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# Long-Term Management of Remote Wetland Sites: Multi-Criteria Analysis of Remediation Options

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# Outline

- ▶ Background
- ▶ Problem Statement
- ▶ Flow and Transport Mechanism in Wetlands
- ▶ Case Study – Options Analysis

# Northern Alberta

wetlands, peat bogs,  
fens, sloughs and rivers

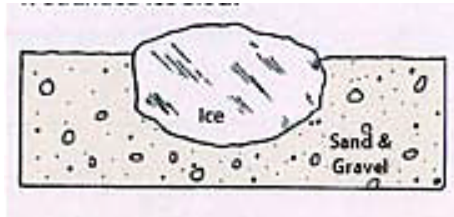


Source: Google Earth

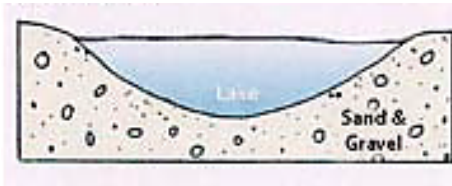
# Challenges

- ▶ Key infrastructure crossing environmentally sensitive areas
- ▶ High sensitivity to water balance and contamination
- ▶ Connected waters - complex shallow flow systems
- ▶ Minimal disturbance preferred
- ▶ Long term management of sites may be required
- ▶ Remote settings

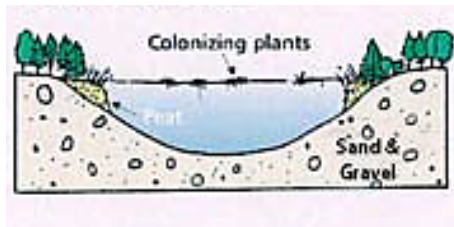
# Wetlands Evolution



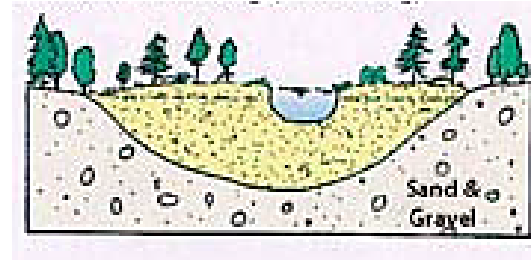
**Stage 1:** Receding glaciers



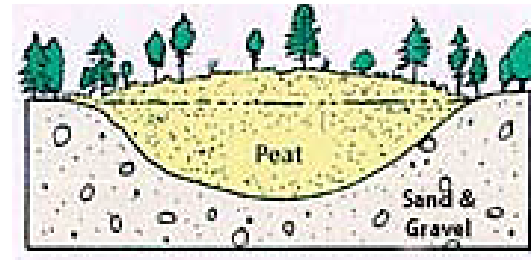
**Stage 2:** Shallow Glacial Lake



**Stage 3:** Colonization by vegetation

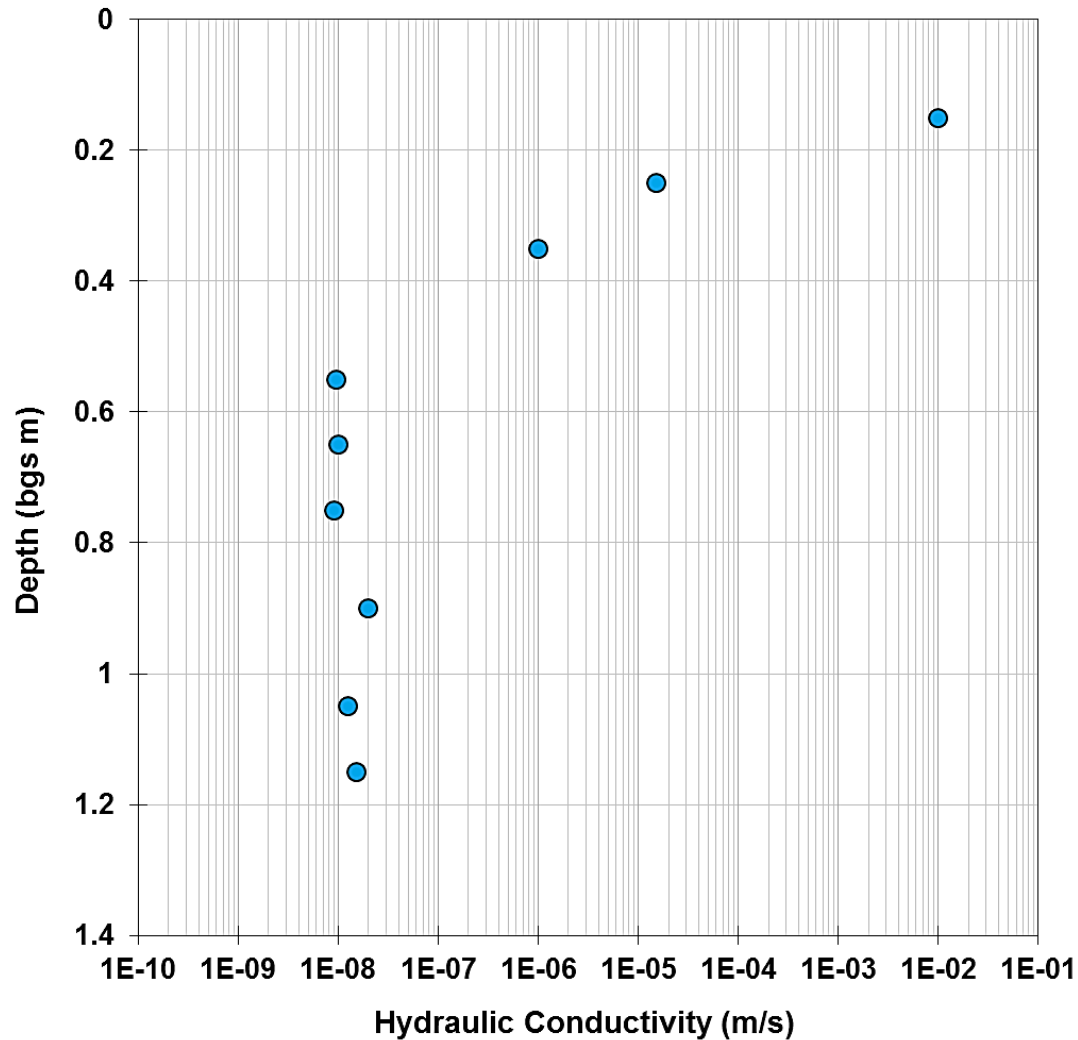


**Stage 4:** Cold and oxygen poor conditions, slow degradation, peat formation



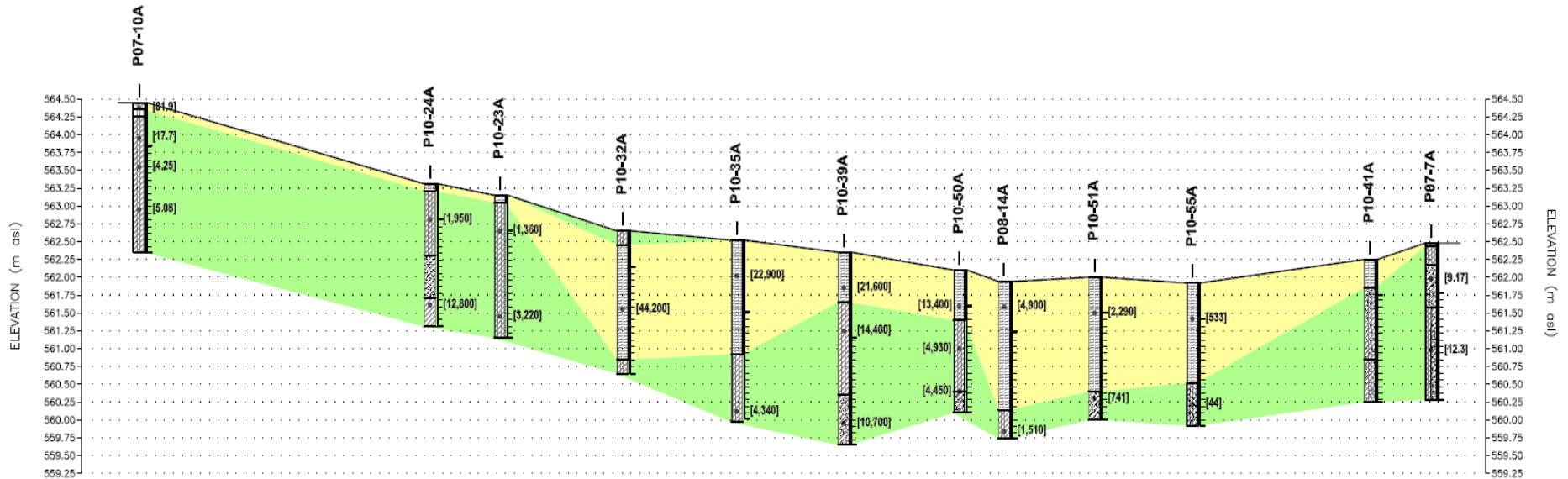
**Stage 5:** Nutrient poor conditions, slow growth and accumulation; layered structure

# Peat Properties



Hoag, R.S., Price, J.S. (1995). *J. of Hydrol.*  
Beckwith, C.W. et al. (2003a). *Hydrol. Process.*  
Quinton, W.L. et al. (2008). *Hydrol. Process.*  
Nagare, R.M. et al. (2013). *Hydrogeology J.*

# Typical Cross Section



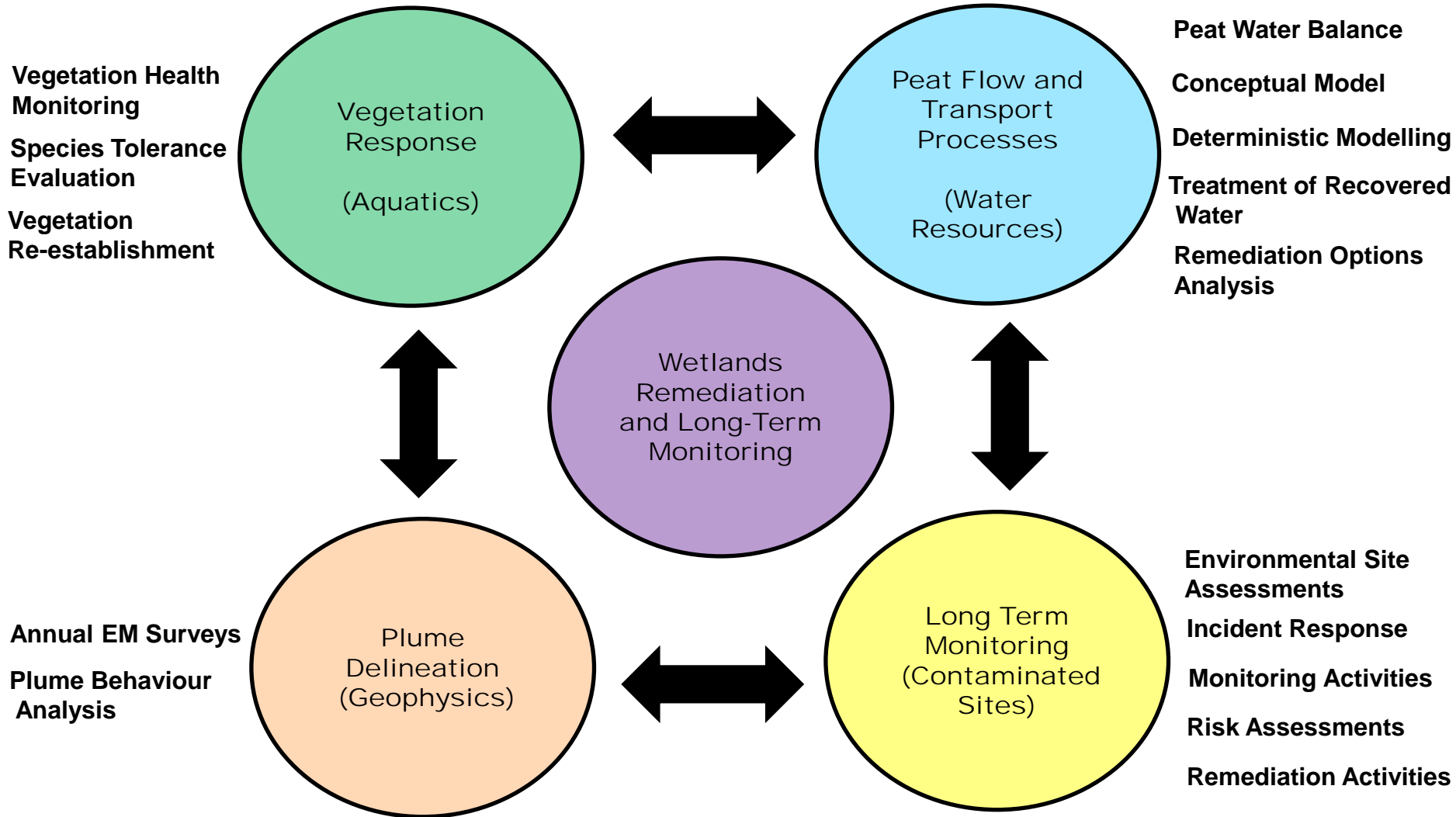
Source: WorleyParsons Canada Services Ltd.

# Contaminant Transport

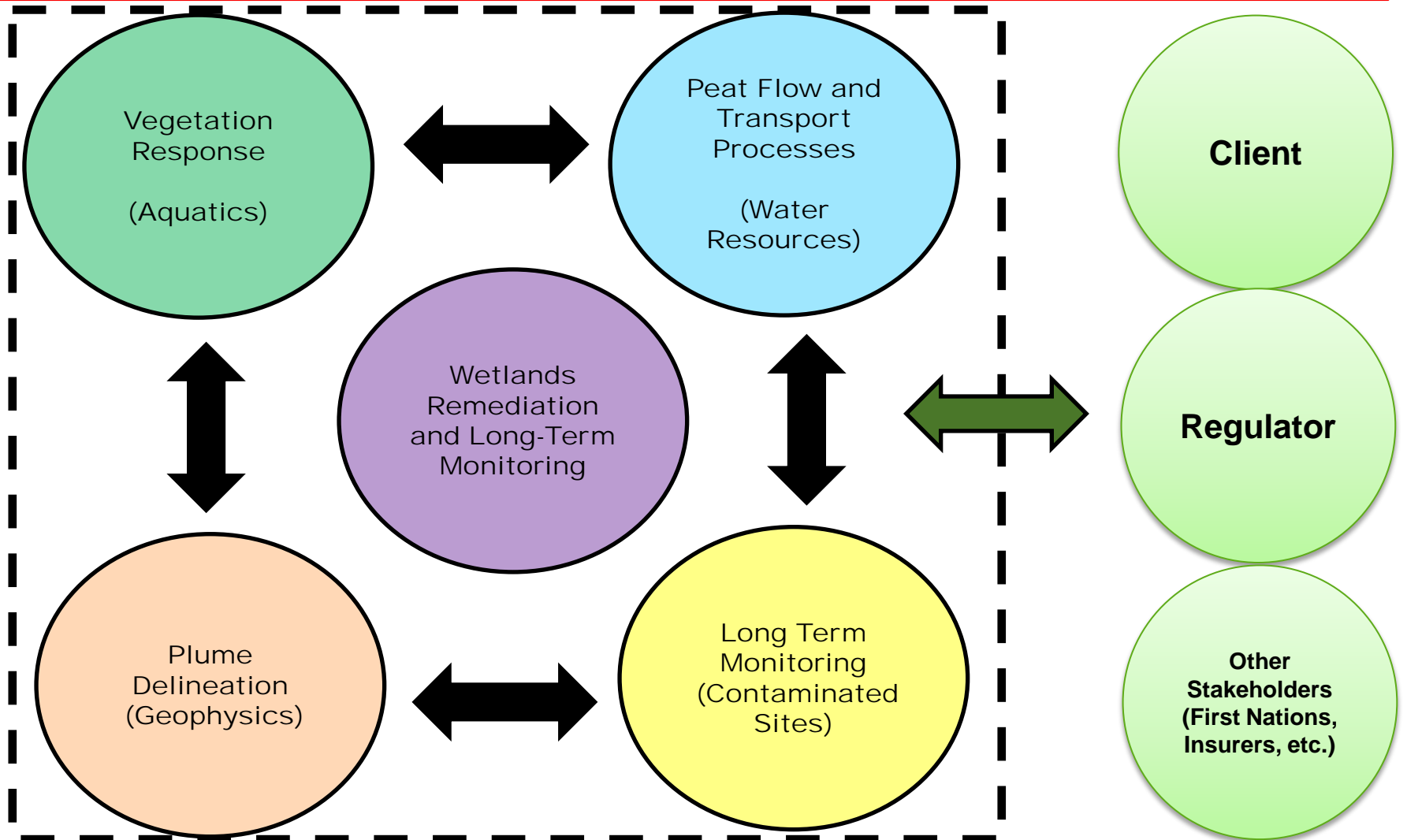
- ▶ Mechanism dominated by K-Depth profile
- ▶ Advection vs. diffusion at different depths
- ▶ Closed pores, backward diffusion, fibre absorption, deep pools unique processes to peat



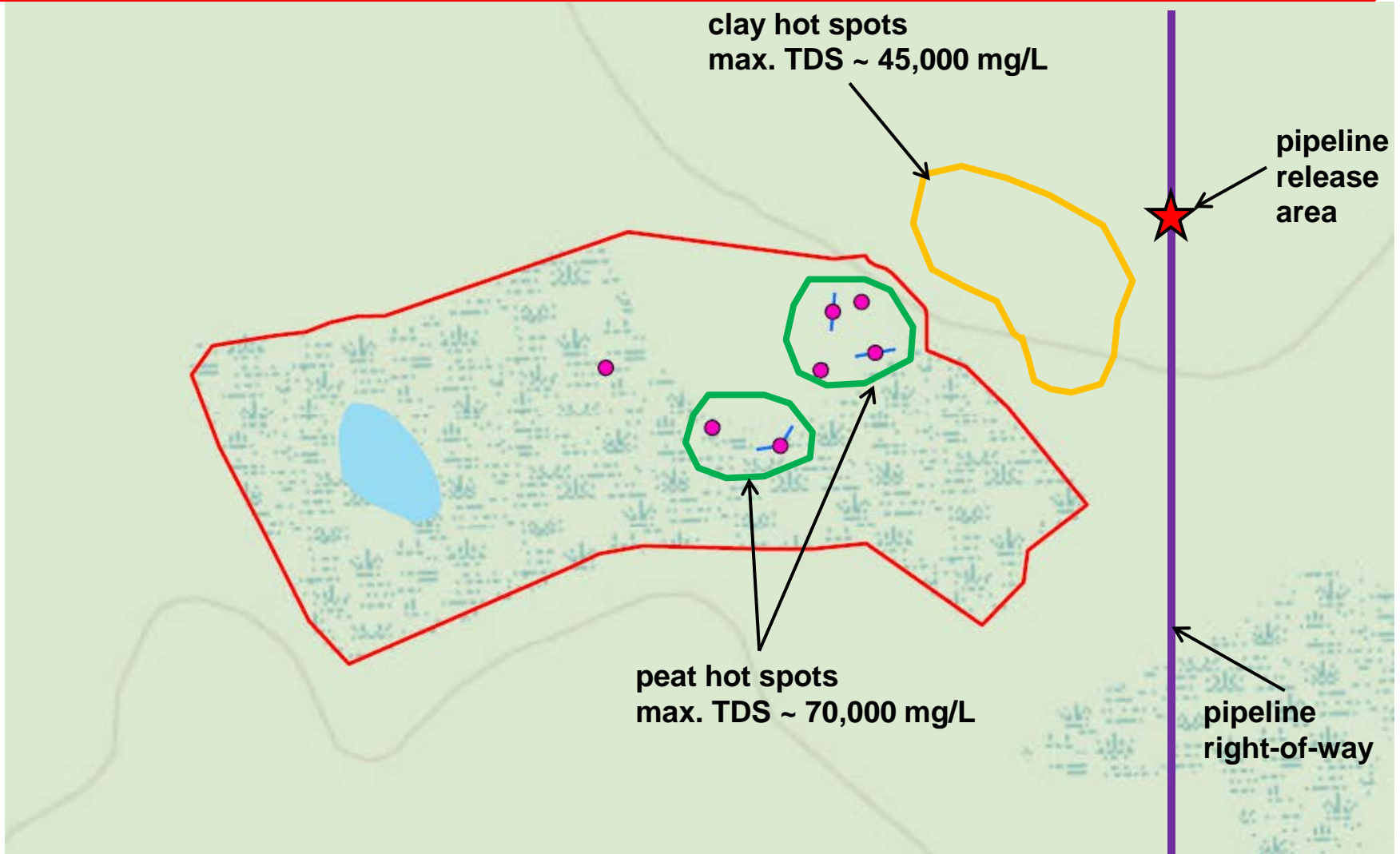
# Multidisciplinary Approach



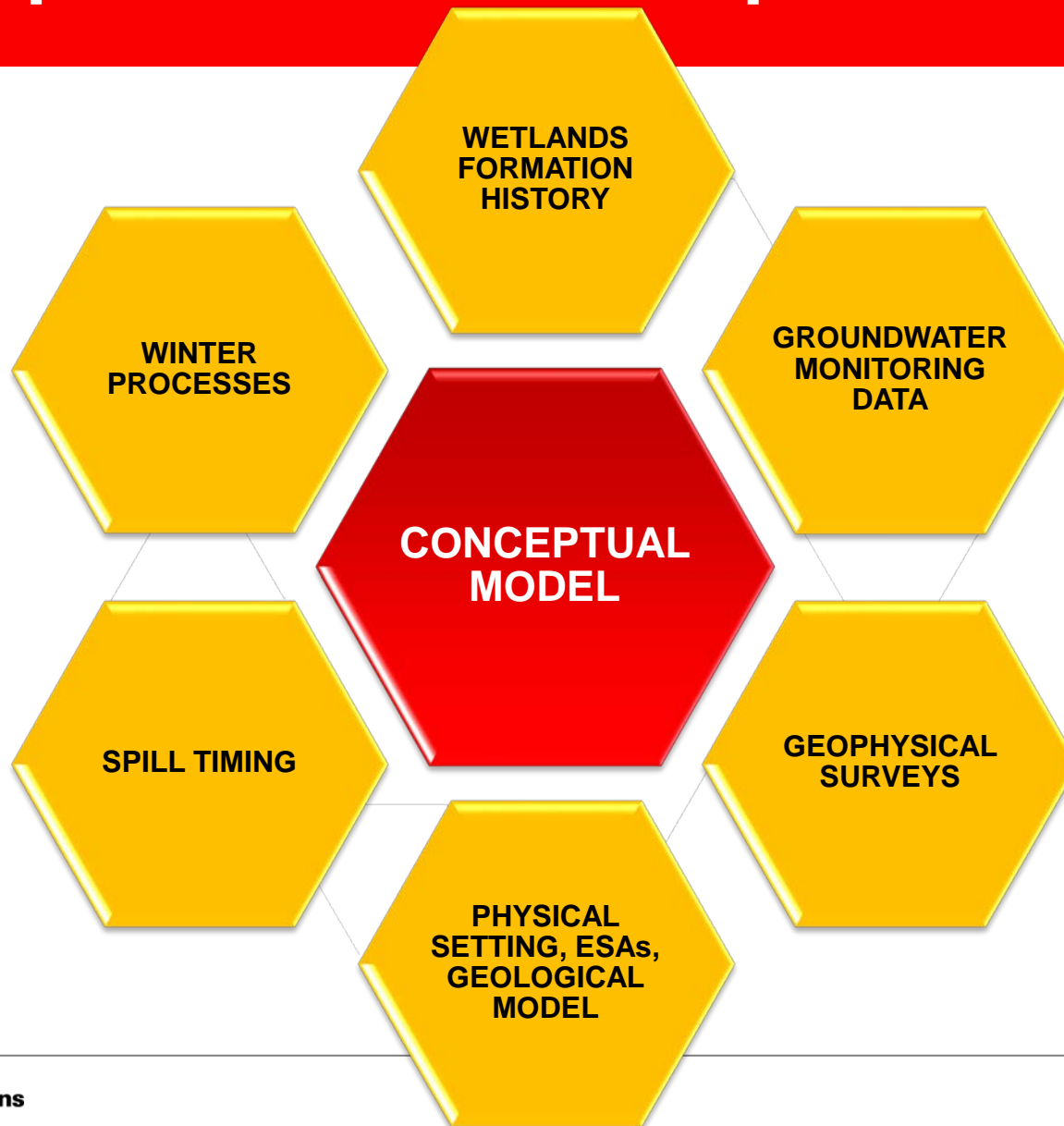
# Multidisciplinary Approach



# Case Study Background



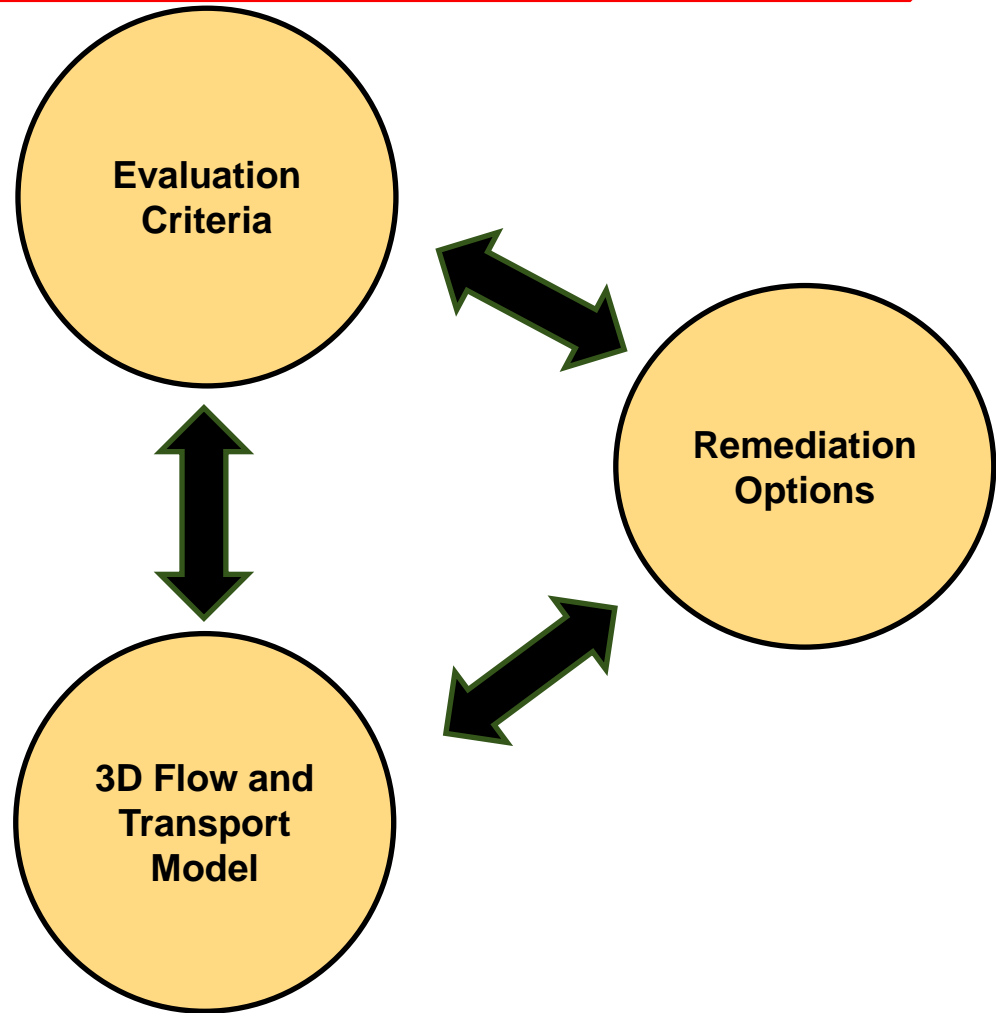
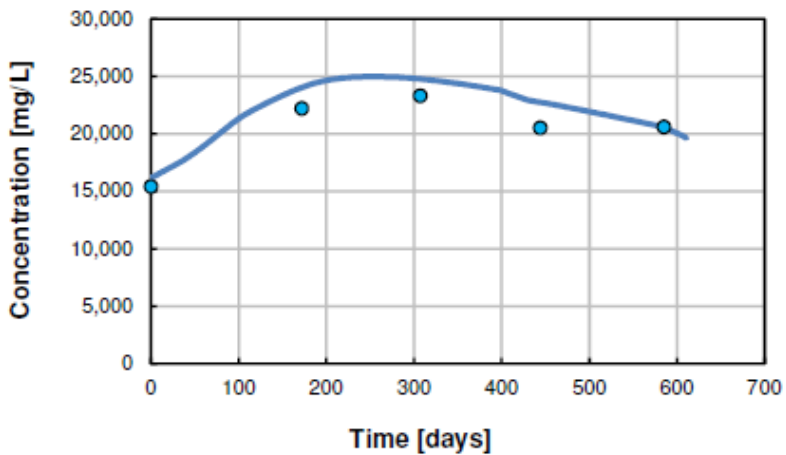
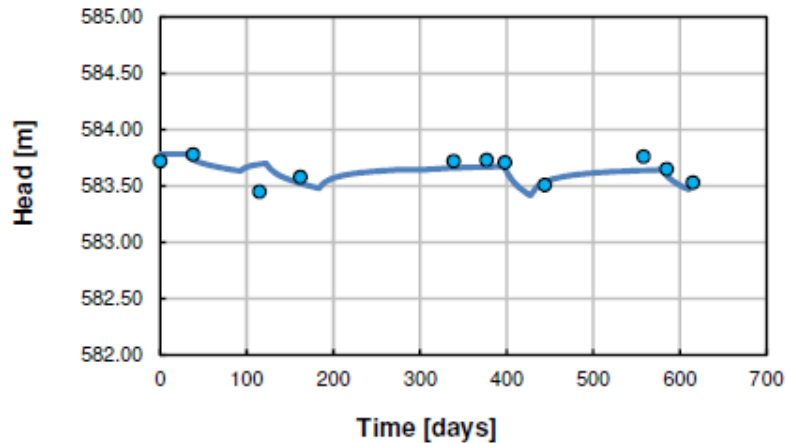
# Conceptual Model Development



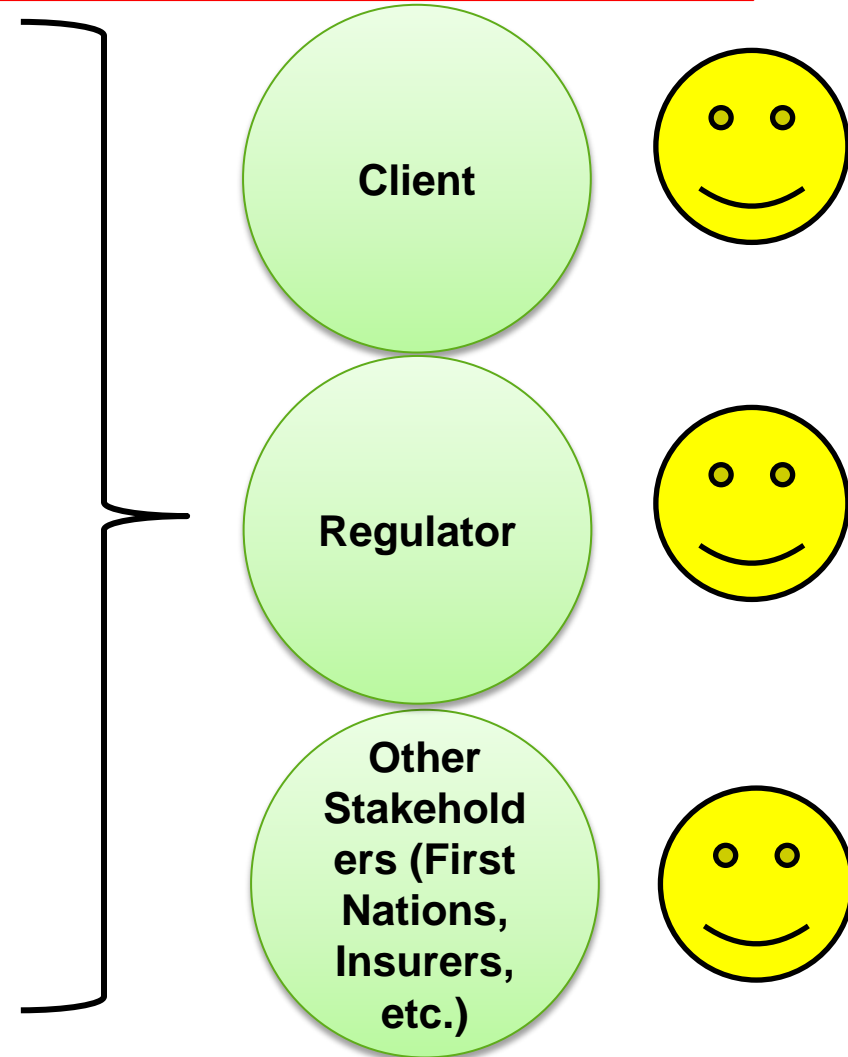
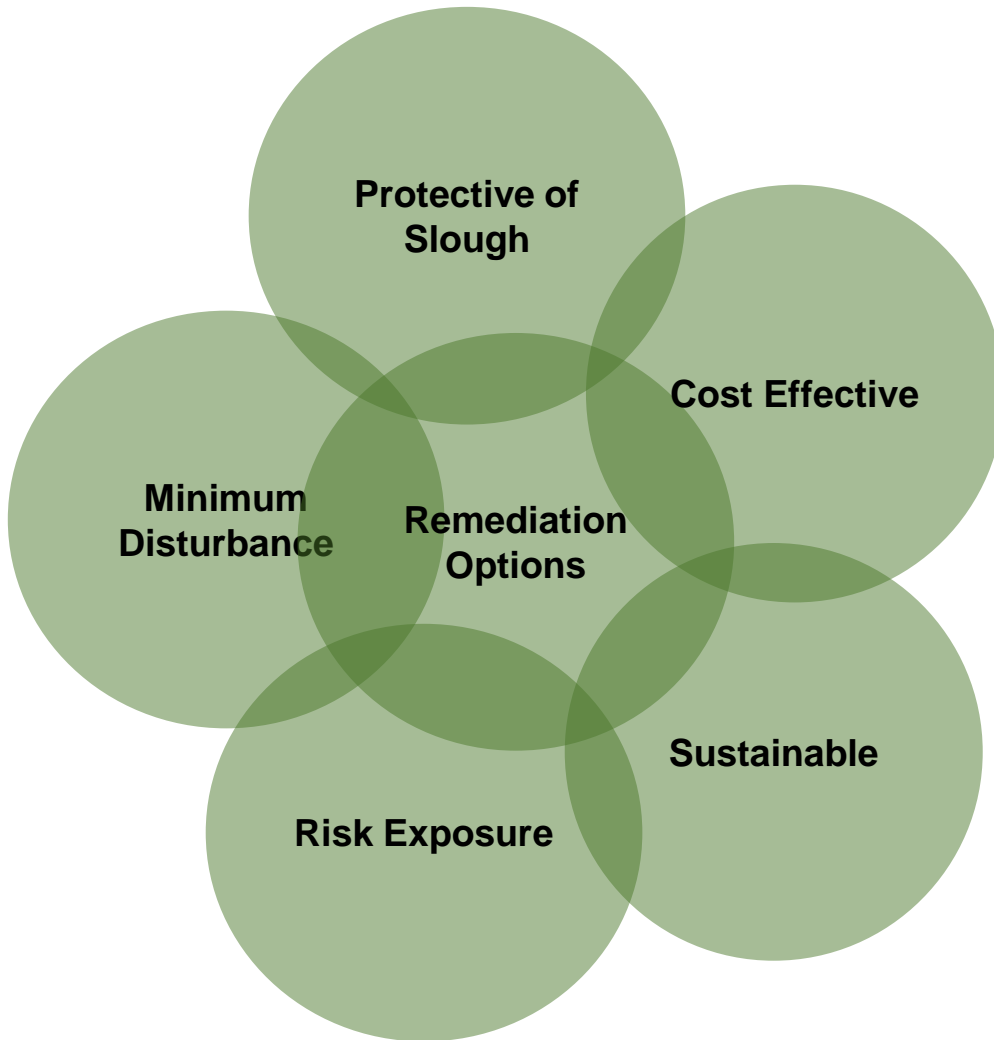
# Conceptual Model Overview

- ▶ Spill of produced water
- ▶ Initial mode of water transport dominantly overland
- ▶ Vertical movement into low K zone
- ▶ Accumulation into thicker peat zones
- ▶ Very little movement between 2007 and 2014

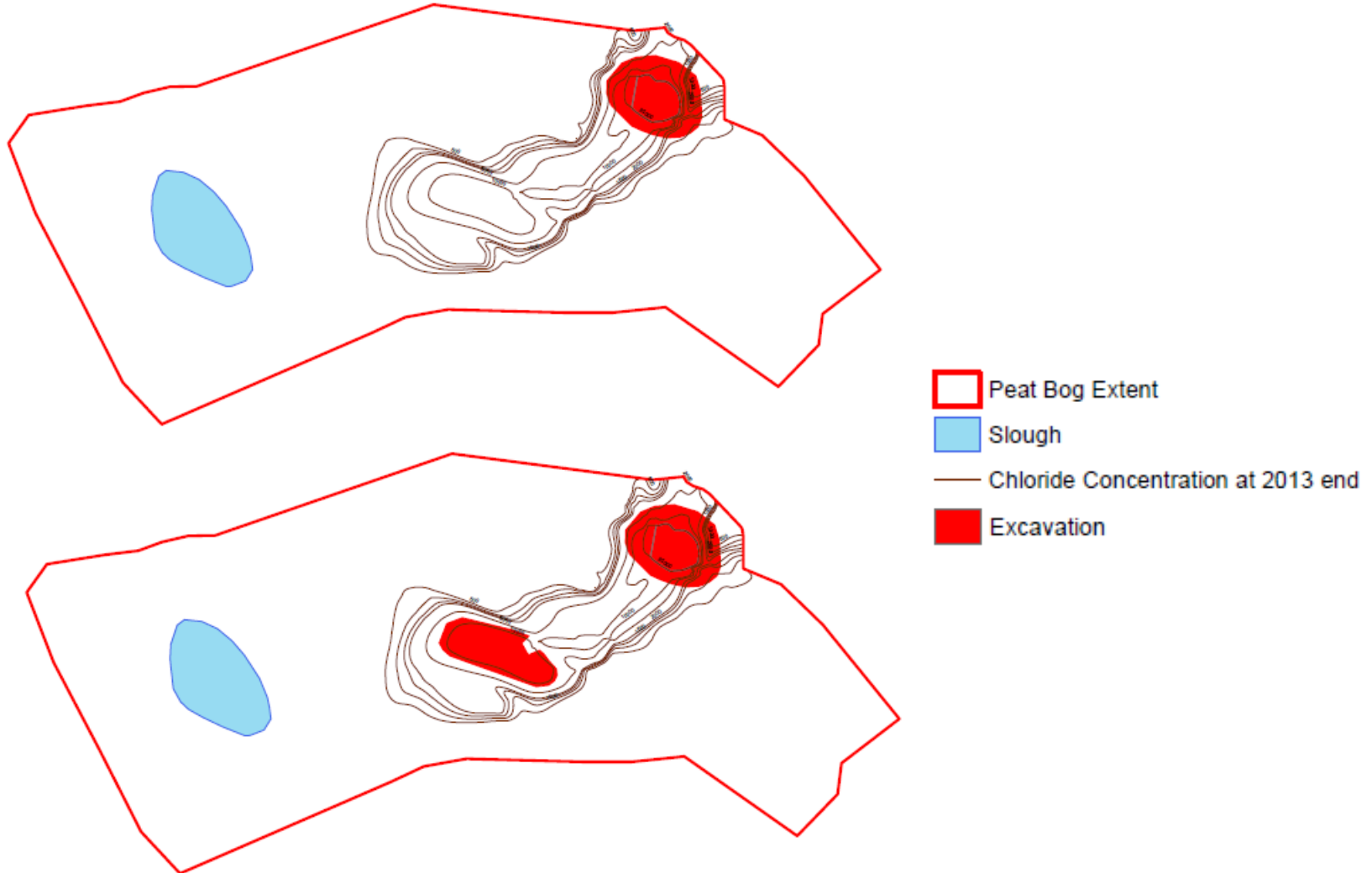
# Remediation Options Analysis



# Options Analysis – Evaluation Criteria

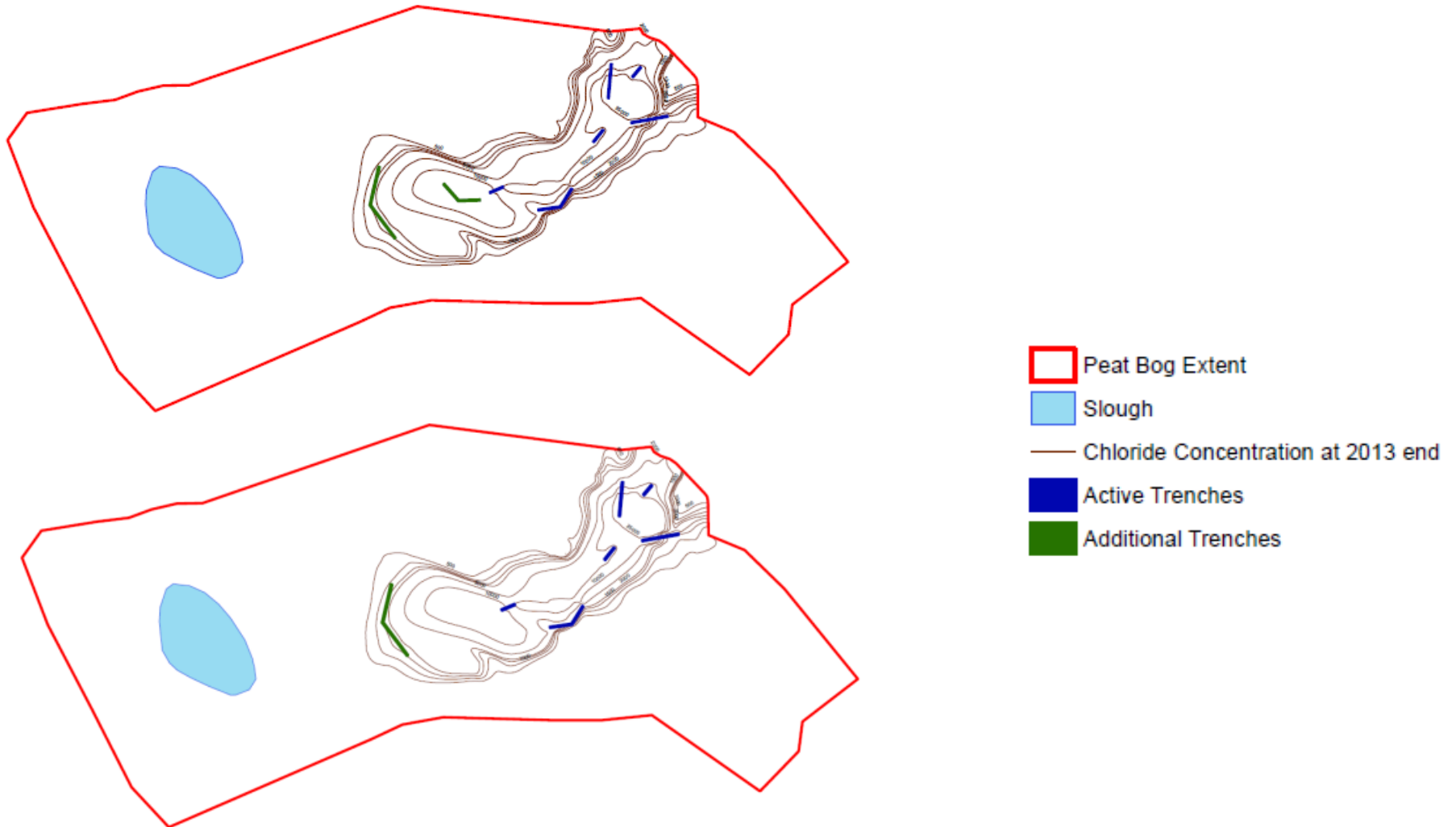


# Option # 1: Excavation

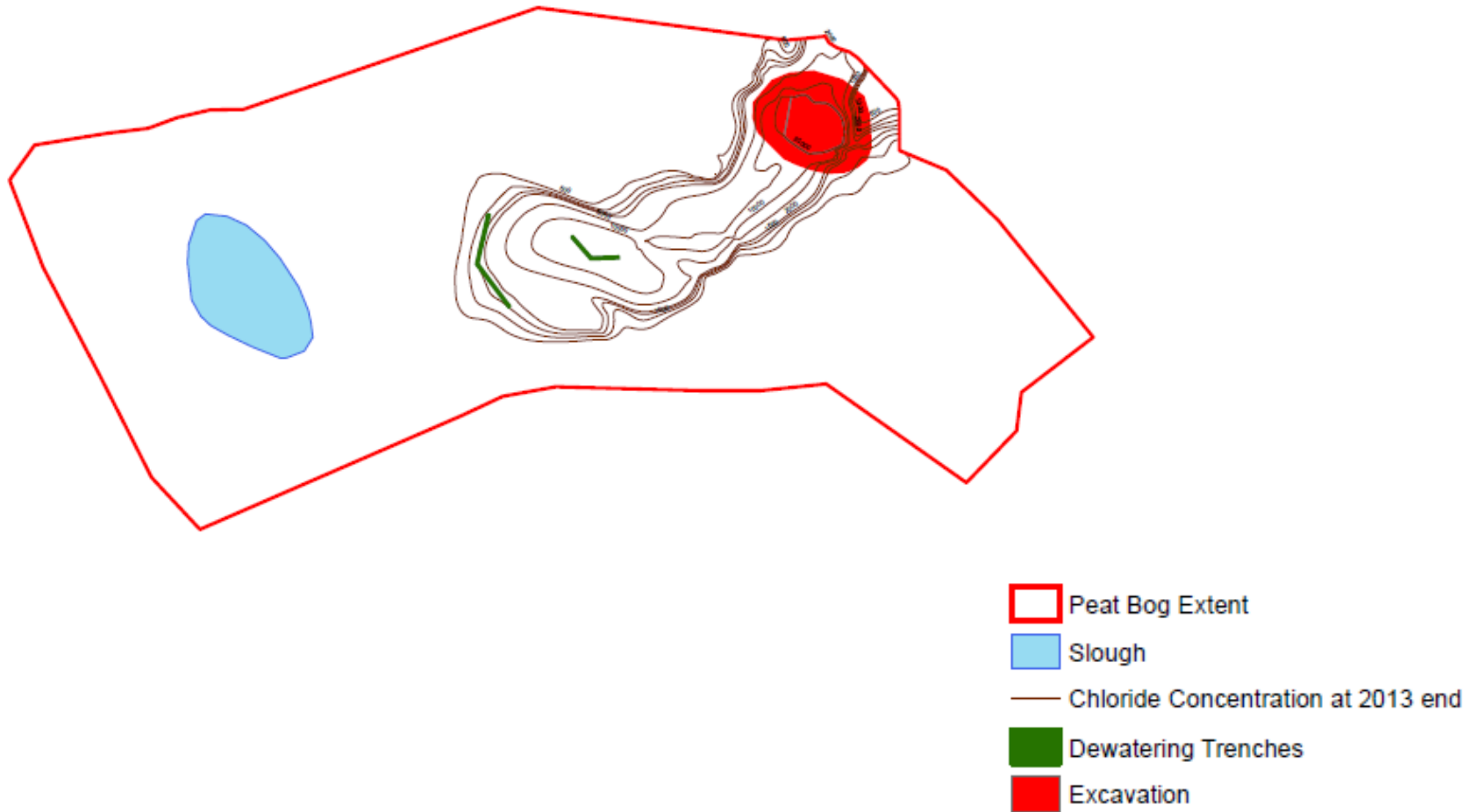




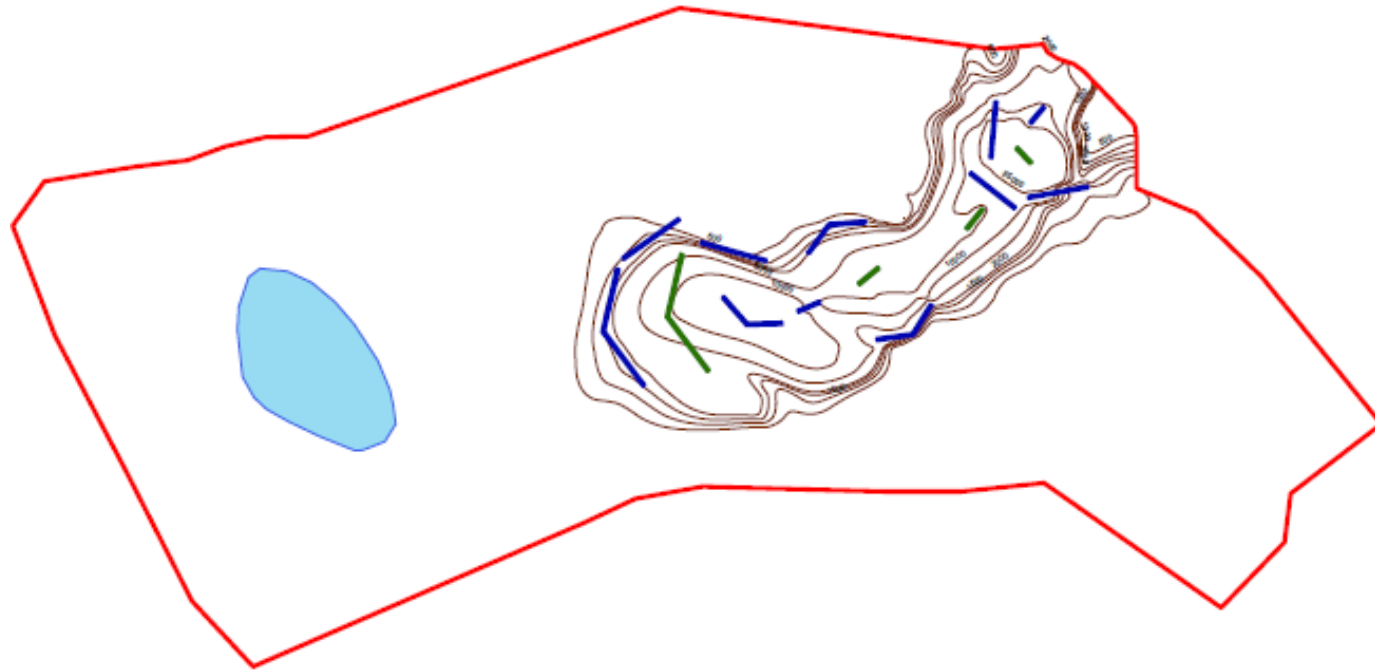
# Option # 2: Dewatering Trenches








# Option # 3: Excavation and Dewatering



# Option # 4: Treatment and Dilution



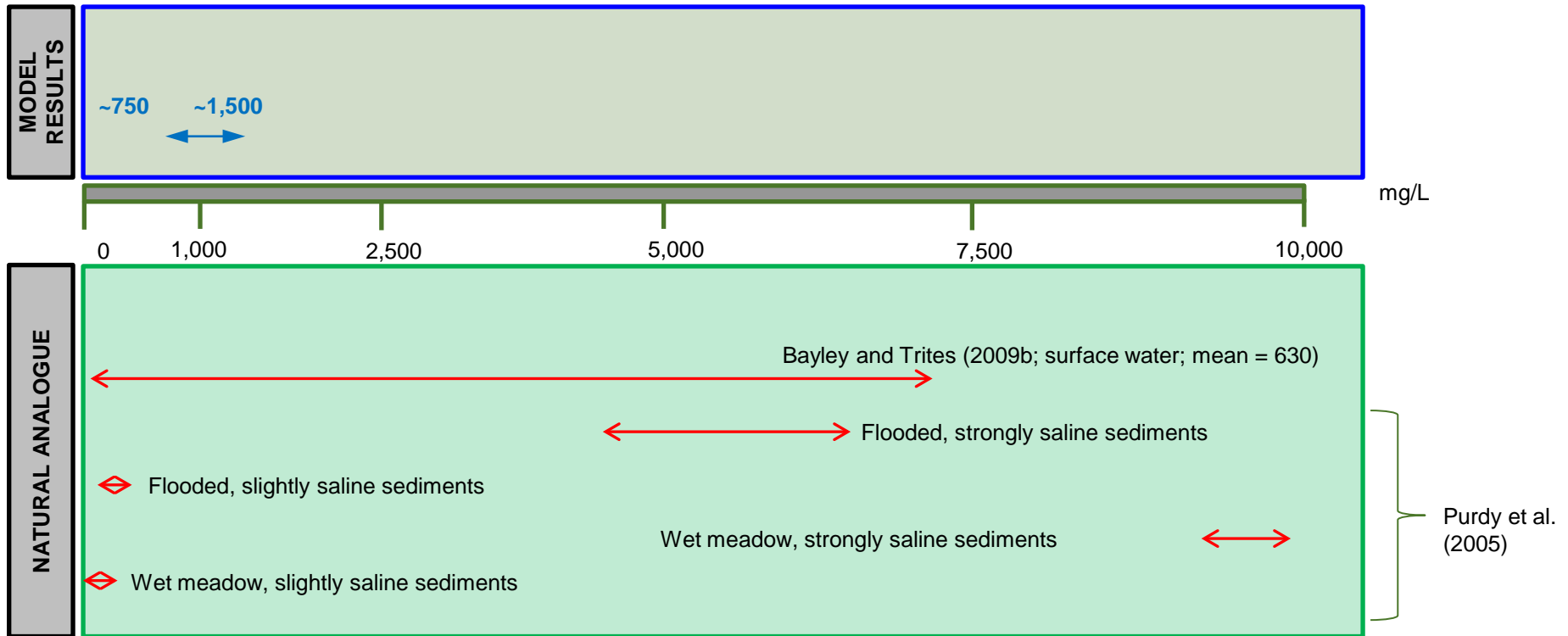
-  Peat Bog Extent
-  Slough
-  Chloride Concentration at 2013 end
-  Dewatering Trenches
-  Infiltration Trenches

# Proposed Approach



# Natural Wetland Tolerances

## Surface water and sediment quality



## Natural Chloride Analog

# Outcomes and Future Work

- ▶ Initial containment and remediation plan in place
- ▶ Guidance on time commitment and cost of remediation
- ▶ Next phase will focus on site specific approach
- ▶ Phased approach, long term monitoring and optimization key to success



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