Final
Feasibility Study Report
Kaiser Trentwood Facility
Spokane Valley, Washington

Volume II
Appendices A - I

Prepared for
Kaiser Aluminum
Washington, LLC

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HARTCROWSER

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ACRONYMS AND ABBREVIATIONS

AOC	area of concern
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
BACT	best available control technology
BCY	bank cubic yards
bgs	below ground surface
BMP	best management practice
CAP	Cleanup Action Plan
CCPL	Continuous Can Process Line
COC	constituent of concern
COPC	constituent of potential concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CQAP	Construction Quality Assurance Plan
CUL	cleanup level
CWA	Clean Water Act
CY	cubic yards
DCA	disproportionate cost analysis
DW	dangerous waste
FCT	Field-Constructed Tanks
FPP	free phase product
FS	feasibility study
FSTM	Feasibility Study Technical Memorandum
GAC	granular activated carbon
gpd	gallons per day
gpm	gallons per minute
HASP	Health and Safety Plan
HDPE	high-density polyethylene
HHERA	Final Human Health and Ecological Risk Assessments
HMA	hot-mix asphalt
IRM	interim remedial measure
LCY	loose cubic yards
LF	linear feet
LNAPL	light non-aqueous phase liquid
MCL	maximum contaminant limit
MGD	million gallons per day
mg/L	milligrams per liter
mmHg	millimeters of mercury
MNA	monitored natural attenuation
MTCA	Model Toxics Control Act
ng/L	nanograms per liter

NPV	net present value
NTU	nephelometric turbidity unit
O&M	operation and maintenance
ORB	Oil Reclamation Building
PAC	powdered activated carbon
PCB	polychlorinated biphenyl
PCUL	preliminary cleanup level
PFD	process flow diagram
POC	point of compliance
PPE	personal protective equipment
psig	pounds per square inch, gauge
RAO	remedial action objective
RBSL	risk-based screening level
RCRA	Resource Conservation and Recovery Act
RCU	Former Rail Car Unloading area
RI	remedial investigation
SAP	Sampling and Analysis Plan
SBR	sequencing batch reactor
scfm	standard cubic feet per minute
SDR	South Discharge Ravine
SDWA	Safe Drinking Water Act
SL	screening level
SPCC Plan	Spill Prevention Control and Countermeasure Plan
sq ft	square feet
SRCAA	Spokane Regional Clean Air Agency
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWPPP	Stormwater Pollution Prevention Plan
TAP	toxic air pollutant
TCLP	toxicity characteristic leaching procedure
TMDL	total maximum daily load
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UIC	Underground Injection Control (Program)
UV	ultraviolet
VOC	volatile organic compound
WDR	West Discharge Ravine
WWTP	Wastewater Treatment Plant
µm	micrometer (micron)
µg/L	micrograms per liter

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COST ESTIMATES FOR NEAR-SURFACE SOIL REMEDIAL ALTERNATIVES

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Table A-1 - Estimated Cost Comparison for Near-Surface Soil Remedial Alternatives

Location: Kaiser Trentwood Facility Spokane Valley, WA **Phase:** Feasibility Study (-35% to +50%) **Base Year:** 2010 **Date:** July 2011	**Description:** Cost comparison of the net present value and incremental cost of Alternative A1 through A6 for remediation of near-surface soil.

DESCRIPTION	TOTAL NET PRESENT VALUE	INCREMENTAL COST	COST TABLE REFERENCE
Alternative A1	$ 13,600,000	Baseline Cost	Table A-2
Alternative A2	$ 15,800,000	$ 2,200,000	Table A-3
Alternative A3	$ 16,300,000	$ 500,000	Table A-4
Alternative A4a	$ 18,700,000	$ 5,100,000	Table A-5
Alternative A4b	$ 20,900,000	$ 5,100,000	Table A-6
Alternative A5a (with A1)	$ 19,100,000	$ 5,500,000	Table A-7
Alternative A5a (with A2)	$ 21,400,000	$ 5,600,000	Table A-7
Alternative A5b (with A1)	$ 19,900,000	$ 6,300,000	Table A-8
Alternative A5b (with A2)	$ 22,200,000	$ 6,400,000	Table A-8
Alternative A6 (with A1)	$ 39,000,000	$ 25,400,000	Table A-9
Alternative A6 (with A2)	$ 41,300,000	$ 25,500,000	Table A-9

Note:
Present value analysis uses a 30-year discount rate of 7%.

Table A-2 - Alternative A1 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative A1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to all of the alternatives that will be evaluated for the remediation of near-surface soil at the Kaiser Facility. Alternative A1 assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
CAPITAL COSTS					
Institutional Controls					
Institutional control plans	1	EA	$ 46,548	$ 46,548	See Table A-11.
Pending upgrades in casting complex	1	LS	$ 1,076,073	$ 1,076,073	See Table A-11.
Restrictive covenant preparation	1	LS	$ 24,970	$ 24,970	See Table A-11.
Institutional Controls Subtotal				**$ 1,147,591**	
Contingency	10%	--	--	**$ 114,759**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					
Project management	6%	--	--	$ 75,741	Percentage of capital cost + contingency. EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Year 0. Kaiser mean annual Ecology costs 2007-2009.
Professional/Technical Services Subtotal				**$ 97,741**	
TOTAL CAPITAL COST				**$ 1,360,091**	
ANNUAL O&M COSTS					
Monitoring, Sampling, Testing, and Analysis					
Protection monitoring	1	YR	$ 44,683	$ 44,683	See Table A-10.
Performance monitoring	1	YR	$ 223,417	$ 223,417	See Table A-10.
Data management	1	YR	$ 29,948	$ 29,948	HC estimate. Data validation; maintain database.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 298,048**	
Institutional Controls (Annual Update and Maintenance)					
Institutional control plans	1	YR	$ 30,018	$ 30,018	See Table A-11.
Institutional controls maintenance	1	YR	$ 259,604	$ 259,604	See Table A-11.
Outfall & treatment plant monitoring	1	YR	$ 101,946	$ 101,946	See Table A-11. Required by NPDES permit and Ecology orders (see Section 2.1.1.1).
Site information database	1	YR	$ 5,743	$ 5,743	See Table A-11.
Institutional Controls Subtotal				**$ 397,311**	
Contingency	10%	--	--	**$ 69,536**	Scope and bid contingency. Percentage of monitoring and institutional controls annual cost.
Professional/Technical Services					
Project management	10%	--	--	$ 76,489	Percentage of annual + contingency costs. EPA 540-R-00-002.
Technical support	10%	--	--	$ 76,489	EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Kaiser mean annual Ecology costs 2007-2009.
Reporting	1	YR	$ 16,182	$ 16,182	Report to Kaiser & Ecology quarterly; EIM reporting.
Professional/Technical Services Subtotal				**$ 191,161**	
TOTAL ANNUAL O&M COST				**$ 956,055**	
PERIODIC COSTS					
Monitoring, Sampling, Testing, and Analysis					
MNA performance monitoring	1	LS	$ 19,257	$ 19,257	Years 5, 10, 15, 20, 25, 30. See Table A-12.
Data management	1	LS	$ 4,500	$ 4,500	Years 5, 10, 15, 20, 25, 30. See Table A-12.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 23,757**	
Institutional Controls (Periodic Update and Maintenance)					
Restrictive covenants	1	EA	$ 6,470	$ 6,470	Years 5, 10, 15, 20, 25, 30. See Table A-11.
Initial acute and chronic toxicity testing	1	LS	$ 45,000	$ 45,000	Years 0, 5, 10, 15, 20, 25. See Table A-11.
Final acute and chronic toxicity testing	1	LS	$ 14,940	$ 14,940	Years 5, 10, 15, 20, 25, 30. See Table A-11.
Institutional Controls Subtotal				**$ 66,410**	
Contingency	10%	--	--	**$ 9,017**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. See Table A-12.
MNA reporting	1	LS	$ 7,000	$ 7,000	Years 5, 10, 15, 20, 25, 30. See Table A-12.
Closure report	1	EA	$ 41,180	$ 41,180	Year 30. See Table A-12.
Professional/Technical Services Subtotal				**$ 57,950**	

Table A-2 - Alternative A1 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative A1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to all of the alternatives that will be evaluated for the remediation of near-surface soil at the Kaiser Facility. Alternative A1 assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 1,405,091	$ 1,405,091	1.000	$ 1,405,091	
Annual O&M	1 - 30	$ 28,681,662	$ 956,055	12.409	$ 11,863,731	
Periodic	5	$ 115,954	$ 115,954	0.713	$ 82,673	
Periodic	10	$ 115,954	$ 115,954	0.508	$ 58,945	
Periodic	15	$ 115,954	$ 115,954	0.362	$ 42,027	
Periodic	20	$ 115,954	$ 115,954	0.258	$ 29,965	
Periodic	25	$ 115,954	$ 115,954	0.184	$ 21,364	
Periodic	30	$ 107,634	$ 107,634	0.131	$ 14,140	
		$ 30,774,155			$ 13,517,936	
TOTAL NET PRESENT VALUE OF ALTERNATIVE A1					**$ 13,517,936**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table A-3 - Alternative A2 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative A2 includes the elements of Alternative A1 plus containment. The containment options considered in Alternative A2 include capping using asphalt, concrete, or multi-layer caps.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Cap Installation					
Permits	1	LS	$ 40,000	$ 40,000	Previous project experience. SEPA checklist; designated shoreline.
Asphalt cap installation	5,741	SY	$ 43	$ 248,276	See Table A-13.
Concrete cap installation	1,013	SY	$ 80	$ 81,195	See Table A-13.
Multi-layer cap installation	2,434	SY	$ 66	$ 159,501	See Table A-13.
Hoffman Tank area cap extension	198	SY	$ 149	$ 29,408	Extension of existing multi-layer cap. See Table A-13.
Cap Installation Subtotal				**$ 558,381**	
Contingency	15%	--	--	**$ 83,757**	Scope and bid contingency. Percentage of cap installation costs.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	6%	--	--	$ 38,528	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	12%	--	--	$ 77,057	EPA 540-R-00-002.
Construction management	8%	--	--	$ 51,371	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost to include cap.
Professional/Technical Services Subtotal				**$ 169,156**	
Institutional Controls					New institutional controls for containment portion of Alt. A2.
Institutional controls plan	50%	--	--	$ 23,274	Assume 50% of Alt. A1 institutional control plan cost to include cap.
Restrictive covenants	25%	--	--	$ 6,243	Assume 25% of Alt. A1 restrictive covenant preparation cost to include cap.
Institutional Controls Subtotal				**$ 29,517**	
TOTAL CAPITAL COST				**$ 840,810**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Containment Operation, Maintenance, and Monitoring					
Cap inspection	0.4	WK	$ 5,375	$ 2,150	Assume annual inspection, 2 days HC staff at HC rates. See Table A-22.
Cap sampling and laboratory analysis	1	YR	$ 15,320	$ 15,320	See Table A-13.
Cap maintenance	5%	--	--	$ 42,041	Assume 20 year cap life. Assume 5% of cap to be replaced annually. Use 5% of cap installation total capital cost as maintenance cost.
Data management	1	YR	$ 3,620	$ 3,620	See Table A-13.
Containment Operation, Maintenance, and Monitoring Subtotal				**$ 63,130**	
Contingency	15%	--	--	**$ 9,470**	Scope and bid contingency. Percentage of annual operation, maintenance, and monitoring costs.
Professional/Technical Services					Percentage of sum of annual cost and contingency.
Project management	10%	--	--	$ 7,260	EPA 540-R-00-002.
Technical support	10%	--	--	$ 7,260	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Reporting	1	YR	$ 5,820	$ 5,820	See Table A-13.
Professional/Technical Services Subtotal				**$ 22,540**	
Institutional Controls (Annual Update and Maintenance)					
Institutional controls plan	50%	--	--	$ 15,009	Assume 50% of Alt. A1 institutional control plan cost to include cap.
Site information database	25%	--	--	$ 1,436	Assume 25% of Alt. A1 site information database cost to include cap.
Institutional Controls Subtotal				**$ 16,445**	
TOTAL ANNUAL O&M COST				**$ 111,584**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Professional/Technical Services					
Five-year reviews	1	EA	$ 19,540	$ 19,540	Years 5, 10, 15, 20, 25, 30. Assume same cost as in Alt. A1. See Table A-12.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. See Table A-12.
Professional/Technical Services Subtotal				**$ 40,130**	

Table A-3 - Alternative A2 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative A2 includes the elements of Alternative A1 plus containment. The containment options considered in Alternative A2 include capping using asphalt, concrete, or multi-layer caps.

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 840,810	$ 840,810	1.000	$ 840,810	
Annual O&M	1 - 30	$ 3,347,528	$ 111,584	12.409	$ 1,384,654	
Periodic	5	$ 19,540	$ 19,540	0.713	$ 13,932	
Periodic	10	$ 19,540	$ 19,540	0.508	$ 9,933	
Periodic	15	$ 19,540	$ 19,540	0.362	$ 7,082	
Periodic	20	$ 19,540	$ 19,540	0.258	$ 5,050	
Periodic	25	$ 19,540	$ 19,540	0.184	$ 3,600	
Periodic	30	$ 40,130	$ 40,130	0.131	$ 5,272	
		$ 4,326,168			$ 2,270,332	Net present value of elements unique to Alternative A2.
Total Net Present Value of Alternative A1					$ 13,517,936	
TOTAL NET PRESENT VALUE OF ALTERNATIVE A2					**$ 15,788,268**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table A-4 - Alternative A3 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative A3 includes Alternative A2 plus soil vapor extraction (SVE) and off-gas treatment for remediation of VOCs in near-surface soil. Alternative A3 assumes an operating period of one or two years for each VOC AOC. There are four near-surface soil VOC AOCs that will be treated by SVE.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals, implementation plans	1	LS	$ 10,000	$ 10,000	SAP, HASP, work plan, stormwater pollution prevention plan, as-built drawings, O&M manual, QA/QC documentation. Based on previous HC estimate.
Permits	1	LS	$ 10,000	$ 10,000	HC estimate based on previous work.
Submittals, Plans, Site Preparation Subtotal				**$ 20,000**	
Installation and Startup					
SVE well installation	1	LS	$ 46,094	46,094	See Table A-16 for backup calculations.
Vapor extraction and treatment system installation	1	LS	$ 48,245	$ 48,245	See Table A-17 for backup calculations.
System startup and testing	17.5%	--	--	$ 16,509	Percentage of SVE installation capital costs. Average percentage of SVE contingency and general bid (EPA 540-R-00-002).
Installation and Startup Subtotal				**$ 110,848**	
Contingency	17.5%	--	--	**$ 22,898**	Percentage of capital costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	8%	--	--	$ 12,300	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	15%	--	--	$ 23,062	EPA 540-R-00-002.
Construction management	10%	--	--	$ 15,375	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 50,736**	
TOTAL CAPITAL COST				**$ 204,483**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Monitoring					
Treatment system operation and maintenance	1	YR	$ 21,120	$ 21,120	See Table A-15 for backup calculations.
Monitoring, sampling, testing, and analysis	1	YR	$ 15,440	$ 15,440	See Table A-18 for backup calculations.
System Operation and Monitoring Subtotal				**$ 36,561**	
Contingency	17.5%	--	--	**$ 6,398**	% of annual costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Professional/Technical Services					
Project management	10%	--	--	$ 4,296	% of sum of annual cost and contingency. EPA 540-R-00-002.
Technical support	15%	--	--	$ 6,444	% of sum of annual cost and contingency. O&M technical support % (EPA 540-R-00-002).
Professional/Technical Services Subtotal				**$ 10,740**	
TOTAL ANNUAL O&M COST				**$ 53,698**	

PERIODIC COSTS

DESCRIPTION	TOTAL	NOTES
Periodic Cost - Years 1 and 2	**$ 29,166**	See Table A-14 for backup calculations.
Periodic Cost - Year 3	**$ 5,186**	
Periodic Cost - Year 4	**$ 10,694**	See Table A-14 for backup calculations.
Periodic Cost - Year 5	**$ 65,507**	See Table A-14 for backup calculations.

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 4

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 204,483	$ 204,483	1.000	$ 204,483	
Annual O&M	1 - 4	$ 214,794	$ 53,698	3.387	$ 181,888	
Periodic	1	$ 29,166	$ 29,166	0.935	$ 27,258	
Periodic	2	$ 29,166	$ 29,166	0.873	$ 25,475	
Periodic	3	$ 5,186	$ 5,186	0.816	$ 4,233	
Periodic	4	$ 10,694	$ 10,694	0.763	$ 8,159	
Periodic	5	$ 65,507	$ 65,507	0.713	$ 46,706	
		$ 558,997			$ 498,202	Net present value of elements unique to Alternative A3.
Total Net Present Value of Alternative A2					$ 15,788,268	
TOTAL NET PRESENT VALUE OF ALTERNATIVE A3					**$ 16,286,470**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table A-5 - Alternative A4a Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative A1 plus excavation and off-site disposal. Alternative A4a assumes an operating period of 30 years in the development of this cost estimate. Elements unique to Alternative A4a are expected to be completed in one year and include only capital costs. Refer to Table A-19 for details.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Soil Excavation and Screening					
Mobilization/demobilization	1	LS	$ 8,000	$ 8,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience. SEPA checklist, etc.
Excavation/stockpile	33,340	CY	$ 11	$ 370,524	2 CY backhoe, 2010 RSMeans 31 23 16.16 6060. Local adjustment factor for Spokane, WA applied (2010 RSMeans p. 696).
Hauling/screening/stockpile	46,676	ton	$ 7	$ 331,630	Cost for previous work provided by Kaiser. Adjusted from 2009 to 2010 basis (2010 RSMeans p. 671).
Acquire, transport, place backfill	38,341	CY	$ 22	$ 835,637	Clean structural fill. Cost for previous work provided by Kaiser.
Soil Excavation and Screening Subtotal				**$ 1,555,792**	
Off-Site Disposal					
Transport & dispose of soil at Subtitle D landfill	30,696	ton	$ 54	$ 1,651,254	Cost for previous work provided by Kaiser. Adjusted from 2009 to 2010 basis (2010 RSMeans p. 671).
Transport & dispose of soil at Subtitle C landfill	1,978	ton	$ 163	$ 322,246	Cost for previous work provided by Kaiser. Adjusted from 2007 to 2010 basis (2010 RSMeans p. 671).
Off-Site Disposal Subtotal				**$ 1,973,500**	
Monitoring, Sampling, Testing, and Analysis (for components not included in A1 or A2)					
Excavation monitoring and sampling	49	WK	$ 5,375	$ 263,395	1 FTE for length of excavation (refer to Table A-22). Includes construction observation, confirmation soil sample collection, dust monitoring.
Analysis of confirmation samples	1	LS	$ 61,905	$ 61,905	Side wall and bottom of excavation samples (analytical costs only). See Table A-19.
Screening sampling and analysis	1	LS	$ 14,900	$ 14,900	Visual inspections of screen/sampling under tears. See Table A-19.
Stockpile sampling and analysis	1	LS	$ 20,495	$ 20,495	Characterization for disposal. See Table A-19.
Data management	5%	--	--	$ 4,865	5% of sampling costs.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 365,560**	
Contingency	10%	--	--	**$ 389,485**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	5%	--	--	$ 214,217	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 342,747	EPA 540-R-00-002.
Construction management	6%	--	--	$ 257,060	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 816,224**	
TOTAL CAPITAL COST				**$ 5,100,560**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL ANNUAL O&M COST				**$ -**	No annual O&M costs for elements unique to Alternative A4a.

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL PERIODIC COSTS				**$ -**	No periodic costs for elements unique to Alternative A4a.

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 5,100,560	$ 5,100,560	1.000	$ 5,100,560	
Annual O&M	1 - 30	$ -	$ -	12.409	$ -	No annual O&M costs for elements unique to Alternative A4a.
Periodic	5	$ -	$ -	0.713	$ -	No periodic costs for elements unique to Alternative A4a.
		$ 5,100,560			$ 5,100,560	Net present value of elements unique to Alternative A4a.
Total Net Present Value of Alternative A1					$ 13,517,936	
TOTAL NET PRESENT VALUE OF ALTERNATIVE A4a					**$ 18,618,496**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table A-6 - Alternative A4b Estimated Cost Summary

Location:	Kaiser Trentwood Facility
	Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative A2 plus excavation and off-site disposal. Alternative A4b assumes an operating period of 30 years in the development of this cost estimate. Elements unique to Alternative A4b are expected to be completed in one year and include only capital costs. Refer to Table A-19 for details.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Soil Excavation and Screening					
Mobilization/demobilization	1	LS	$ 8,000	$ 8,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience. SEPA checklist, etc.
Excavation/stockpile	33,340	CY	$ 11	$ 370,524	2 CY backhoe, 2010 RS Means 31 23 16.16 6060. Local adjustment factor for Spokane, WA, applied (2010 RSMeans p. 696).
Hauling/screening/stockpile	46,676	ton	$ 7	$ 331,630	Cost for previous work provided by Kaiser. Adjusted from 2009 to 2010 basis (2010 RSMeans p. 671).
Acquire, transport, place backfill	38,341	CY	$ 22	$ 835,637	Clean structural fill. Cost for previous work provided by Kaiser.
Soil Excavation and Screening Subtotal				**$ 1,555,792**	
Off-Site Disposal					
Transport & dispose of soil at Subtitle D landfill	30,696	ton	$ 54	$ 1,651,254	Cost for previous work provided by Kaiser (adjusted from 2009 to 2010 basis).
Transport & dispose of soil at Subtitle C landfill	1,978	ton	$ 163	$ 322,246	Cost for previous work provided by Kaiser (adjusted from 2007 to 2010 basis).
Off-Site Disposal Subtotal				**$ 1,973,500**	
Monitoring, Sampling, Testing, and Analysis (for components not included in A1 or A2)					
Excavation monitoring and sampling	49	WK	$ 5,375	$ 263,395	1 FTE for length of excavation (refer to Table A-22). Includes construction observation, confirmation soil sample collection, dust monitoring.
Analysis of confirmation samples	1	LS	$ 61,905	$ 61,905	Sidewall and bottom of excavation samples (analytical costs only). See Table A-19.
Screening sampling and analysis	1	LS	$ 14,900	$ 14,900	Visual inspections of screen/sampling under tears. See Table A-19.
Stockpile sampling and analysis	1	LS	$ 20,495	$ 20,495	Characterization for disposal. See Table A-19.
Data management	5%	--	--	$ 4,865	5% of sampling costs.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 365,560**	
Contingency	10%	--	--	**$ 389,485**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	5%	--	--	$ 214,217	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 342,747	EPA 540-R-00-002.
Construction management	6%	--	--	$ 257,060	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 816,224**	
TOTAL CAPITAL COST				**$ 5,100,560**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL ANNUAL O&M COST				**$ -**	No annual O&M costs for elements unique to Alternative A4b.

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL PERIODIC COSTS				**$ -**	No periodic costs for elements unique to Alternative A4b.

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 5,100,560	$ 5,100,560	1.000	$ 5,100,560	
Annual O&M	1 - 30	$ -	$ -	12.409	$ -	No annual O&M costs for elements unique to Alternative A4b.
Periodic	5	$ -	$ -	0.713	$ -	No periodic costs for elements unique to Alternative A4b.
		$ 5,100,560			$ 5,100,560	Net present value of elements unique to Alternative A4b.
Total Net Present Value of Alternative A1					$ 13,517,936	Net present value of elements unique to Alternative A1.
Total Net Present Value of Alternative A2					$ 2,270,332	Net present value of elements unique to Alternative A2.
TOTAL NET PRESENT VALUE OF ALTERNATIVE A4b					**$ 20,888,828**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table A-7 - Alternative A5a Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative A1 or A2 plus excavation and on-site biotreatment. On-site biotreatment includes a landfarm. Alternative A5a assumes an operating period of 30 years in the development of this cost estimate. Elements unique to Alternative A5a are expected to be complete in 2 years and include capital costs and one year of O&M. Refer to Tables A-19 and A-20 for details.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Soil Excavation and Screening					
Mobilization/demobilization	1	LS	$ 8,000	$ 8,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience. SEPA checklist, etc.
Excavation/stockpile	33,340	CY	$ 11	$ 370,524	2 CY backhoe, 2010 RSMeans 31 23 16.16 6060. Local adjustment factor for Spokane, WA, applied (2010 RSMeans p. 696).
Hauling/screening/stockpile	46,676	ton	$ 7.10	$ 331,630	Cost for previous work provided by Kaiser. Adjusted from 2009 to 2010 basis (2010 RSMeans p. 671).
Acquire, transport, place backfill	38,341	CY	$ 22	$ 835,637	Clean structural fill. Cost for previous work provided by Kaiser.
Soil Excavation and Screening Subtotal				**$ 1,555,792**	
On-Site Biotreatment					
Nutrient amendments	1	LS	$ 72,204	$ 72,204	Ammonium nitrate and tetrapotassium phosphate.
Landfarm construction	1	LS	$ 1,323,387	$ 1,323,387	See Table A-20.
Periodic tilling	1	LS	$ 49,000	$ 49,000	Biweekly tilling for 1 year.
Leachate collection	1	LS	$ 211,596	$ 211,596	See Table A-20.
On-Site Biotreatment Subtotal				**$ 1,656,187**	
Monitoring, Sampling, Testing, and Analysis (for components not included in A1 or A2)					
Excavation monitoring and sampling	49	WK	$ 5,375	$ 263,395	1 FTE for length of excavation (refer to Table A-22). Includes construction observation, confirmation soil sample collection, dust monitoring.
Analysis of confirmation samples	1	LS	$ 61,905	$ 61,905	Side wall and bottom of excavation samples (analytical costs only). See Table A-19.
Screening sampling and analysis	1	LS	$ 14,900	$ 14,900	Visual inspections of screen/sampling under tears. See Table A-19.
Landfarm performance sampling	1	LS	$ 99,880	$ 99,880	See Table A-20.
Data management	5%	--	--	$ 8,834	5% of sampling costs.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 448,914**	
Contingency	20%	--	--	**$ 732,179**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	5%	--	--	$ 219,654	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 351,446	EPA 540-R-00-002.
Construction management	6%	--	--	$ 263,584	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Treatability study	1	LS	$ 50,000	$ 50,000	Engineer's estimate.
Professional/Technical Services Subtotal				**$ 886,884**	
TOTAL CAPITAL COST				**$ 5,279,955**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Monitoring					
Periodic tilling	1	LS	$ 39,000	$ 39,000	See Table A-20 for backup calculations.
Landfarm performance sampling and monitoring	1	LS	$ 99,880	$ 99,880	Performance soil sampling. See Table A-20.
Leachate collection sampling and monitoring	1	LS	$ 33,010	$ 33,010	
Data management	5%	--	--	$ 6,644	
System Operation and Monitoring Subtotal				**$ 178,534**	
Contingency	15%	--	--	**$ 26,780**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					
Project management	10%	--	--	$ 20,531	EPA 540-R-00-002.
Technical support	10%	--	--	$ 20,531	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 43,263**	
TOTAL ANNUAL O&M COST				**$ 248,577**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL PERIODIC COSTS				**$ -**	No periodic costs for elements unique to Alternative A5a.

Table A-7 - Alternative A5a Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative A1 or A2 plus excavation and on-site biotreatment. On-site biotreatment includes a landfarm. Alternative A5a assumes an operating period of 30 years in the development of this cost estimate. Elements unique to Alternative A5a are expected to be complete in 2 years and include capital costs and one year of O&M. Refer to Tables A-19 and A-20 for details.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 1

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 5,279,955	$ 5,279,955	1.000	$ 5,279,955	
Annual O&M	1	$ 248,577	$ 248,577	0.935	$ 232,315	
Periodic	5	$ -	$ -	0.713	$ -	No periodic costs for elements unique to Alternative A5a.
		$ 5,279,955			$ 5,512,270	Net present value of elements unique to Alternative A5a.
Total Net Present Value of Alternative A1					$ 13,517,936	Net present value of elements unique to Alternative A1.
Total Net Present Value of Alternative A2					$ 2,270,332	Net present value of elements unique to Alternative A2.
TOTAL NET PRESENT VALUE OF ALTERNATIVE A5a with A1					**$ 19,030,206**	
TOTAL NET PRESENT VALUE OF ALTERNATIVE A5a with A2					**$ 21,300,538**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table A-8 - Alternative A5b Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative A1 or A2 plus excavation and on-site thermal treatment. Alternative A5b assumes an operating period of 30 years in the development of this cost estimate. Elements unique to Alternative 54b are expected to be completed in one year and include only capital costs. Refer to Tables A-19 and A-21 for details.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Soil Excavation and Screening					
Mobilization/demobilization	1	LS	$ 8,000	$ 8,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience. SEPA checklist, etc.
Excavation/stockpile	33,340	CY	$ 11	$ 370,524	2 CY backhoe, 2010 RSMeans 31 23 16.16 6060. Local adjustment factor for Spokane, WA, applied (2010 RSMeans p. 696).
Hauling/screening/stockpile	46,676	ton	$ 7.10	$ 331,630	Cost for previous work provided by Kaiser. Adjusted from 2009 to 2010 basis (2010 RSMeans p. 671).
Acquire, transport, place backfill	38,341	CY	$ 22	$ 835,637	Clean structural fill. Cost for previous work provided by Kaiser.
Soil Excavation and Screening Subtotal				**$ 1,555,792**	
On-Site Thermal Treatment					
Haul soil to treatment area	23,338	CY	$ 2.02	$ 47,098	See Table A-21.
Thermal desorption treatment	32,673	ton	$ 70	$ 2,287,124	Conservative end of vendor quotation.
Remove, haul soil to final destination	23,338	CY	$ 7.42	$ 173,233	See Table A-21.
On-Site Thermal Treatment Subtotal				**$ 2,287,124**	
Monitoring, Sampling, Testing, and Analysis (for components not included in A1 or A2)					
Excavation monitoring and sampling	49	WK	$ 5,375	$ 263,395	1 FTE for length of excavation (refer to Table A-22). Includes construction observation, confirmation soil sample collection, dust monitoring.
Analysis of confirmation samples	1	LS	$ 61,905	$ 61,905	Side wall and bottom of excavation samples (analytical costs only). See Table A-19.
Screening sampling and analysis	1	LS	$ 14,900	$ 14,900	Visual inspections of screen/sampling under tears. See Table A-19.
Performance monitoring, sampling, and analysis	1	LS	$ 178,880	$ 178,880	Treated soil and emmison sampling. See Table A-21.
Data management	5%	--	--	$ 12,784	5% of sampling costs.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 531,864**	
Contingency	20%	--	--	**$ 874,956**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	5%	--	--	$ 262,487	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 419,979	EPA 540-R-00-002.
Construction management	6%	--	--	$ 314,984	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Treatability study	1	LS	$ 75,000	$ 75,000	Engineer's estimate.
Professional/Technical Services Subtotal				**$ 1,074,650**	
TOTAL CAPITAL COST				**$ 6,324,386**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL ANNUAL O&M COST				**$ -**	No annual O&M costs for elements unique to Alternative A5b.

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL PERIODIC COSTS				**$ -**	No periodic costs for elements unique to Alternative A5b.

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 6,324,386	$ 6,324,386	1.000	$ 6,324,386	
Annual O&M	1 - 30	$ -	$ -	12.409	$ -	No annual O&M costs for elements unique to Alternative A5b.
Periodic	5	$ -	$ -	0.713	$ -	No periodic costs for elements unique to Alternative A5b.
		$ 6,324,386			$ 6,324,386	Net present value of elements unique to Alternative A5b.
Total Net Present Value of Alternative A1					$ 13,517,936	Net present value of elements unique to Alternative A1.
Total Net Present Value of Alternative A2					$ 2,270,332	Net present value of elements unique to Alternative A2.
TOTAL NET PRESENT VALUE OF ALTERNATIVE A5b with A1					**$ 19,842,321**	
TOTAL NET PRESENT VALUE OF ALTERNATIVE A5b with A2					**$ 22,112,654**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table A-9 - Alternative A6 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative A1 or A2 plus excavation and off-site incineration. Alternative A6 assumes an operating period of 30 years in the development of this cost estimate. Elements unique to Alternative A6 are expected to be completed in one year and include only capital costs. Refer to Table A-19 for details.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Soil Excavation and Screening					
Mobilization/demobilization	1	LS	$ 8,000	$ 8,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience. SEPA checklist, etc.
Excavation/stockpile	33,340	CY	$ 11	$ 370,524	2 CY backhoe, 2010 RSMeans 31 23 16.16 6060. Local adjustment factor for Spokane, WA, applied (2010 RSMeans p. 696).
Hauling/screening/stockpile	46,676	ton	$ 7	$ 331,630	Cost for previous work provided by Kaiser. Adjusted from 2009 to 2010 basis (2010 RSMeans p. 671).
Acquire, transport, place backfill	38,341	CY	$ 22	$ 835,637	Clean structural fill. Cost for previous work provided by Kaiser.
Soil Excavation and Screening Subtotal				**$ 1,555,792**	
Off-Site Treatment and Disposal					
Transport	32,673	ton	$ 140	$ 4,574,248	Quote from Clean Harbors. Assume transport to Utah.
Incinerate & dispose of soil	32,673	ton	$ 628	$ 20,518,770	Quote from Clean Harbors.
Off-Site Treatment and Disposal Subtotal				**$ 20,518,770**	
Monitoring, Sampling, Testing, and Analysis (for components not included in A1 or A2)					
Excavation monitoring and sampling	49	WK	$ 5,375	$ 263,395	1 FTE for length of excavation (refer to Table A-22). Includes construction observation, confirmation soil sample collection, dust monitoring.
Analysis of confirmation samples	1	LS	$ 61,905	$ 61,905	Side wall and bottom of excavation samples (analytical costs only). See Table A-19.
Screening sampling and analysis	1	LS	$ 14,900	$ 14,900	Visual inspections of screen/sampling under tears. See Table A-19.
Data management	5%	--	--	$ 3,840	5% of sampling costs.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 344,040**	
Contingency	10%	--	--	**$ 2,241,860**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					
Project management	-	--	--	$ 214,217	Values from Alt. A4, incineration increases overall costs; however, does not require an increase in professional/technical services. See Table A-5.
Remedial design	-	--	--	$ 342,747	Values from Alt. A4, incineration increases overall costs; however, does not require an increase in professional/technical services. See Table A-5.
Construction management	-	--	--	$ 257,060	Values from Alt. A4, incineration increases overall costs; however, does not require an increase in professional/technical services. See Table A-5.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. A1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 816,224**	
TOTAL CAPITAL COST				**$ 25,476,686**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL ANNUAL O&M COST				**$ -**	No annual O&M costs for elements unique to Alternative A6.

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
TOTAL PERIODIC COSTS				**$ -**	No periodic costs for elements unique to Alternative A6.

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 1

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 25,476,686	$ 25,476,686	1.000	$ 25,476,686	
Annual O&M		$ -	$ -	0.935	$ -	No annual O&M costs for elements unique to Alternative A6.
Periodic		$ -	$ -	1.000	$ -	No periodic costs for elements unique to Alternative A6.
		$ 25,476,686			$ 25,476,686	Net present value of elements unique to Alternative A6.
Total Net Present Value of Alternative A1					$ 13,517,936	Net present value of elements unique to Alternative A1.
Total Net Present Value of Alternative A2					$ 2,270,332	Net present value of elements unique to Alternative A2.
TOTAL NET PRESENT VALUE OF ALTERNATIVE A6 with A1					**$ 38,994,621**	
TOTAL NET PRESENT VALUE OF ALTERNATIVE A6 with A2					**$ 41,264,954**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative A1					
Protection & performance monitoring					Protection and performance monitoring costs based on previous project experience.
Labor	1	yr	$ 107,960	$ 107,960	Includes well and equipment maintenance labor. Excludes project management labor.
Equipment, supplies, computer	1	yr	$ 17,480	$ 17,480	Includes well and equipment maintenance.
Travel	1	yr	$ 24,108	$ 24,108	
Sample shipping	1	yr	$ 10,000	$ 10,000	Previous project experience.
Laboratory analysis	1	yr	$ 108,552	$ 108,552	
Subtotal				$ 268,100	
Total qty. of wells sampled	114				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Protection monitoring wells	19				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Performance monitoring wells	95				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Protection monitoring annual total	16.7%	--	--	$ 44,683	Percentage = protection wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Performance monitoring annual total	83.3%	--	--	$ 223,417	Percentage = performance wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Data management	1	yr	$ 29,948	$ 29,948	Data validation; database management.
Reporting	1	yr	$ 16,182	$ 16,182	Report to Kaiser & Ecology quarterly; EIM reporting.

Alternative A1 protection and performance monitoring notes:
- Two 2-person teams plus sample custodian on site during each sample event (5 people total).
- Assumed each sample team can sample 7 wells per day on average.
- Assumed water levels take an entire day with 4 people measuring.
- Assumed 10-hour field days.
- Assumed EIM submittal included for groundwater data plus any additional soil or soil gas data collected during previous 6 months.
- Assumed 2 vehicles for each sampling event.
- Actual well and equipment maintenance costs will depend on upcoming needs.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Monitored Natural Attenuation (MNA) - Periodic Costs					
Total AOC area	82,532 SF				Total area of near-surface soil AOCs, excluding AOCs beneath existing pavement and floor slabs.
Drilling location density	10,000 SF				One location per 10,000 square feet of AOC area.
Drilling locations	8				
Drilling depth	20 ft				
Drilling contractor	160	ft	$ 77	$ 12,299	12 locations to 20-ft depth. Unit cost based on vendor quote. Includes mob/demob, drilling, materials, 8.7% sales tax.
Labor	0.4	WK	$ 5,375	$ 2,150	Assume 2 days HC staff at HC rates. Includes travel. See Table A-22.
Equipment, supplies, computer	2.6%	--	--	$ 460	% of GW monitoring labor. % = (MNA samples/number of wells)/4 quarters per year.
Sample shipping	2.6%	--	--	$ 263	% of GW monitoring labor. % = (MNA samples/number of wells)/4 quarters per year.
Laboratory analysis					
TPH-G - soil	2	samples	$ 60	$ 120	Sample quantity estimate based on 8 sampling locations and relative occurrence of VOCs (TPH-G) and SVOCs (TPH-D, PAHs) in near-surface soil AOCs.
TPH-D - soil	9	samples	$ 60	$ 540	Sample quantity estimate based on 8 sampling locations and relative occurrence of VOCs (TPH-G) and SVOCs (TPH-D, PAHs) in near-surface soil AOCs.
PAHs - soil	1	samples	$ 215	$ 215	Sample quantity estimate based on 8 sampling locations and relative occurrence of VOCs (TPH-G) and SVOCs (TPH-D, PAHs) in near-surface soil AOCs.
Subtotal				$ 16,047	
Project management	10%	--	--	$ 1,605	
Technical support	10%	--	--	$ 1,605	
Total				$ 19,257	
Data management	1	yr	$ 4,500	$ 4,500	Assume work conducted by HC staff at HC rates. See Table A-12.
Reporting	1	yr	$ 7,000	$ 7,000	Assume work conducted by HC staff at HC rates. See Table A-12.

Alternative A1 monitored natural attenuation (MNA) notes:
- Assume monitoring conducted once every five years.
- Assume one exploration per 10,000 sq ft of area per AOC. One sample collected per 10 feet of impacted depth for each analysis (TPH-G, TPH-D, PAHs).
- TPH-G: gasoline-range petroleum hydrocarbons.
- TPH-D: diesel- and heavy oil-range petroleum hydrocarbons.
- PAHs: polycyclic aromatic hydrocarbons.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative A1					
New Institutional Controls					
Pending environmental upgrades at casting complexes					Pending items and approx. costs provided by Kaiser.
Replace melter furnace door jambs	5	locations	$ 20,000	$ 100,000	DC-1, DC-2W, DC-3, DC-8E, DC-8W. Provided by Kaiser, May 23, 2011.
Contain hydraulics/lubrication	1	locations	$ 151,000	$ 151,000	DC-2. Unit cost per Kaiser, April 19, 2010.
Overflow lines to sewer	7	locations	$ 50,000	$ 350,000	DC-2 through DC-8.
Seal DC-7/DC-8 control house sump	1	location	$ 15,000	$ 15,000	Excludes equipment removal cost (approx. $15k). Unit cost per Kaiser, April 19, 2010.
Slip line storm sewers					Pipe lengths from Kaiser storm sewer plan dwg titled: Aluminum
MH 2 to MH 3	133	ft	$ 371	$ 49,386	Works - Trentwood Plant, Storm Sewer - Scheme "O", General
MH 9 to MH 3	280	ft	$ 371	$ 103,971	Arrangement March 8, 1967. Unit cost based on cost of slip lining
MH 3 to MH 5	366	ft	$ 371	$ 135,905	from MH 7B to MH 9 (approx. $120,100 for total length of 390 ft.) in
MH 5 to MH 6	460	ft	$ 371	$ 170,810	2005, adjusted to 2010 dollars (2010 RSMeans p.671).
Subtotal				$ 460,073	
Total				$ 1,076,073	
Preparation of institutional control O&M and monitoring plans					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	60	hr	$ 90	$ 5,400	
Staff	60	hr	$ 75	$ 4,500	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	8	hr	$ 60	$ 480	
Travel	1	ea	$ 566	$ 566	Assume 2-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 15,516	Cost per plan.
Quantity of plans to prepare	3				
Total				$ 46,548	Assume 3 plans in total (e.g., plans for Facility pavement, engineered controls, air emission control system).
Preparation of restrictive covenant					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	40	hr	$ 300	$ 12,000	
Principal	24	hr	$ 180	$ 4,320	
Sr. Project	24	hr	$ 130	$ 3,120	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	16	hr	$ 75	$ 1,200	
Clerical	8	hr	$ 60	$ 480	
Computer	1	ea	$ 250	$ 250	
Total				$ 24,970	
Institutional Controls - Annual Costs					
Environmental upgrades at casting complexes					
Verify pit/sump integrity	9	locations	$ 1,000	$ 9,000	DC-1 through DC-8 plus DC-7/DC-8 control house sump.
Other upgrade maintenance	5%	--	--	$ 53,804	Assume percentage of environmental upgrade capital cost above.
Subtotal				$ 62,804	
Maintenance of physical measures and BMPs					Assume maintenance of signs, fences, gates, access control, existing training programs, waste handling guidance, and BMPs defined in SPCC Plan and SWPPP.
Labor	1920	hr	$ 75	$ 144,000	Assume 1 individual.
Supervisor	480	hr	$ 110	$ 52,800	Assume 25% of labor effort.
Subtotal				$ 196,800	
Total				$ 259,604	
Institutional control O&M and monitoring plans - annual update and maintenance					
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	8	hr	$ 75	$ 600	
Sr. Drafter	4	hr	$ 100	$ 400	
Clerical	2	hr	$ 60	$ 120	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 5,003	Cost per plan.
Quantity of plans to maintain	6				
Total				$ 30,018	Assume 6 plans in total. Includes existing WDR Restoration Monitoring Plan, SPCC Plan, and SWPPP plus institutional control, O&M, and monitoring plans given above.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Site information database - annual update and maintenance					Assume work performed by Hart Crowser staff.
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	24	hr	$ 90	$ 2,160	
Staff	12	hr	$ 75	$ 900	
Clerical	4	hr	$ 60	$ 240	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Total				$ 5,743	
Institutional Controls - Periodic Costs					
Restrictive covenant periodic update and maintenance					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	8	hr	$ 300	$ 2,400	
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	4	hr	$ 130	$ 520	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	4	hr	$ 75	$ 300	
Clerical	2	hr	$ 60	$ 120	
Computer	1	ea	$ 250	$ 250	
Total				$ 6,470	
NPDES Permit and Ecology Order Required Monitoring - Annual Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997), Ecology Agreed Order No. 02WQER-3487 (Ecology 2002), and Ecology Amended Order No. 2868 (Ecology 2005). See Section 2.1.1.1.
NPDES permit - monitoring laboratory analysis					
Sample quantity					Based on weekly sampling frequency.
Outfall 001	104	samples			
Outfall 002	104	samples			
Outfall 003	52	samples			
Plant intake	104	samples			
Laboratory analysis					Unit prices based on laboratory quote.
Outfall 001					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	104	samples	$ 18	$ 1,872	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc, phosphorous.
Cyanide	104	samples	$ 40	$ 4,160	
Hardness	104	samples	$ 25	$ 2,600	
Subtotal				$ 19,032	
Outfall 002					
Oil and grease	260	samples	$ 50	$ 13,000	
TSS	104	samples	$ 18	$ 1,872	
Orthophosphate	104	samples	$ 20	$ 2,080	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, zinc, phosphorous.
Hexavalent chromium	104	samples	$ 50	$ 5,200	
Cyanide	104	samples	$ 40	$ 4,160	
Subtotal				$ 31,512	
Outfall 003					
BOD_5	52	samples	$ 45	$ 2,340	
TSS	52	samples	$ 18	$ 936	
Fecal coliform	52	samples	$ 35	$ 1,820	
Subtotal				$ 5,096	
Plant intake					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	52	samples	$ 18	$ 936	
Total metals	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc.
Subtotal				$ 11,336	
NPDES permit laboratory analysis subtotal				$ 66,976	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Ecology Order - monitoring laboratory analysis					
Sample quantity					Based on biweekly sampling frequency.
Outfall 001	26	samples			
Plant lagoon effluent	26	samples			
Plant lagoon influent	26	samples			
Laboratory analysis					
For 3 locations given above					
PCBs - ultra-low level	78	samples	$ 175	$ 13,650	
Subtotal				$ 13,650	
Ecology Order laboratory analysis subtotal				$ 13,650	
Sampling labor - NPDES permit and Ecology Order required monitoring					
Labor	208	hr	$ 75	$ 15,600	Assume 1 FTE.
Supervisor	52	hr	$ 110	$ 5,720	Assume 0.25 FTE.
Labor subtotal				$ 21,320	
Total Annual Cost				$ 101,946	
NPDES Permit Required Monitoring - Periodic Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997). See Section 2.1.1.1.
Initial acute toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	8	samples	$ 850	$ 6,800	
Daphnid (48-hr static test)	8	samples	$ 700	$ 5,600	
Subtotal				$ 12,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial acute toxicity testing total				$ 16,500	
Final acute toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in years 5, 10, 15, 20, 25, and 30.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	2	samples	$ 850	$ 1,700	
Daphnid (48-hr static test)	2	samples	$ 700	$ 1,400	
Subtotal				$ 3,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final acute toxicity testing total				$ 5,970	
Initial chronic toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	8	samples	$ 1,575	$ 12,600	
Water flea (7-day, full dilution test)	8	samples	$ 1,475	$ 11,800	
Subtotal				$ 24,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial chronic toxicity testing total				$ 28,500	

Table A-11 - Institutional Controls Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Final chronic toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in years 5, 10, 15, 20, 25, and 30.
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	2	samples	$ 1,575	$ 3,150	
Water flea (7-day, full dilution test)	2	samples	$ 1,475	$ 2,950	
Subtotal				$ 6,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final chronic toxicity testing total				$ 8,970	

Table A-12 - Professional Services Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative A1 - Periodic Costs					
Five-year review periodic cost					Assume work performed by Hart Crowser staff. Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Ecology oversight	1	ls	$ 7,500	$ 7,500	
Principal	16	hr	$ 180	$ 2,880	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	40	hr	$ 75	$ 3,000	
Clerical	8	hr	$ 60	$ 480	
Total				$ 19,540	
Closure report periodic cost					Assume work performed by Hart Crowser staff. Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Ecology oversight	1	ls	$ 7,500	$ 7,500	
Principal	40	hr	$ 180	$ 7,200	
Sr. Project	80	hr	$ 130	$ 10,400	
Sr. Staff	80	hr	$ 90	$ 7,200	
Staff	80	hr	$ 75	$ 6,000	
Sr. Drafter	24	hr	$ 100	$ 2,400	
Clerical	8	hr	$ 60	$ 480	
Total				$ 41,180	
MNA - data management periodic cost					Assume work performed by Hart Crowser staff.
Principal	2	hr	$ 180	$ 360	
Sr. Associate	4	hr	$ 160	$ 640	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	12	hr	$ 75	$ 900	
Clerical	2	hr	$ 60	$ 120	
Total				$ 4,500	
MNA - reporting periodic cost					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Associate	2	hr	$ 160	$ 320	
Sr. Project	12	hr	$ 130	$ 1,560	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	16	hr	$ 75	$ 1,200	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	4	hr	$ 60	$ 240	
Total				$ 7,000	
Alternative A2 - Annual Costs					
Containment monitoring - data management					Assume work performed by Hart Crowser staff.
Principal	2	hr	$ 180	$ 360	
Sr. Associate	4	hr	$ 160	$ 640	
Sr. Project	4	hr	$ 130	$ 520	
Sr. Staff	12	hr	$ 90	$ 1,080	
Staff	12	hr	$ 75	$ 900	
Clerical	2	hr	$ 60	$ 120	
Total				$ 3,620	
Containment monitoring - reporting					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Associate	2	hr	$ 160	$ 320	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	12	hr	$ 90	$ 1,080	
Staff	12	hr	$ 75	$ 900	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	4	hr	$ 60	$ 240	
Total				$ 5,820	
Alternative A2 - Periodic Costs					
Five-year reviews	50%	--	--	$ 9,770	Assume 50% of Alt. A1 five-year review cost to include containment system.
Closure report	50%	--	--	$ 20,590	Assume 50% of Alt. A1 remedial action report cost to include containment system.

Table A-13 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative A2					
Total area to be capped	82,692	SF			Total excludes Hoffman Tank area multi-layer cap extension. See Section 2.1.2.1.
Multi-layer cap area	21,903	SF			FCT, WDR, and SDR areas.
Asphalt cap area	51,671	SF			Assume 85% of net remaing area to be asphalt capped (total area minus multi-layer cap area).
Concrete cap area	9,118	SF			Assume 15% of net remaing area to be concrete capped (total area minus multi-layer cap area).
Hoffman Tank area multi-layer cap extension	1,782	SF			Extension of existing multi-layer cap (see Section 2.1.2.1). Assumes dimensions of 22 ft x 81 ft.
Sales tax	8.7%				Effective rate for Spokane Valley, WA, 4/1/10 to 6/30/10. See http://dor.wa.gov/Docs/forms/ExcsTx/LocSalUseTx/LocalSlsUseFlyer_10_Q2_alpha.pdf.
RSMeans location adjustment factor	0.93				Cost adjustment factor for Spokane, WA (2010 RSMeans p. 696). Applied to estimated costs originating from RSMeans cost guide.
Asphalt Capping					
Asphalt cap material quantities					
Compaction ratio	75%				Assume 75%.
Aggregate base course compacted thickness	3	in			
Asphalt base layer compacted thickness	2	in			
Asphalt intermediate layer compacted thickness	2	in			
Asphalt wearing layer compacted thickness	2	in			
Aggregate base course volume (loose)	638	LCY			LCY = loose cubic yards
Asphalt volume (loose)	1,276	LCY			
Railroad track length	402	LF			For railroad track removal.
Railroad ballast depth	1	ft			
Railroad ballast width	6	ft			
Railroad ballast volume	89	CY			
Asphalt cap installation					
Mob/demob	1	LS	$ 4,053	$ 4,053	Previous project experience. Adjusted from 2008 to 2010 basis (2010 RSMeans p. 671).
Railroad track removal					
Ties and track	402	LF	$ 10.93	$ 4,393	2010 RSMeans 02 41 13.33 3500.
Ballast	89	CY	$ 5.44	$ 486	2010 RSMeans 02 41 13.33 3600.
Subgrade preparation	5,741	SY	$ 1.75	$ 10,038	Prepare and roll. 2010 RSMeans 32 11 23.23 7000.
Paving materials hauling	1,914	LCY	$ 4.64	$ 8,881	12 CY trucks, 25 MPH ave., cycle 4 mi. 2010 RSMeans 31 23 23.20 1040.
Aggregate base course	5,741	SY	$ 4.61	$ 26,483	Crushed 3/4-in. stone, compacted, 3 in. deep. 2010 RSMeans 32 11 23.23 0050.
Asphalt base layer	5,741	SY	$ 8.37	$ 48,054	Binder course, 2-in. thick. 2010 RSMeans 32 12 16.13 0120.
Asphalt intermediate layer	5,741	SY	$ 8.37	$ 48,054	Binder course, 2-in. thick. 2010 RSMeans 32 12 16.13 0120.
Asphalt wearing layer	5,741	SY	$ 9.35	$ 53,660	Wearing course, 2-in. thick. 2010 RSMeans 32 12 16.13 0380.
Sealing	5,741	SY	$ 1.64	$ 9,397	Tack coat, emulsion 0.10 gal. per SY. 2010 RSMeans 32 01 13.62 3270.
Sales tax	8.7%	--	--	$ 12,208	Assume sales tax charged on cost of materials.
Subtotal				$ 225,706	
Cap installation quality control	10%	--	--	$ 22,571	Assume QC conducted to ensure appropriate impermeability.
Total				$ 248,276	
Total unit cost		SY	$ 43.24		
Concrete Capping					
Concrete cap material quantities					
Compaction ratio	75%				Assume 75%.
Aggregate base course compacted thickness	3	in			
Concrete thickness	6	in			
Aggregate base course volume (loose)	113	LCY			LCY = loose cubic yards
Concrete volume	169	CY			
Concrete paving pass length	24	LF			

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Concrete cap installation					
Mob/demob	1	LS	$ 4,053	$ 4,053	Previous project experience. Adjusted from 2008 to 2010 basis (2010 RSMeans p. 671).
Subgrade preparation	1,013	SY	$ 1.75	$ 1,771	Prepare and roll area. 2010 RSMeans 32 11 23.23 7000.
Base course material hauling	113	LCY	$ 4.64	$ 522	12 CY trucks, 25 MPH ave., cycle 4 mi. 2010 RSMeans 31 23 23.20 1040.
Aggregate base course	1,013	SY	$ 4.61	$ 4,673	Crushed 3/4-in. stone, compacted, 3 in. deep. 2010 RSMeans 32 11 23.23 0050.
Reinforcing steel for rigid paving	1,013	SY	$ 6.84	$ 6,925	12 lbs/SY. 2010 RSMeans 32 13 13.23 0530.
Dowels	951	EA	$ 2.94	$ 2,794	2 ft long, deformed, #4. 1-ft spacing. 2010 RSMeans 03 21 10.60 2410.
Concrete delivery	169	CY	$ 102	$ 17,274	Normal weight concrete, ready mix, 3,500 psi. Includes local aggregate, sand, Portland cement, and water. 2010 RSMeans 03 31 05.35 0200.
Concrete paving	1,013	SY	$ 21	$ 21,671	Includes joints, finishing, curing. Fixed form, 24-ft pass, 6-in thickness. 2010 RSMeans 32 13 13.23 0410.
Water stops	951	LF	$ 6.88	$ 6,544	PVC, ribbed, w/ center bulb, 6 in. wide, 3/8 in. thick. 2010 RSMeans 03 15 13.50 0550.
Joint filler	951	LF	$ 2.45	$ 2,326	Butyl rubber filler, 1/2 x 1/2 in. 2010 RSMeans 07 91 26.10 4365.
Joint seal	951	LF	$ 1.30	$ 1,238	Silicone, room temp vulcanizing foam seal, 1/2 x 1/2 in. 2010 RSMeans 07 91 26.10 5610.
Sales tax	8.7%	--	--	$ 4,021	Assume sales tax charged on cost of materials.
Subtotal				$ 73,814	
Cap installation quality control	10%	--	--	$ 7,381	Assume QC conducted to ensure appropriate impermeability.
Total				$ 81,195	
Total unit cost		SY	$ 80.14		

Multi-Layer Capping

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Multi-layer cap material quantities					
Compaction ratio	75%				Assume 75%.
Aggregate base course compacted thickness	3	in			
Intermediate layer thickness	12	in			
Top layer thickness	12	in			
Excavation depth	27	in			
Excavation volume	1,825	BCY			BCY = bank cubic yards
Aggregate base course volume	270	LCY			LCY = loose cubic yards
Intermediate layer volume	811	LCY			Assume not compacted.
Top layer volume	811	LCY			Assume not compacted.
Multi-layer cap installation					
Mob/demob	1	LS	$ 4,053	$ 4,053	Previous project experience. Adjusted from 2008 to 2010 basis (2010 RSMeans p. 671).
Clear and grub land	0.26	acre	$ 6,254	$ 1,647	In WDR and SDR areas only. Clear and grub brush including stumps. 2010 RSMeans 31 11 10.10 0160.
Earthwork					
Excavator	1,825	BCY	$ 2.69	$ 4,916	Excavator, hydraulic, crawler mounted, 2 CY capacity. For heavy soil added 60%. 2010 RSMeans 31 23 16.42 0260.
Bulldozer	1,825	BCY	$ 2.49	$ 4,549	300 HP, 150-ft haul, sand & gravel. 2010 RSMeans 31 23 16.46 5200.
Stockpiling	15%	--	--	$ 737	Add 15% of excavator cost. 2010 RSMeans 31 23 16.42 0011-0020.
Finish grading	2,434	SY	$ 2.35	$ 5,726	Grade subgrade for base course, small irregular areas. 2010 RSMeans 31 22 16.10 1050.
Cap material hauling	1,082	LCY	$ 4.64	$ 5,020	12 CY trucks, 25 MPH ave., cycle 4 mi. 2010 RSMeans 31 23 23.20 1040. Assume reuse of native material for top layer.
Aggregate base course	2,434	SY	$ 4.61	$ 11,226	Crushed 3/4-in. stone, compacted, 3 in. deep. 2010 RSMeans 32 11 23.23 0050.
Liner	21,903	SF	$ 1.39	$ 30,351	PVC, 80-mil liner. 2010 RSMeans 02 56 13.10 0620.
Intermediate layer	811	LCY	$ 49	$ 39,985	Bank sand. Ballast cover w/ common borrow material. 2010 RSMeans 02 56 13.10 1120.
Top layer	811	LCY	$ 40	$ 32,290	Assume reuse of native material. 2010 RSMeans 02 56 13.10 1110, excluding material cost.
Seeding	2,434	SY	$ 0.47	$ 1,132	Mechanical seeding, 44 lb. per 1,000 SY. 2010 RSMeans 32 92 19.13 0100.
Water drainage and collection system	64	LF	$ 8.34	$ 535	Assume similar to foundation underdrain system. 4-in diam. perf. PVC pipe. Pipe bedding, graded gravel 3/4 to 1/2 in. 2010 RSMeans assembly A1010 310 1000.
Sales tax	8.7%	--	--	$ 2,835	Assume sales tax charged on cost of materials.
Subtotal				$ 145,001	
Cap installation quality control	10%	--	--	$ 14,500	
Total				$ 159,501	
Total unit cost		SY	$ 65.54		

Table A-13 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Hoffman Tank Area Multi-Layer Cap Extension					
Multi-layer cap material quantities					
Compaction ratio	75%				Assume 75%.
Aggregate base course compacted thickness	3	in			
Intermediate layer thickness	12	in			
Top layer thickness	12	in			
Excavation depth	27	in			
Excavation volume	149	BCY			BCY = bank cubic yards
Aggregate base course volume	22	LCY			LCY = loose cubic yards
Intermediate layer volume	66	LCY			Assume not compacted.
Top layer volume	66	LCY			Assume not compacted.
AST secondary containment length	39	ft			
AST secondary containment width	15	ft			
AST secondary containment height	4	ft			Wall height varies; estimated average height used.
AST secondary containment thickness	6	in			Assume 6-in slab and wall thickness.
AST secondary containment concrete volume	19	CY			
Multi-layer cap installation					
Mob/demob	1	LS	$ 4,053	$ 4,053	Previous project experience. Adjusted from 2008 to 2010 basis (2010 RSMeans p. 671).
Temporary relocation of surface structures					
Remove steam line	90	LF	$ 3.40	$ 306	Steel pipe w/ insulation, 3/4 in. to 4 in. 2010 RSMeans 02 41 13.46 0100.
Relocate AST	1	day	$ 1,535	$ 1,535	Move AST for cap installation; return AST to original location after installation. Temporary crane, 25-ton. 2010 RSMeans 01 54 19.50 0200.
Remove secondary containment	19	CY	$ 134	$ 2,522	Concrete demolition, average reinforcing. 2010 RSMeans 03 05 05.10 0060.
Reconstruct secondary containment	19	CY	$ 173	$ 3,258	Slab on grade (3,500 psi), not including finish, 6-in thickness. 2010 RSMeans 03 30 53.40 4700.
Replace steam line	90	LF	$ 36	$ 3,222	2-in diam. black steel pipe w/ 2-in insulation, align & tackweld on sleepers. 2010 RSMeans 33 61 13.10 1030.
Earthwork					
Excavator	149	BCY	$ 2.69	$ 400	Excavator, hydraulic, crawler mounted, 2 CY capacity. For heavy soil added 60%. 2010 RSMeans 31 23 16.42 0260.
Bulldozer	149	BCY	$ 2.49	$ 370	300 HP, 150-ft haul, sand & gravel. 2010 RSMeans 31 23 16.46 5200.
Stockpiling	15%	--	--	$ 60	Add 15% of excavator cost. 2010 RSMeans 31 23 16.42 0011-0020.
Finish grading	198	SY	$ 2.35	$ 466	Grade subgrade for base course, small irregular areas. 2010 RSMeans 31 22 16.10 1050.
Cap material hauling	88	LCY	$ 4.64	$ 408	12 CY trucks, 25 MPH ave., cycle 4 mi. 2010 RSMeans 31 23 23.20 1040. Assume reuse of native material for top layer.
Aggregate base course	198	SY	$ 4.61	$ 913	Crushed 3/4-in. stone, compacted, 3 in. deep. 2010 RSMeans 32 11 23.23 0050.
Liner	1,782	SF	$ 1.39	$ 2,469	PVC, 80-mil liner. 2010 RSMeans 02 56 13.10 0620.
Intermediate layer	66	LCY	$ 49	$ 3,253	Bank sand. Ballast cover w/ common borrow material. 2010 RSMeans 02 56 13.10 1120.
Top layer	66	LCY	$ 40	$ 2,627	Assume reuse of native material. 2010 RSMeans 02 56 13.10 1110, excluding material cost.
Seeding	198	SY	$ 0.47	$ 92	Mechanical seeding, 44 lb. per 1,000 SY. 2010 RSMeans 32 92 19.13 0100.
Water drainage and collection system	18	LF	$ 8.34	$ 152	Assume similar to foundation underdrain system. 4-in diam. perf. PVC pipe. Pipe bedding, graded gravel 3/4 to 1/2 in. 2010 RSMeans assembly A1010 310 1000.
Sales tax	8.7%	--	--	$ 626	Assume sales tax charged on cost of materials.
Subtotal				$ 26,734	
Cap installation quality control	10%	--	--	$ 2,673	
Total				$ 29,408	
Total unit cost		SY	$ 148.52		
Containment Operation, Maintenance, and Monitoring					
Cap annual sampling and laboratory analysis					
Drilling contractor	87.5%	--	--	$ 10,762	Use % of MNA drilling contractor cost (see monitoring backup worksheet). % = cap sampling locations/MNA sampling locations.
Labor	0.6	WK	$ 5,375	$ 3,225	Assume 3 days HC staff at HC rates. Includes travel. See Table A-22.
Equipment, supplies	87.5%	--	--	$ 403	Use % of MNA equipment & supplies cost (see monitoring backup worksheet). % = cap sampling locations/MNA sampling locations.
Sample shipping	87.5%	--	--	$ 230	Use % of MNA sample shipping cost (see monitoring backup worksheet). % = cap sampling locations/MNA sampling locations.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Laboratory analysis					
Sampling density	10,000	SF			Asphalt and concrete caps only.
Permeability	7	samples	$ 100	$ 700	ASTM Method D 5084. Assume 1 sample per 10,000 SF. Unit cost is engineer's estimate.
Subtotal				$ 15,320	
Data management	1	yr	$ 3,620	$ 3,620	Assume work conducted by HC staff at HC rates. See Table A-12.
Reporting	1	yr	$ 5,820	$ 5,820	Assume work conducted by HC staff at HC rates. See Table A-12.

Table A-14 - SVE Periodic Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Periodic Costs - Years 1 and 2					
Carbon changeout, transport and regeneration	1	ea	$ 5,580	$ 5,580	Includes replacement, removal, regeneration, and labor for carbon changeout for one 2,000-lb bed. Based on vendor quote for existing HC project. Price adjusted per 2010 RSMeans cost index. Assume to occur at end of year.
Mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization based on previous Kaiser vendor cost estimate. Cost accounts for moving of treatment unit. Assume to occur at end of year.
HC oversight	0.6	wk	$ 5,375	$ 3,225	Assume 3 days of oversight for treatment system move. See Table A-22 for backup calculation.
Startup performance monitoring	1	LS	$ 5,186	$ 5,186	See Table A-18 for backup calculations.
Confirmational air sampling	1	LS	$ 5,694	$ 5,694	See Table A-18 for backup calculations.
Contingency	17.5%	--	--	$ 3,620	Percentage of capital costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Project management	10%	--	--	$ 2,431	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 2,431	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Costs - Years 1 and 2				**$ 29,166**	
Periodic Costs - Year 3					
Startup performance monitoring	1	LS	$ 5,186	$ 5,186	See Table A-18 for backup calculations.
Periodic Costs - Year 3				**$ 5,186**	
Periodic Costs - Year 4					
Equipment and appurtenances repair/replacement	1	LS	$ 5,000	$ 5,000	Cost of blower. Price obtained from vendor.
Confirmational air sampling	--	--	--	$ 5,694	See Table A-18 for backup calculations.
Periodic Costs - Year 4				**$ 10,694**	
Demobilization of Treatment System/Professional and Technical Services - Year 5					
Contractor mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization based on previous Kaiser vendor cost estimate.
Carbon transport and regeneration	1	ea	$ 2,790	$ 2,790	Assume 50% of carbon changeout, transport, and regeneration cost.
Treatment unit shipping	1	LS	$ 2,000	$ 2,000	Shipping treatment system from the Facility. Assume same cost as shipping to Facility. Price obtained from SVE vendor.
Piping demolition	385	ft	$ 3.87	$ 1,490	2-in steel piping demolition cost from 2010 RSMeans 22 05 05.10 2050. Location factor adjustment for Spokane, WA, 2010 RSMeans, p. 696.
Well abandonment	--	--	--	$ 12,680	See Table A-16 for backup calculations.
Soil sampling	--	--	--	$ 26,499	See Table A-18 for backup calculations.
Contingency	17.5%			$ 8,130	Percentage of capital costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Project management	10%			$ 5,459	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical support	10%			$ 5,459	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Cost - Year 5				**$ 65,507**	

Table A-15 - SVE Treatment System Annual Operation and Maintenance Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Treatment System Operation and Maintenance					
Maintenance labor	50	hr	$ 110	$ 5,500	Assume 5 days of HC project level staff.
Equipment maintenance	1	LS	$ 2,000	$ 2,000	Based on previous HC estimate.
Spare parts and supplies	1	LS	$ 1,000	$ 1,000	Assume 50% of equipment maintenance.
Equipment rental	12	mo	$ 1,000	$ 12,000	600-SCFM blower, moisture separator, vessels for 2 x 2,000-lb GAC beds, process control, sensors & instrumentation, system enclosure per SVE vendor estimate.
Utilities	13,140	kWh	$ 0.05	$ 620	Based on 1.5 kW demand (600-SCFM motor, 6-8 in mmHg [All-Star RB9 Series]), continuous operation. Cost of electricity based on estimate provided by Kaiser.
Treatment System Operation and Maintenance Subtotal				**$ 21,120**	

Table A-16 - SVE Well Installation and Well Abandonment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Drilling - well installation	380	ft	$ 77	$ 29,260	19 locations to 20-ft depth. Unit cost based on Kaiser vendor previous cost estimate. Includes mob/demob, drilling, materials, 8.7% sales tax.
2-in Well Materials					Prices for well materials based on Kaiser vendor previous cost estimate. Costs adjusted from 2009 to 2010 dollars with 2010 RSMeans historical cost index adjustment (2010 RSMeans p. 671).
SCH 40 PVC screen 2-in diam. x 10 ft, .020 in	166	ft	$ 5.45	$ 905	In ORB area there are 16 x 2-in wells with screen interval 5-15 feet bgs. In Oil House area there are 3 x 2-in wells with screen interval 18-20 feet bgs.
SCH 40 PVC 2-in diam. x 10 ft	214	ft	$ 3.54	$ 758	See note above.
SCH 40 ends 2-in diam.	19	ea	$ 14	$ 259	
Flush monument 8-in	19	ea	$ 237	$ 4,503	8-in monument.
Sand	120	bag	$ 19	$ 2,243	Quote for number of bags provided by Kaiser vendor.
Drums	15	ea	$ 86	$ 1,288	Quote for number of drums provided by Kaiser vendor.
Bentonite	35	bag	$ 15	$ 512	Estimated number of bags based on previous Kaiser vendor cost estimate.
Well permits - WA	19	ea	$ 76	$ 1,439	
2-in Well Materials Subtotal				**$ 11,907**	
Additional Costs for Well Installation					
Transport & dispose of soil at Subtitle D landfill	5.7	ton	$ 54	$ 308	Cost for disposal based on previous Kaiser work and adjusted using 2010 RSMeans historical cost index. Based on cost of 15 drums for disposal. Number of drums generated based on estimate from Kaiser vendor.
HC oversight	0.8	wk	$ 5,375	$ 4,300	For logging well information and protection monitoring. See Table A-16 for backup calculations.
Equipment rental	4	day	$ 80	$ 320	HC equipment cost.
Additional Costs for Well Installation Subtotal				**$ 4,928**	
SVE Well Installation Subtotal				**$ 46,094**	
Well Abandonment					
Ecology filing	19	per well	$ 65	$ 1,235	
Labor	76	hr	$ 110	$ 8,360	4 hrs/well per HC estimate. Assume HC project level staff.
Bentonite chips	19	per well	$ 39	$ 741	3 bags at $13 per HC estimate.
Truck 1/2 day	8	day	$ 85	$ 680	
Additional mileage cost				$ 300	See Table A-22 for backup calculations.
Per diem	8	day	$ 133	$ 1,064	
Trip per diem	2	ea	$ 150	$ 300	See Table A-22 for backup calculations.
Well Abandonment Subtotal				**$ 12,680**	

Table A-17 - Vapor Extraction and Treatment System Installation Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Treatment System Installation					
Contractor mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization (based on previous cost estimate from Kaiser vendor).
Treatment unit shipping	1	LS	$ 2,000	$ 2,000	Shipping treatment unit to the Facility. Based on SVE vendor cost estimate.
Piping conveyance installation	1	LS	$ 15,890	$ 15,890	See SVE conveyance backup calculation below.
Pipe trenching	1	LS	$ 4,980	$ 4,980	See pipe trenching backup calculation below.
Carbon	1	LS	$ 4,000	$ 4,000	For 2 x 2,000-lb. beds. Cost from SVE vendor.
HC oversight	1	wk	$ 5,375	$ 5,375	Assume 1 week of HC oversight during installation of SVE treatment systemt. See Table A-22 for backup calculations.
Power hookup	3	ea	$ 5,000	$ 15,000	Power hookup cost provided by vendor.
Treatment System Installation Subtotal				**$ 48,245**	
SVE Piping Conveyance					
Contractor mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization based on previous cost estimate from Kaiser vendor.
2-in SCH 40 PVC piping - wells	285	ft	$ 8.51	$ 2,425	Assume 20 ft per well. Pipe cost from 2010 RSMeans 22 11 13.74 4216. Subtract cost of coupling and clevis hanger assembly 2010 RSMeans 22 11 13.74 4530. Location factor adjustment for Spokane, WA, 2010 RSMeans, p. 696.
2-in SCH 40 PVC piping - header	100	ft	$ 8.51	$ 851	Distance between AOCs and proposed treatment unit as shown on Figures 2-11 and 2-12. Pipe cost from 2010 RSMeans 22 11 13.74 4216. Subtract cost of coupling and clevis hanger assembly 2010 RSMeans 22 11 13.74 4530. Location factor adjustment for Spokane, WA, 2010 RSMeans, p. 696.
2-in SCH 40 coupling	39	ea	$ 47	$ 1,814	Assume per 10 feet of piping, 2010 RSMeans 22 11 13.76 0410. Location factor adjustment for Spokane, WA, 2010 RSMeans, p. 696.
2-in SCH 40 90 degree elbows	19	ea	$ 115	$ 2,191	Assume 1 per well, 2010 RSMeans 22 11 13.76 0090. Location factor adjustment for Spokane, WA, 2010 RSMeans, p. 696.
2-in SCH 40 tee	19	ea	$ 99	$ 1,873	Assume 1 per well, 2010 RSMeans 22 11 13.76 0290. Location factor adjustment for Spokane, WA, 2010 RSMeans, p. 696.
2-in SCH 40 ball valve	19	ea	$ 115	$ 2,191	Assume 1 per well. Assume same cost as 90-degree elbow.
2-in SCH 40 pressure gage	19	ea	$ 115	$ 2,191	Assume 1 per well. Assume same cost as 90-degree elbow.
Extra piping, fittings	10%			$ 1,354	Assume 10% of materials and labor listed above.
SVE Piping Conveyance Subtotal				**$ 15,890**	

Pipe Trenching

Quantities for Trench Excavation

Description	**QTY**	**Unit**	**Comments**
Length of pipe	385	ft	
Width of trench	1.5	ft	
Depth of trench	3	ft	Assume 4 ft bgs for utilities. Do not want to disturb other utilities
Base course thickness	6	in	Assumed
Asphalt thickness	4	in	Assumed
Pipe bedding thickness (crushed rock)	12	in	assumed
Backfill thickness	1.17	ft	assume using excavated materials
Fraction soil reused as backfill	39%		
Volume of soil around per vault (2x2x3 ft)	12	cf	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Removal of pavement	64	SY	$ 7.91	$ 507	2010 RSMeans 02 41 13.17 5050 with location factor correction. 4 to 6-in-thick pavement.
Trenching	68	BCY	$ 7.30	$ 498	2010 RSMeans 31 23 16.13 6050 with location factor correction. Sand & gravel with no sheeting or dewatering included, 1 to 4 ft deep, 3/8 CY excavator.
Pipe bedding	28	LCY	$ 36	$ 1,020	2010 RSMeans 31 23 23.16 0049 with location factor correction. Utility bedding for pipe & conduit not included. Compaction, crushed or screened bank run gravel. Assume 75% compaction ratio.
Pipe bedding compaction	21	ECY	$ 4.61	$ 99	2010 RSMeans 31 23 23.16 0050 with location factor correction. Compacting bedding in trench.
Backfilling	29	LCY	$ 2.36	$ 68	2010 RSMeans 31 23 16.13 3000 with location factor correction. Backfill trench, F.E. loader, wheel mtd., 1 CY bucket, minimal haul. Assume 15% bulking factor.
Backfilling compaction	25	ECY	$ 4.70	$ 117	2010 RSMeans 31 23 23.13 0600 with location factor correction. Compaction in 6-in layers, vibrating plate.
Base course	64	SY	$ 5.02	$ 322	2010 RSMeans 32 11 23.23 0350 with location factor correction. Bank run gravel, spread and compacted, 6 in deep.
Repaving roadway	64	SY	$ 17	$ 1,062	2010 RSMeans 32 11 26.13 0500 with location factor correction. Roadways and large paved areas. Bitumous concrete, 4-in thick.
Soil disposal	24	ton	$ 54	$ 1,287	Cost for disposal based on previous Kaiser work and adjusted using 2010 RSMeans historical cost index. Assume 25% of soil excavated for trench will be disposed of.
Pipe Trenching Subtotal				**$4,980**	

	Labor Hours			Cost in Dollars					
	Principal	Senior Project	Senior Staff	Labor Subtotal	Travel Expense (includes per diem)	Equipment & Supplies	Lab Analysis + Shipping	Subcontractor	Task Subtotal
Startup System Performance (1st 2 weeks of operation)									
Daily system monitoring	2	4	28	$ 3,560					
Weekly vapor monitoring	2	2	8	$ 1,400		$ 180			
Startup Subtotal	**4**	**6**	**36**	**$ 4,960**		**$ 180**			**$ 5,186**
Annual Performance Monitoring									
Monthly system monitoring visits for one year	12	24	24	$ 7,680					
Quarterly vapor monitoring	4	8	18	$ 3,510		$ 2,760	$ 1,490		
Annual Performance Monitoring Subtotal	**16**	**32**	**42**	**$ 11,190**		**$ 2,760**	**$ 1,490**		**$ 15,440**
Confirmational Sampling									
Vapor monitoring - before treatment unit is moved	3	6	13.5	$ 2,633		$ 1,944	$ 1,118		**$ 5,694**
Soil confirmational sampling	2	4	27	$ 3,465	$ 1,254		$ 1,794	$ 19,986	**$ 26,499**
Confirmational Sampling Subtotal	**5**	**10**	**40.5**	**$ 6,098**	**$ 1,254**	**$ 1,944**	**$ 2,912**	**$ 19,986**	**$ 32,194**
Labor rates	$ 190	$ 130	$ 95						

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Startup Equipment Costs					
Colormetric tubes	16	ea	$ 10	$ 160	HC equipment costs. Conservatively assumed measuring for benzene and toluene.
Hand pump	2	day	$ 10	$ 20	HC equipment costs.
Startup Equipment Costs Subtotal				**$ 180**	
Annual Equipment and Laboratory Costs					
Colormetric tubes	264	ea	$ 10	$ 2,640	HC equipment costs. Conservatively assumed measuring for benzene and toluene.
Hand pump	12	day	$ 10	$ 120	HC equipment costs.
BTEX analysis for Summa cannister samples	4	ea	$ 324	$ 1,296	Based on previous HC estimate from 2007. Cost adjusted using historical cost index from 2010 RSMeans p. 671.
Sample shipping	15%	--	--	$ 194	Assumed percentage of sample analysis cost for Summa cannister samples.
Annual Equipment and Laboratory Costs Subtotal				**$ 4,056**	
Air Confirmational Sampling					Verification that point of diminishing returns has been reached.
BTEX analysis for summa cannisters	3	ea	$ 324	$ 972	Based on previous HC estimate from 2007. Cost adjusted using historical cost index from 2010 RSMeans p. 671.
Sample shipping	15%	--	--	$ 146	
Air Confirmational Sampling Subtotal				**$ 972**	
Soil Confirmational Sampling					
Drilling contractor	260	ft	$ 77	$ 19,986	13 locations to 20-ft depth. Unit cost based on Kaiser vendor previous cost estimate. Includes mob/demob, drilling, materials, 8.7% sales tax.
Laboratory analysis	26	samples	$ 60	$ 1,560	TPH-G - soil.
Sample shipping	15%	--	--	$ 234	Assumed percentage of sample analysis cost.
Soil Confirmational Sampling Subtotal				**$ 21,546**	

Table A-19 - Excavation and Screening Cost Backup

Excavation

Locations	21	AOCs	
Area	75,471	SF	
Depth	various		See FSTM.
Volume	33,340	CY	Volume does not account for side slopes.
Overburden volume	5,863	CY	Volume does not account for side slopes.
Bulking factor	1.15	CY/CY	
Volume to haul	38,341	CY	Haul to screening area.
Bulk density	1.4	ton/CY	
Bulk mass	46,676	ton	

Screening

Gross volume excavated	33,340	CY	
Screening efficiency	70%		
Net volume	23,338	CY	
Bulk density	1.4	ton/CY	
Bulk mass	32,673	ton	

Disposal

Subtitle C percentage	6%		2018 CY of lead in MMD
Subtitle D percentage	94%		
Mass to dispose	32,673	ton	Post screening.
Subtitle C mass	1,978	ton	
Subtitle D mass	30,696	ton	

Excavation Oversight

Total excavated volume	39,203	CY	
Daily output for excation	160	CY/day	2 CY backhoe, 2010 RSMeans 31 23 16.16 6060.
Duration of excavation	245	days	Output decreased 20% to account for coordination and excavated 21 unique areas.
Duration of excavation	49	weeks	

Analysis of Confirmational Samples from Excavations

Assume labor for sampling is part of excavation oversight.

Bottom samples	302	samples	1 sample/ 250 sq ft.
Side wall samples	84	samples	Minimum 4 samples/excavation area.

	quantity	unit	unit cost	total	notes
Equipment/shipping	1	LS	$ 10,000	$ 10,000	Engineer's estimate.
TPH-Dx	270	samples	$ 60	$ 16,200	Assume 70% of samples.
PCBs	116	samples	$ 175	$ 20,300	Assume 30% of samples.
cPAHs	39	samples	$ 215	$ 8,385	Assume 10% of samples.
Metals	39	samples	$ 180	$ 7,020	Assume 10% of samples.
Subtotal				$ 61,905	

Screening Operations Monitoring

2 weeks of oversight	10,750	dollars	Assume HC Senior Staff. See Table A-22.
Analytical costs/sample	415	$/sample	TPH-Dx, PBCs, metals.
Number of samples	10	samples	Assume up to 10 tears in liner.
Subtotal	$ 14,900		

Stockpile Characterization Sampling and Analysis

> 2000 CY soil, 10 samples plus 1 for each additional 500 cy (Ecology 1991).

Number of samples	57	samples

	quantity	unit	unit cost	total	notes
Oversight	2	weeks	$ 5,375	$ 10,750	2 weeks of oversight (see Table A-22).
Equipment/shipping	1	LS	$ 2,000	$ 2,000	Engineer's estimate.
TPH-Dx	40	samples	$ 60	$ 2,400	Assume 70% of samples.
PCBs	17	samples	$ 175	$ 2,975	Assume 30% of samples.
cPAHs	6	samples	$ 215	$ 1,290	Assume 10% of samples.
Metals	6	samples	$ 180	$ 1,080	Assume 10% of samples.
Subtotal				$20,495	

Table A-20 - On-Site Biotreatment Cost Backup

Landfarm Footprint

Volume of soil to be treated	23,338	cy	Screen volume from Table A-19.
Footprint of landfarm at 1 foot thick	630,126	sf	
Footprint (acres)	14.47	acres	

Nutrient Addition Calculations

Average SVOC concentration	4,704	mg/kg	
Total soil mass	32,673	ton	Post-screening soil mass. See Table A-19.
Total soil mass	29,641,127	kg	
Assumed C-content	4,704	mg/kg	Assume SVOC concentration.
Desired C:N:P	100:15:1	ratio of nutrients	
N needed	705.6	mg/kg	
P needed	47.04	mg/kg	
Total N needed (kg)	20,915	kg N	
Total N needed (lbs)	46,109	lbs N	
N source	NH_4NO_3	ammonium nitrate	
Weight fraction - nitrogen	0.35	lb N/lb NH_4NO_3	
Ammonium nitrate needed	131,748	lbs NH_4NO_3	
Total P needed (kg)	1,394	kg P	
Total P needed (lbs)	3,074	lbs P	
P source	$K_4P_2O_7$	tetrapotassium pyrophosphate	
Weight fraction - phosphorus	0.19	lb P/lb $K_4P_2O_7$	
Tetrapotassium pyrophosphate needed	16,392	lbs $K_4P_2O_7$	
K source	$K_4P_2O_7$	tetrapotassium pyrophosphate	
Weight fraction - potassium	0.47	lb K/lb $K_4P_2O_7$	
Tetrapotassium pyrophosphate used	16,392	lbs $K_4P_2O_7$	
Total K (lbs)	7,760	lbs K	

Nutrient Addition	**quantity**	**unit**	**unit cost**	**total**	**notes**
Ammonium nitrate	131,748	LBS	$ 0.36	$ 47,259	Unit price from vendor quotation, 8.7% sales tax.
Tetra potassium pyrophosphate	16,392	LBS	$ 1.52	$ 24,945	Unit price from vendor quotation, 8.7% sales tax.
Total nutrient cost				$ 72,204	

Landfarm Construction/Earthwork	**quantity**	**unit**	**unit cost**	**total**	**notes**
Liner	630,126	SF	$ 0.99	$ 624,261	60 mil HDPE, 2010 RSMeans 02 56 13.10 0722. 8.7% sales tax.
Grading	70,014	SY	$ 0.94	$ 65,764	Grade subgrade for base course 2010 RSMeans 31 22 156.10 1020 .
Berm	874	CY	$ 1.98	$ 1,732	Use screened >2-in material, 2 ft wide, 3 ft high, front-end loader, front-end loader track mtd, 1-1/2 CT cap, 2010 RSMeans 31 23 16.42 1200.
Clean crushed rock base	11,669	CY	$ 25	$ 295,615	6-in thick layer for leachate collection unit cost provided by Kaiser.
Hauling & soil placement in landfarm	23,338	CY	$ 6.98	$ 162,783	Bulldozer, 200 hp, 300-ft haul, common earth, 2010 RSMeans 31 23 16.46 4420.
Remove soil from landfarm	23,338	CY	$ 1.94	$ 45,178	Excavator, 2-CY cap, 2010 RSMeans 31 23 16.42 0260, 15% added for loading into trucks.
Haul soil to final destination	23,338	CY	$ 5.49	$ 128,056	8-CY truck, 15 MPH, cycle 2 miles, 2010 RSMeans 31 23 23.20 0018.
Subtotal				$ 1,323,387	

Periodic Tilling

Purchase roto-tiller tractor	$ 10,000	Engineer's estimate.
Labor	$ 39,000	Laborer at $75/hr, 20 hours every two weeks for year.
Subtotal	$ 49,000	

Leachate Collection	**quantity**	**unit**	**unit cost**	**total**	**notes**
Piping	12,603	ft	$ 11	$ 142,688	50-ft spacing. 4-in perforated PVC. 2010 RSMeans 33 46 16.30 2110. 8.7% sales tax.
Pumps	4	ea	$ 425	$ 1,698	1-1/2-in discharge, 1/4-hp submersible sump pump. 2010 RSMeans 22 14 29.16 7180. 8.7 % sales tax.
Misc fittings/etc.	1	LS	$ 5,000	$ 5,000	Engineer's estimate.
Storage tanks	2	ea	$ 14,600	$ 29,200	Engineer's estimate.
Oversight	6	wk	$ 5,375	$ 32,250	1/2 week/month.
Leachate water sampling	24	ea	$ 24	$ 576	Monthly sampling of each tank for phosphorus.
Utilities	3,888	kWh	$ 0.05	$ 184	Based on 0.44 kW demand per pump (1/4 hp, 60% pump efficiency, 70% motor efficiency, 1 hp = 0.7457kW). Operation 25% of the time. Cost of electricity based on estimate provided by Kaiser.
Subtotal				$ 211,596	

Landfarm Performance Monitoring	**quantity**	**unit**	**unit cost**	**total**	**notes**
Oversight	4	wk	$ 5,375	$ 21,500	Week per sample event.
Equipment/shipping	1	LS	$ 2,000	$ 2,000	Engineer's estimate.
Analytical costs/sample	228	ea	$ 335	$ 76,380	Quarterly sampling for TPH-Dx and conventionals, # of samples/month based on volume, > 2000 CY soil, 10 samples plus 1 for each additional 500 CY (Ecology 1991).
Subtotal				$ 99,880	

Table A-21 - On-Site Thermal Treatment Cost Backup

Volume of soil to be treated	23,338	CY
Mass of soil to be treated	32,673	tons

Earthwork/Transport Material	quantity	unit	unit cost	total	notes
Haul soil to treatment area	23,338	CY	$ 2.02	$ 47,098	Front-end loader, 2-1/2-CY cap, 2010 RSMeans 31 23 16.42 1250.
Remove soil from stockpile	23,338	CY	$ 1.94	$ 45,178	Excavator, 2-CY cap, 2010 RSMeans 31 23 16.42 0260, 15% added for loading into trucks.
Haul soil to final destination	23,338	CY	$ 5.49	$ 128,056	8-CY truck, 15 MPH, cycle 2 miles, 2010 RSMeans 31 23 23.20 0018.

Thermal Performance Monitoring	quantity	unit	unit cost	total	notes
Oversight	24	wk	$ 5,375	$ 129,000	Assume 6 months of oversight. See Table A-22.
Equipment/shipping	1	LS	$ 2,000	$ 2,000	Engineer's estimate.
Soil analytical	120	ea	$ 275	$ 33,000	10 samples/2000 CY soil (Ecology 1991).
Air monitoring (daily monitoring)	24	wk	$ 420	$ 10,080	Weekly rental of air monitoring equipment (multi-parameter meter).
Air monitoring (weekly)	24	ea	$ 200	$ 4,800	Weekly emissions monitoring for TPH, cPAHs (Summa canister).
Subtotal				$ 178,880	

Table A-22 - Hart Crowser and Analytical Rates Cost Backup

HC Kaiser Rates

Sr. Principal	$	190	
Principal	$	180	
Sr. Associate	$	160	
Associate	$	145	
Sr. Project	$	130	
Project	$	110	
Sr. Staff	$	90	
Staff	$	75	
Sr. Drafter	$	100	
Drafter	$	77	
Clerical	$	60	
Sub Markup		12%	
Communication fee		0%	
Mileage		$0.50/mi.	Fed rate (2010)
Truck Rental	$	85	+ mileage for over 50 mi./day (due to gas prices)
Safety ($ per hr.)	$	5	per field labor hour
Trip per diem	$	150	each way
Per diem	$	133	Fed rate for Spokane

Weekly Cost for HC oversight (staff)

Labor	$	3,600	5 days (9 hr) for staff level, plus safety costs
Truck	$	810	5 days truck plus travel day, plus $300 for miles over 50
Travel	$	300	
Per diem	$	665	
Subtotal	$	5,375	per week

Columbia Analytical Services and Advanced Analytical Laboratory Costs

Assume same price for water/soil.

Parameter	Cost / Analysis	
NWTPH-HCID	$	55
TPH-Dx	$	60
TPH-G	$	60
PCBs - Ultra-Low Level	$	175
VOCs	$	130
PAHs (8270 SIM)	$	215
Metals (10)	$	180
Arsenic	$	26
Chromium	$	24
Manganese	$	26
Iron	$	24
Antimony	$	26
TSS	$	18
Chloride	$	18
Nitrate/Nitrite	$	24
Hardness	$	25
TDS	$	18
Alkalinity	$	18
Sulfate	$	18
Total arsenic, chromium, zinc, and phosphorous	$	50
Hexavalent chromium	$	50
Orthophosphate	$	20
Cyanide	$	40
BOD	$	45
Fecal coliform	$	35
Oil & grease	$	50

APPENDIX B
COST ESTIMATES FOR DEEP VADOSE ZONE SOIL REMEDIAL ALTERNATIVES

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APPENDIX B
COST ESTIMATES FOR DEEP VADOSE ZONE SOIL REMEDIAL ALTERNATIVES

TABLES

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Table B-1 - Estimated Cost Comparison for Deep Vadose Zone Soil Remedial Alternatives

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Cost comparison of the net present value and incremental cost of Alternative B1 through B5 for remediation of deep vadose zone soil.

DESCRIPTION	TOTAL NET PRESENT VALUE	INCREMENTAL COST	COST TABLE REFERENCE
Alternative B1	$ 13,600,000	Baseline Cost	Table B-2
Alternative B2	$ 14,700,000	$ 1,100,000	Table B-3
Alternative B3	$ 15,300,000	$ 600,000	Table B-4
Alternative B4	$ 23,200,000	$ 8,500,000	Table B-5
Alternative B5	$ 13,600,000	$ -	Table B-6

Note:
Present value analysis uses a 30-year discount rate of 7%.

Table B-2 - Alternative B1 Estimated Cost Summary

Location:	Kaiser Trentwood Facility	**Description:** Alternative B1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to each of the alternatives that will be evaluated for the remediation of deep vadose zone soil at the Kaiser Facility. Alternative B1 assumes an operating period of 30 years in the development of this cost estimate.
	Spokane Valley, WA	
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls					
Institutional control plans	1	EA	$ 46,548	$ 46,548	See Table B-8.
Pending upgrades in casting complex	1	LS	$ 1,076,073	$ 1,076,073	See Table B-8.
Restrictive covenant preparation	1	LS	$ 24,970	$ 24,970	See Table B-8.
Institutional Controls Subtotal				**$ 1,147,591**	
Contingency	10%	--	--	**$ 114,759**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					
Project management	6%	--	--	$ 75,741	EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Year 0. Kaiser mean annual Ecology costs 2007-2009.
Professional/Technical Services Subtotal				**$ 97,741**	
TOTAL CAPITAL COST				**$ 1,360,091**	

ANNUAL O&M COSTS DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Monitoring, Sampling, Testing, and Analysis					
Protection monitoring	1	YR	$ 44,683	$ 44,683	See Table B-7.
Performance monitoring	1	YR	$ 223,417	$ 223,417	See Table B-7.
Data management	1	YR	$ 29,948	$ 29,948	HC estimate. Data validation; maintain database. See Table B-7.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 298,048**	
Institutional Controls (Annual Update and Maintenance)					
Institutional control plans	1	YR	$ 30,018	$ 30,018	See Table B-8.
Institutional controls maintenance	1	YR	$ 259,604	$ 259,604	See Table B-8.
Outfall & treatment plant monitoring	1	YR	$ 101,946	$ 101,946	See Table B-8. Required by NPDES permit and Ecology orders (see Section 2.1.1.1).
Site information database	1	YR	$ 5,743	$ 5,743	See Table B-8.
Institutional Controls Subtotal				**$ 397,311**	
Contingency	10%	--	--	**$ 69,536**	Scope and bid contingency. Percentage of monitoring and institutional controls annual cost.
Professional/Technical Services					
Project management	10%	--	--	$ 76,489	EPA 540-R-00-002.
Technical support	10%	--	--	$ 76,489	EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Kaiser mean annual Ecology costs 2007-2009.
Reporting	1	YR	$ 16,182	$ 16,182	Report to Kaiser & Ecology quarterly; EIM reporting. See Table B-7.
Professional/Technical Services Subtotal				**$ 191,161**	
TOTAL ANNUAL O&M COST				**$ 956,055**	

PERIODIC COSTS DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Monitoring, Sampling, Testing, and Analysis					
MNA performance monitoring	1	LS	$ 16,857	$ 16,857	Years 5, 10, 15, 20, 25, 30. See Table B-7.
Data management	1	LS	$ 4,500	$ 4,500	Years 5, 10, 15, 20, 25, 30. See Table B-7.
Monitoring, Sampling, Testing, and Analysis Subtotal				$ 21,357	
Institutional Controls (Periodic Update and Maintenance)					
Restrictive covenants	1	EA	$ 6,470	$ 6,470	Years 5, 10, 15, 20, 25, 30. See Table B-8.
Initial acute and chronic toxicity testing	1	LS	$ 45,000	$ 45,000	Years 0, 5, 10, 15, 20, 25. See Table B-8.
Final acute and chronic toxicity testing	1	LS	$ 14,940	$ 14,940	Years 5, 10, 15, 20, 25, 30. See Table B-8.
Institutional Controls Subtotal				**$ 66,410**	
Contingency	10%	--	--	**$ 8,777**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					Project management and technical support cost included in backup tables
Five-year reviews	1	EA	$ 19,540	$ 19,540	Years 5, 10, 15, 20, 25, 30. See Table B-9.
MNA reporting	1	LS	$ 7,000	$ 7,000	Years 5, 10, 15, 20, 25, 30. See Table B-7.
Closure report	1	EA	$ 41,180	$ 41,180	Year 30. See Table B-9.
Professional/Technical Services Subtotal				**$ 67,720**	

Table B-2 - Alternative B1 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative B1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to each of the alternatives that will be evaluated for the remediation of deep vadose zone soil at the Kaiser Facility. Alternative B1 assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 1,409,591	$ 1,409,591	1.000	$ 1,409,591	
Annual O&M	1 - 30	$ 28,681,662	$ 956,055	12.409	$ 11,863,731	
Periodic	5	$ 123,084	$ 123,084	0.713	$ 87,757	
Periodic	10	$ 123,084	$ 123,084	0.508	$ 62,569	
Periodic	15	$ 123,084	$ 123,084	0.362	$ 44,611	
Periodic	20	$ 123,084	$ 123,084	0.258	$ 31,807	
Periodic	25	$ 123,084	$ 123,084	0.184	$ 22,678	
Periodic	30	$ 114,764	$ 114,764	0.131	$ 15,076	
		$ 30,821,436			$ 13,537,821	
TOTAL NET PRESENT VALUE OF ALTERNATIVE B1					**$ 13,537,821**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table B-3 - Alternative B2 Estimated Cost Summary

Location:	Kaiser Trentwood Facility
	Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative B2 includes the elements of Alternative B1 plus containment for remediation of deep vadose zone soil. The containment options considered in Alternative B2 include capping using asphalt, concrete, and multi-layer construction. Alternative B2 assumes an operating period of 30 years in the development of this cost estimate.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Cap Installation					
Permits	1	LS	$ 40,000	$ 40,000	Previous project experience.
Asphalt cap installation	1,520	SY	$ 46	$ 70,268	See Table B-10.
Concrete cap installation	268	SY	$ 95	$ 25,506	See Table B-10.
Hoffman Tank area cap extension	408	SY	$ 111	$ 45,422	Extension of existing multi-layer cap. See Table B-10.
Cap Installation Subtotal				**$ 181,196**	
Contingency	20%	--	--	**$ 36,239**	Scope and bid contingency. Percentage of cap installation costs.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	8%	--	--	$ 17,395	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	15%	--	--	$ 32,615	EPA 540-R-00-002.
Construction management	10%	--	--	$ 21,744	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. B1 Ecology oversight cost to include cap.
Professional/Technical Services Subtotal				**$ 73,954**	
Institutional Controls					New institutional controls for containment portion of Alt. B2.
Institutional controls plan	50%	--	--	$ 23,274	Assume 50% of Alt. B1 institutional control plan cost to include cap.
Restrictive covenants	25%	--	--	$ 6,243	Assume 25% of Alt. B1 restrictive covenant preparation cost to include cap.
Institutional Controls Subtotal				**$ 29,517**	
TOTAL CAPITAL COST				**$ 320,906**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Containment Operation, Maintenance, and Monitoring					
Cap inspection	0.2	WK	$ 5,375	$ 1,075	Assume annual inspection, 1 day HC staff at HC rates. See Table B-17.
Cap sampling and laboratory analysis	1	YR	$ 4,387	$ 4,387	See Table B-10.
Cap maintenance	5%	--	--	$ 16,045	Assume 20 year cap life. Assume 5% of cap to be replaced annually. Use 5% of cap installation total capital cost as maintenance cost.
Data management	1	YR	$ 2,160	$ 2,160	See Table B-10.
Containment Operation, Maintenance, and Monitoring Subtotal				**$ 23,667**	
Contingency	20%	--	--	**$ 4,733**	Scope and bid contingency. Percentage of annual operation, maintenance, and monitoring costs.
Professional/Technical Services					Percentage of sum of annual cost and contingency.
Project management	10%	--	--	$ 2,840	EPA 540-R-00-002.
Technical support	10%	--	--	$ 2,840	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. B1 Ecology oversight cost.
Reporting	1	YR	$ 5,820	$ 5,820	See Table B-10.
Professional/Technical Services Subtotal				**$ 13,700**	
Institutional Controls (Annual Update and Maintenance)					
Institutional controls plan	50%	--	--	$ 15,009	Assume 50% of Alt. B1 institutional control plan cost to include cap.
Site information database	25%	--	--	$ 1,436	Assume 25% of Alt. B1 site information database cost to include cap.
Institutional Controls Subtotal				**$ 16,445**	
TOTAL ANNUAL O&M COST				**$ 58,546**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Professional/Technical Services					Project management and technical support cost included in backup tables
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. Assume same cost as in Alt. B1. See Table B-9.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. Assume same cost as in Alt. B1. See Table B-9.
Professional/Technical Services Subtotal				**$ 30,360**	

Table B-3 - Alternative B2 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative B2 includes the elements of Alternative B1 plus containment for remediation of deep vadose zone soil. The containment options considered in Alternative B2 include capping using asphalt, concrete, and multi-layer construction. Alternative B2 assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 320,906	$ 320,906	1.000	$ 320,906	
Annual O&M	1 - 30	$ 1,756,376	$ 58,546	12.409	$ 726,498	
Periodic	5	$ 9,770	$ 9,770	0.713	$ 6,966	
Periodic	10	$ 9,770	$ 9,770	0.508	$ 4,967	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 9,770	$ 9,770	0.258	$ 2,525	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 30,360	$ 30,360	0.131	$ 3,988	
		$ 2,156,492			$ 1,071,191	Net present value of elements unique to Alternative B2.
Total Net Present Value of Alternative B1					$ 13,537,821	
TOTAL NET PRESENT VALUE OF ALTERNATIVE B2					**$ 14,609,012**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table B-4 - Alternative B3 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative B3 includes Alternative B2 plus soil vapor extraction and off-gas treatment for remediation of VOCs in deep vadose zone soil. Alternative B3 assumes an operating period of one year for each VOC AOC. There are three deep vadose zone VOC AOCs.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals, implementation plans	1	LS	$ 10,000	$ 10,000	SAP, HASP, work plan, SWPPP, as-built drawings, O&M manual, QA/QC documentation. Based on previous HC estimate.
Permits	1	LS	$ 10,000	$ 10,000	HC estimate based on previous work. Building permits will be required.
Submittals, Plans, Site Preparation Subtotal				**$ 20,000**	
Installation and Startup					
SVE well installation	1	LS	$ 115,439	$ 115,439	See Table B-13 for backup calculations.
Vapor extraction and treatment system installation	1	LS	$ 38,465	$ 38,465	See Table B-14 for backup calculations.
System startup and testing	17.5%	--	--	$ 26,933	Percentage of SVE installation capital costs. Average percentage of SVE contingency and general bid (EPA 540-R-00-002).
Installation and Startup Subtotal				**$ 180,837**	
Contingency	17.5%	--	--	**$ 35,147**	Percentage of capital costs. Average percentage of SVE contingency and general bid (EPA 540-R-00-002).
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	8%	--	--	$ 18,879	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	15%	--	--	$ 35,398	EPA 540-R-00-002.
Construction management	10%	--	--	$ 23,598	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. B1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 77,875**	
TOTAL CAPITAL COST				**$ 313,858**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Monitoring					
Treatment system operation and maintenance	1	YR	$ 21,120	$ 21,120	See Table B-12 for backup calculations.
Monitoring, sampling, testing, and analysis	1	YR	$ 14,120	$ 14,120	See Table B-15 for backup calculations.
System Operation and Monitoring Subtotal				**$ 35,241**	
Contingency	17.5%	--	--	**$ 6,167**	% of annual costs. Average percentage of SVE contingency and general bid (EPA 540-R-00-002).
Professional/Technical Services					Percentage of sum of annual cost and contingency.
Project management	10%	--	--	$ 4,141	EPA 540-R-00-002.
Technical support	10%	--	--	$ 4,141	EPA 540-R-00-002.
Professional/Technical Services Subtotal				**$ 8,282**	
TOTAL ANNUAL O&M COST				**$ 49,689**	

PERIODIC COSTS

DESCRIPTION	TOTAL	NOTES
Periodic Cost - Year 1	**$ 29,053**	See Table B-11 for backup calculations.
Periodic Cost - Year 2	**$ 36,921**	See Table B-11 for backup calculations.
Periodic Cost - Year 3	**$ 22,278**	See Table B-11 for backup calculations.
Periodic Cost - Year 4	**$ 130,336**	See Table B-11 for backup calculations.

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 3

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 313,858	$ 313,858	1.000	$ 313,858	
Annual O&M	1 - 3	$ 149,068	$ 49,689	2.624	$ 130,400	
Periodic	1	$ 29,053	$ 29,053	0.935	$ 27,153	
Periodic	2	$ 36,921	$ 36,921	0.873	$ 32,248	
Periodic	3	$ 22,278	$ 22,278	0.816	$ 18,186	
Periodic	4	$ 130,336	$ 130,336	0.763	$ 99,433	
		$ 681,516			$ 621,279	Net present value of elements unique to Alternative B3.
Total Net Present Value of Alternative B2					$ 14,609,012	
TOTAL NET PRESENT VALUE OF ALTERNATIVE B3					**$ 15,230,291**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table B-5 - Alternative B4 Estimated Cost Summary

Location:	Kaiser Trentwood Facility
	Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative B4 includes Alternative B2 plus *in situ* chemical oxidation.
This alternative includes *in situ* ozonation and soil vapor extraction. Refer to Table B-16 for detailed calculations.
Alternative B4 assumes an operating period of 30 years in the development of this cost estimate.
Elements unique to Alternative B4 include capital costs and 26 years of system operation.
System decommissioning occurs in Year 27.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 30,000	$ 30,000	SAP, HASP, work plan, as-built drawings, O&M manual, QA/QC documentation. Based on previous project experience.
Permits	1	LS	$ 30,000	$ 30,000	Previous project experience. SEPA checklist, UIC, etc.
Submittals, Plans, Site Preparation Subtotal				**$ 60,000**	
System Installation and Startup					
Injection/extraction well installation	1	LS	$ 938,315	$ 938,315	See Table B-16.
Ozone generation/SVE system installation	1	LS	$ 1,028,681	$ 1,028,681	See Table B-16.
System Installation and Startup Subtotal				**$ 1,966,996**	
Monitoring, Sampling, Testing, and Analysis (for components not included in B1 or B2)					
System startup monitoring	1	LS	$ 20,424	$ 20,424	Monthly system monitoring. See Table 3-1 in this FS for type and frequency. See Table B-16.
Performance soil sampling and analysis	1	LS	$ 79,494	$ 79,494	Annual soil sampling and analysis of AOCs. See Table B-16.
Data management	5%	--	--	$ 3,975	5% of sampling costs.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 103,893**	
Contingency	20%	--	--	**$ 426,178**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	5%	--	--	$ 127,853	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 204,565	EPA 540-R-00-002.
Construction management	6%	--	--	$ 153,424	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Pilot-scale study	1	LS	$ 207,089	$ 207,089	10% of Installation and Monitoring costs.
Professional/Technical Services Subtotal				**$ 692,931**	
TOTAL CAPITAL COST				**$ 3,249,998**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Monitoring					
Operation	1	LS	$ 99,667	$ 99,667	See Table B-16.
Maintenance	1	LS	$ 59,625	$ 59,625	See Table B-16.
System performance monitoring	1	LS	$ 56,482	$ 56,482	Monthly system monitoring. See Table 3-1 in this FS for type and frequency. See Table B-16.
Performance soil sampling and analysis	1	LS	$ 79,494	$ 79,494	Annual soil sampling and analysis of AOCs. See Table B-16.
Data management	5%	--	--	$ 6,799	
System Operation and Monitoring Subtotal				**$ 302,066**	
Contingency	20%	--	--	**$ 60,413**	Scope and bid contingency.
Professional/Technical Services					Percentage of sum of annual cost and contingency.
Project management	10%	--	--	$ 36,248	EPA 540-R-00-002.
Technical support	10%	--	--	$ 36,248	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. B1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 74,696**	
TOTAL ANNUAL O&M COST				**$ 437,175**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Closeout					
Major equipment replacement/repair	1	LS	$ 200,000	$ 200,000	Year 15. Assume cost of one ozone generator and one SVE system.
Well abandonment	1	LS	$ 102,600	$ 102,600	Year 27. See Table B-16.
System demobilization	1	LS	$ 10,000	$ 10,000	Year 27. Remove piping, units, etc.
System Operation and Closeout Subtotal				**$ 312,600**	
Contingency	10%	--	--	**$ 31,260**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Project management	10%	--	--	$ 34,386	EPA 540-R-00-002.
Technical support	10%	--	--	$ 34,386	EPA 540-R-00-002.
Five-year reviews	5	EA	$ 4,885	$ 24,425	Years 5, 10, 15, 20, 25. Assume 25% of Alt. B1. See Table B-9.
Professional/Technical Services Subtotal				**$ 93,197**	

Table B-5 - Alternative B4 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative B4 includes Alternative B2 plus *in situ* chemical oxidation. This alternative includes *in situ* ozonation and soil vapor extraction. Refer to Table B-16 for detailed calculations. Alternative B4 assumes an operating period of 30 years in the development of this cost estimate. Elements unique to Alternative B4 include capital costs and 26 years of system operation. System decommissioning occurs in Year 27.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 26

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 3,249,998	$ 3,249,998	1.000	$ 3,249,998	
Annual O&M	1 - 26	$ 11,366,555	$ 437,175	11.826	$ 5,169,937	
Periodic	5	$ 4,885	$ 4,885	0.713	$ 3,483	
Periodic	10	$ 4,885	$ 4,885	0.508	$ 2,483	
Periodic	15	$ 268,885	$ 268,885	0.362	$ 97,456	
Periodic	20	$ 4,885	$ 4,885	0.258	$ 1,262	
Periodic	25	$ 4,885	$ 4,885	0.184	$ 900	
Periodic	27	$ 148,632	$ 148,632	0.161	$ 23,919	
		$ 15,053,609			$ 8,549,439	Net present value of elements unique to Alternative B4.
Total Net Present Value of Alternative B2					$ 14,609,012	
TOTAL NET PRESENT VALUE OF ALTERNATIVE B4					**$ 23,158,451**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table B-6 - Alternative B5 Estimated Cost Summary

Location:	Kaiser Trentwood Facility
	Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative B5 includes the elements of Alternative B1 plus containment for the PCB AOCs in the Kaiser Facility Remelt/Hot Line area only, where PCBs are not comingled with SVOCs. These AOCs are located beneath the existing building floor slab, which is assumed to be suitable as a containment cap in its current condition. Thus, installation of new cap will not be required under Alternative B5. Because the institutional controls element of Alternative B1 includes annual and periodic costs related to floor slab O&M and monitoring, these costs are not included as unique elements of Alternative B5.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls					
Floor slab O&M and maintenance plans				$ -	Included in institutional controls element of Alternative B1.
Restrictive covenant				$ -	Included in institutional controls element of Alternative B1.
Institutional Controls Subtotal				**$ -**	
TOTAL CAPITAL COST				**$ -**	No capital cost elements unique to Alternative B5.

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Containment Operation, Maintenance, and Monitoring					
Floor slab inspection				$ -	Included in institutional controls element of Alternative B1.
Floor slab maintenance				$ -	Included in institutional controls element of Alternative B1.
Data management				$ -	Included in institutional controls element of Alternative B1.
Containment Operation, Maintenance, and Monitoring Subtotal				**$ -**	
Institutional Controls (Annual Update and Maintenance)					
Institutional controls plan				$ -	Included in institutional controls element of Alternative B1.
Site information database				$ -	Included in institutional controls element of Alternative B1.
Institutional Controls Subtotal				**$ -**	
TOTAL ANNUAL O&M COST				**$ -**	No annual O&M cost elements unique to Alternative B5.

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Professional/Technical Services					
Five-year reviews				$ -	Included in institutional controls element of Alternative B1.
Closure report				$ -	Included in institutional controls element of Alternative B1.
Professional/Technical Services Subtotal				**$ -**	
Institutional Controls (Periodic Update and Maintenance)					
Restrictive covenant				$ -	Included in institutional controls element of Alternative B1.
Institutional Controls Subtotal				**$ -**	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ -	$ -	1.000	$ -	
Annual O&M	1 - 30	$ -	$ -	12.409	$ -	
Periodic	1 - 30	$ -	$ -	0.000	$ -	
		$ -			$ -	Net present value of elements unique to Alternative B5.
Total Net Present Value of Alternative B1					$ 13,537,821	
TOTAL NET PRESENT VALUE OF ALTERNATIVE B5					**$ 13,537,821**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table B-7 - Monitoring Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative B1					
Protection & Performance Monitoring					Protection and performance monitoring costs based on previous project experience.
Labor	1	yr	$ 107,960	$ 107,960	Includes well and equipment maintenance labor. Excludes project management labor.
Equipment, supplies, computer	1	yr	$ 17,480	$ 17,480	Includes well and equipment maintenance.
Travel	1	yr	$ 24,108	$ 24,108	Previous project experience.
Sample shipping	1	yr	$ 10,000	$ 10,000	Previous project experience.
Laboratory analysis	1	yr	$ 108,552	$ 108,552	Previous project experience.
Subtotal				$ 268,100	
Total qty. of wells sampled	114				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Protection monitoring wells	19				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Performance monitoring wells	95				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Protection monitoring annual total	16.7%	--	--	$ 44,683	Percentage = protection wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Performance monitoring annual total	83.3%	--	--	$ 223,417	Percentage = performance wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Data management	1	yr	$ 29,948	$ 29,948	Data validation; database management. Based on previous project experience.
Reporting	1	yr	$ 16,182	$ 16,182	Report to Kaiser & Ecology quarterly; EIM reporting. Based on previous project experience.

Alternative B1 protection and performance monitoring notes:
- Two 2 person teams plus sample custodian on site during each sample event (5 people total).
- Assumed each sample team can sample 7 wells per day on average.
- Assumed water levels take an entire day with 4 people measuring.
- Assumed 10 hour field days.
- Assumed EIM submittal included for groundwater data plus any additional soil or soil gas data collected during previous 6 months.
- Assumed 2 vehicles for each sampling event.
- Actual well and equipment maintenance costs will depend on upcoming needs.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Monitored Natural Attenuation (MNA) - Periodic Costs					
Total AOC area	16,600 SF				Area of deep vadose zone soil AOCs excluding AOCs beneath existing pavement and floor slabs.
Drilling location density	10,000 SF				One location per 10,000 square feet of AOC area.
Drilling locations	2				
Drilling depth	68 ft				
Drilling contractor	136	ft	$ 77	$ 10,454	2 locations to max. 68-ft depth. Unit cost based on vendor quote. Includes mob/demob, drilling, materials, 8.7% sales tax.
Labor	0.4	wk	$ 5,375	$ 2,150	Assume 2 days HC staff at HC rates. Includes travel. See Table B-17.
Equipment, supplies, computer	2.6%	--	--	$ 460	% of GW monitoring labor. % = (MNA samples/number of wells)/4 quarters per year.
Sample shipping	2.6%	--	--	$ 263	% of GW monitoring labor. % = (MNA samples/number of wells)/4 quarters per year.
Laboratory analysis					
TPH-G - soil	2	samples	$ 60	$ 120	Sample quantity estimate based on 2 sampling locations and relative occurrence of VOCs (TPH-G) and SVOCs (TPH-D) in deep vadose zone soil AOCs.
TPH-D - soil	10	samples	$ 60	$ 600	Sample quantity estimate based on 2 sampling locations and relative occurrence of VOCs (TPH-G) and SVOCs (TPH-D) in deep vadose zone soil AOCs.
Subtotal				$ 14,047	
Project management	10%	--	--	$ 1,405	
Technical support	10%	--	--	$ 1,405	
Total				$ 16,857	
Data management	1	yr	$ 4,500	$ 4,500	Assume work conducted by HC staff at HC rates. See Table B-17.
Reporting	1	yr	$ 7,000	$ 7,000	Assume work conducted by HC staff at HC rates. See Table B-17.

Alternative B1 monitored natural attenuation (MNA) notes:
- Assume monitoring conducted once every five years.
- Assume one exploration per 10000 sq ft of area per AOC. One sample collected per 10 feet of impacted depth for each analysis (TPH-G, TPH-D).
- TPH-G: gasoline-range petroleum hydrocarbons.
- TPH-D: diesel- and heavy-oil-range petroleum hydrocarbons.

Table B-8 - Institutional Controls Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative B1					
New Institutional Controls					
Pending environmental upgrades at casting complexes					Pending items and approx. costs provided by Kaiser.
Replace melter furnace door jambs	5	locations	$ 20,000	$ 100,000	DC-1, DC-2W, DC-3, DC-8E, DC-8W. Provided by Kaiser, May 23, 2011.
Contain hydraulics/lubrication	1	locations	$ 151,000	$ 151,000	DC-2. Unit cost per Kaiser, April 19, 2010.
Overflow lines to sewer	7	locations	$ 50,000	$ 350,000	DC-2 through DC-8.
Seal DC-7/DC-8 control house sump	1	locations	$ 15,000	$ 15,000	Excludes equipment removal cost (approx. $15k). Unit cost per Kaiser, April 19, 2010.
Slip line storm sewers					Pipe lengths from Kaiser storm sewer plan dwg. "Aluminum Works -
MH 2 to MH 3	133	ft	$ 371	$ 49,386	Trentwood Plant, Storm Sewer - Scheme "O", General
MH 9 to MH 3	280	ft	$ 371	$ 103,971	Arrangement" March 8, 1967. Unit cost based on cost of slip lining
MH 3 to MH 5	366	ft	$ 371	$ 135,905	from MH 7B to MH 9 (approx. $120,100 for total length of 390 ft.) in
MH 5 to MH 6	460	ft	$ 371	$ 170,810	2005, adjusted to 2010 dollars (2010 RSMeans p.671).
Subtotal				$ 460,073	
Total				$ 1,076,073	
Preparation of institutional control O&M and monitoring plans					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	60	hr	$ 90	$ 5,400	
Staff	60	hr	$ 75	$ 4,500	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	8	hr	$ 60	$ 480	
Travel	1	ea	$ 566	$ 566	Assume 2-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 15,516	Cost per plan.
Quantity of plans to prepare	3				
Total				$ 46,548	Assume 3 plans in total (e.g., plans for Facility pavement, engineered controls, air emission control system).
Preparation of restrictive covenant					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	40	hr	$ 300	$ 12,000	
Principal	24	hr	$ 180	$ 4,320	
Sr. Project	24	hr	$ 130	$ 3,120	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	16	hr	$ 75	$ 1,200	
Clerical	8	hr	$ 60	$ 480	
Computer	1	ea	$ 250	$ 250	
Total				$ 24,970	
Institutional Controls - Annual Costs					
Environmental upgrades at casting complexes					
Verify pit/sump integrity	9	locations	$ 1,000	$ 9,000	DC-1 through DC-8 plus DC-7/DC-8 control house sump.
Other upgrade maintenance	5%	--	--	$ 53,804	Assume percentage of environmental upgrade capital cost above.
Subtotal				$ 62,804	
Maintenance of physical measures and BMPs					Assume maintenance of signs, fences, gates, access control, existing training programs, waste handling guidance, and BMPs defined in SPCC Plan and SWPPP.
Labor	1920	hr	$ 75	$ 144,000	Assume 1 individual.
Supervisor	480	hr	$ 110	$ 52,800	Assume 25% of labor effort.
Subtotal				$ 196,800	
Total				$ 259,604	
Institutional control O&M and monitoring plans - annual update and maintenance					Assume work performed by Hart Crowser staff.
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	8	hr	$ 75	$ 600	
Sr. Drafter	4	hr	$ 100	$ 400	
Clerical	2	hr	$ 60	$ 120	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 5,003	Cost per plan.
Quantity of plans to maintain	6				
Total				$ 30,018	Assume 6 plans in total. Includes existing WDR Restoration Monitoring Plan, SPCC Plan, and SWPPP plus institutional control O&M and monitoring plans given above.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Site information database - annual update and maintenance					Assume work performed by Hart Crowser staff.
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	24	hr	$ 90	$ 2,160	
Staff	12	hr	$ 75	$ 900	
Clerical	4	hr	$ 60	$ 240	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Total				$ 5,743	
Institutional Controls - Periodic Costs					
Restrictive covenant periodic update and maintenance					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	8	hr	$ 300	$ 2,400	
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	4	hr	$ 130	$ 520	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	4	hr	$ 75	$ 300	
Clerical	2	hr	$ 60	$ 120	
Computer	1	ea	$ 250	$ 250	
Total				$ 6,470	
NPDES Permit and Ecology Order Required Monitoring - Annual Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997), Ecology Agreed Order No. 02WQER-3487 (Ecology 2002), and Ecology Amended Order No. 2868 (Ecology 2005). See Section 2.1.1.1.
NPDES permit - monitoring laboratory analysis					
Sample quantity					Based on weekly sampling frequency.
Outfall 001	104	samples			
Outfall 002	104	samples			
Outfall 003	52	samples			
Plant intake	104	samples			
Laboratory analysis					Unit prices based on laboratory quote.
Outfall 001					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	104	samples	$ 18	$ 1,872	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc, phosphorous.
Cyanide	104	samples	$ 40	$ 4,160	
Hardness	104	samples	$ 25	$ 2,600	
Subtotal				$ 19,032	
Outfall 002					
Oil and grease	260	samples	$ 50	$ 13,000	
TSS	104	samples	$ 18	$ 1,872	
Orthophosphate	104	samples	$ 20	$ 2,080	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, zinc, phosphorous.
Hexavalent chromium	104	samples	$ 50	$ 5,200	
Cyanide	104	samples	$ 40	$ 4,160	
Subtotal				$ 31,512	
Outfall 003					
BOD_5	52	samples	$ 45	$ 2,340	
TSS	52	samples	$ 18	$ 936	
Fecal coliform	52	samples	$ 35	$ 1,820	
Subtotal				$ 5,096	
Plant intake					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	52	samples	$ 18	$ 936	
Total metals	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc.
Subtotal				$ 11,336	
NPDES permit laboratory analysis subtotal				$ 66,976	
Ecology Order - monitoring laboratory analysis					
Sample quantity					Based on biweekly sampling frequency.
Outfall 001	26	samples			
Plant lagoon effluent	26	samples			
Plant lagoon influent	26	samples			

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Laboratory analysis					
For 3 locations given above					
PCBs - ultra-low level	78	samples	$ 175	$ 13,650	
Subtotal				$ 13,650	
Ecology Order laboratory analysis subtotal				$ 13,650	
Sampling labor - NPDES permit and Ecology Order required monitoring					
Labor	208	hr	$ 75	$ 15,600	Assume 1 individual.
Supervisor	52	hr	$ 110	$ 5,720	Assume 25% of labor effort.
Labor subtotal				$ 21,320	
Total Annual Cost				$ 101,946	
NPDES Permit Required Monitoring - Periodic Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997). See Section 2.1.1.1.
Initial acute toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in Years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	8	samples	$ 850	$ 6,800	
Daphnid (48-hr static test)	8	samples	$ 700	$ 5,600	
Subtotal				$ 12,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial acute toxicity testing total				$ 16,500	
Final acute toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in Years 5, 10, 15, 20, 25, and 30.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	2	samples	$ 850	$ 1,700	
Daphnid (48-hr static test)	2	samples	$ 700	$ 1,400	
Subtotal				$ 3,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final acute toxicity testing total				$ 5,970	
Initial chronic toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in Years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	8	samples	$ 1,575	$ 12,600	
Water flea (7-day, full dilution test)	8	samples	$ 1,475	$ 11,800	
Subtotal				$ 24,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial chronic toxicity testing total				$ 28,500	
Final chronic toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in Years 5, 10, 15, 20, 25, and 30.

Table B-8 - Institutional Controls Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	2	samples	$ 1,575	$ 3,150	
Water flea (7-day, full dilution test)	2	samples	$ 1,475	$ 2,950	
Subtotal				$ 6,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final chronic toxicity testing total				$ 8,970	

Table B-9 - Professional Services Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative B1 - Periodic Costs					
Five-year review periodic cost					Assume work performed by Hart Crowser staff.
Ecology oversight	1	LS	$ 7,500	$ 7,500	Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Principal	16	hr	$ 180	$ 2,880	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	40	hr	$ 75	$ 3,000	
Clerical	8	hr	$ 60	$ 480	
Total				$ 19,540	
Closure report periodic cost					Assume work performed by Hart Crowser staff.
Ecology oversight	1	LS	$ 7,500	$ 7,500	Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Principal	40	hr	$ 180	$ 7,200	
Sr. Project	80	hr	$ 130	$ 10,400	
Sr. Staff	80	hr	$ 90	$ 7,200	
Staff	80	hr	$ 75	$ 6,000	
Sr. Drafter	24	hr	$ 100	$ 2,400	
Clerical	8	hr	$ 60	$ 480	
Total				$ 41,180	
MNA - data management periodic cost					Assume work performed by Hart Crowser staff.
Principal	2	hr	$ 180	$ 360	
Sr. Associate	4	hr	$ 160	$ 640	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	12	hr	$ 75	$ 900	
Clerical	2	hr	$ 60	$ 120	
Total				$ 4,500	
MNA - reporting periodic cost					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Associate	2	hr	$ 160	$ 320	
Sr. Project	12	hr	$ 130	$ 1,560	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	16	hr	$ 75	$ 1,200	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	4	hr	$ 60	$ 240	
Total				$ 7,000	
Alternative B2 - Annual Costs					
Containment monitoring - data management					Assume work performed by Hart Crowser staff.
Principal	2	hr	$ 180	$ 360	
Sr. Associate	1	hr	$ 160	$ 160	
Sr. Project	2	hr	$ 130	$ 260	
Sr. Staff	8	hr	$ 90	$ 720	
Staff	8	hr	$ 75	$ 600	
Clerical	1	hr	$ 60	$ 60	
Total				$ 2,160	
Containment monitoring - reporting					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Associate	2	hr	$ 160	$ 320	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	12	hr	$ 90	$ 1,080	
Staff	12	hr	$ 75	$ 900	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	4	hr	$ 60	$ 240	
Total				$ 5,820	
Alternative B2 - Periodic Costs					
Five-year reviews	50%	--	--	$ 9,770	Assume 50% of Alt. B1 five-year review cost to include containment system.
Closure report	50%	--	--	$ 20,590	Assume 50% of Alt. B1 remedial action report cost to include containment system.

Table B-10 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative B2					
Total exposed AOC area	16,560	SF			See Section 3.1.2.1.
Hoffman Tank area SVOC AOC exposed area	467	SF			
Multi-layer cap area	3,675	SF			Extension of existing multi-layer cap in Hoffman Tank area (see Section 3.1.2). Assumes dimensions of 25 ft x 147 ft.
Total area to be capped	19,768	SF			
Asphalt cap area	13,679	SF			Assume 85% of net remaining area to be asphalt capped (total area minus multi-layer cap area).
Concrete cap area	2,414	SF			Assume 15% of net remaining area to be concrete capped (total area minus multi-layer cap area).
Sales tax	8.7%				Effective rate for Spokane Valley, WA, 4/1/10 to 6/30/10. See http://dor.wa.gov/Docs/forms/ExcsTx/LocSalUseTx/LocalSlsUseFlyer_10_Q2_alpha.pdf.
RSMeans location adjustment factor	0.93				Cost adjustment factor for Spokane, WA (2010 RSMeans p. 696). Applied to estimated costs originating from RSMeans cost guide.
Asphalt Capping					
Asphalt cap material quantities					
Compaction ratio	75%				Assume 75%.
Aggregate base course compacted thickness	3	in			
Asphalt base layer compacted thickness	2	in			
Asphalt intermediate layer compacted thickness	2	in			
Asphalt wearing layer compacted thickness	2	in			
Aggregate base course volume (loose)	169	LCY			LCY = "loose cubic yards"
Asphalt volume (loose)	338	LCY			
Railroad track length	201	LF			For railroad track removal.
Railroad ballast depth	1	ft			
Railroad ballast width	6	ft			
Railroad ballast volume	45	CY			
Asphalt cap installation					
Mob/demob	1	LS	$ 4,053	$ 4,053	Previous project experience. Adjusted from 2008 to 2010 basis (2010 RSMeans p. 671).
Railroad track removal					
Ties and track	201	LF	$ 10.93	$ 2,196	2010 RSMeans 02 41 13.33 3500.
Ballast	45	CY	$ 5.44	$ 243	2010 RSMeans 02 41 13.33 3600.
Subgrade preparation	1,520	SY	$ 1.75	$ 2,657	Prepare and roll. 2010 RSMeans 32 11 23.23 7000.
Paving materials hauling	507	LCY	$ 4.64	$ 2,351	12 CY trucks, 25 MPH ave., cycle 4 mi. 2010 RSMeans 31 23 23.20 1040.
Aggregate base course	1,520	SY	$ 4.61	$ 7,011	Crushed 3/4-in. stone, compacted, 3 in. deep. 2010 RSMeans 32 11 23.23 0050.
Asphalt base layer	1,520	SY	$ 8.37	$ 12,721	Binder course, 2-in. thick. 2010 RSMeans 32 12 16.13 0120.
Asphalt intermediate layer	1,520	SY	$ 8.37	$ 12,721	Binder course, 2-in. thick. 2010 RSMeans 32 12 16.13 0120.
Asphalt wearing layer	1,520	SY	$ 9.35	$ 14,206	Wearing course, 2-in. thick. 2010 RSMeans 32 12 16.13 0380.
Sealing	1,520	SY	$ 1.64	$ 2,488	Tack coat, emulsion 0.10 gal. per SY. 2010 RSMeans 32 01 13.62 3270.
Sales tax	8.7%	--	--	$ 3,232	Assume sales tax charged on cost of materials.
Subtotal				$ 63,880	
Cap installation quality control	10%	--	--	$ 6,388	Assume QC conducted to ensure appropriate impermeability.
Total				$ 70,268	
Total unit cost		SY	$ 46.23		
Concrete Capping					
Concrete cap material quantities					
Compaction ratio	75%				Assume 75%.
Aggregate base course compacted thickness	3	in			
Concrete thickness	6	in			
Aggregate base course volume (loose)	30	LCY			LCY = "loose cubic yards"
Concrete volume	45	CY			
Concrete paving pass length	24	LF			

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Concrete cap installation					
Mob/demob	1	LS	$ 4,053	$ 4,053	Previous project experience. Adjusted from 2008 to 2010 basis (2010 RSMeans p. 671).
Subgrade preparation	268	SY	$ 1.75	$ 469	Prepare and roll area. 2010 RSMeans 32 11 23.23 7000.
Base course material hauling	30	LCY	$ 4.64	$ 138	12 CY trucks, 25 MPH ave., cycle 4 mi. 2010 RSMeans 31 23 23.20 1040.
Aggregate base course	268	SY	$ 4.61	$ 1,237	Crushed 3/4-in. stone, compacted, 3 in. deep. 2010 RSMeans 32 11 23.23 0050.
Reinforcing steel for rigid paving	268	SY	$ 6.84	$ 1,833	12 lb/SY. 2010 RSMeans 32 13 13.23 0530.
Dowels	299	EA	$ 2.94	$ 880	2 ft long, deformed, #4. 1-ft spacing. 2010 RSMeans 03 21 10.60 2410.
Concrete delivery	45	CY	$ 102	$ 4,573	Normal weight concrete, ready mix, 3,500 psi. Includes local aggregate, sand, Portland cement, and water. 2010 RSMeans 03 31 05.35 0200.
Concrete paving	268	SY	$ 21	$ 5,737	Includes joints, finishing, curing. Fixed form, 24-ft pass, 6-in thickness. 2010 RSMeans 32 13 13.23 0410.
Water stops	299	LF	$ 6.88	$ 2,061	PVC, ribbed, w/ center bulb, 6 in. wide, 3/8 in. thick. 2010 RSMeans 03 15 13.50 0550.
Joint filler	299	LF	$ 2.45	$ 732	Butyl rubber filler, 1/2 x 1/2 in. 2010 RSMeans 07 91 26.10 4365.
Joint seal	299	LF	$ 1.30	$ 390	Silicone, room temp vulcanizing foam seal, 1/2 x 1/2 in. 2010 RSMeans 07 91 26.10 5610.
Sales tax	8.7%	--	--	$ 1,083	Assume sales tax charged on cost of materials.
Subtotal				$ 23,187	
Cap installation quality control	10%	--	--	$ 2,319	Assume QC conducted to ensure appropriate impermeability.
Total				$ 25,506	
Total unit cost		SY	$ 95.10		

Multi-Layer Capping

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Multi-layer cap material quantities					
Compaction ratio	75%				Assume 75%.
Aggregate base course compacted thickness	3	in			
Intermediate layer thickness	12	in			
Top layer thickness	12	in			
Excavation depth	27	in			
Excavation volume	306	BCY			BCY = bank cubic yards
Aggregate base course volume	45	LCY			LCY = loose cubic yards
Intermediate layer volume	136	LCY			Assume not compacted.
Top layer volume	136	LCY			Assume not compacted.
AST secondary containment length	39	ft			
AST secondary containment width	15	ft			
AST secondary containment height	4	ft			Wall height varies; estimated average height used.
AST secondary containment thickness	6	in			Assume 6-in slab and wall thickness.
AST secondary containment concrete volume	19	CY			
Multi-layer cap installation					
Mob/demob	1	LS	$ 4,053	$ 4,053	Previous project experience. Adjusted from 2008 to 2010 basis (2010 RSMeans p. 671).
Temporary relocation of surface structures					
Remove steam line	150	LF	$ 3.40	$ 511	Steel pipe w/ insulation, 3/4 in. to 4 in. 2010 RSMeans 02 41 13.46 0100.
Relocate AST	1	day	$ 1,535	$ 1,535	Move AST for cap installation; return AST to original location after installation. Temporary crane, 25-ton. 2010 RSMeans 01 54 19.50 0200.
Remove secondary containment	19	CY	$ 134	$ 2,522	Concrete demolition, average reinforcing. 2010 RSMeans 03 05 05.10 0060.
Reconstruct secondary containment	19	CY	$ 173	$ 3,258	Slab on grade (3,500 psi), not including finish, 6-in thickness. 2010 RSMeans 03 30 53.40 4700.
Replace steam line	150	LF	$ 36	$ 5,371	2-in diam. black steel pipe w/ 2-in insulation, align & tackweld on sleepers. 2010 RSMeans 33 61 13.10 1030.
Earthwork					
Excavator	306	BCY	$ 2.69	$ 825	Excavator, hydraulic, crawler mounted, 2 CY capacity. For heavy soil added 60%. 2010 RSMeans 31 23 16.42 0260.
Bulldozer	306	BCY	$ 2.49	$ 763	300 HP, 150-ft haul, sand & gravel. 2010 RSMeans 31 23 16.46 5200.
Stockpiling	15%	--	--	$ 124	Add 15% of excavator cost. 2010 RSMeans 31 23 16.42 0011-0020.
Finish grading	408	SY	$ 2.35	$ 961	Grade subgrade for base course, small irregular areas. 2010 RSMeans 31 22 16.10 1050.
Cap material hauling	181	LCY	$ 4.64	$ 842	12 CY trucks, 25 MPH ave., cycle 4 mi. 2010 RSMeans 31 23 23.20 1040. Assume reuse of native material for top layer.
Aggregate base course	408	SY	$ 4.61	$ 1,884	Crushed 3/4-in. stone, compacted, 3 in. deep. 2010 RSMeans 32 11 23.23 0050.
Liner	3,675	SF	$ 1.39	$ 5,092	PVC, 80-mil liner. 2010 RSMeans 02 56 13.10 0620.
Intermediate layer	136	LCY	$ 49	$ 6,709	Bank sand. Ballast cover w/ common borrow material. 2010 RSMeans 02 56 13.10 1120.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Top layer	136	LCY	$ 40	$ 5,418	Assume reuse of native material. 2010 RSMeans 02 56 13.10 1110, excluding material cost.
Seeding	408	SY	$ 0.47	$ 190	Mechanical seeding, 44 lb. per 1,000 SY. 2010 RSMeans 32 92 19.13 0100.
Water drainage and collection system	26	LF	$ 8.34	$ 219	Assume similar to foundation underdrain system. 4-in diam. perf. PVC pipe. Pipe bedding, graded gravel 3/4 to 1/2 in. 2010 RSMeans assembly A1010 310 1000.
Sales tax	8.7%	--	--	$ 1,018	Assume sales tax charged on cost of materials.
Subtotal				$ 41,293	
Cap installation quality control	10%	--	--	$ 4,129	
Total				$ 45,422	
Total unit cost		SY	$ 111.24		
Containment Operation, Maintenance, and Monitoring					
Cap sampling location density	10,000	SF			One location per 10000 square feet of new asphalt and concrete cap area.
Cap sampling locations	2	samples			
Cap annual sampling and laboratory analysis	29%	--	$ 15,355	$ 4,387	Use % of Alt. A2 cap annual sampling and laboratory analysis cost (see Tables A-3 and A-13). % = Alt. B2 sampling locations/Alt. A2 sampling locations.
Data management	1	yr	$ 2,160	$ 2,160	Assume work conducted by HC staff at HC rates. See Table B-9.
Reporting	1	yr	$ 5,820	$ 5,820	Assume work conducted by HC staff at HC rates. See Table B-9.

Table B-11 - SVE Periodic Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Periodic Costs - Year 1					
Carbon changeout, transport and regeneration	1.0	ea	$ 5,580	$ 5,580	Includes replacement, removal, regeneration, and labor for carbon changeout for one 2,000-lb bed. Based on vendor quote for existing HC project. Price adjusted per 2010 RSMeans Cost Index. Assume to occur at end of year.
Mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization based on previous Kaiser vendor cost estimate. Cost accounts for moving of skid unit.
HC oversight	0.6	wk	$ 5,375	$ 3,225	Assume 3 days of oversight for treatment system move. See Table B-17 for backup calculation.
Startup performance monitoring	1	LS	$ 5,106	$ 5,106	See Table B-15 for backup calculations.
Confirmational air sampling	1	LS	$ 5,694	$ 5,694	See Table B-15 for backup calculations.
Contingency	17.5%	--	--	$ 3,606	Percentage of capital costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Project management	10%	--	--	$ 2,421	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical Support	10%	--	--	$ 2,421	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Costs - Year 1				**$ 29,053**	
Periodic Costs - Year 2					
Carbon changeout, transport and regeneration	2.0	EA	$ 5,580	$ 11,160	Includes replacement, removal, regeneration, and labor for carbon changeout for one 2,000 lb bed. Based on vendor quote for existing HC project. Price adjusted per 2010 RSMeans Cost Index. Assume to occur at end of year.
Mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization based on previous Kaiser vendor cost estimate. Cost accounts for moving of skid unit. Assume to occur at end of year.
HC oversight	0.6	wk	$ 5,375	$ 3,225	Assume 3 days of oversight for treatment system move. See Table B-17 back up calculation.
Startup performance monitoring	1	LS	$ 5,106	$ 5,106	See Table B-15 for backup calculations.
Confirmational air sampling	1	LS	$ 5,694	$ 5,694	See Table B-15 for backup calculations.
Contingency	17.5%	--	--	$ 4,582	Percentage of capital costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Project management	10%	--	--	$ 3,077	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical Support	10%	--	--	$ 3,077	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Costs - Year 2				**$ 36,921**	
Periodic Costs - Year 3					
Equipment and appurtenances repair/replacement	1	LS	$ 5,000	$ 5,000	Cost of blower. Price obtained from vendor.
Startup performance monitoring	1	LS	$ 5,106	$ 5,106	See Table B-15 for backup calculations.
Confirmational air sampling	1	LS	$ 5,694	$ 5,694	See Table B-15 for backup calculations.
Contingency	17.5%	--	--	$ 2,765	Percentage of capital costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Project management	10%	--	--	$ 1,857	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical Support	10%	--	--	$ 1,857	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Costs - Year 3				**$ 22,278**	
Demobilization of Treatment System/Professional and Technical Services - Year 5					
Contractor mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization based on previous Kaiser vendor cost estimate.
Carbon transport and regeneration	1	ea	$ 2,790	$ 2,790	Assume 50% of carbon changeout, transport, and regeneration cost.
Treatment unit shipping	1	LS	$ 2,000	$ 2,000	Shipping treatment system from the Facility. Assume same cost as shipping to Facility. Price obtained from SVE vendor.
Piping demolition	475	ft	$ 3.87	$ 1,838	2-in steel piping demolition cost from 2010 RSMeans 22 05 05.10 2050. Location factor adjustment for Spokane, WA, 2010 RSMeans, p. 696.
Well abandonment	1	LS	$ 15,846	$ 15,846	See Table B-13 for backup calculations.
Soil sampling	1	LS	$ 68,963	$ 68,963	See Table B-15 for backup calculations.
Contingency	17.5%			$ 16,177	Percentage of capital costs. Average percent of SVE contingency and general bid (EPA 540-R-00-002).
Project management	10%			$ 10,861	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical Support	10%			$ 10,861	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Cost - Year 5				**$ 130,336**	

Table B-12 - SVE Treatment System Annual Operation and Maintenance Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Treatment System Operation and Maintenance					
Maintenance labor	50	hr	$ 110	$ 5,500	Assume 5 days of HC project level staff.
Equipment maintenance	1	LS	$ 2,000	$ 2,000	Based on previous HC estimate.
Spare parts and supplies	1	LS	$ 1,000	$ 1,000	Assume 50% of equipment maintenance.
Equipment rental	12	mo	$ 1,000	$ 12,000	600 SCFM blower, knock-out pot, vessels for 2 x 2,000 lb GAC beds, process control, sensors & instrumentation, system enclosure per SVE vendor estimate.
Utilities	13,140	kWh	$ 0.05	$ 620	Based on 1.5 kW demand (600 SCFM motor, 6-8" Hg [All-Star RB9 Series]), continuous operation. Cost of electricity based on estimate provided by Kaiser.
Treatment System Operation and Maintenance Subtotal				**$ 21,120**	

Table B-13 - SVE Well Installation and Well Abandonment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST		TOTAL		NOTES
Drilling - well installation	1088	ft	$	77	$	83,776	16 locations to 68-ft depth (9 extraction wells, 7 vent wells). Unit cost based on vendor quote. Includes mob/demob, drilling,
2" Well Materials							Prices for well materials based on Kaiser vendor previous cost estimate. Costs adjusted from 2009 to 2010 dollars with RSMeans 2010 historical cost index adjustment (2010 RSMeans p. 671).
SCH 40 PVC screen 2" x 10' .020	271	ft	$	5.45	$	1,474	In Tank Farm area there are 9 x 2-in wells with screen interval 41 to 68 ft bgs. In Oil House Area there are 5 x 2-in wells with screen interval 62.5 to 68 ft bgs.
SCH 40 PVC 2" x 10'	682	ft	$	3.54	$	2,413	See note above.
SCH 40 ends 2"	16	ea	$	14	$	218	
Flush monument 8"	7	ea	$	237	$	1,659	8-in monument for vent wells. Extraction wells will have vault.
Cost of vault (to protect wells)	9	ea	$	1,000	$	9,000	9 extraction wells. Estimate provided by vendor. Includes labor, equipment, and materials.
Sand	137	bag	$	19	$	2,561	Quote for number of bags provided by Kaiser vendor.
Drums	5	ea	$	86	$	429	Quote for number of drums provided by Kaiser vendor.
Bentonite	259	bag	$	15	$	3,792	Estimated number of bags based on previous Kaiser vendor cost estimate.
Well permits - WA	16	EA	$	76	$	1,212	
2" Well Materials Subtotal		ea			**$**	**22,758**	
Additional Costs for Well Installation							
Transport & dispose of soil at Subtitle D landfill	15.2	ton	$	54	$	821	Cost for disposal based on previous Kaiser work and adjusted using RSMeans 2010 historical cost index. Based on cost on 35 drums of disposal. Number of drums generated based on estimate from Kaiser vendor.
HC oversight	1.4	wk	$	5,375	$	7,525	For logging well information and protection monitoring. See Table B-17 for backup calculations.
Equipment rental	7	day	$	80	$	560	HC equipment cost.
Additional Costs for Well Installation Subtotal					**$**	**8,906**	
SVE Well Installation Subtotal					**$**	**115,439**	
Well Abandonment							
Ecology filing	16	per well	$	65	$	1,040	
Labor	96	hr	$	110	$	10,560	6 hr/well per HC estimate, assume HC project level staff.
Bentonite chips	16	per well	$	78	$	1,248	Per HC estimate 6 bags per well at $13/bag.
Truck 1/2 day	11	day	$	85	$	935	Based on labor hours above and nine hour work day.
Additional mileage cost					$	300	See Table B-17 for backup calculations.
Per diem	11	day	$	133	$	1,463	
Trip per diem	2	ea	$	150	$	300	See Table B-17 for backup calculations.
Well Abandonment Subtotal					**$**	**15,846**	

Table B-14 - Vapor Extraction and Treatment System Installation Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Treatment System Installation					
Contractor mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization (based on previous cost estimate from Kaiser vendor).
Treatment unit shipping	1	LS	$ 2,000	$ 2,000	Shipping treatment unit to the Facility. Based on SVE vendor cost estimate.
Piping conveyance installation	1	LS	$ 11,047	$ 11,047	See SVE conveyance backup calculation below.
Pipe trenching	1	LS	$ 5,043	$ 5,043	See pipe trenching backup calculation below.
Carbon	1	LS	$ 4,000	$ 4,000	For 2 x 2,000-lb beds. Cost from SVE vendor.
HC oversight	1	wk	$ 5,375	$ 5,375	Assume 1 week of HC oversight during installation of SVE treatment system. See Table B-17 for backup calculations.
Power hookup	2	EA	$ 5,000	$ 10,000	Power hookup cost provided by vendor.
Treatment System Installation Subtotal				**$ 38,465**	
SVE Piping Conveyance					
Contractor mobilization/demobilization	1	LS	$ 1,000	$ 1,000	LS price for contractor mobilization based on previous cost estimate from Kaiser vendor.
2-in SCH 40 PVC piping - wells	180	LF	$ 8.51	$ 1,532	Assume 20 ft per well. Pipe cost from 2010 RSMeans 22 11 13.74 4216. Subtract cost of coupling and clevis hanger assembly (2010 RSMeans 22 11 13.74 4530). Location factor adjustment for Spokane, WA (2010 RSMeans, p. 696).
2-in SCH 40 PVC piping - header	210	LF	$ 8.51	$ 1,787	Distance between AOCs and proposed treatment unit as shown on Figures 2-10 and 2-11. Pipe cost from 2010 RSMeans 22 11 13.74 4216. Subtract cost of coupling and clevis hanger assembly 2010 RSMeans 22 11 13.74 4530. Location factor adjustment for Spokane, WA (2010 RSMeans, p. 696).
2-in SCH 40 coupling	39	EA	$ 47	$ 1,814	Assume per 10 ft of piping. Cost from 2010 RSMeans 22 11 13.76 0410. Location factor adjustment for Spokane, WA (2010 RSMeans, p. 696).
2-in SCH 40 90 degree elbows	9	EA	$ 115	$ 1,038	Assume 1 per extraction well. Cost from 2010 RSMeans 22 11 13.76 0090. Location factor adjustment for Spokane, WA (2010 RSMeans, p. 696).
2-in SCH 40 tee	9	EA	$ 99	$ 887	Assume 1 per extraction well. Cost from 2010 RSMeans 22 11 13.76 0290. Location factor adjustment for Spokane, WA (2010 RSMeans, p. 696).
2-in SCH 40 ball valve	9	EA	$ 115	$ 1,038	Assume 1 per well. Assume same cost as 90-degree elbow.
2-in SCH 40 pressure gage	9	EA	$ 115	$ 1,038	Assume 1 per well. Assume same cost as 90-degree elbow.
Extra piping, fittings	10%			$ 913	Assume 10% of materials and labor listed above.
SVE Piping Conveyance Subtotal				**$ 11,047**	

Pipe Trenching

Quantities for Trench Excavation

Description	**QTY**	**Unit**	**Comments**
Length of pipe	390	ft	
Width of trench	1.5	ft	
Depth of trench	3	ft	Assume 4 ft bgs for utilities.
Base course thickness	6	in	Assumed thickness.
Asphalt thickness	4	in	Assumed thickness.
Pipe bedding thickness (crushed rock)	12	in	Assumed thickness.
Backfill thickness	1.17	ft	Assume using excavated materials.
Fraction soil reused as backfill	39%		
Volume of soil around per vault (2x2x3 ft)	12	cf	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Removal of pavement	65	SY	$ 7.91	$ 514	2010 RSMeans 02 41 13.17 5050 with location factor correction. 4- to 6-in-thick pavement.
Trenching	69	BCY	$ 7.30	$ 504	2010 RSMeans 31 23 16.13 6050 with location factor correction. Sand & gravel with no sheeting or dewatering included, 1 to 4 ft deep, 3/8 CY excavator.
Pipe bedding	29	LCY	$ 36	$ 1,033	2010 RSMeans 31 23 23.16 0049 with location factor correction. Utility bedding for pipe & conduit not included. Compaction, crushed or screened bank run gravel. Assume 75% compaction ratio.
Pipe bedding compaction	22	ECY	$ 4.61	$ 100	2010 RSMeans 31 23 23.16 0050 with location factor correction. Compacting bedding in trench.
Backfilling	29	LCY	$ 2.36	$ 69	2010 RSMeans 31 23 16.13 3000 with location factor correction. Backfill trench, F.E. loader, wheel mtd., 1 CY bucket, minimal haul. Assume 15% bulking factor.
Backfilling compaction	25	ECY	$ 4.70	$ 119	2010 RSMeans 31 23 23.13 0600 with location factor correction. Compaction in 6-in layers, vibrating plate.
Base course	65	SY	$ 5.02	$ 326	2010 RSMeans 32 11 23.23 0350 with location factor correction. Bank run gravel, spread and compacted, 6 in deep.
Repaving roadway	65	SY	$ 17	$ 1,076	2010 RSMeans 32 11 26.13 0500 with location factor correction. Roadways and large paved areas. Bitumous concrete, 4 in thick.
Soil disposal	24	ton	$ 54	$ 1,303	Cost for disposal based on previous Kaiser work and adjusted using 2010 RSMeans historical cost index. Assume 25% of soil excavated for trench will be disposed of.
Pipe Trenching Subtotal				$ 5,043	

Table B-15 - SVE Monitoring Cost Backup

	Labor Hours			Cost in Dollars					
	Principal	Senior Project	Senior Staff	Labor Subtotal	Travel Expense (includes per diem)	Equipment & Supplies	Lab Analysis + Shipping	Subcontractor	Task Subtotal
Start Up System Performance (1st 2 weeks of operation)									
Daily system monitoring	2	4	28	$ 3,560					
Weekly vapor monitoring	2	2	8	$ 1,400		$ 100			
Start Up Subtotal	**4**	**6**	**36**	**$ 4,960**		**$ 100**			**$ 5,106**
Annual Performance Monitoring									
Monthly system monitoring visits for one year	12	24	24	$ 7,680					
Quarterly vapor monitoring	4	8	18	$ 3,510		$ 1,440	$ 1,490		
Annual Performance Monitoring Subtotal	**16**	**32**	**42**	**$ 11,190**		**$ 1,440**	**$ 1,490**		**$ 14,120**
Confirmational Sampling									
Vapor monitoring - before treatment unit is moved	3	6	13.5	$ 2,633		$ 1,944	$ 1,118		**$ 5,694**
Soil confirmational sampling	2	4	27	$ 3,465	$ 1,254		$ 1,518	$ 62,726	**$ 68,963**
Confirmational Sampling Subtotal	**5**	**10**	**40.5**	**$ 6,098**	**$ 1,254**	**$ 1,944**	**$ 2,636**	**$ 62,726**	**$ 74,657**
Labor rates	$ 190	$ 130	$ 95						

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Startup Equipment Costs					
Colormetric tubes	8	ea	$ 10	$ 80	HC equipment costs. Conservatively assumed measuring for benzene and toluene.
Hand pump	2	day	$ 10	$ 20	HC equipment costs.
Startup Equipment Costs Subtotal				**$ 100**	
Annual Equipment and Laboratory Costs					
Colormetric tubes	132	ea	$ 10	$ 1,320	HC equipment costs. Conservatively assumed measuring for benzene and toluene.
Hand pump	12	day	$ 10	$ 120	HC equipment costs.
BTEX analysis for Summa cannister samples	4	ea	$ 324	$ 1,296	Based on previous HC estimate from 2007. Cost adjusted using historical cost index from 2010 RSMeans p. 671.
Sample shipping	15%	--	--	$ 194	Assumed percentage of sample analysis cost for Summa cannister samples.
Annual Equipment and Laboratory Costs Subtotal				**$ 2,736**	
Air Confirmational Sampling					Verification that point of diminishing returns has been reached.
BTEX analysis for summa cannisters	3	ea	$ 324	$ 972	Based on previous HC estimate from 2007. Cost adjusted using historical cost index from 2010 RSMeans p. 671.
Sample shipping	15%	--	--	$ 146	
Air Confirmational Sampling Subtotal				**$ 972**	
Soil Confirmational Sampling					
Drilling contractor	816	ft	$ 77	$ 62,726	12 locations to 68-ft depth. Unit cost based on Kaiser vendor previous cost estimate. Includes mob/demob, drilling, materials, 8.7% sales tax.
Laboratory analysis	22	samples	$ 60	$ 1,320	TPH-G - soil.
Sample shipping	15%	--	--	$ 198	Assumed percentage of sample analysis cost.
Soil Confirmational Sampling Subtotal				**$ 64,046**	

Table B-16 - *In Situ* Treatment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
CAPITAL COSTS					
Injection/Extraction Well Installation					
Drilling	7905	ft	$ 77	$ 608,685	Assume wells are 68 ft deep in AOCs except for Hoffman Tank excavation where wells are 55 ft deep. Screens placed through vertical extent of contamination. Unit cost based on vendor quote. Includes mob/demob, drilling, materials, 8.7% sales tax.
Well construction materials	114	ea	$ 1,946	$ 221,813	Unit cost based on vendor quote. Includes screen, casing, vaults, sand, hole plug, well permits, 8.7% sales tax.
Installation oversight	19	wk	$ 5,375	$ 102,125	Assume HC oversight, 6 wells per week.
Transport & dispose soil at Subtitle D landfill	105	ton	$ 54	$ 5,692	Cost for disposal based on previous Kaiser work and adjusted using RSMeans 2010 historical cost index.
Subtotal				$ 938,315	
Ozone Generation/SVE					
Mobilization	1	LS	$ 4,000	$ 4,000	Engineer's estimate.
Ozone generator	4	ea	$ 125,000	$ 500,000	Four units generating 50 lb ozone/day. Vendor quote.
SVE unit	4	ea	$ 75,000	$ 300,000	Four units.
Carbon units	1	LS	$ 16,000	$ 16,000	Two 2,000-lb bed per unit. Cost from SVE Vendor.
Nickel catalyst unit	4	ea	$ 10,000	$ 40,000	Vendor quote.
Conveyance piping	1	LS	$ 48,490	$ 48,490	Conveyance for 4 systems, assume underground piping. Assumed 4x SVE (see Table B-14 for backup calculations).
Power Hookup	4	ea	$ 5,000	$ 20,000	Engineer's estimate.
Installation oversight	4	wk	$ 5,375	$ 21,500	Assume 4 weeks of HC oversight during installation of treatment system. See Table B-17 for backup.
Sales Tax	8.7%	--	--	$ 78,691	Assume sales tax charged on cost of materials.
Subtotal				$ 1,028,681	
System Monitoring					
Startup system performance	1	LS	$ 20,424	$ 20,424	Assumed 4x SVE monitoring costs. See Table B-15 for backup.
O&M COSTS					
Annual Performance Monitoring	1	LS	$ 56,482	$ 56,482	Assumed 4x SVE monitoring costs. See Table B-15 for backup.
Performance Soil Sampling					
Drilling	612	ft	$ 77	$ 47,124	Assume 1 locations per AOC to 68 ft bgs. Unit cost vendor quote. Includes mob/demob, drilling, materials, 8.7% sales tax.
Labor	2	wk	$ 5,375	$ 10,750	Assume 2 weeks oversight.
Sampling and Analysis	36	ea	$ 545	$ 19,620	Assume 4 samples/boring. Sample for SVOCs, VOCs, PCBs, and metals analyses.
Equipment/shipping	1	LS	$ 2,000	$ 2,000	Engineer's estimate.
Subtotal				$ 79,494	
Operations					
Operation labor	480	hr	$ 75	$ 36,000	Assume 0.25 FTE.
Carbon changeout	4	ea	$ 5,580	$ 22,320	Includes replacement, removal, regeneration, and labor for carbon changeout for one 2,000-lb bed. Based on vendor quote for existing HC project. Price adjusted per 2010 RSMeans Cost Index. Assume to occur at end of year.
Utilities	876000	kWh	$ 0.05	$ 41,347	Based on 25-kW demand per unit, continuous operation. Cost of electricity based on estimate provided by Kaiser.
Subtotal				$ 99,667	
Maintanance					
Mantainance labor	192	hr	$ 75	$ 14,400	Assume 0.1 FTE.
Equipment repair	1	LS	$ 45,225	$ 45,225	Assume 5% of equipment costs.
Subtotal				$ 59,625	
PERIODIC COSTS					
Well abandonment	114	ea	$ 900	$ 102,600	Previous HC experience. Unit cost includes Ecology filing, materials, labor, travel.

Table B-17 - Hart Crowser and Analytical Rates Cost Backup

HC Kaiser Rates

Sr. Principal	$	190	
Principal	$	180	
Sr. Associate	$	160	
Associate	$	145	
Sr. Project	$	130	
Project	$	110	
Sr. Staff	$	90	
Staff	$	75	
Sr. Drafter	$	100	
Drafter	$	77	
WP/PA	$	60	
Sub MU		12%	
Communication fee		0%	
Mileage		$0.50/mi.	Fed rate (2010)
Truck Rental	$	85	+ mileage for over 50 mi./day (due to gas prices)
Safety ($ per hr.)	$	5	per field labor hour
Trip per diem	$	150	each way
Per diem	$	133	Fed rate for Spokane

Weekly Cost for HC oversight (staff)

Labor	$	3,600	5 - 9 hr days for staff level, plus safety costs
Truck	$	810	5 days truck plus travel day, plus $300 for miles over 50
Travel	$	300	
Per diem	$	665	
Subtotal	$	5,375	per week

Columbia Analytical Services and Advanced Analytical Laboratory Costs

Assume same price for water/soil.

Parameter	Cost / Analysis	
NWTPH-HCID	$	55
TPH-Dx	$	60
TPH-G	$	60
PCBs - Ultra-Low Level	$	175
VOCs	$	130
PAHs (8270 SIM)	$	215
Metals (10)	$	180
Arsenic	$	26
Chromium	$	24
Manganese	$	26
Iron	$	24
Antimony	$	26
TSS	$	18
Chloride	$	18
Nitrate/Nitrite	$	24
Hardness	$	25
TDS	$	18
Alkalinity	$	18
Sulfate	$	18
Total aresenic, chromium, zinc, and phosphorous	$	50
Hexavalent chromium	$	50
Orthophosphate	$	20
Cyanide	$	40
BOD	$	45
Fecal coliform	$	35
Oil & grease	$	50

APPENDIX C
COST ESTIMATES FOR PETROLEUM HYDROCARBON GROUNDWATER PLUME AND ASSOCIATED SMEAR ZONE SOIL REMEDIAL ALTERNATIVES

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APPENDIX C
COST ESTIMATES FOR PETROLEUM HYDROCARBON GROUNDWATER PLUME AND ASSOCIATED SMEAR ZONE SOIL REMEDIAL ALTERNATIVES

TABLES

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Table C-1 - Estimated Cost Comparison for Petroleum Hydrocarbon Groundwater Plume and Smear Zone Soil Remedial Alternatives

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Cost comparison of the net present value and incremental cost of Alternative C1 through C4 for remediation of smear zone soil and petroleum hydrocarbon groundwater plumes.

DESCRIPTION	TOTAL NET PRESENT VALUE	INCREMENTAL COST	COST TABLE REFERENCE
Alternative C1	$ 21,000,000	Baseline Cost	Table C-2
Alternative C2 (Scenario C2a)	$ 22,900,000	$ 1,900,000	Table C-3
Alternative C2 (Scenario C2b)	$ 22,900,000	$ 1,900,000	Table C-4
Alternative C2 (Scenario C2c)	$ 21,900,000	$ 900,000	Table C-5
Alternative C3	$ 28,100,000	$ 5,200,000	Table C-6
Alternative C4	$ 41,000,000	$ 18,100,000	Table C-7

Note:
Present value analysis uses a 30-year discount rate of 7%.

Table C-2 - Alternative C1 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative C1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to each of the alternatives that will be evaluated for the remediation of the petroleum hydrocarbon groundwater plumes and associated smear zone soil at the Kaiser Facility. Alternative C1 includes the operation of the existing groundwater Interim Remedial Measure (IRM) and assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls					
Institutional control plans	1	EA	$ 46,548	$ 46,548	See Table C-9.
Pending upgrades in casting complex	1	LS	$ 1,076,073	$ 1,076,073	See Table C-9.
Restrictive covenant preparation	1	LS	$ 24,970	$ 24,970	See Table C-9.
Institutional Controls Subtotal				**$ 1,147,591**	
Contingency	10%	--	--	**$ 114,759**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					
Project management	6%	--	--	$ 75,741	Percentage of capital cost + contingency. EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Year 0. Kaiser mean annual Ecology costs 2007-2009.
Professional/Technical Services Subtotal				**$ 97,741**	
TOTAL CAPITAL COST				**$ 1,360,091**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Monitoring, Sampling, Testing, and Analysis					
Protection monitoring	1	YR	$ 44,683	$ 44,683	See Table C-8.
Performance monitoring	1	YR	$ 223,417	$ 223,417	See Table C-8.
Additional groundwater MNA monitoring	1	YR	$ 34,633	$ 34,633	See Table C-8.
Data management	1	YR	$ 29,948	$ 29,948	HC estimate. Data validation; maintain database. See Table C-8.
MNA monitoring data management	1	YR	$ 4,729	$ 4,729	HC estimate. Data validation; maintain database. See Table C-8.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 337,410**	
Institutional Controls (Annual Update and Maintenance)					
Institutional control plans	1	YR	$ 30,018	$ 30,018	See Table C-9.
Institutional controls maintenance	1	YR	$ 259,604	$ 259,604	See Table C-9.
Outfall & treatment plant monitoring	1	YR	$ 101,946	$ 101,946	See Table C-9. Required by NPDES permit and Ecology orders (see Section 2.1.1.1).
Site information database	1	YR	$ 5,743	$ 5,743	See Table C-9.
Institutional Controls Subtotal				**$ 397,311**	
Groundwater IRM System O&M					
Electricity	7,230,423	kWh	$ 0.05	$ 361,521	Groundwater extraction pump operation. See Table C-11.
FPP recovery	4	wells	$ 8,333	$ 33,333	See Table C-12.
Containment system maintenance	1	YR	$ 54,998	$ 54,998	Includes labor, parts, supplies. See Table C-11.
Groundwater IRM System O&M Subtotal				**$ 449,852**	
Contingency	10%	--	--	**$ 118,457**	Scope and bid contingency. Percentage of monitoring, institutional controls, and IRM sytem O&M annual cost.
Professional/Technical Services					
Project management	6%	--	--	$ 78,182	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 130,303	EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Kaiser mean annual Ecology costs 2007-2009.
Reporting	1	YR	$ 16,182	$ 16,182	Report to Kaiser & Ecology quarterly; EIM reporting. See Table C-8.
MNA reporting	1	YR	$ 2,555	$ 2,555	Report to Kaiser & Ecology quarterly; EIM reporting. See Table C-8.
Professional/Technical Services Subtotal				**$ 249,222**	
TOTAL ANNUAL O&M COST				**$ 1,552,252**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls (Periodic Update and Maintenance)					
Restrictive covenants	1	EA	$ 6,470	$ 6,470	Years 5, 10, 15, 20, 25, 30. See Table C-9.
Initial acute and chronic toxicity testing	1	LS	$ 45,000	$ 45,000	Years 0, 5, 10, 15, 20, 25. See Table C-9.
Final acute and chronic toxicity testing	1	LS	$ 14,940	$ 14,940	Years 5, 10, 15, 20, 25, 30. See Table C-9.
Institutional Controls Subtotal				**$ 66,410**	
Groundwater IRM System Periodic Maintenance					
Groundwater extraction system	4	EA	$ 30,896	$ 123,583	Years 10, 20, 30. Major equipment & infrastructure repair/replacement, 4 extraction locations. Assume equivalent to extraction equipment installation capital cost, per vendor quote (see Tables C-4 and C-5).
FPP recovery system (years 5 and 15)	1	LS	$ 13,596	$ 13,596	Years 5, 15. See Table C-13.
FPP recovery system (year 10)	1	LS	$ 15,972	$ 15,972	Year 10. See Table C-13.
Groundwater IRM System Periodic Maintenance Subtotal				**$ 153,151**	
Contingency	10%	--	--	**$ 21,956**	Scope and bid contingency. Percentage of periodic costs.

Table C-2 - Alternative C1 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative C1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to each of the alternatives that will be evaluated for the remediation of the petroleum hydrocarbon groundwater plumes and associated smear zone soil at the Kaiser Facility. Alternative C1 includes the operation of the existing groundwater Interim Remedial Measure (IRM) and assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

Professional/Technical Services						
Five-year reviews	1	EA	$ 19,540	$	19,540	Years 5, 10, 15, 20, 25, 30. See Table C-10.
Closure report	1	EA	$ 41,180	$	41,180	Year 30. See Table C-10.
Professional/Technical Services Subtotal				**$**	**60,720**	

PRESENT VALUE ANALYSIS - Alternative C1 with IRM System Hydraulic Containment Operating

Discount rate	7.0%		
Time period	30	years	Assumed time period for fixed annual and periodic costs.
RTF	27	years	Weighted average restoration time frame applied to variable annual costs. See Table C-17.
FPP recovery	20	years	Accounts for FPP recovery periods of less than 30 years.

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 1,409,591	$ 1,409,591	1.000	$ 1,409,591	
Annual O&M	1 - 30	$ 44,324,990	$ 1,477,500	12.409	$ 18,334,354	Annual O&M for fixed costs.
Annual O&M	1 - 27	$ 1,422,930	$ 53,486	11.924	$ 637,780	Annual O&M for variable costs.
Annual O&M	1 - 20	$ 425,328	$ 21,266	10.594	$ 225,297	Annual O&M for FPP recovery less than 30 years.
Periodic	5	$ 107,547	$ 107,547	0.713	$ 76,679	
Periodic	10	$ 246,101	$ 246,101	0.508	$ 125,105	
Periodic	15	$ 107,547	$ 107,547	0.362	$ 38,980	
Periodic	20	$ 228,532	$ 228,532	0.258	$ 59,057	
Periodic	25	$ 92,591	$ 92,591	0.184	$ 17,060	
Periodic	30	$ 220,212	$ 220,212	0.131	$ 28,929	
		$ 48,585,370			$ 20,952,833	
TOTAL NET PRESENT VALUE OF ALTERNATIVE C1 with IRM System Hydraulic Containment Operating					**$ 20,952,833**	

PRESENT VALUE ANALYSIS - Alternative C1 with IRM System Hydraulic Containment Shut Off

Discount rate	7.0%		
Time period	30	years	Assumed time period for fixed annual and periodic costs.
RTF	27	years	Weighted average restoration time frame applied to variable annual costs. See Table C-17.
FPP recovery	20	years	Accounts for FPP recovery periods of less than 30 years.

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 1,409,591	$ 1,409,591	1.000	$ 1,409,591	This present value analysis assumes that IRM system hydraulic containment is shut off and exludes annual electricity ($361,521) and maintenance ($54,998) costs associated with system operation, and excludes adjustments for contingency (10%), project management (6%), and technical support (10%) for these annual cost items. Groundwater extraction system periodic maintenance cost ($123,583) and its contingency adjustment (10%) are excluded (years 10, 20, and 30).
Annual O&M	1 - 30	$ 28,380,626	$ 946,021	12.409	$ 11,739,212	
Annual O&M	1 - 27	$ 1,422,930	$ 53,486	11.924	$ 637,780	
Annual O&M	1 - 20	$ 425,328	$ 21,266	10.594	$ 225,297	
Periodic	5	$ 107,547	$ 107,547	0.713	$ 76,679	
Periodic	10	$ 110,160	$ 110,160	0.508	$ 56,000	
Periodic	15	$ 107,547	$ 107,547	0.362	$ 38,980	
Periodic	20	$ 92,591	$ 92,591	0.258	$ 23,927	
Periodic	25	$ 92,591	$ 92,591	0.184	$ 17,060	
Periodic	30	$ 84,271	$ 84,271	0.131	$ 11,070	
		$ 32,233,182			$ 14,235,597	
TOTAL NET PRESENT VALUE OF ALTERNATIVE C1 with IRM System Hydraulic Containment Shut Off					**$ 14,235,597**	This cost is used specifically for estimating Alternative C2, Scenario C2c, net present value. See Table C-5.

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table C-3 - Alternative C2 Estimated Cost Summary - Scenario C2a

Location: Kaiser Trentwood Facility, Spokane Valley, WA **Phase:** Feasibility Study (-35% to +50%) **Base Year:** 2010 **Date:** July 2011	**Description:** Scenario C2a of Alternative C2 expands the hydraulic containment and FPP recovery provided in Alternative C1 by adding the operation of existing groundwater extraction well WW-EW-3 (currently shut off) to the existing groundwater IRM system. This scenario expands the plume capture zone of the existing IRM system to hydraulically contain the ORB area petroleum hydrocarbon groundwater plume. Additional FPP skimming wells will be installed and operated in this alternative. A 30-year operating period is assumed in the development of this cost estimate.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 10,000	$ 10,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience.
Submittals, Plans, Site Preparation Subtotal				**$ 20,000**	
IRM System Expansion					Add operation of WW-EW-3; start 3 new FPP skimming locations.
Extraction system repair/replacement	1	EA	$ 77,239	$ 77,239	Unit cost scaled from vendor quote in Scenario C2b (see Table C-4). Scaling based on ratio of WW-EW-3 modeled flow rate (1.5 MGD) to ORB-FEW-1 modeled flow rate (0.6 MGD) (Appendix E, Table E-3).
Skimming well construction	95	ft	$ 371	$ 35,241	Unit cost based on vendor quote.
Belt skimmer installation	1	LS	$ 9,020	$ 9,020	See Table C-12.
Restart existing skimming wells	2	EA	$ 2,570	$ 5,140	See Table C-12.
Electrical connection	1	EA	$ 50,000	$ 50,000	Previous project experience. One location (new skimming well near WW-MW-6). Assume other locations have existing power supply (WW-EW-3, WW-SK-2, OH-SK-1).
IRM System Expansion Subtotal				**$ 176,641**	
Contingency	10%	--	--	**$ 19,664**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	8%	--	--	$ 17,304	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	15%	--	--	$ 32,446	EPA 540-R-00-002.
Construction management	10%	--	--	$ 21,630	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 73,581**	
Institutional Controls					New institutional controls for IRM system expansion.
Institutional controls plan	50%	--	--	$ 23,274	Assume 50% of Alt. C1 institutional control plan cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Restrictive covenants	50%	--	--	$ 12,485	Assume 50% of Alt. C1 restrictive covenant preparation cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Institutional Controls Subtotal				**$ 35,759**	
TOTAL CAPITAL COST				**$ 325,644**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation, Maintenance, and Monitoring					
Electricity	653,233	kWh	$ 0.05	$ 32,662	Groundwater extraction pump operation. See Table C-11.
FPP recovery	3	wells	$ 8,333	$ 25,000	See Table C-12.
Containment system maintenance	25%	--	--	$ 13,750	Assume 25% of Alt. C1 annual maintenance cost, based on 1:4 extraction well quantity ratio.
Additional GW monitoring	2%	--	--	$ 5,362	Assume approx. 2% of Alt. C1 annual monitoring cost, based on 2:114 well quantity ratio.
Data management	1	YR	$ 4,500	$ 4,500	See Table C-10.
System Operation, Maintenance, and Monitoring Subtotal				**$ 81,273**	
Contingency	10%	--	--	**$ 8,127**	Scope and bid contingency. Percentage of monitoring, institutional controls, and IRM sytem O&M annual cost.
Professional/Technical Services					
Project management	10%	--	--	$ 8,940	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 8,940	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Reporting	1	YR	$ 7,000	$ 7,000	See Table C-10.
Professional/Technical Services Subtotal				**$ 27,080**	
Institutional Controls (Annual Update and Maintenance)					New institutional controls for IRM system expansion.
Institutional controls plan	50%	--	--	$ 15,009	Assume 50% of Alt. C1 institutional control plan cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Site information database	50%	--	--	$ 2,872	Assume 50% of Alt. C1 site information data base cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Institutional Controls Subtotal				**$ 17,881**	
TOTAL ANNUAL O&M COST				**$ 134,361**	

Table C-3 - Alternative C2 Estimated Cost Summary - Scenario C2a

Location: Kaiser Trentwood Facility, Spokane Valley, WA	**Description:** Scenario C2a of Alternative C2 expands the hydraulic containment and FPP recovery provided in Alternative C1 by adding the operation of existing groundwater extraction well WW-EW-3 (currently shut off) to the existing groundwater IRM system. This scenario expands the plume capture zone of the existing IRM system to hydraulically contain the ORB area petroleum hydrocarbon groundwater plume. Additional FPP skimming wells will be installed and operated in this alternative. A 30-year operating period is assumed in the development of this cost estimate.
Phase: Feasibility Study (-35% to +50%)	
Base Year: 2010	
Date: July 2011	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Groundwater IRM System Periodic Maintenance					
Groundwater extraction system	1	EA	$ 77,239	$ 77,239	Years 10, 20, 30. Major equipment and infrastructure repair/replacement, 1 extraction location (WW-EW-3). Assume equivalent of extraction system repair/replacement capital cost.
FPP recovery system	1	LS	$ 27,390	$ 27,390	Year 5. See Table C-13.
Groundwater IRM System Periodic Maintenance Subtotal				**$ 104,629**	
Contingency	10%	--	--	**$ 10,463**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. See Table C-10.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. See Table C-10.
Professional/Technical Services Subtotal				**$ 30,360**	

PRESENT VALUE ANALYSIS

Discount rate	7.0%		
Time period	30	years	Assumed time period for fixed annual and periodic costs.
RTF	27	years	Weighted average restoration time frame applied to variable annual costs. See Table C-17.
FPP recovery	25	years	Accounts for FPP recovery periods of less than 30 years.
FPP recovery	10	years	Accounts for FPP recovery periods of less than 30 years.

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 325,644	$ 325,644	1.000	$ 325,644	
Annual O&M	1 - 30	$ 812,415	$ 27,081	12.409	$ 336,043	Annual O&M for fixed costs.
Annual O&M	1 - 27	$ 1,976,146	$ 74,281	11.924	$ 885,741	Annual O&M for variable costs.
Annual O&M	1 - 25	$ 549,994	$ 22,000	11.654	$ 256,376	Annual O&M for FPP recovery less than 30 years.
Annual O&M	1 - 10	$ 109,999	$ 11,000	7.024	$ 77,259	Annual O&M for FPP recovery less than 30 years.
Periodic	5	$ 39,899	$ 39,899	0.713	$ 28,447	
Periodic	10	$ 94,733	$ 94,733	0.508	$ 48,158	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 94,733	$ 94,733	0.258	$ 24,481	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 30,360	$ 30,360	0.131	$ 3,988	
		$ 4,053,463			$ 1,991,478	Net present value of elements unique to Alternative C2, Scenario C2a.

Cost Savings from Reduced FPP Recovery Period Applied to Alternative C1

Original FPP recovery costs from Alt. C1						
Annual O&M	1 - 30	$ 637,993	$ 21,266	12.409	$ 263,896	2 wells
Annual O&M	1 - 20	$ 425,328	$ 21,266	10.594	$ 225,297	2 wells
Subtotal					$ 489,193	
Reduced FPP recovery operating time applied to wells from Alt. C1						
Annual O&M	1 - 25	$ 531,661	$ 21,266	11.654	$ 247,830	2 wells
Annual O&M	1 - 10	$ 212,664	$ 21,266	7.024	$ 149,366	2 wells
Subtotal					$ 397,197	
Total savings					$ 91,996	
Total Net Present Value of Alternative C1					$ 20,952,833	
Cost Savings Applied to Alt. C1					$ 20,860,836	
TOTAL NET PRESENT VALUE OF ALTERNATIVE C2, SCENARIO C2a					**$ 22,944,310**	
With Cost Savings Applied to Alt. C1					**$ 22,852,314**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table C-4 - Alternative C2 Estimated Cost Summary - Scenario C2b

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Scenario C2b of Alternative C2 expands the hydraulic containment and FPP recovery provided in Alternative C1 through the operation of the existing groundwater IRM system plus the installation and operation of a new groundwater extraction well to hydraulically contain the ORB area petroleum hydrocarbon groundwater plume. Additional FPP skimming wells will be installed and operated in this alternative. A 30-year operating period is assumed in the development of this cost estimate.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 10,000	$ 10,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience.
Submittals, Plans, Site Preparation Subtotal				**$ 20,000**	
IRM System Expansion					1 new extraction well; 3 new FPP skimming locations.
Extraction well construction	195	ft	$ 286	$ 55,764	Unit cost based on vendor quote. One extraction well.
Extraction system installation	1	EA	$ 30,896	$ 30,896	Unit cost based on vendor quote.
Piping installation	1	LS	$ 51,395	$ 51,395	See Table C-11.
Deep monitoring well construction	100	ft	$ 112	$ 11,200	Depth based on well OH-MW-26 (see Table 4-3). Unit cost based on vendor quote.
Skimming well construction	95	ft	$ 371	$ 35,241	Unit cost based on vendor quote. One skimming well.
Belt skimmer installation	1	EA	$ 9,020	$ 9,020	See Table C-12.
Restart existing skimming wells	2	EA	$ 2,570	$ 5,140	See Table C-12.
Electrical connection	2	EA	$ 50,000	$ 100,000	Previous project experience. Two locations (extraction well ORB-FEW-1; new skimming well near WW-MW-6). Assume other locations have existing power supply (WW-SK-2, OH-SK-1).
IRM System Expansion Subtotal				**$ 298,656**	
Contingency	10%	--	--	**$ 31,866**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	8%	--	--	$ 28,042	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	15%	--	--	$ 52,578	EPA 540-R-00-002.
Construction management	10%	--	--	$ 35,052	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 117,872**	
Institutional Controls					New institutional controls for IRM system expansion.
Institutional controls plan	50%	--	--	$ 23,274	Assume 50% of Alt. C1 institutional control plan cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Restrictive covenants	50%	--	--	$ 12,485	Assume 50% of Alt. C1 restrictive covenant preparation cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Institutional Controls Subtotal				**$ 35,759**	
TOTAL CAPITAL COST				**$ 504,153**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation, Maintenance, and Monitoring					
Electricity	489,925	kWh	$ 0.05	$ 24,496	Groundwater extraction pump operation. See Table C-11.
FPP recovery	3	wells	$ 8,333	$ 25,000	See Table C-12.
Containment system maintenance	25%	--	--	$ 13,750	Assume 25% of Alt. C1 annual maintenance cost, based on 1:4 extraction well quantity ratio.
Additional GW monitoring	2%	--	--	$ 5,362	Assume approx. 2% of Alt. C1 annual monitoring cost, based on 2:114 well quantity ratio.
Data management	1	YR	$ 4,500	$ 4,500	See Table C-10.
System Operation, Maintenance, and Monitoring Subtotal				**$ 73,108**	
Contingency	10%	--	--	**$ 7,311**	Scope and bid contingency. Percentage of monitoring, institutional controls, and IRM sytem O&M annual cost.
Professional/Technical Services					
Project management	10%	--	--	$ 8,042	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 8,042	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Reporting	1	YR	$ 7,000	$ 7,000	See Table C-10.
Professional/Technical Services Subtotal				**$ 25,284**	
Institutional Controls (Annual Update and Maintenance)					New institutional controls for IRM system expansion.
Institutional controls plan	50%	--	--	$ 15,009	Assume 50% of Alt. C1 institutional control plan cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Site information database	50%	--	--	$ 2,872	Assume 50% of Alt. C1 site information data base cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Institutional Controls Subtotal				**$ 17,881**	
TOTAL ANNUAL O&M COST				**$ 123,582**	

Table C-4 - Alternative C2 Estimated Cost Summary - Scenario C2b

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Scenario C2b of Alternative C2 expands the hydraulic containment and FPP recovery provided in Alternative C1 through the operation of the existing groundwater IRM system plus the installation and operation of a new groundwater extraction well to hydraulically contain the ORB area petroleum hydrocarbon groundwater plume. Additional FPP skimming wells will be installed and operated in this alternative. A 30-year operating period is assumed in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Groundwater IRM System Periodic Maintenance					
Groundwater extraction system	1	EA	$ 30,896	$ 30,896	Years 10, 20. Major equipment & infrastructure repair/replacement, 1 extraction location (ORB-FEW-1). Assume equivalent of extraction system installation capital cost.
FPP recovery system	1	LS	$ 27,390	$ 27,390	Year 5. See Table C-13.
Groundwater IRM System Periodic Maintenance Subtotal				**$ 58,286**	
Contingency	10%	--	--	**$ 5,829**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. See Table C-10.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. See Table C-10.
Professional/Technical Services Subtotal				**$ 30,360**	

PRESENT VALUE ANALYSIS

Discount rate	7.0%		
Time period	30	years	Assumed time period for fixed annual and periodic costs.
RTF	27	years	Weighted average restoration time frame applied to variable annual costs. See Table C-17.
FPP recovery	25	years	Accounts for FPP recovery periods of less than 30 years.
FPP recovery	10	years	Accounts for FPP recovery periods of less than 30 years.

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 504,153	$ 504,153	1.000	$ 504,153	
Annual O&M	1 - 30	$ 812,415	$ 27,081	12.409	$ 336,043	Annual O&M for fixed costs.
Annual O&M	1 - 27	$ 1,689,402	$ 63,502	11.924	$ 757,217	Annual O&M for variable costs.
Annual O&M	1 - 25	$ 549,994	$ 22,000	11.654	$ 256,376	Annual O&M for FPP recovery less than 30 years.
Annual O&M	1 - 10	$ 109,999	$ 11,000	7.024	$ 77,259	Annual O&M for FPP recovery less than 30 years.
Periodic	5	$ 39,899	$ 39,899	0.713	$ 28,447	
Periodic	10	$ 43,755	$ 43,755	0.508	$ 22,243	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 43,755	$ 43,755	0.258	$ 11,307	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 30,360	$ 30,360	0.131	$ 3,988	
		$ 3,843,272			$ 2,002,375	Net present value of elements unique to Alternative C2, Scenario C2b.

Cost Savings from Reduced FPP Recovery Period Applied to Alternative C1

Original FPP recovery costs from Alt. C1						
Annual O&M	1 - 30	$ 637,993	$ 21,266	12.409	$ 263,896	2 wells
Annual O&M	1 - 20	$ 425,328	$ 21,266	10.594	$ 225,297	2 wells
Subtotal					$ 489,193	
Reduced FPP recovery operating time applied to wells from Alt. C1						
Annual O&M	1 - 25	$ 531,661	$ 21,266	11.654	$ 247,830	2 wells
Annual O&M	1 - 10	$ 212,664	$ 21,266	7.024	$ 149,366	2 wells
Subtotal					$ 397,197	
Total savings					$ 91,996	
Total Net Present Value of Alternative C1					$ 20,952,833	
Cost Savings Applied to Alt. C1					$ 20,860,836	
TOTAL NET PRESENT VALUE OF ALTERNATIVE C2, SCENARIO C2b					**$ 22,955,207**	
With Cost Savings Applied to Alt. C1					**$ 22,863,211**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table C-5 - Alternative C2 Estimated Cost Summary - Scenario C2c

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Scenario C2c of Alternative C2 provides focused containment of the petroleum hydrocarbon groundwater plumes with the hydraulic containment portion of the groundwater IRM system shut off. This scenario assesses localized hydraulic containment of each of the petroleum groundwater plumes at the Facility through installation and operation of extraction wells at the leading edge of each plume, in lieu of providing hydraulic control through operation of the IRM system. Additional FPP skimming wells will be installed and operated in this alternative to expand the FPP recovery portion of the IRM system. A 30-year operating period is assumed in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 10,000	$ 10,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience.
Submittals, Plans, Site Preparation Subtotal				**$ 20,000**	
IRM System Expansion					11 new extraction wells; 3 new FPP skimming locations.
Extraction well construction	1,939	ft	$ 286	$ 554,496	11 wells. See Table C-11 for well depths. Unit cost based on vendor quote.
Extraction system installation	11	EA	$ 30,896	$ 339,853	For 11 wells. Unit cost based on vendor quote.
Indoor piping installation	1	LS	$ 25,001	$ 25,001	See Table C-11.
Outdoor piping installation	1	LS	$ 270,340	$ 270,340	See Table C-11.
Deep monitoring well construction	800	ft	$ 112	$ 89,600	8 wells, 100-ft depth each. Depth based on average depth of wells OH-MW-26 and WW-MW-17 (see Table 4-3). Unit cost based on vendor quote.
Skimming well construction	95	ft	$ 371	$ 35,241	Unit cost based on vendor quote.
Belt skimmer installation	1	EA	$ 9,020	$ 9,020	Engineer's estimate. Includes labor and equipment.
Restart existing skimming wells	2	EA	$ 2,570	$ 5,140	Engineer's estimate.
Electrical connection	5	EA	$ 50,000	$ 250,000	Previous project experience. Four extraction well groups (Wastewater Treatment, ORB, Oil House, Cold Mill areas) plus one new skimming well (near WW-MW-6). Assume other locations have existing power supply (WW-SK-2, OH-SK-1).
IRM System Expansion Subtotal				**$ 1,578,691**	
Contingency	10%	--	--	**$ 159,869**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	6%	--	--	$ 105,514	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	12%	--	--	$ 211,027	EPA 540-R-00-002.
Construction management	8%	--	--	$ 140,685	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 459,426**	
Institutional Controls					New institutional controls for IRM system expansion.
Institutional controls plan	1	EA	$ 46,548	$ 46,548	Assume equivalent to Alt. C1 institutional control plan cost.
Restrictive covenants	1	LS	$ 24,970	$ 24,970	Assume equivalent to Alt. C1 restrictive covenant preparation cost.
Institutional Controls Subtotal				**$ 71,518**	
TOTAL CAPITAL COST				**$ 2,289,504**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation, Maintenance, and Monitoring					
Electricity	3,607,270	kWh	$ 0.05	$ 180,363	Groundwater extraction pump operation. See Table C-11.
FPP recovery	3	wells	$ 8,333	$ 25,000	See Table C-12.
Containment system maintenance	275%	--	--	$ 151,245	Assume 275% of Alt. C1 annual maintenance cost, based on 11:4 extraction well quantity ratio.
Additional GW monitoring	17%	--	--	$ 44,773	Assume approx. 2% of Alt. C1 annual monitoring cost, based on 19:114 well quantity ratio.
Data management	1	YR	$ 4,500	$ 4,500	See Table C-10.
System Operation, Maintenance, and Monitoring Subtotal				**$ 405,881**	
Contingency	10%	--	--	**$ 40,588**	Scope and bid contingency. Percentage of monitoring, institutional controls, and IRM sytem O&M annual cost.
Professional/Technical Services					
Project management	10%	--	--	$ 44,647	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 44,647	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Reporting	1	YR	$ 7,000	$ 7,000	See Table C-10.
Professional/Technical Services Subtotal				**$ 98,494**	
Institutional Controls (Annual Update and Maintenance)					New institutional controls for IRM system expansion.
Institutional controls plan	125%	--	--	$ 37,523	Assume 125% of Alt. C1 institutional control plan cost to include containment and FPP recovery elements unique to Scenario C2c, based on 10:8 well quantity ratio.
Site information database	125%	--	--	$ 7,179	Assume 125% of Alt. C1 site information database cost to include containment and FPP recovery elements unique to Scenario C2c, based on 10:8 well quantity ratio.
Institutional Controls Subtotal				**$ 44,701**	
TOTAL ANNUAL O&M COST				**$ 589,664**	

Table C-5 - Alternative C2 Estimated Cost Summary - Scenario C2c

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Scenario C2c of Alternative C2 provides focused containment of the petroleum hydrocarbon groundwater plumes with the hydraulic containment portion of the groundwater IRM system shut off. This scenario assesses localized hydraulic containment of each of the petroleum groundwater plumes at the Facility through installation and operation of extraction wells at the leading edge of each plume, in lieu of providing hydraulic control through operation of the IRM system. Additional FPP skimming wells will be installed and operated in this alternative to expand the FPP recovery portion of the IRM system. A 30-year operating period is assumed in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Groundwater IRM System Periodic Maintenance					
Groundwater extraction system	11	EA	$ 30,896	$ 339,853	Year 10. Major equipment and infrastructure repair/replacement, 11 extraction locations. Assume equivalent of extraction system installation capital cost per location.
FPP recovery system	1	LS	$ 27,390	$ 27,390	Year 5. See Table C-13.
Groundwater IRM System Periodic Maintenance Subtotal				**$ 367,243**	
Contingency	10%	--	--	**$ 36,724**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 24,425	$ 24,425	Years 5, 10, 15, 20, 25. See Table C-10.
Closure report	1	EA	$ 51,475	$ 51,475	Year 12. See Table C-10.
Professional/Technical Services Subtotal				**$ 75,900**	

PRESENT VALUE ANALYSIS

Discount rate	7.0%		
Time period	30	years	Assumed time period for fixed annual and periodic costs.
RTF	12	years	Weighted average restoration time frame applied to variable annual costs. See Table C-17.
FPP recovery	25	years	Accounts for FPP recovery periods of less than 30 years.
FPP recovery	10	years	Accounts for FPP recovery periods of less than 30 years.

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 2,289,504	$ 2,289,504	1.000	$ 2,289,504	
Annual O&M	1 - 30	$ 1,617,038	$ 53,901	12.409	$ 668,863	Annual O&M for fixed costs.
Annual O&M	1 - 12	$ 6,264,847	$ 502,764	8.137	$ 4,091,189	Annual O&M for variable costs.
Annual O&M	1 - 25	$ 549,994	$ 22,000	11.654	$ 256,376	Annual O&M for FPP recovery less than 30 years.
Annual O&M	1 - 10	$ 109,999	$ 11,000	7.024	$ 77,259	Annual O&M for FPP recovery less than 30 years.
Periodic	5	$ 54,554	$ 54,554	0.713	$ 38,896	
Periodic	10	$ 398,263	$ 398,263	0.508	$ 202,457	
Periodic	12	$ 51,475	$ 51,475	0.430	$ 22,154	
Periodic	15	$ 24,425	$ 24,425	0.362	$ 8,853	
Periodic	20	$ 24,425	$ 24,425	0.258	$ 6,312	
Periodic	25	$ 24,425	$ 24,425	0.184	$ 4,500	
Periodic	30	$ -	$ -	0.131	$ -	
		$ 11,408,949			$ 7,666,363	Net present value of elements unique to Alternative C2, Scenario C2c.

Cost Savings from Reduced FPP Recovery Period Applied to Alternative C1

Original FPP recovery costs from Alt. C1						
Annual O&M	1 - 30	$ 637,993	$ 21,266	12.409	$ 263,896	2 wells
Annual O&M	1 - 20	$ 425,328	$ 21,266	10.594	$ 225,297	2 wells
Subtotal					$ 489,193	
Reduced FPP recovery operating time applied to wells from Alt. C1						
Annual O&M	1 - 25	$ 531,661	$ 21,266	11.654	$ 247,830	2 wells
Annual O&M	1 - 10	$ 212,664	$ 21,266	7.024	$ 149,366	2 wells
Subtotal					$ 397,197	
Total savings					$ 91,996	
Total Net Present Value of Alternative C1 with IRM System Hydraulic Containment Shut Off					$ 14,235,597	Assumes hydraulic containment portion of IRM system is shut off.
Cost Savings Applied to Alt. C1					$ 14,143,600	
TOTAL NET PRESENT VALUE OF ALTERNATIVE C2, SCENARIO C2c					**$ 21,901,959**	
With Cost Savings Applied to Alt. C1					**$ 21,809,963**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table C-6 - Alternative C3 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative C3 includes Alternative C2 plus *in situ* enhanced bioremediation for petroleum groundwater plumes and associated smear zone soil. Alternative C3 assumes an operating period of 30 years in the development of this cost estimate. Refer to Table C-14 for details.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 50,000	$ 50,000	SAP, HASP, work plan, as-built drawings, O&M manual, QA/QC documentation. Based on previous project experience.
Permits	1	LS	$ 50,000	$ 50,000	Previous project experience. SEPA checklist, UIC, etc.
Submittals, Plans, Site Preparation Subtotal				**$ 100,000**	
System Installation and Startup					
Injection well installation	1	LS	$ 1,152,598	$ 1,152,598	See Table C-14.
Treatment equipment and setup	1	LS	$ 205,326	$ 205,326	Tanks, pumps, conveyance piping and installation. See Table C-14.
Utilities	13,806	kWh	$ 0.05	$ 652	Based on 5-kW demand per unit, continuous operation, for 1 day a month. Cost of electricity based on estimate provided by Kaiser. See Table C-14.
Amendments	1	LS	$ 90,377	$ 90,377	Year Zero. See Table C-14.
System Installation and Startup Subtotal				**$ 1,448,953**	
Contingency	20%	--	--	**$ 309,791**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					
Project management	5%	--	--	$ 92,937	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 148,699	EPA 540-R-00-002.
Construction management	6%	--	--	$ 111,525	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Pilot-scale study	1	LS	$ 144,895	$ 144,895	10% of Installation and startup costs.
Professional/Technical Services Subtotal				**$ 498,057**	
TOTAL CAPITAL COST				**$ 2,356,800**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Monitoring					
Operation	1	LS	$ 127,029	$ 127,029	See Table C-14.
Maintenance	1	LS	$ 25,109	$ 25,109	See Table C-14.
Performance groundwater sampling & analysis	1	LS	$ 11,919	$ 11,919	See Table C-14.
System Operation and Monitoring Subtotal				**$ 164,056**	
Contingency	20%	--	--	**$ 32,811**	Scope and bid contingency.
Professional/Technical Services					
Project management	10%	--	--	$ 19,687	EPA 540-R-00-002.
Technical support	10%	--	--	$ 19,687	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 41,573**	
TOTAL ANNUAL O&M COST				**$ 238,441**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Closeout					
Major equipment replacement/repair	1	LS	$ 26,772	$ 26,772	Year 15. 25% of equipment costs. See Table C-14.
System Operation and Closeout Subtotal				**$ 26,772**	
Contingency	10%	--	--	**$ 2,677**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 4,885	$ 4,885	Years 5, 10, 15, 20, 25. See Table C-10.
Closure report	1	EA	$ 10,295	$ 10,295	Year 25. See Table C-10.
Professional/Technical Services Subtotal				**$ 15,180**	

Table C-6 - Alternative C3 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative C3 includes Alternative C2 plus *in situ* enhanced bioremediation for petroleum groundwater plumes and associated smear zone soil. Alternative C3 assumes an operating period of 30 years in the development of this cost estimate. Refer to Table C-14 for details.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate	7.0%		
Time period	30	years	Assumed time period for fixed annual and periodic costs.
RTF	25	years	Weighted average restoration time frame applied to variable annual costs. See Table C-17.

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 2,356,800	$ 2,356,800	1.000	$ 2,356,800	
Annual O&M	1 - 30	$ -	$ -	12.409	$ -	Annual O&M for fixed costs.
Annual O&M	1 - 25	$ 5,938,752	$ 238,441	11.637	$ 2,774,712	Annual O&M for variable costs.
Periodic	5	$ 4,885	$ 4,885	0.713	$ 3,483	
Periodic	10	$ 4,885	$ 4,885	0.508	$ 2,483	
Periodic	15	$ 29,449	$ 29,449	0.362	$ 10,674	
Periodic	20	$ 4,885	$ 4,885	0.258	$ 1,262	
Periodic	25	$ 15,180	$ 15,180	0.184	$ 2,797	
Periodic	30	$ -	$ -	0.131	$ -	
		$ 8,354,837			$ 5,152,212	Net present value of elements unique to Alternative C3.
Total Net Present Value of Alternative C2					$ 22,863,211	Scenario C2b
TOTAL NET PRESENT VALUE OF ALTERNATIVE C3					**$ 28,015,423**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table C-7 - Alternative C4 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative C4 adds *ex situ* treatment of groundwater extracted from the petroelum groundwater plumes at the Kaiser Facility to the treatment elements provided by Alternative C2 (institutional controls, monitoring, MNA, and containment).
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 50,000	$ 50,000	SAP, HASP, work plan, as-built drawings, O&M manual, QA/QC documentation. Based on previous project experience.
Permits	1	LS	$ 30,000	$ 30,000	Previous project experience. SEPA checklist, etc.
Submittals, Plans, Site Preparation Subtotal				**$ 80,000**	
***Ex Situ* Treatment System Construction**					
External Components	--	--	--	$ 3,050,970	See Table C-15.
Treatment System Construction	--	--	--	$ 1,968,945	See Table C-15.
Treatment System Consumables	--	--	--	$ 671,599	See Table C-15.
Extraction wells	--	--	--	$ 210,380	See Table C-15.
***Ex situ* Treatment System Construction Subtotal**				**$ 5,901,894**	
Contingency	10%	--	--	**$ 598,189**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					
Project management	5%	--	--	$ 295,095	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 472,151	EPA 540-R-00-002.
Construction management	6%	--	--	$ 354,114	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. C1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 1,123,560**	
TOTAL CAPITAL COST				**$ 7,703,643**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation, Maintenance, and Monitoring					
Monitoring and maintenance labor	1,920	hr	$ 75	$ 144,000	Assumed 1 FTE for monitoring, equipment repair and replacement annually.
Monitoring and maintenance supervisor	480	hr	$ 110	$ 52,800	Assume 25% of monitoring and maintenance labor.
Carbon change-out, transport, and regeneration	70,000	lb	$ 2.79	$ 195,300	Includes replacement, removal, regeneration, and labor for carbon change-out. Based on vendor quote for existing HC project. Price adjusted per 2010 RSMeans cost index. Assume one GAC bed change-out per year.
Surface filter change-out	96	EA	$ 2,000	$ 192,000	Assume one change-out per vessel per month. Cost of filter is engineer's estimate.
Electricity	2,939,549	kWh	$ 0.05	$ 138,747	1 hp = 0.7457 kW. Assumes continuous operation of 6 x 25 hp submersible pumps and 4 x 75 hp pumps in treatment system.
Sampling and lab analysis	132	EA	$ 253	$ 33,396	TPH-Dx, PCBs, pH @ each well (5), upstream of each unit process (4), downstream of each carbon bed (6), and combined effluent (1).
System Operation, Maintenance, and Monitoring Subtotal				**$ 756,243**	
Contingency	10%	--	--	**$ 75,624**	Scope and bid contingency. Percentage of annual cost. EPA 540-R-00-002.
Professional/Technical Services					
Project management	10%	--	--	$ 83,187	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 83,187	EPA 540-R-00-002.
Professional/Technical Services Subtotal				**$ 166,373**	
TOTAL ANNUAL O&M COST				**$ 998,240**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
10-year major system maintenance	10%	--	--	$ 770,364	Year 10. Engineer's Estimate. Assume 10% of capital cost.
Professional/Technical Services					
Five-year reviews	1	EA	$ 14,655	$ 14,655	Years 5, 10, 15, 20. See Table C-10.
Closure report	1	EA	$ 30,885	$ 30,885	Year 18. See Table C-10.

Table C-7 - Alternative C4 Estimated Cost Summary

Location:	Kaiser Trentwood Facility
	Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative C4 adds *ex situ* treatment of groundwater extracted from the petroelum groundwater plumes at the Kaiser Facility to the treatment elements provided by Alternative C2 (institutional controls, monitoring, MNA, and containment).

PRESENT VALUE ANALYSIS

Discount rate	7.0%		
Time period	30	years	Assumed time period for fixed annual and periodic costs.
RTF	18	years	Weighted average restoration time frame applied to variable annual costs. See Table C-17.

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 7,703,643	$ 7,703,643	1.000	$ 7,703,643	
Annual O&M	1 - 30	$ -	$ -	12.409	$ -	Annual O&M for fixed costs.
Annual O&M	1 - 18	$ 17,779,185	$ 998,240	10.005	$ 9,986,950	Annual O&M for variable costs.
Periodic	5	$ 14,655	$ 14,655	0.713	$ 10,449	
Periodic	10	$ 785,019	$ 785,019	0.508	$ 399,064	
Periodic	15	$ 14,655	$ 14,655	0.362	$ 5,312	
Periodic	18	$ 30,885	$ 30,885	0.300	$ 9,256	
Periodic	20	$ 14,655	$ 14,655	0.258	$ 3,787	
Periodic	25	$ -	$ -	0.184	$ -	
Periodic	30	$ -	$ -	0.131	$ -	
		$ 26,342,697			$ 18,118,460	Net present value of elements unique to Alternative C4.
Total Net Present Value of Alternative C2					$ 22,863,211	Scenario C2b
TOTAL NET PRESENT VALUE OF ALTERNATIVE C4					**$ 40,981,671**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table C-8 - Monitoring Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative C1					
Protection & Performance Monitoring - Annual Costs					Protection and performance monitoring costs based on previous project experience.
Labor	1	yr	$ 107,960	$ 107,960	Includes well and equipment maintenance labor. Excludes project management labor.
Equipment, supplies, computer	1	yr	$ 17,480	$ 17,480	Includes well and equipment maintenance.
Travel	1	yr	$ 24,108	$ 24,108	
Sample shipping	1	yr	$ 10,000	$ 10,000	Previous project experience.
Laboratory analysis	1	yr	$ 108,552	$ 108,552	
Subtotal				$ 268,100	
Total qty. of wells sampled	114				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Protection monitoring wells	19				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Performance monitoring wells	95				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010).
Protection monitoring annual total	16.7%	--	--	$ 44,683	Percentage = protection wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Performance monitoring annual total	83.3%	--	--	$ 223,417	Percentage = performance wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Data management	1	yr	$ 29,948	$ 29,948	Data validation; database management.
Reporting	1	yr	$ 16,182	$ 16,182	Report to Kaiser and Ecology quarterly; EIM reporting.

Alternative C1 protection and performance monitoring notes:
- Two 2-person teams plus sample custodian on site during each sample event (5 people total).
- Assumed each sample team can sample 7 wells per day on average.
- Assumed water levels take an entire day with 4 people measuring.
- Assumed 10-hour field days.
- Assumed EIM submittal included for groundwater data plus any additional soil or soil gas data collected during previous 6 months.
- Assumed 2 vehicles for each sampling event.
- Actual well and equipment maintenance costs will depend on upcoming needs.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Monitored Natural Attenuation (MNA) - Petroleum Hydrocarbon Groundwater Plumes - Annual Costs					Assume MNA samples collected as part of protection and performance monitoring described above.
Total qty. of wells sampled	36				
Sampling frequency	2				Assume semi-annual frequency.
Annual MNA monitoring cost					
Labor	16%	--	--	$ 17,046	Assume % of groundwater protection and performance monitoring labor cost, based on 72:456 annualized well quantity ratio. Labor includes additional sample collection and handling.
Equipment, supplies, computer	16%	--	--	$ 2,760	Assume % of groundwater protection and performance monitoring labor cost, based on 72:456 annualized well quantity ratio.
Sample shipping	16%	--	--	$ 1,579	Assume % of groundwater protection and performance sample shipping cost, based on 72:456 annualized well quantity ratio.
Laboratory analysis - groundwater					See unit costs in Table C-16.
Nitrate	72	samples	$ 24	$ 1,728	
Sulfate	72	samples	$ 18	$ 1,296	
Phosphate	72	samples	$ 20	$ 1,440	
Ammonia	72	samples	$ 24	$ 1,728	Assume same unit cost as for nitrate.
Iron	72	samples	$ 24	$ 1,728	
Manganese	72	samples	$ 26	$ 1,872	
Potassium	72	samples	$ 24	$ 1,728	Assume same unit cost as for iron.
Magnesium	72	samples	$ 24	$ 1,728	Assume same unit cost as for iron.
Total				$ 34,633	
Data management	16%	--	--	$ 4,729	Assume % of groundwater protection and performance monitoring data management cost, based on 72:456 annualized well quantity ratio.
Reporting	16%	--	--	$ 2,555	Assume % of groundwater protection and performance monitoring reporting cost, based on 72:456 annualized well quantity ratio.

Table C-9 - Institutional Controls Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative C1					
New Institutional Controls					
Pending environmental upgrades at casting complexes					Pending items and approx. costs provided by Kaiser.
Replace melter furnace door jambs	5	locations	$ 20,000	$ 100,000	DC-1, DC-2W, DC-3, DC-8E, DC-8W. Provided by Kaiser, May 23, 2011.
Contain hydraulics/lubrication	1	locations	$ 151,000	$ 151,000	DC-2. Unit cost per Kaiser, April 19, 2010.
Overflow lines to sewer	7	locations	$ 50,000	$ 350,000	DC-2 through DC-8.
Seal DC-7/DC-8 control house sump	1	location	$ 15,000	$ 15,000	Excludes equipment removal cost (approx. $15k). Unit cost per Kaiser, April 19, 2010.
Slip line storm sewers					Pipe lengths from Kaiser storm sewer plan dwg titled: Aluminum Works - Trentwood Plant, Storm Sewer - Scheme "O", General Arrangement March 8, 1967. Unit cost based on cost of slip lining from MH 7B to MH 9 (approx. $120,100 for total length of 390 ft.) in 2005, adjusted to 2010 dollars (2010 RSMeans p.671).
MH 2 to MH 3	133	ft	$ 371	$ 49,386	
MH 9 to MH 3	280	ft	$ 371	$ 103,971	
MH 3 to MH 5	366	ft	$ 371	$ 135,905	
MH 5 to MH 6	460	ft	$ 371	$ 170,810	
Subtotal				$ 460,073	
Total				$ 1,076,073	
Preparation of institutional control O&M and monitoring plans					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	60	hr	$ 90	$ 5,400	
Staff	60	hr	$ 75	$ 4,500	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	8	hr	$ 60	$ 480	
Travel	1	ea	$ 566	$ 566	Assume 2-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 15,516	Cost per plan.
Quantity of plans to prepare	3				
Total				$ 46,548	Assume 3 plans in total (e.g., plans for Facility pavement, engineered controls, air emission control system).
Preparation of restrictive covenant					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	40	hr	$ 300	$ 12,000	
Principal	24	hr	$ 180	$ 4,320	
Sr. Project	24	hr	$ 130	$ 3,120	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	16	hr	$ 75	$ 1,200	
Clerical	8	hr	$ 60	$ 480	
Computer	1	ea	$ 250	$ 250	
Total				$ 24,970	
Institutional Controls - Annual Costs					
Environmental upgrades at casting complexes					
Verify pit/sump integrity	9	locations	$ 1,000	$ 9,000	DC-1 through DC-8 plus DC-7/DC-8 control house sump.
Other upgrade maintenance	5%	--	--	$ 53,804	Assume percentage of environmental upgrade capital cost above.
Subtotal				$ 62,804	
Maintenance of physical measures and BMPs					Assume maintenance of signs, fences, gates, access control, existing training programs, waste handling guidance, and BMPs defined in SPCC Plan and SWPPP.
Labor	1920	hr	$ 75	$ 144,000	Assume 1 FTE.
Supervisor	480	hr	$ 110	$ 52,800	Assume 25% of labor effort.
Subtotal				$ 196,800	
Total				$ 259,604	
Institutional control O&M and monitoring plans - annual update and maintenance					Assume work performed by Hart Crowser staff.
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	8	hr	$ 75	$ 600	
Sr. Drafter	4	hr	$ 100	$ 400	
Clerical	2	hr	$ 60	$ 120	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 5,003	Cost per plan.
Quantity of plans to maintain	6				
Total				$ 30,018	Assume 6 plans in total. Includes existing WDR Restoration Monitoring Plan, SPCC Plan, and SWPPP plus institutional control, O&M, and monitoring plans given above.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Site information database - annual update and maintenance					Assume work performed by Hart Crowser staff.
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	24	hr	$ 90	$ 2,160	
Staff	12	hr	$ 75	$ 900	
Clerical	4	hr	$ 60	$ 240	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Total				$ 5,743	
Institutional Controls - Periodic Costs					
Restrictive covenant periodic update and maintenance					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	8	hr	$ 300	$ 2,400	
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	4	hr	$ 130	$ 520	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	4	hr	$ 75	$ 300	
Clerical	2	hr	$ 60	$ 120	
Computer	1	ea	$ 250	$ 250	
Total				$ 6,470	
NPDES Permit and Ecology Order Required Monitoring - Annual Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997), Ecology Agreed Order No. 02WQER-3487 (Ecology 2002), and Ecology Amended Order No. 2868 (Ecology 2005). See Section 2.1.1.1.
NPDES permit - monitoring laboratory analysis					
Sample quantity					Based on weekly sampling frequency.
Outfall 001	104	samples			
Outfall 002	104	samples			
Outfall 003	52	samples			
Plant intake	104	samples			
Laboratory analysis					Unit prices based on laboratory quote.
Outfall 001					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	104	samples	$ 18	$ 1,872	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc, phosphorous.
Cyanide	104	samples	$ 40	$ 4,160	
Hardness	104	samples	$ 25	$ 2,600	
Subtotal				$ 19,032	
Outfall 002					
Oil and grease	260	samples	$ 50	$ 13,000	
TSS	104	samples	$ 18	$ 1,872	
Orthophosphate	104	samples	$ 20	$ 2,080	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, zinc, phosphorous.
Hexavalent chromium	104	samples	$ 50	$ 5,200	
Cyanide	104	samples	$ 40	$ 4,160	
Subtotal				$ 31,512	
Outfall 003					
BOD_5	52	samples	$ 45	$ 2,340	
TSS	52	samples	$ 18	$ 936	
Fecal coliform	52	samples	$ 35	$ 1,820	
Subtotal				$ 5,096	
Plant intake					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	52	samples	$ 18	$ 936	
Total metals	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc.
Subtotal				$ 11,336	
NPDES permit laboratory analysis subtotal				$ 66,976	
Ecology Order - monitoring laboratory analysis					
Sample quantity					Based on biweekly sampling frequency.
Outfall 001	26	samples			
Plant lagoon effluent	26	samples			
Plant lagoon influent	26	samples			
Laboratory analysis					
For 3 locations given above					
PCBs - ultra-low level	78	samples	$ 175	$ 13,650	
Subtotal				$ 13,650	
Ecology Order laboratory analysis subtotal				$ 13,650	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Sampling labor - NPDES permit and Ecology Order required monitoring					
Labor	208	hr	$ 75	$ 15,600	Assume 1 individual
Supervisor	52	hr	$ 110	$ 5,720	Assume 25% of labor effort.
Labor subtotal				$ 21,320	
Total Annual Cost				$ 101,946	
NPDES Permit Required Monitoring - Periodic Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997). See Section 2.1.1.1.
Initial acute toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in Years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	8	samples	$ 850	$ 6,800	
Daphnid (48-hr static test)	8	samples	$ 700	$ 5,600	
Subtotal				$ 12,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial acute toxicity testing total				$ 16,500	
Final acute toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in Years 5, 10, 15, 20, 25, and 30.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	2	samples	$ 850	$ 1,700	
Daphnid (48-hr static test)	2	samples	$ 700	$ 1,400	
Subtotal				$ 3,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final acute toxicity testing total				$ 5,970	
Initial chronic toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in Years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	8	samples	$ 1,575	$ 12,600	
Water flea (7-day, full dilution test)	8	samples	$ 1,475	$ 11,800	
Subtotal				$ 24,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial chronic toxicity testing total				$ 28,500	
Final chronic toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in Years 5, 10, 15, 20, 25, and 30.
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	2	samples	$ 1,575	$ 3,150	
Water flea (7-day, full dilution test)	2	samples	$ 1,475	$ 2,950	
Subtotal				$ 6,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final chronic toxicity testing total				$ 8,970	

Table C-10 - Professional Services Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative C1 - Periodic Costs					
Five-year review periodic cost					Assume work performed by Hart Crowser staff.
Ecology oversight	1	ls	$ 7,500	$ 7,500	Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Principal	16	hr	$ 180	$ 2,880	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	40	hr	$ 75	$ 3,000	
Clerical	8	hr	$ 60	$ 480	
Total				$ 19,540	
Closure report periodic cost					Assume work performed by Hart Crowser staff.
Ecology oversight	1	ls	$ 7,500	$ 7,500	Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Principal	40	hr	$ 180	$ 7,200	
Sr. Project	80	hr	$ 130	$ 10,400	
Sr. Staff	80	hr	$ 90	$ 7,200	
Staff	80	hr	$ 75	$ 6,000	
Sr. Drafter	24	hr	$ 100	$ 2,400	
Clerical	8	hr	$ 60	$ 480	
Total				$ 41,180	
Alternative C2 - Annual Costs					
Containment monitoring - data management annual cost					Assume work performed by Hart Crowser staff.
Principal	2	hr	$ 180	$ 360	
Sr. Associate	4	hr	$ 160	$ 640	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	12	hr	$ 75	$ 900	
Clerical	2	hr	$ 60	$ 120	
Total				$ 4,500	
Containment monitoring - reporting annual cost					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Associate	2	hr	$ 160	$ 320	
Sr. Project	12	hr	$ 130	$ 1,560	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	16	hr	$ 75	$ 1,200	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	4	hr	$ 60	$ 240	
Total				$ 7,000	
Alternative C2 - Periodic Costs					
Five-year reviews - Scenario C2a, C2b	50%	--	--	$ 9,770	Assume 50% of Alt. C1 five-year review cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Closure report - Scenario C2a, C2b	50%	--	--	$ 20,590	Assume 50% of Alt. C1 closure report cost to include IRM system containment and FPP recovery expansion, based on 4:8 well quantity ratio.
Five-year reviews - Scenario C2c	125%	--	--	$ 24,425	Assume 125% of Alt. C1 five-year review cost to include containment and FPP recovery elements unique to Scenario C2c, based on 10:8 well quantity ratio.
Closure report - Scenario C2c	125%	--	--	$ 51,475	Assume 125% of Alt. C1 closure report cost to include containment and FPP recovery elements unique to Scenario C2c, based on 10:8 well quantity ratio.
Alternative C3 - Periodic Costs					
Five-year reviews	25%	--	--	$ 4,885	Assume 25% of Alt. C1 five-year review cost to include containment and FPP recovery elements unique to Alt. C3.
Closure report	25%	--	--	$ 10,295	Assume 25% of Alt. C1 closure report cost to include containment and FPP recovery elements unique to Alt. C3.
Alternative C4 - Periodic Costs					
Five-year reviews	75%	--	--	$ 14,655	Assume 75% of Alt. C1 five-year review cost to include containment and FPP recovery elements unique to Alt. C4, based on 6:8 well quantity ratio.
Closure report	75%	--	--	$ 30,885	Assume 75% of Alt. C1 closure report cost to include containment and FPP recovery elements unique to Alt. C4, based on 6:8 well quantity ratio.

Table C-11 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative C1 - Existing IRM System Annual O&M Costs					
Groundwater extraction					
OH-EW-1					
Pump motor input power	100	hp			Existing pump, 100 hp (Hart Crowser 2003).
Pump motor input power	74.6	kW			
WW-EW-1					
Pump motor input power	400	hp			Existing pump, 400 hp (Hart Crowser 2003).
Pump motor input power	298.3	kW			
WW-EW-2					
Pump motor input power	400.0	hp			Existing pump, 400 hp (Hart Crowser 2003).
Pump motor input power	298.3	kW			
WW-UVB-1					Neglect friction, velocity head, and minor losses.
Pump efficiency	80%				Approximation based on average of range (Lindeburg 2003).
Motor efficiency	70%				
Elevation head	151	ft			Assume elevation head equal to well depth.
Flow rate	3,035	gpm			
Specific gravity	1.0				
Hydraulic power	115.8	hp			
Hydraulic power	86.4	kW			1 hp = 0.7457 kW.
Brake pump power	144.8	hp			
Brake pump power	108.0	kW			Existing pump power rating not available. Pump power
Pump motor input power	206.9	hp			requirement estimate based on modeled flow rate (Appendix E,
Pump motor input power	154.3	kW			Table E-3) and elevation head (151 feet).
Annual electricity usage and cost					
Total motor input power	825.4	kW			Sum of OH-EW-1, WW-EW-1, WW-EW-2, and WW-UVB-1.
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	7,230,423	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 361,521	$/yr			
IRM system maintenance annual cost					labor, parts, supplies. Use same labor unit costs as for inst. controls.
Labor	416	hr	$ 75	$ 31,200	Assume 0.2 FTE.
Supervisor	104	hr	$ 110	$ 11,440	Assume 25% of labor effort.
Parts, supplies	10%		$ 123,583	$ 12,358	Assume 10% of extraction system installation cost (see Tables C-4 and C-5), 4 locations.
Total				$ 54,998	
Alternative C2 - Scenario C2a Annual O&M Costs					
Groundwater extraction					
WW-EW-3					
Pump motor input power	100	hp			Existing pump, 100 hp (Hart Crowser 2003).
Pump motor input power	74.6	kW			
Annual electricity usage and cost					
Total motor input power	74.6	kW			
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	653,233	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 32,662	$/yr			
Alternative C2 - Scenario C2b Annual O&M Costs					
Groundwater extraction					
ORB-FEW-1					
Pump motor input power	75	hp			75 hp per vendor quote.
Pump motor input power	55.9	kW			
Annual electricity usage and cost					
Total motor input power	55.9	kW			
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	489,925	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 24,496	$/yr			
Conveyance piping - outdoor					
Branch from extraction well	1,050	LF	$ 46	$ 48,337	Conveyance to WWTP. Steel pipe, black, with 2-in polyurethane insulation, align and tackweld on sleepers, 4-in diameter. 2010 RSMeans 33 61 13.10 1060.
Subtotal				$ 48,337	
Sales tax	8.7%	--	--	$ 3,058	Assume sales tax charged on cost of materials.
Total				$ 51,395	

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative C2 - Scenario C2c Annual O&M Costs					
Groundwater extraction - calculated power requirements					Pump power requirement estimate based on modeled flow rate (Appendix E, Table E-3) and elevation head. Assumes that elevation head is equal to well depth. Estimate neglects friction, velocity head, and minor losses.
Pump efficiency	80%				
Motor efficiency	70%				
WW-FEW-1					
Elevation head	190	ft			Assume well depth similar to WW-EW-1 (190 feet, see Table 4-3).
Flow rate	1.05	MGD			
Flow rate	729	gpm			
Specific gravity	1.0				
Hydraulic power	35.0	hp			
Hydraulic power	26.1	kW			1 hp = 0.7457 kW.
Brake pump power	43.8	hp			
Brake pump power	32.6	kW			
Motor input power	62.5	hp			
Motor input power	46.6	kW			
WW-FEW-2					
Elevation head	190	ft			Assume well depth similar to WW-EW-1 (190 feet, see Table 4-3).
Flow rate	1.35	MGD			
Flow rate	938	gpm			
Specific gravity	1.0				
Hydraulic power	45.0	hp			
Hydraulic power	33.6	kW			1 hp = 0.7457 kW.
Brake pump power	56.3	hp			
Brake pump power	42.0	kW			
Motor input power	80.4	hp			
Motor input power	60.0	kW			
WW-FEW-3					
Elevation head	190	ft			Assume well depth similar to WW-EW-1 (190 feet, see Table 4-3).
Flow rate	1.12	MGD			
Flow rate	778	gpm			
Specific gravity	1.0				
Hydraulic power	37.4	hp			
Hydraulic power	27.9	kW			1 hp = 0.7457 kW.
Brake pump power	46.7	hp			
Brake pump power	34.8	kW			
Motor input power	66.7	hp			
Motor input power	49.7	kW			
WW-FEW-4					
Elevation head	190	ft			Assume well depth similar to WW-EW-1 (190 feet, see Table 4-3).
Flow rate	0.97	MGD			
Flow rate	674	gpm			
Specific gravity	1.0				
Hydraulic power	32.4	hp			
Hydraulic power	24.1	kW			1 hp = 0.7457 kW.
Brake pump power	40.4	hp			
Brake pump power	30.2	kW			
Motor input power	57.8	hp			
Motor input power	43.1	kW			
CM-FEW-1					
Elevation head	133	ft			Assume well depth similar to OH-EW-1 (133 feet, see Table 4-3).
Flow rate	0.79	MGD			
Flow rate	549	gpm			
Specific gravity	1.0				
Hydraulic power	18.4	hp			
Hydraulic power	13.8	kW			1 hp = 0.7457 kW.
Brake pump power	23.1	hp			
Brake pump power	17.2	kW			
Motor input power	32.9	hp			
Motor input power	24.6	kW			
CM-FEW-2					
Elevation head	133	ft			Assume well depth similar to OH-EW-1 (133 feet, see Table 4-3).
Flow rate	0.79	MGD			
Flow rate	549	gpm			
Specific gravity	1.0				
Hydraulic power	18.4	hp			
Hydraulic power	13.8	kW			1 hp = 0.7457 kW.
Brake pump power	23.1	hp			
Brake pump power	17.2	kW			
Motor input power	32.9	hp			
Motor input power	24.6	kW			

Table C-11 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
ORB-FEW-1					
Elevation head	133	ft			Assume well depth similar to OH-EW-1 (133 feet, see Table 4-3).
Flow rate	0.75	MGD			
Flow rate	521	gpm			
Specific gravity	1.0				
Hydraulic power	17.5	hp			
Hydraulic power	13.1	kW			1 hp = 0.7457 kW.
Brake pump power	21.9	hp			
Brake pump power	16.3	kW			
Motor input power	31.3	hp			
Motor input power	23.3	kW			
OH-FEW-1					
Elevation head	195	ft			Assume well depth similar to OH-EW-2 (195 feet, see Table 4-3).
Flow rate	0.82	MGD			
Flow rate	569	gpm			
Specific gravity	1.0				
Hydraulic power	28.1	hp			
Hydraulic power	20.9	kW			1 hp = 0.7457 kW.
Brake pump power	35.1	hp			
Brake pump power	26.2	kW			
Motor input power	50.1	hp			
Motor input power	37.4	kW			
OH-FEW-2					
Elevation head	195	ft			Assume well depth similar to OH-EW-2 (195 feet, see Table 4-3).
Flow rate	0.90	MGD			
Flow rate	625	gpm			
Specific gravity	1.0				
Hydraulic power	30.8	hp			
Hydraulic power	23.0	kW			1 hp = 0.7457 kW.
Brake pump power	38.5	hp			
Brake pump power	28.7	kW			
Motor input power	55.0	hp			
Motor input power	41.0	kW			
OH-FEW-3					
Elevation head	195	ft			Assume well depth similar to OH-EW-2 (195 feet, see Table 4-3).
Flow rate	0.60	MGD			
Flow rate	417	gpm			
Specific gravity	1.0				
Hydraulic power	20.5	hp			
Hydraulic power	15.3	kW			1 hp = 0.7457 kW.
Brake pump power	25.7	hp			
Brake pump power	19.1	kW			
Motor input power	36.7	hp			
Motor input power	27.3	kW			
OH-FEW-4					
Elevation head	195	ft			Assume well depth similar to OH-EW-2 (195 feet, see Table 4-3).
Flow rate	0.75	MGD			
Flow rate	521	gpm			
Specific gravity	1.0				
Hydraulic power	25.7	hp			
Hydraulic power	19.1	kW			1 hp = 0.7457 kW.
Brake pump power	32.1	hp			
Brake pump power	23.9	kW			
Motor input power	45.8	hp			
Motor input power	34.2	kW			
Annual electricity usage and cost					
Total motor input power	411.8	kW			Sum of WW-FEW-1, WW-FEW-2, WW-FEW-3, WW-FEW-4, CM-FEW-1, CM-FEW-2, ORB-FEW-1, OH-FEW-1, OH-FEW-2, OH-FEW-3, and OH-FEW-4.
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	3,607,270	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 180,363	$/yr			
Conveyance piping - indoor					
Branch from extraction well	360	LF	$ 66	$ 23,938	For extraction wells inside Cold Mill area building. Steel pipe, black, sch. 40, 4-in diameter, threaded, with couplings and clevis hanger assemblies. 2010 RSMeans 22 11 13.44 0650.
Subtotal				$ 23,938	
Sales tax	8.7%	--	--	$ 1,063	Assume sales tax charged on cost of materials.
Total				$ 25,001	

Table C-11 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Conveyance piping - outdoor					
Branch from extraction well	2,100	LF	$ 46	$ 96,674	Conveyance to header. Steel pipe, black, with 2-in polyurethane insulation, align and tackweld on sleepers, 4-in diameter. 2010 RSMeans 33 61 13.10 1060.
Header	1,725	LF	$ 93	$ 160,425	Conveyance to WWTP or plant process. Steel pipe, black, with 2-in polyurethane insulation, align and tackweld on sleepers, 8-in diameter. 2010 RSMeans 33 61 13.10 1090.
Subtotal				$ 257,099	
Sales tax	8.7%	--	--	$ 13,242	Assume sales tax charged on cost of materials.
Total				$ 270,340	

Table C-12 - Skimming System Capital and Annual Operation and Maintenance Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Skimming System Capital Costs					
Belt skimmer installation					
Equipment	1	LS	$ 8,200	$ 8,200	Skimmer motor (explosion proof), poly belt, tank, float switch, enclosure. Based on vendor quote.
Labor	8	hr	$ 75	$ 600	Assume 1 individual.
Supervisor	2	hr	$ 110	$ 220	Assume 25% of labor effort.
Total per belt skimmer				$ 9,020	
Restart existing skimming wells					
Parts, supplies	1	LS	$ 1,750	$ 1,750	Based on vendor quote.
Labor	8	hr	$ 75	$ 600	Assume 1 individual.
Supervisor	2	hr	$ 110	$ 220	Assume 25% of labor effort.
Total per skimming well				$ 2,570	
Skimming System Operation and Maintenance (per well)					
Maintenance labor					
Labor	50	hr	$ 75	$ 3,750	Assume 1 individual, 5 days per year.
Supervisor	12.5	hr	$ 110	$ 1,375	Assume 25% of labor effort.
Equipment maintenance	1	LS	$ 2,000	$ 2,000	Based on previous HC estimate.
Spare parts and supplies	1	LS	$ 1,000	$ 1,000	Assume 50% of equipment maintenance cost.
Waste disposal	1	ton	$ 54	$ 54	Estimate 300 gallons/year from existing IRM (Section 4.1.1.2). Assume specific gravity = 0.8. Cost for disposal based on previous Kaiser work and adjusted using 2010 RSMeans historical cost index.
Utilities	3,266	kWh	$ 0.05	$ 154	Assume 1/2 hp motor per vendor specification.
Treatment System Operation and Maintenance Subtotal				**$ 8,333**	Per skimming well.

Table C-13 - Skimming Periodic Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
For Alternative C1					
Periodic Costs - Years 5, 15					
Belt	4	EA	$ 1,500	$ 6,000	Cost of belt. Price obtained from vendor.
HC oversight/labor	0.8	WK	$ 5,375	$ 4,300	Assume 4 days for skimming belt replacement (1 day/well). See worksheet HC rate for backup calculation.
Contingency	10%	--	--	$ 1,030	Scope and bid contingency (EPA 540-R-00-002).
Project management	10%	--	--	$ 1,133	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical Support	10%	--	--	$ 1,133	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Costs - Years 5, 15				**$ 13,596**	Per year.
Periodic Costs - Years 10					
Belt	2	EA	$ 1,500	$ 3,000	Cost of belt. Price obtained from vendor.
Motor	2	EA	$ 250	$ 500	Cost of motor. Price obtained from vendor.
HC oversight/labor	1.6	WK	$ 5,375	$ 8,600	Assume 4 days for skimming belt and motor replacement (2 days/well). See worksheet HC rate for backup calculation.
Contingency	10%	--	--	$ 1,210	Scope and bid contingency (EPA 540-R-00-002).
Project management	10%	--	--	$ 1,331	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical Support	10%	--	--	$ 1,331	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Costs - Years 10				**$ 15,972**	
For Alternative C2					
Periodic Costs - Year 5					
Belt	6	EA	$ 1,500	$ 9,000	Cost of belt skimmer. Assume replace of belts at OH-SK-02 and OH-SK-04 (currently running per IRM) and four belts in wastewater (new and existing IRM locations). Price obtained from vendor.
Motor	4	EA	$ 250	$ 1,000	Cost of motor. Price obtained from vendor. Assume motor replacement for four skimmers in wastewater.
HC oversight/labor	2	WK	$ 5,375	$ 10,750	Assume 1 for belt-only replacement and 2 days for belt and motor replacement. See worksheet HC rate for backup calculation.
Contingency	10%	--	--	$ 2,075	Scope and bid contingency (EPA 540-R-00-002).
Project management	10%	--	--	$ 2,283	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Technical Support	10%	--	--	$ 2,283	Percentage of sum of periodic cost and contingency. EPA 540-R-00-002.
Periodic Costs - Year 5				**$ 27,390**	

Table C-14 - *In Situ* Treatment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Injection Well Installation					
Drilling	9,878	ft	$ 77	$ 760,617	117 wells. Assume wells are 90 ft deep in AOCs except for Wastewater Treatment area where wells are 75 ft deep. Screens placed through vertical extent of contamination (20 ft). Unit cost based on vendor quote. Includes mob/demob, drilling, materials, 8.7% sales tax.
Well construction materials	117	ea	$ 1,946	$ 227,650	Unit cost based on vendor quote. Includes screen, casing, monument, sand, hole plug, well permits, 8.7% sales tax.
Installation oversight	29	wk	$ 5,375	$ 157,219	Assume HC oversight, 4 wells per week. See Table C-16.
Transport & dispose soil at Subtitle D landfill	132	ton	$ 54	$ 7,112	Cost for disposal based on previous Kaiser work and adjusted using RSMeans 2010 historical cost index.
Subtotal				$ 1,152,598	
Treatment Equipment and Setup					
Mobilization	1	LS	$ 4,000	$ 4,000	Previous project experience.
Nutrient Mixing Tanks	6	ea	$ 489	$ 2,935	200 gallon applicator tanks. Unit cost based on vendor quote. 8.7% sales tax.
Pumps	9	ea	$ 1,182	$ 10,634	3-hp centrifugal pumps. Flow rates 35 - 170 gpm. Unit cost based on vendor quote. 8.7% sales tax.
Conveyance piping	3,340	LF	$ 28	$ 93,520	Cost per linear foot estimated from Table B-14.
Conveyance piping installation	3,340	LF	$ 13	$ 43,420	Assume 3-ft-deep trench for underground piping installation. Cost per linear foot estimated from Table B-14.
Power hookup	1	LS	$ 20,000	$ 20,000	Previous project experience.
Installation oversight	4	wk	$ 5,375	$ 21,500	Assume 4 weeks of HC oversight during installation of treatment system. See Table C-16.
Sales Tax	8.7%	--	--	$ 9,317	Assume sales tax charged on cost of materials.
Subtotal				$ 205,326	
Amendments - Annual Use					
Ammonium nitrate	701	lbs	$ 0.33	$ 231	C:N:P ratio of 100:10:1. Unit cost from vendor quotation. 8.7% sales tax.
Tetrapotassium pyrophosphate	130	lbs	$ 1.40	$ 181	C:N:P ratio of 100:10:1. Unit cost from vendor quotation. 8.7% sales tax.
Hydrogen peroxide	192	gal	$ 3.45	$ 662	50% by weight. Unit cost from vendor quotation.
Surfactant	802	gal	$ 100	$ 80,229	Vendor quote.
Sales Tax	8.7%	--	--	$ 7,073	Assume sales tax charged on cost of materials.
Shipping	1	LS	$ 2,000	$ 2,000	Engineer's estimate.
Subtotal				$ 90,377	
O&M COSTS					
Performance GW Sampling					
Labor	1	wk	$ 5,375	$ 5,375	Assume 1 week oversight. See Table C-16.
Laboratory analysis	14	ea	$ 284	$ 3,976	2 wells/small AOCs, 5 wells/large AOC. Sample for nitrogen, phosphorus, DO, SVOCs and metals. See Table C-16.
Equipment/shipping	1	LS	$ 2,000	$ 2,000	Engineer's estimate.
Data management	5%	--	--	$ 568	Engineer's estimate.
Subtotal				$ 11,919	
Operation					
Operation labor	480	hr	$ 75	$ 36,000	Assume 0.25 FTE.
Amendments	1	LS	$ 90,377	$ 90,377	See above.
Utilities	13,806	kWh	$ 0.05	$ 652	Based on 5-kW demand per pump (3 HP, 60% pump efficiency, 70% motor efficiency, 1hp = 0.7457kW), continuous operation for 1 day a month. Cost of electricity based on estimate provided by Kaiser.
Subtotal				$ 127,029	
Maintenance					
Maintenance labor	192	hr	$ 75	$ 14,400	Assume 0.1 FTE.
Equipment repair/replacement	1	LS	$ 10,709	$ 10,709	10% of equipment costs.
Subtotal				$ 25,109	

Table C-15 - *Ex Situ* Treatment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
***Ex Situ* Treatment System Construction**					
External Components					
Oil-water separator	1	EA	$ 171,120	$ 171,120	100,000-gal steel water storage tank. 2010 RSMeans 33 16 13.13 0910 (p. 458).
Depth filters	5	EA	$ 421,290	$ 2,106,450	1/2-MG prestressed concrete aboveground water utility storage tanks. 2010 RSMean 33 16 13.13 0300 (p.458).
Surface filters	8	EA	$ 3,650	$ 29,202	1,000-gal capacity, 1/4-in-thick shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5520 (p.254).
GAC vessels	6	EA	$ 11,532	$ 69,192	10,000-gal capacity, 1/4-in-thick shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5560 (p.254).
Transfer pumps	8	EA	$ 24,645	$ 197,160	Domestic water pump, general utility, 75 hp, to 2,500 gpm. 2010 RSMeans 22 11 23.10 3190 (p.237). Assume 4 in operation (along treatment train) and a spare for each.
Treatment shed	1	LS	$ 100,000	$ 100,000	Engineer's estimate.
Misc. equipment	5%	--	--	$ 133,656	Percentage of system equipment cost.
Sales tax	8.7%	--	--	$ 244,190	
External Components Total				**$ 3,050,970**	
Treatment System Construction					
Equipment transportation	1	LS	$ 20,000	$ 20,000	Vendor quote.
Electrical connection	1	LS	$ 20,000	$ 20,000	Previous project experience.
Conveyance piping - straight pipe	1,144	LF	$ 86	$ 98,363	Based on estimated unit cost derived in Table 5-9. Includes material, labor, and equipment costs for trenching, bedding, backfill, compaction, and 16-in-diameter, black steel, plain end, welded, 1/4-in wall pipe, 4 ft deep. Includes sales tax on bedding and pipe materials. See Table D-9.
Installation labor for vessels	30%	--	--	$ 915,291	Percentage of system equipment. Engineer's estimate.
Heavy equipment for installing vessels	30%	--	--	$ 915,291	Percentage of system equipment. Engineer's estimate.
System Construction Subtotal				**$ 1,968,945**	
Treatment System Consumables					
Depth filtration media - sand and anthracite	12,994	ton	$ 14	$ 181,913	Cost from previous project. Assume sand is 1.4 ton/CY.
Depth filtration media - gravel (underdrain)	4,331	CY	$ 29	$ 124,870	Bank run gravel. 2010 RSMeans 31 05 16.10 0100 (p.237).
Surface filtration media	8	EA	$ 2,000	$ 16,000	Cost of filter is engineer's estimate.
GAC	70,000	lb	$ 1.00	$ 70,000	Based on vendor pricing from previous HC project.
Heavy equipment for installation	30%	--	--	$ 117,835	Percentage of internals. Engineer's estimate.
Addition materials for installation	10%	--	--	$ 51,062	Percentage of internals. Engineer's estimate.
Shipping	10%			$ 56,168	Engineer's Estimate
Sales tax	8.7%	--	--	$ 53,753	
Treatment System Consumables Subtotal				**$ 671,599**	
Extraction Wells					
Extraction well construction	482	ft	$ 286	$ 137,838	Unit cost based on vendor quote. 12-in-diameter well with 0.6 MGD production.
Electrical connection	1	LS	$ 20,000	$ 20,000	Previous project experience.
Extraction pumps	6	EA	$ 7,324	$ 43,943	6 wells each with 6-in submersible pump, 25 to 150 ft deep, 25 hp, 249 to 297 gpm. 2010 RSMeans 33 21 13.10 3000 (p.459).
Shipping	10%			$ 4,394	Engineer's Estimate
Sales tax	8.7%	--	--	$ 4,205	
Extraction Wells Subtotal				**$ 210,380**	

Table C-16 - Hart Crowser and Analytical Rates Cost Backup

HC Kaiser Rates

Sr. Principal	$	190	
Principal	$	180	
Sr. Associate	$	160	
Associate	$	145	
Sr. Project	$	130	
Project	$	110	
Sr. Staff	$	90	
Staff	$	75	
Sr. Drafter	$	100	
Drafter	$	77	
Clerical	$	60	
Sub Markup		12%	
Communication fee		0%	
Mileage		$0.50/mi.	Fed rate (2010)
Truck Rental	$	85	+ mileage for over 50 mi./day (due to gas prices)
Safety ($ per hr.)	$	5	per field labor hour
Trip per diem	$	150	each way
Per diem	$	133	Fed rate for Spokane

Weekly Cost for HC oversight (staff)

Labor	$	3,600	5 days (9 hr) for staff level, plus safety costs
Truck	$	810	5 days truck plus travel day, plus $300 for miles over 50
Travel	$	300	
Per diem	$	665	
Subtotal	$	5,375	per week

Columbia Analytical Services and Advanced Analytical Laboratory Costs

Assume same price for water/soil.

Parameter	Cost / Analysis	
NWTPH-HCID	$	55
TPH-Dx	$	60
TPH-G	$	60
PCBs - Ultra-Low Level	$	175
VOCs	$	130
PAHs (8270 SIM)	$	215
Metals (10)	$	180
Arsenic	$	26
Chromium	$	24
Manganese	$	26
Iron	$	24
Antimony	$	26
TSS	$	18
Chloride	$	18
Nitrate/Nitrite	$	24
Hardness	$	25
TDS	$	18
Alkalinity	$	18
Sulfate	$	18
Total arsenic, chromium, zinc, and phosphorous	$	50
Hexavalent chromium	$	50
Orthophosphate	$	20
Cyanide	$	40
BOD	$	45
Fecal coliform	$	35
Oil & grease	$	50

Table C-17 - Weighted Average of Estimated Restoration Time Frames

AOC	Estimated TPH Mass to Be Treated in Soil (in Pounds)	RTF (in Years) C1	C2a	C2b	C2c	C3	C4
OH North	272,054	28	28	28	13	27	18
OH South	22,318	4	4	4	2	4	3
WW North	224,844	34	34	34	17	30	24
WW South	29,761	11	11	11	7	11	8
CM - Total	141,244	19	19	19	7	19	12
Total	690,221						
Min		4	4	4	2	4	3
Max		34	34	34	17	30	24
Weighted Average RTF		27	27	27	12	25	18

Notes:
Estimated restoration time frames (RTFs) and TPH mass to be treated from Section 4, Table 4-7.

APPENDIX D
COST ESTIMATES FOR THE REMELT/HOT LINE GROUNDWATER PLUME AND ASSOCIATED SMEAR ZONE SOIL REMEDIAL ALTERNATIVES

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APPENDIX D
COST ESTIMATES FOR THE REMELT/HOT LINE GROUNDWATER PLUME AND ASSOCIATED SMEAR ZONE SOIL REMEDIAL ALTERNATIVES

TABLES

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Table D-1 - Estimated Cost Comparison for Remelt/Hot Line PCB Plume and Associated Smear Zone Soil Remedial Alternatives

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Cost comparison of the net present value and incremental cost of Alternatives D1 through D4 for remediation of the Remelt/Hot Line PCB plume and associated smear zone soil.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

DESCRIPTION	TOTAL NET PRESENT VALUE	INCREMENTAL COST	COST TABLE REFERENCE
Alternative D1	$ 19,800,000	Baseline Cost	Table D-2
Alternative D2 (Scenario D2a)	$ 22,900,000	$ 3,100,000	Table D-3
Alternative D2 (Scenario D2b)	$ 23,100,000	$ 3,300,000	Table D-4
Alternative D3 [a]	$ 50,200,000	$ 28,100,000	Table D-5
Alternative D4	$ 27,000,000	$ 7,200,000	Table D-6

Note:
Present value analysis uses a 30-year discount rate of 7%.
(a) The Alternative D3 incremental cost is based on a modified net present value cost of $22.3 million for Alternative D2 (Scenario D2b). The modification excludes items from the baseline cost that are not part of Alternative D3. See Table D-4.

Location:	Kaiser Aluminum Washington, LLC Spokane Valley, WA	**Description:** Alternative D1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to each of the alternatives that will be evaluated for the remediation of Remelt/Hot Line PCB plume and smear zone soil AOCs. Alternative D1 assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls					
Institutional control plans	1	EA	$ 46,548	$ 46,548	See Table D-8.
Pending upgrades in casting complex	1	LS	$ 1,076,073	$ 1,076,073	See Table D-8.
Restrictive covenant preparation	1	LS	$ 24,970	$ 24,970	See Table D-8.
Institutional Controls Subtotal				**$ 1,147,591**	
Contingency	10%	--	--	**$ 114,759**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					
Project management	6%	--	--	$ 75,741	Percentage of capital cost + contingency. EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Year 0. Kaiser mean annual Ecology costs 2007-2009.
Professional/Technical Services Subtotal				**$ 97,741**	
TOTAL CAPITAL COST				**$ 1,360,091**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Monitoring, Sampling, Testing, and Analysis					
Protection monitoring	1	YR	$ 44,683	$ 44,683	See Table D-7.
Performance monitoring	1	YR	$ 223,417	$ 223,417	See Table D-7.
MNA analysis	--	--	--	$ -	MNA analysis included in protection and performance monitoring cost.
Data management	1	YR	$ 29,948	$ 29,948	Data validation; maintain database. See Table D-7.
Monitoring, Sampling, Testing, and Analysis Subtotal				**$ 298,048**	
Institutional Controls (Annual Update and Maintenance)					
Institutional control plans	1	YR	$ 30,018	$ 30,018	See Table D-8.
Institutional controls maintenance	1	YR	$ 259,604	$ 259,604	See Table D-8.
Outfall & treatment plant monitoring	1	YR	$ 101,946	$ 101,946	See Table D-8. Required by NPDES permit and Ecology orders (see Section 2.1.1.1).
Site information database	1	YR	$ 5,743	$ 5,743	See Table D-8.
Institutional Controls Subtotal				**$ 397,311**	
Groundwater IRM System O&M					
Electricity	7,230,423	kWh	$ 0.05	$ 361,521	Groundwater extraction pump operation. See Table D-10.
Containment system maintenance	1	YR	$ 54,998	$ 54,998	Includes labor, parts, supplies. See Table D-10.
Groundwater IRM System O&M Subtotal				**$ 416,519**	
Contingency	10%	--	--	**$ 111,188**	Scope and bid contingency. Percentage of monitoring, institutional controls, and IRM sytem O&M annual cost.
Professional/Technical Services					
Project management	6%	--	--	$ 73,384	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 122,307	EPA 540-R-00-002.
Ecology oversight	1	YR	$ 22,000	$ 22,000	Kaiser mean annual Ecology costs 2007-2009.
Reporting	1	YR	$ 16,182	$ 16,182	Report to Kaiser & Ecology quarterly; EIM reporting. See Table D-7.
Professional/Technical Services Subtotal				**$ 233,873**	
TOTAL ANNUAL O&M COST				**$ 1,456,938**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Institutional Controls (Periodic Update and Maintenance)					
Restrictive covenants	1	EA	$ 6,470	$ 6,470	Years 5, 10, 15, 20, 25, 30. See Table D-8.
Initial acute and chronic toxicity testing	1	LS	$ 45,000	$ 45,000	Years 0, 5, 10, 15, 20, 25. See Table D-8.
Final acute and chronic toxicity testing	1	LS	$ 14,940	$ 14,940	Years 5, 10, 15, 20, 25, 30. See Table D-8.
Institutional Controls Subtotal				**$ 66,410**	
Groundwater IRM System Periodic Maintenance					
Groundwater extraction system	4	EA	$ 30,896	$ 123,583	Years 10, 20, 30. Major equipment & infrastructure repair/replacement, 4 extraction locations. Based on cost used in Table C-2 in Appendix C for groundwater extraction system maintenance.
Groundwater IRM System Periodic Maintenance Subtotal				**$ 123,583**	
Contingency	10%	--	--	**$ 18,999**	Scope and bid contingency. Percentage of periodic costs.

Table D-2 - Alternative D1 Estimated Cost Summary

Location:	Kaiser Aluminum Washington, LLC Spokane Valley, WA	**Description:** Alternative D1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA) and is common to each of the alternatives that will be evaluated for the remediation of Remelt/Hot Line PCB plume and smear zone soil AOCs. Alternative D1 assumes an operating period of 30 years in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

Professional/Technical Services						
Five-year reviews	1	EA	$ 19,540	$ 19,540	Years 5, 10, 15, 20, 25, 30. See Table D-9.
Closure report	1	EA	$ 41,180	$ 41,180	Year 30. See Table D-9.
Professional/Technical Services Subtotal				**$ 60,720**	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 1,409,591	$ 1,409,591	1.000	$ 1,409,591	
Annual O&M	1 - 30	$ 43,708,153	$ 1,456,938	12.409	$ 18,079,209	
Periodic	5	$ 92,591	$ 92,591	0.713	$ 66,016	
Periodic	10	$ 228,532	$ 228,532	0.508	$ 116,174	
Periodic	15	$ 92,591	$ 92,591	0.362	$ 33,559	
Periodic	20	$ 228,532	$ 228,532	0.258	$ 59,057	
Periodic	25	$ 92,591	$ 92,591	0.184	$ 17,060	
Periodic	30	$ 220,212	$ 220,212	0.131	$ 28,929	
		$ 46,072,794			$ 19,809,595	
TOTAL NET PRESENT VALUE OF ALTERNATIVE D1					**$ 19,809,595**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table D-3 - Alternative D2 Estimated Cost Summary - Scenario D2a

Location:	Kaiser Aluminum Washington, LLC Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Scenario D2a of Alternative D2 adds hydraulic containment of the Remelt/Hot Line PCB plume to Alternative D1 through the installation and operation of a new groundwater extraction well (PCB-FEW-1) at the leading edge of the plume. Extracted groundwater will be conveyed to an infiltration gallery located upgradient of the Oil House area. A 30-year operating period is assumed in the development of this cost estimate.

CAPITAL COSTS **DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 10,000	$ 10,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience.
Submittals, Plans, Site Preparation Subtotal				**$ 20,000**	
Groundwater Extraction and Infiltration System Installation					
Extraction well construction	130	ft	$ 477	$ 61,960	One extraction well, 20-in diameter. Unit cost scaled from vendor quote for 12-in diameter well, based on 20:12 diameter ratio.
Extraction system installation	1	EA	$ 62,112	$ 62,112	Approx. 150 hp. Unit cost scaled from vendor quote for 75 hp system, based on 150:75 power requirement ratio.
Electrical connection	1	EA	$ 50,000	$ 50,000	Previous project experience. One location (extraction well PCB-FEW-1).
Buried pipe installation	5,150	LF	$ 86	$ 443,833	See Table D-10.
Infiltration gallery construction	200	LF	$ 83	$ 16,579	See Table D-10.
Groundwater Extraction and Infiltration System Installation Subtotal				**$ 634,484**	
Contingency	10%	--	--	**$ 65,448**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	6%	--	--	$ 43,196	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	12%	--	--	$ 86,392	EPA 540-R-00-002.
Construction management	8%	--	--	$ 57,595	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. D1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 189,382**	
Institutional Controls					New institutional controls for extraction/infiltration system.
Institutional controls plan	50%	--	--	$ 23,274	Assume 50% of Alt. D1 institutional control plan cost to include groundwater extraction and infiltration system.
Restrictive covenants	50%	--	--	$ 12,485	Assume 50% of Alt. D1 restrictive covenant preparation cost to include groundwater extraction and infiltration system.
Institutional Controls Subtotal				**$ 35,759**	
TOTAL CAPITAL COST				**$ 945,074**	

ANNUAL O&M COSTS **DESCRIPTION**	**QUANTITY**	**UNIT**	**UNIT COST**	**TOTAL**	**NOTES**
System Operation, Maintenance, and Monitoring					
Electricity	984,933	kWh	$ 0.05	$ 49,247	Groundwater extraction pump operation (approx. 3.7 MGD). See Table D-10.
System maintenance	1	YR	$ 50,509	$ 50,509	See Table D-10.
Data management	1	YR	$ 4,500	$ 4,500	See Table D-9.
System Operation, Maintenance, and Monitoring Subtotal				**$ 104,256**	
Contingency	10%	--	--	**$ 10,426**	Scope and bid contingency. Percentage of annual O&M and monitoring cost.
Professional/Technical Services					
Project management	10%	--	--	$ 11,468	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 11,468	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. D1 Ecology oversight cost.
Reporting	1	YR	$ 7,000	$ 7,000	See Table D-9.
Professional/Technical Services Subtotal				**$ 32,136**	
Institutional Controls (Annual Update and Maintenance)					New institutional controls for extraction/infiltration system.
Institutional controls plan	50%	--	--	$ 15,009	Assume 50% of Alt. D1 institutional control plan annual update and maintenance cost to include groundwater extraction and infiltration system.
Site information database	50%	--	--	$ 2,872	Assume 50% of Alt. D1 site information database annual update and maintenance cost to include groundwater extraction and infiltration system.
Institutional Controls Subtotal				**$ 17,881**	
TOTAL ANNUAL O&M COST				**$ 164,698**	

Table D-3 - Alternative D2 Estimated Cost Summary - Scenario D2a

Location:	Kaiser Aluminum Washington, LLC
	Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Scenario D2a of Alternative D2 adds hydraulic containment of the Remelt/Hot Line PCB plume to Alternative D1 through the installation and operation of a new groundwater extraction well (PCB-FEW-1) at the leading edge of the plume. Extracted groundwater will be conveyed to an infiltration gallery located upgradient of the Oil House area. A 30-year operating period is assumed in the development of this cost estimate.

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Groundwater Extraction and Infiltration System Periodic Maintenance					
Groundwater extraction system	1	EA	$ 62,112	$ 62,112	Years 10, 20, 30. Major equipment & infrastructure repair/replacement, 1 extraction location (PCB-FEW-1). Assume equivalent of extraction system installation capital cost.
Piping and infiltration gallery	10%	--	--	$ 46,041	Years 10, 20, 30. Major infrastructure repair/replacement for buried pipeline and infiltration gallery. Assume 10% of capital cost of pipeline and infiltration gallery installation.
Groundwater Extraction and Infiltration System Periodic Maintenance Subtotal				**$ 108,153**	
Contingency	10%	--	--	**$ 10,815**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. See Table D-9.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. See Table D-9.
Professional/Technical Services Subtotal				**$ 30,360**	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 945,074	$ 945,074	1.000	$ 945,074	
Annual O&M	1 - 30	$ 4,940,942	$ 164,698	12.409	$ 2,043,745	
Periodic	5	$ 9,770	$ 9,770	0.713	$ 6,966	
Periodic	10	$ 128,738	$ 128,738	0.508	$ 65,444	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 128,738	$ 128,738	0.258	$ 33,268	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 149,328	$ 149,328	0.131	$ 19,617	
		$ 6,322,132			$ 3,119,456	Net present value of elements unique to Alternative D2, Scenario D2a.
Total Net Present Value of Alternative D1					$ 19,809,595	
TOTAL NET PRESENT VALUE OF ALTERNATIVE D2, SCENARIO D2a					**$ 22,929,051**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Location:	Kaiser Aluminum Washington, LLC Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Scenario D2b of Alternative D2 adds hydraulic containment of the Remelt/Hot Line PCB plume to Alternative D1 through the installation and operation of three new groundwater extraction well (PCB-FEW-2, PCB-FEW-2, and PCB-FEW-4) at the midpoint of the plume. Extracted groundwater will be conveyed to an infiltration gallery located upgradient of the Oil House area. A 30-year operating period is assumed in the development of this cost estimate.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 10,000	$ 10,000	Previous project experience.
Permits	1	LS	$ 10,000	$ 10,000	Previous project experience.
Submittals, Plans, Site Preparation Subtotal				**$ 20,000**	
Groundwater Extraction and Infiltration System Installation					
Extraction well construction	390	ft	$ 381	$ 148,704	Three extraction wells, 16-in diameter, 130-ft depth. Unit cost scaled from vendor quote for 12-in diameter well, based on 16:12 diameter ratio.
Extraction system installation	3	EA	$ 30,896	$ 92,687	Unit cost based on vendor quote. One system per well.
Electrical connection	3	EA	$ 50,000	$ 150,000	Previous project experience. Three locations (extraction wells PCB-FEW-2, PCB-FEW-3, PCB-FEW-4).
Buried pipe installation	4,430	LF	$ 86	$ 381,782	See Table D-10.
Infiltration gallery construction	200	LF	$ 83	$ 16,579	See Table D-10.
Groundwater Extraction and Infiltration System Installation Subtotal				**$ 789,753**	
Contingency	10%	--	--	**$ 80,975**	Scope and bid contingency. Percentage of institutional controls cost.
Professional/Technical Services					Percentage of sum of capital cost and contingency.
Project management	6%	--	--	$ 53,444	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	12%	--	--	$ 106,887	EPA 540-R-00-002.
Construction management	8%	--	--	$ 71,258	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. D1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 233,789**	
Institutional Controls					New institutional controls for extraction/infiltration system.
Institutional controls plan	50%	--	--	$ 23,274	Assume 50% of Alt. D1 institutional control plan cost to include groundwater extraction and infiltration system.
Restrictive covenants	50%	--	--	$ 12,485	Assume 50% of Alt. D1 restrictive covenant preparation cost to include groundwater extraction and infiltration system.
Institutional Controls Subtotal				**$ 35,759**	
TOTAL CAPITAL COST				**$ 1,160,277**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation, Maintenance, and Monitoring					
Electricity	806,580	kWh	$ 0.05	$ 40,329	Groundwater extraction pump operation (approx. 3.0 MGD). See Table D-10.
System maintenance	1	YR	$ 53,567	$ 53,567	See Table D-10.
Data management	1	YR	$ 4,500	$ 4,500	See Table D-9.
System Operation, Maintenance, and Monitoring Subtotal				**$ 98,396**	
Contingency	10%	--	--	**$ 9,840**	Scope and bid contingency. Percentage of annual O&M and monitoring cost.
Professional/Technical Services					
Project management	10%	--	--	$ 10,824	Percentage of annual cost + contingency. EPA 540-R-00-002.
Technical support	10%	--	--	$ 10,824	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. D1 Ecology oversight cost.
Reporting	1	YR	$ 7,000	$ 7,000	See Table D-9.
Professional/Technical Services Subtotal				**$ 30,847**	
Institutional Controls (Annual Update and Maintenance)					New institutional controls for extraction/infiltration system.
Institutional controls plan	50%	--	--	$ 15,009	Assume 50% of Alt. D1 institutional control plan annual update and maintenance cost to include groundwater extraction and infiltration system.
Site information database	50%	--	--	$ 2,872	Assume 50% of Alt. D1 site information database annual update and maintenance cost to include groundwater extraction and infiltration system.
Institutional Controls Subtotal				**$ 17,881**	
TOTAL ANNUAL O&M COST				**$ 156,963**	

Location:	Kaiser Aluminum Washington, LLC Spokane Valley, WA	**Description:** Scenario D2b of Alternative D2 adds hydraulic containment of the Remelt/Hot Line PCB plume to Alternative D1 through the installation and operation of three new groundwater extraction well (PCB-FEW-2, PCB-FEW-2, and PCB-FEW-4) at the midpoint of the plume. Extracted groundwater will be conveyed to an infiltration gallery located upgradient of the Oil House area. A 30-year operating period is assumed in the development of this cost estimate.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Groundwater Extraction and Infiltration System Periodic Maintenance					
Groundwater extraction system	1	EA	$ 92,687	$ 92,687	Years 10, 20, 30. Major equipment & infrastructure repair/replacement, 3 extraction locations (PCB-FEW-2, PCB-FEW-3, PCB-FEW-4). Assume equivalent of extraction system installation capital cost.
Piping and infiltration gallery	10%	--	--	$ 39,836	Years 10, 20, 30. Major infrastructure repair/replacement for buried pipeline and infiltration gallery. Assume 10% of capital cost of pipeline and infiltration gallery installation.
Groundwater Extraction and Infiltration System Periodic Maintenance Subtotal				**$ 132,523**	
Contingency	10%	--	--	**$ 13,252**	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. See Table D-9.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. See Table D-9.
Professional/Technical Services Subtotal				**$ 30,360**	

PRESENT VALUE ANALYSIS - Including Pipeline and Infiltration Gallery Costs

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 1,160,277	$ 1,160,277	1.000	$ 1,160,277	
Annual O&M	1 - 30	$ 4,708,882	$ 156,963	12.409	$ 1,947,757	
Periodic	5	$ 9,770	$ 9,770	0.713	$ 6,966	
Periodic	10	$ 155,546	$ 155,546	0.508	$ 79,072	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 155,546	$ 155,546	0.258	$ 40,196	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 176,136	$ 176,136	0.131	$ 23,138	
		$ 6,385,695			$ 3,262,747	Net present value of elements unique to Alternative D2, Scenario D2b.
Total Net Present Value of Alternative D1					$ 19,809,595	
TOTAL NET PRESENT VALUE OF ALTERNATIVE D2, SCENARIO D2b Including Pipeline and Infiltration Gallery Costs					**$ 23,072,342**	

PRESENT VALUE ANALYSIS - Excluding Pipeline and Infiltration Gallery Costs

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 608,148	$ 608,148	1.000	$ 608,148	This present value analysis (PVA) excludes the capital costs associated with buried pipeline ($381,782) and infiltration gallery ($41,608) installation, and associated adjustments for contingency (10%), project management (6%), remedial design (12%), and construction management (8%). Annual costs exclude infiltration gallery maintenance ($25,481) and associated adjustments for contingency (10%), project management (10%), and technical support (10%). Periodic maintenance cost for the piping and infiltration gallery ($42,339) and contingency adjustment (10%) are excluded (years 10, 20, and 30).
Annual O&M	1 - 30	$ 3,699,834	$ 123,328	12.409	$ 1,530,380	
Periodic	5	$ 9,770	$ 9,770	0.713	$ 6,966	
Periodic	10	$ 111,726	$ 111,726	0.508	$ 56,796	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 111,726	$ 111,726	0.258	$ 28,872	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 132,316	$ 132,316	0.131	$ 17,382	
		$ 4,693,059			$ 2,253,884	Net present value of elements unique to Alternative D2, Scenario D2b, excluding pipeline and infiltration gallery costs.
Total Net Present Value of Alternative D1					$ 19,809,595	
TOTAL NET PRESENT VALUE OF ALTERNATIVE D2, SCENARIO D2b Excluding Pipeline and Infiltration Gallery Costs					**$ 22,063,480**	This cost is used specifically for estimating Alternative D3 net present value. See Table D-5.

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table D-5 - Alternative D3 Estimated Cost Summary

Location:	Kaiser Aluminum Washington, LLC
	Spokane Valley, WA
Phase:	Feasibility Study (-35% to +50%)
Base Year:	2010
Date:	July 2011

Description: Alternative D3 includes Alternative D2 (Scenario D2b, excluding pipeline and infiltration gallery) plus *ex situ* groundwater treatment. Alternative D3 assumes an operating period of 30 years in the development of this cost estimate. Refer to Table D-10 for details.

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 50,000	$ 50,000	SAP, HASP, work plan, as-built drawings, O&M manual, QA/QC documentation. Based on previous project experience.
Permits	1	LS	$ 30,000	$ 30,000	Previous project experience. SEPA checklist, etc.
Submittals, Plans, Site Preparation Subtotal				**$ 80,000**	
System Installation and Startup					
Treatment system equipment	1	LS	$ 1,665,401	$ 1,665,401	See Table D-11.
Treatment system construction	1	LS	$ 1,129,731	$ 1,129,731	See Table D-11.
Treatment system consumables	1	LS	$ 136,598	$ 136,598	Year Zero. See Table D-11.
Buried pipe installation	3,350	LF	$ 86	$ 288,707	From extraction wells to treatment system and treatment systen to infiltration gallery. See Table D-10 for unit cost.
Infiltration gallery construction	200	LF	$ 83	$ 16,579	See Table D-10.
System Installation and Startup Subtotal				**$ 3,237,015**	
Contingency	20%	--	--	**$ 663,403**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					
Project management	5%	--	--	$ 199,021	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 318,433	EPA 540-R-00-002.
Construction management	6%	--	--	$ 238,825	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Pilot-scale study	1	LS	$ 323,702	$ 323,702	10% of Installation costs.
Professional/Technical Services Subtotal				**$ 1,079,981**	
TOTAL CAPITAL COST				**$ 5,060,400**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Monitoring					
Labor	1	LS	$ 144,000	$ 144,000	See Table D-11.
Equipment repair/replacement	1	LS	$ 119,270	$ 119,270	See Table D-11.
Consumables	1	LS	$ 1,209,636	$ 1,209,636	See Table D-11.
Performance groundwater sampling & analysis	1	LS	$ 25,654	$ 25,654	See Table D-11.
System Operation and Monitoring Subtotal				**$ 1,498,560**	
Contingency	10%	--	--	**$ 149,856**	Scope and bid contingency.
Professional/Technical Services					
Project management	5%	--	--	$ 82,421	EPA 540-R-00-002.
Technical support	5%	--	--	$ 82,421	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. D1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 167,042**	
TOTAL ANNUAL O&M COST				**$ 1,815,457**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Major treatment system maintenance	10%	--	--	$ 506,040	Years 10, 20, 30. 10% of system capital costs.
Contingency	10%	--	--	$ 50,604	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. See Table D-9.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. See Table D-9.

Table D-5 - Alternative D3 Estimated Cost Summary

Location:	Kaiser Aluminum Washington, LLC Spokane Valley, WA	**Description:** Alternative D3 includes Alternative D2 (Scenario D2b, excluding pipeline and infiltration gallery) plus *ex situ* groundwater treatment. Alternative D3 assumes an operating period of 30 years in the development of this cost estimate. Refer to Table D-10 for details.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 5,060,400	$ 5,060,400	1.000	$ 5,060,400	
Annual O&M	1 - 30	$ 54,463,715	$ 1,815,457	12.409	$ 22,528,083	
Periodic	5	$ 9,770	$ 9,770	0.713	$ 6,966	
Periodic	10	$ 566,414	$ 566,414	0.508	$ 287,936	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 566,414	$ 566,414	0.258	$ 146,372	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 587,004	$ 587,004	0.131	$ 77,113	
		$ 61,273,256			$ 28,112,211	Net present value of elements unique to Alternative D3.
Total Net Present Value of Alternative D2, Scenario D2b					$ 22,063,480	Cost excludes pipeline and infiltration gallery costs from D2b. See Table D-4.
TOTAL NET PRESENT VALUE OF ALTERNATIVE D3					**$ 50,175,690**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table D-6 - Alternative D4 Estimated Cost Summary

Location:	Kaiser Trentwood Facility	**Description:** Alternative D4 include Alternative D1 and extraction and *ex situ* treatment of 300,00 gpd. Alternative D4 assumes an operating period of 30 years in the development of this cost estimate. Refer to Table D-12 for details.
	Spokane Valley, WA	
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Submittals, Plans, Site Preparation					
Pre- and post-construction submittals	1	LS	$ 50,000	$ 50,000	SAP, HASP, work plan, as-built drawings, O&M manual, QA/QC documentation. Based on previous project experience.
Permits	1	LS	$ 30,000	$ 30,000	Previous project experience. SEPA checklist, etc.
Submittals, Plans, Site Preparation Subtotal				**$ 80,000**	
Groundwater Extraction and Infiltration System Installation					
Extraction well construction	130	ft	$ 381	$ 49,568	One extraction wells, 16-in diameter, 130-ft depth. Unit cost scaled from vendor quote for 12-in diameter well, based on 16:12 diameter ratio. See Table D-10.
Extraction system installation	1	EA	$ 30,896	$ 30,896	Unit cost based on vendor quote. One system per well.
Electrical connection	1	EA	$ 50,000	$ 50,000	Previous project experience. Three locations (extraction wells PCB-FEW-2, PCB-FEW-3, PCB-FEW-4).
Buried pipe installation	3,350	LF	$ 86	$ 288,707	From extraction wells to treatment system and treatment systen to infiltration gallery. See Table D-10 for unit cost.
Infiltration gallery construction	200	LF	$ 83	$ 16,579	See Table D-10.
Groundwater Extraction and Infiltration System Installation Subtotal				**$ 435,750**	
System Installation and Startup					
Treatment system equipment	1	LS	$ 398,196	$ 398,196	See Table D-12.
Treatment system construction	1	LS	$ 340,099	$ 340,099	See Table D-12.
Treatment system consumables	1	LS	$ 34,150	$ 34,150	Year Zero. See Table D-12.
System Installation and Startup Subtotal				**$ 772,445**	
Contingency	20%	--	--	**$ 257,639**	Scope and bid contingency. Percentage of capital costs.
Professional/Technical Services					
Project management	5%	--	--	$ 77,291.67	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Remedial design	8%	--	--	$ 123,666.67	EPA 540-R-00-002.
Construction management	6%	--	--	$ 92,750.00	EPA 540-R-00-002. Includes reports referenced in WAC 173-340-400(6)(b).
Pilot-scale study	1	LS	$ 77,244	$ 77,244	10% of Installation costs.
Professional/Technical Services Subtotal				**$ 370,953**	
TOTAL CAPITAL COST				**$ 1,916,786**	

ANNUAL O&M COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
System Operation and Monitoring					
Extraction Well Electricity	239,578	kWh	$ 0.05	$ 11,979	Groundwater extraction pump operation (approx. 0.3 MGD). See Table D-12.
Labor	1	LS	$ 108,000	$ 108,000	See Table D-12.
Equipment repair/replacement	1	LS	$ 58,284	$ 58,284	See Table D-12.
Consumables	1	LS	$ 148,119	$ 148,119	See Table D-12.
Performance groundwater sampling & analysis	1	LS	$ 14,133	$ 14,133	See Table D-12.
System Operation and Monitoring Subtotal				**$ 328,536**	
Contingency	10%	--	--	**$ 32,854**	Scope and bid contingency.
Professional/Technical Services					
Project management	5%	--	--	$ 18,069	EPA 540-R-00-002.
Technical support	5%	--	--	$ 18,069	EPA 540-R-00-002.
Ecology oversight	10%	--	--	$ 2,200	Assume 10% of Alt. D1 Ecology oversight cost.
Professional/Technical Services Subtotal				**$ 38,339**	
TOTAL ANNUAL O&M COST				**$ 399,728**	

PERIODIC COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Groundwater Extraction and Infiltration System Periodic Maintenance					
Groundwater extraction system	1	EA	$ 30,896	$ 30,896	Years 10, 20, 30. Major equipment & infrastructure repair/replacement, 3 extraction locations (PCB-FEW-2, PCB-FEW-3, PCB-FEW-4). Assume equivalent of extraction system installation capital cost.
Piping and infiltration gallery	10%	--	--	$ 30,529	Years 10, 20, 30. Major infrastructure repair/replacement for buried pipeline and infiltration gallery. Assume 10% of capital cost of pipeline and infiltration gallery installation.
Major treatment system maintenance	10%	--	--	$ 191,679	Year 10, 20, 30. 10% of system capital costs.
Contingency	10%	--	--	$ 25,310	Scope and bid contingency. Percentage of periodic costs.
Professional/Technical Services					
Five-year reviews	1	EA	$ 9,770	$ 9,770	Years 5, 10, 15, 20, 25, 30. See Table D-9.
Closure report	1	EA	$ 20,590	$ 20,590	Year 30. See Table D-9.

Table D-6 - Alternative D4 Estimated Cost Summary

Location:	Kaiser Trentwood Facility Spokane Valley, WA	**Description:** Alternative D4 include Alternative D1 and extraction and *ex situ* treatment of 300,00 gpd. Alternative D4 assumes an operating period of 30 years in the development of this cost estimate. Refer to Table D-12 for details.
Phase:	Feasibility Study (-35% to +50%)	
Base Year:	2010	
Date:	July 2011	

PRESENT VALUE ANALYSIS

Discount rate 7.0%
Total years 30

COST TYPE	YEAR	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	NET PRESENT VALUE	NOTES
Capital	0	$ 1,916,786	$ 1,916,786	1.000	$ 1,916,786	
Annual O&M	1 - 30	$ 11,991,853	$ 399,728	12.409	$ 4,960,246	
Periodic	5	$ 9,770	$ 9,770	0.713	$ 6,966	
Periodic	10	$ 288,183	$ 288,183	0.508	$ 146,498	
Periodic	15	$ 9,770	$ 9,770	0.362	$ 3,541	
Periodic	20	$ 288,183	$ 288,183	0.258	$ 74,472	
Periodic	25	$ 9,770	$ 9,770	0.184	$ 1,800	
Periodic	30	$ 308,773	$ 308,773	0.131	$ 40,563	
		$ 14,823,089			$ 7,150,872	Net present value of elements unique to Alternative D3.
Total Net Present Value of Alternative D1					$ 19,809,595	
TOTAL NET PRESENT VALUE OF ALTERNATIVE D4					**$ 26,960,467**	

Notes:
Costs taken from RSMeans have been adjusted by Spokane location adjustment factor of 0.93.
Costs from previous work greater than 1 year old have been adjusted using historical cost index factors provided by 2010 RSMeans (p. 671).
Present value analysis uses a 30-year discount rate of 7.0%.

Table D-7 - Monitoring Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative D1					
Protection & Performance Monitoring - Annual Costs					Protection and performance monitoring costs based on previous project experience.
Labor	1	yr	$ 107,960	$ 107,960	Includes well and equipment maintenance labor. Excludes project management labor.
Equipment, supplies, computer	1	yr	$ 17,480	$ 17,480	Includes well and equipment maintenance.
Travel	1	yr	$ 24,108	$ 24,108	
Sample shipping	1	yr	$ 10,000	$ 10,000	Previous project experience.
Laboratory analysis	1	yr	$ 108,552	$ 108,552	
Subtotal				$ 268,100	
Total qty. of wells sampled	114				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010a).
Protection monitoring wells	19				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010a).
Performance monitoring wells	95				See SAP, as amended (Hart Crowser 2007a, Kaiser 2010a).
Protection monitoring annual total	16.7%	--	--	$ 44,683	Percentage = protection wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Performance monitoring annual total	83.3%	--	--	$ 223,417	Percentage = performance wells sampled/total wells sampled. Annual total. Monitoring events occur quarterly.
Data management	1	yr	$ 29,948	$ 29,948	Data validation; database management.
Reporting	1	yr	$ 16,182	$ 16,182	Report to Kaiser & Ecology quarterly; EIM reporting.

Alternative D1 protection and performance monitoring notes:
- Two 2-person teams plus sample custodian on site during each sample event (5 people total).
- Assumed each sample team can sample 7 wells per day on average.
- Assumed water levels take an entire day with 4 people measuring.
- Assumed 10-hour field days.
- Assumed EIM submittal included for groundwater data plus any additional soil or soil gas data collected during previous 6 months.
- Assumed 2 vehicles for each sampling event.
- Actual well and equipment maintenance costs will depend on upcoming needs.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative D1					
New Institutional Controls					
Pending environmental upgrades at casting complexes					Pending items and approx. costs provided by Kaiser.
Replace melter furnace door jambs	5	locations	$ 20,000	$ 100,000	DC-1, DC-2W, DC-3, DC-8E, DC-8W. Provided by Kaiser, May 23, 2011.
Contain hydraulics/lubrication	1	locations	$ 151,000	$ 151,000	DC-2. Unit cost per Kaiser, April 19, 2010.
Overflow lines to sewer	7	locations	$ 50,000	$ 350,000	DC-2 through DC-8.
Seal DC-7/DC-8 control house sump	1	location	$ 15,000	$ 15,000	Excludes equipment removal cost (approx. $15k). Unit cost per Kaiser, April 19, 2010.
Slip line storm sewers					Pipe lengths from Kaiser storm sewer plan dwg titled: Aluminum Works - Trentwood Plant, Storm Sewer - Scheme "O", General Arrangement March 8, 1967. Unit cost based on cost of slip lining from MH 7B to MH 9 (approx. $120,100 for total length of 390 ft.) in 2005, adjusted to 2010 dollars (2010 RSMeans p.671).
MH 2 to MH 3	133	ft	$ 371	$ 49,386	
MH 9 to MH 3	280	ft	$ 371	$ 103,971	
MH 3 to MH 5	366	ft	$ 371	$ 135,905	
MH 5 to MH 6	460	ft	$ 371	$ 170,810	
Subtotal				$ 460,073	
Total				$ 1,076,073	
Preparation of institutional control O&M and monitoring plans					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	60	hr	$ 90	$ 5,400	
Staff	60	hr	$ 75	$ 4,500	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	8	hr	$ 60	$ 480	
Travel	1	ea	$ 566	$ 566	Assume 2-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 15,516	Cost per plan.
Quantity of plans to prepare	3				
Total				$ 46,548	Assume 3 plans in total (e.g., plans for Facility pavement, engineered controls, air emission control system).
Preparation of restrictive covenant					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	40	hr	$ 300	$ 12,000	
Principal	24	hr	$ 180	$ 4,320	
Sr. Project	24	hr	$ 130	$ 3,120	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	16	hr	$ 75	$ 1,200	
Clerical	8	hr	$ 60	$ 480	
Computer	1	ea	$ 250	$ 250	
Total				$ 24,970	
Institutional Controls - Annual Costs					
Environmental upgrades at casting complexes					
Verify pit/sump integrity	9	locations	$ 1,000	$ 9,000	DC-1 through DC-8 plus DC-7/DC-8 control house sump.
Other upgrade maintenance	5%	--	--	$ 53,804	Assume percentage of environmental upgrade capital cost above.
Subtotal				$ 62,804	
Maintenance of physical measures and BMPs					Assume maintenance of signs, fences, gates, access control, existing training programs, waste handling guidance, and BMPs defined in SPCC Plan and SWPPP.
Labor	1920	hr	$ 75	$ 144,000	Assume 1 FTE.
Supervisor	480	hr	$ 110	$ 52,800	Assume 25% of labor effort.
Subtotal				$ 196,800	
Total				$ 259,604	
Institutional control O&M and monitoring plans - annual update and maintenance					Assume work performed by Hart Crowser staff.
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	8	hr	$ 75	$ 600	
Sr. Drafter	4	hr	$ 100	$ 400	
Clerical	2	hr	$ 60	$ 120	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Subtotal				$ 5,003	Cost per plan.
Quantity of plans to maintain	6				
Total				$ 30,018	Assume 6 plans in total. Includes existing WDR Restoration Monitoring Plan, SPCC Plan, and SWPPP plus institutional control, O&M, and monitoring plans given above.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Site information database - annual update and maintenance					Assume work performed by Hart Crowser staff.
Principal	4	hr	$ 180	$ 720	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	24	hr	$ 90	$ 2,160	
Staff	12	hr	$ 75	$ 900	
Clerical	4	hr	$ 60	$ 240	
Travel	1	ea	$ 433	$ 433	Assume 1-day site visit.
Computer	1	ea	$ 250	$ 250	
Total				$ 5,743	
Institutional Controls - Periodic Costs					
Restrictive covenant periodic update and maintenance					Assume work performed by Hart Crowser staff. Includes attorney fees.
Attorney fees	8	hr	$ 300	$ 2,400	
Principal	8	hr	$ 180	$ 1,440	
Sr. Project	4	hr	$ 130	$ 520	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	4	hr	$ 75	$ 300	
Clerical	2	hr	$ 60	$ 120	
Computer	1	ea	$ 250	$ 250	
Total				$ 6,470	
NPDES Permit and Ecology Order Required Monitoring - Annual Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997), Ecology Agreed Order No. 02WQER-3487 (Ecology 2002), and Ecology Amended Order No. 2868 (Ecology 2005). See Section 2.1.1.1.
NPDES permit - monitoring laboratory analysis					
Sample quantity					Based on weekly sampling frequency.
Outfall 001	104	samples			
Outfall 002	104	samples			
Outfall 003	52	samples			
Plant intake	104	samples			
Laboratory analysis					Unit prices based on laboratory quote.
Outfall 001					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	104	samples	$ 18	$ 1,872	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc, phosphorous.
Cyanide	104	samples	$ 40	$ 4,160	
Hardness	104	samples	$ 25	$ 2,600	
Subtotal				$ 19,032	
Outfall 002					
Oil and grease	260	samples	$ 50	$ 13,000	
TSS	104	samples	$ 18	$ 1,872	
Orthophosphate	104	samples	$ 20	$ 2,080	
Total Al, Cr, Zn, P	104	samples	$ 50	$ 5,200	Aluminum, chromium, zinc, phosphorous.
Hexavalent chromium	104	samples	$ 50	$ 5,200	
Cyanide	104	samples	$ 40	$ 4,160	
Subtotal				$ 31,512	
Outfall 003					
BOD_5	52	samples	$ 45	$ 2,340	
TSS	52	samples	$ 18	$ 936	
Fecal coliform	52	samples	$ 35	$ 1,820	
Subtotal				$ 5,096	
Plant intake					
Oil and grease	104	samples	$ 50	$ 5,200	
TSS	52	samples	$ 18	$ 936	
Total metals	104	samples	$ 50	$ 5,200	Aluminum, chromium, recoverable zinc.
Subtotal				$ 11,336	
NPDES permit laboratory analysis subtotal				$ 66,976	
Ecology Order - monitoring laboratory analysis					
Sample quantity					Based on biweekly sampling frequency.
Outfall 001	26	samples			
Plant lagoon effluent	26	samples			
Plant lagoon influent	26	samples			

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Laboratory analysis					
For 3 locations given above					
PCBs - ultra-low level	78	samples	$ 175	$ 13,650	
Subtotal				$ 13,650	
Ecology Order laboratory analysis subtotal				$ 13,650	
Sampling labor - NPDES permit and Ecology Order required monitoring					
Labor	208	hr	$ 75	$ 15,600	Assume 1 individual
Supervisor	52	hr	$ 110	$ 5,720	Assume 25% of labor effort.
Labor subtotal				$ 21,320	
Total Annual Cost				$ 101,946	
NPDES Permit Required Monitoring - Periodic Costs					Required by NPDES Permit No. WA-000089-2 (Ecology 1997). See Section 2.1.1.1.
Initial acute toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in Years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	8	samples	$ 850	$ 6,800	
Daphnid (48-hr static test)	8	samples	$ 700	$ 5,600	
Subtotal				$ 12,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial acute toxicity testing total				$ 16,500	
Final acute toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in Years 5, 10, 15, 20, 25, and 30.
Laboratory analysis					
Fathead minnow (96-hr static-renewal test)	2	samples	$ 850	$ 1,700	
Daphnid (48-hr static test)	2	samples	$ 700	$ 1,400	
Subtotal				$ 3,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final acute toxicity testing total				$ 5,970	
Initial chronic toxicity testing					Assume conducted quarterly for one year, once per permit cycle.
Sample quantity					Assume 5-year permit cycle.
River intake	4	samples			Assume conducted in Years 0, 5, 10, 15, 20, and 25.
Final effluent	4	samples			Unit prices based on laboratory quote.
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	8	samples	$ 1,575	$ 12,600	
Water flea (7-day, full dilution test)	8	samples	$ 1,475	$ 11,800	
Subtotal				$ 24,400	
Sampling and reporting labor					
Labor	40	hr	$ 75	$ 3,000	Assume 1 individual performs sampling and reporting.
Supervisor	10	hr	$ 110	$ 1,100	Assume 25% of labor effort.
Labor subtotal				$ 4,100	
Initial chronic toxicity testing total				$ 28,500	
Final chronic toxicity testing					Assume conducted once in the last summer, once in the last winter, of the permit cycle.
Sample quantity					Assume 5-year permit cycle.
Final effluent	2	samples			Assume conducted in Years 5, 10, 15, 20, 25, and 30.

Table D-8 - Institutional Controls Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Laboratory analysis					
Fathead minnow (7-day, full dilution test)	2	samples	$ 1,575	$ 3,150	
Water flea (7-day, full dilution test)	2	samples	$ 1,475	$ 2,950	
Subtotal				$ 6,100	
Sampling and reporting labor					
Labor	28	hr	$ 75	$ 2,100	Assume 1 individual performs sampling and reporting.
Supervisor	7	hr	$ 110	$ 770	Assume 25% of labor effort.
Labor subtotal				$ 2,870	
Final chronic toxicity testing total				$ 8,970	

Table D-9 - Professional Services Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative D1 - Periodic Costs					
Five-year review periodic cost					Assume work performed by Hart Crowser staff.
Ecology oversight	1	ls	$ 7,500	$ 7,500	Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Principal	16	hr	$ 180	$ 2,880	
Sr. Project	16	hr	$ 130	$ 2,080	
Sr. Staff	40	hr	$ 90	$ 3,600	
Staff	40	hr	$ 75	$ 3,000	
Clerical	8	hr	$ 60	$ 480	
Total				$ 19,540	
Closure report periodic cost					Assume work performed by Hart Crowser staff.
Ecology oversight	1	ls	$ 7,500	$ 7,500	Historical mean non-zero quarterly Ecology cost at Kaiser 2007-2009.
Principal	40	hr	$ 180	$ 7,200	
Sr. Project	80	hr	$ 130	$ 10,400	
Sr. Staff	80	hr	$ 90	$ 7,200	
Staff	80	hr	$ 75	$ 6,000	
Sr. Drafter	24	hr	$ 100	$ 2,400	
Clerical	8	hr	$ 60	$ 480	
Total				$ 41,180	
Alternative D2 - Annual Costs					
System monitoring - data management annual cost					Assume work performed by Hart Crowser staff.
Principal	2	hr	$ 180	$ 360	
Sr. Associate	4	hr	$ 160	$ 640	
Sr. Project	8	hr	$ 130	$ 1,040	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	12	hr	$ 75	$ 900	
Clerical	2	hr	$ 60	$ 120	
Total				$ 4,500	
System monitoring - reporting annual cost					Assume work performed by Hart Crowser staff.
Principal	8	hr	$ 180	$ 1,440	
Sr. Associate	2	hr	$ 160	$ 320	
Sr. Project	12	hr	$ 130	$ 1,560	
Sr. Staff	16	hr	$ 90	$ 1,440	
Staff	16	hr	$ 75	$ 1,200	
Sr. Drafter	8	hr	$ 100	$ 800	
Clerical	4	hr	$ 60	$ 240	
Total				$ 7,000	
Alternative D2 - Periodic Costs					
Five-year reviews - Scenario D2a, D2b	50%	--	--	$ 9,770	Assume 50% of Alt. D1 five-year review cost to include groundwater extraction and infiltration system.
Closure report - Scenario D2a, D2b	50%	--	--	$ 20,590	Assume 50% of Alt. D1 remedial action report cost to include groundwater extraction and infiltration system.
Alternative D3 - Periodic Costs					
Five-year reviews	50%	--	--	$ 9,770	Assume additional 50% of Alt. D1 five-year review cost to include *ex situ* treatment system.
Closure report	50%	--	--	$ 20,590	Assume additional 50% of Alt. D1 remedial action report cost to include *ex situ* treatment system.

Table D-10 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Alternative D1 - Existing IRM System Annual O&M Costs					
Groundwater extraction					
OH-EW-1					
Pump motor input power	100	hp			Existing pump, 100 hp (Hart Crowser 2003).
Pump motor input power	74.6	kW			
WW-EW-1					
Pump motor input power	400	hp			Existing pump, 400 hp (Hart Crowser 2003).
Pump motor input power	298.3	kW			
WW-EW-2					
Pump motor input power	400	hp			Existing pump, 400 hp (Hart Crowser 2003).
Pump motor input power	298.3	kW			
WW-UVB-1					Neglect friction, velocity head, and minor losses.
Pump efficiency	80%				Approximation based on average of range (Lindeburg 2003).
Motor efficiency	70%				
Elevation head	151	ft			Assume elevation head equal to well depth.
Flow rate	3,035	gpm			
Specific gravity	1.0				
Hydraulic power	115.8	hp			
Hydraulic power	86.4	kW			1 hp = 0.7457 kW.
Brake pump power	144.8	hp			
Brake pump power	108.0	kW			Existing pump power rating not available. Pump power requirement estimate based on modeled flow rate (Appendix E, Table E-3) and elevation head (151 feet).
Pump motor input power	206.9	hp			
Pump motor input power	154.3	kW			
Annual electricity usage and cost					
Total motor input power	825.4	kW			Sum of OH-EW-1, WW-EW-1, WW-EW-2, and WW-UVB-1.
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	7,230,423	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 361,521	$/yr			
IRM system maintenance annual cost					labor, parts, supplies. Use same labor unit costs as for inst. controls.
Labor	416	hr	$ 75	$ 31,200	Assume 0.2 FTE.
Supervisor	104	hr	$ 110	$ 11,440	Assume 25% of labor effort.
Parts, supplies	10%		$ 123,583	$ 12,358	Based on parts and supplies cost used in Table C-11 in Appendix C.
Total				$ 54,998	
Alternative D2 - Scenario D2a Capital Costs					
Pipeline length	5,150	LF			
Infiltration gallery length	200	LF			
Infiltration gallery width	3	ft			
Infiltration gallery depth	10	ft			
Infiltration gallery volume (bank)	222	BCY			
Bulking factor	1.15				
Infiltration gallery volume (loose)	256	LCY			
Sales tax	8.7%				Effective rate for Spokane Valley, WA, 4/1/10 to 6/30/10. See http://dor.wa.gov/Docs/forms/ExcsTx/LocSalUseTx/LocalSlsUseFlyer_10_Q2_alpha.pdf.
Location adjustment factor	0.93				Cost adjustment factor for Spokane, WA (2010 RSMeans p. 696). Applied to estimated costs originating from RSMeans cost guide.
Estimate unit cost for 16-in diameter pipe					Cost data for 16-in diameter steel pipe not available in 2010 RSMeans. Unit cost for 16-in pipe estimated from 2010 RSMeans cost data for 12-in pipe and 18-in pipe below.
12-in diameter pipe		LF	$ 63		Black steel, plain end, welded, 1/4-in wall. 2010 RSMeans 33 11 13.40 1020.
18-in diameter pipe		LF	$ 80		Black steel, plain end, welded, 1/4-in wall. 2010 RSMeans 33 11 13.40 1030.
Estimated 16-in diameter pipe unit cost		LF	$ 74		Result of interpolation of 12-in and 18-in pipe unit costs.

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Estimate unit cost for buried 16-in diameter pipe installation					Cost data for 16-in-diameter steel pipe installation not available in 2010 RSMeans. Unit cost for 16-in pipe installation estimated from 2010 RSMeans cost data for 12-in pipe installation below.
Trenching, bedding, backfill, compaction, 12-in pipe unit cost		LF	$ 78		12-in, 1/4-in wall black steel pipe, 4 ft deep. 2010 RSMeans assembly G3010 122 2550.
Subtract 12-in diameter pipe unit cost		LF	$ (63)		Black steel, plain end, welded, 1/4-in wall. 2010 RSMeans 33 11 13.40 1020.
Trenching, bedding, backfill, compaction without 12-in pipe		LF	$ 15		
Add estimated unit cost for 16-in diameter pipe		LF	$ 74		Result of interpolation of 12-in and 18-in pipe unit costs above.
Estimated unit cost for trenching, bedding, backfill, compaction with 16-in pipe		LF	$ 89		
Apply location cost adjustment factor		LF	$ 82		
Material unit cost for sales tax calculation					
12-in diameter pipe material unit cost		LF	$ 34		Black steel, 1/4-in wall. 2010 RSMeans 33 11 13.40 1020.
18-in diameter pipe material unit cost		LF	$ 45		Black steel, 1/4-in wall. 2010 RSMeans 33 11 13.40 1030.
Estimated 16-in diameter pipe material unit cost		LF	$ 41		Result of interpolation of 12-in and 18-in pipe material unit costs.
Bedding material unit cost		LF	$ 6.74		Crushed stone. 2010 RSMeans p. 601.
Total material unit cost		LF	$ 48		
Apply location cost adjustment factor		LF	$ 45		
Sales tax unit cost	8.7%	LF	$ 3.88		Sales tax per linear foot of pipe.
Buried pipeline installation cost	5,150	LF	$ 86	$ 443,833	Based on estimated unit cost derived above. Includes material, labor, and equipment costs for trenching, bedding, backfill, compaction, and 16-in-diameter, black steel, plain end, welded, 1/4-in wall pipe, 4 ft deep. Includes sales tax on bedding and pipe materials.
Infiltration gallery construction					
Trench excavation	222	BCY	$ 6.32	$ 1,405	Sand and gravel, 10 ft deep, 3/4 CY excavator. 2010 RSMeans 31 23 16.13 6140.
Loading excavated soil	15%	--	--	$ 211	Loading onto trucks. 2010 RSMeans 31 23 16.42 0020.
Hauling excavated soil	256	LCY	$ 3.39	$ 867	Two 12-CY trucks, 20 MPH ave, cycle 1 mile, 15-min wait/load/unload. 2010 RSMeans 31 23 23.20 1028. Assume soil is clean and stockpiled on site.
Drainage material	222	CY	$ 33	$ 7,440	Round, river stone. 2010 RSMeans 03 05 13.25 1055.
Backfill trench	222	CY	$ 7.44	$ 1,653	Front-end loader, wheel-mounted, 2-1/4-CY bucket, 200-ft min. haul. 2010 RSMeans 31 23 16.13 3100.
Access tees	4	ea	$ 316	$ 1,265	Galvenized, uncoated, 12-in diameter, 16 gauge. 2010 RSMeans 33 41 13.40 2728.
End section	1	ea	$ 194	$ 194	Galvenized, uncoated, 12-in diameter, 16 gauge. 2010 RSMeans 33 41 13.40 2790.
Utility boxes	4	ea	$ 688	$ 2,753	Hand hole, precast concrete, 1.5-in thick, light duty, 1 ft x 2 ft x 1.75 ft. 2010 RSMeans 33 05 16.13 0400.
Sales tax	8.7%	--	--	$ 790	Assume sales tax charged on cost of materials.
Total				$ 16,579	
Total unit cost		LF	$ 83		

Alternative D2 - Scenario D2a Annual O&M Costs

Groundwater extraction					
PCB-FEW-1					Neglect friction, velocity head, and minor losses.
Pump efficiency	80%				Efficiency approximation based on average of range (Lindeburg 2003).
Motor efficiency	70%				
Elevation head	130	ft			Assume elevation head equal to well depth.
Flow rate	3.7	MGD			
Flow rate	2,569	gpm			
Specific gravity	1.0				
Hydraulic power	84.4	hp			
Hydraulic power	63.0	kW			1 hp = 0.7457 kW.
Brake pump power	105.5	hp			
Brake pump power	78.7	kW			
Pump motor input power	150.8	hp			Pump power requirement estimate based on modeled flow rate
Pump motor input power	112.4	kW			(Appendix E, Table E-4) and elevation head (130 feet).

Table D-10 - Containment Cost Backup

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Annual electricity usage and cost					
Total motor input power	112.4	kW			
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	984,933	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 49,247	$/yr			
Extraction and infiltration system maintenance annual cost					labor, parts, supplies. Use same labor unit costs as for inst. controls.
Labor	416	hr	$ 75	$ 31,200	Assume 0.2 FTE.
Supervisor	104	hr	$ 110	$ 11,440	Assume 25% of labor effort.
Parts, supplies	10%	--	$ 78,691	$ 7,869	Assume 10% of extraction and infiltration system installation costs (see Table D-3), 1 location.
Total				$ 50,509	
Alternative D2 - Scenario D2b Capital Costs					
Pipeline length	4,430	LF			
Buried pipeline installation cost	4,430	LF	$ 86	$ 381,782	Based on estimated unit cost derived above for Scenario D2a. Includes material, labor, and equipment costs for trenching, bedding, backfill, compaction, and 16-in-diameter, black steel, plain end, welded, 1/4-in wall pipe, 4 ft deep. Includes sales tax on bedding and pipe materials.
Infiltration gallery construction	200	LF	$ 83	$ 16,579	Assume same capital cost as in Scenario D2a.
Alternative D2 - Scenario D2b Annual O&M Costs					
PCB-FEW-2, PCB-FEW-3, and PCB-FEW-4					Neglect friction, velocity head, and minor losses.
Pump efficiency	80%				Efficiency approximation based on average of range (Lindeburg 2003).
Motor efficiency	70%				
Elevation head per well	130	ft/well			Assume elevation head equal to well depth. Three wells.
Total flow rate	3.03	MGD			
Total flow rate	2,104	gpm			
Total flow rate per well	701	gpm/well			Assume equivalent flow rate for each well.
Specific gravity	1.0				
Hydraulic power per well	23.0	hp/well			
Hydraulic power per well	17.2	kW/well			1 hp = 0.7457 kW.
Brake pump power per well	28.8	hp/well			
Brake pump power per well	21.5	kW/well			
Pump motor input power per well	41.2	hp/well			Pump power requirement estimate based on modeled flow rate
Pump motor input power per well	30.7	kW/well			(Appendix E, Table E-4) and elevation head (130 feet).
Total pump motor input power	92.1	kW			
Annual electricity usage and cost					
Total motor input power	92.1	kW			
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	806,580	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 40,329	$/yr			
Extraction and infiltration system maintenance annual cost					labor, parts, supplies. Use same labor unit costs as for inst. controls.
Labor	416	hr	$ 75	$ 31,200	Assume 0.2 FTE.
Supervisor	104	hr	$ 110	$ 11,440	Assume 25% of labor effort.
Parts, supplies	10%	--	$ 109,266	$ 10,927	Assume 10% of extraction and infiltration system installation costs (see Table D-4), 3 locations.
Total				$ 53,567	

Table D-11 - *Ex Situ* Treatment Cost Backup

Alternative D3 - CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Treatment System Equipment					
Rapid mixing tank	8	ea	$ 4,563	$ 36,503	1,000-gal capacity, 7 gauge shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5520 (p.254). Assume 25% markup for impeller.
Flocculation tanks	8	ea	$ 45,000	$ 360,000	21,000-gal flocculation tanks. Unit cost from vendor quote.
Sand filter unit	4	ea	$ 4,800	$ 19,200	4-vessel sand filter unit. Each sand filter bed approximately has 3,600 pounds of sand. Unit cost from vendor quote.
Cartridge filter unit	20	ea	$ 32,000	$ 640,000	Duplex cartridge unit, five units per 500 gal. Each cartridge unit carries 20 cartridge filters, 40 in long.
GAC units	8	ea	$ 11,532	$ 92,256	10,000-gal capacity, 1/4-in-thick shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5560 (p.254).
Metering pumps	12	ea	$ 1,300	$ 15,600	Metering injection pumps for coagulant, acid, and base addition. Unit cost from vendor quote.
HCl holding tank	4	ea	$ 14,415	$ 57,660	10,000-gal capacity, 1/4-in-thick shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5560 (p.254). Will hold approximately monthly supply of HCl. Add 25% markup so tank is HCl compatible.
NaOH holding tank	4	ea	$ 4,563	$ 18,251	1,000-gal capacity, 7 gauge shell, single-wall, steel fuel-oil tank. 2010 RSMeans 23 13 13.09 5520 (p.254). Add additional 25% to tank system parts are NaOH compatible.
Instrumentation associated with acid and base addition systems	1	LS	$ 20,000	$ 20,000	Engineer's estimate. Instrumentation that will be used to monitor and inject acid or base to reach target pH.
Conveyance pumps	8	ea	$ 12,460	$ 99,680	30-hp pumps. Unit cost from vendor
Treatment shed	1	LS	$ 100,000	$ 100,000	Engineer's estimate.
Misc. equipment	5%	--	--	$ 72,957	Percentage of system equipment cost.
Sales tax	8.7%	--	--	$ 133,293	
Equipment Subtotal				**$ 1,665,401**	
Treatment System Construction					
Equipment transportation	1	LS	$ 20,000	$ 20,000	Vendor quote.
Electrical connection	1	LS	$ 20,000	$ 20,000	Previous project experience.
Conveyance piping - straight pipe	1,050	LF	$ 86	$ 90,490	See Table D-10 for unit cost.
Installation labor for vessels	30%	--	--	$ 499,620	Percentage of system equipment. Engineer's estimate.
Heavy equipment for installing vessels	30%	--	--	$ 499,620	Percentage of system equipment. Engineer's estimate.
System Construction Subtotal				**$ 1,129,731**	
Treatment System Consumables					
Cartridge filters - 10 µm	160	ea	$ 9.00	$ 1,440	4 treatment trains. Per treatment train, one 10-µm duplex cartridge unit. Each unit carries 40 cartridge filters (or 20 cartridge filters per vessel). Specification sheet for duplex cartridge unit from vendor. Price per cartridge filter from vendor.
Cartridge filters - 5 µm	160	ea	$ 9.00	$ 1,440	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 2 µm	160	ea	$ 9.00	$ 1,440	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 1 µm	160	ea	$ 9.00	$ 1,440	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 0.5 µm	160	ea	$ 9.00	$ 1,440	See description for "Cartridge filters - 10 µm" above.
Granular activated carbon	80,000	lbs	$ 1.35	$ 108,000	4 carbon treatment units. Each unit has two vessels that hold 10,000 pounds of carbon. Cost of carbon from vendor.
Shipping	10%			$ 11,376	Engineer's estimate.
Sales tax	8.7%	--	--	$ 10,022	
Consumables Subtotal				**$ 136,598**	

Alternative D3 - ANNUAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Labor					
Operation labor	1,920	hr	$ 75	$ 144,000	Assume 1 FTE.
Equipment repair/replacement					
Maintenance labor	480	hr	$ 75	$ 36,000	Assume 0.25 FTE.
Equipment repair/replacement	1	LS	$ 83,270	$ 83,270	5% of equipment costs.
Equipment Subtotal				**$ 119,270**	
Consumables - Coagulant, filter media, cartridge filters carbon					
Coagulant	48	tote	$ 2,500	$ 120,000	Assume 1 tote per month per treatment train. 275-gal totes of chitosan 1%, price from vendor.
Depth filtration media	29	ton	$ 14	$ 409	Cost from previous project experience. Each sand filter unit holds 14,500 pounds of sand.
Cartridge filters - 10 µm	4,160	ea	$ 9.00	$ 37,440	4 treatment trains. Per treatment train, one 10µm duplex cartridge unit. Each unit carries 40 cartridge filters (or 20 cartridge filters per vessel). Specification sheet for duplex cartridge unit from vendor. Assume 1 change-out of 1 vessel per week. Price per cartridge filter from vendor.
Cartridge filters - 5 µm	4,160	ea	$ 9.00	$ 37,440	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 2 µm	4,160	ea	$ 9.00	$ 37,440	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 1 µm	4,160	ea	$ 9.00	$ 37,440	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 0.5 µm	4,160	ea	$ 9.00	$ 37,440	See description for "Cartridge filters - 10 µm" above.
Carbon	40,000	lbs	$ 1.35	$ 54,000	One bed per treatment train replaced each year. Cost of carbon from vendor.
Shipping	10%			$ 36,161	Engineer's estimate.
Sales tax	8.7%			$ 31,460	
Consumables - Coagulant, filter media, cartridge filters carbon Subtotal				**$ 429,230**	
Consumables - Other					
Acid	351,860	gal	$ 0.98	$ 346,230	Actual acid used and addition rate required will be determined during bench- and pilot-scale testing. Assume approximately 960 gpd based on theoretical quantity of acid required to lower pH from 7.7 to 4.8 (average alkalinity of 158 mg/L). Assume 31% hydrochloric acid is used (liquid) to raise pH. Vendor cost on delivery.
Base	73,730	gal	$ 4.86	$ 358,328	Actual base used and addition rate required will be determined during bench- and pilot-scale testing. Assume approximately 202 gpd based on based upon theoretical equilibrium equations to raise pH from 4.8 to 7. Assume 50% sodium hydroxide solution used to raise pH. Vendor cost on delivery.
Utilities	1,606,954	kWh	$ 0.05	$ 75,848	12 metering pumps (assumed 1/2 hp) and 8 conveyance pumps (30 hp).
Consumables - Other Subtotal				**$ 780,406**	
Consumables Total				**$ 1,209,636**	
Performance GW Sampling					
Laboratory analysis - combined influent and effluent	24	ea	$ 247	$ 5,928	PCBs, pH, TSS, TDS, alkalinity. Sample points include combined influent and effluent. Monthly sampling.
Laboratory analysis - each treatment train	64	ea	$ 211	$ 13,504	For each treatment train will sample at GAC beds (upstream, interbed, downstream) and treatment train effluent (4 x 4 = 16). Assume quarterly sampling.
Equipment/shipping	1	LS	$ 5,000	$ 5,000	Engineer's estimate.
Data management	5%	--	--	$ 1,222	Engineer's estimate.
Sampling Subtotal				**$ 25,654**	

Alternative D4 - CAPITAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Treatment System Equipment					
Rapid mixing tank	2	ea	$ 3,023	$ 6,045	500-gal capacity, 7 gauge shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5520 (p.254). Assume 25% markup for impeller.
Flocculation tanks	2	ea	$ 45,000	$ 90,000	21,000-gal flocculation tanks. Unit cost from vendor quote.
Sand filter unit	1	ea	$ 3,600	$ 3,600	3-vessel sand filter unit. Each sand filter bed approximately has 3,600 lb of sand. Unit cost from vendor quote.
Cartridge filter unit	5	ea	$ 32,000	$ 160,000	Duplex cartridge unit. Cartridge unit carries 20 cartridge filters, 40 in long.
GAC units	2	ea	$ 11,532	$ 23,064	10,000-gal capacity, 1/4-in-thick shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5560 (p.254).
Metering pumps	3	ea	$ 1,300	$ 3,900	Metering injection pumps for coagulant, acid, and base addition. Unit cost from vendor quote.
HCl holding tank	1	ea	$ 4,563	$ 4,563	1,000-gal capacity, 1/4-in-thick shell, single-wall, steel fuel-oil tanks. 2010 RSMeans 23 13 13.09 5560 (p.254). Will hold approximately months supply of HCl. Add 25% markup for HCl compatibility.
NaOH holding tank	1	ea	$ 2,790	$ 2,790	500-gal capacity, 7 gauge shell, single-wall, steel fuel-oil tank. 2010 RSMeans 23 13 13.09 5520 (p.254). Add additional 25% to tank system parts are NaOH compatible.
Instrumentation associated with acid and base addition systems	1	LS	$ 5,000	$ 5,000	Engineer's estimate. Instrumentation that will be used to monitor and inject acid or base to reach target pH.
Conveyance pumps	2	ea	$ 12,460	$ 24,920	30-hp pumps. Unit cost from vendor
Treatment shed	1	LS	$ 25,000	$ 25,000	Engineer's estimate.
Misc. equipment	5%	--	--	$ 17,444	Percentage of system equipment cost.
Sales tax	8.7%	--	--	$ 31,870	
Equipment Subtotal				**$ 398,196**	
Treatment System Construction					
Equipment transportation	1	LS	$ 7,500	$ 7,500	Vendor quote.
Electrical connection	1	LS	$ 7,500	$ 7,500	Previous project experience.
Conveyance piping - straight pipe	1,000	LF	$ 86	$ 86,181	See Table D-10 for unit cost.
Installation labor for vessels	30%	--	--	$ 119,459	Percentage of system equipment. Engineer's estimate.
Heavy equipment for installing vessels	30%	--	--	$ 119,459	Percentage of system equipment. Engineer's estimate.
System Construction Subtotal				**$ 340,099**	
Treatment System Consumables					
Cartridge filters - 10 µm	40	ea	$ 9.00	$ 360	Unit carries 40 cartridge filters (or 20 cartridge filters per vessel). Specification sheet for duplex cartridge unit from vendor. Price per cartridge filter from vendor.
Cartridge filters - 5 µm	40	ea	$ 9.00	$ 360	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 2 µm	40	ea	$ 9.00	$ 360	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 1 µm	40	ea	$ 9.00	$ 360	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 0.5 µm	40	ea	$ 9.00	$ 360	See description for "Cartridge filters - 10 µm" above.
Granular activated carbon	20,000	lb	$ 1.35	$ 27,000	Two vessels that hold 10,000 lb of carbon. Cost of carbon from vendor.
Shipping	10%			$ 2,844	Engineer's estimate.
Sales tax	8.7%	--	--	$ 2,506	
Consumables Subtotal				**$ 34,150**	

Alternative D4 - ANNUAL COSTS

DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL	NOTES
Extraction Well Electricity and O&M					Neglect friction, velocity head, and minor losses.
Pump efficiency	80%				Efficiency approximation based on average of range (Lindeburg 2003).
Motor efficiency	70%				
Elevation head per well	130	ft/well			Assume elevation head equal to well depth. Three wells.
Total flow rate	0.3	MGD			
Total flow rate	208	gpm			
Specific gravity	1.0				
Hydraulic power per well	6.8	hp/well			
Hydraulic power per well	5.1	kW/well			1 hp = 0.7457 kW.
Brake pump power per well	8.6	hp/well			
Brake pump power per well	6.4	kW/well			
Pump motor input power per well	12.2	hp/well			Pump power requirement estimate based on modeled flow rate
Pump motor input power per well	9.1	kW/well			(Appendix E, Table E-4) and elevation head (130 feet).
Total pump motor input power	27.3	kW			
Annual electricity usage and cost					
Total motor input power	27.3	kW			
Total operating time	8,760	hr			Assume continuous operation.
Total electricity consumption	239,578	kWh			
Electricity unit cost	$ 0.05	$/kWh			Cost of electricity based on estimate provided by Kaiser.
Total annual electricity cost	$ 11,979	$/yr			
Labor					
Operation labor	1,440	hr	$ 75	$ 108,000	Assume 0.75 FTE.
Equipment repair/replacement					
Maintenance labor	480	hr	$ 75	$ 36,000	Assume 0.25 FTE for extraction and treatment system.
Equipment repair/replacement	1	LS	$ 22,284	$ 22,284	5% of equipment costs for extraction and treatment system.
Equipment Subtotal				**$ 58,284**	
Consumables - Coagulant, filter media, cartridge filters carbon					
Coagulant	6	tote	$ 2,500	$ 15,000	Assume 1 tote per month per treatment train. 275-gal totes of chitosan 1%, price from vendor.
Depth filtration media	5	ton	$ 14	$ 76	Cost from previous project experience. Sand filter unit holds 10,800 lb sand.
Cartridge filters - 10 µm	480	ea	$ 9.00	$ 4,320	Unit carries 40 cartridge filters (or 20 cartridge filters per vessel). Specification sheet for duplex cartridge unit from vendor. Assume 2 change-outs per month. Price per cartridge filter from vendor.
Cartridge filters - 5 µm	480	ea	$ 9.00	$ 4,320	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 2 µm	480	ea	$ 9.00	$ 4,320	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 1 µm	480	ea	$ 9.00	$ 4,320	See description for "Cartridge filters - 10 µm" above.
Cartridge filters - 0.5 µm	480	ea	$ 9.00	$ 4,320	See description for "Cartridge filters - 10 µm" above.
Carbon	10,000	lb	$ 1.35	$ 13,500	One bed replaced each year. Cost of carbon from vendor.
Shipping	10%			$ 5,018	Engineer's estimate.
Sales tax	8.7%			$ 4,365	
Consumables - Coagulant, filter media, cartridge filters carbon Subtotal				**$ 59,559**	
Consumables - Other					
Acid	34,675	gal	$ 0.98	$ 34,120	Actual acid used and addition rate required will be determined during bench- and pilot-scale testing. Assume approximately 95 gpd based on theoretical quantity of acid required to lower pH from 7.7 to 4.8 (average alkalinity of 158 mg/L). Assume 31% hydrochloric acid is used (liquid) to raise pH. Vendor cost on delivery.
Base	7,300	gal	$ 4.86	$ 35,478	Actual base used and addition rate required will be determined during bench- and pilot-scale testing. Assume approximately 20 gpd based on based on theoretical equilibrium equations to raise pH from 4.8 to 7. Assume 50% sodium hydroxide solution used to raise pH. Vendor cost on delivery.
Utilities	401,738	kWh	$ 0.05	$ 18,962	12 metering pumps (assumed 1/2 hp) and 8 conveyance pumps (30 hp).
Consumables - Other Subtotal				**$ 88,560**	
Consumables Total				**$ 148,119**	
Performance GW Sampling					
Laboratory analysis - influent and effluent	24	ea	$ 247	$ 5,928	PCBs, pH, TSS, TDS, alkalinity. Sample points include influent and effluent. Monthly sampling.
Laboratory analysis - carbon tanks	12	ea	$ 211	$ 2,532	Sample at GAC beds (upstream, interbed, downstream). Assume quarterly sampling.
Equipment/shipping	1	LS	$ 5,000	$ 5,000	Engineer's estimate.
Data management	5%	--	--	$ 673	Engineer's estimate.
Sampling Subtotal				**$ 14,133**	

Table D-13 - Hart Crowser and Analytical Rates Cost Backup

HC Kaiser Rates

Sr. Principal	$	190	
Principal	$	180	
Sr. Associate	$	160	
Associate	$	145	
Sr. Project	$	130	
Project	$	110	
Sr. Staff	$	90	
Staff	$	75	
Sr. Drafter	$	100	
Drafter	$	77	
Clerical	$	60	
Sub Markup		12%	
Communication fee		0%	
Mileage		$0.50/mi.	Fed rate (2010)
Truck Rental	$	85	+ mileage for over 50 mi./day (due to gas prices)
Safety ($ per hr.)	$	5	per field labor hour
Trip per diem	$	150	each way
Per diem	$	133	Fed rate for Spokane

Weekly Cost for HC oversight (staff)

Labor	$	3,600	5 days (9 hr) for staff level, plus safety costs
Truck	$	810	5 days truck plus travel day, plus $300 for miles over 50
Travel	$	300	
Per diem	$	665	
Subtotal	$	5,375	per week

Columbia Analytical Services and Advanced Analytical Laboratory Costs

Assume same price for water/soil.

Parameter		Cost / Analysis
NWTPH-HCID	$	55
TPH-Dx	$	60
TPH-G	$	60
PCBs - Ultra-Low Level	$	175
VOCs	$	130
PAHs (8270 SIM)	$	215
Metals (10)	$	180
Arsenic	$	26
Chromium	$	24
Manganese	$	26
Iron	$	24
Antimony	$	26
TSS	$	18
Chloride	$	18
Nitrate/Nitrite	$	24
Hardness	$	25
TDS	$	18
Alkalinity	$	18
Sulfate	$	18
Total arsenic, chromium, zinc, and phosphorous	$	50
Hexavalent chromium	$	50
Orthophosphate	$	20
Cyanide	$	40
BOD	$	45
Fecal coliform	$	35
Oil & grease	$	50

APPENDIX E
GROUNDWATER MODELING AND PCB ATTENUATION ANALYSIS

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APPENDIX E
GROUNDWATER MODELING AND PCB ATTENUATION ANALYSIS

E.1 PURPOSE AND SCOPE

This appendix documents groundwater modeling, capture zone analysis, and PCB attenuation analysis are used to evaluate groundwater containment remedial alternatives in support of the 2012 Feasibility Study (FS) for the Facility.

E.2 GROUNDWATER MODELING

For the FS, we used groundwater modeling to evaluate the hydraulic performance of the existing groundwater system and groundwater remedial alternatives involving groundwater extraction, hydraulic containment, recirculation, infiltration and reinjection of water within the aquifer beneath the Facility. The groundwater modeling was the basis for capture zone analysis and supported the evaluation of restoration time frames.

The general process of groundwater modeling completed for this FS includes the following tasks:

- Review the regional site-wide groundwater modeling developed for earlier RI/FS studies by Hart Crowser;
- Develop a local model from the regional site-wide groundwater model using telescoping mesh refinement (TMR) methods;
- Modify the local model to reflect current groundwater extraction and infiltration systems, and incorporate the latest vertical and horizontal survey datum;
- Verify the calibration of the local groundwater model using water level data collected in the spring and fall of 2008; and
- Use the local model to evaluate the hydraulic performance of various remedial alternatives evaluated in the FS.

E.2.1 Model Construction

The site-wide groundwater model was first developed in 1996 (Hart Crowser 1996). The model was updated in 2001 and 2003 (Hart Crowser 2001, 2003) to incorporate additional data and/or changes in Facility conditions (e.g., installation of additional pumping wells). The development of the site-wide groundwater flow model is documented in these three reports. The site-wide groundwater flow model was developed using the USGS MODFLOW code (McDonald and Harbaugh 1988). Figure E-1 illustrates the site-wide groundwater model grid in plan view.

For the FS, groundwater modeling was conducted using USGS MODFLOW 2000 (Harbaugh et al. 2000) an updated version of MODFLOW. Groundwater Vistas 5 (ESI 2007) was used for developing the model input files and for post processing the model output files. MODFLOW 2000 was selected primarily because of its ability to simulate wells that extend across multiple model layers (referred to as multiple node wells [MNW]) (Konikow et al. 2009).

Groundwater modeling analysis for the FS was conducted using a submodel or "local" model taken from the regional site-wide groundwater flow model. This TMR allows use of a small, detailed model in the area of interest by taking boundary conditions from a larger model that encompasses the model in the area of interest (Ward et al. 1987, Leake and Claar 1999). For this report, the terms "regional model" and "local model" are used to refer to the larger site-wide model and smaller embedded model, respectively. The local model allows the use of a finer grid, which provides for a more accurate representation of the extraction wells and infiltration galleries, while reducing the data handling, computer storage, and computation time that would be involved if a finer grid was used in the larger regional model.

E.2.1.1 Local Model Grid and Layers

Figure E-2 presents the local model grid in plan view. Figures E-3 and E-4 schematically illustrate the layout of the local grid in cross section.

The Spokane Valley Aquifer is represented by eight vertical layers. Layer 1 spans the water table. The no-flow boundary forming the bottom of Layer 8 represents the basement bedrock complex. The purpose of the multiple layers developed in the regional model is to allow for more accurate representation of the effects of pumping Facility groundwater extraction wells. The configuration of the local model layers inherited from the regional model was not modified except that an adjustment of 3 feet was added to the elevations to account for a change in the vertical datum.

The local model used a finer grid spacing than the regional model. The regional model used a grid with 106 columns, 83 rows, and 8 layers for a total of 70,384 cells. The local model uses 204 columns, 193 rows, and 8 layers for a total of

314,976 finite-difference cells. Local grid spacing ranges from 20 feet within the interior of the model to 120 feet along its margins.

The models were run under steady state conditions.

E.2.1.2 Boundary Conditions

The local model grid is bounded by a combination of constant head boundaries and no flow boundaries inherited from the regional model. No-flow or inactive cells are used to represent bedrock outcrops along the western edge of the model grid beneath the area of Mirabeau Point Park. Boundary conditions are shown in plan on Figure E-2, and in cross section on Figures E-3 and E-4.

A review of potentiometric data collected from nested wells indicates that there is no significant difference in vertical head between wells screened in different layers within the model domain. Therefore, differences in vertical head between model layers were not incorporated into the boundary conditions.

The constant head boundaries inherited from the regional model were adjusted to reflect water level conditions in spring and fall of 2008.

E.2.1.3 Spokane River

The effect of the Spokane River on groundwater flow near the Facility was simulated in both the regional and local models using the river package in MODFLOW. To do this, river nodes were specified along the track of the Spokane River in the regional model as shown on Figure E-1 and the local model shown on Figure E-2.

For the local model, the river bottom elevation, riverbed conductance, and a single constant value for river stage were specified for each river cell based on the Kaiser staff gage readings collected in April and October 2008, and spatial river-level trends used in the regional model. The river bottom elevation was assumed to be 5 feet below the October 2008 river stage. A high riverbed conductance was used so any restrictions on flow between the aquifer and river were minimized.

E.2.1.4 Baseline Pumping Wells and Infiltration Galleries

Kaiser IRM Extraction Wells. As part of an Interim Remedial Measure (IRM), Kaiser has installed various extraction wells at the Facility (e.g., WW-EW-1, WW-EW-2, OH-EW-1, WW-UVB-1). The wells are treated as extraction wells pumping from multiple layers. The pumping rates between model layers are allocated by the MNW package in MODFLOW-2000. Flow through the well bore of an MNW is distributed dynamically based on transmissivity and hydraulic head differences between the respective model layers. Drawdown constraints are specified, which are set to the top of screen for each well withdrawal if the hydraulic head drops to the top of the screen. Because of the high transmissivity of the aquifer, most of the pumping from each well is allocated by the model to the top layer that the well is assigned to. Historical pumping wells and associated pumping rates are presented in Table E-1.

Kaiser Water Supply Wells. Potable water is currently supplied to Kaiser from the North Water Supply Well. In the model, the North Water Supply Well is assigned a constant pumping rate of 0.26 million gallons per day (MGD).

Off-Site Wells. No off-site pumping wells are located within the local model domain.

Infiltration Galleries. A series of infiltration galleries are used to infiltrate groundwater extracted from WW-UVB-1. These infiltration galleries are designated WW-UVB-1-HSS, WW-UVB-1-HSM, and WW-UVB-1-HSN. The infiltration galleries are simulated by defining a series of injection wells in cells along the alignment of the galleries. The infiltration volume is divided equally among the injections wells. The total volume of infiltration groundwater is equal to the total volume of groundwater extracted from WW-UVB-1 in 2008, which for modeling purposes is about 3.35 MGD.

E2.2 Calibration and Verification

Calibration is defined by the ASTM as "the process of refining the model representation of the hydrogeologic framework, hydraulic properties, and boundary conditions to achieve a desired degree of correspondence between the model simulations and observations of the groundwater flow system" (ASTM 1993). Calibration of a flow model is a demonstration that the model is capable of reproducing measured heads and flows. Calibration is accomplished by finding a set of parameters and boundary conditions that produce simulated heads and fluxes that match field-measured values within an acceptable range of error. The regional model was calibrated using a time-drawdown data from pumping tests data from wells TF-EW-1, OH-EW-2, and WW-EW-1. The development, calibration, and verification of the regional model are documented in the 2003 RI/FS (Hart Crowser 2003).

Verification is a process in which the calculated heads are compared to observed head values collected from a period of time different from the observations used in calibration. The process of verification is very similar to the calibration process except that changes to the model are limited to those parameters that can be expected to change with time. The verification process also provides a measure of the model's ability to simulate differing hydrologic conditions. The regional model calibration was verified using an 18-month (Feb 1994-Sept 1995) transient simulation of monthly water level data from 10 wells. The verification procedure indicated that the calibrated model adequately represents groundwater flow conditions at Facility (Hart Crowser 2003).

E.2.2.1 Local Model Verification

Procedure. Verification of the local model under steady state conditions was achieved using groundwater level data collected in April and October 2008. During the verification process, model layers, hydraulic conductivity, and recharge were not changed from those values established during calibration of the regional model. The pumping rates of extraction wells active during the verification period were assigned the average 2008 pumping rates and were not changed during the verification process. Note that extraction wells WW-EW-2 and the WW-UVB-1 extraction and injection systems were not operational when the regional model was calibrated. The river stage and constant head conditions were adjusted during the verification to reflect seasonal changes in the hydrologic system. The head values observed in April 2008 were consistently higher, in the range of 4 to 5 feet, than heads observed in October. Adjustments were made to the constant head boundary values to reasonably reflect the overall higher groundwater elevations.

Model verification is based on target head values from groundwater levels measured in monitoring wells within the model grid. A target is defined as a field-measured value that is used to compare with model-computed values. The target heads were derived from manual water level measurements taken from a wide variety of monitoring, skimming, and pumping wells. No attempt was made to exclude water levels from wells that are suspected to have potential errors because of inconsistent survey datum (e.g., WW-MW-017 and WW-SKI-1). Table E-2 provides a list of the wells included as verification targets.

The verification results are considered successful if a reasonable match between the calculated head values and the observed target head values are achieved based on residual statistics. Large differences in observed and model-predicted heads were noted in several wells, which could not be accommodated without significantly modifying the aquifer properties. No attempt was made in developing the local model to change model layers, hydraulic conductivity, and recharge. The differences between the observed and model-predicted heads can also be caused by local variations such as recharge (e.g., leaking sewers), aquifer parameters (e.g., subsurface high permeability channels or low permeability silt lenses), proximity to pumping wells (e.g., local variations caused by a cone of depression and/or rapid changes in gradient), or errors in head (e.g., measurement error and/or inconsistent survey datum).

The residual is the difference between the observed value of head in a monitoring well and the calculated value of head from the model cell containing the monitoring well. According to the sign convention established in Groundwater Vistas, a residual is considered positive when the calculated value of head is less than the observed head value. Several simple statistical measures were used to evaluate the residuals, including mean, absolute mean, standard deviation, and sum of squared residuals.

While there are no absolute measures for verification of a groundwater model, the author of Groundwater Vistas has suggested that a good calibration of the model is achieved when the ratio for the residual standard deviation to the total change in head is less than 10 percent; and the residual standard deviation is ± 5 percent of the range in head (ESI 2007).

Verification Results. The model statistics for the April and October 2008 verification simulations are presented in Table E-2. The head residual for both the April and October 2008 simulations had a mean value of less than 1.50 feet. The residual mean standard deviation was less than 1.00, and the ratio of standard deviation to total head change of about 5 percent (Table E-2). In general the model tends to predict lower heads than the corresponding field measurements. The maximum difference between the calculated and observed heads for the April and October 2008 simulations was only 3.58 and 3.84 feet, respectively. Also, the corresponding range of observations was less than 18 feet within the modeled area. The residual statistics indicate a good calibration of the local model has been achieved.

The verification analysis using 2008 water levels indicates that the initial model calibration is very robust for use in reproducing groundwater conditions many years after the regional model was first calibrated. Based on the local model ability to represent groundwater level data collected in 2008, the local model is considered to be a reliable tool for use in evaluating groundwater remedies at the Facility.

E.3 CAPTURE ZONE ANALYSIS

Hydraulic containment is one of the primary objectives of groundwater extraction at the Facility. Capture zone analysis was performed to determine the effectiveness of the current IRM for hydraulic containment at the Facility and to evaluate various groundwater containment remedial alternatives evaluated as part of the FS.

Capture zone refers to the three-dimensional region that contributes the groundwater extracted by one or more wells or drains. A capture zone in this context is equivalent to the "zone of hydraulic containment." If a contaminant plume is hydraulically contained, contaminants moving with the groundwater will not spread beyond the capture zone.

Capture zone analysis was performed using the following procedure.

Step 1. Review site geology and hydrogeology data, site conceptual model, and remedy objectives.

Step 2. Define target capture zone based on containment-specific, 3-dimensional (3-D) plume dimensions.

Step 3. Define pumping rates to achieve hydraulic containment using site-specific groundwater flow model in combination with particle tracking.

Six petroleum plumes and one PCB plume were identified that will potentially require hydraulic containment. These plumes are located in the following areas of the site:

- Oil House Area North Plume;
- Oil House Area South Plume;
- Wastewater Treatment Area North Plume;
- Wastewater Treatment Area South Plume;
- Cold Mill Area Plume;
- Oil Reclamation Building (ORB) Area Plume; and
- Remelt/Hot Line PCB Plume

The footprint of each plume is based on the extent of contamination, shown on Figures 4-1 through 4-3. The local model was used to evaluate the capture zone of the existing IRM and to estimate the pumping rates required to hydraulically contain the contaminant plumes for various remedial alternatives.

Particle tracking was used to evaluate the capture zone created by the existing IRM and hypothetical extraction wells. Particle tracking was performed using a version of MODPATH 3.0 provided with Groundwater Vistas. Particle tracking helps to visualize the groundwater flow field, evaluate capture zones, and to track contaminant flow paths. The following general procedures were used for particle tracking analysis. One particle was assigned to each model cell in the defined capture zone. Particles were placed at the midpoint of each layer. For all MODPATH simulations, particles were specified to stop as they enter a weak sink cell.

Particle tracking was conducted using two methods. The first method used a forward tracking approach. At the beginning of the simulation, clouds of particles corresponding to the footprint of each plume requiring capture were released and allowed to migrate toward the extraction wells. One particle was assigned to each model cell within the footprint of the contaminant plume. Particles were placed at the midpoint of each layer and were specified to stop as they enter the cell containing an extraction well or boundary cell. Forward particle tracking is the preferred method of determining hydraulic containment of the footprint of a plume. Containment was considered successful if at least 98 percent of the particles defining the capture zone were captured by a well.

The second method used a reverse tracking approach. At the beginning of the simulation, particles are introduced into a well and are tracked backward along flow path lines to their source or point of origin. Reverse particle tracking is the preferred method for determining the capture zone for an individual well. The number of particles introduced into an individual well varied from 20 to 40. A larger number of particles were used (e.g., WW-EW-1) when necessary to enhance the definition of the capture zone around the upgradient side of a well.

E.4 REMEDIAL ALTERNATIVE SCENARIO EVALUATIONS

The local model was used to quantitatively assess hydraulic containment and capture zones under various scenarios of well placement and operation. Details of each model scenario are summarized in Table E-3.

E.4.1 Petroleum Hydrocarbon Model Scenarios

Scenario 1— Alternative C1: Existing IRM

Scenario 1 represents the baseline IRM featuring extraction from the four operating groundwater extraction wells WW-EW-1, WW-EW-2, WW-UVB-1, and OH-EW-1, currently operating at the Facility. These wells pump groundwater from deep in the aquifer and do not contain detectable contamination such as that detected in the shallow portion of the aquifer. Scenario 1 is equal to FS Alternative C1. The extraction rates assigned to the extraction wells are based on the 2008 values presented in Table E-3. Groundwater from extraction wells WW-EW-1, WW-EW-2 and OH-EW-1 is either used on site as process water or discharged to the Wastewater Treatment area outfall without treatment prior to discharge to the Spokane River. Groundwater from WW-UVB-1 is discharged to the horizontal infiltration galleries WW-UVB-1-HSN, WW-UVB-1-HSM, and WW-UVB-1-HSS in the Wastewater Treatment area. The UVB horizontal infiltration galleries were treated as a series of injections wells. Figure E-5 shows the layout of the extraction wells and horizontal infiltration galleries defined for the baseline Scenario 1.

The modeled extent of the hydraulic containment defined by reverse particle tracking provided by the baseline IRM is shown on Figure E-5. Figure E-6 demonstrates the containment of petroleum hydrocarbons plumes by forward particle tracking. The capture zone of the baseline IRM provides hydraulic containment for the Oil House, Cold Mill, and Wastewater Treatment areas petroleum hydrocarbon plumes but not the ORB petroleum hydrocarbon plume.

Scenario 2— Alternative C2 Scenario C2a Expanded IRM (WW-EW-3)

Scenario 2 is FS Alternative C2 Scenario C2a. This scenario features the baseline IRM groundwater extraction wells, infiltration galleries for WW-UVB-1, plus pumping from extraction well WW-EW-3. In addition to the four wells included in Scenario 1, WW-EW-3 extracts groundwater at a rate of 1.5 MGD (Table E-3). Under this alternative, oxygenated water from WW-UVB-1 and WW-EW-3 are discharged to vertical and horizontal screens in the Wastewater Treatment area. The water from WW-EW-3 is discharged to infiltration galleries WW-EW-3-HS. Figure E-7 shows the well and horizontal screen layout used for this scenario.

The capture zone of the expanded IRM defined by reverse particle tracking under Scenario 2 is shown on Figure E-7. Figure E-8 shows the containment of petroleum hydrocarbons plumes by forward particle tracking. The capture zone of the expanded IRM provides containment for the Oil House, Cold Mill, and Wastewater Treatment areas petroleum hydrocarbon plumes as well as ORB area plume.

Scenario 3— Alternative C2 Scenario C2b Baseline IRM with ORB Containment

This scenario features the baseline IRM groundwater extraction wells, infiltration galleries, and pumping from hypothetical wells to provide hydraulic containment for the ORB petroleum plume. Scenario 3 is equal to FS Alternative C2 Scenario C2b. In addition to the four wells included in baseline Scenario 1, an extraction well ORB-FEW-1 was added to provide hydraulic containment of the ORB petroleum plume. The pumping rate for ORB-FEW-1 was adjusted until the capture zone incorporated the lateral extent of the ORB petroleum hydrocarbon plume. ORB-FEW-1 was assigned a final rate pumping rate of 0.6 MGD. Under this scenario, oxygenated water from WW-UVB-1 is discharged to vertical and horizontal screens in the Wastewater Treatment area and the water from ORB-FEW-1 is pumped to the Wastewater Lagoon prior to discharge to the Spokane River. Figure E-9 shows the well and horizontal screen layout used for this scenario.

The capture zone of the Scenario 3 system defined by reverse particle tracking is shown on Figure E-9. Figure E-10 demonstrates the containment of petroleum hydrocarbons plumes by forward particle tracking. The capture zone of the Scenario 3 system provides containment for the Oil House, Cold Mill, Wastewater Treatment, and ORB areas petroleum hydrocarbon plumes.

Scenario 4— Alternative C2 Scenario C2c Plume Specific Containment

Scenario 4 is FS Alternative C2 Scenario C2c. Scenario 4 evaluates the pumping requirements to provide plume-specific containment without operation of the baseline IRM groundwater extraction wells. Forward particle tracking was used to evaluate hydraulic containment under Scenario 4. Initially, one extraction well was placed at the downgradient edge of each petroleum plume. Additional wells were added to provide containment and minimize pumping rates. The pumping rates were adjusted until the particles used to define the plume were captured by extraction well(s). One extraction well was sufficient to hydraulically contain the four smaller plumes (ORB, Cold Mill, Oil House South, and Wastewater Treatment South) and three wells were necessary to contain the larger Oil House North and Wastewater Treatment North plumes. The pumping rates to achieve hydraulic containment for each of the plumes are summarized in Table E-3. Under this scenario, extracted water is treated before disposal into the Spokane River or some other off-site location. Figure E-11 shows the well layout used for Scenario 4 and illustrates the containment of the petroleum hydrocarbon plumes using forward particle tracking.

Scenario 5— Alternative C4 Baseline IRM with Plume Pump and Treat

Scenario 5 includes the baseline IRM groundwater extraction wells and pumping from hypothetical wells to provide enhanced groundwater treatment of the petroleum hydrocarbon plumes. Scenario 5 is Alternative C4. One additional extraction well was placed in the center of the six plumes. The extraction rates for the hypothetical Scenario 5 wells were set at the flow rate of groundwater passing through each plume. The basis for estimates of groundwater flow for each plume is presented in Table E-4. The IRM and Scenario 5 extraction well rates are summarized in Table E-3. Under this alternative, groundwater extracted from the new pump and treat wells is treated before being discharged into the Spokane River or some other off-site location. Figure E-12 shows the well and infiltration gallery layout used for Scenario 5 and also demonstrates the containment of the petroleum hydrocarbon plumes using forward particle tracking methods.

E.4.2 PCB Model Scenarios

Five model scenarios were evaluated for containment of the Remelt/Hot Line PCB plume. To demonstrate containment of the Remelt/Hot Line PCB plume groundwater particles were assigned to cells corresponding to the plume footprint in Layers 2, 3, and 4. Water from the new PCB plume containment wells was infiltrated into a horizontal gallery upgradient of the Oil House area. Infiltration was simulated by assigning recharge values to model cells in Layer 1 equal to the amount of water from the extraction wells.

Baseline – Alternative D1

The baseline conditions representing the baseline IRM was evaluated as Scenario 1. Scenario 1 does not provide containment for the Remelt/Hot Line PCB plume (see Figures E-5 and E-6).

Scenario 6— Alternative D2a Leading Edge of the PCB Containment

Scenario 6 represents the baseline IRM provided in Scenario 1 and containment at the leading edge of the Remelt/Hot Line PCB plume. One hypothetical pumping well PCB-FEW-1 was located at the leading edge of the PCB plume and assigned to Model Layer 2. Scenario 6 is FS Alternative D2a. The pumping rate for PCB-FEW-1 was adjusted until the capture zone incorporated the lateral and vertical footprint (Model Layers 1 through 4) of the Remelt/Hot Line PCB plume. PCB-FEW-1 was assigned a final rate pumping rate of 3.76 MGD. Water from PCB-FEW-1 is infiltrated in a horizontal gallery upgradient of the Oil House area specified as 10 recharge cells in Layer 1. The recharge rate to simulate infiltration of water from the PCB extraction wells is 84.48 inches per day. Figure E-13 shows the layout of the extraction wells and horizontal infiltration galleries defined for Scenario 6. Baseline pumping rates are presented in Table E-4.

Figure E-13 demonstrates the complete containment of Remelt/Hot Line PCB plume under Scenario 6 by forward particle tracking.

Scenario 7— Alternative D2b - Containment of the PCB Plume.

This scenario features the baseline IRM groundwater extraction wells, infiltration galleries, and pumping from three hypothetical wells (PCB-FEW-2, PCB-FEW-3 and PCB-FEW-4) assigned to Model Layer 2 to provide hydraulic containment of the Remelt/Hot Line PCB plume. Scenario 7 is essentially equivalent to FS Alternative D2b. The pumping wells were located at the leading edge of the deeper portion of the PCB plume, which is located historically between deep wells HL-MW-24DD (<5 ng/L) and HL-MW-28DD (20 ng/L). The pumping rates for PCB wells were adjusted until the capture zone incorporated the lateral and vertical (Model Layers 1 through 4) extent of the Remelt/Hot Line PCB plume. The total extraction rate is 3.03 MGD. Under this scenario, water from PCB extraction wells is discharged to horizontal infiltration galleries upgradient of the Oil House area specified as 10 recharge cells in Layer 1. The recharge rate to simulate infiltration from the PCB extraction wells is 69.29 inches per day. Figure E-14 shows the well and horizontal screen layout used for this scenario.

Figure E-14 demonstrates containment of Remelt/Hot Line PCB plume under Scenario 7 by forward particle tracking. The capture zone of the Scenario 7 system provides containment for the Remelt/Hot Line PCB plume east of the PCB extraction wells.

Scenario 8— Alternative D3 PCB Containment with Treatment, and Reinjection Upgradient of the Remelt Building

Scenario 8 is the same as Scenario 7 except that extracted PCB containment water is infiltrated into the ground in an area upgradient of the Remelt building.

Under this scenario, water from PCB extraction wells are discharged to horizontal infiltration galleries upgradient of the Remelt building specified as five recharge cells in Layer 1. The recharge rate to simulate infiltration from the PCB extraction wells is 139.66 inches per day. Figure E-15 shows the well and horizontal screen layout used for this scenario.

Figure E-15 demonstrates containment of Remelt/Hot Line PCB plume under Scenario 7 by forward particle tracking. The capture zone of the Scenario 7 system provides containment for the Remelt/Hot Line PCB plume east of the PCB extraction wells.

Scenario 9 - Alternative D4 Baseline IRM with Partial Source Removal

This scenario features the baseline IRM groundwater extraction wells, infiltration galleries, and pumping from a hypothetical well (PCB-FEW-6) assigned to Model Layer 2 located near the source area to provide partial contaminant mass removal of PCBs. Scenario 9 is FS Alternative D4. The pumping well is located close to the source area but outside the Remelt building. The total extraction rate is 300,000 gpd. Under this scenario, water from PCB extraction wells are discharged to horizontal infiltration galleries upgradient of the Remelt building specified as five recharge cells in Layer 1. The recharge rate to simulate infiltration from the PCB extraction well is 13.79 inches per day.

Figure E-16 shows the well and horizontal screen layout used for Scenario 9. Table E-4 summarizes the pumping and infiltration rates under Scenario 9.

Figure E-16 presents the area of containment of Remelt PCB plumes by reverse particle tracking. The capture zone of the Scenario 9 system provides partial containment for the Remelt/Hot Line PCB plume.

Scenario 10 - Preferred Alternative D2b Baseline IRM with PCB Containment and Infiltration

Figure E-17 shows the well and horizontal screen layout used for the Preferred Alternative which is essentially equal to Scenario 7 (Alternative D2b). Table E-4 summarizes the pumping and infiltration rates under Scenario 7. Figure E-17 also presents the area of containment of the Preferred Alternative by reverse particle tracking.

E.5 GROUNDWATER FLUX AND FLUSH RATES

Groundwater flux rates through the petroleum hydrocarbon and PCB plumes were calculated for existing (baseline) conditions and for each of the remedial alternatives using a particle tracking approach using MODPATH simulations of the various scenarios. MODPATH is program that takes the output of groundwater flow distribution generated by MODFLOW to calculate the groundwater velocity distribution throughout the groundwater system, which then is used to determine flow paths or pathlines of particles. The pathlines of these particles that can be used to visualize groundwater flow system and calculate groundwater travel times.

The baseline groundwater flux conditions were calculated from average hydraulic conductivity of 3,000 ft/day, gradients from 2008 groundwater contour maps, and dimensions of the plumes as observed in isoconcentration maps from data collected through 2010. Baseline groundwater volume and flux calculations for each of the petroleum hydrocarbon and PCB plumes are presented in Table E-5.

The change in groundwater flux generated by the various model scenario simulations was evaluated using particle tracking methods. The faster a modeled particle moves through the plume the greater the groundwater flux. It was assumed that particle travel time through a plume is inversely proportional to change in groundwater flux. Varying the volume of groundwater extraction and to a lesser extent the number and location of extraction wells can influence the particle travel time. For example, increasing the volume of groundwater extraction will decrease the particle travel time. Adding extraction wells can also decrease the travel time by increasing the groundwater flux through a plume. By measuring the changes in particle travel times the average change in groundwater flux generated by the various scenarios can be compared.

To evaluate the change in groundwater flux created by the various scenarios, the change in particle travel times were compared to baseline groundwater travel times though each plume. For example, under baseline conditions the longest travel time it takes a particle to travel through the Oil House area North plume is 20 days. For Scenario 4 groundwater travel time through the same plume is just 9 days. Assuming that the decrease in travel time is inversely proportional to groundwater flux rate, the effective groundwater flux through the Oil House area North plume is increased by 122 percent compared to baseline under Scenario 4.

Particle travel times were measured during a combination of reverse and forward tracking methods. For the forward tracking, a line of particles was placed on the upgradient side of the plume. The time it took the particles to either be captured by a pumping well or pass completely through the plume was recorded. Reverse tracking, where particles are place in the pumping well and the flow is reversed, was also used to record travel times. Results of the two methods were used to determine the travel times through the plumes. The travel times through the plumes using particle tracking is presented in Table E-6.

E.6 RESTORATION TIME FRAME – REMELT/HOT LINE PCB PLUME

The time required to meet the groundwater cleanup goals for the Remelt/Hot Line PCB plume was estimated using a mass balance approach to model the mass transfer from smear zone soil to groundwater. The method is discussed below.

Colloidal transport of PCBs in the Remelt/Hot Line PCB plume is suspected (Hart Crowser 2012). However, the effect of colloidal particles on the mass transfer of PCBs is not well understood. For the purposes of this FS, the sole mechanism for reducing the mass of PCBs in smear zone soil is assumed to be through leaching of PCBs from smear zone soil into groundwater. The time required to meet the groundwater preliminary cleanup levels (PCULs) for PCBs in the Remelt/Hot Line plume (Section 5) was estimated by analyzing the relationship between the contaminant concentration in smear zone soil and the contaminant concentration in groundwater. The analysis was completed under the following assumptions:

- The equilibrium relationship between soil and groundwater contaminant concentrations is linear;
- Equilibrium between the sorbed and aqueous phases is attained virtually instantaneously;
- There are no continuing sources of mobile contamination, such as residual oil, in the unsaturated zone, and that the contaminant mass in smear zone soil acts as the sole source of contaminants that could leach into groundwater;
- Based on the high water content of the saturated zone and the low vapor pressure of the contaminant, the contaminant concentration in the gaseous phase is negligible;
- The PCB mass in the smear zone is 100 percent leachable; and
- Restoration of groundwater is complete once the concentration of PCBs in smear zone soil are below the calculated concentration judged to be protective of groundwater and/or surface water (although groundwater will ultimately be considered to meet CULs once it is empirically demonstrated to do so).

These assumptions result in an estimated optimistic restoration time frame. Longer time frames would result if the following were considered, such as the amount of time that is actually required for contaminant in smear zone soil and groundwater to reach equilibrium.

Additionally, as the water table fluctuates through the smear zone, the contaminants at the top of the smear zone are in contact with groundwater for a very short time and may continue to act as an ongoing source long after the majority of the contaminant mass that is in contact with groundwater has been removed.

The equilibrium groundwater contaminant concentration is related to soil contaminant concentration on a macroscopic scale by a soil/water partitioning coefficient (in L/kg) (K_d), assuming a linear relationship between groundwater (C_w) and soil contaminant concentration (C_s) according to the following equation:

$$C_s = K_d \cdot C_w \quad (5)$$

The dynamics of the groundwater and smear zone soil system were analyzed using a mass balance approach, in which the rate of mass entering the system is defined as being equal to the rate of mass leaving the system plus accumulation of mass in the system.

$$input = output + accumlation \quad (6)$$

Substituting parameters specific to the groundwater and smear zone soil system results in the following differential equation:

$$Q \cdot C_{w1} = Q \cdot C_{w2} + \frac{dm_s}{dt} \quad (7)$$

where:

Q is the volumetric groundwater flow rate through the system (L/day);
C_{w1} is the groundwater contaminant concentration entering the system (ng/L);
C_{w2} is the groundwater contaminant concentration leaving the system (ng/L); and
dm_s/dt is the differential change in contaminant mass in the system per time (ng/day).

Volumetric flow rate is defined in units of volume per time. Groundwater concentration is defined as contaminant mass per unit volume of groundwater. The contaminant concentration entering the system is assumed to be zero, and, therefore, the equation reduces to the following differential equation:

$$\frac{dm_s}{dt} = -Q \cdot C_{w2} \quad (8)$$

Thus, the rate of change of contaminant mass in the system is equal to the concentration of contaminant leaving the system (for example, through groundwater extraction or biological degradation) multiplied by the groundwater flow rate through the system.

The mass of contaminant in the system is defined as residing in the sorbed phase in smear zone soil. For contaminant mass to leave the system, contaminant mass must transfer from the sorbed phase into the groundwater that flows through the system. This evaluation assumes that this transfer occurs virtually instantaneously and is defined on a macroscopic scale by the soil/water partitioning relationship defined in equation (5). This is accounted for by substituting equation (5) into equation (9) for C_{w2}, which results in equation (9):

$$\frac{dm_s}{dt} = -Q \cdot \frac{C_s}{K_d} \qquad (9)$$

The units of contaminant concentration in soil (C_s) are defined as mass of contaminant (m_s) per unit mass of soil (M). Substituting this definition into equation (9) gives:

$$\frac{dm_s}{dt} = -Q \cdot \frac{m_s}{K_d M} \qquad (10)$$

where:

M is the mass of the soil (kg).

Solving equation (10) results in the following first-order decay relationship:

$$m(t) = m_0 \cdot e^{\frac{-Q}{K_d M} t} \qquad (11)$$

where:

m(t) is the contaminant mass at time t (grams); and
m_0 is the initial contaminant mass in the system (grams).

The change in contaminant mass over time in the groundwater and smear zone soil system is described as a first-order decay process, where the mass decreases at a rate proportional to its value at time t (i.e., the lower the mass, the slower the mass removal rate), as shown in equation (10) above.

Equation (11) can be rearranged to solve for the restoration time frame:

$$t = \frac{-K_d M}{Q} \ln\left(\frac{m(t)}{m_o}\right) \qquad (12)$$

where:

t is the restoration time frame (days); and
m(t) is the mass in smear zone soil that is protective of groundwater.

The relationship shown in equation (12) is used to estimate the restoration time frames for the COCs discussed in Section 5 of this FS. Results of these estimates are presented in Table 2 of the PCB Restoration Time Frame Memorandum in Appendix I.

E.7 PCB GROUNDWATER ATTENUATION FACTOR

The Remelt/Hot Line PCB plume extends to the west southwest from one or more sources areas in the Remelt area. PCB concentrations show a steady decline from a high of 2,000 ng/L to less than 5 ng/L within 500 feet of the Spokane River. The cause of this steady decline in PCB concentrations is not known but is presumed to be caused by processes such as colloidal transport, biodegradation, sorption, and dispersion. To predict the PCBs concentration at the Spokane River from the Remelt/Hot Line PCB plume and to support the development of remedial alternatives, the historical attenuation of PCB in the plume was modeled using regression analysis. This approach assumes that attenuation processes act equally and predictably along the entire length of the plume.

Regression models are statistical models that describe the variation in one variable (in this case PCBs) when another variable (distance) varies. A plot of the average concentration of total PCBs from indicator wells along the centerline of the plume is shown on Figure E-18. Indicator wells located along the centerline of the plume are considered to be representative of trends in PCB within the Remelt/Hot Line PCB plume. The wells are:

- RM-MW-17S represents source area concentrations;
- HL-MW-29S is located a distance of 450 feet from the source;
- HL-MW-14S is located a distance of 950 feet from the source;
- HL-MW-30S is located a distance of 1,450 feet from the source; and
- HL-MW-32S is located a distance of 1,810 feet from the source.

Historical PCB concentrations from the wells along the centerline of the Remelt/Hot Line PCB plume are presented in Table E-7. For reference the eastern bank of the Spokane River is located approximately 2,300 feet from the source (RM-MW-17S).

Regression analysis was conducted on mean PCB data from the indicator wells along the Remelt/Hot Line plume alignment. A variety of curves were fitted to the data including linear, log, power, polynomial (3-order), and exponential (Figure E-19). The regression analysis was completed using the programs EXCEL and CurveExpert.

The sample correlation coefficient (r) values for the various curves presented in Table E-8 ranged from 0.8361 to 0.9987.

Table E-8 - Results of Regression Analysis

Curve Type	Correlation Coefficient (r)	Coefficient of Determination (R2)	Standard Error (S)
Logarithm	0.9987	0.9974	51
Exponential	0.9968	0.9936	82
Polynomial (3-order)	0.9984	0.9968	100
Geometric	0.9951	0.9902	101
Power	0.9867	0.9736	166
Linear	0.8361	0.6991	563

The decline in PCB concentrations along the plume alignment is best represented by an exponential curve (Figure E-20). Although the logarithm and polynomial curves have higher r values than the exponential curve fit, the Type 1 error analysis shows that difference in r values between the logarithm, polynomial and exponential curve matches are not significant. The logarithm and polynomial curve fit equations were not selected because extrapolated concentrations can be negative, which is impossible in nature. Predicated PCB concentrations using the exponential curve fitted equation are unlikely to be negative.

The exponential regression is represented by the following equation:

$$y = b\ \exp^{(mx)}$$

Where

y is the concentration;

x is the distance from source;

b is the PCB concentration in the source area (y intercept); and

m is the slope of the line.

Exponential regression curves were generated to the following PCB datasets (Table E-8).

- Mean total PCB concentrations;

- April 2010 total PCB concentrations; and

- October 2010 total PCB concentration.

The best fit exponential regression equations are presented below

- Mean total PCBs

$$y = 2158.37exp^{-0.00298345x} \quad (13)$$

- April 2010 PCBs

$$y = 1994.7exp^{-0.0031x} \quad (14)$$

- October 2010 PCBs

$$y = 1153.5exp^{-0.0025x} \quad (15)$$

Plots of the best fit exponential regression curves are shown on Figure E-19.

Using the exponential regression equations, the predicted concentrations as a function of distance from the source area are shown in Table E-9. Based on extrapolation of the regression curves, the total PCB concentration in groundwater at the shoreline of the Spokane River is predicted to be between 2 to 3 ng/L (Table E-9). Predications from regression equations are most reliable for data interpolated within the range of the data. Predications of PCB concentrations extrapolated downgradient of HL-MW-32A must be used with some caution since predications outside the range of the regression data are less certain than predications made within the range of data.

Using the regression equation based on the mean total PCB concentration predications were made for a combination of starting concentrations, distances from the river, and PCB concentrations at the Spokane River. These include the following:

- The PCB source concentrations at RM-MW-17S (approximately 2,300 feet from the river), which does not exceed at concentrations of 0.0064 ng/L at the river. This concentration is predicted to be 60 ng/L (Table E-9).

- The starting PCB concentrations at two injection trenches (located approximately 2,870 and 3,250 feet from the river), which does not exceed the 0.0064 ng/L at the river. These concentrations are predicted to be 325 and 1,035 ng/L, respectively (Table E-10).

E.8 REFERENCES FOR APPENDIX E

American Society for Testing and Materials (ASTM), 1993. Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information, D 5490-93. West Conshochoken, Pennsylvania.

Bolke, E.L., and J.J. Vaccaro, 1981. Digital-Model Simulation of the Hydrologic Flow System, With Emphasis on Ground Water, In the Spokane Valley, Washington and Idaho, USGS Open-File Report 80-1300.

Brusseau, M., 1996. Evaluation of Simple Methods of Estimating Contaminant Removal by Flushing Groundwater. Ground Water 34:19-22.

Environmental Simulations, Inc. (ESI), 2007. Guide to Using Groundwater Vistas. Version 5. ESI, Herndon, Virginia.

EPA, 1988c. Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites. Environmental Protection Agency, Office of Solid Waste and Emergency Response.

EPA, 1996j. Soil Screening Guidance: Technical Background Document. EPA/540/R95/128.

EPA, 2010. EPA Regional Screening Level Tables.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000. MODFLOW-2000, the U.S. Geological Survey modular ground-water model – User guide to modularization concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92, 121 p.

Hart Crowser, 1996c. Draft Groundwater Remedial Investigation/Feasibility Study, Kaiser Trentwood Facility, Spokane, Washington, J-2644-58. September 1996.

Hart Crowser, 2001. Draft Groundwater Remedial Investigation/Feasibility Study, Kaiser Trentwood Facility, Spokane, Washington, 2644-73. July 12, 2001.

Hart Crowser, 2003. Draft Groundwater Remedial Investigation/Feasibility Study, Kaiser Trentwood Facility, Spokane, Washington, J-2644-76. Modified July 2003.

Hart Crowser, 2012. Final Site-Wide Groundwater Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Hill, M.C., 1998. Methods and Guidelines for Effective Model Calibration. United States Geological Survey Water-Resources Investigation Report 98-4005.

Konikow, L.F., Hornberger, G.Z., Halford, K.J., and Hanson, R.T., 2009. Revised multi-node well (MNW2) package for MODFLOW ground-water flow model: U.S. Geological Survey Techniques and Methods 6–A30, p. 67.

Leake, S.A., and Claar, D.V., 1999. Procedures and computer programs for telescopic mesh refinement using MODFLOW: U.S. Geological Survey Open-File Report 99-238, p. 53.

McDonald, M.G., and A.W. Harbaugh, 1988. *MODFLOW, A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model,* United States Geological Survey, Open-File Report 83-875.

National Research Council, 1994. Alternatives for Ground Water Cleanup. Washington D.C.: National Academy Press p. 315

Pankow, J.F., and J.A. Cherry, 1996. Dense Chlorinated Solvents and other DNAPLs in Groundwater. Portland, Oregon: Waterloo Press. p. 522.

Pollock, D.W., 1989. Documentation of Computer Programs to Compute and Display Pathlines Using Results from the U.S. Geological Survey Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, U.S.G.S. Open File Report 89-381.

Pollock, D.W., 1994. 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. United States Geological Survey, Reston, Virginia. September 1994.

Ward, D.S., Buss, D.R., Mercer, J.W., and Hughes, S.S., 1987. Evaluation of a groundwater corrective action at the Chem-Dyne hazardous waste site using a telescope mesh refinement modeling approach: Water Resources Research, v. 23, no. 4, p. 603–617.

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Table E-1 - Historical Groundwater Extraction Pumping Rates

Year	OH-EW-01		WW-EW-01		WW-EW-02		WW-EW-03		WW-UVB-01		North Supply Well	
	MGD	ft^3/d	MGD	ft^3/d	MGD	ft^3/d	MGD	ft^3/d	MGD	ft^3/d	MGD	ft^3/d
2002	1.27	169,786	5.03	672,460	5.06	676,471	2.38	318,182	2.49	332,888	0.26	34,759
2003	1.17	156,417	3.57	477,273	5.76	770,053	1.48	197,861	0.66	88,235	0.26	34,759
2004	1.26	168,449	4.17	557,487	7.62	1,018,717	0.00	0	0	0	0.26	34,759
2005	1.13	151,070	3.19	426,471	5.10	681,818	0.00	0	0	0	0.26	34,759
2006	1.27	169,786	4.42	590,909	4.14	553,476	1.56	208,556	0.00	0	0.26	34,759
2007	1.29	172,460	2.31	308,824	6.40	855,615	1.10	147,059	1.67	223,262	0.26	34,759
2008	1.28	171,123	4.42	590,909	7.32	978,610	1.17	156,417	3.35	447,861	0.26	34,759

Notes:

Pumping rates are average annual rates in million gallons per day (MGD).

WW-EW-03 was shut down in the summer of 2008.

Table E-2 - Summary of Verification Statistics

		Apr-08			Oct-08		
Name	Layer	Observed	Computed	Residual	Observed	Computed	Residual
CM-MW-01S	1	1940.24	1939.10	1.14	1936.50	1935.11	1.39
CM-MW-02S	1	1940.13	1939.05	1.08	1936.40	1935.06	1.34
CM-MW-03S	1	1940.12	1939.13	0.99	1936.40	1935.14	1.26
CM-MW-04S	1	1938.61	1937.52	1.09	1934.74	1933.53	1.21
CM-MW-05S	1	1938.65	1937.59	1.06	1934.77	1933.60	1.17
CM-MW-06S	1	1938.91	1937.72	1.19	1934.99	1933.73	1.26
CM-MW-07S	1	1940.34	1939.34	1.00	1936.69	1935.36	1.33
CM-MW-08S	1				1936.79	1935.56	1.23
FO-MW-01S	1	1934.13	1932.96	1.17	1929.90	1928.94	0.96
HL-MW-01	1	1934.55	1933.48	1.07	1930.28	1929.46	0.82
HL-MW-02	1	1935.12	1933.36	1.76	1931.23	1929.35	1.88
HL-MW-04	1	1934.76	1933.21	1.55	1930.97	1929.19	1.78
HL-MW-05	1	1934.85	1933.09	1.76	1931.03	1929.07	1.96
HL-MW-06A	1	1933.72	1931.87	1.85	1929.79	1927.85	1.94
HL-MW-07S	1	1934.21	1932.34	1.87	1930.46	1928.32	2.14
HL-MW-08D	1	1934.23	1932.32	1.91	1930.42	1928.31	2.11
HL-MW-10S	1	1933.21	1931.52	1.69	1928.87	1927.49	1.38
HL-MW-12S	1	1934.46	1932.65	1.81	1930.72	1928.64	2.08
HL-MW-14S	1	1933.30	1931.21	2.09	1929.45	1927.19	2.26
HL-MW-16S	1	1935.05	1933.10	1.95	1931.23	1929.08	2.15
HL-MW-17S	1	1936.00	1934.82	1.18	1932.33	1930.82	1.51
HL-MW-18S	1	1935.77	1934.57	1.20	1931.98	1930.57	1.41
HL-MW-19S	1	1935.58	1934.41	1.17	1931.76	1930.40	1.36
HL-MW-20S	1	1935.35	1933.84	1.51	1931.52	1929.83	1.69
HL-MW-21S	1	1934.75	1933.22	1.53	1930.63	1929.20	1.43
HL-MW-22S	1	1935.23	1934.29	0.94	1931.10	1930.28	0.82
HL-MW-23S	1	1929.15	1928.20	0.95	1924.45	1924.19	0.26
HL-MW-24DD	4	1933.47	1931.15	2.32	1929.61	1927.13	2.48
HL-MW-25S	1	1930.79	1931.75	-0.96	1929.99	1927.73	2.26
HL-MW-26S	1	1934.84	1933.14	1.70	1931.12	1929.13	1.99
HL-MW-28DD	3	1934.56	1932.42	2.14	1930.75	1928.41	2.34
HL-MW-29S	1	1934.85	1933.13	1.72	1931.05	1929.12	1.93
HL-MW-30S	1	1931.33	1929.33	2.00	1927.06	1925.31	1.75
MW-02	1	1928.27	1926.29	1.98	1922.65	1922.30	0.35
MW-04	1	1943.02	1944.54	-1.52	1940.15	1940.54	-0.39
MW-05	1	1941.53	1939.92	1.61	1937.52	1935.93	1.59
MW-08	1	1932.21	1931.57	0.64	1927.42	1927.56	-0.14
MW-09	1	1931.13	1930.40	0.73	1926.41	1926.39	0.02
MW-10	1	1942.47	1942.40	0.07	1938.93	1938.41	0.52
MW-12A	1	1928.43	1926.65	1.78	1922.49	1922.65	-0.16
MW-13	1	1929.87	1929.58	0.29	1925.13	1925.57	-0.44
MW-14	1	1928.42	1927.38	1.04	1922.78	1923.38	-0.60
MW-15	1	1928.05	1926.56	1.49	1922.09	1922.57	-0.48
MW-16	1	1929.77	1927.27	2.50	1925.40	1923.28	2.12
MW-17S	1	1928.92	1927.68	1.24	1924.28	1923.67	0.61
MW-18D	1	1928.94	1927.71	1.23	1924.29	1923.70	0.59
MW-19S	1	1929.20	1928.89	0.31	1923.93	1924.88	-0.95
MW-20D	1	1929.24	1928.92	0.32	1923.96	1924.90	-0.94
MW-21S	1	1928.16	1926.98	1.18	1922.35	1922.98	-0.63
MW-22D	1	1928.13	1927.00	1.13	1922.40	1923.00	-0.60
MW-23S	1	1927.98	1926.13	1.85	1921.74	1922.14	-0.40
MW-24D	1	1928.02	1926.17	1.85	1921.79	1922.17	-0.38
MW-25S	1	1928.66	1926.85	1.81	1923.93	1922.86	1.07
MW-26D	1	1928.66	1926.85	1.81	1923.90	1922.86	1.04

Table E-2 - Summary of Verification Statistics

		Apr-08			Oct-08		
Name	**Layer**	**Observed**	**Computed**	**Residual**	**Observed**	**Computed**	**Residual**
OH-MW-03	1	1937.31	1936.74	0.57	1933.50	1932.73	0.77
OH-MW-05	1				1933.37	1932.46	0.91
OH-MW-08	1				1935.16	1934.18	0.98
OH-MW-10	1	1937.32	1936.69	0.63	1933.58	1932.69	0.89
OH-MW-13	1	1936.92	1936.44	0.48	1932.87	1932.44	0.43
OH-MW-18	1	1936.37	1935.55	0.82	1932.49	1931.55	0.94
OH-MW-24	1	1936.91	1936.31	0.60	1933.07	1932.30	0.77
OH-MW-25	1				1933.31	1932.44	0.87
OH-MW-26	1	1936.99	1936.39	0.60	1933.16	1932.35	0.81
OH-MW-27	1	1935.19	1935.54	-0.35	1932.11	1931.54	0.57
OH-SK-02	1				1934.42	1932.33	2.09
OH-SK-03	1				1932.50	1931.75	0.75
RM-MW-01S	1	1937.71	1934.13	3.58	1931.83	1930.13	1.70
RM-MW-03S	1	1936.73	1935.77	0.96	1933.10	1931.77	1.33
RM-MW-04D	4	1936.74	1935.76	0.98	1933.26	1931.76	1.50
RM-MW-05S	1	1937.91	1937.51	0.40	1934.57	1933.52	1.05
RM-MW-08S	1	1937.51	1936.68	0.83	1933.92	1932.69	1.23
RM-MW-09S	1	1938.88	1938.42	0.46	1935.51	1934.42	1.09
RM-MW-10S	1	1936.93	1936.02	0.91	1933.36	1932.02	1.34
RM-MW-12S	1	1937.61	1936.84	0.77	1934.08	1932.84	1.24
RM-MW-13S	1	1937.15	1936.22	0.93	1933.60	1932.22	1.38
RM-MW-14S	1	1936.73	1935.79	0.94	1933.12	1931.79	1.33
RM-MW-15S	1	1936.62	1935.57	1.05	1932.98	1931.57	1.41
RM-MW-16S	1	1936.39	1935.21	1.18	1932.77	1931.20	1.57
RM-MW-17S	1	1936.21	1934.89	1.32	1932.52	1930.88	1.64
TF-MW-02	1				1934.74	1933.67	1.07
TF-MW-03	1				1935.12	1933.85	1.27
TF-MW-04	1	1938.04	1937.39	0.65	1934.22	1933.39	0.83
TL-MW-01A	1	1935.85	1935.34	0.51	1931.44	1931.34	0.10
TL-MW-04	1	1931.43	1930.03	1.40	1926.80	1925.97	0.83
TS-MW-01S	1	1936.54	1935.58	0.96	1932.65	1931.58	1.07
TS-MW-02S	1	1936.32	1935.42	0.90	1932.46	1931.42	1.04
WW-MW-03	1				1925.25	1924.87	0.38
WW-MW-06	1				1926.49	1925.72	0.77
WW-MW-07	1	1932.63	1930.76	1.87	1928.16	1926.72	1.44
WW-MW-08	1	1932.13	1930.44	1.69	1927.79	1926.39	1.40
WW-MW-09	1	1931.39	1929.94	1.45	1926.90	1925.90	1.00
WW-MW-10	1	1932.74	1931.14	1.60	1928.31	1927.10	1.21
WW-MW-11	1	1928.86	1927.93	0.93	1923.66	1923.91	-0.25
WW-MW-12	1	1929.12	1928.42	0.70	1924.54	1924.38	0.16
WW-MW-15	1	1928.43	1927.50	0.93	1922.96	1923.50	-0.54
WW-MW-17	3	1928.84	1925.93	2.91	1923.91	1921.86	2.05
WW-MW-18	1	1928.79	1927.95	0.84	1923.39	1923.95	-0.56
WW-MW-19	1	1929.69	1928.51	1.18	1924.87	1924.41	0.46
WW-SK-02	1				1925.30	1924.82	0.48
WW-SK-04	1	1929.62	1928.34	1.28	1924.69	1924.28	0.41
Residual Mean (RM)				1.21			1.01
Absolute Residual. Mean (ARM)				1.27			1.16
Residual. Std. Dev. (RSD)				0.73			0.86
Sum of Squares (SS)				180.61			177.60
RMS Error				1.41			1.33
Min. Residual				-1.52			-0.95
Max. Residual				3.58			3.80
Range in Observations (RIO)				15.04			18.41
RSD/RIO				0.05			0.05
Scaled Abs. Mean				0.08			0.06
Scaled RMS				0.09			0.07
Number				90			101

Table E-3 - Petroleum Hydrocarbon Scenario Groundwater Pumping and Injection Rates

Scenario	Name	Pumping/Injection Rate		Model Location				Top Screen Elevation
		in MGD	in ft^3/day	Row	Column	Top Layer	Bottom Layer	in feet
1 (Alternative C1)	OH-EW-01	-1.28	-171,123	85	143	1	3	1910
	WW-EW-01	-4.42	-590,909	122	77	4	7	1860
	WW-EW-02	-7.32	-978,610	121	78	4	7	1864
	WW-UVB-01	-3.35	-447,861	131	68	3	5	1953
	North Supply Well	-0.26	-34,759	51	177	7	7	NA
	Total Extraction	**-16.63**	**-2,223,262**					
	WW-UVB-01-HSN	1.62	216,580	(a)	(a)	1	1	NA
	WW-UVB-01-HSM	0.97	129,678	(b)	(b)	1	1	NA
	WW-UVB-01-HSS	1.78	237,966	(c)	(c)	1	1	NA
	Total Injection	**4.37**	**584,224**					
2 (Alternative C2, C2a)	Baseline IRM Extraction	-16.63	-2,223,262					
	Baseline IRM Injection	4.37	584,224					
	WW-EW-03	-1.50	-200,000	110	67	1	5	1966
	WW-EW-03-HS	1.50	200,000	(d)	(d)	1	1	NA
	Total Extraction	**-18.13**	**-2,423,262**					
	Total Injection	**5.87**	**784,224**					
3 (Alternative C2, C2b)	Baseline IRM Extraction	-16.63	-2,223,262					
	Baseline IRM Injection	4.37	584,224					
	ORB-FEW-1	-0.75	-100,000	77	107	1	1	NA
	Total Extraction	**-17.38**	**-2,323,262**					
	Total Injection	**4.37**	**584,224**					
4 (Alternative C2, C2c)	WW-FEW-1	-1.05	-140,000	113	67	1	1	NA
	WW-FEW-2	-1.35	-180,000	117	67	1	1	NA
	WW-FEW-3	-1.12	-150,000	123	68	1	1	NA
	WW-FEW-4	-0.97	-130,000	130	76	1	1	NA
	CM-FEW-1	-0.79	-105,000	109	167	1	1	NA
	CM-FEW-2	-0.79	-105,000	114	160	1	1	NA
	ORB-FEW-1	-0.75	-100,000	77	107	1	1	NA
	OH-FEW-1	-0.82	-110,000	85	134	1	1	NA
	OH-FEW-2	-0.90	-120,000	92	135	1	1	NA
	OH-FEW-3	-0.60	-80,000	96	134	1	1	NA
	OH-FEW-4	-0.75	-100,000	104	142	1	1	NA
	North Supply Well	-0.26	-34,759	51	177	7	7	NA
	Total Extraction	**-9.87**	**-1,354,759**					
	Total Injection	**0.00**	**0**					
5 (Alternative C4)	Baseline IRM Extraction	-16.63	-2,223,262					
	Baseline IRM Injection	4.37	584,224					
	WW-FEW-5	-1.18	-157,500	113	83	1	1	NA
	WW-FEW-6	-0.59	-78,750	131	80	1	1	NA
	CM-FEW-3	-0.56	-75,000	103	145	1	1	NA
	ORB-FEW-1	-0.60	-80,000	77	107	1	1	NA
	OH-FEW-5	-0.73	-97,500	87	140	1	1	NA
	OH-FEW-6	-0.43	-57,000	103	145	1	1	NA
	Total Extraction	**-20.71**	**-2,769,012**					
	Total Injection	**4.37**	**584,224**					

Notes

(a) - WW-UVB-01-HSN is simulated by 17 wells injecting at a rate of 12,740 ft^3/day (0.1 MGD)

(b) - WW-UVB-01-HSM is simulated by 6 wells injecting at a rate of 21,613 ft^3/day (0.16 MGD)

(c) - WW-UVB-01-HSS is simulated by 6 wells injecting at a rate of 39,661 ft^3/day (0.3 MGD)

(d) - WW-EW-03-HS is simulated by 16 wells injecting at a rate of 12,500 ft^3/day

MODFLOW convention extraction shown by negative pumping rates and injection shown by positive pumping rates

NA - not applicable

Table E-4 - PCBs Scenario Groundwater Pumping and Injection Rates

Scenario	Name	Pumping/Injection Rate		Model Location				Top Screen Elevation in feet
		in MGD	in ft^3/day	Row	Column	Top Layer	Bottom Layer	
Baseline System (Alternative D1)	OH-EW-01	-1.28	-171,123	85	143	1	3	1910
	WW-EW-01	-4.42	-590,909	122	77	4	7	1860
	WW-EW-02	-7.32	-978,610	121	78	4	7	1864
	WW-UVB-01	-3.35	-447,861	131	68	3	5	1953
	North Supply Well	-0.26	-34,759	51	177	7	7	NA
	Total Extraction	**-16.63**	**-2,223,262**					
	WW-UVB-01-HSN	1.62	216,580	(a)	(a)	1	1	NA
	WW-UVB-01-HSM	0.97	129,678	(b)	(b)	1	1	NA
	WW-UVB-01-HSS	1.78	237,966	(c)	(c)	1	1	NA
	Total Injection	**4.37**	**584,224**					
6 (Alternative D2a)	Baseline Extraction	-16.63	-2,223,262					
	PCB-1	-3.67	-490,000	89	66	2	2	NA
	Total Extraction	**-20.30**	**-2,713,262**					
	Baseline Injection	4.37	584,224					
	PCB Injection System	3.67	490,000					
	Total Injection	**8.04**	**1,074,224**					
7 (Alternative D2b)	Baseline Extraction	-16.63	-2,223,262					
	PCB-2	-0.90	-120,000	65	85	2	2	NA
	PCB-3	-1.23	-165,000	68	87	2	2	NA
	PCB-4	-0.90	-120,000	73	89	2	2	NA
	New Extraction	-3.03	-405,000					
	Total Extraction	**-19.66**	**-2,628,262**					
	Baseline Injection	4.37	584,224					
	PCB Injection System	3.03	405,000					
	Total Injection	**7.40**	**989,224**					
8 (Alternative D3)	Baseline Extraction	-16.63	-2,223,262					
	PCB-2	-0.90	-120,000	65	85	2	2	NA
	PCB-3	-1.23	-165,000	68	87	2	2	NA
	PCB-4	-0.90	-120,000	73	89	2	2	NA
	New Extraction	-3.03	-405,000					
	Total Extraction	-19.66	-2,628,262					
	Baseline Injection	**4.37**	**584,224**					
	PCB Injection System	3.03	405,000					
	Total Injection	**4.37**	**989,224**					
9 (Alternative D4)	Baseline Extraction	-16.63	-2,223,262					
	PCB-6	-0.30	-40,000	53	108	2	2	NA
	Total Extraction	**-16.93**	**-2,263,262**					
	Baseline Injection	4.37	584,224					
	PCB Injection System	0.30	40,000					
	Total Injection	**4.67**	**624,224**					

Notes

(a) - WW-UVB-01-HSN is simulated by 17 wells injecting at a rate of 12,740 ft3/day (0.1 MGD)

(b) - WW-UVB-01-HSM is simulated by 6 wells injecting at a rate of 21,613 ft3/day (0.16 MGD)

(c) - WW-UVB-01-HSS is simulated by 6 wells injecting at a rate of 39,661 ft3/day (0.3 MGD)

MODFLOW convention extraction shown by negative pumping rates and injection shown by positive pumping rates

NA - not applicable

Table E-5 - Calculated Groundwater Flux and Volume of Contaminant Plumes - Alternatives C1 and D1

Name	Gradient in ft/ft (1)	HC in ft/day (2)	GW Flux in $ft^3/day/ft^2$	Depth of Plume in feet (4)	Width of Plume in feet (5)	GW Flux (6)			Length of Plume in feet (7)	Footprint of Plume in ft^2 (8)	Plume Volume in ft^3 (9)
						in ft^3/day	in MGD	in gpm			
Oil House North	0.0033	3,000	9.9	30	325	96,525	0.72	501	825	191,500	1,723,500
Oil House South	0.0033	3,000	9.9	30	190	56,430	0.42	293	250	33,900	305,100
Wastewater North	0.0050	3,000	15.0	30	350	157,500	1.18	818	1,000	309,000	2,781,000
Wastewater South	0.0050	3,000	15.0	30	175	78,750	0.59	409	325	40,900	368,100
Cold Mill	0.0027	3,000	8.1	30	300	72,900	0.55	379	350	81,000	729,000
ORB	0.0036	3,000	10.8	30	200	64,800	0.48	337	250	37,400	336,600
Remelt PCB	0.0030	3,000	9.0	30	350	94,500	0.71	491	2,200	223,700	2,013,300

Notes

(1) gradient based on plume-specific values observed in October 2008
(2) hydraulic conductivity based on value assigned to Layer 1 in area of plume
(3) flux calculated from gradient x hydraulic conductivity x area of 1 ft^2
(4) depth is the average saturated thickness of model layer 1
(5) width based on measured maximum width of plume based on data in 2010.
(6) groundwater flux = flux (ft^2) x depth x width of plume.
(7) measured length of plume based on data in 2010.
(8) footprint determined from map area of plumes based on data in 2010.
(9) plume volume = footprint (ft^2) x depth (ft) x porosity of 0.3
HC = hydraulic conductivity; GW = groundwater

Table E-6 - Scenario Travel Time Estimates from Particle Tracking

	Scenario 1 (Alts C1 - D1)		Scenario 2 (Alt C2a)		Scenario 3 (Alt C2b)		Scenario 4 (Alt C2c)		Scenario 5 (Alt C3)		Scenario 6 (Alt D2a)		Scenarios 7 & 8 (Alt D2b)	
Name	Travel Time in days	Increase from Baseline	Travel Time in days	Increase from Baseline	Travel Time in days	Increase from Baseline	Travel Time in days	Increase from Baseline	Travel Time in days	Increase from Baseline	Travel Time in days	Increase from Baseline	Travel Time in days	Increase from Baseline
Oil House North	20	NA	20	0	20	0	9	122	14	43	NA	NA	NA	NA
Oil House South	7	NA	7	0	7	0	3	133	6	17	NA	NA	NA	NA
Wastewater North	20	NA	20	0	20	0	10	100	15	38	NA	NA	NA	NA
Wastewater South	3	NA	3	0	3	0	2	50	2	30	NA	NA	NA	NA
Cold Mill	11	NA	11	0	11	0	4	175	7	57	NA	NA	NA	NA
ORB	6	NA	6	0	4	50	4	50	4	50	NA	NA	NA	NA
Remelt PCB Plume	73	NA	NA	NA	NA	NA	NA	NA	NA	NA	46	59	43	71

Notes

NA - not applicable

Increase from baseline is in percent

Table E-7 Summary of Total PCBs Concentrations - Remelt/Hot Line PCB Plume

Sample Date	RM-MW-17S	HL-MW-29S	HL-MW-14S	HL-MW-30S	HL-MW-32S
Oct-2003			220 JP		
Mar-2004			200		
Jun-2004			150		
Oct-2004			120		
Jul-2005			120		
Oct-2005			120		
Jan-2006			99		
Apr-2006			210		
Jul-2006			230 J		
Oct-2006	1800		150		
Feb-2007	2000		180		
Apr-2007	3400		160		
Jul-2007	2500	520	230	160 JP	
Oct-2007	990	440	170	110	
Jan-2008	1700	400 JP	280	120	
Apr-2008	2300	240	160	100 JP	
Jul-2008	1900	1000	170	150	
Oct-2008	2200	510	290	120 JP	
Jan-2009	2500	400	270	140	
Apr-2009	4500	410	240	170	
Jul-2009	1700	1000	400	140	
Oct-2009	1800	460	240	110	10 U
Feb-2010				190	10 U
Apr-2010	2000	420	240	180	10 U
May-2010				220	10
Jul-2010				130 J	7.1
Oct-2010	1100	330	140	26 J	11
Jan-2011				150	5 U
Distance From Source in Feet	0	450	950	1450	1810
Statistics					
Mean	2159	511	200	139	9
Median	2000	430	190	140	10
Geomean	2018	470	189	128	9
Std Deviation	868	240	69	44	2
Min	990	240	99	26	5
Max	4500	1000	400	220	11
Count	15	12	24	16	7

Notes

Total PCB concentrations in ng/L

Table E-9 Predicated PCB Concentrations - Remelt/Hot Line PCB Plume

Distance from Source in Feet	Total PCB Concentration in ng/L			
	Mean	April	October	Mean Data
1	2,157	1,993	1,153	2159
100	1,601	1,468	889	
200	1,188	1,082	685	
300	881	797	528	
400	654	587	407	411
500	485	432	314	
600	360	319	242	
700	267	235	187	
800	198	173	144	
900	147	127	111	200
1,000	109	94	86	
1,100	81	69	66	
1,200	60	51	51	
1,300	45	37	39	
1,400	33	28	30	139
1,500	25	20	23	
1,600	18	15	18	
1,700	14	11	14	
1,800	10	8	11	9
1,900	7.4	6.0	8.2	
2,000	5.5	4.4	6.4	
2,100	4.1	3.3	4.9	
2,200	3.0	2.4	3.8	
2,300	2.3	1.8	2.9	

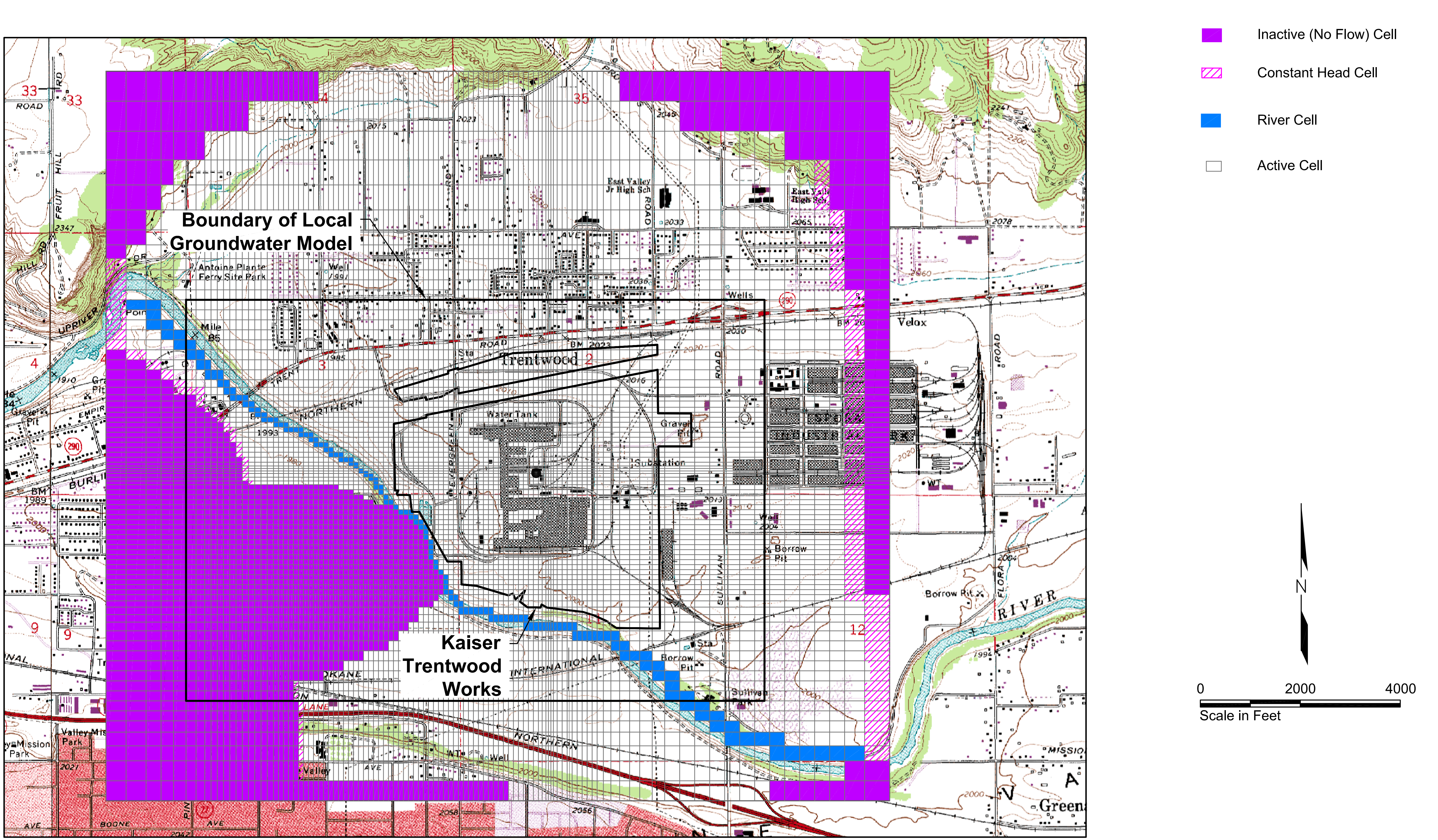
Notes:

Expotential regression based on Mean, April 2010 and October 2010 data

Table E-10 Predicated PCB Concentrations based on Mean PCB Regression Equation

	Starting PCB Concentration at Source in ng/L							
Distance from Source in Feet	50	60	100	200	500	1000	2000	4000
0.1	49.985	59.982	99.970	199.940	499.851	999.702	1999.403	3998.807
100	37.093	44.511	74.186	148.371	370.929	741.857	1483.715	2967.429
200	27.526	33.031	55.052	110.103	275.258	550.517	1101.033	2202.066
300	20.426	24.512	40.853	81.705	204.263	408.527	817.053	1634.106
400	15.158	18.190	30.316	60.632	151.579	303.159	606.318	1212.635
500	11.248	13.498	22.497	44.994	112.484	224.968	449.935	899.871
600	8.347	10.017	16.694	33.389	83.472	166.944	333.888	667.775
700	6.194	7.433	12.389	24.777	61.943	123.885	247.771	495.542
800	4.597	5.516	9.193	18.387	45.966	91.933	183.865	367.731
900	3.411	4.093	6.822	13.644	34.111	68.221	136.443	272.885
1000	2.531	3.038	5.063	10.125	25.313	50.626	101.251	202.502
1100	1.878	2.254	3.757	7.514	18.784	37.568	75.136	150.273
1200	1.394	1.673	2.788	5.576	13.939	27.879	55.757	111.514
1300	1.034	1.241	2.069	4.138	10.344	20.688	41.376	82.752
1400	0.768	0.921	1.535	3.070	7.676	15.352	30.704	61.409
1500	0.570	0.684	1.139	2.279	5.696	11.393	22.785	45.570
1600	0.423	0.507	0.845	1.691	4.227	8.454	16.908	33.817
1700	0.314	0.376	0.627	1.255	3.137	6.274	12.547	25.095
1800	0.233	0.279	0.466	0.931	2.328	4.656	9.311	18.622
1900	0.173	0.207	0.345	0.691	1.727	3.455	6.910	13.819
2000	0.128	0.154	0.256	0.513	1.282	2.564	5.127	10.255
2100	0.095	0.114	0.190	0.380	0.951	1.902	3.805	7.610
2200	0.071	0.085	0.141	0.282	0.706	1.412	2.824	5.647
2300	0.052	0.063	0.105	0.210	0.524	1.048	2.095	4.191
2400	0.039	0.047	0.078	0.155	0.389	0.777	1.555	3.110
2500	0.029	0.035	0.058	0.115	0.289	0.577	1.154	2.308
2600	0.021	0.026	0.043	0.086	0.214	0.428	0.857	1.713
2700	0.016	0.019	0.032	0.064	0.159	0.318	0.636	1.271
2750	0.014	0.016	0.027	0.055	0.137	0.274	0.548	1.095
2800	0.012	0.014	0.024	0.047	0.118	0.236	0.472	0.943
2850	0.010	0.012	0.020	0.041	0.102	0.203	0.406	0.813
2900	0.009	0.011	0.018	0.035	0.088	0.175	0.350	0.700
2950	0.008	0.009	0.015	0.030	0.075	0.151	0.302	0.603
3000	0.006	0.008	0.013	0.026	0.065	0.130	0.260	0.519
3050	0.006	0.007	0.011	0.022	0.056	0.112	0.224	0.447
3100	0.005	0.006	0.010	0.019	0.048	0.096	0.193	0.385
3150	0.004	0.005	0.008	0.017	0.042	0.083	0.166	0.332
3200	0.004	0.004	0.007	0.014	0.036	0.072	0.143	0.286
3300	0.003	0.003	0.005	0.011	0.027	0.053	0.106	0.212
3400	0.002	0.002	0.004	0.008	0.020	0.039	0.079	0.158
3500	0.001	0.002	0.003	0.006	0.015	0.029	0.058	0.117
3600	0.001	0.001	0.002	0.004	0.011	0.022	0.043	0.087
3700	0.001	0.001	0.002	0.003	0.008	0.016	0.032	0.064
3800	0.001	0.001	0.001	0.002	0.006	0.012	0.024	0.048
3900	0.000	0.001	0.001	0.002	0.004	0.009	0.018	0.035
4000	0.000	0.000	0.001	0.001	0.003	0.007	0.013	0.026

Regional Groundwater Model Grid



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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Figure E-1

Local Groundwater Model Grid

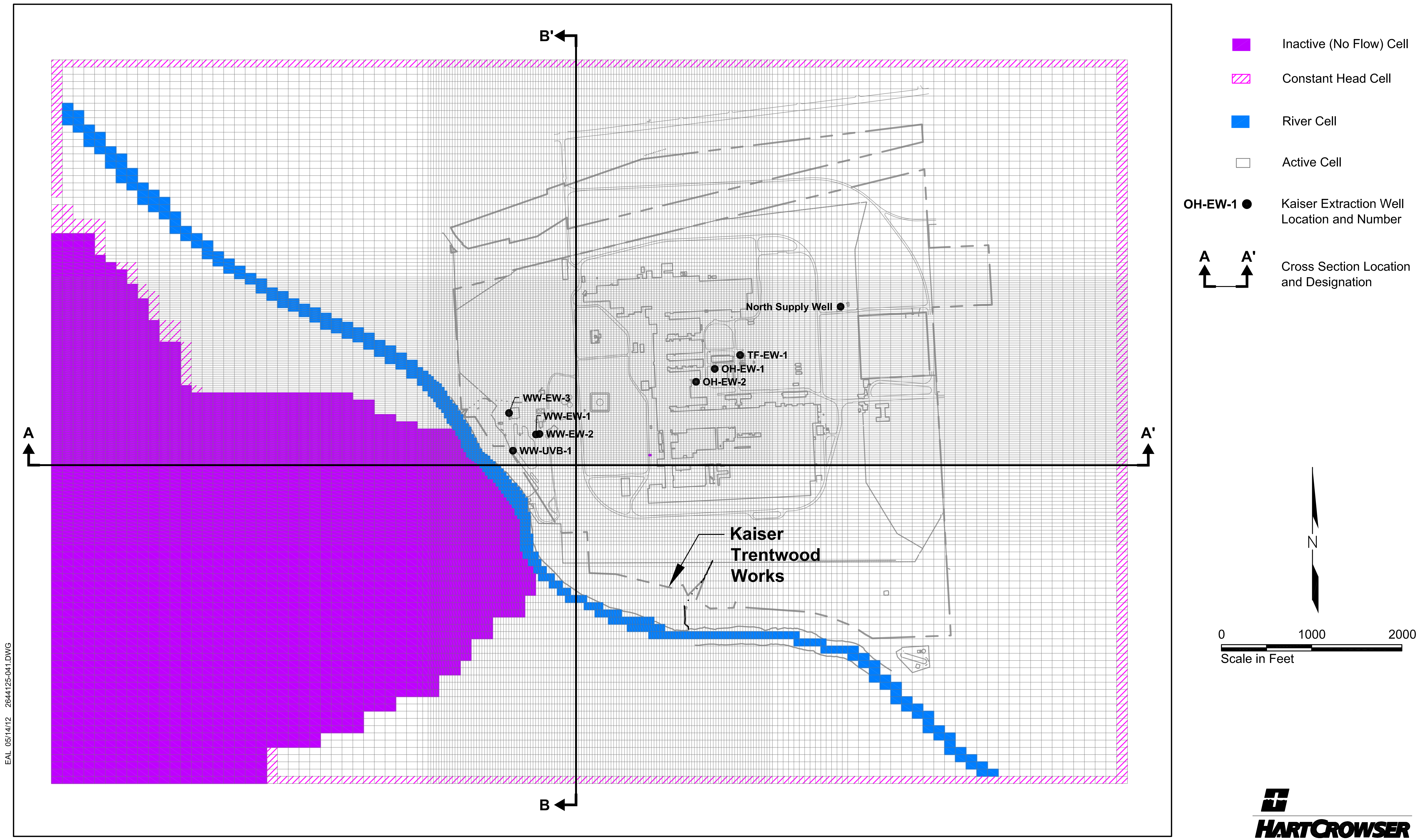

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Figure E-2

Schematic Finite Difference Grid
Cross Section A-A'

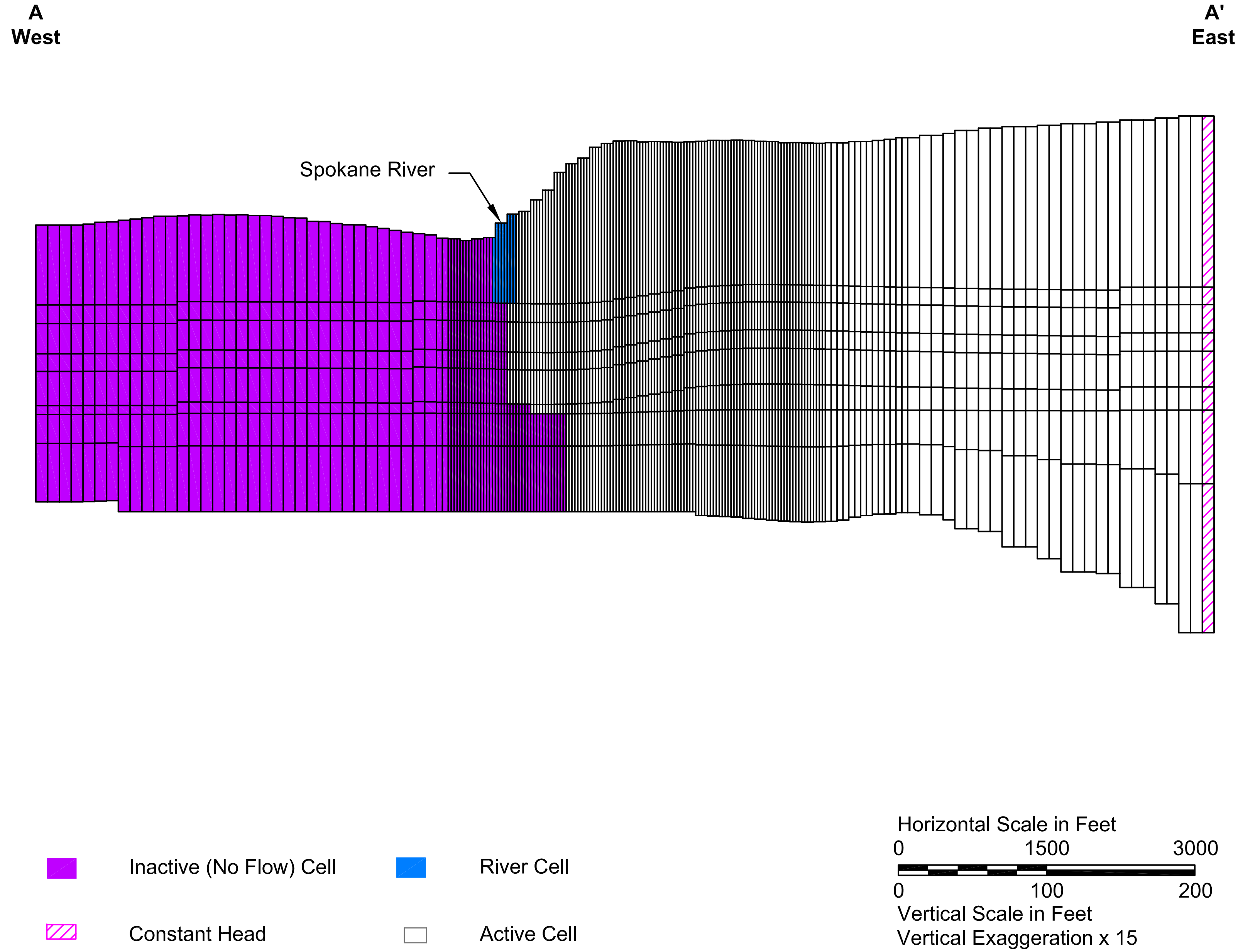

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Figure E-3

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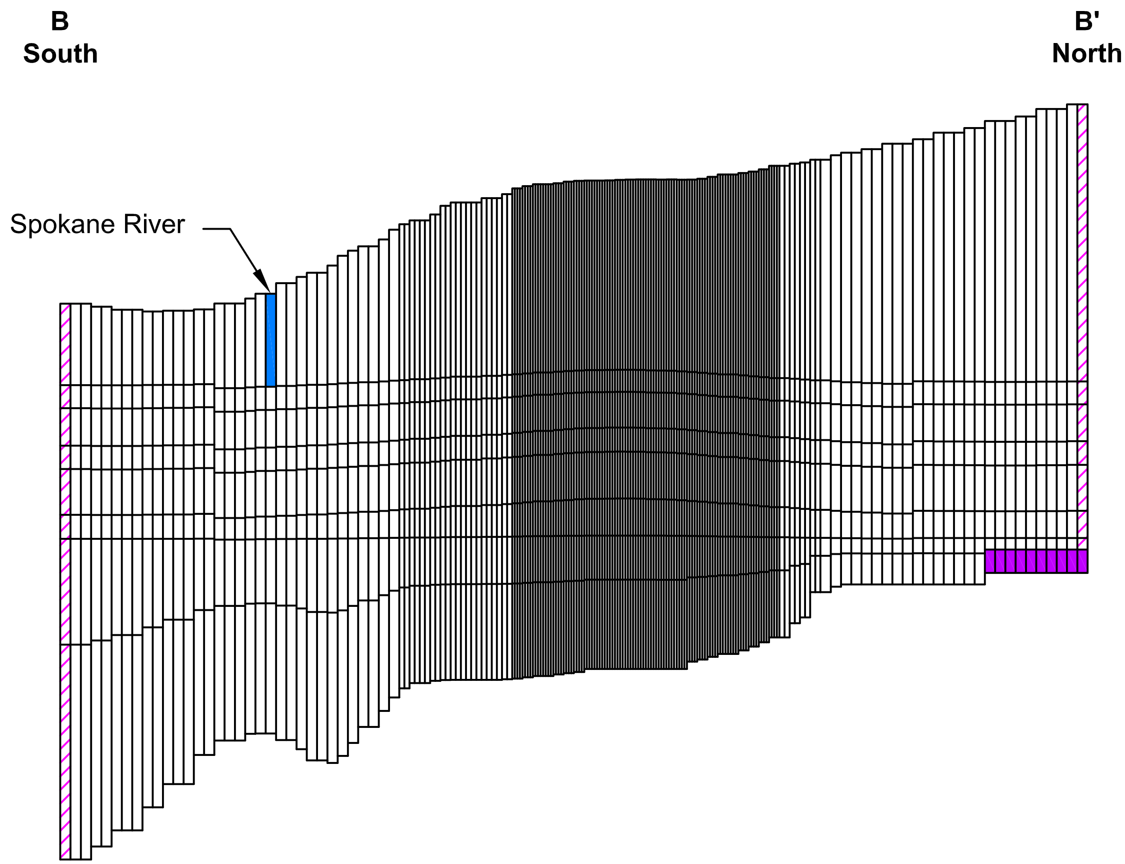
Schematic Finite Difference Grid

Cross Section B-B'



Inactive (No Flow) Cell

River Cell

Constant Head

Active Cell

Horizontal Scale in Feet
0 1500 3000
0 100 200
Vertical Scale in Feet
Vertical Exaggeration x 15

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Figure E-4

Capture Zone by Reverse Particle Tracking - Alternative C-1: Baseline IRM

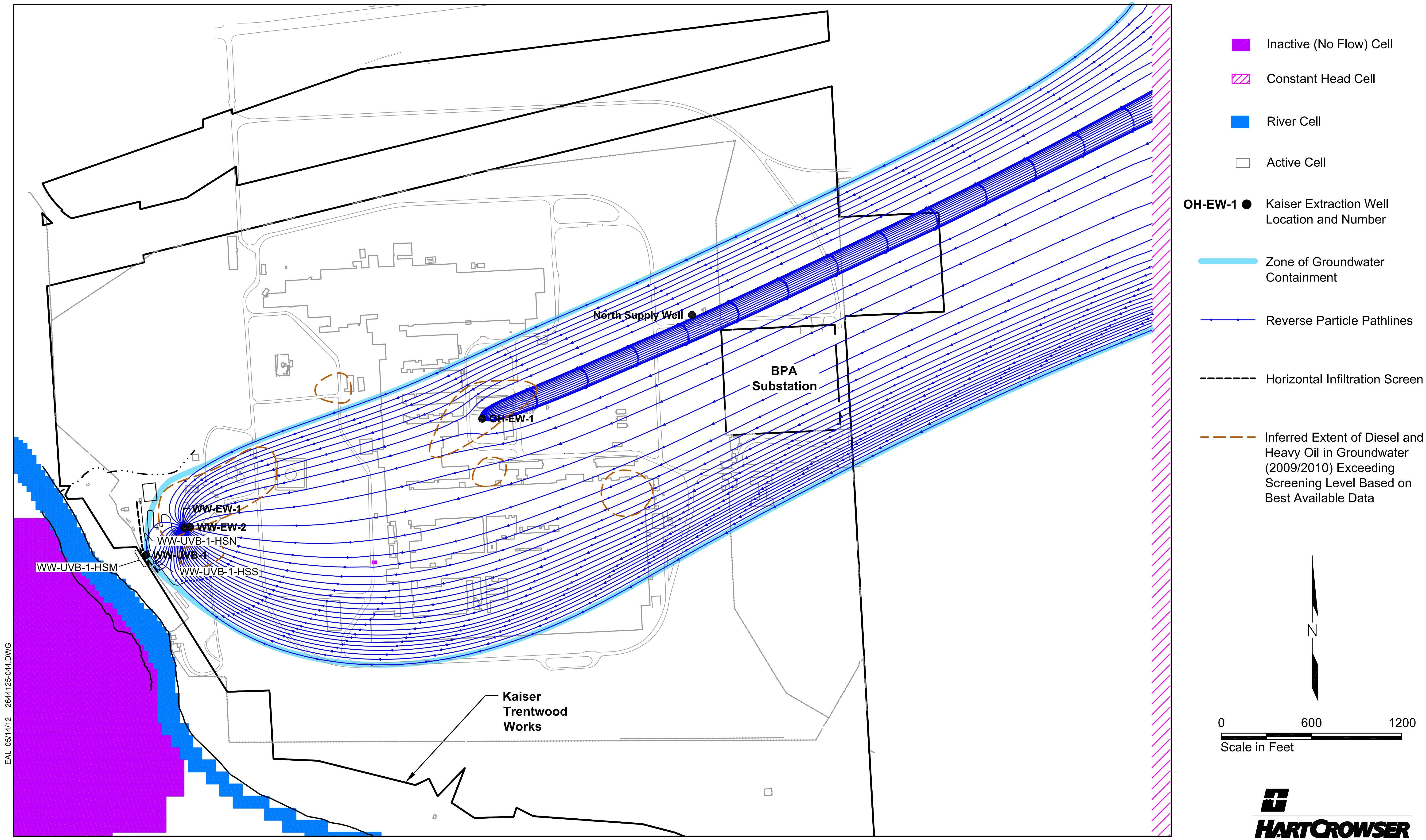

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Figure E-5

Capture Zone by Forward Particle Tracking - Alternative C-1: Baseline IRM

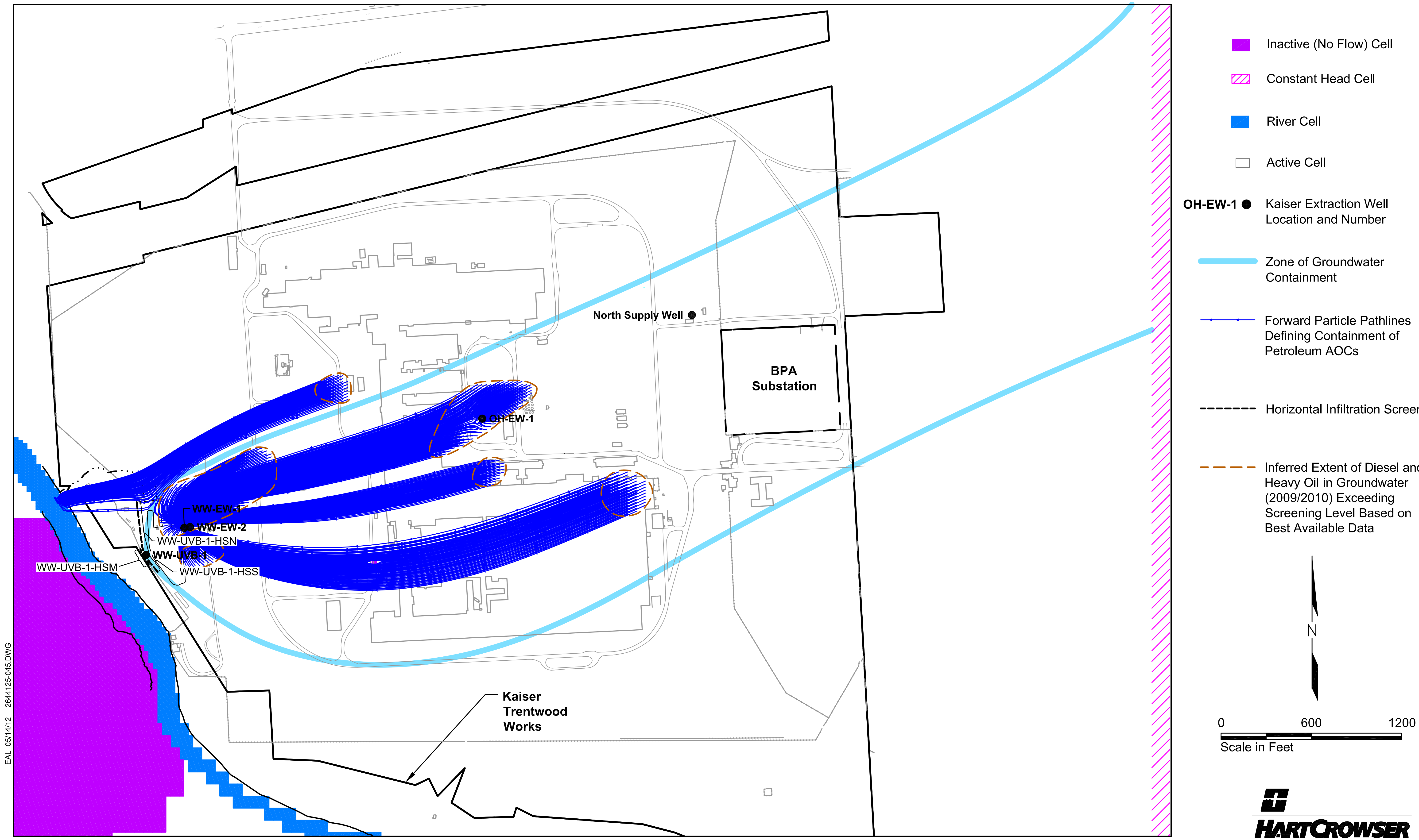

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Figure E-6

Capture Zone by Reverse Particle Tracking - Alternative C2 Scenario C2a: Expanded IRM

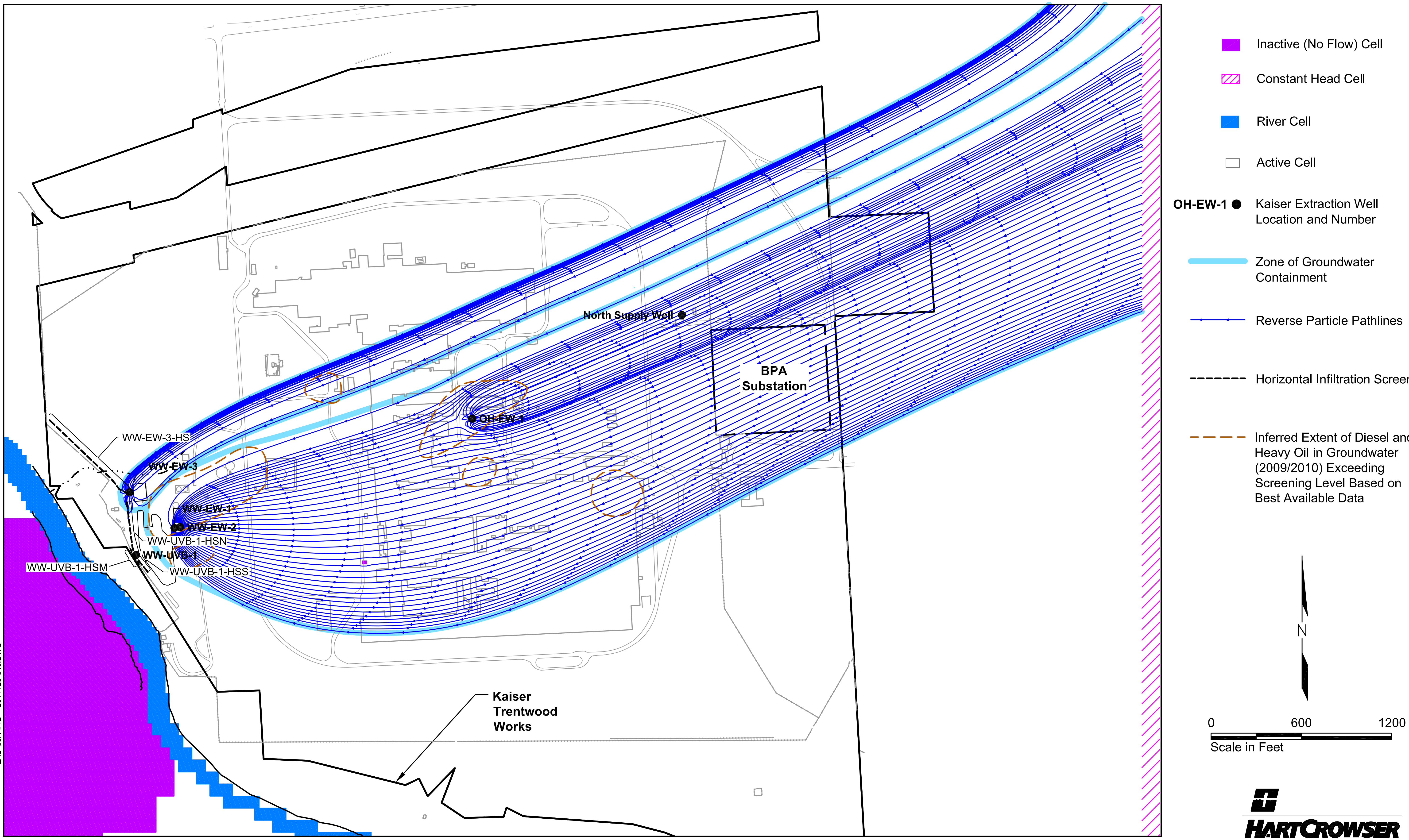

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Figure E-7

Capture Zone by Forward Particle Tracking - Alternative C2 Scenario C2a: Expanded IRM

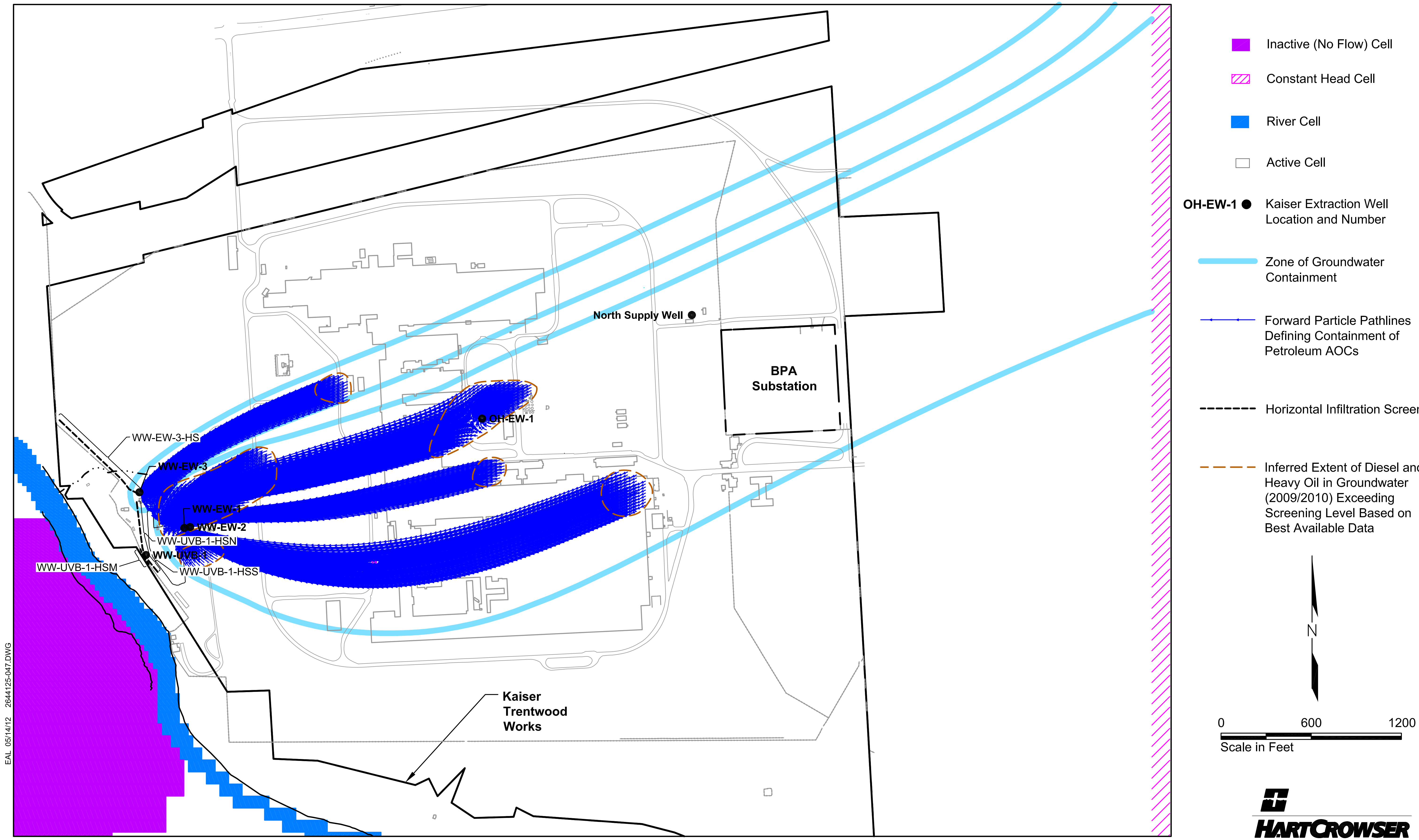

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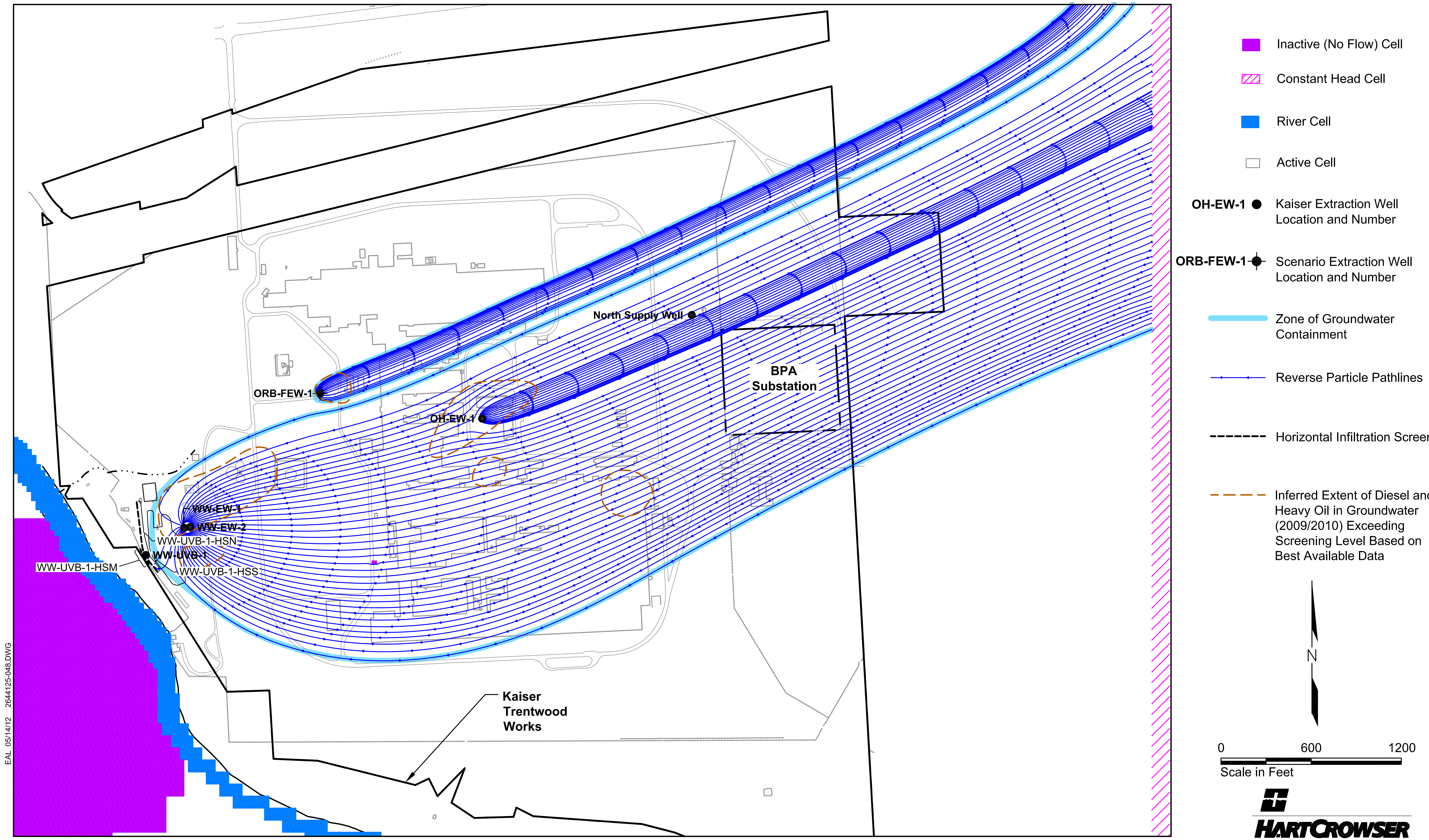
Figure E-8

Capture Zone by Reverse Particle Tracking - Alternative C2 Scenario C2b: Expanded IRM



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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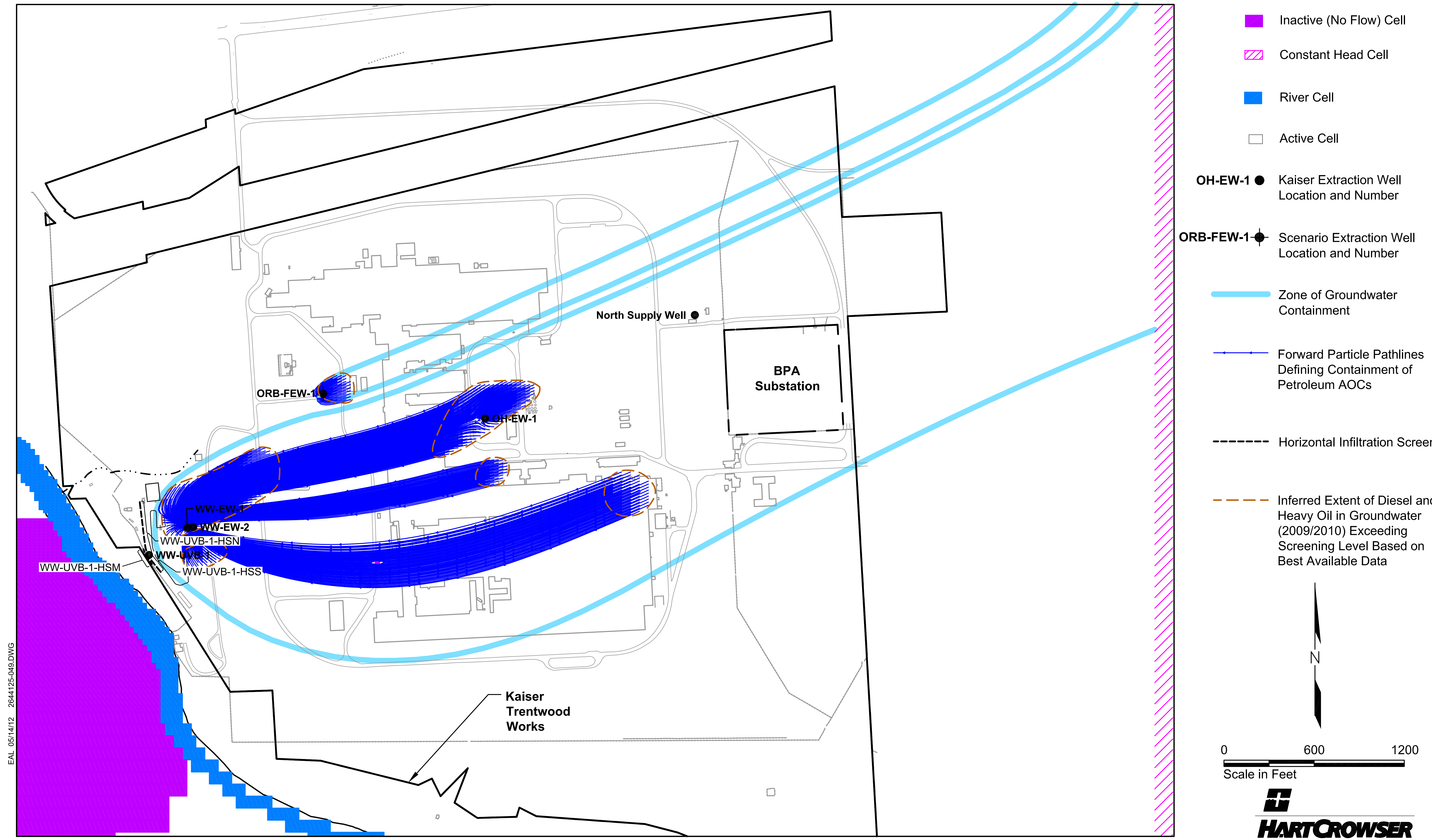
Figure E-9

Capture Zone by Forward Particle Tracking - Alternative C2 Scenario C2b: Expanded IRM



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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Figure E-10

Capture Zone by Forward Particle Tracking - Alternative C2 Scenario C2c: Plume-Specific Hydraulic Containment

Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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Figure E-11

Capture Zone by Forward Particle Tracking - Alternative C4: Pump and Treat

Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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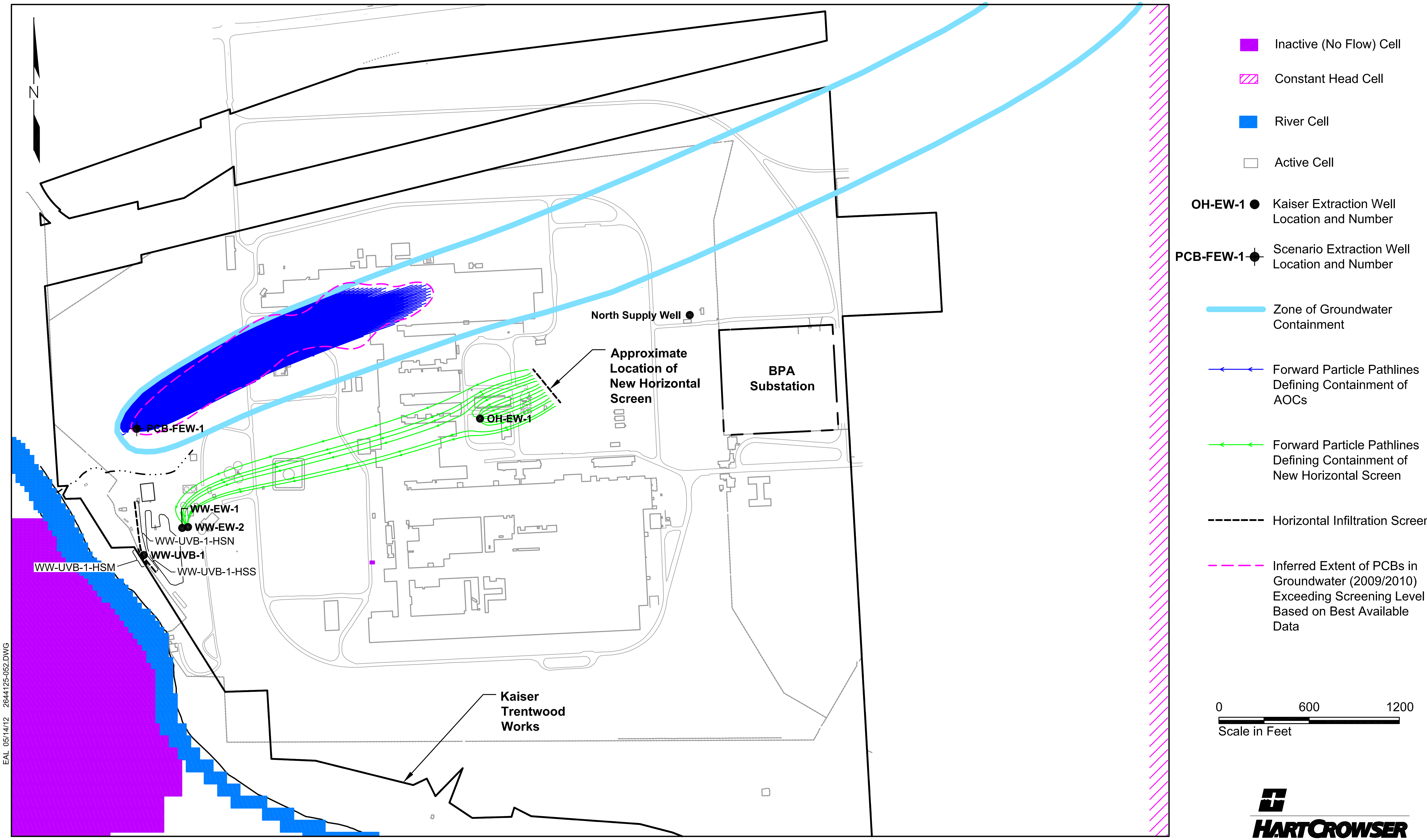
Figure E-12

Capture Zone by Forward Particle Tracking - Alternative D2a Leading Edge PCB Plume Containment



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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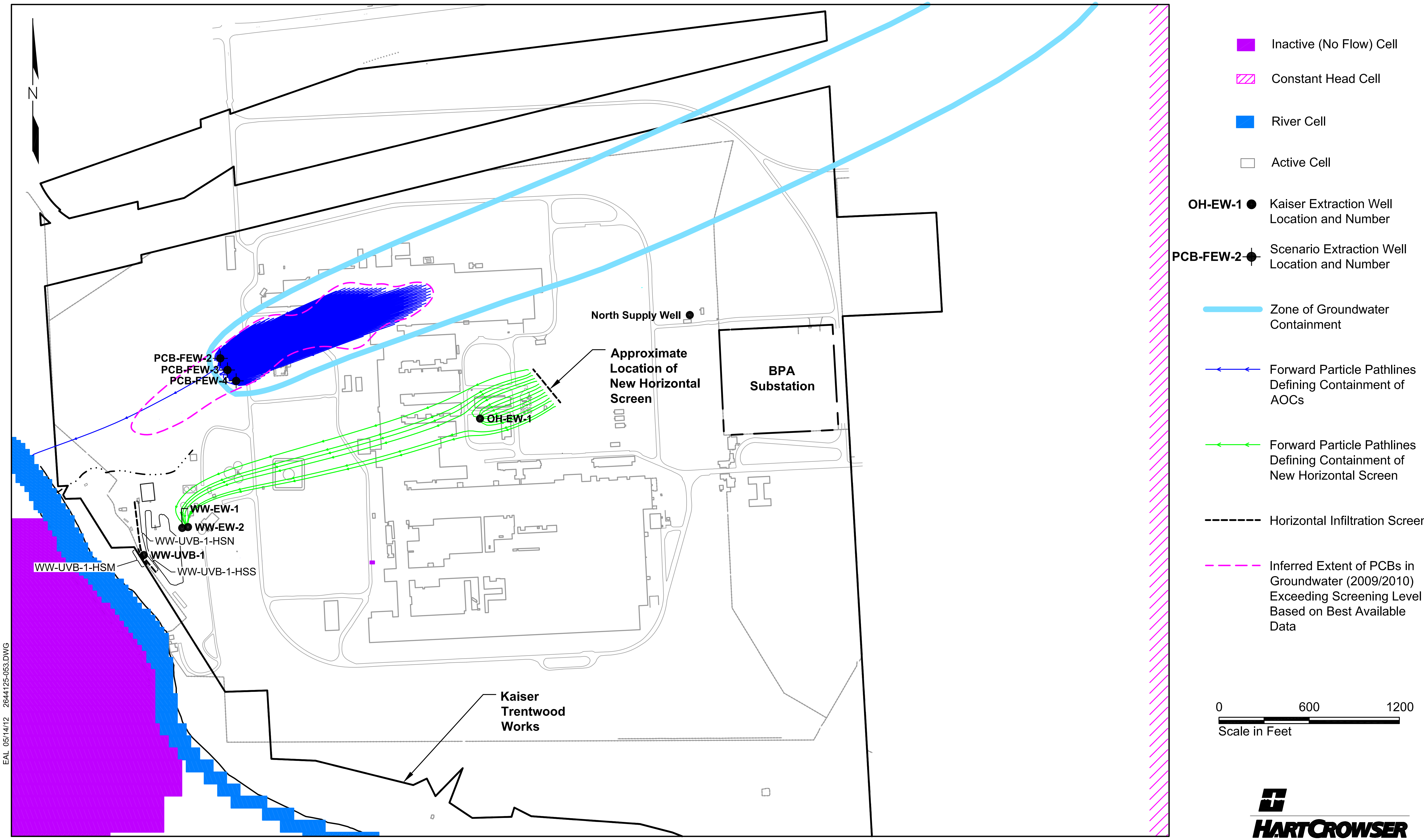
Figure E-13

Capture Zone by Forward Particle Tracking - Alternative D2b PCB Plume Containment



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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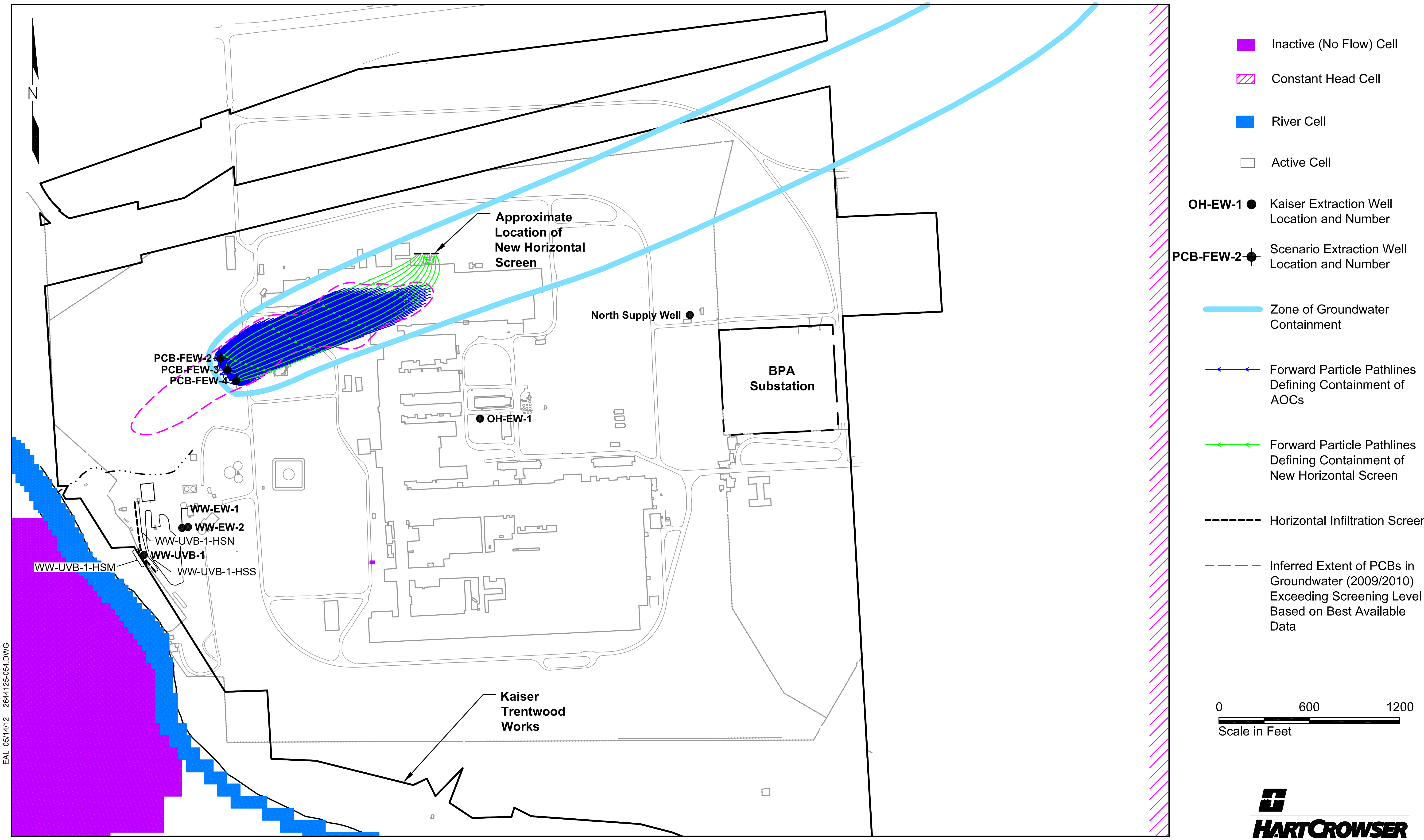
Figure E-14

Capture Zone by Forward Particle Tracking - Alternative D3 PCB Plume Containment with Remelt Injection



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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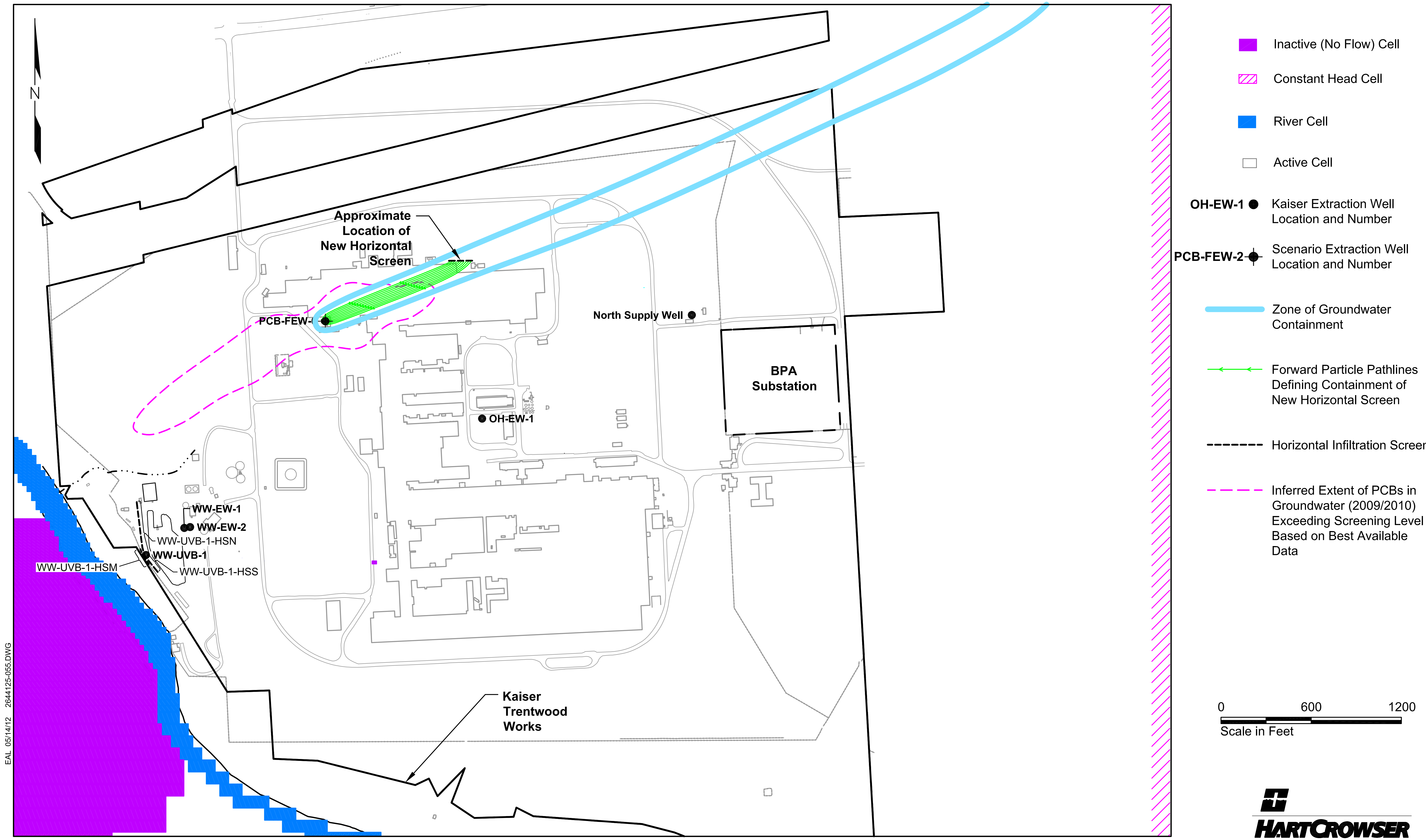
Figure E-15

Capture Zone by Forward Particle Tracking - Alternative D4 Partial PCB Plume Containment



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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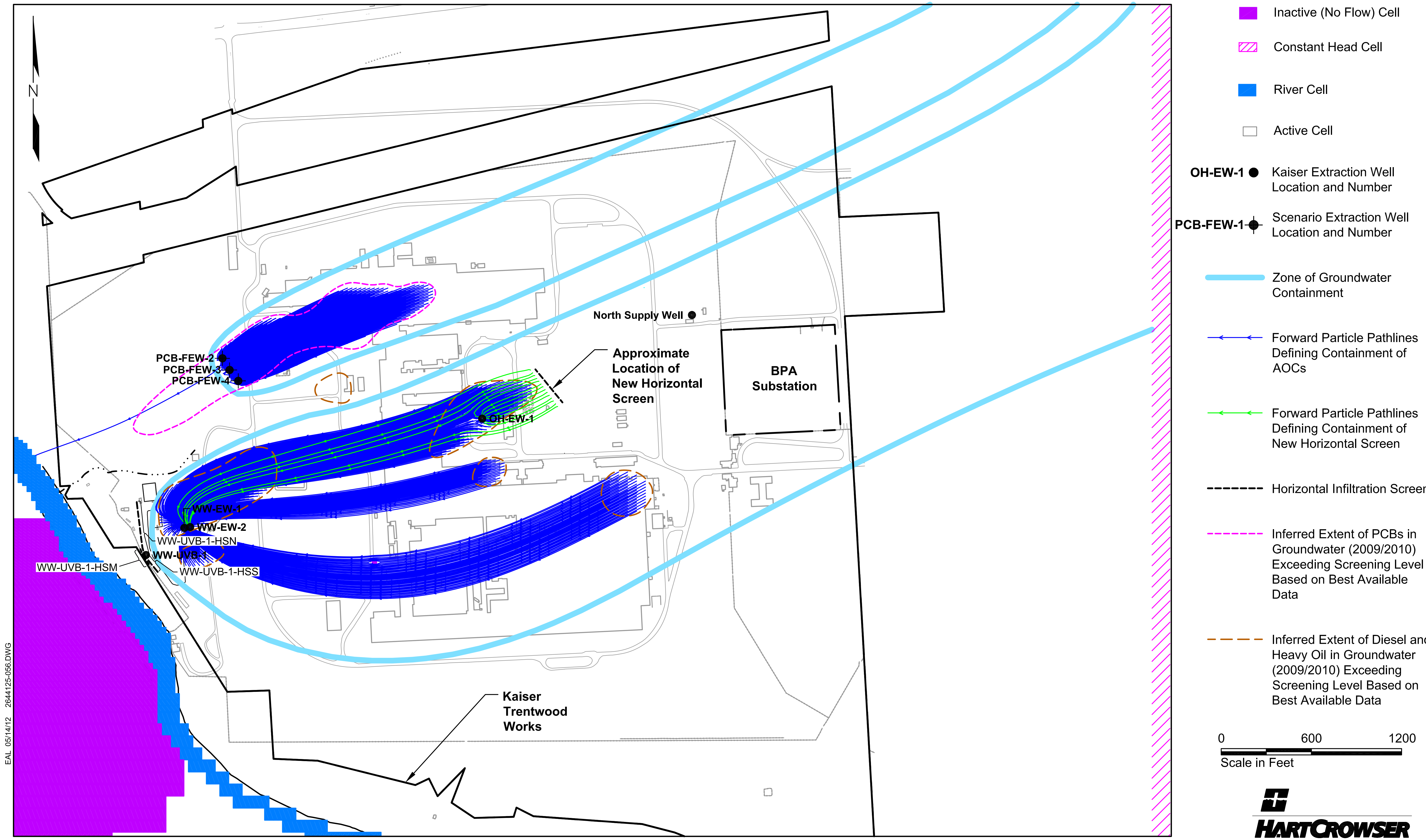
Figure E-16

Capture Zone by Forward Particle Tracking - Preferred Alternative Containment



Basemap: Greenacres USGS Topographic Quadrangle, 7.5 Minute Series (1986).

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Figure E-17

PCB Concentrations Indicator Wells Centerline of Remelt Plume

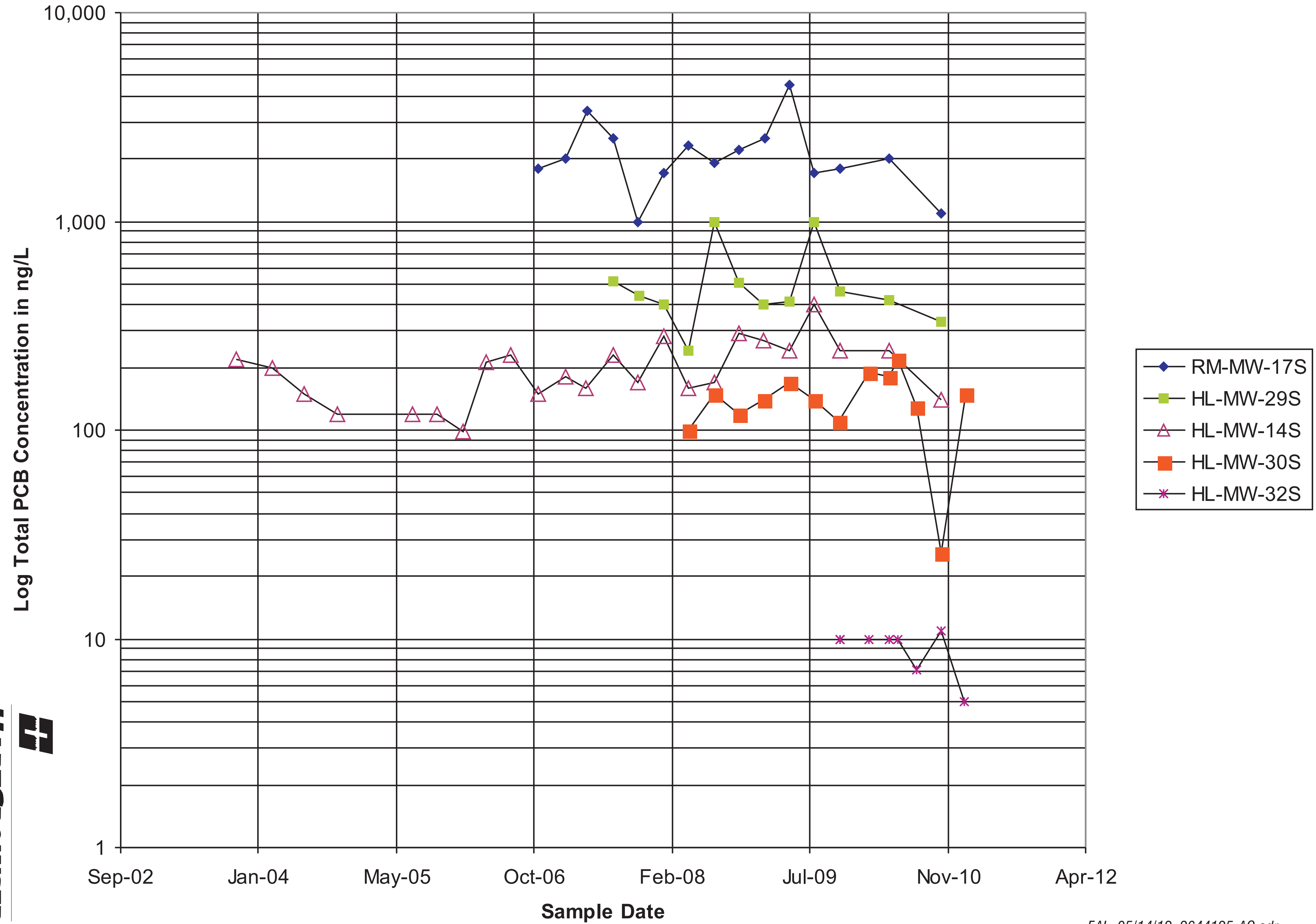

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Figure E-18

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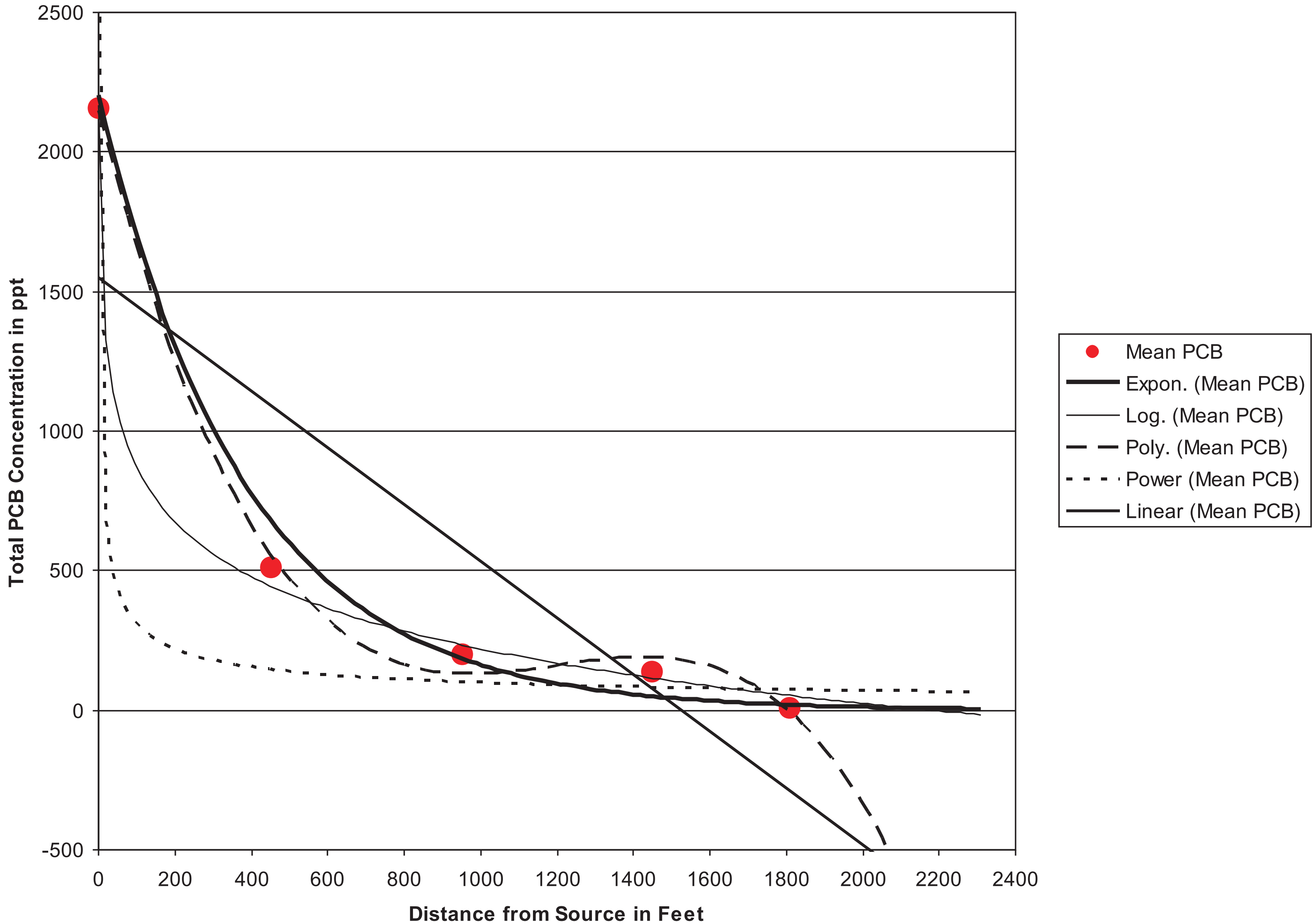
Regression Analysis of Mean PCB Concentrations Remelt Plume



HARTCROWSER
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Figure E-19

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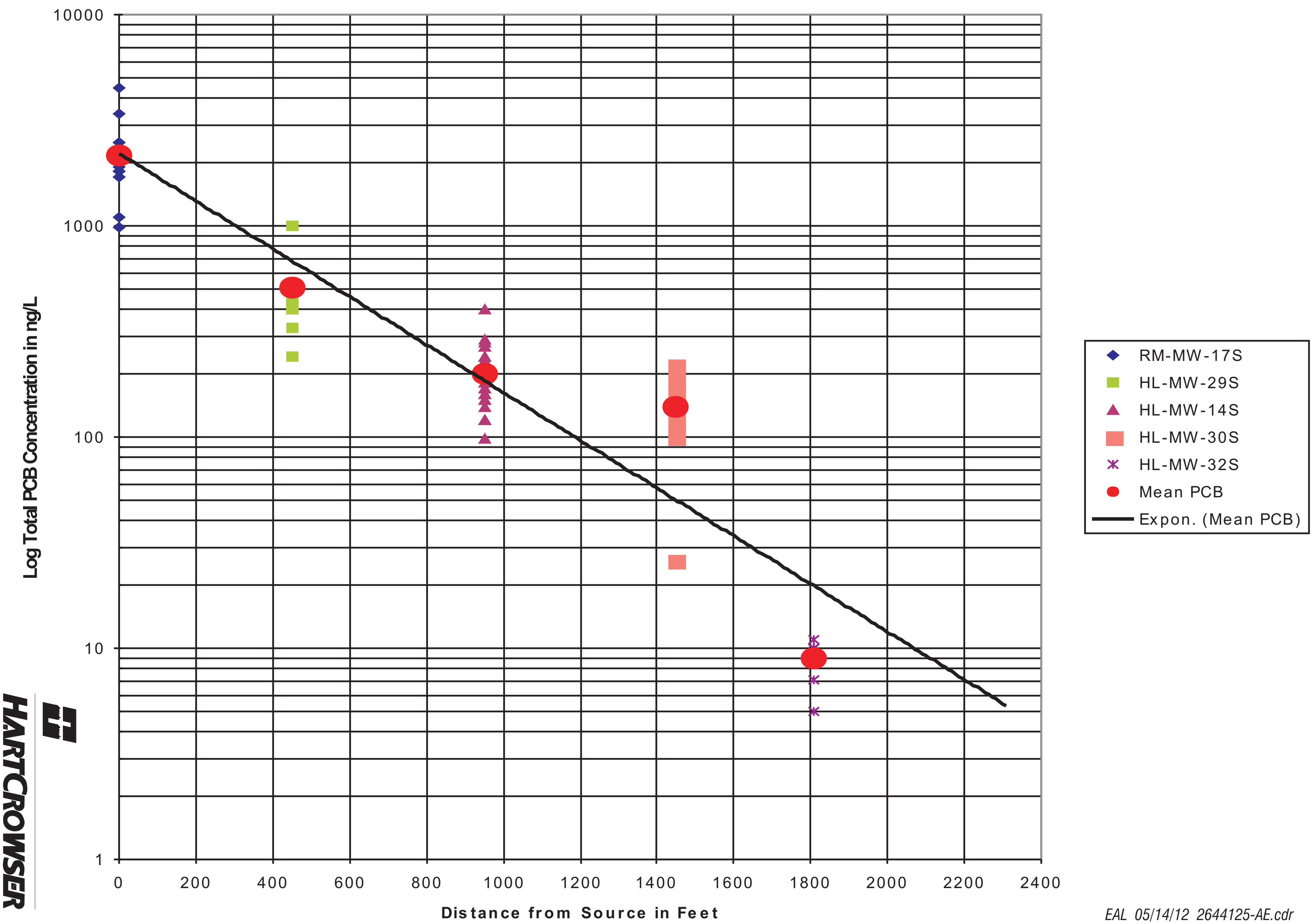
Exponential Regression Best Fit Curve - Centerline Remelt Plume



HARTCROWSER
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Figure E-20

EAL 05/14/12 2644125-AE.cdr

APPENDIX F
NATURAL ATTENUATION AT THE KAISER FACILITY

CONTENTS Page

FIGURES

APPENDIX F
NATURAL ATTENUATION AT THE KAISER FACILITY

F.1 INTRODUCTION

This appendix assesses the occurrence of natural attenuation of petroleum hydrocarbons in groundwater at the Kaiser Facility. This assessment is based on published information on chemical, physical, and biological breakdown of petroleum as well as data from years of monitoring at the Facility. This appendix also presents a summary of published information on the chemical, physical, and biological breakdown of PCBs and PCBs comingled with petroleum products.

F.2 NATURAL ATTENUATION OF PETROLEUM AT THE KAISER FACILITY

Natural attenuation of petroleum hydrocarbons in groundwater can occur through physical, chemical, and biological processes. Physical processes such as advection, diffusion, and dilution typically reduce contaminant concentrations for more effective treatment through biological and chemical processes. Biological and chemical processes destroy hydrocarbon mass, reducing both concentrations and plume dimensions. The following paragraphs focus on biological processes and related lines of evidence for monitored natural attenuation (MNA) as a remedial approach at the Kaiser Facility.

The Final Site-Wide Groundwater Remedial Investigation (Hart Crowser 2012a) and the Final Site-Wide Soil Remedial Investigation (Hart Crowser 2012b) were used to develop the lines of evidence for determining whether natural attenuation has historically occurred, is currently occurring, and will continue to occur in the future at the Facility. Data used include the groundwater flux through the Facility, site-specific contaminant characteristics, biological indicators of natural attenuation, and ongoing groundwater recovery. In general, there is good evidence that natural attenuation is occurring at the Facility.

Ecology has published a guidance document titled Guidance on Remediation of Petroleum-Contaminated Ground Water by Natural Attenuation (Ecology 2005b). This guidance identifies five factors that should be considered and evaluated to consider MNA as a cleanup alternative. This section is organized into the following subsections to reflect the Ecology guidance:

- F.2.1 What Is the Status of the Petroleum Groundwater Plume at the Site?

- F.2.2 Are Chemical or Biological Degradation Substantial Mechanisms of Natural Attenuation of Petroleum at the Site?

- F.2.3 What is the Estimated Restoration Time Frame?

- F.2.4 Will the Use of Natural Attenuation Be Protective of Human Health and the Environment during the Estimated Restoration Time Frame?

- F.2.5 Has Source Control Been Conducted to the Maximum Extent Practicable?

F.2.1 What Is the Status of the Petroleum Groundwater Plume at the Site?

Groundwater velocities average 33 feet per day throughout the Facility (Hart Crowser 2012a, Section 7.1). This average groundwater velocity typically results in expanding plumes through diffusion and dispersion, smearing hydrocarbons downgradient of source areas. The Facility has six dissolved petroleum plume areas that are composed of high-molecular-weight hydrocarbons with defined extent, which are discussed individually below (refer to Figures 4-1 through 4-3). High-molecular-weight petroleum hydrocarbons are naturally hydrophobic and are thermodynamically driven to adhere to the soil matrix. Generally, as the molecular weight of the hydrocarbon increases, mobility decreases. These physical characteristics of diesel and heavy oil constituents, combined with the significant flux of native electron acceptors (oxygen and nitrate) transported through the area, improve the viability of MNA. Dissolved oxygen (DO) readings have been collected consistently throughout the Facility, and nitrate data are primarily limited to the extraction wells (Hart Crowser 2012a). Other naturally occurring electron acceptors used by microbes include iron, manganese, and arsenic.

Groundwater is currently being extracted from the Oil House (OH-EW-1) and the Wastewater Treatment (WW-EW-1, WW-EW-2, and WW-UVB-1) areas. A portion of the groundwater that is extracted is used for process water at the Facility, and it is assumed that this will continue for the foreseeable future; for the purposes of this FS, a period of 30 years is assumed. The physical and chemical characteristics of the contamination mentioned above, combined with evidence of current natural attenuation discussed in the following paragraphs, support the conclusion that the current site conditions are resulting in shrinking plumes.

The extent of the free phase product (FPP) plumes has decreased by 82 and 94 percent in the Wastewater Treatment and Oil House areas, respectively, from historical highs (Table 5-6 in Hart Crowser 2012a; Figures 4-6 through 4-8 in Hart

Crowser 2012c). More than 4,000 gallons of FPP have been removed by pumps and belt skimmers from the source areas at the Facility (Hart Crowser 2012a, Table 5-4). Seasonal variations in groundwater elevations have allowed FPP to adsorb to the soil matrix generating a smear zone that is very conservatively estimated to contain approximately 1.58 million pounds of hydrocarbons (see Section 4 of this FS). Adsorption to the soil matrix is likely responsible for removing the bulk of the FPP from the surface of the groundwater in the FPP source areas. These soils seasonally adsorb and demobilize FPP onto the soil matrix. As FPP is trapped in certain areas, hydrocarbon mass is dissolved and released into groundwater in other areas, temporarily increasing local hydrocarbon concentrations. These dissolved concentrations are then degraded through biological mechanisms, which are discussed in more detail in the following sections.

F.2.1.1 Oil House Area

The dissolved plume in the Oil House area appears to be shrinking and is now considered to consist of two smaller plumes (refer to Figure 4-3), based on the comparison of the maximum historical lateral extent of hydrocarbons to the recent extent (2008) (Hart Crowser 2012a, Figures 5.1 through 5.4). The groundwater concentrations within this plume have also decreased over the past decade (Hart Crowser 2012a, Table 5-4).

The aquifer at the Facility is naturally oxidative, with a DO concentration of more than 8 milligrams per liter (mg/L) and an oxidation-reduction potential (ORP) of more than 50 millivolts (mV). One line of evidence for the activity of biological mechanisms within the Oil House area is based on DO and ORP readings that are consistently lower than the background conditions. This is indicative of biological activity that is degrading the hydrocarbon mass in the groundwater. The relatively lower DO concentrations and ORP measurements at wells within the plume areas are shown on Figures F-1 and F-2, respectively. Other lines of evidence supporting the reduction of hydrocarbon mass through biological activity include general increases in iron, manganese, and arsenic concentrations within the plume (i.e., iron greater than 300 micrograms per liter [µg/L], manganese greater than 50 µg/L, or arsenic greater than 5 µg/L), as shown on Figures F-3, F-4, and F-5, respectively. Background concentrations outside of the plumes are generally lower and in many cases below the detection limit.

DO concentrations of more than 8 mg/L (shown on Figure F-1) and nitrate concentrations of 2 mg/L (well OH-EW-1, Hart Crowser 2012a) are migrating through Facility groundwater. This influx of groundwater continues to provide electron acceptors that are likely responsible for feeding microbes that are destroying hydrocarbons and creating a shrinking plume. Local iron concentrations in excess of 9 mg/L (Figure F-3) confirm that iron continues to be an important electron donor within the plumes.

F.2.1.2 Cold Mill Area

The plume in the Cold Mill area appears to be shrinking based on the maximum lateral extent of hydrocarbons compared to the current extent (Hart Crowser 2012a, Figures 5-1 through 5-4). The shrinking status is somewhat less certain for this plume primarily because of the limited number of monitoring wells and apparent increases in hydrocarbon concentrations at a few locations within the plume (Hart Crowser 2012a, Table 5-4). However, biological breakdown of lower-mobility, longer-chain hydrocarbons may be responsible for mobilizing hydrocarbons from the soil matrix, resulting in higher groundwater concentrations of these breakdown products, which are more mobile than the parent hydrocarbons. In general, groundwater data indicate the Cold Mill plume is shrinking and wells within the Cold Mill area will continue to be monitored to further substantiate this downward trend in petroleum concentrations.

Lines of evidence that confirm the presence of biological processes include increases in iron, manganese, and arsenic concentrations, as compared to the background well concentrations (CM-MW-7S and CM-MW-8S) immediately upgradient, as shown on Figures F-3, F-4, and F-5, respectively. The lack of reduction in measured DO concentrations may be attributed to the groundwater flux containing highly oxidative groundwater that may be outpacing the rate at which the microbes are able to reduce DO concentrations in this portion of the aquifer. The ORP measurement at CM-MW-3S of -20 mV (compared to background measurements immediately upgradient at CM-MW-7S and CM-MW-8S, of 70 and 100 mV, respectively) is indicative of biological processes that are creating a reducing environment by destroying petroleum hydrocarbons and coincides with the footprint of the plume in this area.

F.2.1.3 Wastewater Treatment Area

The dissolved plume in the Wastewater Treatment area appears to be shrinking and is now considered to be two smaller plumes (refer to Figure 4-2), based on the comparison of the historical maximum lateral extent of hydrocarbons and the recent extent (2008) (Hart Crowser 2012a, Figures 5-1 through 5-4,). The groundwater concentrations within this plume have also decreased over the past decade (Hart Crowser 2012a, Table 5-4).

The line of evidence for biological mechanisms within the Wastewater Treatment area is based on the reduced DO and ORP at wells within the plume area and are shown on Figures F-1 and F-2, respectively. Other indirect lines of evidence supporting the reduction of hydrocarbon mass through biological activity include general increases in iron of more than 2 mg/L (WW-MW-19), and more moderate increases of manganese and arsenic concentrations within the plume shown on Figures F-3, F-4, and F-5, respectively. The lower DO concentrations (in wells HL-MW-1 and FO-MW-1S) between the Oil House area and the Wastewater Treatment area suggest that microbes in the presence of hydrocarbons are using DO as an electron acceptor, or that much of the DO was consumed in the Oil House area. Approximately 2 mg/L of nitrates (estimated from nitrate concentrations from nearby extraction wells) are flowing into the Wastewater Treatment source area. Both DO and nitrates are providing the microbes with electron acceptors that are likely responsible for the shrinking plumes.

F.2.1.4 Oil Reclamation Building Area

The plume in the Oil Reclamation Building (ORB) area appears to be shrinking based on the maximum lateral extent of hydrocarbons compared to the 2008 extent (Hart Crowser 2012a, Figures 5-1 through 5-4). Hydrocarbon concentrations within the plume are also lower for the same period (Hart Crowser 2012a).

Lines of evidence to support the presence of biological activity in this area include a reduction in DO and ORP concentrations within the ORB plume area at wells HL-MW-2, HL-MW-20S, and HL-MW-21S (Figures F-1 and F-2). Other lines of evidence that biological mechanisms are occurring include increases in iron, manganese, and arsenic concentrations (Figures F-3, F-4, and F-5).

F.2.2 Are Chemical or Biological Degradation Substantial Mechanisms for Natural Attenuation of Petroleum at the Site?

Biological destruction of contaminants involves the microbially mediated transfer of electrons from petroleum hydrocarbons (electron donors) to one of numerous electron acceptors. In groundwater systems, electron acceptors include dissolved oxygen (DO), nitrates, manganese (IV), arsenic (IV), iron (III), sulfates, and carbon dioxide. The source of these electron acceptors can be either natural or enhanced through manual addition. For MNA, the natural presence and ongoing flux of these electron acceptors into the various plume areas is necessary for contamination remediation.

For natural attenuation to be viable, a healthy population of microbes is necessary to destroy contamination. Viable microbial populations rely on energy-yielding reactions between electron donors and electron acceptors for survival. These reactions require various nutrients to support cellular growth, repair, and enzyme production. Nutrients are divided broadly into macro- and micro-type categories based on prevalence and demand. Macronutrients include nitrogen, phosphorous, potassium, and sulfur. Micronutrients include elements such as iron, chromium, manganese, and selenium. Greater biological availability of these nutrients increases microbial viability and the ability to support robust natural attenuation.

Soil and groundwater concentrations of electron acceptors, electron donors, and nutrients can be used to assess the potential for microbial activity. Absence of any of these elements will limit the effectiveness of MNA. By comparing the electron acceptors within the petroleum plumes' extent, the natural flux of groundwater into impacted areas, and hydrocarbon analytical data, it can be established whether biological processes appear to be degrading petroleum hydrocarbons.

The first line of evidence for natural attenuation of Facility petroleum hydrocarbons in groundwater is the presence and consumption of native electron acceptors. This can be inferred through changes in iron, arsenic, and manganese concentrations. ORP in areas outside of the plumes is generally oxidative (Figure F-2). In their oxidized state, iron, arsenic, and manganese exist as mineral salts within the soil matrix, which reduces their dissolved concentrations. In the presence of electron donors, such as petroleum hydrocarbons, these metals are reduced. The reduced form of iron, arsenic, and manganese are much more water soluble. Thus, increases in groundwater concentrations of these metals (Figures F-3, F-4, and F-5), concurrent with low ORP measurements (Figure F-2), suggest that microbes are actively degrading petroleum hydrocarbons at the Facility.

As groundwater moves out of hydrocarbon-impacted areas, a process termed "redox recovery" occurs in which reduced metals reoxidize through various biotic or abiotic mechanisms and readsorb to the soil matrix. Facility groundwater data are consistent with the pattern of biological use of native metals as terminal electron acceptors for the degradation of petroleum hydrocarbons, coupled with subsequent redox recovery and demobilization. The line of evidence is shown on Figures F-3, F-4, and F-5 as non-detect metal concentrations and higher ORP readings (Figure F-2) downgradient of the hydrocarbon plumes.

In addition to the extensive metals data collected at the Facility, nitrate is detected in extracted groundwater. Nitrate yields more energy for microbes than metals reduction, and thus is a preferred electron acceptor compared to iron, manganese, or arsenic. Positive detection of nitrate (approximately 2 mg/L at OH-EW-1, WW-EW-1, and North Supply Well, for example, (Hart Crowser

2012a) in extracted groundwater, combined with the velocity of groundwater at the Facility (33 feet per day), suggests significant nitrate mass is continually entering the plume areas. Since microbes yield more energy from using oxygen and nitrates than from iron, manganese, or arsenic, and it has been shown in previous paragraphs that microbes are using these metals as electron acceptors, the microbes must be using both oxygen and nitrates at the Facility for ongoing dissolved-phase hydrocarbon attenuation.

F.2.3 What Is the Estimated Restoration Time Frame?

The restoration time frame for MNA is difficult to estimate based on the variety of physical, chemical, and biological activities at the Facility, but the time frame is likely to be long. Based on the conservative estimated mass of more than 1.58 million pounds of petroleum hydrocarbons in the soil smear zone, the physical process of adsorption is likely responsible for removing much of the FPP from the groundwater in the FPP source areas, even though FPP skimming operations are ongoing in the Wastewater Treatment and Oil House areas. These soils seasonally adsorb and demobilize FPP, changing the mass of hydrocarbons available for diffusion into groundwater as the groundwater table fluctuates. At the same time that FPP is trapped in certain areas, hydrocarbon mass is dissolved, or mobilized, through biological processes discussed above, and released into groundwater in other areas, temporarily increasing local hydrocarbon concentrations. These dissolved concentrations are then degraded through biological mechanisms, as described above. The mass of SVOCs in smear zone soil is likely to provide a source for SVOCs in groundwater for some time. The expected restoration time frame for each petroleum groundwater plume has been estimated. The restoration time frame varies from approximately 4 years for the South plume in the Oil House area to approximately 34 for the North plume years in the Wastewater Treatment area (refer to Appendix I).

Based on the continuing influx of electron acceptors, microbes will continue to oxidize and degrade dissolved-phase petroleum hydrocarbons and reduce overall hydrocarbon mass. Hydrocarbon destruction through biological processes is maximized in the seasons with high groundwater elevations to provide electron acceptors to the entire smear zone.

F.2.4 Will the Use of Natural Attenuation Be Protective of Human Health and the Environment During the Estimated Restoration Time Frame?

The previous sections have shown that natural attenuation processes appear to be effectively degrading petroleum hydrocarbon mass at the Facility, creating shrinking hydrocarbon plumes and contributing to reductions in FPP under existing site conditions. These site conditions include a groundwater recirculation system, recovering groundwater for Facility processes, and the continuous availability of native electron acceptors for biological oxidative processes. Groundwater recovery at the Facility will continue for the foreseeable future (30+ years) during the restoration time frame. This recovery has slowed the transport of dissolved hydrocarbons and is likely aiding the biological processes that are creating shrinking plumes.

Based on FPP still present on the groundwater, the extensive smear zone mass (approximately 1.58 million pounds), and the fluctuating groundwater elevations, it is difficult to estimate how long the FPP will remain, and how long it will take to reduce the concentrations through biological process. An estimate of the amount of time needed to remove FPP is provided in Section 4 of this FS and in Appendix I.

MNA is protective of human health during the restoration time frame, as the smear zone soil and groundwater are approximately 70 feet below the ground surface and groundwater is not being used as drinking water source. Under the current conditions at the Facility, MNA is also protective of ecological receptors. Sampling conducted as part of the 2008 Groundwater Remedial Investigation (Hart Crowser 2012a), and more recent riverside groundwater well data show that no SVOCs are migrating to the Spokane River. However, this approach by itself may not be protective of the ecological receptors in the Spokane River if the groundwater recirculation or recovery is reduced from the current volumes. A long-term monitoring program would be required to verify that conditions remain protective, with enhanced monitoring if groundwater recovery is reduced. This long-term monitoring program is part of Alternatives C1 through C4 discussed in Section 4 of this FS.

F.2.5 Has Source Control Been Conducted to the Maximum Extent Practicable?

Known ongoing releases of petroleum to soil and groundwater have been eliminated at the Facility. Existing source areas include smear zone soil and groundwater containing FPP at approximately 70 feet below the ground surface. Belt skimmers have removed more than 4,000 gallons of FPP and have become less effective as FPP thickness is reduced and the recovery volumes become asymptotic. Groundwater recovery and recirculation are anticipated to continue for the foreseeable future (30+ years) and appear to be retarding the dissolved plume migration as biological processes destroy dissolved-phase hydrocarbons, resulting in shrinking plumes.

Several remedial alternatives for the petroleum groundwater plumes are being reviewed as part of this FS to determine the most appropriate approach for each of the source areas. Detailed discussions of these alternatives are provided in Section 4 (and summarized in Section 6). Source area control will be conducted to the maximum extent practicable as part of the remedial alternative that is selected for implementation at the Facility.

F.3 NATURAL ATTENUATION OF PCBS AND PCBS COMINGLED WITH PETROLEUM

The fate of PCBs in the environment has been investigated for many years. This fate is a function of a number of chemical, physical, and biological processes and properties. These processes and properties related to groundwater conditions at the Facility include: water solubility, octanol/water partitioning coefficient, vapor pressure, Henry's law constant, volatility from water, adsorption (sorption) to soils and sediments, hydrolysis, oxidation in water, and biodegradation (Leifer 1983).

In general, the persistence of PCBs in the environment increases with the degree of chlorination (i.e., the number of chlorine atoms added to the biphenyl molecule). Mono-, di-, and trichlorinated biphenyls biodegrade relatively rapidly. Tetra-chlorinated biphenyls degrade more slowly, and more highly chlorinated biphenyls are resistant to biodegradation (Borja 2005, Pieper 2008).

PCB soil adsorption increases with the degree of chlorination. PCBs do not leach significantly in aqueous soil systems, with the more highly chlorinated PCBs having a lower tendency to leach than the less chlorinated PCBs. In water, PCBs adsorb to sediments and suspended matter. Adsorption can immobilize PCBs for relatively long periods of time; although, the eventual re-dissolution into the water column has been shown to occur. Less chlorinated PCBs have a much greater water solubility than more highly chlorinated PCBs (refer to Table 2-4 of the FSTM).

Volatilization of PCBs is an important transport process. Henry's law constants for PCBs range from approximately 1 to 400 Pa m^3/mol (refer to Table 2-4 of the FSTM). Vapor loss of PCBs from soil surfaces appears to be an important fate mechanism, with the rate of volatilization decreasing with increasing chlorination (Ecology 2011).

Recently, evidence for the widespread dechlorination of PCBs has been documented in wastewater collection systems, groundwater, and landfill leachate. In wastewater collection systems, dechlorination occurs after the stormwater (and presumably wastewater) enters the collection system and before it reaches the treatment plant. Anaerobic treatment occurs in the sewer, which reduces the chlorination level of the PCBs, followed by aerobic treatment in the activated sludge or other aerobic treatment process. In groundwater that contains TPH and PCBs, it is thought that the presence of TPH and other hydrocarbons speed the transition to methanogenic conditions and provide an energy source for dechlorinating bacteria to become active. Landfill leachate contains the less chlorinated breakdown products of the biodegradation of highly chlorinated PCBs that were not known to be present in the materials placed in the landfill (Rodenburg 2010).

Aerobic and anaerobic bacteria are known to degrade PCBs in groundwater, soil, and sediment. Biodegradation of PCBs depends in large part on the availability of microorganisms. Only compounds in the aqueous phase can be degraded through biological processes. As with other physical and chemical processes mentioned above, the rate of a specific biological process is dependent on the degree of PCB chlorination. These biodegradation processes are discussed below.

F.3.1 Biodegradation of PCBs in the Environment

Bioavailability is one of the major limiting factors in bioremediation processes, and a number of factors influence the bioavailability of PCBs or other COCs: (1) diffusion limitation from sequestration of the COC in micropores; (2) binding to soil minerals by ionic or electrostatic interactions; (3) oxidative covalent coupling of the COC with soil organic matter via enzymic or chemical catalysis; and (4) partition/dissolution of the COCs into soil organic matter. There is a scientific consensus that partitioning/dissolution of organic COCs to organic matter is the most important mechanism reducing the bioavailability of organic COCs, in organic-rich soil and sediment. When the organic carbon fraction declines to less than approximately 0.4 percent organic carbon, the catalytic effect of soil minerals may result in greater proportion of pollutant immobilization via oxidative covalent coupling with soil organic matter (Head 1998).

Since biodegradation is an aqueous phase process, the solubility of PCBs becomes an important factor in estimating the potential for biological degradation. The solubility of PCBs decreases as the degree of chlorination increases (refer to Table 2-4 of the FSTM). Thus, penta-chlorinated biphenyls are much less likely to be available for bioremediation in aqueous media than mono-chlorinated biphenyls, and would exhibit much slower degradation rates.

The tendency for PCBs (particularly highly chlorinated PCBs) to adsorb to the soil matrix and organic matter also reduces their availability for biodegradation. The presence of petroleum or other oils with the PCBs could also reduce the availability of PCBs, since PCBs would preferentially partition to the oil phase, rather than dissolve in the aqueous phase (Jonker 2006, Zwiernik 1999).

Pollutant concentration is a major factor affecting biodegradation. In general, a low pollutant concentration may not provide a sufficient energy source for degradative enzymes or to sustain growth of competent organisms. On the other hand, a very high concentration may render the compound toxic to organisms. At low concentrations, degradation increases linearly with increase in concentration until such time as the rate essentially becomes constant regardless of further increase in pollutant concentration. Other factors affecting degradation are temperature, pH, presence of toxic or inhibitory substances and competing substrates; availability of suitable electron acceptors, micro-, and macronutrients; and interactions among organisms (Borja 2005).

F.3.2 Aerobic Biodegradation of PCBs in the Environment

The aerobic biodegradation of PCBs is widely known and has been well studied (Clark 1979, Furukawa 1979, Mohn 1997, Di Toro 2006, Pieper 2005, Pieper 2008, Strand 2008). As a general rule, aerobic biodegradation of PCBs proceeds more slowly with increased degree of chlorination. Half lives of 1 to 2 days for activated sludge processes, 2 to 4 days for fresh water, and 6 to 10 days for soil have been reported for the aerobic bioremediation of mono- and di-chlorinated biphenyls. Longer half lives of 2 to 5 days for activated sludge processes, 1 week to 2 months for fresh water, and 12 to 30 days for soil have been reported for tri- and tetra-chlorinated biphenyls (Liefer 1983).

Several microorganisms have been isolated that can aerobically degrade PCBs (Clark 1979, Furukawa 1978, Di Toro 2006, Barriault 1998, Pieper 2008). One aerobic process that has been identified includes degradation by 2,3-dioxygenase and metacleavage to form benzoates (Strand 2008).

Some of these aerobic organisms can degrade PCBs directly while other organisms rely on the presence of other organisms to be able to degrade PCBs. Cometabolism is the process by which a contaminant is fortuitously degraded by an enzyme or cofactor produced during the microbial metabolism of another compound. Methanotrophs, methane oxidizing bacteria, produce methane monooxygenase, which can oxidize recalcitrant compounds such as PCBs (probably mono- and di-chlorinated PCBs) (Hazen 2006). This cometabolic pathway may be present in the Oil House and Wastewater Treatment area groundwater plumes that contain PCBs comingled with SVOCs, and may be a means by which mono- to tri-chlorinated biphenyls are degraded in smear zone soil and groundwater in these areas.

In another example of aerobic cometabolism, an increase in the rate of degradation of dilute concentrations of PCBs was noted when a secondary energy source (sodium acetate) was added. The microorganisms used acetate for growth, while oxidizing the PCBs (Clark 1979).

F.3.3 Anaerobic Biodegradation of PCBs in the Environment

The anaerobic dechlorination of Aroclors 1242, 1248, 1254, and 1260 (with approximately three, four, five and six chlorines, respectively) obtained from sediments in the Hudson River, and from sediments obtained from near Silver Lake, Massachusetts, was demonstrated as early as 1990 (Quensen 1990). These PCBs are frequently present in contaminated sediments. Based on relative bioavailablity, the dechlorination rate of Aroclors 1254 and 1260 was less than rates measured for Aroclors 1242 and 1248.

Similar results were obtained when sediments obtained from Lake Hartwell, South Carolina, were evaluated (Pakdeesusuk 2003). These sediments contained primarily Aroclors 1016 and 1254. These sediments contained microbial communities that were able to anaerobically dechlorinate the PCBs. The microbial communities dechlorinated the hexachlorobiphenyl to a pentachlorobiphenyl, and the pentachlorobiphenyl to a tetrachlorobiphenyl, and so on. The concentration of PCBs shifted from predominantly more chlorinated to less chlorinated PCBs as biodegradation proceeded. These results were confirmed by other investigators (Furukawa 2008).

Discussions of the microbial communities that have been shown to be able to dechlorinate Aroclor 1260 have been published (Furukawa 2008, Field 2008, Bedard 2008, Bedard 2007). These microbial communities were obtained from the Housatonic River near Lenox, Massachusetts, and from other sediments containing PCBs.

PCB-dechlorinating microorganisms can be present in PCB-free environments (Abramowicz 1995). This suggests that PCB-dechlorinating activity may be the result of a common reductive pathway present in many different anaerobic microbes located throughout the environment.

The microbial strain dehalococcoides (Dhc) is capable of dechlorinating chlorinated ethenes in reducing environments and has also been identified as an anaerobic dechlorinator of PCBs (Bedard 2007). Dhc strains appear very commonly throughout the United States. In one study, the Dhc strains were identified at all 26 locations from unique sites across the country using biotraps (Ogles et al. 2008). Another study conducted at 10 Air Force Bases (AFBs) identified Dhc in 14 of the 16 wells under anaerobic conditions (Lu 2006). The

Dhc strain was also identified in five wells at Tinker and Dover AFBs under aerobic conditions. Another study of 24 sites across the country and Europe contained naturally occurring Dhc at 21 of the sites (Hendrickson et al. 2002). These results suggest the Dhc strain is common in nearly all sites, includes a variety of geologic settings and geochemical conditions, and can potentially survive in non-favorable conditions.

PCB dechlorination in sediments probably results from the action of multiple distinct PCB-dechlorinating populations interacting with non-dechlorinating microorganisms in syntropic communities (Wu 1996).

Cometabolic biodegradation has been used for over 20 years on some of the most recalcitrant compounds known, including chlorinated ethenes, PAHs, halogenated aliphatics and aromatics, explosives, dioxanes, PCBs, and pesticides (Hazen 2009).

Fungi strains have been shown to be very effective in degrading both less chlorinated and more highly chlorinated PCBs through cometabolic processes (Strand 2008). These fungi can degrade highly chlorinated PCBs but only at low concentrations (less than 500 µg/L), while aerobic bacteria are able to degrade PCBs at concentrations up to 10 mg/L.

F.3.4 Biodegradation in the Oil House and Wastewater Treatment Areas

The free-phase and high dissolved-phase petroleum concentrations within the Oil House and Wastewater Treatment areas correspond very closely to the negative ORP values in these areas. A negative ORP is the most reliable indicator of favorable conditions for anaerobic degradation and dechlorination processes. These ORP values increase a short distance from the source area as the groundwater flux containing high DO concentrations continues to provide electron acceptors to the area (refer to Figure F-2). As the ORP values increase, anoxic conditions make anaerobic processes less favorable, until positive ORP conditions and other indicators (e.g., DO, nitrates) continue to increase, and eventually only aerobic degradation processes are possible.

PCBs originating from the center of the Oil House area could be dechlorinated under anaerobic conditions, as the ORP values in this area are negative. As mentioned above, mono- and dichlorobiphenyls are more available for biodegradation and are easier to dechlorinate than the trichlorobiphenyls and more chlorinated PCBs. This should result in a higher ratio of trichlorobiphenyls and more highly chlorinated PCBs compared to mono- and dichlorobiphenyls in this area.

As PCBs migrate toward the Wastewater Treatment area, ORP values increase and become positive. This aerobic zone would provide a favorable environment for aerobic degradation through several processes. If aerobic biodegradation of PCBs is occurring in this area at concentrations in the parts per trillion (ppt) range, the byproduct (benzoate) concentrations would not be detected using current PAH analysis methods and would be difficult to verify.

Aerobic processes are also much more effective in destroying mono-, di-, and trichlorobiphenyls than more highly chlorinated PCBs, which would result in increased ratios of more highly chlorinated PCBs compared to less chlorinated PCBs detected in groundwater.

High concentrations of PCBs were detected only in areas of negative ORP or anaerobic conditions within the Oil House area, and were not detected at any downgradient locations that had positive ORPs. Based on the groundwater flux through the area, it is not likely that the aerobes would be capable of providing sufficient degradation to both less chlorinated and more chlorinated PCBs in a distance less than a few hundred feet. Since biodegradation of highly chlorinated PCBs is relatively slow, it is reasonable to assume that a much longer PCB plume, similar to the plume in the Remelt area would be created. Since there is no evidence that this plume exists, it suggests that the PCBs are highly sorbed to the smear zone soil and FPP in the Oil House area, are not bioavailable, and are not migrating beyond the limited area of a few wells where FPP has been encountered, or are being degraded as the PCBs partition to the aqueous phase. These FPP well locations are also consistent with the extent of negative ORPs in the presence of FPP.

F.3.5 Biodegradation/Chemical Degradation in the Remelt Groundwater Plume

PCBs are located on the upgradient edge of the Remelt area within an aerobic portion of the site as indicated by positive ORP values. If biodegradation of PCBs is occurring in this area, it is through aerobic processes for the first 500 to 600 feet of downgradient migration. PCBs originating from the upgradient edge of the Remelt area could be degraded through a variety of aerobic degradation processes, such as by 2,3-oxygenase and metacleavage, as the ORP values in this area are positive (Strand 2008). As mentioned above, mono- and dichlorobiphenyls are more available for biodegradation and are easier to degrade than the trichlorobiphenyls and more chlorinated PCBs. This would result in trichlorobiphenyls and more highly chlorinated PCB concentrations remaining in the plume in this area. These more highly chlorinated PCBs would also tend to adsorb to the soil matrix, retarding downgradient migration.

There is some unsupported indication that the PCB-containing hydraulic oil used at the Kaiser Facility may have been a Monsanto product trademarked as Pydraul. There were many formulations of this hydraulic oil, and it is not known which one(s) may have been used at the Kaiser Facility. In general, Pydraul formulations consisted of various mixtures of PCB Aroclors and organophosphate carriers. If Pydraul is a carrier for PCBs within the Remelt area, this would reduce the bioavailability of PCBs to microbes, since PCBs would preferentially partition to the oil phase, rather than dissolve in the aqueous phase (Jonker 2006, Zwiernik 1999).

Within the Remelt building, the ORP values can become slightly negative, and dissolved oxygen concentrations are lower at wells RM-MW-14S and RM-MW-17S. At this point, aerobic processes slow, and anoxic or anaerobic processes may become more favorable. This area may be classified as anoxic (containing both characteristics of aerobic and anaerobic conditions), based on variations in ORP throughout the PCB plume. This can be beneficial, as both aerobes and anaerobes are capable of degrading hydrocarbons and PCBs through a variety of processes in these conditions. The anoxic conditions persist for approximately 1,600 feet downgradient of HL-MW-23S. During the migration of PCBs in the anoxic zone, concentrations reduce from approximately 2,000 ppt to less than 250 ppt. This may be the result of a combination of anaerobic, aerobic, and cometabolic processes, and other physical and chemical processes that could reduce PCB concentrations to PCULs over time.

At these low concentrations, PCBs are not likely to provide a large enough energy source to sustain a population of dechlorinators. However, it is possible that microbes are producing enzymes during the metabolism of other hydrocarbons that are capable of degrading PCBs through cometabolic processes (Hazen 2009). These species can release enzymes that neither benefit from, nor rely on the PCBs for energy, so a minimum concentration of PCBs is not required for this degradation pathway. Certain fungi have been identified as cometabolic PCB degraders (Strand 2008) but require aerobic or anoxic conditions.

As mentioned above, mono- and di-chlorinated biphenyls are both more available for biodegradation and are easier to degrade than trichlorobiphenyls and more chlorinated PCBs. This should result in increased ratios of trichlorobiphenyls and more highly chlorinated PCBs in this area. Reviewing the data at downgradient locations (MW-17S, MW-12A, HL-MW-23S, HL-MW-30S, and HL-MW-32S), the data clearly show that the trichlorobiphenyls and more highly chlorinated biphenyls account for more than 90 percent of the entire remaining PCB mass in the groundwater samples.

The aquifer becomes highly aerobic (ORP greater than 100 mV) in the remaining few hundred feet to the Spokane River. It is likely that several aerobic degradation processes could be occurring in this location. Because of the extremely low concentrations remaining in this area, it is likely these processes would be limited to cometabolism, as the amount of energy available from PCB concentrations could not in itself sustain an anaerobic dechlorinating microbial population.

Based on the short distance from the downgradient wells to the river, it is likely that other physical and chemical processes are also responsible for the fate of PCBs in this area. These may include increased dispersion and adsorption of the remaining PCBs. Other immobilization processes affecting PCBs may be occurring in this area, such as catalytic effects from soil minerals, as discussed above.

The reduction of PCB concentrations along the length of the plume is likely a result of several biological, physical, and chemical processes occurring at the Facility. Since there is no continuing source for PCBs, it is also likely that these concentrations will continue to decrease with time.

F.4 REFERENCES FOR APPENDIX F

Abraham, W., et al., 2002. Polychlorinated Biphenyl-Degrading Microbial Communities in Soils and Sediments. Current Opinion in Microbiology, 5:246-253.

Abramowicz, D.A., 1995. Aerobic and Anaerobic PCB Biodegradation in the Environment. Environ. Health Perspectives, 103:97-99.

Barriault, D., et al., 1998. Degradation of Polychlorinated Biphenyls Metabolites by Naphthalene-Catabolizing Enzymes. App. and Environ. Microbiology, 64:4637-4642.

Bedard, D.L., et al., 2007. The *Dehalococcoides* Population in Sediment-Free Mixed Cultures Metabolically Dechlorinates the Commercial Polychlorinated Biphenyl Mixture Aroclor 1260. App. and Environ. Microbiology, 73:2513-2521.

Bedard, D.L., 2008. A Case Study for Microbial Biodegradation: Anaerobic Bacterial Reductive Dechlorination of Polychlorinated Biphenyls-from Sediment to Defined Medium. Annual Rev. Microbiol.. 62:253-270.

Borja, J., et al., 2005. Polychlorinated Biphenyls and Their Biodegradation. Process Biochemistry, 40:1999-2013.

Clark, R.R., et al., 1979. Degradation of Polychlorinated Biphenyls by Mixed Microbial Cultures. App. and Environ. Microbiology, 37:680-685.

Di Toro, S., et al., 2006. Intensification of The Aerobic Bioremediation of an Actual Site Soil Historically Contaminated by PCBs through Bioaugmentation with Non-Acclimated, Complex Source of Microorganisms. Microbial Cell Factories, 5:1.

Ecology, 2011. Spokane River PCB Source Assessment 2003–2007. Toxics Studies Unit, Environmental Assessment Program, Washington State Department of Ecology. Publication No. 11-03-013. April 2011.

Field, J.A., and R. Sierra-Alvarez, 2008. Microbial Transformation and Degradation of Polychlorinated Biphenyls. Environmental Pollution, 155:1-12.

Furukawa, K., and H. Fujihara, 2008. Microbial Degradation of Polychlorinated Biphenyls: Biochemical and Molecular Features. J. of Bioscience and Bioengineering, 5:433-449.

Furukawa, K., et al., 1978. Effect of Chlorine Substitution on the Biodegradability of Polychlorinated Biphenyls. App. and Environ. Microbiology, 35:223-227.

Furukawa, K., et al., 1979. Effect of Chlorine Substitution on the Bacterial Metabolism of Various Polychlorinated Biphenyls. App. and Environ. Microbiology, 38:301-310.

Hart Crowser, 2012a. Final Site-Wide Groundwater Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Hart Crowser, 2012b. Final Site-Wide Soil Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Hazen, T.C., 2006. Cometabolic Bioremediation. Lawrence Berkeley National Laboratory. U.S. DOE Contract No. DE-AC02-05CH11231.

Head, I.M., 1998. Bioremediation: Towards a Credible Technology. Microbiology, 144:599-608.

Iwamoto, T., and M. Nasu, 2001. Current Bioremediation Practice and Perspective. J. of Bioscience and Bioeng. 92:1-8.

Jonker, M.T.O., and A. Barendregt, 2006. Oil is a Sedimentary Supersorbent for Polychlorinated Biphenyls. Environ. Sci. and Technology, 40:3829-3835.

LaJoie, C.A., et al., 1994. Cometabolic Oxidation of Polychlorinated Biphenyls in Soil with a Surfactant-Based Field Application Vector. App. and Environ. Microbiology, 60:2826-2833.

Leifer, A., et al., 1983. Environmental Transport and Transformation of Polychlorinated Biphenyls. EPA 560/5-83-025. December 1983.

Mikszewski, A., 2004. Emerging Technologies for the In-situ Remediation of PCB-Contaminated Soils and Sediments: Bioremediation and Nanoscale Zero-Valent Iron. EPA OSWER.

Mohn, W.W., et al., 1997. Aerobic Biodegradation of Biphenyl and Polychlorinated Biphenyl by Arctic Soil Microorganisms. App. and Environ. Microbiology, 63:3378-3384.

Pakdeesusuk, U., et al., 2003. Reductive Dechlorination of Polychlorinated Biphenyls in Sediment from the Twelve Mile Creek Arm of Lake Hartwell, South Carolina, USA. Environ. Tox. And Chemistry. 22:1214-1220.

Pieper, D.H., 2005. Aerobic Degradation of Polychlorinated Biphenyls. Appl. Microbiol. Biotechnol., 67:170-191.

Pieper, D.H., and M. Seeger, 2008. Bacterial Metabolism of Polychlorinated Biphenyls. J Mol. Microbiol. Biotechnology, 15:121-138.

Quensen, J.F., et al., 1990. Dechlorination of Four Commercial Polychlorinated Biphenal Mixtures (Aroclors) by Anaerobic Microorganisms from Sediment. App. and Environ. Microbiology, 56:2360-2369.

Renner, R., 1998. Natural Remediation of DDT, PCBs Debated. Environ. Sci. and Technology, 32:360A-363A.

Rodenburg, L.A., et al., 2010. Evidence of Widespread Dechlorination of Polychlorinated Biphenyls in Groundwater, Landfills, and Wastewater Collection Systems. Environ. Sci. and Technology, 44:7534-7540.

Van Dort, H.M., and D.L. Bedard, 1991. Reductive *ortho* and *meta* Dechlorination of a Polychlorinated Biphenyl Congener by Anaerobic Microorganisms. App. and Environ. Microbiology, 57:1576-1578.

Wu, Q,, et al., 1996. Influence of Incubation Temperature on the Microbial Reductive Dechlorination of 2,3,4,6-Tetrachlorobiphenyl in Two Freshwater Sediments. App. and Environ. Microbiology, 62:4174-4179.

Zwiernik, M.J., et al., 1999. Residual Petroleum in Sediments Reduces the Bioavailability and Rate of Reductive Dechlorination of Aroclor 1242. Environ. Sci. and Technology, 33:3574-3578.

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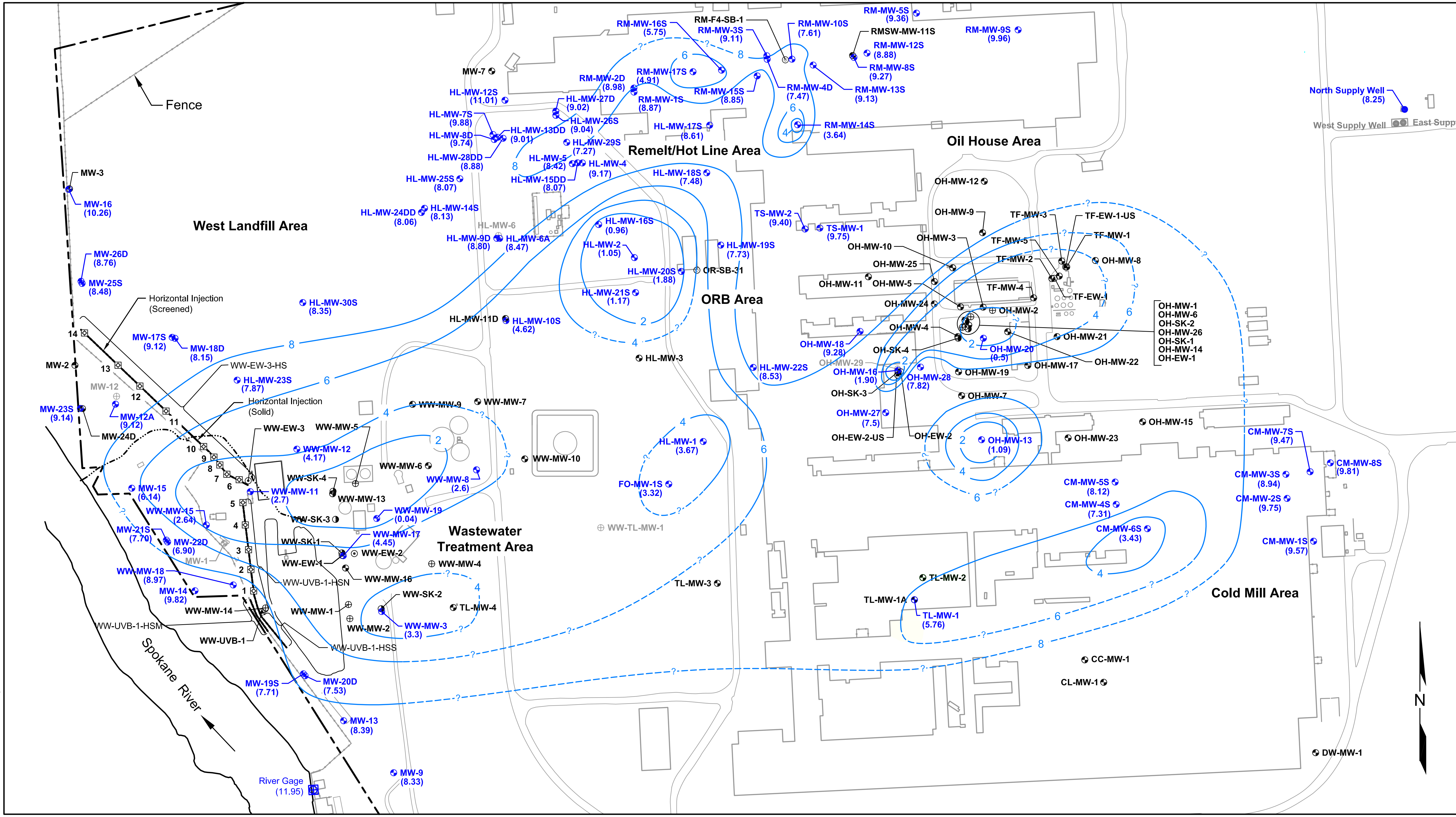
Dissolved Oxygen Concentrations in Groundwater - Most Recently Measured



Exploration Location and Number

OH-EW-1	Extraction Well	OH-SK-1	Skimming Well	West Supply Well	Backup Supply Well
OH-MW-03	Monitoring Well	TF-EW-1-US	Upper Screen Well	(3.3)	Dissolved Oxygen Concentration in mg/L
TL-MW-3	Abandoned Monitoring Well	North Supply Well	Supply Well	— 6 —	Dissolved Oxygen Concentration Contour in mg/L

0 300 600

Scale in Feet

HARTCROWSER

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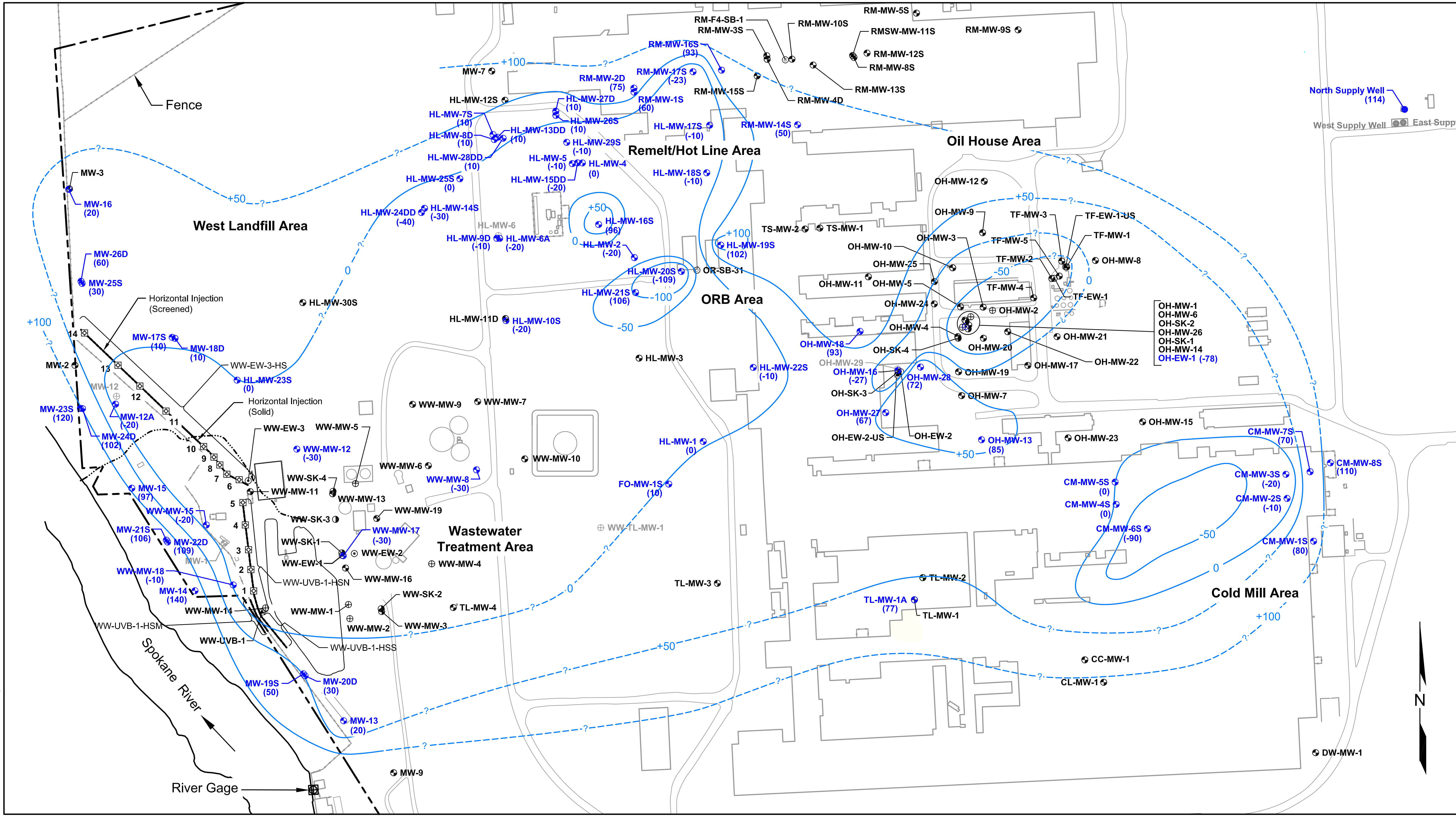
Figure F-1

Oxidation-Reduction Potential in Groundwater - Most Recently Measured



Exploration Location and Number

OH-EW-1 Extraction Well

OH-MW-03 Monitoring Well

TL-MW-3 Abandoned Monitoring Well

OH-SK-1 Skimming Well

TF-EW-1-US Upper Screen Well

North Supply Well Supply Well

West Supply Well Backup Supply Well

(10) ORP Reading in Millivolts

+50 ORP Reading Contour in Millivolts

0 300 600

Scale in Feet

HARTCROWSER

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Figure F-2

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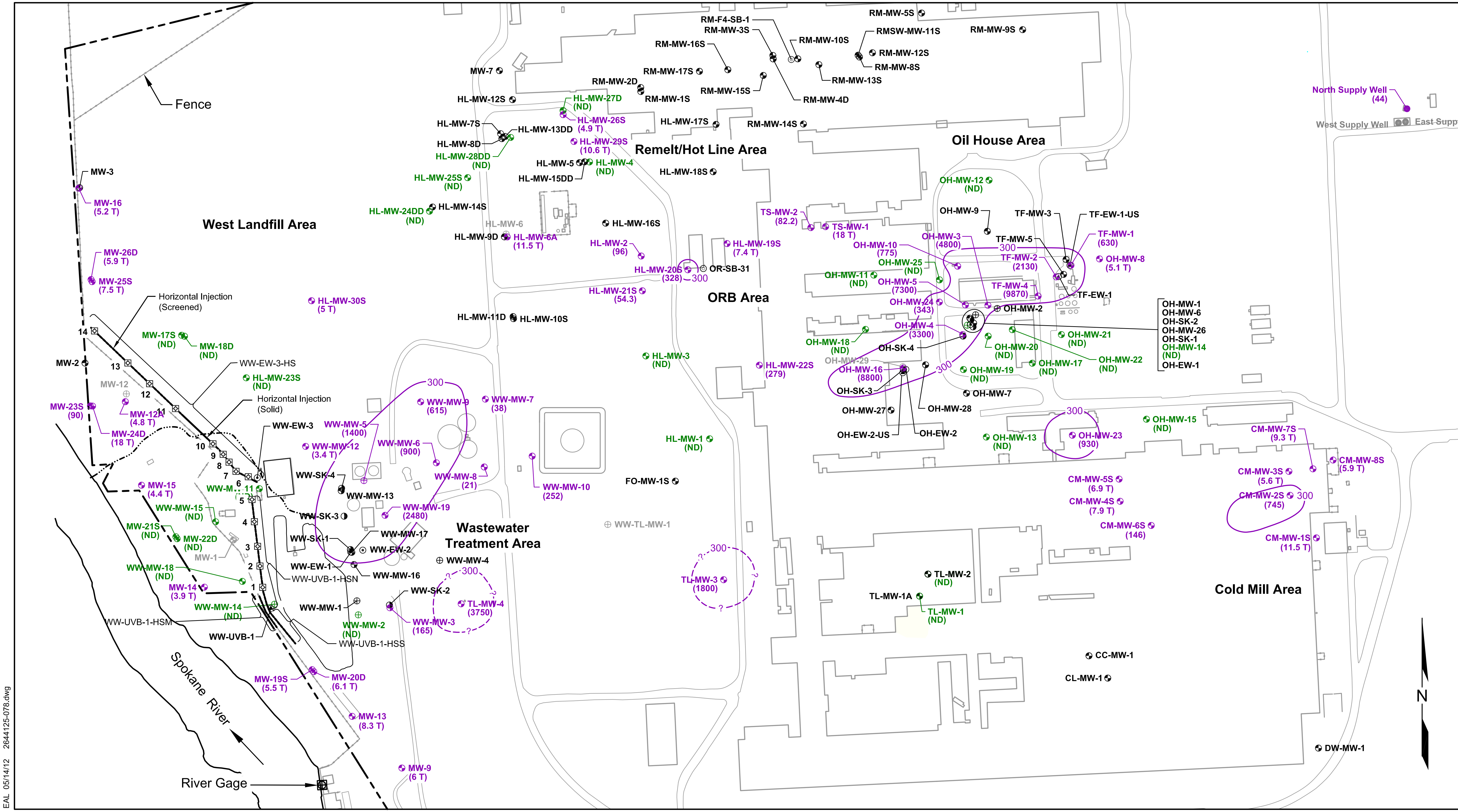
Iron Concentrations in Groundwater - Most Recently Measured



Exploration Location and Number

OH-EW-1	Extraction Well	OH-SK-1	Skimming Well	West Supply Well	Backup Supply Well
OH-MW-03	Monitoring Well	TF-EW-1-US	Upper Screen Well	(3.0)	Iron Concentration in ug/L
TL-MW-3	Abandoned Monitoring Well	North Supply Well	Supply Well	T	Value between the MDL and MRL

J Estimated Value

(ND) Not Detected

—300— Iron Concentration Contour in ug/L (SL/CUL)

0 300 600

Scale in Feet

HARTCROWSER

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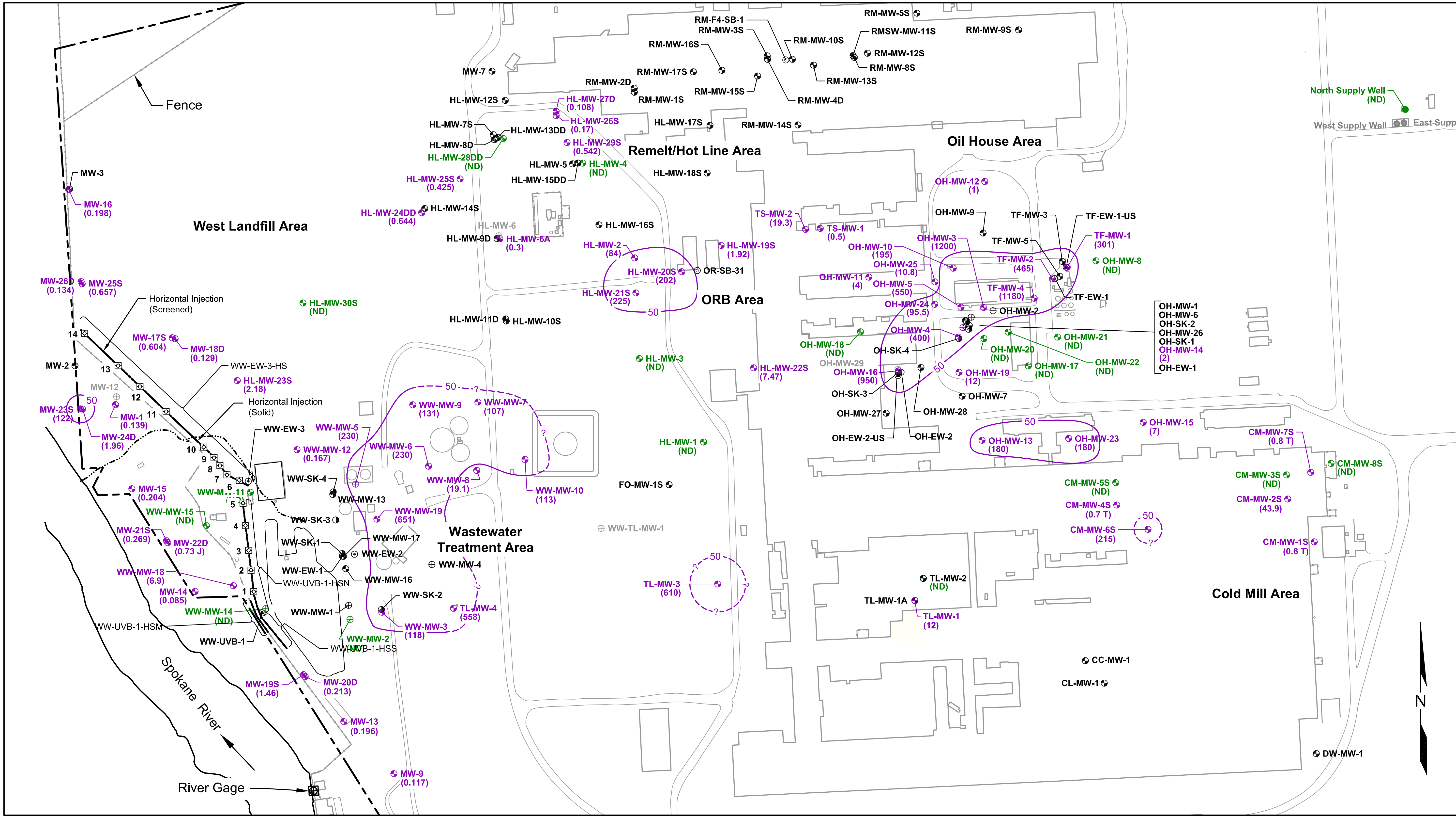
Figure F-3

Manganese Concentrations in Groundwater - Most Recently Measured



Exploration Location and Number

OH-EW-1	Extraction Well	OH-SK-1	Skimming Well	West Supply Well	Backup Supply Well	J	Estimated Value
OH-MW-03	Monitoring Well	TF-EW-1-US	Upper Screen Well	(3.0)	Manganese Concentration in µg/L	(ND)	Not Detected
TL-MW-3	Abandoned Monitoring Well	North Supply Well	Supply Well	T	Value between the MDL and MRL	—50—	Manganese Concentration Contour in µg/L (SL/CUL)

0 300 600
Scale in Feet

HARTCROWSER

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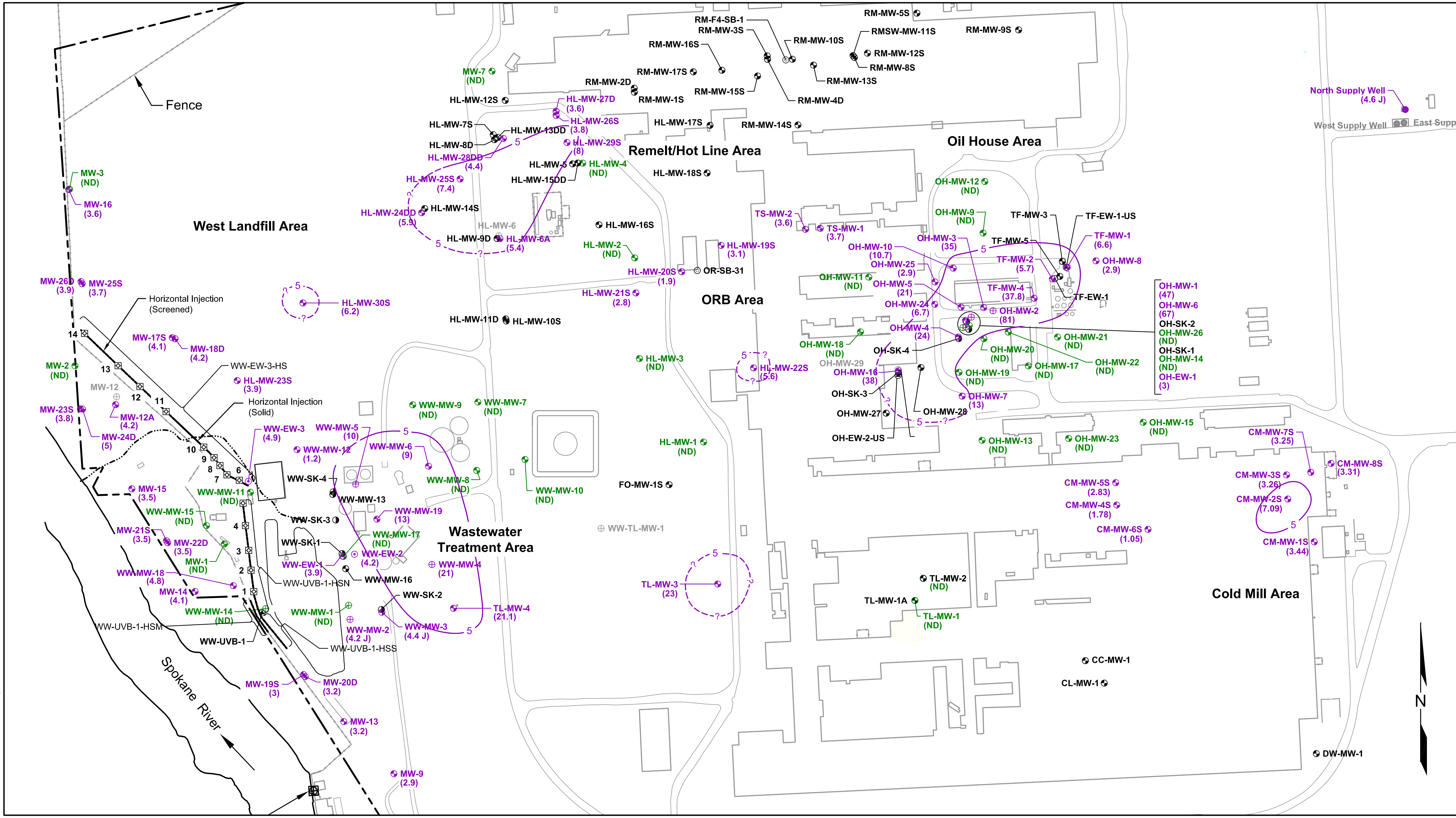
Figure F-4

Arsenic Concentrations in Groundwater - Most Recently Measured



Exploration Location and Number

OH-EW-1 Extraction Well	OH-SK-1 Skimming Well	West Supply Well Backup Supply Well
OH-MW-03 Monitoring Well	TF-EW-1-US Upper Screen Well	(3.0) Arsenic Concentration in µg/L
TL-MW-3 Abandoned Monitoring Well	North Supply Well Supply Well	J Estimated Value

(ND) Not Detected

— 5 — Arsenic Concentration Contour in µg/L (SL/CUL)

0 300 600
Scale in Feet

HARTCROWSER
2644-125 5/12
Figure F-5

APPENDIX G
IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CONTENTS

TABLES

APPENDIX G
IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This appendix identifies and discusses potential applicable or relevant and appropriate requirements (ARARs) to be used in assessing and implementing remedial actions at the Kaiser Facility. Specific potential requirements pertaining to waste management, remediation of contaminated media, and surface water protection are presented. The potential ARARs focus on federal or state statutes, regulations, criteria, and guidelines. The specific types of potential ARARs evaluated include contaminant-, location-, and action-specific ARARs. Each type of ARAR is evaluated for the Kaiser Facility and discussed in the sections that follow.

Contaminant-Specific ARARs are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical contaminant values that are generally recognized by the regulatory agencies as allowable to protect human health and the environment.

Action-Specific ARARs are pertinent to particular remediation methods and technologies, and to actions conducted to support cleanup.

Location-Specific ARARs are restrictions placed on the presence of hazardous substances, or the conduct of activities, solely because they occur in specific locations.

In general, only the substantive requirements of ARARs are applied to Model Toxics Control Act (MTCA) cleanup sites being conducted under a legally binding agreement with the Washington State Department of Ecology (Ecology) (WAC 173-340-710[9][b]). Thus, cleanup actions under a formal agreement with Ecology are exempt from the administrative and procedural requirements specified in state and federal laws. This exemption also applies to permits or approvals required by local governments.

G.1 CONTAMINANT-SPECIFIC ARARS

A contaminant-specific requirement sets concentration limits in various environmental media for specific hazardous substances, pollutants, or contaminants. The potential federal and state contaminant-specific ARARs for the Kaiser Facility are summarized below.

The determination of contaminant-specific ARARs for the Facility was implemented beginning with the development of constituents of potential concern (COPCs), constituents of concern (COCs), and screening levels (SLs) in Section 1 of the Final Feasibility Study Technical Memorandum (FSTM) (Hart Crowser 2012c) (see Tables G-1 and G-2). Preliminary cleanup levels (PCULs) for the soil and groundwater COCs were subsequently determined by Ecology during preparation of this FS (Ecology 2010a and 2010b) (see Tables 2-1 and 4-1 in the main body of this FS). Cleanup levels and points of compliance (POCs) will be finalized in the Cleanup Action Plan (CAP) prepared by Ecology.

COPCs were identified in the Final Groundwater RI (Hart Crowser 2012a), the Final Soil RI (Hart Crowser 2012b), and the Final Human Health and Ecological Risk Assessments (HHERA) (Pioneer 2012). See Section 1 of the FSTM for detailed discussion of the identification of COPCs and the specific criteria used to evaluate COPCs. In general, the COPCs were identified by (1) comparison to background concentrations; (2) evaluation of the frequency of detection; and (3) the risk-based screening summarized in the Final Groundwater RI, the Final Soil RI, and the Final HHERA.

SLs for soil and groundwater at the Kaiser Facility were established following MTCA regulations. The establishment of SLs for the COPCs in each environmental medium included consideration of site-specific conditions, such as land use, and comparison of the risk-based MTCA SLs with other chemical-specific ARARs. The SLs for soil and groundwater are summarized in Tables G-1 and G-2, respectively.

G.1.1 Constituents of Concern and Screening Levels for Soil

G.1.1.1 Screening Levels for Soil

Screening levels for soil were derived under MTCA by considering the following pathways:

- Protection of human health during the ingestion of or direct exposure to the upper 15 feet of the soil horizon (refer to the HHERA [Pioneer 2012]);
- Protection of groundwater resources based on potential leaching of chemicals from soil to groundwater (refer to the Final Soil RI [Hart Crowser 2012b]);
- Protection of workplace air (VOCs only); and

- Protection of wildlife during the ingestion of soil or the ingestion of COPCs that have accumulated in the food that they consume.

The site-specific information that was relevant in the development of the SLs for soil is described in detail in Section 1.2.1 of the FSTM. Table G-1 lists the COPCs for soil at the Facility and their risk-based MTCA screening levels that were derived based on one of the following pathways:

- **Ingestion/Direct Contact with Soil.** Concentrations were derived using the procedures and default exposure assumptions for industrial sites as defined in WAC 173-340-745.

- **Protection of Wildlife.** The HHERA (Pioneer 2012) determined that the risk to wildlife was below the ecological risk criteria that were established.

- **Protection of Groundwater.** Concentrations were derived using the Fixed Parameter 3-Phase Partitioning model (WAC 173-340-747[4] and MTCA Method B CULs, or limitations established by the Clean Water Act [CWA] or Maximum Contaminant Levels [MCLs] established by the Safe Drinking Water Act [SDWA], whichever was lower for groundwater). This pathway was determined to have the most impact on the SLs established for soil at the Facility.

- **Protection of Workplace Air.** Potential adverse effects caused by the inhalation of soil gas vapors were evaluated and compared to Washington State Industrial Safety and Health Act (WISHA) permissible exposure levels (PELs) in the HHERA (Pioneer 2012, Section 7.8) and to MTCA Method B ambient air CULs.

Adjustment of the soil CUL may be necessary based on natural or area background, multiple exposure pathways, or multiple constituents per WAC 173-340-740(5) (unrestricted site use) or WAC 173-340-745(6) (industrial site use).

G.1.1.2 Constituents of Concern for Soil

The COPCs that were identified for soil are listed in Table G-1. When the concentration of a COPC exceeded the SL, it was then further evaluated to determine whether it is a COC. Each of the COPCs that exceeded SLs was examined to determine whether it was contributing to an actual risk to human health and the environment and whether it should be carried forward as a soil COC.

The following COCs were identified for soil for all or portions of the Kaiser Facility:

- Diesel and heavy oil;
- Gasoline and Stoddard solvent;
- PCBs (total);
- cPAHs;
- Metals causing potential human or ecological health risk (arsenic, chromium, and lead); and
- Metals causing potential adverse secondary (aesthetic) effects to groundwater (iron and manganese).

G.1.1.3 Point of Compliance for Soil

The standard point of compliance (POC) for soil under MTCA is defined as throughout the Facility for protection of groundwater and workplace air. The POC for soil cleanup levels based on human exposure through direct contact (WAC 173-340-740[6][b,c,d]) and wildlife exposure through the ingestion of Facility soil is from the ground surface to 15 feet below ground surface (bgs).

G.1.2 Constituents of Concern and Screening Levels for Groundwater

G.1.2.1 Screening Levels for Groundwater

The maximum beneficial uses of groundwater in the alluvial aquifer at the Kaiser Facility are as a potential drinking water source and as a discharge to the Spokane River; therefore, cleanup levels for groundwater are derived under MTCA by considering the following pathways:

- Humans, flora, or fauna consuming groundwater from a potential well installed within the area of groundwater contamination; and

- Humans, flora, or fauna exposed to surface water downgradient of the Facility if COCs were to reach the Spokane River.

Protection of Drinking Water

MTCA groundwater cleanup standards are defined in WAC 173-340-720. The standards must be at least as protective as the requirements established by the following state and federal statutes and regulations:

- Federal Safe Drinking Water Act MCL (40 CFR part 141);

- State Safe Drinking Water MCLs (WAC 246-290-310);

- Federal Safe Drinking Water Act secondary MCLs for non-carcinogens based on aesthetic effects(40 CFR Part 143) to the extent that Ecology has established human health or environmental protection based standards for the constituents;

- MTCA Methods A and B (WAC 173-340-720[3,4]); and

- MTCA Surface Water Standards (WAC 173-340-730), unless it can be shown that the COPCs are not likely to reach surface water. (Some PCBs, free phase petroleum, iron, manganese, and arsenic may not reach the Spokane River via groundwater, according to the Final Groundwater RI, Section 6 [Hart Crowser 2012a].)

In addition, for those COPCs for which there is no value in MTCA Table 720-1, or in applicable state or federal laws, the CUL cannot be higher than the calculated values using Equations 720-1 (non-carcinogens) and 720-2 (carcinogens). Adjustments to the total risk are required when there are multiple pathways or multiple constituents per WAC 173-340-720(7)(a). CULs established under state and federal law may also need to be adjusted downward if they exceed a hazard quotient of 1 (non-carcinogens) or an excess cancer risk of 1:100,000 per WAC 173-340-720(7)(b). Additional adjustments can be made to CULs based on state-wide or area background concentrations (e.g., some metals and ubiquitous organics).

Protection of Surface Water

Surface water SLs at the Kaiser Facility were established based on consideration of the following regulatory criteria:

- EPA National Recommended Water Quality Criteria (National Toxics Rule) (40 CFR Part 131) for protection of aquatic species in fresh water;

- EPA National Recommended Water Quality Criteria (National Toxics Rule) (40 CFR Part 131) for protection of human health through the consumption of aquatic species;

- Washington Surface Water Quality Standards (Chapter 173-201A WAC);

- Clean Water Act Section 304 Standards for Freshwater Human Health and Chronic Aquatic Life; and

- MTCA Method B cleanup criteria for the protection of human health through the consumption of aquatic species (WAC 173-340-730[3]).

Adjustment of the surface water CULs may be necessary based on natural or area background, multiple exposure pathways, or multiple constituents per WAC 173-340-730(5).

Protection of Workplace Air

Groundwater at the Kaiser Facility is more than 70 feet bgs, and the occurrence of volatile constituents in groundwater is so low (refer to Final Groundwater RI, Section 5.2 [Hart Crowser 2012a]) that protection of the groundwater to air pathway was not considered for volatile organic compounds (VOCs).

G.1.2.2 Constituents of Concern for Groundwater

The COPCs that were identified for groundwater are listed in Table G-2. When the concentration of a COPC exceeded the SL, it was then evaluated to determine whether it is a COC. Each of the COPCs that exceeded SLs was examined to determine whether it was contributing to an actual risk to human health and the environment and whether it should it should be carried forward as a groundwater COC.

The following COCs were identified for groundwater for the Kaiser Facility:

- Diesel and heavy oil;
- Gasoline and Stoddard solvent (select areas of the Facility);
- PCBs (total);
- cPAHs; and
- Metals (arsenic, iron, and manganese).

G.1.3 Preliminary Cleanup Levels Established by Ecology

The remediation alternatives in the FS are developed for the areas of concern (AOCs) that are defined for each COC. The AOCs for each near-surface soil COC at the Facility were defined in Section 2 of the FSTM, and are consolidated on Figure 2-3 of this FS. These AOCs were developed using the SLs that were originally identified in Section 1 of the FSTM. During preparation of the FS, Ecology developed preliminary cleanup levels (PCULs) for unsaturated soil, saturated soil, and groundwater at the Kaiser Facility. Soil SLs and PCULs for the Facility are compared in Table 2-1 in this FS, and those for groundwater are compared in Table 4-1.

MTCA authorizes Ecology to adopt standards for cleanup actions at sites impacted by hazardous substances. Chapter 173-340 WAC (MTCA Cleanup Regulation) describes a process for developing and selecting cleanup standards for environmental media (e.g., groundwater, surface water), and these standards are considered potential ARARs. Under the MTCA regulations, cleanup standards may be established by one of three methods:

- Method A may be used if a routine cleanup action, as defined in WAC 173-340-200, is being conducted at the site or relatively few hazardous substances are involved for which Method A cleanup standards have been specified in the regulation. This method is designed to be protective for unrestricted site use (e.g., residential sites).

- Under Method B, an excess cancer risk level of 10^{-6} and a hazard quotient of 1 (non-carcinogen) are established, and risk-based calculations of cleanup levels are developed for individual constituents and pathways present at the site using residential use assumptions.

- Method C industrial soil cleanup levels represent concentrations that are protective of human health and the environment based on industrial site use assumptions. Method C industrial soil cleanup levels may be established for qualifying industrial sites. The Kaiser Trentwood Facility qualifies for the use of these industrial soil cleanup levels. However, soil cleanup levels at industrial sites must also be protective of other environmental media (e.g., groundwater, surface water) and exposure pathways. For media other than soil (e.g., surface water and groundwater), Method C may be used in certain instances (see WAC 173-340-706[1]). In such cases where Method C is approved by Ecology, the CULs must meet applicable state and federal laws and be protective of human health and the environment. Generally, Method C is used to establish Remediation Levels or when Methods A or B cannot be achieved.

Because the Kaiser Facility qualifies as an industrial site per WAC 173-340-745(1), development of soil cleanup levels included an evaluation of industrial soil cleanup levels. The unsaturated and saturated soil PCULs were developed using standard MTCA soil Method C criteria, which incorporated the preliminary groundwater cleanup levels that were developed. Groundwater PCULs were established using standard MTCA Method B criteria, which include consideration of criteria protective of both drinking water and surface water because site groundwater discharges into the Spokane River.

During the development of the PCULs for soil, chromium and lead were eliminated from consideration because of the low detection frequencies of these substances (Ecology 2010b). Therefore, PCULs were not developed for these COCs.

Groundwater and soil PCULs were developed for both a standard POC and conditional POC (Ecology 2010a). If a conditional POC is granted, cleanup levels for groundwater COCs that are based on the protection of surface water should be met at the point or points where groundwater discharges into surface water. Concentrations for groundwater COCs elsewhere throughout the Facility may exceed surface water standards but would be required to meet drinking water standards, which are typically higher concentrations than surface water standards. (For example, the surface water standard for total PCBs is 6.4×10^{-5} µg/L, but the drinking water standard is 0.22 µg/L [see Table 4-1].)

Similarly, if a conditional POC is granted, soil COC concentrations would have to be protective of surface water at or near the vicinity of the point of discharge to surface water; however, elsewhere throughout soil at the Facility, COC concentrations should not exceed the concentrations that are protective of drinking water. The decision to grant a conditional POC will be made in the CAP, in which final cleanup standards (i.e., cleanup levels and points at which these levels must be met) for the Facility will be determined.

The selected remedy for the Facility could leave hazardous substances behind in excess of cleanup levels. Then the cleanup action would be considered to comply with cleanup standards provided that the remedy (e.g., containment) is permanent to the maximum extent practicable using the procedures in WAC 173-340-360; that a compliance monitoring program demonstrates the long-term integrity of the containment system; and that institutional controls are in place (WAC 173-340-740 [6][f]).

G.2 ACTION-SPECIFIC REQUIREMENTS

Action-specific ARARs are requirements that may need to be satisfied during the performance of specific remedial actions because they prescribe how certain activities (e.g., treatment and disposal practices, media monitoring programs) must occur. Indeed, several of the potential contaminant- and location-specific ARARs discussed in this appendix also include provisions for potential action-specific ARARs to be applied once a remedial action is selected. Typically, action-specific ARARs are not fully defined until a preferred response action has been selected and the corresponding remedial action can be more completely refined. However, preliminary consideration of the range of potential action-specific ARARs may help focus the process of selecting a preferred response action and remedial action alternatives. Table G-3 presents the significant potential action-specific ARARs that may apply to the various response actions being considered for the Kaiser Facility. Brief summaries of the requirements associated with these potential action-specific ARARs are provided below.

G.2.1 Soil Requirements

PCB-impacted soil at low concentrations may be left in place under the Toxic Substances Control Act (TSCA). However, if PCB-impacted soil is left in place, remediation requirements pertaining to institutional controls, capping, and cleanup must be met, as discussed in Section 2.3 of the FSTM (Hart Crowser 2012c) and in Section 2.1.2.2 of this FS. These requirements depend further on future land use of the AOC.

G.2.2 Groundwater Requirements

Chapter 90.48 RCW, the Washington State Water Pollution Control Act, establishes programs for regulating and controlling pollutants in waters of the State of Washington, which includes groundwater. Among other mandates, the law requires use of all known, available, and reasonable treatment technologies (AKART) for treating pollutants prior to discharge to groundwater. Implementing regulations appear principally in Chapter 173-216 WAC (State Waste Discharge Permit Program). Chapter 173-218 WAC (Underground Injection Control Program) addresses underground injection of materials into the subsurface.

Remedial actions (such as pump and treat) that involve pumping water to the surface of the ground and discharge to groundwater may need to meet the substantive requirements of the State Waste Discharge Permit requirements (Chapter 173-216 WAC and Chapter 173-220 WAC). This activity may also be required to employ treatment technologies to prevent or minimize the presence of pollutants and achieve AKART prior to discharge. In addition, return of treated water that is brought to the surface and is injected into the ground may be subject to requirements of the underground injection control (UIC) program (e.g., registration of the injection well[s], removal and treatment of constituents).

If contaminated groundwater is maintained entirely under the ground and does not breach the surface of the soil, the State Waste Discharge Permit requirements would not apply. In such cases, the water remains below the ground surface and as such it does not constitute a *discharge into* groundwater (emphasis added). The use of the word "into" in the regulatory prohibition indicates that a discharge of waste materials must break the surface of the ground to constitute a "discharge ... into waters of the state." Alternatives where groundwater does not breach the surface of the soil do not fall under this program because they would move entirely underground and will not break the ground surface.

The State Waste Discharge Program requires that discharges to waters of the state be treated using AKART. If the State Waste Discharge Program applied to an action at the Kaiser Facility, it would also need to address the AKART requirement. Groundwater within the Remelt/Hotline PCB plume at the Facility presents a unique situation. PCBs are present in extremely low concentrations and there is compelling evidence that colloidal transport is a significant transport mechanism. There is no known treatment method for low concentrations of PCBs that are a mixture of dissolved and colloidal phases. Because of this unique situation, there are no known and available methods of treatment. As such, the Pollution Control Hearings Board (PCHB) specifically has stated that AKART does not authorize the use of testing to identify a treatment method, and Ecology has relied upon the PCHB's decision in its Permit Writer's Manual. Since there is no known technology to treat such low levels of PCBs consisting of both dissolved and colloidal phases, any alternative that requires treatment cannot be AKART.

In addition to not being applicable, the unique situation presented by the Remelt/Hot Line PCB plume would also cause the State Waste Discharge requirements (including AKART) to not be relevant and appropriate in that the requirements do not address problems or situations that are "sufficiently similar to those encountered at the site that their use is well suited to the particular site." For example, there is not known treatment for dilute dissolved and colloidal PCBs in water.

Similarly, groundwater that is maintained entirely under the surface is not a regulated discharge under the UIC program (Chapter 173-218 WAC). Again, it would not be discharged *into* the groundwater (emphasis added). In addition, for the UIC program to apply the system would need to meet the definition of a UIC well. Systems that do not employ screened wells or that are otherwise without perforated pipe do not meet this definition.

Installation of groundwater wells is regulated under Chapter 173-160 WAC, and these requirements are potential ARARs for any monitoring and withdrawal wells installed at the Kaiser Facility. The licensing and regulation of well contractors and operators is established under RCW 18.104 and addressed in Chapter 173-162 WAC.

G.2.3 Surface Water Requirements

Regulations adopted pursuant to the CWA under the National Pollutant Discharge Elimination System (NPDES) mandate use of best available treatment (BAT) technologies prior to discharging contaminants to surface waters. Pertinent regulations appear in 40 CFR 129.105 (specifically for PCBs) and 40 CFR Part 467 (for aluminum forming operations). Chapter 90.48 RCW also establishes programs for regulating and controlling surface water quality in Washington State. Chapters 173-216 and 173-220 WAC require application of AKART prior to discharges of pollutants to surface waters. NPDES requirements could constitute potential ARARs for remedial actions that would result in discharge of treated wastewaters to the Spokane River. Thus, associated treatment and/or pretreatment systems could be required to use BAT and/or AKART (e.g., precipitation, decanting, separation) to prevent or minimize the presence of pollutants prior to discharge.

Certain remedial actions may result in the release of total phosphorous to the Spokane River. Examples may include *in situ* bioremediation through nutrient addition to enhance biodegradation, and pump and treat systems that use phosphorous in the treatment system. Actions that result in the generation of water that contains phosphorous will be restricted if these waters are discharged to the Spokane River because of the Total Maximum Daily Load (TMDL) imposed by the State Surface Water Quality Standards (WAC 173-201A-602). Actions that result in the generation of water that contains cadmium, lead, or zinc will need to be evaluated by Ecology because of the TMDL for metals, but as long as the concentrations are less than the chronic standards described in the TMDL, restrictions are not expected.

The Spokane County Shoreline Master Plan is promulgated and authorized pursuant to Chapter 173-19 WAC, the Shoreline Management Act of 1971 – State Master Program. In keeping with the policies and objectives of the Spokane County Master Plan, remedial actions that may impact the shoreline (e.g., if a new discharge outfall must be constructed) should be designed and implemented in a manner that will minimize loss of shoreline, stabilize existing and remaining shoreline areas, and retain a property configuration that encourages water-dependent uses.

Similarly, if new outfalls, diffusers, or other discharge units will need to be constructed in conjunction with a selected remedial action (e.g., as part of a pump and treat alternative), U.S. Army Corps of Engineers requirements for construction in navigable waters (33 CFR Part 322) may be potential ARARs. In general, new discharge units (if needed) would need to avoid impacts on navigation within the Spokane River.

G.2.4 Water Rights

Water rights are required for removal and use of waters of the state. This includes groundwater under the Kaiser Facility and any water withdrawals from the Spokane River. Chapter 173-150 WAC is intended to ensure that available water sources are not exhausted and that water withdrawals do not adversely affect other water rights holders. Kaiser is currently withdrawing water from the Spokane River in addition to groundwater, as allowed under its current water right. This potential ARAR may limit the amount of groundwater that could be withdrawn under remedial action alternatives that involve extraction of groundwater for treatment.

G.2.5 Air Requirements

Toxic air pollutant regulations for new air emission sources, promulgated in Chapter 173-460 WAC, require use of best available control technology for air toxics (T-BACT). The toxic air pollutant regulations may be potential ARARs for remedial actions selected for the Facility. VOCs are not typically encountered in groundwater at the Facility. Minor detections of VOCs in groundwater are 35 to 80 feet below ground surface, and the groundwater to air pathway is not a viable pathway. However, implementation of technologies to treat VOC impacts in soil (such as soil vapor extraction [SVE]) may trigger discharge requirements established by the Spokane Regional Clean Air Agency (SRCAA), which would regulate treatment system emissions to the atmosphere and necessary emission controls.

G.2.6 Waste Management Requirements

Although we do not anticipate that it will be necessary at the Kaiser Facility, to the extent that any wastewater from groundwater treatment is discharged to a sanitary sewer, several potential ARARs may apply. Discharges to the sanitary sewer may need to meet substantive pretreatment requirements addressed under Chapters 173-216 and 173-240 WAC, and 40 CFR Parts 403 and 467. In addition, it may be necessary to obtain the approval of the sewage treatment plant operator so that the sewage treatment plant may receive project wastewaters without violating pretreatment or other conditions of the plant's permit. Satisfaction of the substantive discharge limits should allow approval to be obtained.

During remedial actions at the Facility, wastes and recovered products may be generated that will need to be treated, stored, recycled, or disposed of. At this time we do not anticipate generating regulated hazardous or dangerous waste as defined by EPA and Washington State. However, regulations adopted pursuant to the Resource Conservation and Recovery Act (RCRA) describe numerous action-specific requirements may be potential ARARs if wastes are hazardous or otherwise subject to the recycling provisions of the RCRA regulations, including hazardous waste management under RCRA Subtitle C (40 CFR Parts 260 to 279). In addition, solid waste land disposal restrictions described in 40 CFR 268 and WAC 173-303-140 may be potential ARARs for management of waste. Recovered product may be subject to the used oil recycling requirements.

EPA regulations promulgated under RCRA Subtitle D set forth management standards for municipal and solid wastes (40 CFR Parts 257 and 258) and Washington State regulations describe management standards for solid waste in Chapter 173-350 WAC and for municipal solid waste landfills in Chapter 173-351 WAC. Some of these management standards may be potential ARARs for non-hazardous solid wastes generated during remedial actions at the Facility.

Federal regulations at 40 CFR Part 761 describe management requirements for PCB wastes and materials. If PCB-affected wastes are generated, the PCB management standards may be potential ARARs for such wastes.

In general, the kinds of action-specific requirements that may apply to wastes and recovered product may involve the following actions and precautions:

- Packaging, labeling, placarding, and manifesting of off-site waste shipments;
- Inspecting waste management areas to ensure proper performance and safe conditions;
- Preparation of plans and procedures to train personnel and respond to emergencies; and
- Management standards for containers, tanks, and treatment units.

Many of these requirements will depend on the particular remedial actions undertaken, the types of waste and/or recovered product generated, and their methods of disposition.

G.2.7 Other Requirements

Other potential ARARs may exist that pertain to the construction of the remedial action. Implementation of some remedial actions may need to meet permitting requirements, such as meeting the requirements of the Construction Stormwater General Permit established by Title 33 USC, 1251 and RCW 90.48, and complying with substantive requirement of grading activities necessary for soil work.

Implementation of the remedial actions will need to observe the requirements of the WISHA regulations described in Chapter 296-24 WAC.

G.3 LOCATION-SPECIFIC REQUIREMENTS

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in a specific location. Some examples of special locations include floodplains, wetlands, historic sites, and sensitive ecosystems or habitats. Table G-4 catalogs the location-specific standards identified in existing federal and state requirements, and indicates which of these may be potential ARARs. The "Comments" column of Table G-4 states the rationale for a requirement being, or not being, identified as a potential ARAR. In summary, the following requirements have been identified as potential location-specific ARARs:

- **Groundwater.** The Kaiser Facility is located in the vicinity of the Spokane Valley Sole Source Aquifer. Because of this sole source designation, activities that may affect the aquifer are potentially subject to various restrictions (e.g., prohibition of waste disposal, limits on discharges that could enter the aquifer). Thus, the sole source aquifer standards may be potential ARARs. Another state regulation limits withdrawal of groundwater to prevent potential depletion or excessive level decline of the aquifer. Since the proposed remedial actions at the Facility may involve substantial groundwater withdrawal, this regulation would constitute a potential ARAR.

- **Shorelines and Surface Waters.** A number of requirements constrain activities in proximity to shorelines and surface waters. Remedial actions at the Facility may occur in proximity to shorelines or in the floodplain associated with the Spokane River. Potential ARARs would require that precautions (e.g., ensure no net loss of shoreline, preserve beneficial values of floodplain) be taken to minimize adverse effects.

  The Spokane River adjacent to the Facility has a TMDL for dissolved oxygen as required by WAC 173-201A. Kaiser and other dischargers are under an allocation that restricts the pounds of phosphorous, ammonia, and carbonaceous biological oxygen demand (CBOD) the Facility can discharge in a day. Because of Kaiser's location along the river reach covered by the dissolved oxygen TMDL, restrictions may be placed on activities that result in increased loadings of these parameters to the river.

- **Water Rights.** Water rights are required for removal and use of waters of the state. This includes the groundwater under the Kaiser Facility and any water withdrawals from the Spokane River.

- **Cadmium, Lead, and Zinc TMDL.** In August 1999, Ecology issued TMDLs for cadmium, lead, and zinc in the Spokane River. The TMDLs were initiated as a result of high metals concentrations entering Washington from mining operations in Idaho, which have resulted in exceedances of water quality standards for these three metals in the river. The TMDLs prohibit discharge of cadmium, lead, and zinc at concentrations that exceed the hardness-based water quality standard at the end of the discharge pipe. The limits for any individual discharger may be performance-based. Existing wastewater dischargers are not allowed to discharge these three metals at concentrations that are statistically above what their treatment system can consistently achieve, even if it is well below the water quality standard. Kaiser has recently been issued a facility-specific permit limit incorporating the revised metal TMDL approach for its NPDES permit discharge. It is not likely, however, that groundwater discharges to the Spokane River from the Facility will be affected by the TMDLs for cadmium, lead, and zinc. The Kaiser and area-wide concentrations of these metals in groundwater are less than the water quality standards. However, any groundwater remedial action conducted by Kaiser that results in an increase in the concentration of these three metals in discharges to the river would need to be evaluated by Ecology in consideration of the TMDLs.

- **Polychlorinated Biphenyls.** A draft TMDL for PCB was issued by Ecology in June 2006, but it has not been finalized. Because there are a variety of known PCB sources to the river, and others that may be identified by the regulatory agencies, Ecology is in the process of implementing a toxics reduction strategy for the Spokane River. This strategy includes PCB source identification and reduction activities. A TMDL for PCBs may eventually be established for the Spokane River in the future. This TMDL, if established, will be an ARAR for the Facility.

- **Air.** The Facility is located in the Spokane Valley airshed. The Spokane Valley airshed has been in nonattainment for particulate matter (PM10) and carbon monoxide (CO) in the past but is current meeting attainment for both of these parameters. If the airshed were to become a nonattainment area for one or more parameter in the future, sources of air emissions would typically be subject to greater restrictions in these areas. Thus, these restrictions may be potential ARARs for remedial actions at the Facility that could result in emissions of PM10 or CO.

G.4 REFERENCES FOR APPENDIX G

Ecology, 1994. Natural Background Soil Metals Concentrations in Washington State. Toxics Cleanup Program, Washington State Department of Ecology. Publication no. 94-115, October 1994.

Ecology, 1998. Cadmium, Lead, and Zinc in the Spokane River Recommendations for Total Maximum Daily Loads and Waste Load Allocations. Washington State Department of Ecology Publication No. 98-329. September 1998.

Ecology, 2001. Model Toxics Control Act Cleanup Levels and Risk Calculations (CLARC 3) Update. Washington State Department of Ecology Publication No. 94-145. August 2001.

Ecology, 2010a. Kaiser Trentwood Site Draft Cleanup Standards. Issued to Kaiser Aluminum Washington, LLC, by the Washington State Department of Ecology. May 2010.

Ecology, 2010b. Kaiser Trentwood Site – Ecology's Responses to Kaiser's June 17, 2010 Comments on May 2010 Draft Cleanup Standards. Letter to Bernard P. Leber, Jr., Kaiser Aluminum Fabricated Products, LLC., from Dr. Teresita Bala, Washington State Department of Ecology. August 17, 2010.

Hart Crowser, 2012a. Final Site-Wide Groundwater Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Hart Crowser, 2012b. Final Site-Wide Soil Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Hart Crowser, 2012c. Final Feasibility Study Technical Memorandum, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Pioneer, 2012. Final Kaiser Trentwood Facility Human Health and Ecological Risk Assessments, Pioneer Technologies Corporation. May 2012.

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Table G-1 - Soil Screening Level Concentrations

COPCs	Unsaturated Soil Background in mg/kg (5)	Ingestion/Direct Contact with Soil in mg/kg (1)	Protection of Wildlife in mg/kg (2)	Protection of Groundwater Unsaturated Soil in mg/kg (3)	Protection of Groundwater Saturated Soil in mg/kg (4)	Screening Levels Unsaturated Soil in mg/kg (6)	Screening Levels Saturated Soil in mg/kg (6)	Reason for Proposed SLs
Metals								
Antimony	3.1 - 7.6	140	NA	5.42	NA			
Arsenic	**1.13 - 10.32**	**9 (a)**	**7 (c)**	**0.0341**	**0.0017**	**10.32**	**10.32**	natural background concentration
Cadmium	**0.125 - 0.685**	350	14	**0.7**	**0.0349**	**(g)**	**(g)**	
Chromium III		N.A.	NA	2,000	100			
Chromium VI		1,050	67	NA	NA			
Copper	**4.04 - 29.03**	12,950	NA	260	NA			
Iron	9,670 - 27,000	NA	NA	NA	NA	**(j)**	**(j)**	
Lead	**6.75 - 16**	**1,000 (b)**	**118**	250 (f)	250 (f)	**1,000 (i)**	NA	Human health risk is present (i)
Manganese	354.5 - 769.5	49,000	1,500	**52.2**	**3**	769.5 (j)	769.5 (j)	natural background concentration
Selenium	0.1 - 0.4362	1750	**0.3**	5	NA	**(h)**		
Zinc	**29.7 - 71**	105,000	NA	5,970	NA			
PCBs								
Total PCBs		6.6	**0.34 (d)**	**0.272**	**0.014**	**0.272**	**0.014**	Lowest of soil SLs
Aroclor 1248		**6.6**	**0.34 (d)**	**0.272**	**0.014**	**0.272**	**0.014**	Lowest of soil SLs
Aroclor 1254		**6.6**	**0.34 (d)**	**0.272**	**0.014**	**0.272**	**0.014**	Lowest of soil SLs
PAHs								
cPAH - TEQ		**0.42**	12 (e)	**0.233**	**0.012**	**0.233**	**0.012**	Lowest of soil SLs
Other SVOCs								
2-Methylnapthalene		NA	NA	**2,190**	**0.112**	**(g)**	**(g)**	
N-Nitrosodiphenylamine		NA	NA	**536**	NA	**(g)**		
TPH								
Gasoline/Stoddard Solvent		2,909	5,000	**100 (f)**	**100 (f)**	**100 (i)(g)**	**100 (i)(g)**	Lowest of soil SLs
Diesel		**2,667**	**6,000**	**2,000 (f)**	**2,000 (f)**	**2,000**	**2,000**	Lowest of soil SLs
Heavy Oil		**98,000**	6,000	**2,000 (f)**	2,000 (f)	**2,000**	**2,000**	Lowest of soil SLs
VOCs								
Benzene		136	NA	**0.005**	NA	**0.005 (g)**	NA	Lowest of soil SLs
Ethyl Benzene		NA	NA	**5.99**	NA	**(g)**		
Methylene Chloride		NA	NA	**0.022**	NA	**(g)**		
PCE		3,500	NA	0.9	**0.00005**	**(g)**	**0.00005 (g)**	Lowest of soil SLs
TCE		1,010	NA	NA	NA	NA	NA	
Total Xylenes		NA	NA	**14,500**	NA	**(g)**		

Notes:

Table adapted from FSTM Table 1-2 (Hart Crowser 2012c).

Bolded text indicates that the criteria have been exceeded at the Facility (refer to the appropriate RI document for the screening criteria that were used).

NA - Not detected, or detected at a frequency of less than 5 percent of samples analyzed.

(1) Refer to HHERA Tables 4.2 and 4.3 (Pioneer 2012). Human health risk above criteria found for Aroclor 1248 (Oil House French drain area), diesel (Hoffman Tank area), and for lead (ORB Man-Made Depressions area).

(2) Refer to HHERA Tables 11.1 and 11.2 (Pioneer 2012). No risk to wildlife above criteria was identified.

(3) Refer to the Kaiser Final Site-Wide Soil RI Table 1.1 (Hart Crowser 2012b).

(4) Refer to the Kaiser Final Site-Wide Soil RI Table 1.2 (Hart Crowser 2012b).

(5) The natural background concentration ranges from Ecology 1994 were used except for background concentrations for antimony and selenium, which were derived using methods described in WAC 173-340-709 (refer to HHERA Appendix C [Pioneer 2012]).

(6) Lowest concentration for which an exceedance was observed.

(a) Natural background concentration (refer to HHERA Appendix C [Pioneer 2012]).

(b) MTCA Method A - Industrial properties (Table 745-1E).

(c) MTCA indicator soil concentration (ISC) value for As(III) used (Table 749-3).

(d) Site-specific ISC value (shrew) for total PCBs used (refer to the HHERA Table 11-6 [Pioneer 2012]).

(e) MTCA ISC value of benzo(a)pyrene used.

(f) MTCA Method A (Table 740-1).

(g) Not considered a groundwater COPC. Refer to Kaiser Final Site-Wide Groundwater RI Section 5.2 (Hart Crowser 2012a).

(h) Refer to HHERA Section 11 (Pioneer 2012).

(i) COC present only in some areas of the site: lead in the ORB Man-Made Depressions area, and gasoline in Oil House, ORB, Truck Shop, and G-1 Transfer Line areas.

(j) Considered a COC in the Kaiser Final Groundwater RI Section 5.2 (Hart Crowser 2012a) for potential adverse secondary (aesthetic) effects.

Table G-2 - Groundwater Screening Level Concentrations

COPC	Screening Level in µg/L	Protection of Drinking Water: Federal and State Safe Drinking Water Act Primary MCL in µg/L	Protection of Drinking Water: Federal Safe Drinking Water Act Secondary MCL in µg/L	Protection of Drinking Water: MTCA Method A in µg/L	Protection of Drinking Water: MTCA Method B Carcinogen in µg/L	Protection of Drinking Water: MTCA Method B Non-Carcinogen in µg/L	Protection of Surface Water: Ch. 173-201A WAC in µg/L [a]	Protection of Surface Water: Clean Water Act §304 Freshwater Aquatic Life Chronic in µg/L	Protection of Surface Water: Clean Water Act §304 Freshwater Human Health in µg/L	Protection of Surface Water: National Toxics Rule 40 CFR 131 Aquatic Species in Fresh Water in µg/L	Protection of Surface Water: National Toxics Rule 40 CFR 131 Human Health Consumption of Aquatic Species in µg/L	Protection of Surface Water: MTCA Method B Carcinogen in µg/L	Protection of Surface Water: MTCA Method B Non-Carcinogen in µg/L	PQL in µg/L
Conventionals		--	--	--	--	--	--	--	--	--	--	--	--	
Nitrate	10,000	**10,000**	--	--	--	--	--	--	**10,000**	--	--	--	--	
Metals (Total and Dissolved)														
Antimony	6	**6**	--	--	--	6.4	--	--	5.6	--	14	--	1,000	0.05
Arsenic	0.018	10	--	5	0.058	4.8	190	150	**0.018**	190	**0.018**	0.098	18	0.5
Cadmium	0.25	5	--	5	--	8	0.37	**0.25**	--	1	--	--	20	0.05
Chromium	50	100	--	**50**	--	--	--	--	--	--	--	--	--	0.2
Copper	3.50	1,300	1,000	--	--	590	**3.5**	9	--	11	--	--	2,700	
Iron	300	--	**300**	--	--	--	--	1,000	**300**	--	--	--	--	20
Lead	0.54	15		15	--	--	**0.54**	2.5	--	2.5	--	--	--	0.02
Manganese	50	--	**50**	--	--	2,200	--	--	**50**	--	--	--	--	0.05
Zinc	32	--	5,000	--	--	4,800	**32**	120	7,400	100	--	--	17,000	
cPAHs														
TEQ [b]	0.0028	0.2	--	0.100	0.012	--	--	--	0.0038	--	**0.0028**	0.030	--	0.02
Volatiles														
1,2-Dichloroethane (EDC)	0.38	5	--	5	0.48	160	--	--	**0.38**	--	**0.38**	59	43,000	
Benzene	0.8	5	--	5	**0.8**	32	--	--	2.2	--	1.2	23	2,000	
Tetrachloroethene	0.081	5	--	5	**0.081**	80	--	--	0.690	--	0.8	0.390	840	
Trichloroethene (TCE)	0.49	5	--	5	**0.49**	2.4	--	--	2.5	--	2.7	6.7	71	
Pesticides/PCBs														
Total PCBs	0.000064	0.5	--	0.1	0.044	--	0.014	0.014	**0.000064**	0.14	0.00017	0.00011	--	0.005
TPH														
Gasoline	800	--	--	**800/1,000 [c]**	--	--	--	--	--	--	--	--	--	
Diesel	500	--	--	**500**	--	--	--	--	--	--	--	--	--	
Heavy Oil	500	--	--	**500**	--	--	--	--	--	--	--	--	--	

Notes:
Table adapted from FSTM Table 1-3 (Hart Crowser 2010).
MCL = Maximum contaminant level.
PQL = Practical quantitation limit.
-- = No data.
*Based on state MCL. No federal MCL for constitue
Bold value represents the most conservative value and is used as the screening level. Analytes in bold type are considered to be COCs for groundwater at the Kaiser Facility.
(a) Calculations for hardness-dependent metals were based on a hardness of 25.
Individual formulas are as follows:
Cadmium
≤ (0.909)(e(0.7852[ln(hardness)]-3.490)) at hardness = 100. Conversions factor (CF) of 0.909 is hardness dependent. CF is calculated for other hardnesses as follows: CF = 1.101672 - [(ln hardness)(0.041838)].
Chromium III
≤ (0.860)e(0.8190[ln(hardness)]+ 1.561)
Copper
≤ (0.960)(e(0.8545[ln(hardness)] - 1.465))
Lead
≤ (0.791)(e(1.273[ln(hardness)] - 4.705)) at hardness = 100. Conversion factor (CF) of 0.791 is hardness dependent. CF is calculated for other hardnesses as follows: CF = 1.46203 - [(ln hardness)(0.145712)].
(b) Screening levels are based on mixtures of cPAH values based on Toxicity Equivalency Quotient (TEQ) calculation from WAC 173-304-708 as calculated in FSTM Table 1-4 (Hart Crowser 2010).
The reference compound for Total cPAHs is benzo(a)pyrene (BaP).
(c) Benzene present/no benzene present.

Table G-3 - Potential Action-Specific ARARs for the Kaiser Facility

Response Action	Potential Action-Specific ARARs	Citation	ARAR?	Comments
Institutional Controls	Long-term groundwater monitoring consistent with MTCA.	Chapter 173-340 WAC	Yes	Groundwater monitoring system with quarterly sampling and analysis; potential 30-year (typical for post-closure care) monitoring time period.
	Groundwater well construction and maintenance consistent with state requirements.	Chapters 173-160 and 173-162 WAC	Yes	Construction and maintenance of monitoring wells to prevent adverse impacts to groundwater.
Monitored Natural Attenuation (MNA)	Natural attenuation as a remedial action consistent with expectations defined by MTCA.	WAC 173-340-370(7)	Yes	Ecology expects that natural attenuation may be appropriate at sites where source control has been conducted to the maximum practicable extent; remaining impacts do not pose an unacceptable risk to human health or the environment; there is evidence that natural attenuation is occurring; and appropriate monitoring is conducted.
Surface Containment/ Capping	Capping of soil containing PCBs consistent with federal TSCA requirements.	40 CFR 761	Potential	PCB-impacted soil at low concentrations may be left in place under TSCA; however, remediation requirements such as institutional controls, capping, and cleanup must be met.
Hydraulic Containment	Groundwater withdrawal consistent with groundwater right requirements.	Chapter 173-150 WAC	Yes	Withdrawal of groundwater consistent with existing water right and in a manner that will avoid impacts on other water right holders.
	Groundwater well construction and maintenance consistent with state requirements.	Chapters 173-160 and 173-162 WAC	Yes	Construction and maintenance of withdrawal well(s) to prevent adverse impacts on groundwater.
In Situ Treatment	Construction, operation, and maintenance of soil and groundwater *in situ* treatment systems consistent with State Waste Discharge Standards.	Chapter 173-216 WAC	Potential	Treatment system must be constructed and function in a manner that will not degrade groundwater quality.
	Construction, operation, and maintenance of soil and groundwater *in situ* treatment systems consistent with Underground Injection Control (UIC) Program requirements.	Chapter 173-218 WAC	Potential	The injection of materials into the subsurface from aboveground locations may require registration with the UIC Program if the injection points are classified as UIC wells.
	Groundwater well construction and maintenance consistent with state requirements.	Chapters 173-160 and 173-162 WAC	Yes	Treatment system well(s) must be constructed and maintained to prevent adverse groundwater impacts.

Table G-3 - Potential Action-Specific ARARs for the Kaiser Facility

Response Action	Potential Action-Specific ARARs	Citation	ARAR?	Comments
Groundwater Extraction and *Ex Situ* Treatment				
Extraction	Groundwater withdrawal consistent with groundwater right requirements.	90-54 RCW; Chapter 173-150 WAC	Yes	Withdrawal of groundwater consistent with existing water right and in a manner that will avoid impacts on other water right holders.
	Groundwater well construction and maintenance consistent with state requirements.	Chapters 173-160 and 173-162 WAC	Yes	Construction and maintenance of extraction well(s) to prevent adverse impacts to groundwater.
Ex Situ Treatment	Treatment of extracted groundwater consistent with state Groundwater Quality Standards.	Chapter 173-200 WAC	No	Does not apply to cleanup actions approved by Ecology under MTCA.
	Treatment of extracted groundwater consistent with State Waste Discharge Standards.	Chapter 173-216 WAC	Potential	The effluent of groundwater treatment systems may be considered a waste material in some situations.
	Treatment of extracted groundwater consistent with UIC Program requirements.	Chapter 173-218 WAC	Potential	Prevention of the discharge of fluids into UIC wells that will endanger groundwater, requiring the use of all known, available, and reasonable methods of prevention, control, and treatment (AKART) to the discharge of fluids and waste fluids into the waters of the state.
	Construction, operation, and maintenance of treatment system consistent with wastewater treatment facility requirements.	Chapter 173-240 WAC	Potential	Treatment system must be constructed and function in a manner that will not degrade groundwater and surface water quality.
Discharge/ Reinfiltration	Discharge of treated effluent consistent with State Groundwater Quality Standards.	Chapter 173-200 WAC	No	Does not apply to cleanup actions approved by Ecology under MTCA.
	Discharge of treated effluent to surface water must be in accordance with State Surface Water Quality Standards.	WAC 173-201A-602	Potential	Treated water discharged to surface water must meet discharge requirements. Will be applicable if discharge to surface water is used during cleanup.
	Discharge of treated effluent to surface water (if any) consistent with NPDES requirements and Kaiser's NPDES permit.	40 CFR 129.105 and 467; Chapter 173-220 WAC; Kaiser's NPDES permit	Potential	Treated water discharged to the Spokane River would have to achieve applicable NPDES treatment limits for the effluent. Will be applicable if discharge to surface water is used during cleanup.

Response Action	Potential Action-Specific ARARs	Citation	ARAR?	Comments
	Discharge of treated effluent consistent with State Waste Discharge Permit Program.	Chapter 173-216 WAC	Potential	The effluent of groundwater treatment systems may be considered a waste material in some situations.
	Effluent discharges to sanitary sewer system (if any) consistent with applicable pretreatment standards.	40 CFR 403 and 467; Chapters 173-216 and 173-240 WAC	No	Treated water discharged to the sanitary sewer system must meet pretreatment standards.
	Discharge of treated effluent must be in accordance with the Spokane River Phosphorous Management Plan.	Spokane River Phosphorous TMDL	Potential	Minimum 259 kg phosphorous/day in Long Lake. Kaiser must not exceed their phosphorous allocation. No new sources of phosphorous.
	Discharge of treated effluent consistent with Underground Injection Control (UIC) Program.	Chapter 173-218 WAC	Potential	The injection of materials into the subsurface from aboveground locations may require registration with the UIC Program if the injection points are classified as UIC wells.
	Construction of effluent dischargers (if any) consistent with Spokane County shoreline management plan and Army Corps standards for work in navigable waters.	33 CFR 322; WAC 173-19-400	No	Pipelines, diffusers, or other discharge units (if any) to be constructed for effluent discharge must be protective of shoreline and not interfere with navigation in the Spokane River.
Free Phase Product Recovery				
Extraction	Groundwater well construction and maintenance consistent with state requirements.	Chapters 173-160 and173-162 WAC	Yes	Construction and maintenance of extraction well(s) to prevent adverse impacts on groundwater.
Recovery/ Discharge	Construction, operation, and maintenance of recovery system consistent with State Waste Discharge Standards.	Chapter 173-216 WAC	Potential	Recovery system must be constructed and function in a manner that will not degrade groundwater and surface water quality.
	Recycling, reuse, and management of recovered product consistent with state and federal requirements.	40 CFR Part 761; Chapters 173-303, 173-304, and 173-351 WAC	Yes	Recovered product must be stored, treated, and recycled/disposed of as appropriate for the type of waste (e.g., used oil, PCB-contaminated oil).
	Management of excess/residual water consistent with treatment and disposal standards appropriate for selected method of disposal.	40 CFR 129.105, 467, and 761; Chapter 173-220 WAC; Kaiser's NPDES permit	Yes	Treatment and discharge of excess/residual water generated during product recovery must satisfy requirements for type of management method employed (e.g., NPDES for discharge to Spokane River, pretreatment for discharge to sewer, TSCA for management and disposal if >50 ppm PCBs).

Table G-3 - Potential Action-Specific ARARs for the Kaiser Facility

Response Action	Potential Action-Specific ARARs	Citation	ARAR?	Comments
Excavation and Off-Site Disposal	Transportation of impacted soil or hazardous materials consistent with state and federal requirements.	49 CFR 100 and 177; Chapter 446-50 WAC	Yes	Transportation of hazardous waste or materials required to meet state and federal requirements.
	Management of excavated soil consistent with solid waste handling and disposal facility requirements.	40 CFR 241 and 257; Chapters 173-350 and 173-351 WAC	Yes	Handling and disposal of solid waste required to meet state and federal requirements.
	Management of excavated soil consistent with solid waste land disposal restrictions.	40 CFR 268; WAC 173-303-140	Potential	Best management practices for dangerous wastes required to meet state and federal requirements.
	Disposal of waste consistent with RCRA Subtitle C requirements for management of hazardous waste.	40 CFR 260 to 279	Potential	Off-site disposal of impacted soil meeting hazardous waste criteria may require disposal at Subtitle C landfill.
	Disposal of waste consistent with RCRA Subtitle D requirements for management of solid waste.	40 CFR 257 and 258	Potential	Disposal of impacted soil not defined as hazardous waste may be disposed of at Subtitle D landfill.
Soil Vapor Extraction (SVE) and Off-Gas Treatment	Discharge of effluent from SVE systems consistent with Spokane Regional Clean Air Agency (SRCAA) requirements.	SRCAA Regulation I	No	SVE system effluent emitted to the atmosphere required to meet SRCAA discharge requirements.
Construction of Response Action	Implementation of response action consistent with occupational health and safety requirements.	Chapter 296-24 WAC	Yes	Worker and visitor health and safety requirements established by the Washington Industrial Safety and Health Act (WISHA) will be met during implementation of the response action.
	Implementation of response action consistent with local permitting requirements.	City of Spokane Valley Ordnance	Yes	Appropriate substantive requirements to be met for implementation of response action (for example, meeting runoff quality requiremnts for grading activities).
	Implementation of response action consistent with construction stormwater general permit.	Title 33 USC, 1251 RCW 90.48	Potential	Appropriate permitting requirements to be met during implementation of response action.

Table G-4 - Potential Location-Specific ARARs for the Kaiser Facility

Geological

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
On or adjacent to a fault displaced in Holocene time	Solid waste landfills and hazardous waste facilities prohibited.	Waste management within 200 feet (solid waste) or 500 feet (hazardous waste) of a Holocene fault.	40 CFR 264.18 WAC 173-303-282, and WAC 173-351-130	No	No solid or hazardous waste management facilities will be established.
Seismic impact zones and subsidence areas	Solid and hazardous waste facilities prohibited in areas with potential for impacts during seismic events.	Solid and hazardous waste management activities in seismic impact zones and unstable areas.	WAC 173-303-282, WAC 173-304-130, and WAC 173-351-130	No	No solid or hazardous waste management facilities will be established.
Slopes	Solid and hazardous waste facilities prohibited from areas with unstable slopes or soils.	Solid or hazardous waste management on an unstable slope or soil.	WAC 173-303-282 and WAC 173-304-130	No	No solid or hazardous waste management facilities will be established.
Salt dome and salt bed formations, underground mines, and caves	Placement of non-containerized or bulk liquid hazardous wastes is prohibited.	Hazardous waste placement in salt dome, salt bed, mine, or cave.	40 CFR 264.18	No	No bulk liquid hazardous waste will be managed.

Drinking Water Supply

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Drinking water supply well	Solid waste management prohibited near drinking water supply well.	Solid waste management within 1,000 feet or 90-day travel time upgradient of drinking water supply well.	WAC 173-304-130 and WAC 173-351-140	No	No drinking water supply wells are within 1,000 feet downgradient of project.
Water supply intake	Hazardous waste management facilities prohibited near surface water and groundwater intake for domestic use.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of intake.	WAC 173-303-282	Potential	If hazardous waste is encountered during cleanup, management activities will need to be conducted in accordance with the state set back requirements.
Watershed	Solid and hazardous waste management areas prohibited within a watershed used by a public water supply system for municipal drinking water.	Solid and hazardous waste management within a public watershed.	WAC 173-303-282, WAC 173-304-130, and WAC 173-351-140	No	No solid or hazardous waste management will occur within a designated watershed used for water supply.

Table G-4 - Potential Location-Specific ARARs for the Kaiser Facility

Groundwater

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Sole-source aquifer	Solid and hazardous waste land based management facilities prohibited over a sole-source aquifer.	Disposal or land based management over a sole source aquifer.	WAC 173-303-282, WAC 173-304-130, and WAC 173-351-140	Potential	Actions may occur in the vicinity of the Spokane Sole-Source Aquifer.
Aquifer	Prevent depletion, excessive level decline, and/or reduction in water quality of the aquifer.	Withdrawal of groundwater from the aquifer.	Chapter 173-154 WAC	Potential	Actions may involve withdrawal of groundwater from the aquifer.
	Bottom of lowest liner of solid waste disposal facility must be at least 10 feet above seasonal high water in the aquifer (5 feet if hydraulic gradient controls installed).	Solid waste disposal within 10 feet above aquifer.	WAC 173-304-130 and WAC 173-351-140	No	No solid waste disposal facility will be established.
	Hazardous waste management facilities prohibited in close proximity to aquifer.	Hazardous waste management within 10 feet (non-land based) or 50 feet (land based) above aquifer.	WAC 173-303-282	No	No hazardous waste management facility will be established
Aquifer Protection Areas	Activities restricted within designated Aquifer Protection Areas.	Activities within an Aquifer Protection Area.	RCW 36.36	Future Potential	No Aquifer Protection Area has been designated yet. This may occur in the future.
Groundwater Management Areas	Activities restricted within Groundwater Management Areas.	Activities within a Groundwater Management Area.	Chapter 173-100 WAC; WAC 173-303-282	Future Potential	No Groundwater Management Area has been defined. This may occur in the future.
Special Protection Areas	Activities restricted within Special Protection Areas.	Activities within a Special Protection Area. Hazardous waste management facilities prohibited.	WAC 173-200-090 and WAC 173-303-282	Future Potential	No Special Protection Area has been defined. This may occur in the future.
Wellhead Protection Areas	Activities restricted within Wellhead Protection Areas.	Activities within a Wellhead Protection Area.	WAC 246-290-135	Future Potential	Wellhead Protection program has not been established. Such a program, which may integrate the sole source aquifer, aquifer protection, and special protection programs may be established in the future.
Groundwater use	Water right required for groundwater use.	Withdrawal of groundwater requires a right.	RCW 90.54; Chapter 173-150 WAC	Yes	Kaiser has a water right for groundwater withdrawal.

Surface Water

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Rivers and streams	Avoid diversion, channeling, or other actions that modify streams or rivers, or adversely affect fish or wildlife habitats and water resources.	Actions modifying a stream or river and affecting fish or wildlife.	Chapters 220-110 and 232-14 WAC	No	No modification or diversion of rivers or streams will occur,
Shorelines/Surface waters	Actions prohibited near shorelines of statewide significance unless permitted,	Actions within 200 feet of shorelines.	RCW 90.58; Chapters 173-14 and 173-16 WAC	Potential	Actions may occur within 200 feet of the Spokane River,
	Solid waste facilities prohibited near surface water.	Solid waste disposal within 200 feet of surface water (stream, lake, pond, river, saltwater body).	WAC 173-304-130 and WAC173-351-140	No	No solid waste disposal facility will be established within 200 feet of a surface water.
	Hazardous waste management facilities prohibited near perennial surface water bodies.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of water body.	WAC 173-303-282	No	No hazardous waste management facility will be established.
	Restrictions on dissolved oxygen loading to the Spokane River	TMDL for dissolved oxygen restricts pounds of phosphorous, ammonia, and carbonaceous BOD. No new sources are allowed. Kaiser cannot exceed its current allocation.	Chapter 173-201A WAC; Dissolved oxygen TMDL	Yes	No exceedence of dissolved oxygen TMDL.
	Restrictions on cadmium, lead, and zinc loading in the Spokane River.	TMDLs for these metals cannot be exceeded.	Ecology 1998	Yes	Not likely to be a limiting factor for soil or groundwater remediation at the Kaiser Facility.
Floodplains	Solid and hazardous waste facilities must be designed, built, operated, and maintained to prevent washout.	Solid or hazardous waste management in a 100-year floodplain.	40 CFR 264.18; WAC 173-303-282, WAC 173-304-460, and WAC 173-351-130	No	No solid or hazardous waste management facility will be established.
	Hazardous waste land-based facilities prohibited in 500-year floodplain.	Hazardous waste disposal/land-based management in a 500-year floodplain.	WAC 173-303-282	No	No hazardous waste disposal facility will be established.
	Avoid adverse effects, minimize potential harm, restore/preserve natural and beneficial values in floodplains.	Actions occurring in a floodplain.	Chapters 173-16 and 173-158 WAC	Potential	Actions may occur within a designated floodplain.

Table G-4 - Potential Location-Specific ARARs for the Kaiser Facility

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Wetlands	Solid waste facilities prohibited in wetlands.	Solid waste management in a wetland (swamps, marshes, bogs, estuaries, and similar areas).	WAC 173-304-130 and WAC 173-351-130	No	No delineated wetlands located in vicinity of project.
	Hazardous waste facilities prohibited near wetlands.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of wetlands	WAC 173-303-282	No	No delineated wetlands located in vicinity of project.
	Work or structures in navigable waters prohibited without permit. Discharge of dredged or fill materials into wetlands prohibited without a permit.	Work or construction in navigable waters; discharges to wetlands.	40 CFR 230 to 233; 33 CFR 322 to 323	No	No actions within navigable waters. No discharges to delineated wetlands.
	Minimize potential harm, avoid adverse effects, preserve and enhance wetlands.	Construction or management of property in wetlands.	Chapters 173-16 and 173-22 WAC	No	No delineated wetlands located in vicinity of project.

Air

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Non-attainment areas	Spokane Valley has been nonattainment for PM10 and CO in the past but is mow meeting attainment. If the restrictions on air emissions would be required if nonattainment were to reoccur under state and federal air quality programs.	Activities within a designated non-attainment area and Class I PSD Air Quality Zones.	40 CFR 51 and 52; Chapter 173-400 WAC and WAC 173-303-282	Potential	Would only apply if Spokane Valley becomes a nonattainment area again. In such cases actions at Kaiser may occur within a designated non-attainment area.

Land Use

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Neighboring properties	Solid and hazardous waste management prohibited near Facility's property line.	Solid waste management within 100 feet of Facility's property line; hazardous waste management within 200 feet (non land-based) or 500 feet (land-based) of Facility property line.	WAC 173-304-130, WAC 173-351-140, and WAC 173-303-282	No	No solid or hazardous waste management facilities will be established.
	No solid waste management areas within 250 feet of property line of residential zone properties.	Solid waste management within 250 feet of property line of residential property.	WAC 173-304-130 and WAC 173-351-140	No	No residential zone properties in vicinity of project.
	Hazardous waste management prohibited near residences or public gathering places.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (incineration and land-based) of residences or public gathering places.	WAC 173-303-282	No	No hazardous waste management facility will be established.
Farmland	Hazardous waste management prohibited near prime farmland.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of prime farmland	WAC 173-303-282	No	No prime farmland in vicinity of project.
Proximity to airports	Disposal of solid waste that could attract birds prohibited near airport runways.	Solid waste disposal within 5,000 feet (piston-type aircraft) or 10,000 feet (turbojet aircraft) of airport runways.	WAC 173-304-130	No	No airport runways in vicinity of project.

Sensitive Environments

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Endangered/threatened species habitats	Solid waste management prohibited from areas designated by US Fish and Wildlife Service as critical habitats for endangered or threatened species.	Solid waste management within critical habitats.	WAC 173-304-130, 173-351-140	No	No actions will occur within a critical habitat.
	Hazardous waste management prohibited near critical habitats and habitats essential for recovery of state threatened or endangered species.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of critical and essential habitats.	WAC 173-303-282	No	No critical or essential habitats in vicinity of project.
	Actions within critical habitats must conserve endangered and threatened species.	Activities where endangered or threatened species exist.	50 CFR 17, 222 to 227, 402, and 424; Chapter 232-12 WAC	No	No actions will occur within a critical habitat or affect endangered/threatened species.

Table G-4 - Potential Location-Specific ARARs for the Kaiser Facility

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Parks/Recreation areas/Monuments	Solid waste management prohibited near state or national park.	Solid waste management within 1,000 feet of state/national park.	WAC 173-304-130 and WAC 173-351-140	No	No solid waste management facilities will be established.
	Hazardous waste management prohibited near state or federal park, recreation area, or national monument.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of state or federal park, recreation area, or national monument.	WAC 173-303-282	No	No hazardous waste management facilities will be established.
	Restrictions on activities in areas that are designated state parks, or recreation/conservation areas.	Activities within state parks or recreation/conservation areas.	Chapter 352-32 WAC	No	No actions will occur within state parks or recreation/conservation areas.
Wilderness areas	Actions within designated wilderness areas must ensure area is preserved and not impaired.	Activities within designated wilderness areas.	50 CFR 35	No	No wilderness areas in vicinity of project.
	Hazardous waste management prohibited near wilderness areas.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of wilderness area	WAC 173-303-282	No	No wilderness areas in vicinity of project.
Wildlife refuge	Restrictions on actions in areas that are part of the National Wildlife Refuge System.	Activities within designated wildlife refuges.	50 CFR 27	No	No wildlife refuges in vicinity of project.
	Hazardous waste management prohibited near wildlife refuge, preserve, or bald eagle protection area.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of wildlife refuge, preserve, or bald eagle protection area.	WAC 173-303-282	No	No wildlife refuges, preserves, or bald eagle protection areas in vicinity of project.
Natural area preserves	Activities restricted in areas designated as having special habitat value (Natural Heritage Resources).	Activities within identified natural area preserve.	Chapter 332-60 WAC	No	No natural area preserve in vicinity of project.
	Hazardous waste management prohibited near natural area preserves.	Hazardous waste management within 500 feet (non land-based) or 1/4 mile (land-based) of natural area preserve.	WAC 173-303-282	No	No natural area preserve in vicinity of project.

Table G-4 - Potential Location-Specific ARARs for the Kaiser Facility

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Wild, scenic, or recreational rivers	Avoid actions that would have adverse effects on designated wild, scenic, or recreational rivers.	Activities near wild, scenic, and recreational rivers; hazardous waste management facilities prohibited within viewshed.	16 USC 1261 et seq.; RCW 79.72; WAC 173-303-282	No	No designated wild, scenic, or recreational rivers in vicinity of project.

Unique Lands and Properties

Location	Requirement	Prerequisite	Citation	ARAR?	Comments
Natural resource conservation areas	Restrictions on activities within designated conservation areas.	Activities within designated conservation areas.	RCW 79.71	No	No conservation areas in vicinity of project.
Forest lands	Activities restricted within state forest lands to minimize fire hazards and other adverse impacts.	Activities within state forest lands.	Chapter 332-24 WAC	No	Project is not within state forest land.
	Restrictions on activities in state and federal forest lands.	Activities within state and federal forest lands.	16 USC 1601 et seq.; RCW 76.09	No	Project is not within state or federal forest land.
Public lands	Activities on public lands are restricted, regulated, or proscribed.	Activities on state-owned lands.	RCW 79.01	No	No actions will occur on state-owned land.
Scenic vistas	Restrictions on activities that can occur in designated scenic areas.	Activities within designated scenic vista area.	RCW 47.42	No	Project is not within scenic vista area.
Historic areas	Actions must be taken to preserve and recover significant artifacts, preserve historic and archaeologic properties and resources, and minimize harm to national landmarks.	Activities that could affect historic or archaeologic sites or artifacts; hazardous waste management facilities prohibited in archaeologic and historic sites.	16 USC 469, 470 et seq.; 36 CFR 65 and 800; RCW 27.34, 27.44, 27.48, 27.53, and 27.58; Chapters 25-46 and 25-48 WAC, and WAC 173-303-282	No	No known historic or archaeologic sites or artifacts in vicinity of project.

APPENDIX H
TECHNOLOGY EVALUATION FOR FREE PHASE PRODUCT REMOVAL

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APPENDIX H
TECHNOLOGY EVALUATION FOR FREE PHASE PRODUCT REMOVAL

Free phase product (FPP) recovery is a part of Alternatives C1 through C4. This appendix evaluates the FPP recovery technologies that were carried forward as potentially implementable and reliable by the FSTM (Hart Crowser 2012b), and identifies the FPP technology judged to be appropriate for each alternative.

Several FPP recovery technologies were retained from the FSTM for application in the petroleum hydrocarbon groundwater plume and associated smear zone soil AOCs. As discussed below, these recovery technologies are further evaluated in this appendix, based on physical and chemical applicability, implementability, and reliability to determine which technologies should be retained for use at the Kaiser Facility. These retained technologies are applied in combination with Alternatives C1 through C4.

The discussion below describes the FPP plumes, and further evaluates the potential FPP recovery technologies identified in the FSTM.

H.1 DESCRIPTION OF THE CURRENT FPP PLUMES

FPP continues to be observed on occasion during late summer and fall at the Oil House and the Wastewater Treatment areas (refer to Figures 4-6 and 4-7 in Section 4). As discussed in the Final Site-Wide Groundwater Remedial Investigation (RI) Report (Hart Crowser 2012a), over the past 20 years there have been significant reductions in the areal extent and thickness of petroleum in these areas from FPP removal measures and natural attenuation processes.

An evaluation of the quantities of FPP present in the Oil House and Wastewater Treatment AOCs was conducted using the 2009 groundwater monitoring data. In 2009, five areas with FPP were identified in the Oil House and Wastewater Treatment AOCs: three areas in the Oil House area and two in the Wastewater Treatment area (see Figures 4-6 and 4-7). Product thickness measurements were taken in select wells during groundwater monitoring events in 2009. Average FPP thicknesses were calculated for the five areas. Where no FPP was measured, one half of the oil/water interface probe's detection limit was used to calculate average FPP thickness (0.005 foot). In the five FPP areas in 2009, average product thickness was less than 1 inch.

To estimate the volume of FPP present, the average product thickness was multiplied by the estimated area of each plume and by the effective soil porosity.

An effective porosity of 0.3, as defined in Section 4 of the Final Site-Wide Groundwater RI (Hart Crowser 2012b), was used in the FPP volume calculations. The same method was used in the FSTM to calculate FPP volumes based on 2008 data.

Approximately 4,700 gallons were estimated to be present in 2009, and approximately 80 percent of this volume is located in the Wastewater Treatment area. The volume of FPP estimated to be present in 2008 was 5,600 gallons (FSTM Table 4-21). Table 4-6 in Section 4 presents the estimated FPP volume in each area based on measurements in 2009. The volumes in this table are used to evaluate the cost and restoration time frame for FPP recovery at the Kaiser Facility.

H.2 FPP RECOVERY TECHNOLOGIES

FPP recovery technologies were discussed in Sections 4 and 5 of the FSTM for the petroleum hydrocarbon groundwater plumes and associated smear zone soil. Belt skimmers, dual vacuum extraction (DVE), FPP recovery with water table depression, and *ex situ* oil/water separation were retained as potential technologies for FPP recovery from the petroleum groundwater plumes associated smear zone soil.

H.2.1 Belt Skimmers

A belt skimmer uses a continuous loop (a “belt”) of material that attracts petroleum hydrocarbons and slowly cycles down into and out of the recovery well, removing FPP as the belt moves through the oil/water interface at the water table surface. As the belt reaches the skimming unit installed above the well, the product is skimmed from the belt and collected in a holding tank before that section of the belt goes back into the well. These skimmers are simple mechanical systems that can operate in 4-inch or larger diameter wells. Belt skimmers are able to skim even thin FPP layers, but the FPP removal rate can be low in such cases. Belt skimmers can be used in conjunction with water table depression to improve FPP recovery (EPA 1996).

Skimming systems alone remove small volumes of FPP and are often used during emergency or short-term remedial actions. Typically, skimming equipment alone is applicable in settings where hydraulic control of the dissolved hydrocarbon plume is not required. Skimmers are typically located in permeable conduits where significant product is present (EPA 1996).

The capital cost of standalone skimming systems is relatively low. Belt skimming system installation and startup typically require a few days and involve installing equipment at appropriate levels in the wells, inspecting mechanical and electrical components of the skimmers and FPP collection systems, and inspecting the collected liquids for water content and emulsified oil. Annual O&M costs for these systems are relatively low and consist of electricity required to operate the belt skimmers, monitoring FPP thicknesses in the wells, recording the total amount of product recovery at each recovery point, inspecting belt skimmer electrical and mechanical components, completing necessary maintenance and repair of the equipment, and transferring and disposing of the FPP from the collection tank if necessary (EPA 1996). Periodic costs include major equipment replacement such as belts and motors.

Skimming is typically terminated when FPP recovery is no longer cost effective. However, since there is a chance of FPP rebound, wells should be monitored on a regular basis after system shutoff for recurrence of FPP accumulation. Typically, a threshold criterion is set to restart skimming activities (for example, a product thickness greater than 0.1 foot). System operation may be finally terminated when monitoring measurements do not show product accumulations above threshold requirements over a continuous time period (for example, for two years monitored on a quarterly basis) (EPA 1996).

There are other types of FPP recovery technologies, which include mechanical skimming systems, such as floating skimmers, and pneumatic pumps. These technologies were discussed in the FSTM but screened out on the basis of reliability, since belt skimmers are currently being used successfully at the Kaiser Facility. For this reason, belt skimmers are retained as the most appropriate means of FPP recovery from the petroleum groundwater plumes and associated smear zone soil.

H.2.2 Dual-Phase Vacuum Extraction (DVE)

Dual-phase vacuum extraction (DVE) simultaneously extracts a combination of two of the following: soil vapor, separate-phase hydrocarbons, or groundwater from the subsurface, using a vacuum. There are several ways that DVE technology can be installed. In one type of installation, called vapor extraction/groundwater extraction (VE/GE), the suction point for vapor extraction is different from the suction point for liquid extraction. A surface-mounted vacuum pump or regenerative blower extracts vapor, and a submersible pump extracts groundwater. These systems are designed to expose the smear zone and the capillary fringe by pumping groundwater while simultaneously volatilizing the residual petroleum hydrocarbons in the smear zone with vacuum extraction. VE/GE systems are typically used after other FPP recovery methods have removed as much mobile product as feasible. These systems are ineffective for non-volatile hydrocarbons and are typically used for fine-grained soil with moderate to low permeability, for aquifers with thicker capillary zones, and where conventional pumping techniques have become ineffective (EPA 1996).

Based on the physical and chemical characteristics of soil and FPP at the Kaiser Facility, VE/GE is not considered a viable technology for FPP recovery. VE/GE is not considered applicable because there is still mobile product present at the Facility, the soil matrix is gravelly and porous (prone to short circuiting), and FPP at Kaiser consists mostly of longer-chain, semivolatile hydrocarbons in the diesel- to heavy oil-range (Hart Crowser 2012b).

Another setup option for DVE involves a single extraction point. The suction point may be at the water table to extract groundwater and FPP or may be set at the air and FPP interface. If the extraction suction point is located at the air/FPP interface, the technology is commonly called "bioslurping." Based on the location of the extraction point in bioslurping, air circulation is facilitated, which helps bioactivity in vadose zone soil. Bioslurping can improve FPP recovery efficiency without extracting large quantities of groundwater. DVE with a single extraction point is most applicable to media with low to medium permeability, media with thin saturated thickness, locations where the water table is at 5 to 20 feet bgs or in situations where settings for conventional pumping are inappropriate or ineffective (EPA 1996).

DVE with a single extraction point is eliminated based on physical characteristics of soil and the groundwater table at the Facility. The subsurface consists of a very permeable gravelly soil matrix, and the water table is deeper than 20 feet. As stated in the FSTM, the average water table depth in the Wastewater Treatment area is 55 feet bgs and, in the eastern portion of the Facility, is 68 feet bgs.

H.2.3 Water Table Depression

This method of recovery uses shallow groundwater extraction to create a cone of depression and direct FPP toward pumping wells within the plume area. Both FPP and groundwater are extracted during recovery using this method. Product recovery systems using water table depression are most applicable when hydraulic control of the hydrocarbon plume is necessary. These systems are used for a wide range of soil permeabilities and geologic media. However, because of the costs associated with the separation and treatment of dissolved hydrocarbons, these systems are better suited for formations of moderate to high permeability (greater than 10^{-4} cm/s). Typically, FPP recovery with water table depression is used in long-term operations (greater than one year). Typical configurations are single- and dual-pump systems (EPA 1996).

In single-pump systems, one pump extracts groundwater and product simultaneously. Aboveground treatment is required to separate oil and water (see oil/water separation discussion below). Emulsified oil may require other levels of treatment. In two-pump recovery systems, one pump extracts groundwater to create a cone of depression in the water table, and a second pump is used to collect FPP. This two-pump system optimizes product recovery while minimizing smearing and prevents mixing of FPP with water. By carefully balancing the extraction rates for groundwater and FPP, product recovery becomes more efficient, and efforts for oil/water separation minimize. It is likely that groundwater will need to be treated for residual contamination. For product recovery in two-pump systems, a product pump can be used or an equivalent FPP technology can be employed (such as floating skimmers, pneumatic pumps, or belt skimmers) (EPA 1996).

At the Kaiser Facility, the current IRM system installation could be considered a modified two-pump system, since extraction pumps WW-EW-1 and WW-EW-2 are in the vicinity of skimming well WW-SK-1, and extraction pump OH-EW-1 is in the vicinity of skimming well OH-SK-2. However, the main purpose of these extraction pumps is to provide hydraulic containment of the TPH plume and not to create a cone of depression. The hydraulic containment system is discussed in Section 4.1.1.2. Any cone of depression created by the extraction wells is incidental to groundwater pumping. Based on pumping test data from the Facility, a significant cone of depression is not created by the IRM extraction pumps (Hart Crowser 2003 and 2012a).

Water table depression meets physical and chemical screening criteria for the Kaiser Facility, since the soil matrix is permeable and the groundwater matrix can be pumped. Based on the existing groundwater extraction, it is assumed that a water table depression system could be installed and operated at the Facility. However, based on the high groundwater flow and porous matrix, it is likely that high groundwater extraction rates would be needed to create a significant cone of depression, and extracted groundwater would require treatment. It is judged inappropriate to extract groundwater just to recover FPP. The extracted FPP would have to be recovered by an oil/water separator or by other means, in any event.

H.2.4 Oil/Water Separation

Oil/water separators are used to remove oil and grease from wastewater. Oil may be present as a free phase or as emulsified oil. The separation of free phase oil occurs by gravity and normally occurs by allowing oil to float to the surface of the water, where the oil is skimmed off by mechanical means. Sludges accumulate at the bottom of the separator and periodically need to be removed.

In the FSTM, two types of oil/water separation technologies were retained: American Petroleum Institute (API) separators and dissolved air flotation (DAF) processes. The design of an API separator is based on settling velocities and the density and size of an oil particle. In the API separator, the wastewater stream enters a retention tank that creates a quiescent zone. In this part of the separator, oil droplets and lighter particulate matter rise to the surface, and heavier material settles to the bottom of the tank. Floating product and settled solids periodically have to be removed from the tank. Typically, treated water exits the tank by flowing around a baffle designed to prevent product from leaving the tank. For example, water may have to flow under a baffle that holds product back in the quiescent zone where it can periodically be skimmed off. The API separator is an established technology and commonly used for oil/water separation (Metcalf and Eddy 2003, Suthersan 1997).

In the DAF process, product is separated from wastewater through attachment to air bubbles, which transport the product to the water surface. DAF is typically used to separate suspended solids and emulsified oil mixtures. The process involves several steps. First, the wastewater stream is pressurized to several atmospheres, compressed air is added, and the mixture is held in a vessel to allow the air to dissolve into the wastewater. Second, from the pressurized vessel, the pressurized wastewater stream passes through a pressure-reducing valve into a floatation tank that is open to the atmosphere. Here, the dissolved air comes out of solution, and product and particulate matter attach to the resulting bubbles, which together rise to the water surface. From the water surface, the floating product and particulate matter can be skimmed off and collected. DAF systems, at a minimum, require a pump, a pressure vessel, and a compressed air source (Metcalf and Eddy 2003, Suthersan 1997).

The API separator is retained for this FS because it is an established technology and it is assumed that the extracted groundwater and FPP mixture could be separated using this technology; however, bench-scale studies may be required to determine how to efficiently separate oil from groundwater at the Facility. Since the design and operation of an API separator is relatively simple and is currently in use at the Kaiser Facility at the Wastewater Lagoon, it is judged likely that this technology can be implemented and operated reliably at the Kaiser Facility.

The DAF system is eliminated for reliability and implementability reasons. The O&M of the DAF system will be more complex than the O&M of an API separator, since the DAF system requires pumps to pressurize the wastewater stream, a compressed air source, and a vessel that can operate at high pressures.

To summarize, belt skimmers for the *in situ* recovery of FPP from smear zone soil and from groundwater, and API oil/water separators for the *ex situ* recovery of FPP from extracted groundwater are retained for use in this FS.

H.3 REFERENCES FOR APPENDIX H

EPA, 1996. How to Effectively Recover Free Product At Leaking Underground Storage Tank Sites: A Guide For State Regulators. 510-R-96-001. September.

Hart Crowser, 2003. Draft Groundwater Remedial Investigation/Feasibility Study, Kaiser Trentwood Facility, Spokane, Washington. Prepared for Kaiser Aluminum & Chemical Corporation by Hart Crowser, Inc. Modified July 2003.

Hart Crowser, 2012a. Final Site-Wide Groundwater Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Hart Crowser, 2012b. Final Feasibility Study Technical Memorandum, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Washington, LLC, by Hart Crowser, Inc. May 2012.

Metcalf & Eddy, 2003. Wastewater Engineering – Treatment and Reuse, 4th Edition. Metcalf & Eddy, Inc. G. Tchobanoglous, F.L. Burton, and H.D. Stensel, revisors. San Francisco. McGraw-Hill.

Suthersan, S., 1997. Remediation Engineering Design Concepts. Boca Raton, Florida. CRC Press, Inc.

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APPENDIX I
RESTORATION TIME FRAME MEMORANDA

SOLUBILITY OF PCBS AND COMINGLED PCB RESTORATION TIME FRAME MEMO

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MEMORANDUM

DATE: July 20, 2011

TO: Bud Leber, PE, Kaiser Aluminum Washington, LLC

FROM: Will Abercrombie, Hart Crowser, Inc.
Peter Smiltins, PE, Hart Crowser, Inc.
Roy Jensen, LHG, Hart Crowser, Inc.
Dan McCarthy, PE, ECS

RE: **Solubility of PCBs and Comingled PCB Restoration Time Frame**
Kaiser Aluminum Washington, LLC
Spokane Valley, Washington
2644-125

This memorandum presents our evaluation of the solubility of PCBs in petroleum products and the restoration time frame for comingled PCBs.

Solubility of PCBs in Petroleum Products

Polychlorinated biphenyls (PCBs) are highly hydrophobic compounds that exhibit low solubility in water but are freely soluble in relatively nonpolar organic solvents such as petroleum products (ATSDR 2000, EPA 1980, EPA 1983). In a setting where water and other phases are present (e.g., solids, immiscible organic liquids, petroleum products), these properties are evident in the strong tendency that PCBs display for partitioning into the non-aqueous phase in much greater proportion than the dissolved phase. The degree to which PCBs preferentially partition into the non-aqueous phase is demonstrated by their high partition coefficient values (log K_{ow}) and low aqueous solubilities, as shown in Table 4-3 (attached) for select Aroclors (ATSDR 2000). The partitioning coefficients and solubilities of PCBs are compared to those present in petroleum hydrocarbons in Table 2-4 of the FSTM (Hart Crowser 2010). In the natural aqueous environment, for example in waterways or in groundwater, the hydrophobic properties of PCBs translate into an affinity for adsorbing to soil particle surfaces, organic carbon, or associating with sediments rather than entering the dissolved phase.

The hydrophobic behavior of PCBs has been observed at the Kaiser Facility in the Oil House and Wastewater Treatment areas, where PCBs are comingled with free phase petroleum (FPP) at the

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water table. The Oil House and Wastewater Treatment areas were designed and constructed for the management of petroleum hydrocarbons in the form of used product and in wastewater mixtures. As a result, the PCBs detected in the Oil House and Wastewater Treatment areas were in contact with petroleum before being released to the environment. It is logical to assume that, because of the presence of petroleum, the PCBs would have had ample opportunity to comingle with the carbon source.

PCBs present in groundwater samples from Oil House and Wastewater Treatment area wells are associated with FPP or dissolved petroleum products. When petroleum hydrocarbons are absent, PCBs have not been detected in groundwater from the Oil House and Wastewater Treatment areas. It is believed that the lack of PCBs in groundwater in these two areas is a direct result of comingling effects of PCBs and petroleum. Sorption to soil and/or degradation are also factors that reduce the mobility of PCBs into the aquifer.

The most recently measured groundwater PCB concentrations in the Wastewater Treatment and Oil House areas are presented respectively on Figures 1 and 2, attached (Draft Final FS Figures 4-4 and 4-5 updated to 2011). These figures include the most recent analytical results for PCBs between 1991 and January 2011. PCB detection limits for analysis of groundwater samples using EPA Method 8082 have generally been 50 nanograms per liter (ng/L) before 2000 and 5 to 10 ng/L after 2000. Historically, PCBs have been detected in 11 monitoring wells in the Wastewater Treatment area at concentrations ranging from 6.3 to 17,000,000 ng/L, and PCBs have been detected in 17 monitoring wells in the Oil House area at concentrations ranging from 210 to 130,000,000 ng/L. In each case, when PCBs are detected in samples from these wells, FPP or dissolved petroleum has been present.

Downgradient wells have been sampled and analyzed periodically and show that migration of PCBs associated with petroleum from the Oil House and Wastewater Treatment areas has not occurred. For example, wells immediately downgradient of the Wastewater Treatment area (i.e., MW-14S, MW-15, MW-21S) have been sampled more than 100 times without detecting PCBs, except for one tentative detection of PCBs in well MW-15 (1.9 T ng/L) in July 2007. (Note that the "T" qualifier indicates the PCB detection is between the detection limit and the quantification limit and represents an estimate.)

Restoration Time Frame Evaluation

Because of the properties of PCBs, one can assume that, over time, PCBs will remain associated with the FPP present, and that the removal rate of FPP from the smear zone would be a factor in the restoration time frame for comingled PCBs. The presence of FPP would be indicated by the residual saturation default value of 2,000 mg/kg for petroleum hydrocarbons in soil. It can be assumed that comingled PCBs may still be present if the petroleum hydrocarbon concentration in the soil exceeds this default value, and that the estimated restoration time frame for comingled PCBs may be associated with the time needed for the concentration of petroleum hydrocarbons to decline to this value.

The estimated recovery time for FPP in Alternative C2 is estimated to be approximately 10 years in the Oil House area and 25 years in the Wastewater Treatment area of the Facility (refer to Section 4.1.3.4 of the Draft Final FS). The restoration time frame for comingled PCBs may be associated with these time frames for the removal of FPP, but may also be associated with the restoration time frame for SVOCs in the petroleum plumes and associated smear zone soil to attain screening levels (SLs) and preliminary cleanup levels (PCULs) by natural attenuation. The SL and PCUL for SVOCs in smear zone soil is 2,000 mg/kg, which is the default residual saturation value for diesel and heavy oil. Petroleum hydrocarbon concentrations in soil above the residual saturation value may indicate the presence of free phase product. The concentration of SVOCs in smear zone soil is expected to be below 2,000 mg/kg for petroleum hydrocarbons at the end of the restoration time frames for the petroleum plumes, which range from approximately 4 years (Oil House area South plume) to 34 years (Wastewater Treatment area North plume) (see Table 4-7 in the Draft Final FS).

It can be assumed that comingled PCBs may still be present if the petroleum hydrocarbon concentration in the soil exceeds the residual saturation default value of 2,000 mg/kg, and that the estimated restoration time frame for comingled PCBs may be associated with the time needed for the concentration of petroleum hydrocarbons to decline to this value. However, considering the potential for non-recoverable product to remain in the subsurface (even if the concentration of SVOCs declines to below 2,000 mg/kg), the restoration time frame for comingled PCBs may be longer.

The available evidence indicates that the estimated restoration time frame for PCBs that are comingled with SVOCs for Alternative C2 will be approximately the same as the estimated restoration time frame for SVOCs alone.

References

ATSDR, 2000. Toxicological Profile for Polychlorinated Biphenyls (PCBs). U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. November 2000.

EPA, 1980. Ambient Water Quality Criteria for Polychlorinated Biphenyls. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division. EPA 540/5-80-068. October 1980.

EPA, 1983. Environmental Transport and Transformation of Polychlorinated Biphenyls. U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances. EPA 560/5-83-025. December 1983.

Hart Crowser, 2010. Draft Final Feasibility Study Technical Memorandum, Kaiser Trentwood Facility, Spokane Valley, Washington. Job 2644-120. March 2010.

Hart Crowser, 2011. Draft Final Feasibility Study Report, Kaiser Trentwood Facility, Spokane Valley, Washington. Job 2644-125.

Attachments:
Table 4-3 – Physical and Chemical Properties of Some Aroclors (from ATSDR 2000)
Table 2-4 – Chemical and Physical Properties of COPCs (from Hart Crowser 2010)
Figure 1 – PCB Concentrations Associated with Petroleum Hydrocarbons in Groundwater, West Area – Most Recently Measured
Figure 2 – Total PCB Concentrations Associated with Petroleum Hydrocarbons in Groundwater, East Area – Most Recently Measured

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Table 4-3. Physical and Chemical Properties of Some Aroclors[a]

Property	Aroclor 1016	Aroclor 1221	Aroclor 1232	Aroclor 1242
Molecular weight[b]	257.9[c]	200.7[c]	232.2[c]	266.5[c]
Color	Clear	Clear	Clear	Clear
Physical state	Oil	Oil	Oil	Oil
Melting point, °C	No data	1[d]	No data	No data
Boiling point, °C	325–356	275–320	290–325	325–366
Density, g/cm^3 at 25 °C	1.37	1.18	1.26	1.38
Odor	No data	No data	No data	Mild hydrocarbon[d]
Odor threshold:				
Water	No data	No data	No data	No data
Air	No data	No data	No data	No data
Solubility:				
Water, mg/L	0.42 (25 °C)[e]	0.59 (24 °C)[f]	0.45 (25 °C)	0.24[c]; 0.34 (25 °C)[e] 0.10 (24 °C)[f]
Organic solvent(s)	Very soluble[g]	Very soluble[g]	Very soluble[g]	Very soluble[g]
Partition coefficients:				
Log K_{ow}[h]	5.6	4.7	5.1	5.6
Log K_{oc}	No data	No data	No data	No data
Vapor pressure, mm Hg at 25 °C	$4x10^{-4}$[c]	$6.7x10^{-3}$[c]	$4.06x10^{-3}$[c]	$4.06x10^{-4}$[c]
Henry's law constant, atm-m^3/mol at 25 °C[i]	$2.9x10^{-4}$	$3.5x10^{-3}$	No data	$5.2x10^{-4}$
Autoignition temperature	No data	No data	No data	No data
Flashpoint, °C (Cleveland open cup)	170	141–150	152–154	176–180
Flammability limits, °C	None to boiling point	176	328	None to boiling point
Conversion factors				
Air (25 °C)[j]	1 mg/m^3=0.095 ppm	1 mg/m^3=0.12 ppm	1 mg/m^3=0.105 ppm	1 mg/m^3=0.092 ppm
Explosive limits	No data	No data	No data	No data

Table 4-3. Physical and Chemical Properties of Some Aroclors[a] *(continued)*

Property	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
Molecular weight[b]	328[c]	357.7[c]	389	453
Color	Light yellow	Light yellow	No data	Clear[k]
Physical state	Viscous liquid	Sticky resin	No data	Viscous liquid[k]
Melting point	No data	No data	No data	No data
Boiling point, °C	365–390	385–420	390–425	435–450
Density, g/cm^3 at 25 °C	1.54	1.62	1.64	1.81
Odor	Mild hydrocarbon[d]	No data	No data	No data
Odor threshold:				
Water	No data	No data	No data	No data
Air	No data	No data	No data	No data
Solubility:				
Water, mg/L	0.012[c]; 0.057 (24 °C)	0.0027[c];0.08 (24 °C)[f]	0.052 (24 °C)[f]	0.300 (24 °C)[f]
Organic solvent(s)	Very soluble[g]	Very soluble[g]	No data	Soluble
Partition coefficients:				
Log K_{ow}	6.5	6.8	No data	No data
Log K_{oc}	No data	No data	No data	No data
Vapor pressure, mm Hg at 25 °C	$7.71x10^{-5}$ [c]	$4.05x10^{-5}$ [c]	No data	No data
Henry's law constant, atm-m^3/mol at 25 °C[i]	$2.0x10^{-3}$	$4.6x10^{-3}$	No data	No data
Autoignition temperature	No data	No data	No data	No data
Flashpoint °C (Cleveland open cup)	No data	No data	195°C	195°C

Table 4-3. Physical and Chemical Properties of Some Aroclors[a] *(continued)*

Property	Aroclor 1254	Aroclor 1260	Aroclor 1262	Aroclor 1268
Flammability limits, •C	None to boiling point	None to boiling point	None to boiling point	None to boiling point
Conversion factors, Air (25 •C)[j]	1 mg/m^3=0.075 ppm	1 mg/m^3=0.065 ppm	1 mg/m^3=0.061 ppm	1 mg/m^3=0.052 ppm
Explosive limits	No data	No data	No data	No data

[a]All information obtained from Monsanto Chemical Company 1985 and Hutzinger et al. 1974 unless otherwise noted.
[b]Average weight from Table 3-3.
[c]EPA 1979h; data on temperature not available.
[d]NIOSH 1997
[e]Paris et al. 1978
[f]Hollifield 1979
[g]EPA 1985b
[h]These log K_{ow} values represent an average value for the major components of the individual Aroclor. Experimental values for the individual components were obtained from Hansch and Leo 1985.
[i]These Henry's law constants were estimated by dividing the vapor pressure by the water solubility. The first water solubility given in this table was used for the calculation. The resulting estimated Henry's law constant is only an average for the entire mixture; the individual chlorobiphenyl isomers vary significantly from the average. Burkhard et al. (1985) estimated the following Henry's law constants (atm-m^3/mol) for various Aroclors at 25 •C: 1221 (2.28×10^{-4}), 1242 (3.43×10^{-4}), 1248 (4.4×10^{-4}), 1254 (2.83×10^{-4}), and 1260 (4.15×10^{-4}).
[j]These air conversion factors were calculated by using the average molecular weight and ideal gas law.
[k]Chemical Health and Safety Data; National Toxicology Program (http://ntp-server.niehs.nih.gov)

Table 2-4 - Chemical and Physical Properties of COPCs

Analyte	CAS Number	Molecular Weight in g/mol	Boiling Point in °C	Melting Point in °C	Specific Gravity	Form at 20°C	Vapor Pressure in atm	Volatile[c]	Aqueous Solubility in mg/L	Henry's Law Constant in atm-m^3/mol	Partitioning Coefficient Organic Carbon to Water (Koc) in L/kg	Mobility in Water
Selected Petroleum Hydrocarbon Constituents[a]												
Benzene	71432	78	80 [b]	5.5 [b]	0.88	liquid	0.1	moderate	1,750	5.56E-03	62	high
Toluene	108883	92	111 [b]	-95 [b]	0.87	liquid	0.03	moderate	526	6.63E-03	140	high
Ethylbenzene	100414	106	136 [b]	-94 [b]	0.87	liquid	0.009	low	169	7.88E-03	204	moderate
Total Xylenes	NA	106			0.88	liquid		low	171	6.80E-03	233	moderate
n-Hexane	110543	86	69 [d]	-95 [d]	0.66	liquid	0.2	moderate	9.5	1.80E+00	3,410	low
Kensol 51 [e]	64741442		> 271	-12	0.82	liquid	<1 mmHg	not volatile	insoluble		NA	insoluble
Selected cPAH constituents [d]												
Benzo(b)fluoranthene	205992	252.3	NA	168	NA	solid	6.58E-10	not volatile	1.40E-02	2.47E-07	357,537 [d]	insoluble
Benzo(a)pyrene	50328	252.32	495	179	1.35	solid	7.22E-12	not volatile	3.80E-03	2.17E-07	968,774 [d]	insoluble
Chrysene	218019	228.3	448	258.2	1.27	solid	8.30E-12	not volatile	2.00E-03	7.26E-10	1,860,000 [e]	insoluble
Aliphatics Hydrocarbons[f]												
EC > 5-6		81			0.67	liquid		moderate	3.60E+01	8.05E-01	800	low
EC > 6-8		100			0.70	liquid		moderate	5.40E+00	1.22E+00	3,800	low
EC > 8-10		130			0.73	liquid		low	4.30E-01	1.95E+00	30,200	insoluble
EC > 10-12		160			0.75	liquid		low	3.40E-02	2.93E+00	234,000	insoluble
EC > 12-16		200			0.77	liquid		low	7.60E-04	1.27E+01	5,370,000	insoluble
EC > 16-21		270			0.78	liquid		low	1.30E-06	1.20E+02	9,550,000,000	insoluble
EC > 21-34		400			0.79	liquid		low	1.50E-11	2.44E+03	10,700,000,000	insoluble
Aromatic Hydrocarbons[f]												
EC > 8-10		120			0.87	liquid		moderate	6.50E+01	1.17E-02	1,580	low
EC > 10-12		130			0.90	liquid		moderate	2.50E+01	3.41E-03	2,510	low
EC > 12-16		150			1.00	liquid		moderate	5.80E+00	1.29E-03	5,010	insoluble
EC > 16-21		190			1.16	liquid		low	5.10E-01	3.17E-04	15,800	insoluble
EC > 21-34		240			1.30	liquid		low	6.60E-03	1.63E-05	126,000	insoluble
PCB Congener[g,h]												
Monochlorobiphenyls						solid	1.82E-06 to 1.38E-05	not volatile	1.34E+00 to 4.83E+00	5.73E-04 to 7.36E-04	25,119 to 33,113	insoluble
Trichlorobiphenyl						solid	1.36E-07 to 1.38E-06	not volatile	4.44E-02 to 4.00E-01	1.00E-04 to 2.50E-04	1 to 181,970	insoluble
Pentachlorobiphenyls						solid	8.59E-09 to 1.47E-07	not volatile	2.62E-03 to 5.42E-02	4.70E-05 to 1.20E-04	1 to 891,251	insoluble
Heptachlorobiphenyls						solid	8.26E-10 to 7.16E-09	not volatile	3.14E-04 to 4.54E-03	1.30E-06 to 3.33E-05	1 to 4,570,882	insoluble
Decachlorobiphenyl						solid	1.39E-10	not volatile	7.43E-06	2.18E-06	1	insoluble

Notes:
a) Molecular Weight, Density, Solubility, Henry's Law Constant and Koc derived from Table 747-4 (Petroleum EC Fraction Physical/Chemical Values) in WAC 173-340-900 and from Ecology 2007a, Part IX Tables.
b) From CRC Handbook of Chemistry and Physics published by Cleveland Chemical and Rubber Company.
c) Volatile designation determined by vapor pressure: not volatile <0.001 atm, low 0.001 to 0.01 atm, moderate 0.01 to 0.2 atm, high >0.2 atm
d) From Montgomery Groundwater Chemicals Desk Reference, 1996
e) From Material Safety Data Sheet (MSDS)
f) Table derived from Table 747-4 (Petroleum EC Fraction Physical/Chemical Values) in WAC 173-340-900 and from Ecology 2007a, Part IX Tables.
g) Koc data from Hansen et al. 1999 and Solubility, Vapor pressure, Henry's Law Constant data from Oberg 2001. Some Solubility, Vapor Pressure, and Henry's Law Constant values are based on predicted or calculated value.
h) Congeners are individual PCB compounds. Aroclors are a mixture of different congeners. The following lists selected Aroclors with their respective average number of chlorine atoms per molecule: Aroclor 1221, 1.15; Aroclor 1242, 3.1; Aroclor 1262, 6.8. Note that Aroclors are not solids at room temperature.
EC - Equivalent carbon.
Shaded area indicates data are not available or not applicable.

Analyte	CAS Number	Molecular Weight in g/mol	Boiling Point in °C	Melting Point in °C	Specific Gravity	Form at 20°C	Vapor Pressure in atm	Volatile[c]	Aqueous Solubility in mg/L	Henry's Law Constant in atm-m^3/mol	Partitioning Coefficient Organic Carbon to Water (Koc) in L/kg	Mobility in Water
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Kensol 51 [e]	64741442		> 271	-12	0.82	liquid	<1 mmHg	not volatile	insoluble		NA	insoluble
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Benzo(a)pyrene	50328	252.32	495	179	1.35	solid	7.22E-12	not volatile	3.80E-03	2.17E-07	968,774 [d]	insoluble
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EC > 6-8		100			0.70	liquid		moderate	5.40E+00	1.22E+00	3,800	low
EC > 8-10		130			0.73	liquid		low	4.30E-01	1.95E+00	30,200	insoluble
EC > 10-12		160			0.75	liquid		low	3.40E-02	2.93E+00	234,000	insoluble
EC > 12-16		200			0.77	liquid		low	7.60E-04	1.27E+01	5,370,000	insoluble
EC > 16-21		270			0.78	liquid		low	1.30E-06	1.20E+02	9,550,000,000	insoluble
EC > 21-34		400			0.79	liquid		low	1.50E-11	2.44E+03	10,700,000,000	insoluble
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EC > 21-34		240			1.30	liquid		low	6.60E-03	1.63E-05	126,000	insoluble
PCB Congener[g,h]												
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Decachlorobiphenyl						solid	1.39E-10	not volatile	7.43E-06	2.18E-06	1	insoluble

Notes:

a) Molecular Weight, Density, Solubility, Henry's Law Constant and Koc derived from Table 747-4 (Petroleum EC Fraction Physical/Chemical Values) in WAC 173-340-900 and from Ecology 2007a, Part IX Tables.

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e) From Material Safety Data Sheet (MSDS)

f) Table derived from Table 747-4 (Petroleum EC Fraction Physical/Chemical Values) in WAC 173-340-900 and from Ecology 2007a, Part IX Tables.

g) Koc data from Hansen et al. 1999 and Solubility, Vapor pressure, Henry's Law Constant data from Oberg 2001. Some Solubility, Vapor Pressure, and Henry's Law Constant values are based on predicted or calculated value.

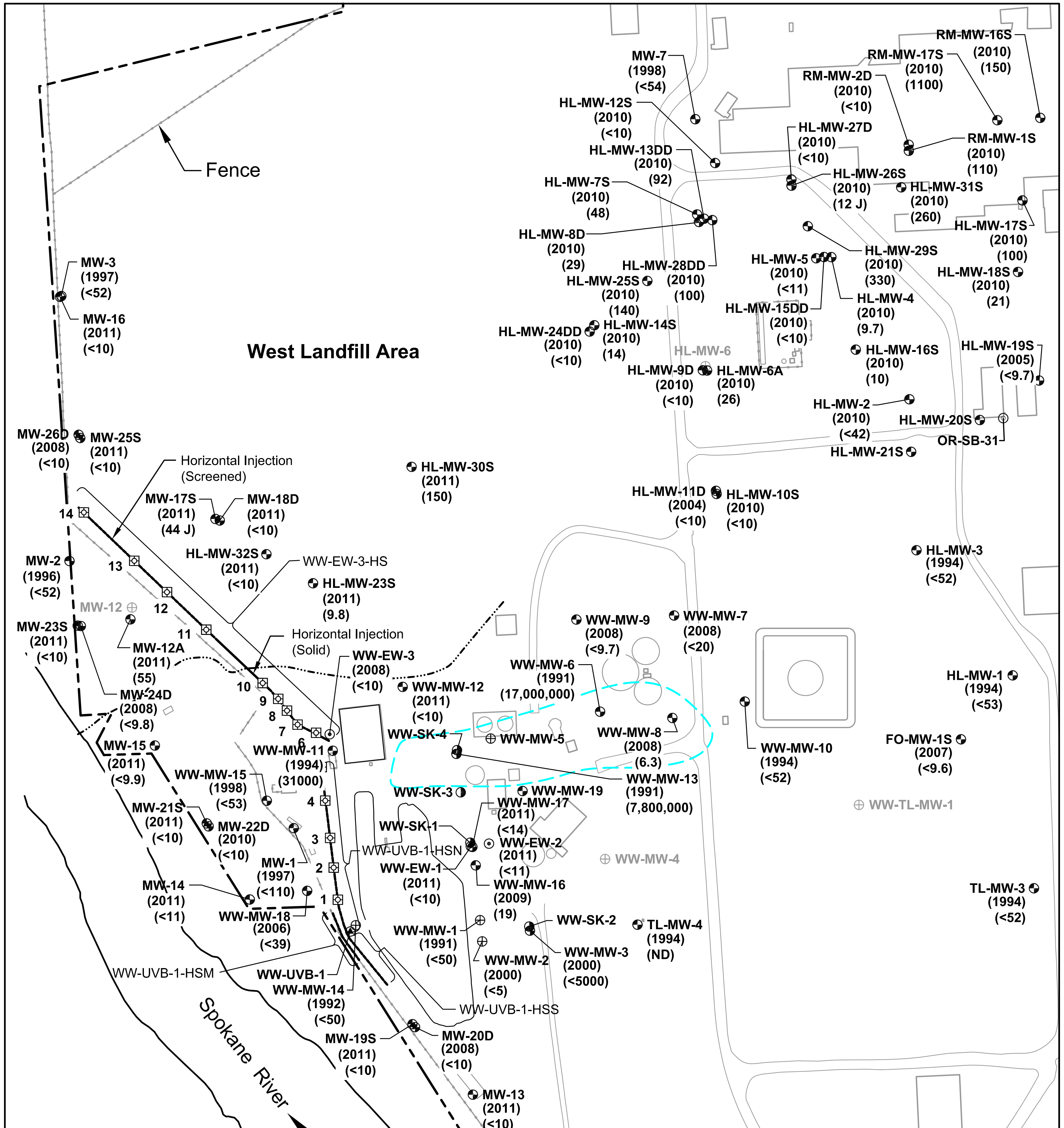
h) Congeners are individual PCB compounds. Aroclors are a mixture of different congeners. The following lists selected Aroclors with their respective average number of chlorine atoms per molecule: Aroclor 1221, 1.15; Aroclor 1242, 3.1; Aroclor 1262, 6.8. Note that Aroclors are not solids at room temperature.

EC - Equivalent carbon.

Shaded area indicates data are not available or not applicable.

Total PCB Concentrations Associated with Petroleum Hydrocarbons in Groundwater

West Area - Most Recently Measured



Exploration Location and Number

- OH-EW-1 Extraction Well
- OH-MW-03 Monitoring Well
- TL-MW-3 Abandoned Monitoring Well
- OH-SK-1 Skimming Well
- TF-EW-1-US Upper Screen Well
- North Supply Well Supply Well
- West Supply Well Backup Supply Well
- (3.0) Total PCB Concentration in ng/L
- J Estimated Value
- P GC Confirmation Criteria was Exceeded
- T Value is between the MDL and MRL
- (ND) Not Detected
- (2004) Year Data was Collected
- Inferred Extent of PCB Concentrations Exceeding Screening Level Associated with Petroleum Hydrocarbons. PCB Concentrations Are Associated with Petroleum and Are Not Dissolved in Groundwater.

Notes:

1. PCBs associated with the Remelt plume are discussed in Section 5.
2. Total PCB concentrations are from 2008. If not sampled in 2008, then the sampling year is provided.

N

0 250 500
Scale in Feet

HARTCROWSER

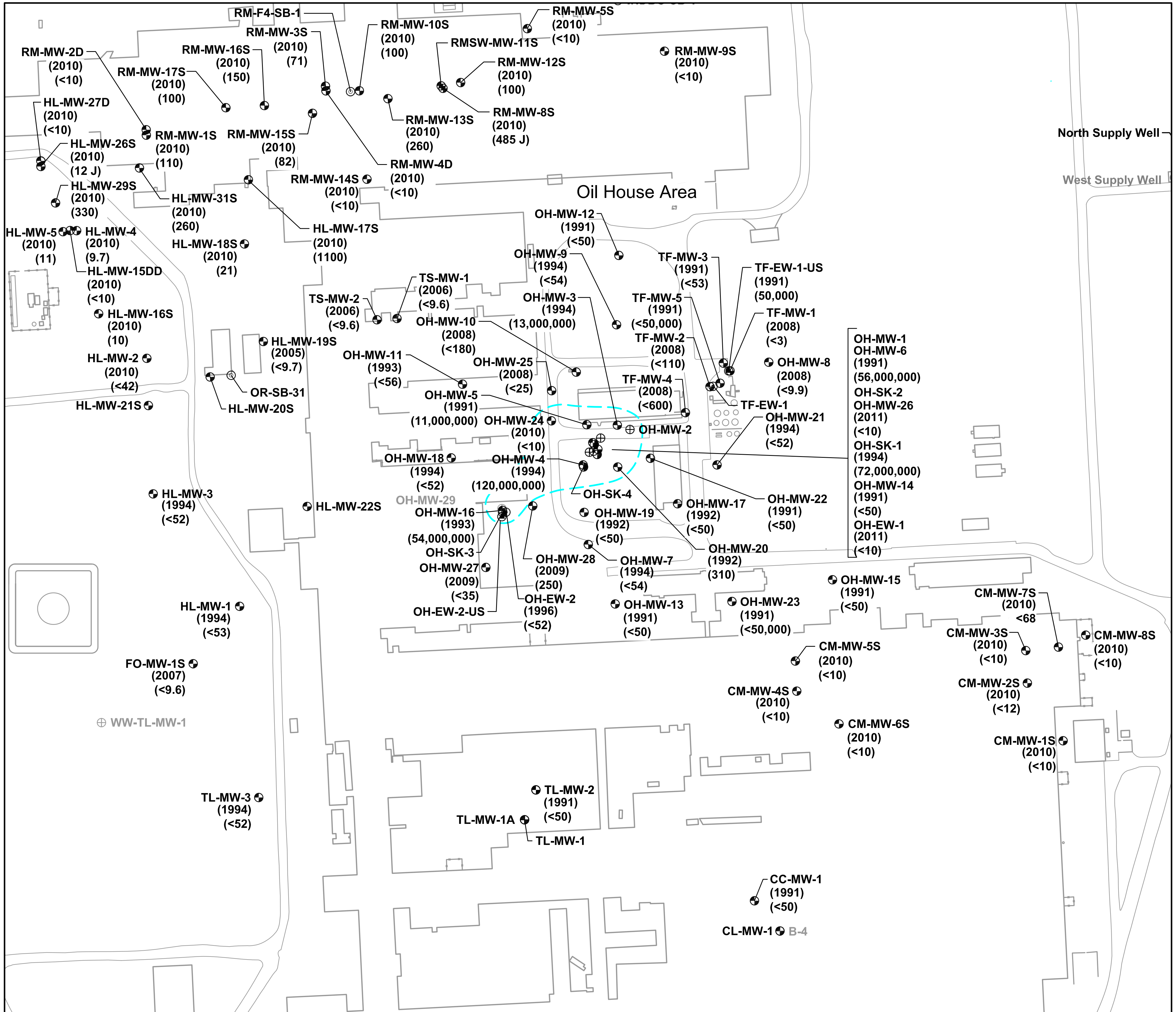
2644-125 ***5/12***

Figure 1

EAL 05/14/12 2644125-081.DWG

Total PCB Concentrations Associated with Petroleum Hydrocarbons in Groundwater

East Area - Most Recently Measured



Exploration Location and Number

OH-EW-1	Extraction Well
OH-MW-03	Monitoring Well
TL-MW-3	Abandoned Monitoring Well
OH-SK-1	Skimming Well
TF-EW-1-US	Upper Screen Well
North Supply Well	Supply Well
West Supply Well	Backup Supply Well
(3.0)	Total PCB Concentration in ng/L
J	Estimated Value
P	GC Confirmation Criteria was Exceeded
T	Value is between the MDL and MRL
(2006)	Year Data was Collected
— — —	Inferred Extent of PCB Concentrations Exceeding Screening Level Associated with Petroleum Hydrocarbons. PCB Concentrations Are Associated with Petroleum and Are Not Dissolved in Groundwater.

Notes:

1. PCBs associated with the Remelt plume are discussed in Section 5.
2. Total PCB concentrations are from 2008. If not sampled in 2008, then the sampling year is provided.

0 250 500
Scale in Feet

N

HARTCROWSER

2644-125 ***5/12***

Figure 2

EAL 05/14/12 2644125-082.DWG

PCB RESTORATION TIME FRAME EVALUATION MEMO

MEMORANDUM

DATE: July 20, 2011

TO: Bud Leber, Kaiser Aluminum Washington, LLC

FROM: William Abercrombie, Hart Crowser, Inc.
Roy Jensen LHG, Hart Crowser, Inc.
Kimberly Reinauer, EIT, LEED, Hart Crowser, Inc.
Peter Smiltins, PE, Hart Crowser, Inc.
Dan McCarthy, PE, ECS

RE: **PCB Restoration Time Frame Evaluation**
Remelt/Hot Line Plume
Kaiser Aluminum Washington, LLC
2644-125

This memo presents our revised evaluation of the restoration time frames for the various alternatives for the Remelt/Hot Line PCB plume and associated smear zone soil. The original restoration time frames for Alternatives D2 and D3 are presented in Table 5-4 of the Draft Feasibility Study (FS) (Hart Crowser 2010b).

Alternative D4 has been added to the Draft Final FS at the request of Ecology (Ecology 2011). This alternative was developed to evaluate the impacts of the extraction and treatment of a portion of the Remelt/Hot Line PCB plume. Alternative D3 extracts and treats the entire plume through three extraction wells as shown on Figure 5-6 of the Draft Final FS. Alternative D4 includes the installation of one extraction well at a location in the centerline of the Remelt/Hot Line PCB plume just to the southwest of the Remelt building as shown on Figure 5-6 of the Draft Final FS. Alternative D4 extracts groundwater at a rate of approximately 300,000 gallons per day (gpd) (approximately 10 percent of the extraction rate associated with Alternative D3). The extracted water in Alternative D4 will be treated by the same treatment methods that were summarized in the Draft Final FS for Alternative D3.

Restoration time frames were calculated using the first order method described in Section E.6 in the Draft Final FS. The inputs and assumptions are described below.

PCB CLEANUP CRITERIA

Ecology has established preliminary cleanup levels (PCULs) for total PCBs for a standard point of compliance (POC) and for a conditional POC (Ecology 2010). If a conditional POC is granted, CULs for PCBs that are based on the protection of surface water should be met at the point or points of discharge to the surface water. Concentrations of PCBs everywhere else at the Facility may exceed surface water standards but must meet drinking water standards and MTCA threshold requirements.

Standard Groundwater Point of Compliance

The PCUL for the standard groundwater POC established by Ecology is 0.000064 µg/L, which is based on the criteria for the protection of surface water published under Section 304 of the Clean Water Act for protection of human health from water and fish ingestion. Ecology adjusted this value to 0.0045 µg/L, the method detection limit (MDL) for the analytical method used to measure PCB concentrations in groundwater, modified Method 8082 (Ecology 2010). The MDL may be subject to further discussions. Under a standard POC, this PCUL would need to be met throughout the Facility from the uppermost level of the saturated zone extending vertically to the lowest depth which could potentially be affected by constituents of concern (COCs) at the Facility.

Conditional Groundwater Point of Compliance

If a conditional groundwater POC is granted, the PCUL is 0.000064 µg/L (adjusted up to 0.0045 µg/L, the MDL based on modified Method 8082) at the points where the groundwater flows into the surface water, and 0.22 µg/L (adjusted down from 0.44 µg/L, the drinking water criterion to bring total cancer risk down to 0.5×10^{-5}) and MTCA threshold requirements everywhere else throughout the Facility (Ecology 2010).

Upgradient Groundwater Concentration Protective of the Spokane River

The PCB concentration in the Remelt/Hot Line PCB plume declines from a high of 2 µg/L in the Remelt area to less than 0.005 µg/L within 650 feet of the Spokane River. The groundwater concentration in the source area that will be protective of the PCUL at the point where the groundwater flows into the surface water was calculated with the knowledge that some attenuation is occurring as the groundwater travels from the source area to the river. This attenuation is likely from a variety of factors including adsorption, dispersion, and degradation. The regression analysis is described in Section E.7 in the Draft Final FS.

The PCB source concentration at well RM-MW-17S (approximately 2,300 feet from the Spokane River), that would not exceed a concentration of 0.000064 μg/L at the river is predicted to be 0.06 μg/L (Table E-9 of the Draft Final FS).

Soil Concentrations Protective of PCULs

Soil concentrations protective of groundwater PCULs were calculated using the soil/water partitioning coefficient (in L/kg) (K_d), assuming a linear relationship between groundwater (C_w) and soil contaminant concentration (C_s) according to the following equation:

$$C_s = K_d C_w \qquad (1)$$

The K_d value was calculated by multiplying the organic carbon partition coefficient (K_{oc}) for total PCBs from the CLARC database (310,000 L/kg) by the fraction of organic carbon (f_{oc}) value of 0.001. A f_{oc} value of 0.001 was used because this is the representative value for subsurface soil reported in the Draft Final Groundwater RI (Hart Crowser 2009a).

Soil concentrations considered protective of groundwater PCULs are presented in Table 2.

MASS TRANSFER MECHANISM

Mass of PCBs

The PCB area of concern in the Remelt area smear zone soil was described in Appendix D of the FSTM (Hart Crowser 2010a). The mass of PCBs in the smear zone soil was estimated to be 40 pounds (Table D-1 in the FSTM) based on assumptions that were designed to be conservative.

The soil matrix at the Facility consists mostly of gravel and cobbles (Hart Crowser 2009b). The PCBs in the sample were associated with the silt (when present), sand, and organic material (if any) that were present in the sample. The gravel and cobble portion of the sample was either not sent to or not analyzed by the laboratory since cobbles would not fit in the sample jar and gravel would have to be pulverized in the laboratory prior to analysis. As a result, the concentration of PCBs reported by the laboratory is an overestimate of the actual *in situ* concentration of PCBs in smear zone soil. Nonetheless, the laboratory values were reported in the Draft Final Soil RI (Hart Crowser 2009b) since they represent a conservative estimate of the actual concentration of PCBs present at the site, and contribute to a conservative approach to estimating risks to human health and the environment posed by PCBs. Site data indicate that at least 30 percent of Facility soil is greater than

2 inches in diameter. Grain size distribution data from the Facility indicates that an average of 54 percent of the material is retained on a No. 4 sieve (0.187 inch) (Hart Crowser 2009b).

A revised PCB mass was calculated based on the following assumptions:

- The PCB concentrations measured in Remelt area smear zone soil was reduced by 54 percent to develop a more accurate estimate of PCB mass in the Remelt area smear zone soil (refer to Table 1).

- Only areas where smear zone soil and groundwater plumes overlap (refer to Figure 5-1 in the Draft Final FS) were included in the calculation of mass (i.e., if no groundwater plume is present in an area, then the mass present in the smear zone in that area was not included in the calculation, refer to Table 1).

- PCBs leaching from smear zone soil into groundwater is assumed to occur only within the approximately 10-foot-thick smear zone.

Based on these modified assumptions, the revised estimate of the PCB mass within the smear zone in the Remelt area is approximately 11 pounds (Table 1).

Groundwater Flux

The groundwater flux for the Remelt/Hot Line plume under the existing condition with no additional pumping was presented in Table E-5 for the Draft Final FS as 9 $ft^3/day/ft^2$ (67.3 $gal/day/ft^2$). The groundwater flux through the smear zone increases with downgradient groundwater extraction. Based on a vertical depth of 30 feet, the groundwater flux through the Remelt area plume under existing conditions is estimated to be approximately 1 million gallons per day (MGD).

The groundwater flux though the Remelt/Hot Line plume was calculated for Alternatives D2, D3, and D4 accounting for the increase in pumping. The groundwater extraction rate for Alternatives D2 and D3 is based on hydraulic containment of the Remelt/Hot Line plume from the results of groundwater modeling (Appendix E Draft Final FS). The extraction rate for D4 is based on a pumping rate of 300,000 gpd from a well located in vicinity of the plume source area.

The change in groundwater flux generated by the various alternatives was evaluated from the results of groundwater modeling using changes in travel time as a proxy for changes in groundwater flux. The faster a modeled particle moves through the groundwater the greater the groundwater flux. It was assumed that particle travel time in a plume is inversely proportional to change in groundwater flux. The groundwater flux for Alternatives D2 and D3 are discussed in Section E.5 of the Draft Final

FS. The flux for Alternative D2a increases by a factor of 1.6, while the flux for Alternatives D2b and D3 increases by a factor of 1.7. Because Alternative D4 does not include complete containment it was not possible to calculate the increase in flux from the particle tracking method. Under Alternative D4 we estimated that the flux will increase by about 200,000 gpd or a factor of 1.2 from the baseline case.

Mass Transfer

In the first order method (Section E.5.2 in the Draft Final FS), groundwater that enters the smear zone upgradient of the Remelt building is assumed to contain no PCBs (i.e., background PCBs in groundwater entering the Kaiser Facility are not considered). As the groundwater flows through the smear zone, PCBs are transferred from the soil to the groundwater. PCB leaching from smear zone soil into groundwater is assumed to occur only within the approximately 10-foot-thick smear zone. The predicted PCB concentration of the groundwater leaving the smear zone is calculated using the K_d value.

The groundwater flow rate through smear zone soil was calculated by multiplying the groundwater flux (gpd/square foot) by the cross sectional area of the smear zone normal to the groundwater flow direction. The cross sectional area was conservatively estimated by multiplying the widest portion of the smear zone, perpendicular to groundwater flow, by the thickness of the smear zone (about 10 feet).

The mass of PCBs transferred from the smear zone soil to the groundwater is calculated by multiplying the predicted concentration of PCBs in groundwater leaving the smear zone by the groundwater flow rate.

ESTIMATED RESTORATION TIME FRAMES

Estimated restoration time frames to meet the standard POC for the Remelt/Hot Line PCB plume are relatively long. To put these evaluation criteria into perspective we have estimated restoration time frames for both a standard and conditional POC for Alternatives D1 through D4.

For the purposes of this evaluation, the sole mechanism for reducing the mass of PCBs in smear zone soil is assumed to be through leaching of PCBs from smear zone soil into groundwater. Colloidal transport of PCBs in the Remelt/Hot Line PCB plume is suspected (Hart Crowser 2009a). However, the effect of colloidal particles on the mass transfer of PCBs is not well understood.

The restoration time frame was estimated by establishing a mass balance for the smear zone soil and groundwater in the Remelt/Hot Line area. The calculations used to establish this mass balance are provided in Appendix E of the Draft Final FS (Hart Crowser 2010b). The calculations are based upon the following assumptions:

- The PCB concentrations in groundwater and soil reach equilibrium instantaneously;
- A K_d value of 310 L/kg is representative of the K_d values associated with the distribution of PCBs present in the smear zone soil in the Remelt area. (A K_d of 78.1 L/kg (for Aroclor 1242) was used in the Draft FS);
- There is a linear equilibrium relationship (proportional to the K_d value) between the PCB concentration in soil and PCB concentration in groundwater;
- The PCB mass in the smear zone is 100 percent leachable; and
- Restoration of groundwater is complete once the concentration of PCBs in smear zone soil declines to a concentration that would result in a groundwater concentration below the PCUL (although groundwater will ultimately be considered to meet CULs once it is empirically demonstrated to do so).

Restoration time frames are presented in Table 2 for both a standard and conditional POC.

Estimation of Restoration Time Fame for Alternative D1

The estimated restoration time frame for Alternative D1 for the standard POC is approximately 280 years to reach the modified Method 8082 MDL of 0.0045 µg/L and soil to groundwater PCUL of 0.0014 mg/kg and 590 years to reach 0.000064 µg/L. If a conditional POC is granted, it is expected to take 6 years for the PCB concentration in the plume to be less than the PCUL of 0.22 µg/L and the concentration of PCBs in the smear zone soil in the Remelt area to decline to 0.068 mg/kg (Table 2). PCBs are not currently reaching the Spokane River from the Remelt/Hot Line plume at concentrations above the current PCUL (modified Method 8082 MDL of 0.0045 µg/L).

If the PCUL for a conditional POC is established as 0.000064 µg/L, the PCB concentration in groundwater in the Remelt source area would need to be approximately 0.060 µg/L (with a smear zone soil concentration of approximately 0.019 mg/kg) for the concentration to decline to 0.000064 µg/L by the time the PCBs reach the Spokane River (see above). It is expected to take about 100 years for the PCB concentrations in groundwater and smear zone soil to decline to these values.

Estimation of Restoration Time Fame for Alternative D2a

The estimated restoration time frame for a standard POC for Alternative D2a is approximately 180 years to reach a groundwater concentration of 0.0045 µg/L and 370 years to reach a groundwater concentration of 0.000064 µg/L (Table 2).

If a conditional POC is granted, it is expected to take approximately 4 years for the PCB concentration in the plume to be less than the PCUL of 0.22 µg/L, and the concentration of PCBs in the smear zone soil in the Remelt area to decline to 0.068 mg/kg (Table 2). PCBs are not currently reaching the Spokane River from the Remelt/Hot Line plume at concentrations above the current PCUL (modified Method 8082 MDL of 0.0045 µg/L).

If the PCUL for a conditional POC is established as 0.000064 µg/L at the groundwater/surface water interface, the PCB concentration in groundwater in the Remelt source area would need to be approximately 0.060 µg/L (with a smear zone soil concentration of approximately 0.019 mg/kg) for the concentration to decline to 0.000064 µg/L by the time the PCBs reach the Spokane River (see above). It is expected to take about 60 years for the PCB concentrations to decline to these values (Table 2). The hydraulic containment provided by Alternative D2a will prevent PCBs at concentrations above 0.000064 µg/L from reaching the Spokane River during this time.

Estimation of Restoration Time Frame for Alternatives D2b and D3

The estimated restoration time frame for a standard POC for Alternatives D2b and D3 is approximately 180 years for the soil concentration in the Remelt area to decline to 0.0014 mg/kg, and the concentration of PCBs in the groundwater plume to decline to 0.0045 µg/L, and 370 years to reduce PCB concentrations in the plume to 0.000064 µg/L.

The restoration time frame for the conditional POC is estimated to be approximately 4 years (time for the soil concentration in the Remelt area to decline to 0.068 mg/kg, and the concentration of PCBs in the groundwater plume to decline to 0.22 µg/L for protection of drinking water use). PCBs are not currently reaching the Spokane River from the Remelt/Hot Line plume at concentrations above the MDL (0.0045 µg/L).

If the PCUL for a conditional POC is established as 0.000064 µg/L at the groundwater/surface water interface, the PCB concentration in groundwater in the Remelt source area would need to be approximately 0.060 µg/L for the concentration to decline to 0.000064 µg/L by the time the PCBs reach the Spokane River (see above). It is expected to take about 60 years for the PCB concentrations to decline to this value. The hydraulic containment provided in these alternatives will prevent PCBs at concentrations above 0.000064 µg/L from reaching the Spokane River during this time.

Restoration Time Frame for Alternative D4

The estimated restoration time frame for the standard POC for Alternative D4 is approximately 240 years for concentrations to decline to the PCULs of 0.0045 µg/L and PCUL for the soil to groundwater pathway of 0.0014 mg/kg; and 490 years to reduce PCB concentrations in the plume to 0.000064 µg/L.

It is expected to take approximately 5 years for the PCB concentration in the plume to decline to less than 0.22 µg/L, and the concentration of PCBs in groundwater to decline to 0.068 mg/kg (Table 2).

If the PCUL for a conditional POC is established as 0.000064 µg/L at the groundwater/surface water interface, the PCB concentration in groundwater in the Remelt source area would need to be approximately 0.060 µg/L (with a smear zone soil concentration of approximately 0.019 mg/kg) for the concentration to decline to 0.000064 µg/L by the time the PCBs reach the Spokane River (see above). It is expected to take about 80 years for the PCB concentrations in groundwater and smear zone soil to decline to these values.

EXTRACTED GROUNDWATER CHARACTERISTICS

The PCB concentration in groundwater is expected to decrease over time as the PCB mass is extracted by the groundwater flowing through the Remelt area. The extracted groundwater will have a lower concentration than the predicted plume concentration, because the extraction pumps draw from groundwater areas that are not contaminated in addition to contaminated groundwater areas. The initial concentration of PCBs in extracted groundwater can be predicted by dividing the mass transferred from the soil to the groundwater flowing through the smear zone (predicted groundwater PCB concentration times flow rate through the smear zone) by the extraction pumping rate.

The estimated initial extracted groundwater concentration for Alternatives D2a and D3 is 30 ng/L, and the estimated concentration for Alternative D4 is 70 ng/L (Table 2). The concentrations estimated for Alternatives D2a and D3 are less than the concentrations presented in the Draft FS (Section 5.1.5.2) because of the reduced estimation of total mass of PCBs in the smear zone soil.

Alternatives D2a and D3 place three extraction wells along a transect located near wells HL-MW-14S, HL-MW-24 DD and HL-MW9D, and HL-MW6A (refer to Figure 5-6 in the Draft Final FS). The extraction wells are designed to remove groundwater from the upper 30 feet of the aquifer. Thus, wells HL-MW-14S and HL-MW6A are the closest wells to the proposed extraction points. The average value of the PCB data collected from these wells (taken from Figures 5-2, 5-3, and 5-4 of the Draft FS) in CY 2009 and in April 2010 is approximately 135 ng/L.

The extraction well proposed for Alternative D4 is located south of well HL-MW-31S. The average value of the PCB data collected from this well (taken from Figures 5-2, 5-3, and 5-4 of the FS) during October 2009 and in April 2010 is approximately 265 ng/L.

Estimated extracted water concentrations will be updated from pilot studies and/or treatability studies and will ultimately be determined from site performance data.

REFERENCES

Ecology, 2010. Kaiser Trentwood Site, Development of Draft Cleanup Standards. Department of Ecology. May 2010.

Ecology, 2011. Kaiser Trentwood Site – Ecology's Review Comments of the September 8, 2010 Draft Feasibility Study Report. Letter to Bernard P. Leber, Jr., Kaiser Aluminum Fabricated Products, LLC, from Teresita Bala, Washington State Department of Ecology. January 19, 2011.

Hart Crowser, 2009a. Draft Final Site-Wide Groundwater Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Fabricated Products, LLC, by Hart Crowser, Inc. November 2009.

Hart Crowser, 2009b. Draft Final Site-Wide Soil Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Fabricated Products, LLC, by Hart Crowser, Inc. November 2009.

Hart Crowser, 2010a. Draft Final Feasibility Study Technical Memorandum, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Fabricated Products, LLC, by Hart Crowser, Inc. March 2010.

Hart Crowser, 2010b. Draft Feasibility Study Report, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Fabricated Products, LLC, by Hart Crowser, Inc. September 2010.

Hart Crowser, 2011. Draft Final Feasibility Study Report, Kaiser Trentwood Facility, Spokane Valley, Washington. Prepared for Kaiser Aluminum Fabricated Products, LLC, by Hart Crowser, Inc. July 2011.

Attachments:
Table 1 - Updated PCB Mass Calculation in the Remelt/Hot Line Area
Table 2 - PCB Restoration Time Frame Calculations

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Table 1 - Updated PCB Mass in Remelt/Hot Line Area

Updated Average Concentration Calculation

Wells/Borings [a]	Depth in Feet	Date Collected	Concentration in mg/kg		Adjusted Concentration in mg/kg [b]	
RM-MW-1S S-1	75-80	10/6/2003	0.022	J	0.010	J
RM-MW-2D S-1	75 to 80	10/5/2003	0.2	U	0.100	U
RM-MW-3S S-5	75 to 75.9	9/27/2003	0.19	U	0.095	U
RM-MW-8S/S-11	75 to 75.8	3/2/2005	0.2	U	0.100	U
RM-MW-10S S-4	70.5-71	9/20/2004	0.11		0.051	
RMSW-MW-11S-S10	70	4/23/2005	0.55		0.253	
RMSW-MW-11S-S10	80	4/23/2005	0.55		0.253	
RM-MW-13S-S11	75	4/27/2005	0.2	U	0.100	U
RM-MW-15S/S-7	70 to 71.5	9/18/2006	0.012		0.006	
RM-MW-15S/S-8	80 to 81.5	9/18/2006	0.012		0.006	
RM-MW-16S/S-8	80 to 81.5	9/15/2006	0.0056	J	0.003	J
RM-MW-16S/S-7	70-70.6	9/15/2006	0.061		0.028	
RM-MW-17S/S-7	70-71.5	9/14/2006	0.072		0.033	
RM-MW-17S/S-8	80-81.5	9/14/2006	0.1		0.046	
RM-F4-SB-1 S-11	76-76.5	9/16/2004	0.059		0.027	
AVERAGE					**0.074**	

Updated Mass Calculation

Area overlap plume and smear zone ($feet^2$) [c]	148,672
Depth Interval (feet)	10
ROM Volume ($feet^3$)	1,486,720
ROM Volume (CY)	55,064
ROM Mass Soil (tons)	77,089
Avg. Conc. (mg/kg)	0.074
ROM Mass of PCBs in Impacted Soil (pounds)	11.4

Notes:

J Estimated value.

U Not detected at the value noted.

ROM: Rough Order of Magnitude

(a) Only wells/borings within the footprint of the Remelt/Hot Line groundwater plume are included.

(b) Concentrations were reduced by 54 percent to account for gravel and cobbles. One half of the reporting limit was used for non-detect samples to calculate the average concentration.

(c) Area modified from Table D-1 in the FSTM to account only for groundwater plume and smear zone soil overlap.

Table 2 - PCB Restoration Time Frame Calculations

Preliminary Cleanup Criteria:

PCUL (ug/L)	Soil Concentration Protective of PCUL (mg/kg) [a]	Groundwater Concentration in Source Zone to be Protective of PCUL at River (ug/L) [b]	Soil Concentration in Source that is Protective of PCUL at River (mg/kg) [a]
0.0045	0.0014	0.22	0.068
0.000064	0.00002	0.06	0.019

System Inputs:

Depth (ft)	10
Width (ft) [c]	327
Kd (L/kg)	310
Average soil concentration (mg/kg) [d]	0.07
Predicted GW concentration (ug/L) [e]	0.24
Initial PCB Mass in Soil (lb)	11.4
Mass of Soil (tons)[f]	77089

	Flux (gal/day/ft2) [g]	Flow rate (gpd) [(i)]
Alternative D1	67.3	220,071
Alternative D2a	107.7	352,114
Alternative D2b	114.41	374,121
Alternative D3	114.41	374,121
Alternative D4	80.76	264,085

Restoration Time Frame:

	Standarad POC Restoration Time Frame (years)		Conditional POC Restoration Time Frame (years) [(j)]		
	River and Groundwater POC		Time to reduce groundwater concentration in source to 0.22 ug/L	Groundwater restoration time frame to be protective of river	
	PCUL = 0.0045 ug/L	PCUL = 0.000064 ug/L		for a PCUL = 0.0045 ug/L [(k)]	for a PCUL = 0.000064 ug/L [(l)]
Alternative D1	283	586	6	0	98
Alternative D2a	177	367	4	0	62
Alternative D2b	167	345	4	0	58
Alternative D3	167	345	4	0	58
Alternative D4	236	489	5	0	82

Extracted GW Characteristics:

	Pumping Rate (MGD)	Initial Concentration of Extracted GW (ng/L)	Extracted mass (gram/day)
Alternative D1	NA	NA	NA
Alternative D2a	3.7	23	0.32
Alternative D2b	3.0	29	0.34
Alternative D3	3.0	29	0.34
Alternative D4	0.3	210	0.24

Notes:
(a) Based on soil/water partitioning.
(b) Groundwater concentration in source area (0.06 ug/L) that was predicted to be protective of PCUL at the River based on equation 13 developed in Appendix E. Under a conditional POC groundwater in the source will need to be protective of the drinking water PCUL (0.22 ug/L), this concentration is predicted to be protective of the MDL (0.0045 ug/L) at the River.
(d) The maximum width of the plume.
(e) From Table 2.
(f) Based on soil/water partitioning using average soil concentration and Kd.
(g) Adjusted from Table D-1 in the FSTM to account for the reduced area.
(h) Flux for Alternative D1 from FSTM Table E-5. Extraction pumping increases the flux for Alternative D2a by a factor of 2.2, Alternatives D2b and D3 by a factor of 2, and Alternative D4 by a factor of 1.2.
(i) Groundwater flow rate through 10-foot smear zone.
(j) Restoration timeframe calculated by first order decay equation (Equation 12) in Appendix E.
(k) Equation results is negative numbers indicating the PCB concentration at the river is estimated to be protective of the PCUL of 0.0045 ug/L with attenuation as described in Appendix E.
(l) For Alternatives D2 and D3, which employ containment, the concentration of PCBs at the River is expected to be below 0.000064 ug/L shortly after the containment system is in place.

PETROLEUM HYDROCARBON AREAS OF CONCERN MEMO

MEMORANDUM

DATE: July 20, 2011

TO: Bud Leber, Kaiser Aluminum Washington, LLC

FROM: Will Abercrombie, Hart Crowser, Inc.
Craig Dockter, Hart Crowser, Inc.
Kimberly Reinauer, PE, LEED, Hart Crowser, Inc.
Roy Jensen, LHG, Hart Crowser, Inc.
Dan McCarthy, PE, ECS

RE: **Petroleum Hydrocarbon Areas of Concern**
Restoration Time Frame Evaluation
Kaiser Trentwood
2644-125

This memo presents our restoration time frame evaluation for petroleum hydrocarbon (TPH) groundwater areas of concern (AOCs) at the Kaiser Trentwood Facility. The restoration time frame evaluation for the PCB groundwater AOCs is provided in a separate technical memorandum.

TPH Cleanup Criteria

Cleanup Levels and Point of Compliance

Ecology has established preliminary cleanup levels (PCULs) for petroleum hydrocarbons as diesel and heavy oil for a standard point of compliance (POC) (Ecology 2010). The PCULs for the standard POC established by Ecology are based on MTCA Method A cleanup levels. The PCULs for both diesel and heavy oil is 500 micrograms per liter (µg/L). Also, the sum of diesel and heavy oil concentrations cannot exceed 500 µg/L.

Under a standard POC, this PCUL would need to be met throughout the Facility from the uppermost level of the saturated zone extending vertically to the lowest depth which could potentially be affected by constituents of concern (COCs) at the Facility.

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Soil Concentrations Protective of PCULs

Ecology-established soil cleanup levels protective of groundwater were calculated using MTCA's 4-phase model (Ecology 2010a). The saturated soil concentration of TPH (total) protective of drinking water established by Ecology is 2,000 mg/kg (Ecology 2010b). The actual smear zone soil concentrations that are protective of groundwater will ultimately be those concentrations that will result in meeting groundwater cleanup levels.

Soil concentrations protective of groundwater PCULs throughout the Facility were calculated using the soil/water partitioning coefficient (in L/kg) (K_d), assuming a linear relationship between groundwater (C_w) and soil contaminant concentration (C_s) according to the following equation:

$$C_s = K_d C_w$$

The K_d values from site-specific tests are 2,250 L/kg for diesel and 1,987 L/kg for heavy oil were reported in the Draft Final Groundwater RI (Hart Crowser 2009).

Soil concentrations protective of the groundwater PCUL of 500 µg/L throughout the Facility were calculated by multiplying the K_d values by 500 µg/L in each AOC and are presented in Table 1.

Mass of TPH

The TPH smear zone soil AOCs were described in Appendix D of the Draft Feasibility Study Technical Memorandum (FSTM) (Hart Crowser 2010a). The TPH mass has been recalculated based on the soil/water partitioning coefficient discussed above and the results are provided in Table 1. The revised TPH mass was calculated based on the following assumptions:

- The TPH in AOCs at this Facility are present in mature groundwater plumes that have established equilibrium between the COCs in the smear zone soils and the groundwater. Therefore, groundwater concentrations measured in each AOC are representative of the TPH distribution and mass within the soil matrix.

- The average groundwater concentrations (Table 1) used in calculating the TPH mass in each AOC are based on the maximum concentration for each well measured in four quarters of 2009 and the first two quarters of 2010, as reported in Table 4-2 of the Draft Final Feasibility Study (FS) (Hart Crowser 2011).

- The average groundwater diesel concentration in the Oil House area North plume was higher than the solubility limit for diesel fuel. We initially estimated the mass of COCs in the Oil House area North plume by using a solubility limit of 1.75 mg/L, based on a site-specific K_d of 2,250 L/kg. The estimated TPH mass in the Oil House area North plume that was calculated based on a groundwater TPH concentration of 1.75 mg/L is approximately 415,000 pounds (refer to Table 1 of the April 24, 2011, restoration time frame memorandum for petroleum AOCs).

  As we have discussed, the soil at the Facility contain approximately 30 percent materials that are greater than 2 inches in diameter. In addition to these cobble materials, Facility soil also contains a total of approximately 24 percent of materials that are less than 2 inches in diameter but retained on a #4 sieve (0.187 inch) (Hart Crowser 2009). These two larger grain size materials can be classified as cobbles and gravels. The cobble and gravel portion of soil samples were either not sent to or not analyzed by the laboratory, since cobbles would not fit in the sample jar and the laboratory does not pulverize gravel prior to analysis. Thus, the laboratory analytical results overestimate the concentration of COCs in soil by at least 54 percent. Refer to the FSTM, Section 2.6, for a more detailed discussion of this topic, and for a discussion of additional reasons why the concentration values reported by the laboratory and contained in the Draft Final FS are still conservatively high.

  The resulting estimated mass of TPH in the Oil House area smear zone soil associated with the North plume is approximately 272,000 pounds. The corresponding value of TPH concentration in the groundwater is 1.32 mg/L (Table 1).

- The groundwater flux and plume dimension values used to calculate mass were reported in Draft Final FS Appendix E, Table E-5. The average width of the plume was calculated using the footprint of the plume and dividing it by the length of the plume.

- The K_d value from site-specific tests of 2,250 for diesel and 1,987 L/kg for oil reported in the FSTM are appropriate values for calculating the soil concentration by using the following equation: $C_s = K_d C_w$

- The TPH mass in pounds being reduced in soil was calculated for each AOC using the average groundwater concentration minus the PCUL of 0.5 mg/L, the appropriate K_d value (diesel and heating oil), soil bulk density (110 pounds/cubic foot), effective porosity of 30 percent, treatment area volume of soil in cubic feet, and converting from milligrams to kilograms as shown in the equation:

  - $(C_{wo} - C_{wpcul}) \cdot K_d \cdot 110 \cdot (1 - 0.30) \cdot (\text{width} \cdot \text{length} \cdot \text{height}) / 1{,}000{,}000$

- The TPH mass in pounds being reduced in groundwater was calculated for each AOC using the average groundwater concentration minus the PCUL of 0.5 mg/L, volume of groundwater in the treatment area in cubic feet, effective porosity of 30 percent, converting cubic feet to liters by multiplying by 28.32, converting milligrams to kilograms, and converting kilograms to pounds as shown in the equation:

  - $(C_{wo} - C_{wpcul}) \cdot (\text{width} \cdot \text{length} \cdot \text{height}) \cdot 0.30 \cdot 28.32 / 1{,}000{,}000 \cdot 2.2$

- The TPH mass shown in Tables 1 and 2 represents the mass of TPH that has to be treated to reduce the concentration of TPH in smear zone soil to a concentration of 1,125 mg/kg. This mass was calculated by using the average groundwater concentration and subtracting the PCUL concentration of 500 ug/L.

- Only areas where smear zone soil and groundwater plumes overlap were included in the calculation of mass (i.e., if no groundwater plume is present in an area, then the mass present in the smear zone in that area was not included in the calculation). The inputs used in calculating the TPH mass for each AOC is presented in Attachment A.

Based on these assumptions, the revised estimate of the TPH mass within the smear zone at the Facility is summarized in Table 1.

Biodegradation Mechanism

The biodegradation mechanism and approach used in calculating the restoration time frame in each AOC is based on hydrogen equivalents for moles of hydrogen/electron donors (petroleum hydrocarbons) and hydrogen/electron acceptors (dissolved oxygen [DO], nitrates, and sulfates). The restoration is considered complete when the groundwater entering the plume provides the same number of moles of hydrogen/electron acceptors as the calculated moles of hydrogen/electron donors of petroleum hydrocarbons in the soil and groundwater for each AOC.

The estimated TPH mass to be treated described above is used to calculate the moles of hydrogen/electron donor. The model assumes that 20 percent of the TPH are completely oxidized to CO_2 and H_2O, and the remaining 80 percent of hydrogen moles are converted to volatile fatty acids and biomass that further enhances the destruction of electron donors (petroleum hydrocarbons). The value used in calculating complete oxidation typically ranges from 10 to 20 percent based on the plume maturity. The more mature the plume, the more opportunity the microbes have had to adapt to site conditions, and the more petroleum hydrocarbons that are converted to biomass for an increased efficiency. Although the plumes are very mature, we have assumed the more conservative value of 20 percent complete oxidation for our calculations.

The model also assumes the following:

- The TPH mass to be treated calculated in the previous section for each AOC is appropriate for calculating the moles of electron donors (petroleum hydrocarbons).

- Groundwater flow through each of the AOCs is based on the results of groundwater flow modeling (Appendix E in the Draft Final FS) and the assumption that groundwater is in contact with the 10-foot smear zone 60 percent of the year.

- Inputs for the DO, nitrate, and sulfate concentrations were taken from site-specific analytical results immediately upgradient of each AOC when possible (refer to Figures F-1, F-2, and F-3 in Appendix F of the Draft Final FS).

- The number of moles for the electron donors (TPH) in soil and groundwater was calculated for each AOC using the pounds of TPH calculated above, converting pounds to kilograms, converting kilograms to grams, dividing by the molecular weight (grams per mole), and multiplying by the number of moles of hydrogen to oxidize one mole of TPH, as shown in the equation:

  - Pounds TPH / 2.2 • 1,000 / g TPH/mole TPH • moles H2/mole TPH

- Electron acceptors are available for biodegradation, and the electron acceptors are the limiting factor in biological processes at the Facility.

- The electron acceptors are used to oxidize the TPH or convert the mass to fatty acids and biomass.

- The number of moles for the native electron acceptors in groundwater was calculated for each AOC using the concentration of electron acceptor in mg/L, converting milligrams to grams, dividing by the molecular weight (grams per mole), and multiplying by the number of moles of hydrogen to reduce one mole of electron acceptor, and multiplying by the total flow in liters moving through the treatment area during the restoration time frame, as shown in the equation:

  - C_w / 1,000 / g TPH/mole TPH • moles H2/mole TPH • liters

Groundwater Flow Rate

The groundwater flow rates for Alternatives C2 (Scenarios C2a, C2b, and C2c) and C4 were calculated from the results of groundwater modeling using changes in travel time as a proxy for changes in groundwater flux (Table E-6, Appendix E Draft Final FS). Alternative C1 (Model Scenario 1) was considered the existing or baseline condition. The groundwater flux (changes in travel time) for the individual AOCs under Alternatives C2 (Scenarios C2a, C2b, and C2c) and C4 (Model Scenarios 2 through 4) were adjusted relative to the baseline case. The adjusted flux values are presented in the individual alternative restoration time frame estimates below.

Estimated Restoration Time Frames

Estimated restoration time frames to meet the cleanup standard for TPH plumes are based on reducing the existing average groundwater TPH concentration in each AOC to the PCUL of 500 ug/L. The average TPH concentration, extent of each AOC, and electron donors available in each AOC make for highly variable results in the restoration time frame calculations.

The restoration for the Oil Reclamation Building (ORB) area is considered complete, since the current average groundwater concentrations for diesel and heavy oil are less than 500 µg/L.

The restoration time frame was estimated to be the point at which the mass balance of moles of hydrogen/electron donor and hydrogen/electron acceptor is achieved. The model inputs used to calculate the mass balance are provided in Attachment A. The calculations are based upon the following assumptions:

- The TPH concentrations in groundwater and soil reach equilibrium instantaneously;
- A K_d value of 2,250 L/kg for diesel and 1,987 L/kg for oil is representative of the K_d values associated with the distribution of TPH present in the smear zone soils in each of the AOCs.
- The TPH mass in soil and groundwater is destroyed through biological processes resulting in a shrinking plume;
- Groundwater is in contact with the smear zone 60 percent of the time; and
- Restoration of groundwater is considered complete once the concentration of TPH in smear zone soil declines to a concentration that would result in a groundwater concentration below the PCUL.

The input parameters and results for each AOC are detailed in Attachment A and the restoration time frames are summarized in Table 2.

Estimation of Restoration Time Frame for Alternative C1

Alternative C1 consists of institutional controls, monitoring, and monitored natural attenuation (MNA), and operation of the existing groundwater Interim Remedial Measure (IRM) system for the remediation of the petroleum hydrocarbon and free phase product (FPP) groundwater plumes and associated smear zone soil at the Kaiser Facility.

The restoration time frames for Alternative C1 range from 4 years for the Oil House area South plume to 34 years for the Wastewater Treatment area North plume. The input parameters and results for each AOC are detailed in Attachment A and summarized in Table 2.

Estimation of Restoration Time Frame for Alternative C2, Scenario C2a

Scenario C2a of Alternative C2 adds the additional protection of hydraulic containment from EW-3 to Alternative C1. Scenario C2a extends the containment footprint but does increase the groundwater flux through the AOCs.

The restoration time frames for Scenario C2a are the same as Alternative C1. The restoration time frames for Scenario C2a range from 4 years for the Oil House area South plume to 34 years for the Wastewater Treatment area North plume. The input parameters and results for each AOC are detailed in Attachment A and summarized in Table 2.

Estimation of Restoration Time Frame for Alternative C2, Scenario C2b

Scenario C2b of Alternative C2 adds hydraulic containment to the ORB AOC to Alternative C1. The restoration time frames for Scenario C2b are generally the same as for Alternative C1. The input parameters and results for each AOC are detailed in Attachment A and summarized in Table 2.

Estimation of Restoration Time Frame for Alternative C2, Scenario C2c

Scenario C2c of Alternative C2 provides plume-specific hydraulic containment for the petroleum plumes without the baseline IRM containment system operating. To simulate the effect of plume-specific hydraulic containment, the groundwater flux was increased based on the increases in travel time presented in Appendix E, Table E-6, in the Draft Final FS. The flux increase from Alternative C1 to Scenario C2c for selected AOCs is as follows:

- 122 percent for the Oil House area North plume;
- 133 percent for the Oil House area South plume;
- 100 percent for the Wastewater Treatment area North plume;
- 50 percent for the Wastewater Treatment area South plume;
- 175 percent for the Cold Mill area; and
- 50 percent for the ORB area.

The restoration time frames for Scenario C2c range from 2 years for the Oil House area South plume to 17 years for the Wastewater Treatment area North plume. The input parameters and results for each AOC are detailed in Attachment A and summarized in Table 2.

Estimation of Restoration Time Frame for Alternative C3

Alternative C3 adds *in situ* treatment using *in situ* biodegradation for AOCs where TPH is present in smear zone soil and/or in petroleum-contaminated groundwater at concentrations above screening levels.

The *in situ* biodegradation treatment consists of injecting hydrogen peroxide (H_2O_2) and nutrients into the petroleum hydrocarbon groundwater plumes. Hydrogen peroxide adds additional oxygen for biodegradation of TPH. Additional nutrients would be added to each plume because existing nutrients may be present in the subsurface at concentrations that are insufficient for adequate biodegradation.

Assuming a DO concentration of 9 mg/L in upgradient groundwater, there would be sufficient DO in the groundwater entering the petroleum groundwater plumes to degrade the SVOCs present, based on the predicted concentrations of SVOCs for each plume (see Table 1). However, the DO concentration would decline as groundwater travels the length of the plumes, and the larger plumes (i.e., Oil House area North and Wastewater Treatment area North plumes) may require replenishment of DO at their midpoints to promote biodegradation of SVOCs at the downgradient end of the plumes. Hydrogen peroxide solution would be injected at a concentration of 200 mg/L at the midpoint of the larger plumes. Based on this concentration, and AOC-specific daily injection rates (Attachment A), the moles of H_2O_2 (electron acceptors) were calculated and added to the daily flux of naturally occurring electron acceptors (DO, nitrate and sulfate). The restoration time frame was considered complete when the mass balance of electron donors (petroleum hydrocarbons) and all electron acceptors were equal.

The mass injection rate of H_2O_2 in pounds per day was calculated by multiplying the volumetric rate of solution injected (in gallons per day) by the concentration (200 mg/L), converting gallons to liters, converting milligrams to kilograms, and converting kilograms to pounds, as shown in the equation:

- H_2O_2 (gallons per day) • C_w • 3.78 / 1,000,000 • 2.2

The number of moles of hydrogen peroxide (electron acceptors) injected was calculated for each AOC using the mass injection rate (in pounds per day) calculated above, multiplying by the number of injection days, multiplying by the number of moles of hydrogen to reduce one pound of H_2O_2, and dividing by the assumed metabolic efficiency as shown in the equation:

- H_2O_2 (pounds per day) • days • moles H_2/ pound H_2O_2 / 0.20

The restoration time frames for Alternative C3 range from 4 years for the Oil House area South plume to 30 years for the Wastewater Treatment area North plume. The input parameters and results for each AOC are detailed in Attachment A and summarized in Table 2.

Estimation of Restoration Time Frame for Alternative C4

Alternative C4, incorporates Alternative C1 and employs additional groundwater extraction and *ex situ* treatment for remediation of the petroleum hydrocarbon groundwater plumes at the Kaiser Facility. To simulate the effect of additional groundwater extraction, the flux was increased based on the pore volume flush rates presented in Appendix E, Table E-6, in the Draft Final FS. The flux increase from Alternative C1 to C4 for selected AOCs is as follows:

- 43 percent for the Oil House area North plume;
- 17 percent for the Oil House area South plume;
- 38 percent for the Wastewater Treatment area North plume;
- 30 percent for the Wastewater Treatment area South plume;
- 57 percent for the Cold Mill area diesel and heavy oil plumes; and
- 50 percent for the ORB area diesel and heavy oil range plumes.

The restoration time frames for Alternative C4 range from 3 years for the Oil House area South plume to 24 years for the Wastewater Treatment area North plume. The input parameters and results for each AOC are detailed in Attachment A and summarized in Table 2.

REFERENCES

Ecology 2010a. Kaiser Trentwood Draft Cleanup Standards. Washington Department of Ecology. May 19, 2010.

Ecology 2010b. Kaiser Trentwood Site – Ecology's Responses to Kaiser's June 17, 2010 Comments on May 2010 Draft Cleanup Standards. August 17, 2010.

Hart Crowser 2009. Draft Final Site-Wide Groundwater Remedial Investigation, Kaiser Trentwood Facility, Spokane Valley, Washington. Job 2644-114. November 2009.

Hart Crowser 2010a. Draft Final Feasibility Study Technical Memorandum, Kaiser Trentwood Facility, Spokane Valley, Washington. Job 2644-120. March 2010.

Hart Crowser 2011. Draft Final Feasibility Study Report, Kaiser Trentwood Facility, Spokane Valley, Washington. Job 2644-121.

Attachments
Table 1 – TPH Concentrations and Mass Based on Groundwater Concentrations
Table 2 – Restoration Time Frame for Petroleum Plumes Based on Electron Donor Demands
Attachment A – AOC Restoration Time Frame Based on Electron Donor Demand Calculations

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Table 1 : TPH Concentrations and Mass Based on Groundwater Concentrations
Kaiser Aluminum Washington Facility
Spokane Valley, Washington

		Groundwater Concentration [a]		TPH Soil Concentrations Calculated from GW Concentration[b]		TPH Mass Calculated from GW Concentration[c]	
Area of Concern	Petroleum Hydrocarbon Range	PCUL GW Concentration in mg/L	Average GW Concentration in mg/L	PCUL Soil Concentration Protective of GW in mg/kg	Estimated TPH Soil Concentration in mg/kg	Estimated TPH Mass to be Treated in GW in Pounds	Estimated TPH Mass to be Treated in Soil in Pounds
Oil House area North plume	Diesel	0.50	1.32	1,125	2,970	29.4	272,054
Oil House area South plume	Diesel	0.50	0.88	1,125	1,980	2.4	22,318
Wastewater area North plume	Diesel	0.50	0.92	1,125	2,070	24.3	224,844
Wastewater area South plume	Diesel/Heavy Oil	0.50	0.92	994	1,828	3.2	29,761
Cold Mill area	Diesel	0.50	1.48	1,125	3,330	14.8	137,526
Cold Mill area	Heavy Oil	0.50	0.53	994	1,053	0.5	3,718
ORB area	Diesel	0.50	0.25	1,125	563	1.7	16,199
ORB area	Heavy Oil	0.50	0.25	994	497	1.7	14,305

Notes:

(a) Average GW Concentrations from FS Table 4-2.

(b) TPH soil concentrations calculated using partitioning coefficient (K_d) and the average TPH GW concentration.

(c) TPH mass to be treated calculated using partitioning coefficient (K_d) and the difference between the average TPH GW concentration and the PCUL of 0.50 mg/L.

TPH - Total Petroleum Hydrocarbons; PCUL - Preliminary Cleanup Level; GW - groundwater; ORB - Oil Reclamation Building

mg/L - milligrams per liter; mg/kg - milligrams per kilogram; lbs - pounds, L/kg - liters per kilogram

K_d - Diesel = 2250 L/kg; Heavy Oil = 1,987 L/kg

GW flux and plume dimensions from FS Table E-5

Table 2 : Restoration Time Frame for Petroleum Plumes Based on Electron Donor Demands
Kaiser Aluminum Washington Facility
Spokane Valley, Washington

Area of Concern	TPH Range	Average GW Concentration in mg/L [a]	Estimated TPH Mass to be Treated in GW[b] in Pounds	Estimated TPH Mass to be Treated in Soil[a] in Pounds	Restoration Time Frame in Years					
					C1	C2a	C2b	C2c	C3	C4
Oil House area North plume	Diesel	1.32	29.4	272,054	28	28	28	13	27	18
Oil House area South plume	Diesel	0.88	2.4	22,318	4	4	4	2	4	3
Wastewater area North plume	Diesel	0.92	24.3	224,844	34	34	34	17	30	24
Wastewater area South plume	Diesel/Heavy Oil	0.92	3.2	29,761	11	11	11	7	11	8
Cold Mill area	Diesel	1.48	14.8	137,526	19	19	19	7	19	12
Cold Mill area	Heavy Oil	0.53	0.5	3,718						
ORB area	Meets Cleanup Criteria - NFA									

Notes:

(a) Average GW Concentrations from FS Table 4-2.

(b) TPH mass to be treated calculated using partitioning coefficient (K_d) and the difference between the average TPH GW concentration and the PCUL of 0.50 mg/L.

TPH - Total Petroleum Hydrocarbons; PCUL - Preliminary Cleanup Level; GW - groundwater; ORB - Oil Reclamation Building; NFA - No Further Action

mg/L - milligrams per liter; mg/kg - milligrams per kilogram; lbs - pounds, L/kg - liters per kilogram

K_d - Diesel = 2250 L/kg; Heavy Oil = 1,987 L/kg

GW flux and plume dimensions from FS Table E-5

GW Cleanup level = 0.5 mg/L

ATTACHMENT A
AOC RESTORATION TIME FRAME BASED ON ELECTRON DONOR DEMAND CALCULATIONS

Table A-1 - Cold Mill Plume - Alternative C1
Reduce Groundwater Concentration for Diesel from 1.48 to 0.5 mg/L and Heavy Oil from 0.53 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	28	
Treatment Width (ft)	231	Extraction / Flux Rate (gpd)	145,411	Based on daily groundwater flow through the Cold Mill Area.
Treatment Length (ft) (parallel to GW flow)	350	Extraction / Flux Duration (days)	6,935	Adjusted until a minimum of 100 percent treatment was achieved.
Effective Porosity	0.30			
Average Diesel Concentration (mg/L)	1.48			
Diesel Kd (L/kg)	2,250			
Average Oil in Groundwater (mg/L)	0.53			
Oil Kd (L/kg)	1,987	**Extraction Duration (years)**	**19**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	605,056,003	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	2,293,162,252	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	137,526	226	49	13,553,433	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	14.8	226	49	1,462	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Soil TPH-Ox	3,718	400	86	363,338	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Total Groundwater TPH-Ox	0.5	400	86	44	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**2,783,655**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.6	32	2	1,375,897	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Nitrate (as Nitrogen)	1.7	62	3	835,636	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Sulfate	6.0	96.1	4	572,694	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**2,784,227**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**2,784,227**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Table A-2 - Cold Mill Area Plume - Alternative C2, Scenario C2a
Reduce Groundwater Concentration for Diesel from 1.48 to 0.5 mg/L and Heavy Oil from 0.53 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	28	
Treatment Width (ft)	231	Extraction / Flux Rate (gpd)	145,411	Based on daily groundwater flow through the Cold Mill Area.
Treatment Length (ft) (parallel to GW flow)	350	Extraction / Flux Duration (days)	6,935	Adjusted until a minimum of 100 percent treatment was achieved.
Effective Porosity	0.30			
Average Diesel Concentration (mg/L)	1.48			
Diesel Kd (L/kg)	2,250			
Average Oil in Groundwater (mg/L)	0.53			
Oil Kd (L/kg)	1,987	**Extraction Duration (years)**	**19**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	605,056,003	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	2,293,162,252	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	137,526	226	49	13,553,433	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	14.8	226	49	1,462	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Soil TPH-Ox	3,718	400	86	363,338	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Total Groundwater TPH-Ox	0.5	400	86	44	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**2,783,655**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.6	32	2	1,375,897	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Nitrate (as Nitrogen)	1.7	62	3	835,636	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Sulfate	6.0	96.1	4	572,694	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**2,784,227**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**2,784,227**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Table A-3 - Cold Mill Area Plume - Alternative C2, Scenario C2b
Reduce Groundwater Concentration for Diesel from 1.48 to 0.5 mg/L and Heavy Oil from 0.53 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	28	
Treatment Width (ft)	231	Extraction / Flux Rate (gpd)	145,411	Based on daily groundwater flow through the Cold Mill Area.
Treatment Length (ft) (parallel to GW flow)	350	Extraction / Flux Duration (days)	6,935	Adjusted until a minimum of 100 percent treatment was achieved.
Effective Porosity	0.30			
Average Diesel Concentration (mg/L)	1.48			
Diesel Kd (L/kg)	2,250			
Average Oil in Groundwater (mg/L)	0.53			
Oil Kd (L/kg)	1,987	**Extraction Duration (years)**	**19**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	605,056,003	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	2,293,162,252	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	137,526	226	49	13,553,433	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	14.8	226	49	1,462	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Soil TPH-Ox	3,718	400	86	363,338	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Total Groundwater TPH-Ox	0.5	400	86	44	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**2,783,655**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.6	32	2	1,375,897	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Nitrate (as Nitrogen)	1.7	62	3	835,636	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Sulfate	6.0	96.1	4	572,694	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**2,784,227**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**2,784,227**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Table A-4 - Cold Mill Area Plume - Alternative C2, Scenario C2c
Reduce Groundwater Concentration for Diesel from 1.48 to 0.5 mg/L and Heavy Oil from 0.53 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	77	Increased flux by 175 percent from baseline conditions.
Treatment Width (ft)	231	Extraction / Flux Rate (gpd)	399,881	Based on daily groundwater flow through the Cold Mill Area.
Treatment Length (ft) (parallel to GW flow)	350	Extraction / Flux Duration (days)	2,555	Adjusted until a minimum of 100 percent treatment was achieved.
Effective Porosity	0.30			
Average Diesel Concentration (mg/L)	1.48			
Diesel Kd (L/kg)	2,250			
Average Oil in Groundwater (mg/L)	0.53			
Oil Kd (L/kg)	1,987	**Extraction Duration (years)**	**7**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	613,017,266	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	2,323,335,440	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	137,526	226	49	13,553,433	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	14.8	226	49	1,462	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Soil TPH-Ox	3,718	400	86	363,338	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Total Groundwater TPH-Ox	0.5	400	86	44	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**2,783,655**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.6	32	2	1,394,001	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Nitrate (as Nitrogen)	1.7	62	3	846,631	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Sulfate	6.0	96.1	4	580,229	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**2,820,862**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**2,820,862**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Table A-5 - Cold Mill Area Plume - Alternative C3
Reduce Groundwater Concentration for Diesel from 1.48 to 0.5 mg/L and Heavy Oil from 0.53 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	28	
Treatment Width (ft)	231	Extraction / Flux Rate (gpd)	145,411	Based on daily groundwater flow through the Cold Mill Area.
Treatment Length (ft) (parallel to GW flow)	350	Extraction / Flux Duration (days)	6,935	Adjusted until a minimum of 100 percent treatment was achieved.
Effective Porosity	0.30	Injection Treatment Volume (gpd)	0	Total groundwater reinjection in gallons per day
Average Diesel Concentration (mg/L)	1.48	Solution Concentration (mg/L)	0	Concentration of electron acceptor in milligrams per liter
Diesel Kd (L/kg)	2,250			
Average Oil in Groundwater (mg/L)	0.53			
Oil Kd (L/kg)	1,987	**Extraction/ Flux Duration (years)**	**19.0**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	605,056,003	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	2,293,162,252	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	TPH Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	137,526	226	49	13,553,433	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	14.8	226	49	1,462	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Soil TPH-Ox	3,718	400	86	363,338	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Total Groundwater TPH-Ox	0.5	400	86	44	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**2,783,655**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.6	32	2	1,375,897	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Nitrate (as Nitrogen)	1.7	62	3	835,636	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Sulfate	6.0	96.1	4	572,694	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**2,784,227**	
Added Electron Acceptor	**Amendment Added (pounds/day)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
Hydrogen Peroxide	0	20%	6.5	0	Assumes no injection of Hydrogen Peroxide.
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**2,784,227**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Table A-6 - Cold Mill Area Plume - Alternative C4
Reduce Groundwater Concentration for Diesel from 1.48 to 0.5 mg/L and Heavy Oil from 0.53 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	44	Increased flux by 57 percent from baseline conditions.
Treatment Width (ft)	231	Extraction / Flux Rate (gpd)	228,296	Based on daily groundwater flow through the Cold Mill Area.
Treatment Length (ft) (parallel to GW flow)	350	Extraction / Flux Duration (days)	4,417	Adjusted until a minimum of 100 percent treatment was achieved.
Effective Porosity	0.30			
Average Diesel Concentration (mg/L)	1.48			
Diesel Kd (L/kg)	2,250			
Average Oil in Groundwater (mg/L)	0.53			
Oil Kd (L/kg)	1,987	**Extraction / Flux Duration (years)**	**12**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	604,960,468	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	2,292,800,174	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	TPH Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	137,526	226	49	13,553,433	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	14.8	226	49	1,462	Based on reducing the estimated groundwater diesel concentration from 1.48 to 0.5 mg/L.
Estimated Total Soil TPH-Ox	3,718	400	86	363,338	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Total Groundwater TPH-Ox	0.5	400	86	44	Based on reducing the estimated groundwater oil-range concentration from 0.53 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**2,783,655**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.6	32	2	1,375,680	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Nitrate (as Nitrogen)	1.7	62	3	835,504	Based on upgradient groundwater concentrations at CM-MW-2S and CM-MW-7S.
Sulfate	6.0	96.1	4	572,604	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**2,783,787**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**2,783,787**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Table A-7 - Oil House Area North Plume - Alternative C1
Reduce Groundwater Diesel Concentration from 1.32 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	232	Extraction / Flux Rate (gpd)	171,890	Based on daily groundwater flow through the Oil House North plume area.
Treatment Length (ft) (parallel to GW flow)	825	Extraction / Flux Duration (days)	10,330	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	1.32			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**28**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	1,065,325,132	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	4,037,582,251	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	272,054	226	49	26,811,483	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	29.4	226	49	2,893	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**5,362,875**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	2,389,744	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	1,990,593	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	1,008,345	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**5,388,682**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**5,388,682**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-8 - Oil House Area North Plume - Alternative C2, Scenario C2a
Reduce Groundwater Diesel Concentration from 1.32 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	232	Extraction / Flux Rate (gpd)	171,890	Based on daily groundwater flow through the Oil House North plume area.
Treatment Length (ft) (parallel to GW flow)	825	Extraction / Flux Duration (days)	10,330	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	1.32			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**28**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	1,065,325,132	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	4,037,582,251	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	272,054	226	49	26,811,483	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	29.4	226	49	2,893	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**5,362,875**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	2,389,744	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	1,990,593	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	1,008,345	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**5,388,682**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**5,388,682**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:
L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.
Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.
Green boxes are treatment option variables for input.
Yellow boxes are treatment option outputs.
Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-9 - Oil House Area North Plume - Alternative C2, Scenario C2b
Reduce Groundwater Diesel Concentration from 1.32 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	232	Extraction / Flux Rate (gpd)	171,890	Based on daily groundwater flow through the Oil House North plume area.
Treatment Length (ft) (parallel to GW flow)	825	Extraction / Flux Duration (days)	10,330	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	1.32			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**28**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	1,065,325,132	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	4,037,582,251	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	272,054	226	49	26,811,483	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	29.4	226	49	2,893	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**5,362,875**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	2,389,744	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	1,990,593	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	1,008,345	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**5,388,682**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**5,388,682**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:
L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.
Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.
Green boxes are treatment option variables for input.
Yellow boxes are treatment option outputs.
Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-10 - Oil House Area North Plume - Alternative C2, Scenario C2c
Reduce Groundwater Diesel Concentration from 1.32 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	73	Increased flux by 122 percent from baseline conditions.
Treatment Width (ft)	232	Extraction / Flux Rate (gpd)	381,597	Based on daily groundwater flow through the Oil House North plume area.
Treatment Length (ft) (parallel to GW flow)	825	Extraction / Flux Duration (days)	4,745	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	1.32			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**13**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	1,086,405,771	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	4,117,477,871	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	272,054	226	49	26,811,483	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	29.4	226	49	2,893	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**5,362,875**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	2,437,032	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	2,029,983	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	1,028,298	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**5,495,314**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**5,495,314**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**102%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-11 - Oil House Area North Plume - Alternative C3
Reduce Groundwater Diesel Concentration from 1.32 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	232	Extraction / Flux Rate (gpd)	171,890	Based on daily groundwater flow through the Oil House North plume area.
Treatment Length (ft) (parallel to GW flow)	825	Extraction / Flux Duration (days)	9,746	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	1.32	Injection Treatment Volume (gpd)	544	Total groundwater reinjection in gallons per day
Effective Porosity	0.30	Solution Concentration (mg/L)	200	Concentration of electron acceptor in milligrams per liter
Kd (L/kg)	2,250	**Extraction/ Flux Duration (years)**	**27**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	1,005,094,736	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	3,809,309,049	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	TPH Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	272,054	226	49	26,811,483	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	29.4	226	49	2,893	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**5,362,875**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	2,254,635	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	1,878,051	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	951,336	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**5,084,022**	
Added Electron Acceptor	**Amendment Added (pounds/day)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
Hydrogen Peroxide	0.90	20%	6.5	286,570	Assumes injecting 544 gallons of water per day at a H_2O_2 concentration of 200 mg/L for 27 years years.
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				286,570	
Estimated Moles of Hydrogen Acceptor:				**5,370,592**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-12 - Oil House Area North Plume - Alternative C4
Reduce Groundwater Diesel Concentration from 1.32 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	47	Increased flux by 43 percent from baseline conditions.
Treatment Width (ft)	232	Extraction / Flux Rate (gpd)	245,803	Based on daily groundwater flow through the Oil House North plume area.
Treatment Length (ft) (parallel to GW flow)	825	Extraction / Flux Duration (days)	7,155	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	1.32			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**20**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	1,055,233,447	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	3,999,334,763	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	272,054	226	49	26,811,483	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	29.4	226	49	2,893	Based on reducing the estimated groundwater concentration from 1.32 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**5,362,875**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	2,367,106	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	1,971,737	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	998,793	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**5,337,636**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**5,337,636**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.
Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.
Green boxes are treatment option variables for input.
Yellow boxes are treatment option outputs.
Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-13 - Oil House Area South Plume - Alternative C1
Reduce Groundwater Diesel Concentration from 0.88 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	136	Extraction / Flux Rate (gpd)	100,415	Based on daily groundwater flow through the Oil House South plume area.
Treatment Length (ft) (parallel to GW flow)	250	Extraction / Flux Duration (days)	1,460	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.88			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**4**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	87,963,113	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	333,380,196	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	**COC Mass (pounds)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Oxidize / Mole Analyte**	**Moles of H_2 Donor In Treatment Area**	
Native Electron Donors					
Estimated Total Soil TPH-Dx	22,318	226	49	2,199,488	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	2.4	226	49	237	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**439,945**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	**Groundwater Concentration (mg/L)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Reduce Mole Analyte**	**Moles of H_2 Through Treatment Area**	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	197,319	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	164,362	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	83,258	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**444,940**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**444,940**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:
L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.
Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.
Green boxes are treatment option variables for input.
Yellow boxes are treatment option outputs.
Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-14 - Oil House Area South Plume - Alternative C2, Scenario C2a
Reduce Groundwater Diesel Concentration from 0.88 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	136	Extraction / Flux Rate (gpd)	100,415	Based on daily groundwater flow through the Oil House South plume area.
Treatment Length (ft) (parallel to GW flow)	250	Extraction / Flux Duration (days)	1,460	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.88			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**4**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	87,963,113	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	333,380,196	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	22,318	226	49	2,199,488	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	2.4	226	49	237	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**439,945**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	197,319	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	164,362	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	83,258	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**444,940**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**444,940**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-15 - Oil House Area South Plume - Alternative C2, Scenario C2b
Reduce Groundwater Diesel Concentration from 0.88 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	136	Extraction / Flux Rate (gpd)	100,415	Based on daily groundwater flow through the Oil House South plume area.
Treatment Length (ft) (parallel to GW flow)	250	Extraction / Flux Duration (days)	1,460	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.88			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**4**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	87,963,113	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	333,380,196	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	22,318	226	49	2,199,488	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	2.4	226	49	237	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**439,945**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	197,319	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	164,362	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	83,258	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**444,940**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**444,940**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-16 - Oil House Area South Plume - Alternative C2, Scenario C2c
Reduce Groundwater Diesel Concentration from 0.88 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	77	Increased flux by 133 percent from baseline conditions.
Treatment Width (ft)	136	Extraction / Flux Rate (gpd)	233,966	Based on daily groundwater flow through the Oil House South plume area.
Treatment Length (ft) (parallel to GW flow)	250	Extraction / Flux Duration (days)	639	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.88			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**2**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	89,667,398	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	339,839,438	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	22,318	226	49	2,199,488	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	2.4	226	49	237	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**439,945**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	201,142	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	167,546	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	84,871	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**453,560**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**453,560**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**103%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-17 - Oil House Area South Plume - Alternative C3
Reduce Groundwater Diesel Concentration from 0.88 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	33	
Treatment Width (ft)	136	Extraction / Flux Rate (gpd)	100,415	Based on daily groundwater flow through the Oil House South plume area.
Treatment Length (ft) (parallel to GW flow)	250	Extraction / Flux Duration (days)	1,460	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.88	Injection Treatment Volume (gpd)	0	Total groundwater reinjection in gallons per day
Effective Porosity	0.30	Solution Concentration (mg/L)	0	Concentration of electron acceptor in milligrams per liter
Kd (L/kg)	2,250	**Extraction / Flux Duration (years)**	**4.0**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	87,963,113	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	333,380,196	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	**TPH Mass (pounds)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Oxidize / Mole Analyte**	**Moles of H_2 Donor In Treatment Area**	
Native Electron Donors					
Estimated Total Soil TPH-Dx	22,318	226	49	2,199,488	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	2.4	226	49	237	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**439,945**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	**Groundwater Concentration (mg/L)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Reduce Mole Analyte**	**Moles of H_2 Through Treatment Area**	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	197,319	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	164,362	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	83,258	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**444,940**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
Hydrogen Peroxide	0	20%	6.5	0	Assumes no hydrogen peroxide is injected.
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**444,940**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-18 - Oil House Area South Plume - Alternative C4
Reduce Groundwater Diesel Concentration from 0.88 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	39	Increased flux by 17 percent from baseline conditions.
Treatment Width (ft)	136	Extraction / Flux Rate (gpd)	117,485	Based on daily groundwater flow through the Oil House South plume area.
Treatment Length (ft) (parallel to GW flow)	250	Extraction / Flux Duration (days)	1,252	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.88			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction / Flux Duration (years)**	**3**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	88,251,192	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	334,472,017	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	TPH Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	22,318	226	49	2,199,488	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	2.4	226	49	237	Based on reducing the estimated groundwater concentration from 0.88 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**439,945**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0	
Estimated Moles of Hydrogen Donor Extracted:		**0**

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	9.5	32	2	197,966	Based on upgradient groundwater concentrations at CM-MW-7S.
Nitrate (as Nitrogen)	2.3	62	3	164,900	Based on upgradient groundwater concentrations at OH-MW-8.
Sulfate	6.0	96.1	4	83,531	Based on reduction of average groundwater concentrations at HL-MW-1.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**446,397**	

Added Electron Acceptor	Amendment Added (pounds)	Assumed Metabolic Efficiency	Moles H_2/Lb.	Moles H_2 Acceptor Added
AnoxEA-aq™	0	10%	11.6	0
Added Hydrogen Acceptor Subtotal				0
Estimated Moles of Hydrogen Acceptor:				**446,397**
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-19 - Wastewater Treatment Area North Plume - Alternative C1
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	309	Extraction / Flux Rate (gpd)	346,698	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	1,000	Extraction / Flux Duration (days)	12,337	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**34**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	2,566,327,936	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	9,726,382,876	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	224,844	226	49	22,158,787	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	24.3	226	49	2,391	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20% Efficiency)				**4,432,235**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	2,431,596	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	416,979	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	1,619,377	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**4,467,952**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**4,467,952**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-20 - Wastewater Treatment Area North Plume - Alternative C2, Scenario C2a
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	309	Extraction / Flux Rate (gpd)	346,698	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	1,000	Extraction / Flux Duration (days)	12,337	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**34**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	2,566,327,936	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	9,726,382,876	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	224,844	226	49	22,158,787	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	24.3	226	49	2,391	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20% Efficiency)				**4,432,235**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	2,431,596	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	416,979	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	1,619,377	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**4,467,952**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**4,467,952**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-21 - Wastewater Treatment Area North Plume - Alternative C2, Scenario C2b
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	309	Extraction / Flux Rate (gpd)	346,698	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	1,000	Extraction / Flux Duration (days)	12,337	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**34**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	2,566,327,936	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	9,726,382,876	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	224,844	226	49	22,158,787	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	24.3	226	49	2,391	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20% Efficiency)				**4,432,235**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	2,431,596	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	416,979	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	1,619,377	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**4,467,952**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**4,467,952**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-22 - Wastewater Treatment Area North Plume - Alternative C2, Scenario C2c
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	100	Increased flux by 100 percent from baseline conditions.
Treatment Width (ft)	309	Extraction / Flux Rate (gpd)	693,396	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	1,000	Extraction / Flux Duration (days)	6,205	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**17**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	2,581,513,308	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	9,783,935,437	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	**COC Mass (pounds)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Oxidize / Mole Analyte**	**Moles of H_2 Donor In Treatment Area**	
Native Electron Donors					
Estimated Total Soil TPH-Dx	224,844	226	49	22,158,787	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	24.3	226	49	2,391	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20% Efficiency)				**4,432,235**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	**Groundwater Concentration (mg/L)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Reduce Mole Analyte**	**Moles of H_2 Through Treatment Area**	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	2,445,984	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	419,447	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	1,628,959	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**4,494,390**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**4,494,390**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-23 - Wastewater Treatment Area North Plume - Alternative C3
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	309	Extraction / Flux Rate (gpd)	346,698	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	1,000	Extraction / Flux Duration (days)	10,950	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92	Injection Treatment Volume (gpd)	769	Total groundwater reinjection in gallons per day
Effective Porosity	0.30	Solution Concentration (mg/L)	200	Concentration of electron acceptor in milligrams per liter
Kd (L/kg)	2,250	**Extraction / Flux Duration (years)**	**30**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	2,277,805,860	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	8,632,884,209	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	TPH Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	224,844	226	49	22,158,787	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	24.3	226	49	2,391	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20% Efficiency)				**4,432,235**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	2,158,221	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	370,100	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	1,437,317	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**3,965,638**	
Added Electron Acceptor	**Amendment Added (pounds/day)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
Hydrogen Peroxide	1.28	20%	6.5	455,164	Assumes injecting 769 gallons of water per day at a H2O2 concentration of 200 mg/L for 30 years.
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				455,164	
Estimated Moles of Hydrogen Acceptor:				**4,420,802**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:
L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.
Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.
Green boxes are treatment option variables for input.
Yellow boxes are treatment option outputs.
Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-24 - Wastewater Treatment Area North Plume - Alternative C4
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	69	Increased flux by 38 percent from baseline conditions.
Treatment Width (ft)	309	Extraction / Flux Rate (gpd)	478,443	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	1,000	Extraction / Flux Duration (days)	8,833	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction / Flux Duration (years)**	**24**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	2,535,653,483	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	9,610,126,702	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability					
Constituent	**TPH Mass (pounds)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Oxidize / Mole Analyte**	**Moles of H_2 Donor In Treatment Area**	
Native Electron Donors					
Estimated Total Soil TPH-Dx	224,844	226	49	22,158,787	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	24.3	226	49	2,391	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20% Efficiency)				**4,432,235**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).
Hydrogen/Electron Donor Removed by Groundwater Extraction System					
TPH-Dx (mg/L)	0				Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:				**0**	
Hydrogen/Electron Acceptors					
Constituent	**Groundwater Concentration (mg/L)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Reduce Mole Analyte**	**Moles of H_2 Through Treatment Area**	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	2,402,532	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	411,995	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	1,600,021	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**4,414,548**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**4,414,548**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.
Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.
Green boxes are treatment option variables for input.
Yellow boxes are treatment option outputs.
Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-25 - Wastewater Treatment Area South Plume - Alternative C1
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	126	Extraction / Flux Rate (gpd)	141,199	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	325	Extraction / Flux Duration (days)	3,979	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**11**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	337,057,051	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	1,277,446,223	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	29,761	226	49	2,932,991	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	3.2	226	49	316	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**586,662**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	319,362	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	54,765	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	212,686	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**586,813**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**586,813**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards,

Table A-26 - Wastewater Treatment Area South Plume - Alternative C2, Scenario C2a
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	126	Extraction / Flux Rate (gpd)	141,199	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	325	Extraction / Flux Duration (days)	3,979	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**11**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	337,057,051	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	1,277,446,223	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	29,761	226	49	2,932,991	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	3.2	226	49	316	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**586,662**	Assumes 20% of TPH completely oxidized to CO_2/H_2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	319,362	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	54,765	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	212,686	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**586,813**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**586,813**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards,

Table A-27 - Wastewater Treatment Area South Plume - Alternative C2, Scenario C2b
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	126	Extraction / Flux Rate (gpd)	141,199	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	325	Extraction / Flux Duration (days)	3,979	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**11**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	337,057,051	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	1,277,446,223	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	COC Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	29,761	226	49	2,932,991	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	3.2	226	49	316	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**586,662**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	319,362	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	54,765	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	212,686	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**586,813**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**586,813**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards,

Table A-28 - Wastewater Treatment Area South Plume - Alternative C2, Scenario C2c
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		**Operational Assumptions**		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	75	Increased flux by 50 percent from baseline conditions.
Treatment Width (ft)	126	Extraction / Flux Rate (gpd)	211,799	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	325	Extraction / Flux Duration (days)	2,701	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction Duration (years)**	**7**	
Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	343,241,584	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	1,300,885,604	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	**COC Mass (pounds)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Oxidize / Mole Analyte**	**Moles of H_2 Donor In Treatment Area**	
Native Electron Donors					
Estimated Total Soil TPH-Dx	29,761	226	49	2,932,991	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	3.2	226	49	316	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**586,662**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	**Groundwater Concentration (mg/L)**	**Molecular Weight (g/mol)**	**Moles of H_2 to Reduce Mole Analyte**	**Moles of H_2 Through Treatment Area**	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	325,221	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	55,770	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	216,589	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**597,580**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**597,580**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**102%**	

NOTES:
L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.
Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.
Green boxes are treatment option variables for input.
Yellow boxes are treatment option outputs.
Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards,

Table A-29 - Wastewater Treatment Area South Plume - Alternative C3
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	50	
Treatment Width (ft)	126	Extraction / Flux Rate (gpd)	141,199	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	325	Extraction / Flux Duration (days)	4,015	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92	Injection Treatment Volume (gpd)	0	Total groundwater reinjection in gallons per day
Effective Porosity	0.30	Solution Concentration (mg/L)	0	Concentration of electron acceptor in milligrams per liter
Kd (L/kg)	2,250	**Extraction / Flux Duration (years)**	**11**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	340,149,318	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	1,289,165,913	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	TPH Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	29,761	226	49	2,932,991	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	3.2	226	49	316	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20% Efficiency)				**586,662**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	322,291	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	55,268	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	214,637	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**592,197**	
Added Electron Acceptor	**Amendment Added (pounds/day)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
Hydrogen Peroxide	0.00	20%	6.5	0	Assumes no hydrogen peroxide is injected.
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**592,197**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**101%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards, and the diesel range hydrocarbons would be preferentially reduced.

Table A-30 - Wastewater Treatment Area South Plume - Alternative C4
Reduce Groundwater Diesel Concentration from 0.92 to 0.5 mg/L
Restoration Time Frame Based on Electron Donor Demand Calculations

Treatment Target Area Specifications		Operational Assumptions		
Vertical Treatment (ft)	10	Groundwater Velocity (ft/d)	65	Increased flux by 30 percent from baseline conditions.
Treatment Width (ft)	126	Extraction / Flux Rate (gpd)	183,559	Based on daily groundwater flow through the Waste Water area.
Treatment Length (ft) (parallel to GW flow)	325	Extraction / Flux Duration (days)	3,066	Adjusted until a minimum of 100 percent treatment was achieved.
Average Groundwater Concentration (mg/L)	0.92			
Effective Porosity	0.30			
Kd (L/kg)	2,250	**Extraction / Flux Duration (years)**	**8**	
Bulk Density (lbs/ft^3)	110	Treatment Flux Volume (gal)	337,675,504	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.
Effective Flux Treatment Duration	60%	Treatment Flux Volume (L)	1,279,790,161	Assumes groundwater is in contact with 10 feet of smear zone 60 percent of the time.

Hydrogen/Electron Donor Availability

Constituent	TPH Mass (pounds)	Molecular Weight (g/mol)	Moles of H_2 to Oxidize / Mole Analyte	Moles of H_2 Donor In Treatment Area	
Native Electron Donors					
Estimated Total Soil TPH-Dx	29,761	226	49	2,932,991	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Total Groundwater TPH-Dx	3.2	226	49	316	Based on reducing the estimated groundwater concentration from 0.92 to 0.5 mg/L.
Estimated Moles of Hydrogen Donor Available for Treatment (20%)				**586,662**	Assumes 20% of TPH completely oxidized to CO2/H2O, 80% to volatile fatty acids and biomass incorporation (not completely oxidized).

Hydrogen/Electron Donor Removed by Groundwater Extraction System

TPH-Dx (mg/L)	0		Assumes no TPH is being physically removed by the groundwater extraction system.
Estimated Moles of Hydrogen Donor Extracted:		**0**	

Hydrogen/Electron Acceptors

Constituent	Groundwater Concentration (mg/L)	Molecular Weight (g/mol)	Moles of H_2 to Reduce Mole Analyte	Moles of H_2 Through Treatment Area	
Native Electron Acceptors					
Dissolved Oxygen	4.0	32	2	319,948	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Nitrate (as Nitrogen)	0.2	62	3	54,866	Based on upgradient groundwater concentrations at WW-MW-7 and WW-MW-10.
Sulfate	4.0	96.1	4	213,076	Based on typical reduction from background concentrations across the site.
Hydrogen Acceptor Based on Flux of System Operation and Duration				**587,890**	
Added Electron Acceptor	**Amendment Added (pounds)**	**Assumed Metabolic Efficiency**	**Moles H_2/Lb.**	**Moles H_2 Acceptor Added**	
AnoxEA-aq™	0	10%	11.6	0	
Added Hydrogen Acceptor Subtotal				0	
Estimated Moles of Hydrogen Acceptor:				**587,890**	
Estimated Oxidative Treatment Progress Based on Design Assumptions:				**100%**	

NOTES:

L = liters; ft=feet; gal = gallons; 1ft3 = 28.32 L,mg/L = milligrams per liter; gpd = gallons per day; H2 = hydrogen.

Electron and hydrogen equivalents per Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents, Air Force Center for Environmental Excellence, August 2004.

Green boxes are treatment option variables for input.

Yellow boxes are treatment option outputs.

Reduction for oil range hydrocarbons was not calculated since the current concentration of 0.25 mg/L is less than MTCA standards,