Modelling Groundwater Flow and Transport in Peat with Focus on Northern Alberta

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Outline

- Background
- Problem Statement
- Case Study

Northern Alberta

Key Infrastructure

Photo Source: www.albertawilderness.ca

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Problem Statement

- Maintain infrastructure and protect environment
- Spills and contaminant concentrations
- Remediate and manage contaminated wetlands
- Conceptual models must integrate peat properties

Key Definitions

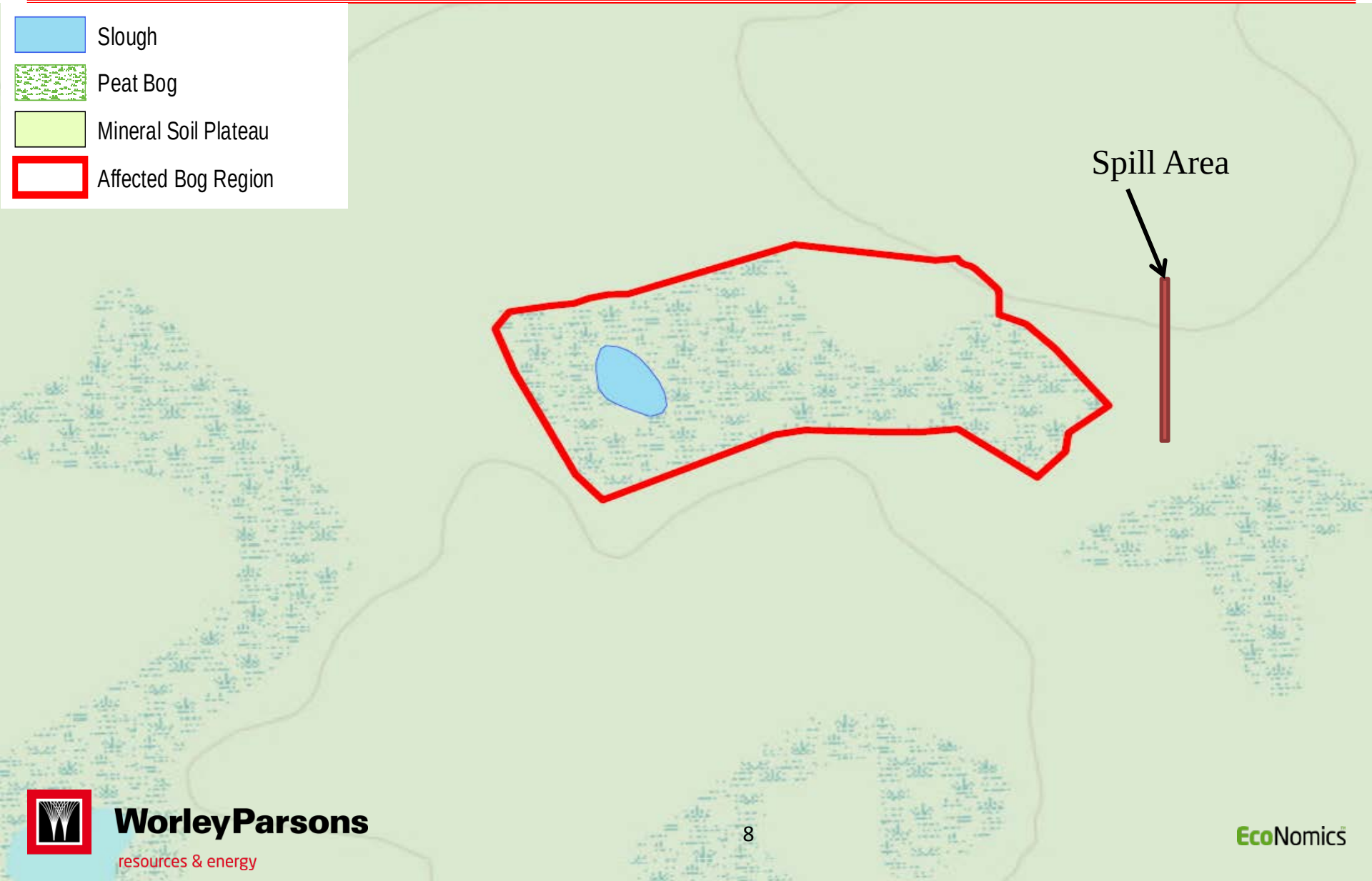
- *Hydraulic conductivity (K)* is ability of a porous medium to transmit water under a given hydraulic gradient

- *Anisotropy* (of K) means that K is directionally dependent

- *Heterogeneity* (in K) refers to distinctly non-uniform distribution of K in space

Northern Alberta

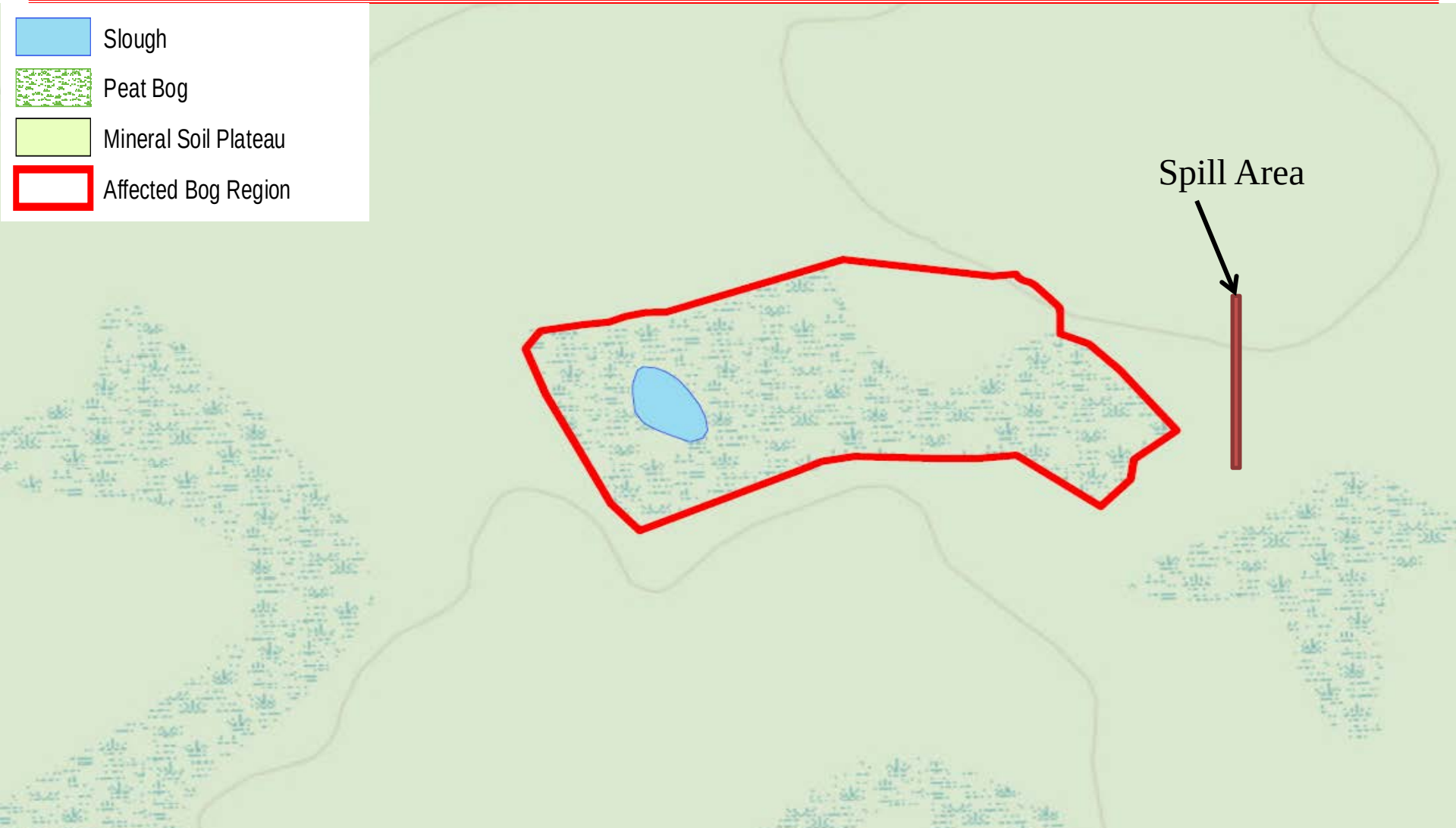
Case Study


Slough
Peat Bog
Mineral Soil Plateau
Affected Bog Region
Spill Area

Objectives

- Investigate the impacts of spill
- Propose conceptual model and predict movement
- Propose management options

Case Study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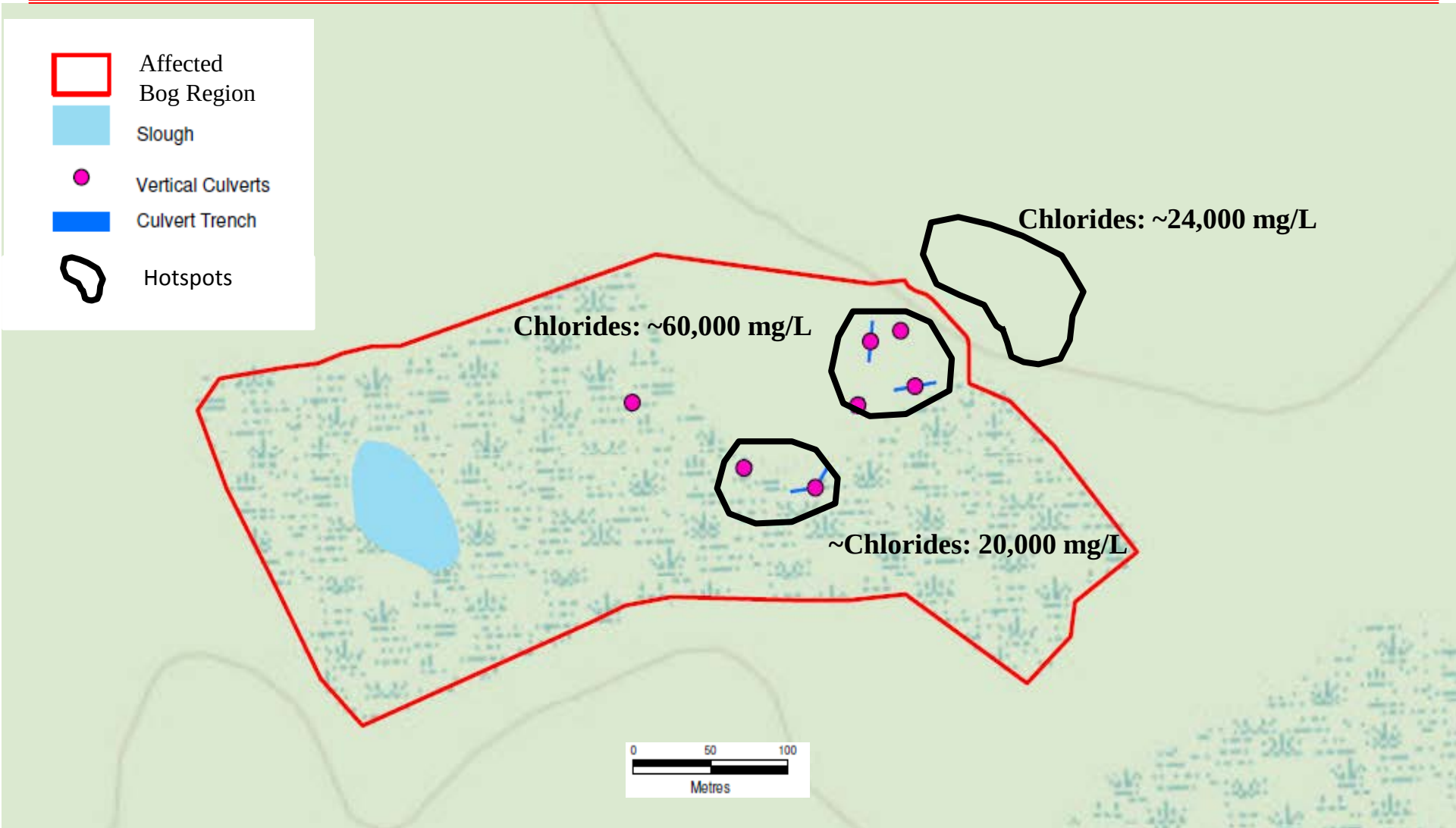
Contamination Hotspots



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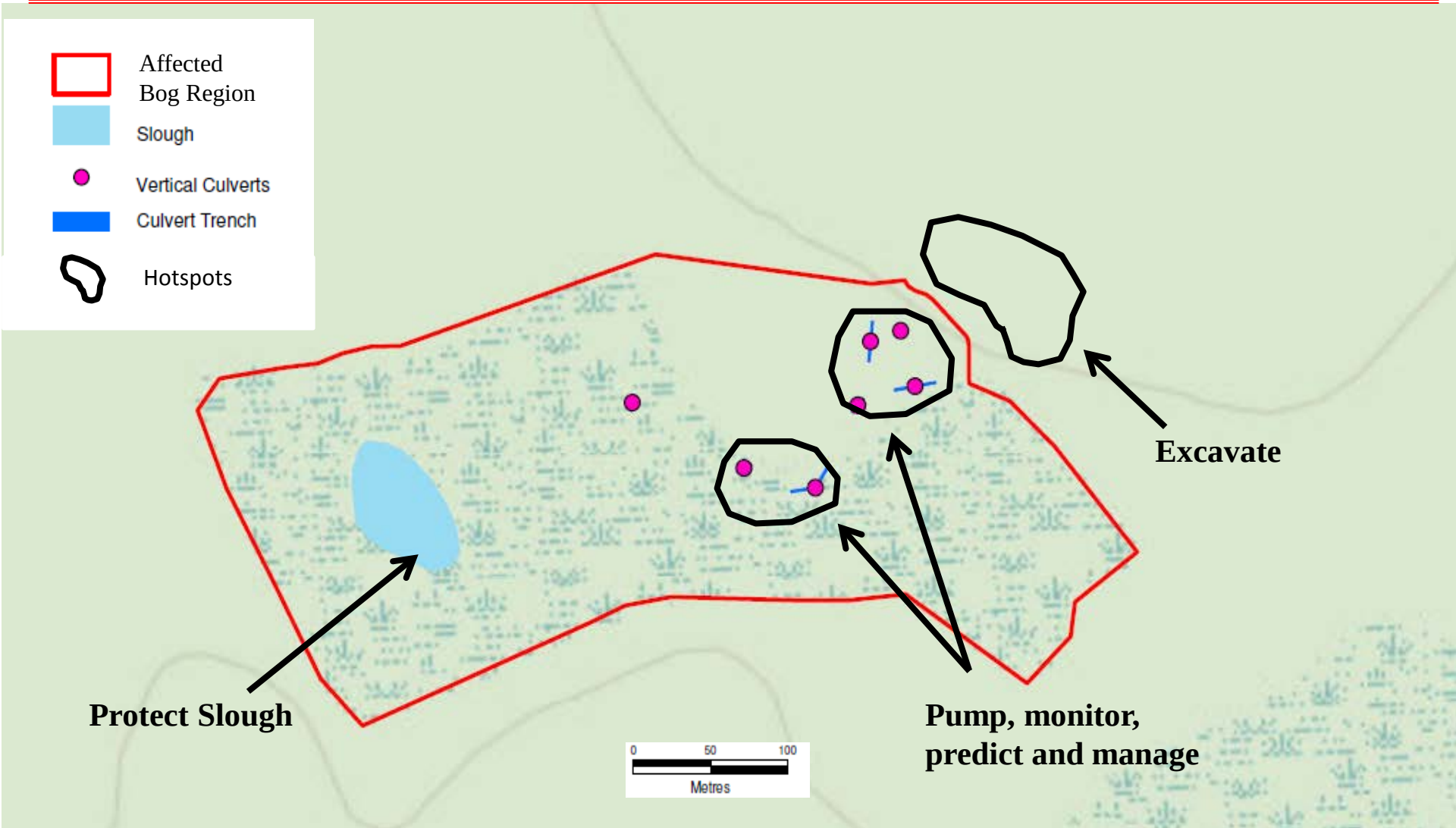
Management Plan

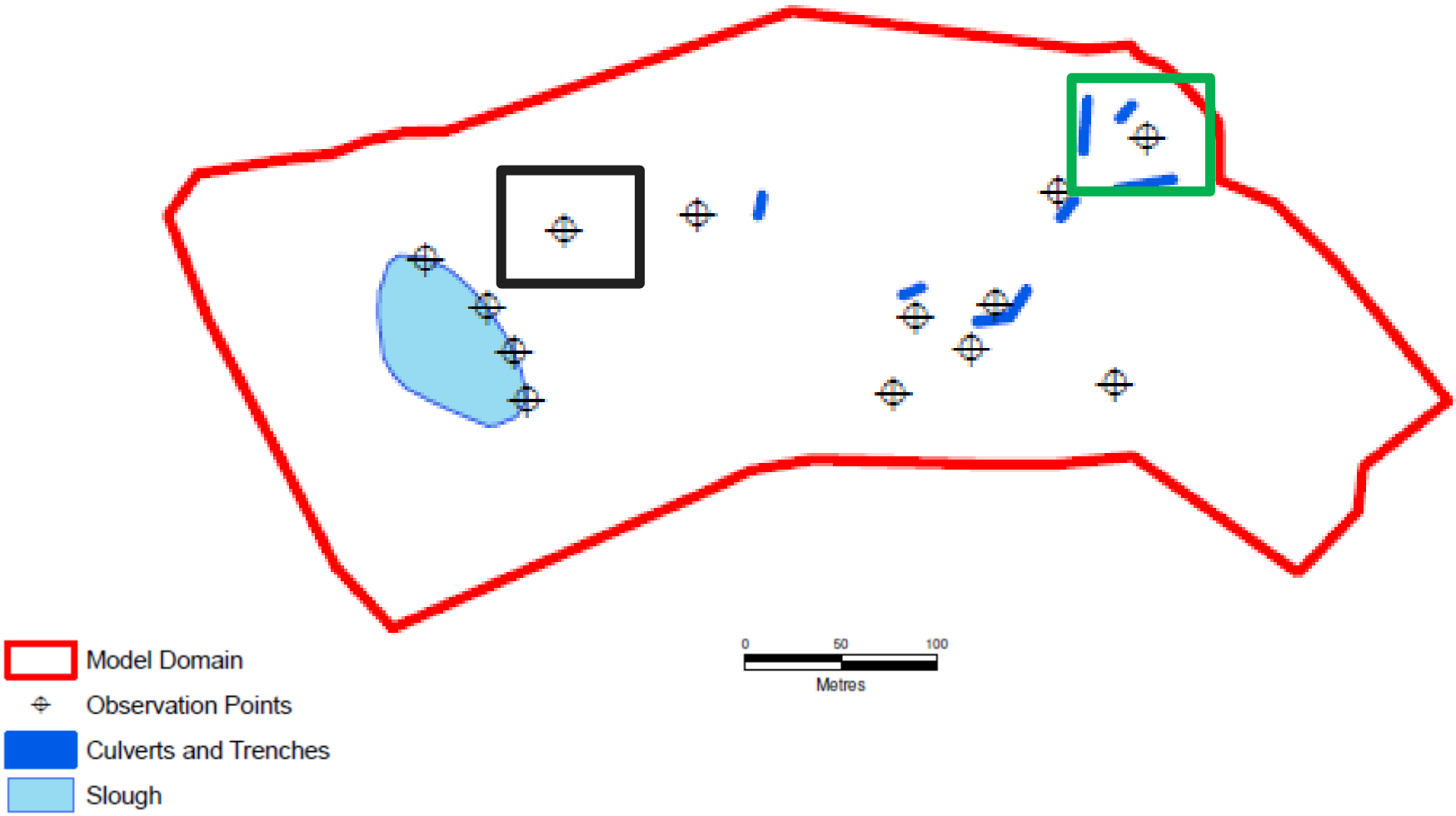


Prediction

- FEFLOW Groundwater flow and transport model
- Predict Slough concentrations
- Improve conceptual model
- Propose management options

Konikow, L.F. (2011). Ground Water, 49(2): 144-159.

Flow Calibration



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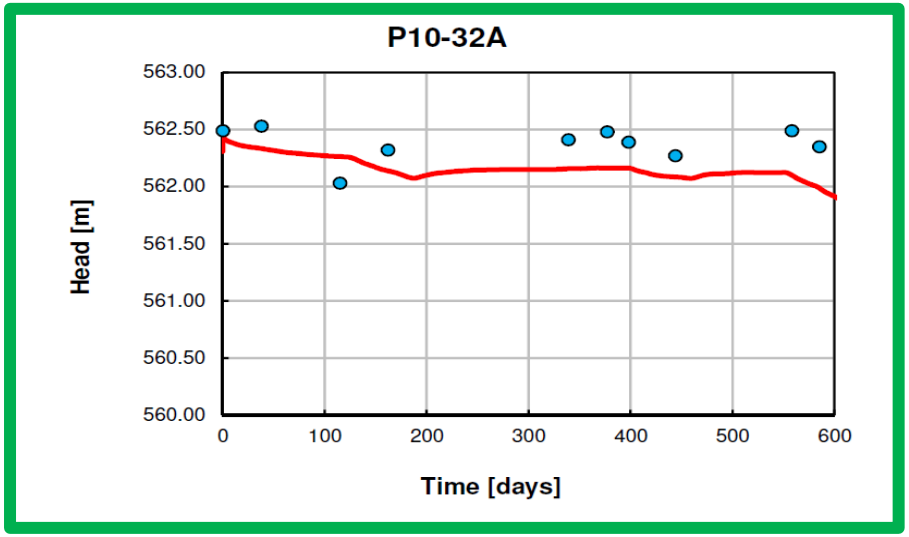
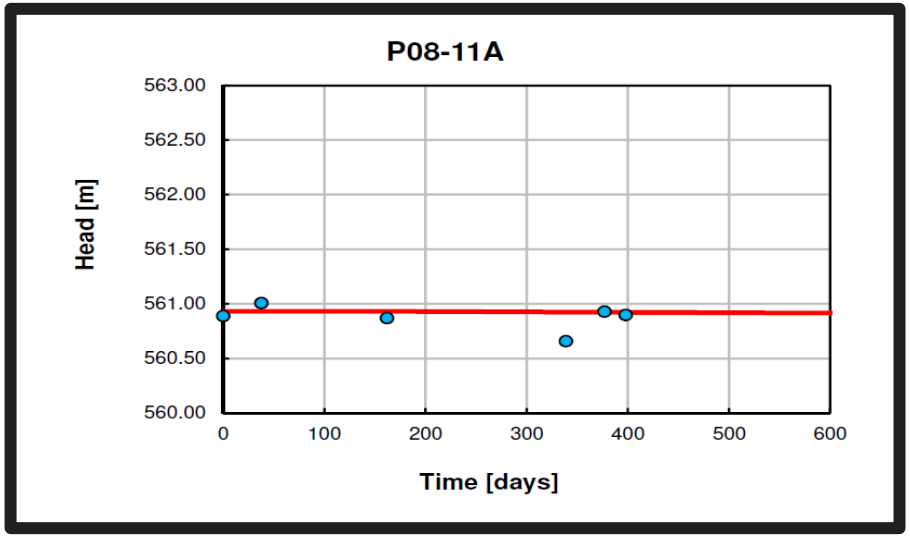
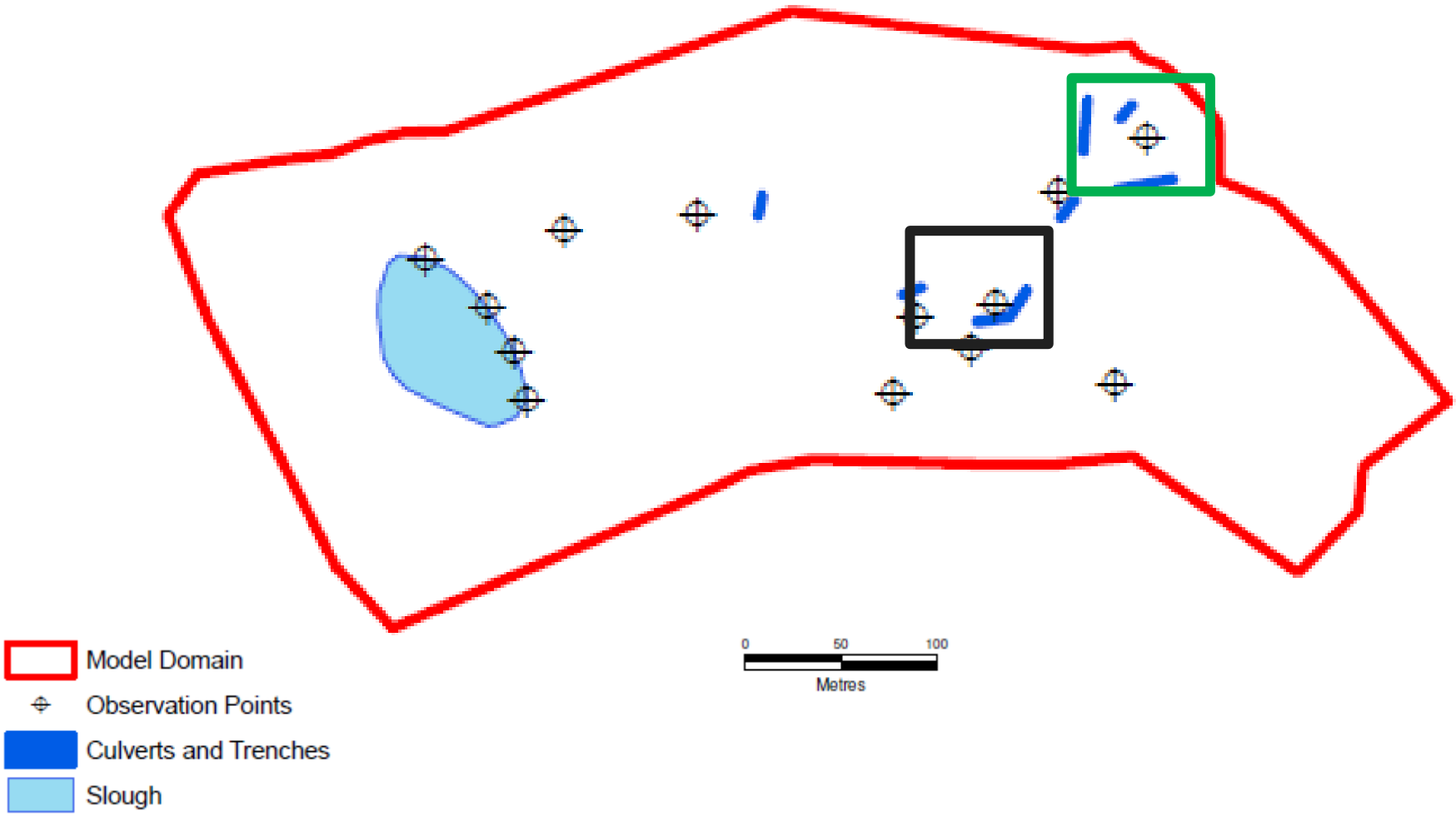
Flow Calibration





Observed Simulated

Transport Calibration



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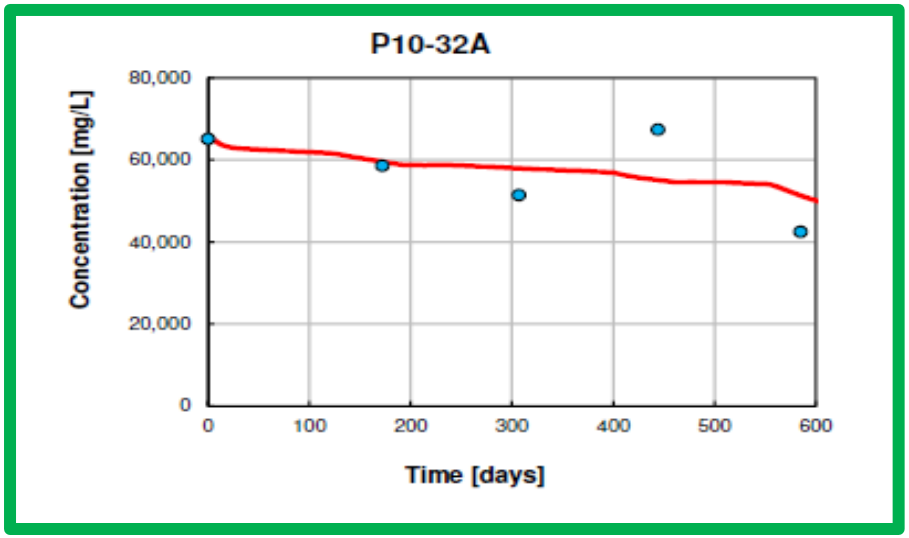
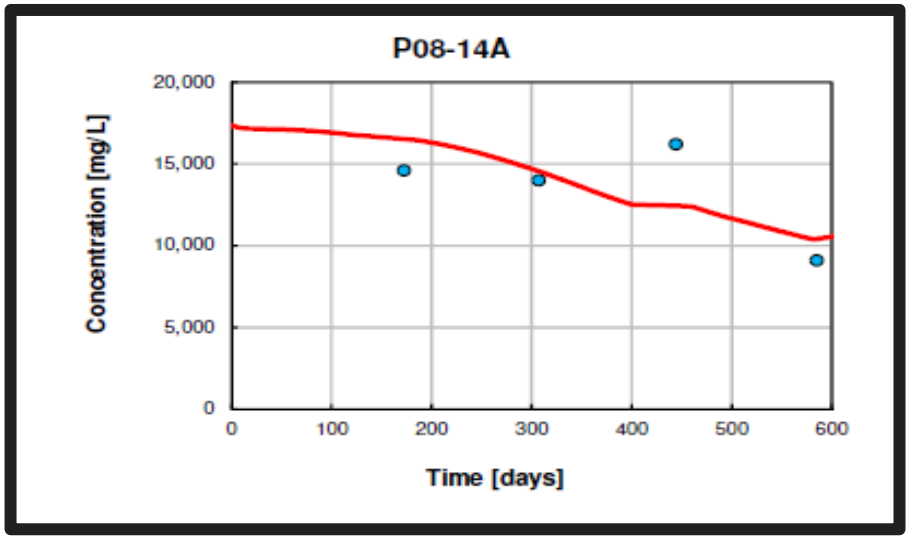
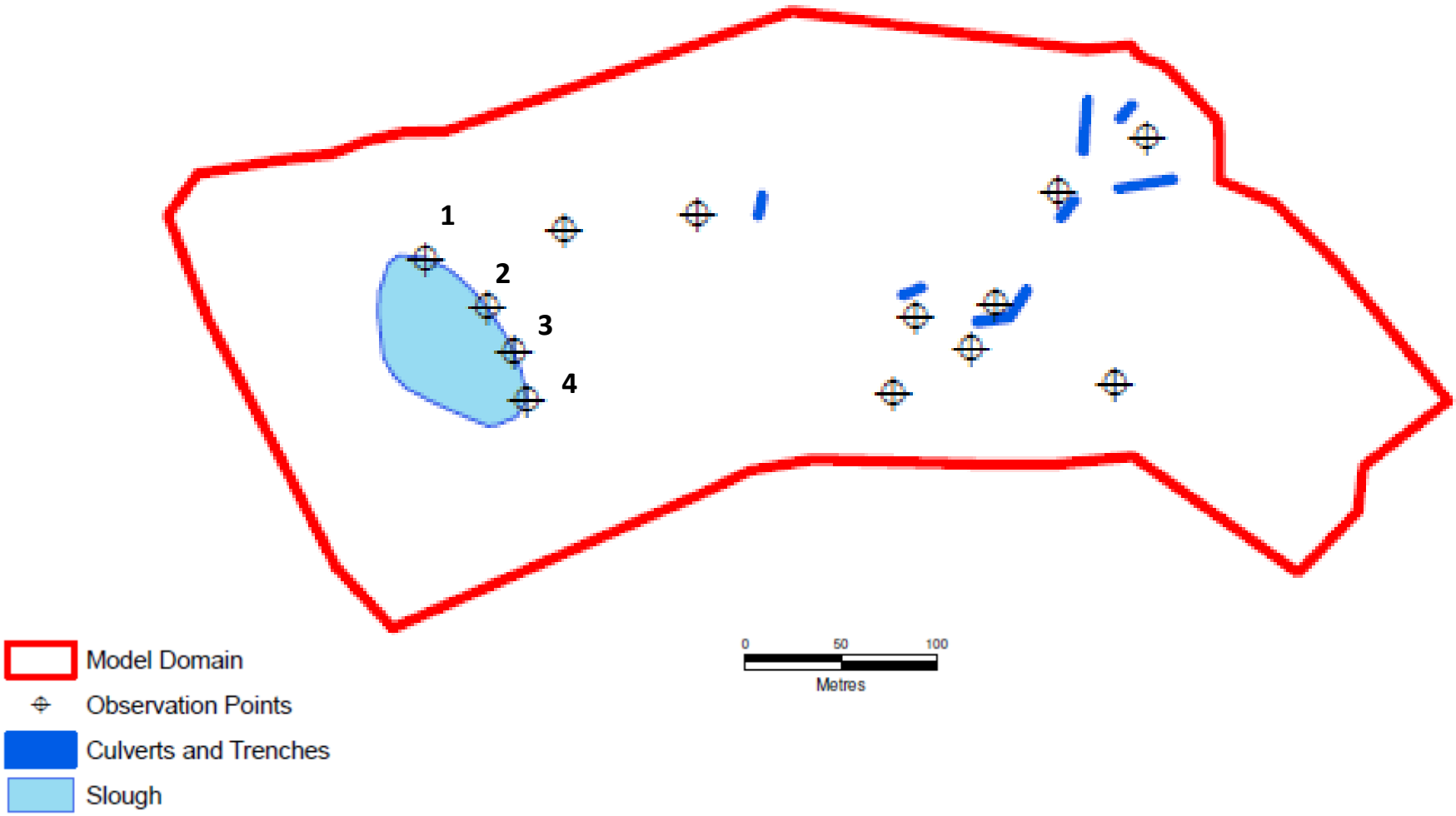
Transport Calibration





Observed Simulated

Scenario Modelling



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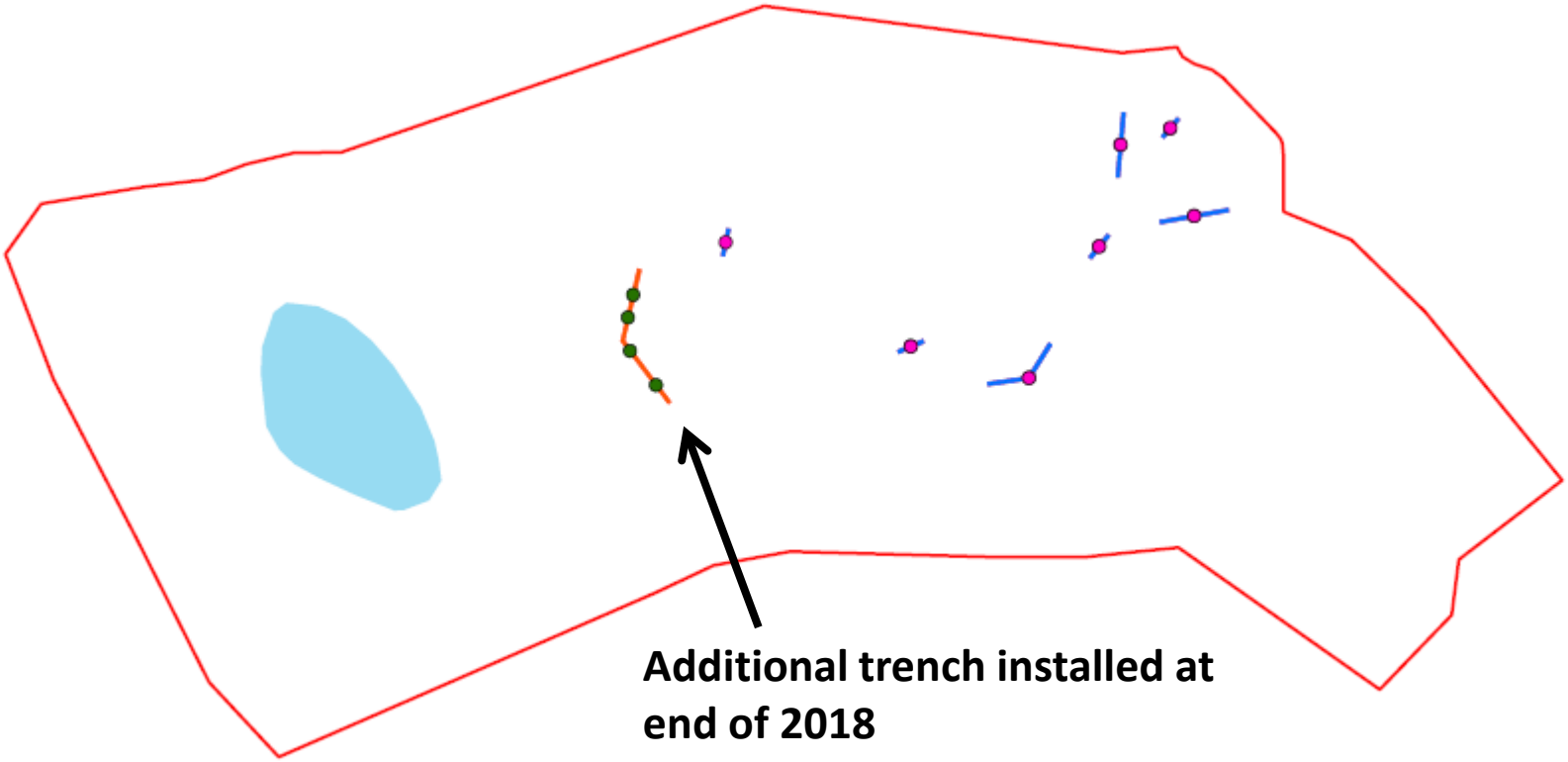
Scenario Modelling



Model Domain

Additional Vertical Culvert

Existing Vertical Culvert

Existing Culvert Trench

Additional Culvert Trench

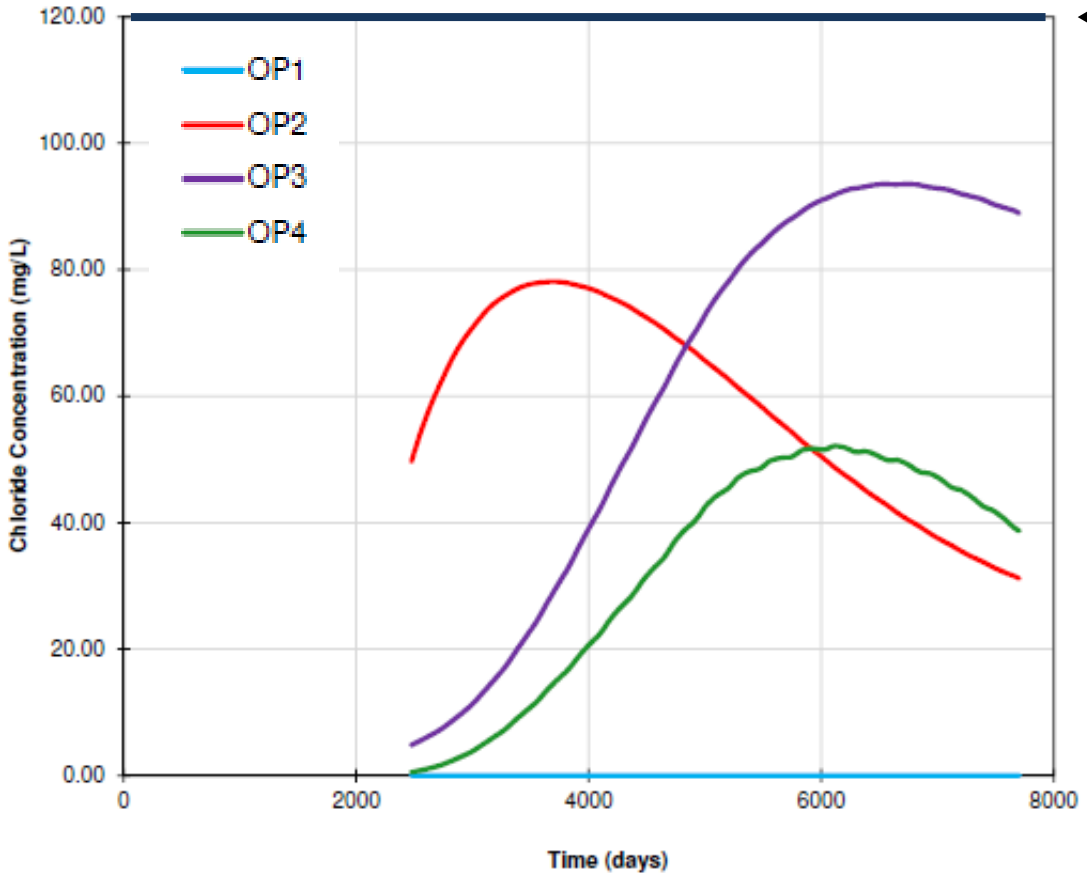
Slough

0 50 100

Metres

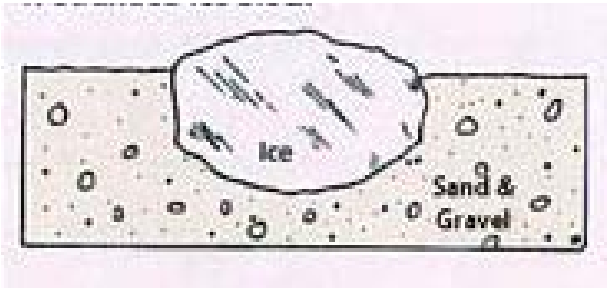
Scenario Modelling

Chloride concentrations at Slough with time

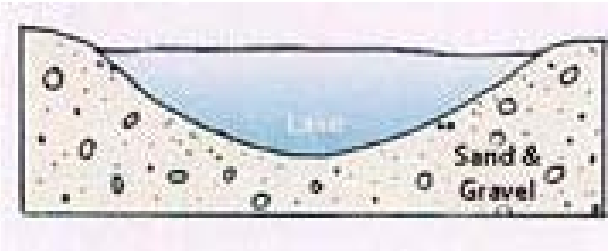


← **Guideline for Surface Water: 120 mg/L**

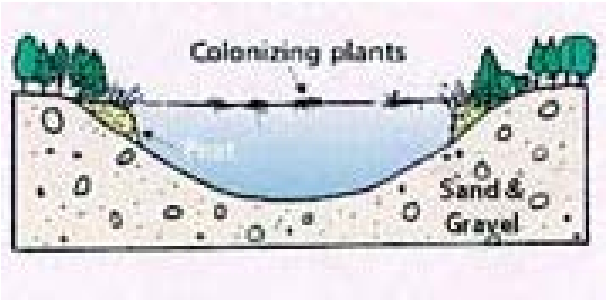
Formation Sequence



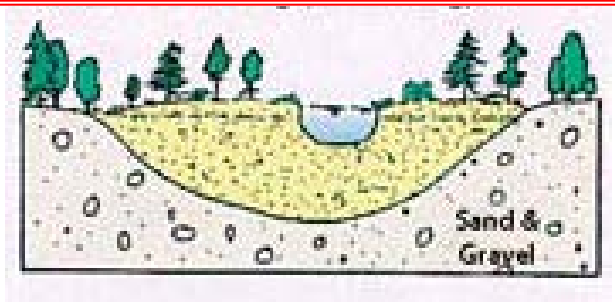
Stage 1: Receding glaciers



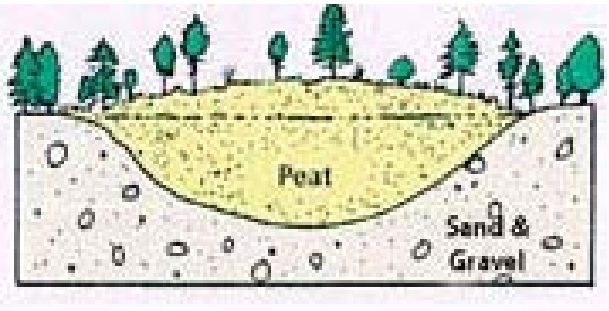
Stage 2: Shallow Glacial Lake



Stage 3: Colonization by vegetation



Stage 4: Cold and oxygen poor conditions Prevent normal degradation of sinking dead plants resulting into formation of peat

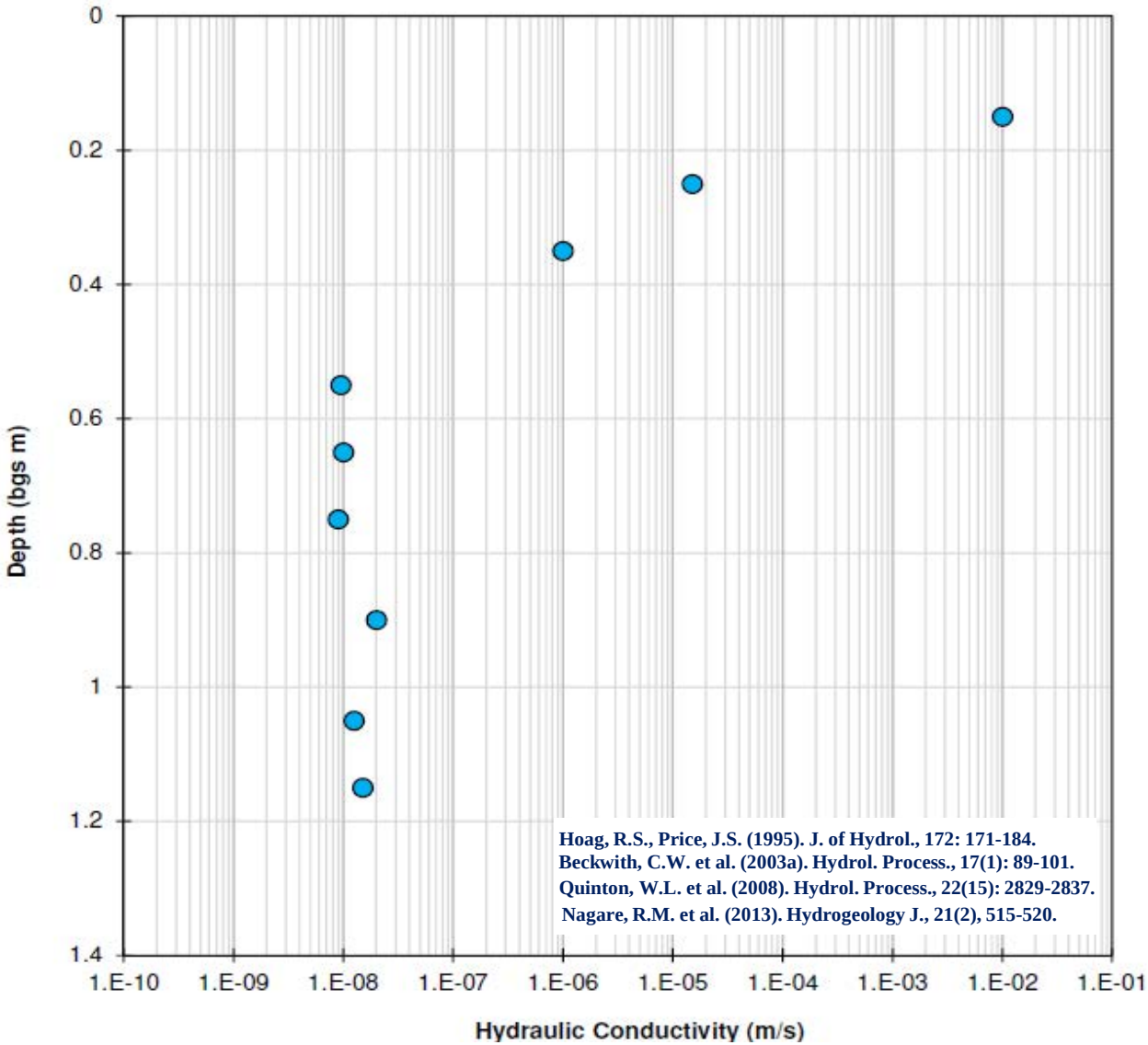


Stage 5: Accumulation continues; nutrient poor conditions result into slow growth and accumulation; older, deeper peat continues to degrade further, while fresh vegetation on top creates more porous surface layer

Peat Properties

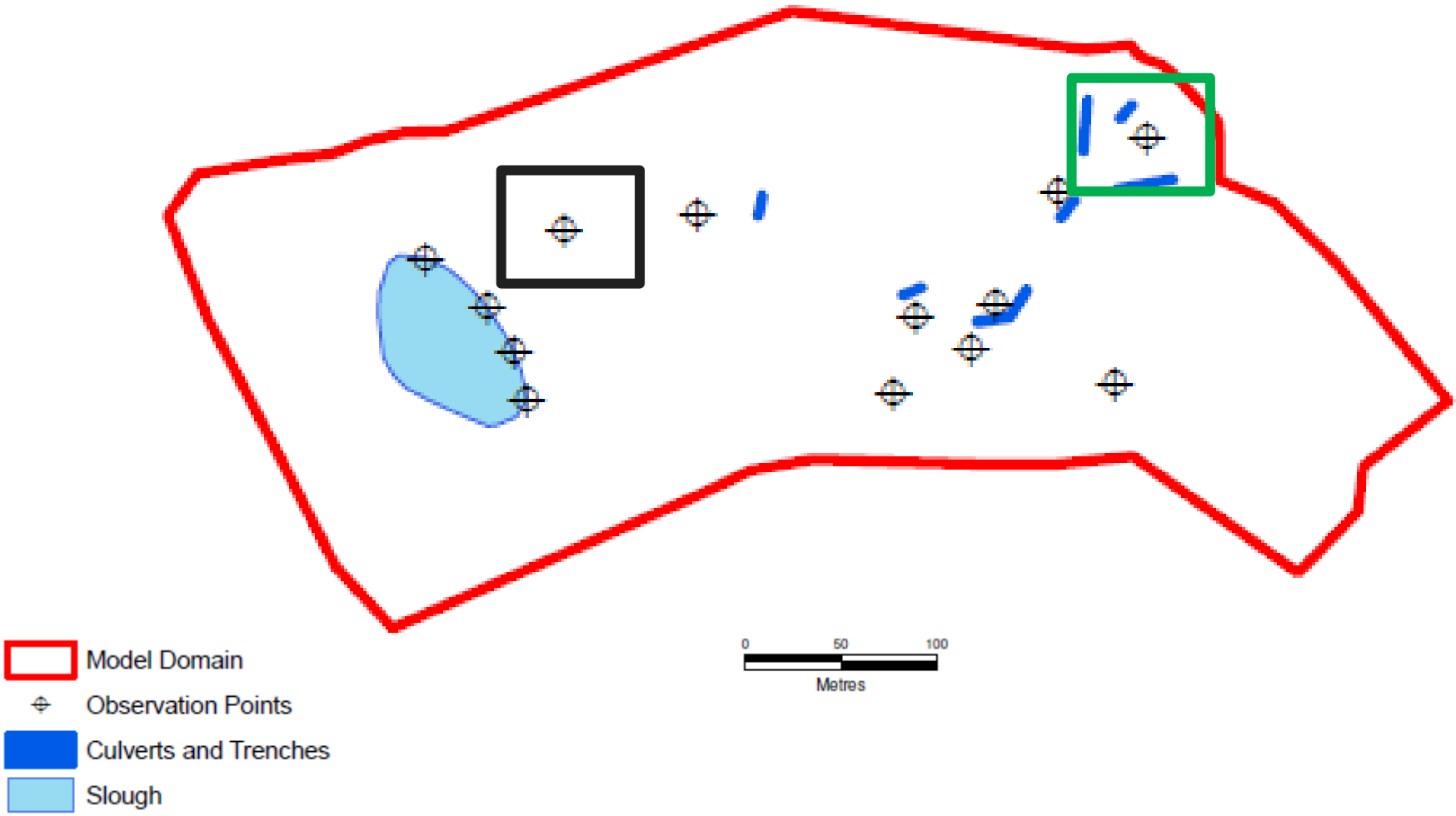
- Exponential decrease in saturated hydraulic conductivity (K) with depth
- High degree of anisotropy and heterogeneity
- Pools of peat deposits – deposition history
- Closed pores, backward diffusion, fibre absorption, deep pools unique processes to peat

K-Depth Relationship



Hoag, R.S., Price, J.S. (1995). J. of Hydrol., 172: 171-184.
Beckwith, C.W. et al. (2003a). Hydrol. Process., 17(1): 89-101.
Quinton, W.L. et al. (2008). Hydrol. Process., 22(15): 2829-2837.
Nagare, R.M. et al. (2013). Hydrogeology J., 21(2), 515-520.

Flow Calibration



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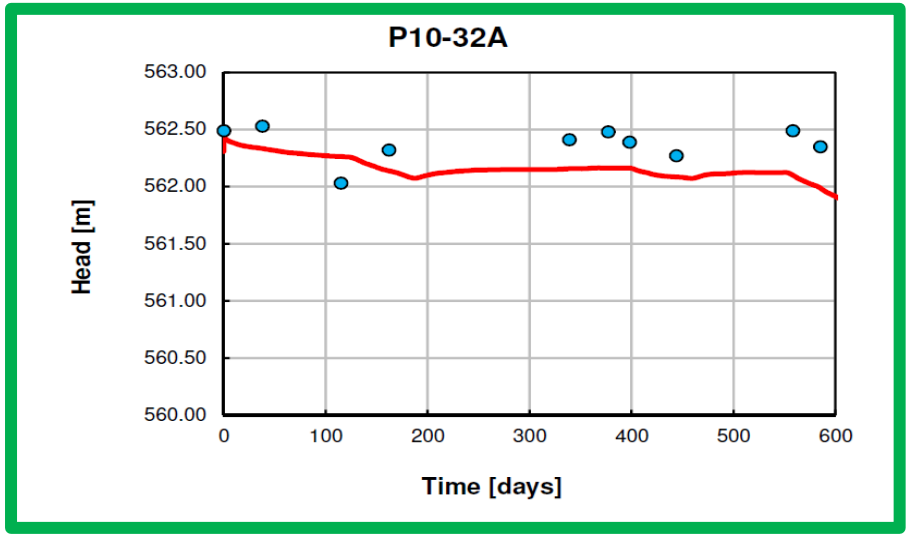
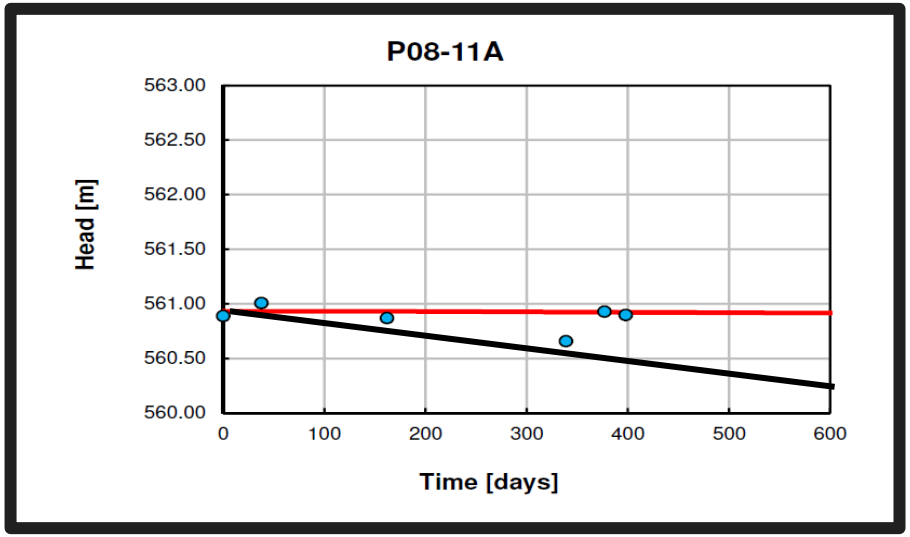
Flow Calibration





Observed

Simulated without layered peat

Simulated with layered peat

Peat Properties

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- High degree of anisotropy and heterogeneity
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- Closed pores, backward diffusion, fibre absorption, deep pools unique processes to peat

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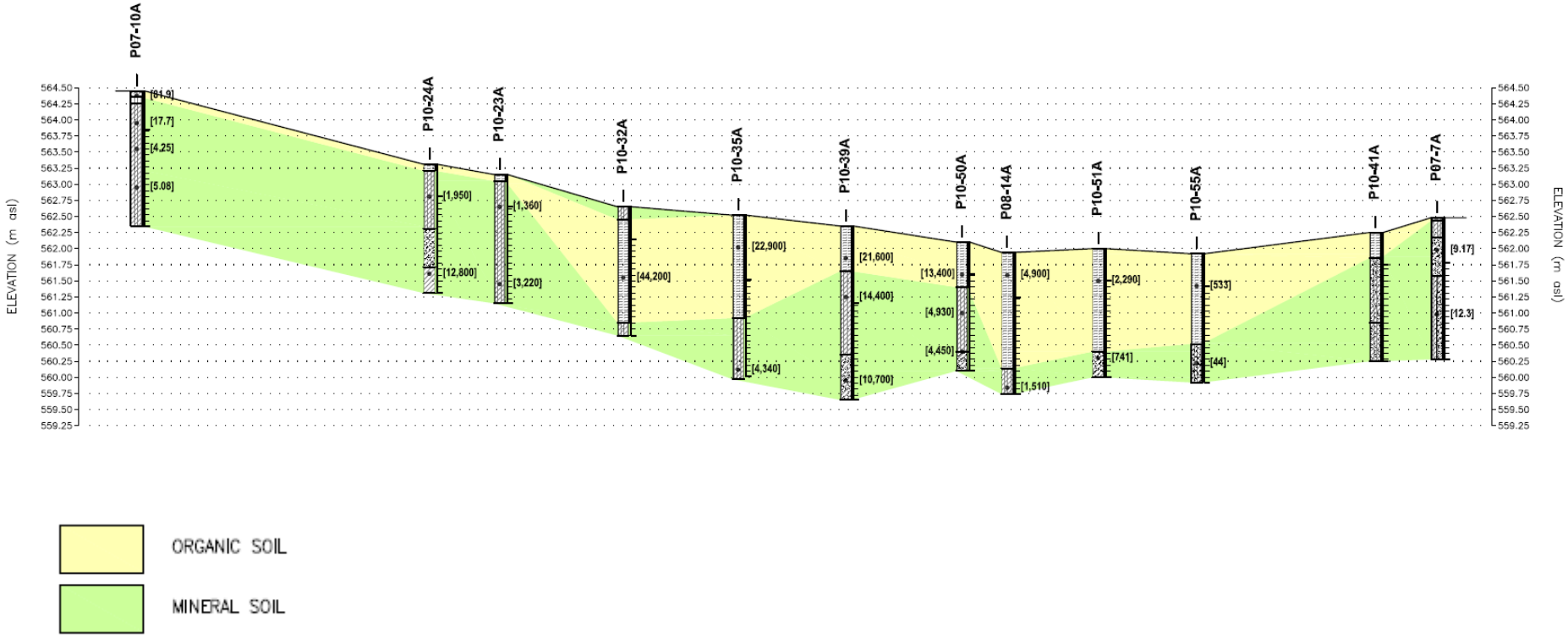
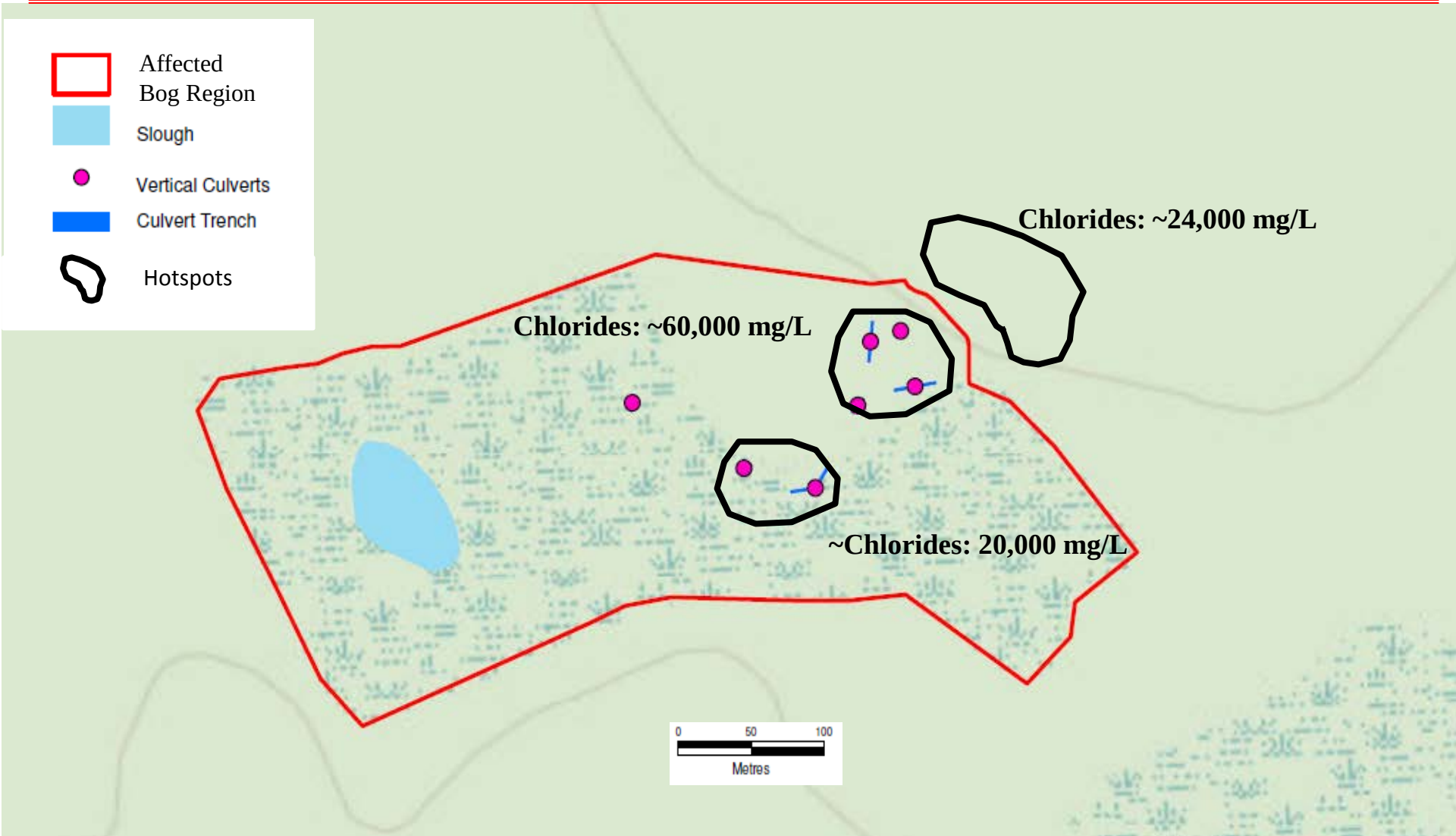
Peat Pools

TYPICAL CROSS SECTION



Source: WorleyParsons Canada Services Ltd.

Peat Pools


Affected Bog Region
Slough
Vertical Culverts
Culvert Trench
Hotspots
Chlorides: ~24,000 mg/L
Chlorides: ~60,000 mg/L
~Chlorides: 20,000 mg/L
0
50
100
Metres

Peat Properties

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- High degree of anisotropy and heterogeneity
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Conceptual Model

- Initial mode of water transport dominantly overland
- Vertical movement into low K zone
- Accumulation into thicker peat zones
- Freshwater movement in upper high K zone

Discussion

- Flow and transport in peat is different than mineral soils
- Solutions need to consider anisotropy and peat layering
- Long term implications of peat properties

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