



WorleyParsons

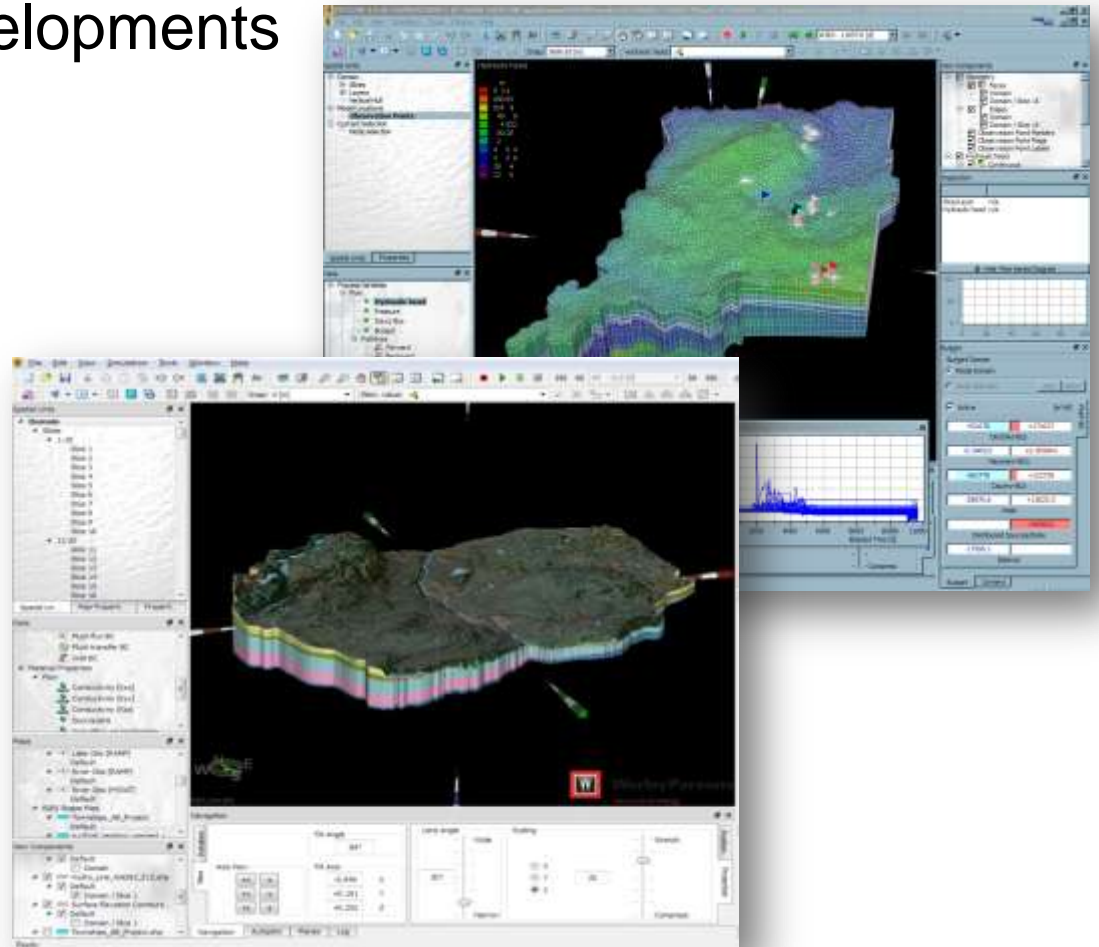
resources & energy

Groundwater Flow Model Development for Cumulative Effects Management within the Athabasca Oil Sands

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Jos Beckers, PhD, P Geoph
Matthew Webb, MSc

Overview

- ▶ Groundwater Management Framework Tools
- ▶ Modelling Tool Developments
 - Methodology
 - Conceptualization
 - Numerical Model
- ▶ Continued Work
- ▶ Challenges



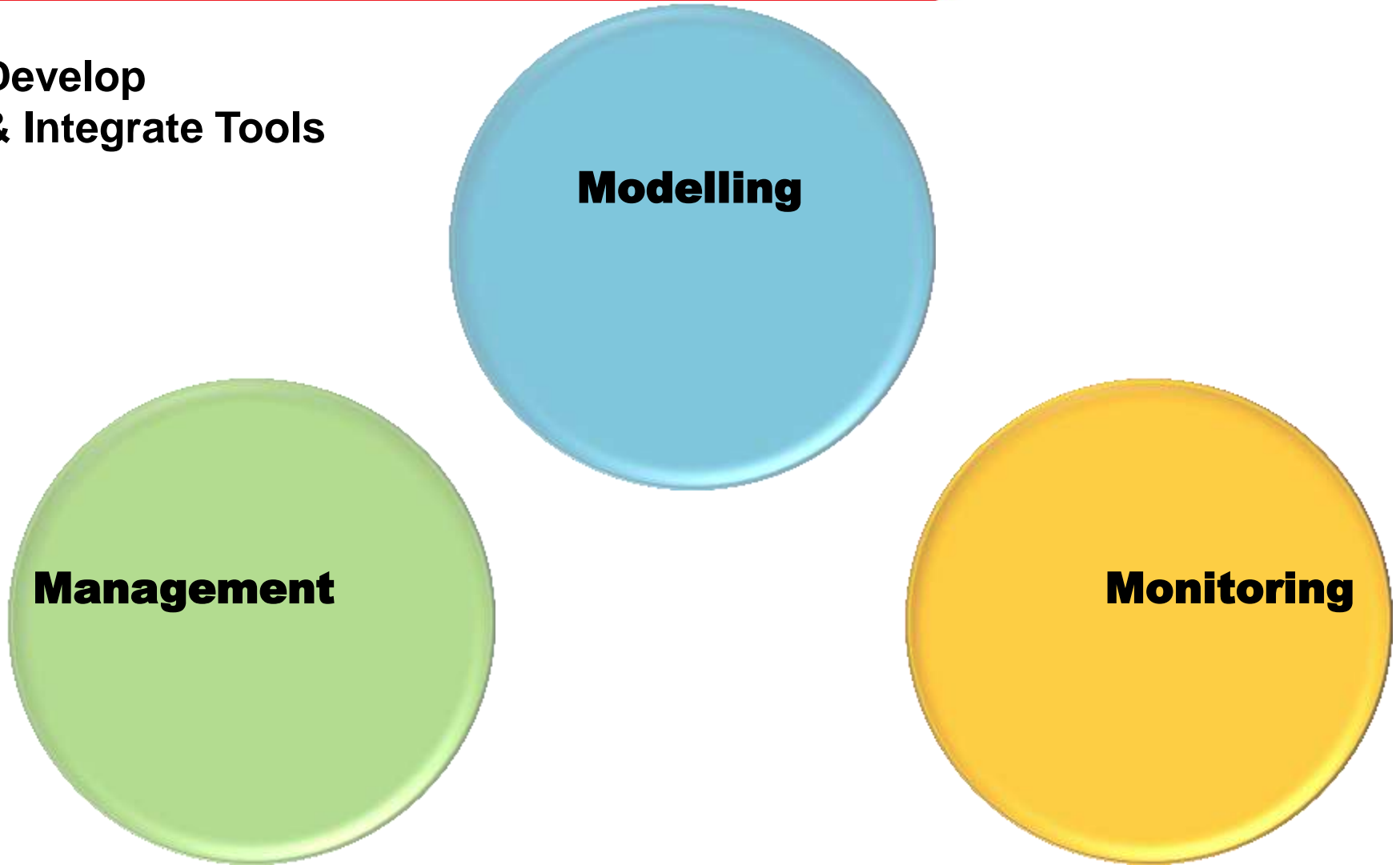
Groundwater Management Framework Tools

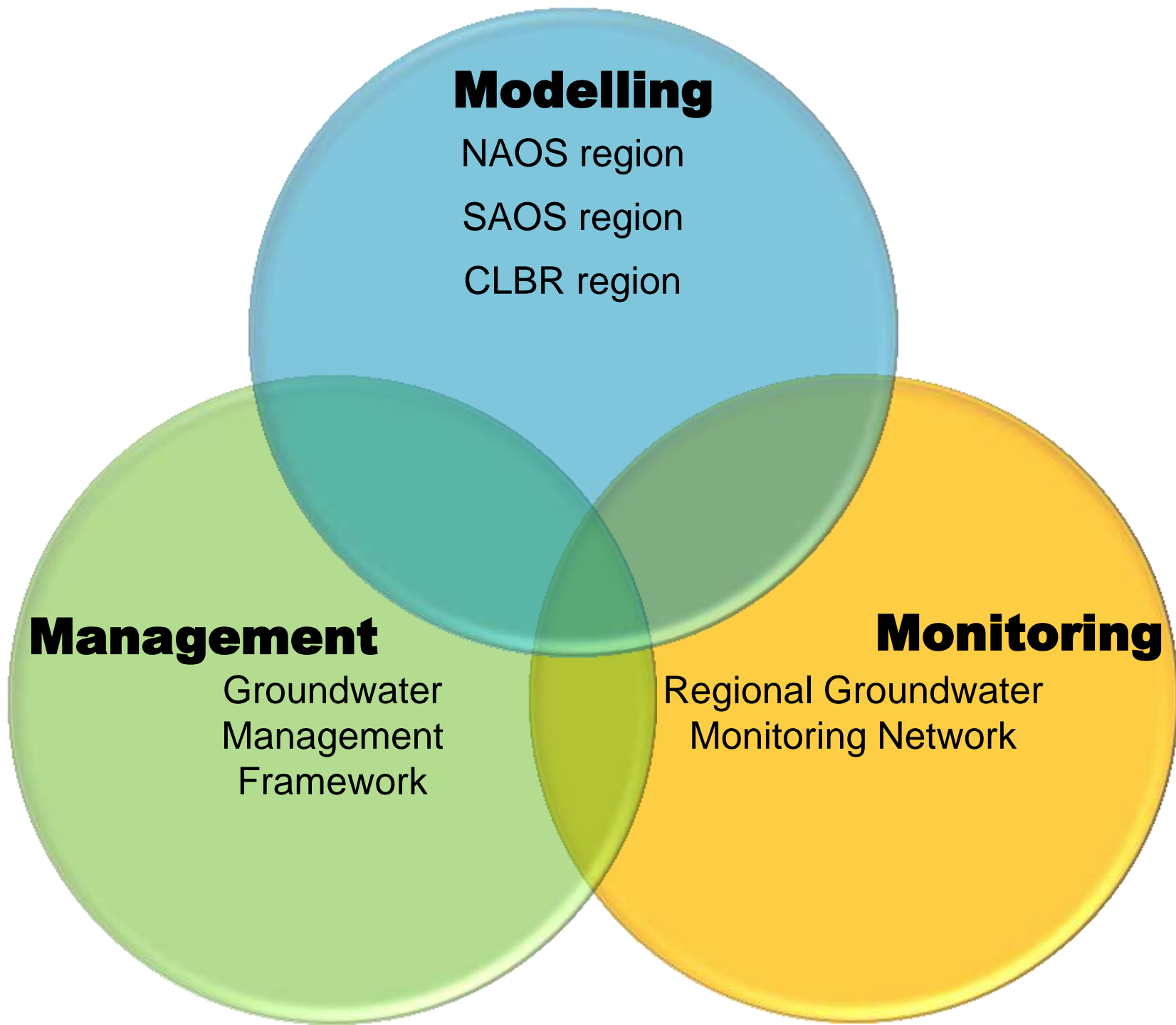
**Develop
& Integrate Tools**

Modelling

Management

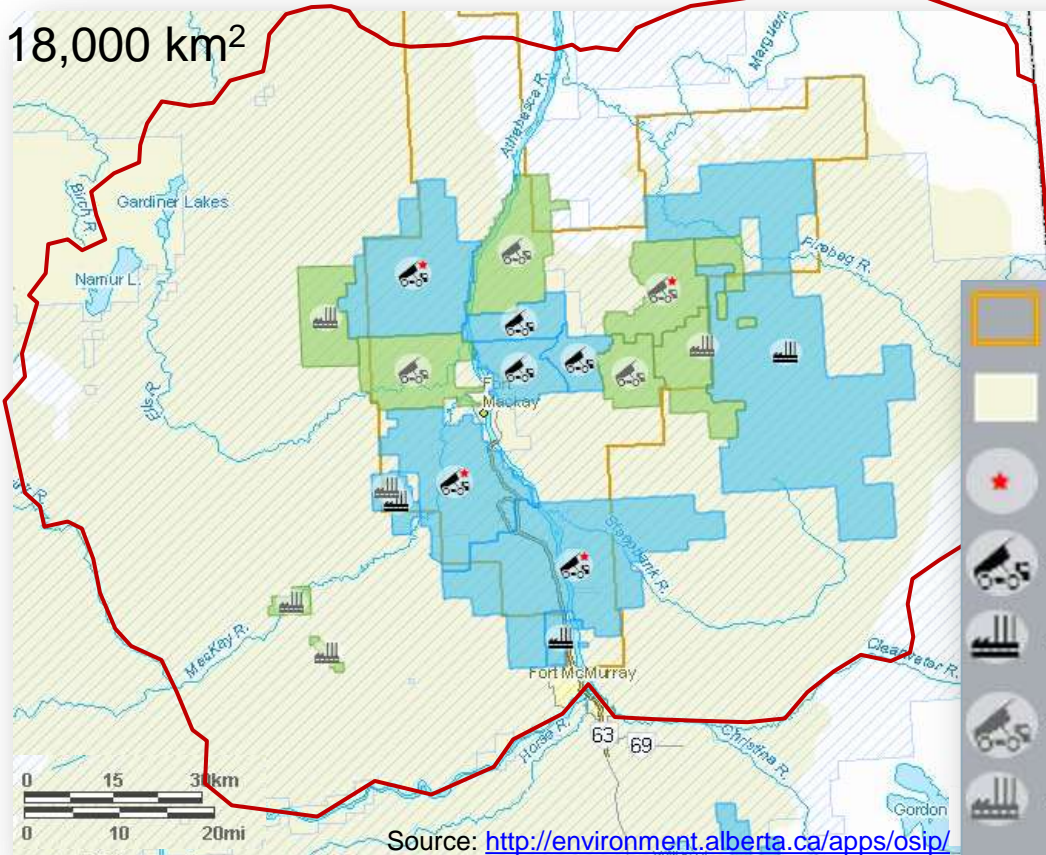
Monitoring





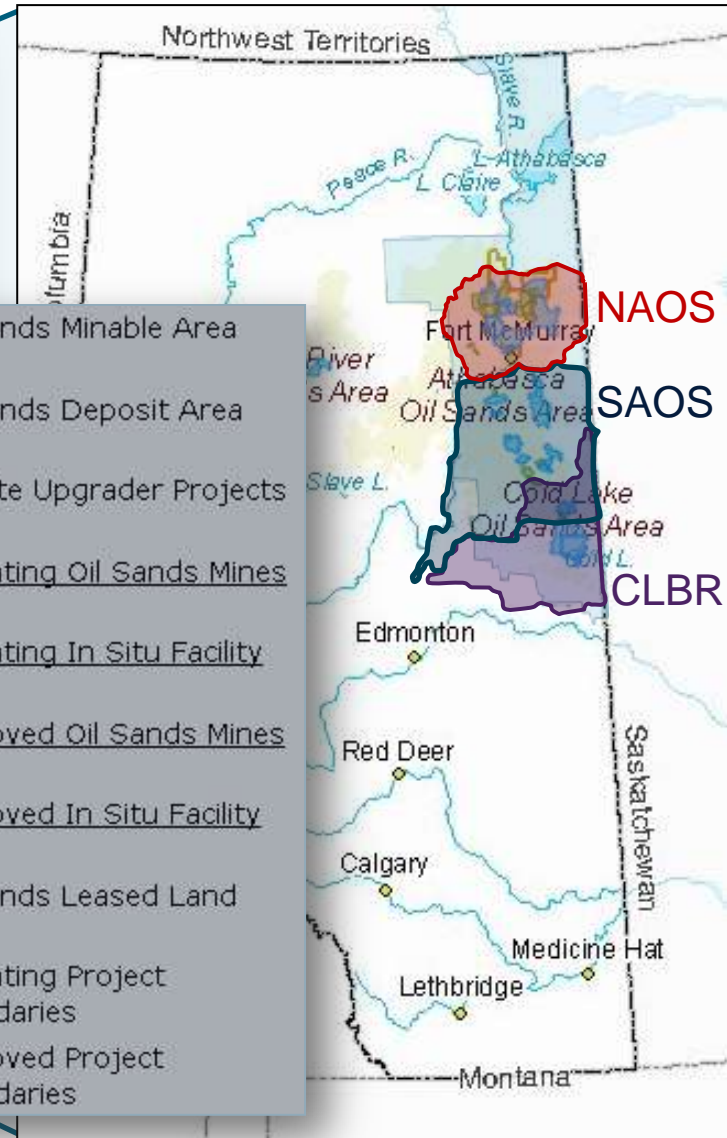
NAOS Region

18,000 km²



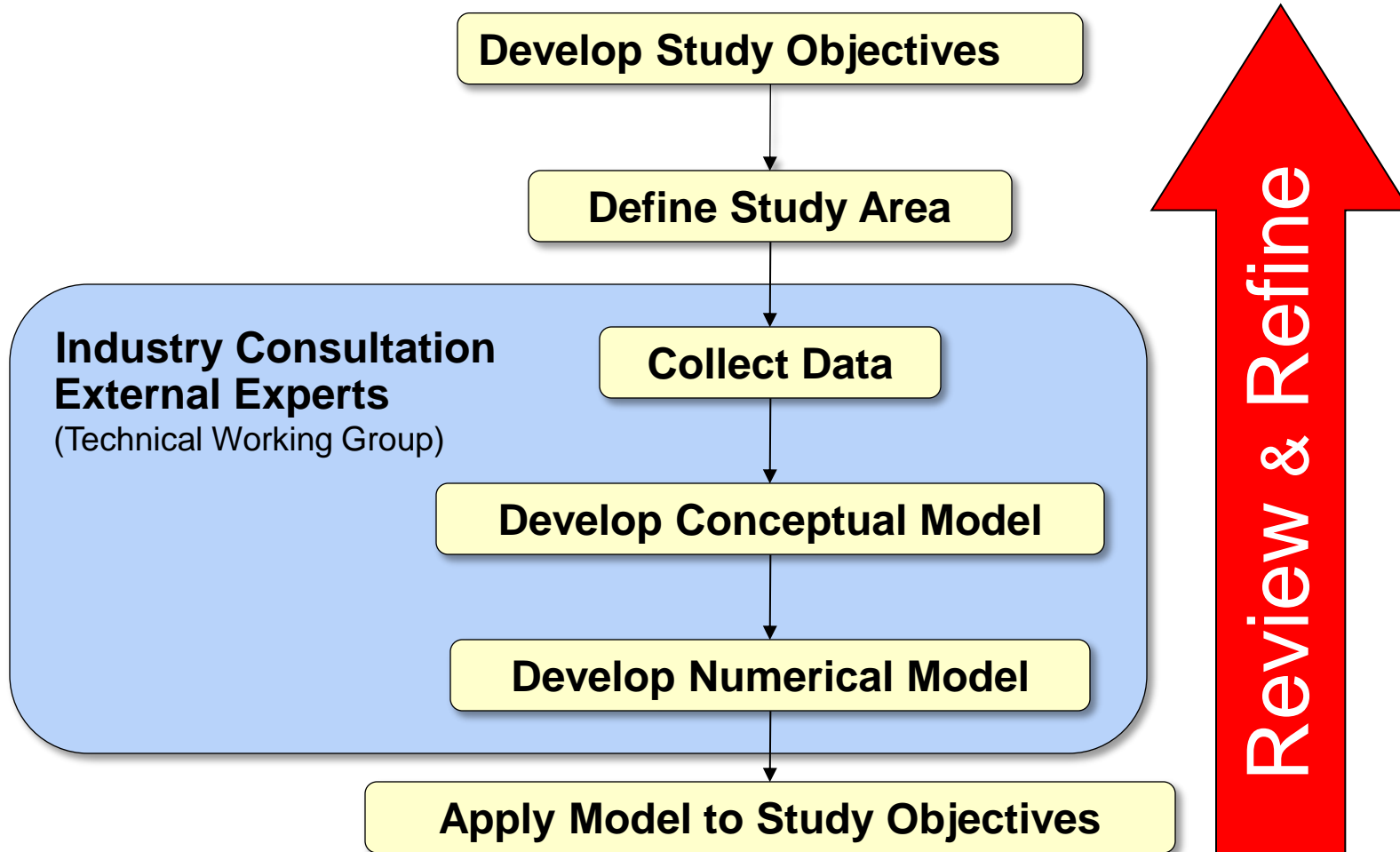
Source: <http://environment.alberta.ca/apps/osip/>

-  Oil Sands Minal Area
-  Oil Sands Deposit Area
-  On-site Upgrader Projects
-  Operating Oil Sands Mines
-  Operating In Situ Facility
-  Approved Oil Sands Mines
-  Approved In Situ Facility
-  Oil Sands Leased Land
-  Operating Project Boundaries
-  Approved Project Boundaries



NAOS
SAOS
CLBR

Methodology



Industry Participants



External Experts

Alfonso Rivera

- ▶ Director of Geoscience for the Geological Survey of Canada
- ▶ Member of expert panel that reviewed the NAOS Groundwater Management Framework

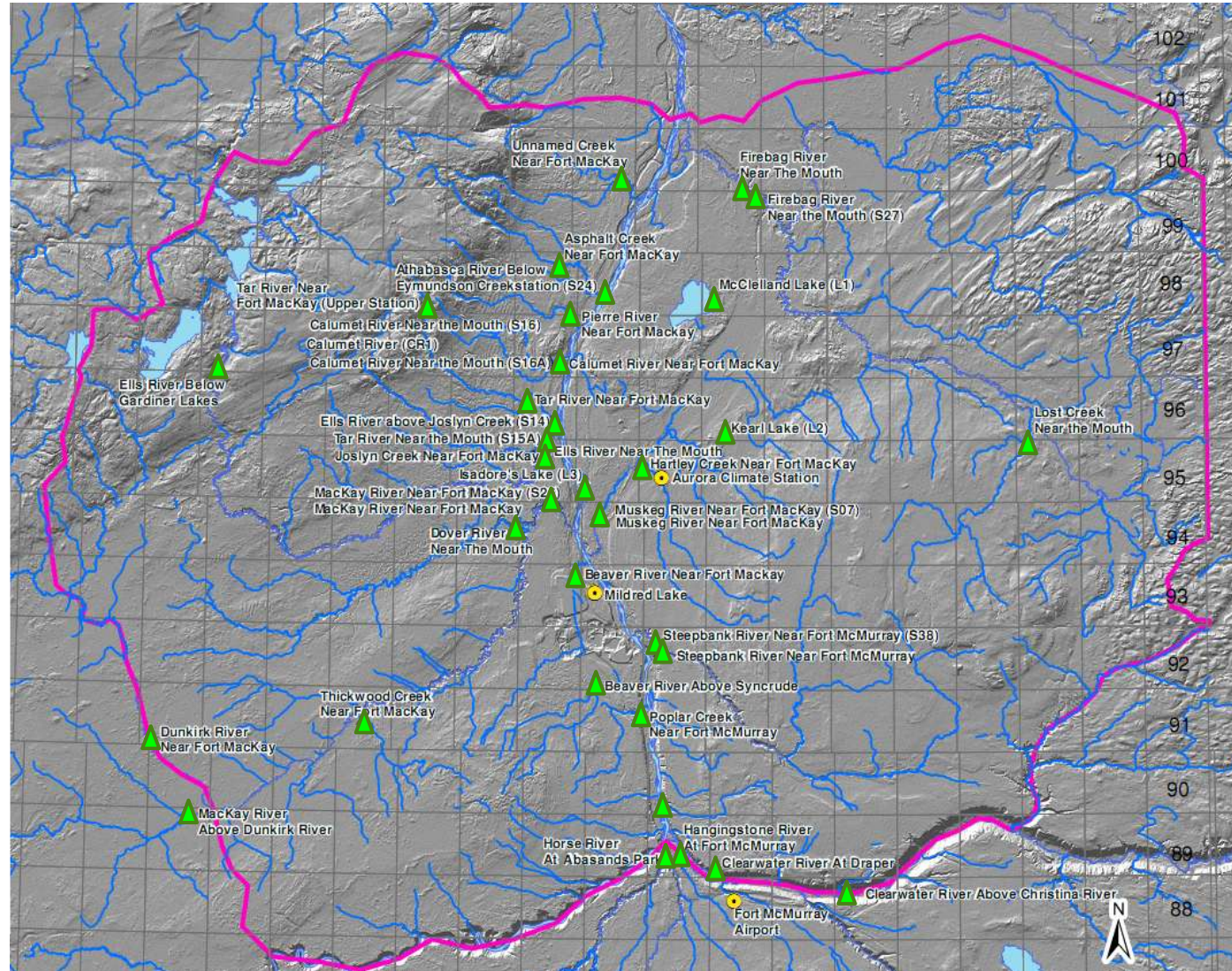
René Therrien



- ▶ Chair, Department of Geology and Geological Engineering at Université Laval
- ▶ Member of the Royal Society of Canada Expert Panel

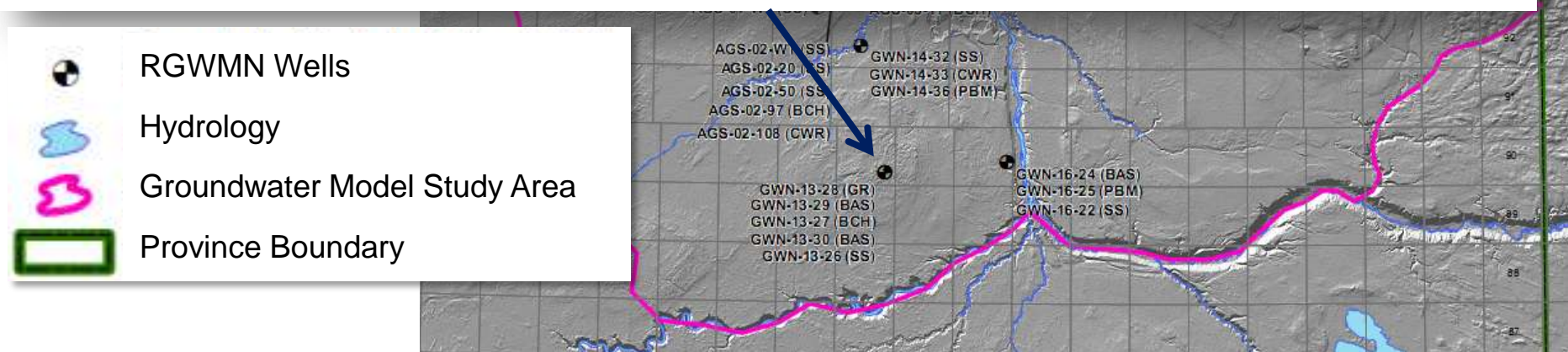
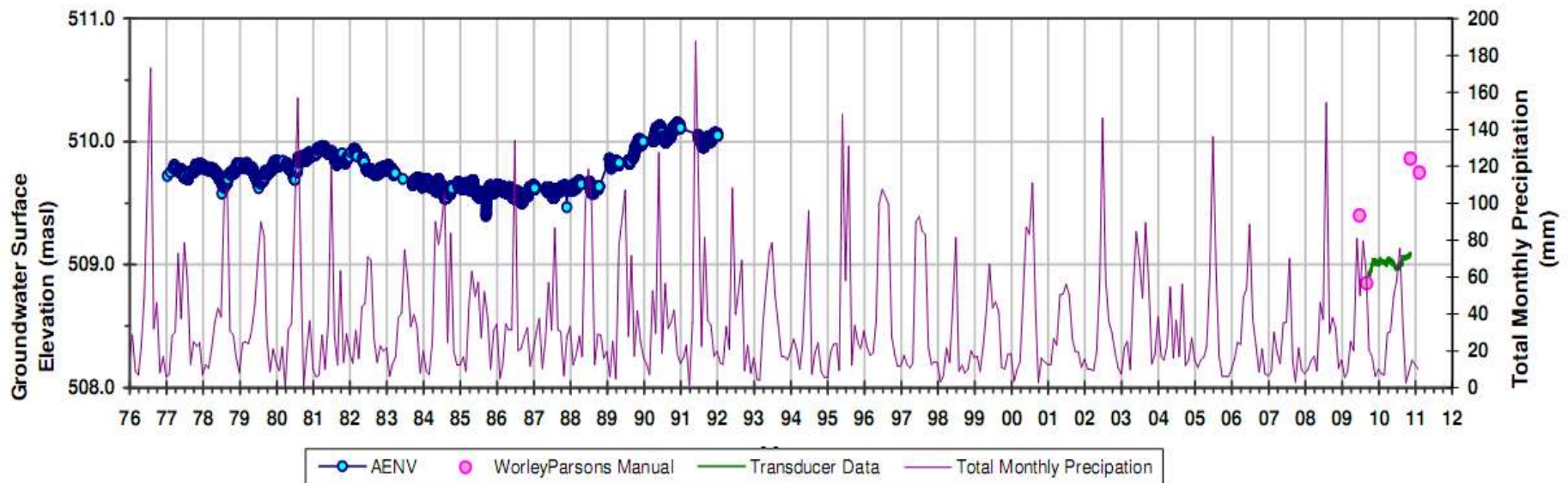
Hydrology

- Meteorology
 - Fort McMurray Airport
 - Mildred Lake
 - Aurora Climate Station
- Hydrometric Stations
 - ▲ 13 RAMP
 - ▲ 27 WSC HYDAT



Hydrogeology

GWN-13-27 (BCH)



Hydrostratigraphy

Period	Group	Formation	Hydrostratigraphy	
Quaternary		Surficial Deposits	Undifferentiated Overburden	
		Sands		Sand Aquifer 1
		Tills		Till Aquitard 1
		Sands		Sand Aquifer 2
		Tills		Till Aquitard 2
		Coarse Fluvial Sediments	Bedrock Channel Aquifer	
Cretaceous	Colorado	La Biche	Colorado Aquitard	
		Viking (Pelican)		
		Joli Fou		
	Upper Mannville	Grand Rapids	Upper Grand Rapids 1 Aquifer	
			Upper Grand Rapids 2 Aquifer	
			Lower Grand Rapids 1 Aquifer	
Lower Grand Rapids 2 Aquifer				

Continued

Hydrostratigraphy (continued)

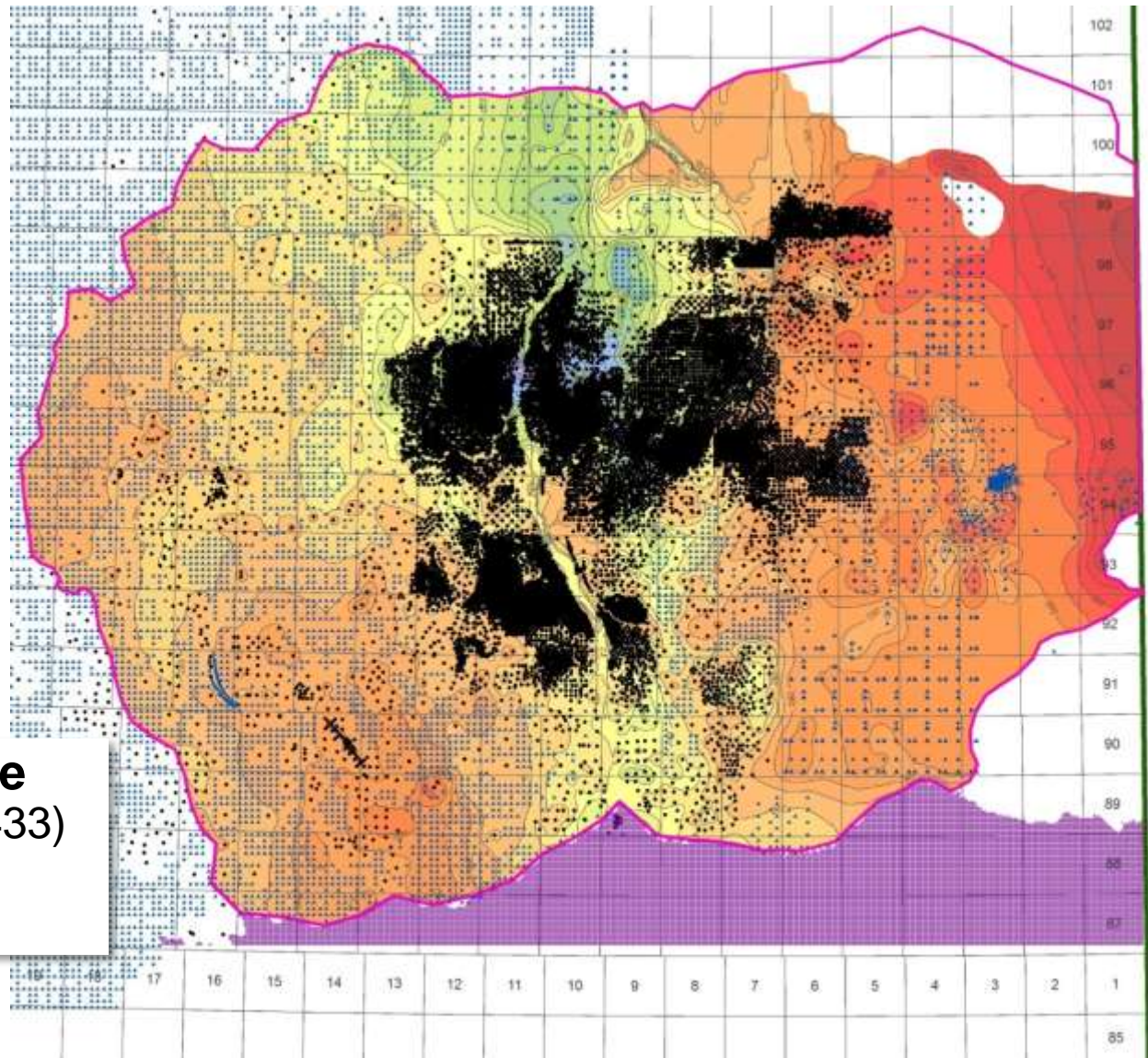
Period	Group	Formation	Hydrostratigraphy	
Cretaceous	Mannville	Clearwater	Clearwater Aquitard	
		McMurray		Upper
			Middle (Top Water)	Middle McMurray Top Water Aquifer
			Middle (Bitumen)	McMurray Aquitard
			Lower (Bitumen)	
			Lower (Basal Sand)	McMurray Basal Sand Aquifer
Sub-Cretaceous Unconformity				
Devonian	Beaverhill Lake	Waterways	Beaverhill Lake-Cooking Lake Aquifer/Aquitard	
		Slave Point		
		Fort Vermillion		
	Elk Point	Watt Mountain		
		Muskeg	Prairie Aquitard/Aquiclude	
		Keg River	Keg River Aquifer	
		Contact Rapids	Contact Rapids Aquitard	
		Basal Red Beds/La Loche	Basal Aquifer	

Surface & Isopach Development

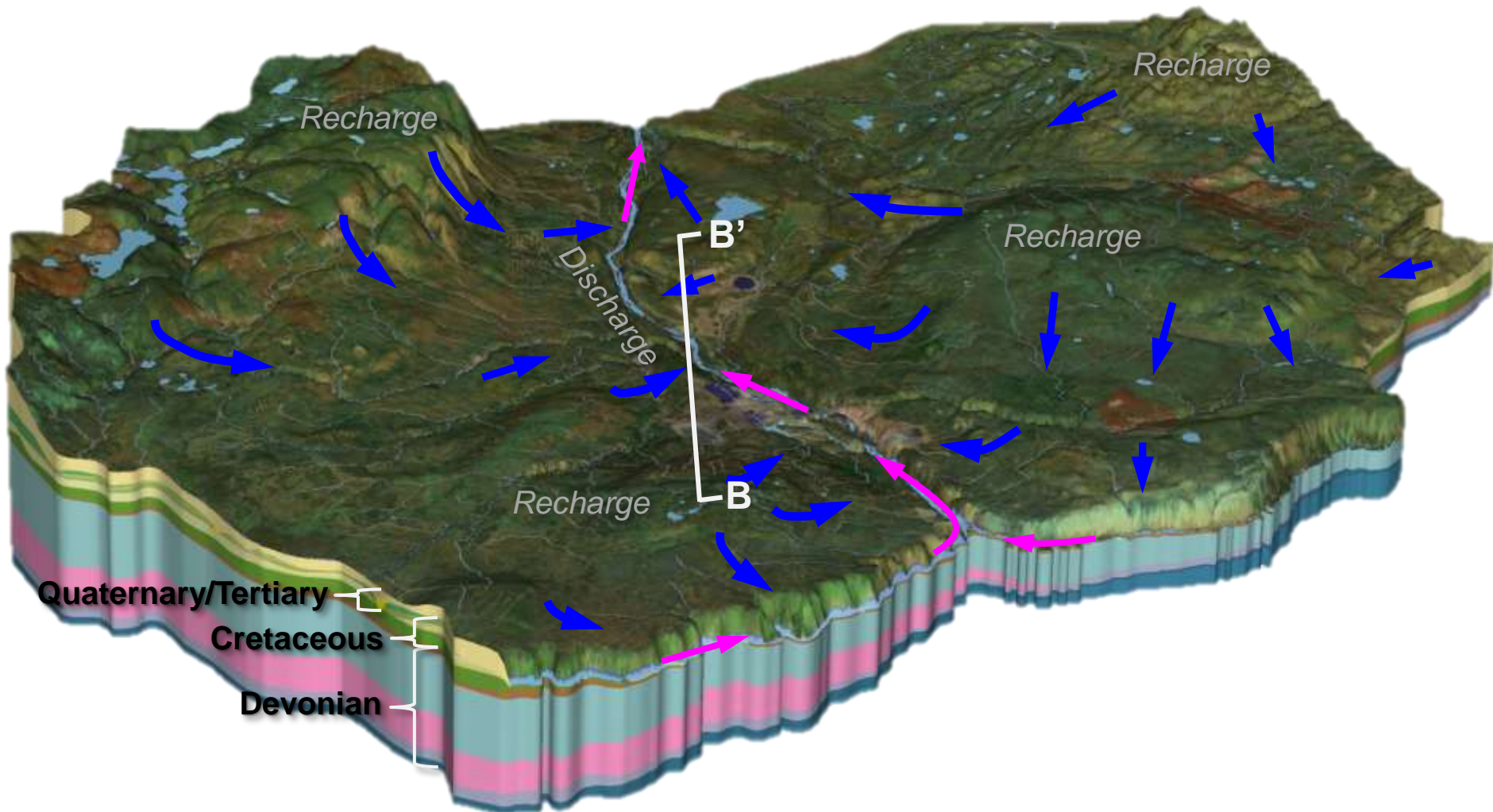
- ▶ Data compiled in relational databases
- ▶ Developed database tools to QA/QC data
- ▶ Linked databases to visualization software

Devonian Surface

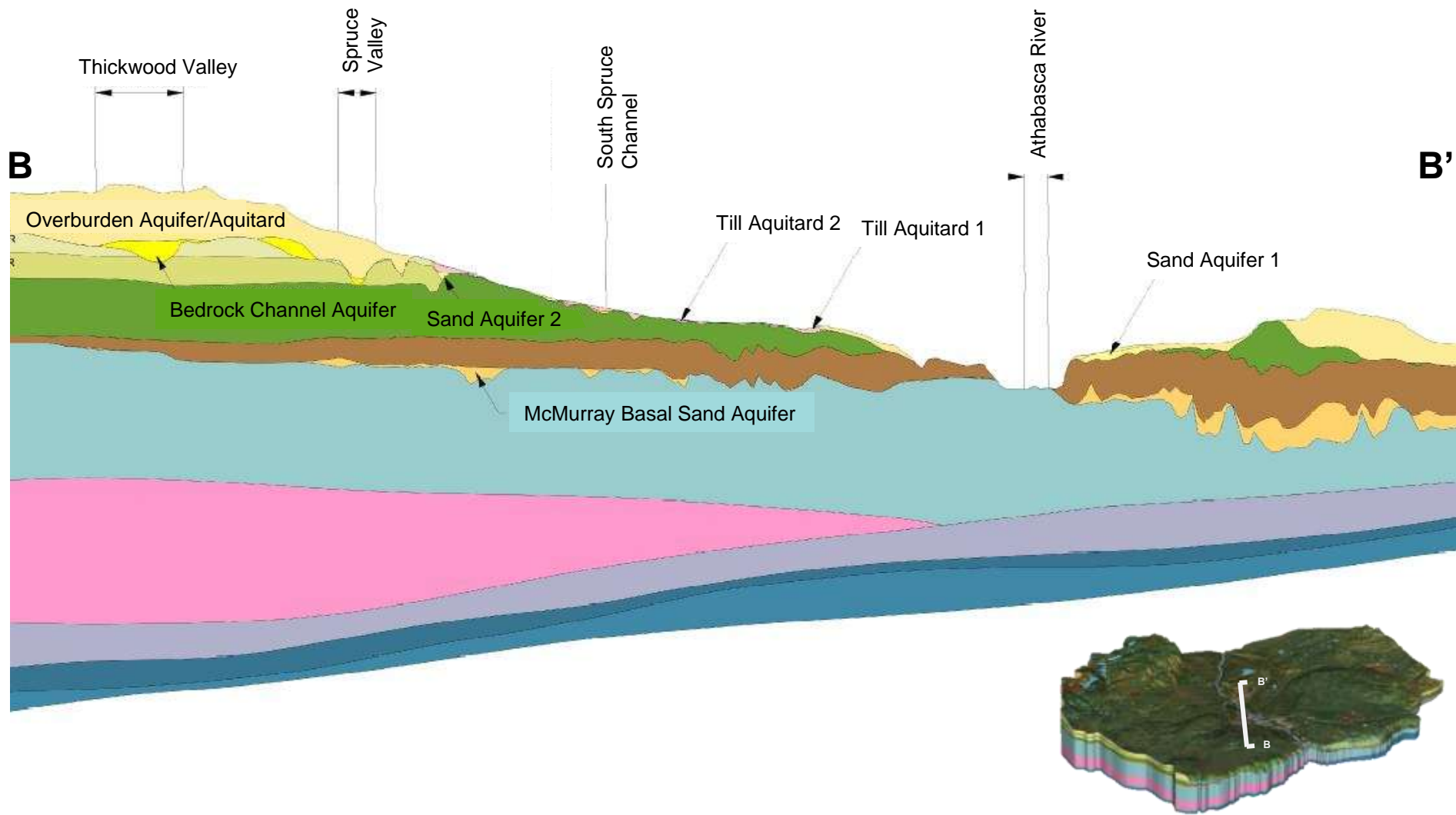
Operator Tops (50,433)
Grid Data (10,485)
Control Points (5)



Conceptualization



Conceptualization



Model Design & Calibration

21 layer FEFLOW model (3.0 million elements)

Calibration Methodology

1. Steady state calibration:

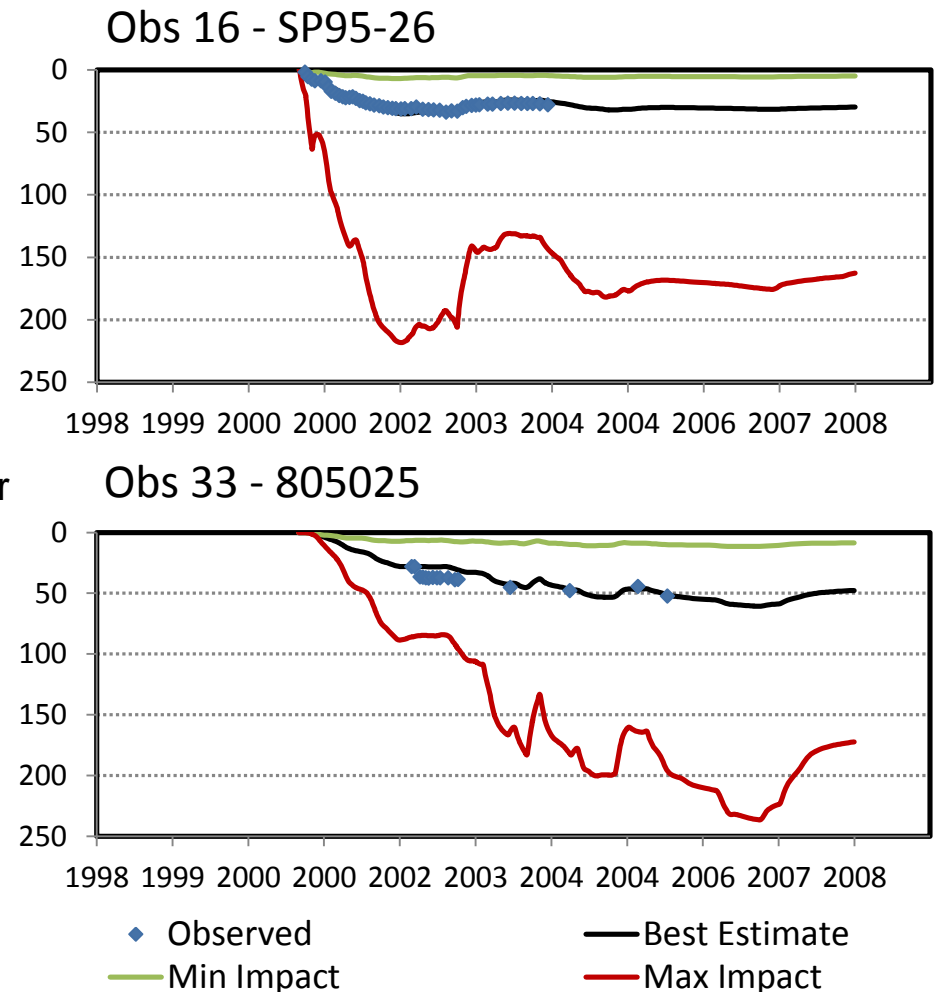
- Manual
- Automated (PEST) to optimize parameters and recharge rates

2. Transient calibration:

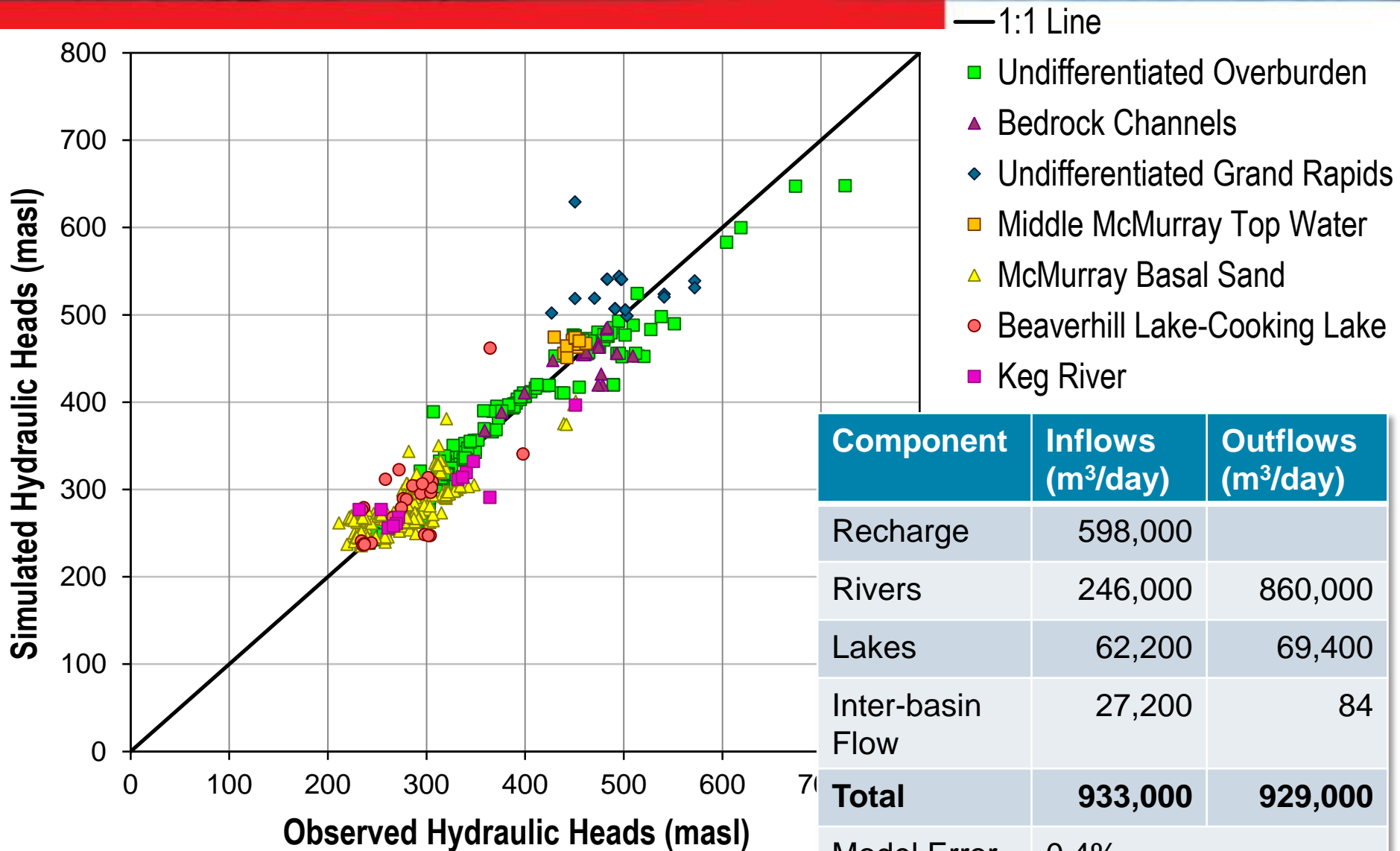
- Initial for McMurray Basal Sand Aquifer
- Complete (future)

3. Sensitivity Analysis:

- Preliminary based on SAOS model parameter confidence bounds
- Complete following finalized transient calibration



Calibration Quality

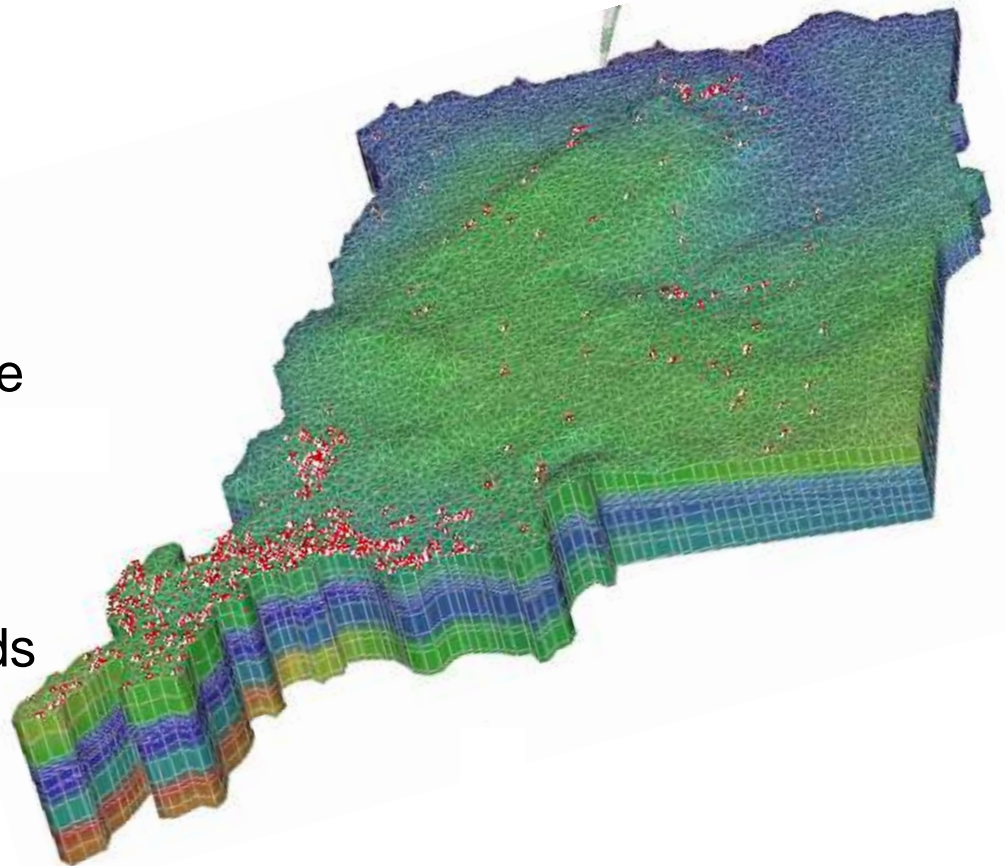


Component	Inflows (m ³ /day)	Outflows (m ³ /day)
Recharge	598,000	
Rivers	246,000	860,000
Lakes	62,200	69,400
Inter-basin Flow	27,200	84
Total	933,000	929,000
Model Error	0.4%	

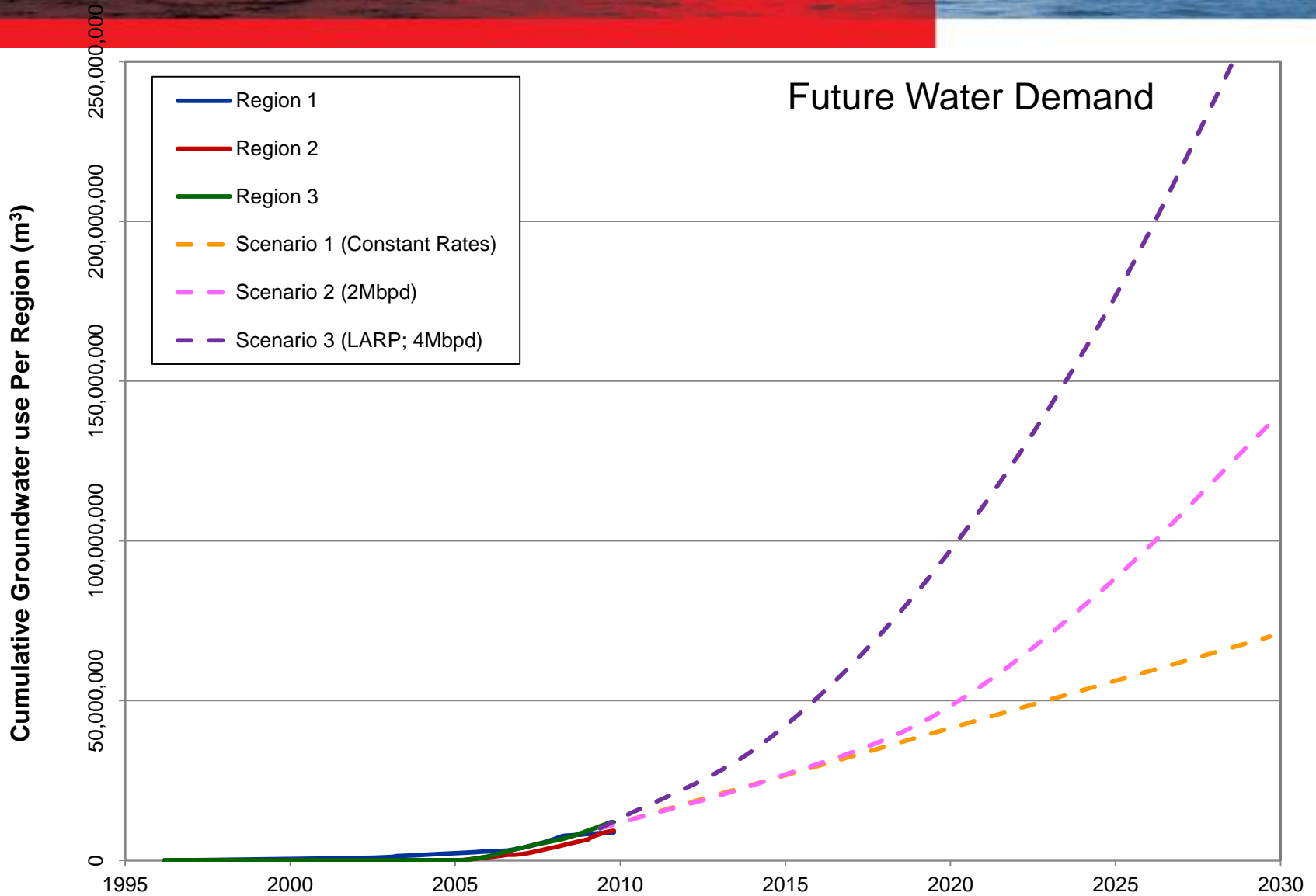
Model Design

25 layer FEFLOW model (292,075 elements)

1. Three model versions to assess prediction confidence
 - Best Estimate Model
 - Min Impact Model
 - Max Impact Model
2. Calibration
 - Initial manual steady state calibration
 - Automated (PEST) to optimize parameters and assess confidence bounds
 - Transient calibration to historic groundwater use/injection in region



Predictive Scenarios

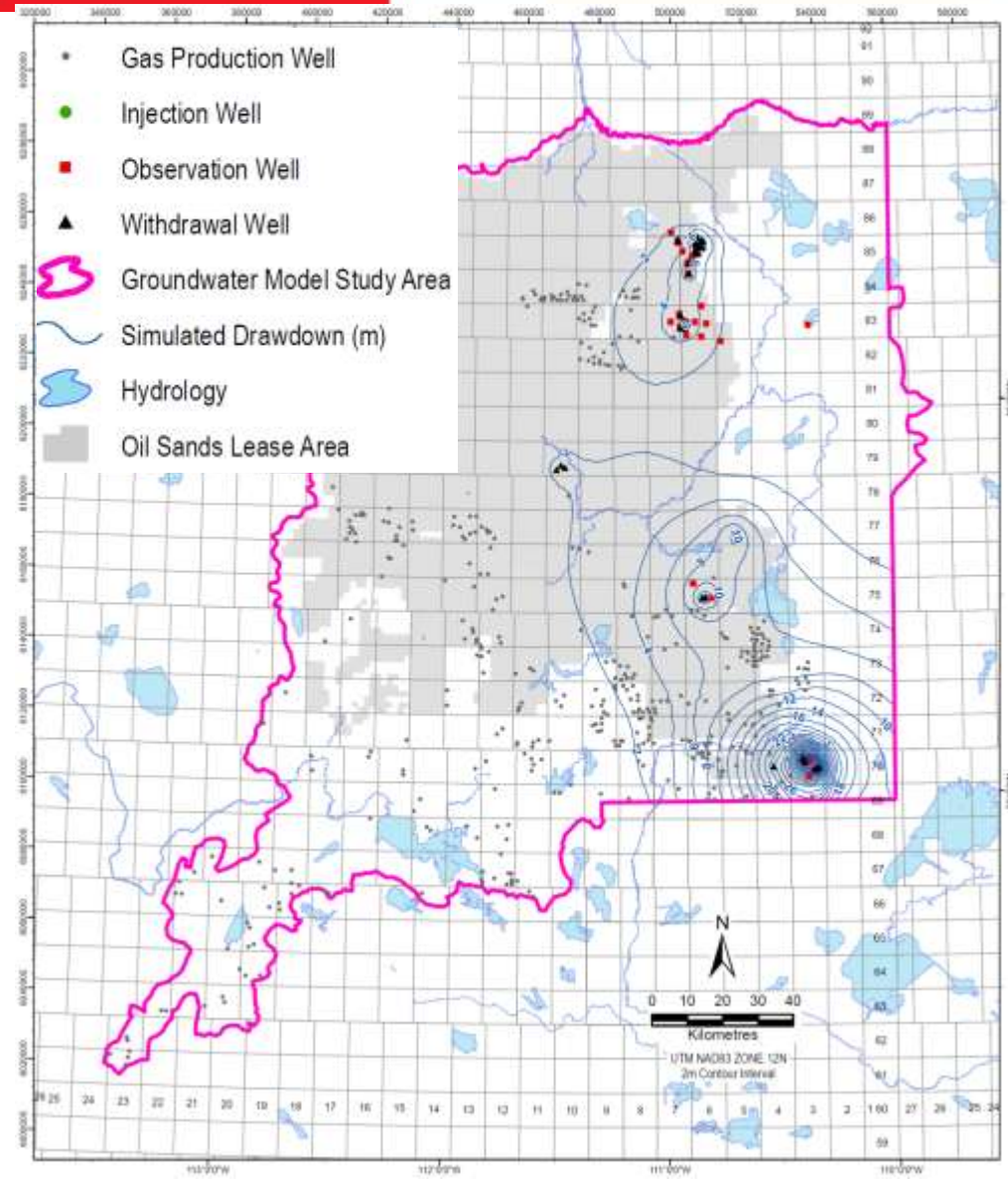


Scenario 1 Results

Drawdown in Lower Grand Rapids Aquifer

► Scenario results can be used to :

- Quantify regional cumulative impacts
- Recommendations for monitoring network development
- Assess projected drawdown at proposed MWs (targets)
- Assess effectiveness of existing guidelines



Performance Monitoring

Proposed Regional Monitoring Well Location - Approximate



Primary Location



Secondary Location




Locations not Currently Considered




Groundwater Framework and Model Study Area

Oil Sands Leases

Status

 Producing / Active

 Proposed / Under Construction

Modified DRASTIC

VALUE

 59 - 71

 71 - 80

 80 - 94

 94 - 107

 107 - 120

 120 - 135

 135 - 147

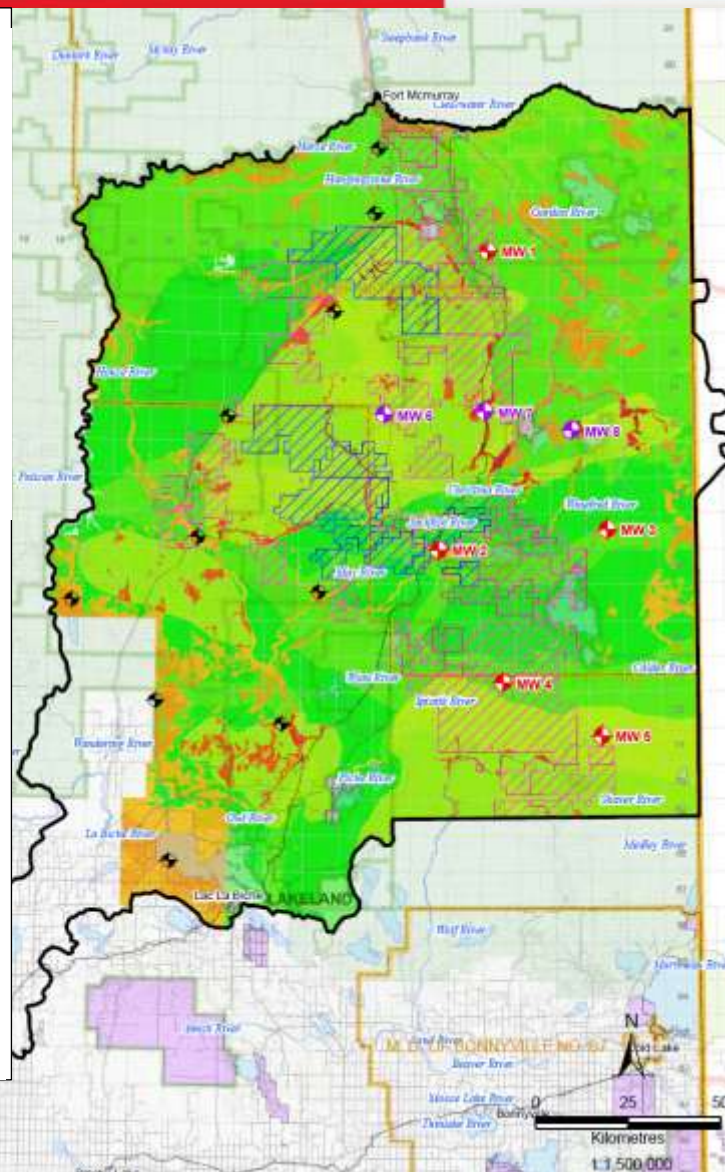
 147 - 158

 158 - 170

 170 - 182

 182 - 194

 194 - 211



Challenges & Continued Work

- ▶ Data compilation and management (*ongoing*)
 - Data sharing agreements
 - Database development
 - Data formats and standards
- ▶ Defining & applying development scenario(s) to identify locations for RGWMN expansion (*NAOS Phase 2*)
- ▶ Communication
 - Between expanding Technical Working Group (*ongoing*)
 - Presenting NAOS & SAOS model results to the public (*Phase 3*)
- ▶ Conceptual and numerical model updates (*NAOS & SAOS*)
 - Schedule updates
 - Define data submission requirements
 - Increase model complexity (density dependent flow & transport and integrated SW/GW modelling)
- ▶ Targeted regional studies (*future*)



Questions?

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