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Application of Site Specific Risk Assessment and Risk Based Novel Remediation Action Plan At Salt Impacted Sites

SMA Environmental Forum 2018

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October 18, 2018

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Saskatchewan Orphan Well and Facility Liability Management

- Introduced in 2007, Liability Management Program (LMP) pays for wells and facilities where owners have gone defunct.
- Uses Security Deposit system
- Where inadequate security exists, annual levy, paid for solely by oil and gas licensee, pays for the shortfall

$$LLR = \frac{Deemed\ Asset}{Deemed\ Liability} = \sum \frac{OE\ m^3 \text{ x } Industry\ Net\ Back \text{ x } 3\ year}{(Abandonment + Reclamation\ cost) \text{ x } PVS}$$

÷

< 1 → $$$

For defunct licensee with inadequate security deposit

$$Soley\ Industry\ Funded\ Orphan\ Levy = Cleanup \times \frac{Company\ Deemed\ Liability}{Industry\ Deemed\ Liability}$$

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Redwater Case

- Redwater Energy Corp., a small Alberta oil and gas producer went into bankruptcy in 2015
- Months before bankruptcy, Redwater secured a loan from Alberta Treasury Branches (ATB).
- Redwater defaulted on loan payments, ATB applied to the court to appointed receiver to liquidate their assets.
- Receiver applied Albert a Energy Regulator (AER) to sell (transfer the license) Redwater's best wells (20 wells) while leaving the remainder (71 wells) for the Orphan Levy to pay for the clean up.

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Court Case

- Leaving cost of clean up of 71 unsellable wells to the Orphan Levy sets a precedent where secured creditors would be repaid before the environmental cleanup costs were covered. This position is supported by the *Canada Bankruptcy and Insolvency Ac*t.
- On the other side, AER has regulatory support to restrict receiver from transfer license (selling) just the “best wells” unless they put a security deposit or reclaim the non-sellable well.
- Saskatchewan Wells and Facility Total Deemed Liability is $4.37B.
- Actual liabilities may be much greater as liabilities are calculated on deemed values, assumes that turn-key reclamation cost of a well is <$25K.

Courts Decision

- On May 17, 2016, the Alberta Court of Queen’s Bench released its decision siding with the receiver:
  - Receiver permitted to renounce unsellable assets
  - Receiver cannot be considered a licensee
  - Receiver cannot be forced to assume liabilities on unsellable assets
  - Receiver cannot be bound by reclamation orders
  - AER cannot to refuse the asset transfer application
- On April 24, 2017, in a 2-1 ruling, the Alberta Court of Appeal upheld the lower court’s decision.
- On February 15, 2018 appeal hearing is held by Supreme Court of Canada, decision is pending

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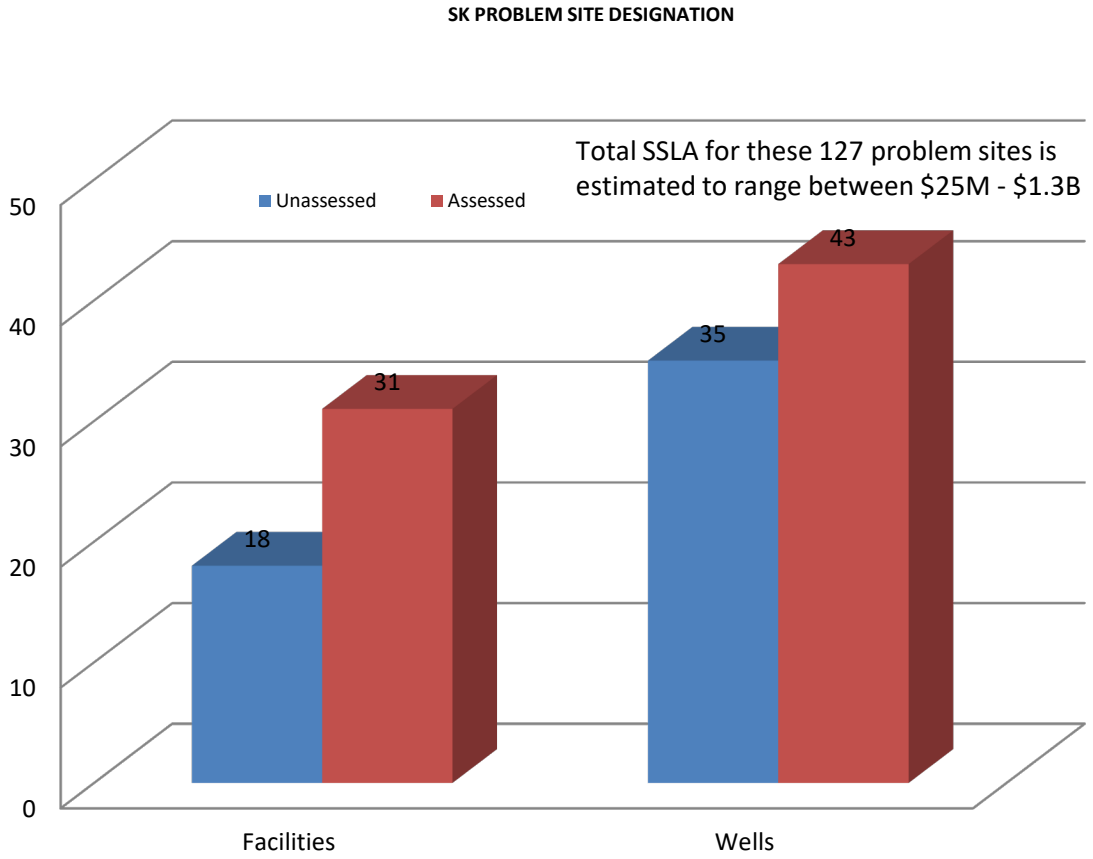
Site Specific Liability Assessment (SSLA)*:

- SSLA consists of a stand-alone PI, PII ESA and SSLA report.
- SSLA details true cost estimate of various applicable remediation options and remediation schedule.
- Must include a full remediation cost (background or Tier 1).
- Track accurate liabilities under the LLR program to protect the Orphan Fund.
- SSLA site remediation costs ranges from $200K to over tens of millions of dollars per site.
- Nearly all of the SSLA site's Contaminant of Concern is chloride associated with produced water.



*Based on draft document

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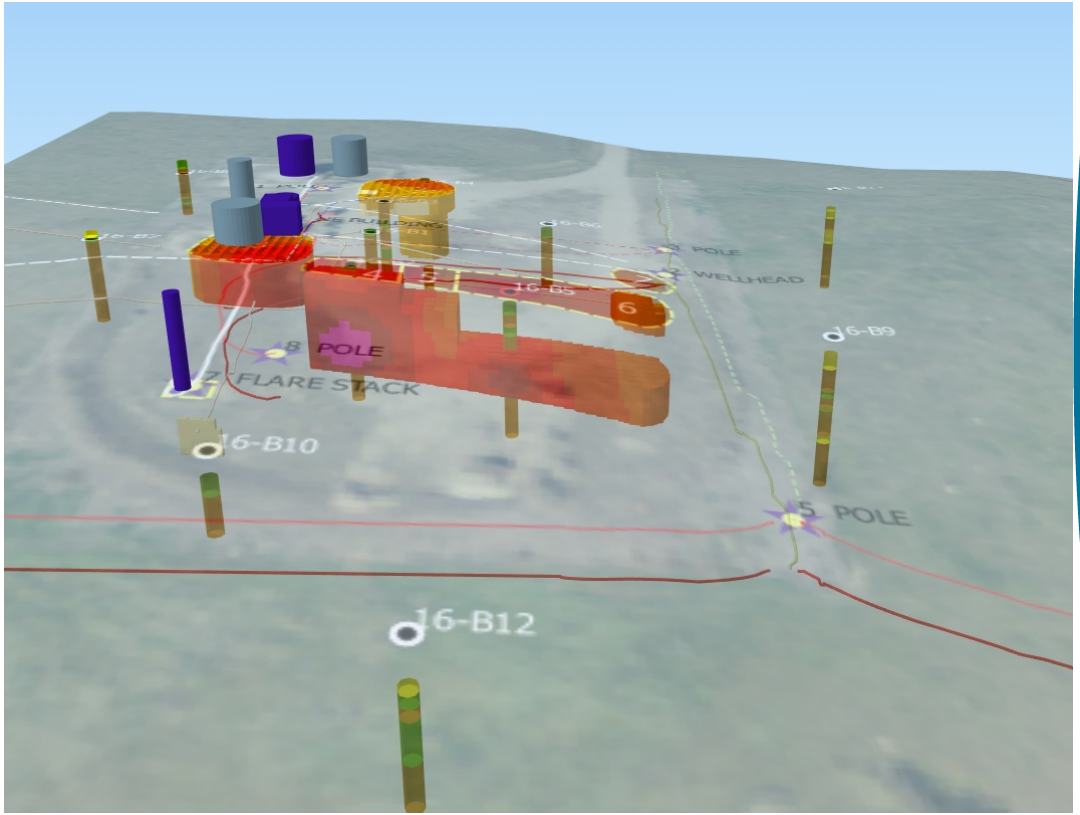
Site Specific Risk Assessment (SSRA)

- Protects applicable site specific receptors and prevent unnecessary work
- Provide high level of certainty on permanency of the remediation work
- Compatible with existing and active operations
- Reduced environmental footprint of ex-situ remediation, landfill space, traffic, GHG and topsoil and subsoil borrow area



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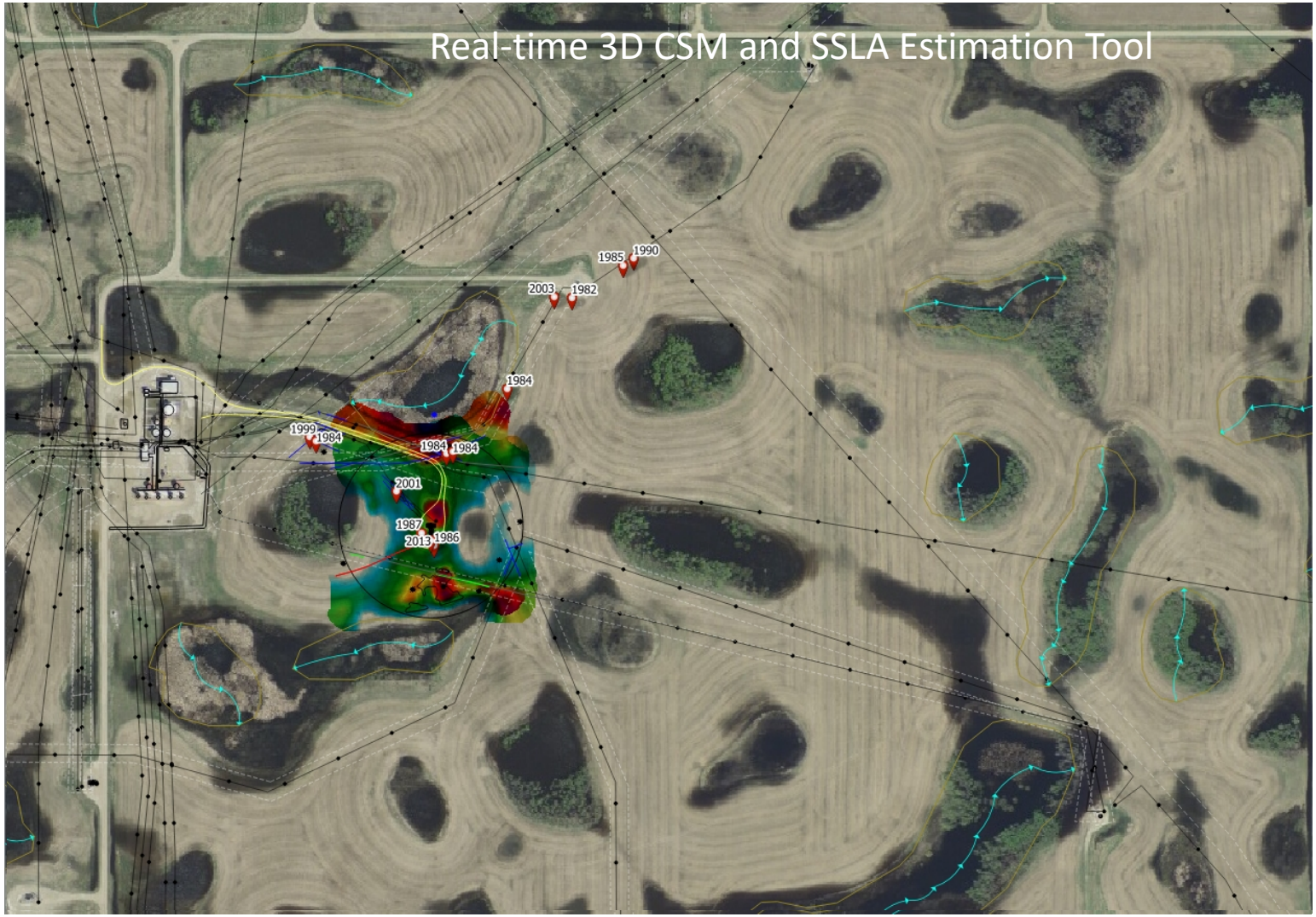
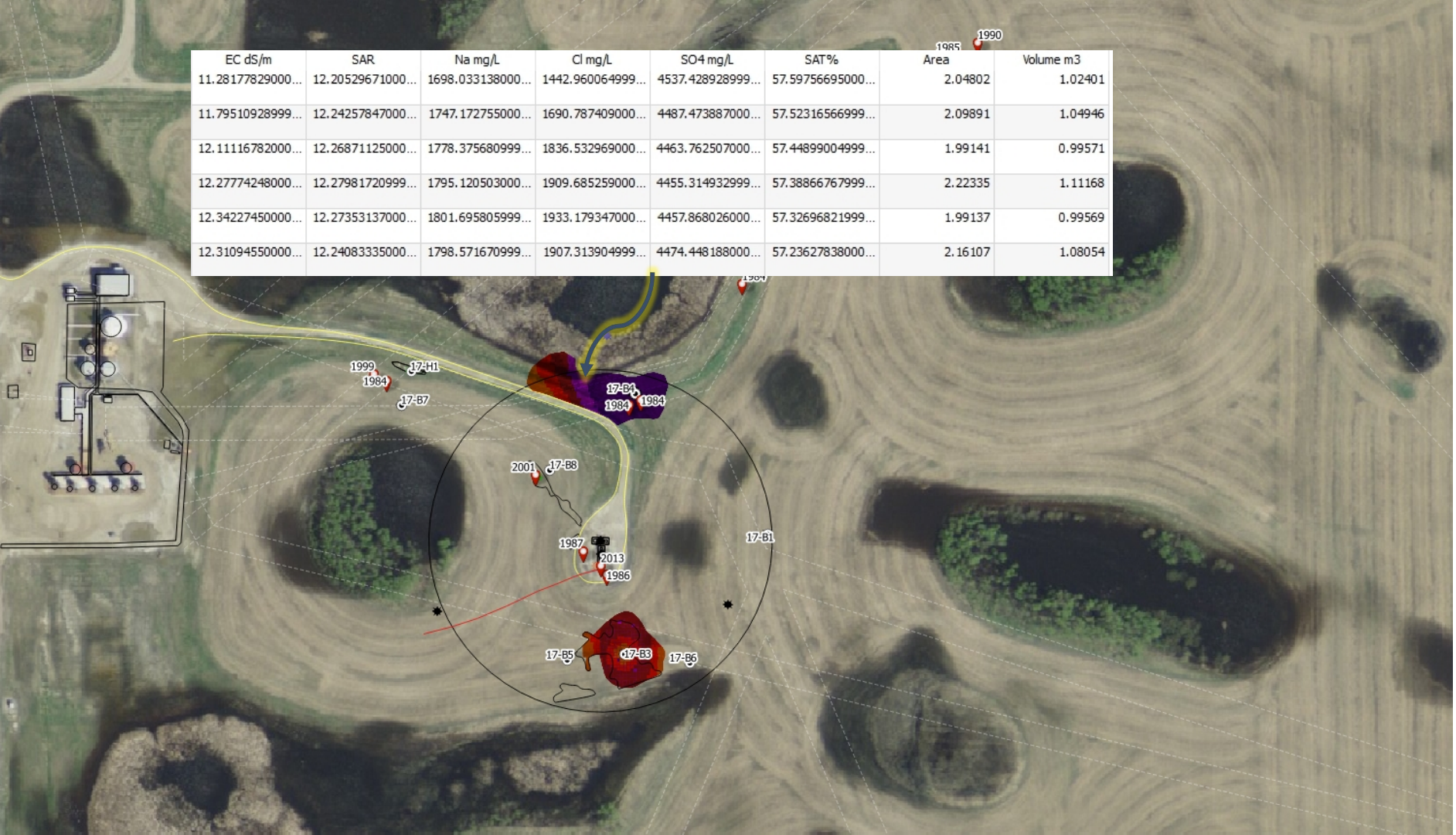
Real-time 3D CSM and SSLA Estimation Tool

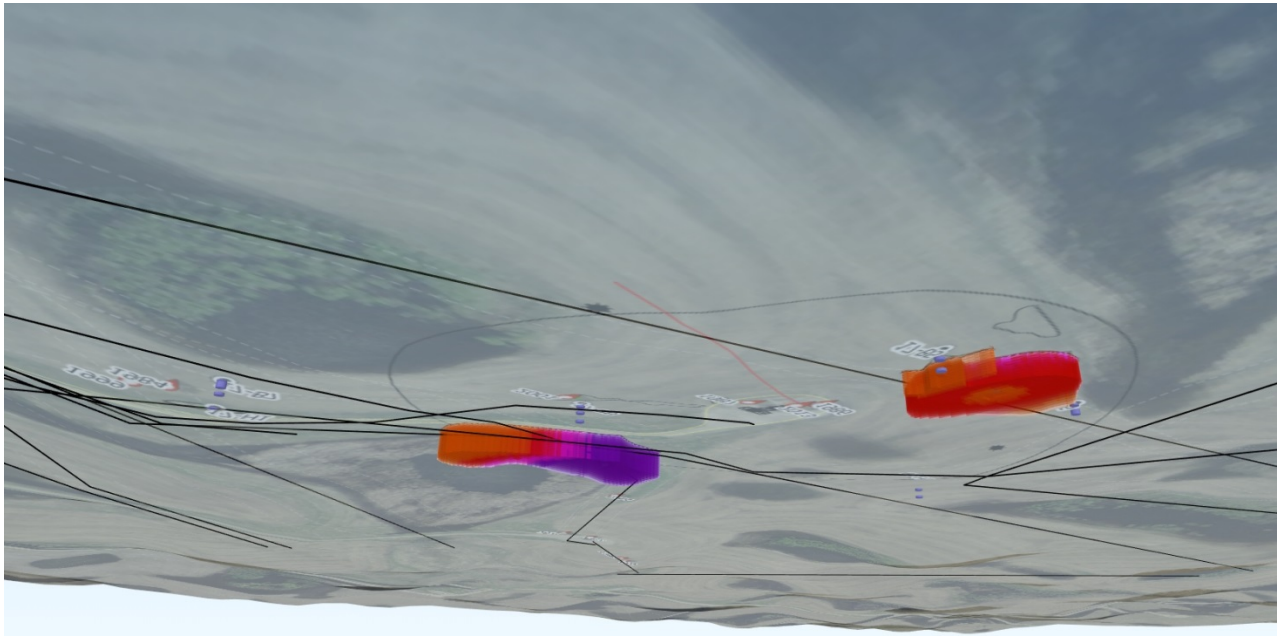


- Improved accessibility and organization of PI ESA information to construct a conceptual site model that assist in rapidly developing a defensible and representative PII ESA
- All information organized in this process can be viewed from GIS interface and incorporated into in proceeding modeling and analytical work

EC dS/m	SAR	Na mg/L	Cl mg/L	SO4 mg/L	SAT%	Area	Volume m3
11.28177829000...	12.20529671000...	1698.033138000...	1442.960064999...	4537.428928999...	57.59756695000...	2.04802	1.02401
11.79510928999...	12.24257847000...	1747.172755000...	1690.787409000...	4487.473887000...	57.52316566999...	2.09891	1.04946
12.11116782000...	12.26871125000...	1778.375680999...	1836.532969000...	4463.762507000...	57.44899004999...	1.99141	0.99571
12.27774248000...	12.27981720999...	1795.120503000...	1909.685259000...	4455.314932999...	57.38866767999...	2.22335	1.11168
12.34227450000...	12.27353137000...	1801.695805999...	1933.179347000...	4457.868026000...	57.32696821999...	1.99137	0.99569
12.31094550000...	12.24083335000...	1798.571670999...	1907.313904999...	4474.448188000...	57.23627838000...	2.16107	1.08054



Near instant 3D Conceptual Site Model Visualization output viewed under popular web browsers



Excavation Depth	Volume each Layer[1]	Estimated Salt Mass		
from surface to m bgs	(m^3)	in each of the Layer[1]		
		(t)		
		Na	Cl	SO4
6.5 - 7.0	925.1	1.276	1.776	2.720
6.0 - 6.5	925.1	1.278	1.785	2.714
5.5 - 6.0	923.8	1.278	1.795	2.701
5.0 - 5.5	923.8	1.281	1.807	2.692
4.5 - 5.0	925.9	1.289	1.822	2.692
4.0 - 4.5	925.9	1.293	1.839	2.679
3.5 - 4.0	932.1	1.308	1.861	2.694
3.0 - 3.5	932.1	1.313	1.883	2.677
2.5 - 3.0	932.1	1.318	1.905	2.658
2.0 - 2.5	933.4	1.325	1.929	2.644
1.5 -2.0	933.4	1.329	1.950	2.624
1.0 - 1.5	933.4	1.332	1.968	2.606
0.5 - 1.0	934.4	1.335	1.984	2.596
0.2 - 0.5	560.6	0.802	1.199	1.551
0.0 - 0.2	374.2	0.536	0.804	1.032
Total	13015.4	18.3	26.3	37.3

SSLA Contaminated Salt Mass Quantification

	TOTAL SSLA VOLUME				SSLA VOLUME SPIGEC 4 CRITERIA				SSLA VOLUME ROOTING ZONE SPIGEC 4			
Depth	Volume	Na (t)	Cl (t)	SO4 (t)	Volume	Na (t)	Cl (t)	SO4 (t)	Volume	Na (t)	Cl (t)	SO4 (t)
-7	541.1	0.6	1.2	0.9	449.4	0.5	1.1	0.7	0.0	0.0	0.0	0.0
-6.5	541.1	0.6	1.2	0.9	448.5	0.5	1.1	0.7	0.0	0.0	0.0	0.0
-6	541.1	0.6	1.2	0.9	448.5	0.5	1.1	0.7	0.0	0.0	0.0	0.0
-5.5	541.1	0.6	1.2	0.9	447.7	0.5	1.1	0.7	0.0	0.0	0.0	0.0
-5	541.1	0.6	1.2	0.9	447.7	0.5	1.1	0.7	0.0	0.0	0.0	0.0
-4.5	925.9	1.3	1.8	2.7	832.5	1.2	1.7	2.4	0.0	0.0	0.0	0.0
-4	932.1	1.3	1.9	2.7	838.7	1.2	1.8	2.5	0.0	0.0	0.0	0.0
-3.5	932.1	1.3	1.9	2.7	838.7	1.2	1.8	2.4	0.0	0.0	0.0	0.0
-3	932.1	1.3	1.9	2.7	838.7	1.2	1.8	2.4	0.0	0.0	0.0	0.0
-2.5	933.4	1.3	1.9	2.6	839.0	1.2	1.8	2.4	0.0	0.0	0.0	0.0
-2	933.4	1.3	1.9	2.6	839.0	1.2	1.8	2.4	0.0	0.0	0.0	0.0
-1.5	933.4	1.3	2.0	2.6	837.9	1.2	1.9	2.4	837.9	1.2	1.9	2.4
-1	934.4	1.3	2.0	2.6	838.1	1.2	1.9	2.4	838.1	1.2	1.9	2.4
-0.5	560.6	0.8	1.2	1.6	502.3	0.7	1.1	1.4	502.3	0.7	1.1	1.4
0	374.2	0.5	0.8	1.0	334.4	0.5	0.8	0.9	334.4	0.5	0.8	0.9
Grand Total	**11,097**	15.0	23.5	28.4	**9,781**	13.6	22.1	25.1	**2,513**	3.7	5.6	7.0

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Real-time Cost Estimates

FULL REMEDIATION with Compacted Clay Replacement	Calculated Estimates	Reference
	Total Unit cost per m3	Total Unit cost per m3
Project Coordination & Management	$12.63	$12.00
Ground Disturbance Preparation	$3.62	$2.66
Site Stripping and Top Soil Salvage	$5.79	$4.25
Overburden or Salvage Soil Excavation	$15.73	$13.77
Impacted Soil Excavation, Hauling and Disposal	$40.26	$38.26
BackFill	$17.32	$16.28
Site Restoration	$6.95	$5.11
Laboratory Analysis (Confirmatory Sampling)	$0.58	$0.55
TOTAL	$102.88	$92.88

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Input interface integrated default values or ability change any values

Descriptions	Input	Calculated	Units
Excavation Volumes			
Impacted Soil Excavation Volume	13015.40	13015.40	cubic metres
Surface Area stripped	1870	1,870.00	Square metres
Overburden Subsoil- Excavated and Salvaged On Site	0	0.00	cubic metres
Topsoil -Total Volume Excavated	d	561.00	cubic metres
Topsoil- Excavated Volume Not Impacted-Salvaged	0	0.00	cubic metres
Ground Disturbance Preparation	2.00	2	$CDN
Site Stripping and Top Soil Salvage	0	0	$CDN
Overburden or Salvage Soil Excavation	d	15.73125899	$CDN
Excavation Equipment Cost			
Excavation Equipment Average Cost/hr	d	160.00	$CDN
Excavation Operator Avg cost/hour	d	50.00	$CDN
Excavation (Admin/Foreman/Year/Tear/OT Avg/hr)	d	25.00	$ CDN
Calculated Excavation Cost/Volume of excavated impacted soil		16.11	$CDN/m3
Non Default Value Co-efficient (Do Not Remove)		1.000	
Landfill Hauling and Disposal			
Distance to Waste Disposal Facility	77	77	kilometres
Average Hauling Speed	100	100	kilometres/hour
Loading Time	0.2	0.2	hour
Unloading Time	0.2	0.2	hour
Hauling Time		1.17	hour
Truck Haul Capacity per Load	d	13	cubic metres
Trucking Cost	d	145	$CDN
Tipping Fee	d	13	$CDN/cubic metres
Backfill Imported Material Volume			
Backfill-Import -Topsoil	d	561.00	cubic metres
Backfill-Import -Subsoil	d	15,920.22	cubic metres
Backfill-Import-Sand (only applies to Rooting zone remediation area"0.1m)		0.00	cubic metres
Backfill-Import-Geotextile(only applies to Rooting zone remediation area)		0.00	square metres
Backfilling (place in lifts, compact and contour) (Subsoil engineered system (RZ) i	d	17.32	$CDN
Calculated Backfilling hauled in material		6.78	$CDN/m3
Backfill Cost Table (for each fill type), hauling			
Site Restoration	d	6.953951299	$CDN
Project Coordination & Management	6	6	$CDN
Work plan development	d	5%	percent (please input as decim
Project Coordination and Project Management	d	15%	percent (please input as decim
Client, Regulator and Landowner consultations and updates, H&S Obligations, Kick-off meetings	d	5%	percent (please input as decim
Data Acquisition, Management and IT (Lab analyses, GIS and IT)	d	8%	percent (please input as decim
Engineering, Design and Technical Analysis	0.12	12%	percent (please input as decim
Final Report	0.15	15%	percent (please input as decim
Field Work (Sample,Monitor,Supervise,Audit, Per Diem, Accommodation, Equipment, Mileage)	0.4	40%	percent (please input as decim
		100%	
		Sum equals 100%, good job!	
Project Coordination & Management			
Average Cost per hour	d	130	$CDN
Laboratory			
Laboratory Analysis (Confirmatory Sampling) Cost	3	3	$CDN

Instant Output – Detail SSLA Remediation Cost Details

Rooting Zone Remediation Costs (SPIGEC 4 Applied)

ROOTING ZONE	Unit Price	Hours/Otherwise specified	Cost ($CDN)
Project Coordination & Management			
Work Plan Development	5% of $130	18.39	$2,390.53
Project Coordination and Project Management	10% of $130	36.78	$4,781.06
Client, Regulator and Landowner consultations and updates, H&S Obligations, Kick-off meetings	5% of $130	18.39	$2,390.53
Data Acquisition, Management and IT (Lab analyses, GIS and IT)	8% of $130	29.42	$3,824.85
Engineering, Design and Technical Analysis	17% of $130	62.52	$8,127.80
Final Report	15% of $130	55.17	$7,171.59
Field Work (Sample,Monitor,Supervise,Audit, Per Diem, Accommodation, Equipment, Mileage)	40% of $130	147.11	$19,124.23
Laboratory			
Laboratory Analysis (Confirmatory Sampling)	$3.00/m3 of ISE		$7,542.00
Ground Disturbance			
Ground Disturbance Preparation (calculated on total excavation volume)	$2.00/m3 of ISE		$5,028.00
Site Stripping and/or Top Soil Salvage			
Excavation, Earth Moving, Liner, Segregation, Storage	$235/hour	0.00	$0.00
Overburden or Salvage Soil Excavation			
Excavation, Earth Moving, Liner, Segregation, Storage	$235/hour	0.00	$0.00
Impacted Soil Excavation, Hauling and Disposal			
Hauling	$145/hour	226.26	$32,807.70
Landfill Disposal	$13/m3	2,514.00 m3	$32,682.00
Excavation	$235/hour	259.50	$60,981.35
Factors used:			
Distance from site to landfill: [redacted]	77 km		
Average speed velocity	100 km/hour		
Total hauling time per load*	1.17 hour/load		
*sum of loading, unloading and hauling	0.2 hour	0.2 hour	0.77 hour
Truck payload capacity	13 m3		
Backfill			
Topsoil	$12.31/m3	502.8 m3	$6,189.47
Clay (impermeable subsoil backfill)	$1.99/m3	3,075.08 m3	$6,119.42
Sand (Rooting zone engineered capillary cut-off)	$7.69/m3	167.6 m3	$1,288.84
Geotextile (Rooting zone engineered system)	$1.09/m2	1,676. m2	$1,820.86
Hauling	$48.62 /load	322.01	$18,395.87
Fill in lifts, moisturize, compact	$235/hour	345.87	$81,280.35
Assumption factor used:			
Backfill volume is greater than excavated volume as imported fill materials will be compacted in the excavation to prevent subsidence and resist recontamination	backfill dry bulk density ~1370 kg/m3	compaction to maxium dry bulk density ~1677 kg/m3 at optimum moisture ~21%	disposed volume *1.2232
Hauling cost based on borrow site to project site to be within:	20 km		
Restoration			
Site Restoration (Topsoil placement, contour, drainage, amendments, vegetation)	$10.47/m3 of ISE		$26,327.27
TOTAL			**$328,273.71**

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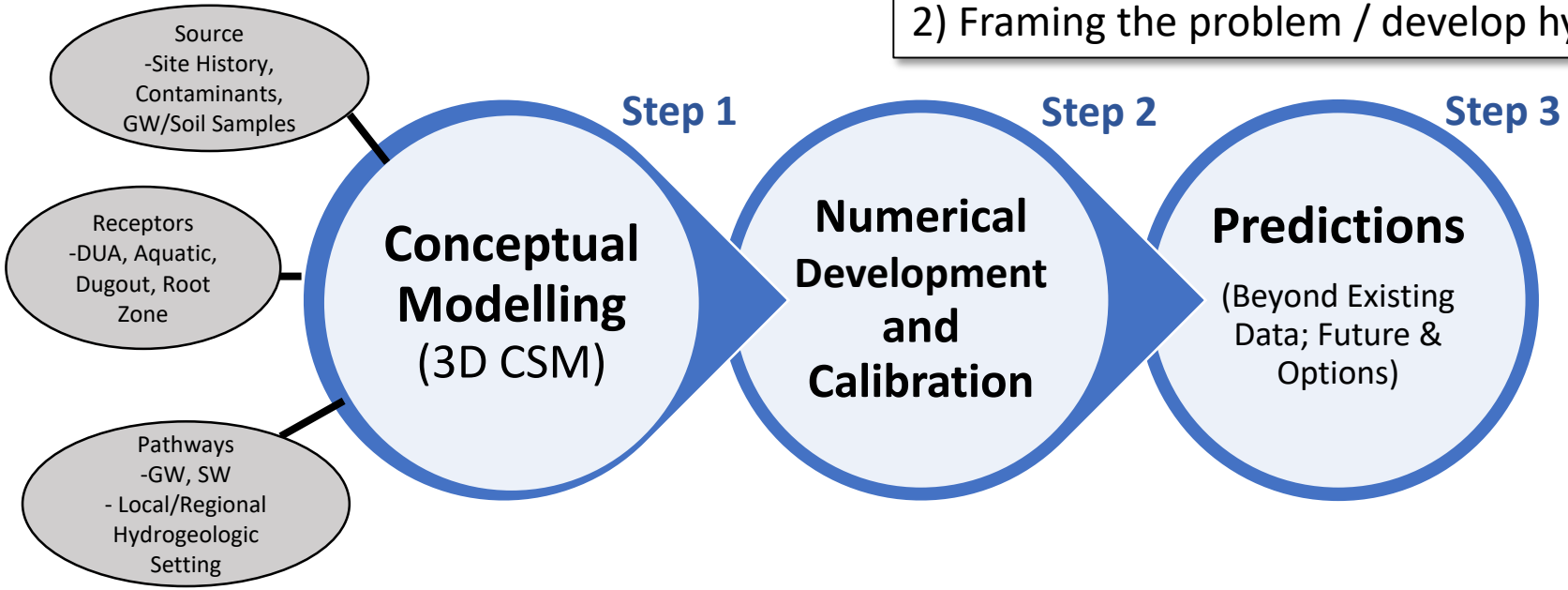
Modelling Workflow - CSM

1) Understanding derived from available data
2) Framing the problem / develop hypotheses



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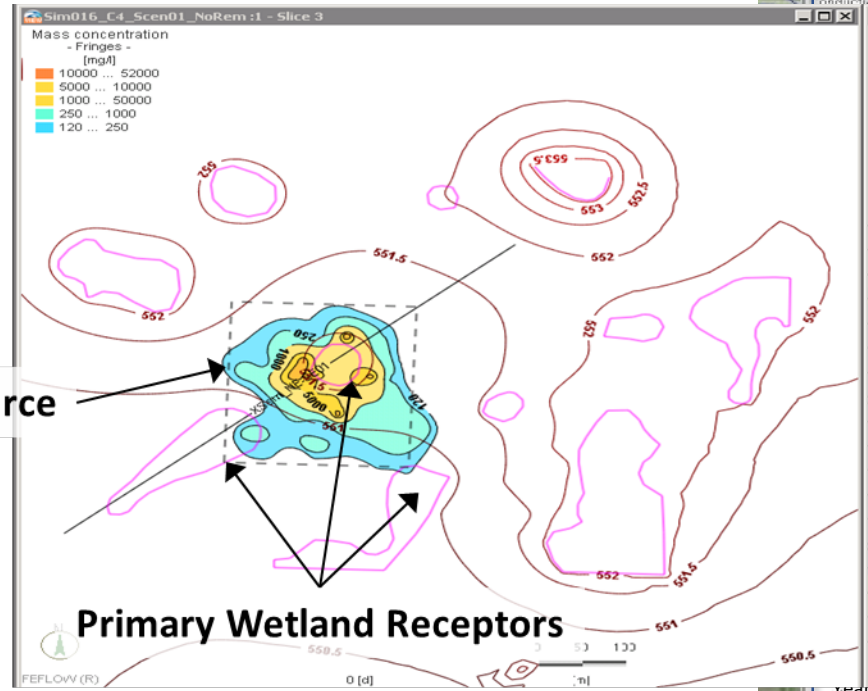
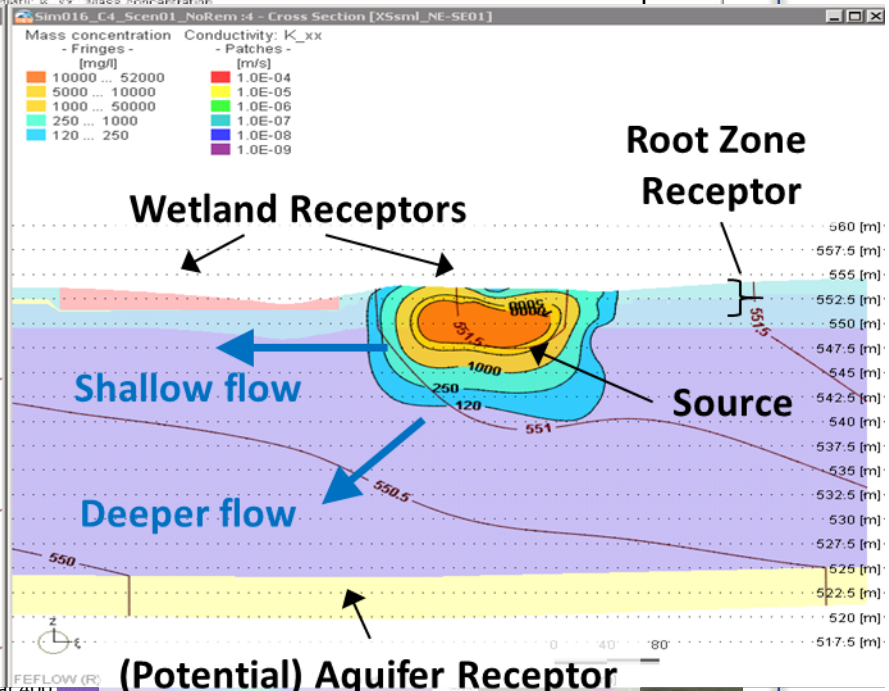
Numerical Models





*Based on draft documents.

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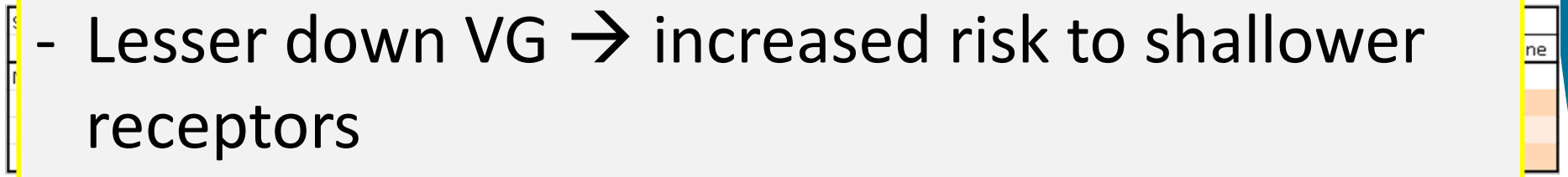
Uncertainty – Numerical Model

Test different interpretations and assumptions.

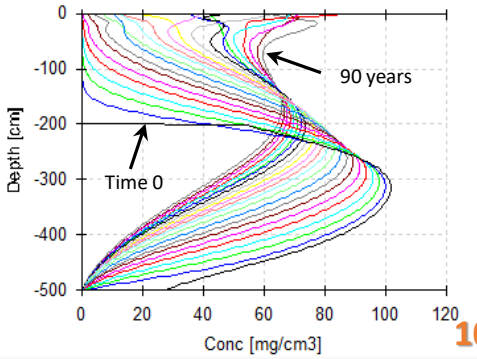
Conservative with respect to assessing risk to receptor:

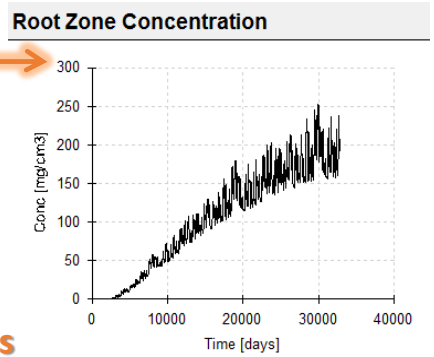
- Greater down VG → increased risk to deeper receptors
- Lesser down VG → increased risk to shallower receptors

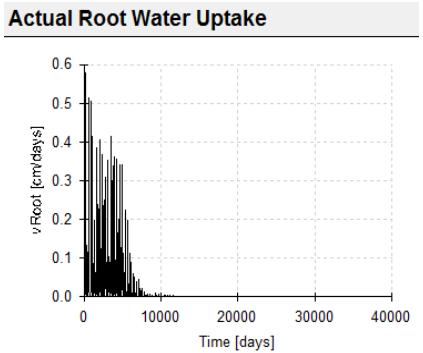


Lighter orange – near guideline; Darker orange – well beyond guideline

Sodium chloride contaminated soil excavation to 2m bgs

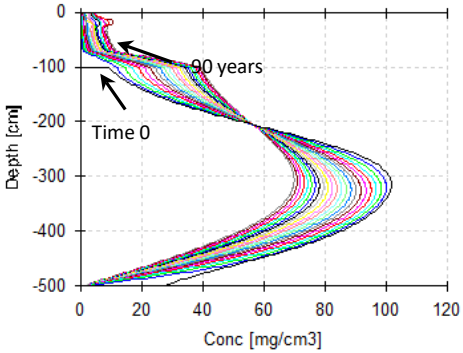


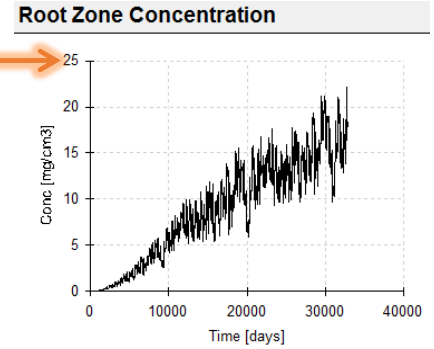


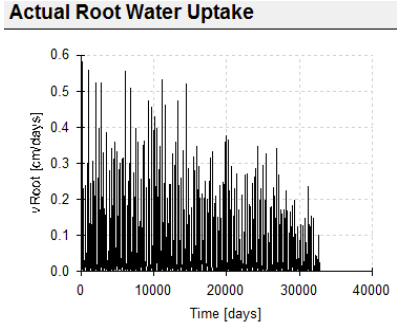


10X less

Sodium chloride contaminated soil excavation to 1m bgs and install 30 cm capillary-cut off layer







Remediation Scenarios Model Comparison

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Remediation Scenario Modeled Crop Productivity

Simulated Transpiration (mm/year over 90 year simulations)

	Grass		Alfalfa		Beans	
Full remediation	223.2	100%	223.6		235.2	100%
No remediation	16.2	7%	32.8	15%	23.7	10%
1m excavation + cut off layer	190.2	85%	240.5	108%	219.5	93%
1.5m excavation + cut off layer	190.5	85%	259.4	116%	218.4	93%

30 cm capillary cut-off sand layer equivalent installed

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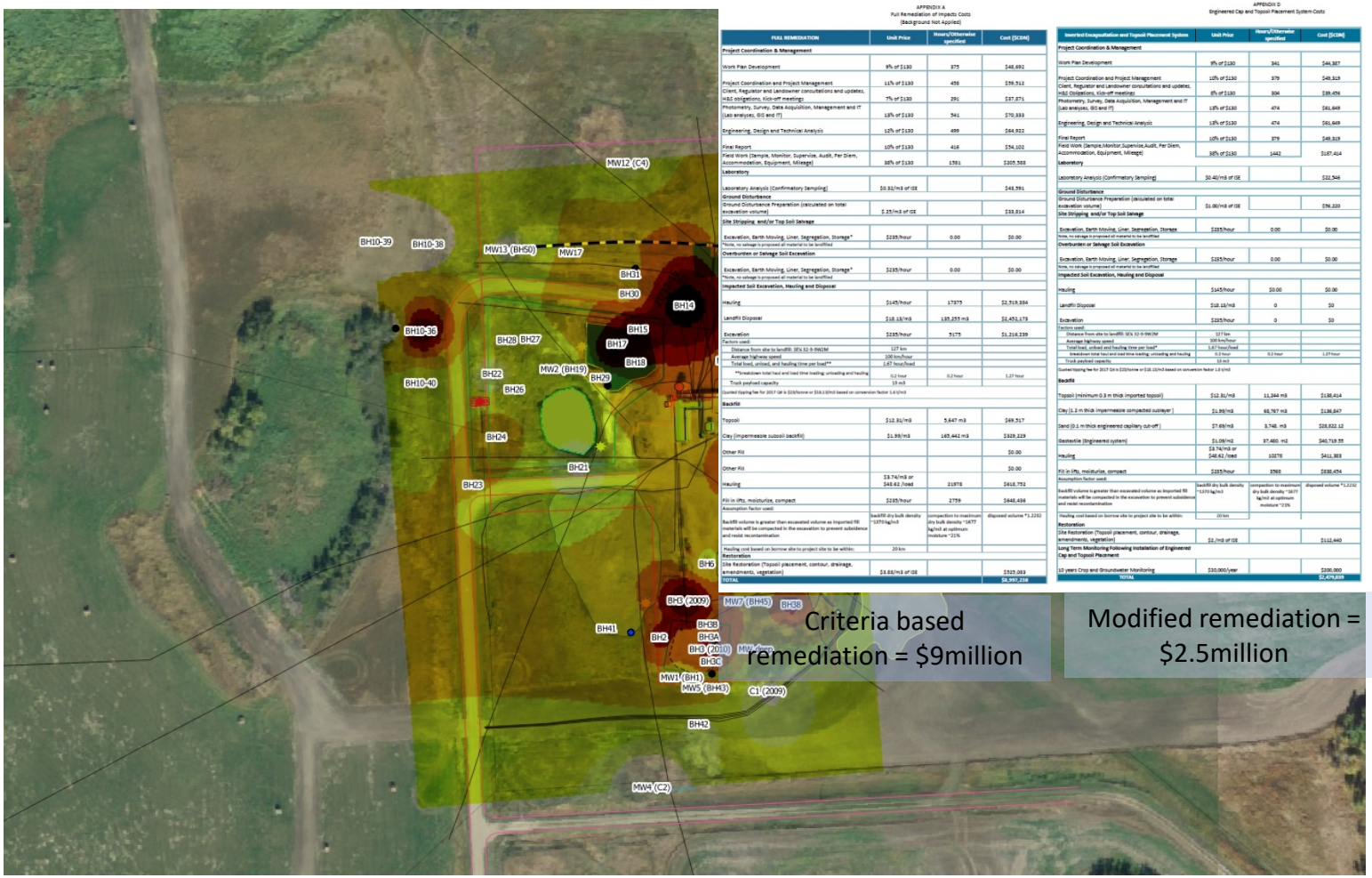
Applying the process to a Complex Active Facility



APPENDIX A
Full Remediation of Impacts Costs
(Background Not Applied)

FULL REMEDIATION	Unit Price	Hours/Otherwise specified	Cost ($CDN)
Project Coordination & Management			
Work Plan Development	9% of $130	375	$48,692
Project Coordination and Project Management	11% of $130	456	$59,312
Client, Regulator and Landowner consultations and updates, H&S obligations, Kick-off meeting)	7% of $130	291	$37,871
Photometry, Survey, Data Acquisition, Management and IT (Lab analyses, GIS and IT)	13% of $130	541	$70,333
Engineering, Design and Technical Analysis	12% of $130	499	$64,922
Final Report	10% of $130	416	$54,102
Field Work (Sample, Monitor, Supervise, Audit, Per Diem, Accommodation, Equipment, Mileage)	38% of $130	1581	$205,568
Laboratory			
Laboratory Analysis (Confirmatory Sampling)	$0.32/m3 of ISE		$43,591
Ground Disturbance			
Ground Disturbance Preparation (calculated on total excavation volume)	$.25/m3 of ISE		$33,914
Site Stripping and/or Top Soil Salvage			
Excavation, Earth Moving, Liner, Segregation, Storage*	$235/hour	0.00	$0.00
*Note, no salvage is proposed all material to be landfilled			
Overburden or Salvage Soil Excavation			
Excavation, Earth Moving, Liner, Segregation, Storage*	$235/hour	0.00	$0.00
*Note, no salvage is proposed all material to be landfilled			
Impacted Soil Excavation, Hauling and Disposal			
Hauling	$145/hour	17875	$2,519,884
Landfill Disposal	$18.18/m3	135,255 m3	$2,452,179
Excavation	$235/hour	5175	$1,214,239
Factors used:			
Distance from site to landfill: SEV.32-9-9W2M	127 km		
Average highway speed	100 km/hour		
Total load, unload, and hauling time per load**	1.67 hour/load		
**breakdown total haul and load time loading, unloading and hauling	0.2 hour	0.2 hour	1.27 hour
Truck payload capacity	13 m3		
Quoted tipping fee for 2017 GK is $23/tonne or $18.13/m3 based on conversion factor 1.6 t/m3			
Backfill			
Topsoil	$12.31/m3	5,647 m3	$69,517
Clay (impermeable subsoil backfill)	$1.99/m3	165,442 m3	$329,229
Other Fill			$0.00
Other Fill			$0.00
Hauling	$3.74/m3 or $48.62 /load	21978	$818,752
Fill in lifts, moisturize, compact	$235/hour	2759	$648,436
Assumption factor used:			
Backfill volume is greater than excavated volume as imported fill materials will be compacted in the excavation to prevent subsidence and resist recontamination	backfill dry bulk density ~1970 kg/m3	compaction to maximum dry bulk density ~1677 kg/m3 at optimum moisture ~21%	disposed volume *1.2232
Hauling cost based on borrow site to project site to be within:	20 km		
Restoration			
Site Restoration (Topsoil placement, contour, drainage, amendments, vegetation)	$3.88/m3 of ISE		$525,083
TOTAL			**$8,997,238**

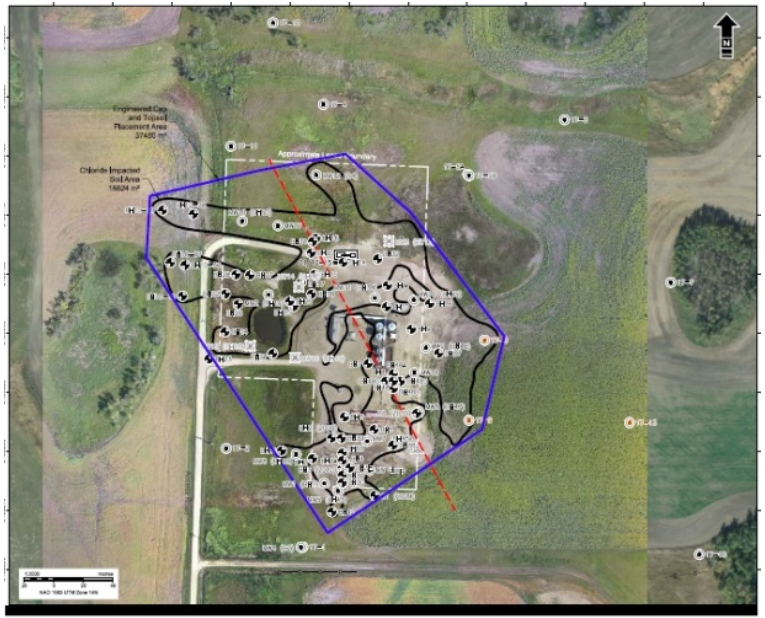
APPENDIX D
Engineered Cap and Topsoil Placement System Costs

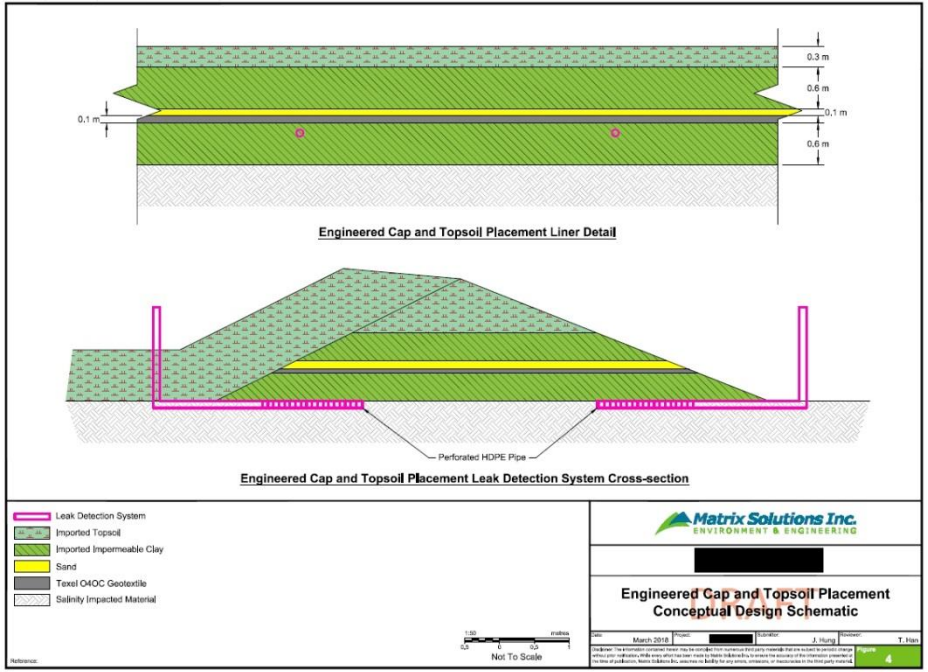
Inverted Encapsulation and Topsoil Placement System	Unit Price	Hours/Otherwise specified	Cost ($CDN)
Project Coordination & Management			
Work Plan Development	9% of $130	341	$44,387
Project Coordination and Project Management	10% of $130	379	$49,319
Client, Regulator and Landowner consultations and updates, H&S Obligations, Kick-off meeting)	8% of $130	304	$39,456
Photometry, Survey, Data Acquisition, Management and IT (Lab analyses, GIS and IT)	13% of $130	474	$61,649
Engineering, Design and Technical Analysis	13% of $130	474	$61,649
Final Report	10% of $130	379	$49,319
Field Work (Sample,Monitor,Supervise,Audit, Per Diem, Accommodation, Equipment, Mileage)	38% of $130	1442	$187,414
Laboratory			
Laboratory Analysis (Confirmatory Sampling)	$0.40/m3 of ISE		$22,546
Ground Disturbance			
Ground Disturbance Preparation (calculated on total excavation volume)	$1.08/m3 of ISE		$56,320
Site Stripping and/or Top Soil Salvage			
Excavation, Earth Moving, Liner, Segregation, Storage	$235/hour	0.00	$0.00
Note, no salvage is proposed all material to be landfilled			
Overburden or Salvage Soil Excavation			
Excavation, Earth Moving, Liner, Segregation, Storage	$235/hour	0.00	$0.00
Note, no salvage is proposed all material to be landfilled			
Impacted Soil Excavation, Hauling and Disposal			
Hauling	$145/hour	$0.00	$0.00
Landfill Disposal	$18.18/m3	0	$0
Excavation	$235/hour	0	$0
Factors used:			
Distance from site to landfill: SEV.32-9-9W2M	127 km		
Average highway speed	100 km/hour		
Total load, unload, and hauling time per load*	1.67 hour/load		
breakdown total haul and load time loading, unloading and hauling	0.2 hour	0.2 hour	1.27 hour
Truck payload capacity	13 m3		
Quoted tipping fee for 2017 GK is $23/tonne or $18.13/m3 based on conversion factor 1.6 t/m3			
Backfill			
Topsoil (minimum 0.3 m thick imported topsoil)	$12.31/m3	11,344 m3	$139,614
Clay (1.2 m thick impermeable compacted subliyer)	$1.99/m3	68,767 m3	$136,847
Sand (0.1 m thick engineered capillary cut-off)	$7.69/m3	3,748 m3	$28,822.12
Geotextile (Engineered system)	$1.09/m2	37,480 m2	$40,718.55
Hauling	$3.74/m3 or $48.62 /load	10278	$411,369
Fill in lifts, moisturize, compact	$235/hour	3760	$838,454
Assumption factor used:			
Backfill volume is greater than excavated volume as imported fill materials will be compacted in the excavation to prevent subsidence and resist recontamination	backfill dry bulk density ~1970 kg/m3	compaction to maximum dry bulk density ~1677 kg/m3 at optimum moisture ~21%	disposed volume *1.2232
Hauling cost based on borrow site to project site to be within:	20 km		
Restoration			
Site Restoration (Topsoil placement, contour, drainage, amendments, vegetation)	$3.7m3 of ISE		$112,440
Long Term Monitoring Following Installation of Engineered Cap and Topsoil Placement			
10 years Crop and Groundwater Monitoring	$20,000/year		$200,000
TOTAL			**$2,479,039**

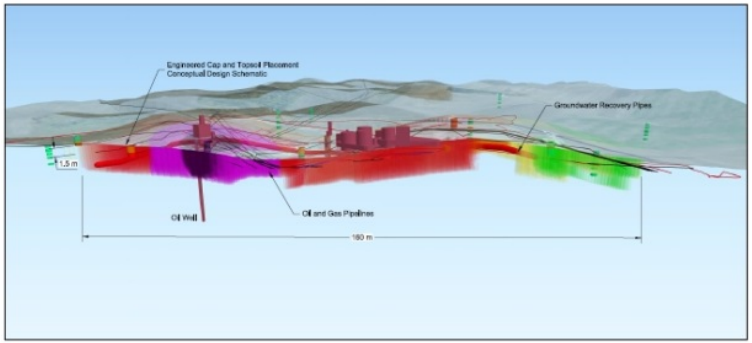
Criteria based remediation = $9million

Modified remediation = $2.5million

Modified System – Engineered Cap







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Summary

- CSM and SSLA tools facilitates in rapidly accessing and analyzing a large set of information (GIS), allows complex concept to be realized into 3D visual models and frees up time and money to focus on acquiring better delineation data, Numerical Modeling and uncertainty analysis, and explore larger numbers of remedial options and calculate the costs in real-time
- All data created from SSLA are geospatial can be used in all future modeling, assessment and analysis
- SSRA protects applicable receptors and prevent unnecessary intrusive excavation work by helping to reduce the environmental footprint of ex-situ remediation, i.e., landfill space, traffic, GHG and topsoil and subsoil borrow area, disturbance to wetlands
- Provides a higher level of certainty on permanency and efficacy of the proposed remediation work (uncertainty analysis)
- Remediation actions take into account compatibility with existing and on-going active operations (pipelines, EOR facilities)
- Currently working with the regulators to develop a site closure through SSRA

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