APPENDIX A

Remedial Alternative Cost Estimates

Table A-1 - Summary of Cost Estimates for Remedial Alternatives

Project No. 070188, Chlor-Alkali RAU, GP West Site, Bellingham, Washington

	Remedial Alternatives for Chlor-Alkali RAU	Total Estimated Cost
1)	Containment and In-Situ Treatment of Accessible Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	$ 12,200,000
2)	Aggressive Removal of Obstructions and In Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	$ 16,200,000
3)	Removal of Soils with Visible Hg and Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	$ 22,800,000
4)	Neutralization of "Caustic Core," Aggressive Removal of Obstructions and In-Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	$ 18,400,000
5)	Neutralization of Groundwater with pH > 8.5, Aggressive Removal of Obstructions and In-Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA	$ 24,200,000
6)	Neutralization of Groundwater with pH > 8.5, Removal of Hg-Impacted Soils to Achieve Groundwater Protection, Capping of Residual Impacted Soils, and Groundwater MNA	$ 39,100,000
7)	Removal of All Soils Exceeding Cleanup Levels, Neutralization of Groundwater with pH > 8.5, and Groundwater MNA	$ 63,800,000
8)	Removal of All Soils Exceeding Cleanup Levels, Neutralization of Groundwater with pH > 8.5, In-Situ Treatment of Fill Unit Groundwater Impacted by Hg and PAHs, and MNA for Residual Impacted Groundwater	$ 69,800,000

Notes:

1) Costs are in 2017 dollars. Costs were estimated using Net Present Value (NPV) analysis, assuming a discount rate of 0.7 percent. Long-term inspection, monitoring, and maintenance ("O&M") costs were evaluated over a 30-year period, consistent with EPA guidance. The estimates are order-of-magnitude, with an intended accuracy in the range of -30 to +50 percent.
2) Estimates are rounded to the nearest $100,000.

Table A-2 - Alternative 1 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: Alternative: 1 Containment and In-Situ Treatment of Accessible Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

		Cap Quantities
7.4	acre	capping area
1.5	ton/BCY	soil density
15	each	MNA wells
		Visible Mercury Soils Containment and In Situ Stabilization Quantities
21,897	ton	weight of soil and debris in target area
1,533	ton	weight of surficial debris removed
383	ton	weight of surficial debris requiring encapsulation
75%		% of target area accessible for in situ stabilization
25%		auger overlap
25%		percentage cement amendment (in situ)
2%		percentage sulfur amendment (in situ)
5,600	BCY	import soil to smooth grade after ISS
1,293	ft	total containment wall length
107,886	ft2	asphalt pavement area
		Soil Excavation Quantities - WW Settling Basin Soils with [Hg] > 300 mg/kg
2,501	BCY	overburden soil excavation volume
2,189	BCY	impacted soil excavation volume
1,094	BCY	volume classified as hazardous
1,094	BCY	volume classified as non-hazardous
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
675	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Soil Capping					
Mobilization/demobilization	1	LS	$ 70,000	$ 70,000	
Existing Cap	**50%**				
-No Cost	3.7	acre	$ -	$ -	
New Cap	**50%**				
Soil Cover as Cap	*0%*				
-Site Preparation	-	acre	$ 4,500	$ -	clearing and leveling
-Geotextile marker layer	-	SY	$ 2	$ -	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	0	CY	$ 18	$ -	2' thick
Asphalt Pavement as Cap	*100%*				
-Site Preparation	1.2	acre	$ 4,500	$ 5,507	clearing and leveling
-Pregrading	1.2	acre	$ 5,200	$ 6,364	light grading for asphalt
-Asphalt	1.2	acre	$ 115,400	$ 141,224	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*0%*				
-No Cost	-		$ -	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	6,450	LF	$ -	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	10%			$ 27,309	
Construction management and reporting	10%			$ 27,309	
Subtotal				*$ 327,713*	
Tax	8.7%		$ 223,094	$ 19,409	
Contingency	15%		$ 347,122	$ 52,068	
Subtotal Soil Cap Cost				*$ 399,190*	
Containment and ISS of Accessible Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Transport/disposal of contaminated debris - Hazardous Waste	383	ton	$ 650	$ 249,076	Subtitle C landfill with macro-encapsulation
Auger solidification	16,423	ton	$ 70	$ 1,149,581	accessible soils containing visible elemental Hg
Portland cement amendment	4,106	ton	$ 45	$ 184,754	25% by wt
Sulfur amendment	328	ton	$ 40	$ 13,138	2% by wt
Import, place, and compact fill	5,600	BCY	$ 20	$ 112,000	to smooth surface following ISS
Soil/bentonite slurry wall	1,293	LF	$ 150	$ 193,950	
Asphalt pavement	107,886	SF	$ 2.9	$ 311,791	
Remedial design & pre-design testing	20%			$ 521,251	includes add'l characterization
Construction management and reporting	15%			$ 390,938	
Subtotal				*$ 3,518,445*	
Tax	8.7%		$ 2,606,256	$ 226,744	
Contingency	15%		$ 3,745,190	$ 561,778	
Subtotal Containment and ISS of Accessible Soils with Visible Hg				*$ 4,306,968*	
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin					
Mobilization/demobilization	1	LS	$ 60,000	$ 60,000	
Dewatering	12	day	$ 800	$ 9,380	
Excavate/stockpile/replace overburden soil	2,501	BCY	$ 20	$ 50,027	
Excavation, transport, and disposal - Non-Hazardous Waste	1,642	ton	$ 100	$ 164,150	
Excavation, transport, and disposal - Hazardous Waste	1,642	ton	$ 240	$ 393,960	
Import, place, and compact fill	2,189	BCY	$ 20	$ 43,773	
Remedial design	10%			$ 72,129	
Construction management and reporting	8%			$ 57,703	
Subtotal				*$ 851,122*	
Tax	8.7%		$ 721,290	$ 62,752	
Contingency	10%		$ 913,874	$ 91,387	
Subtotal Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin				*$ 1,005,262*	
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale					
Mobilization/demobilization	1	LS	$ 20,000	$ 20,000	includes BNSF access agreement, flagger, etc.
Remove/replace chain link fence	700	lf	$ 4	$ 2,800	
Remove/stockpile crushed concrete	900	BCY	$ 8	$ 7,201	
Consolidate soils from BNSF onto Port property	675	BCY	$ 6	$ 4,050	
Import, place, and compact fill	1,125	BCY	$ 20	$ 22,502	restore BNSF grade (no import fill needed on Port property)
Remedial design	20%			$ 11,311	
Construction management and reporting	30%			$ 16,966	
Subtotal				*$ 84,829*	
Tax	8.7%		$ 56,553	$ 4,920	
Contingency	10%		$ 89,749	$ 8,975	
Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale				*$ 98,724*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	15	each	$ 4,000	$ 60,000	
Remedial design	15%			$ 11,250	
Construction management and reporting	20%			$ 15,000	
Subtotal				*$ 101,250*	
Tax	8.7%		$ 75,000	$ 6,525	
Contingency	20%		$ 107,775	$ 21,555	
Subtotal Monitored Natural Attenuation				*$ 129,330*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 11,259,819	$337,795	
Total Estimated Capital Costs				**$ 11,597,613**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems	1	30	$ 6,000	$ 180,000	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 16,000	$ 32,000	
Groundwater quality monitoring, Years 3+	3	30	$ 8,000	$ 224,000	
Subtotal Periodic O&M Cost				*$ 436,000*	
Contingency		20.0%		$ 87,200	
				$ 523,200	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 26,160	
Project management/reporting		6%		$ 31,392	
Total, Periodic O&M Net Present Value:				**$ 580,752**	
TOTAL ESTIMATED COST				**$ 12,180,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table A-3 - Alternative 2 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: Alternative: **2** Aggressive Removal of Obstructions and In Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

		Cap Quantities
7.4	acre	capping area
1.5	ton/BCY	soil density
15	each	MNA wells
		Visible Mercury Soils Aggressive Removal of Obstructions and In Situ Stabilization Quantities
21,897	ton	weight of soil and debris in target area
1,533	ton	weight of removed surficial debris
657	ton	weight of removed piles
25%		percentage of surficial debris requiring encapsulation
19,707	ton	weight of soil in target area for in situ stabilization
1,150	ton	weight of inert surficial debris
25%		auger overlap
25%		percentage cement amendment (in situ)
2%		percentage sulfur amendment (in situ)
5,600	BCY	import soil to smooth grade after ISS
		Soil Excavation Quantities - WW Settling Basin Soils with [Hg] > 300 mg/kg
2,501	BCY	overburden soil excavation volume
2,189	BCY	impacted soil excavation volume
1,094	BCY	volume classified as hazardous
1,094	BCY	volume classified as non-hazardous
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
675	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Soil Capping					
Mobilization/demobilization	1	LS	$ 70,000	$ 70,000	
Existing Cap	**50%**				
-No Cost	3.7	acre	$ -	$ -	
New Cap	**50%**				
Soil Cover as Cap	*0%*				
-Site Preparation	-	acre	$ 4,500	$ -	clearing and leveling
-Geotextile marker layer	-	SY	$ 2	$ -	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	0	CY	$ 18	$ -	2' thick
Asphalt Pavement as Cap	*100%*				
-Site Preparation	3.7	acre	$ 4,500	$ 16,652	clearing and leveling
-Pregrading	3.7	acre	$ 5,200	$ 19,243	light grading for asphalt
-Asphalt	3.7	acre	$ 115,400	$ 427,037	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*0%*				
-No Cost	-		$ -	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	6,450	LF	$ -	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	10%			$ 58,293	
Construction management and reporting	10%			$ 58,293	
Subtotal				*$ 699,518*	
Tax	8.7%		$ 532,932	$ 46,365	
Contingency	15%		$ 745,884	$ 111,883	
Subtotal Soil Cap Cost				*$ 857,766*	
Aggressive Removal of Obstructions and ISS of Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.)	14,598	BCY	$ 125	$ 1,824,731	
Dewatering	24	day	$ 800	$ 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of contaminated debris - Hazardous Waste	1,040	ton	$ 650	$ 676,063	Subtitle C landfill with macro-encapsulation
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Portland cement amendment	4,927	ton	$ 45	$ 221,705	25% by wt
Sulfur amendment	394	ton	$ 40	$ 15,766	2% by wt
Auger solidification	19,707	ton	$ 70	$ 1,379,497	accessible soils containing visible elemental Hg
Import, place, and compact fill	5,600	BCY	$ 20	$ 112,000	to smooth surface following ISS
Remedial design & pre-design testing	15%			$ 696,179	includes add'l characterization
Construction management and reporting	15%			$ 696,179	
Subtotal				*$ 6,033,550*	
Tax	8.7%		$ 4,641,192	$ 403,784	
Contingency	20%		$ 6,437,334	$ 1,287,467	
Subtotal Aggressive Removal of Obstructions and ISS of Soils with Visible Hg				*$ 7,724,800*	
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin					
Mobilization/demobilization	1	LS	$ 60,000	$ 60,000	
Dewatering	12	day	$ 800	$ 9,380	
Excavate/stockpile/replace overburden soil	2,501	BCY	$ 20	$ 50,027	
Excavation, transport, and disposal - Non-Hazardous Waste	1,642	ton	$ 100	$ 164,150	
Excavation, transport, and disposal - Hazardous Waste	1,642	ton	$ 240	$ 393,960	
Import, place, and compact fill	2,189	BCY	$ 20	$ 43,773	
Remedial design	10%			$ 72,129	
Construction management and reporting	8%			$ 57,703	
Subtotal				*$ 851,122*	
Tax	8.7%		$ 721,290	$ 62,752	
Contingency	10%		$ 913,874	$ 91,387	
Subtotal Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin				*$ 1,005,262*	
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale					
Mobilization/demobilization	1	LS	$ 20,000	$ 20,000	includes BNSF access agreement, flagger, etc.
Remove/replace chain link fence	700	lf	$ 4	$ 2,800	
Remove/stockpile crushed concrete	900	BCY	$ 8	$ 7,201	
Consolidate soils from BNSF onto Port property	675	BCY	$ 6	$ 4,050	
Import, place, and compact fill	1,125	BCY	$ 20	$ 22,502	restore BNSF grade (no import fill needed on Port property)
Remedial design	20%			$ 11,311	
Construction management and reporting	30%			$ 16,966	
Subtotal				*$ 84,829*	
Tax	8.7%		$ 56,553	$ 4,920	
Contingency	10%		$ 89,749	$ 8,975	
Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale				*$ 98,724*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	15	each	$ 4,000	$ 60,000	
Remedial design	15%			$ 11,250	
Construction management and reporting	20%			$ 15,000	
Subtotal				*$ 101,250*	
Tax	8.7%		$ 75,000	$ 6,525	
Contingency	20%		$ 107,775	$ 21,555	
Subtotal Monitored Natural Attenuation				*$ 129,330*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 15,136,227	$454,087	
Total Estimated Capital Costs				**$ 15,590,314**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems	1	30	$ 6,000	$ 180,000	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 16,000	$ 32,000	
Groundwater quality monitoring, Years 3+	3	30	$ 8,000	$ 224,000	
Subtotal Periodic O&M Cost				*$ 436,000*	
Contingency		20.0%		$ 87,200	
				$ 523,200	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 26,160	
Project management/reporting		6%		$ 31,392	
Total, Periodic O&M Net Present Value:				**$ 580,752**	
TOTAL ESTIMATED COST				**$ 16,170,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table A-4 - Alternative 3 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site:	Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit	
Remedial Action Description:	Alternative: 3	Removal of Soils with Visible Hg and Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and Groundwater MNA
Cost Estimate Accuracy:	FS Screening Level (+50/-30 percent)	

Key Assumptions and Quantities:

		Cap Quantities
7.4	acre	capping area
1.5	ton/BCY	soil density
15	each	MNA wells
		Visible Mercury Soils Removal, Treatment, and Offsite Disposal Quantities
21,897	ton	weight of removed soil & debris
1,533	ton	weight of removed surficial debris
657	ton	weight of removed piles
19,707	ton	weight of soil in target area
25%		percentage of surficial debris requiring encapsulation
1,150	ton	weight of inert surficial debris
25%		percentage cement amendment (ex situ)
2%		percentage sulfur amendment (ex situ)
		Soil Excavation Quantities - WW Settling Basin Soils with [Hg] > 300 mg/kg
2,501	BCY	overburden soil excavation volume
2,189	BCY	impacted soil excavation volume
1,094	BCY	volume classified as hazardous
1,094	BCY	volume classified as non-hazardous
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
675	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Soil Capping					
Mobilization/demobilization	1	LS	$ 70,000	$ 70,000	
Existing Cap	**50%**				
-No Cost	3.7	acre	$ -	$ -	
New Cap	**50%**				
Soil Cover as Cap	*0%*				
-Site Preparation	-	acre	$ 4,500	$ -	clearing and leveling
-Geotextile marker layer	-	SY	$ 2	$ -	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	0	CY	$ 18	$ -	2' thick
Asphalt Pavement as Cap	*100%*				
-Site Preparation	3.7	acre	$ 4,500	$ 16,652	clearing and leveling
-Pregrading	3.7	acre	$ 5,200	$ 19,243	light grading for asphalt
-Asphalt	3.7	acre	$ 115,400	$ 427,037	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*0%*				
-No Cost	-		$ -	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	6,450	LF	$ -	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	10%			$ 58,293	
Construction management and reporting	10%			$ 58,293	
Subtotal				*$ 699,518*	
Tax	8.7%		$ 532,932	$ 46,365	
Contingency	15%		$ 745,884	$ 111,883	
Subtotal Soil Cap Cost				*$ 857,766*	
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.)	14,598	BCY	$ 125	$ 1,824,731	
Dewatering	24	day	$ 800	$ 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of contaminated debris - Hazardous Waste	1,040	ton	$ 650	$ 676,063	Subtitle C landfill with macro-encapsulation
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Portland cement amendment	4,927	ton	$ 45	$ 221,705	25% by wt
Sulfur amendment	394	ton	$ 40	$ 15,766	2% by wt
Ex situ solidification and load for offsite transport	19,707	ton	$ 50	$ 985,355	
Transport/disposal of solidified mix - Hazardous Waste	26,999	ton	$ 220	$ 5,939,720	includes added water wt. @ 10% of soil wt.
Import, place, and compact fill	13,138	BCY	$ 20	*$ 262,761*	
Remedial design & pre-design testing	5%			$ 516,877	includes add'l characterization
Construction management and reporting	5%			$ 516,877	
Subtotal				*$ 11,371,285*	
Tax	8.7%		$ 10,337,532	$ 899,365	
Contingency	15%		$ 12,270,650	$ 1,840,598	
Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg				*$ 14,111,248*	
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin					
Mobilization/demobilization	1	LS	$ 60,000	$ 60,000	
Dewatering	12	day	$ 800	$ 9,380	
Excavate/stockpile/replace overburden soil	2,501	BCY	$ 20	$ 50,027	
Excavation, transport, and disposal - Non-Hazardous Waste	1,642	ton	$ 100	$ 164,150	
Excavation, transport, and disposal - Hazardous Waste	1,642	ton	$ 240	$ 393,960	
Import, place, and compact fill	2,189	BCY	$ 20	$ 43,773	
Remedial design	10%			$ 72,129	
Construction management and reporting	8%			$ 57,703	
Subtotal				*$ 851,122*	
Tax	8.7%		$ 721,290	$ 62,752	
Contingency	10%		$ 913,874	$ 91,387	
Subtotal Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin				*$ 1,005,262*	
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale					
Mobilization/demobilization	1	LS	$ 20,000	$ 20,000	includes BNSF access agreement, flagger, etc.
Remove/replace chain link fence	700	lf	$ 4	$ 2,800	
Remove/stockpile crushed concrete	900	BCY	$ 8	$ 7,201	
Consolidate soils from BNSF onto Port property	675	BCY	$ 6	$ 4,050	
Import, place, and compact fill	1,125	BCY	$ 20	$ 22,502	restore BNSF grade (no import fill needed on Port property)
Remedial design	20%			$ 11,311	
Construction management and reporting	30%			$ 16,966	
Subtotal				*$ 84,829*	
Tax	8.7%		$ 56,553	$ 4,920	
Contingency	10%		$ 89,749	$ 8,975	
Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale				*$ 98,724*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	15	each	$ 4,000	$ 60,000	
Remedial design	15%			$ 11,250	
Construction management and reporting	20%			$ 15,000	
Subtotal				*$ 101,250*	
Tax	8.7%		$ 75,000	$ 6,525	
Contingency	20%		$ 107,775	$ 21,555	
Subtotal Monitored Natural Attenuation				*$ 129,330*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 21,522,674	$645,680	
Total Estimated Capital Costs				**$ 22,168,354**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems	1	30	$ 6,000	$ 180,000	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 16,000	$ 32,000	
Groundwater quality monitoring, Years 3+	3	30	$ 8,000	$ 224,000	
Subtotal Periodic O&M Cost				*$ 436,000*	
Contingency		20.0%		$ 87,200	
				$ 523,200	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 26,160	
Project management/reporting		6%		$ 31,392	
Total, Periodic O&M Net Present Value:				**$ 580,752**	
TOTAL ESTIMATED COST				**$ 22,750,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table A-5 - Alternative 4 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: Alternative: 4 Neutralization of "Caustic Core," Aggressive Removal of Obstructions and In-Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

		Cap Quantities
7.4	acre	capping area
1.5	ton/BCY	soil density
15	each	MNA wells
		Visible Mercury Soils Aggressive Removal of Obstructions and In Situ Stabilization Quantities
21,897	ton	weight of soil and debris in target area
1,533	ton	weight of removed surficial debris
657	ton	weight of removed piles
25%		percentage of surficial debris requiring encapsulation
19,707	ton	weight of soil in target area for in situ stabilization
1,150	ton	weight of inert surficial debris
25%		auger overlap
25%		percentage cement amendment (in situ)
2%		percentage sulfur amendment (in situ)
5,600	BCY	import soil to smooth grade after ISS
		Soil Excavation Quantities - WW Settling Basin Soils with [Hg] > 300 mg/kg
2,501	BCY	overburden soil excavation volume
2,189	BCY	impacted soil excavation volume
1,094	BCY	volume classified as hazardous
1,094	BCY	volume classified as non-hazardous
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
675	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous
		Elevated Groundwater pH Neutralization Quantities
1,725	BCY	excavation volume
1,035	ft	total trench length
1,413	ton	ferrous sulfate
115	BCY	topping soil
10	each	monitoring wells

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Soil Capping					
Mobilization/demobilization	1	LS	$ 70,000	$ 70,000	
Existing Cap	**50%**				
-No Cost	3.7	acre	$ -	$ -	
New Cap	**50%**				
Soil Cover as Cap	*0%*				
-Site Preparation	-	acre	$ 4,500	$ -	clearing and leveling
-Geotextile marker layer	-	SY	$ 2	$ -	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	0	CY	$ 18	$ -	2' thick
Asphalt Pavement as Cap	*100%*				
-Site Preparation	3.7	acre	$ 4,500	$ 16,652	clearing and leveling
-Pregrading	3.7	acre	$ 5,200	$ 19,243	light grading for asphalt
-Asphalt	3.7	acre	$ 115,400	$ 427,037	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*0%*				
-No Cost	-		$ -	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	6,450	LF	$ -	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	10%			$ 58,293	
Construction management and reporting	10%			$ 58,293	
Subtotal				*$ 699,518*	
Tax	8.7%		$ 532,932	$ 46,365	
Contingency	15%		$ 745,884	$ 111,883	
Subtotal Soil Cap Cost				*$ 857,766*	
Aggressive Removal of Obstructions and ISS of Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.)	14,598	BCY	$ 125	$ 1,824,731	
Dewatering	24	day	$ 800	$ 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of contaminated debris - Hazardous Waste	1,040	ton	$ 650	$ 676,063	Subtitle C landfill with macro-encapsulation
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Portland cement amendment	4,927	ton	$ 45	$ 221,705	25% by wt
Sulfur amendment	394	ton	$ 40	$ 15,766	2% by wt
Auger solidification	19,707	ton	$ 70	$ 1,379,497	accessible soils containing visible elemental Hg
Import, place, and compact fill	5,600	BCY	$ 20	$ 112,000	to smooth surface following ISS
Remedial design & pre-design testing	15%			$ 696,179	includes add'l characterization
Construction management and reporting	15%			$ 696,179	
Subtotal				*$ 6,033,550*	
Tax	8.7%		$ 4,641,192	$ 403,784	
Contingency	20%		$ 6,437,334	$ 1,287,467	
Subtotal Aggressive Removal of Obstructions and ISS of Soils with Visible Hg				*$ 7,724,800*	
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin					
Mobilization/demobilization	1	LS	$ 60,000	$ 60,000	
Dewatering	12	day	$ 800	$ 9,380	
Excavate/stockpile/replace overburden soil	2,501	BCY	$ 20	$ 50,027	
Excavation, transport, and disposal - Non-Hazardous Waste	1,642	ton	$ 100	$ 164,150	
Excavation, transport, and disposal - Hazardous Waste	1,642	ton	$ 240	$ 393,960	
Import, place, and compact fill	2,189	BCY	$ 20	$ 43,773	
Remedial design	10%			$ 72,129	
Construction management and reporting	8%			$ 57,703	
Subtotal				*$ 851,122*	
Tax	8.7%		$ 721,290	$ 62,752	
Contingency	10%		$ 913,874	$ 91,387	
Subtotal Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin				*$ 1,005,262*	
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale					
Mobilization/demobilization	1	LS	$ 20,000	$ 20,000	includes BNSF access agreement, flagger, etc.
Remove/replace chain link fence	700	lf	$ 4	$ 2,800	
Remove/stockpile crushed concrete	900	BCY	$ 8	$ 7,201	
Consolidate soils from BNSF onto Port property	675	BCY	$ 6	$ 4,050	
Import, place, and compact fill	1,125	BCY	$ 20	$ 22,502	restore BNSF grade (no import fill needed on Port property)
Remedial design	20%			$ 11,311	
Construction management and reporting	30%			$ 16,966	
Subtotal				*$ 84,829*	
Tax	8.7%		$ 56,553	$ 4,920	
Contingency	10%		$ 89,749	$ 8,975	
Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale				*$ 98,724*	
Neutralization of Elevated Groundwater pH					
Mobilization/demobilization	1	LS	$ 80,000	$ 80,000	One Pass trencher transport, assembly and disassembly
Trenching	1,035	LF	$ 375	$ 388,125	excavation and media placement
Transport and disposal - Non-Hazardous Waste	2,588	ton	$ 80	$ 207,000	Subtitle D landfill
Treatment media	1,413	ton	$ 300	$ 423,833	ferrous sulfate heptahydrate, includes transport
Import, place, and compact fill	115	BCY	$ 20	$ 2,300	soil replaced above treatment media
Monitoring well installation	10	each	$ 4,000	$ 40,000	
Remedial design & pre-design testing	25%			$ 285,314	includes add'l characterization
Construction management and reporting	15%			$ 171,189	
Subtotal				*$ 1,597,761*	
Tax	8.7%		$ 1,141,258	$ 99,289	
Contingency	20%		$ 1,697,050	$ 339,410	
Subtotal Neutralization of Elevated Groundwater pH				*$ 2,036,460*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	15	each	$ 4,000	$ 60,000	
Remedial design	15%			$ 11,250	
Construction management and reporting	20%			$ 15,000	
Subtotal				*$ 101,250*	
Tax	8.7%		$ 75,000	$ 6,525	
Contingency	20%		$ 107,775	$ 21,555	
Subtotal Monitored Natural Attenuation				*$ 129,330*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 17,172,687	$515,181	
Total Estimated Capital Costs				**$ 17,687,867**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems	1	30	$ 6,000	$ 180,000	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 24,000	$ 48,000	
Groundwater quality monitoring, Years 3+	3	30	$ 12,000	$ 336,000	
Subtotal Periodic O&M Cost				*$ 564,000*	
Contingency		20.0%		$ 112,800	
				$ 676,800	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 33,840	
Project management/reporting		6%		$ 40,608	
Total, Periodic O&M Net Present Value:				**$ 751,248**	
TOTAL ESTIMATED COST				**$ 18,440,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table A-6 - Alternative 5 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: Alternative: **5** Neutralization of Groundwater with pH > 8.5, Aggressive Removal of Obstructions and In-Situ Treatment of Soils with Visible Hg, Removal of Hg-Impacted Soils Near Log Pond, Capping of Residual Impacted Soils, and

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

		Cap Quantities
7.4	acre	capping area
1.5	ton/BCY	soil density
15	each	MNA wells
		Visible Mercury Soils Aggressive Removal of Obstructions and In Situ Stabilization Quantities
21,897	ton	weight of soil and debris in target area
1,533	ton	weight of removed surficial debris
657	ton	weight of removed piles
25%		percentage of surficial debris requiring encapsulation
19,707	ton	weight of soil in target area for in situ stabilization
1,150	ton	weight of inert surficial debris
25%		auger overlap
25%		percentage cement amendment (in situ)
2%		percentage sulfur amendment (in situ)
5,600	BCY	import soil to smooth grade after ISS
		Soil Excavation Quantities - WW Settling Basin Soils with [Hg] > 300 mg/kg
2,501	BCY	overburden soil excavation volume
2,189	BCY	impacted soil excavation volume
1,094	BCY	volume classified as hazardous
1,094	BCY	volume classified as non-hazardous
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
675	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous
		Elevated Groundwater pH Neutralization Quantities
7,815	BCY	excavation volume
4,689	ft	total trench length
6,400	ton	ferrous sulfate
521	BCY	topping soil
20	each	monitoring wells

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Soil Capping					
Mobilization/demobilization	1	LS	$ 70,000	$ 70,000	
Existing Cap	**50%**				
-No Cost	3.7	acre	$ -	$ -	
New Cap	**50%**				
Soil Cover as Cap	*0%*				
-Site Preparation	-	acre	$ 4,500	$ -	clearing and leveling
-Geotextile marker layer	-	SY	$ 2	$ -	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	0	CY	$ 18	$ -	2' thick
Asphalt Pavement as Cap	*100%*				
-Site Preparation	3.7	acre	$ 4,500	$ 16,652	clearing and leveling
-Pregrading	3.7	acre	$ 5,200	$ 19,243	light grading for asphalt
-Asphalt	3.7	acre	$ 115,400	$ 427,037	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*0%*				
-No Cost	-		$ -	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	6,450	LF	$ -	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	10%			$ 58,293	
Construction management and reporting	10%			$ 58,293	
Subtotal				*$ 699,518*	
Tax	8.7%		$ 532,932	$ 46,365	
Contingency	15%		$ 745,884	$ 111,883	
Subtotal Soil Cap Cost				*$ 857,766*	
Aggressive Removal of Obstructions and ISS of Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.)	14,598	BCY	$ 125	$ 1,824,731	
Dewatering	24	day	$ 800	$ 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of contaminated debris - Hazardous Waste	1,040	ton	$ 650	$ 676,063	Subtitle C landfill with macro-encapsulation
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Portland cement amendment	4,927	ton	$ 45	$ 221,705	25% by wt
Sulfur amendment	394	ton	$ 40	$ 15,766	2% by wt
Auger solidification	19,707	ton	$ 70	$ 1,379,497	accessible soils containing visible elemental Hg
Import, place, and compact fill	5,600	BCY	$ 20	$ 112,000	to smooth surface following ISS
Remedial design & pre-design testing	15%			$ 696,179	includes add'l characterization
Construction management and reporting	15%			$ 696,179	
Subtotal				*$ 6,033,550*	
Tax	8.7%		$ 4,641,192	$ 403,784	
Contingency	20%		$ 6,437,334	$ 1,287,467	
Subtotal Aggressive Removal of Obstructions and ISS of Soils with Visible Hg				*$ 7,724,800*	
Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin					
Mobilization/demobilization	1	LS	$ 60,000	$ 60,000	
Dewatering	12	day	$ 800	$ 9,380	
Excavate/stockpile/replace overburden soil	2,501	BCY	$ 20	$ 50,027	
Excavation, transport, and disposal - Non-Hazardous Waste	1,642	ton	$ 100	$ 164,150	
Excavation, transport, and disposal - Hazardous Waste	1,642	ton	$ 240	$ 393,960	
Import, place, and compact fill	2,189	BCY	$ 20	$ 43,773	
Remedial design	10%			$ 72,129	
Construction management and reporting	8%			$ 57,703	
Subtotal				*$ 851,122*	
Tax	8.7%		$ 721,290	$ 62,752	
Contingency	10%		$ 913,874	$ 91,387	
Subtotal Removal of Soils with [Hg] > 300 mg/kg from North WW Settling Basin				*$ 1,005,262*	
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale					
Mobilization/demobilization	1	LS	$ 20,000	$ 20,000	includes BNSF access agreement, flagger, etc.
Remove/replace chain link fence	700	lf	$ 4	$ 2,800	
Remove/stockpile crushed concrete	900	BCY	$ 8	$ 7,201	
Consolidate soils from BNSF onto Port property	675	BCY	$ 6	$ 4,050	
Import, place, and compact fill	1,125	BCY	$ 20	$ 22,502	restore BNSF grade (no import fill needed on Port property)
Remedial design	20%			$ 11,311	
Construction management and reporting	30%			$ 16,966	
Subtotal				*$ 84,829*	
Tax	8.7%		$ 56,553	$ 4,920	
Contingency	10%		$ 89,749	$ 8,975	
Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale				*$ 98,724*	
Neutralization of Elevated Groundwater pH					
Mobilization/demobilization	1	LS	$ 80,000	$ 80,000	One Pass trencher transport, assembly and disassembly
Trenching	4,689	LF	$ 375	$ 1,758,375	excavation and media placement
Transport and disposal - Non-Hazardous Waste	11,723	ton	$ 80	$ 937,800	Subtitle D landfill
Treatment media	6,400	ton	$ 300	$ 1,920,146	ferrous sulfate heptahydrate, includes transport
Import, place, and compact fill	521	BCY	$ 20	$ 10,420	soil replaced above treatment media
Monitoring well installation	20	each	$ 4,000	$ 80,000	
Remedial design & pre-design testing	15%			$ 718,011	includes add'l characterization
Construction management and reporting	8%			$ 382,939	
Subtotal				*$ 5,887,691*	
Tax	8.7%		$ 4,786,741	$ 416,446	
Contingency	20%		$ 6,304,137	$ 1,260,827	
Subtotal Neutralization of Elevated Groundwater pH				*$ 7,564,965*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	15	each	$ 4,000	$ 60,000	
Remedial design	15%			$ 11,250	
Construction management and reporting	20%			$ 15,000	
Subtotal				*$ 101,250*	
Tax	8.7%		$ 75,000	$ 6,525	
Contingency	20%		$ 107,775	$ 21,555	
Subtotal Monitored Natural Attenuation				*$ 129,330*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 22,701,192	$681,036	
Total Estimated Capital Costs				**$ 23,382,227**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems	1	30	$ 6,000	$ 180,000	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 32,000	$ 64,000	
Groundwater quality monitoring, Years 3+	3	27	$ 16,000	$ 400,000	
Subtotal Periodic O&M Cost				*$ 644,000*	
Contingency		20.0%		$ 128,800	
				$ 772,800	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 38,640	
Project management/reporting		6%		$ 46,368	
Total, Periodic O&M Net Present Value:				**$ 857,808**	
TOTAL ESTIMATED COST				**$ 24,240,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table A-7 - Alternative 6 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: Alternative: **6** Neutralization of Groundwater with pH > 8.5, Removal of Hg-Impacted Soils to Achieve Groundwater Protection, Capping of Residual Impacted Soils, and Groundwater MNA

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

		Cap Quantities
7.4	acre	capping area
1.5	ton/BCY	soil density
15	each	MNA wells
		Visible Mercury Soils Removal, Treatment, and Offsite Disposal Quantities
21,897	ton	weight of removed soil & debris
1,533	ton	weight of removed surficial debris
657	ton	weight of removed piles
19,707	ton	weight of soil in target area
25%		percentage of surficial debris requiring encapsulation
1,150	ton	weight of inert surficial debris
25%		percentage cement amendment (ex situ)
2%		percentage sulfur amendment (ex situ)
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
675	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous
		Soil Excavation Quantities - Additional Soils Exceeding Cleanup Levels or Groundwater Protection Levels
28,385	BCY	excavation volume
4,461	BCY	volume classified as hazardous
23,924	BCY	volume classified as non-hazardous
		Elevated Groundwater pH Neutralization Quantities
6,858	BCY	excavation volume
4,115	ft	total trench length
5,617	ton	ferrous sulfate
457	BCY	topping soil
20	each	monitoring wells

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Soil Capping					
Mobilization/demobilization	1	LS	$ 70,000	$ 70,000	
Existing Cap	**50%**				
-No Cost	3.7	acre	$ -	$ -	
New Cap	**50%**				
Soil Cover as Cap	*0%*				
-Site Preparation	-	acre	$ 4,500	$ -	clearing and leveling
-Geotextile marker layer	-	SY	$ 2	$ -	Specification 9 33.2(1) Table 3 (WSDOT, 2012)
-Import, place, and compact fill	0	CY	$ 18	$ -	2' thick
Asphalt Pavement as Cap	*100%*				
-Site Preparation	3.7	acre	$ 4,500	$ 16,652	clearing and leveling
-Pregrading	3.7	acre	$ 5,200	$ 19,243	light grading for asphalt
-Asphalt	3.7	acre	$ 115,400	$ 427,037	6" stone base, 2" binder layer, 1" topping layer
Buildings as Cap	*0%*				
-No Cost	-		$ -	$ -	Assume buildings cost are redevelopment, not cleanup
Stormwater collection and conveyance system	6,450	LF	$ -	$ -	Assumed redevelopment cost
Institutional Controls Plan	1	LS	$ 50,000	$ 50,000	includes I&M manual for cover systems, legal support
Remedial design	10%			$ 58,293	
Construction management and reporting	10%			$ 58,293	
Subtotal				*$ 699,518*	
Tax	8.7%		$ 532,932	$ 46,365	
Contingency	15%		$ 745,884	$ 111,883	
Subtotal Soil Cap Cost				*$ 857,766*	
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.)	14,598	BCY	$ 125	$ 1,824,731	
Dewatering	24	day	$ 800	$ 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of contaminated debris - Hazardous Waste	1,040	ton	$ 650	$ 676,063	Subtitle C landfill with macro-encapsulation
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Portland cement amendment	4,927	ton	$ 45	$ 221,705	25% by wt
Sulfur amendment	394	ton	$ 40	$ 15,766	2% by wt
Ex situ solidification and load for offsite transport	19,707	ton	$ 50	$ 985,355	
Transport/disposal of solidified mix - Hazardous Waste	26,999	ton	$ 220	$ 5,939,720	includes added water wt. @ 10% of soil wt.
Import, place, and compact fill	13,138	BCY	$ 20	*$ 262,761*	
Remedial design & pre-design testing	5%			$ 516,877	includes add'l characterization
Construction management and reporting	5%			$ 516,877	
Subtotal				*$ 11,371,285*	
Tax	8.7%		$ 10,337,532	$ 899,365	
Contingency	15%		$ 12,270,650	$ 1,840,598	
Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg				*$ 14,111,248*	
Stockpiling Crushed Concrete and Consolidating Soils with [Hg] > 24 mg/kg in Stormwater Swale					
Mobilization/demobilization	1	LS	$ 20,000	$ 20,000	includes BNSF access agreement, flagger, etc.
Remove/replace chain link fence	700	lf	$ 4	$ 2,800	
Remove/stockpile crushed concrete	900	BCY	$ 8	$ 7,201	
Consolidate soils from BNSF onto Port property	675	BCY	$ 6	$ 4,050	
Import, place, and compact fill	1,125	BCY	$ 20	$ 22,502	restore BNSF grade (no import fill needed on Port property)
Remedial design	20%			$ 11,311	
Construction management and reporting	30%			$ 16,966	
Subtotal				*$ 84,829*	
Tax	8.7%		$ 56,553	$ 4,920	
Contingency	10%		$ 89,749	$ 8,975	
Subtotal Stockpiling Concrete & Consolidating Soils in Stormwater Swale				*$ 98,724*	
Neutralization of Elevated Groundwater pH					
Mobilization/demobilization	1	LS	$ 80,000	$ 80,000	One Pass trencher transport, assembly and disassembly
Trenching	4,115	LF	$ 375	$ 1,543,125	excavation and media placement
Transport and disposal - Non-Hazardous Waste	10,288	ton	$ 80	$ 823,000	Subtitle D landfill
Treatment media	5,617	ton	$ 300	$ 1,685,093	ferrous sulfate heptahydrate, includes transport
Import, place, and compact fill	457	BCY	$ 20	$ 9,144	soil replaced above treatment media
Monitoring well installation	20	each	$ 4,000	$ 80,000	
Remedial design & pre-design testing	15%			$ 633,054	includes add'l characterization
Construction management and reporting	8%			$ 337,629	
Subtotal				*$ 5,191,045*	
Tax	8.7%		$ 4,220,362	$ 367,171	
Contingency	20%		$ 5,558,217	$ 1,111,643	
Subtotal Neutralization of Elevated Groundwater pH				*$ 6,669,860*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Removal of Additional Soils Exceeding Cleanup Levels or Groundwater Protection Levels					
Mobilization/demobilization	1	LS	$ 100,000	$ 100,000	
Dewatering	71	day	$ 800	$ 56,770	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	35,886	ton	$ 100	$ 3,588,575	Subtitle D landfill
Excavation, transport and disposal - Hazardous Waste	6,692	ton	$ 240	$ 1,605,960	Subtitle C landfill, assuming no treatment required
Surcharge for difficult/unexpected subsurface conditions	8,515	ton	$ 100	$ 851,545	applied to 20 percent of excavated material
Import, place, and compact fill	28,385	BCY	$ 20	$ 567,697	
Remedial design	5%			$ 338,527	includes add'l characterization
Construction management and reporting	8%			$ 541,644	
Subtotal				*$ 7,650,717*	
Tax	8.7%		$ 6,770,546	$ 589,038	
Contingency	20%		$ 8,239,755	$ 1,647,951	increase due to likelihood of encountering debris
Subtotal Removal of Additional Soils Above Cleanup Levels				*$ 9,887,706*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	15	each	$ 4,000	$ 60,000	
Remedial design	15%			$ 11,250	
Construction management and reporting	20%			$ 15,000	
Subtotal				*$ 101,250*	
Tax	8.7%		$ 75,000	$ 6,525	
Contingency	20%		$ 107,775	$ 21,555	
Subtotal Monitored Natural Attenuation				*$ 129,330*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 37,074,978	$1,112,249	
Total Estimated Capital Costs				**$ 38,187,227**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems	1	30	$ 6,000	$ 180,000	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 32,000	$ 64,000	
Groundwater quality monitoring, Years 3+	3	27	$ 16,000	$ 400,000	
Subtotal Periodic O&M Cost				*$ 644,000*	
Contingency		20.0%		$ 128,800	
				$ 772,800	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 38,640	
Project management/reporting		6%		$ 46,368	
Total, Periodic O&M Net Present Value:				**$ 857,808**	
TOTAL ESTIMATED COST				**$ 39,050,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table A-8 - Alternative 7 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: Alternative: **7** Removal of All Soils Exceeding Cleanup Levels, Neutralization of Groundwater with pH > 8.5, and Groundwater MNA

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

		Cap Quantities
0.0	acre	capping area
1.5	ton/BCY	soil density
15	each	MNA wells
		Visible Mercury Soils Removal, Treatment, and Offsite Disposal Quantities
21,897	ton	weight of removed soil & debris
1,533	ton	weight of removed surficial debris
657	ton	weight of removed piles
19,707	ton	weight of soil in target area
25%		percentage of surficial debris requiring encapsulation
1,150	ton	weight of inert surficial debris
25%		percentage cement amendment (ex situ)
2%		percentage sulfur amendment (ex situ)
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
0	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous
		Soil Excavation Quantities - Additional Soils Exceeding Cleanup Levels or Groundwater Protection Lev
105,691	BCY	excavation volume
13,261	BCY	volume classified as hazardous
92,430	BCY	volume classified as non-hazardous
		Elevated Groundwater pH Neutralization Quantities
6,523	BCY	excavation volume
3,914	ft	total trench length
5,343	ton	ferrous sulfate
435	BCY	topping soil
20	each	monitoring wells

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.)	14,598	BCY	$ 125	$ 1,824,731	
Dewatering	24	day	$ 800	$ 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of contaminated debris - Hazardous Waste	1,040	ton	$ 650	$ 676,063	Subtitle C landfill with macro-encapsulation
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Portland cement amendment	4,927	ton	$ 45	$ 221,705	25% by wt
Sulfur amendment	394	ton	$ 40	$ 15,766	2% by wt
Ex situ solidification and load for offsite transport	19,707	ton	$ 50	$ 985,355	
Transport/disposal of solidified mix - Hazardous Waste	26,999	ton	$ 220	$ 5,939,720	includes added water wt. @ 10% of soil wt.
Import, place, and compact fill	13,138	BCY	$ 20	*$ 262,761*	
Remedial design & pre-design testing	5%			$ 516,877	includes add'l characterization
Construction management and reporting	5%			$ 516,877	
Subtotal				*$ 11,371,285*	
Tax	8.7%		$ 10,337,532	$ 899,365	
Contingency	15%		$ 12,270,650	$ 1,840,598	
Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg				*$ 14,111,248*	
Neutralization of Elevated Groundwater pH					
Mobilization/demobilization	1	LS	$ 80,000	$ 80,000	One Pass trencher transport, assembly and disassembly
Trenching	3,914	LF	$ 375	$ 1,467,750	excavation and media placement
Transport and disposal - Non-Hazardous Waste	9,785	ton	$ 80	$ 782,800	Subtitle D landfill
Treatment media	5,343	ton	$ 300	$ 1,602,783	ferrous sulfate heptahydrate, includes transport
Import, place, and compact fill	435	BCY	$ 20	$ 8,698	soil replaced above treatment media
Monitoring well installation	20	each	$ 4,000	$ 80,000	
Remedial design & pre-design testing	15%			$ 603,305	includes add'l characterization
Construction management and reporting	8%			$ 321,762	
Subtotal				*$ 4,947,098*	
Tax	8.7%		$ 4,022,031	$ 349,917	
Contingency	20%		$ 5,297,015	$ 1,059,403	
Subtotal Neutralization of Elevated Groundwater pH				*$ 6,356,417*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Removal of Additional Soils Exceeding Cleanup Levels or Groundwater Protection Levels					
Mobilization/demobilization	1	LS	$ 100,000	$ 100,000	
Dewatering	264	day	$ 800	$ 211,381	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	138,644	ton	$ 100	$ 13,864,433	Subtitle D landfill
Excavation, transport and disposal - Hazardous Waste	19,892	ton	$ 240	$ 4,773,960	Subtitle C landfill, assuming no treatment required
Surcharge for difficult/unexpected subsurface conditions	31,707	ton	$ 100	$ 3,170,717	applied to 20 percent of excavated material
Import, place, and compact fill	105,691	BCY	$ 20	$ 2,113,811	
Remedial design	5%			$ 1,211,715	includes add'l characterization
Construction management and reporting	8%			$ 1,938,744	
Subtotal				*$ 27,384,762*	
Tax	8.7%		$ 24,234,302	$ 2,108,384	
Contingency	20%		$ 29,493,146	$ 5,898,629	increase due to likelihood of encountering debris
Subtotal Removal of Additional Soils Above Cleanup Levels				*$ 35,391,775*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	15	each	$ 4,000	$ 60,000	
Remedial design	15%			$ 11,250	
Construction management and reporting	20%			$ 15,000	
Subtotal				*$ 101,250*	
Tax	8.7%		$ 75,000	$ 6,525	
Contingency	20%		$ 107,775	$ 21,555	
Subtotal Monitored Natural Attenuation				*$ 129,330*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 61,309,114	$1,839,273	
Total Estimated Capital Costs				**$ 63,148,388**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems			$ -	$ -	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 32,000	$ 64,000	
Groundwater quality monitoring, Years 3+	3	27	$ 16,000	$ 400,000	
Subtotal Periodic O&M Cost				*$ 464,000*	
Contingency		20.0%		$ 92,800	
				$ 556,800	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 27,840	
Project management/reporting		6%		$ 33,408	
Total, Periodic O&M Net Present Value:				**$ 618,048**	
TOTAL ESTIMATED COST				**$ 63,770,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

Table A-9 - Alternative 8 Cost Estimate

Project #070188 - Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Site: Former Georgia-Pacific West Site - Pulp/Tissue Mill Remedial Action Unit

Remedial Action Description: Alternative: **8** Removal of All Soils Exceeding Cleanup Levels, Neutralization of Groundwater with pH > 8.5, In-Situ Treatment of Fill Unit Groundwater Impacted by Hg and PAHs, and MNA for Residual Impacted Groundwater

Cost Estimate Accuracy: FS Screening Level (+50/-30 percent)

Key Assumptions and Quantities:

		Cap Quantities
0.0	acre	capping area
1.5	ton/BCY	soil density
3	each	MNA wells
		Visible Mercury Soils Removal, Treatment, and Offsite Disposal Quantities
21,897	ton	weight of removed soil & debris
1,533	ton	weight of removed surficial debris
657	ton	weight of removed piles
19,707	ton	weight of soil in target area
25%		percentage of surficial debris requiring encapsulation
1,150	ton	weight of inert surficial debris
25%		percentage cement amendment (ex situ)
2%		percentage sulfur amendment (ex situ)
		SW Swale Quantities - Stockpiling Overburden and Consolidating BNSF Soils with [Hg] > 24 mg/kg
700	lf	length of fence to remove/replace
900	BCY	volume of concrete to excavate/stockpile
0	BCY	volume of BNSF soil to consolidate
		Soil Excavation Quantities - TPH-Impacted Soils in SE Corner of Cell Building
1,291	BCY	excavation volume
0	BCY	volume classified as hazardous
1,291	BCY	volume classified as non-hazardous
		Soil Excavation Quantities - Additional Soils Exceeding Cleanup Levels or Groundwater Protection Levels
105,691	BCY	excavation volume
13,261	BCY	volume classified as hazardous
92,430	BCY	volume classified as non-hazardous
		Elevated Groundwater pH Neutralization Quantities
6,523	BCY	excavation volume
3,914	ft	total trench length
5,343	ton	ferrous sulfate
435	BCY	topping soil
20	each	monitoring wells
		Additional GW Treatment Quantities
4,148	BCY	ZVI trench excavation volume
3,111	lf	total trench length
2,397	ton	ZVI mass
2,397	ton	sand mass
1,152	BCY	topping soil
10	each	ZVI monitoring wells
91	each	number of injection points
19	day	days required for injection
2,730	lb	total injected mass
6	each	EAB monitoring wells

CONSTRUCTION COSTS

Item	Quantity	Unit	Unit Cost	Total Cost	Notes
Caustic Plume-Cell Building Interim Actions (2013-2014 and 2017)					
Sunk cost	1	LS	$ 4,900,000	$ 4,900,000	including remedial design, construction, and oversight
Subtotal Caustic Plume-Cell Building Interim Actions				*$ 4,900,000*	
Removal, Treatment, and Offsite Disposal of Soils with Visible Hg					
Mobilization/demobilization	1	LS	$ 300,000	$ 300,000	includes dewatering equipment and installation
Material removal (soil, foundation elements, etc.)	14,598	BCY	$ 125	$ 1,824,731	
Dewatering	24	day	$ 800	$ 19,464	based on 400 yd/day removal rate, includes daily sampling
Transport/disposal of contaminated debris - Hazardous Waste	1,040	ton	$ 650	$ 676,063	Subtitle C landfill with macro-encapsulation
Transport/disposal of surficial concrete as Non-hazardous Waste	1,150	ton	$ 80	$ 91,966	
Portland cement amendment	4,927	ton	$ 45	$ 221,705	25% by wt
Sulfur amendment	394	ton	$ 40	$ 15,766	2% by wt
Ex situ solidification and load for offsite transport	19,707	ton	$ 50	$ 985,355	
Transport/disposal of solidified mix - Hazardous Waste	26,999	ton	$ 220	$ 5,939,720	includes added water wt. @ 10% of soil wt.
Import, place, and compact fill	13,138	BCY	$ 20	*$ 262,761*	
Remedial design & pre-design testing	5%			$ 516,877	includes add'l characterization
Construction management and reporting	5%			$ 516,877	
Subtotal				*$ 11,371,285*	
Tax	8.7%		$ 10,337,532	$ 899,365	
Contingency	15%		$ 12,270,650	$ 1,840,598	
Subtotal Removal, Treatment, and Offsite Disposal of Soils with Visible Hg				*$ 14,111,248*	
Neutralization of Elevated Groundwater pH					
Mobilization/demobilization	1	LS	$ 80,000	$ 80,000	One Pass trencher transport, assembly and disassembly
Trenching	3,914	LF	$ 375	$ 1,467,750	excavation and media placement
Transport and disposal - Non-Hazardous Waste	9,785	ton	$ 80	$ 782,800	Subtitle D landfill
Treatment media	5,343	ton	$ 300	$ 1,602,783	ferrous sulfate heptahydrate, includes transport
Import, place, and compact fill	435	BCY	$ 20	$ 8,698	soil replaced above treatment media
Monitoring well installation	20	each	$ 4,000	$ 80,000	
Remedial design & pre-design testing	15%			$ 603,305	includes add'l characterization
Construction management and reporting	8%			$ 321,762	
Subtotal				*$ 4,947,098*	
Tax	8.7%		$ 4,022,031	$ 349,917	
Contingency	20%		$ 5,297,015	$ 1,059,403	
Subtotal Neutralization of Elevated Groundwater pH				*$ 6,356,417*	
ZVI Treatment Walls					
Mobilization/demobilization	1	LS	$ -	$ -	One Pass trencher mobilization included above
Trenching	3,111	LF	$ 375	$ 1,166,625	excavation and media placement
Transport and disposal - Non-Hazardous Waste	6,222	ton	$ 80	$ 497,760	Subtitle D landfill
Treatment media	2,397	ton	$ 1,127	$ 2,700,993	ZVI, includes transport by rail
Sand filler	2,397	ton	$ 20	$ 47,932	
Media/Filler mixing	4,793	ton	$ 5	$ 23,966	
Import, place, and compact fill	1,152	BCY	$ 20	$ 23,044	soil replaced above treatment media
Monitoring well installation	10	each	$ 4,000	$ 40,000	
Remedial design & pre-design testing	20%			$ 900,064	includes add'l characterization
Construction management and reporting	10%			$ 450,032	
Subtotal				*$ 4,683,793*	
Tax	8.7%		$ 4,500,321	$ 391,528	
Contingency	20%		$ 5,075,321	$ 1,015,064	
Subtotal ZVI Treatment Walls				*$ 6,090,385*	
Enhanced Aerobic Biodegredation					
Mobilization/demobilization	1	LS	$ 5,000	$ 5,000	Direct push probe, mixing tanks
Probe injection event	18	day	$ 2,000	$ 36,400	5 injection points per day, 91 points total
Treatment media	2,730	lb	$ 10	$ 27,300	ORC, 30lb per injection point
Monitoring well installation	6	each	$ 4,000	$ 24,000	
Remedial design & pre-design testing	30%			$ 27,810	includes add'l characterization
Construction management and reporting	15%			$ 13,905	
Subtotal				*$ 134,415*	
Tax	8.7%		$ 92,700	$ 8,065	
Contingency	20%		$ 142,480	$ 28,496	
Subtotal Enhanced Aerobic Biodegradation				*$ 170,976*	
Removal of TPH-Impacted Soils in SE Corner of Cell Building					
Mobilization/demobilization	1	LS	$ 40,000	$ 40,000	
Dewatering	3	day	$ 800	$ 2,581	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	1,936	ton	$ 100	$ 193,600	Subtitle D landfill
Import, place, and compact fill	1,291	BCY	$ 20	$ 25,813	
Remedial design	15%			$ 39,299	includes add'l characterization
Construction management and reporting	10%			$ 26,199	
Subtotal				*$ 327,493*	
Tax	8.7%		$ 261,995	$ 22,794	
Contingency	20%		$ 350,287	$ 70,057	increase due to likelihood of encountering debris
Subtotal Removal of TPH-Impacted Soils in SE Corner of Cell Building				*$ 420,344*	
Removal of Additional Soils Exceeding Cleanup Levels or Groundwater Protection Levels					
Mobilization/demobilization	1	LS	$ 100,000	$ 100,000	
Dewatering	264	day	$ 800	$ 211,381	based on 400 yd/day removal rate, includes daily sampling
Excavation, transport and disposal - Non-Hazardous Waste	138,644	ton	$ 100	$ 13,864,433	Subtitle D landfill
Excavation, transport and disposal - Hazardous Waste	19,892	ton	$ 240	$ 4,773,960	Subtitle C landfill, assuming no treatment required
Surcharge for difficult/unexpected subsurface conditions	31,707	ton	$ 100	$ 3,170,717	applied to 20 percent of excavated material
Import, place, and compact fill	105,691	BCY	$ 20	$ 2,113,811	
Remedial design	5%			$ 1,211,715	includes add'l characterization
Construction management and reporting	8%			$ 1,938,744	
Subtotal				*$ 27,384,762*	
Tax	8.7%		$ 24,234,302	$ 2,108,384	
Contingency	20%		$ 29,493,146	$ 5,898,629	increase due to likelihood of encountering debris
Subtotal Removal of Additional Soils Above Cleanup Levels				*$ 35,391,775*	
Monitored Natural Attenuation					
Groundwater monitoring plan	1	LS	$ 15,000	$ 15,000	
Monitoring wells	3	each	$ 4,000	$ 12,000	
Remedial design	15%			$ 4,050	
Construction management and reporting	20%			$ 5,400	
Subtotal				*$ 36,450*	
Tax	8.7%		$ 27,000	$ 2,349	
Contingency	20%		$ 38,799	$ 7,760	
Subtotal Monitored Natural Attenuation				*$ 46,559*	
Professional Services (as percent of capital costs)					
Project administration	3%		$ 67,487,704	$2,024,631	
Total Estimated Capital Costs				**$ 69,512,335**	

O&M COSTS - Net Present Value

Item	Start Year	End Year	Annual Cost	NPV Cost	Notes
Periodic O&M					
Inspection and maintenance of cover systems			$ -	$ -	
Groundwater quality monitoring, Years 1 and 2	1	2	$ 40,000	$ 80,000	
Groundwater quality monitoring, Years 3+	3	11	$ 12,000	$ 108,000	
Subtotal Periodic O&M Cost				*$ 188,000*	
Contingency		20.0%		$ 37,600	
				$ 225,600	
Professional Services (as percent of Periodic O&M costs)					
Project administration		5%		$ 11,280	
Project management/reporting		6%		$ 13,536	
Total, Periodic O&M Net Present Value:				**$ 250,416**	
TOTAL ESTIMATED COST				**$ 69,760,000**	

Notes:
0.7% discount rate for NPV analysis based on real interest rate on US Treasury 30-year notes and bonds, Circular A-94 Appendix C, Office of Management and Budget (Revised November 2016).
Mobilization/Demobilization costs are assumed to include equipment transport and setup, temporary erosion and sedimentation control (TESC) measures, bonds, and insurance.
Contingency costs include miscellaneous costs not currently itemized due to the current (preliminary) stage of design development, as well as costs to address unanticipated conditions encountered during construction.
Taxes are not applied to project administration, design, and reporting costs.

APPENDIX B

Engineering Calculations Supporting Remedial Alternative Development

Sheet B-1 - *In-Situ* Solidification/Stabilization (ISS) of Chlorine Plant Area Soils with Visible Elemental Hg

Project No. 070188, Chor-Alkali RAU, GP West Site, Bellignham, WA

Engineering Calculation Sheet B-1: *In Situ* Solidification/Stabilization (ISS) of Chlorine Plant Area Soils with Visible Elemental Hg

			Engineer	Date
Site:	Former GP West site			
Calculation:	Estimate the containment area and length of containment wall (Alt 1).	Checked By:	DAH	1/19/2018
	Estimate the amount of amendments for ISS.			
	Estimate the amount of debris requiring removal.			

Assumptions:

Soil will be amended and mixed *in situ* using an 8-foot auger.

75	%	% of target area accessible for ISS (within Cell Bldg footprint, assume only grade beams are removed).
25	%	% weight of surficial debris requiring macro-encapsulation
100	%	% weight of piles requiring macro-encapsulation
25	%	Assumed auger overlap
25	%	Cement amendment
2	%	Sulfur amendment
1,293	ft	Length of containment wall (Alt 1)
107,886	ft2	Area of containment (Alt 1)

Stabilization Area Calculations

21,897	ton	Estimated total weight of soil containing visible Hg (Sheet B-2)
1,533	ton	Estimated weight of surficial debris to be removed (Sheet B-2)
657	ton	Estimated weight of piles to be removed (Sheet B-2)

Equations: Total accessible soil = % of target area accessible * (Estimated weight of soil containing visible Hg - Estimated weight of surficial debris)

14,890	ton	Calculated total weight of accessible soil for ISS
383	ton	Calculated weight of surficial debris requiring macro-encapsulation
1,150	ton	Calculated weight of debris disposed of as inert waste or used as base course
657	ton	Calculated weight of piles requiring macro-encapsulation

Notes:

Conversion factors:

1 acre = 43,560 SF

1 cy = 27 CF

Sheet B-2 - Soil Excavation Volumes

Project No. 070188, Chlor-Alkili RAU, GP West, Bellingham, Washington

Engineering Calculation Sheet B-2: Soil Excavation Volumes

			Engineer	Date
Site:	Former GP West			
Calculations:	Estimate the volume of hazardous and non-hazardous soil to be removed in each Alternative.	Checked By:	DAH	2/9/2018

Assumptions: Chemfix area soil removal volume assumed to be 10% greater than estimated slurry volume.

Soil containing elemental Hg or above industrial cleanup levels would be designated as hazardous waste, including a percentage of the Chlorine Plant Area, Wastewater Settling Basin, and Chemfix Area soils.

Equations: Excavated Soil Volume = Area x Averae Depth

Chlorine Plant Hazardous Soil Volume = Assumed Percentage x Excavated Soil Volume

Chemfix Area Hazardous Soil Volume = 110% x Reported Slurry Volume

Total Haz Soil Volume = Chlorine Plant Haz Soil Volume + Chemfix Area Haz Soil Volume + % of Remaining Volume for Misc Haz

Non-Hazardous Soil Volume = Excavated Soil Volume - Hazardous Soil Volume

Assumed areal percentage of Chlorine Plant Soils containing elemental Hg:	20	%
Assumed percentage of removed material is surficial foundation components & debris:	7	%
Assumed percentage of removed material is piles:	3	%
Ex Situ treatment cement amendment by weight:	25	%
Ex Situ treatment sulfur amendment by weight:	2	%
Assumed bank density for soil and debris:	1.5	ton/CY
Reported volume of Chemfix area slurry:	8,000	BCY

Chlorine Plant Area debris and soil containing visible Hg estimates

Alternatives	Description	Estimated Remaining in Tons
2 thru 8	Weight of surficial foundation components and debris	1,533
	Weight of Piles	657
	Weight of soil with visible Hg	19,707
	Weight of soil and debris	21,897

Hg Containing Soil and Overburden Volumes

Alternative	Description	Area in Square Feet[1]	Average Thickness in Feet[2]	Excavated Soil Volume in BCY	Assumed % Haz (for disposal)	Hazardous Soil Volume in BCY	Non-Haz Soil Vol in BCY
3, 6, 7, & 8	CPA Soils With Visible Hg[3]	28,153	14	14,598	100	14,598	0
6, 7, & 8	CPA Soils Exceeding 100 mg/kg (but no visible Hg)	26,406	14	13,692	20	2,738	10,954
7 & 8	Additional CPA Soils Exceeding 24 mg/kg	89,748	14	45,245	0	0	45,245
1 thru 5	WW Settling Basin Area Soils Exceeding 300 mg/kg	8,442	7	2,189	50	1,094	1,094
1 thru 5	OVERBURDEN SOIL w.r.t 300 mg/kg soil in WW Basin	8,442	8	2,501			
6, 7, & 8	WW Settling Basin Area Soils Exceeding 100 mg/kg	24,897	15	13,832	same BCY as previous	1,094	12,737
7 & 8	Add'l WW Settling Basin Area Soils Exceeding 24 mg/kg	11,523	15	6,402	0	0	6,402
7 & 8	Chemfix Area Soils	81,457	5	15,085	58	8,800	6,285
6, 7, & 8	Stormwater Swale Soils Exceeding 100 mg/kg	1,365	1.5	76	0	0	76
7 & 8	Add'l Stormwater Swale Soils Exceeding 24 mg/kg	22,937	1.5	1,274	0	0	1,274
1 thru 8	OVERBURDEN CRUSHED CONCRETE in Stormwater Swale	24,302	1	900			
6, 7, & 8	Laurel St. Pipe Rack Soils Exceeding 100 mg/kg	1,767	12	785	80	628	157
7 & 8	Add'l Laurel St. Pipe Rack Soils Exceeding 24 mg/kg	1,867	12	830	0	0	830

TPH Containing Soil Volumes

Alternative	Description	Area in Square Feet[1]	Average Thickness in Feet[2]	Excavated Soil Volume in BCY	Assumed % Haz (for disposal)	Hazardous Soil Volume in BCY	Hazardous Soil Volume in BCY
1 thru 8	Cell Building Area	6,970	5	1,291	0	0	1,291
1 thru 8	Northwest Chlorine Plant Area	1,307	5	242	0	0	242
7, 8	Million Gallon Tanks Area	17,860	9	5,953	0	0	5,953
7, 8	Lignin Warehouse	16,988	4	2,517	0	0	2,517

Notes:

[1]Areas based on AutoCAD area analysis from Figure 5-1.

[2]Impacted soils are assumed to extend from ground surface (i.e., no overburden soils) with the exception of: a) soils in the WW Settling Basin w/ [Hg] > 300 mg/kg, which are assumed to be in the 8- to 15-foot depth interval; and b) soils in the Stormwater Swale, which are assumed to be in the 3- to 4.5-foot depth interval.

[3]Amounts based on test pit investigation in February 2014 (Aspect, 2014d).

Conversion factors:

1 cy = 27 CF

Sheet B-3 - Ferrous Sulfate Trenches for Neutralization of Groundwater with Elevated pH

Project No. 070188, Chlor-Alkili RAU, GP West, Bellignham, Washington

Engineering Calculation Sheet B-3: Ferrous Sulfate Trenches for Neutralization of Groundwater with Elevated pH

			Engineer	Date
Site:	Former GP West Site			
Calculations:	Estimate the volume of soil to be removed for groundwater neutralization trenches. Estimate volume of amendments for the groundwater neutralization trenches.	Checked By:	DAH	9/29/2016

Assumptions:

Excavated soils are assumed to be non-hazardous.

Treatment material placed to 1-foot below grade.

Equations:

Volume = Length x Width x Depth

Ferrous Sulfate Volume = Total Trench Length x Width x Depth x Density

Trench Dimesions:

Width **3** ft

Depth **15** ft

Top of material below grade: **1** ft

Ferrous Sulfate Heptahydrate density: **65** lb/ft^3

Description	Number of Trenches	Total Length of Trenches in feet(1)	Amount of Ferrous Sulfate Required in tons	Volume of Excavated Soil in BCY	Volume of Import Soil in BCY
Alt 4 - Caustic Core Only	5	1,035	1,413	1,725	115
Alt 5 - Groundwater pH > 8.5	8	4,689	6,400	7,815	521
Alt 6 - Groundwater pH > 8.5	11	4,115	5,617	6,858	457
Alts 7 & 8 - Groundwater pH > 8.5	9	3,914	5,343	6,523	435

Notes:

(1) Total trench length based on AutoCAD analysis from Figures 7-5 through 7-9.

Conversion factors:

1 cy = 27 CF

1 ton = 2000 lb

Sheet B-4 - PRBs Containing ZVI for Treating Dissolved Hg Outside Areas of Elevated pH

Project No. 070188, Chlor-Alkili RAU, GP West, Bellingham, Washington

Engineering Calculation Sheet B-4: PRBs Containing ZVI for Treating Dissolved Hg Outside Areas of Elevated pH

			Engineer	Date
Site:	Former GP West			
Calculations:	Estimate volume of zero valent iron (ZVI) required	Checked By:	DAH	9/29/2016
	Estimate breakthrough time of permeable reactive barrier (PRB)			

Assumptions:

Groundwater flux based test results from June-July 2011 (see Section 4.2.2.1 of the RI).
ZVI usage rate calculated from column testing under similar groundwater conditions (Weisener et al., 2005)

Equations:

ZVI Usage Rate ($tons_{ZVI}/ft^3_{Water}$) = ZVI mass / Flow Rate / Breakthrough Time
Time to Breakthrough (years) = ZVI Mass (tons) / ZVI Usage Rate ($tons/ft^3$) / Flowrate (ft^3/day) / 365 (days/year)
Volume = Depth x Width x Length
Mass = Density x Volume

Column Test Results (Weisener et al., 2005)

ZVI weight	1066.85	g
ZVI % by weight	50	%
Flowrate	1.96	L/day
Hg Concentration	40	ug/L
Residence Time	2.5	hours
Breakthrough Time	28	days
Estimated ZVI Usage Rate	**0.00060066**	$tons_{ZVI}/ft^3_{Water}$

Conversions:
1 cubic foot = 28.3168 L
1 year = 365 days
1 ton = 2000 lb
1 lb = 453.592 g

Treatment Walls - Within low-level Hg plume

Parameter	Value		Notes/Assumptions
Treatment Wall			
Minimum Width	2	ft	
Length	3,111	ft	
Average Treatment Media Height	13	ft	18' Total Depth
Composition Calculations			
Average Groundwater Flux	0.0147	ft3/ft2/day	see RI Section 4.2.2.1
Assumed porosity	0.49		
Velocity	0.0300	ft/day	
Wall Width	2	ft	
Residence Time	67	days	
ZVI Composition	50	percent by weight	
Mass of ZVI per ft2 of cross section area	0.05926		
Time to Breakthrough	18.4	years	
Target Lifetime	10	years	
Earthwork Calculations			
Average Width	2.0	ft	
Average Depth	18	ft	18' total depth
Volume of Soil Excavated	4,148	cy	
Volume Sand Fill	2,996	cy	sand
Volume of Fill to Grade	1,152	cy	
Total Mass	4,793	tons	Assumed density of 1.6 tons per cubic yard
ZVI Mass	2,397	tons	
Sand Mass	2,397	tons	

Conversions:
1 cubic foot = 7.48 gallons
1 year = 365 days

Sheet B-5 - Enhanced Aerobic Biodegradation for Treating PAHs in Groundwater

Project No. 070188, Chlor-Alkili RAU, GP West, Bellingham, Washington

Engineering Calculation Sheet B-5: Enhanced Aerobic Biodegradation for Treating PAHs in Groundwater

			Engineer	Date
Site:	Former GP West Site			
Calculations:	Estimate the mass of ORC to be injected at each point.[1]	Checked By:	DAH	9/29/2016

Assumptions:

Injections are completed by direct-push probe.

A single round of ORC injection is sufficient to achieve the treatment objective.

Equations:

Injections per day:	**5**	per day
Number of injection points[2]:	**91**	each
Mass to be injected at each point[3]:	**30**	lb
Days required to complete injections:	**19**	days
Total injection mass:	**2730**	lb

Notes:

[1] Calculations are based on enhancing the aerobic biodegradation of PAHs by injecting Oxygen-Release Compound (ORC) supplied by Regenesis.

[2] Number of injection points based on 20-foot injection spacing along rows oriented perpendicular to groundwater flow direction and spaced at 60-foot intervals; refer to Figure 7-9.

[3] ORC mass based on successful treatment of PAHs at Florida site (Regenesis case study).

Conversion factors:

1 cy = 27 CF

1 ton = 2000 lb

APPENDIX C

Restoration Time Frame Estimation for Mercury in Groundwater and Soil Vapor

ANCHOR QEA

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DRAFT MEMORANDUM

To:	Steve Germiat (Aspect Consulting)	**Date:**	November 11, 2016
From:	Masa Kanematsu, Minna Carey, and Dimitri Vlassopoulos (Anchor QEA, LLC)	**Project:**	150204-04.01
Re:	Chlor-Alkali RAU Alternatives Modeling, G-P West Site		

This memorandum presents a summary of reactive transport modeling performed to evaluate the effectiveness and estimate groundwater restoration timeframes of selected remedial alternatives being considered to address mercury (Hg) concentrations and elevated pH in groundwater within the Chlor-Alkali Remedial Action Unit (RAU) as part of the Feasibility Study (FS) conducted for the Georgia-Pacific West Site in Bellingham, Washington.

MODELING METHODS

The reactive transport model was developed using the numerical groundwater flow and geochemical transport simulator PHAST (Parkhurst et al. 2010). PHAST is a well-documented, robust computer code capable of simulating 3-dimensional groundwater flow and multicomponent chemical transport with equilibrium and kinetic reactions. PHAST couples the flow and transport finite-difference code HST3D (Kipp 1997) with the geochemical modeling code PHREEQC (Parkhurst and Appelo 1999) to simulate geochemical reactions in groundwater flow systems. Modeling approaches to simulate the remediation scenarios are described in the following sections.

Model Development

Input Data

Site-specific hydraulic, groundwater, and soil chemistry data from the Remedial Investigation (RI) were used as input for the reactive transport model. A high quality, internally consistent thermodynamic database developed by the Lawrence Livermore National Laboratory (llnl.dat) was used with several updates and modifications, which are summarized in Table A1.

Model Configuration

The 3-dimensional model domain was constructed to encompass groundwater flowing from the Chlorine Plant Area and Caustic Plume towards Bellingham Bay and Whatcom Waterway (Figure 1). The horizontal extents (X and Y directions) of the model domain are 2,500 and 1,800 feet, respectively, with 15–foot grid spacing (refined [9-foot] grid spacing surrounding the PRB treatment trenches). The vertical extent (i.e., Z direction) of the model domain is 48 feet with 4-foot grid spacing. The model domain is divided into three layers: Fill Unit (16 to -4 ft MLLW), Tidal Flat Aquitard (-4 to -10 ft MLLW), and Lower Sand (-10 to -32 ft MLLW). Different hydrologic parameters are assigned to the different vertical layers as described below (Table 1). The caustic Hg plume was defined based on Figure 1 in the *Results from Supplemental Groundwater and Porewater Sampling and Analysis, Chlor-Alkali RAU* Memorandum (October 22, 2015). The soil Hg concentration, treatment trench, and PRB boundaries were defined based on RI Figures 7-1 to 7-10 (Remedial Design Concepts). Trenches and PRBs extend to the base of the Fill Unit. Boundary conditions were defined to reproduce the Fill Unit groundwater elevation contours shown in RI Figure 4-5.

Hydrologic Parameters

Hydrogeologic parameters used in the model were derived largely from previous field work and preliminary modeling conducted as part of the RI. For modeling purposes, the aquifer is treated as unconfined and homogenous, and steady state flow is assumed. A list of aquifer parameters are summarized in Table 1.

Table 1

Hydrologic Model Parameters

Parameter	Units	Fill Unit	Lower Sand	Tidal Flat Aquitard
Horizontal hydraulic conductivity	feet/day	2.55	5.67	0.0085
Vertical hydraulic conductivity	feet/day	0.255	0.567	8.5e-7
Effective porosity	-	0.25	0.25	0.20
Longitudinal dispersivity	Feet	13.8	13.8	13.8
Horizontal dispersivity	feet	1.38	1.38	1.38
Vertical dispersivity	feet	0.135	0.135	0.135

Groundwater Chemistry

Groundwater data collected in October 2009 and April 2010 include groundwater geochemistry analyses that were used to define initial solution chemistry conditions in the PHAST model. The model domain is divided into five different solution chemistry zones, and it is assumed that within each zone, groundwater chemistry is homogeneous and extends to the base of the Fill Unit. Initial groundwater chemistry in each zone was assigned based on water chemistry data from specific wells as summarized in Table 2. The solution chemistries of the different groundwater chemistry zones are listed in the Appendix in Table A1.

Table 2

Groundwater Chemistry Zones and Representative Chemistry

Zone	Description	Representative Groundwater Chemistry
1	Caustic Plume Zone A (Hg > 0.059 μg/L, pH < 8.5)	CP-MWB2 (04/06/2010)
2	Caustic Plume Zone B (Hg > 10 μg/L, pH > 10)	AMW-02 (10/02/2009)
3	Groundwater with Hg > 0.059 μg/L and pH > 8.5	CP-MWC1 (04/06/2010)
4	Wastewater Settling Basin	EMW-14S (10/01/2009)
5	Background Groundwater and Soil Removal Zones	CP-MWA2 (10/02/2009)

Remedial Alternative Model Scenarios

Table 3 describes the remedial alternative scenarios that were set up in PHAST to simulate post-remediation Hg plume evolution and estimate groundwater restoration timeframes.

Table 3

Remedial Alternatives

Remedial Alternative	Components of Remedy
5	• Aggressive removal of obstructions and *in situ* stabilization (ISS) of soils with visible elemental Hg • Soil capping • Neutralization of "caustic core" groundwater (pH greater than 10) • Groundwater monitored natural attenuation (MNA)
6	• Aggressive removal of obstructions and ISS of soils with visible elemental Hg • Soil capping

	• Neutralization of groundwater with pH greater than 8.5 • Groundwater MNA
7	• Removal of all soils with Hg greater than 100 mg/kg to achieve groundwater protection • Soil capping • Neutralization of groundwater with pH greater than 8.5 • Groundwater MNA
9	• Removal of all soils exceeding Hg cleanup levels (24 mg/kg) • Neutralization of groundwater with pH greater than 8.5, • Permeable reactive barrier (PRB) for *in situ* treatment of Fill Unit groundwater impacted by Hg • MNA for residual impacted groundwater

All four of the modeled remedial alternative scenarios include installation of treatment trenches containing ferrous sulfate ($FeSO_4 \cdot 7H_2O$) for neutralization of groundwater pH. The associated groundwater solution chemistry in the trenches was initially equilibrated with melanterite ($FeSO_4 \cdot 7H_2O$) which was included as solid phase within the trenches at a concentration of 0.1 mole/L. Alternative 9 also includes installation of PRBs containing zero-valent iron (ZVI) for Hg removal from groundwater prior to discharge to surface water. ZVI is oxidized in water to iron oxides, which adsorb Hg. A concentration of iron oxide sorption sites of 2 moles/L was assigned to the model cells located within the PRBs to simulate removal of Hg from groundwater by the PRB media. This is approximately equivalent to the amount of ferrihydrite [$Fe(OH)_3$] that would be produced by an initial concentration of 50 % by weight of ZVI in the PRB with a sorption capacity of 0.2 mole/mole Fe. Model simulations were run for a simulation period of 100 years in 1 year time steps. The simulations evaluated the effect of geochemical attenuation mechanisms on the evolution of dissolved Hg concentrations following completion of active remediation at the site to estimate aquifer restoration timeframes. The simulated attenuation and remediation mechanisms include:

- Hg sulfide (i.e., metacinnabar) precipitation
- Adsorption of inorganic Hg on iron oxides
- Adsorption of Hg-DOM complexes on iron oxides

Surface complexation reactions used to simulate Hg adsorption on ferrihydrite are taken from Dzombak and Morel (1990). Hg speciation and solubility reactions and equilibrium

constants are largely sourced from Leterme et al. (2014). Sorption of Hg-DOM complexes is modeled by the Langmuir equation (Kothawala et al. 2008). The relevant reactions are summarized in the Appendix in Table A2.

MODEL RESULTS

Evolution of the Groundwater Mercury Plume Following Remediation

Alternative 5

This remedial alternative involves aggressive removal of obstructions and *in situ* stabilization (ISS) of soils with visible elemental mercury (to the base of the Fill Unit), neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the caustic core plume (defined as the area where groundwater pH is greater than 10 and dissolved Hg concentrations are greater than 10 μg/L), and monitored natural attenuation (MNA). Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 1 and model predicted concentrations after 1, 10, 20 and 50 year simulation times are shown in Figures 2 through 5, respectively. Within the caustic core, pH neutralization induces metacinnabar (HgS) precipitation which reduces dissolved Hg concentrations. Dissolved Hg concentrations outside the caustic core are attenuated relatively slowly, requiring several decades for concentrations less than 0.059 μg/L to be achieved across the site. During this time, Hg at concentrations greater than 0.059 μg/L are predicted to reach the property boundary and shoreline.

Alternative 6

This remedial alternative involves aggressive removal of obstructions and ISS of soils with visible elemental mercury (to the base of the Fill Unit), neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the area where groundwater pH exceeds 8.5, and MNA. Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 6 and model predicted concentrations after 1 and 10 years simulation times are shown in Figures 7 and 8, respectively. Following neutralization of groundwater pH neutralized, rapid and significant reduction of dissolved Hg concentrations are predicted across the site. Further attenuation of dissolved Hg concentrations occurs at a slower rate, with concentrations across the site predicted to drop below 0.059 μg/L within a few decades. Due to the lower Hg concentrations resulting immediately following completion of active

remediation, Hg concentrations reaching the property boundary and shoreline are predicted to exceed 0.059 μg/L for a few years.

Alternative 7

This remedial alternative involves removal of all soils with Hg concentrations greater than 100 mg/kg to the base of the Fill Unit to achieve groundwater protection, neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the area where groundwater pH exceeds 8.5, and MNA. Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 9 and model predicted concentrations after 1 and 10 years simulation times are shown in Figures 10 and 11, respectively. The predicted Hg plume evolution following completion of active remediation is similar overall to Alternative 6, with minor differences primarily due to the additional removal of Hg impacted soils.

Alternative 9

This remedial alternative involves removal of all soils with Hg concentrations exceeding the standard for unrestricted direct contact (24 mg/kg) to the base of the Fill Unit, neutralization of groundwater pH by ferrous sulfate emplaced within trenches across the area where groundwater pH exceeds 8.5, installation of permeable reactive barriers to treat the Hg plume where it reaches the shoreline, and groundwater MNA. Post active remediation dissolved Hg concentrations in groundwater are shown in Figure 12 and model predicted concentrations after 5 years simulation time are shown in Figure 13.

Groundwater Restoration Timeframes

Table 4 summarizes the groundwater restoration timeframes to achieve dissolved Hg concentrations lower than the cleanup level of 0.059 μg/L for the different remediation alternatives at the following locations: the entire site, the port property boundary, and the shoreline (Bellingham Bay and Whatcom Waterway).

Table 4

Groundwater Restoration Timeframes[1]

Remedial Alternative	Restoration Timeframe (years)		
	Site-Wide	Port Property Boundary	Shoreline
5	74	55	54
6	26	11	5
7	26	10	4
9	10	10	2

Note:
1. As defined by the groundwater cleanup level for mercury of 0.059 μg/L

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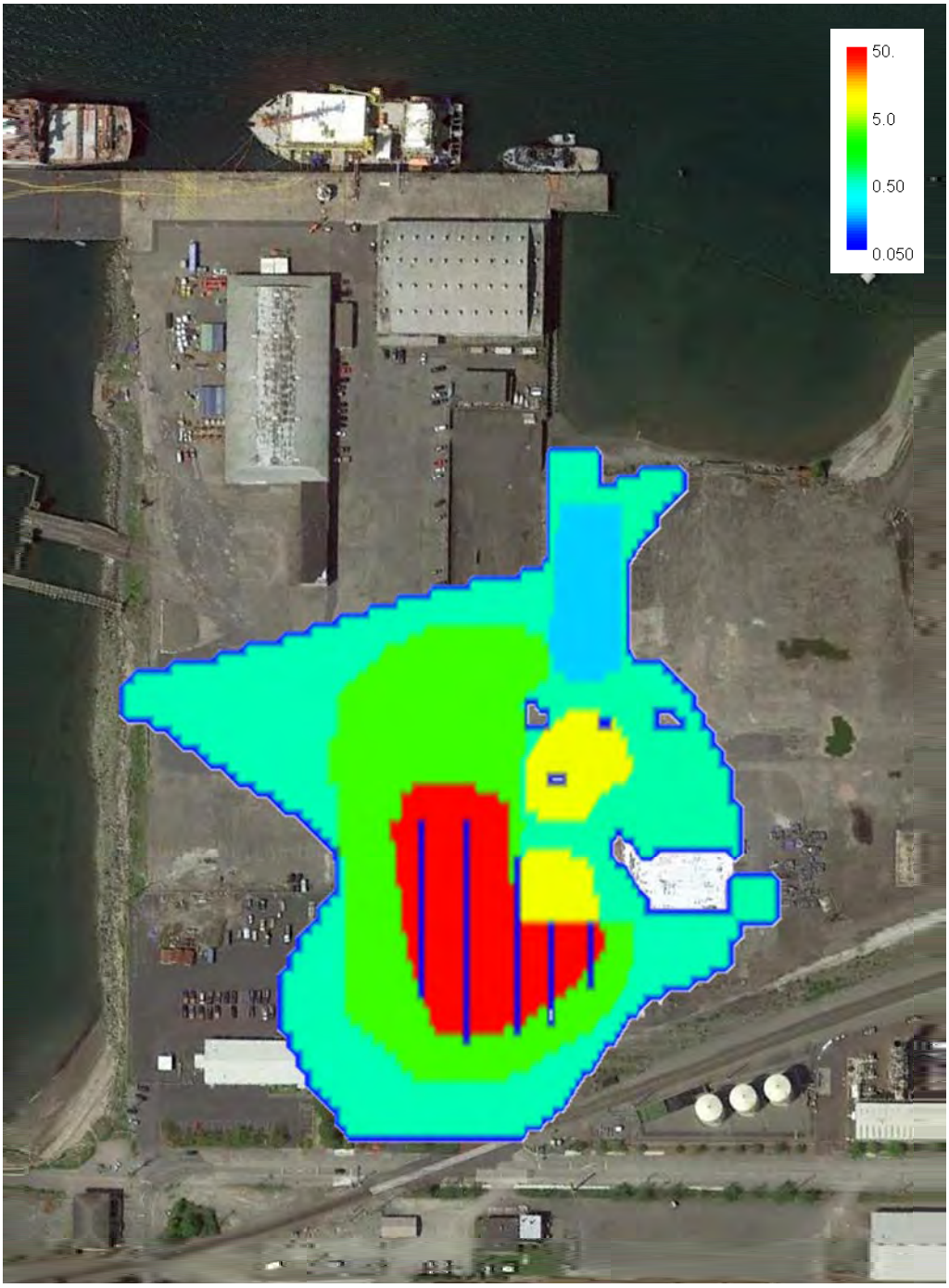

Figure 1

Hg concentrations in groundwater post active remediation for Alternative 5

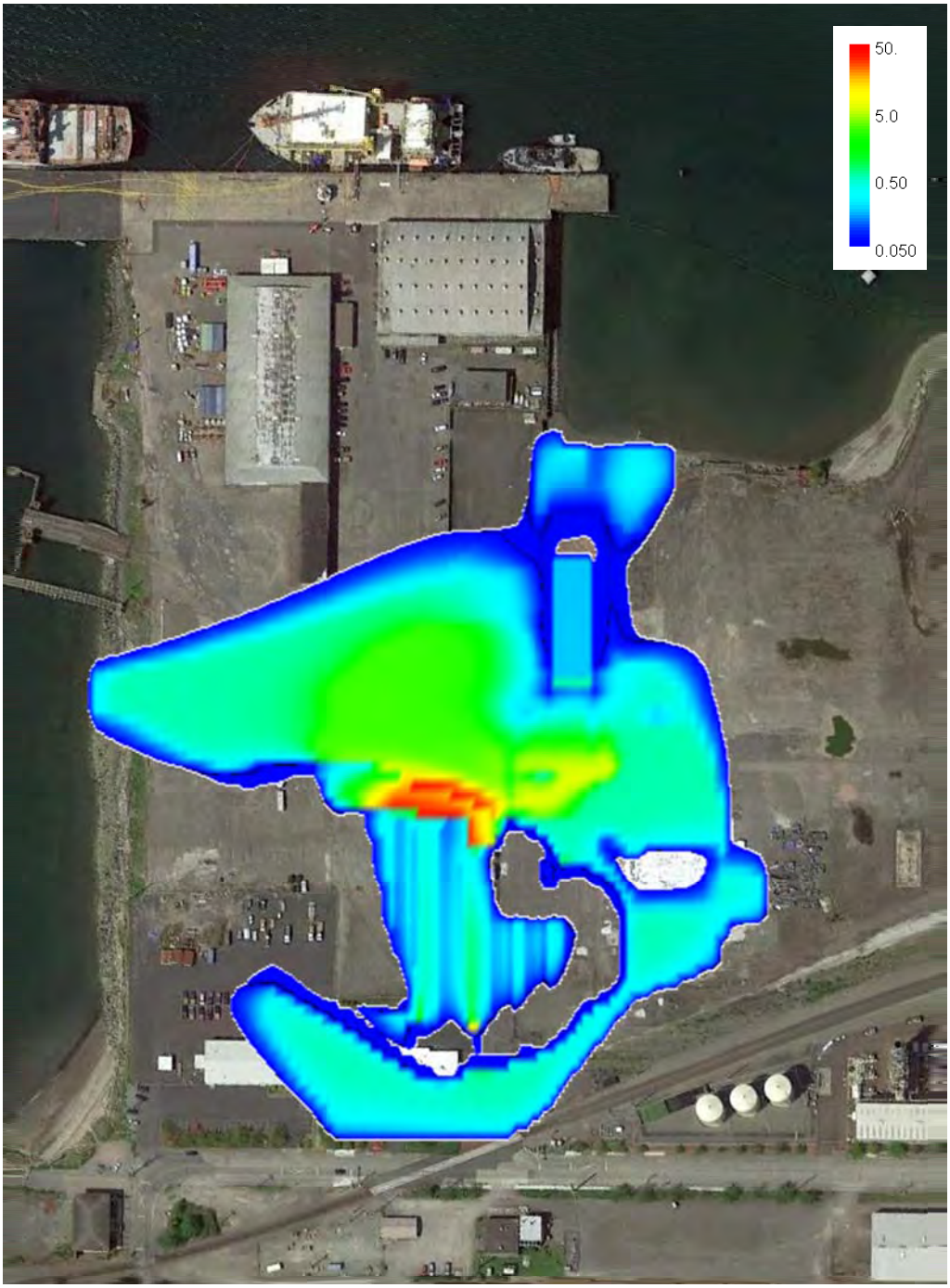

Figure 2

Simulated Hg concentrations in groundwater 1 year after active remediation for Alternative 5

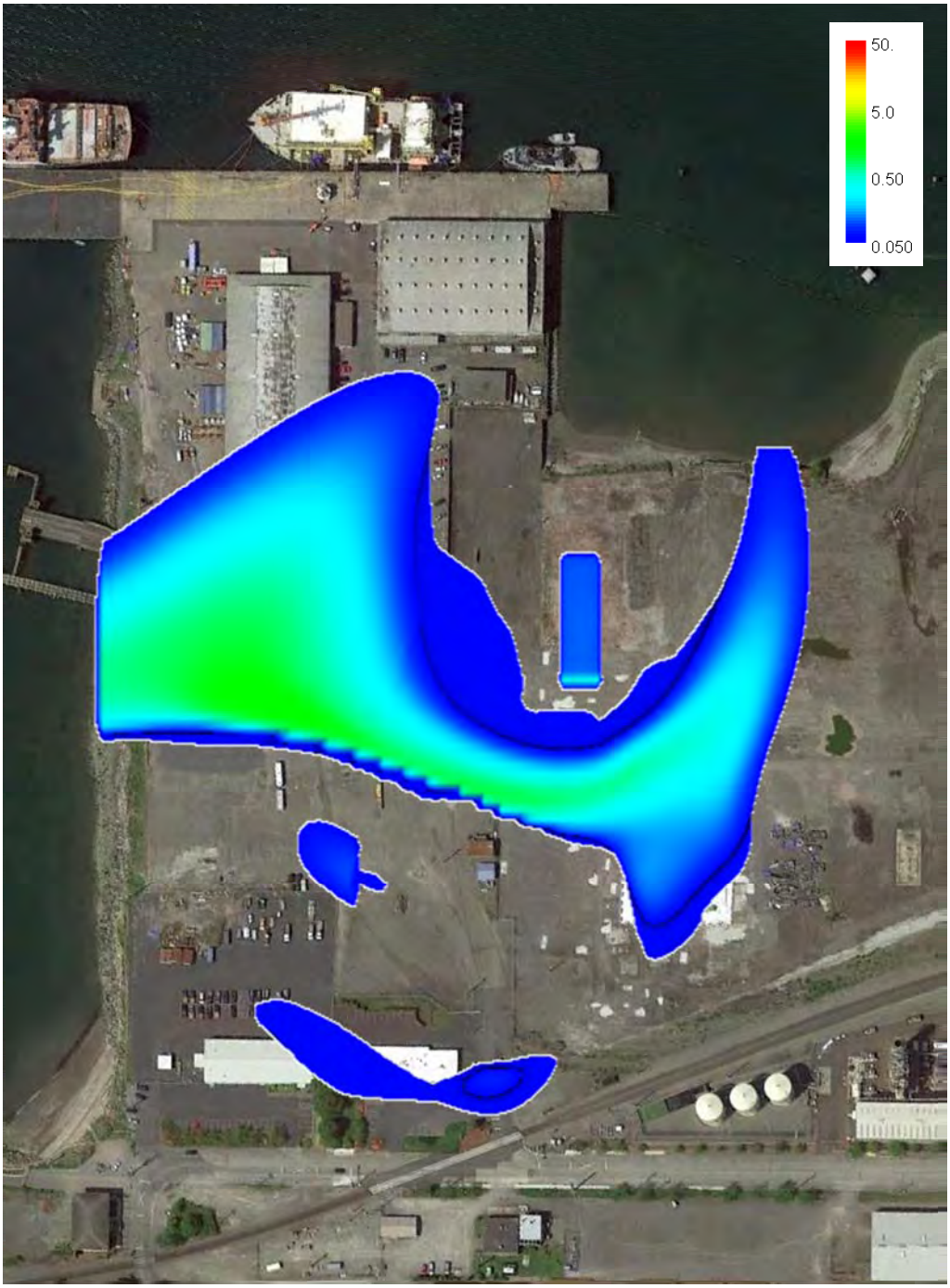

Figure 3

Simulated Hg concentrations in groundwater 10 years after active remediation for Alternative 5

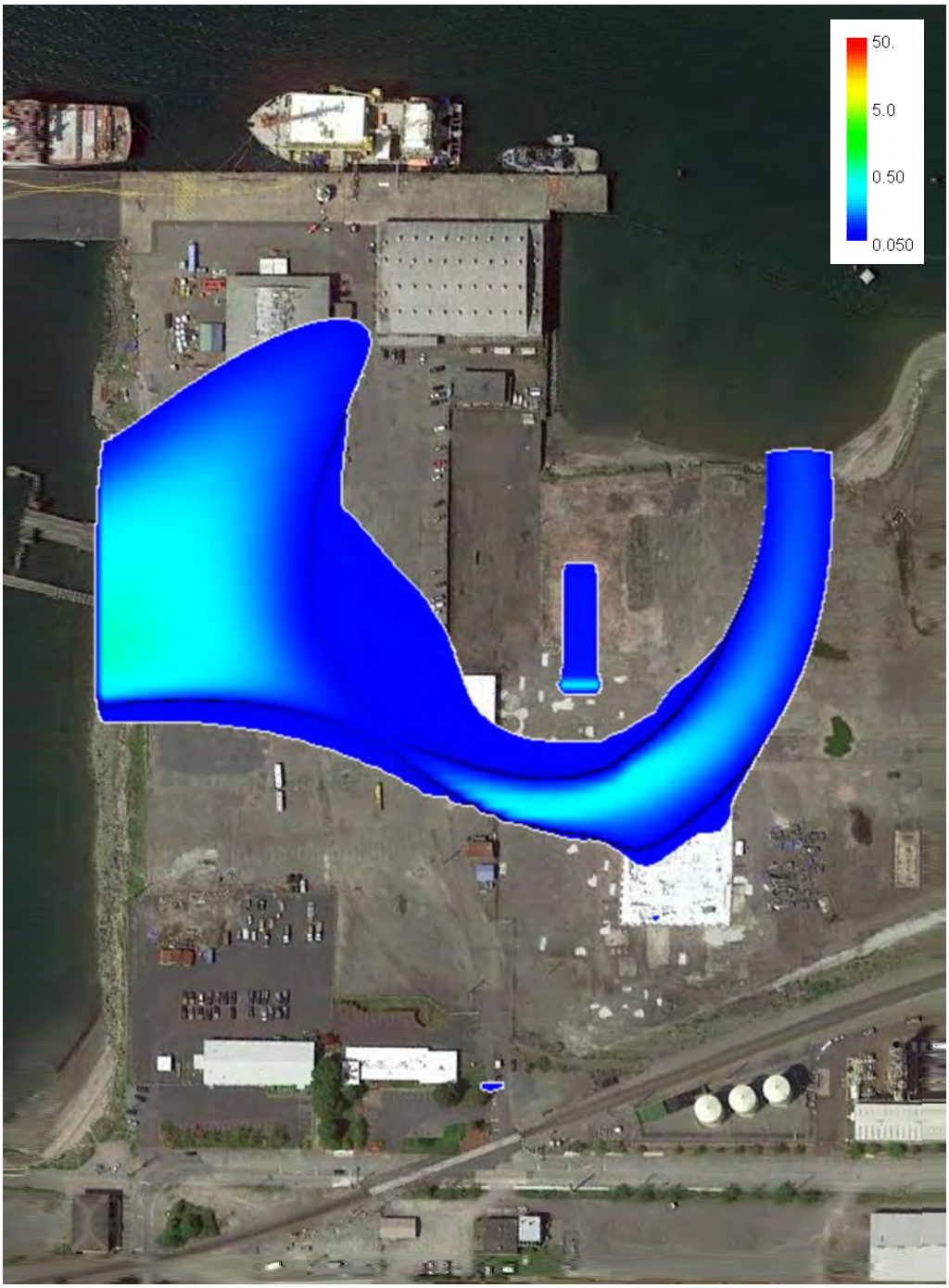

Figure 4

Simulated Hg concentrations in groundwater 20 years after active remediation for Alternative 5

Figure 5

Simulated Hg concentrations in groundwater 50 years after active remediation for Alternative 5

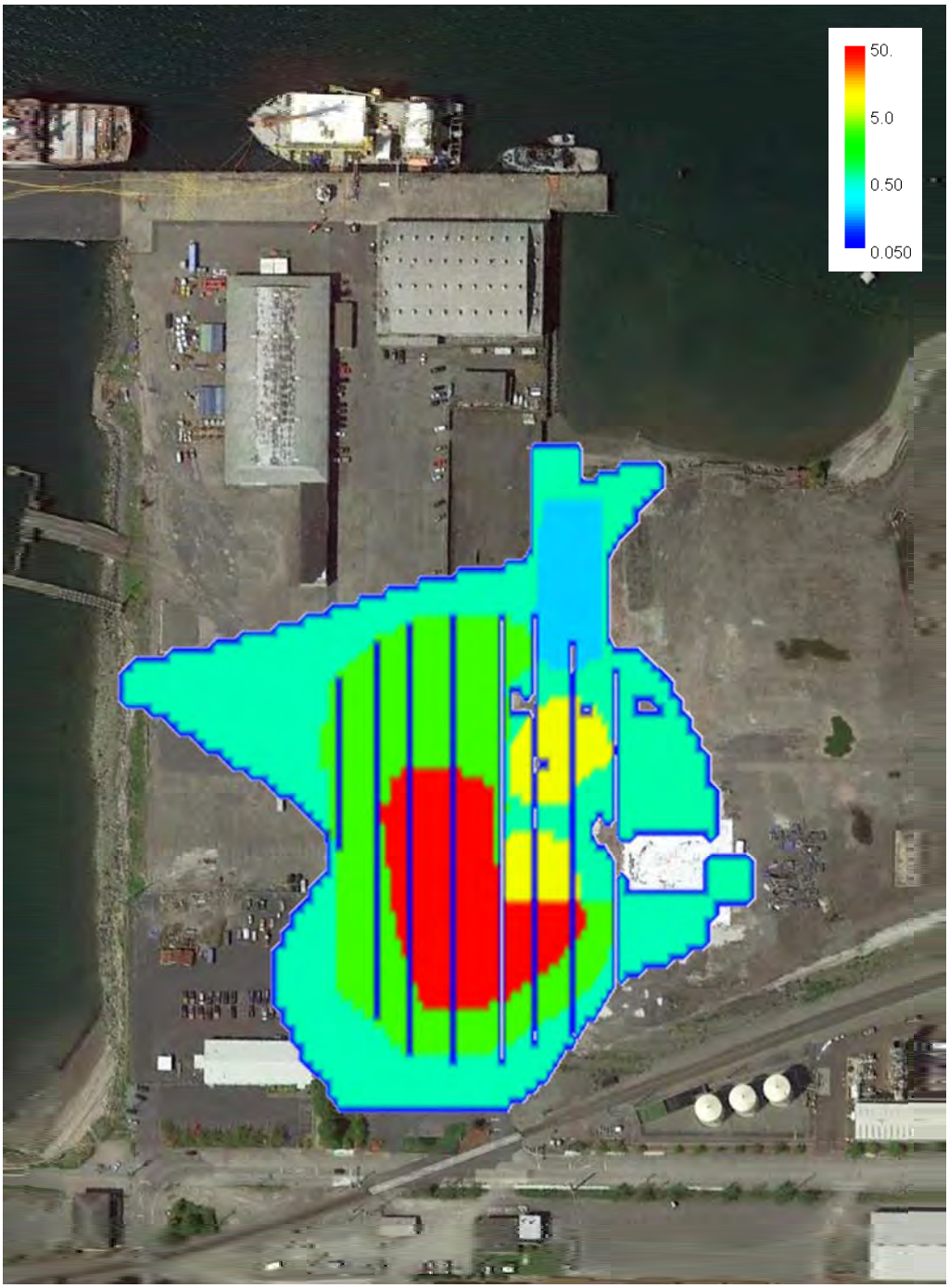

Figure 6

Hg concentrations in groundwater post active remediation for Alternative 6

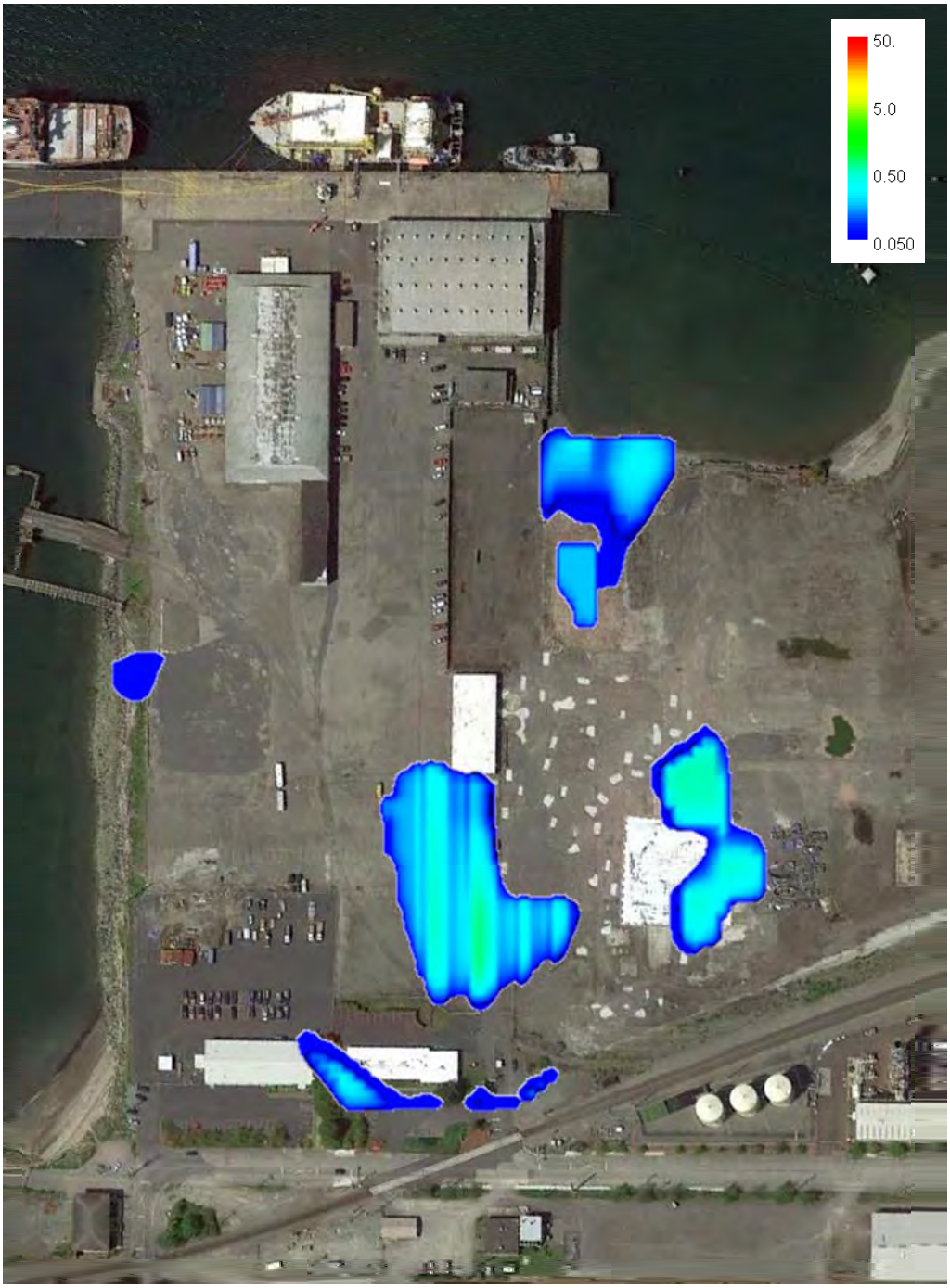

Figure 7

Simulated Hg concentrations in groundwater 1 year after active remediation for Alternative 6

Figure 8

Simulated Hg concentrations in groundwater 10 years after active remediation for Alternative 6

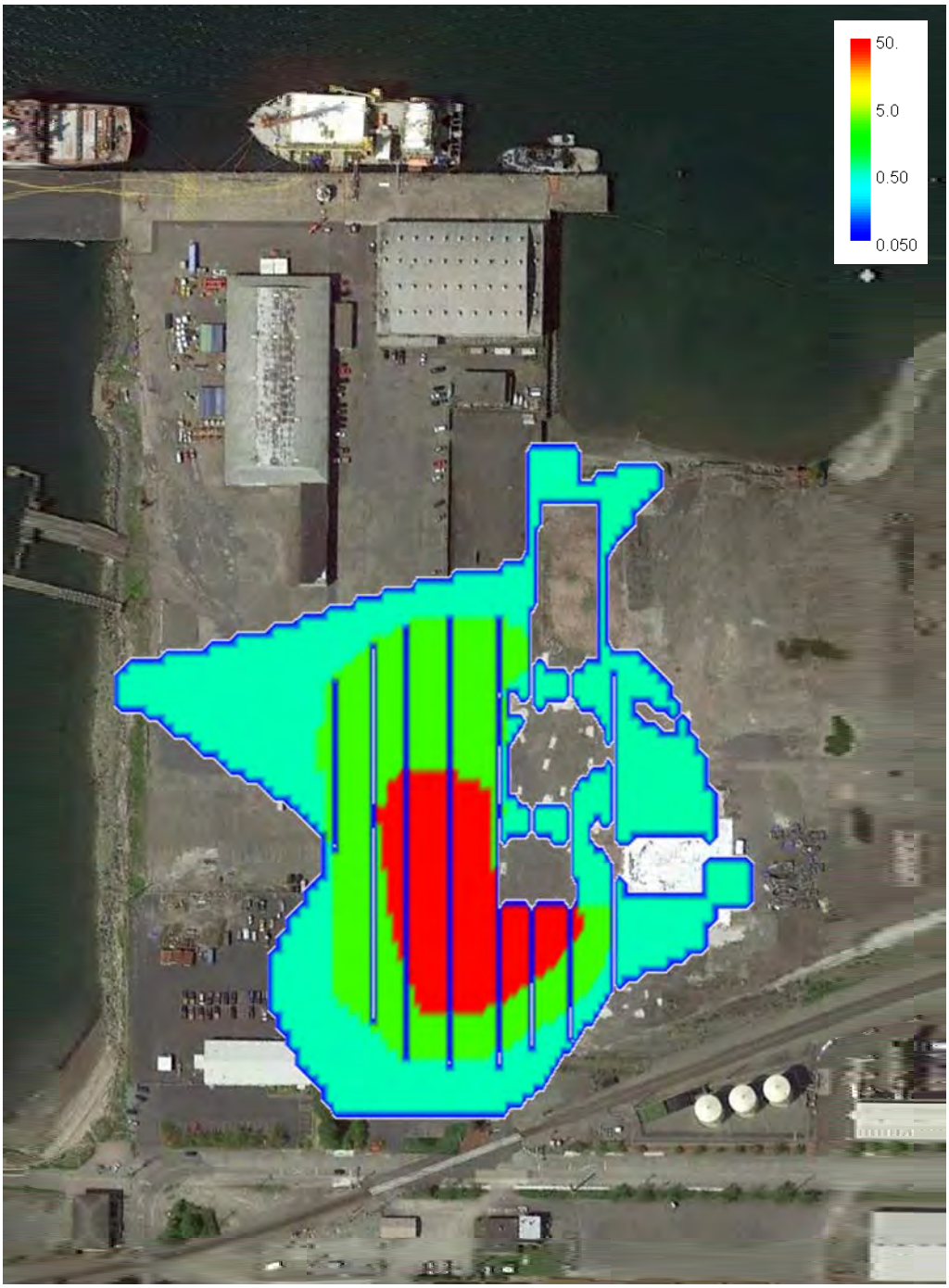

Figure 9

Hg concentrations in groundwater post active remediation for Alternative 7

Figure 10

Simulated Hg concentrations in groundwater 1 year after active remediation for Alternative 7

Figure 11

Simulated Hg concentrations in groundwater 10 years after active remediation for Alternative 7

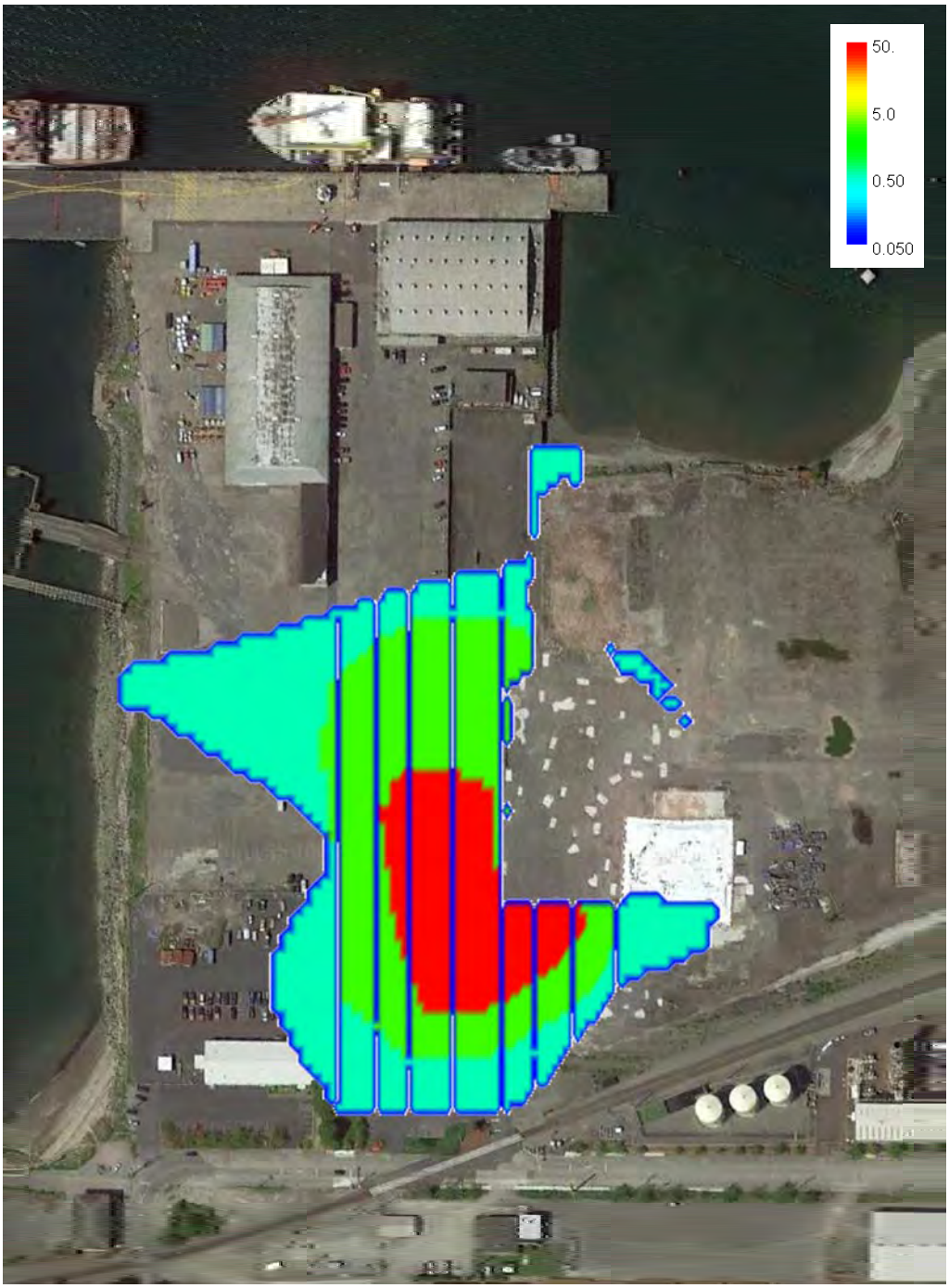

Figure 12

Hg concentrations in groundwater post active remediation for Alternative 9

Figure 13

Simulated Hg concentrations in groundwater 5 years after active remediation for Alternative 9

APPENDIX

Table A1

Initial groundwater chemistry zones and mineral distributions

Zone	1	2	3	4	5
Parameter	**Caustic Plume Zone A**	**Caustic Plume Zone B**	**Hg > 0.059 μg/L, pH > 8.5**	**Wastewater Settling Basin**	**Background Groundwater**
Solution Chemistry[1]					
pH	7.11	10.92	9.76	8.36	6.72
pe	-0.89	-4.63	-0.13	-0.36	-1.86
Alkalinity[2]	1.73E-02	8.34E-02	1.05E-02	5.09E-02	1.23E-02
Calcium	1.00E-03	8.32E-06	1.21E-05	1.06E-04	2.41E-03
Chloride	1.91E-01	2.44E-02	2.40E-02	1.78E-02	1.83E-03
DOM (thiol)	5.70E-06	1.07E-04	5.35E-06	5.70E-06	5.70E-06
Iron	6.28E-07	2.94E-07	1.35E-06	1.87E-07	1.73E-05
Mercury	2.69E-09	2.08E-07	1.37E-08	8.83E-10	1.55E-11
Magnesium	1.99E-03	2.85E-05	1.57E-05	2.62E-05	4.53E-03
Potassium	7.67E-05	675E-04	7.93E-05	4.58E-05	1.31E-03
Sodium	2.02E-01	3.28E-01	3.47E-02	2.31E-02	1.54E-02
Sulfate	5.21E-05	5.41E-04	1.56E-04	2.39E-04	2.08E-06
Sulfide	8.62E-05	1.23E-03	1.49E-04	1.86E-05	6.55E-06
Minerals[1,3]					
Metacinnabar[4]	0.0023 / 0.0006 / 0*				0*
Mackinawite	0.1	0.1	0.1		0.1
Ferrihydrite	0*	0*	0*		0*
Siderite	0*	0*	0*		0*
Calcite	0.1	0.1	0.1		0.1

Notes:

1. Concentrations in moles/L water
2. As $CaCO_3$
3. An asterisk indicates the mineral is not present initially but is allowed to precipitate as a result of reactions and transport
4. Initial distribution of metacinnabar in the model domain is based on soil Hg concentrations: 0.0023 mole/L in areas where soil Hg > 100 mg/kg; 0.0006 mole/L in areas where soil Hg > 24 mg/kg; 0 where soil Hg < 24 mg/kg.

Table A2

Updated, modified, and additional chemical equilibrium reactions

Reaction	log K	Reference
Aqueous Species		
$Hg^{2+} + H_2O = HgOH^+ + H^+$	-3.40	Powell et al. (2005)
$Hg^{2+} + 2H_2O = Hg(OH)_2 + 2H^+$	-5.98	Powell et al. (2005)
$Hg^{2+} + 3H_2O = Hg(OH)_3^- + 3H^+$	-21.1	Powell et al. (2005)
$Hg^{2+} + Cl^- = HgCl^+$	7.31	Powell et al. (2005)
$Hg^{2+} + 2Cl^- = HgCl_2$	14.0	Powell et al. (2005)
$Hg^{2+} + 3Cl^- = HgCl_3^-$	14.93	Powell et al. (2005)
$Hg^{2+} + 4Cl^- = HgCl_4^{2-}$	15.54	Powell et al. (2005)
$Hg^{2+} + Cl^- + H_2O = HgOHCl + H^+$	4.27	Powell et al. (2005)
$Hg^{2+} + CO_3^{2-} = HgCO_3$	11.46	Powell et al. (2005)
$Hg^{2+} + OH^- + CO_3^{2-} = Hg(OH)CO_3^-$	19.32	Powell et al. (2005)
$Hg^{2+} + CO_3^{2-} + H^+ = HgHCO_3^+$	15.79	Powell et al. (2005)
$Hg^{2+} + SO_4^{2-} = HgSO_4$	2.40	Powell et al. (2005)
$Hg^{2+} + 2HS^- = Hg(SH)_2$	39.1	Drott et al. (2013)
$Hg^{2+} + 2HS^- = HgS_2H^- + H^+$	32.5	Drott et al. (2013)
$Hg^{2+} + 2HS^- = HgS_2^{2-} + 2H^+$	23.2	Drott et al. (2013)
$RS^- + H^+ = RSH$	10.0	Skyllberg (2008)
$Hg^{2+} + 2RSH = Hg(RS)_2 + 2H^+$	22.0	Skyllberg (2008)
Mineral Solubility		
Mackinawite: $FeS(s) + H^+ = Fe^{2+} + HS^-$	-4.65	wateq4f.dat
Metacinnabar: $HgS(s) + H^+ = Hg^{2+} + HS^-$	-36.9	Drott et al. (2013)
Surface Complexation Reactions		
$Hfo\_sOH + Hg^{2+} = Hfo\_sOHg^+ + H^+$	7.76	Dzombak and Morel (1990)
$Hfo\_wOH + Hg^{2+} = Hfo\_wOHg^+ + H^+$	3.75	Dzombak and Morel (1990)
Sorption of Dissolved Organic Matter and Hg-NOM complexes		
$S + Ls^- = S\_Ls^-$	2.05	Kothawala et al. (2008)
$S + LsH = S\_LsH$	2.05	Kothawala et al. (2008)
$2\ S\_Ls^- + Hg(RS)_2 = (S\_Ls)_2Hg + 2RS^-$	0	Kothawala et al. (2008)

APPENDIX D

Restoration Time Frame Estimation for Naphthalene in Groundwater

Contents – Appendix D

List of Tables

List of Figures

D.1. Objectives

This appendix presents the methods and results of the natural attenuation modeling of naphthalene concentrations in the Million Gallon Tanks (MGT) Subarea within the Chlor-Alkali Remedial Action Unit (RAU). The modeling was conducted to estimate the restoration time frame for naphthalene in Million Gallon Tanks subarea groundwater, as a component of evaluation for remedial alternatives for the RAU. The natural attenuation model was constructed using data presented in the remedial investigation for the Georgia Pacific West Site (RI; Aspect, 2013).

D.2 Model Methods

The BIOSCREEN model simulates contaminant natural attenuation in groundwater. The model was developed for EPA and is programmed into an Excel spreadsheet based on the Domenico three-dimensional analytical solute transport model (EPA, 1986). The model has the ability to simulate dissolved contaminant advection, dispersion, adsorption, and aerobic decay as well as anaerobic decay reactions. The model also presents results from three different levels of biodegradation (decay) including no biodegradation, first-order decay, and instantaneous reaction.

The model assumes one-dimensional groundwater flow conditions along the centerline of the naphthalene plume. First-order biodegradation (decay) model was selected based on data calculated from MGT Subarea wells, as outlined below. Well MG-MW05 has the highest naphthalene concentration measured within the plume and is assumed to be in the source area. Downgradient wells MG-MW03 and CF-MW01 are located along the centerline of the plume and have concentrations that decrease exponentially with distance (see Figure D-1). Wells EMW-12S and EMW-7S bound the upgradient and downgradient extents of the plume, respectively, along the centerline of the plume. Wells EMW-16S and MG-MW01 are within the high-concentration portion of the plume, and have been used to calculate the first-order decay rate constant for naphthalene used in the model.

D.2.1 Input Data

The BIOSCREEN model requires input data in the following categories:

1. Hydrogeology—Data inputs include the groundwater seepage velocity (Vs); alternatively, BIOSCREEN can calculate Vs by applying Darcy's Law of the form Vs = hydraulic conductivity (K) x average annual hydraulic gradient (i) ÷ porosity (n). The chosen values for the MGT Subarea, as presented in Table 4-1 of the RI, are listed below:

    - Vs = 75 ft/yr
    - K = 2.4×10^{-3} cm/sec

- I = 0.0075 ft/ft (seasonal average from wet and dry seasons)
- n = 0.25

2. Dispersion—Data inputs include the estimated plume length (Lp). The estimated plume length is assumed to be the distance between MG-MW05 (the source) and CF-MW01, which is approximately 500 feet. Longitudinal, transverse, and vertical dispersivity calculations are calculated by the model based on the estimated plume length:

   - Lp = 500 ft

3. Adsorption—Data inputs include either an assumed retardation factor, or a calculated retardation factor based on the soil bulk density (ρ), partition coefficient (K_{oc}), and fractional organic carbon (f_{oc}). For this model, the retardation factor was used as a calibration parameter with final value of:

   - R = 1.5

4. Biodegradation—Data inputs include a first-order decay coefficient (λ). The first-order decay coefficient was calculated using the average rate of decay from groundwater naphthalene concentrations at higher-concentration wells MG-MW01 and EMW-16S between March 2004 and December 2010 (see Table D-1), as follows:

   - $\lambda = 0.35\ yr^{-1}$

5. General—Data inputs include an estimated length and width of the model area, and a simulation time for the model. The numbers were assumed such that the entire plume area of interest would be captured, as follows:

   - Length = 550 ft
   - Width = 115 ft
   - Simulation Time = 100 yr

6. Source Data—Data inputs include source thickness in the saturated zone, concentration of source, width of the source, and the amount of soluble mass within the source, all of which are estimates. The source thickness is assumed to be the smear zone based on seasonal high/low water tables, which have been observed to fluctuate up to 1 foot in the plume vicinity. The soluble mass was used as a calibration parameter. The source concentration was assumed to be the approximate solubility limit of naphthalene in water obtained from the Groundwater Chemicals Desk Reference (Montgomery, 1996).

   - Width = 40 ft
   - Source Thickness = 2 ft
   - Concentration = 25 mg/L
   - Soluble Mass = 10.5 kg

7. Field Data for Comparison—Data inputs include measured concentration data along the centerline of the plume at specified distances downgradient of the source. Three data points were entered along the plume centerline based on naphthalene

concentrations at MG-MW05, MG-MW03, and CF-MW01. See Table D-2 for concentration and distance data developed in the RI. Figure D-1 provides a plot of naphthalene concentrations versus distance down the plume; a logarithmic regression closely fits the measured data ($R^2 = 0.986$; Figure D-1), providing confidence in using the data set.

D.2.2 Model Calibration

The exact time and amount of naphthalene release at the MGT Subarea is unknown and likely occurred over a period of time. For the purposes of this model, it was assumed that the spill happened 40 years prior to the last (2010) RI sampling event. Regardless of when the spill actually occurred, the BIOSCREEN model run at 40 years is taken to be the year 2010 and calibrated in order to match the measured groundwater concentrations collected at that time.

The amount of soluble mass and the retardation factor were the main calibration parameters used to match the concentration versus distance curve. Values of 10.5 kg for soluble mass and 1.5 for the retardation factor resulted in the closest fit to the actual analytical data collected in 2010.

The predicted naphthalene centerline concentration curves for 2010 conditions, assuming both first-order decay and no degradation as modeled by BIOSCREEN, are shown on Figure D-2. The 2010 analytical data points ("field data from site") are also displayed for comparison. The first-order decay model (blue line on Figure D-2) proves to be an excellent match for the 2010 analytical data, indicating that model is adequately calibrated to allow its use for predictive evaluation. Without decay (red line on Figure D-2), the model predicts a more uniform distribution of naphthalene along the plume centerline, which is completely inconsistent with the measured data.

The model results demonstrate that biological degradation (permanent destruction) of naphthalene is occurring in MGT Subarea groundwater, consistent with the groundwater quality measurements over time.

D.3 Model Results

The calibrated BIOSCREEN model predicts a MGT Subarea naphthalene plume restoration time frame of approximately 40 years from 2010, based on first-order decay. Specifically, the BIOSCREEN model predicts a concentration of 8 µg/L at the source (well MG-MW05) in the year 2050, just below the groundwater cleanup level of 8.9 µg/L based on vapor intrusion for unrestricted site use (residential exposure). Figure D-3 presents the model results for year 2050.

The model also predicts that the groundwater naphthalene concentrations will decline to an 83 µg/L concentration based on marine protection at well MG-MW05 by the year 2027 (17 years from the year 2010). In other words, the model predicts an 82 percent reduction (450 to 83 µg/L) in the 2010 naphthalene concentration occurring in the first 17

years with an additional 17 percent reduction (83 µg/L to 8 µg/L) occurring in the subsequent 23 years.

In conclusion, the modeling predicts a groundwater naphthalene restoration time frame of 34 years from 2016, the preparation date for this FS.

D.4 References for Appendix D

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Table D-1 - Naphthalene First-Order Decay Coefficient Estimation

Project 070188, Chlor-Alkali RAU, GP West Site, Bellingham, Washington

Estimate first-order degradation rate constant (λ, in units of t^{-1}) for naphthalene in MGT groundwater plume

$\ln(C/Co) = -\lambda t$

$\lambda = -\ln(C/Co)/t$

Use data for the high-concentration naphthalene-impacted wells with data spanning 5 years (EMW-16S and MG-MW05). Use the average concentration and time from the three 2009-2010 sampling events to define the "now" condition (C, t).

	Well EMW-16S				Well MG-MW05			
	(C_o, t_o)	(C, t)			(C_o, t_o)	(C, t)		
	EMW-16S 07/26/04 Pre-RI	EMW-16S 09/30/09 RI	EMW-16S 03/30/10 RI	EMW-16S 12/16/10 RI	MG-MW01 07/27/04 Pre-RI	MG-MW01 09/28/09 RI	MG-MW01 03/29/10 RI	MG-MW01 12/16/10 RI
Sample Date:	7/26/2004	9/30/2009	3/30/2010	12/16/2010	7/27/2004	9/28/2009	3/29/2010	12/16/2010
Naphthalene Concentration (ug/L):	210	64	59	42	27	5.4	0.072	0.31 U
Elapsed Time (day):	0	1892	2073	2334	0	1889	2071	2333

	EMW-16S	MG-MW05
Average Time (t, in day):	2100	2098
Average Concentration (C, in ug/L):	55	2
$\lambda = -\ln(C/Co)/t$ (day^{-1}):	6.4E-04	1.3E-03

Average λ from two wells (day^{-1})	**9.5E-04**
Average λ from two wells ($year^{-1}$)	**0.35**

ug/L = micrograms per liter

Notes:

C_0 = initial contaminant concentration at time = 0 (t_0).

C = contaminant concentration at time = t.

Table D-2 - Groundwater Napthalene Data Along Plume Centerline, Million Gallon Tanks Subarea

Project No. 070188, Chlor-Alkali RAU, GP West, Bellingham, Washington

Chemical Name	CF-MW01 09/30/09 RI	CF-MW01 03/31/10 RI	MG-MW03 03/29/10 RI	MG-MW03 12/16/10 RI	MG-MW05 12/20/10 RI
Distance from Source (ft)	500		185		1
Polycyclic Aromatic Hydrocarbons (PAHs)					
Naphthalene in ug/L	0.045	0.062	87	160	450
Average Naphthalene in ug/L	**0.054**		**124**		**450**

ft = feet

ug/L = micrograms per liter

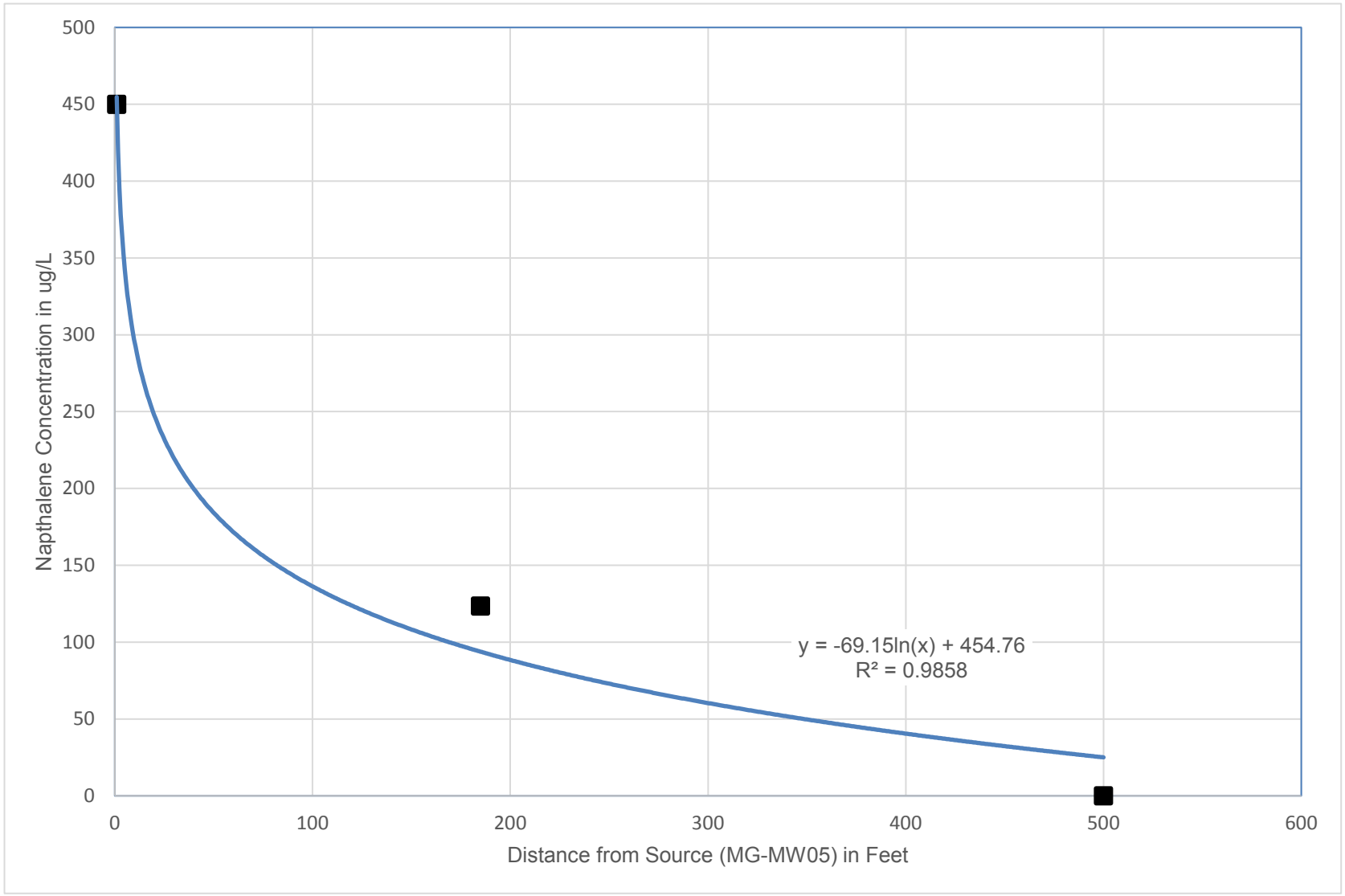
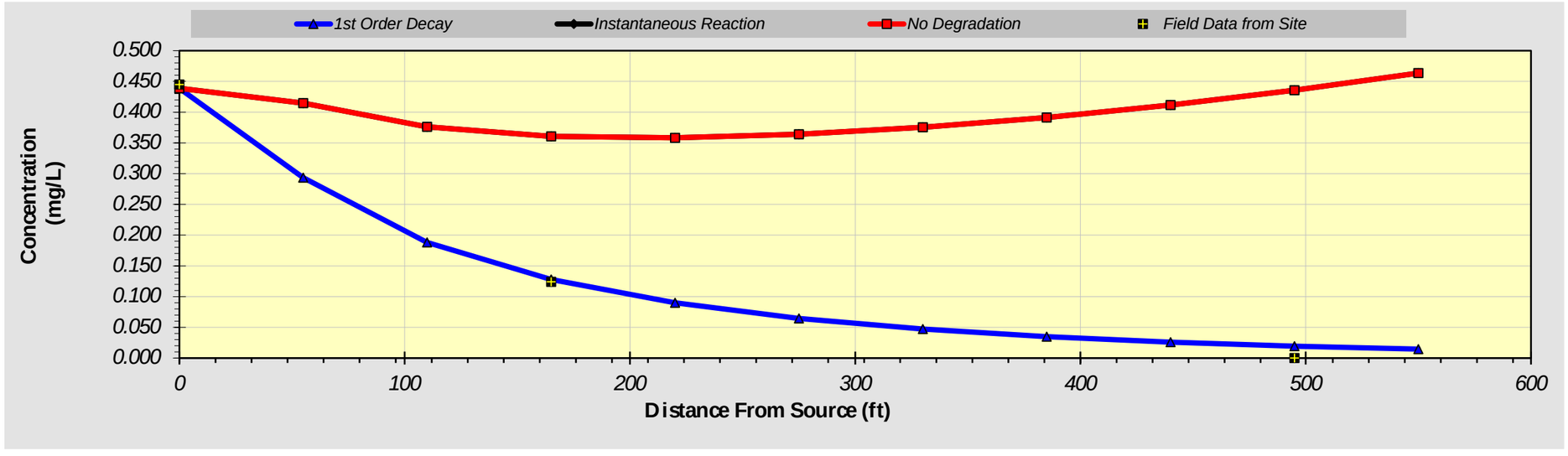


Figure D-1
Groundwater Naphthalene Concentrations versus Distance Down Plume Centerline
Chlor-Alkali RAU Feasibility Study

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	55	110	165	220	275	330	385	440	495	550
No Degradation	0.439	0.415	0.376	0.361	0.358	0.364	0.375	0.391	0.411	0.436	0.463
1st Order Decay	0.439	0.293	0.188	0.128	0.090	0.065	0.047	0.035	0.026	0.019	0.015
Inst. Reaction	0.439	0.415	0.376	0.361	0.358	0.364	0.375	0.391	0.411	0.436	0.463
Field Data from Site	0.445			0.124						0.000	



DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	55	110	165	220	275	330	385	440	495	550
No Degradation	0.008	0.007	0.007	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008
1st Order Decay	0.008	0.005	0.003	0.002	0.002	0.001	0.001	0.001	0.000	0.000	0.000
Inst. Reaction	0.008	0.007	0.007	0.006	0.006	0.006	0.007	0.007	0.007	0.008	0.008
Field Data from Site	0.445			0.124						0.000