforated carbon steel
SS = stainless steel
TS = telescoping screen
ND = not documented

A prominent erosional channel in the Ringold Upper Mud is present between the former 116-K-2 Trench and the existing 100-KR-4 injection well field. The maximum measured relief is approximately 24 m (79 ft) measured between wells 199-K-156 and 199-K-122A. This geologic feature has affected the pump-and-treat design by creating a saturated aquifer locally up to approximately 32 m (106 ft) thick in well 199-K-156 (Figure 2-2). This feature may also provide a deep, preferred flow path approximately parallel to the Columbia River. Hydrogeologic cross-sections displayed in Figures 2-3 and 2-4 show the site geology both parallel and normal to the Columbia River. Many of the existing 100-KR-4 wells penetrated the Ringold Unit E to the Ringold Upper Mud, and Tables 2-1 and 2-2 summarize the well construction details and aquifer thickness and parameters, as available. Well summary sheets providing summary construction details and sediment descriptions for 100-KR-4 expansion wells are included in Appendix C.

Figure 2-1. Hydrographs of Wells 199-K-32A (Shallow) and 100-K-32B (Deep).



NOTES:

1. Well 199-K-32A is screened 45 to 65 ft below ground surface in the Ringold Unit E uppermost unconfined aquifer.
2. Well 199-K-32B is screened 157 to 167 ft below ground surface in the first producing horizon below the top of the Ringold Upper Mud Unit.

2.3 100-K AREA HEXAVALENT CHROMIUM PLUME DISTRIBUTION AND SUMMARY OF CO-CONTAMINANT CONCENTRATIONS

The target chromium plume for the original 100-KR-4 pump-and-treat system is shown in Figure 2-5. The plume was believed to be limited to the area downgradient of the 116-K-2 Trench based on existing wells. The original 1997 extraction and injection well fields are also displayed in Figure 2-5. The June 2007 hexavalent chromium plume is shown in Figure 2-6.

The highest historic hexavalent chromium concentrations in 100-KR-4 pump-and-treat extraction or monitoring wells have been approximately 200 µg/L. If sodium dichromate were added to raw water at a concentration of 0.5 to 1.0 mg/L during the 1960s (DUN-4847), the range of maximum resultant hexavalent chromium concentration would be 176 to 352 µg/L. Therefore, it is reasonable to attribute the historic plume concentrations to sodium dichromate added to raw water as a rust inhibitor and not a continuing source of highly concentrated sodium dichromate (e.g., spill). This treated water was utilized as coolant water in the single pass and disposed to liquid effluent sites such as the 116-K-2 trench.

Figure 2-2. Saturated Thickness Uppermost Aquifer.

Figure 2-3. Section A-A' Along the Columbia River – View Northwest.

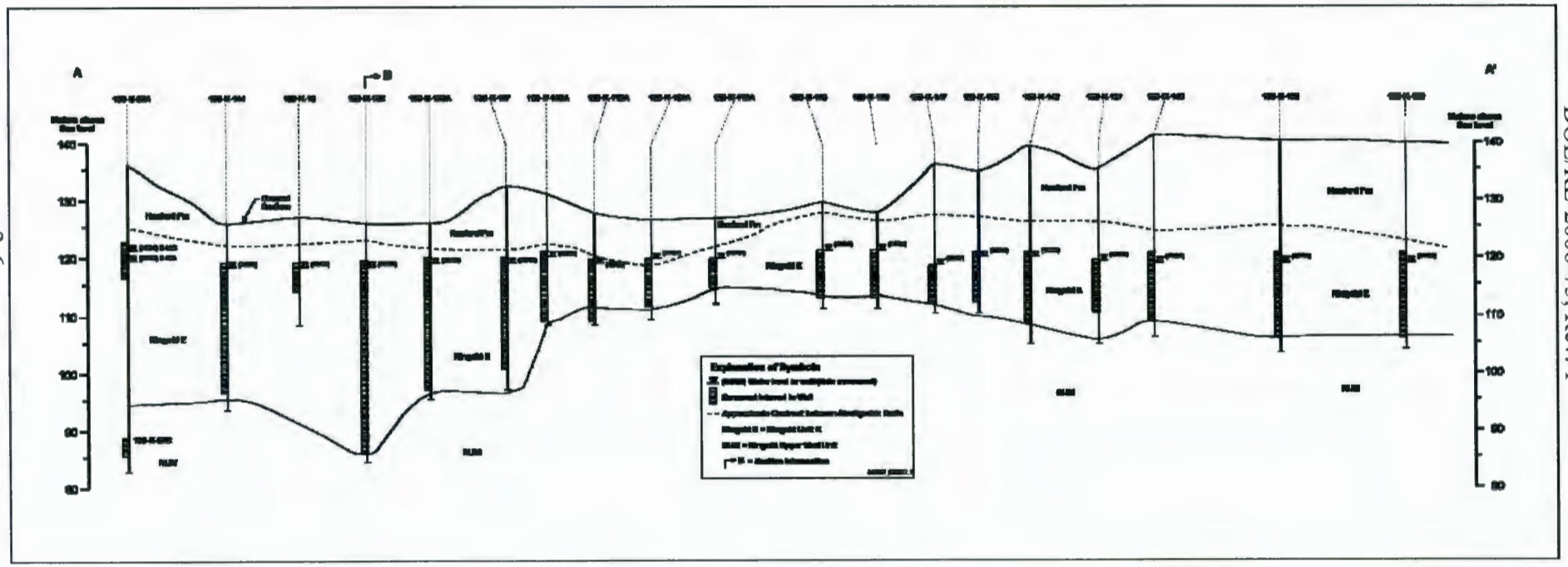


Figure 2-4. Section B-B' Through 100-KR-4 Area, View Northeast.

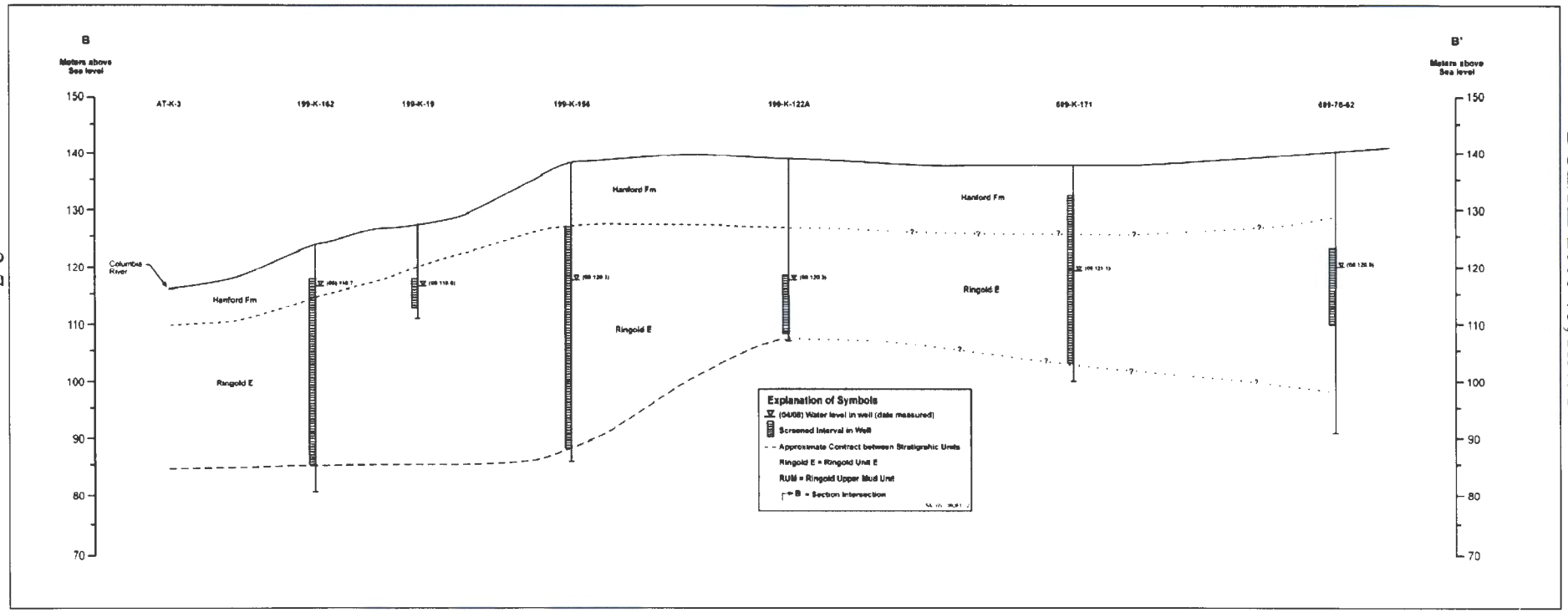


Table 2-2. Well Development Summary for 100-KR-4 Pump-and-Treat Wells. (4 sheets)

Well	Date	Depth to Water (ft)	DTB	Q (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft dd)	Sat. Thickness (ft)	Aquifer Description
199-K-112A	10/31/96	23.6	48.8	29	10.5	2.76	25	18 to 48 ft: sandy gravel; 48 to 54 ft: sandy silt
199-K-113A	10/3/96	21.8	43.08	25	19.4	1.29	19	22 to 29 ft: sandy gravel; 29 to 41 ft: silty sandy gravel; 41 to 44 ft: sandy silt
199-K-114A	10/4/96	22.9	39.11	85	1.8	47.2	18	21 to 24 ft: sandy gravel; 24 to 41 ft: silty sandy gravel; 41 to 51 ft: sandy silt
199-K-115A	10/4/96	23.7	53.98	38	12.8	2.97	30	16 to 24 ft: sandy gravel; 24 to 54 ft: silty sandy gravel; 54 to 61 ft: silt
199-K-116A	10/16/96	34	93.68	82	.067	122.4	52	21 to 55 ft: sandy gravel; 55 to 66 ft: silty sandy gravel; 66 to 87 ft: sandy gravel; 87 to 92 ft: sandy silt
199-K-117A	10/17/96	27.7	70.96	80	5	16	40	14 to 36 ft: sandy gravel; 36 to 50 ft: silty sandy gravel; 50 to 68 ft: sandy gravel; 68 to 73 ft: sandy silt
199-K-118A	10/23/96	40.2	75.15	52	47	1.11	35	19 to 37 ft: sandy gravel; 37 to 75.5 ft: silty sandy gravel; 75.5 to 81 ft: sandy silt
199-K-119A	10/17/96	40.8	89.4	68	12.7	5.35	40.8	16 to 22 ft: sandy gravel; 22 to 50 ft: silty sandy gravel; 50 to 89 ft: sandy gravel; 89 to 92 ft: clay (Ringold Upper Mud)
199-K-120A	10/15/96	17.2	97	80	2.5	32	79	3 to 43 ft: sandy gravel; 43 to 82 ft: silty sandy gravel; 82 to 96 ft: sandy gravel; 96 to 101 ft: sandy silt
199-K-121A	10/1/96	70.3	93.49	25	23.5	6.2	26	54 to 72 ft: sandy gravel; 72 to 79 ft: gravelly sand; 79 to 96 ft: sandy gravel; 96 to 98 ft: sandy silt
199-K-122A	10/1/96	68.8	98	17	10.5	8.5	31	39 to 75 ft: sandy gravel; 75 to 100 ft: silty sandy gravel; 100 to 101 ft: sandy silt
199-K-123A	10/2/96	68.9	93.1	12	19.2	4.8	-	38 to 72 ft: sandy gravel; 72 to 81 ft: silty sandy gravel; 81 to 98 ft: sandy gravel

Table 2-2. Well Development Summary for 100-KR-4 Pump-and-Treat Wells. (4 sheets)

Well	Date	Depth to Water (ft)	DTB	Q (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft dd)	Sat. Thickness (ft)	Aquifer Description
199-K-124A	10/2/96	67.8	94.9	12	14.5	2.9	-	36 to 65 ft: sandy gravel; 65 to 75: silty sandy gravel; 75 to 88 ft: silty sandy gravel; 88 to 100 ft: sandy gravel
199-K-125A	8/8/98	32.9	75.2	45	7.2	6.25	42	28 to 60 ft: sandy gravel; 60 to 75 ft: silty sandy gravel; 75 to 78 ft: silt
199-K-126	7/26/99	67.6	84.41	17	-	-	-	57 to 63 ft: gravelly silty sand; 63 to 70.5 ft: gravelly sand;70.5 to 87 ft: sandy gravel; 87 to 90 ft: gravel
199-K-127	2/27/02	43.3	103.1	-	-	-	72	15 to 45 ft: silty sandy gravel; 45 to 61.4 ft: sandy gravel; 61.4 to 115 ft: silty sandy gravel
199-K-128	1/7/02	73	93.4	-	-	-	-	55 to 72 ft: slightly silty gravelly sand; 72 to 97.9 ft: sandy gravel
199-K-129	2/21/03	28.2	49.5	-	-	-	-	28 to 31 ft: gravelly sand; 31 to 48 ft: sandy gravel; 48 to 51 ft: silt (Ringold Upper Mud)
199-K-130	2/24/03	48.7	78.9	50	8.8	5.68	27	48 to 60 ft: gravelly sand; 60 to 80 ft: sand and gravel
199-K-131	9/22/04	51.4	84.85	25	3.9	6.41	47	30 to 75 ft: sandy gravel; 75 to 94 ft: gravelly sand; 94 to 98 ft: silty sandy gravel; 98 to 99 ft: silt (Ringold Upper Mud)
199-K-143	2/25/07	53.8	95				-	
199-K-144	3/13/08	23.7	97	32	0.7	46	73	11 to 29 ft: sandy gravel; 29 to 33 ft: gravel; 33 to 37 ft: sandy gravel; 37 to 48 ft: gravel; 48 to 60 ft: sandy gravel; 60 to 95 ft: gravelly sand; 95 to 97 ft: gravelly silty sand; 97 to 107 ft: Ringold Upper Mud
199-K-145	4/11/08	22.5	121	19	0.5	38	96	12 to 115 ft: sandy gravel; 115 to 118 ft: silty sandy gravel; 118 to 124 ft: Ringold Upper Mud

Table 2-2. Well Development Summary for 100-KR-4 Pump-and-Treat Wells. (4 sheets)

Well	Date	Depth to Water (ft)	DTB	Q (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft dd)	Sat. Thickness (ft)	Aquifer Description
199-K-146	12/17/07	31.6	56	15	5.7	2.39	21	27 to 53 ft: sandy gravel; 53 to 56 ft: Ringold Upper Mud
199-K-147	11/13/07	53.2	81	22	4.6	5	26	53 to 63 ft: sandy gravel; 63 to 67 ft: silty sandy gravel; 67 to 77 ft: sandy gravel; 77 to 79 ft: silty gravel; 79 to 81 ft: Ringold Upper Mud
199-K-148	11/7/07	63.2	103	38	0.22	173	37	63 to 100 ft: sandy gravel; 100 to 103 ft: Ringold Upper Mud
199-K-149	10/30/07	70.2	108	16	1.9	8.4	36	70 to 80 ft: sandy gravel; 80 to 95 ft: gravelly sand; 95 to 106 ft: sandy gravel; 106 to 108 ft: Ringold Upper Mud
199-K-150	1/11/08	68.2	115	15	0.28	56	44	68 to 80 ft: gravel; 80 to 112 ft: sandy gravel; 112 to 118 ft: Ringold Upper Mud
199-K-151	12/12/07	68.8	118			382.1	46	10 to 100 ft: sandy gravel; 100 to 115 ft: sand; 115 to 119 ft: Ringold Upper Mud
199-K-152	1/8/08	69.7	118	16	1.5	11	47	68 to 116 ft: sandy gravel; 116 to 118 ft: Ringold Upper Mud
199-K-153	10/19/07	8.8	103	30	1.2	25	41	10 to 89 ft: sandy gravel; 89 to 100 ft: sand; 100 to 103 ft: Ringold Upper Mud
199-K-154	11/14/07	58.8	105	23/19	0.3/0.18	77/106	43	30 to 102 ft: sandy gravel; 102 to 105 ft: Ringold Upper Mud
199-K-156	2/11/08	66.3	166	11/30	0.25/1.6	44/19	100	57 to 79 ft: sandy gravel; 79 to 90 ft: gravelly sand; 90 to 166 ft: sandy gravel; 166 to 172 ft: Ringold Upper Mud
199-K-157	1/29/08	61.7	141	21	~0		77	20 to 139 ft: sandy gravel; 139 to 143 ft: Ringold Upper Mud
199-K-159	10/23/07	68.6	113	19	2	9.5	42	55 to 75 ft: sandy gravel; 75 to 80 ft: gravelly sand; 80 to 110 ft: sandy gravel; 110 to 113 ft: Ringold Upper Mud

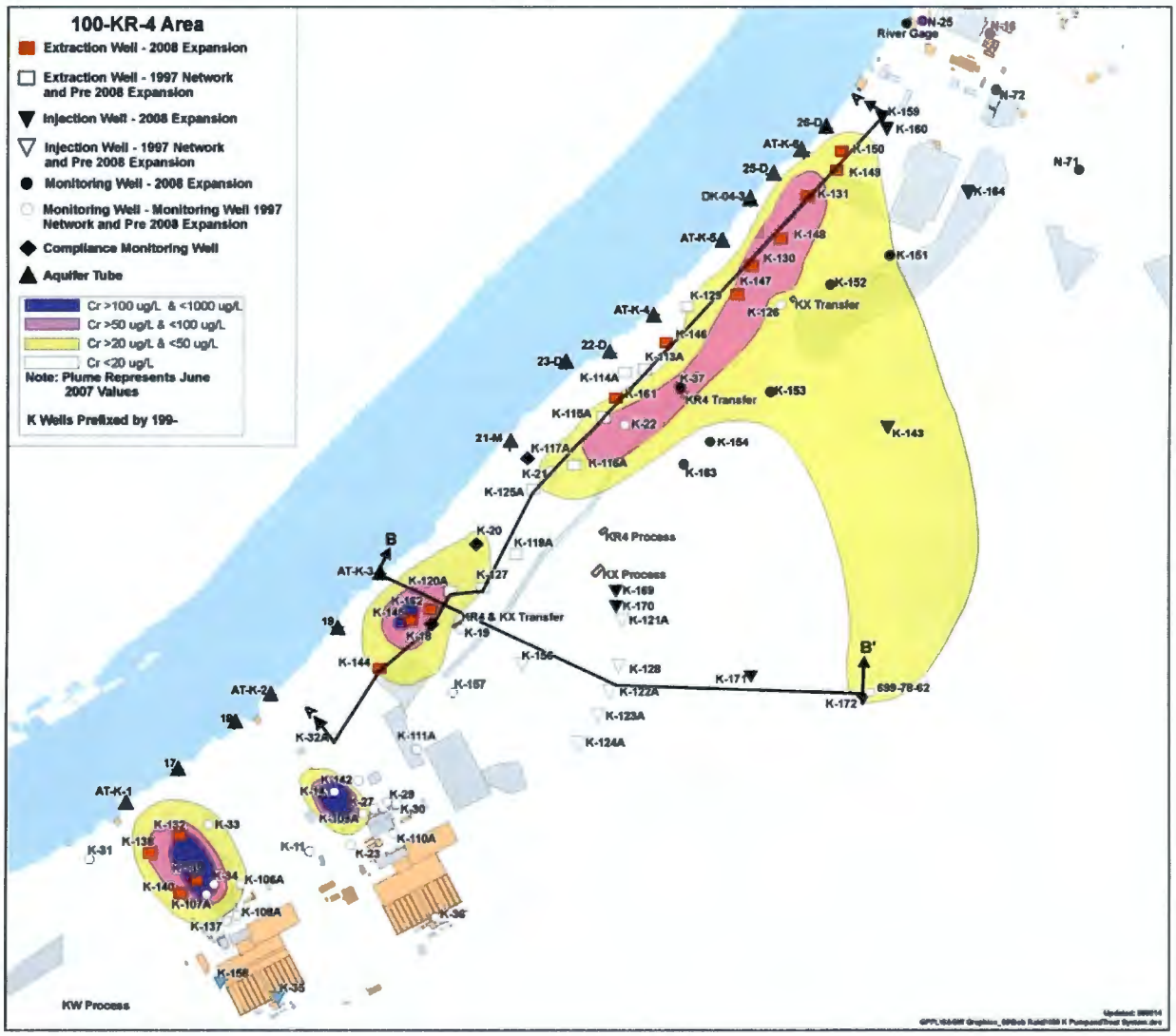
Table 2-2. Well Development Summary for 100-KR-4 Pump-and-Treat Wells. (4 sheets)

Well	Date	Depth to Water (ft)	DTB	Q (gpm)	Drawdown (ft)	Specific Capacity (gpm/ft dd)	Sat. Thickness (ft)	Aquifer Description
199-K-160	10/19/07	68.8	116	20	1.4	14	44	1 to 113 ft: sandy gravel; 113 to 116 ft: Ringold Upper Mud
199-K-161	12/5/07	26.1	52	30	4.1	7.3	23	2 to 49 ft: sandy gravel; 49 to 51 ft: gravelly silt; 51 to 52 ft: Ringold Upper Mud
199-K-162	2/22/08	22.1	130	27/15	0.41/0.13	66/115	106	10 to 128 ft: sandy gravel; 128 to 133 ft: ringold Upper Mud
199-K-163	11/6/07	61.2	110	27	1.6	17	48	20 to 70 ft: sandy gravel; 70 to 75 ft: gravelly sand; 75 to 109 ft: sandy gravel; 109 to 110 ft: Ringold Upper Mud
199-K-164	4/10/08	72	114	17	1	17	48	40 to 112 ft: sandy gravel; 112 to 119 ft: Ringold Upper Mud
699-78-62	2/19/07	76.0	106				44	

DTB = depth to bottom
gpm = gallons per minute
gpm/ft dd = gallons per minute per foot withdrawn
Q = pumping rate
TOC = top of casing

Figure 2-5. 1997 100-KR-4 Target Chromium Plume.

Figure 2-6. 100-KR-4 Hexavalent Chromium Plume – June 2007.



Wells 199-K-157 and 199-K-162, located upgradient and downgradient of the former 116-K-2 Trench, were sampled at multiple depths with a Solinst® sampler to evaluate whether hexavalent chromium concentrations change with depth in the former trench area. The results are summarized in Table 2-3, which shows little change in concentration with depth in well 199-K-162 located downgradient of the trench, but significant decrease in hexavalent chromium depth in well 199-K-157 located upgradient of the former trench. The decrease in hexavalent chromium concentration in at approximately 110 feet depth in well 199-K-157 may be related to a less porous more resistant lithologic horizon encountered at depth.

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Table 2-3. Depth-Discrete Hexavalent Chromium Concentrations in Wells 199-K-162 and 199-K-157.

Well	Depth Below Water Table (ft)	Cr^{+6} (µg/L)	Well	Cr^{+6} (µg/L)
199-K-162	3	43.8	199-K-157	66.8
199-K-162	8	52.7	199-K-157	66.8
199-K-162	13	50.1	199-K-157	66.8
199-K-162	18	51.4	199-K-157	70.7
199-K-162	23	51.4	199-K-157	69.4
199-K-162	28	51.4	199-K-157	68.1
199-K-162	33	51.4	199-K-157	66.8
199-K-162	38	50.1	199-K-157	59.2
199-K-162	43	48.9	199-K-157	51.5
199-K-162	48	46.3	199-K-157	36.1
199-K-162	53	52.7	199-K-157	31
199-K-162	58	53.9	199-K-157	28.4
199-K-162	63	55.2	199-K-157	28.4
199-K-162	68	53.9	199-K-157	25.8
199-K-162	73	53.9	199-K-157	24.5
199-K-162	78	53.9	199-K-157	-
199-K-162	83	55.2	199-K-157	-
199-K-162	88	53.9	199-K-157	-
199-K-162	93	53.9	199-K-157	-

NOTES:
1. Depth to water (water table) 22 ft in well 199-K-162 and 62 ft in well 199-K-157.

Recent hexavalent chromium concentrations and co-contaminant values available during the revision of this document are displayed in Table 2-4. The 621,000 pCi/L tritium concentration in well 199-K-157 and the 286,000 pCi/L tritium concentration in well 199-K-144 are of interest, and the source of this contaminant is probably the 118-K-1 Burial Ground. The potential effects of the tritiated groundwater on safety and design were being.

Table 2-4. 100-KR-4 Expansion – Injection and Performance Well Contaminant Concentrations. (3 sheets)

Injection Wells	Cr^{+6} (µg/L)					Co-Contaminants			Contaminants of Interest	
	Well Development Grab		Other Sampling			Date	Sr-90 (pCi/L)	H-3 (pCi/L)	Tc-99 (pCi/L)	C-14 (pCi/L)
	Date	Concentration	Date	Concentration	Type					
199-K-143	Converted monitoring well		4/23/08; 6/25/08	16; 3 (B)	Quarterly	4/23/08	0.14 (U)	370	1.37 (U)	-3.81 (U)
199-K-159	11/12/07	7	4/23/08	2 (U)	Baseline	4/23/08	0.207 (U)	327	1.75 (U)	7.78 (U)
199-K-160	11/13/07	10	4/23/08	2 (U)	Baseline	4/23/08	0.0733 (U)	306 (U)	3.76 (U)	10.7
199-K-164	4/11/08; 4/16/08	2 (U); 2 (U)	4/23/08	2 (U)	Baseline	4/23/08	-0.0895 (U)	106 (U)	0.595 (U)	0.815 (U)
199-K-156	2/12/08	7 and 2	5/6/08; 7/2/08	8; 9	Baseline	5/6/08	0.162 (U)	6380	TBD	10.9

Extraction Wells	Cr^{+6} (µg/L)					Co-Contaminants			Contaminants of Interest		
	Well Development Grab		Other Sampling								
	Date	Concentration	Date	Concentration	Type	Date	Sr-90 (pCi/L)	H-3 (pCi/L)	Tc-99 (pCi/L)	C-14 (pCi/L)	Total Cr (UF)
199-K-130	Converted monitoring well		10/5/07; 5/19/08	79.7; 59.2	Monthly	10/5/07	0.138 (U)	1,250	TBD	TBD	
199-K-131	Converted monitoring well		10/5/07; 3/11/08	74.5; 78.3	Monthly	10/5/07	0.17 (U)	4,300	TBD	TBD	
199-K-144	4/7/08	38	4/23/08	40	Baseline	4/23/08	7.7	286,000	-1.48 (U)	150	
199-K-145	4/15/08	25	4/23/08	20	Baseline	4/23/08	0.217 (U)	5,970	-2.74 (U)	9.08	
199-K-146	1/4/08	110	5/1/08	51	Baseline	5/1/08	0.237 (U)	25.5 (U)	TBD	5.13 (U)	
199-K-147	11/15/07	38	4/23/08	38	Baseline	4/23/08	0.334 (U)	13.8 (U)	-0.262 (U)	1.06 (U)	
199-K-148	11/14/07	74	4/23/08	55	Baseline	4/23/08	0.12 (U)	5,200	1.89 (U)	18.2	
199-K-149	11/14/07	64	4/23/08	70	Baseline	4/23/08	0.19 (U)	3,540	2.85 (U)	6.92 (U)	

Table 2-4. 100-KR-4 Expansion – Injection and Performance Well Contaminant Concentrations. (3 sheets)

Extraction Wells	Cr^{+6} (µg/L)										
	Well Development Grab		Other Sampling			Co-Contaminants			Contaminants of Interest		
	Date Collected	Concentration	Date	Concentration	Type	Date	Sr-90 (pCi/L)	H-3 (pCi/L)	Tc-99 (pCi/L)	C-14 (pCi/L)	Total Cr (UF) (µg/L)
199-K-150	2/1/08	54	4/23/08	54	Baseline	4/23/08	0.199 (U)	3,060	2.04 (U)	8.46 (U)	-
199-K-161	1/4/08	44	4/23/08	102	Baseline	4/23/08	20.1	71.5 (U)	0.245 (U)	1.49 (U)	-
199-K-162	4/4/2008	88	5/1/08	75	Baseline	5/1/08	-0.123 (U)	28,000	3.36 (U)	26.6	-
Monitoring Wells	**Cr^{+6} (µg/L)**										
	Well Development Grab		Other Sampling			Co-Contaminants			Contaminants of Interest		
	Date	Date	Date	Date	Date	Date Collected	Sr-90 (pCi/L)	H-3 (pCi/L)	Tc-99 (pCi/L)	C-14 (pCi/L)	Total Cr (UF) (µg/L)
199-K-151	12/13/07	45	1/31/08	58	Baseline		TBD	TBD	TBD	TBD	-
199-K-152	2/1/08	69	6/30/08	83	Baseline	6/30/08	NA	NA	NA	NA	-
199-K-153	1/3/08	37	1/31/08	52	Baseline	6/30/08	NA	NA	NA	NA	-
199-K-154	11/20/07	99	2/4/08	104	Baseline	6/30/08	NA	NA	NA	NA	-
199-K-163	11/16/07	129	2/4/08	147	Baseline	7/2/08	NA	NA	NA	NA	-
199-K-157	1/31/07	47	5/28/08	Various 71-25	Depth discrete	5/1/08	0.189 (U)	621,000	TBD	168	-
199-K-18	-	-	10/11/07; 5/28/08	146; 163	Monthly	10/17/07; 1/24/94; 1/28/05	0.0404 (U)	31,300	1.22	6.4 (U)	143
199-K-19	-	-	10/17/07; 5/5/08	41.5; 29.7	Semi-annual	10/18/04; 10/17/07; 1/25/96; 6/15/93	10.3	3,600	-0.44 (U)	13.8 (J)	45.7
199-K-20	-	-	11/7/07; 5/29/08	8.4; 6.6	Monthly	10/5/07; 6/9/93; 1/25/93	6.05	5,600	10	13.3 (J)	16

Table 2-4. 100-KR-4 Expansion – Injection and Performance Well Contaminant Concentrations. (3 sheets)

Monitoring Wells	Cr^{+6} (µg/L)										
	Well Development Grab		Other Sampling			Co-Contaminants			Contaminants of Interest		
	Date Collected	Concentration	Date	Concentration	Type	Date Collected	Sr-90 (pCi/L)	H-3 (pCi/L)	Date Collected	Tc-99 (pCi/L)	C-14 (pCi/L)
199-K-21	-	-	10/16/07	4.9	Semi-annual	10/16/07; 1/23/96; 6/25/93	32.5	330	-0.56 (U)	15.3 (J)	21.2
199-K-22	-	-	10/16/07; 4/22/08	116; 142	Semi-annual	10/16/07; 6/8/93; 1/4/96	7.3	180 (U)	0.14 (U)	7.84 (J)	137
199-K-117A	-	-	10/5/07; 5/29/08	2 (U); 2 (U)	Monthly	10/5/07	1.72	195 (U)	--	--	9.1
199-K-111A	-	-	10/11/07	32.5	Annual	1/11/08; 4/9/08	-4.6 (U)	11,000; 10,000	-0.4.6 (U)	156	35.8;31.5
199-K-126	-	-				11/29/07; 5/28/08; 11/3/04	0.20 (U)	990	--	--	123; 31.3
199-699-78-62	-	-	12/3/07	20.4	Annual	12/3/07; 6/26/93; 1/23/96	0.12 (U)	35.4 (U)	1.1 (U)	0.92 (U)	22.9
199-N-71	-	-				12/18/07; 11/6/98; 11/20/92	0.27 (U)	811	--	26.8	13.6
199-N-72	-	-				12/18/07; 11/20/92; 5/10/93	-0.15 (U)	-27 (U)	--	-0.61 (U)	10

NOTE: Analytical laboratory qualifiers: U = undetected; J = estimated; B = detected at less than contract-required detection limit but greater than the method or instrument detection limit, whichever is applicable.
NA = results not yet available
TBD = not yet sampled; results to be determined
UF = unfiltered

2.4 HEXAVALENT CHROMIUM CONCENTRATIONS IN VADOSE ZONE SOIL SAMPLES

The water table was significantly higher in the 100-KR-4 OU area during active operations, especially around the 116-K-2 Trench, which received thousands of liters per minute of reactor coolant water. Split-spoon soil samples were collected about 5 and 10 ft above the average water table depth in 10 wells during drilling operations to evaluate whether there is any remaining hexavalent chromium in the vadose zone sediment that may slowly move down to the saturated zone and adding contaminant to the groundwater. The coarse nature of the sediments often resulted in little or no sample recovery in the split spoon sample and a grab sample was collected of available material.

Table 2-5 summarizes the results from vadose sampling of 19 samples. Results suggested that there is little, if any, hexavalent chromium remaining in the vadose zone (previously wetted) because hexavalent chromium was not detected 17 of 19 samples, at a detection limit of 0.35 mg/kg. The maximum sample concentration was 0.76 mg/kg collected 20 ft below ground surface and 10 ft above the water table in well 199-K-146, although the hexavalent chromium detection limit for all the soil samples was 0.35 mg/kg. The validity of this sample result is undergoing further review. The only other sample with detected hexavalent chromium was 0.48 mg/kg collected 57-59 ft below ground surface and 10 ft above the water table in well 199-K-152.

Table 2-5. Hexavalent Chromium Concentrations in Vadose Zone Samples Collected in 100-KR-4 Expansion Wells.

Sample Number	Well Name	Sample Depth (ft)	Water Table Depth (ft)	Date	Value	Analytical Units	Lab Qualifier	Review Qualifier
B1PYH0	199-K-144	12.6 to 14.6	23.7	02/14/08	0.35	mg/kg	U	
B1PYH1	199-K-144	17.3 to 19.3	23.7	02/14/08	0.35	mg/kg	U	
B1PYH2	199-K-145	12.5 to 14.5	22.5	03/17/08	0.35	mg/kg	U	
B1PYH3	199-K-145	17.7 to 19.7	22.5	03/17/08	0.35	mg/kg	U	
B1PYH4	199-K-146	17.5 grab	31.6	12/11/07	0.35	mg/kg	U	
B1PYH5	199-K-146	20 grab	31.6	12/11/07	0.76	mg/kg		F
B1PYF4	199-K-148	51.3 to 53.3	66.4	11/01/07	0.35	mg/kg	U	
B1PYF5	199-K-148	56.0 to 58.0	66.4	11/01/07	0.35	mg/kg	U	
B1PYH6	199-K-150	58 grab	68.2	12/20/07	0.35	mg/kg	U	
B1PYH7	199-K-150	64 grab	68.2	12/20/07	0.35	mg/kg	U	
B1RP08	199-K-152	57 to 59	69.5	12/17/07	0.48	mg/kg		
B1RP09	199-K-152	61.6 to 63.6	69.5	12/17/07	0.35	mg/kg	U	
B1RP10	199-K-156	5.5 to 57.5	68.3	01/16/08	0.35	mg/kg	U	
B1RP11	199-K-156	59.5 grab	68.3	01/17/08	0.35	mg/kg	U	
B1RP12	199-K-157	46.9 to 48.9	61.2	01/14/08	0.35	mg/kg	U	
B1PYF8	199-K-161	18.2 to 20.2	28.5	11/28/07	0.33316	mg/kg	U	
B1PYF9	199-K-161	26 to 28	28.5	11/29/07	0.35	mg/kg	U	
BIPYH8	199-K-162	14 to 16	22.1	02/05/08	0.35	mg/kg	U	
BIPYH95	199-K-162	18 to 20	22.1	02/05/08	0.35	mg/kg	U	

NOTE: F = Results undergoing further review.

3.0 REMEDIAL DESIGN

This section describes the engineering, hydrogeologic, and regulatory design basis for the 100-KR-4 chromium plume pump-and-treat system and provides a general description of the system's components and their functions.

3.1 SUPPORTING DOCUMENTATION

The following subsections describe the conceptual design and final design documents for the expansion of the 100-KR-4 pump-and-treat system.

3.1.1 Conceptual Design Documents

Significant documents completed during the conceptual design phase include the following:

- *Design Criteria for the Expansion of the 100-KR-4 Pump-and-Treat System* (WMP-30899): This document identifies relevant criteria applicable to the pump-and-treat design and describes the design basis. The document serves as a project work plan for the design team. This document describes the basis for the design of the 1,136 L/min (300 gpm) expansion of the treatment system capacity. The basis for the design is the same for the 2,271-L/min (600-gpm) expansion.
- Drawings, specifications, and system design description: These items show the general layout of the pump-and-treat system and the configuration of the system's controls and interfaces. All drawings and specifications have been updated to reflect the current 2,271-L/min (600-gpm) expansion.
- *Mitigation Action Plan for the 100-HR-3 and 100-KR-4 Pump-and-Treat Project* (DOE/RL-96-107): This document describes the prioritized actions designed to minimize or lessen project impacts on cultural or natural resources. It was prepared for the 100-HR-3 and 100-KR-4 pump-and-treat systems, but it can also be applied to the expansion of the 100-KR-4 pump-and-treat system.

3.1.2 Final Design Documents

The principal documents produced during the final design include final design drawings, specifications, and other related information for bidding on and construction of the pump-and-treat system. The final design drawings were incorporated into the following procurement packages:

- *Description of Work for the Installation of Nineteen Wells to Support the 100-KR-4 Pump-and-Treat System Expansion* (SGW-34556): This document provides information regarding the (1) location and construction of the new extraction and injection wells, (2) use of existing wells within the pump-and-treat system, and (3) management of drilling and development wastes generated during drilling, completion, and well development operations. The 19 new wells have been constructed since this document was issued. There are currently four additional injection wells planned, and SGW-34556 has been updated to include the four additional wells.

- Balance of plant procurement package: This package contains the final drawings and specifications necessary to construct the pump-and-treat system, exclusive of the wells. It includes detailed information on the site grading, piping layout, well controls, tank locations, the groundwater treatment system, and electrical mechanical connections. All drawings and specifications have been updated to reflect the current planned 2,271-L/min (600-gpm) expansion of the treatment system capacity.

3.2 ENGINEERING AND HYDROGEOLOGIC DESIGN BASIS

The primary RAO for the 100-KR-4 pump-and-treat system expansion is to prevent the discharge of hexavalent chromium to the Columbia River substrate at concentrations exceeding those that are considered protective of aquatic life in the river and riverbed sediments. This objective will be achieved by pumping groundwater from extraction wells located within the plume area, treating the groundwater to remove hexavalent chromium by applying an ion-exchange (IX) treatment method, and returning the treated groundwater to the aquifer via injection wells. This section describes the general approach used to select extraction and injection well locations, the criteria for piping and flow control and monitoring equipment (i.e., balance of plant), and the rationale for vessel alignment in the IX system.

3.2.1 General Approach

The 100-KR-4 expansion will incorporate the design criteria from the existing 100-KR-4 system and the experiences gained in 10 years of operating six pump-and-treat systems into a stand-alone pump-and-treat system. The system will be designed to meet the following expansion goals:

- Control the northward migration of the chromium plume before it reaches the 100-NR-2 OU.
- Protect the Columbia River by removing high-concentration areas and eliminating gaps in capture between extraction wells.
- Remediate the remainder of the chromium plume to less than the RAO.

Selected well locations and well designs for the 100-KR-4 expansion were developed and evaluated by performing the following tasks and activities:

- Evaluating existing chromium plume maps and individual well trend plots
- Updating geologic cross-sections and isopach/structure contour maps
- Running numerical model simulations using extraction and injection rates estimated from specific capacity data derived from well development tests in existing wells and expansion wells
- Conducting onsite field discussions with affected Tribal members and cultural resources specialists
- Briefing the EPA regularly with conceptual design details.

3.2.2 Details of Design Basis

Details for the design basis are listed below:

- Plume area: The fall and spring 100-KR-4 chromium plumes are displayed in Figures 2-1 and 2-6, respectively.
- Supplementary system groundwater wells: The system expansion will include extraction, injection, and monitoring wells. The well locations are shown in Figure 3-1.
- 100-KR-4 expansion well locations: Well design details, design flow rates, modeled flow rates, specific capacities, and estimated saturated aquifer thickness (above the Ringold Upper Mud) are presented in Table 3-1.
- Extraction wells: The design goals will focus on containing the plume, filling gaps in extraction well capture, and reducing the mass of the 100-KR-4 hexavalent chromium plume. Figure 3-1 shows the locations of the extraction wells. Appendix B contains numerical modeling simulations that display the locations of the extraction wells selected to stop the northward migration, control the southern plume, fill gaps in capture, and reduce contaminant mass. The locations selected for the simulation have been adjusted as needed based on Tribal and cultural concerns, as well as existing operations. The modeled extraction rates were initially established to achieve capture and evolved based on well development results to the design volumes. Actual operational extraction rates will likely vary based on aquifer conditions.
- Injection wells: Treated groundwater will be injected in nine wells, as shown in Figure 3-1. The modeled injection rates were input into an analytical simulation to evaluate the mounding effect on the northern plume area. Flow rates, specific capacities of nearby wells, and average saturated thickness of the Ringold Unit E are shown in Table 3-1. The effect on mounding on the northern plume area is discussed and illustrated in Appendix B. The proposed monitoring well locations for four new injection wells are shown in Figure 3-1.
- Monitoring wells to support system expansion: Six new monitoring wells were installed to provide data to be used to evaluate the effectiveness of the expanded pump-and-treat system in meeting project goals. These wells could be added to the pump-and-treat network in the future if needed.
- IX system: The supplementary stand-alone IX system will include six treatment trains, each with a capacity of approximately 378.5 L/min (100 gpm).

3.2.3 Design Uncertainties

The design uncertainties are described below:

- Aquifer parameters: No long-term pumping tests have been conducted to determine sustainable well yields or to identify boundary conditions that could limit extraction well effectiveness. Pumping rates were estimated based on sustained rates at nearby wells or well-development data obtained following construction of existing monitoring wells. The effect of not having a long-term test could be that the long-term production rates may be lower than those assumed in the design, which could result in a smaller capture zone

than anticipated. A possible response to low well efficiency would be to add additional wells to the extraction network. Well yields will be adjusted based on operational tests of the treatment system.

- Placement of injection wells and receptive capacity: The injection wells have been located where they will help to accelerate flow through the plume area, where chromium concentrations are relatively low based on the recent sampling results (as indicated in Table 2-4) and where injection is expected to further reduce migration of the plume near the 100 N Area. The current well locations are compatible with ongoing cleanup operations and existing infrastructure and have been identified to Tribal representatives. The receptive capacities of the wells have been estimated based on well development data or on well development data from nearby existing wells, if available. In addition, the well screens were carried into the vadose zone, which in some cases included the more conductive Hanford formation. Flow rates may need to be adjusted for the four new wells if well-development testing changes estimated receptive capacities.
- Variable river stage: The groundwater flow direction is toward the Columbia River except for annual high river stage from mid-April through mid-August. During periods of high river stage, the gradient may be reversed, which may improve capture between the extraction well and the river. During periods of lower river stage, the groundwater flow gradient may be steepened, which would result in a more narrow capture zone. It may be possible to widen capture zones by increasing pumping rates in those wells in which the saturated Ringold Unit E is thicker; however, maximum pumping capacity may be limited by pipe diameter and well pump selection.
- Conceptual model limitations: The current conceptual model is based on a widely dispersed hexavalent chromium plume with few monitoring wells inland of the existing 100-KR-4 injection well field. High chromium concentrations are not expected if the source of the plume was reactor effluent disposed to the 116-K-2 Trench. If high concentrations of hexavalent chromium are detected, which could be attributed to an ongoing sodium dichromate source, the site conceptual model will require revision.

3.3 GENERAL DESCRIPTION AND OPERATION OF THE PUMP-AND-TREAT SYSTEM

The expanded 100-KR-4 pump-and-treat system will use a series of extraction wells equipped with submersible pumps to draw groundwater from the unconfined aquifer. Extracted groundwater will be conveyed through aboveground piping to a collection tank(s) where it will be combined with water from the other extraction wells. From the collection tank(s), the water will be pumped to an enclosed treatment system where chromium will be removed by IX. Treated groundwater will be transferred through an aboveground pipe to the injection well network.

3.3.1 Groundwater Extraction System

The groundwater extraction system in the expanded 100-KR-4 pump-and-treat network will consist of nine new extraction wells (199-K-144 through 199-K-150, 199-K-161, and 199-K-162) and two existing monitoring wells (199-K-130 and 199-K-131) that will be converted to extraction wells. Existing wells 199-K-130 and 199-K-131 were completed as 15.2–cm (6-in.) stainless-steel wells with 0.020-in. (20-slot) screens. Well 199-K-131 fully

penetrated the unconfined aquifer in the Ringold Unit E. The saturated thickness of this well is about 14.6 m (48 ft) based on an average depth to water of 16.5 m (54 ft) (Table 2-2). The new extraction wells were constructed as fully penetrating, 15.2-cm (6-in.)-diameter,stainless-steel wells with 0.020-in. (20-slot) screens. Well design details for the new extraction wells are shown in Table 3-1.

The extraction rates for these wells ranged from 37.8 to 283-9 L/min (10 to 75 gpm) (Table 3-1). The extraction rates will be modified during operations to adjust to actual aquifer performance.

Table 3-1. 100-KR-4 Expansion – Estimated Flow Rates and Well Design Details.

Extraction Wells in Final Design		Borehole Total Depth (ft)	Depth to Top of Ringold Upper Mud (ft)	Fall 2007/Winter 2008 Depth to Water (ft)	Surface Elev. (ft)	Water Table Elev. (ft)	Screened Interval (ft)	Est. Pump Intake Depth (ft)	Available Saturated Thickness (ft)	Avg. Spec. Cap. (gpm/ft)	80% Avg. Spec. Cap.	0.5 Avail. Sat. Thickness (ft)	Calculated Max. Yield (gpm)	Design Yield (gpm)	Baseline Cr^{+6} Concen. (µg/L)	Sample Date
Well Name	Well ID															
199-K-130	C4120	80	Not reached	48.74	415.22	389.66	46-76	71	22.26	5.68	4.54	11.13	50.57	60	59	5/19/08
199-K-131	C4561	99	97.97	51.36	440.86	389.5	52-82	77	25.64	6.41	5.13	12.82	65.74	50	78	3/11/08
199-K-146	C5362	58	53	31.6	421.22	389.62	28-53	48	16.4	2.39	1.91	8.20	15.68	10	51	5/1/08
199-K-147	C5363	84	79	53.17	443.03	389.86	59-79	74	20.83	5.41	4.33	10.42	45.08	20	38	4/23/08
199-K-148	C5364	109	100	66.55	453.03	386.48	60-100	95	28.45	13.28	10.62	14.23	151.13	50	55	4/23/08
199-K-149	C5365	113	106	72.98	459.13	386.15	65-105	100	27.02	8.2	6.56	13.51	88.63	50	70	4/23/08
199-K-150	C5366	117	112	71.6	457.17	385.57	62-112	107	35.4	14.2	11.36	17.70	201.07	40	54	4/23/08
199-K-161	C5939	56	49	26.2	410	380	24-48	43	16.8	7.31	5.85	8.40	49.12	30	102	4/23/08
199-K-144	C5360	107	97	23.7	414.59	390.89	19-94	89	65.3	47.8	38.24	32.65	1248.54	75	40	4/23/08
199-K-145	C5361	123.7	118	22.54	411.67	389.13	18-118	113	90.46	31.95	25.56	45.23	1156.08	75	20	4/23/08
199-K-162	C5940	133.6	128	22.13	411.38	389.25	17-127	123	100.87	83	66.40	50.44	3348.88	75	75	5/1/08
Injection Wells in Final Design		**Borehole Total Depth (ft)**	**Depth to Top Ringold Upper Mud (ft)**	**Fall 2007/Winter 2008 Depth to Water (ft)**	**Surface Elev. (ft)**	**Water Table Elev. (ft)**	**Screened Interval (ft)**	**Sand Pack Top and Bottom (ft)**	**Total Thickness of Sand Pack (ft)**	**Avg. Spec. Cap. (gpm/ft)**	**80% Avg. Spec. Cap.**	**90% Available Thickness**	**Calculated Max. Inflow (gpm)**	**Design Inflow (gpm)**		**Sample Date**
Well Name	Well ID															
199-K-159	C5937	115	110	66.56	455.72	389.16	40-110	24-115	91	10.6	8.48	81.9	694.512	75	2 (U)	4/23/08
199-K-160	C5938	117		68.81	456.64	387.83	43-113	17-118	101	12.45	9.96	90.9	905.364	75	2 (U)	4/23/08
199-K-143	C5305	95	Not reached	53.8	445.23	391.43	42-94	42-94	52	13.28	10.624	46.8	497.2032	65	16	4/23/08
199-K-164	C6386	119	112	71.22	461.3	390.08	42-112	27-112	85	15.6	12.48	76.5	954.72	45	2 (U)	4/23/08
199-K-156	C5372	172	169	66.21	460.77	394.56	34-164	18-164	146	61	48.8	131.4	6412.32	65	8	7/2/08
199-K-169	C6744	TBD												60		
199-K-170	C6745	TBD												60		
199-K-171	C6746	TBD												55		
199-K-172	C6747	TBD												45		
Monitoring Wells (with Specific Capacity and Available Saturated Aquifer Values)																
Well Name	**Well ID**	**Total Depth**	**Depth to Ringold Upper Mud**	**Depth to Water**	**Surface Elev.**	**Water Table Elev.**	**Screened Interval (ft)**	**Concep. Pump Intake Depth (ft)**	**Avail .Sat. Thickness (ft)**	**Avg. Spec. Cap. (gpm/ft)**	**80% Avg. Spec. Cap.**	**0.5 Avail Sat. Thickness (ft)**	**Calculated Max. Inflow (gpm)**			**Sample Date**
199-K-151	C5367	118	115	68.76	458.58	389.82	44-114	109	40.24	382.1	305.68	20.12	6150.2816	45		1/31/08
199-K-152	C5368	118	116	68.7	460.02	391.32	40-116	111	42.3	11.5	9.2	21.15	194.58	83		6/30/08
199-K-153	C5369	105	100	58.76	450.7	391.94	30-100	95	36.24	23.7	18.96	18.12	343.5552	48		6/30/08
199-K-154	C5370	108	102	58.8	447	388.2	42-102	97	38.2	58.3	46.64	28.65	1336.236	110		6/30/08
199-K-163 (155)	C6172	114	109	61.25	452.44	391.19	37-110	105	43.75	15.8	12.64	32.8125	414.75	134		7/2/08
199-K-157	C5373	142	139	61.72	455.4	393.68	39-139	134	72.28	21.5	17.2	54.21	932.412	60		7/2/08

NOTES:
1. Depth to water based average of available data.
2. Surface elevation 199-K-161 and 199-K-154 estimated based on top of casing elevation minus measured stick up.

gpm = gallons per minute
ID = identification

Figure 3-1. Expanded 100-KR-4 Pump-and-Treat System.

Extraction wells will be equipped with electric, adjustable-frequency drive, submersible pumps; pressure transducers for water-level monitoring; high/low set points for pump on/off control; high-pressure shut-off sensors; sample ports; and in-line flow sensors. The conveyance pipe at each well will allow water to drain back into the well in the event of system shutdown.

3.3.2 Groundwater Injection System

The groundwater system in the expanded 100-KR-4 pump-and-treat network will consist of nine wells, all of which will have been completed (Figure 3-1) prior to end of FY08. Wells 199-K-159 and 199-K-160 are located at the northern end of the 100-KR-4 OU to provide a hydraulic barrier to migration of the hexavalent chromium plume toward the 100-NR-2 OU. Well 199-K-156 is located near the upstream end of the former 116-K-2 Trench, upgradient from the plume area where concentrations of hexavalent chromium have been detected above 100 µg/L in well 199-K-118A. Injection well 199-K-164 is located inland from extraction wells

199-K-143 and 199-K-150. Well 199-K-143 is a monitoring well that has been converted to an injection well; it is located inland of the downstream end of the former 116-K-2 Trench.

Injection wells 199-K-169 and 199-K-170, will be located north of the existing 100-KR-4 injection well field and completed by the end of FY08. Wells 199-K-171 and 199-K-172 will be located east of the existing 100-KR-4 injection well field.

The wells will be fully penetrating to the top of the Ringold Upper Mud Unit with 15.2-cm (6-in.)-diameter, stainless-steel casing and 0.020-in. (20-slot) screens. The well screens will extend at least 6.1 m (20 ft) above the average static water level in the wells. Well design details are displayed in Table 3-1. The initial injection rates for each well were set to 189.3 L/min (50 gpm) for the analytical modeling but are subject to change based on actual aquifer and vadose zone properties.

3.3.3 Balance of Plant

The balance of plant will include all control systems, piping, valves, pumps, and electrical and mechanical equipment that enables groundwater from the extraction wells conveyed to the treatment system and returned to the injection wells and to the aquifer.

The 100-KR-4 expanded pump-and-treat system has been designed to run with minimal operator interface. This capability results from the use of programmable logic controllers (PLCs) that receive and transmit electronic signals to and from the field control devices. Data are also transmitted via optical cable to the primary human/machine interface (HMI) where they can be viewed by the operator and system adjustments can be performed if necessary.

The HMI will be located in the treatment building and represents the primary link between the operator and the pump-and-treat system. From the operator interface control (OIC), the operator can view all tank levels, pump status, flow rates, pumping water levels, and alarm status. The OIC also serves as a data storage and retrieval device and will be configured so the system status can be viewed via a laptop computer from offsite locations.

Piping and electrical lines to wells will be run overland to minimize any cultural resource impacts. Freeze-control design will be included as part of the treatment system. No freeze protection will be applied to overland piping.

3.3.4 Groundwater Treatment System

The groundwater treatment system is constructed with a treatment capacity of 2,271 L/min (600 gpm). This design capacity is based on experience gained from operation of the existing 100-KR-4 pump-and-treat system. The nominal system operational flow rates will depend on aquifer conditions and groundwater transfer subsystem capacity.

The treatment system operational and acceptance testing has been scheduled for the Fall of 2008 to implement the remedial action as quickly as possible.

The selected treatment process will use an IX system with Dowex® 21K resin that has effectively removed hexavalent chromium at the 100-HR-3 and 100-KR-4 pump-and-treat systems. If an alternate resin or other treatment system is identified, it may be used if approved by EPA. Spent resin may be regenerated offsite or at the Effluent Treatment Facility, or otherwise managed in a manner approved by EPA for this remedial action.

Dowex® is a registered trademark of Dow Chemical Company, Midland, Michigan.

The Dowex 21K resin beds capture hexavalent chromium and other ions with similar properties (e.g., uranium, which is naturally occurring in the 100 Areas in low concentrations). Co-contaminants such as strontium-90 and tritium are not removed by the resin.

The alignment of the vessels is designed to remove hexavalent chromium, which is the interim remedial action target contaminant. Individual vessels can be bypassed during resin changeout so the treatment system can continue operation.

Influent and effluent samples are collected at each vessel in the train and provide indications of resin saturation and removal effectiveness/efficiencies. As the resin in a vessel approaches saturation, the resin is removed and the vessel alignment is re-plumbed so the vessel with the freshest resin is always the polish, or last, vessel in the train. When saturated with hexavalent chromium resin in the lead, lag, and polish vessels are changed out so the treated groundwater will contain less than the standard 10 μg/L hexavalent chromium at reinjection.

3.3.5 System Monitoring and Shut-Off Devices

The expanded 100-KR-4 pump-and-treat system will include a number of devices designed to detect typical system upsets. To protect against tank overflows, high-level sensors are located in each collection tank. These sensors will shut down extraction wells when the high-level set point is exceeded. Leakage from pipe/joint failures can be detected by flow sensors that shut down the appropriate extraction well if the flow in the line drops below the low-flow set point. Blocked conveyance piping will be detected by high-pressure shut-off switches. Water-level drawdown in wells will be monitored by a sensor that shuts the pump off if the water level drops below the low-level set point.

Moisture sensors have been set in low points in the floor around pumps and trains and would shut the system down if water is detected. Chemical spill kits are available in the treatment facility and acid will be stored on spill pallets designed to absorb up to four times the volume of the container stored on them.

A relatively constant groundwater temperature of 10 to 13°C (50 to 55°F) is expected to provide sufficient freeze protection under normal operating and weather conditions. During extreme conditions, drainage of extraction and injection well piping will occur automatically after the system is shut down. External polyvinyl chloride piping and the collection tanks will be heat-traced, and the groundwater treatment system buildings will be heated and insulated.

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4.0 100-KR-4 EXPANSION SYSTEM IMPLEMENTATION

This section discusses the planned construction, startup, operation, and maintenance activities for the expansion of the 100-KR-4 pump-and-treat system.

4.1 CONSTRUCTION

The following subsections describe the construction tasks associated with the 100-KR-4 pump-and-treat implementation.

4.1.1 Well Drilling

Four additional new injection wells will be completed by the end of FY08 for the 100-KR-4 pump-and-treat system expansion. These wells will include 199-K-169, 199-K-170, 199-K-171, and 199-K-172. Their approximate locations are shown in Figure 3-1. Nine injection wells will support the 100-KR-4 pump-and-treat expansion.

Well construction will be controlled by the *Description of Work for Installation of Four Wells at the 100-KW Pump-and-Treat System for the 100-KR-4 Groundwater Operable Unit, FY 2006* (WMP-30101). A schematic diagram of typical new injection wells is provided in Figure 4-1.

This response action will avoid or minimize impacts to cultural resources, and the steps taken for cultural resource protection will be documented. The management of drill cuttings and other waste from drilling operations will be conducted in accordance with the *Interim Action Waste Management Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-97-01).

New injection wells will be tested by injecting potable water to confirm adequate capacity.

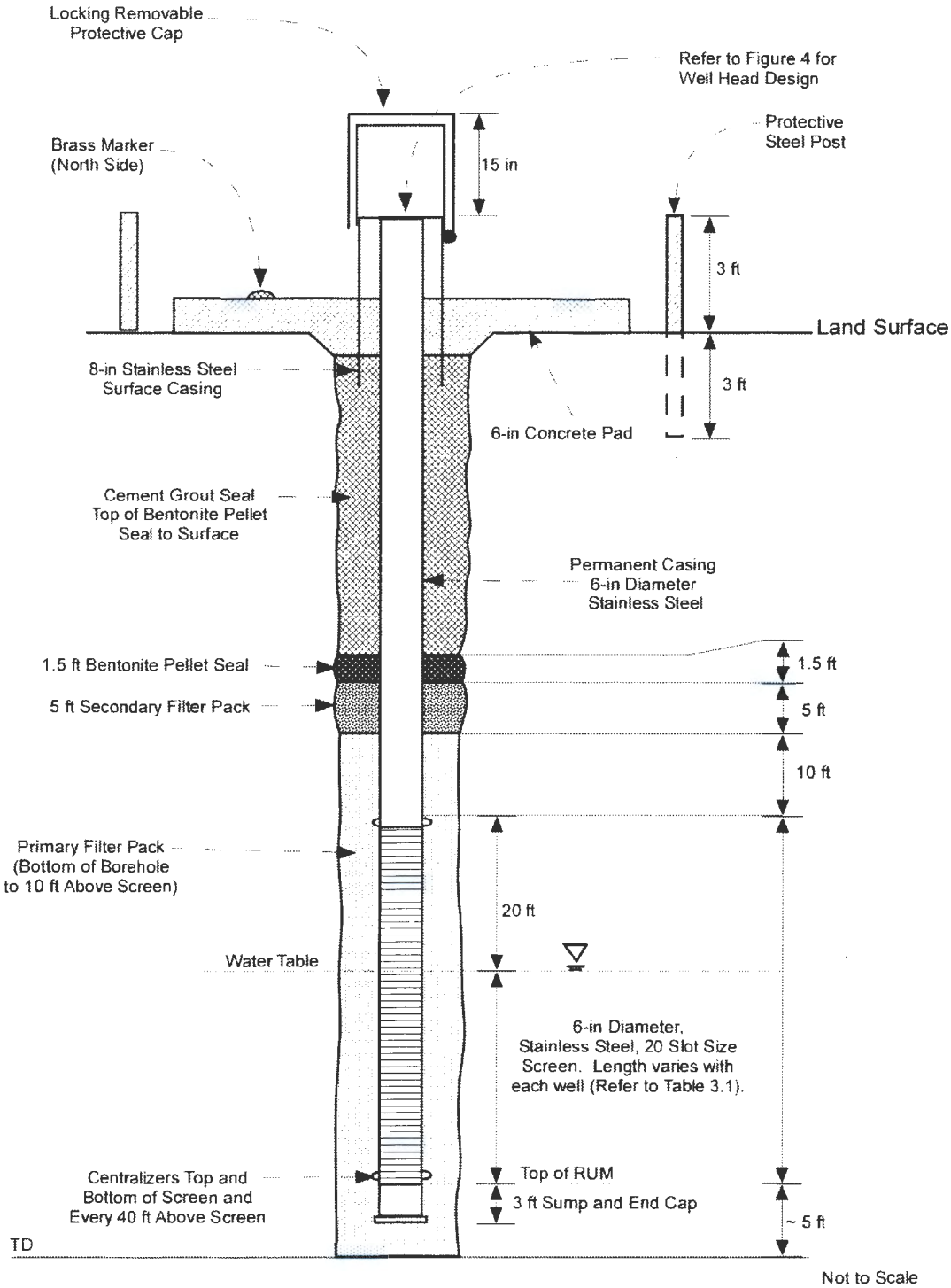
4.1.2 Balance of Plant

In general, the balance of plant includes all system components, from the extraction well pumps through the injection well pipes. The major balance of plant components includes the following:

- Extraction well pumps
- Extraction well head assemblies and control equipment
- Piping from well heads to the transfer building tank
- Piping from transfer building tank to process building influent tank
- Influent storage tank, feed pumps, and piping to the IX unit
- Piping from the IX unit to the effluent tank
- Booster pumps (HMI), flow control values, and piping to injection well assemblies
- Injection well head assemblies
- Injection well pipes
- Power supplies for equipment and instrumentation
- Instrumentation
- Control system.

Balance of plant will follow the schedule presented in Section 6.0 of this document.

Figure 4-1. Well Design for Injection Wells 199-K-169, 199-K-170, 199-K-171, and 199-K-172.



4.1.3 Groundwater Treatment System Construction and Delivery

The original expansion of the 100-KR-4 pump-and-treat called for a 1,136-L/min (300-gpm) expansion. Construction of three 378.5–L/min (100-gpm) IX units for the original expansion occurred at the vendor's facility, and they were delivered to the treatment facility as completed

products. The three 378.5-L/min (100-gpm) IX units are equipped with appropriate flanges, and also electrical and control connections, to allow connection to the balance of plant described above. Construction of the three 378.5-L/min (100-gpm) IX units was controlled through a procurement contract issued to the IX unit manufacturer. The procurement contract included a schedule for delivery of the three 378.5-L/min (100-gpm) IX units, which were delivered in February 2007 and will be placed for operation by September 2008. Acceptance testing of the system will start in October 2008.

The current expansion calls for a 2,271-L/min (600-gpm) increase to the treatment system capacity. Three additional 378.5-L/min (100-gpm) IX units have been constructed and procured in a manner similar to the first three units.

4.1.4 Restoration of Disturbed Areas

Disturbance of natural vegetation and habitat is expected to be minimal because most, if not all, of the expanded pump-and-treat area has been disturbed by prior construction or cleanup operations. A cultural resource and ecological review was conducted to identify controls to limit disturbances. Where disturbances do occur, restoration will be conducted in accordance with the existing mitigation action plan (DOE/RL-96-107). Areas of potential disturbance include the following:

- Drill pads and access roads
- Water transfer lines
- Power pole installations.

Construction of drill pads, and possibly access roads, will be necessary to allow access for drilling equipment and follow-up sampling rigs. Following completion of the interim action, the wells will likely be used for monitoring; therefore, the roads will still be required for well access.

At the completion of the interim action, the need for the transfer pump buildings will be evaluated. If the buildings are needed by another project, they will be transferred to that project. If the buildings are not needed and no other source remediation is scheduled for the future, the buildings will be demolished and the site restored. A similar evaluation will be conducted for water transfer lines and power poles.

4.1.5 Safety and Health During Construction

A site-specific health and safety plan was prepared and implemented for the 19 wells drilled and constructed during 2007 and 2008. That plan has been augmented as necessary to include the planned four injection wells to be completed by the end of FY08. The health and safety plan addresses the health and safety considerations for construction, construction oversight personnel, and visitors. Every subcontractor performing work associated with the 100-KR-4 pump-and-treat expansion project is required to submit a subcontractor health and safety plan. Subcontractor health and safety plans are reviewed for compliance with Hanford Site requirements and will be approved by prime contractor representatives before the subcontractor begins work.

4.2 ACCEPTANCE TESTING

After construction, the startup phase will be initiated and acceptance testing will continue through the fall of 2008. An acceptance testing plan will be developed prior to system startup.

The plan will address acceptance testing, testing of system components, and testing and startup of the overall system. The startup procedure will ensure that the system meets design requirements, will operate safely, and will result in a fully functioning treatment system.

It is anticipated that the startup of the extraction network will involve a phased approach. One extraction well will be started and then additional wells started in 1- to 3-day increments until all wells are operational. This ramping-up period will allow the wells and the transfer piping to be observed and troubleshooting to be performed as needed.

If a problem is found in one treatment system during startup activities, an evaluation will be conducted to determine whether the problem is unique to that component or if it affects the entire system.

4.3 OPERATIONAL TESTING

Operational testing of the system will be conducted after acceptance testing has been completed. It is anticipated that some downtime may occur due to weather conditions.

An operational testing plan will be developed to identify activities and documents that will be completed to support system operations. The plan will identify the persons responsible for various operational testing items and will include the appropriate procedures and checklists for the operational testing plan. Instrumentation calibrations will be performed prior to the start of operational testing.

4.4 OPERATION AND MAINTENANCE

The following subsections describe the operation and maintenance of the extraction well system, treatment system, and injection well system.

4.4.1 Controlling Documents

System operations will be controlled by operations and maintenance procedures. Defined preventative maintenance will be prepared prior to startup of operations and will specify the maintenance and calibration schedules.

The 100-KR-4 health and safety plan will be modified prior to startup of operations. The health and safety plan will identify the requirements for safe operation of the treatment system.

The operations waste management plan will be modified to manage waste produced during system operations. The waste management plan will specify waste characterization requirements for various waste types, waste storage requirements, and waste disposal requirements. This waste management plan will be finalized before startup of operations.

4.4.2 Extraction Well System Operation and Maintenance

Operation of the extraction well system will be on a continuous basis during the initial phase of the remedial action. A revised pumping system, or changes in well use, may be implemented as RAOs are close to being met. Individual well pumping rates are monitored continuously and the data will be stored in the project-specific database. Individual wells located where the saturated aquifer is thin as shown on Table 3-1, will likely be affected by low river stage.

Extraction wells may be shut down occasionally so maintenance activities can be performed. Maintenance activities will be limited and are likely to include possible well redevelopment

activities and pump maintenance. The efficiency of the extraction wells may change over time because well screens and filter packs may plug, especially where existing monitoring wells have been converted to extraction or injection wells. If performance is degraded, occasional maintenance may be necessary to clear the well screens and filter packs. Well pumps may fail occasionally and require replacement. Downtime for maintenance will be kept to the minimum required. Although unlikely, extraction wells may be shut down occasionally during extremely cold weather. In the event of a shutdown, transfer lines from the extraction wells to the transfer pump building are designed to drain back to the extraction wells by gravity drainage. In the event of an extended shutdown for cold weather, undrained water in the water transfer lines may freeze. This may render the transfer lines unusable until thawed and necessitate shutdown of the extraction wells. However, the water transfer lines are designed to freeze and thaw without damaging the lines.

4.4.3 Treatment System Operation and Maintenance

Operation of the treatment system will be controlled by an operating procedure that will be developed as the system design progresses. The operating procedure will be finalized before the startup of full-scale operations. Preventative maintenance and instrument calibration requirements will be defined by preventative maintenance schedules. Operation of the treatment system will be essentially continuous or will be of durations necessary to process water from continuous operation of the extraction well network. The network will not be shut down during resin changeouts.

The expected facility operational availability will be 95%, as measured by the amount of time the system is processing groundwater through the IX trains, divided by the amount of time the system was neither undergoing planned maintenance nor debilitated by events beyond control of the Soil and Groundwater Remediation Project (e.g., utility power outages, range fires, etc.).

4.4.4 Injection Well System Operation and Maintenance

The injection well system will operate in conjunction with the treatment system to inject treated water. The injection system will include the four new wells (199-K-169, 199-K-170, 199-K-171, and 199-K-172). As the 100-KR-4 remedial action progresses, the efficiency of the injection wells may decrease because of air entrainment, bio-fouling, well screen encrustation, or other effects. If injection well efficiency decreases significantly, maintenance will be performed, as practicable, to address the problem.

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5.0 100-KR-4 PUMP-AND-TREAT EXPANSION MONITORING PROGRAM

This section discusses the approach for monitoring performance of the 100-KR-4 pump-and-treat system and the method for assessing system effectiveness. The monitoring program is displayed in Table 5-1 and will include the following distinct monitoring elements:

- Compliance monitoring: The objectives for compliance monitoring are to perform the appropriate sampling, analysis, and data evaluation necessary to meet the requirements of the 100-KR-4 OU interim action ROD (EPA et al. 1996).
- Performance monitoring: The objectives for performance monitoring are to obtain water-level and water quality data necessary to optimize performance of the groundwater extraction system, to document aquifer and chromium plume response to pumping and injection, and to obtain supplemental data to support final remedy selection.
- Operations monitoring: The objectives for operations monitoring are to conduct the appropriate level of sampling, analysis, and equipment inspection to ensure the safe operation and functioning of the groundwater extraction, injection, and treatment systems.

The monitoring activities described in this section are designed to meet the requirements of the 100-KR-4 OU interim action ROD within which the expanded 100-KR-4 pump-and-treat system will be operating. Sampling and analysis procedures to support the performance monitoring and operational monitoring will be conducted in accordance with the updated QAPjP (see Appendix A).

The following wells are designated as compliance wells for the original pump-and-treat system and the expansion described in this document:

- Original 100-KR-4 pump-and-treat system: wells 199-K-18, 199-K-20, 199-K-114A, 199-K-117A, and 199-K-129
- 100-KR-4 expansion: wells 199-K-130, 199-K-131, 199-K-144, 199-K-145, 199-K-146, 199-K-147, 199-K-148, 199-K-149, 199-K-150, 199-K-161, and 199-K-162.

5.1 100-KR-4 PUMP-AND-TREAT EXPANSION MONITORING APPROACH

This section describes how the expanded 100-KR-4 pump-and-treat system will be monitored to demonstrate its effectiveness and how the monitoring data will be evaluated to show that the RAOs are being met, or that adequate progress is being achieved.

The interim action ROD, which covers 100-KR-4 pump-and-treat implementation and monitoring, describes three RAOs to allow for measurement of success:

- Protect aquatic receptors from chromium-contaminated groundwater discharging to the Columbia River by lowering hexavalent chromium concentration to less than 22 µg/L in compliance wells.
- Protect human health from exposure to groundwater containing above 100 µg/L chromium and other co-contaminants exceeding EPA/Washington State Department of Ecology (Ecology) maximum contaminant concentrations.
- Provide information to select a final remedy.

The expanded 100-KR-4 pump-and-treat system was designed to achieve three goals:

- Control the northward migration of the chromium plume before it reaches the 100-NR-2 OU.
- Protection of the Columbia River by removing high-concentration areas and eliminating gaps in coverage between existing 100-KR-4 extraction wells.
- Remediation of the remainder of the plume to below the 22 µg/L RAO.

5.1.1 Protection of Aquatic Receptors

Protection of aquatic receptors is the primary RAO requiring a high level of data quality and technical consideration. Because it is impractical to routinely monitor chromium concentrations at potential aquatic receptor exposure points, on-shore monitoring of groundwater near the river and data evaluation will be used to assess the effectiveness of the expanded 100-KR-4 pump-and-treat system in achieving this objective. Protection of aquatic receptors will be demonstrated by evaluating pump-and-treat monitoring data to show the following:

- Decrease the concentration of chromium in groundwater discharged to the river to below 11 µg/L (and 22 µg/L as measured in near-river wells). Chromium concentrations will be regularly monitored at locations as near to the river as practicable. The wells below have been designated as compliance wells. The 100-KR-4 compliance wells will also serve as extraction wells to best meet the goals of the interim action.
  - Original 100-KR-4 pump-and-treat system: wells 199-K-18, 199-K-20, 199-K-114A, 199-K-117A, and 199-K-129
  - 100-KR-4 expansion: wells 199-K-130, 199-K-131, 199-K-144, 199-K-145, 199-K-146, 199-K-147, 199-K-148, 199-K-149, 199-K-150, 199-K-161, and 199-K-162.
- Influence the hydraulic gradient. Groundwater elevations will be measured in selected wells adjacent to and inland from the river. A decreased hydraulic gradient between the aquifer and the river, or groundwater flow from the river toward the extraction wells, will be a positive indication of interim action effectiveness.

5.1.2 Protection of Human Health

The primary pathway for human exposure to groundwater containing chromium and other co-contaminants are seeps along the riverbank. Control of this pathway will be achieved by implementing the following actions for the duration of the interim action, or until such time that the pathway is eliminated or contaminant concentrations decline below health-based levels:

- Maintain institutional controls that prevent access to areas where seeps or groundwater contain contaminants above maximum contaminant levels and risk-based levels to only those activities authorized in this remedial action.
- Maintain signs along the river shoreline within the 100-KR-4 area, indicating a restricted access area.
- Modify, if necessary, the existing groundwater-use notification to identify areas where chromium and other co-contaminants exceed protective levels. The notification would consist of maps and narrative descriptions of areas where groundwater use is restricted.

5.1.3 Provide Information for Final Remedy

Monitoring of the expanded 100-KR-4 pump-and-treat system will generate data that can be used to assess the cost and technical feasibility of the pump-and-treat operation to decrease contaminant concentrations to levels protective of human health and the environment. During system operations, information will be reported annually on treatment cost, system efficiency, hydraulic impacts, and contaminant removal efficiency. The following subsections describe the approach that will be used for calculating these parameters.

5.1.3.1 Treatment Cost. The cost of treatment will be determined on the basis of dollars per liter of groundwater extracted and gram of chromium removed. The cost will be determined using the expanded 100-KR-4 pump-and-treat system (amortized over an assumed 10-year design lifetime), plus annual operations and maintenance costs, divided by the annual volume of groundwater extracted.

5.1.3.2 System Efficiency. System efficiency will be based collectively on chromium removal efficiency and system on-line percentage. Chromium removal efficiency will be determined based on the percentage of chromium removed by the system. This will involve subtracting the effluent from the influent concentration and dividing by the influent concentration. System on-line percentage will be determined by dividing the time that the groundwater treatment system operates by the total time available for operation. Extraction well flow rates during the year will vary with river stage.

5.1.3.3 Hydraulic Impacts. A numerical model will be used to assess the hydraulic impacts of the expanded 100-KR-4 pump-and-treat system on capturing the chromium plume based on fall groundwater levels and river stage.

5.1.3.4 Effectiveness of Contaminant Removal. The effectiveness of chromium removal will be determined using monitoring results after the expanded 100-KR-4 pump-and-treat interim action is terminated. Co-contaminants will not be included in this evaluation because they are not the subject of the interim action.

5.2 APPROACH FOR MONITORING SYSTEM DESIGN REQUIREMENTS

In addition to collecting data necessary to satisfy the RAOs, the interim action ROD (EPA et al. 1996) contains specific requirements for the design of the interim action monitoring network. These requirements include the following for the expanded pump-and-treat remedial action:

- Compliance points will be near-river wells located above the common high-water mark that are listed below:
  - Original 100-KR-4 pump-and-treat system: wells 199-K-18, 199-K20, 199-K-114A, 199-K-117A, and 199-K-129
  - 100-KR-4 expansion: wells 199-K-130, 199-K-131, 199-K-144, 199-K-145, 199-K-146, 199-K-147, 199-K-148, 199-K-149, 199-K-150, 199-K-161, and 199-K-162.
- Baseline sampling (pre-startup) will be conducted prior to startup of pump-and-treat operations in all new wells

- Sampling and hexavalent chromium analysis will be conducted weekly in extraction/compliance wells and monthly in performance wells for at least 3 months after startup of operations. Subsequently, extraction/compliance wells will be sampled at least monthly, and performance wells will be sampled quarterly (Table 5-1).

The complete analyte list shall include the following:

- Unfiltered hexavalent chromium
- Specific conductance
- Temperature, pH, turbidity, and dissolved oxygen
- Co-contaminants:
  - Tritium
  - Strontium-90
- Contaminants of interest:
  - Carbon-14 and technetium-99 (depending on well location).

The depth to water will be recorded each time the well is sampled, in performance monitoring wells without transducers.

Compliance wells are necessary to assess the effect of the pump-and-treat system on the plume and to identify when the system has reached the RAO. The compliance wells are sampled to obtain water quality data and water-level data as close to the river as practicable. Data collected from the compliance wells will be used to assess the effectiveness of the interim action at protecting aquatic receptors. Because of access and space limitations along the river, and the effect of river stage on wells located near the Columbia River, some extraction wells will be used as compliance wells.

Performance wells are monitoring wells used for water-level and less frequent water quality measurements at inland areas and will provide verification of interim action effectiveness at reducing chromium flux toward the river. The eight performance wells (199-K-151, 199-K-152, 199-K-153, 199-K-154, 199-K-157, 199-K-126, 199-K-163, and 699-78-62) will be monitored quarterly after the 3-month startup to provide information regarding the effectiveness of the initial well network at remediating the plume in a timely manner. Data from these wells will also help to evaluate whether additional wells are necessary or whether changes in well use (e.g., converting performance wells to extraction or injection wells) should be considered during upcoming remedial process optimization. These locations will be identified after monitoring system startup has been completed.

5.2.1 Monitoring Well Construction and Location

Monitoring wells are constructed similar to extraction or injection wells and in accordance with *Washington Administrative Code* (WAC) 173-160 standards. New wells have been constructed so the well screen fully penetrates the saturated thickness of the aquifer to provide improved monitoring flexibility, to promote cost effectiveness, and to enable the wells to be converted to extraction wells or injection wells as needed to complete remediation. Transducers will be installed in selected wells to help evaluate plume capture. Figures 4-1 shows the construction details for the new injection wells.

Table 5-1. 100-KR-4 Pump-and-Treat Monitoring Schedule. (2 sheets)

Sample Group	Pre-Startup (Baseline)			Startup[d]			Operation		
	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b]	Co-Contaminants[a,c] and Contaminants of Interest
Extraction/Compliance Wells									
199-K-114A	Existing 100-KR-4 pump-and-treat network						T	M	SA
199-K-129							T	M	SA
199-K-18	Existing 100-KR-4 pump-and-treat network						T	M	A
199-K-20							T	M	A
199-K-117A							T	M	A
199-K-130	T	X	X	T	W	--	T	M	SA
100-K-131	T	X	X	T	W	--	T	M	SA
100-K-147	T	X	X	T	W	-	T	M	SA
100-K-148	T	X	X	T	W	-	T	M	SA
100-K-149	T	X	X	T	W	-	T	M	SA
100-K-161	T	X	X	T	W	-	T	M	SA
199-K-144	T	X	X	T	W	-	T	M	SA
199-K-145	T	X	X	T	W	-	T	M	SA
199-K-146	T	X	X	T	W	-	T	M	SA
199-K-150	T	X	X	T	W	-	T	M	SA
199-K-162	T	X/Y	X	T	W	-	T	M	SA
Injection Wells									
199-K-159	T	X	X	T	--	--	T	--	--
199--K-143	T	X	X	T	--	--	T	--	--
199-K-156	T	X	X	T	--	--	T	--	--
199-K-160	T	X	X	T	--	--	T	--	--
199-K-164	T	X	X	T	-	-	T	-	-
199-K-169	T	X	X	T	-	-	T	-	-
199-K-170	T	X	X	T	-	-	T	-	-

Table 5-1. 100-KR-4 Pump-and-Treat Monitoring Schedule. (2 sheets)

Sample Group	Pre-Startup (Baseline)			Startup[d]			Operation		
	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b]	Co-Contaminants[a,c] and Contaminants of Interest
199-K-171	T	X	X	T	-	-	T	-	-
199-K-172	T	X	X	T	-	-	T	-	-
Performance Wells									
699-78-62	T	X	X	T	M	-	T	Q	A
199-K-19	T	X	X	T	M	-	T	Q	A
199-K-21	T	X	X	T	M	-	T	Q	A
199-K-111A	T	X	X	T	M	-	T	Q	A
199-K-126	T	X	X	T	M	-	T	Q	A
199-K-151	T	X	X	T	M	--	T	Q	A
199-K-152	T	X	X	T	M	--	T	Q	A
199-K-153	T	X	X	T	M	--	T	Q	A
199-K-154	T	X	X	T	M	--	T	Q	A
199-K-163	T	X	X	T	M		T	Q	A
199-K-157	T	X/Y	X	T	M	--	T	Q	A
Treatment System									
Influent	--	--	--	--	W	--	--	M	SA
Effluent	--	--	--	--	W	--	--	M	SA

[a] Co-contaminants, in accordance with 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), are strontium-90 and tritium. Carbon-14 and technetium-99 are contaminants of interest.

[b] Groundwater samples associated with routine pump-and-treat operations are analyzed for hexavalent chromium by operators using a Hach® (registered trademark of the Hach Company, Loveland, Colorado) kit. All other samples are analyzed at Waste Sampling and Characterization Facility using U.S. Environmental Protection Agency (EPA) Method 7196.

[c] Specific conductance, temperature, pH, turbidity, and dissolved oxygen will be measured for all laboratory samples.

[d] Startup duration is approximately 3 months.

A = annual M = monthly Q = quarterly SA = semi-annually
T = hourly transducer W = weekly X = one-time event Y = vertical profiling using Solinst ™ sampler

5.2.2 Monitoring Parameters

Interim action performance will be based on the ability to capture the existing plume, hydraulically control chromium flux to the river, and reduce contaminant mass so interim action can be terminated. Proposed monitoring parameters include water-level measurements, field hexavalent chromium, co-contaminants, and the field parameters described in Section 5.2.

Pressure transducers will be installed in extraction wells, injection wells, and selected performance wells to help assess the effect of operations on the local hydrology (Table 5-1). Water-level data from the extraction wells and injection wells will be available on a real-time basis through the OIC. Water-level data from extraction/compliance and performance monitoring wells will either be manually downloaded or telemetered to a central project location. The data will also be available in the Hanford Environmental Information System (HEIS) database.

Hexavalent chromium samples from monitoring wells will be analyzed at the Waste Sampling and Characterization Facility (WSCF) or equivalent laboratory using a modified version of the EPA 7196 method. The practical quantitation limit of this colorimetric method is approximately 5 µg/L. Quality control (QC) will initially be provided through a 10% field duplicate and spike samples and 10% sample splits with an EPA-certified laboratory. These requirements may be reduced to 5% field duplicates and 5% field splits after review of QC results and concurrence by EPA.

Samples associated with routine pump-and-treat operations (weekly or monthly influent and effluent samples) are collected and analyzed for hexavalent chromium by operators using a Hach® kit. The estimated practical quantitation limit for this method is 10 µg/L.

Monitoring for co-contaminants will be performed over the course of the interim action to obtain information for final remedy selection. The interim action ROD (EPA et al. 1996) identified the 100-KR-4 OU co-contaminants as tritium and strontium-90. Carbon-14 and technetium-99 are contaminants of interest. Monitoring for co-contaminants and contaminants of interest will be semi-annual in extraction wells and groundwater treatment system influent and effluent; performance wells will be sampled annually for co-contaminants and contaminants of interest. Analyses will be performed by certified laboratories using methods listed in Table A-1 of Appendix A.

5.2.3 Sampling Frequency

Prior to system startup, an initial average chromium concentration will be established for each new well. The average may include several samples collected over the timeframe between well construction and system startup.

During the first 3 months of operation (i.e., the startup period), compliance/extraction wells will be tested weekly and performance monitoring wells will be tested monthly for chromium to provide timely information on initial interim action performance. At the end of the 3-month startup period, the sampling frequency will be reduced to monthly for extraction and compliance wells and quarterly for performance wells until such time that an alternate frequency is warranted with EPA approval.

Hach® is a registered trademark of the Hach Company, Loveland, Colorado.

Sampling for co-contaminants and contaminants of interest will be performed semi-annually at each of the extraction well locations and from the treatment system influent and effluent. This frequency will be maintained until an alternate frequency is determined with EPA approval. Sampling locations, parameters, and their frequencies are shown in Table 5-1.

5.2.4 Vertical Sampling

During the pre-startup period, extraction wells 199-K- 162 and 199-K-157 were sampled at multiple depths to assess the vertical distribution of chromium in the aquifer. These wells are located where the saturated aquifer is thickest. Samples were collected using Solinst™ sampler to isolate discrete intervals from which the sample will be withdrawn. The samples were collected at 1.5-m (5-ft) intervals starting at the water table to document chromium concentrations at all depths prior to remediation. The test results are presented in Table 2-3.

5.2.5 Sediment Sampling During Well Drilling

Several different types of samples will be collected during drilling of wells to provide archive samples, samples for chemical analysis, and to confirm the selection of well-screen slot size. Samples will be collected in accordance with existing procedures to the extent those procedures do not contradict this remedial design report/remedial action work plan supplement.

- Archive sampling:
  - The primary purpose of collecting sediment samples during well drilling is to describe the materials on a geologic log that will be used to characterize local geologic units and also optimally site the well screen.
  - In addition, the geologist will collect cuttings from surface to total depth at 1.5-m (5-ft) intervals, at changes in lithology, and in areas of suspicious coloration (e.g., stained soil). These samples will be archived so they can be reviewed at a later date if necessary.
- Samples collected for chemical analysis:
  - Split-spoon samples were collected 1.5 and 3 m (5 and 10 ft) above the average water level in proposed injection wells 199-K-169, 199-K-170, 199-K-171, and 199-K-172. These samples were analyzed for hexavalent chromium using Method 7196A and the results will be presented in an upcoming report.
  - Suspiciously stained sediment from other wells can be processed similarly.
- Samples collected for particle size analysis:
  - Two split-spoon samples were collected from the saturated zone in each proposed new injection well. The finer of the two samples were selected for a sieve analysis that will provide particle size distribution. This distribution was used to help confirm the suitability of the screen slot size.

5.3 TREATMENT SYSTEM PERFORMANCE CRITERIA APPROACH

The interim action ROD (EPA et al. 1996) requires that the groundwater treatment system meet the following performance requirements:

- The groundwater treatment system will reduce effluent chromium concentrations to the maximum extent practicable; however, groundwater above 50 µg/L will not be discharged.
- The extraction and treatment system will be designed and operated to run on an essentially continuous basis.
- The expanded 100-KR-4 pump-and-treat system will continue until selection of the final action, or until termination is determined to be appropriate.

5.3.1 Monitoring for Groundwater Treatment System Removal Efficiency and Injection Discharge

The interim action ROD (EPA et al. 1996) requires that the groundwater treatment system remove chromium to the maximum extent practicable, with chromium concentrations not to exceed 50 µg/L in the treatment system discharge. This requirement will be met through analysis of groundwater treatment system influent and effluent samples.

During the startup period, groundwater treatment system effluent sampling and analysis will be conducted weekly. The weekly data will be used for comparison with the 50 µg/L discharge limit and a target treatment level to be developed during the startup and operations periods. The target treatment level will represent a balance between the level that is technically feasible, cost effective, and optimizes resin use. Chromium removal efficiency will be determined from the difference between the weekly influent and effluent concentrations. The maximum 100-KR-4 effluent concentration in 2006 from the existing system was about 10 µg/L (*Calendar Year 2006 Annual Summary Report for the 100-HR-3 and 100-KR-4 Operable Unit Pump-and-Treat Operations* [DOE/RL-2006-76]).

Analysis of samples collected from the groundwater treatment system will be performed using the modified Hach method. Field analysis provides the most effective method for obtaining timely information on system operation. Laboratory confirmation of field analysis results will be performed initially on a weekly basis until confidence in field analyses is established. After establishing the precision of field analyses, laboratory confirmation analyses can be reduced to a monthly or quarterly frequency as approved by EPA.

5.3.2 Design for System Operation Efficiency

The groundwater extraction and treatment systems have been designed to operate on an essentially continuous basis. The design allows various system components to be isolated for maintenance and repair, thereby allowing other system components to continue operating.

5.3.3 Resin Regeneration and Disposal

Resin that has been saturated will be regenerated and reused until it must be replaced so frequently that it is no longer cost effective to use. All resins sent to Environmental Restoration Disposal Facility to date from the existing 100-KR-4 and KW Reactor pump-and-treat facilities have passed toxicity characteristic leaching procedure/chromium disposal requirements

5.4 INTERIM ACTION TERMINATION

The interim action ROD (EPA et al. 1996) provides three criteria for termination of the interim action: (1) successful completion of the interim action is demonstrated, (2) the interim action is no longer effective, and (3) a final remedy is selected. The proposed criteria for termination are described in the following subsections.

5.4.1 Successful Completion of the Interim Action

The pump-and-treat portion of the remedial action will continue until the selection of a final action or it is demonstrated to EPA and Ecology's satisfaction that termination (of intermittent operation) is appropriate because (1) sampling indicates that hexavalent chromium is below the compliance value, and site data indicate that it will remain below the compliance value; or (2) based on an evaluation of the following criteria:

- The effectiveness of the treatment technology does not justify further operation.
- An alternate treatment technique, such as in situ chemical reduction or other improved treatment technique is evaluated and proves to be more effective, and/or less costly and is consistent with RAOs.

5.4.2 Interim Action No Longer Cost Effective

If the cost of chromium removal from the aquifer increases disproportionately to the environmental benefit received, the expanded 100-KR-4 interim action may no longer be cost effective. Additionally, if new technologies are developed that provide equivalent or greater environmental protection at a lower cost, the current interim action may no longer be cost effective. Any cost-effectiveness determination would be studied carefully and EPA concurrence obtained before implementation.

5.4.3 Selection of a Final Remedy

Selection of a final remedy includes evaluation of cumulative risks associated with residual contamination resulting from cleanup of the 100-KR-4 chromium plume or failure to reach cleanup goals because cleanup was determined to be technically impracticable. Prior to selecting a final remedy, a baseline risk assessment will be performed to assess the human health and ecological exposures that result from all remaining contaminants. A finding that unacceptable risk levels still remain would require that additional cleanup alternatives be evaluated and a final feasibility study report prepared. The final feasibility study report would be the basis for a final proposed plan and ROD.

5.5 REPORTING OF 100-KR-4 PUMP-AND-TREAT EXPANSION INTERIM ACTION DATA

The expanded 100-KR-4 pump-and-treat well chemistry and water-level data for the expanded 100-KR-4 system will be available for review in the HEIS database. The project performance will be reported as a section in the calendar year annual summary report for the 100-KR-4 pump-and-treat operations that is transmitted to EPA by May 31 each year. A semi-annual technical memorandum that is essentially a data transmittal will also be prepared to cover the period of January 1 through June 30 each year. These reports will highlight significant operational or monitoring changes observed during the reporting period.

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6.0 SCHEDULE

The following milestone is established for the expansion of the 100-KR-4 pump-and-treat system:

- May 31, 2009: The 2,271-L/min (600-gpm) treatment capacity expansion of the 100-KR-4 pump-and-treat system becomes operational.

A system becomes operational after acceptance testing and operational testing have been completed.

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APPENDIX A

QUALITY ASSURANCE PROJECT PLAN

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LIST OF TERMS

ALARA	as low as reasonably achievable
CFR	*Code of Federal Regulations*
CRDL	contract-required detection limit
DOE	U.S. Department of Energy
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FH	Fluor Hanford, Inc.
HEIS	Hanford Environmental Information System
MCL	maximum contaminant level
MDC	minimum detectable concentration
OU	operable unit
PNNL	Pacific Northwest National Laboratory
PQL	practical quantitation limit
QA	quality assurance
QC	quality control
QAPjP	quality assurance project plan
RAO	remedial action objective
RCT	radiological control technician
RDR/RAWP	remedial design report/remedial action work plan
RL	U.S. Department of Energy, Richland Operations Office
S&GRP	Soil and Groundwater Remediation Project
SAF	sampling authorization form
SAP	sampling and analysis plan
Tri-Party *Agreement*	*Hanford Federal Facility Agreement and Consent Order*
WSCF	Waste Sampling and Characterization Facility

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APPENDIX A
QUALITY ASSURANCE PROJECT PLAN

A1.0 INTRODUCTION

This quality assurance project plan (QAPjP) supports the data collection activities associated with monitoring the 100-KR-4 pump-and-treat-system expansion, which is described in the main text of this document. The monitoring activities will include well sampling and analytical testing to support pump-and-treat operations and to assess the impact of the remedial action on the chromium plume. Water-level measurements will also be conducted to provide hydraulic-head data to help evaluate capture of the plume by the extraction well network and the impact of injection.

The 100-KR-4 pump-and-treat-system expansion will consist of 11 extraction/compliance wells and 9 injection wells. The injection wells consist of five existing wells and four new wells to be drilled in the summer of 2008.

The selected groundwater treatment system incorporates an ion-exchange system using the Dowex® 21K resin that has successfully removed hexavalent chromium for the existing 100-HR-3 and 100-KR-4 Operable Unit (OU) pump-and-treat-systems. Spent resin will be regenerated, if feasible. Resin that cannot be regenerated will be sent to the Environmental Restoration Disposal Facility (ERDF), which is a low-level waste facility located on the Hanford Site.

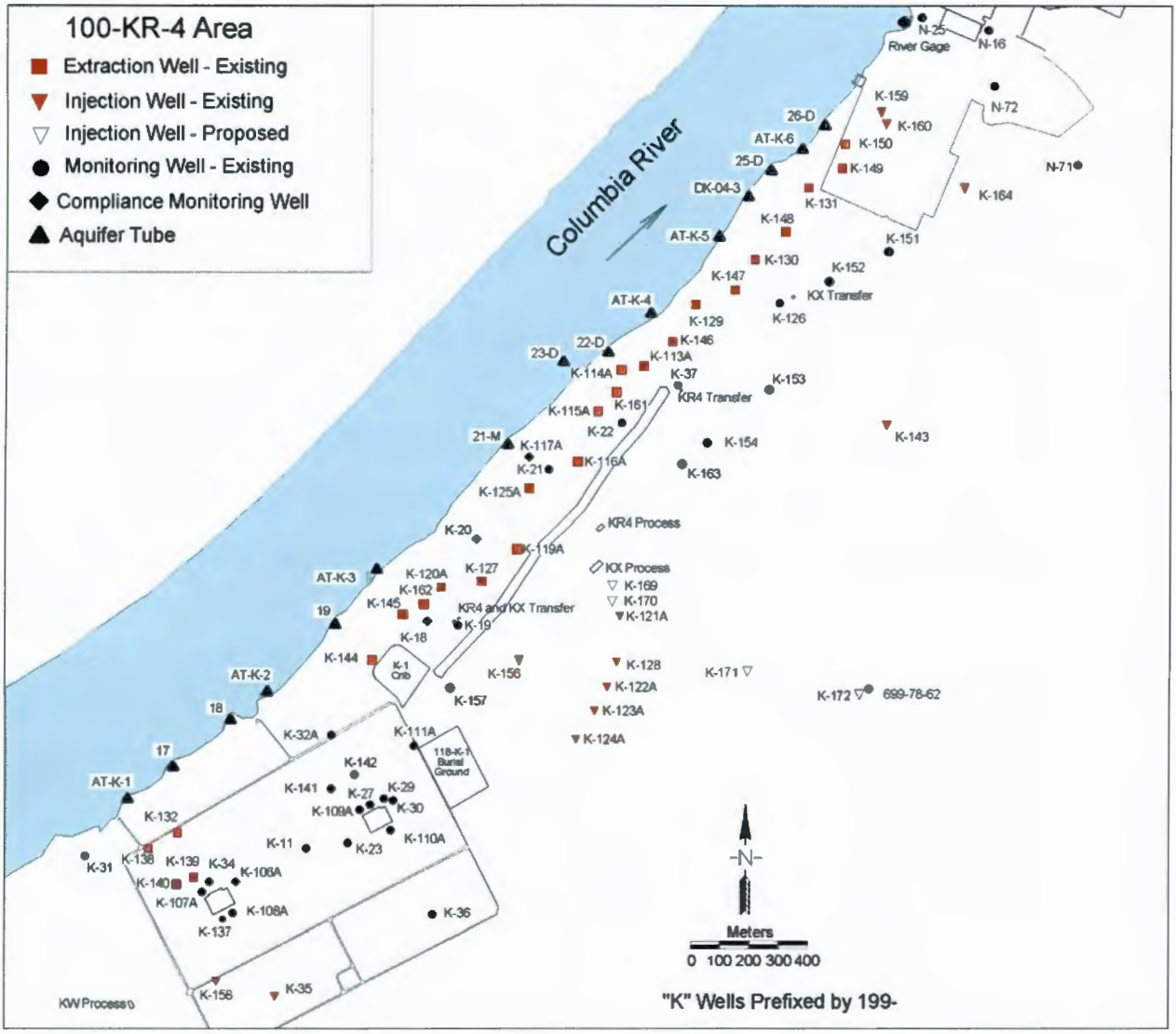
A1.1 BACKGROUND AND LOCATION

Background information on contamination in the 100-KR-4 OU is available in *Calendar Year 2007 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Pump-and-Treat Operations* (DOE-RL-2008-05). A brief description of the conceptual model is provided in Section 2.0 in the main text of this remedial design report/remedial action work plan (RDR/RAWP) supplement. Historical hydrochemical data are available electronically in the Hanford Environmental Information System (HEIS) database and in *Conceptual Site Models for Groundwater Contamination at the 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units* (BHI-00917).

The expanded 100-KR-4 pump-and-treat-system will be located in the 100-KR-4 OU, in the vicinity of the 116-K-2 Trench. Figure A-1 shows the locations of the proposed and existing wells in the project area.

DOWEX® is a registered trademark of Dow Chemical Company, Midland, Michigan.

Figure A-1. Expanded 100-KR-4 Pump-and-Treat.



A1.2 SITE DESCRIPTION AND HISTORY

The hexavalent chromium contaminant plume that is the target of this interim action is essentially parallel to the 116-K-2 Trench and extends from the 116-K-1 Crib to the south edge of the 100-NR-2 OU. The highest 2007 concentrations were 156 µg/L in well 199-K-18. Sodium dichromate was added to reactor coolant water as a rust inhibitor while the reactor was operational from 1955 to 1970.

A1.3 CONTAMINANTS OF CONCERN

The interim action is being implemented to address the hexavalent chromium plume centered on the 116-K-2 Trench. The co-contaminants, which are constituents that may be above maximum contaminant levels (MCLs), are tritium and strontium-90. Carbon-14 and technetium-99 are constituents of interest.

A1.4 DATA QUALITY OBJECTIVES

The data quality objectives (DQO) process was used to prepare the sampling and analytical requirements for monitoring the 100-KR-4 pump-and-treat-system, as described in the *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-96-90). The sampling and analytical requirements for the 100-KR-4 pump-and-treat-system expansion have been carried over from the 100-KR-4 OU to the 100-KR-4 pump-and-treat-system.

A2.0 QUALITY ASSURANCE PROJECT PLAN

This QAPjP establishes the quality requirements for environmental data collection, including sampling, field measurements, and laboratory analysis. The QAPjP has been updated from the QAPjP in the monitoring plan (DOE/RL-96-90) because an additional pump-and-treat-system has been added and the contractor changed from Bechtel Hanford, Inc. to Fluor Hanford, Inc. (FH). This QAPjP complies with the requirements of the following:

- U.S. Department of Energy (DOE) O 414.1C, *Quality Assurance*
- 10 *Code of Federal Regulations* (CFR) 830, Subpart A, "Quality Assurance Requirements"
- *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5 (EPA/240/B-01/003).

The following sections describe the quality requirements and the controls applicable to this investigation.

A2.1 PROJECT MANAGEMENT

The following subsections address the basic areas of project management, ensuring that the project has a defined goal, that the participants understand the goal and approach to be used, and that the planned outputs have been appropriately documented.

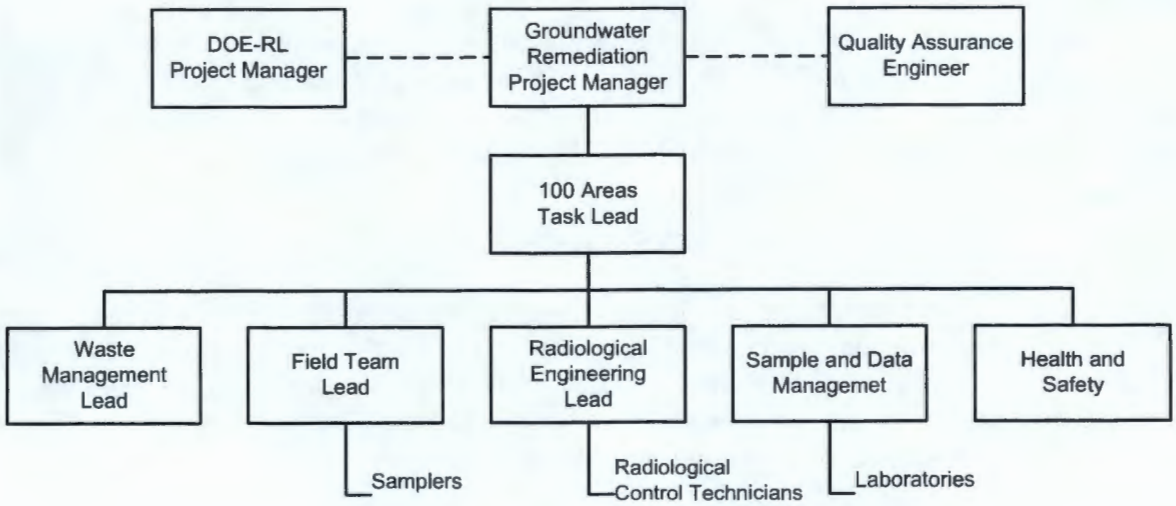
A2.1.1 Project/Task Organization

The Project Hanford Management Contractor Soil and Groundwater Remediation Project (S&GRP) is responsible for planning, coordinating, sampling, preparing, packaging, and shipping soil samples to the laboratory. The project organization is described in the subsections that follow and is shown in Figure A-2.

A2.1.2 Soil and Groundwater Remediation Project Manager

The S&GRP project manager provides oversight for all activities and coordinates with the U.S. Department of Energy, Richland Operations Office (RL) and the regulators in support of sampling activities. In addition, the S&GRP project manager provides support to the 100 Areas task lead to ensure that work is performed safely and cost effectively. The S&GRP project manager maintains the approved QAPjP.

Figure A-2. Project Organization.



A2.1.3 100 Areas Task Lead

The 100 Areas task lead is responsible for direct management of sampling documents and requirements, field activities, and subcontracted tasks. The task lead works closely with Quality Assurance (QA), Health and Safety, and the field team lead to integrate these and the other lead disciplines in planning and implementing the workscope. The 100 Areas task lead also coordinates with and reports to RL and FH on all sampling activities. The 100 Areas task lead supports RL in coordinating sampling activities with the regulators.

A2.1.4 Quality Assurance Engineer

The QA engineer is matrixed to the S&GRP project manager and is responsible for QA issues on the project. Responsibilities include oversight of implementation of the project QA requirements, review of project documents (including sampling and analysis plans [SAPs] and the QAPjP), and participation in QA assessments on sample collection and analysis activities, as appropriate.

A2.1.5 Waste Management Lead

The waste management lead communicates policies and procedures and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner. Other responsibilities include identifying waste management sampling/characterization requirements to ensure regulatory compliance of the characterization data to generate waste designations, profiles, and other documents that confirm compliance with waste acceptance criteria.

A2.1.6 Field Team Lead

The field team lead has the overall responsibility for the planning, coordinating, and executing field characterization activities. Specific responsibilities include converting the sampling design requirements into field task instructions that provide specific direction for field activities. Responsibilities also include directing training, mock-ups, and practice sessions with field personnel to ensure that the sampling design is understood and can be performed as specified. The field team lead communicates with the 100 Areas task lead to identify field constraints that could affect the sampling design. In addition, the field team lead directs the procurement and installation of materials and equipment needed to support field work.

The field team lead oversees field sampling activities that include sample collection, packaging, provision of certified clean sampling bottles/containers, documentation of sampling activities in controlled logbooks, chain-of-custody documentation, and packaging and transportation of samples to the laboratory or shipping center.

The field team lead, samplers, and others responsible for implementation of the SAP and QAPjP will be provided with current copies of this document and any revisions thereto.

A2.1.7 Radiological Engineering Lead

The Radiological Engineering lead is responsible for the radiological engineering and health physics support to the project. Specific responsibilities include conducting as low as reasonably achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization for all work planning. In addition, radiological hazards are identified and appropriate controls are implemented to maintain worker exposures to the hazards ALARA. The Radiological Engineering lead interfaces with the project Health and Safety representative and plans and directs radiological control technician (RCT) support for all activities.

A2.1.8 Sample and Data Management

The Sample and Data Management organization selects the laboratories that perform the analyses. This organization also ensures that the laboratories conform to Hanford Site internal laboratory QA requirements (or equivalent), as approved by RL, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology). Sample and Data Management receives the analytical data from the laboratories, enters the data into the HEIS database, and arranges for data validation. Validation will be performed on 10% of completed data packages by qualified FH personnel or by a qualified independent contractor.

A2.1.9 Health and Safety Representative

The responsibilities of the Health and Safety representative include coordinating industrial safety and health support to the project as carried out through health and safety plans, activity job hazard analyses, and other pertinent safety documents required by Federal regulations or by internal FH work requirements. In addition, assistance is provided to project personnel in complying with applicable health and safety standards and requirements. Personal protective clothing requirements are coordinated with Radiological Engineering.

A2.2 PROBLEM DEFINITION/BACKGROUND

The purpose of the 100-KR-4 pump-and-treat-system expansion is to address the hexavalent chromium plume that presents a threat to human health or the environment. The interim action will achieve three remedial action objectives (RAOs) that were identified in 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), namely the following:

- Protect aquatic receptors from chromium-contaminated groundwater discharging to the Columbia River above 22 µg/L as measured in compliance wells.
- Protect human health from exposure to groundwater containing chromium and other co-contaminants exceeding EPA/Ecology MCLs.
- Provide information to select a final remedy.

Extraction/compliance wells and monitoring wells must be sampled to verify that progress is being made to reach the three RAOs listed above. Influent into the groundwater treatment system and treated effluent are also sampled and analyzed to confirm satisfactory system operations.

A2.3 PROJECT/TASK DESCRIPTION

The monitoring elements and their objectives for this project are listed below:

- Operational monitoring: The objective for operational monitoring is to conduct the appropriate level of sampling, analysis, and equipment inspection necessary for safe operation and function of the pump-and-treat-system to treat to the maximum extent practicable, protecting the Columbia River and removing contaminant mass. Extraction wells, injection wells, influent, effluent, and the treatment system are sampled as part of this monitoring. Chromium removal efficiency is also calculated.
- Compliance monitoring: The objective for compliance monitoring is to perform the appropriate level of sampling, analysis, and data evaluation to determine whether the groundwater chemistry requirements of the interim action have been achieved.
- Performance monitoring: The objective for performance monitoring is to obtain water quality and groundwater-level data from monitoring wells within the plume area to determine whether groundwater extraction is reducing contaminant concentrations in the plume and to provide data to assess plume capture.

The use of individual wells in the network may change to respond to change or lack of change in groundwater chemistry. The water quality and water-level data gathered from the 100-KR-4 expansion wells will be used to prepare figures and tables that will be included in annual reports.

A2.4 QUALITY OBJECTIVES AND CRITERIA

The QA objective of this plan is to develop implementation guidance that will provide data of known and appropriate quality. Data quality is assessed by accuracy and precision. The applicable quality control (QC) guidelines, quantitative target limits, and levels of effort for assessing data quality are dictated by the intended use of the data and the nature of the analytical method. Each of these is addressed below.

Groundwater quality objectives and criteria for measurement data are presented in Table A-1.

Table A-1. Performance Requirements for 100-KR-4 Pump-and-Treat Contaminant Analysis.

Type of Contaminant	Contaminant	Analytical Methods[a,d]	PQL (µg/L)[b]	Precision[c] Required	Accuracy Required[c]
Nonradiological					
Metals	Chromium, hexavalent	SW-7196	5	±20%	75-125%
	Chromium, hexavalent	Hach®	10	None	None
Radiological					
	Contaminant	**Methods**	**MDC (pCi/L)**	**Precision Required**	**Accuracy Required**
	Strontium-90	Gas proportional counting	2	±20%	75-125%
	Tritium	Liquid scintillation	400	±20%	75-125%
	Carbon-14	Liquid scintillation	200	±20%	75-125%
	Technetium-99	Liquid scintillation	15	+20%	75-125%

NOTE: Hach® is a registered trademark of the Hach Company, Loveland, Colorado. The Hach Method 8023 used to support operations is a colorimetric method that uses an acidic buffer combined with 1,5-diphenylcarbohydrazide, which reacts to give a purple color which is proportional to the amount of hexavalent chromium in solution.

[a] Analytical method selection based on available methods by laboratories currently contracted to the Hanford Site. Equivalent methods may be substituted in future sampling and analysis plans or other documents. Four-digit methods are from EPA's *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* (SW-846); other methods are referenced to source.

[b] Typical MDC based on current Hanford laboratory contracts. The PQL in documents may decrease depending on method selection and contract laboratory but will not increase. Units are "µg/L" for nonradiological contaminants of concern and "pCi/L" for future radiological contaminants of concern, unless otherwise noted. Listed PQL equivalent to Waste Sampling and Characterization Facility method detection limit x 10.

[c] Precision and accuracy in accordance with existing requirements for the 100-KR-4 pump-and-treat system.

[d] Specific procedures vary from laboratory to laboratory.

EPA = U.S. Environmental Protection Agency
MDC = minimum detectable concentration
PQL = practical quantitation limit

A2.4.1 Accuracy

Accuracy is an assessment of the closeness of the measured value to the true value. Accuracy of chemical test results is assessed by spiking samples with known standards and establishing the average recovery. A matrix spike is the addition to a sample of a known amount of a standard compound similar to the compounds being measured. For radionuclide measurements that are analyzed by gamma spectroscopy, laboratories typically compare results of blind audit samples against known standards to establish accuracy. Validity of calibrations are evaluated by

comparing results from the measurement of a standard to known values and/or by generation of in-house statistical limits based on three standard deviations (±3 standard deviations). Table A-1 lists the accuracy requirements for fixed laboratory analyses for the project.

A2.4.2 Precision

Precision is a measure of the data spread when more than one measurement has been taken on the same sample. Precision can be expressed as the relative percent difference for duplicate measurements. Analytical precision requirements for fixed laboratory analyses are listed in Table A-1.

A2.4.3 Detection Limits

Detection limits are functions of the analytical method used to provide the data and the quantity of the sample available for analyses. The minimum detection concentrations for radiological co-contaminants and contract-required detection limits (CRDLs) for hexavalent chromium and nitrate are listed in Table A-1.

A2.5 SPECIAL TRAINING/CERTIFICATION

Typical training or certification requirements have been instituted by the FH team to meet training requirements imposed by the Project Hanford Management Contract, regulations, DOE orders, contractor requirements documents, American National Standards Institute/American Society of Mechanical Engineers standards, the *Washington Administrative Code*, etc., for example:

- Training or certification requirements needed by sampling personnel will be in accordance with Hanford Site analytical quality requirements.

The environmental health and safety training program provides workers with the knowledge and skills necessary to safely execute assigned duties. Field personnel typically will have completed the following training before starting work:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training and supervised 24-hour hazardous waste site experience
- 8-Hour Hazardous Waste Worker Refresher Training (as required)
- Hanford General Employee Radiation Training
- Radiological Worker Training.

A graded approach is used to ensure that workers receive a level of training that is commensurate with their responsibilities and that complies with applicable DOE orders and government regulations. Specialized employee training includes pre-job briefings, on-the-job training, emergency preparedness, plan-of-the-day activities, and facility/worksite orientations.

Field personnel training records will be documented and kept on file by the training organization.

A2.6 DOCUMENTATION AND RECORDS

The 100 Areas task lead ensures that the field team lead, samplers, and others responsible for implementation of the SAP and QAPjP are provided with current copies of this document and any revisions thereto.

Documentation and records, regardless of medium or format, are controlled in accordance with internal work requirements and processes that comprise a collection of document control systems and processes that use a graded approach for the preparation, review, approval, distribution, use, revision, storage/retention, retrieval, disposition, and protection of documents and records generated or received in support of FH work.

All information pertinent to field sampling and analysis will be recorded in bound logbooks. The sampling team will be responsible for recording all relevant sampling information in the logbooks. Entries made in the logbooks will be dated and signed by the individual making the entry.

Primary documents under the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al. 2003) (e.g., supplements to the RDR/RAWP, such as this document) will be submitted to the Administrative Record. All other documentation will be prepared, approved, and maintained in accordance with RL and contractor requirements for these processes.

A3.0 DATA GENERATION AND ACQUISITION

This section presents the requirements for sampling methods, sample handling and custody, analytical methods, and field and laboratory QC. Instrument calibration, maintenance supply inspection, and data management requirements are also addressed.

A3.1 SAMPLING PROCESS DESIGN

The goal of the operational sampling for the 100-KR-4 pump-and-treat-system expansion is to provide influent and effluent groundwater chemistry data to help calculate percent saturation of the resin and to breakthrough that could result in high chromium concentrations in treated effluent. Sampling will be conducted approximately weekly in the treatment train to account for fluctuations in influent concentrations that could lead to breakthrough concentrations in the effluent. Sampling frequency may decrease as trends are established.

The compliance/extraction wells will also be sampled to provide a check on the overall influent concentrations and also to provide information on the effect of river stage on groundwater chemistry. These wells will be sampled weekly during system startup and on a monthly and annual basis (depending on constituent) during operations. Sampling frequency may change as trends are established, or the use of individual wells in the pump-and-treat network and may be adjusted to optimize the efficiency of the system.

Performance wells will be sampled quarterly or annually (depending on constituent) during operation to assess the effect of remediation on the chromium contaminant plume.

Compliance/extraction well samples will be analyzed for co-contaminants strontium-90, carbon-14, tritium, and nitrate, as the Dowex 21K resin will not remove these contaminants and they will be reinjected.

Sample design specifications are presented in Section 3.0 in the main text of this document.

A3.2 SAMPLING METHODS

The proposed well and treatment train sampling for the 100-KR-4 pump-and-treat-system expansion will be performed in accordance with established sampling practices and requirements pertaining to sample collection, collection equipment, and sample handling.

Preservation requirements, containers, and holding times for chemical and radiological analytes of interest are presented in Table A-2. Final sample collection requirements will be identified on the sampling authorization form (SAF).

If samples are not collected as scheduled, if insufficient quantity is collected, or if temperature controls or preservation requirements are not implemented, the 100 Areas task lead will be notified. The 100 Areas task lead and the Sample and Data Management project coordinator will decide whether a resampling is required.

Additional details on sampling methods are provided in Section 3.0 in the main text of this document.

A3.3 SAMPLE HANDLING AND CUSTODY

Level I EPA pre-cleaned sample containers will be used for samples collected for laboratory chemical and radiological analysis. Container sizes may vary depending on laboratory-specific volumes/requirements for meeting analytical detection limits. If, however, the dose rate on the outside of a sample jar or the curie content exceeds levels acceptable by an offsite laboratory, the sampling lead and waste site remediation task lead can send smaller volumes to the laboratory after consultation with Sample and Data Management to determine acceptable volumes. The final container types and volumes will be indicated on the SAF.

The FH Sample and Data Tracking database will be used to track the samples from the point of collection through the laboratory analysis process. The HEIS database is the repository for the laboratory analytical results. The HEIS sample numbers will be issued to the sampling organization for this project in accordance with onsite organization procedures. Each chemical/ radiological and physical properties sample will be identified and labeled with a unique HEIS sample number. The sample location, depth, and corresponding HEIS numbers will be documented in the sampler's field logbook.

Table A-2. 100-KR-4 Pump-and-Treat Monitoring Schedule. (2 sheets)

Sample Group	Pre-Startup (Baseline)			Start Up[d]			Operation		
	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b]	Co-Contaminants[a,c] and Contaminants of Interest
Extraction/Compliance Wells									
199-K-114A	Existing 100-KR-4 pump-and-treat network						T	M	SA
199-K-129							T	M	SA
199-K-18	Existing 100-KR-4 pump-and-treat network						T	M	A
199-K-20							T	M	A
199-K-117A							T	M	A
199-K-130	T	X	X	T	W	--	T	M	SA
100-K-131	T	X	X	T	W	--	T	M	SA
100-K-147	T	X	X	T	W	-	T	M	SA
100-K-148	T	X	X	T	W	-	T	M	SA
100-K-149	T	X	X	T	W	-	T	M	SA
100-K-161	T	X	X	T	W	-	T	M	SA
199-K-144	T	X	X	T	W	-	T	M	SA
199-K-145	T	X	X	T	W	-	T	M	SA
199-K-146	T	X	X	T	W	-	T	M	SA
199-K-150	T	X	X	T	W	-	T	M	SA
199-K-162	T	X/Y	X	T	W	-	T	M	SA
Injection Wells									
199-K-159	T	X	X	T	--	--	T	--	--
199--K-143	T	X	X	T	--	--	T	--	--
199-K-156	T	X	X	T	--	--	T	--	--
199-K-160	T	X	X	T	--	--	T	--	--
199-K-164	T	X	X	T	-	-	T	-	-
199-K-169	T	X	X	T	-	-	T	-	-
199-K-170	T	X	X	T	-	-	T	-	-

Table A-2. 100-KR-4 Pump-and-Treat Monitoring Schedule. (2 sheets)

Sample Group	Pre-Startup (Baseline)			Start Up[d]			Operation		
	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b,c]	Co-Contaminants[a,c] and Contaminants of Interest	Water Level	Cr[b]	Co-Contaminants[a,c] and Contaminants of Interest
199-K-171	T	X	X	T	-	-	T	-	-
199-K-172	T	X	X	T	-	-	T	-	-
Performance Wells									
699-78-62	T	X	X	T	M	-	T	Q	A
199-K-19	T	X	X	T	M	-	T	Q	A
199-K-21	T	X	X	T	M	-	T	Q	A
199-K-111A	T	X	X	T	M	-	T	Q	A
199-K-126	T	X	X	T	M	-	T	Q	A
199-K-151	T	X	X	T	M	--	T	Q	A
199-K-152	T	X	X	T	M	--	T	Q	A
199-K-153	T	X	X	T	M	--	T	Q	A
199-K-154	T	X	X	T	M	--	T	Q	A
199-K-163	T	X	X	T	M		T	Q	A
199-K-157	T	X/Y	X	T	M	--	T	Q	A
Treatment System									
Influent	--	--	--	--	W	--	--	M	SA
Effluent	--	--	--	--	W	--	--	M	SA

[a] Co-contaminants, in accordance with 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), are strontium-90 and tritium. Carbon-14 and technetium-99 are contaminants of interest.

[b] Groundwater samples associated with routine pump-and-treat operations are analyzed for hexavalent chromium by operators using a Hach® (registered trademark of the Hach Company, Loveland, Colorado) kit. All other samples are analyzed at Waste Sampling and Characterization Facility using U.S. Environmental Protection Agency (EPA) Method 7196.

[c] Specific conductance, temperature, pH, turbidity, and dissolved oxygen will be measured for all laboratory samples.

[d] Startup duration is approximately 3 months.

A = annual M = monthly Q = quarterly SA = semi-annually
T = hourly transducer W = weekly X = one-time event Y = vertical profiling using Solinst™ sampler

Each sample container will be labeled with the following information using a waterproof marker on firmly affixed, water-resistant labels:

- SAF
- HEIS number
- Sample collection date/time
- Name of person collecting the sample
- Analysis required
- Preservation method (if applicable).

Samples collected to support pump-and-treat operations will be kept under the immediate control of the operator (sampler) unit the analysis has been completed.

A3.4 LABORATORY SAMPLE CUSTODY

Sample custody during laboratory analysis will be addressed in the applicable laboratory's standard operating procedures. Laboratory custody procedures will ensure the maintenance of sample integrity and identification throughout the analytical process.

All information pertinent to field sampling and analysis will be recorded in field checklists and bound logbooks in accordance with existing sample collection protocols. The sampling team will be responsible for recording all relevant sampling information. Entries made in the logbook will be dated and signed by the individual making the entry. Program requirements for managing the generation, identification, transfer, protection, storage, retention, retrieval, and disposition of records will be followed.

Sample custody will be maintained in accordance with existing Hanford Site protocols. The custody of samples will be maintained from the time that the samples are collected until the ultimate disposal of the samples, as appropriate. A chain-of-custody record will be initiated in the field at the time of sampling and will accompany each set of samples shipped to any laboratory. Wire or laminated waterproof tape will be used to seal the coolers. The analyses requested for each sample will be indicated on the accompanying chain-of-custody form. Chain-of-custody procedures will be followed throughout sample collection, transfer, analysis, and disposal to ensure that sample integrity is maintained. Each time the responsibility changes for the custody of the sample, the new and previous custodians will sign the record and note the date and time. The sampler will make a copy of the signed record before sample shipment and will transmit the copy to Sample and Data Management within 48 hours of shipping.

A custody seal (i.e., evidence tape) will be affixed to the lid of each sample jar or to the bag containing volatile organic analyte samples in such a way to indicate potential tampering with the sample. The container seal will be inscribed with the sampler's initials and the date.

The RCT will measure the contamination levels on the outside of each sample jar and the dose rates on each sample jar. The RCT also will measure the radiological activity on the outside of the sample container (through the container) and will document the highest contact radiological reading in millirem per hour (mR/hr). This information, along with other data, will be used to select proper packaging, marking, labeling, and shipping paperwork in accordance with U.S. Department of Transportation regulations (49 CFR, "Transportation") and to verify that the sample can be received by the analytical laboratory in accordance with the laboratory's

acceptance criteria. The sampler will send copies of the shipping documentation to Sample and Data Management within 48 hours of shipping.

As a general rule, samples with activities of <1 mR/hr will be shipped to an offsite laboratory. Samples with activities between 1 mR/h and 10 mR/hr may be shipped to an offsite laboratory. Samples with dose rates in this range will be evaluated on a case-by-case basis by Sample and Data Management. Samples with activities of >10 mR/h will be sent to an onsite laboratory arranged for by Sample and Data Management.

A3.5 ANALYTICAL METHODS

The analytical parameters and methods are listed in Table A-1. These analytical methods are controlled in accordance with the laboratory's QA plan and the requirements of this QAPjP.

Errors reported by the laboratories are reported to the Sample and Data Management project coordinator, who initiates a sample disposition record in accordance with FH procedures. This process is used to document analytical errors and to establish resolution with the project task lead. In addition, the FH QA engineer receives quarterly reports that provide summaries and summary statistics of the analytical errors.

A3.6 QUALITY CONTROL

The QC procedures must be followed in the field and laboratory to ensure that reliable data are obtained. When field sampling is performed, care should be taken to prevent the cross-contamination of sampling equipment, sample bottles, and other equipment that could compromise sample integrity.

Field QC samples will be collected to evaluate the potential for cross-contamination and laboratory performance. Field QC requirements include field duplicates, field splits, equipment rinsate blanks, and trip blank samples. The QC samples and the required frequency for collection are described in this section. The QC samples will be collected as part of the verification and confirmatory sampling activities.

The collection of QC samples for onsite measurements is not applicable to the field-screening techniques described in this report. Field-screening instrumentation will be calibrated and controlled as discussed in Sections 2.2.7 and 2.2.8 in the main text of this document, as applicable.

The laboratory method blanks, laboratory control sample/blank spike, and matrix spike are defined in Chapter 1 of *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods* (SW-846) and will be run at the frequency specified in that reference.

A3.6.1 Field Duplicates

Field duplicates are independent samples collected as close as possible to the same point in space and time, taken from the same source, stored in separate containers, and analyzed independently. These samples are not to be homogenized together. This QA will be provided by collecting 5% field duplicate samples.

Sampling for operational purposes also includes QC duplicates that are collected for each sampling event (date that sampling occurs).

A3.6.2 Field Splits

A split sample is divided into two separate aliquots in the field and sent to two independent laboratories. A split sample will be used to verify the performance of the primary laboratory. This QA will be provided by splitting 5% of field sample.

Split samples will be analyzed for all of the analytes listed in Table A-1.

A3.7 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

All onsite environmental instruments will be tested, inspected, and maintained in accordance with the manufacturer's operating instructions and approved work packages. Results from testing, inspection, and maintenance activities are documented in logbooks and/or work packages.

Analytical laboratory instruments and measuring equipment are tested, inspected, and maintained in accordance with the laboratories' QA plans. Daily response checks for radiological field survey instruments are performed in accordance with approved work packages.

Measurement and testing equipment used in the field or in the laboratory that directly affects the quality of analytical data will be subject to preventive maintenance measures to ensure minimization of measurement system downtime. Laboratories and onsite measurement organizations must maintain and calibrate their equipment. Maintenance requirements (e.g., parts lists and documentation of routine maintenance) will be included in the individual laboratory and the onsite organization QA plan or operating procedures (as appropriate). Calibration of laboratory instruments will be performed in a manner consistent with EPA's SW-846 or with auditable DOE Hanford Sitewide and contractual requirements. Calibration of radiological field instruments is discussed in Section 2.2.8 in the main text of this document.

Consumables, supplies, and reagents will be reviewed in accordance with SW-846 requirements and will be appropriate for their use. Note that contamination is monitored using the QC sample process discussed in Section 2.2 in the main text of this document.

A3.8 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

All onsite environmental instruments are calibrated in accordance with the manufacturer's operating instructions, internal work requirements and processes, and/or work packages that provide direction for equipment calibration or verification of accuracy by analytical methods. The results from all instrument calibration activities are recorded in logbooks and/or work packages. The Hach® Model DR/4000 spectrophotometer will be used to process the samples collected to support pump-and-treat operations.

Analytical laboratory instruments and measuring equipment are calibrated in accordance with laboratories' QA plans. Calibration of radiological field survey instruments on the Hanford Site is performed under contract by Pacific Northwest National Laboratory (PNNL) on an annual basis, as specified in their program documentation. Calibration is performed with certified standards and/or equipment with known relationship to nationally recognized standards, where appropriate.

Hach® is a registered trademark of the Hach Company, Loveland, Colorado.

A3.9 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Supplies and consumables procured by FH that are used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes that describe the FH acquisition system and the responsibilities and interfaces necessary to ensure that structures, systems, and components, or other items and services procured/acquired for FH meet the specific technical and quality requirements. The procurement process ensures that purchased items and services comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users prior to use.

Supplies and consumables procured by the analytical laboratories are procured, checked, and used in accordance with the laboratories' QA plans.

A3.10 NONDIRECT MEASUREMENTS

Nondirect measurements include data obtained from sources such as computer databases, programs, literature files, and historical databases. Nondirect measurements will not be evaluated as part of this activity.

A3.11 DATA MANAGEMENT

Data resulting from the implementation of this QAPjP will be managed and stored in accordance with applicable programmatic requirements governing data management procedures. At the direction of the 100 Areas task lead, all analytical data packages shall be subject to final technical review by qualified personnel before the results are submitted to the regulatory agencies or prior to inclusion in reports. Electronic data access, when appropriate, shall be via a database (e.g., HEIS or a project-specific database). Where electronic data are not available, hardcopies shall be provided in accordance with Section 9.6 of the Tri-Party Agreement (Ecology et al. 2003).

Planning for sample collection and analysis shall be in accordance with the programmatic requirements governing fixed laboratory sample collection activities, as discussed in the sample teams' procedures. In the event that specific procedures do not exist for a particular work evolution, or if additional guidance to complete certain tasks is needed, a work package will be developed to adequately control the activities, as appropriate. Examples of the sample teams' requirements include the activities associated with the following:

- Chain-of-custody/sample analysis requests
- Project and sample identification for sampling services
- Control of certificates of analysis
- Logbooks, checklists
- Sample packaging and shipping.

Radiological controls are not expected within the scope of this investigation other than standard morning/afternoon checks of equipment and cuttings by the RCTs. However, if necessary, approved work control packages and procedures will be used to document radiological measurements. Examples of the types of documentation for field radiological data include the following:

- Instructions regarding the minimum requirements for documenting radiological controls information in accordance with 10 CFR 835, "Occupational Radiation Protection"
- Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval of Hanford Site radiological records
- Minimum standards and practices necessary for preparing, performing, and retaining radiological-related records
- Indoctrination of personnel on the development and implementation of survey/ sample plans
- Requirements associated with preparing and transporting regulated material.

Data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpretation of the investigation results.

Errors reported by the laboratories are reported to the Sample and Data Management project coordinator, who initiates a sample disposition record in accordance with FH procedures. This process is used to document analytical errors and to establish the resolution with the project task lead. In addition, the FH QA engineer receives quarterly reports that provide summaries and summary statistics of the analytical errors.

A4.0 ASSESSMENT AND OVERSIGHT ACTIVITIES

Assessment and oversight activities evaluate the effectiveness of project implementation and associated QA and QC activities. The purpose of assessment is to ensure that the QAPjP is implemented as prescribed.

A4.1 ASSESSMENTS AND RESPONSE ACTION

The FH Compliance and Quality Programs organization may conduct random surveillance and assessments to verify compliance with the requirements outlined in this QAPjP, project work packages, the project quality management plan, procedures, and regulatory requirements.

Deficiencies identified by these assessments shall be reported in accordance with existing programmatic requirements. The S&GRP's QA engineers coordinate the corrective actions/ deficiencies in accordance with the FH QA program. When appropriate, corrective actions will be taken by the project engineer and/or task lead.

Oversight activities in the analytical laboratories, including corrective action management, are conducted in accordance with the laboratories' QA plans.

A data quality assessment will be performed on the resulting analytical data in accordance with *Guidance for Data Quality Assessment, Practical Methods for Data Analysis*, EPA QA/G-9 (EPA/600/R-96/084). The data quality assessment will determine if the data are the right type, quality, and quantity to support the intended use. The data evaluation for this project includes the following: (1) reviewing analytical data, including data packages and QA reports; (2) drawing conclusions from the data; and (3) interpreting and communicating the test results.

A4.2 REPORTS TO MANAGEMENT

Management will be made aware of all deficiencies identified by self-assessments, surveillances, audits, or management assessments. Identified deficiencies also will be reported to the waste site remediation manager, as appropriate.

A5.0 DATA VALIDATION AND USABILITY

Data validation and usability activities occur after the data collection phase of the project is completed. Implementation of these elements determines whether or not the data conform to the specified criteria, thus satisfying the project objectives and are accepted, or they are rejected or qualified.

A5.1 DATA REVIEW, VERIFICATION, AND VALIDATION

Data review, verification, and validation are performed on analytical data sets, primarily to confirm that sampling and chain-of-custody documentation is complete, sample numbers can be tied to the specific sampling location, samples were analyzed within required holding times, and analyses met the data quality requirements specified in the field sampling plan. Following this review, the data will be accepted, rejected, or qualified.

A5.2 VERIFICATION AND VALIDATION METHODS

Completed data packages will be validated by qualified Sample and Data Management personnel or by a qualified independent contractor. Validation will consist of verifying required deliverables, comparing requested versus reported analyses, and identifying transcription errors. Validation also will include evaluating and qualifying the results, based on holding times, method blanks, laboratory control samples, laboratory duplicates, and chemical and tracer recoveries, as appropriate. No other validation or calculation checks will be performed.

Relative to analytical data, physical data and/or field screening results are of lesser importance in making inferences of risk. Because of the secondary importance of such data, no validation for physical property data and/or field screening results will be performed; however, field QA/QC will be reviewed to ensure that the data are useable. Field instrumentation, calibration, and QA checks will be performed in accordance with the following.

- Calibration of radiological field instruments on the Hanford Site is performed under contract by PNNL, as specified in their program documentation.
- Daily calibration checks will be performed and documented for each instrument used to characterize areas that are under investigation. These checks will be made on standard materials that are sufficiently like the matrix under consideration that direct comparison of data can be made. Analysis times will be sufficient to establish detection efficiency and resolution.

The approval of field-data collection plans by the Radiological Engineering manager represents the data validation and usability review for hand-held field radiological measurements.

A5.3 RECONCILIATION WITH USER REQUIREMENTS

The data quality assessment process compares completed field sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the data evaluation is to determine if quantitative data are of the correct type and are of adequate quality and quantity to meet the project DQOs. The EPA's data quality assessment process (EPA/600/R-96/084) identifies five steps for evaluating data generated from this project, as summarized below:

- Step 1 – Review DQOs and sampling design: This step requires a comprehensive review of the sampling and analytical requirements outlined in the interim action monitoring plan (DOE/RL-96-90). Note that there are no accuracy or precision requirements for field screening analyses.
- Step 2 – Conduct a preliminary data review: In this step, a comparison is made between the actual QA/QC achieved (e.g., detection limits, precision, and accuracy) and the requirements determined during the DQO process. Field chromium results will be compared to laboratory results, as appropriate, and any significant deviations will be documented. Basic statistics may be calculated from the analytical data at this point, as appropriate to the data set, including an evaluation of the distribution of the data. This process is described in steps 3 through 5 below.
- Step 3 – Select the statistical test: Using the data evaluated in step 2, an appropriate statistical hypothesis test is selected and justified.
- Step 4 – Verify the assumptions: In this step, the validity of the data analyses is assessed by determining if the data support the underlying assumptions necessary for the analyses or if the data set must be modified (e.g., transposed or augmented with additional data) before further analysis. If one or more assumptions are questioned, step 3 is repeated.
- Step 5 – Draw conclusions from the data: The statistical test is applied in this step and the results either reject the null hypothesis or fail to reject the null hypothesis. If the latter is true, the data should be analyzed further. If the null hypothesis is rejected, the overall performance of the sampling design should be evaluated by performing a statistical power calculation to assess the adequacy of the sampling design.

A6.0 FIELD SAMPLING PLAN

A6.1 SAMPLING OBJECTIVES

The primary objective of this field sampling plan is to update the sampling requirements presented in the *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action* (DOE/RL-96-84) and the interim action monitoring plan (DOE/RL-96-90) with the requirements for 100-KR-4 pump-and-treat-system expansion. The scope of the sampling will include groundwater wells and influent and effluent streams into the treatment system.

A6.2 SAMPLING LOCATIONS AND FREQUENCY

The wells associated with the 100-KR-4 pump-and-treat-system expansion are listed in Table A-3. This table also lists the sampling frequency and the analytical testing requirements. Sampling frequency may be modified during operations if trends are difficult to establish. Well use in the network may change in response to changes in plume concentrations or configuration. The data quality requirements are listed in Table A-1, and sample volumes and preservation requirements are provided in Table A-2.

Table A-3. Field Sampling Requirements for 100-KR-4 Pump-and-Treat System.

Analysis	Matrix	# of Bottles	Type	Amount	Preservation	Packing Requirements	Holding Time
Radionuclides							
Strontium-89/90	Water	1	G/P	2 x 1,000 mL	HNO_3 to pH <2	None	6 months
Tritium (H-3)	Water	1	G	500 mL	None	None	6 months
Carbon-14	Water	1	G/P	125 mL	None	None	6 months
Technetium-99	Water	1	G/P	2 x 1L	pH < 2	None	6 months
Chemicals							
Chromium hexavalent (7196)	Water	1	G/P	500 mL	None	Cool 4°C	24 hours

A6.3 PRE-SHIPMENT

A representative portion of each sample to be shipped to an offsite laboratory will be analyzed for total activity analysis at the 222-S Radiological Counting Facility (or other suitable onsite laboratory) before the sample is shipped. Total activities will be used for sample pre-shipment characterization. Samples that slightly exceed the offsite laboratory criterion discussed in Section 2.2.3 (see main text of this document) may be reduced in volume to allow for offsite shipment. Onsite and offsite laboratories will be identified before field activities are initiated and will be mutually acceptable to the Sample and Data Management organization and the waste site remediation task lead.

A7.0 SAMPLING PROCEDURES

Sampling, recording of field parameters, cleaning of sampling equipment, control of monitoring equipment, and other related task will be conducted in accordance with applicable FH procedures.

A7.1 SAMPLE MANAGEMENT

Sample management activities will be performed in accordance with appropriate FH procedures that are applicable to custody, containers, preservation, holding times, packaging, shipping, and field documentation.

A7.2 ANALYTICAL TESTING

A7.2.1 Field Analyses

Field screening analyses of hexavalent chromium and measurement of field parameters (e.g., specific conductance, temperature, dissolved oxygen, turbidity, and pH) will be conducted in accordance with applicable FH procedures.

A7.2.2 WSCF Laboratory Analyses

Analyses at the Waste Sampling and Characterization Facility (WSCF) will be conducted in accordance with the WSCF standard operating procedures. Data quality will meet the CRDLs and the accuracy and precision requirements specified in Table A-1.

A8.0 HEALTH AND SAFETY

All field operations will be performed in accordance with FH health and safety requirements and the appropriate waste disposal/S&GRP procedures. In addition, a work control package will be prepared in accordance with procedures that will further control site operations. This package will include an activity job hazard analysis, a site-specific health and safety plan, and applicable radiological work permits. Work will be performed in accordance with the site-specific health and safety plans and applicable radiological work permits.

The sampling procedures and associated activities will take into consideration exposure reduction and contamination control techniques that will minimize radiation exposure to the sampling team, as required by the procedures previously mentioned.

Health and safety personnel will use data collected during the removal action as input to determine exposure levels to workers and to conduct health and safety assessments in accordance with the health and safety plan.

A9.0 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Waste generated by sampling activities will be managed consistent with the approved 100-KR-4 waste management plan. Unused samples and associated laboratory waste for analysis will be dispositioned in accordance with the laboratory contract and agreements for return to the Hanford Site. In accordance with 40 CFR 300.440, ("National Oil and Hazardous Substances Pollution Contingency Plan; Procedures for Planning and Implementing Off-Site Response Actions"), task lead approval is required before unused samples or waste are returned from offsite laboratories.

A10.0 SCHEDULE

The following milestones are established for the expansion of the 100-KR-4 pump-and-treat system:

- May 31, 2009: The 2,271-L/min (600-gal/minute) system expansion of the 100-KR-4 pump-and-treat system becomes operational.

A system becomes operational after acceptance testing and operational testing have been completed.

A11.0 REFERENCES

10 CFR 830, Subpart A, "Quality Assurance Requirements," *Code of Federal Regulations*.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*.

40 CFR 300.440, "National Oil and Hazardous Substances Pollution Contingency Plan; Procedures for Planning and Implementing Off-Site Response Actions," *Code of Federal Regulations*.

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APPENDIX B

NUMERICAL MODELING

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Table B-2. Names, Geographic Coordinates, and Extraction and Injection Rates at the Wells Proposed for Inclusion in the 100-KR-4 Pump-and-Treat System Expansion. (2 sheets) B-12

LIST OF TERMS

CY	calendar year
MODFLOW	three-dimensional modular groundwater flow model
OU	operable unit
USGS	U.S. Geological Survey

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APPENDIX B
NUMERICAL MODEL

B1.0 INTRODUCTION

This appendix describes numerical groundwater flow modeling undertaken to support the placement of extraction and injection wells as part of the 100-KR-4 pump-and-treat system expansion.

B2.0 GROUNDWATER FLOW MODEL DESIGN

B2.1 INTRODUCTION

Groundwater flow models have been used at the 100-D, 100-H, 100-K, and 100-N Operable Units (OUs) to support the design of the pump-and-treat interim remedies, and also to evaluate the performance of the operating remedies. These groundwater flow models were constructed to simulate patterns of groundwater flow and other features local to each OU and, as such, were of limited spatial extent. Since the size and influence of the various 100 Area groundwater pump-and-treat remedies have increased over time, recent efforts have focused on the development of a single groundwater flow model that encompasses these various pump-and-treat remedies and can be used to support decisions at each of the 100-D, 100-H, 100-K, and 100-N Area OUs.

Development of a groundwater flow model encompassing the 100-D, 100-H, 100-K, and 100-N OUs commenced in April 2008. A separate report, *100 Area Model Development Report*, is currently being prepared that details all aspects of the model construction and assignment of parameter values, including the types and sources of information used to support the model development, and the model calibration. Therefore, this appendix provides details of the simulation code selected for the groundwater model, the extent and general structure of the model, and the parameterization of the model to support the application of the model in the evaluation of remedy expansion alternatives at 100-KR-4.

B2.2 SIMULATION CODE

The groundwater flow model is constructed using the U.S. Geological Survey (USGS) three-dimensional modular groundwater flow model (MODFLOW) ("A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model" [McDonald and Harbaugh 1988]; *User's Documentation for MODFLOW-96 – An Update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model* [Harbaugh and McDonald 1996]; *MODFLOW-2000 – The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process* [Harbaugh et al. 2000]; "MODFLOW-2005, the U.S. Geological Survey Modular Ground-Water Model – The Ground-Water Flow Process" [Harbaugh 2005]).

The MODFLOW code was selected since it has the necessary simulation capabilities yet is relatively simple to use and can be executed on a variety of computers and operating systems without modification. MODFLOW simulates groundwater flow using the block-centered finite-difference approach (McDonald and Harbaugh 1988). The finite difference approach simulates three-dimensional groundwater flow using a series of model layers that may represent individual

aquifers or aquitards, or that may be used to provide vertical discretization detail within thick aquifers or aquitards. Layers can be simulated as unconfined (e.g., water table aquifers), confined, or as convertible between unconfined and confined conditions.

The USGS MODPATH program (*User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S. Geological Survey Finite-Difference Ground-Water Flow Model* [Pollock 1994]), a particle-tracking post-processing program developed for MODFLOW, was used to evaluate the approximate directions and rates of groundwater flow, and the approximate extent of hydraulic capture developed by alternate pump-and-treat expansion scenarios.

B2.3 100-D, 100-H, 100-K, AND 100-N AREA MODFLOW MODEL

B2.3.1 Extents and Structure

Figure B-1 illustrates the spatial extents of the 100-D, 100-H, 100-K, and 100-N Area MODFLOW model, as well as the location of the 100-D, 100-H, 100-K, and 100-N OUs. The model finite difference grid is rotated 50 degrees from east, so the northwest and northeast boundaries of the flow model are parallel and adjacent to the Columbia River. The model extends southward toward Gable Butte. The model grid spacing is relatively coarse throughout much of the model, but it is refined in the area of the 100-KR-4 OU. Further refinements are planned in the area of the 100-D, 100-H, and 100-N OUs in support of remedy evaluations.

At the present time, groundwater flow is simulated using one layer. The base of the model is assumed to be the top of the Ringold Upper Mud Unit where present, and the top of the basalt where the Ringold Upper Mud is absent; this typically occurs in the southern portions of the model approaching Gable Butte. A single model layer was used because the majority of the extraction wells installed in the 100-KR-4 penetrate most of the saturated thickness of the aquifer materials lying above the Ringold Upper Mud in the 100-KR-4 OU. Throughout much of the area to the west of the modeled area (including 100-KR-4), the water table lies within the Ringold Unit E sands, whereas toward the east and north of the modeled area, the water table lies within the Hanford formation sands and gravels. The appropriateness of using a single layer is discussed further in the report being prepared that details the model development, and this will be re-evaluated as the model is used to support remedy design and evaluation

B2.3.2 Boundary Conditions and MODFLOW Packages

Using the finite-difference discretization, a MODFLOW model domain comprises active cells where the flow of groundwater is simulated and inactive cells where the flow of groundwater is not simulated. Figure B-2 illustrates the distribution of active and inactive cells in the 100-D, 100-H, 100-K, and 100-N Area MODFLOW model. In general, the inactive cells are located (1) beyond the shores of the Columbia River that form the lateral extents of the model to the northwest and northeast, and (2) in the area of Gable Butte to the south.

Figure B-1. Spatial Extents of the 100-D, 100-H, 100-K, and 100-N Area MODFLOW Model, and Location of the 100-D, 100-H, 100-K, and 100-N Operable Units.

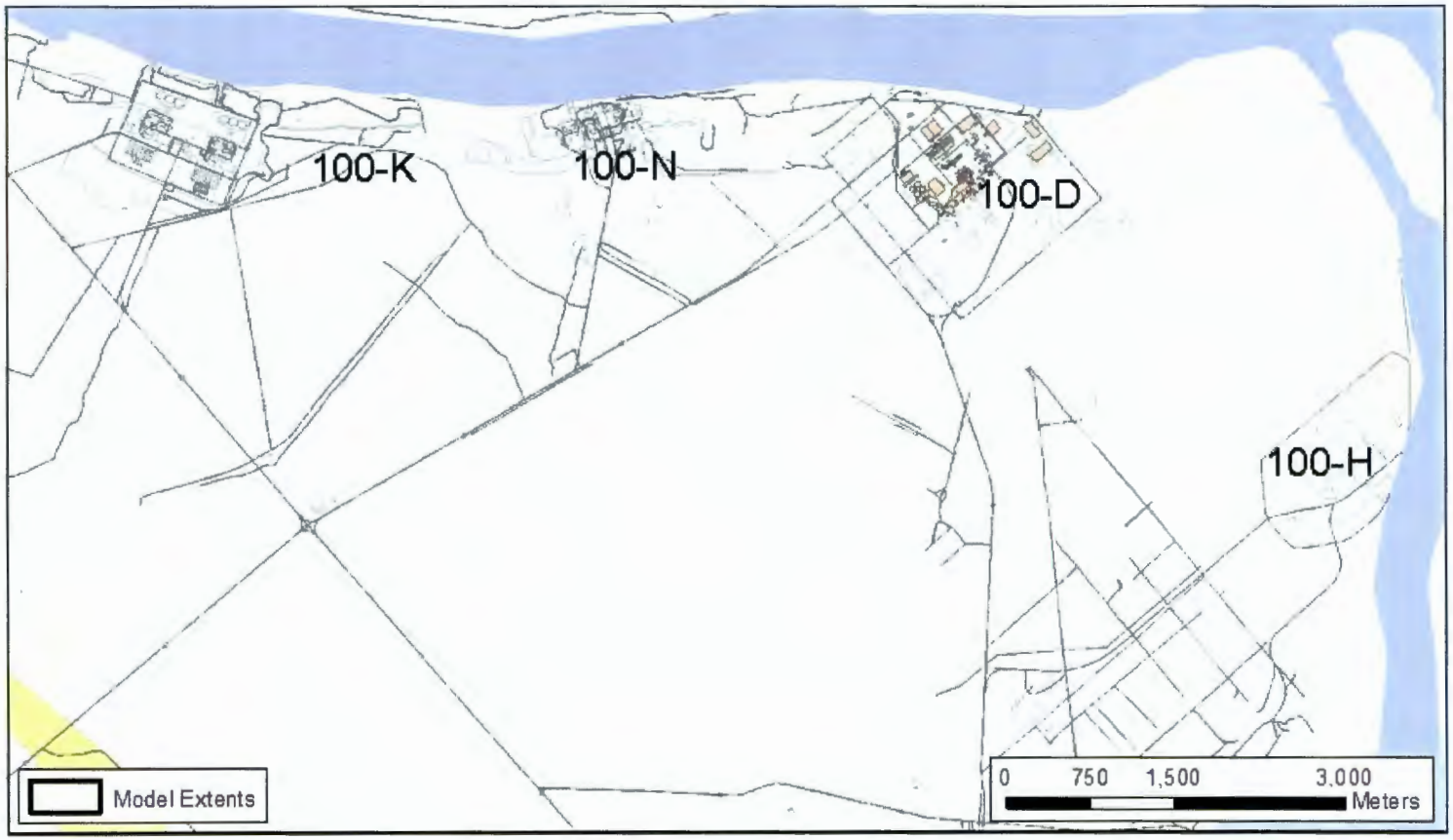

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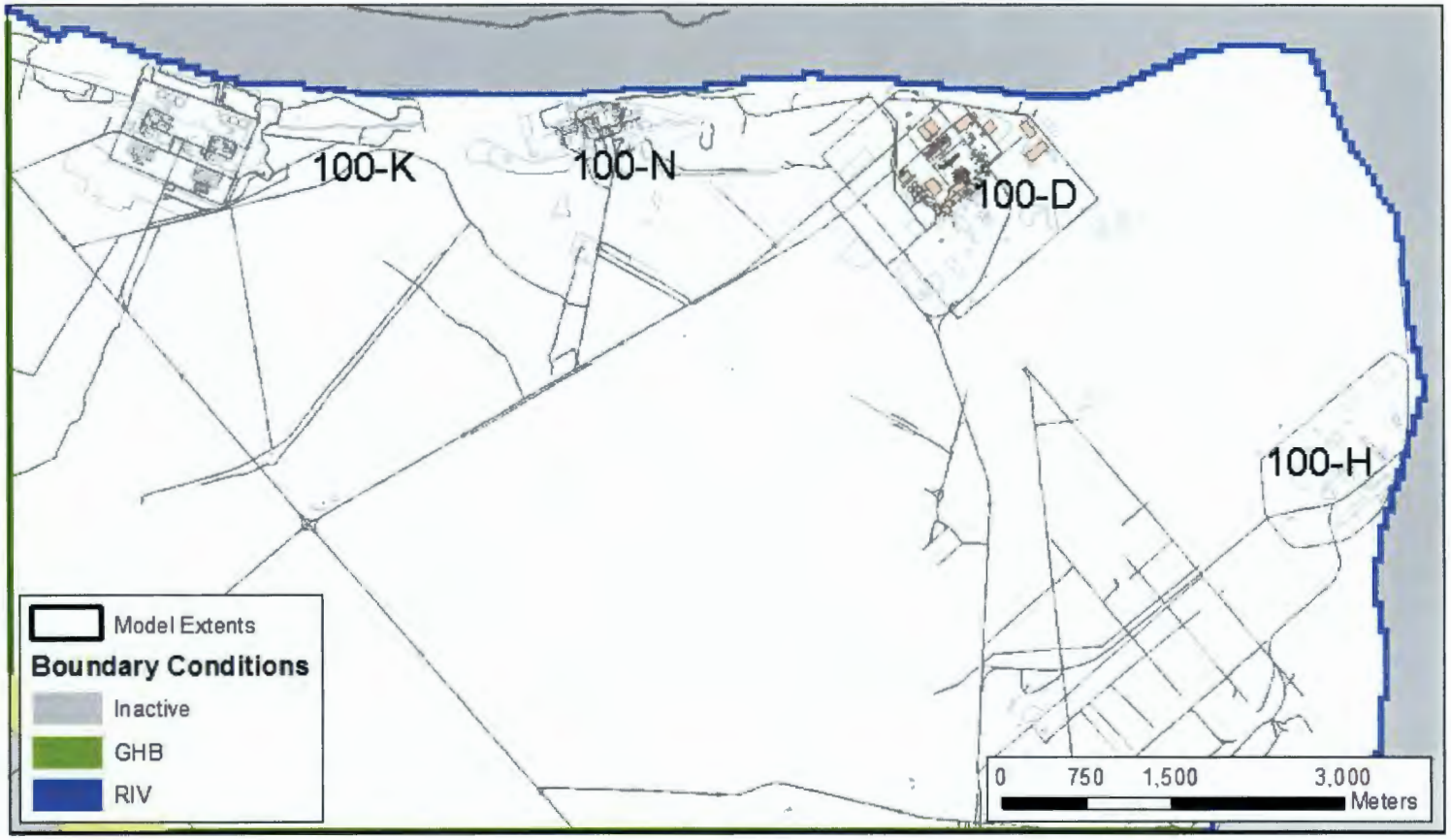
Figure B-2. Distribution of Active and Inactive Cells and Lateral Boundaries Specified for the 100-D, 100-H, 100-K, and 100-N Area MODFLOW Model.



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The MODFLOW simulation code comprises a main program that provides the basic requirements for the simulation of groundwater flow and a series of essentially independent packages that provide the capability to simulate specific features of the groundwater system. The 100-D, 100-H, 100-K, and 100-N Area MODFLOW model uses packages that simulate the flow of water to and from wells (well package: WEL); the flow of water to and from surface water bodies (river package: RIV); aerial recharge (recharge package: RCH); and a package that enables the simulation of flow into and out of the model domain on the basis of information about the aquifer transmissivity and hydraulic gradients (general head boundary package: GHB).

Figure B-2 illustrates the lateral boundaries specified for the 100-D, 100-H, 100-K, and 100-N Area MODFLOW model. Along the northwest and northeast boundaries of the model, the river package is used to represent the flow of water to and from the Columbia River. The river stage specified for the river package was calculated using the low river stage recorded at the 100-B, 100-D, 100-N, 100-H, and 100-F river gauges during calendar year 2007 (CY07). Along the southwest and southeast boundaries of the model, the general head boundary package is used to represent the flow of groundwater into and out of the model domain through the aquifer. The head specified for the general head boundary package was calculated on the basis of a map of Sitewide groundwater elevations provided by Pacific Northwest National Laboratory.

B2.3.3 Parameter Values

Since the MODFLOW model, at present, simulates steady-state groundwater flow within a single layer, the principal aquifer property that is specified in the model is the spatially varying hydraulic conductivity of the saturated aquifer materials, although the transmissivity that is calculated when this hydraulic conductivity is multiplied by the saturated thickness (calculated using the model) should correspond with independent sources of information. The hydraulic conductivity distributions in the model were developed from hydraulic property testing described in several reports, including the following:

- *Limited Field Investigation Report for the 100-HR-3 Operable Unit* (DOE/RL-93-43)
- *Limited Field Investigation Report for the 100-KR-4 Operable Unit* (DOE/RL-93-79)
- *Pilot-Scale Treatability Test Summary for the 100-HR-3 Operable Unit* (DOE/RL-95-83)
- *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report* (PNL-10886)
- *Estimating Aquifer Hydraulic Properties Using the Ferris Method, Hanford Site, Washington* (DOE/RL-92-64)
- *Interim Characterization Report for the Area Surrounding the 183-H Basins* (PNL-6471)
- *Geohydrologic Characterization of Area Surrounding 183*-PNL-6728).

The model is currently being updated to reflect the analyses of data collected during the recent Horn area investigation, as well as aquifer properties based on data collected by the hydraulic monitoring networks and pump-and-treat operations at each of the 100-D, 100-H, 100-K, and 100-N OUs.

In addition to hydraulic conductivity, a value for aerial recharge from precipitation must be specified. The value specified in the 100-D, 100-H, 100-K, and 100-N Area MODFLOW model is 10 mm/year, which is assumed to be constant throughout the model domain.

B3.0 100-KR-4 GROUNDWATER FLOW MODELING

B3.1 INTRODUCTION

The 100-D, 100-H, 100-K, and 100-N Area MODFLOW model was developed using a relatively coarse grid spacing of about 50 m (160 ft) throughout the model domain. The grid was refined to a spacing of about 12 m (40 ft) in the vicinity of the 100-KR-4 pump-and-treat system to provide finer resolution of the groundwater heads calculated by the model for use in particle tracking analyses. Figure B-3 illustrates the area of local grid refinement in the vicinity of 100-KR-4 and depicts the extents for later figures that present the results of the modeling analyses.

B3.2 CURRENT CONDITIONS

Figure B-4 illustrates the approximate distribution of dissolved hexavalent chromium in the vicinity of 100-KR-4 that is the target of the pump-and-treat remedy. Figure B-5 illustrates the existing extraction and injection well locations for the 100-KR-4 pump-and-treat system, as well as average extraction and injection rates during CY07. Figure B-6 illustrates groundwater elevations calculated using the 100-D, 100-H, 100-K, and 100-N Area MODFLOW model using these extraction and injection rates. Figure B-7 illustrates the approximate rates and directions of groundwater flow calculated by particle tracking using the calculated groundwater elevations presented as Figure B-6. Also shown is the approximate extent of dissolved hexavalent chromium.

Comparison of the distribution of hexavalent chromium together with the particle tracking results indicates that in some areas, the hexavalent chromium does not appear to be captured by the current remedy. This is most evident (1) at the northeast margins of 100-KR-4, between 100-KR-4 and the 100-N Area; and (2) at the southwest margins of 100-KR-4, in the vicinity of 100-K West.

B3.3 PROPOSED EXPANSION SCENARIO

The proposed remedy expansion focuses on improving the extent of hydraulic capture at the northeast margins of 100-KR-4 between 100-KR-4 and 100-N, and at the southwest margins of 100-KR-4 in the vicinity of 100-K West. Remedy expansion simulations were undertaken by an iterative process where extraction and/or injection wells were located in strategic areas, the model was executed, and the outputs of the model simulation processed to provide calculated groundwater elevations, pathways, and capture zones.

Table B-1 lists the names, geographic coordinates, and extraction and injection rates at the current wells in the 100-KR-4 pump-and-treat system, and Table B-2 lists this information for the wells proposed for inclusion in the 100-KR-4 pump-and-treat system expansion at the completion of the modeling analyses. Figure B-8 illustrates the locations of these extraction and injection well locations, as well as the proposed extraction and injection rates.

Figure B-3. Area of Local Grid Refinement in the Vicinity of the 100-KR-4 Operable Unit.

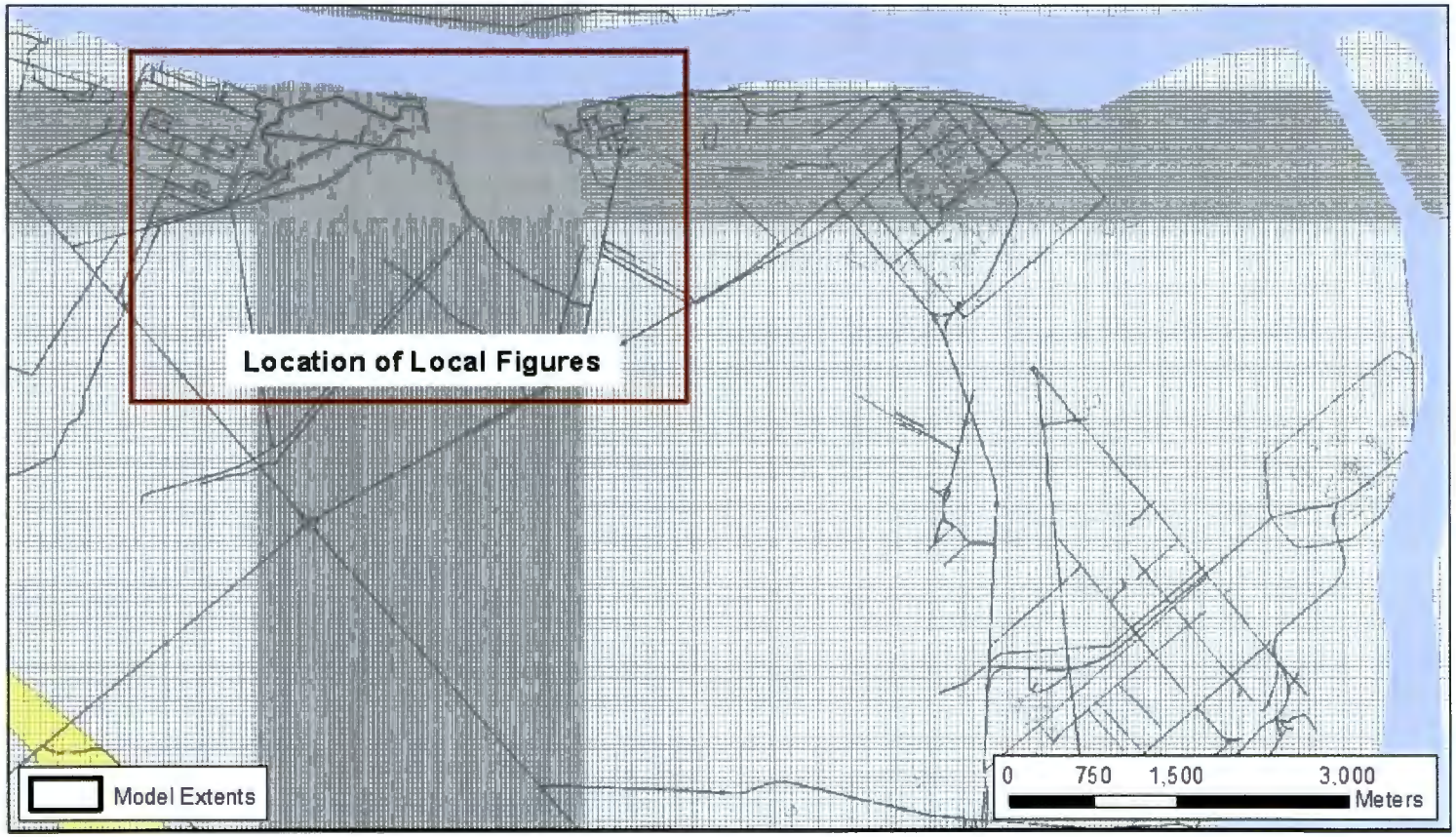

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Figure B-4. Approximate Distribution of Dissolved Hexavalent Chromium in Vicinity of 100-KR-4 Pump-and-Treat System.

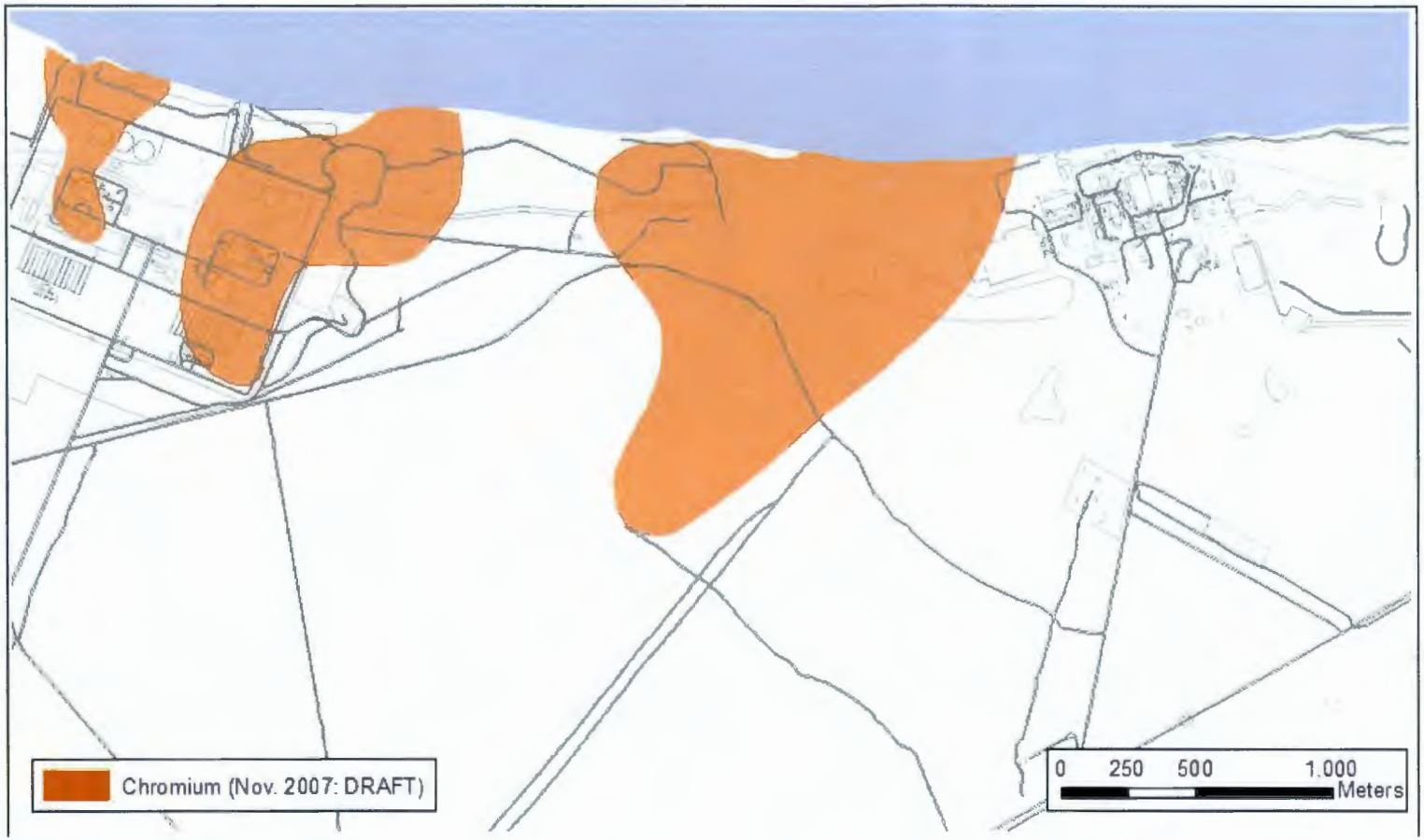

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Figure B-5. Existing Extraction and Injection Well Locations for 100-KR-4 Pump-and-Treat System, and Average Extraction and Injection Rates During Calendar Year 2007.

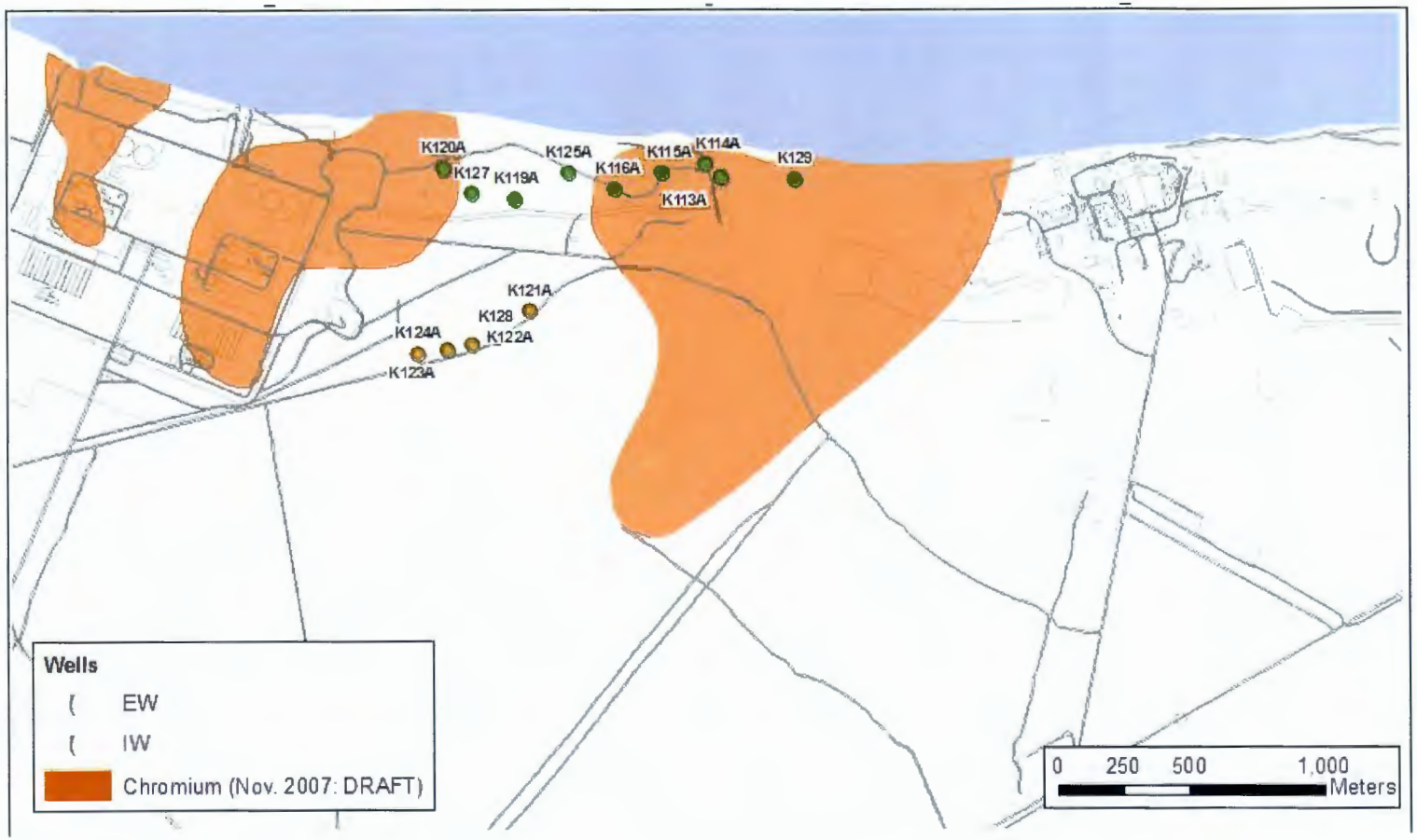

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Figure B-6. Groundwater Elevations Calculated Using Average Extraction and Injection Rates During Calendar Year 2007.

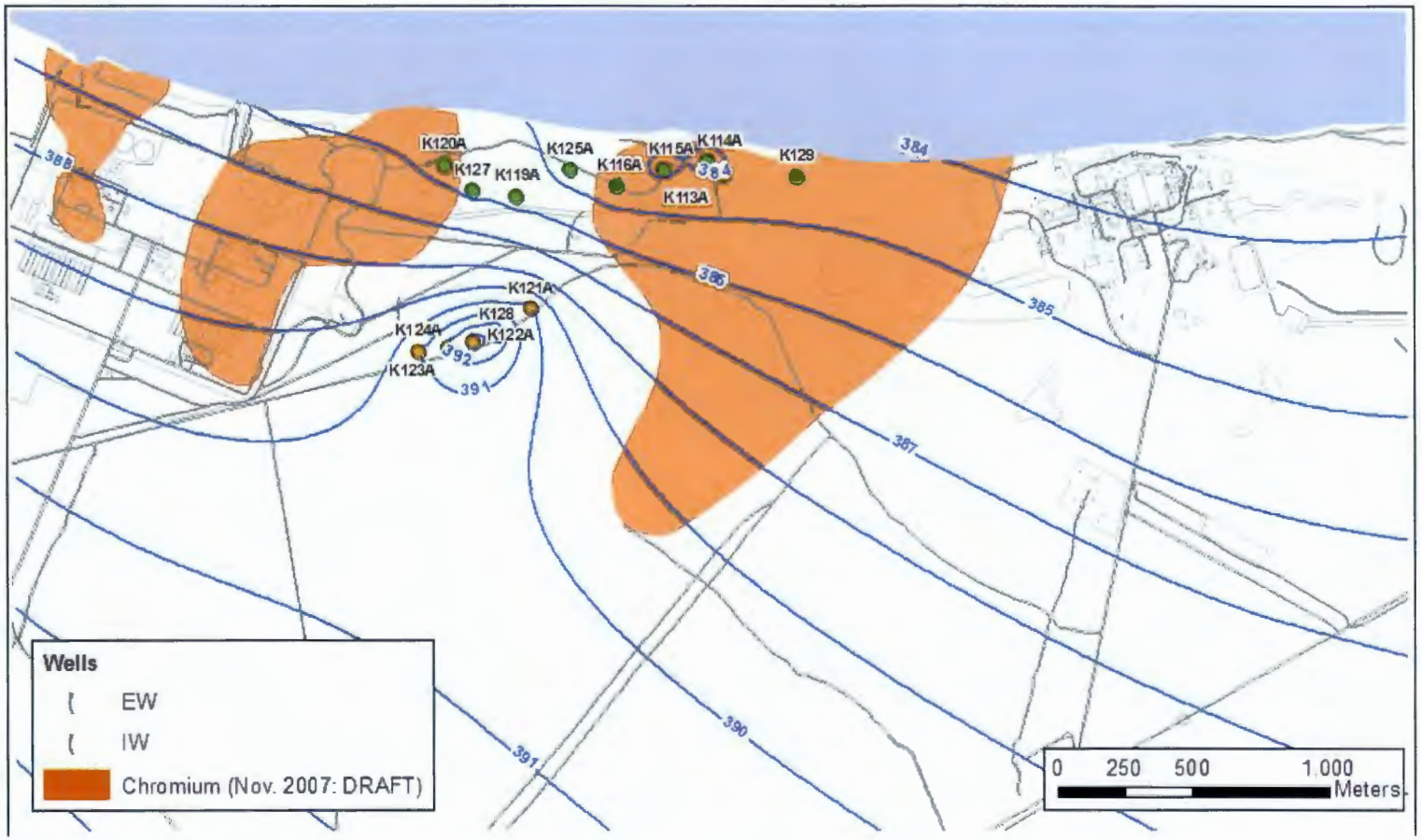

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Figure B-7. Approximate Rates and Directions of Groundwater Flow Calculated Using Average Extraction and Injection Rates During Calendar Year 2007.

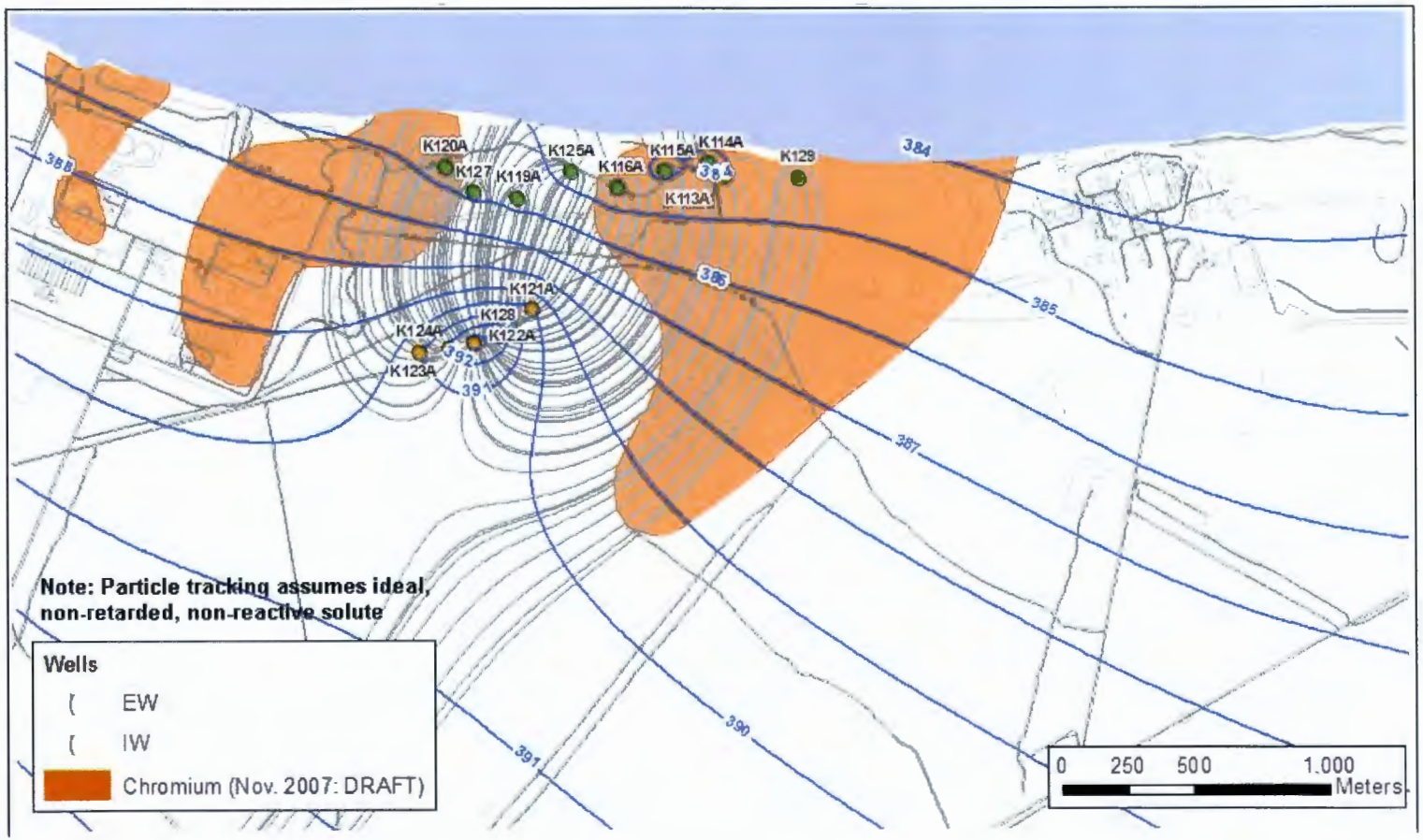

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Table B-1. Names, Geographic Coordinates, and Extraction and Injection Rates at the Currently 100-KR-4 Pump-and-Treat System Wells.

Well Name	Type	Rate (gpm) *Extraction -ve Injection +ve*	Easting	Northing
K113A	EW	-13	570098	148294
K114A	EW	-28	570020	148281
K115A	EW	-39	569940	148135
K116A	EW	-46	569871	147960
K119A	EW	-21	569662	147650
K120A	EW	-47	569400	147518
K125A	EW	-43	569713	147866
K127	EW	-31	569539	147539
K129	EW	-13	570284	148503
K121A	IW	39	570017	147418
K122A	IW	84	569975	147173
K123A	IW	40	569931	147090
K124A	IW	19	569868	146992
K128	IW	80	570010	147258

Table B-2. Names, Geographic Coordinates, and Extraction and Injection Rates at the Wells Proposed for Inclusion in the 100-KR-4 Pump-and-Treat System Expansion. (2 sheets)

Well Name	Type	Rate (gpm) *Extraction -ve Injection +ve*	Easting	Northing
K130	EW	-60	570462	148657
K131	EW	-60	570645	148899
K146	EW	-10	570180	148375
K147	EW	-20	570394	148553
K148	EW	-50	570567	148763
K149	EW	-50	570761	148966
K150	EW	-40	570771	149049
K161	EW	-30	569987	148198
K144	EW	-75	569146	147261

Table B-2. Names, Geographic Coordinates, and Extraction and Injection Rates at the Wells Proposed for Inclusion in the 100-KR-4 Pump-and-Treat System Expansion. (2 sheets)

Well Name	Type	Rate (gpm) *Extraction -ve Injection +ve*	Easting	Northing
K145	EW	-75	569251	147420
K162	EW	-75	569323	147456
K159	IW	75	570894	149155
K160	IW	75	570902	149112
K164	IW	45	571183	148897
K143	IW	65	570917	148084
K156	IW	65	569657	147266
K171	IW	45	570544	147187
K172	IW	55	570861	147175
K169	IW	60	570005	147562
K170	IW	60	570019	147490
K113A	EW	-15	570098	148294
K114A	EW	-30	570020	148281
K115A	EW	-40	569940	148135
K116A	EW	-45	569871	147960
K119A	EW	-20	569662	147650
K120A	EW	-45	569400	147518
K121A	IW	45	570017	147418
K122A	IW	85	569975	147173
K123A	IW	45	569931	147090
K124A	IW	25	569868	146992
K125A	EW	-45	569713	147866
K127	EW	-30	569539	147539
K128	IW	85	570010	147258
K129	EW	-15	570284	148503

Figure B-8. Proposed Extraction and Injection Well Locations for the 100-KR-4 Pump-and-Treat Expansion.

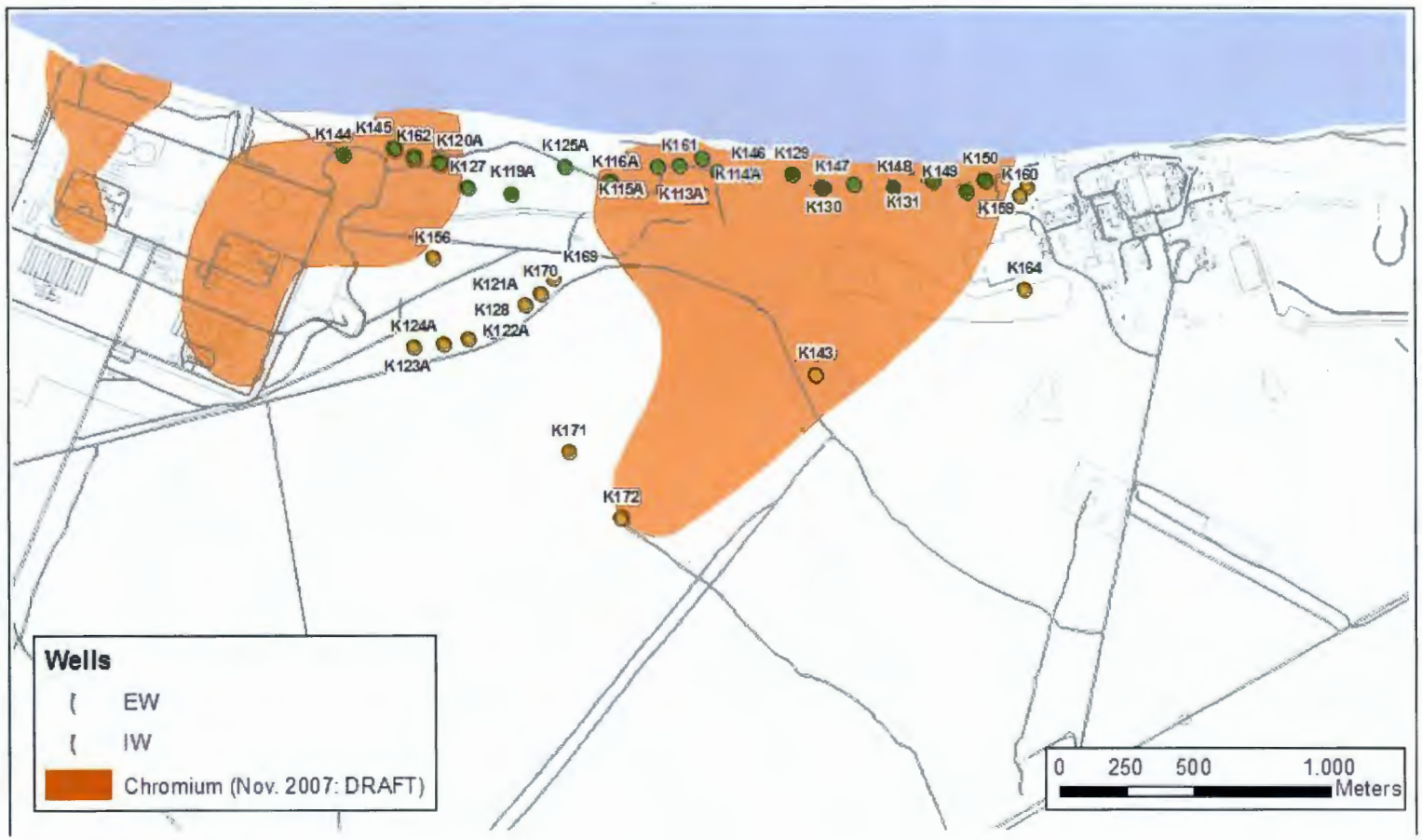

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Figure B-9 illustrates groundwater elevations calculated using the 100-D, 100-H, 100-K, and 100-N Area MODFLOW model using the proposed extraction and injection well locations and rates. Figure B-10 illustrates the pattern of drawdown, calculated by subtracting the groundwater elevations presented in Figure B-8 from those that are calculated using the 100-D, 100-H, 100-K, and 100-N Area MODFLOW model assuming a non-pumping condition (i.e., assuming that there is no pump-and-treat remedy).

Figure B-11 illustrates the approximate rates and directions of groundwater flow calculated by particle tracking using the calculated groundwater elevations presented as Figure B-9. Also shown is the approximate extent of dissolved hexavalent chromium. Figure B-11 illustrates the approximate extent of hydraulic capture developed by the expanded 100-KR-4 pump-and-treat remedy calculated using the proposed extraction and injection well locations and rates. Figure B-11 shows that the expanded pump-and-treat system would provide greatly improved hydraulic capture in the two targeted areas.

Figure B-12 illustrates the approximate effect that the proposed 100-KR-4 remedy expansion may have on rates and directions of groundwater flow in the vicinity of the 100-N Area strontium-90 contamination. Note that strontium-90 has an estimated retardation rate that ranges from approximately 10 to 100, indicating that the illustrated changes in rates and directions of migration of groundwater flow are about 10 to 100 times greater than the changes in the rates and directions of migration of strontium-90 dissolved in the groundwater. Figure B-12 illustrates two sets of particle paths, prepared using the following process:

1. Define particle initial locations (starting points) along the margins of the strontium-90 contamination (fiscal year 2007 annual average).
2. Track the particles forward assuming the following:
    a. Groundwater flow conditions simulated assuming current remedy extraction and injection rates.
    b. Groundwater flow conditions simulated assuming the proposed remedy expansion extraction and injection rates.

Figure B-12 suggests that groundwater along the margins of the strontium-90 contamination would migrate approximately 270 m (886 ft) over a period of 5 years under current remedy operations, and would migrate approximately 400 m (1,312 ft) over a period of 5 years under proposed remedy conditions. Assuming retardation rates of 10 and 100 for strontium-90, respectively, this suggests a difference in the migration of strontium-90 over a 5-year period under current and proposed remedial conditions of approximately 13 m and 1.3 m (43 ft and 4 ft), respectively.

Figure B-9. Groundwater Elevations Calculated Using the Proposed Extraction and Injection Well Locations and Rates.

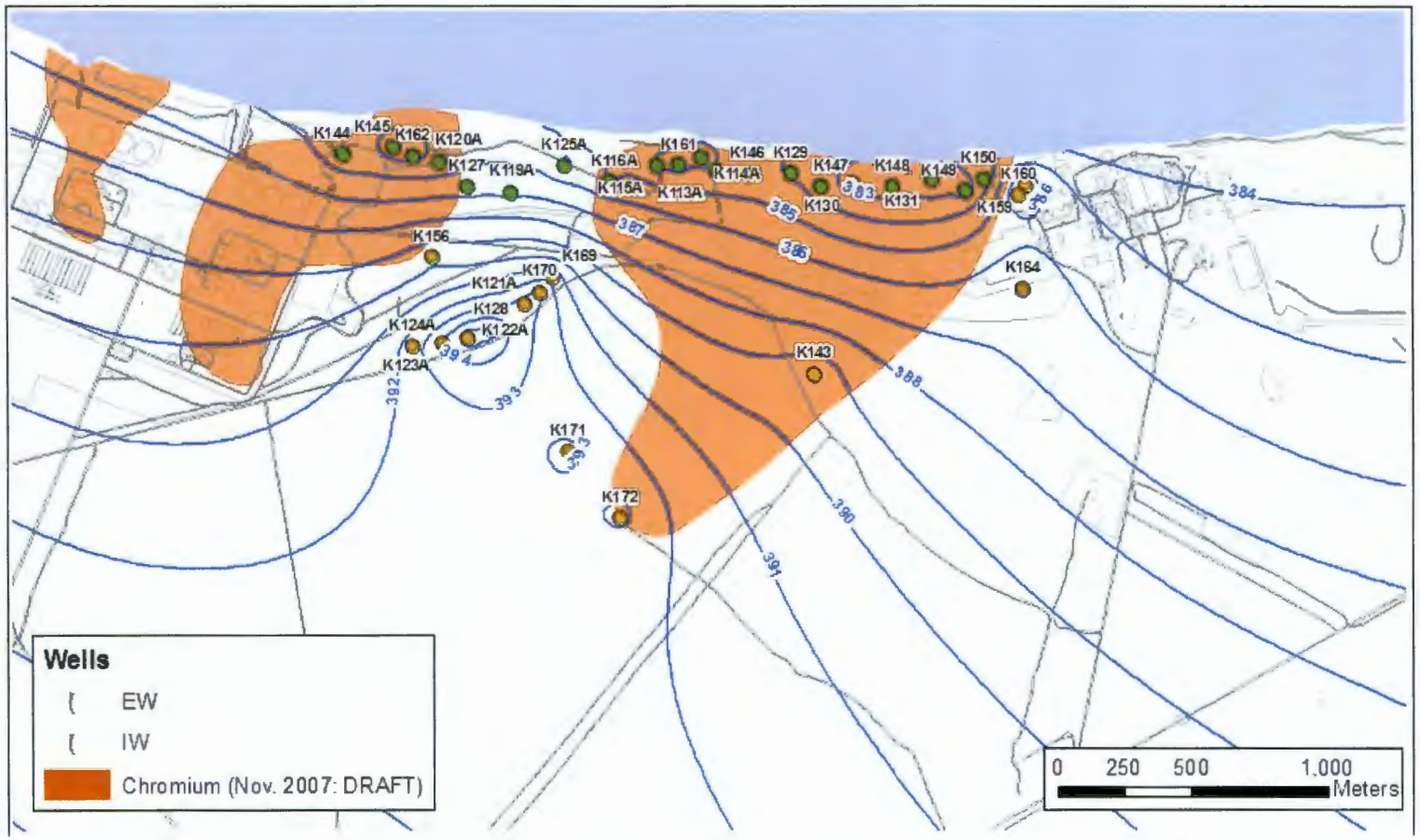

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Figure B-10. Pattern of Drawdown Calculated Assuming the Extraction and Injection Well Locations and Rates.

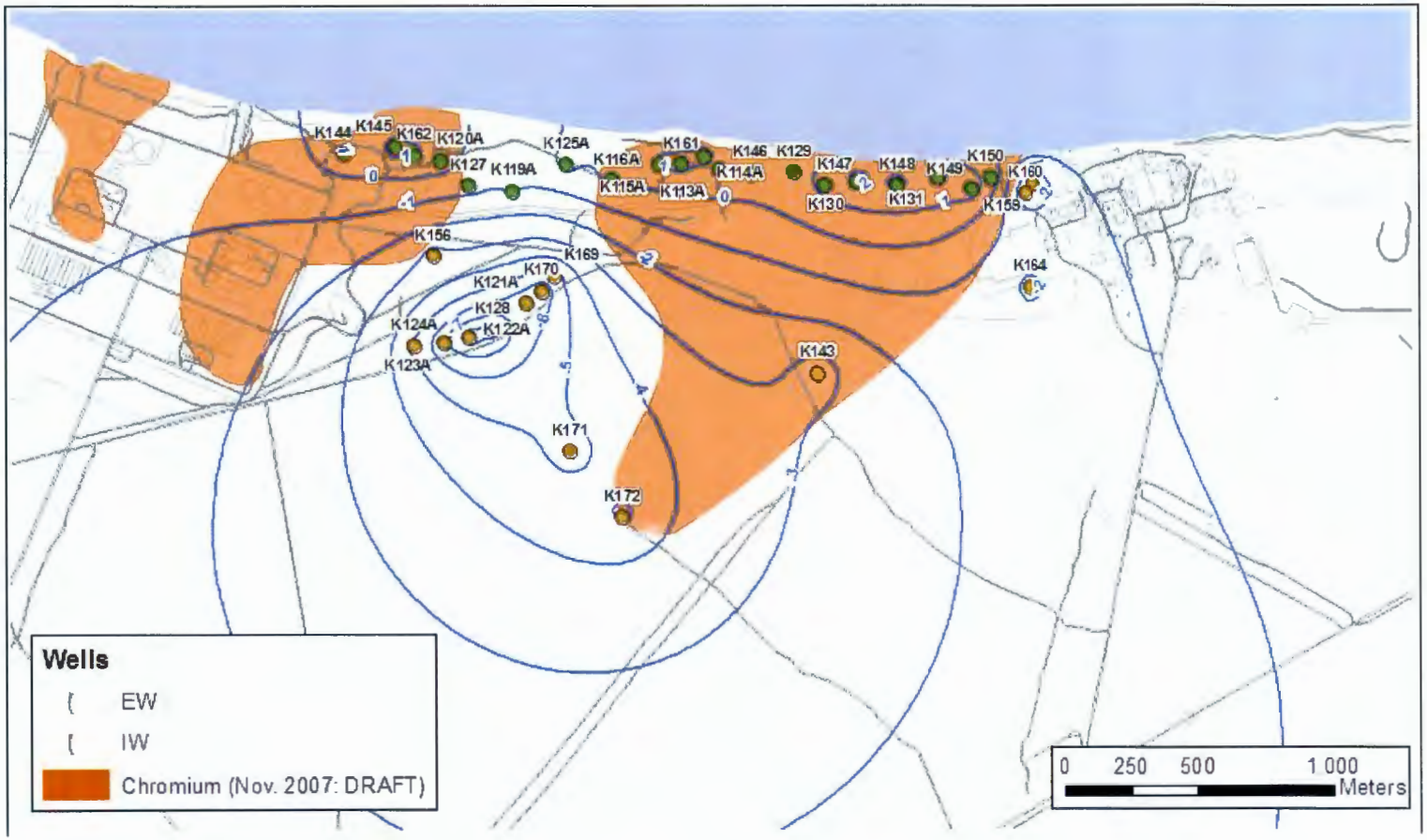

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Figure B-11. Approximate Rates and Directions of Groundwater Flow Calculated Using the Proposed Extraction and Injection Well Locations and Rates.

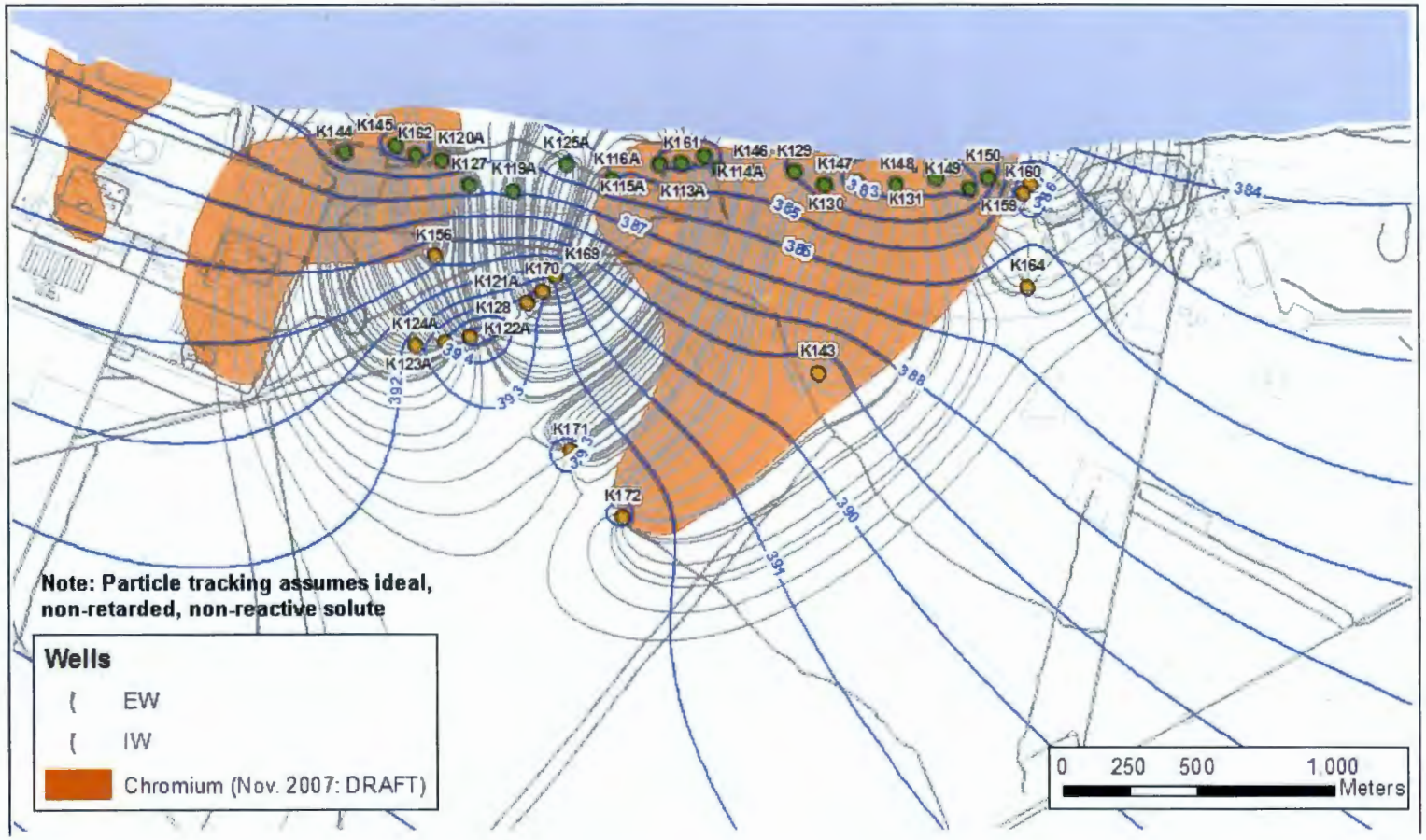

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Figure B-12. Approximate Effect of Proposed 100-KR-4 Remedy Expansion on Rates and Directions of Groundwater Flow in Vicinity of 100-N Area Strontium-90 Contamination.

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B4.0 LIMITATIONS OF MODELING ANALYSES

Principal limitations of the modeling analyses are as follows:

1. The model simulates two-dimensional groundwater flow. This assumes that the effects of three-dimensional flow (e.g., that occurring near partially penetrating wells) are negligible. This assumption is considered reasonable in the 100-KR-4 OU since most extraction wells penetrate almost the full saturated thickness of aquifer.
2. The model simulates quasi-steady-state groundwater flow assuming a low river stage in the Columbia River. This assumption is considered to be conservative because it produces higher-than-average hydraulic gradients across the 100-KR-4 OU, leading to higher-than-average groundwater flows.
3. The model is currently being revised to reflect information collected as part of the recent Horn area investigation study, and as part of a shutdown test conducted at the 100-KR-4 OU. This will be documented in the *100 Area Model Development Report*, which is currently being prepared.

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APPENDIX C

WELL SUMMARY SHEETS

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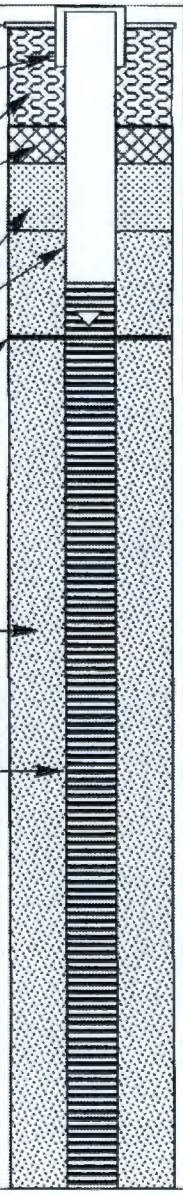
WELL SUMMARY SHEET	Start Date: 02/14/08 Finish Date: 03/13/08	Page 1 of 2

Well ID: C5360		Well Name: 199-K-144	
Location: 200m west of P&T office		Project: KR-4 Expansion Wells	
Prepared By: Brett Mayhew	Date: 3/24/08	Reviewed By: L. D. Walker	Date: 4/25/08
Signature: Brett Mayhew		Signature: L D Walker	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad 8-in I.D. Type 304/304L Stainless Steel Protective Casing: +3.0 ft ags Portland Cement Type I/II: 0 - 7.4 ft 1/4-in Bentonite Pellets: 7.4 - 10.4 ft Secondary Filter Pack 20-40 Mesh Layne Mt Sand: 10.4 - 15.2 ft 6-in I.D., Sch ~~40~~ 10, Type 314L Stainless Steel Casing: +2.0 - 19.3 ft Static Water Level: 23.7 ft bgs (2/11/2008) Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 15.2 - 107.1 ft 6-in I.D. Type 314L Stainless Steel, 20 Slot (0.020-in) Screen: 19.3 - 94.3 ft	

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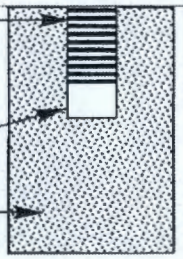
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-2 Gravel Fill
		2-11 Gravelly Silty Sand; gmS
10		11-29 Sandy Gravel; sG
20		
		29-33 Gravel; G
30		
		33-37 Sandy Gravel; sG
		37-48 Gravel; G
40		
50		48-60 Sandy Gravel; sG
60		
		60-95 Gravely Sand; gS
70		
80		

WELL SUMMARY SHEET		Start Date: 02/14/08 Finish Date: 03/13/08	Page 2 of 2
Well ID: C5360		Well Name: 199-K-144	
Location: 200m west of P&T office		Project: KR-4 Expansion Wells	
Prepared By: Brett Mayhew	Date:3/24/08	Reviewed By: L.D. Walker	Date: 4/25/08
Signature: Brett Mayhew		Signature: L.D. Walker	

CONSTRUCTION DATA

Description	Diagram
6-in I.D. 314L Stainless Steel, 20 Slot (0.020-in) Screen: 19.3 - 94.3 ft 6-in, I.D. 314L Stainless Steel End Cap: 94.3 - 97.3 ft Primary Filter pack 10-20 Mesh Colorado Silica Sand: 15.2 - 107.1 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		
		95-97 Gravelly Silty Sand; mgS
		97-107.1 Mud; M
100		
		107.1 Total Depth Drilled (2/22/2008)
110		
120		
130		
140		
150		
160		
170		

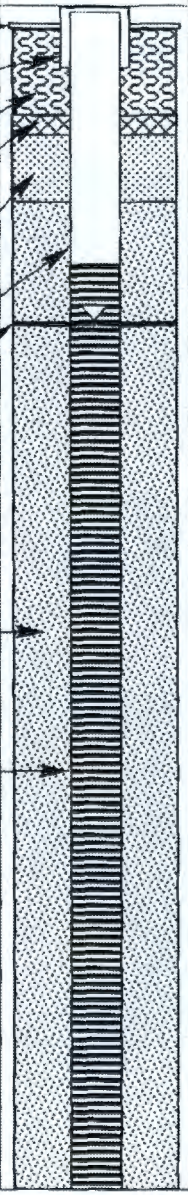
All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

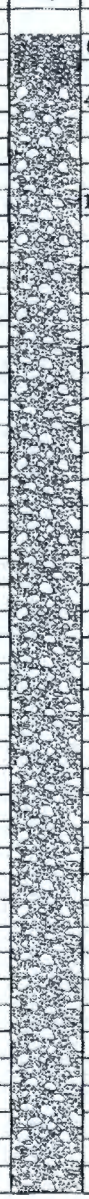
All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 03/17/08 Finish Date: 04/11/08	Page 1 of 2
Well ID: C5361	Well Name: 199-K-145	
Location: N of 1607 KA building	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage — Date: 04/16/08	Reviewed By: L.D. Walker — Date: 4/25/08	
Signature: Patrick Cabbage	Signature: L.D. Walker	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad 8-in I.D. Type 304/304L Stainless Steel Protective Casing: +2.9 ft ags Portland Cement Type I/II: 0 - 6.5 ft 1/4-in Bentonite Pellets: 6.5 - 8.1 ft Secondary Filter Pack 20-40 Mesh Layne Mt Sand: 8.1 - 13.2 ft 6-in I.D., Sch. ~~40~~ 10 LW 4-30-08, Type 314L Stainless Steel Casing: +1.9 - 18.0 ft Static Water Level: 22.54 ft bgs (03/25/2008) Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 13.2 - 123.7 ft 6-in I.D. Type 314L Stainless Steel, 20 Slot (0.020-in) Screen: 18.0 - 118.0 ft	

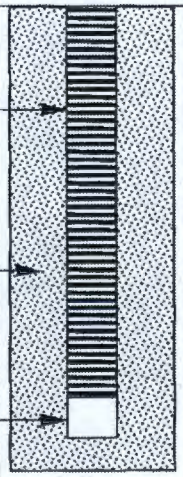
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-4 Gravel Fill
		4-12 Silty Sandy Gravel; msG
10		
		12-115 Sandy Gravel; sG
20		
30		
40		
50		
60		
70		
80		

WELL SUMMARY SHEET		Start Date: 03/17/08 Finish Date: 04/11/08	Page 2 of 2
Well ID: C5361		Well Name: 199-K-145	
Location: N of 1607 KA building		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date:04/16/08	Reviewed By: L. D. Walker	Date: 4/25/08
Signature: Patrick Cabbage		Signature: L D Walker	

CONSTRUCTION DATA

Description	Diagram
6-in I.D. 314L Stainless Steel, 20 Slot (0.020-in) Screen: 18.0 - 118.0 ft	
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 13.2 - 123.7 ft	
6-in, I.D. 314L Stainless Steel End Cap: 118.0 - 121.0 ft	
All depths are in feet below ground surface.	
Borehole drilled with 7 3/4 x 10 3/4 -inch casing.	
All temporary drill casing was removed from the ground.	



GEOLOGIC/HYDROLOGIC DATA

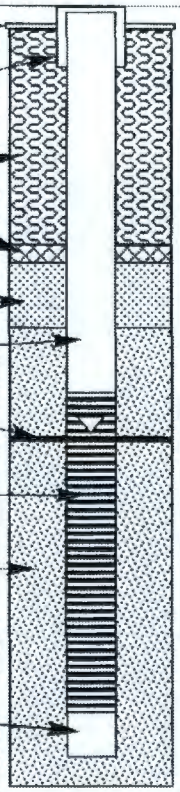
Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		12-115 Sandy Gravel; sG
100		
110		
		115-118 Silty Sandy Gravel; msG
120		118-123.7 Mud; M Clay LW 4-30-08
		123.7 Total Depth Drilled (03/19/2008)
130		
140		
150		
160		
170		

WELL SUMMARY SHEET	Start Date: 12/10/07 Finish Date: 12/17/07	Page 1 of 1

Well ID: C5362	Well Name: 199-K-146
Location: 100m NE of 1606k Building	Project: KR-4 Expansion Wells
Prepared By: Patrick Cabbage Date: 01/18/08	Reviewed By: L. D. Walker Date: 1/21/08
Signature: Patrick Cabbage	Signature: LD Walker

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +2.5 ft ags	
Portland Cement Type I/II: 0 - 16.6 ft	
1/4-in Bentonite Pellets: 16.6 - 18 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 18 - 23 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +1.1 - 28 ft	
Static Water Level: 31.6 ft bgs (12/17/2007)	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 28 - 53 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 23 - 57.9 ft	
6-in, I.D. 316L Stainless Steel End Cap: 53 - 56 ft	



All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 - inch casing.

All temporary drill casing was removed from the ground.

GEOLOGIC/HYDROLOGIC DATA

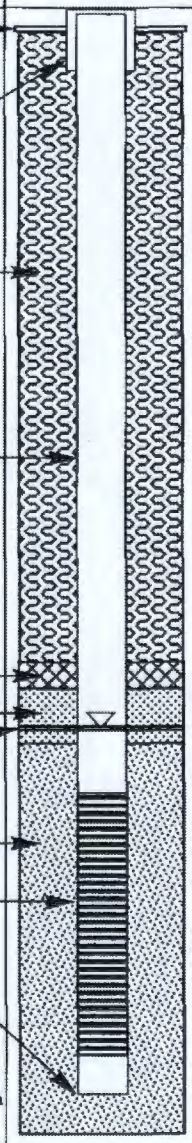
Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-2 Gravel Fill
		2-49 Sandy Gravel; sG
10		8 - 14 Sandy Gravel; sG
		14 - 18 Gravel; G
		17 - 18 Sandy Gravel; sG
20		18 - 27 Gravel; G
30		27 - 53 Sandy Gravel; sG
40		
50		
		53-57.9 Mud; M
60		Total Depth Drilled: 57.9 ft bgs
70		
80		

WELL SUMMARY SHEET	Start Date: 11/08/07 Finish Date: 11/13/07	Page 1 of 1
Well ID: C5363	Well Name: 199-K-147	
Location: 100m NW of building 1606KA	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/26/07
Signature: Patrick Cabbage	Signature: L. D. Walker	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.0 ft ags	
Portland Cement Type I/II: 0 - 48.3 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +2.0 - 58.0 ft	
1/4-in Bentonite Pellets: 48.3 - 50.2 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 50.2 - 54.5 ft	
Static Water Level: 53.17 ft bgs (11/13/2007)	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 54.5 - 84.1 ft	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 58.0 - 78.0 ft	
6-in, I.D. 316L Stainless Steel End Cap: 78.0 - 81.0 ft	

All depths are in feet below ground surface.
Borehole drilled with 7 3/4 x 10 3/4 -inch casing.
All temporary drill casing was removed from the ground.



GEOLOGIC/HYDROLOGIC DATA

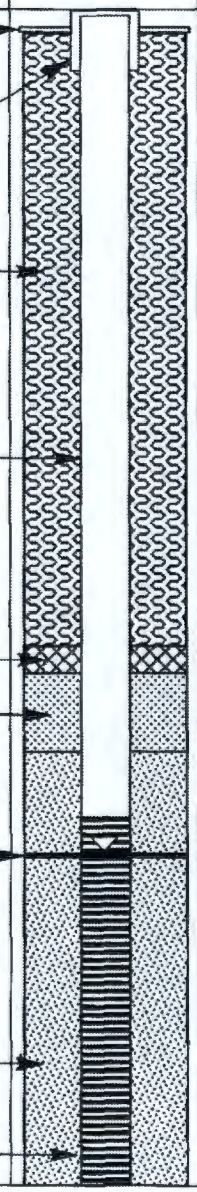
Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-1 Gravel Fill
		1-4 Gravel; G
		4-8 Gravelly Sand; gS
		8-24 Sandy Gravel; sG
10		
20		
		24-27 Silty Sandy Gravel; msG
		27-39 Sandy Gravel; sG
30		
40		39-42 Sand; S
		42-63 Sandy Gravel; sG
50		
60		
		63-67 Silty Sandy Gravel; msG
		67-77 Sandy Gravel; sG
70		
		77-79 Silty Gravel; mG
80		79-84.1 Mud; M
		84.1 Total Depth Drilled (10-30-2007)

WELL SUMMARY SHEET	Start Date: 10/22/07 Finish Date: 10/30/07	Page 1 of 2

Well ID: C5364		Well Name: 199-K-148	
Location: 100m NE of building 1606KA		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/26/07
Signature: Patrick Cabbage		Signature: L D Walker	

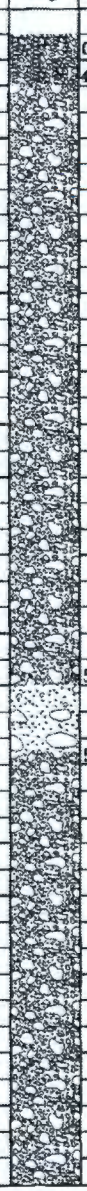
CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.0 ft ags	
Portland Cement Type I/II: 0 - 47.2 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +2.0 - 60.0 ft	
1/4-in Bentonite Pellets: 47.2 - 49.2 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 49.2 - 55.0 ft	
Static Water Level: 63.22 ft bgs (11/02/2007)	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 55.0 - 108.8 ft	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 60.0 - 100.0 ft	



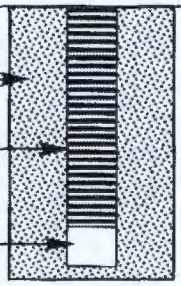
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-4 Gravel Fill
		4-50 Sandy Gravel; sG
10		
20		
30		
40		
50		50-55 Gravelly Sand; gS
		55-100 Sandy Gravel; sG
60		
70		
80		



WELL SUMMARY SHEET		Start Date: 10/22/07 Finish Date: 10/30/07	Page 2 of 2
Well ID: C5364		Well Name: 199-K-148	
Location: 100m NW of building 1606KA		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/26/07
Signature: Patrick Cabbage		Signature: D Walker	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 55.0 - 108.8 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 60.0 - 100.0 ft 6-in, I.D. 316L Stainless Steel End Cap: 100.0 - 103.0 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		55-100 Sandy Gravel; sG
100		100-108.8 Mud; M
110		108.8 Total Depth Drilled (10-30-2007)
120		

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

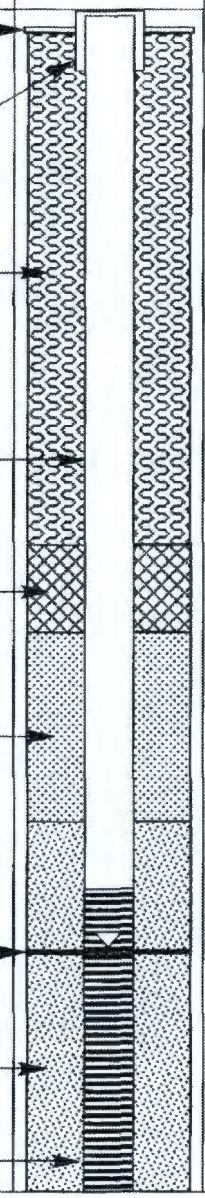
All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 10/22/07 Finish Date: 10/30/07	Page 1 of 2

Well ID: C5365		Well Name: 199-K-149	
Location: 200m west of N Reactor		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/26/07
Signature: Patrick Cabbage		Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +2.9 ft ags	
Portland Cement Type I/II: 0 - 39.0 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +1.9 - 65.1 ft	
1/4-in Bentonite Pellets: 39.0 - 45.6 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 45.6 - 60.2 ft	
Static Water Level: 70.18 ft bgs (10/30/2007)	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 60.2 - 113.2 ft	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 65.1 - 105.1 ft	



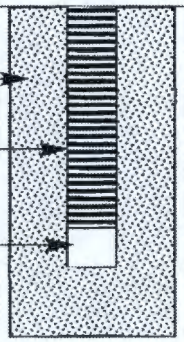
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-1.5 Gravel Fill
		1.5-4 Sandy Silt; sM
		4-6 Gravel; G
		6-45 Sandy Gravel; sG
10		
20		
30		
40		
		45-50 Silt Sandy Gravel; msG
50		50-80 Sandy Gravel; sG
60		
70		
80		80-95 Gravelly Sand; gS

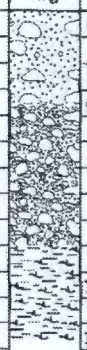
WELL SUMMARY SHEET	Start Date: 10/04/07 Finish Date: 10/23/07	Page 2 of 2

Well ID: C5365		Well Name: 199-K-149	
Location: 200m west of N reactor		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/26/07
Signature: Patrick Cabbage		Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 60.2 - 113.2 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 65.1 - 105.1 ft 6-in, I.D. 316L Stainless Steel End Cap: 105.1 - 108.1 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		80-95 Gravelly Sand; gS
		95-106 Sandy Gravel; sG
100		
110		106-113.2 Mud; M
		113.2 Total Depth Drilled (10-30-2007)
120		

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

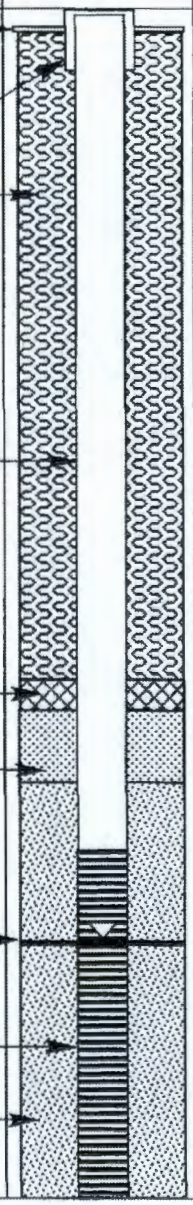
All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 12/19/07 Finish Date: 01/11/08	Page 1 of 2

Well ID: C5366		Well Name: 199-K-150	
Location: 200m west of N reactor		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 02/15/08	Reviewed By: L. D. Walker	Date: 3/19/08
Signature: Patrick Cabbage		Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.0 ft ags	
Portland Cement Type I/II: 0 - 49.2 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +2.1 - 62.0 ft	
1/4-in Bentonite Pellets: 49.2 - 51.2 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 51.2 - 56.8 ft	
Static Water Level: 68.20 ft bgs (12/21/2007)	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 62.0 - 112.0 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 56.8 - 117.2 ft	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-2 Gravel Fill
		2-15 Silty Sandy Gravel; msG
10		
		15-18 Gravel; G
20		18-68 Sandy Gravel; sG
30		
40		
50		
60		
70		68-80 Gravel; G
80		
		80-112 Sandy Gravel; sG

WELL SUMMARY SHEET	Start Date: 12/19/07 Finish Date: 01/11/08	Page 2 of 2
Well ID: C5366	Well Name: 199-K-150	
Location: 200m west of N reactor	Project: KR-4 Expansion	
Prepared By: Patrick Cabbage — Date: 02/15/08	Reviewed By: L. D. Walker — Date: 3/19/08	
Signature: Patrick Cabbage	Signature: [signature]	

CONSTRUCTION DATA

Description

Primary Filter pack
10-20 Mesh Colorado Silica Sand:
56.8 - 117.2 ft

6-in I.D. 316L Stainless Steel,
20 Slot (0.020-in) Screen:
62.0 - 112.0 ft

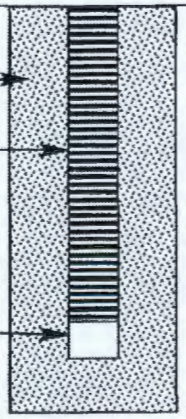
6-in, I.D. 316L Stainless Steel
End Cap: 112.0 - 115.0 ft

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

All temporary drill casing was removed from the ground.

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 90, 100, 110, 120

Graphic Log

Lithologic Description/Groundwater Sample Depths (ft bgs)

80-112 Sandy Gravel; sG

112-117.5 Clay; M

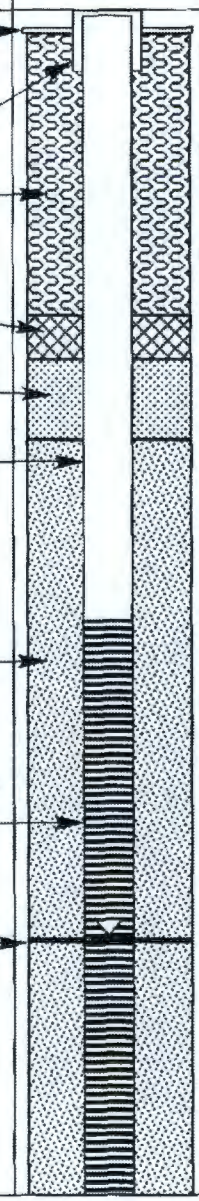
117.5 Total Depth Drilled (12-21-2007)

WELL SUMMARY SHEET	Start Date: 12/04/07 Finish Date: 12/12/07	Page 1 of 2

Well ID: C5367	Well Name: 199-K-151
Location: 100m east of 1606KA building	Project: KR-4 Expansion Wells
Prepared By: Patrick Cabbage — Date: 01/18/08	Reviewed By: L. D. Walker — Date: 4/25/08
Signature: Patrick Cabbage	Signature: L D Walker

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.0 ft ags	
Portland Cement Type I/II: 0 - 21.3 ft	
1/4-in Bentonite Pellets: 21.3 - 24.9 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 24.9 - 30.9 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +1.7 - 44.5 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 30.9 - 118.8 ft	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 44.5 - 114.5 ft	
Static Water Level: 68.76 ft bgs (12/5/2007)	

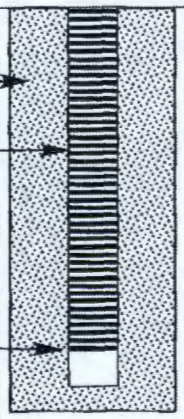


GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-1 Gravel Fill
		1-10 Silty Sandy Gravel; msG
10		10-100 Sandy Gravel; sG
20		
30		
40		
50		
60		
70		
80		

WELL SUMMARY SHEET		Start Date: 12/04/07 Finish Date: 12/12/07	Page 2 of 2
Well ID: C5367		Well Name: 199-K-151	
Location: 100m east of 1606KA building		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 01/18/08	Reviewed By: L.D. Walker	Date: 4/25/08
Signature: Patrick Cabbage		Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: LW 4-25-08 ~~32.25~~ 30.9 - 118.8 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 44.5 - 114.5 ft 6-in, I.D. 316L Stainless Steel End Cap: 114.5 - 117.5 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		10-100 Sandy Gravel; sG
100		100-115 Sand; S
110		118.0' 115-~~118.8 Clay; M~~ LW 4-30-08 Silty SAND (mS)
120		118.8 Total Depth Drilled (~~11~~-06-2007) 12 118.0 - 118.8': SILT (M)

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4-inch casing.

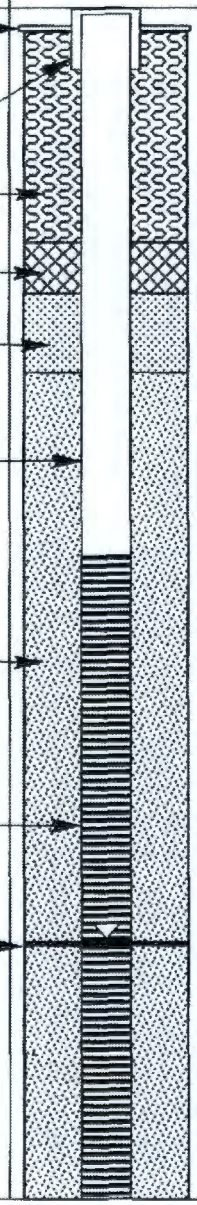
All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 12/14/07 Finish Date: 01/08/08	Page 1 of 2

Well ID: C5368	Well Name: 199-K-152
Location: 50m east of 1606KA building	Project: KR-4 Expansion Wells
Prepared By: Patrick Cabbage — Date: 02/15/08	Reviewed By: L. D. Walker — Date: 3/19/08
Signature: Patrick Cabbage	Signature: LD Walker

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.1 ft ags	
Portland Cement Type I/II: 0 - 16.0 ft	
1/4-in Bentonite Pellets: 16.0 - 19.7 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 19.7 - 25.8 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +2.1 - 39.5 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 25.8 - 118.6 ft	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 39.5 - 114.5 ft	
Static Water Level: 68.70 ft bgs (12/18/2007)	



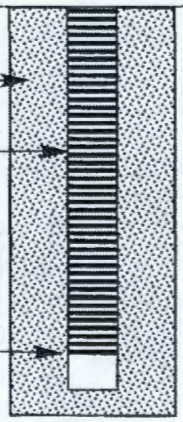
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-1 Gravel Fill
		1-55 Sandy Gravel; sG
10		
20		
30		
40		
50		
		55-60 Gravel; G
60		60-65 Sandy Gravel; sG
		65-68 Gravely Sand; gS
		68-~~118.6~~ Sandy Gravel; sG
70		116'
		LW 3-19-08
80		

WELL SUMMARY SHEET	Start Date: 12/14/07 Finish Date: 01/08/08	Page 2 of 2

Well ID: C5368		Well Name: 199-K-152	
Location: 50m east of 1606KA building		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 02/15/08	Reviewed By: L. D. Walker	Date: 3/19/08
Signature: Patrick Cabbage		Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 25.8 - 118.6 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 39.5 - 114.5 ft 6-in, I.D. 316L Stainless Steel End Cap: 114.5 - 117.5 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		68-116 Sandy Gravel; sG
100		
110		118.6 LW 3-19-08 116-~~118.6~~ Clay; M
120		118.6 Total Depth Drilled (12-17-2007)

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

All temporary drill casing was removed from the ground.

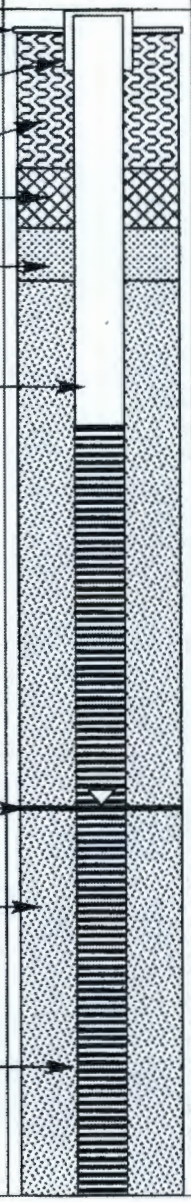
WELL SUMMARY SHEET		Start Date: 10/9/07 Finish Date: 10/19/07	Page 1 of 2
Well ID: C5369		Well Name: 199-K-153	
Location: 100m SW of building 1606KA		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 01/28/08	Reviewed By: L.D. Walker	Date: 1/31/08
Signature: Patrick Cabbage		Signature: L.D. Walker	

CONSTRUCTION DATA

Description

- 6-in Concrete Pad
- 8-in I.D. Type 304/304L Stainless Steel Protective Casing: +2.3 ft ags
- Portland Cement Type I/II: 0 - 10.3 ft
- 1/4-in Bentonite Pellets: 10.3 - 14.8 ft
- Secondary Filter Pack 20-40 Mesh Layne Mt Sand: 14.8 - 18.9 ft
- 6-in I.D., Sch. 40, Type 314L Stainless Steel Casing: +1.3 - 30.0 ft
- Static Water Level: 58.76 ft bgs (11/27/2007)
- Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 18.9 - 104.6 ft
- 6-in I.D. Type 314L Stainless Steel, 20 Slot (0.020-in) Screen: 30.0 - 100.0 ft

Diagram



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet: 0, 10, 20, 30, 40, 50, 60, 70, 80

Graphic Log

Lithologic Description/Groundwater Sample Depths (ft bgs)

- 0-1 Gravel Fill; Fill
- 1-10 Gravelly Sand; gS
- 10-89 Sandy Gravel; sG
- 89-100 Sand; S

GM 2/27/08

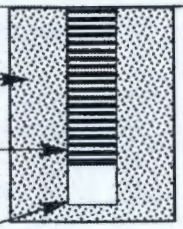
WELL SUMMARY SHEET

Start Date: 10/9/07
Finish Date: 10/19/07

Page 2 of 2

Well ID: ~~C5938~~ C5369	Well Name: 199-K-153
Location: 100m SW of building 1606KA	Project: KR-4 Expansion Wells
Prepared By: Patrick Cabbage Date: 01/28/08	Reviewed By: L. D. Walker Date: 1/31/08
Signature: Patrick Cabbage	Signature: [signature]

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 18.9 - 104.6 ft 6-in I.D. 314L Stainless Steel, 20 Slot (0.020-in) Screen: 30.0 - 100.0 ft 6-in, I.D. 314L Stainless Steel End Cap: 100.0 - 103.0 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		89-100 Sand; S
100		100-104.6 Mud; M
		104.6 Total Depth Drilled (11/30/2007)
110		
120		

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4-inch casing.

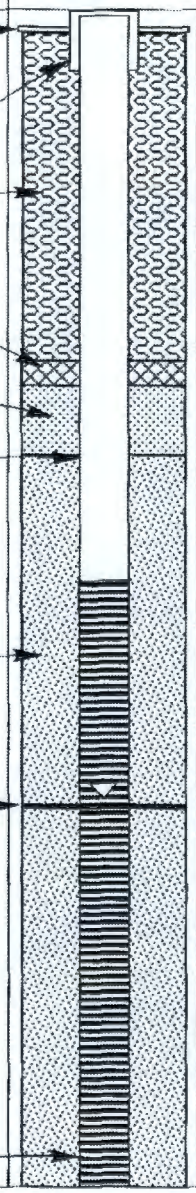
All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 11/07/07 Finish Date: 11/14/07	Page 1 of 2

Well ID: C5370		Well Name: 199-K-154	
Location: 400m East of KR-4 Pump and Treat		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 01/18/08	Reviewed By: L. D. Walker	Date: 1/21/08
Signature: Patrick Cabbage		Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.1 ft ags	
Portland Cement Type I/II: 0 - 25.25 ft	
1/4-in Bentonite Pellets: 25.25 - 26.66 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 26.66 - 32.25 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +1.1 - 42 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 32.25 - 107.9 ft	
Static Water Level: 58.8 ft bgs (11/14/2007)	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 42 - 102 ft	

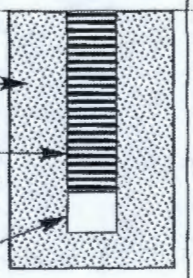


GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-3 Gravel Fill
		3-8 Silty Sandy Gravel; msG
10		8-13 Gravel; G
		13-20 Sandy Gravel; sG
20		
		20-30 Silty Gravel; sG
30		
40		
50		
60		
70		
		30-102 Sandy Gravel; sG
80		

WELL SUMMARY SHEET		Start Date: 11/07/07 Finish Date: 11/14/07	Page 2 of 2
Well ID: C5370		Well Name: 199-K-154	
Location: 400m East of KR-4 Pump and Treat		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 01/18/08	Reviewed By: L.D. Walker	Date: 1/21/08
Signature: Patrick Cabbage		Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 32.25 - 107.9 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 42 - 102 ft 6-in, I.D. 316L Stainless Steel End Cap: 102 - 105 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		30-102 Sandy Gravel; sG
100		
		102-107.9 Clay; M
		107.9 Total Depth Drilled (11-06-2007)
110		
120		

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET		Start Date: 10/24/07	Page 1 of 1
		Finish Date: 10/29/07	
Well ID: C 5371		Well Name: 199-K-155	
Location: 100-KR-4		Project: 100-KR-4 Pump & Treat Expansion	
Prepared By: L.D. Walker	Date: 3/19/08	Reviewed By: George Kelty	Date: 3/19/08
Signature: [signature]		Signature: [signature]	

CONSTRUCTION DATA

Description	Diagram
Portland Cement 0 → 10'	
Granular Bentonite 10' → 32.6'	
Drill casing 10 3/4" OD	
All drill casing removed from the ground	
Borehole decommissioned - No permanent casing left in ground	

GEOLOGIC/HYDROLOGIC DATA

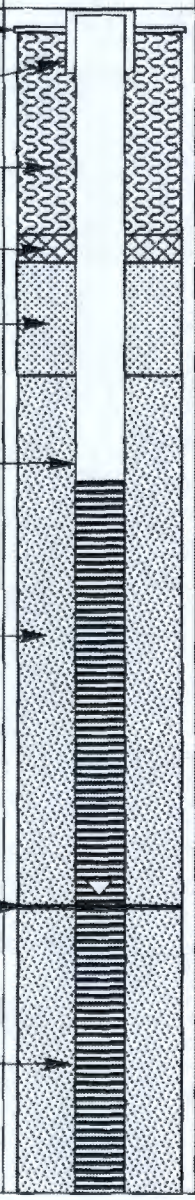
Depth in Feet	Graphic Log	Lithologic Description
0		0-2': Gravel Fill
		2' → 32.6': Sandy GRAVEL (SG)
10		
20		
30		TD = 32.6' bgs
40		Borehole could not be advanced beyond 32.6' bgs.

A-6003-643 (03/03)

WELL SUMMARY SHEET	Start Date: 01/15/08 Finish Date: 02/11/08	Page 1 of 2
Well ID: C5372	Well Name: 199-K-156	
Location: 200m East of K-East Reactor	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage — Date: 02/15/08	Reviewed By: L.A. Walker — Date: 4/25/08	
Signature: Patrick Cabbage	Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 304/304L Stainless Steel Protective Casing: +3.1 ft ags	
Portland Cement Type I/II: 0 - 15.5 ft	
1/4-in Bentonite Pellets: 15.5 - 17.7 ft	
Secondary Filter Pack 20-40 Mesh Layne Mt Sand: 17.7 - 25.9 ft	
6-in I.D., Sch. 40, Type 314L Stainless Steel Casing: +2.0 - 34.0 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 25.9 - 172.2 ft	
Static Water Level: 66.21 ft bgs (2/11/2008)	
6-in I.D. Type 314L Stainless Steel, 20 Slot (0.020-in) Screen: 34.0 - 164.0 ft	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-4 Gravel Fill
		4-19 Silty Sandy Gravel; msG
10		
		19-57 Gravel; G
20		
30		
40		
50		
		57-79 Sandy Gravel; sG
60		
70		
		79-90 Gravely Sand; gS
80		

WELL SUMMARY SHEET	Start Date: 01/15/08 Finish Date: 02/11/08	Page 2 of 2
Well ID: C5372	Well Name: 199-K-156	
Location: 200m East of K-East Reactor	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage — Date: 02/15/08	Reviewed By: L. D. Walker — Date: 4/25/08	
Signature: Patrick Cabbage	Signature: [signature]	

CONSTRUCTION DATA

Primary Filter pack
10-20 Mesh Colorado Silica Sand:
25.9 - 172.2 ft

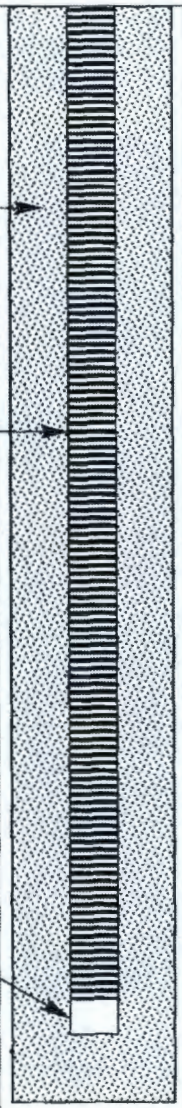
6-in I.D. 314L Stainless Steel,
20 Slot (0.020-in) Screen:
34.0 - 164.0 ft

6-in, I.D. 314L Stainless Steel
End Cap: 164.0 - 167.0 ft

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4-inch casing.

All temporary drill casing was removed from the ground.



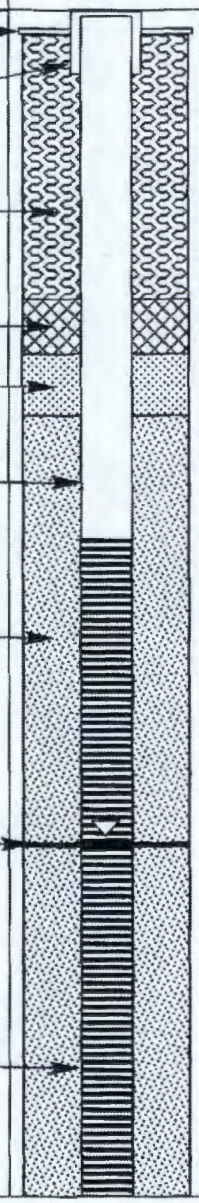
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Lithologic Description/Groundwater Sample Depths (ft bgs)
90	79-90 Gravely Sand; gS
	90-166 Sandy Gravel; sG
100	
110	
120	
130	
140	
150	
160	
	166-172.2 Mud; M
170	172.2 Total Depth Drilled (01/29/2008)

WELL SUMMARY SHEET	Start Date: 01/11/08 Finish Date: 01/29/08	Page 1 of 2
Well ID: C5373	Well Name: 199-K-157	
Location: 100m East of K-East Reactor	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage — Date: 02/15/08	Reviewed By: L. A. Walker — Date: 4/25/08	
Signature: Patrick Cabbage	Signature: [signature]	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad 8-in I.D. Type 304/304L Stainless Steel Protective Casing: +3.1 ft ags	
Portland Cement Type I/II: 0 - 20.3 ft	
1/4-in Bentonite Pellets: 20.3 - 24.3 ft	
Secondary Filter Pack 20-40 Mesh Layne Mt Sand: 24.3 - 29.1 ft	
6-in I.D., Sch. ~~40~~ 10 w 4-30-01, Type 314L Stainless Steel Casing: +2.0 - 38.4 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 29.1 - 143.3 ft	
Static Water Level: 61.72 ft bgs (01/16/2008)	
6-in I.D. Type 314L Stainless Steel, 20 Slot (0.020-in) Screen: 38.4 - 138.4 ft	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-3 Gravel Fill
		3-20 Silty Sandy Gravel; msG
10		
20		20-139 Sandy Gravel; sG
30		
40		
50		
60		
70		
80		

WELL SUMMARY SHEET	Start Date: 01/11/08 Finish Date: 01/29/08	Page 2 of 2

Well ID: C5373		Well Name: 199-K-157	
Location: 100m East of K-East Reactor		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date:02/15/08	Reviewed By: L. b. Walker	Date: 4/25/08
Signature: Patrick Cabbage		Signature: [illegible]	

CONSTRUCTION DATA

Primary Filter pack
10-20 Mesh Colorado Silica Sand:
29.1 - 143.3 ft

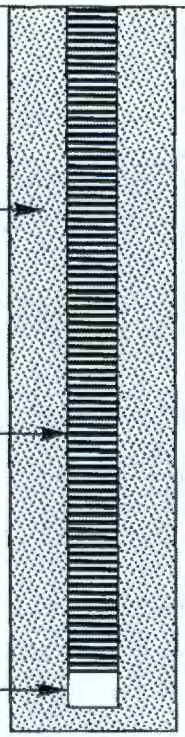
6-in I.D. 314L Stainless Steel,
20 Slot (0.020-in) Screen:
38.4 - 138.4 ft

6-in, I.D. 314L Stainless Steel
End Cap: 138.4 - 141.4 ft

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

All temporary drill casing was removed from the ground.



GEOLOGIC/HYDROLOGIC DATA

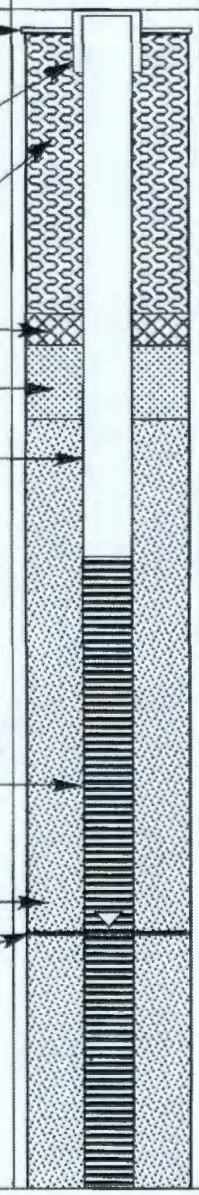
Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		20-139 Sandy Gravel; sG
100		
110		
120		
130		
		Silt and Clay cw 4/30/08
140		139-143.3 ~~Mud~~; M
		143.3 Total Depth Drilled (01/15/2008)
150		

WELL SUMMARY SHEET	Start Date: 10/04/07 Finish Date: 10/23/07	Page 1 of 2

Well ID: C5937	Well Name: 199-K-159
Location: 100m west of N Reactor	Project: KR-4 Expansion Wells
Prepared By: Patrick Cabbage — Date: 12/19/07	Reviewed By: L.P. Walker — Date: 12/26/07
Signature: Patrick Cabbage	Signature: [illegible]

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +2.8 ft ags	
Portland Cement Type I/II: 0 - 21.4 ft	
1/4-in Bentonite Pellets: 21.4 - 23.8 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 23.8 - 29.5 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +1.7 - 39.8 ft	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 39.8 - 109.8 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 29.5 - 117.0 ft	
Static Water Level: 68.56 ft bgs (10/25/2007)	



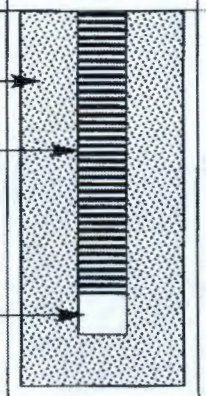
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-1 Gravel Fill
		1-25 Sandy Gravel; sG
10		
20		
		25-30 Gravel; G
30		30-50 Sandy Gravel; sG
40		
50		50-55 Gravel; G
		55-75 Sandy Gravel; sG
60		
70		
		75-80 Gravelly Sand; gS
80		80-110 Sandy Gravel; sG

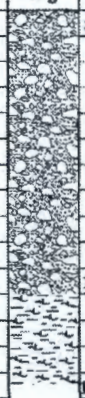
WELL SUMMARY SHEET	Start Date: 10/04/07 Finish Date: 10/23/07	Page 2 of 2

Well ID: C5937		Well Name: 199-K-159	
Location: 100m west of N reactor		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/26/07
Signature: Patrick Cabbage		Signature: [signature]	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 29.5 - 117.0 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 39.8 - 109.8 ft 6-in, I.D. 316L Stainless Steel End Cap: 109.8 - 112.8 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		80-110 Sandy Gravel; sG
100		
110		110-117 Mud; M
		117.0 Total Depth Drilled (10-23-2007)
120		

All depths are in feet below ground surface.

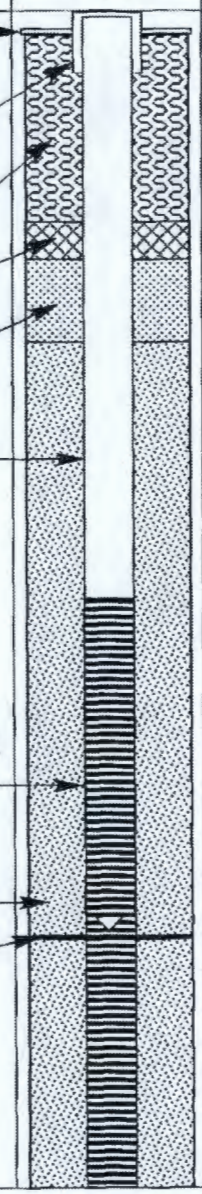
Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 10/09/07 Finish Date: 10/19/07	Page 1 of 2
Well ID: C5938	Well Name: 199-K-160	
Location: 100m west of N Reactor	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/26/07
Signature: Patrick Cabbage	Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.1 ft ags	
Portland Cement Type I/II: 0 - 14.3 ft	
1/4-in Bentonite Pellets: 14.3 - 17.0 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 17.0 - 23.5 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +2.1 - 42.9 ft	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 42.9 - 112.9 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 23.5 - 118.0 ft	
Static Water Level: 68.81 ft bgs (10/19/2007)	

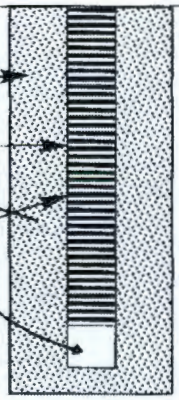


GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-1 Gravel Fill
		1'
10		1-113 Sandy Gravel; sG
		4W 12-26-07
20		
30		
40		
50		
60		
70		
80		

WELL SUMMARY SHEET	Start Date: 10/09/07 Finish Date: 10/19/07	Page 2 of 2
Well ID: C5938	Well Name: 199-K-160	
Location: 100m west of N reactor	Project: KR-4 Expansion	
Prepared By: Patrick Cabbage — Date: 12/19/07	Reviewed By: L.D. Walker — Date: 12/26/07	
Signature: Patrick Cabbage	Signature: LD Walker	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 23.5 - 118.0 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 42.9 - 112.9 ft 12-26-07 LW 6-in, I.D. 316L Stainless Steel End Cap: 112.9 - 115.9 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		0-113 Sandy Gravel; sG
100		
110		113-118 Mud; M
		118.0 Total Depth Drilled (10-19-2007)
120		

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

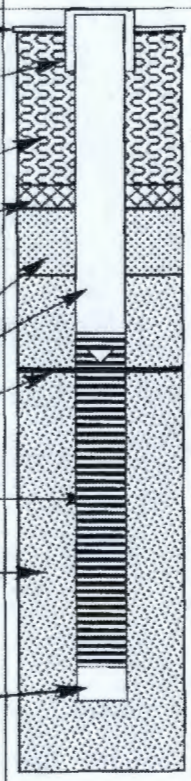
All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 11/27/07 Finish Date: 12/05/07	Page 1 of 1

Well ID: C5939	Well Name: 199-K-161
Location: 100m west of 1606k Building	Project: KR-4 Expansion Wells
Prepared By: Patrick Cabbage — Date: 01/18/08	Reviewed By: L. D. Walker — Date: 1/21/08
Signature: Patrick Cabbage	Signature: L D Walker

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +2.5 ft ags	
Portland Cement Type I/II: 0 - 11.5 ft	
1/4-in Bentonite Pellets: 11.5 - 13.7 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 13.7 - 18.5 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +1.4 - 23.5 ft	
Static Water Level: 26.2 ft bgs (12/5/2007)	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 23.5 - 48.5 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 18.5 - 56.5 ft	
6-in, I.D. 316L Stainless Steel End Cap: 48.5 - 51.5 ft	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-2 Gravel Fill
		2-49 Sandy Gravel; sG
10		
20		
30		
40		
		49-51 Gravelly Silt; gM
50		51-56.5 Mud; M
		Total Depth Drilled: 56.5 ft bgs
60		
70		
80		

All depths are in feet below ground surface.

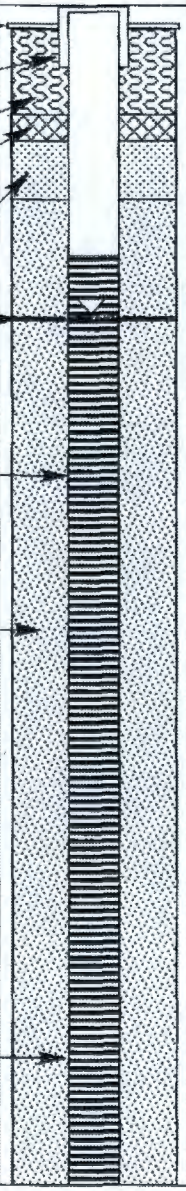
Borehole drilled with 7 3/4 x 10 3/4 - inch casing.

All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 02/04/08 Finish Date: 02/22/08	Page 1 of 2

Well ID: C5940		Well Name: 199-K-162	
Location: 50m NW of building 1607K		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date: 04/14/08	Reviewed By: L. D. Walker	Date: 4/25/08
Signature: Patrick Cabbage		Signature: LDWalker	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad 8-in I.D. Type 304/304L Stainless Steel Protective Casing: +2.9 ft ags Portland Cement Type I/II: 0 - 6.4 ft 1/4-in Bentonite Pellets: 6.4 - 8.4 ft Secondary Filter Pack 20-40 Mesh Layne Mt Sand: 8.4 - 13.1 ft Static Water Level: 22.13 ft bgs (02/06/2008) 6-in I.D., Sch. ~~40~~ 10 Type 314L Stainless Steel Casing: +2.0 - 17.4 ft Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 13.1 - 133.6 ft 6-in I.D. Type 314L Stainless Steel, 20 Slot (0.020-in) Screen: 17.4 - 127.4 ft	

GEOLOGIC/HYDROLOGIC DATA

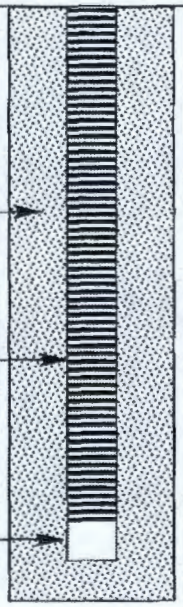
Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-2 Gravel Fill
		2-10 Silty Sandy Gravel; msG
10		10-128 Sandy Gravel; sG
20		
30		
40		
50		
60		
70		
80		

WELL SUMMARY SHEET	Start Date: 02/04/08 Finish Date: 02/22/08	Page 2 of 2

Well ID: C5940		Well Name: 199-K-162	
Location: 50m NW of building 1607K		Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage	Date:04/14/08	Reviewed By: L. D. Walker	Date: 4/25/08
Signature: Patrick Cabbage		Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 13.1 - 133.6 ft	
6-in I.D. 314L Stainless Steel, 20 Slot (0.020-in) Screen: 17.4 - 127.4 ft	
6-in, I.D. 314L Stainless Steel End Cap: 127.4 - 130.4 ft	



GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		10-128 Sandy Gravel; sG
100		
110		
120		
130		128-133.6 Mud; M (silt/clay) LW 4-30-08
		133.6 Total Depth Drilled (02/06/2008)
140		

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 10/30/07 Finish Date: 11/06/07	Page 1 of 2
Well ID: C6172	Well Name: 199-K-163	
Location: 300m East of KR-4 Pump and Treat	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage — Date: 12/19/07	Reviewed By: L. D. Walker — Date: 12/21/07	
Signature: Patrick Cabbage	Signature: L D Walker	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +2.7 ft ags	
Portland Cement Type I/II: 0 - 19.9 ft	
1/4-in Bentonite Pellets: 19.9 - 21.8 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 21.8 - 26.8 ft	
6-in I.D., Sch. 10, Stainless Steel casing: +1.9 - 36.8 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 26.8 - 113.7 ft	
Static Water Level: 61.25 ft bgs (11/01/2007)	
6-in I.D. ~~sch. 10~~ LD 12-21-07, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 36.8 - 106.8 ft	

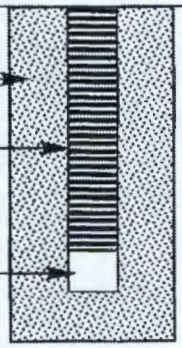
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-3 Gravel Fill
		3-10 Sandy Gravel; sG
10		10-20 Gravel; G
20		20-70 Sandy Gravel; sG
30		
40		
50		
60		
70		70-75 Gravelly Sand; gS
		75-109 Sandy Gravel; sG
80		

WELL SUMMARY SHEET	Start Date: 10/04/07 Finish Date: 10/23/07	Page 2 of 2

Well ID: C6172		Well Name: 199-K-163	
Location: 300m East of KR-4 Pump and Treat		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 12/19/07	Reviewed By: L. D. Walker	Date: 12/21/07
Signature: Patrick Cabbage		Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 26.8 - 113.7 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 36.8 - 106.8 ft 6-in, I.D. 316L Stainless Steel End Cap: 106.8 - 109.8 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		75-109 Sandy Gravel; sG
100		
110		109-113.7 Mud; M
		113.7 Total Depth Drilled (11-06-2007)
120		

All depths are in feet below ground surface.

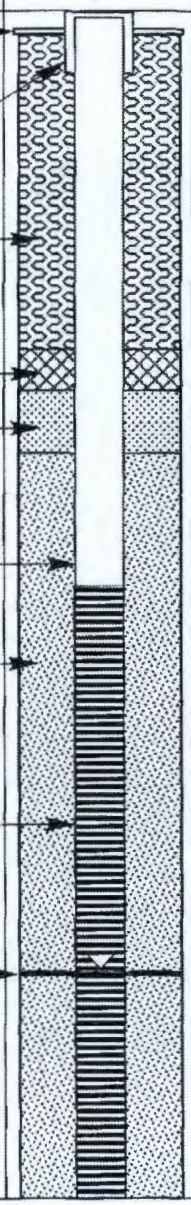
Borehole drilled with 7 3/4 x 10 3/4 -inch Dual wall casing.

All temporary drill casing was removed from the ground.

WELL SUMMARY SHEET	Start Date: 03/26/08 Finish Date: 04/10/08	Page 1 of 2
Well ID: C6386	Well Name: 199-K-164	
Location: 30 m. S of substation, SW of N Reactor	Project: KR-4 Expansion Wells	
Prepared By: Patrick Cabbage — Date: 04/10/08	Reviewed By: L. D. Walker — Date: 4/25/08	
Signature: Patrick Cabbage	Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
6-in Concrete Pad	
8-in I.D. Type 316L Stainless Steel Protective Casing: +3.0 ft ags	
Portland Cement Type I/II: 0 - 24.0 ft	
1/4-in Bentonite Pellets: 24.0 - 27.2 ft	
Secondary Filter Pack 20-40 Mesh Lane Mt Sand: 27.2 - 31.9 ft	
6-in I.D., Sch. 10, Stainless Steel casing: 2.0 - 41.8 ft	
Primary Filter Pack 10-20 Mesh Colorado Silica Sand: 31.9 - ~~110.8~~ ft 119.0 [illegible]	
6-in I.D. sch. 10, 316L Stainless Steel, 20 Slot (0.020-in) Screen: 41.8 - 111.8 ft	
Static Water Level: 71.22 ft bgs (04/08/2008)	



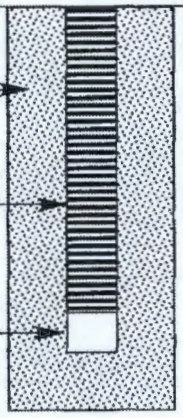
GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
0		0-1 Gravel Fill
		1-20 Silty Sandy Gravel; msG
10		
20		20-30 Sandy Gravel; sG
30		30-40 Silty Sandy Gravel; msG
40		40-112 Sandy Gravel; sG
50		
60		
70		
80		

WELL SUMMARY SHEET	Start Date: 03/26/08 Finish Date: 04/10/08	Page 2 of 2

Well ID: C6386		Well Name: 199-K-164	
Location: 30 m. S of substation, SW of N Reactor		Project: KR-4 Expansion	
Prepared By: Patrick Cabbage	Date: 04/10/08	Reviewed By: L.D. Walker	Date: 4/25/08
Signature: Patrick Cabbage		Signature: [illegible]	

CONSTRUCTION DATA

Description	Diagram
Primary Filter pack 10-20 Mesh Colorado Silica Sand: 31.9 - 119.0 ft 6-in I.D. 316L Stainless Steel, 20 Slot (0.020-in) Screen: 41.8 - 111.5 ft 6-in, I.D. 316L Stainless Steel End Cap: 111.5 - 114.5 ft	

GEOLOGIC/HYDROLOGIC DATA

Depth in Feet	Graphic Log	Lithologic Description/Groundwater Sample Depths (ft bgs)
90		40-112 Sandy Gravel; sG
100		
110		
		112-119.0 Clay; M
		119.0 Total Depth Drilled (03-28-2008)
120		

All depths are in feet below ground surface.

Borehole drilled with 7 3/4 x 10 3/4 -inch casing.

All temporary drill casing was removed from the ground.

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