KERR WOOD LEIDAL
consulting engineers

APPENDIX A

PRELIMINARY HYDROGEOLOGY RESULTS

Garden City Lands

Hydrogeological Assessment

For

Water and Ecosystem Resource Management Plan

Richmond

Enterprise Geoscience Services Ltd.

KERR WOOD LEIDAL
consulting engineers

Contents

- Project Understanding and Objectives
- Development of Seepage Model
  - Results
  - Uncertainties
  - Recommendations

Objectives

- Objective is to develop the western portion of the GCL into a working farm with community ammenities and to restore the eastern portion of the site as a functioning peat bog.

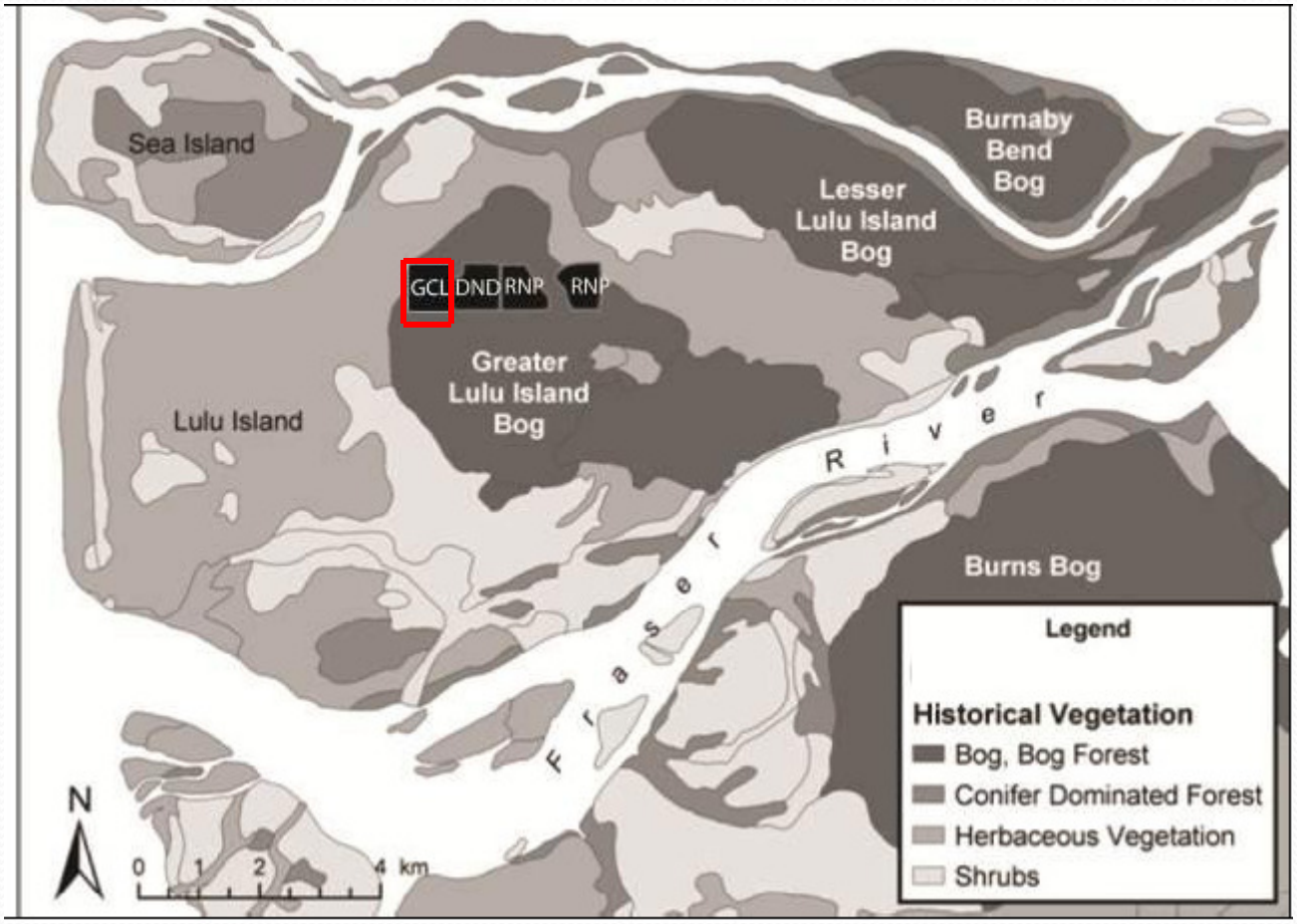
Hydrogeological Assessment

- Hydrogeological assessment and modeling was carried out in support of the plan to:
  - Evaluate hydraulic separation of the two areas of the site consistent with draining the agricultural land and maintaining a water mound in the bog area which is critical for bog health
  - Evaluate incorporating landscape elements (e.g. perimeter trails) to maintain water levels in the peat by reducing seepage losses from the peat to ditches and utility trenches
  - Evaluate use of pumping groundwater from the sand aquifer for farm irrigation

Seepage Model

- Gather background information on topography, soil profile, water level measurements, soil hydraulic properties, drainage and utilities
- Develop a conceptual site model
- Prepare a numerical finite element model
- Calibrate the model to observed conditions
- Run model simulations incorporating drainage, barriers, groundwater pumping

Garden City Lands – Remnant of the Greater Lulu Island Bog

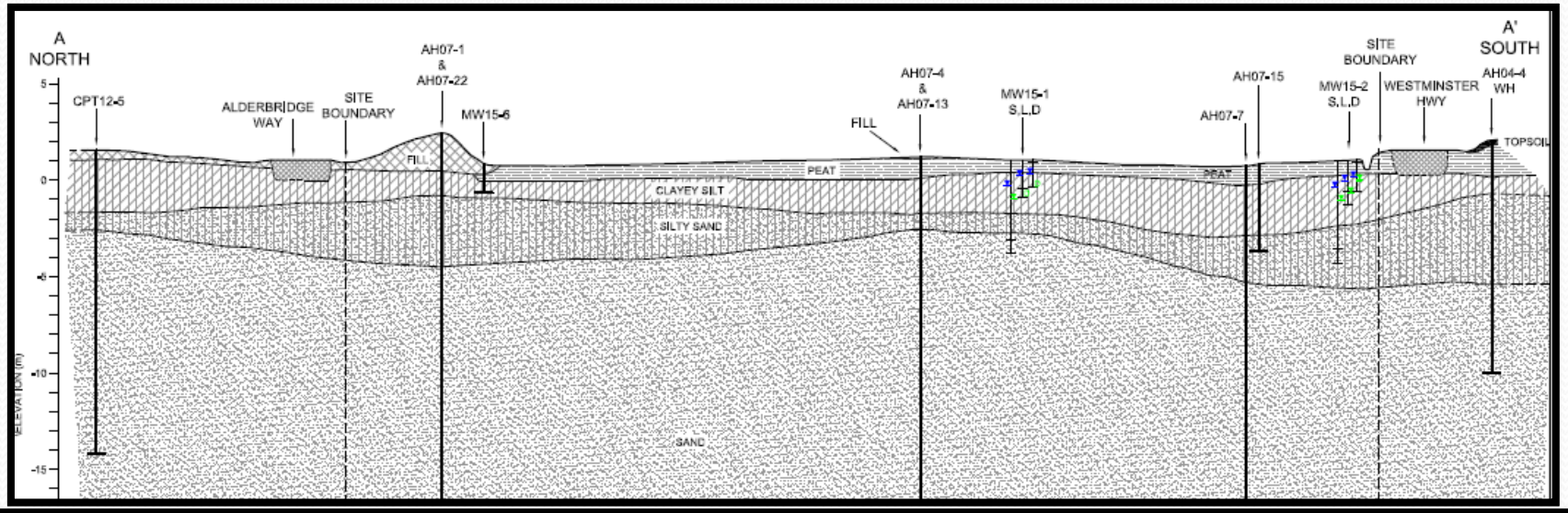


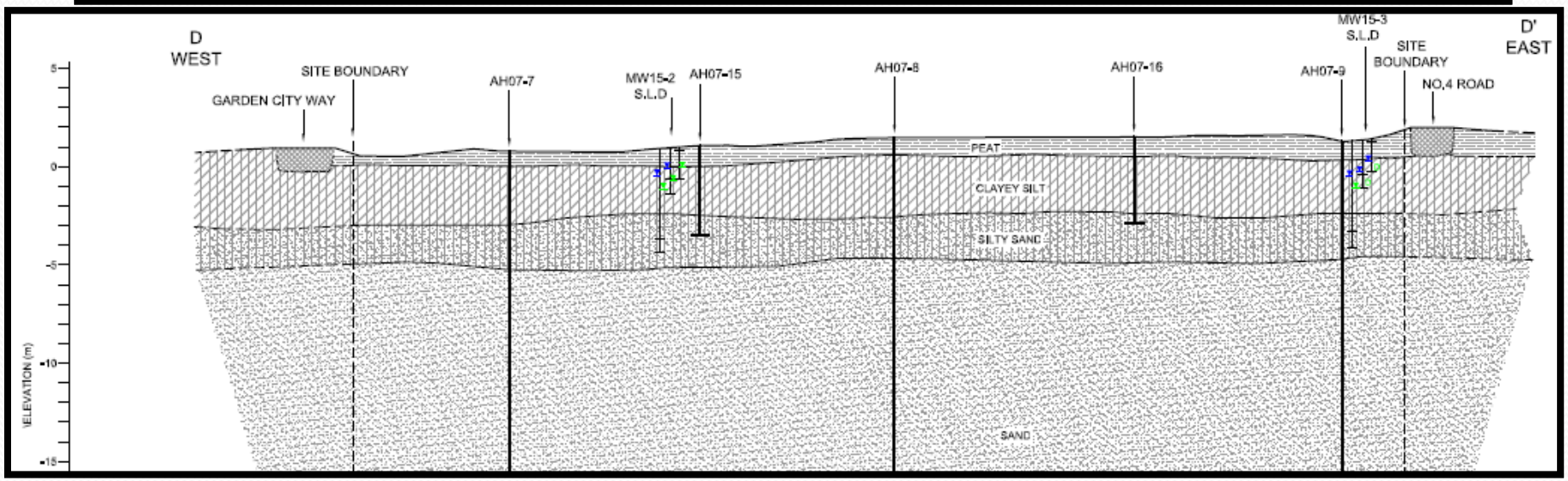
Site

GCL – Garden City Lands
DND – Department of National Defence
RNP – Richmond Nature Park

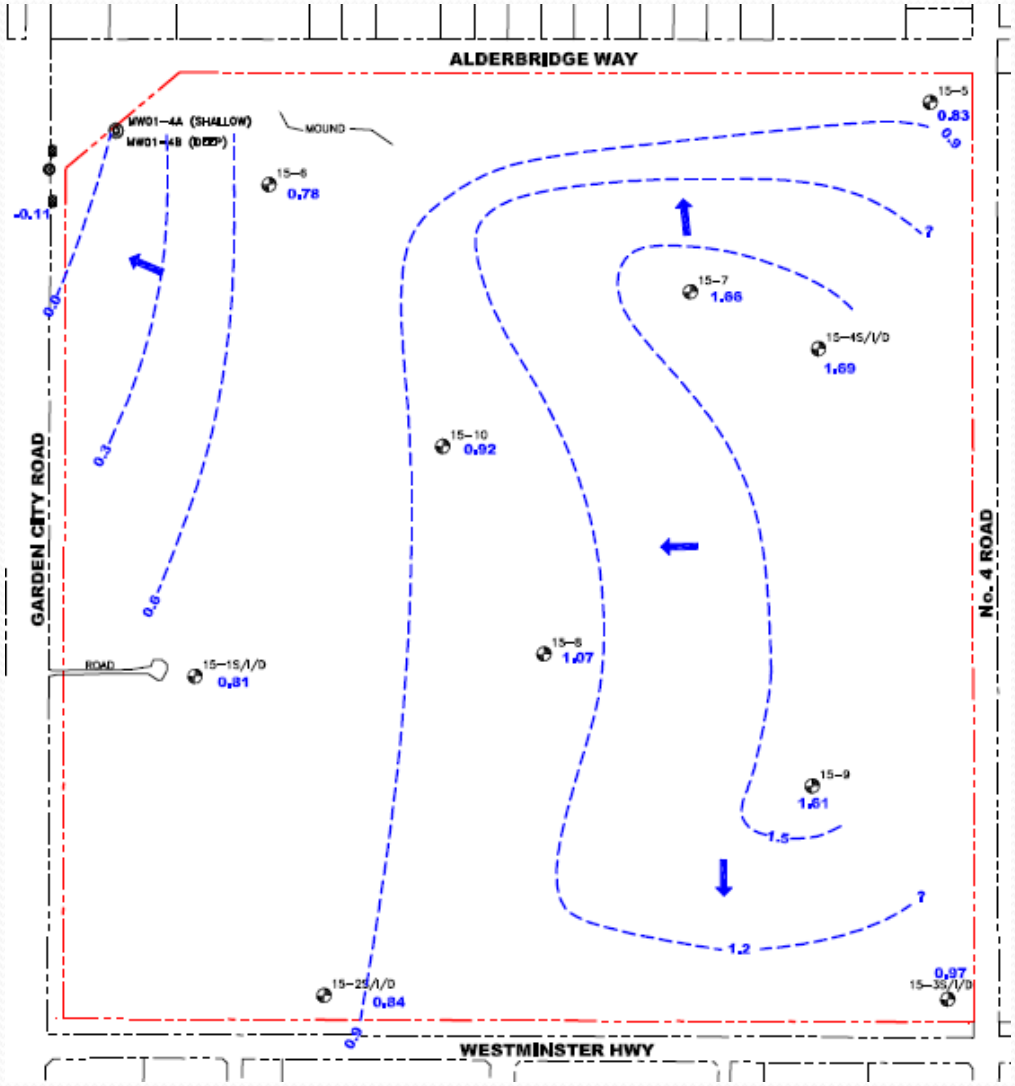
Source:
Diamond Head Consulting, 2013. Richmond Garden City Lands Biophysical Inventory and Analysis

Typical Cross Sections Through GCL



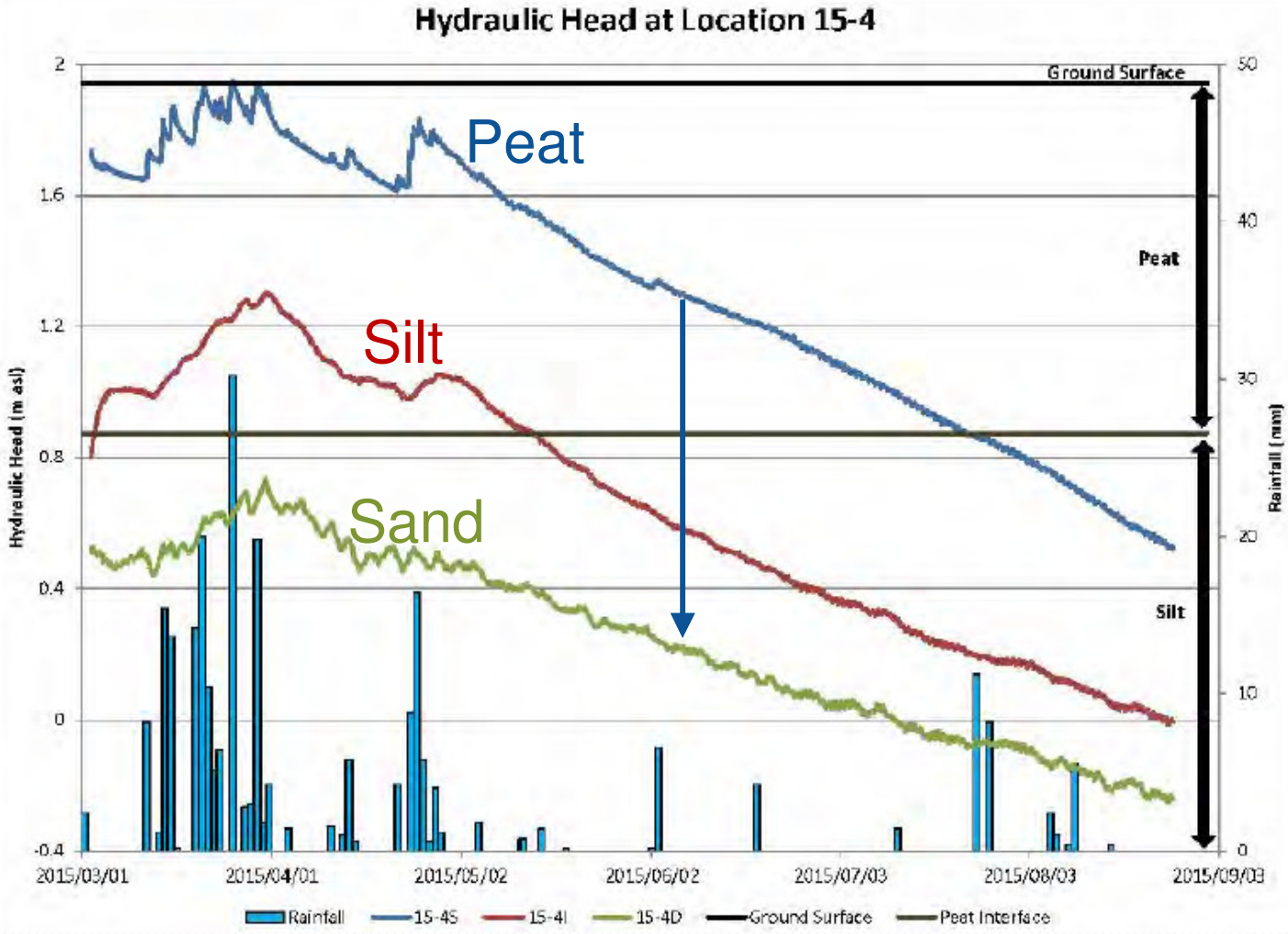


Winter Water Table in Peat



Source: SNC-Lavalin, 2015, Hydrogeological Investigation: Garden City Lands, Richmond, BC

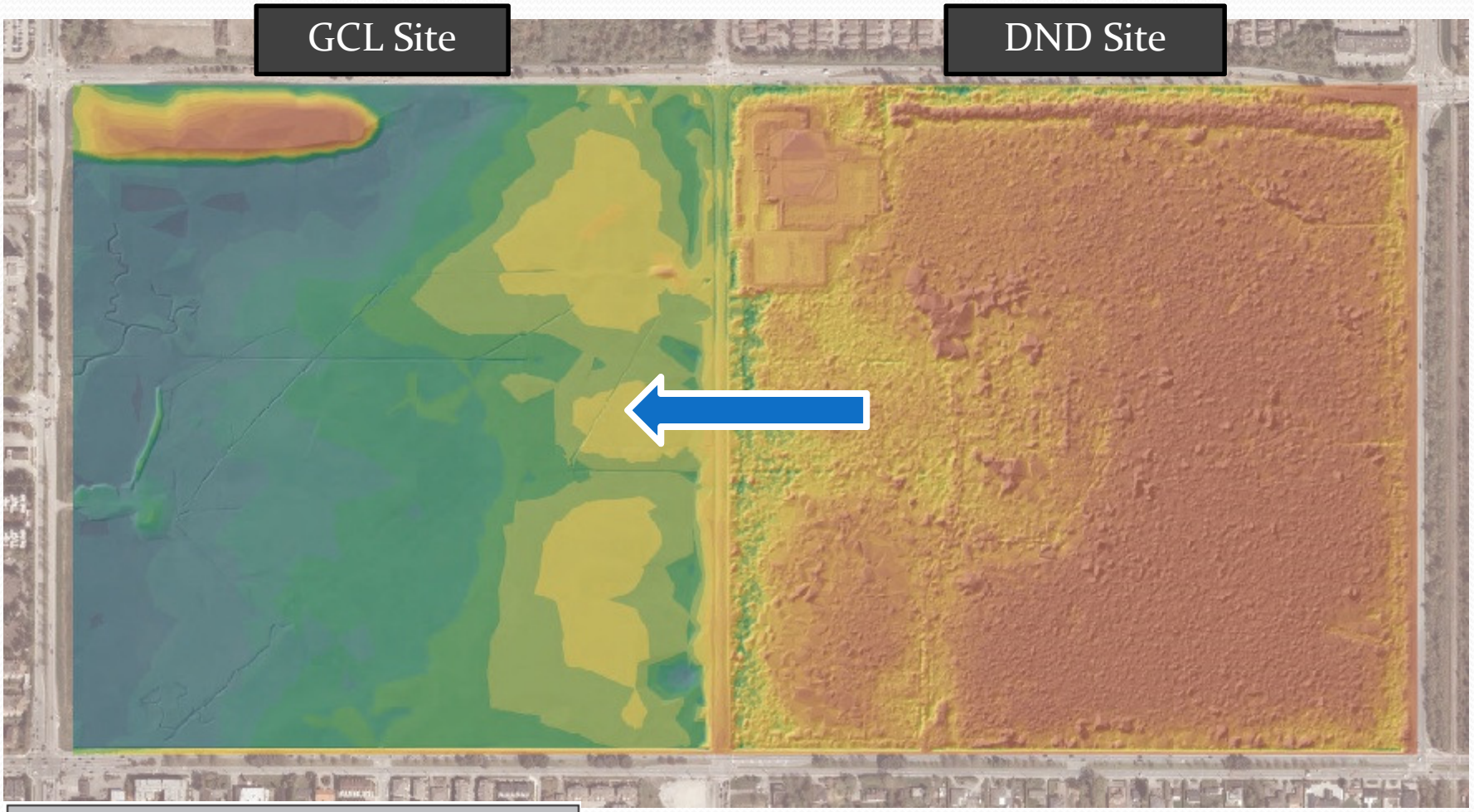
Water Level Monitoring March to August, 2015



- Downward seepage losses from peat to sand aquifer
- Pumping sand aquifer for irrigation would minimally increase seepage losses
- Peat layer completely dry in Summer 2015

Source:
SNC-Lavalin, 2015. Hydrogeological Investigation: Garden City Lands, Richmond

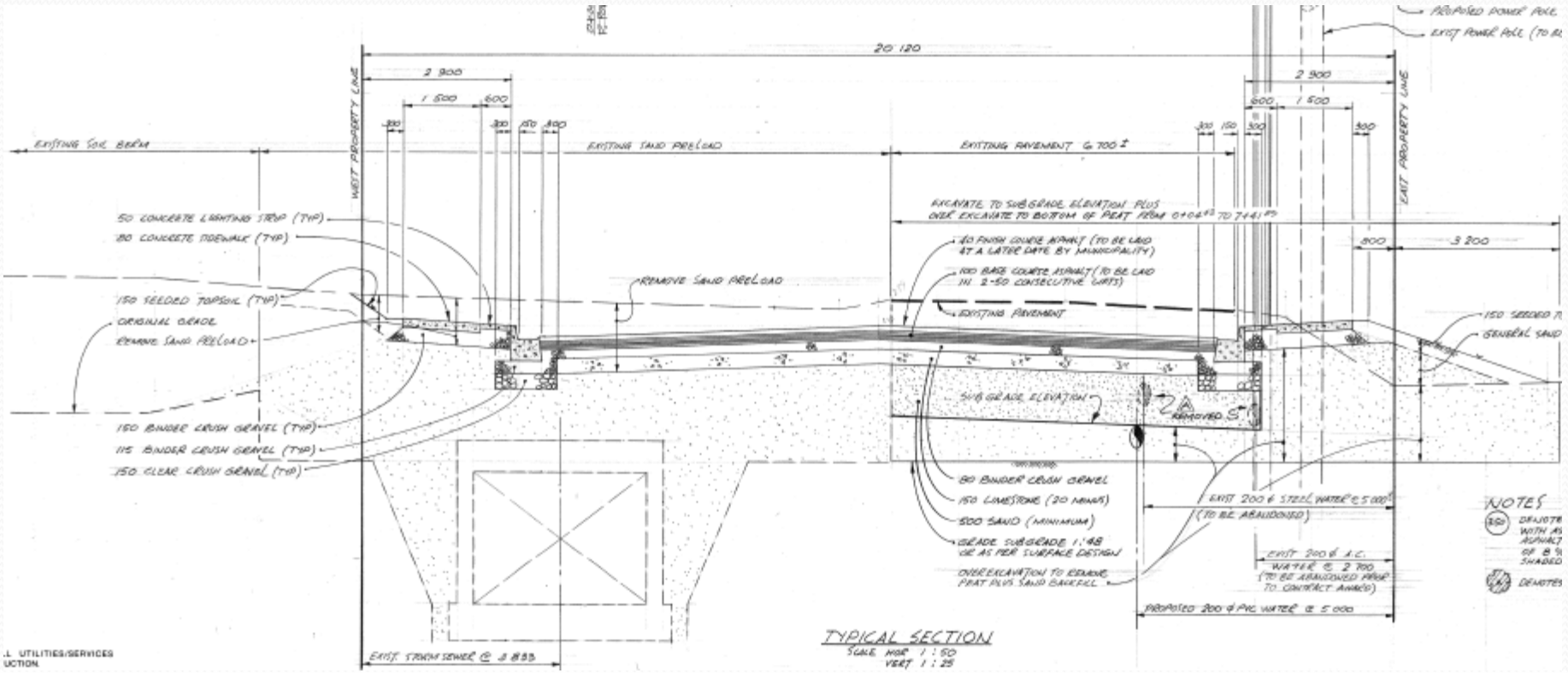
Topography



Notes:
Base data provided by City of Richmond, 2015.

Projection: UTM Zone 9N
Datum: NAD83

Cross Section Through No. 4 Road



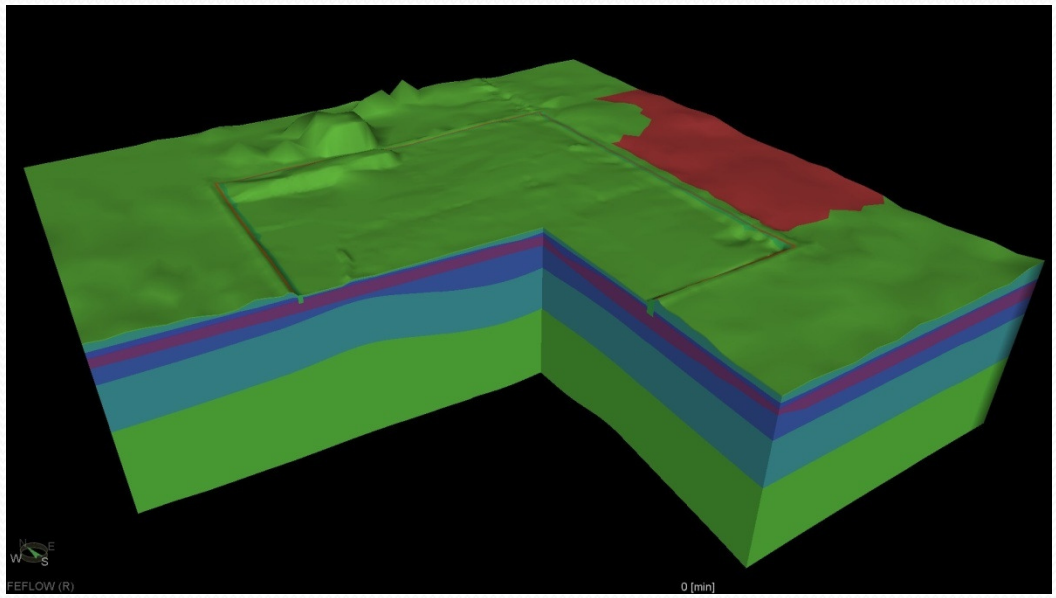
Perimeter Drainage Features

- Western drains

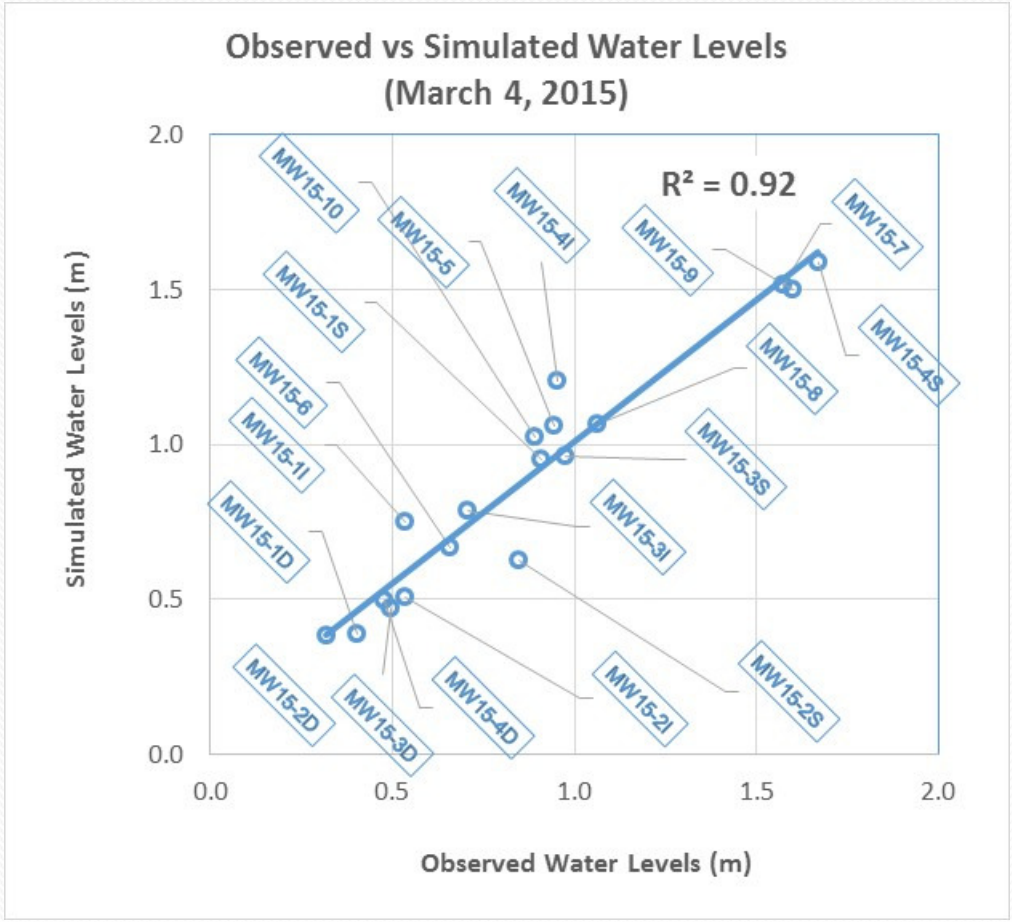
- Southern ditch

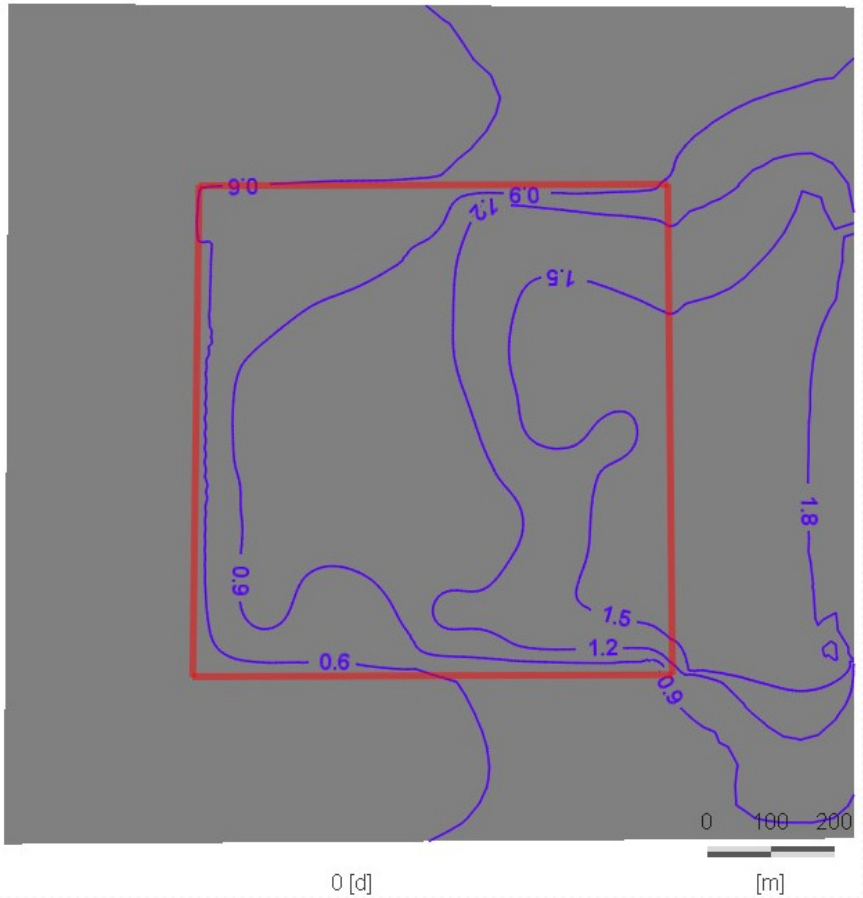
Construction of Numerical Seepage Model

Three-dimensional finite element model with hydrostratigraphic layers (peat, clayey silt, sand aquifer), boundary conditions and precipitation recharge



Calibration of Model to Measured Water Levels (Hydraulic Head) in peat, clayey silt and sand aquifer layers

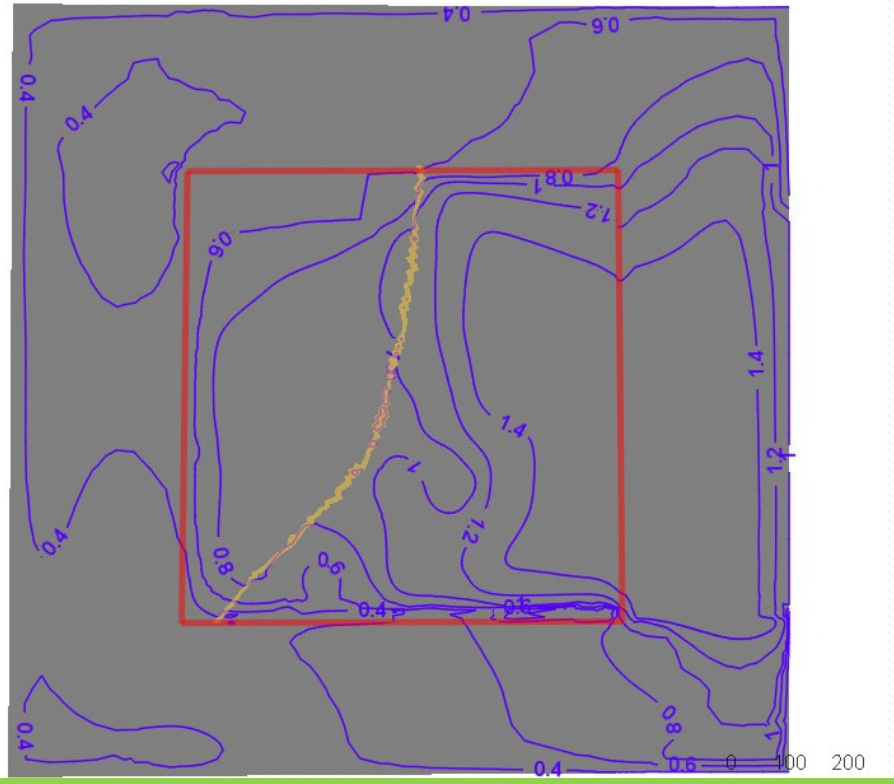




Predictive Simulations

1) Effect of adding N-S barrier across peat layer with no agricultural drainage - effect on water table in bog area
2) Effect of N-S barrier with agricultural drainage and flow barrier along north and south sides of bog area.
3) Effect of pumping wells for irrigation on vertical seepage losses from peat in bog area

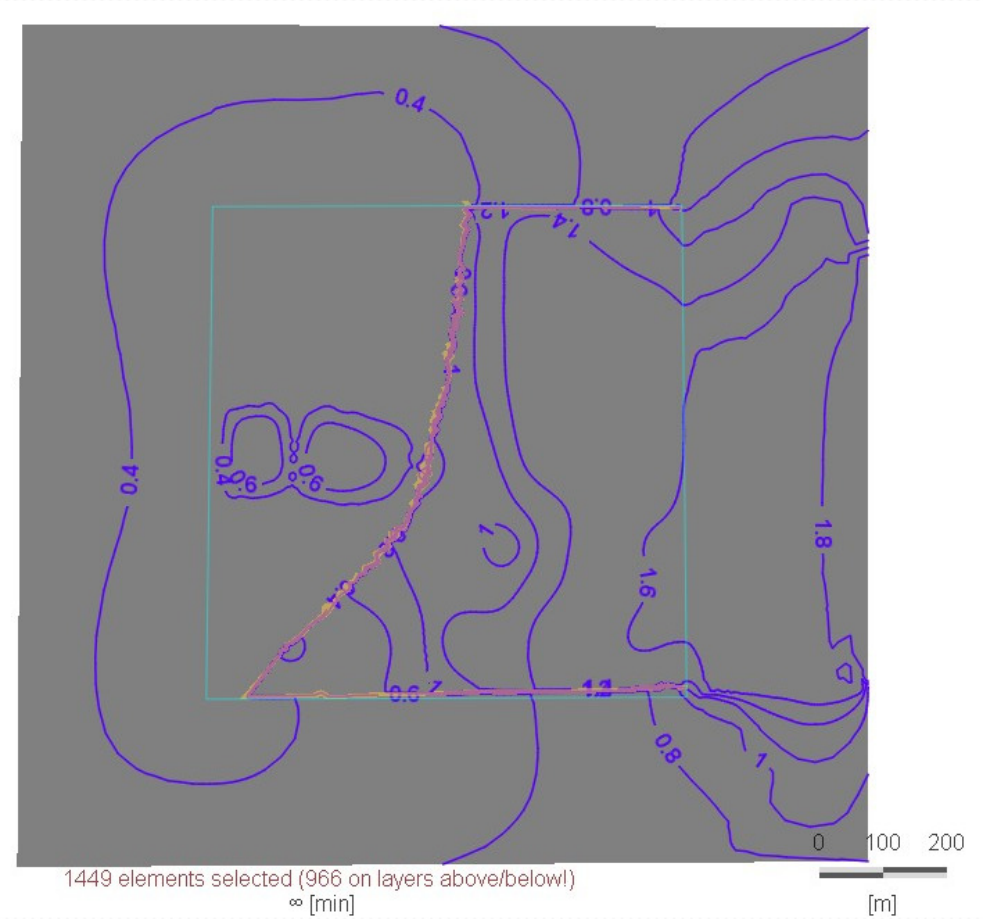
Predictive Simulations: N-S Barrier with no agricultural drainage



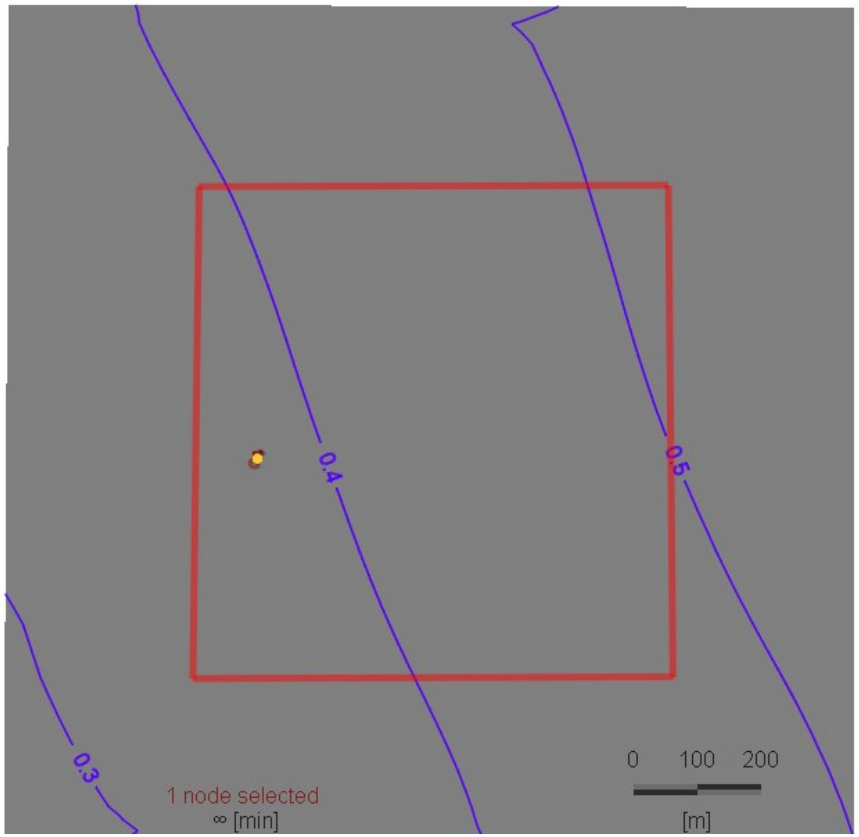
Percentage of Seepage Losses from Peat in Eastern Bog area during March through August

Pathway	Barrier	East	North	South	Down across Clayey Silt Layer
%	0.0%	0.6%	0.4%	0.1%	98.9%

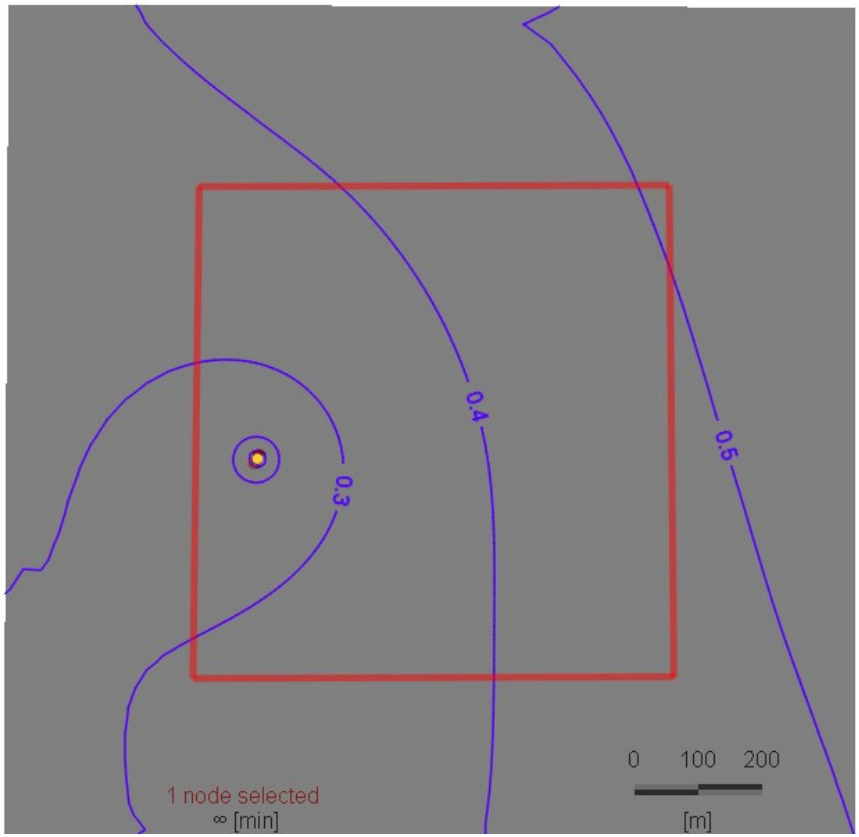
Predictive Simulations: N-S Barrier and Barriers Along North and South Sides of Bog with Agricultural Drainage



Predictive Simulations - Heads in Sand With and Without Pumping Well

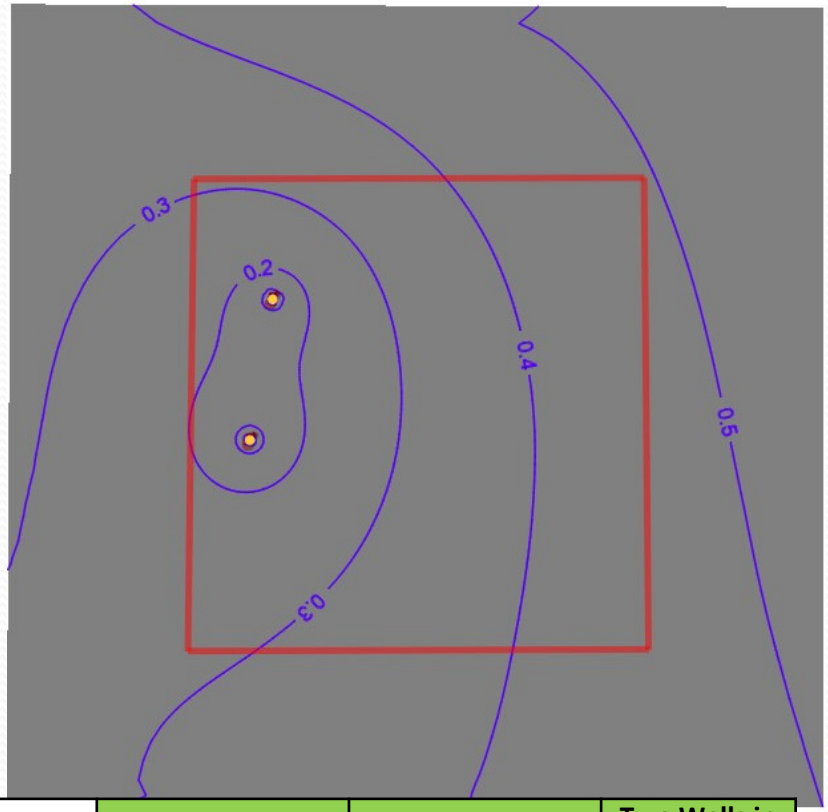


- No Well



- One Well

Predictive Simulation - Head in Sand with two Pumping Wells



		no Well in Sandy Aquifer	One Well in Sandy Aquifer	Two Wells in Sandy Aquifer
Water Gain	Recharge (m3/day)	38.89	38.89	39.89
Water Loss	Barrier (m3/day)	< 1.0E-7	< 1.0E-7	< 1.0E-7
	Alderbridge (m3/day)	< 1.0E-7	< 1.0E-7	< 1.0E-7
	Westminister (m3/day)	< 1.0E-7	< 1.0E-7	< 1.0E-7
	No.4 (m3/day)	0.31	0.27	0.23
	Peat Bottom (m3/day)	38.58	38.62	38.66

Uncertainties

- Site-specific soil hydraulic conductivity: uncertainty in seepage predictions, particularly downwards seepage losses from the peat, across clayey silt to sand aquifer
- Influence of box culvert in No. 4 Road on intercepting seepage from DND site
- Bog water hydrochemical characteristics
- Annual range of water levels, particularly for a “normal” summer period (2015 unusually dry)

Conclusions

- Incorporating a hydraulic barrier between the farm and bog area will be effective at minimizing the impact of draining the farm land on water levels in the bog area
- Development of No. 4 Road and a deep box culvert appears to have diverted the historical flow of seepage from peat lands on the DND site to the east of GCL, reducing the water table in the peat on the GCL
- Incorporating hydraulic barriers across the peat layer along the north and south sides of the bog will reduce seepage losses from the peat to ditches and utility trenches, but the impact will be relatively small
- The vast majority of seepage losses from the peat under current conditions are vertically downwards to the sand aquifer. Groundwater pumping from the sand aquifer for irrigation does not appear to significantly increase these losses.

Recommendations

- Site-specific soil hydraulic conductivity measurements are required, particularly for the clayey silt underlying the peat in order to better constrain the downwards seepage losses from the peat;
- Installation of a sensor or other methods to determine the water level in the box culvert on No. 4 Road to confirm interception of peat seepage from DND to GCL;
- Download the existing dataloggers in the monitoring wells on-site to establish seasonal ranges in groundwater levels, including summer water table levels in 2016;
- Sample the monitoring wells for basic major ion chemistry and nutrient levels to classify bog water characteristics and establish baseline conditions