Ecological Risk Assessment of Oil Sands Reclamation and Closure Landscapes

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Outline

- Overview
- 2016 Field Program
- Problem Formulation
- Methods
- Wildlife Health Risk Assessment Results
- Data Gaps
- Recommendations

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Project Overview

- Golder and Intrinsik conducted an Environmental Risk Assessment of Oil Sands Reclamation and Closure Landscapes
- Aim = Use a risk assessment framework to provide guidance for closure and reclamation planning
- Focused on:
  - Human health
  - Wildlife risk
- Data Gap Assessment completed in early 2016
- Field program conducted in 2016

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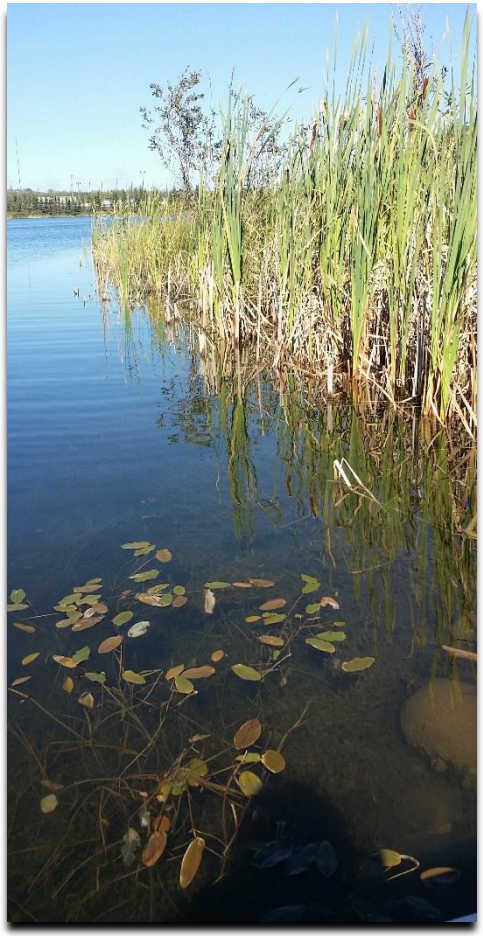
2016 Field Program

- Targeted five landform-substrate combinations:
  - Structural fill - Sand and coke capped consolidated tailings (SCCT)
  - Structural fill - Consolidated tailings (CT)
  - Structural fill - Regular tailings (RT)
  - End pit lake - Mature fine tailings (MFT)
  - Non-structural fill - Dried mature fine tailings (dMFT)
- Sampling sites differed in reclamation status (unreclaimed vs reclaimed)



2016 Field Program



- Collected soil, sediment, and water samples co-located with vegetation:
  - Leaves (e.g., aspen, willow)
  - Grass (e.g., wild rye, fescue)
  - Berries (rosehip)
  - Aquatic plants (cattail, water sedge)
- Samples analyzed for inorganics, naphthenic acids, PAHs (parent and alkylated), petroleum hydrocarbons

Problem Formulation – COPC Selection

Media	Receptor-Pathway Guideline	COPC
Surface Water	Livestock and wildlife water (AEP, BC MoE and CCME)	TDS, fluoride, sulphate, vanadium, phenols
Soil	Direct soil contact*, wildlife food and soil ingestion (AEP, BC MoE, CCME, US EPA)	Arsenic, boron, manganese, molybdenum, nickel, vanadium, sodium, benzo(a)pyrene, HMW PAHs, PHC F3 and PHC F4
Sediment	Direct soil contact*, wildlife food and soil ingestion (AEP, BC MoE, CCME, US EPA)	Boron, manganese, molybdenum, nickel, selenium, vanadium, sodium, benzo(a)pyrene, HMW PAHs and PHC F1 to F4
"Special Considerations"		*Naphthenic acids, alkyl PAHs, cobalt, selenium, thallium*

*Invertebrates and/or plants

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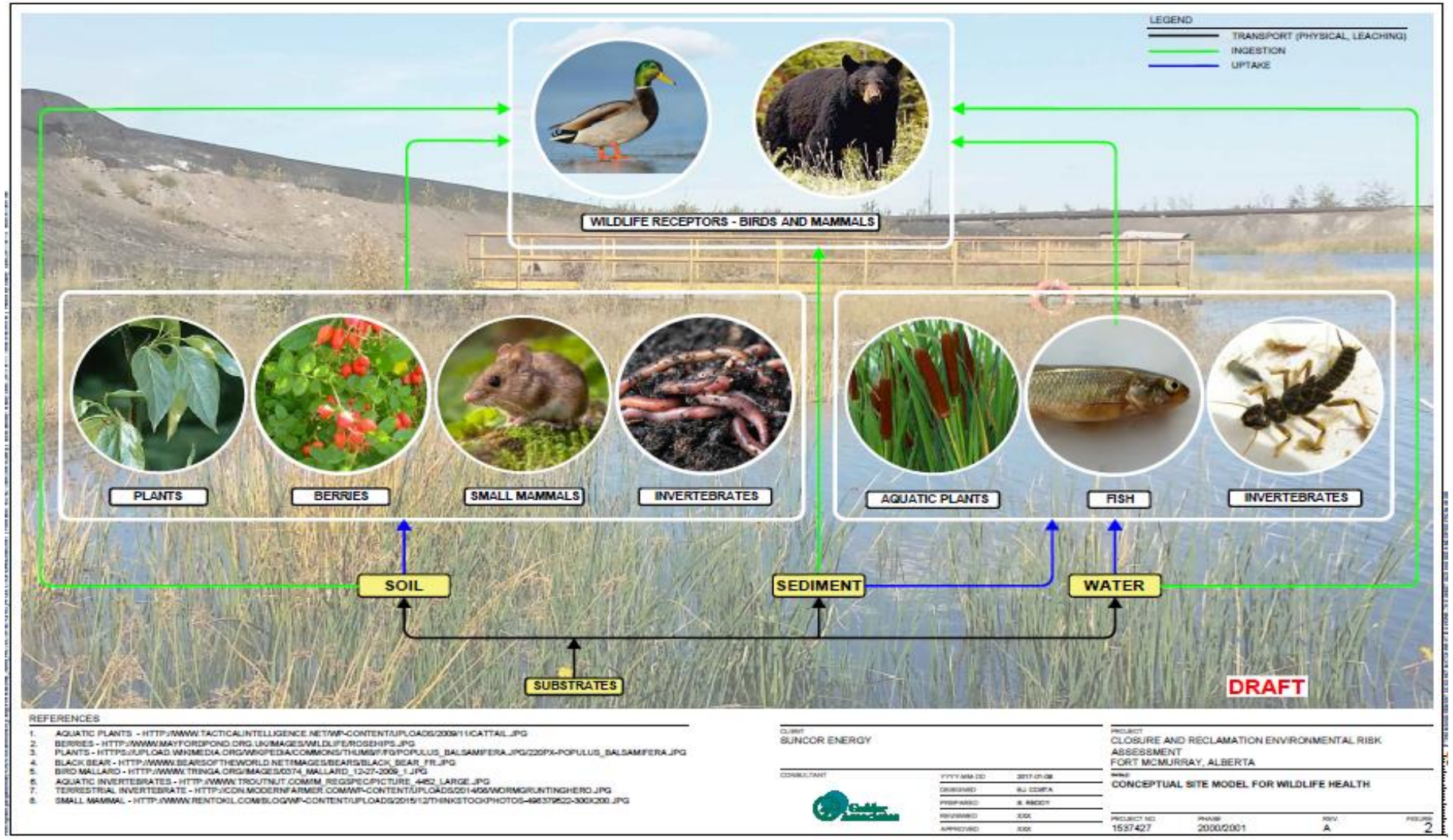
Problem Formulation – Receptor Selection

- Receptors: Wildlife that may access the future reclamation landscape
  - Federal and provincial status (i.e., Species at Risk).
  - Species listed as priority indicators by the Cumulative Environmental Management Association (CEMA).
  - Species of ecological, economic and cultural importance.
  - Species relevant to the closure landform-substrates (i.e., animals potentially present at the landform-substrates).

Problem Formulation

- Exposure Pathways: Various exposure scenarios evaluated
  - Ingestion was identified as the prominent potential route of exposure for the identified COPCs
  - Potentially exposed to COPCs through the ingestion of water, sediment, soils, vegetation or invertebrates (i.e., aquatic and benthic)
  - Transfer of persistent chemicals through the food chain may also lead to exposure to piscivores, carnivores and omnivores through the ingestion of fish or prey animals

Wildlife Conceptual Model



Receptors and Exposure Pathways

Receptors of Concern	Relevant Exposure Pathways									
	Terrestrial					Aquatic				
	Soil	Plants	Berries	Inverts	Small Mammals	Water	Sediment	Plants	Inverts	Fish
Mammals										
Beaver	◆	◆	—	—	—	◆	◆	◆	—	—
Black bear	◆	◆	◆	◆	◆	◆	◆		—	◆
Deer mouse	◆	◆	◆	◆	—	◆	—	—	—	—
Fisher	◆	—	—	—	◆	◆	—	—	—	—
Meadow vole	◆	◆	◆	—	—	◆	—	—	—	—
Moose	◆	◆	—	—	—	◆	◆	◆	—	—
Muskrat	—	—	—	—	—	◆	◆	◆	◆	—
Northern myotis	◆	—	—	◆	—	◆	—	—	—	—
Northern river otter	◆	—	—	—	◆	◆	◆	—	◆	◆
Birds										
Black capped chickadee	◆	◆	◆	◆	—	◆	—	—	—	—
Common nighthawk	◆	—	—	◆	—	◆	—	—	—	—
Horned grebe	—	—	—	—	—	◆	◆	—	◆	◆
Mallard	◆	—	◆	◆	—	◆	◆	◆	◆	—
Short-eared owl	◆	—	—	—	◆	◆	—	—	—	—
Tree swallow	◆	—	—	◆	—	◆	—	—	—	—
Whooping crane	◆	—	◆	—	◆	◆	◆	◆	◆	◆

◆ = relevant exposure pathway

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Measured Data

	Measured Data									
	Aquatic Plant	Berry	Cattail	Fish	Grass	Leaf	Sediment	Soil	Surface Water	Count
End Pit Lake - Mature Fine Tailings										
PAHs	✓	✓	✓	×	✓	✓	✓	✓	✓	8
Metals	✓	✓	✓	×	✓	✓	✓	✓	✓	8
Non-structural Fill - dried MFT										
PAHs	×	×	✓	×	×	×	✓	×	✓	3
Metals	×	×	✓	×	×	×	✓	✓	✓	4
Structural Fill - Consolidated Tailings										
PAHs	✓	✓	✓	×	✓	✓	✓	✓	✓	8
Metals	✓	✓	✓	×	✓	✓	✓	✓	✓	8
Structural Fill - Sand and Coke Capped CT										
PAHs	✓	×	✓	×	✓	✓	✓	✓	✓	7
Metals	✓	×	✓	×	✓	✓	✓	✓	✓	7
Structural Fill - Regular Tailings										
PAHs	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Metals	✓	✓	✓	✓	✓	✓	✓	✓	✓	9

- Exposure Point Concentrations (EPC) based on maximum or 90th percentile
- Measured data missing for invertebrates and small mammals

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Hazard Assessment

- Effects assessment is concerned with identifying and understanding the exposure level to a COPC at which adverse population level effects could occur
- Typically focus on endpoints relating to reproduction, growth and survival (GoC 2012)
- Toxicity reference values can be either:
  - Dose-based (milligram of chemical per kilogram body weight per day) or
  - Concentration-based (mg/kg or mg/L) in soil, sediment or surface water.

Hazard Assessment

Concentration-based Toxicity Reference Values (TRVs):

- Fluoride, Naphthenic acids, Phenol, Sodium, Sulphate, TDS
- Insufficient toxicological data were available to derive concentration based TRVs for the alkylated PAHs.
- Calculated interim water quality guidelines based on body weight, water ingestion rate and TRV

Hazard Assessment – Fluoride Example

Group	ROC	Body Weight [kg]	Water Ingestion Rate [L/day]	Toxicity Reference Value [mg/kg/day]	Allocation Factor	Interim Guideline [mg/L]
Bird	Black-Capped_Chickadee	1.1E-02	2.8E-03	4	0.25	3.8
Bird	Common_nighthawk	6.2E-02	9.2E-03	4	0.25	6.8
Bird	Horned_grebe	4.3E-01	3.4E-02	4	0.25	12.8
Bird	Mallard	1.2E+00	6.7E-02	4	0.25	18.0
Bird	Short-eared_owl	3.5E-01	2.9E-02	4	0.25	12.0
Bird	Tree_Swallow	2.0E-02	4.3E-03	4	0.25	4.7
Bird	Whooping_crane	5.8E+00	1.9E-01	4	0.25	30.4
Mammal	Bear	6.8E+01	4.4E+00	1	0.25	3.9
Mammal	Beaver	1.9E+01	1.4E+00	1	0.25	3.4
Mammal	Moose	4.0E+02	2.2E+01	1	0.25	4.6
Mammal	Otter	7.5E+00	6.1E-01	1	0.25	3.1
Small Mammal	Deer_Mouse	2.2E-02	3.2E-03	2.7	0.25	4.7
Small Mammal	Fisher	5.0E+00	4.2E-01	2.7	0.25	8.0
Small Mammal	Meadow_Vole	3.5E-02	4.8E-03	2.7	0.25	4.9
Small Mammal	Muskrat	1.0E+00	9.9E-02	2.7	0.25	6.8
Small Mammal	Northern_myotis_bat	9.0E-03	1.4E-03	2.7	0.25	4.2
Average	Bird					10.0
	Mammal					3.7
	Small Mammal					5.6

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Hazard Assessment

- Dose-based Toxicity Reference Values
- Developed using published TRVs:
  - AEP
  - CCME
  - Oak Ridge National Laboratory
  - US EPA Ecological Soil Screening Levels [Eco-SSLs]
- Objective is to describe the probability and magnitude of adverse effects

Risk Characterization

The characterization of risks for COPC involved multiple lines of evidence:

- The extent of potential adverse effects considering the full distribution of exposure concentrations with the aim of characterizing the likelihood of adverse effects
- Consideration of background concentrations
- The magnitude of potential adverse effects considering alternative toxicological endpoints (when available) to gain a better understanding of the exposure-response data.

Results

COPC	End Pit	Non-structural Fill	Structural Fill		
	Mature Fine Tailings (MFT)	Dried MFT	Regular Tailings	Sand and Coke Capped CT	Consolidated Tailings
Metals					
Arsenic	○	--	--	--	--
Boron	○	○	●	○	●
Cobalt	○	○	○	○	○
Manganese	--	○	○	●	○
Molybdenum	○	○	○	○	--
Nickel	○	●	--	●	--
Selenium	○	○	○	○	○
Thallium	○	○	○	○	○
Vanadium	--	●	--	●	--
PAHs					
PAHs (parent)	○	○	--	●	○
PAHs (alkyl)	?	?	?	?	?

●	**Potential risk**
○	Low risk
--	Not a COPC for this landform
?	Uncertain

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Results (continued)

COPC	End Pit	Non-structural Fill	Structural Fill		
	Mature Fine Tailings	Dried MFT	Regular Tailings	Sand and Coke Capped CT	Consolidated Tailings
PHCs					
F1	--	--	--	--	○
F2	--	○	--	○	○
F3	○	○	○	○	○
F4	○	○	--	--	○
Organics					
Naphthenic acids	●	●	●	●	●
Phenol	○	○	○	○	--
Salinity, Anions, Nutrients and Other					
Fluoride	○	--	○	--	○
Sodium	○	○	○	○	○
Sulphate	--	--	--	○	○
TDS	--	--	--	○	○

●	**Potential risk**
○	Low risk
--	Not a COPC for this landform
?	Uncertain

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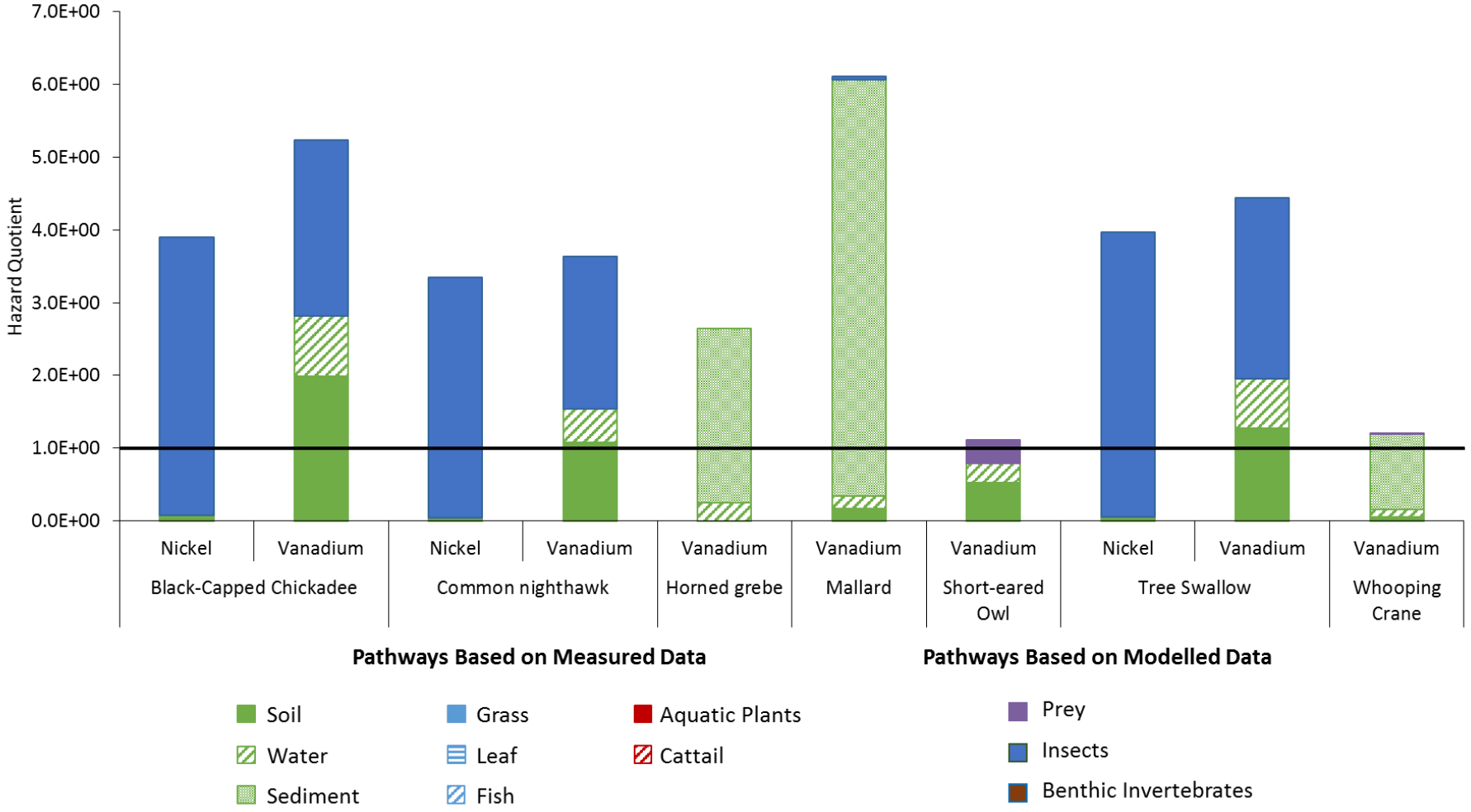
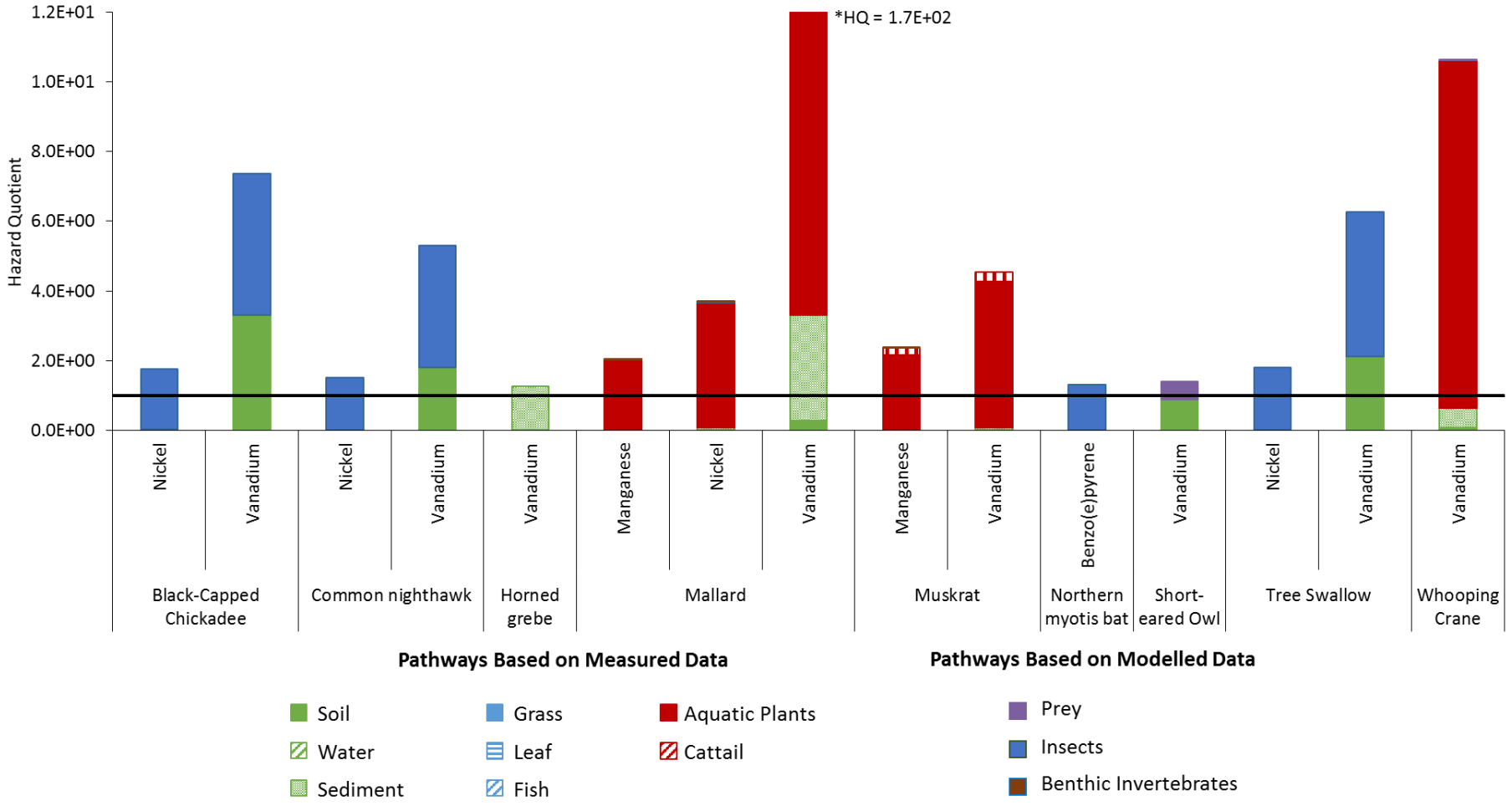
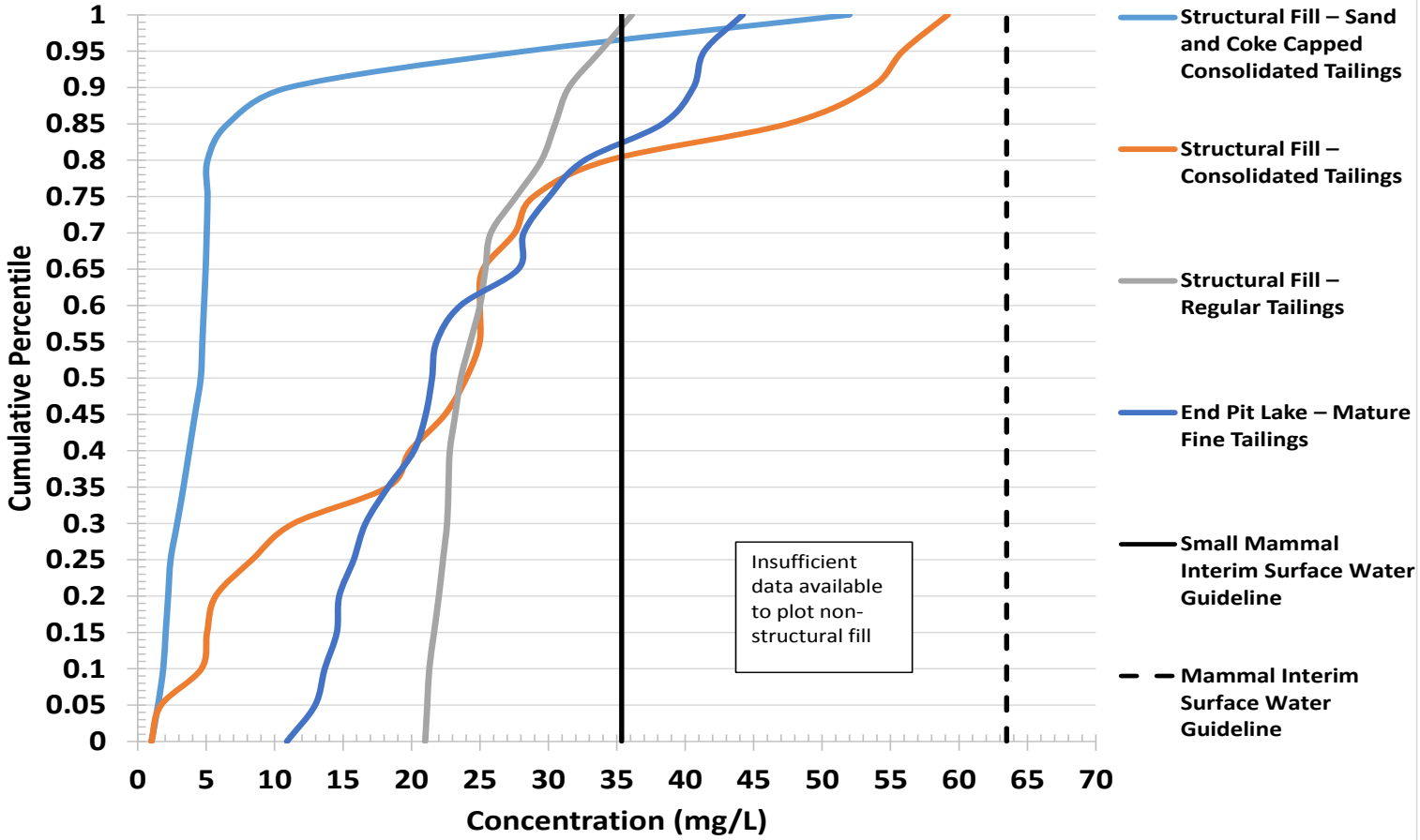
Wildlife Risks for Non-structural Fill – dMFT



Wildlife Risks for Structural Fill - Sand and Coke Capped tailings



Use of Concentration-based TRVs – Naphthenic Acids



*Insufficient toxicological data available to derive objective for avian receptors

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Key Observations

- Risks to wildlife (mammalian and avian) are generally low
- Risk estimates highest for Non Structural Fill-Dried Mature Fine Tailings and Structural Fill-Coke and Sand-Capped Consolidated Tailings
- Risks moderate to high for vanadium
  - Predicted exposures greater than literature based reproductive, growth and/or survival limits
- Risk estimates generally higher for avian species
- Risks often “driven” by aquatic-related exposure pathways
- Significant uncertainty remains with respect to the naphthenic acid related risks

Data Gaps and Recommendations

- Need for more aquatic plant data
- Improve understanding of naphthenic toxicity and exposure potential
- Additional alkylated PAH data (and improve understanding of alkylated PAH toxicity and exposure potential)
- Proper characterization of (and comparison to) baseline/reference conditions
- Exploration of other lines of evidence (e.g., biological surveys, bioaccessibility studies)
- Field program conducted in 2017 to address data gaps (results pending)

Reclamation Recommendations – "Knowledge Transfer"

Landform-Substrate	Receptor /Scenario	Is there a potential health risk?	Basis of Risk	Recommendations
Structural Fill – Sand and Coke Capped Consolidated Tailings	People	Yes	Sulphate in drinking water (surface water) PAHs in sediment	Surface water not suitable for use as drinking water due to elevated sulphate concentrations and potential aesthetic impacts (e.g., taste). People should not swim in these reclamation sites due to high PAHs in sediments. Recommendations for additional reclamation: • Consideration of alternative cover systems (e.g., engineered covers; thinner or thicker covers, as required; barriers for upward movement of contaminants; rooting zone above contaminants) would need to be determined by modelling and trials. • Consider chemistry and rooting zone of each area and appropriate vegetation accordingly.
		Possible	Sodium in drinking water Cobalt, iron, lithium, manganese and vanadium in berries and/or game Naphthenic acids in surface water	
	Wildlife (Mammalian and Avian)	Yes	Vanadium (sediment and aquatic plants) for aquatic birds	
		Possible	Nickel (aquatic plants) for aquatic birds Nickel (insects – based on soil) for terrestrial birds Manganese (aquatic plants) for muskrat Vanadium (insects and soil) for terrestrial birds Naphthenic acids for small mammals (no avian information available)	

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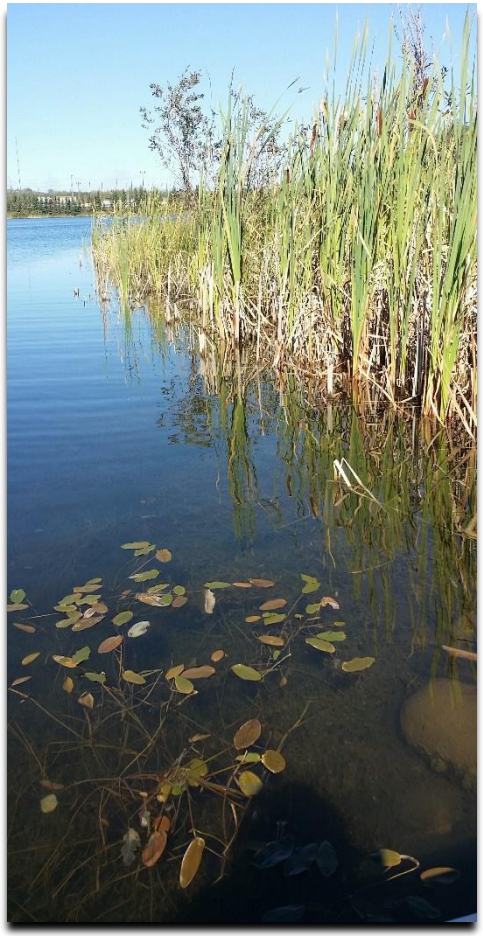
Acknowledgements



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Questions?

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