Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Developing the Insights Required for Informed-Decision-Making at Salt-Impacted Sites

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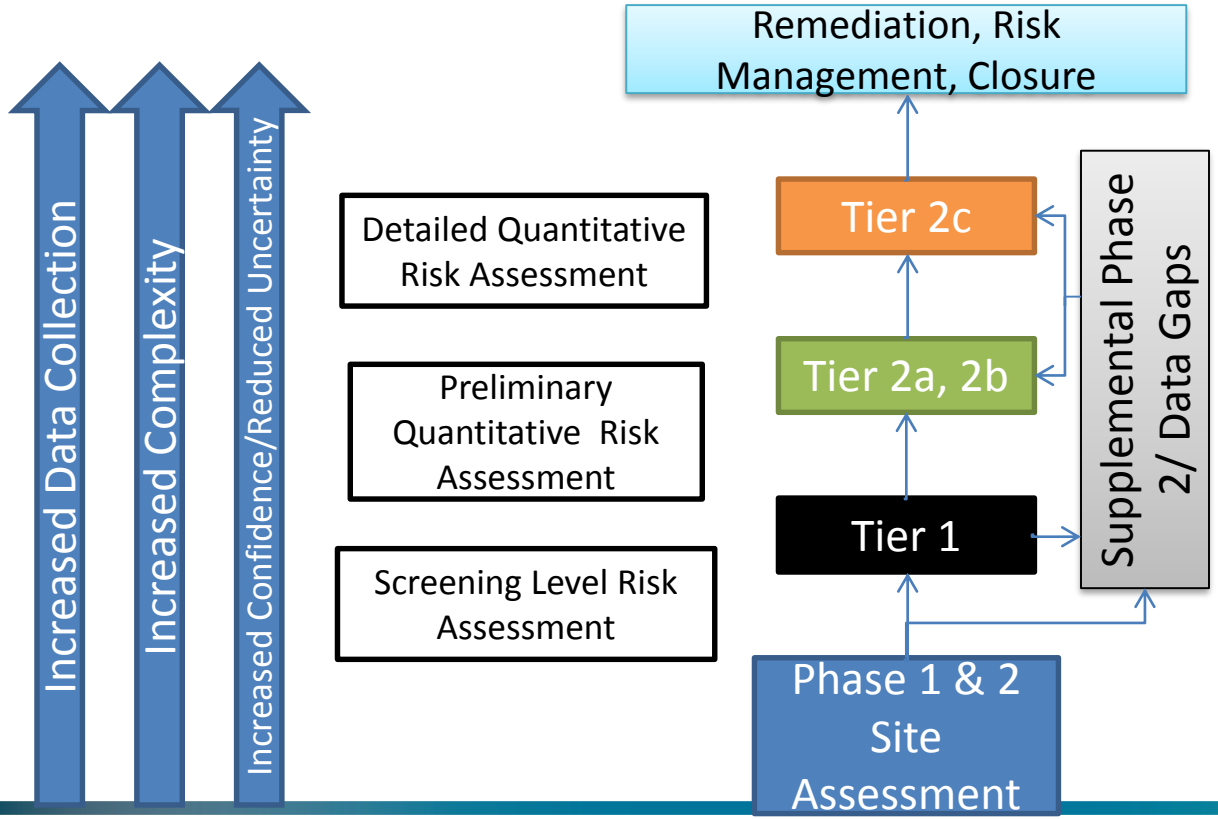
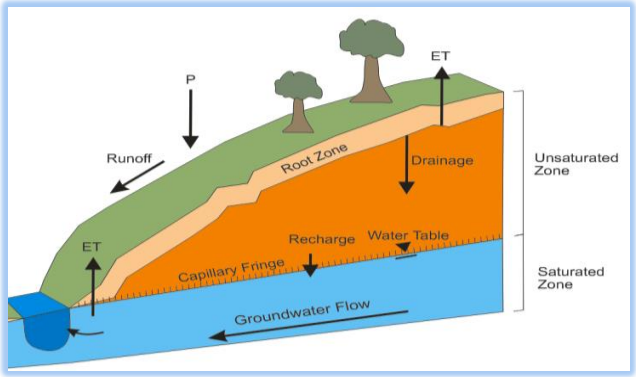
Liability Landscape for Salt Impacted Sites

- All companies under pressure to improve operations, and find more cost-effective solutions for remediation and to reduce liability
- Legacy salt sites are large and require more site-specific approaches
- Tier 1 Generic Remediation Guidelines result in large excavation volumes
- Tier 2 Modified Remediation Guidelines with SST can reduce volumes but has limitations
- Opportunity for more identifying more balanced remediation and management options:
  - Detailed Site-Specific Risk Assessment employing concepts of Sustainable Remediation supported by 3D numerical modelling

Tiered Approach to Risk Assessment



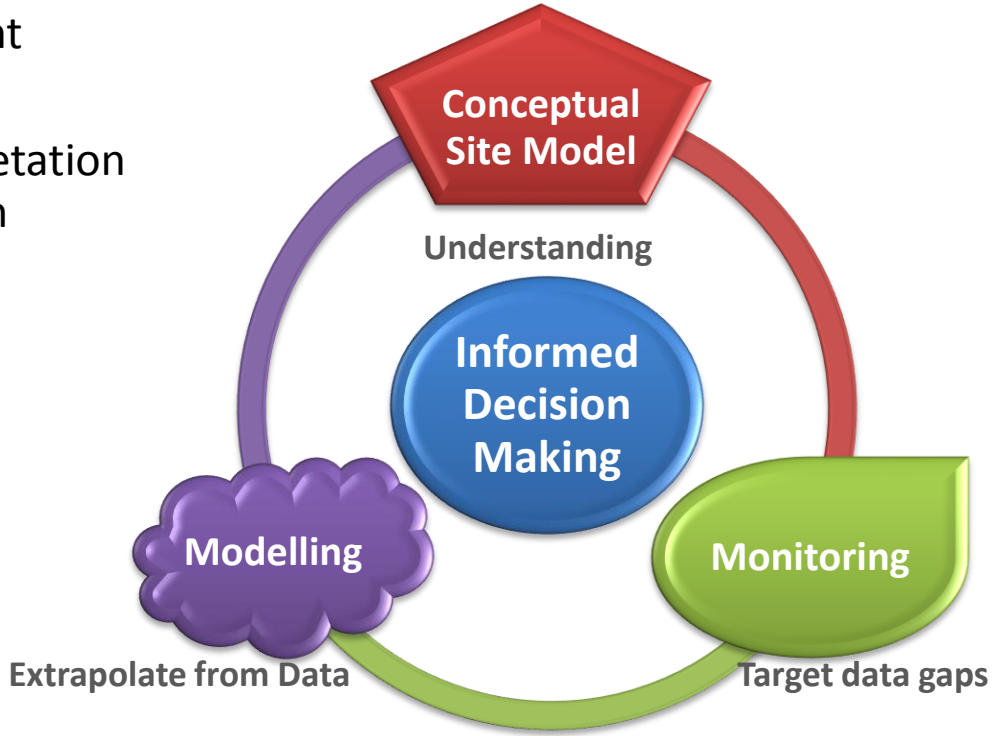
Conceptual Site Model (CSM)



Conceptual Site Model of Groundwater Flow and Chloride Transport

Matrix View – Risk Assessment Process

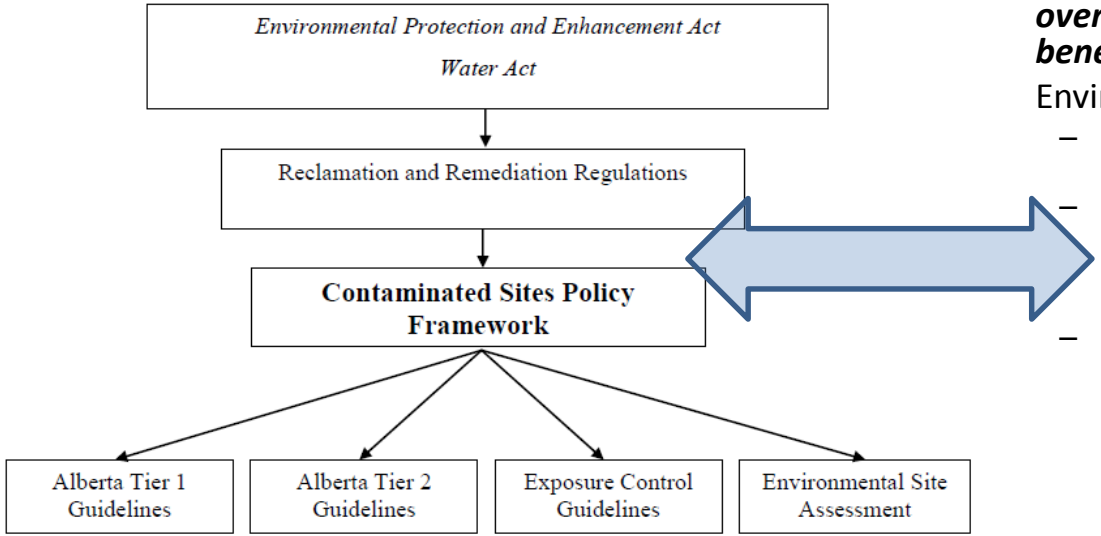
- Conceptual Site Model Development
  - Integrate multiple data sources
    - data management, interpretation visualization / interpolation
- Monitoring
  - Fill gaps in CSM
  - Targeted data collection
  - Static and temporal
- Modelling
  - Test CSMs
  - Extend beyond data
  - Remedial options evaluation



Balancing Environment, Social, Economic

Alberta Contaminated Sites Policy Framework

- Four Pillars: Protective. Effective. Efficient. Credible



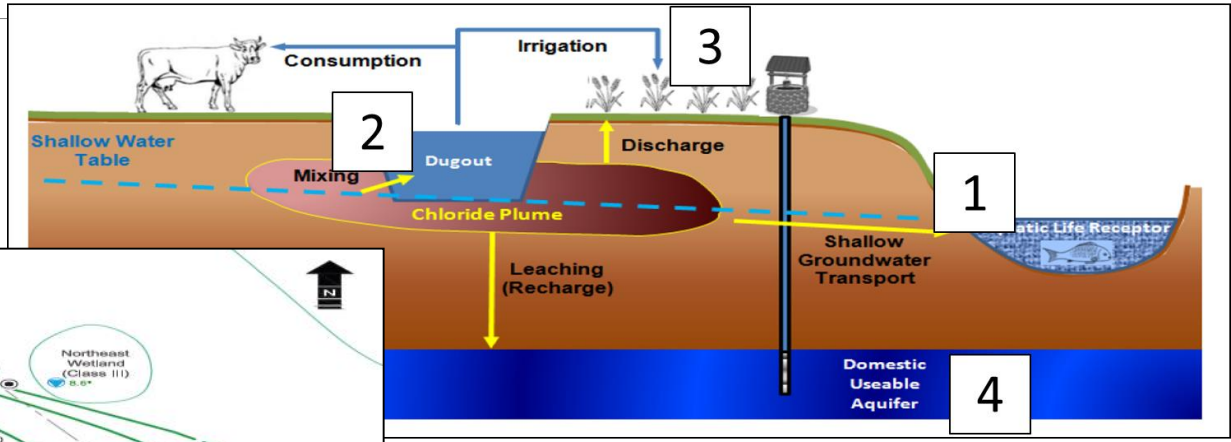
Sustainable Remediation

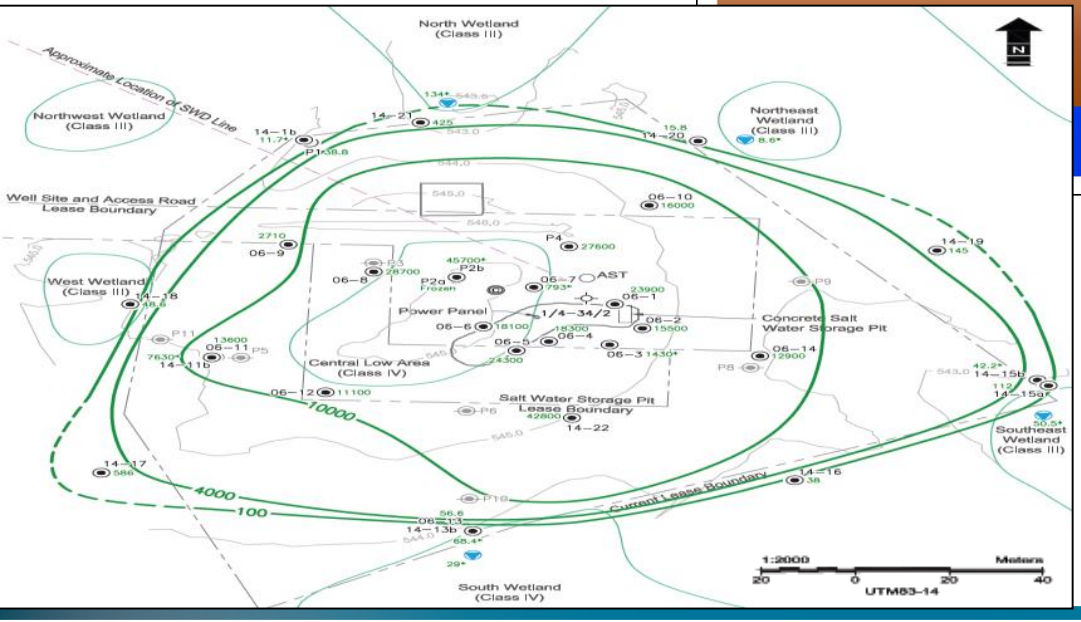
- **Choose *approaches that manage or eliminate the contamination risks but also maximize the overall environmental, social and economic benefits***

  Environmentally friendly practices and methods:

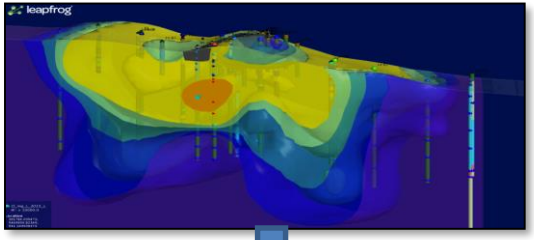
  - Soil Excavation, In-situ Remediation Optimization, Groundwater Pump and Treat Optimization
  - Benefits of lower: project costs, energy consumption, emissions, material consumption, water use, waste generation, dust, noise, vehicle congestion
  - Benefits of more: use of renewable energy, ecosystem and habitat protection, stakeholder involvement and confidence, use of local services / providers, local employment, use of on-site sampling and analytical techniques, use of more passive in-situ remediation / risk management options

Case Study 1 – Former Saltwater Storage Area

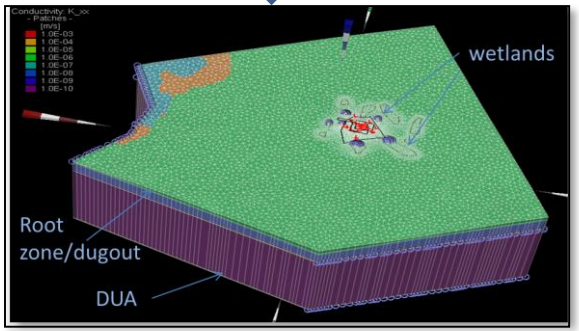




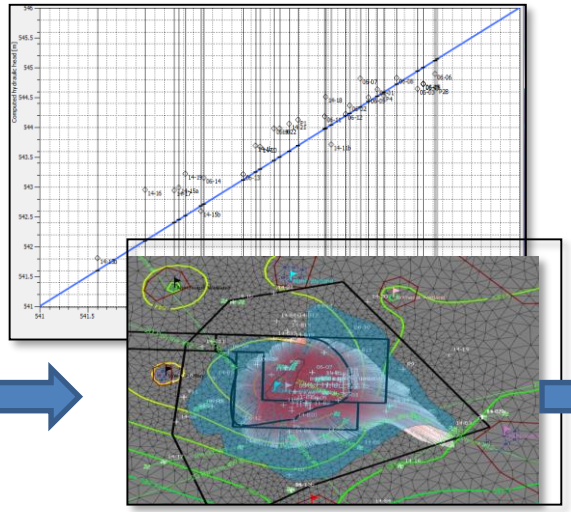
Numerical Modelling for Risk Assessment



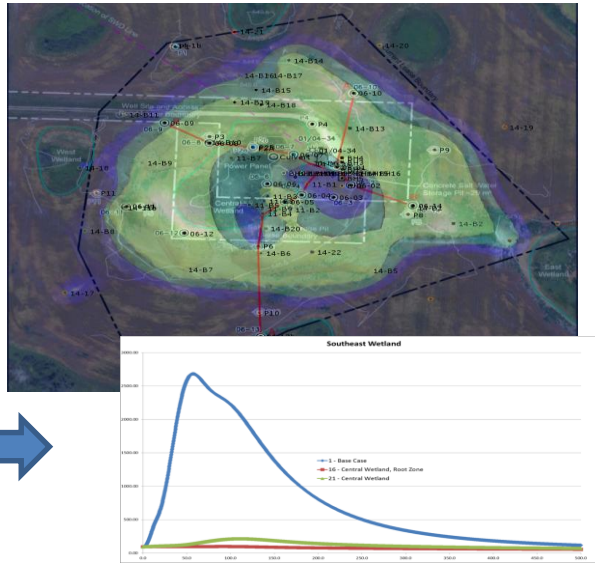
3D Conceptual Site Model



3D Numerical Model Representation of the CSM

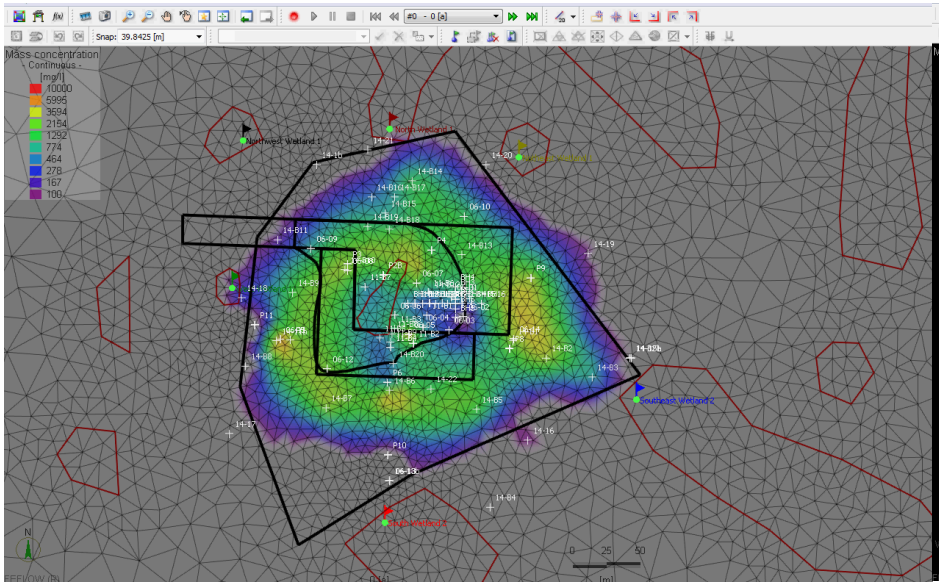


Calibration of input parameters to site observations of water levels etc.

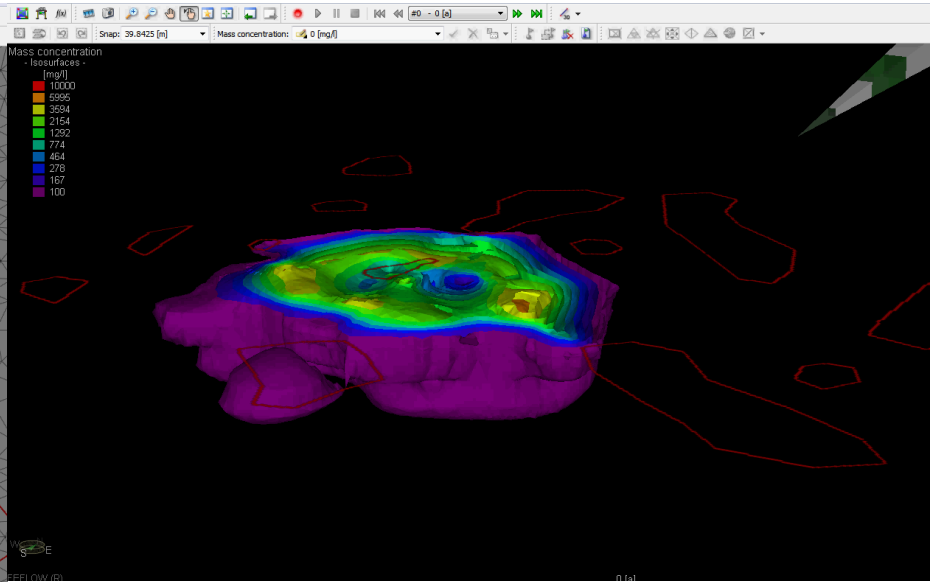


Simulation of Chloride Transport.

Scenario 1 – Base Case (100 year simulation)



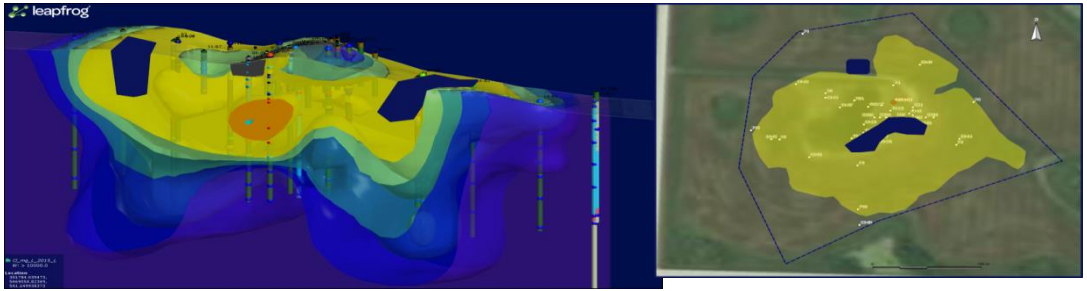
Plan View Chloride Concentrations over time

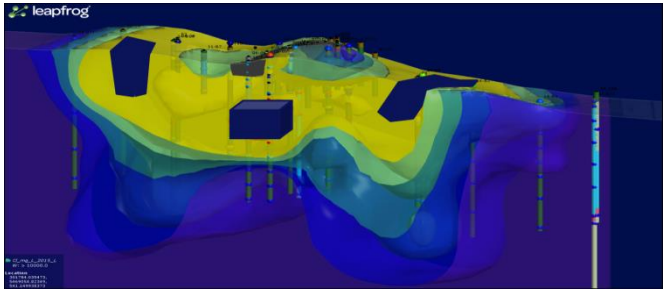


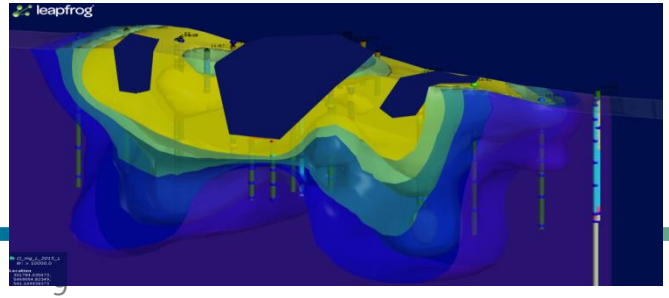
3D View Chloride Concentrations over time

Remedial Options Considered

- Excavations
  - Hydrocarbon
  - Root Zone
  - Hot Spots
  - Toward SE Wetland
- Barriers
  - Flow to Wetland
  - Root Zone Diffusion
- Re-Grade Site
  - Central Wetland
- Pumping / Trench
  - Not tested
  - Time restrictive







Remedial Options Scenario Analysis

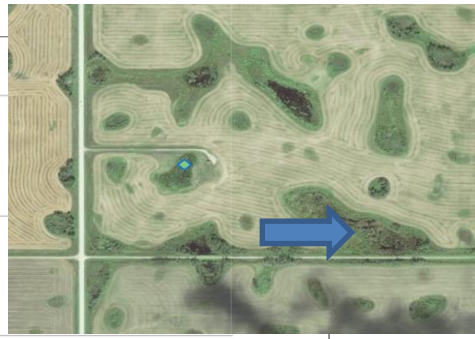
Excavation Volume

DUA

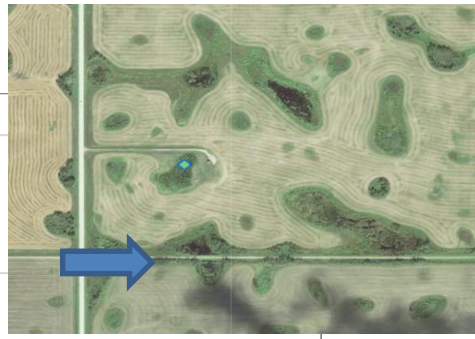
Wetlands

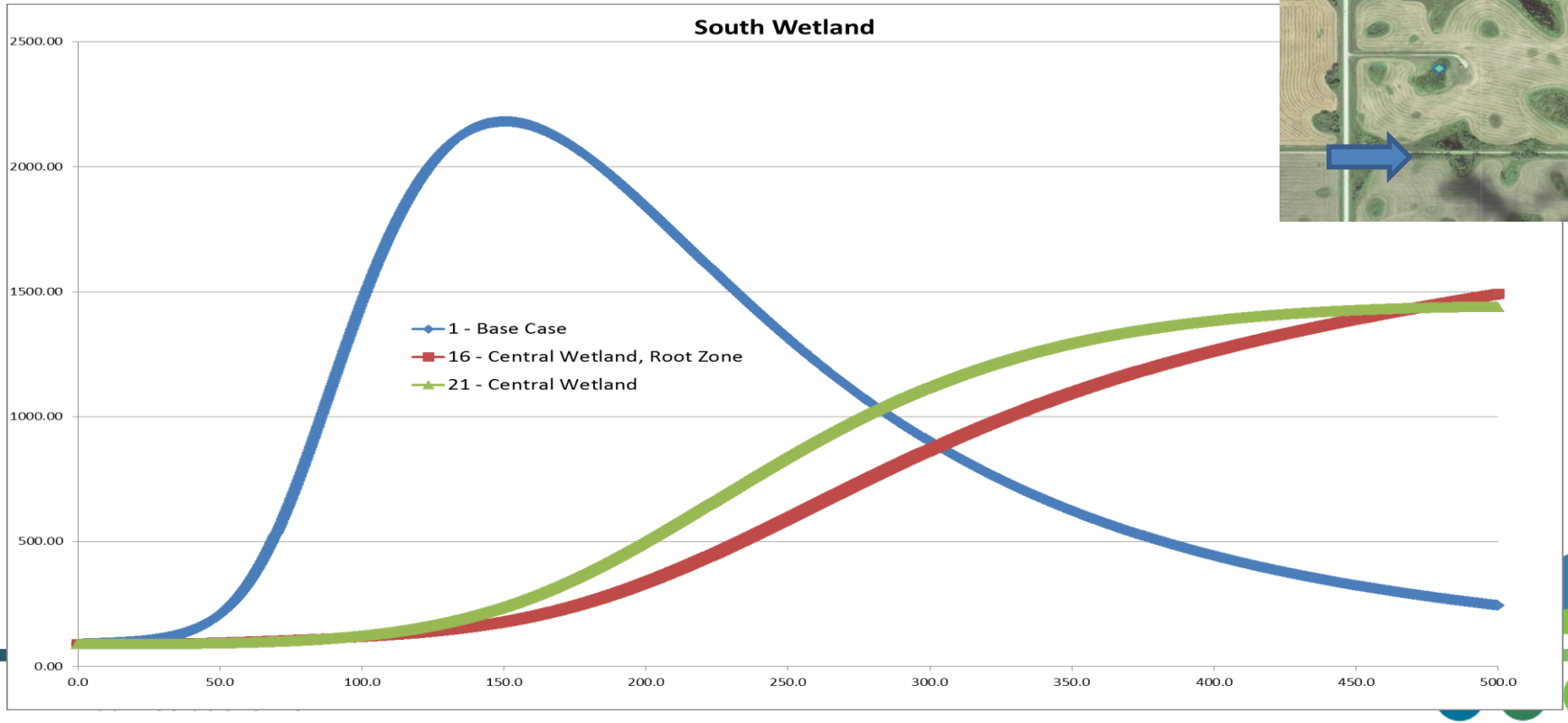
	Remedial Options										Results - Peak Concentration (mg/L) and Time (yr)													
	PHC	Root Zone	HotSpot		Toward	Remove	HDPE			Int Sand Aq		WetB - SE		WetC - South		WetE - West		WetG - NW		WetI - North		WetJ - NE	
SimId			Excavation	Backfill	SW Wetland	Central Wetland	Liner	Vol Excav (m3)	Max Depth (m)	Conc	Time	Conc	Time	Conc	Time	Conc	Time	Conc	Time	Conc	Time	Conc	Time
1										111	615	2680	57	2181	150	1283	207	752	431	1480	269	1706	235
2	✓			Clean				3,338	3.0	109	500	2680	57	2180	150	1283	207	752	431	1456	270	1705	235
3	✓	✓ (1.7m)						64,758	2.3	104	500	1853	94	1350	169	974	221	621	442	1220	277	1124	254
4	✓	✓ (1.7m)	✓ (10000 mg/l)	Native				81,753	6.0	100	500	1574	74	930	172	834	200	305	447	494	263	787	251
5	✓	✓ (1.7m)	✓ (10000 mg/l)	Clean				103,982	6.0	94	500	1556	70	448	113	696	170	189	379	262	86	465	168
6	✓	✓ (1.7m)	✓ (10000 mg/l)	Clean	✓ (6m)			198,312	6.0	94	500	636	85	448	113	94	0	170	369	90	339	425	174
7	✓	✓ (1.7m)	✓ (5000 mg/l)	Clean				121,238	6.0	93	500	574	10	324	106	360	127	134	360	262	86	373	157
11	✓	✓ (5m)						272,158		92	500	170	138	111	215	127	280	101	494	151	337	95	316
14	✓	✓ (1.7m)				✓				97	500	307	130	1457	445	206	0	90	0	137	0	90	0
15	✓	✓ (1.7m)				✓	✓			95	500	175	56	1610	500	206	0	90	0	137	0	90	0
16	✓	✓ (1.5m)				✓	✓	54,752	3.0	96	500	98	92	1491	500	206	0	90	0	137	0	90	0
17	✓	✓ (1.5m)	✓ (10000 mg/l)			✓	✓	76,263	5.5	95	500	98	92	846	500	206	0	90	0	137	0	90	0
21	✓					✓		3,338	3.0	100	500	212	111	1440	500	206	0	90	0	137	0	90	0
22	✓					✓		3,338	3.0	99	500	190	180	1709	389	206	0	90	0	137	0	90	0

Predictions – SE Wetland

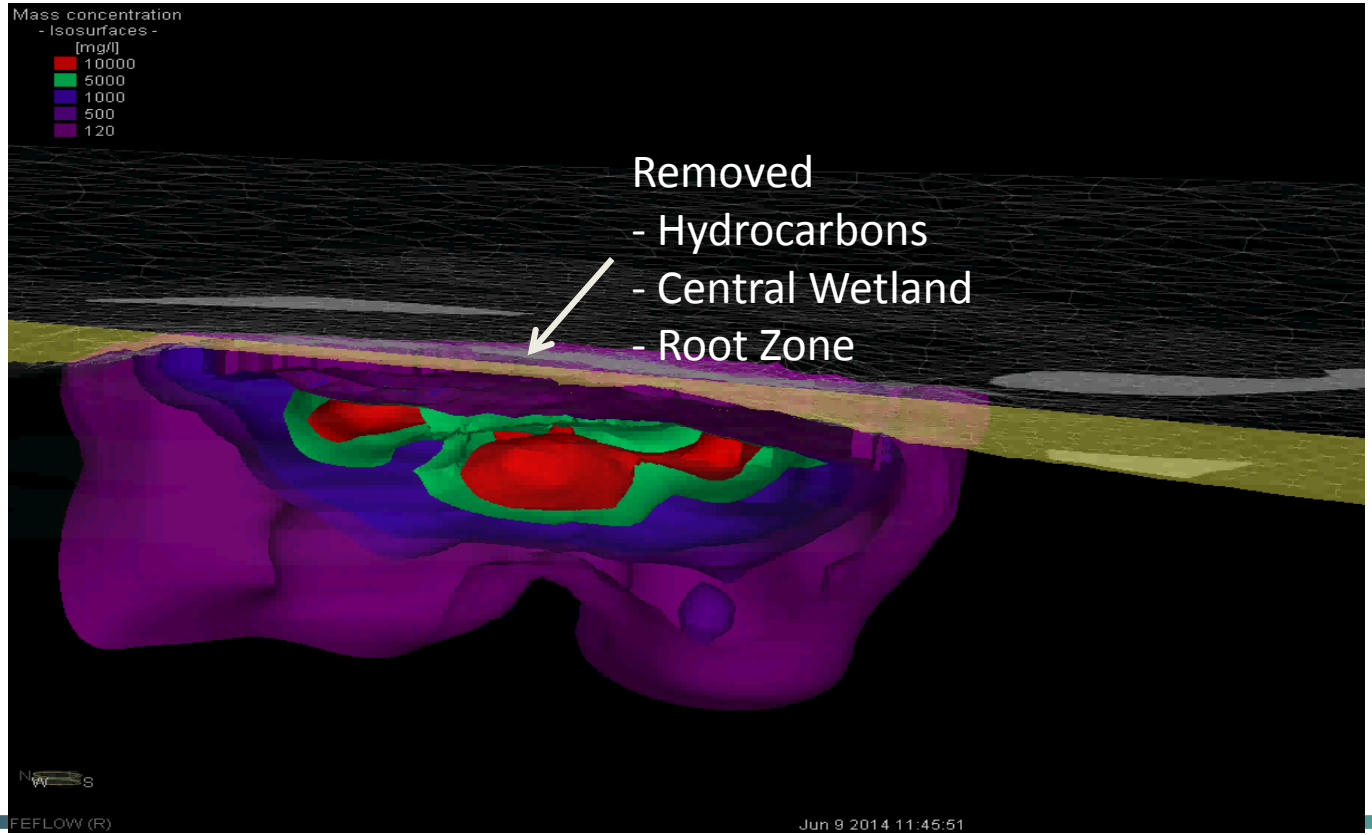


Predictions – South Wetland





Preferred Option - 16



Balancing Environment, Social, Economic

- Balancing cost, protection of receptors and stakeholder needs
- Engaging Stakeholders in Collaborative discussion around site management
- Weighing the effectiveness of remediating central wetland, and loss of the wetland, compared to the benefit to the other wetlands
- Undertaking biological assessment of wetland to identify site-specific objectives
- Weighing long time period to peak concentrations at wetlands against impacts associated with a deeper and larger excavation
- Weighing roots zone excavation which does not provide much benefit for wetland but requires 20 times more excavation
- Uncertainty analysis provides confidence in the model simulations
  - Tells us what are key pieces (e.g. vertical gradient)
  - Provides transparency and confidence in the CSM

Data Gaps – Uncertainty Analysis

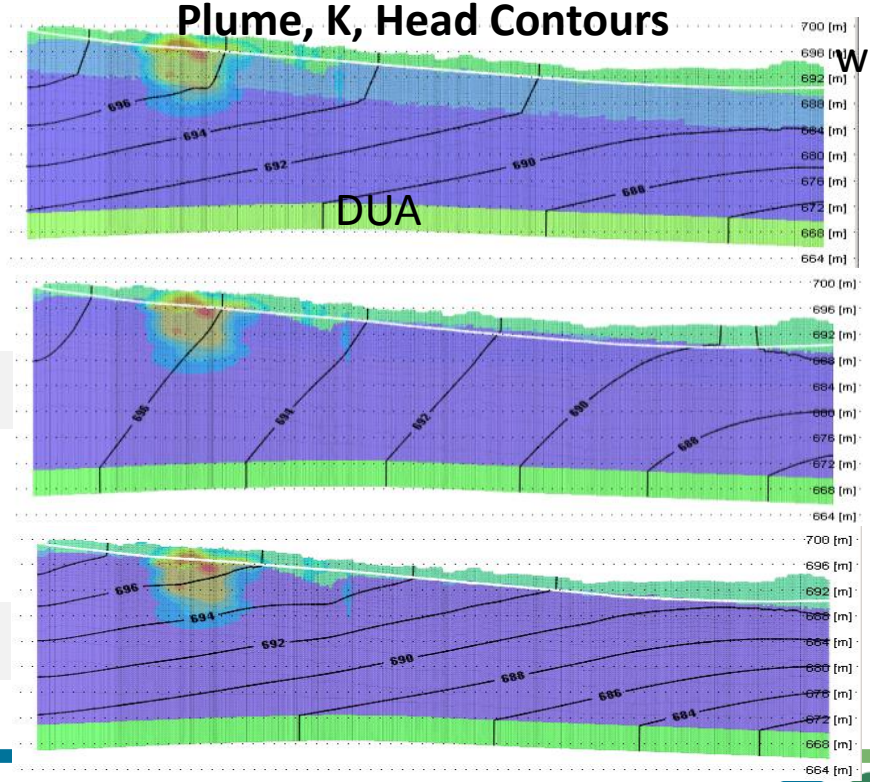
Conceptual Model

Model Cross-Section
Plume, K, Head Contours

Baseline / Moderate Vertical Gradient

Uncertainty 1 / Lower Vertical Gradient

Uncertainty 2 / Greater Vertical Gradient



Case Study Example – Uncertainty Analysis

Scenario			Receptor	Guideline (mg/)	Base Case: Moderate Downward Vertical Gradient	Uncertainty Case 1: Weaker Downward Vertical Gradient	Uncertainty Case 2: Stronger Downward Vertical Gradient
1) No Further Remediation	Cost		Potential DUA	250	165 mg/L at 292 yr	75 mg/L at 944 yr	330 mg/L at 407 yr
	Vol.		Wetland C	120	97 mg/L at 200 yr	321 mg/L at 500 yr	42 mg/L
	Mass		Wetland D	120	42 mg/L (background)	130 mg/L at 850 yr	42 mg/L
2) Excavate Cl > 2400 mg/L to 2 m bgs	Cost	$930,000	Potential DUA	250	129 mg/L at 290 yr	66 mg/L at 942 yr	239 mg/L at 405 yr
	Vol.	7,800 m^3	Wetland C	120	66 mg/L at 200 yr	233 mg/L at 450 yr	42 mg/L (background)
	Mass	10.1 tn	Wetland D	120	42 mg/L (background)	97 mg/L at 800 yr	42 mg/L (background)
3) Excavate Cl > 2400 mg/L to 2 m bgs + Excavate All Cl > 10,000 mg/L	Cost	$1,450,000	Potential DUA	250	93 mg/L at 280 yr	56 mg/L at 876 yr	153 mg/L at 377 yr
	Vol.	12,100 m^3	Wetland C	120	42 mg/L (background)	119 mg/L at 500 yr	42 mg/L (background)
	Mass	18.1 tn	Wetland D	120	42 mg/L (background)	86 mg/L at 850 yr	42 mg/L (background)
4) Excavate Cl > 2400 mg/L to 4 m bgs + Excavate All Cl > 10,000 mg/L	Cost	$1,994,000	Potential DUA	250	82 mg/L at 252 yr	53 mg/L at 844 yr	132 mg/L at 343 yr
	Vol.	16,600 m^3	Wetland C	120	42 mg/L (background)	82 mg/L at 549 yr	42 mg/L (background)
	Mass	20.4 tn	Wetland D	120	42 mg/L (background)	44 mg/L at 850 yr	42 mg/L (background)

Summary Points

- Risk Management Framework supported by site-specific numerical modelling and concepts of sustainable remediation enable
  - Cost-benefit analysis of alternative management plans
  - Uncertainty Analysis to provide context dialogue with decision makers
  - Additional assessment options, e.g. wetland assessment
- Numerical model provides insight to balance environment, social, economic factors
- Dialogue with stakeholders
- Trade-offs need to be presented to enable holistic approach