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Tidal Implications for Remediation of a Coal Waste Pile in Union Bay, BC

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Tidal Implications - Remediation of a Coal Waste Pile in Union Bay, BC

Ian Mitchell, M.Sc, P.Geo., Jim Malick, Ph.D, R.P.Bio, P.Ag.

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Outline

- Site Description and History
- Environmental Investigations
- Detailed Hydrogeological assessments
- Remediation/Reclamation Plan



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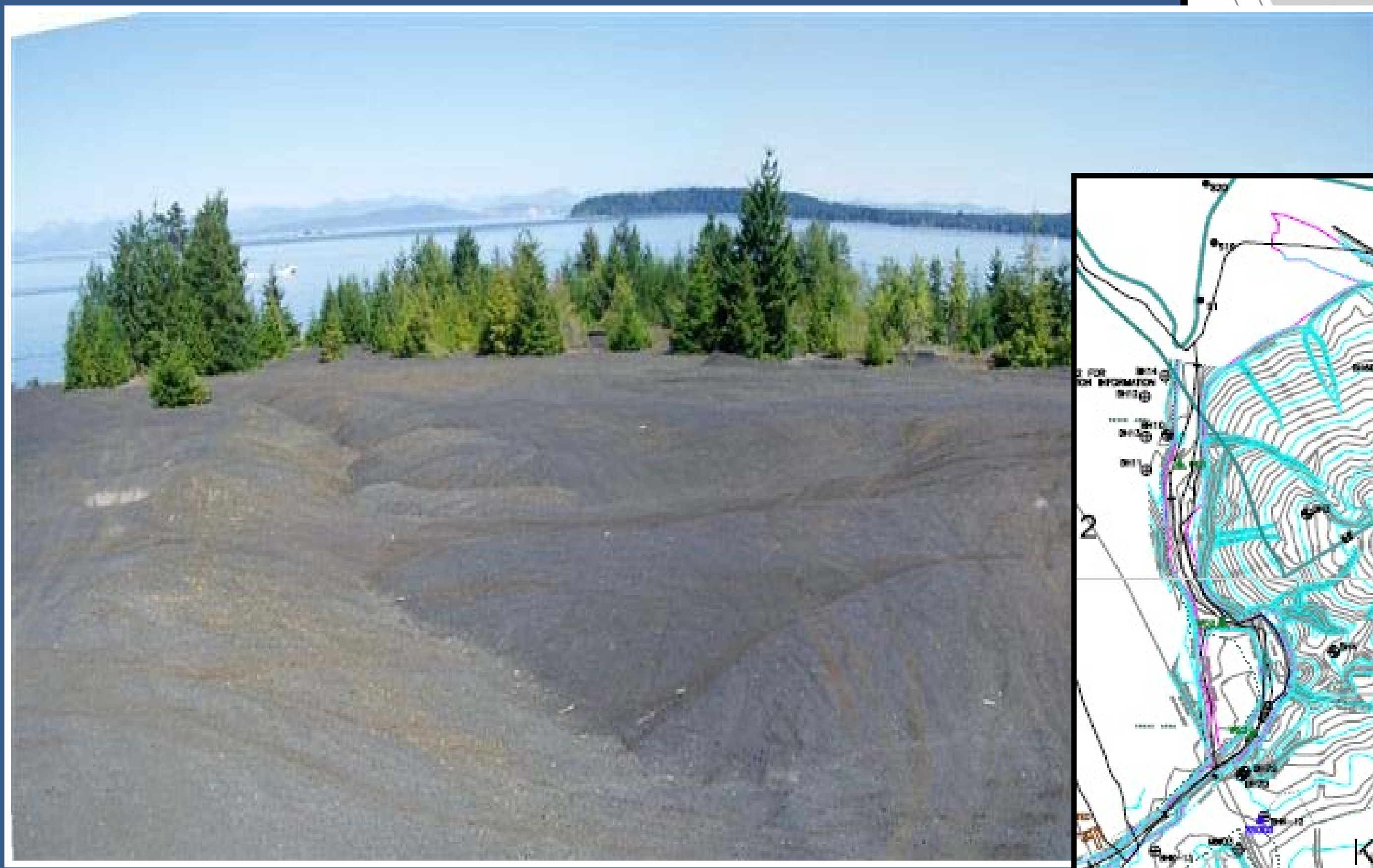
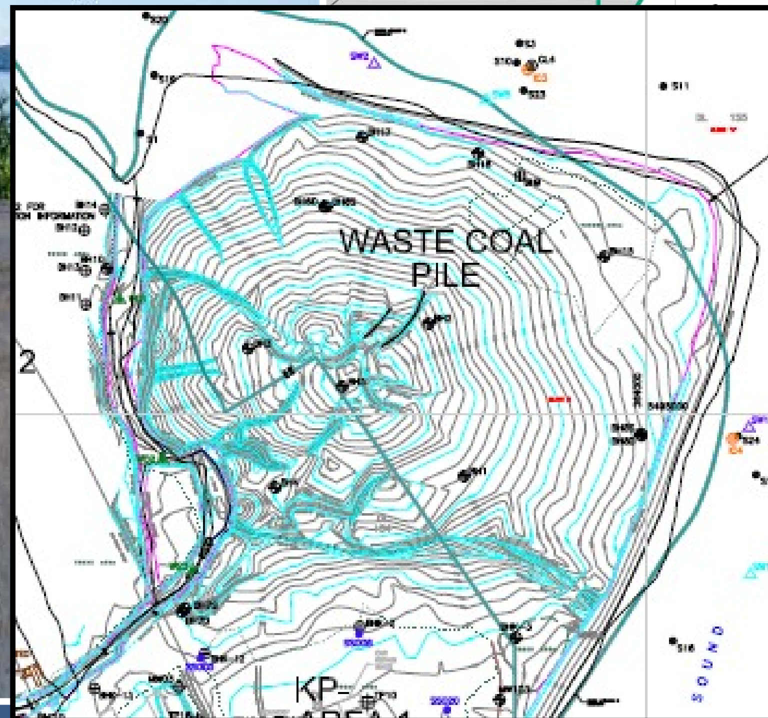
Site Description

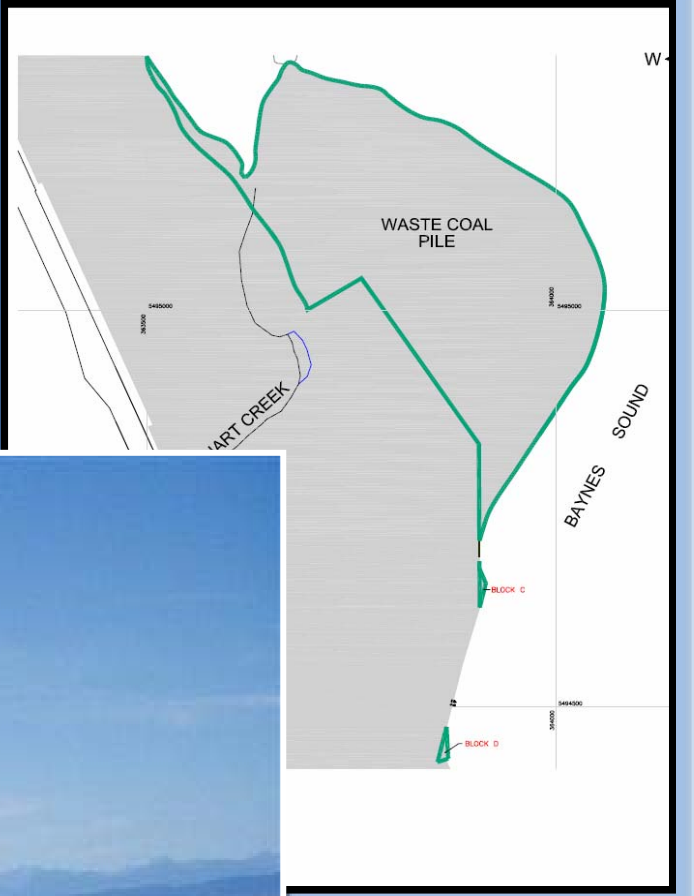
- 13 ha waste coal pile in Union Bay, BC





Site Description

- 13 ha waste coal pile in Union Bay, BC
- Bounded to north and east by Pacific Ocean



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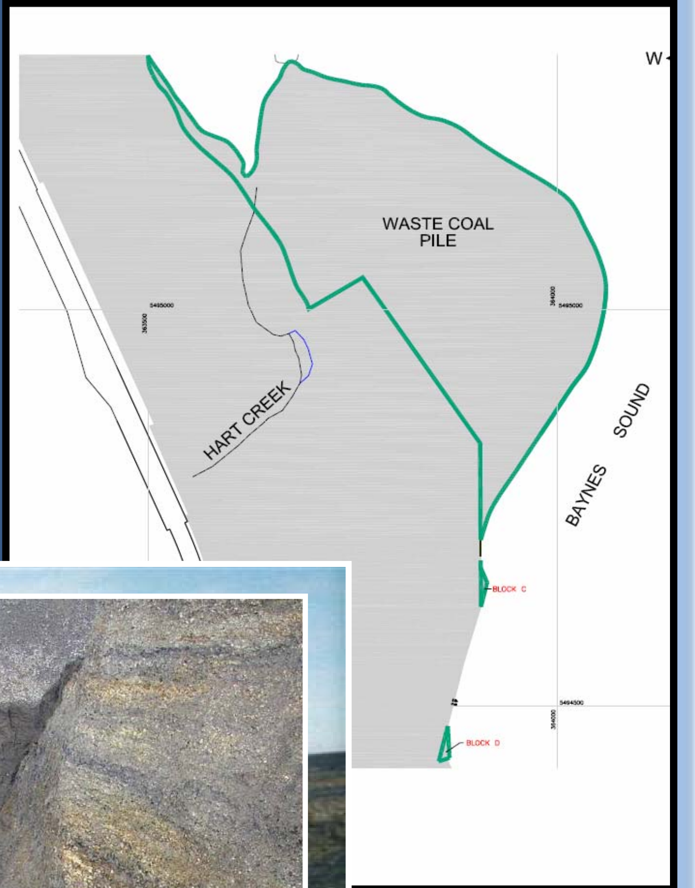
Site Description

- 13 ha waste coal pile in Union Bay, BC
- Bounded to north and east by Pacific Ocean
- Bounded to west by Hart Creek



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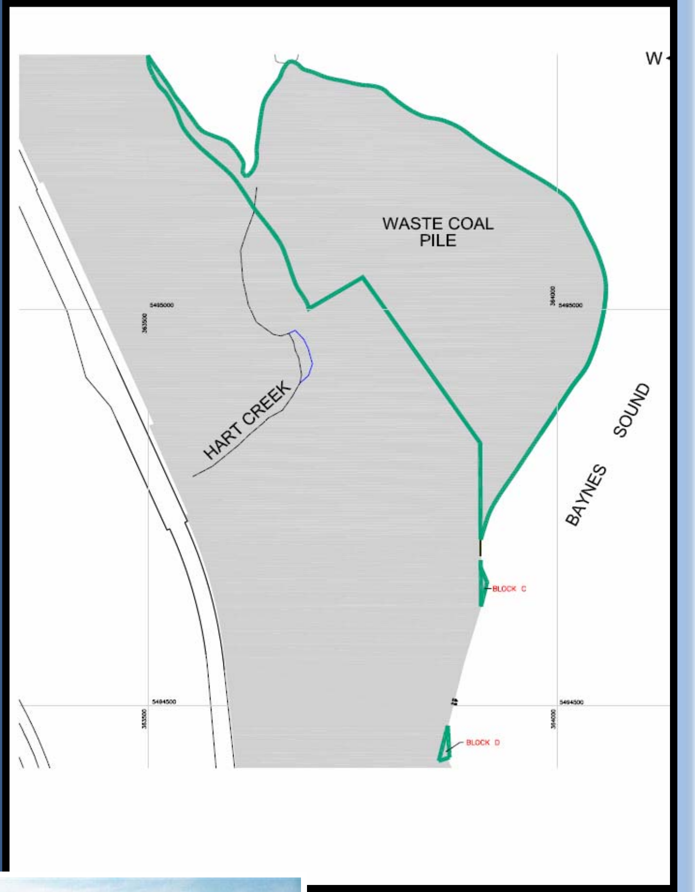
Site Description

- 13 ha waste coal pile in Union Bay, BC
- Bounded to north and east by Pacific Ocean
- Bounded to west by Hart Creek
- Future land use: golf course



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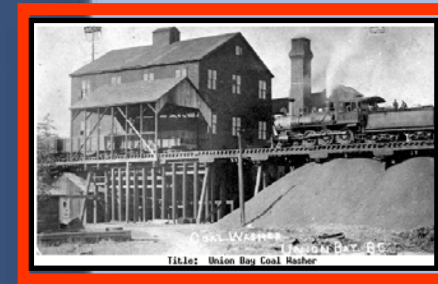
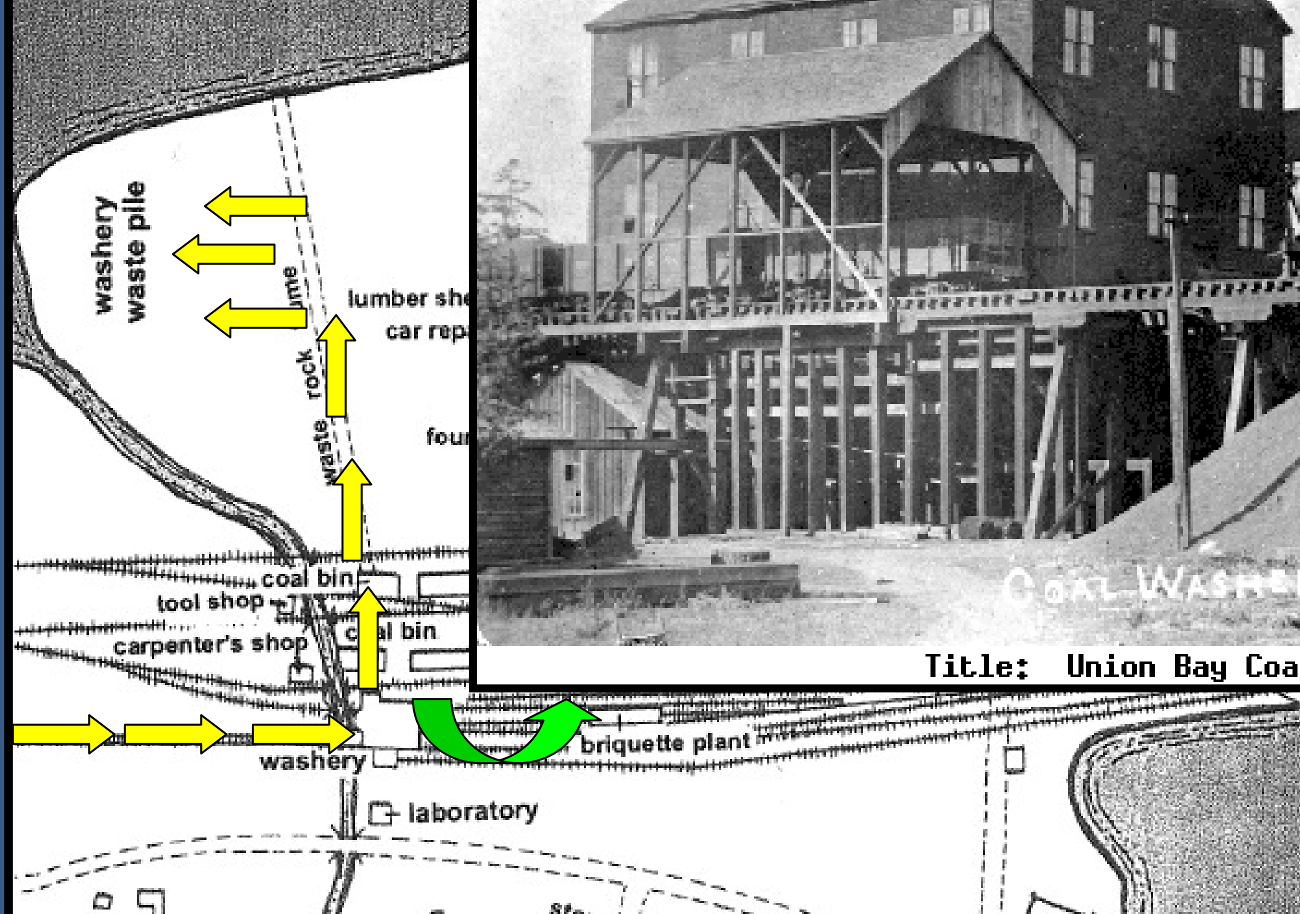
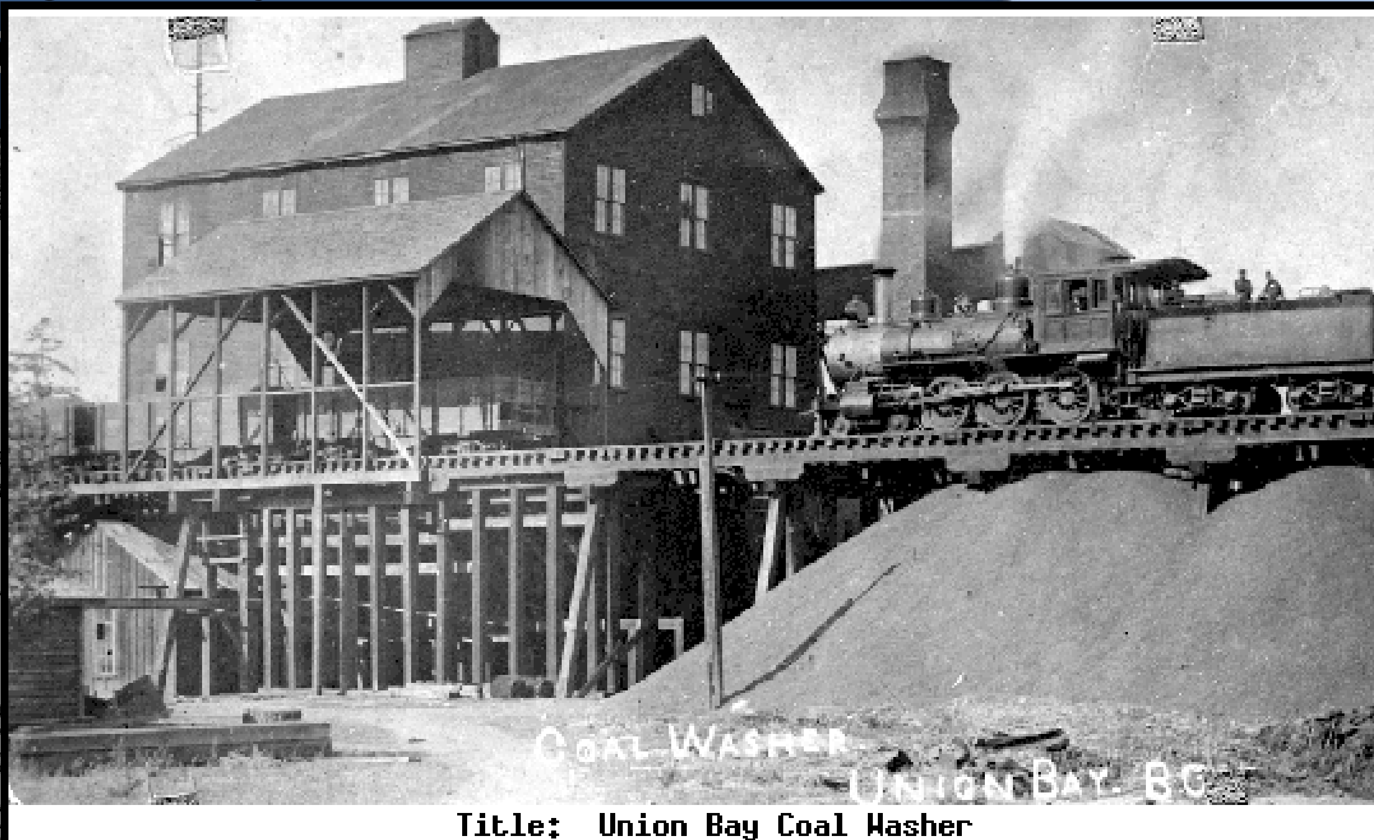
Site History

- Coal Processing Facility
- 1888 to ~ 196







Historical photographs from BC Archive at www.bcarchives.gov.bc.ca.

Site History

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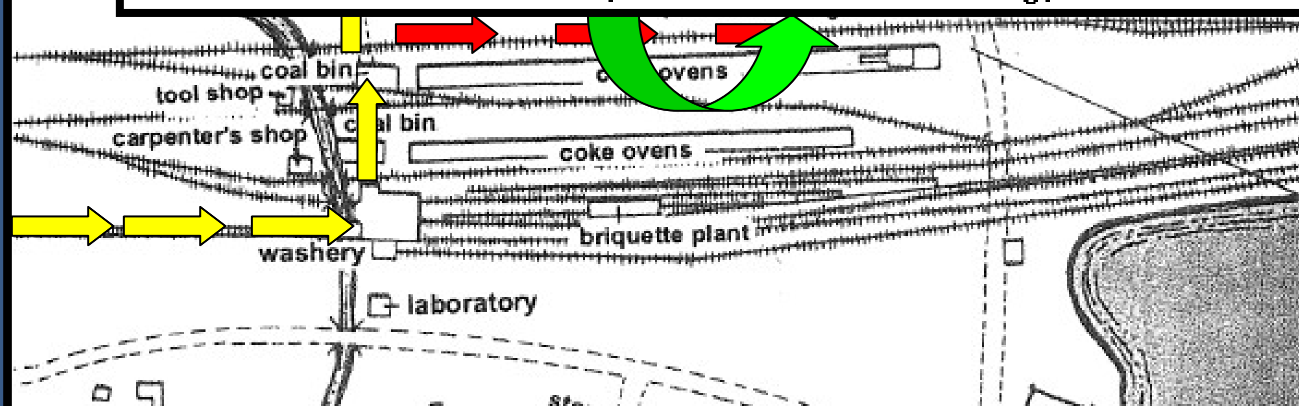
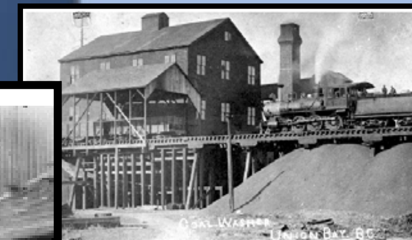
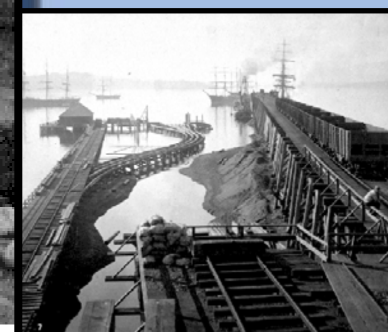
- 18



Title: Coke Ovens at Union Bay.



Title: Union Bay Coal Washer



Title: Coal Docks at Union Bay.

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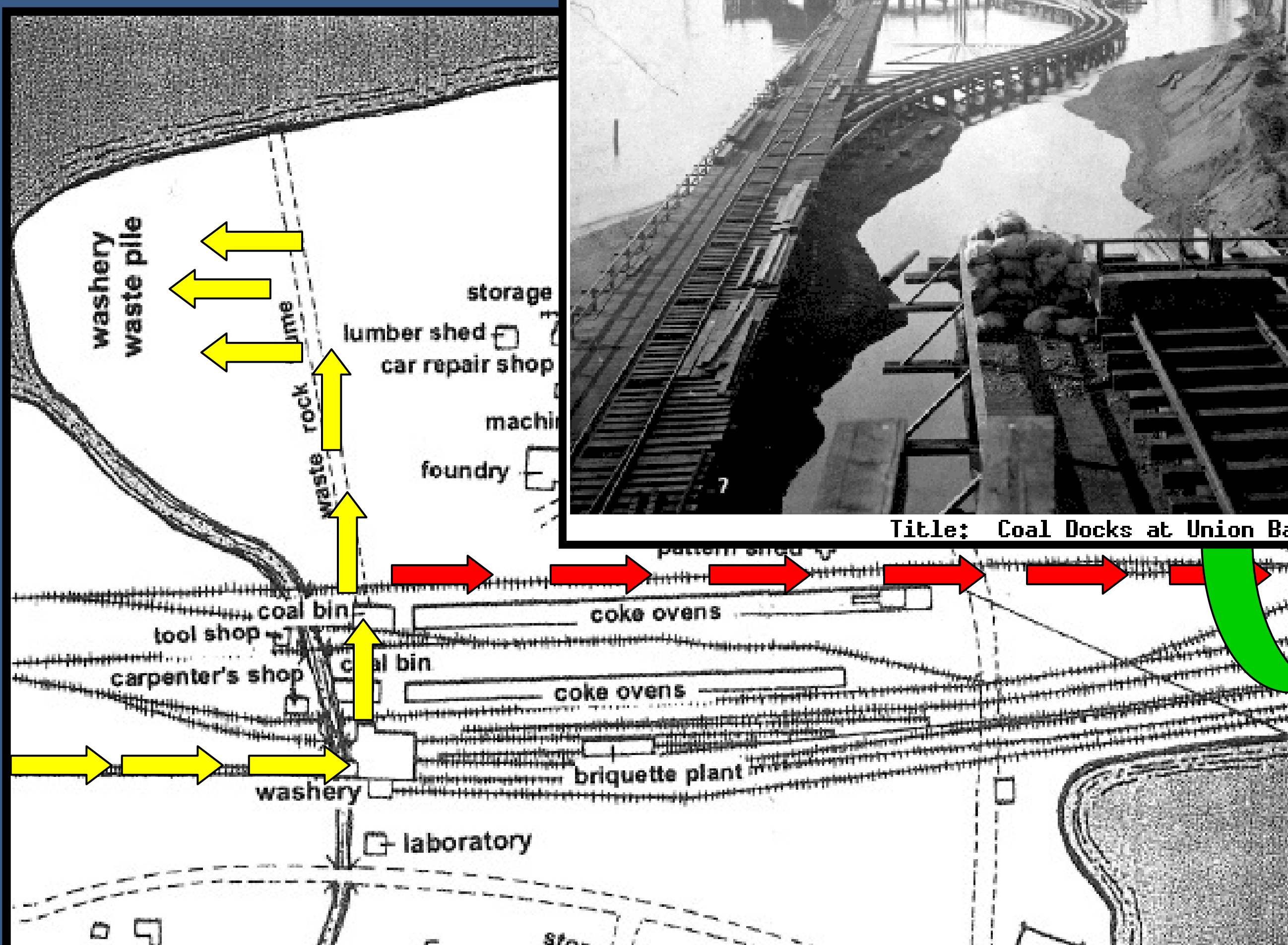
Historical photographs from BC Archive at www.bcarchives.gov.bc.ca.

Site History

- Coal Processing F
- 1888 to ~ 1960




Title: Coal Docks at Union Bay.

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Historical photographs from BC Archive at www.bcarchives.gov.bc.ca.

Environmental Investigations

- Waste Coal Pile and adjacent properties, Baynes Sound and Hart Creek
- Samples of waste coal, native soil, groundwater, sediment and surface water analysed for PCOCs
- PCOCs include metals, PAHs, sulphate
- ABA, kinetic testing and other geochemical parameters

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Waste Coal Pile - Results

- Waste Coal: arsenic, copper, naphthalene and phenanthrene > standards
- Native soils: < standards
- Groundwater: cadmium, cobalt, copper, nickel, zinc and sulphate > standards for aquatic life; PAHs < standards

Hart Creek - Results

- Surface Water: < criteria
- Sediment: PAHs and metals > criteria in 1 sample

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Baynes Sound - Results

- Waste coal present to > 30 m offshore
- Iron staining present in sediments north and east of coal pile in areas of groundwater discharge
- Sediment: PAHs and metals > criteria
- Seep water: Metals > criteria

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Geochemistry

- Geochemical characterization conducted by SRK Consulting (Canada) Inc.
- Static and kinetic testing indicated that all material is potentially acid generating and some already acidic
- Geochemical Profile
  - Sulphide sulphur present throughout
  - Accumulation of sulphate within top 2 m
  - Increasing pH and NP with depth
- Under existing conditions, acidification expected to continue for decades to a century

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Detailed Hydrogeology Assessment – Phase 1

- Stratigraphic characterization
- Groundwater chemistry
- Hydraulic Conductivity Tests
- Analysis of tidal effects/gradients
- Groundwater flow assessment
- Infiltration tests at pile surface
- Climate data evaluation
- Numerical modelling (HELP)
- Detailed evaluation of water balance
- Conceptual hydrogeological model

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Phase 1 Conclusions

- Waste coal hydraulic conductivity an order of magnitude higher than underlying native soil; promotes seepage at base of pile
- Upgradient side of pile not recharged by Hart Ck.
- Tidal influence extends to back of pile, however mixing of groundwater with saline water limited to 20-75 metres inland from foreshore
- Upgradient groundwater flow through pile is a relatively small component of overall discharge

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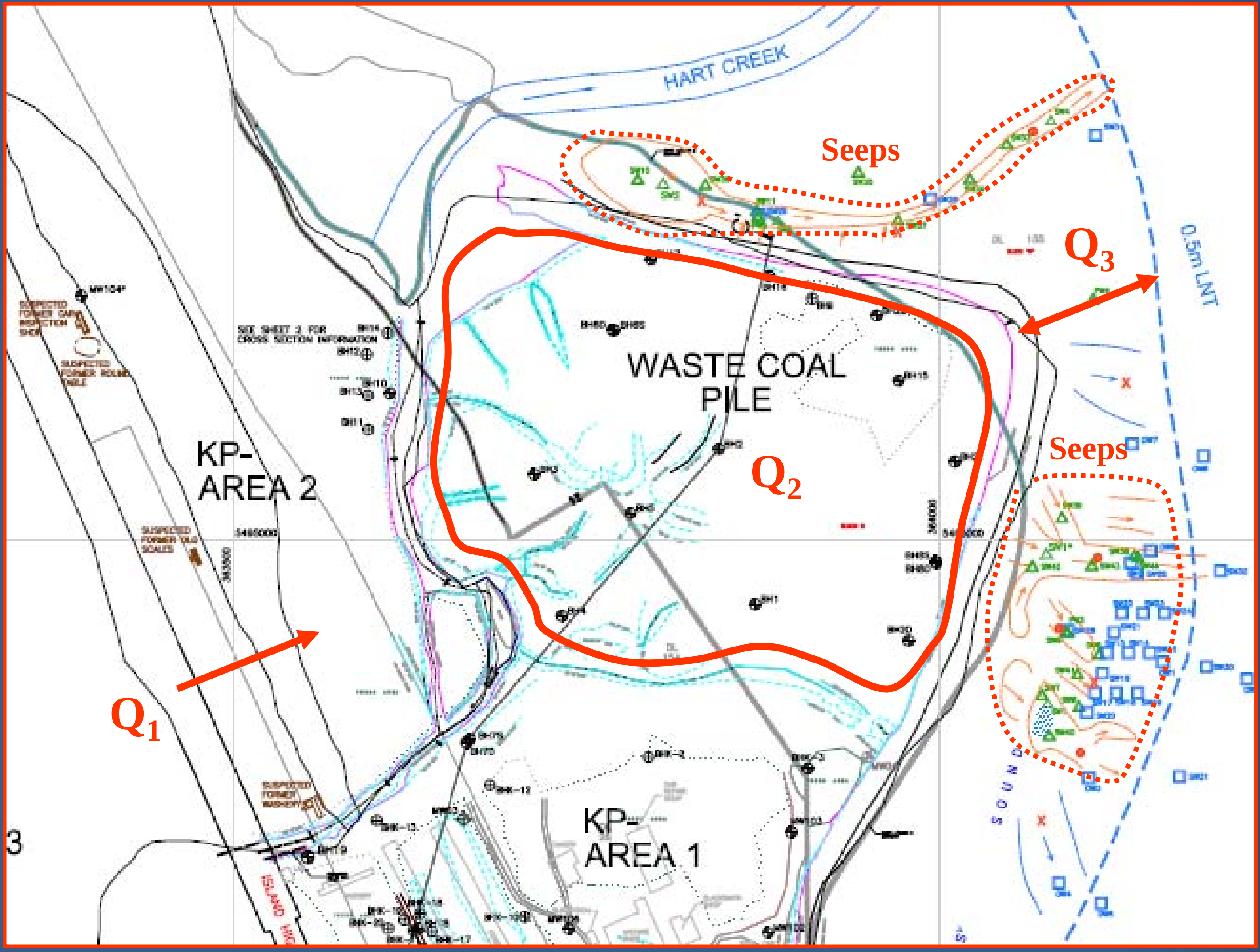
Conceptual Model



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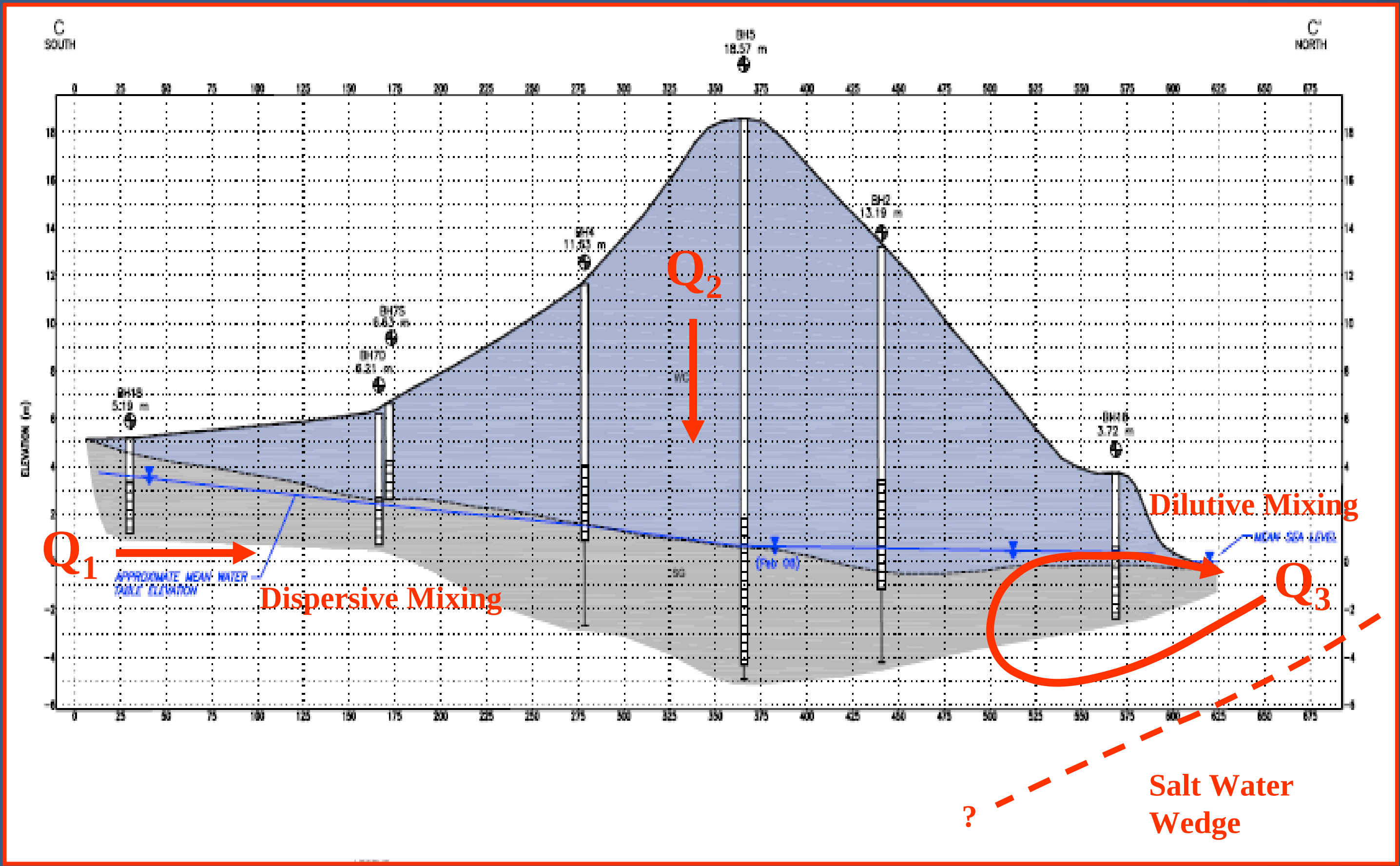
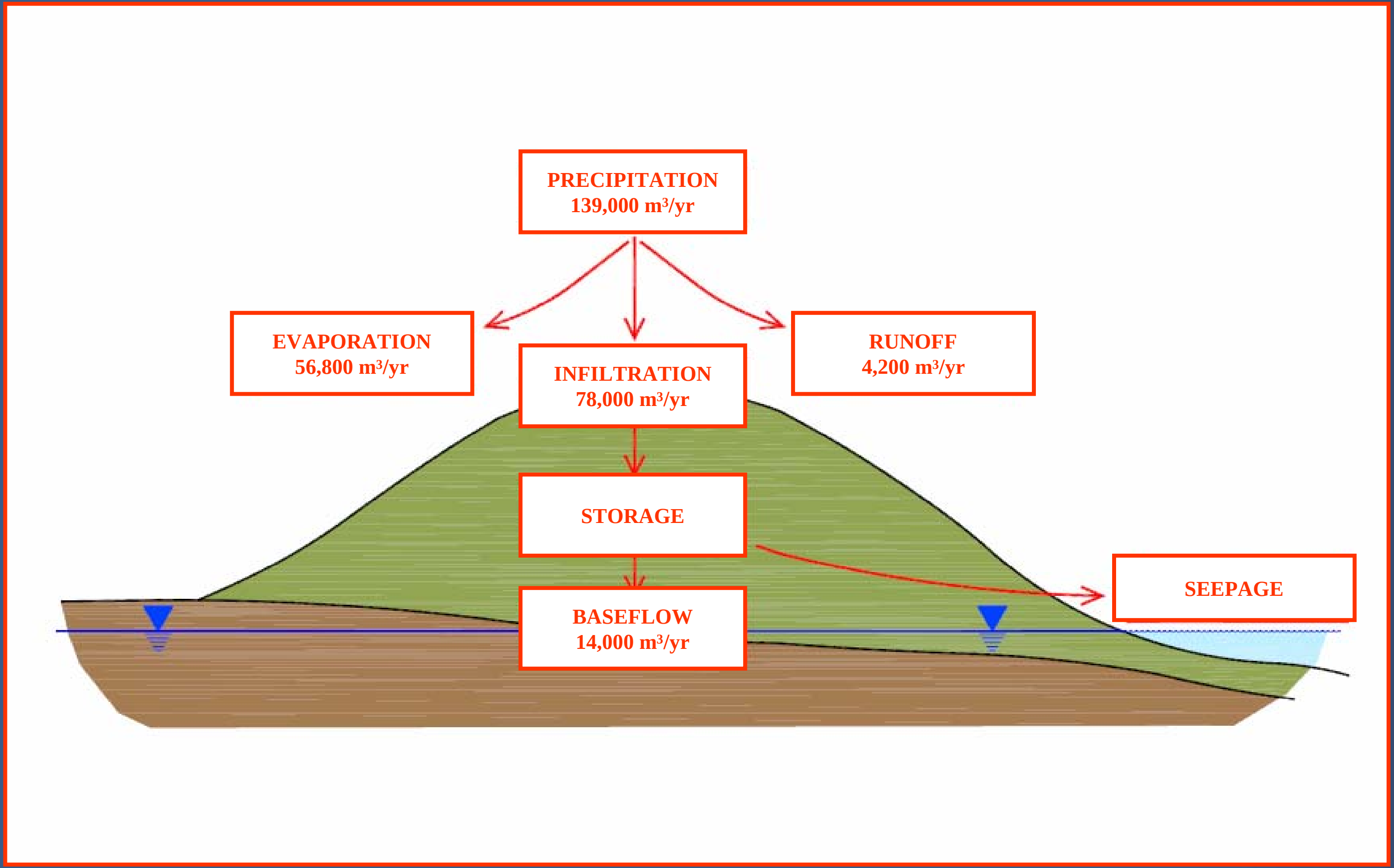


Water Balance



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Detailed Hydrogeology Assessment – Phase 2

- Literature Review
- Spatial and temporal characterization of seepage chemistry
- Evaluation of seepage flowrates
- Shallow depth porewater profiling in the intertidal zone
- Coastal dispersion modelling
- Seawater dilution evaluation
- Update conceptual hydrogeological model

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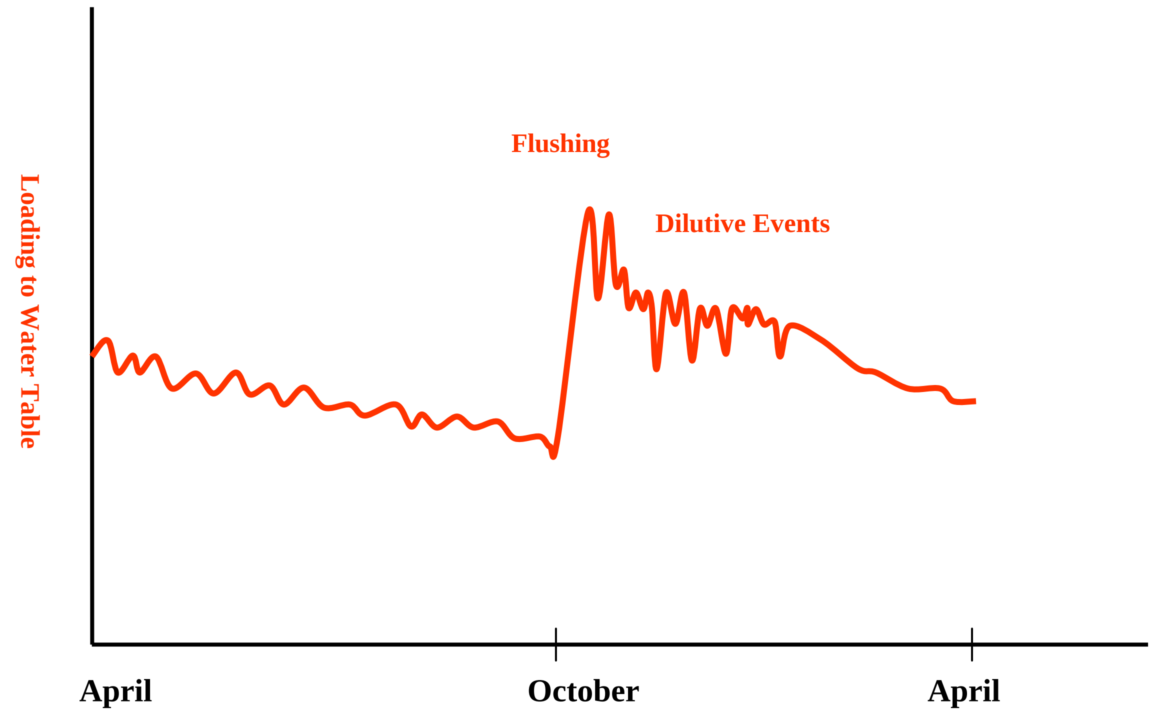
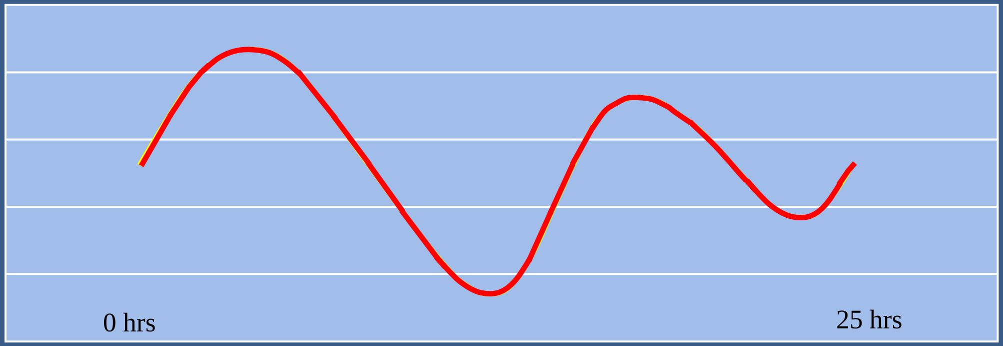
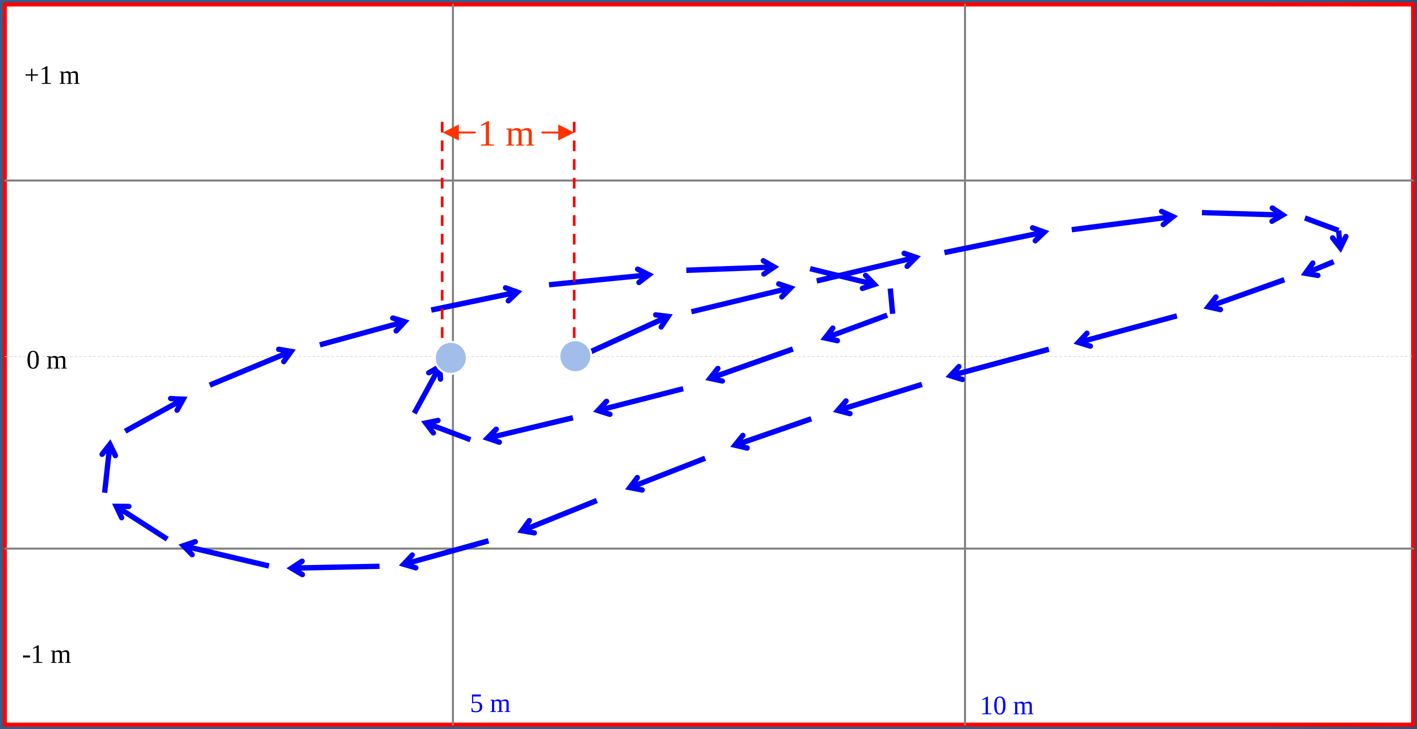
Conceptual Loadings



Conceptual Particle Tracking





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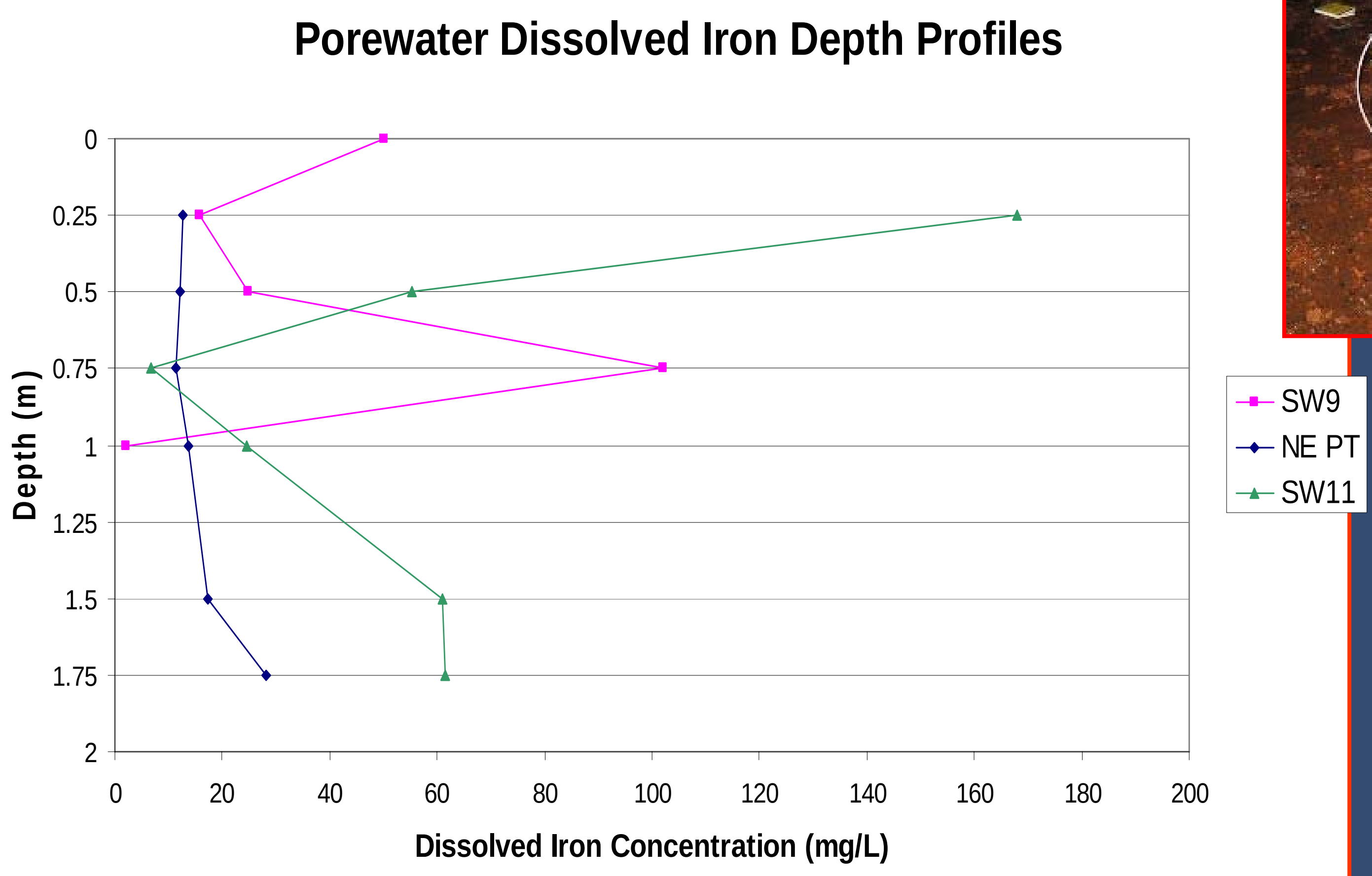
Porewater Profiling
Intertidal Zone



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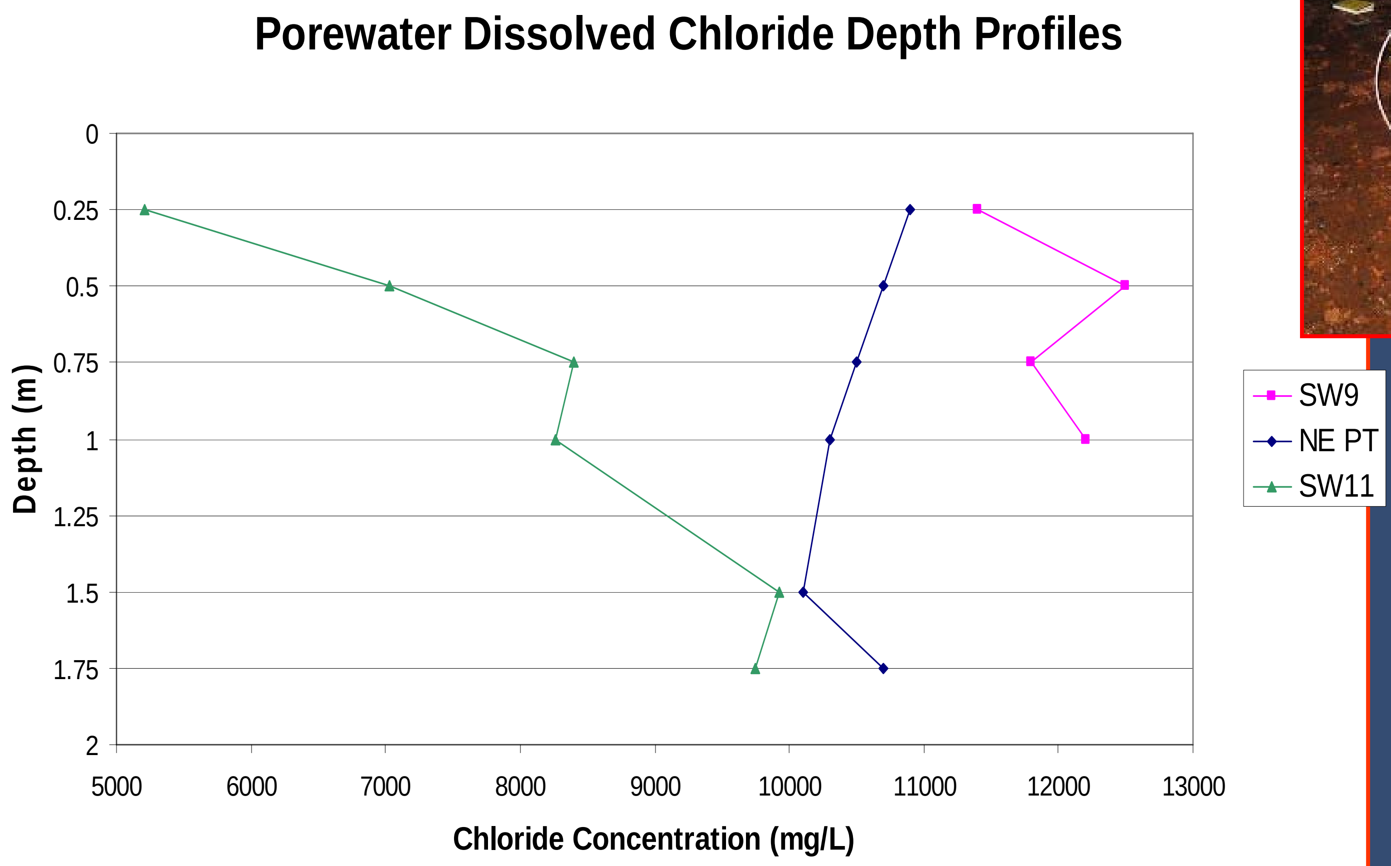

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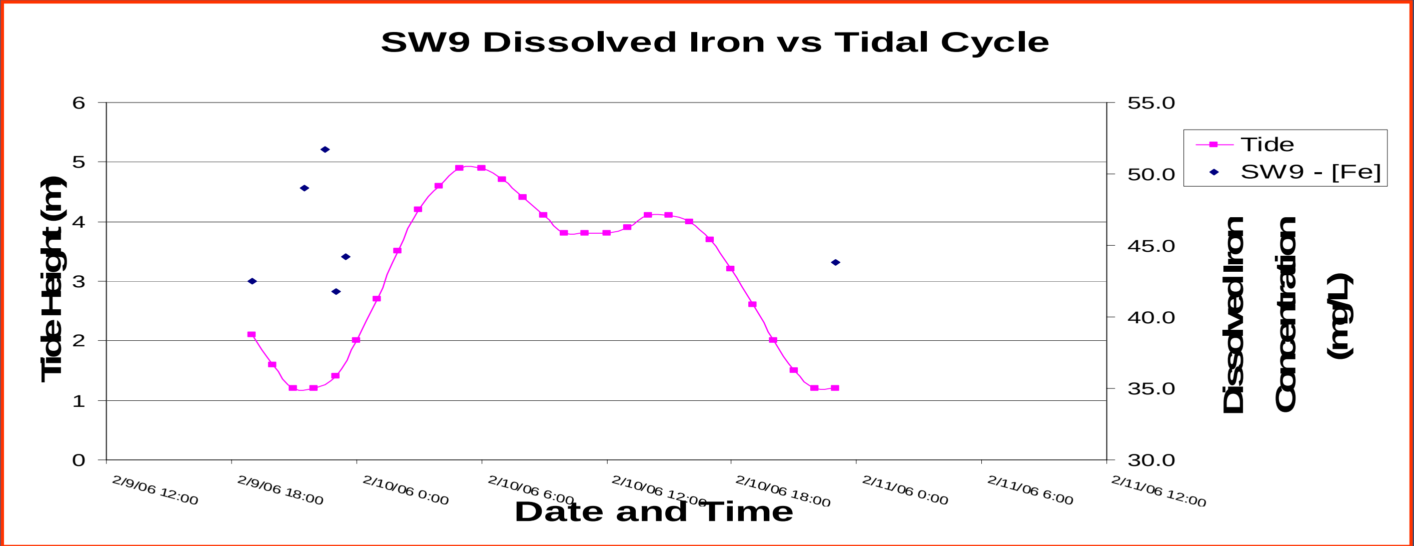
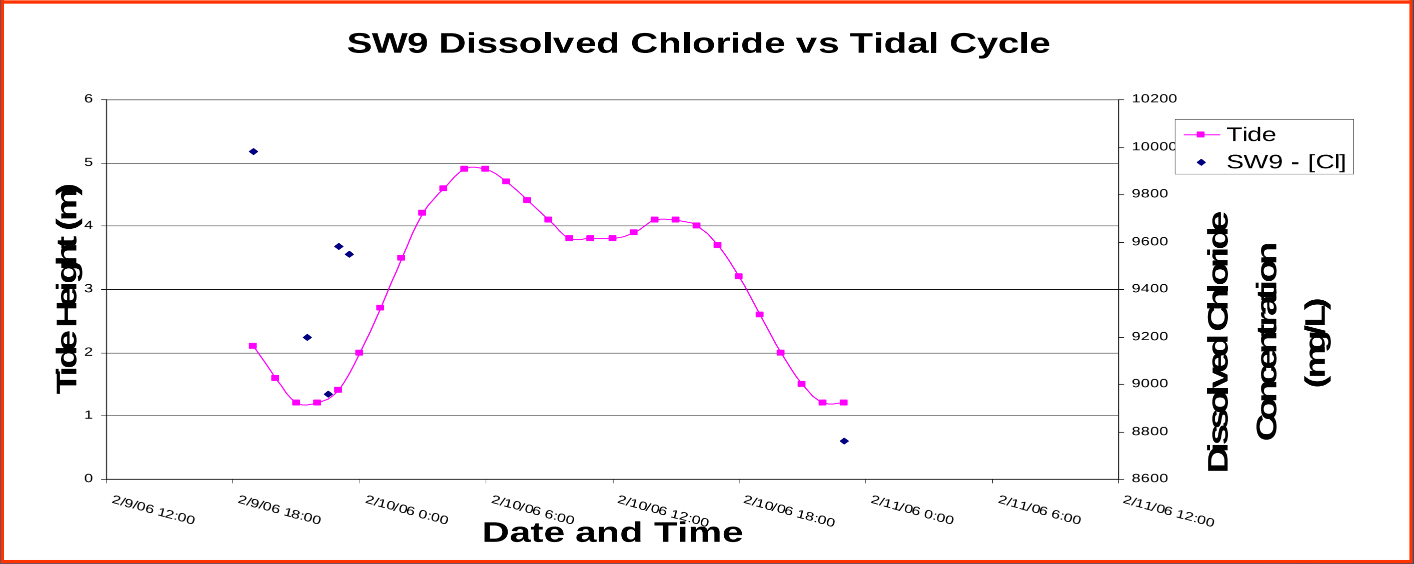
Iron vs Chloride Seepwater Trend Evaluation





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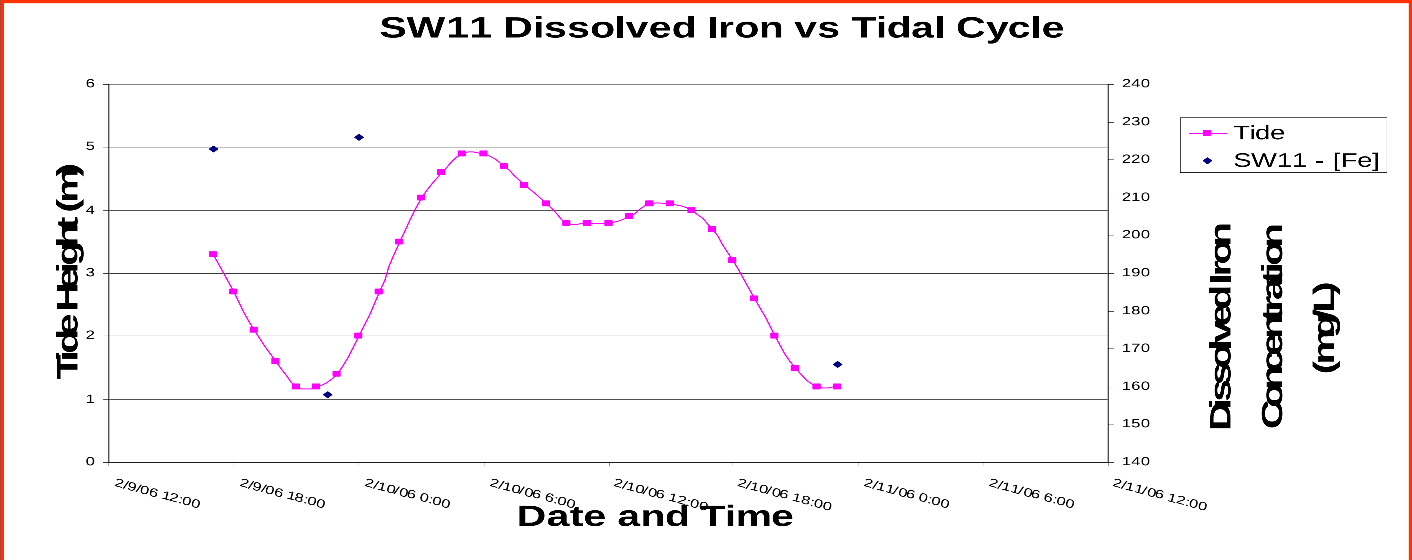

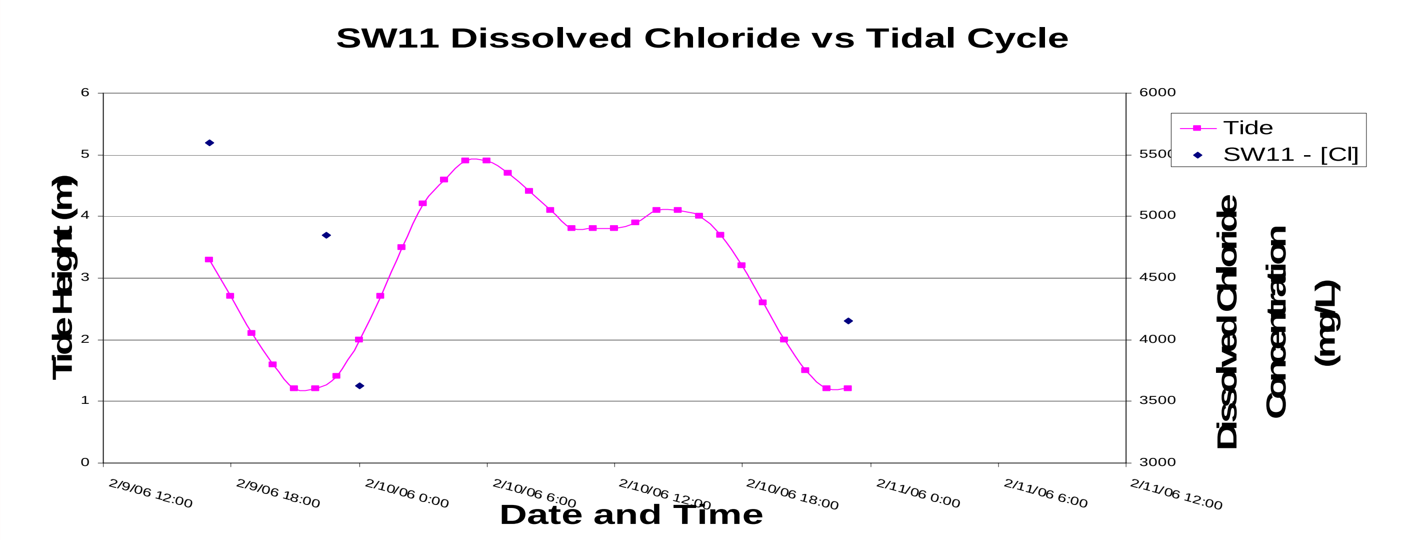

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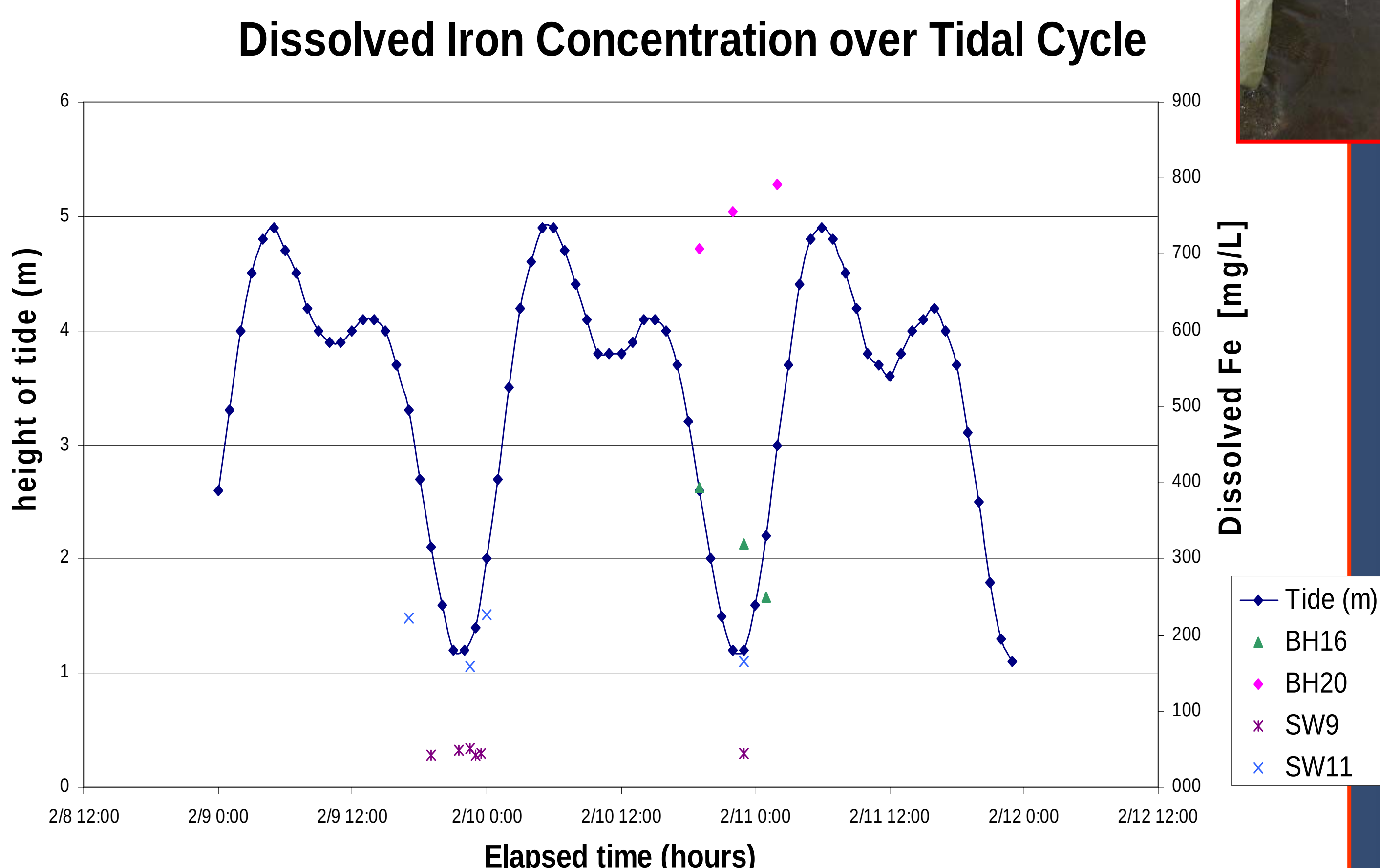
Groundwater – Seepwater Trend Evaluation



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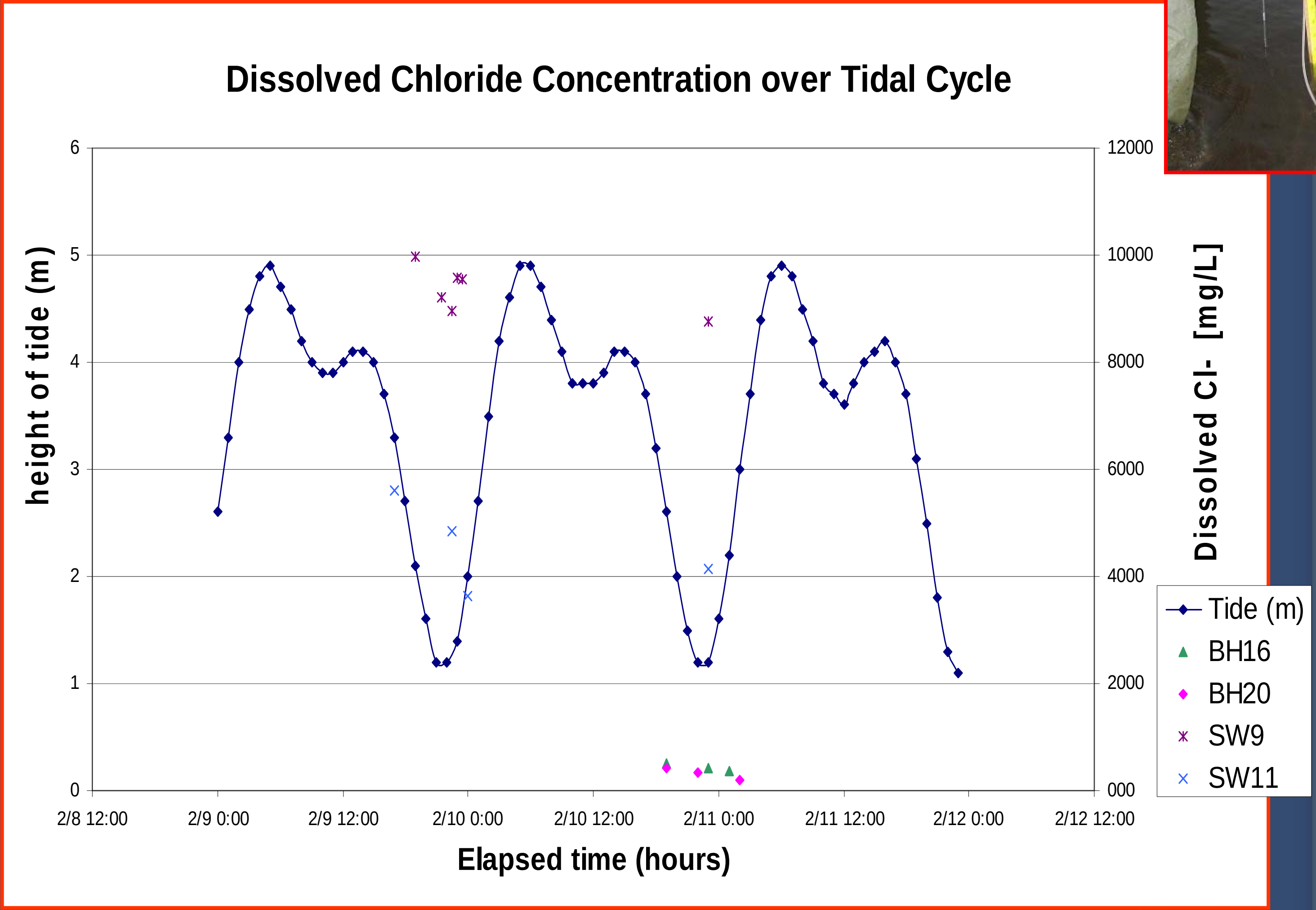

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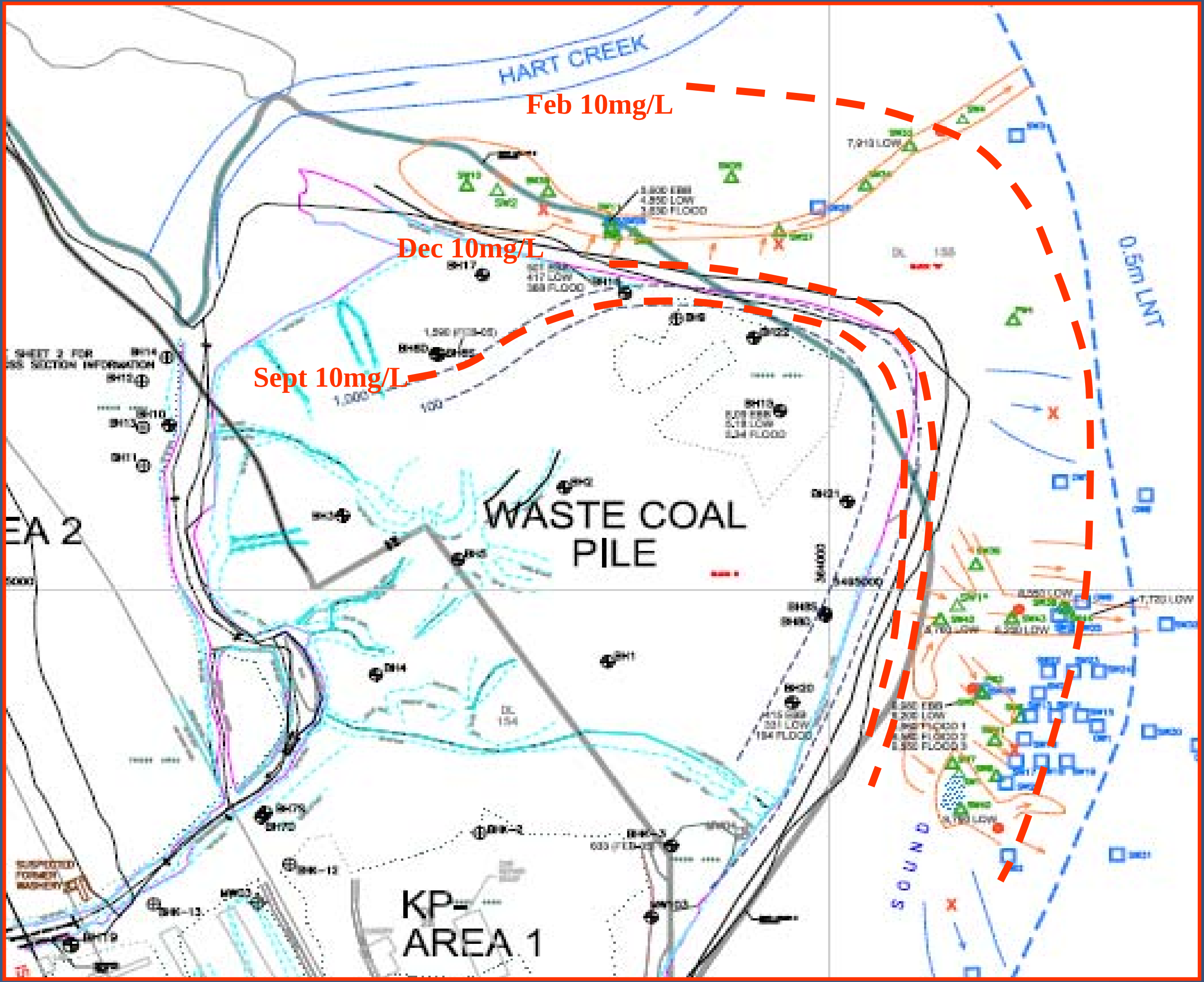
Seawater Intrusion



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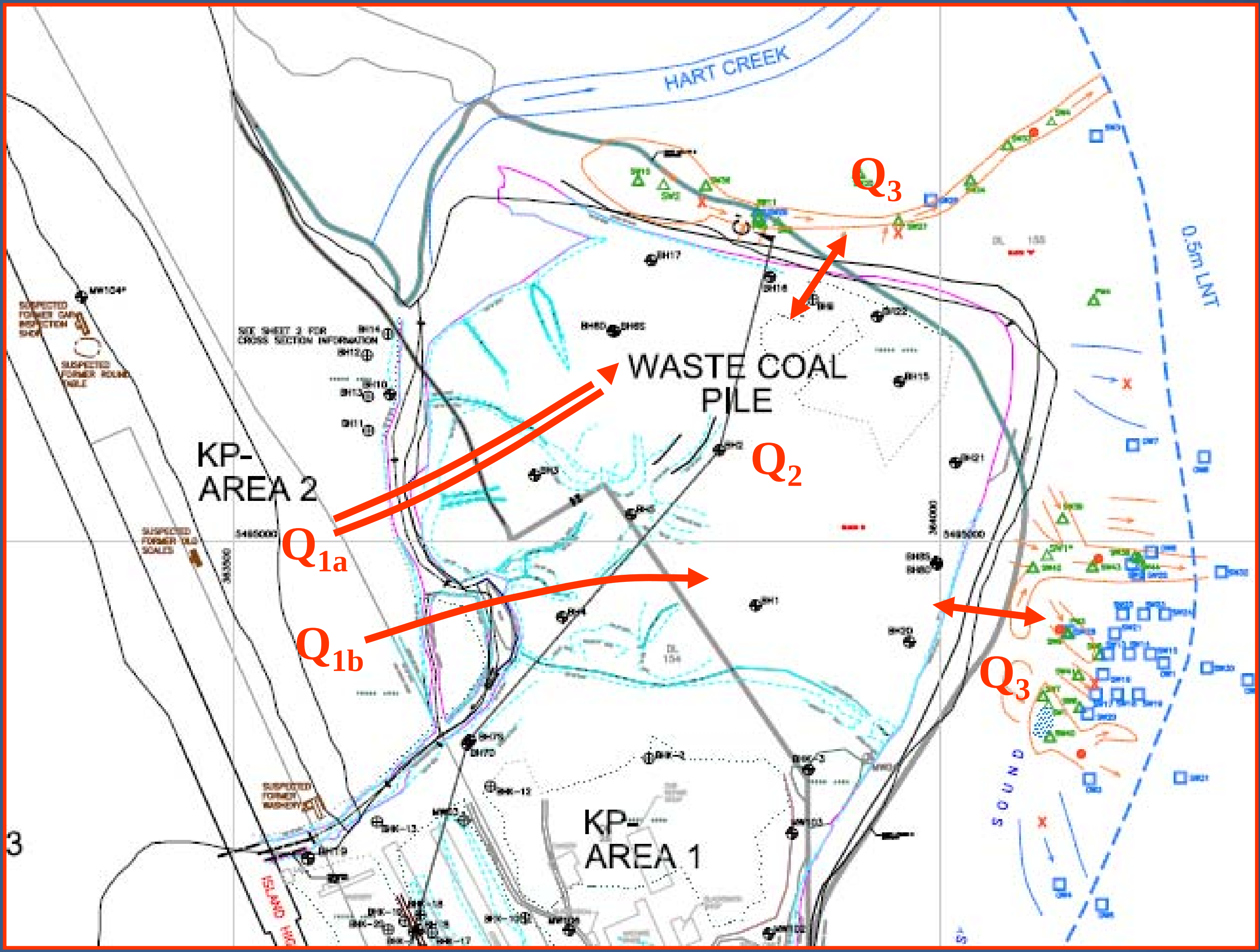

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Dilution Assessment

Estimated Average Seawater Dilution between Perimeter Wells and Seeps based on Iron Concentrations					
Location	Dissolved Fe (mg/L)				
	September 2005	October 2005	December 2005	January 2006	February 2006
BH20	475	400	340	480	750
SW9	110	200	85	30	50
Approx.Dilution	77%	50%	75%	94%	93%
BH16	960	710	265	185	320
SW11	60	45	20	200	170
Approx.Dilution	94%	94%	93%	0%	47%

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Dilution Assessment

Estimated Average Seawater Dilution between Pile and Seeps Based on Water Balance Method

Location	Combined Seepage Measured Flow Rates (L/sec)	Estimated Total Annual Seepage (m^3/yr)	Estimated Pile Groundwater Discharge (m^3/yr)	Approx. Dilution by Seawater
North Face	17.0	490,000	78,000	84%
East Face	9.2			
Spatially Distributed	5.0			

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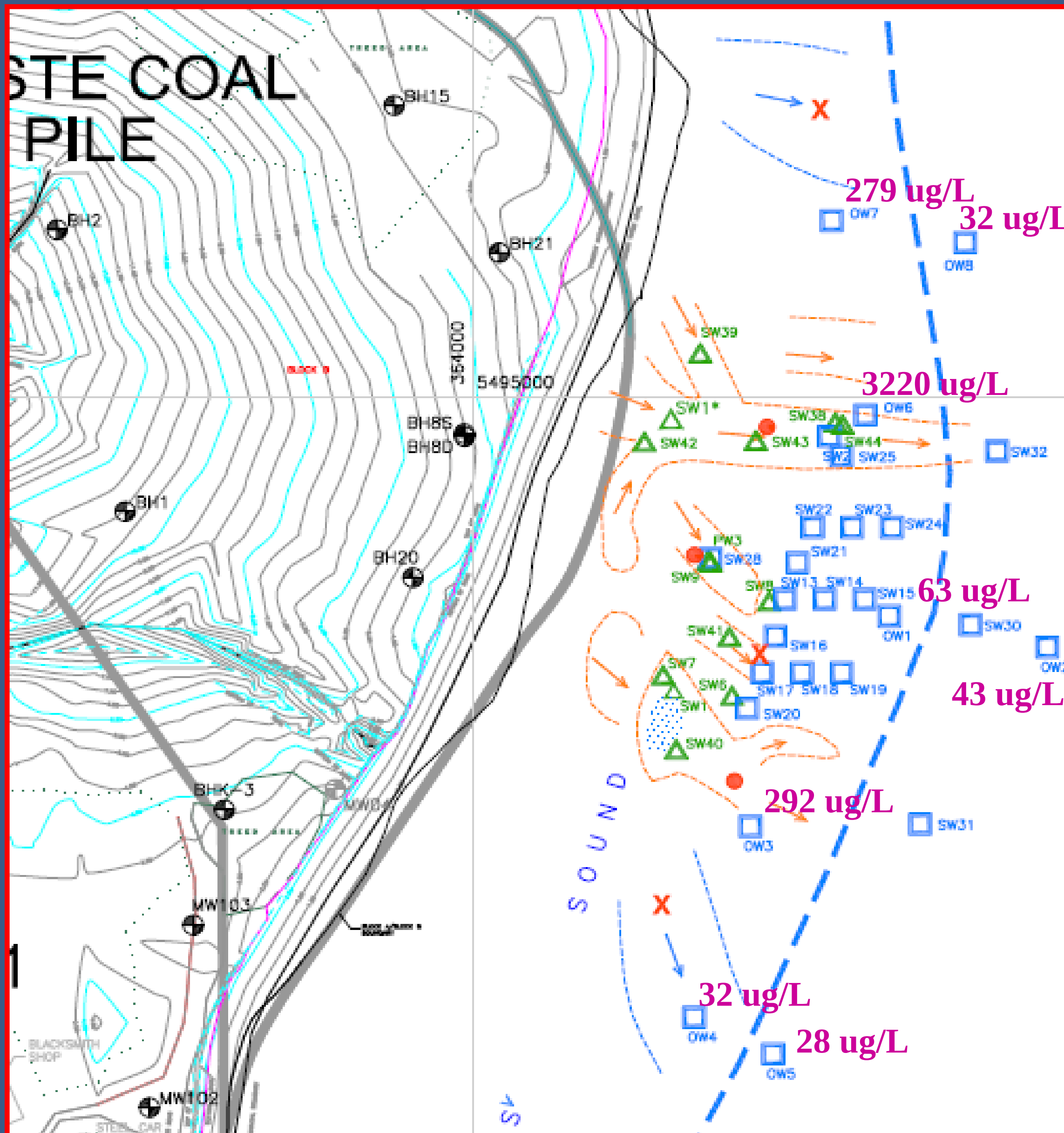
Ocean Water Results – Feb 2006



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Coastal Dispersion Modeling

- Surface water dispersion model (Lam et al., 1994) used to examine behavior of Fe in Baynes Sound
  - Used to identify distance from and along shoreline from seepage discharges with Fe concentrations > 300 ug/L

Table A. Results of coastal dispersion model runs at Union Bay.

Parameter	Run 1	Run 2	Run 3
M_o (µg/s)	629,000	629,000	629,000
k (1/s)	0.00019	0.00019	0.00019
u (m/s)	0.01	0.1	1
E_z (m^2/s)	0.6	0.6	0.6
E_x (m^2/s)	0.2	0.2	0.2
D_x^a (m)	<50	<100	<100
D_z^b (m)	<100	<50	<50

[a] Distance from shoreline (m) at which dissolved iron water column concentration falls below 300 µg/L.

[b] Distance along shoreline (m) from the point of release at which dissolved iron water column concentration falls below 300 µg/L.

  - Model results indicate rapid reduction of Fe concentrations within 50-100 m from point of discharge (in all directions)
  - Close agreement between sampling results and model results

Lam, DCL, Murthy, CR and Simpson, RB. 1984. Effluent Transport and Diffusion Models for the Coastal Zone (Lecture Notes of Coastal and Estuarine Studies, 5). Springer-Verlag, New York, NY. 168 pp.

Phase 2 Conclusions

- Groundwater discharge occurs primarily within the top 1 metre of saturated materials
- Seawater intrusion and mixing with groundwater is highly variable but causes approximately 90% dilution at the pile perimeter on a net annual basis
- Seep flowrate from SW9 and SW11 (combined) is about 6% of the observed seepage discharge
- Groundwater discharge at north side of the pile is approximately twice as high as the east side
- In general, dissolved iron is inversely proportional to chloride concentrations

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Remediation/Reclamation Plan

- Waste coal in 4 different zones:
  - Main pile (reclamation)
  - Hart Creek deposit (rechannelling)
  - Intertidal Zone deposit (no action)
  - Subtidal deposit (no action)

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Remediation Plan

- Barrier wall installation around perimeter
- Contaminated soil relocation to pile
- Low permeability cover to reduce infiltration
- Groundwater and leachate treatment as part of ongoing sewage management

Hart Creek Realignment

- 2006 – Hart Creek realigned to reduce erosion of Waste Coal Pile into estuary

Conclusions

- Groundwater concentrations beneath the pile are expected to remain highly variable
- Seepage flow rates are not expected to be significantly reduced
- Seep locations and discharge characteristics may change over time
- To assess future loadings in a meaningful way, data must be evaluated based on net annual trends as opposed to isolated monitoring events so that short term variability is kept within context

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Conclusions

- Permanent remedial solution for Waste Coal Pile
- Greater than 90% reduction in annual contaminant loadings to the environment are expected
- Barrier wall insurable, reduces leachate migration to foreshore
- Deep soil mixing technology is proven on Vancouver Island and elsewhere for improving soil stability
- Post-remedial development will provide economic opportunities for local community

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Thank You

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