Alberta
Government

Session 3

Day 2 – Session 3

David Lyder – AESRD

BIOGRAPHY

David Lyder is an air emissions engineer with the Air Policy Group of Alberta Environment and Sustainable Resource Development. He started with the department in 2008 with the focus of his work being modelling or modelling related issues on a provincial or national/international scale. Prior to this, David worked as a freelance research scientist for a number of different agencies looking at modelling and characterizing a variety of natural systems ranging from the effects of climate change on forest growth to the detection of cracks in egg shells using real-time imagery. David graduated from the University of Victoria in 1997 with a PhD in observational astronomy.

Day 2 – Session 3

Sunny Cho– AESRD

BIOGRAPHY

Dr. Sunny Cho earned a Ph.D. in atmospheric science from York University, Canada. She held a postdoctoral fellowship at the Air Quality Research Section at Environment Canada ,before joining the Government of Alberta, Environment and Sustainable Resource Development. Her research covers air contaminants, source emissions, fate and risk assessment, and air quality modelling. Dr. Cho is responsible for establishing and sustaining state-of-the-art research in air related issues in Alberta's Oil Sands. Dr. Cho is an adjunct faculty member of Civil and Environmental Engineering at the University of Alberta.

Day 2 – Session 3

David Lyder & Sunny Cho– AESRD

ABSTRACT

Alberta Environment and Sustainable Resource Development (ESRD) develops and implements cumulative effects management (CEM) across media (air, land and water) in the context of sustainable development on an ongoing basis. One of the critical aspects to moving toward CEM is to increase requirements for multi-scale and multi-objective assessment and decision making that considers economic and social systems, as well as the ecosystem. Integration of management activities, and also of the modelling undertaken to support management, has become an important thing.

The air quality component of CEM, in the broadest sense, can be characterized as either regulatory or non-regulatory in nature. While both approaches may serve different purposes or have different technical requirements within a CEM system, they are complimentary to one another.

This presentation will highlight some of the regulatory and non-regulatory air quality management currently being undertaken within ESRD in the context of cumulative effects management with a focus on opportunities for synergies across media and possible air model linkages of an information transfer among components of integrated modelling systems and interfaces to information exchange.

A Quick Look at Current Air Quality Modelling Being Undertaken by AESRD in the Context of Cumulative Effects Management

AESRD CMO Workshop 2013

March 13 - 14, 2013

Edmonton, Alberta

David Lyder, Sunny Cho

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Outline

- Regulatory air quality modelling
- Non-regulatory air quality modelling
- Integration of air quality modelling in a CEMS context

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Regulatory Modelling

Why?

"…a description of potential positive and negative environmental, social, economic and cultural impacts of the proposed activity, including cumulative, regional, temporal and spatial considerations."

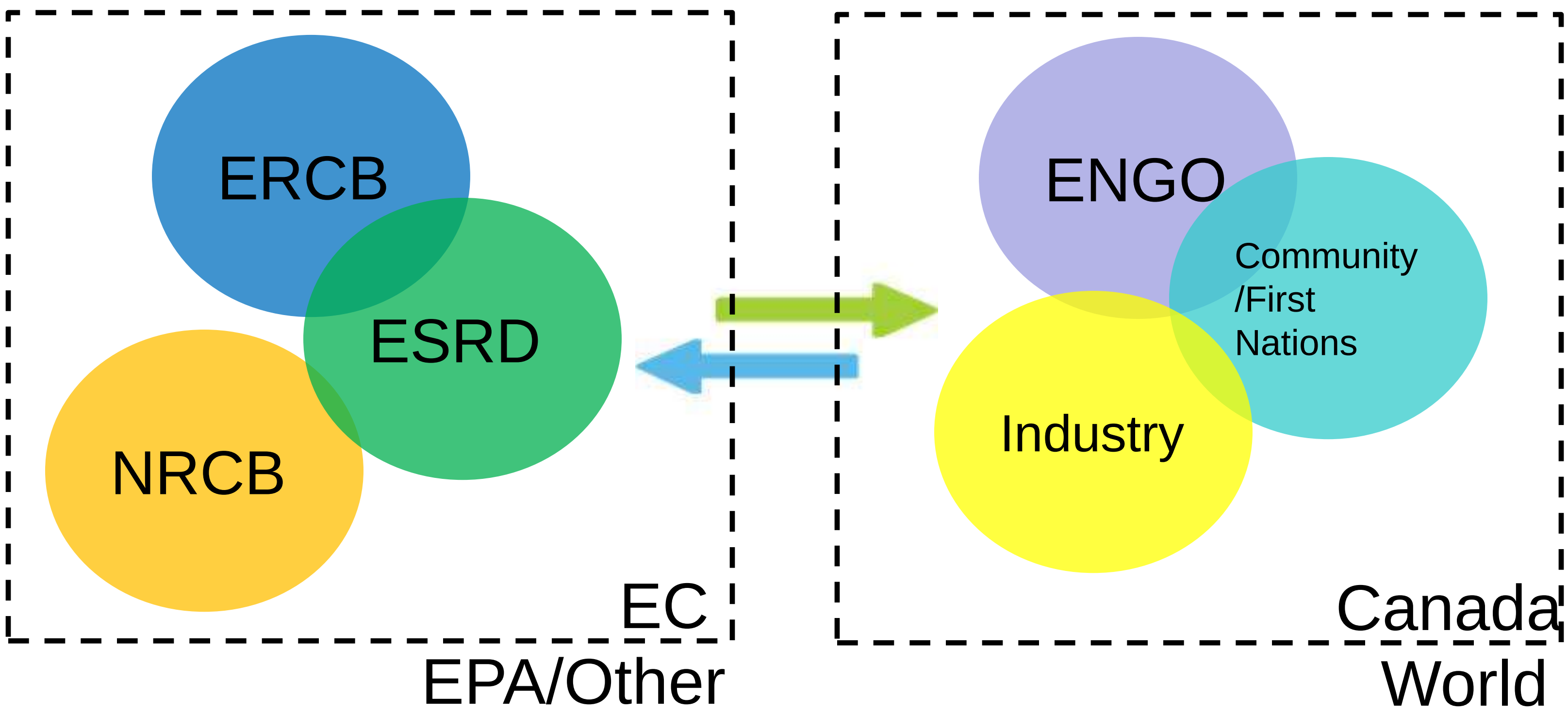
» **Alberta Environment Protection and Enhancement Act s.47(d)**

Regulatory Modelling

Who?

- **Regulators**

Non-Regulators



Regulatory Modelling

When?

- EIAs
- Permitting
- Special regulatory applications
  - Evaluating new AAAQOs
  - Evaluating new data sets

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Regulatory Modelling

What?

- **Perform modelling according to ESRD's Air Quality Modelling Guideline**
- **For non-routine flaring perform modelling according to ERCB's Non-Routine Flaring Guideline**
    - **Emission sources/values**
    - **Background levels**
    - **Meteorology**
    - **Models/Model settings**
    - **Objectives**

Non-Regulatory Modelling

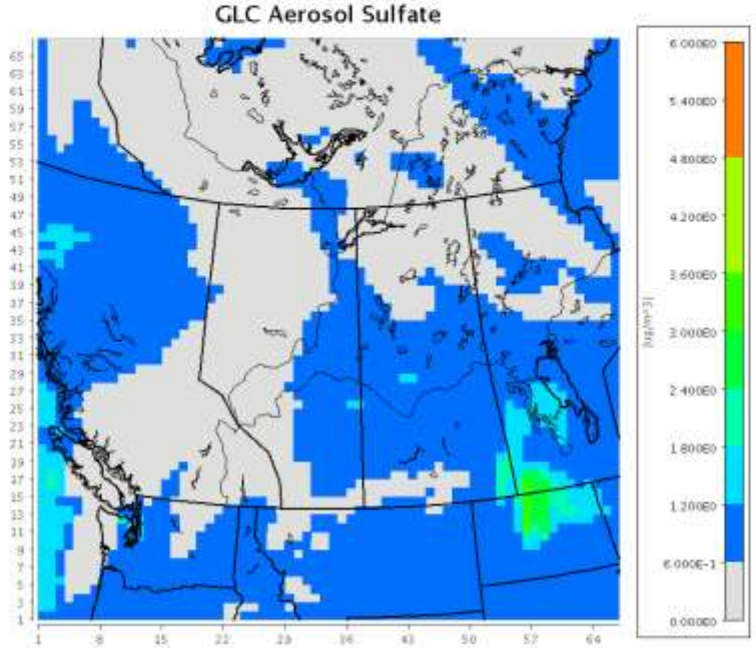
What?

- Not currently tied to an EIA or permitting exercise
- May be tied directly into CEMS:
  - Frameworks
  - Regional/international initiatives
- Emergency response

Non-Regulatory Modelling

Frameworks

- Acid Deposition Framework
  - Provincial/Western Canadian in scale
  - Non-regulatory data sets and models



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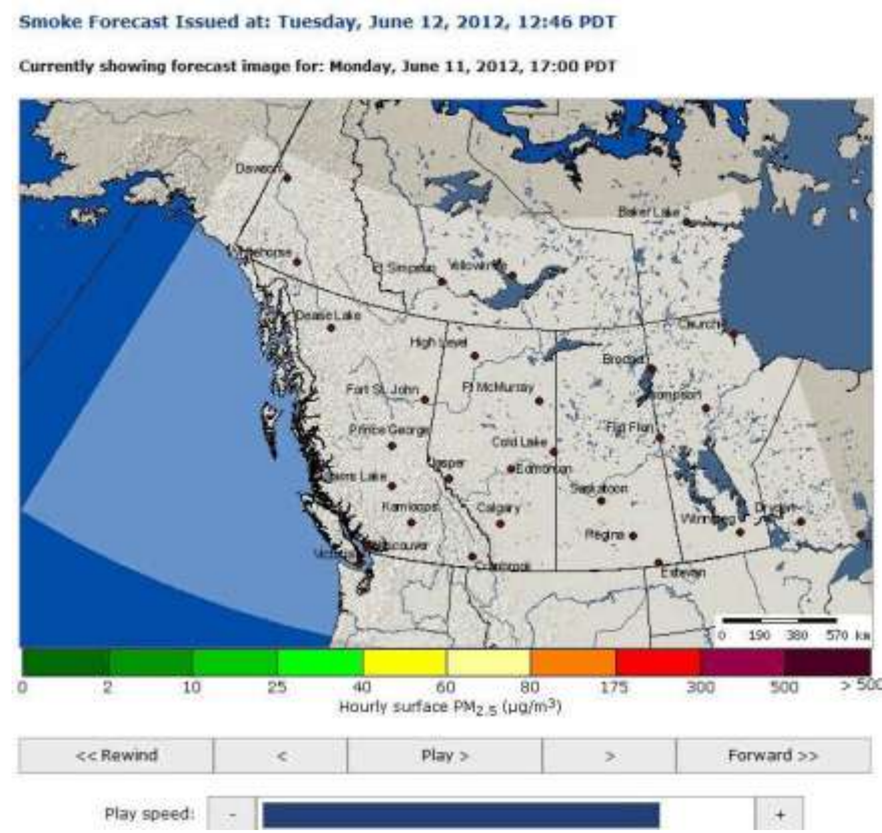
Non-Regulatory Modelling

Regional/International Initiatives

- **BlueSky**
  - **Provincial/Western Canadian in scale**
  - **Non-regulatory data sets and models**
  - **Multi-purpose**
    - Health
    - Emergency response
    - Prescribed burns



http://www.bcairquality.ca/bluesky/

Non-Regulatory Modelling

Emergency Release/Evacuation

- EAMAS
  - Developed for LARP region by ASERT (Martin Bundred)
  - Non-regulatory data
  - Information for first responders

Outline

- ✓ **Regulatory air quality modelling**
- ✓ **Non-regulatory air quality modelling**

- **Integration of air quality modelling in a CEMS context**

Integration

What's CEMS?

- **Manage activities that affect the environment, economy and society in a particular place**

	Current Approach	What is Needed
Environmental media	Single (one by one)	Air, land, water and biodiversity together
Spatial context	Project/local	Multiple scales
Scope	Regulated activities	Regulated and unregulated activities
Approach	Reactive	Proactive
Results	Mitigated impacts	Defined results
System organization	Fragmented	Connected
Responsibility/participation	Agency-by-agency	Collective action
Performance measurement	As required	Essential, more comprehensive

What's the renewed ESRD clean air strategy?

"… resource management decisions are integrated to minimize cumulative environmental effects."

- Air quality management is *integrated* with land, water and biodiversity management to be certain that ecosystems are sustained.

Integration

What needs?

- Local to global scale, across – nesting, coupling, or model integration
- Implications of different spatial (and temporal) resolutions
- Different environmental compartments

→ support for complex and cumulative problems

Integration

What's Model Integration?

- *Model integration* means? "Different things to different people"
- Two basic models for application integration
  - Integral (Deep) modelling: to build the model as a whole; produces a single new model that combines two or more given models

  - Assemblage (Functional) approaches: to assemble already built or extant models; leaves the given models as they were

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Integration

Air Integrated Models (Non-regulatory)

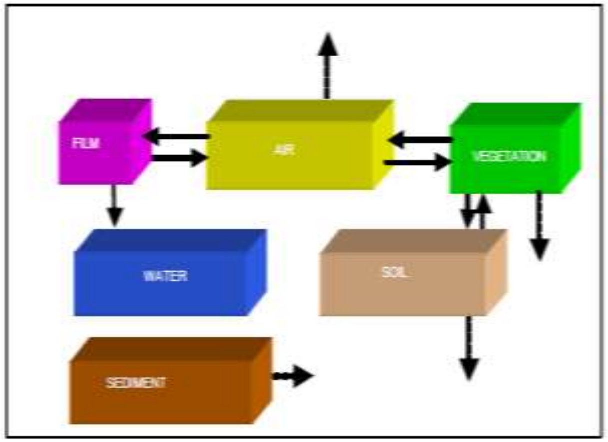
AirQUIS (Integrated air quality management system)

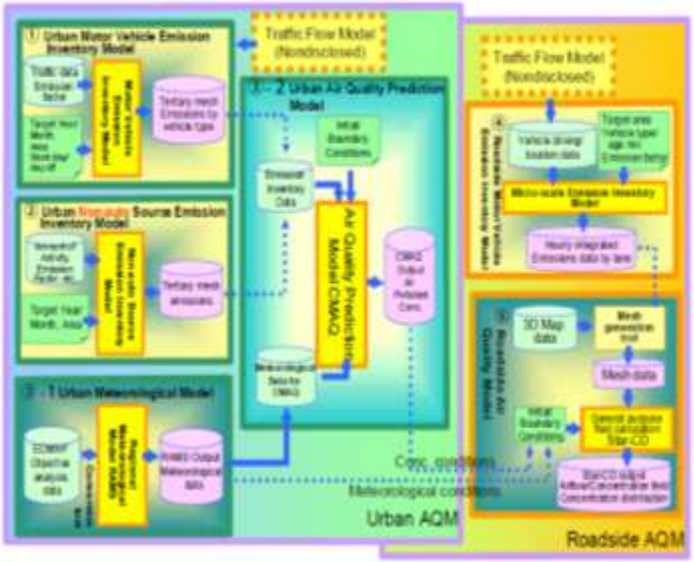
- An atmospheric transport model that produces atmospheric deposition fields for nutrients and other constituents
  - Community Multi-Scale Air Quality modelling system (US EPA)
  - GEM-MACH (EC)
  - AirQUIS (Norway)

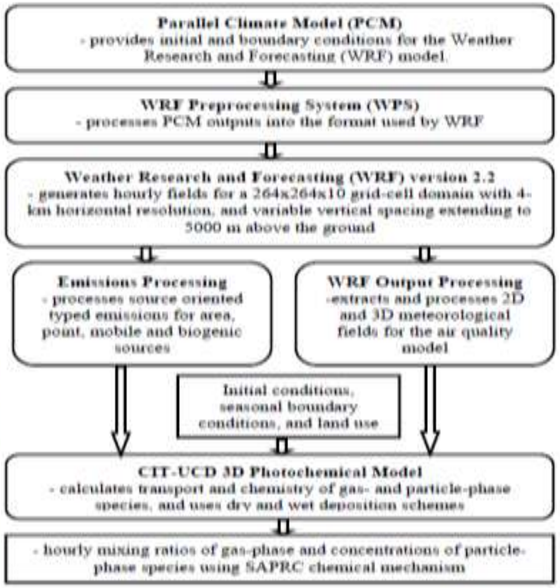
Integration

Air Integrated Models (Multi-media/scale/topic Applications)

- Climate/Air quality
- Multi-media (Air/Water/Soil/Sediment/Vegetation)
- Multi-scale (Regional/local)







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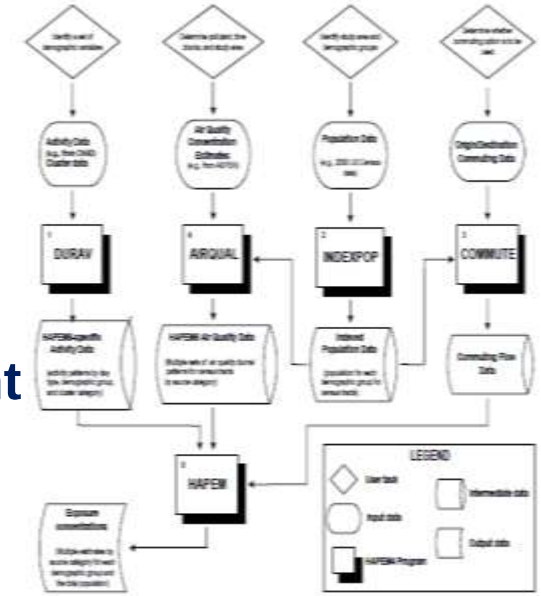
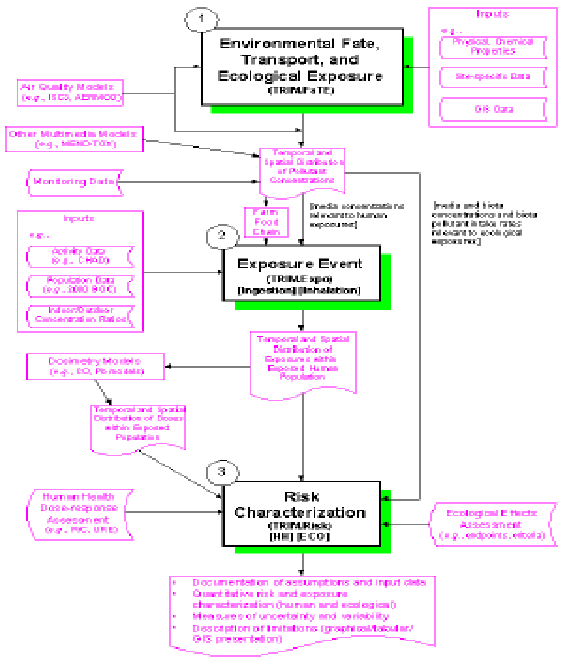
Integration

Air Integrated Models (Human Health & Risk Applications)

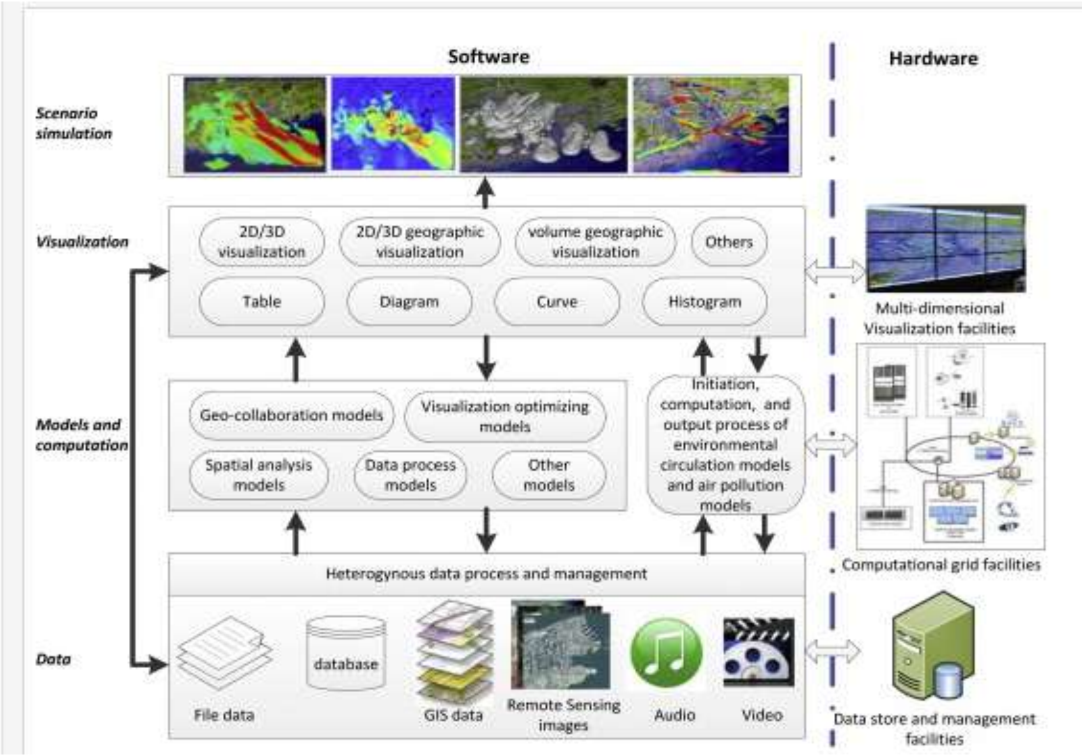
- Air Toxics Exposure Assessments
- Hazardous Air Pollutant Exposure
- Total Risk Integrated Multimedia





Integration

2nd Generation Integrated Modelling System



Software + Hardware

(Visualization GIS/ Data/Models/ Scenario)

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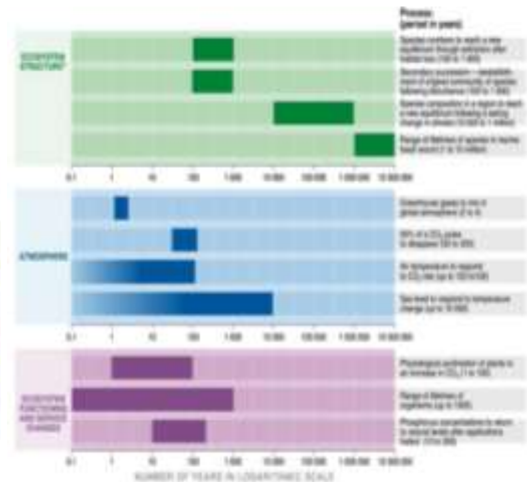
Integration

Common Issues

Mismatched scales

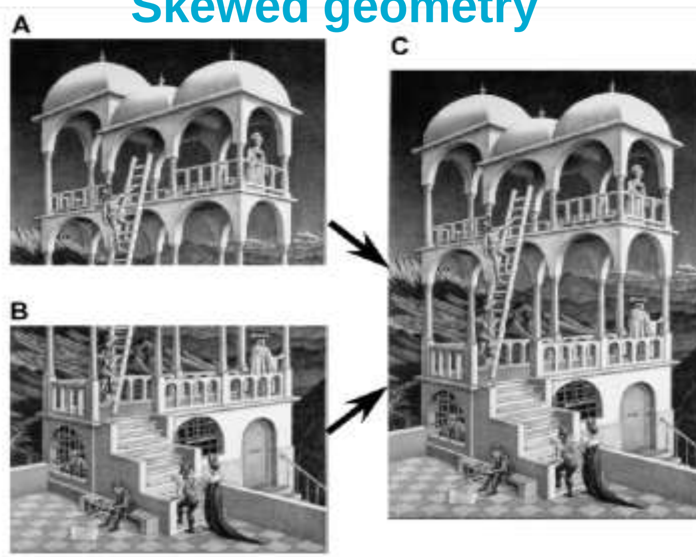
Ugly construct

Temporal Dynamics



Overwhelming complexity

Skewed geometry



Confusion of tongues

Ref.: Voinov, A. et al., Environmental Modelling & Software 39 (2013) 149-158.

Integration

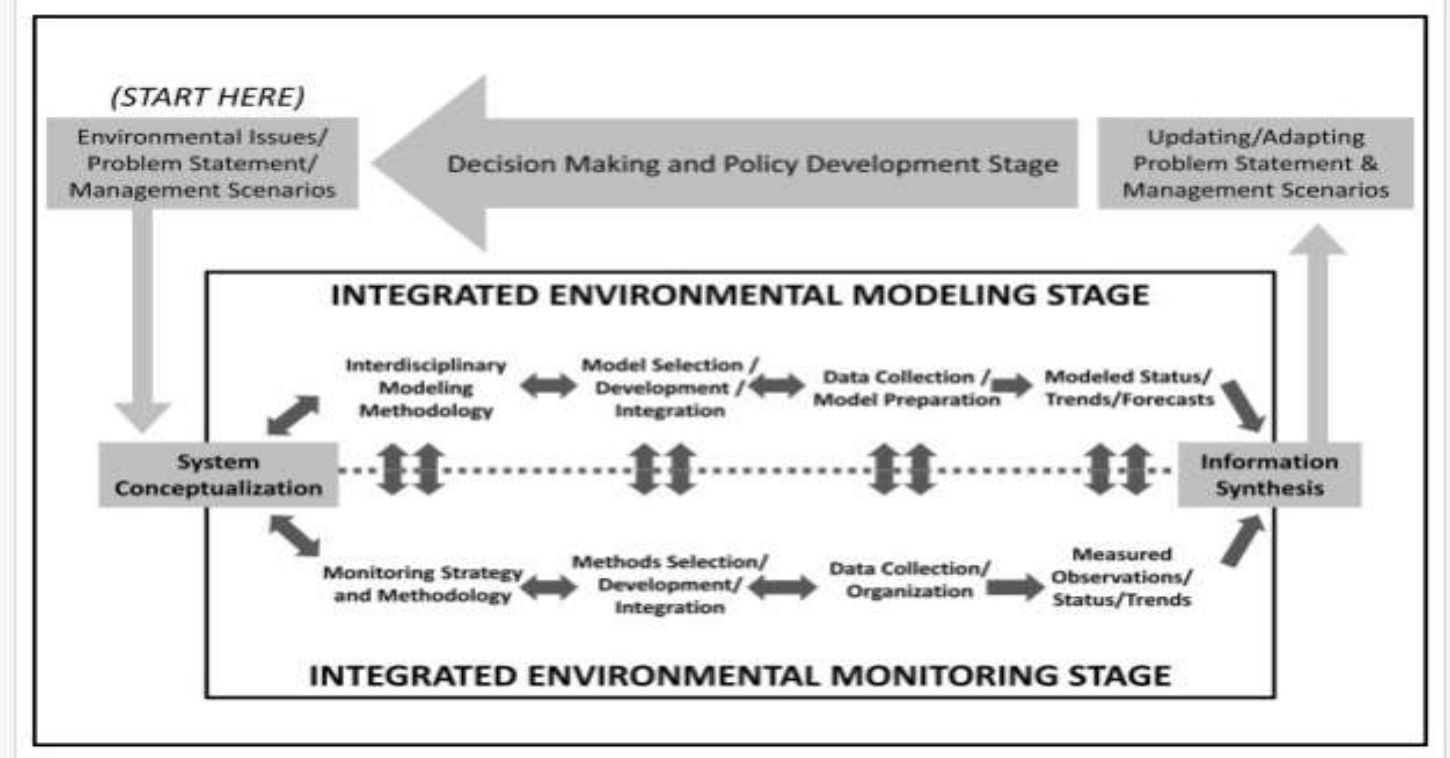
Supporting for CEMS or Decision Making

- Applied for **policy decision support** have achieved a substantial level of **maturity**
- A **growing understanding of the complexity** of the systems modelled, applying systems theory and control theory in model design and development, as well as carefully choosing the level of ambition and precision required

- **Decision makers** are often **expecting an accurate** representation of reality in models and results that pinpoint individual options or deliver an exact number
  - This is not a trivial problem to overcome, but improvements in **communication between model developers and users** can significantly reduce this problem

Integration

Decision Process (example)



Ref. Laniak G. et al, Environment Modelling & Software, 39, (2013) 3–23.

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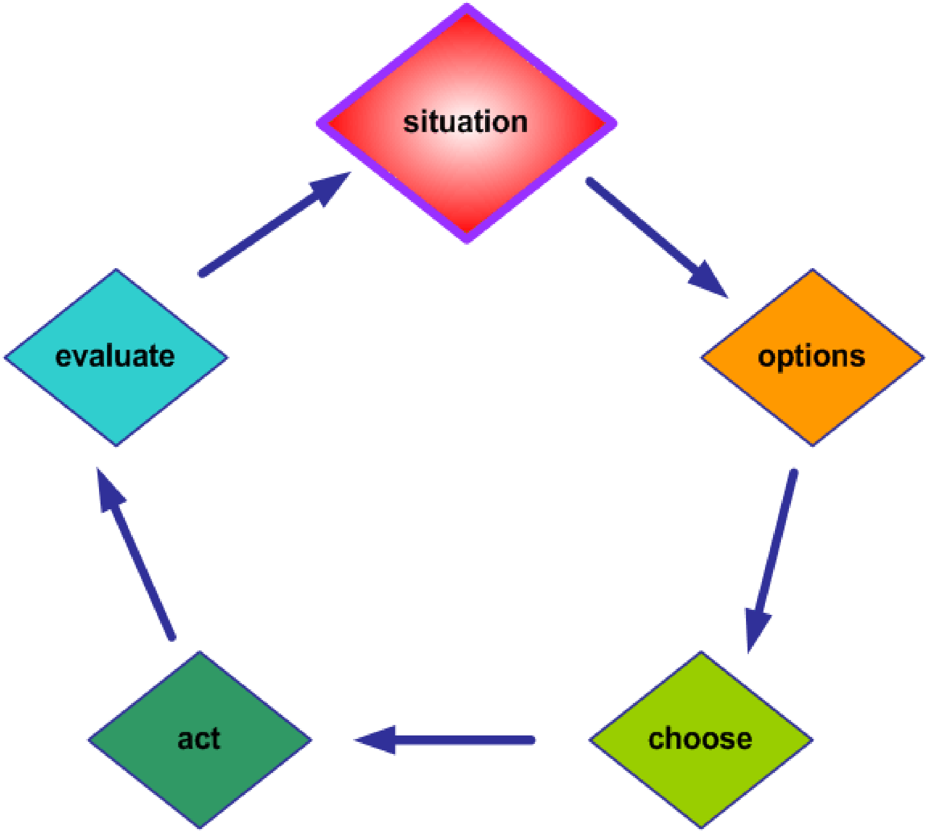
Closing …



- **Outcomes based**
- **Place based**
- **Performance management based**
- **Collaborative implications**

Day 2 – Session 3

Robert Magai – AESRD

BIOGRAPHY

Robert Magai is an Environmental Modeler in the Science, Research and Innovation Section of the Clean Energy Policy Branch in ESRD. He holds a Ph.D. in Atmospheric Sciences from the University of Missouri, where he also earned a masters degree in Remote Sensing and GIS.

Before joining the Oil Sands Environmental Management Division aka Clean Energy Branch, Robert was in the Northern Region as a Water Quality Modeler and GIS Scientist. Prior to joining AENV, he was a research scientist and lecturer in GIS and Remote Sensing at Selkirk College Geospatial Research Center in Castlegar, BC and he also held a Senior Geospatial Database Manager position at the University of British Columbia in the Faculty of Forestry.

Previous employment experiences in the United States include working for the Missouri Department of Natural Resources as a Water Quality Modeler and GIS Scientist and a lecturer at Richland College in Dallas, Texas, teaching information technology courses. When Robert is not nursing sports-related injuries and otherwise, he likes to play squash. He is also an avid sports fan. To cap it all off, he is the current chair of a “think-tank” group known as OACiS (Organization of Arm Chair Critics in Sports).

Day 2 – Session 3

Robert Magai – AESRD

ABSTRACT

Data and knowledge management remains a fundamental challenge in the implementation of management frameworks, which by their very nature, are data intensive. Since management framework outcomes are meant to be measured and evaluated continuously, data compilation and assessments in near real time are critical. It is for this reason that the Science, Research and Innovation Section in the Clean Energy Policy Branch was tasked with the development of a data and knowledge management tool to assist in regional data storage and analysis. It was realized during the development of this tool that regional data integration requires consistent data formats in a centralized location. We thus have developed a comprehensive and integrated air, surface and ground water data management system capable of storing a wide variety of spatio-temporal data types and also capable of providing information for decision support for both operational and strategic planning.

The Cumulative Effects Management Analytical and Knowledge Base Tool (CEMTool) is a GIS based tool with built-in analytical tools for data analysis and for generating specialized reports. The key features of the data and knowledge base include a system that generates annual performance summary reports on industrial activities; facilitates cumulative effects monitoring and reporting and can be accessible from a portal.

Prototyping a Tool for Integrating Regional CEMS Data, Information and Quantifying Effects!

Robert Magai, PhD
Environmental Modeler

Science, Research and Innovation Section
Clean Energy Policy Branch
ESRD

Presented at the

Environmental Modeling Workshop
University of Alberta Lister Center
March 13 -14, 2013

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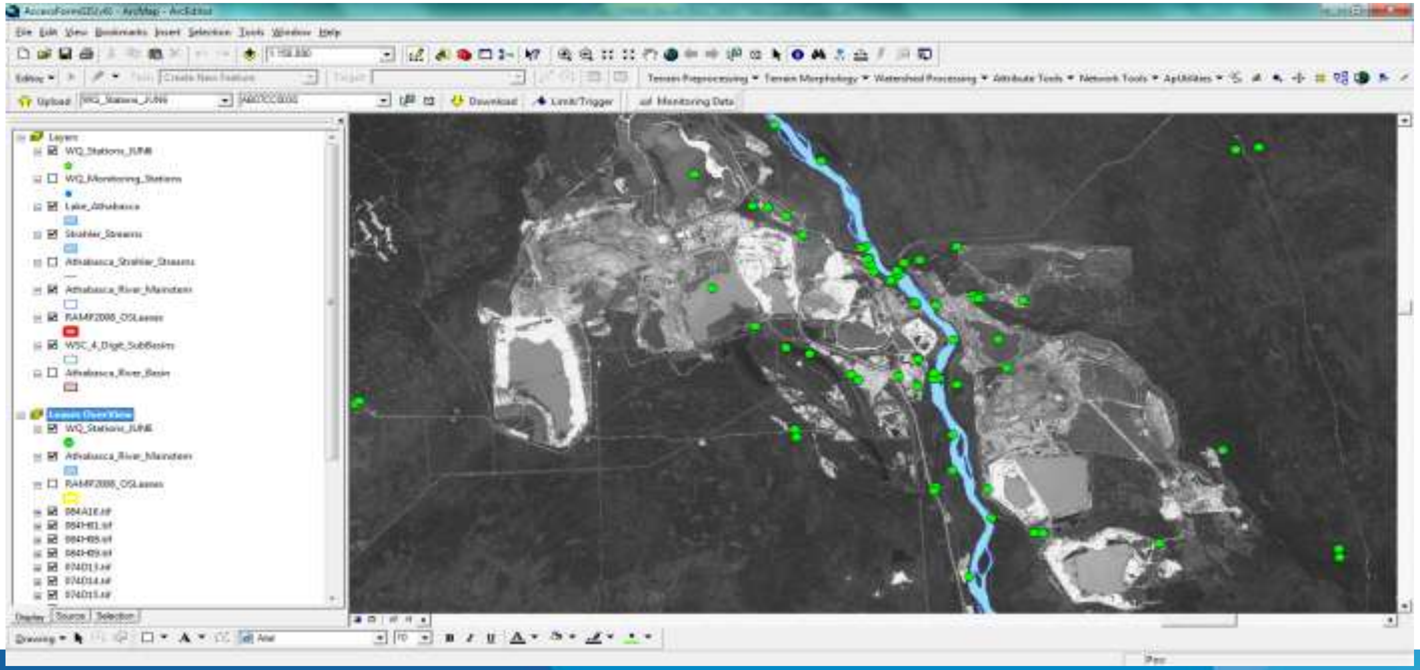
Government of Alberta

Presentation Outline

- Objective
- Rationale and Benefits of CEMTool
- Methods for studying CEs
- Demo
  - GIS Interface and Visualization
  - Data Analytics
    - Excel app
    - R - Stats
- Summary and Next Steps
- Acknowledgements
- Discussion

Objective

Provide an overview of the cumulative effects analytical, evaluation and reporting tool



Rationale

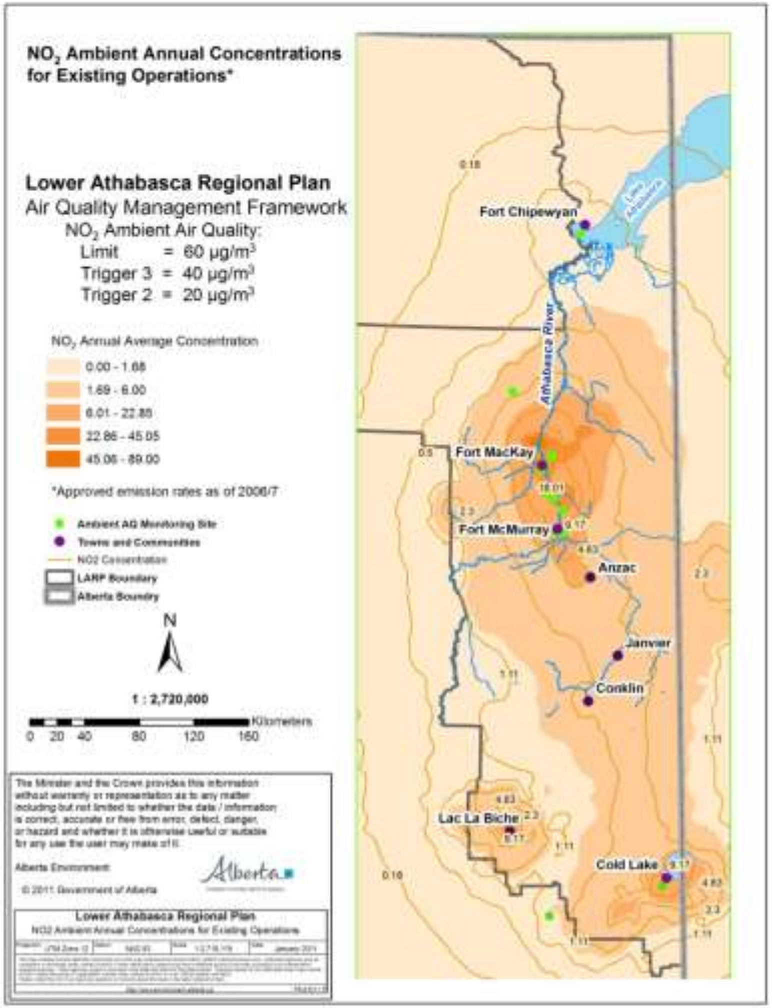
- Rationale for developing CEMTOOL
  - Regional plans require tools to develop thresholds, limits and outcomes.
    - Cumulative impacts are data intensive
    - Outcomes need to be measured and evaluated continuously
      - Data compilation and assessment in near real-time is critical
  - Management frameworks all contain enhanced reporting requirements to the public
    - Require knowledge and information generation

Benefits

- Why the CEMTool may be useful in CEM
  - Consistent and specified data formats in a centralized warehouse
  - Tool for mapping, evaluation, visualization and reporting
  - Assist managers with site-specific decisions or decisions regarding geographic areas and communities adjoining the site
  - Expedite availability, use, storage, search and retrieval of data and permit sharing for concurrent or future purposes
  - Efficiencies gained free up scarce resources needed to pursue site and regional goals
  - Potential to better communicate environmental data to the public
  - Facilitate review and assessment of environmental impacts on regional scale
  - Merge regional data across programs to provide managers a holistic view of specific sites as well as geographic regions

Primary Methods for Studying CEs

- Overlay mapping and GIS
  - Incorporate locational information into CEs
  - Set boundaries of the analysis
  - Identify areas where effects will be greatest
- Trend analysis
  - Assess status of resources and/or ecosystems over period of time
  - Establish appropriate environmental baselines
  - Project future cumulative effects
- Modeling
  - quantify the cause and effect relationships leading to CEs



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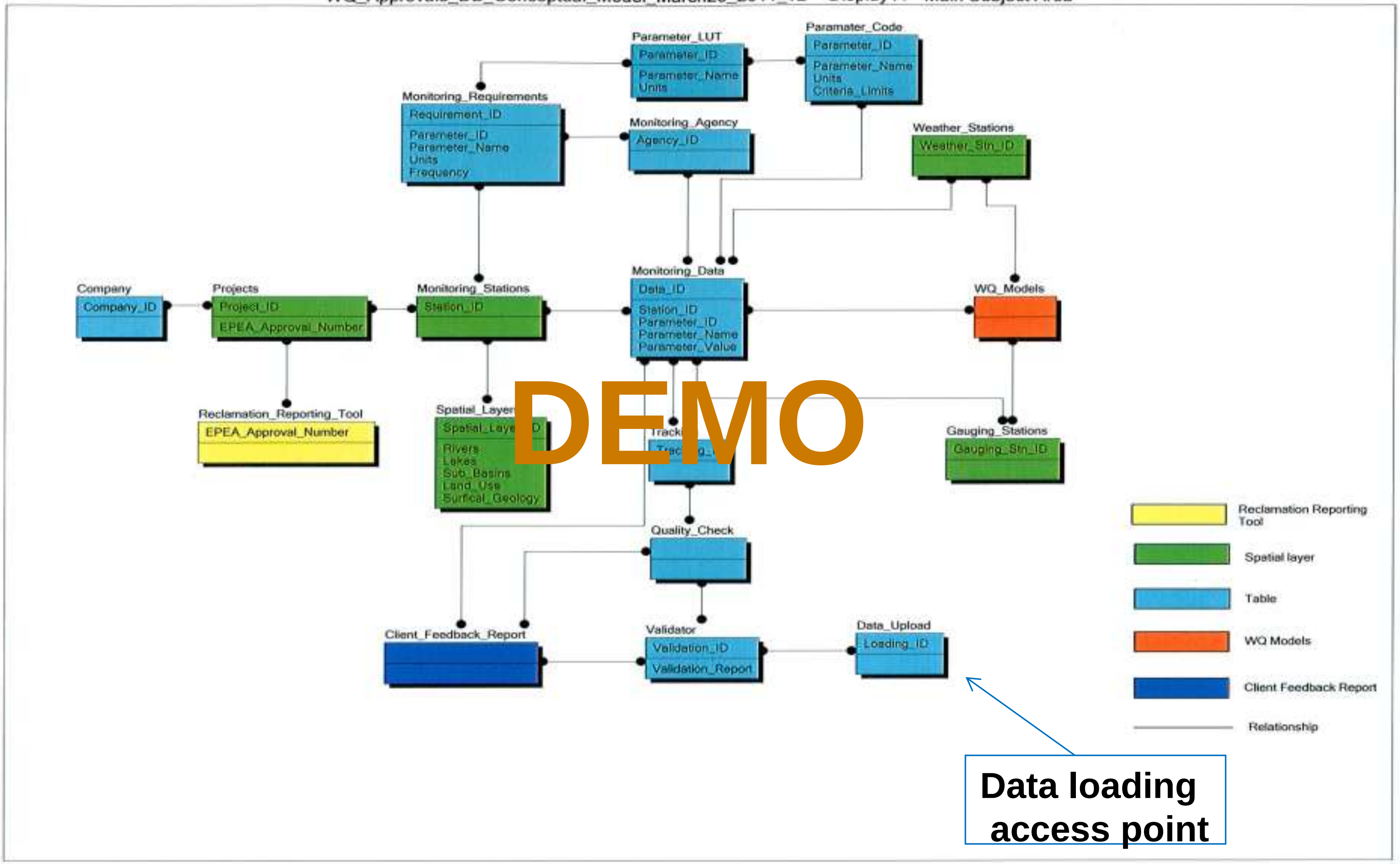

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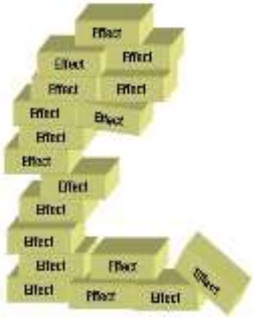
Cumulative Effects Management Tool

- Demo
  - GIS Interface and Visualization
    - Surface water
    - Groundwater and
    - Air quality
  - Data Analytics
    - Excel
    - R – Stats
  - Air and groundwater quality visualization
  - Electronic reporting and evaluation

Summary and Next Steps

- Summary
  - CEMTool will
    - Provide consistent standard across all regional plans
    - Facilitate data sharing, storage, and communication
    - Time saving
    - Vastly Improved data evaluation and visualization

- Next Steps
  - Connect to Enterprise Data warehouse
  - Incorporate biodiversity data
  - Build an interface for R-Stats



Acknowledgements

- Science, Research and Innovation Team
  - Roger Ramcharita – Director and Sponsor
  - Preston McEachern – former Section Head
  - Robert Magai
  - Hannah McKenzie
  - Susan Satterthwaite
  - Vignesh Devendran
  - Wendell Noordof
  - Lizzy Chow

Questions and Discussion

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Day 2 – Session 3

Amandeep Singh – ERCB

BIOGRAPHY

Dr. Amandeep Singh joined AGS(ERCB) as a Hydro-geologist in February 2011. He received his PhD in “Environmental and Water Resources Systems” from Cornell University, Ithaca, NY with minors in “Computational Science and Engg.” and “Hydraulics and Hydrology “. Before Cornell he worked as an Engineer (Design) in Water Resources Division with RITES India Ltd.(A Govt. of India Enterprise). He obtained his Masters and Bachelors of Technology from Indian Institute of Technology (IIT) Delhi and National Institute of Technology (NIT), Jalandhar respectively.

Day 2 – Session 3

Amandeep Singh – ERCB

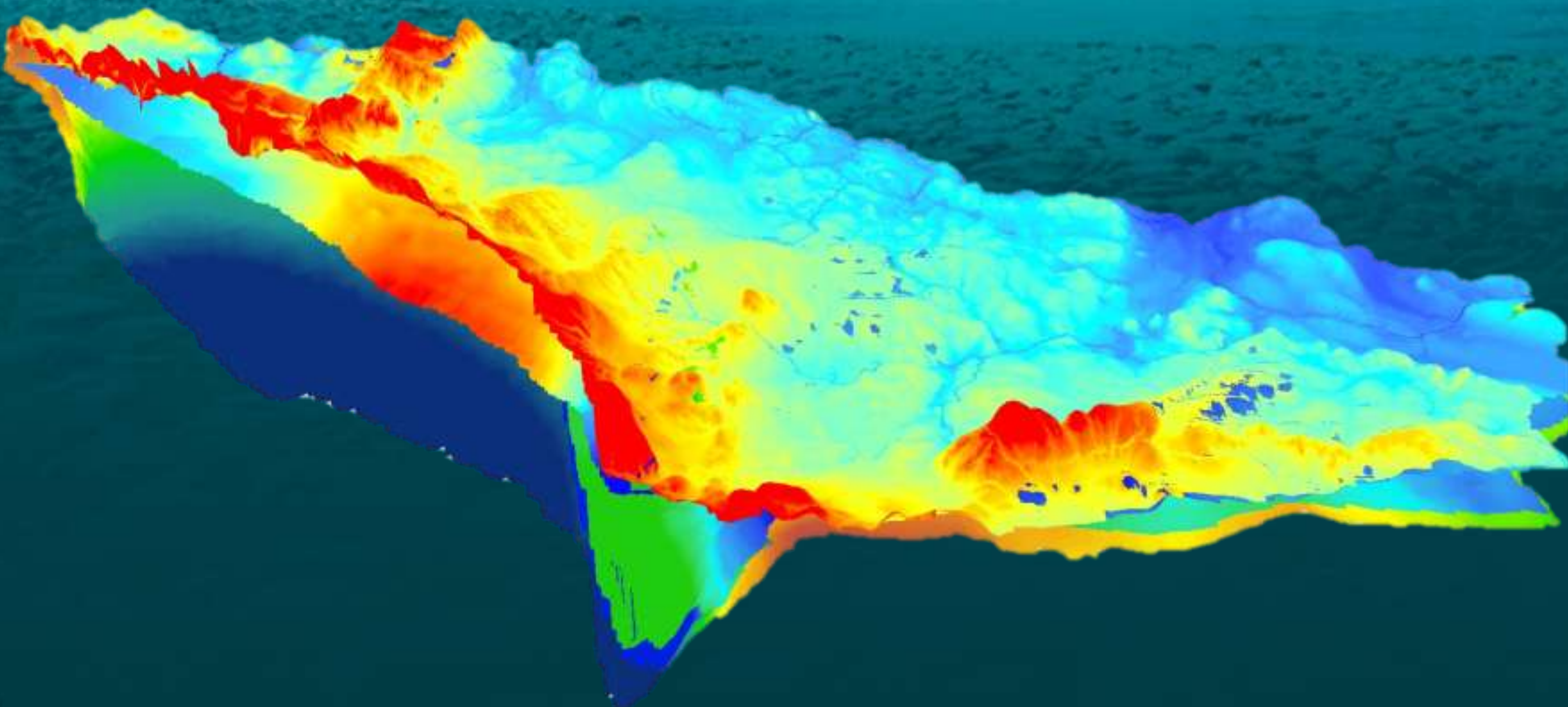
ABSTRACT

The Alberta Geological Survey (AGS) and Environment and Sustainable Resource Development (ESRD) are working together on the Provincial Groundwater Inventory Program (PGIP) to develop adaptable and science-based decision making tools supporting policy development and regulation to manage groundwater resources. The first phase of PGIP is focused on developing a static geological model that integrates multiple sources of data and analysis into a single framework that will be used for the subsequent phases (i.e. building groundwater models and integrating them in a decision support system). To support the modelling phase of PGIP, a regional-scale study of groundwater flow is being undertaken in the Western Canada Sedimentary Basin, comprising parts of Alberta, Saskatchewan and British Columbia. The objective of the study is to develop a regional scale numerical model of basin-scale hydrogeology which will subsequently provide boundary conditions for local-scale groundwater management models.

The regional scale model under development includes post-Colorado group aquifers, composed of late Cretaceous to Recent sediments, attaining maximum thicknesses of >2600 m. The study area is bound to the west by the Brazeau-Waptiti thrust (deformation) belt and to the south by the Canada-USA international border. The Belly River group zero edge along with Pierre Shale Group (Saskatchewan) forms lateral boundaries in the north and east, whereas top of Colorado group (Lea Park formation) forms the basal boundary of our model. Major surface water bodies and their larger tributaries within the modelled area are the Peace, Athabasca, North and South Saskatchewan rivers and mountain streams. Aquifer units identified for the study include the major litho-stratigraphic units and their equivalents from land surface to the top of the Lea Park Formation consisting of the Quaternary sediments, and the Paskapoo, Scollard, Horseshoe Canyon formations and the Belly River Group. The regional aquitards in the study area have been delineated as the Battle and Bear Paw formations. Previous work in the Alberta Basin has demonstrated that, in addition to topography controlled flow regimes, a substantial part of the basin contains sub-hydrostatic flow regimes. The flow model attempts to honor the effects of sub-hydrostatic conditions to reflect its influence on regional water balance and flow directions. The block-centric, finite difference groundwater code MODFLOW is being used to construct the basin-scale model.

Preliminary results from the groundwater flow modelling indicate predominance of topography-driven, local- to intermediate-scale flow systems in the upper hydrostratigraphic units (Quaternary, Paskapoo, Scollard) with recharge of these units occurring in the foothills of the Rocky Mountains. The Battle aquitard, where present, acts as a regional flow barrier in the model. Flow paths in the Horseshoe Canyon Formation and Belly River Group hydrostratigraphic units are controlled by regional scale topography-driven flow systems and sub-hydrostatic pressure regimes. The upper units (i.e. the Paskapoo and the Scollard units) are influenced by the presence of sub-hydrostatic conditions in deeper units but in general the affected zone is beyond typical groundwater water source wells.

Numerical Modelling in Support of the Provincial Groundwater Inventory Program



Amandeep Singh

ERCB - Alberta Geological Survey

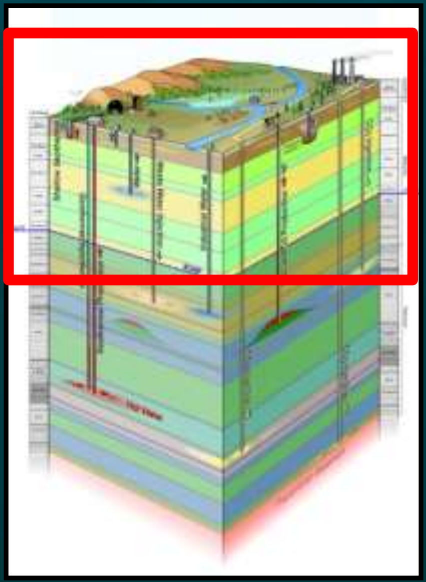
Environmental Modelling Workshop

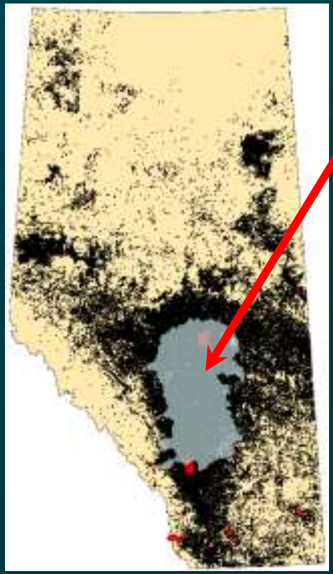
March 14, 2013

Objectives & Background

Provincial Groundwater Inventory Program (*PGIP*)

- MOU with Alberta Environment & Water
- Evaluates fresh groundwater (above Base of GW Protection)
- Evaluate quantity, quality, and thresholds between sustainable/ unsustainable use of groundwater resources through use of numerical flow models





Edmonton-Calgary Corridor (ECC)

- 1st study area
- ~50 000 km^2
- Dense population
- Rapid growth
- Based on 10 drainage basins
- Data-rich subsurface (both water well & oil and gas data)

Outline / Numerical Model Workflow

- Establish the **PURPOSE** of the model.
- Develop a **CONCEPTUAL MODEL** of the system.
  - Gather data
- **GOVERNING EQUATION** and **COMPUTER CODE**
- **DESIGN**
- **CALIBRATION**
  - Conduct a **CALIBRATION SENSITIVITY ANALYSIS**
  - Determine how the model responds to uncertainty in parameter values.
- **VALIDATE** the model
- **PRESENT RESULTS** of model and model design
- **POSTAUDIT**

Regional Geomodel (SARGS)

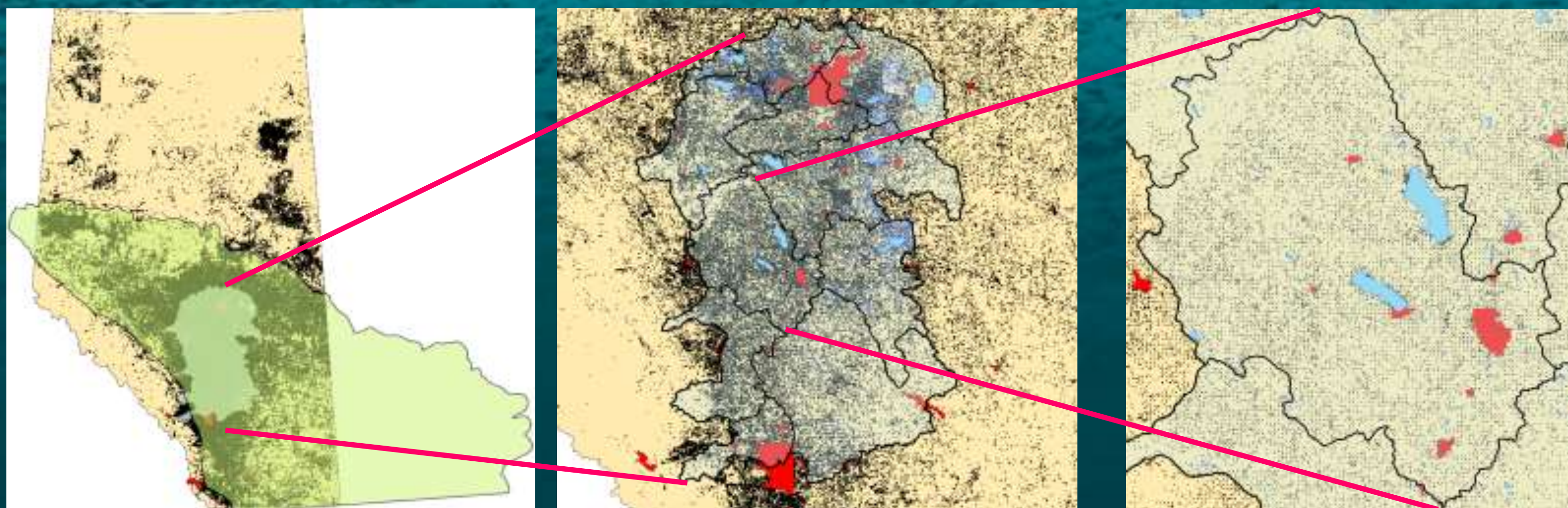
- Southern Alberta Regional Groundwater Simulation (SARGS)
  - Develop ~420 000 km^2 Steady State numerical model (Top of Colorado Group to Surface)
- Why is SARGS so big?
  - Sound, geologically-based boundary conditions (exception of US border: General Head Boundary)
  - Western Boundary : Deformation Belt
  - Eastern Boundary : Belly River Zero Edge & Pierre Shale in Saskatchewan
  - Basal Boundary : Top of Lea Park/Colorado Group
  - Effects of boundary conditions well removed from boundaries of management-scale models (local-scale models to be developed)

ERCB | AGS

Energy Resources Conservation Board | Alberta Geological Survey

Modelling Objective

SARGS – Objective is to provide a reliable set of boundary conditions (water budget analysis) for sub-basin modeling.



SARGS ECC* Sub-basin

- **Provides regional context for management scale**
  - **Allows for use of Local Grid Refinement Package (LGR) in ModFlow**
  - ***ALL MODELS ARE WRONG BUT SOME ARE USEFUL*****
  - **Reduces influence of BC’s on management-scale model**
- **Accounts for groundwater flux between sub-basins**

**For illustration only*

Concept of Hydrostatic Pressure

$$h = z + \psi$$

Hydraulic head **Elevation head** **Pressure head**

$$\psi = \frac{P}{\rho g}$$

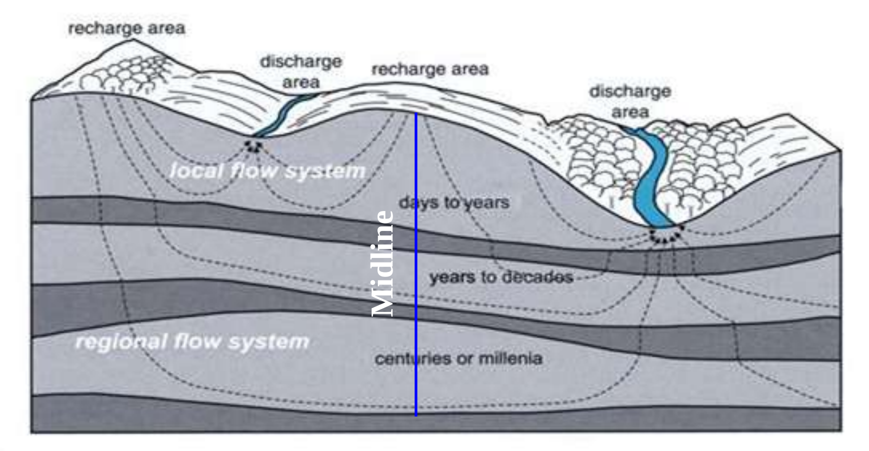
Formation fluid pressure

Density of fluid × Gravitational constant

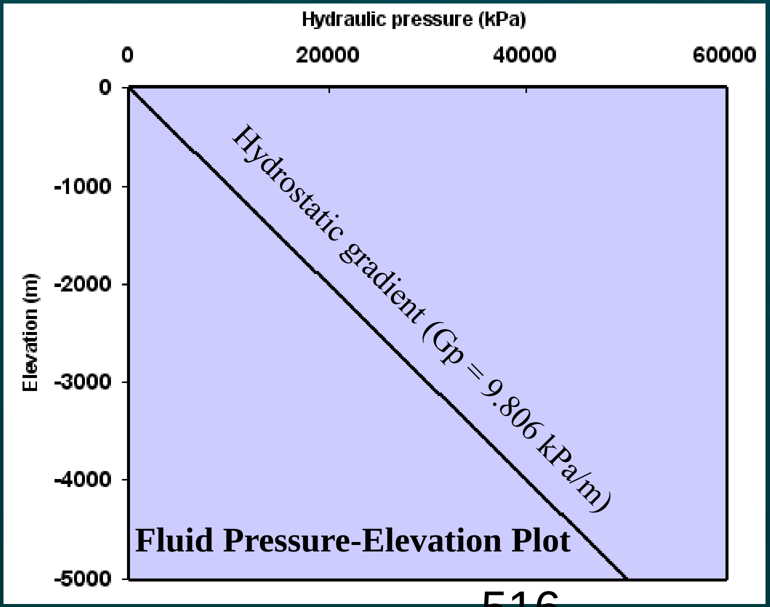
$$h = z + \frac{P}{\rho g}$$

i.e. *h remaining constant,* $P \propto 1/z$

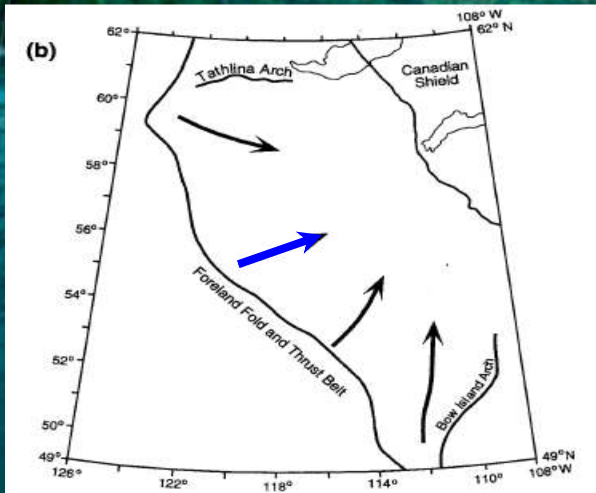
Under normal (hydrostatic) conditions, hydrostatic pressure increases by 9.8 kPa for every meter increase in depth



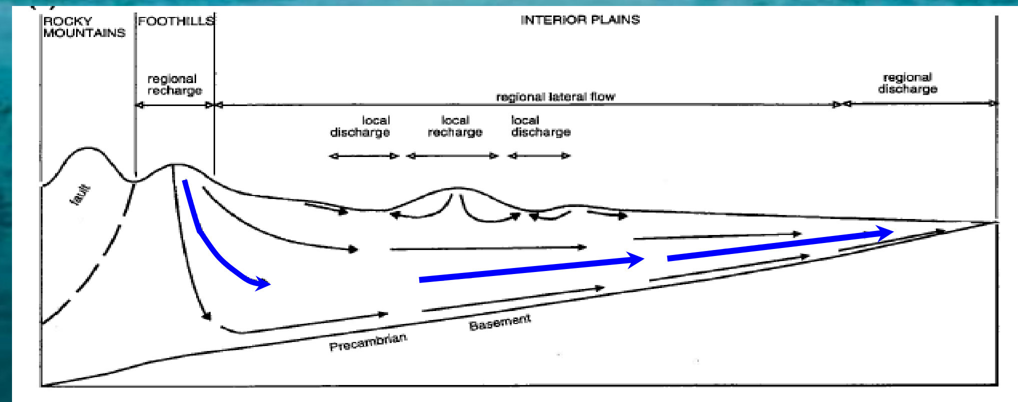
Groundwater flow systems (MAC education)**



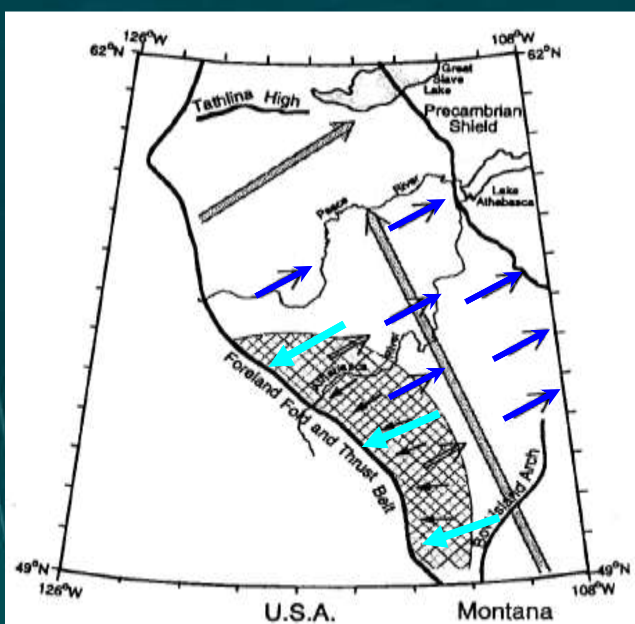
Existing knowledge of Basin-scale Flow in the Alberta Basin



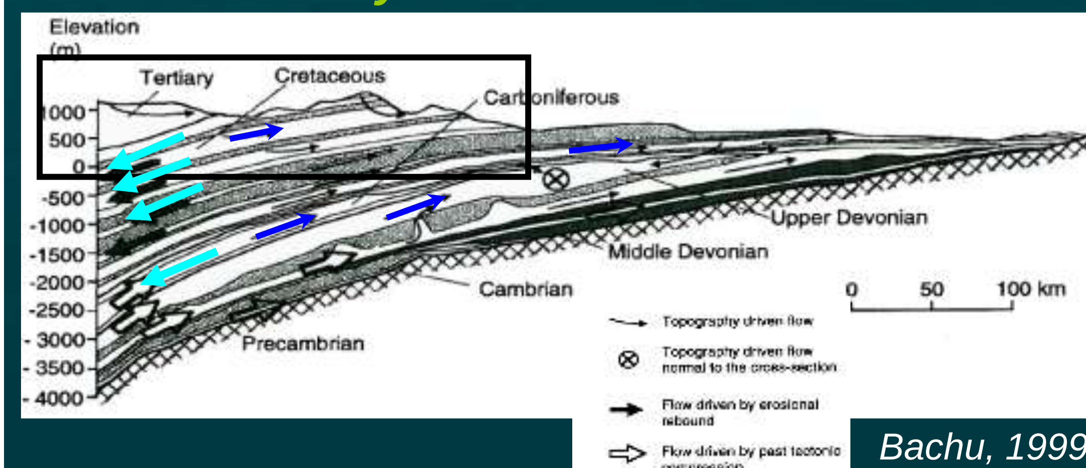
←BC Alberta SK→



Hitchon, 1984

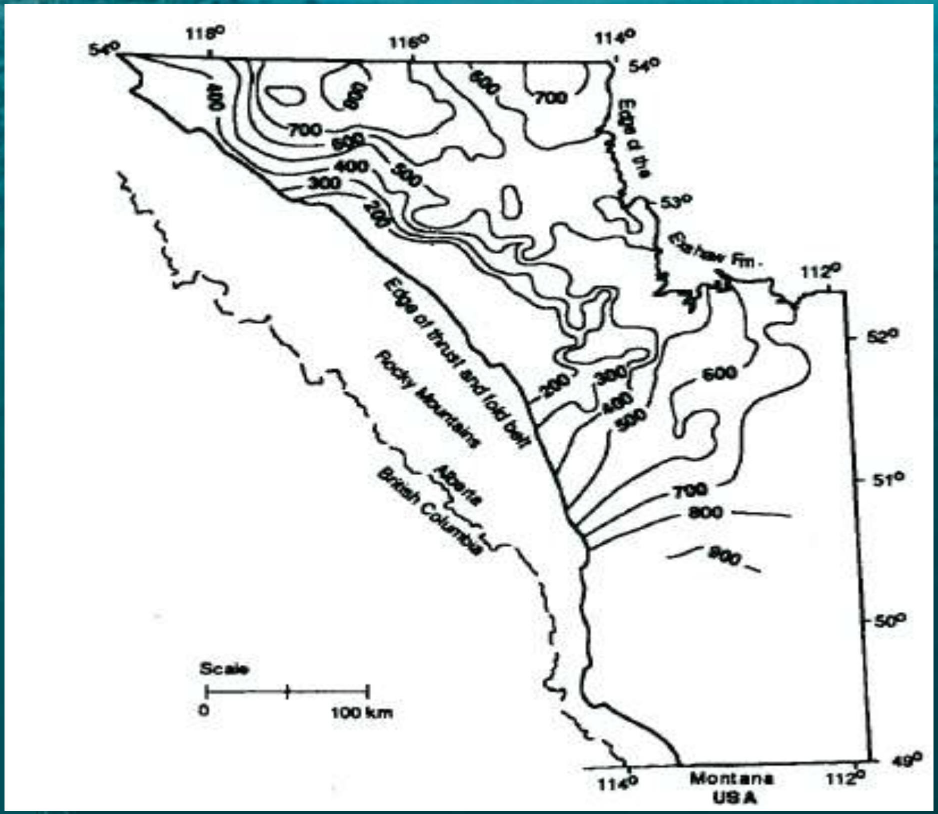


This study

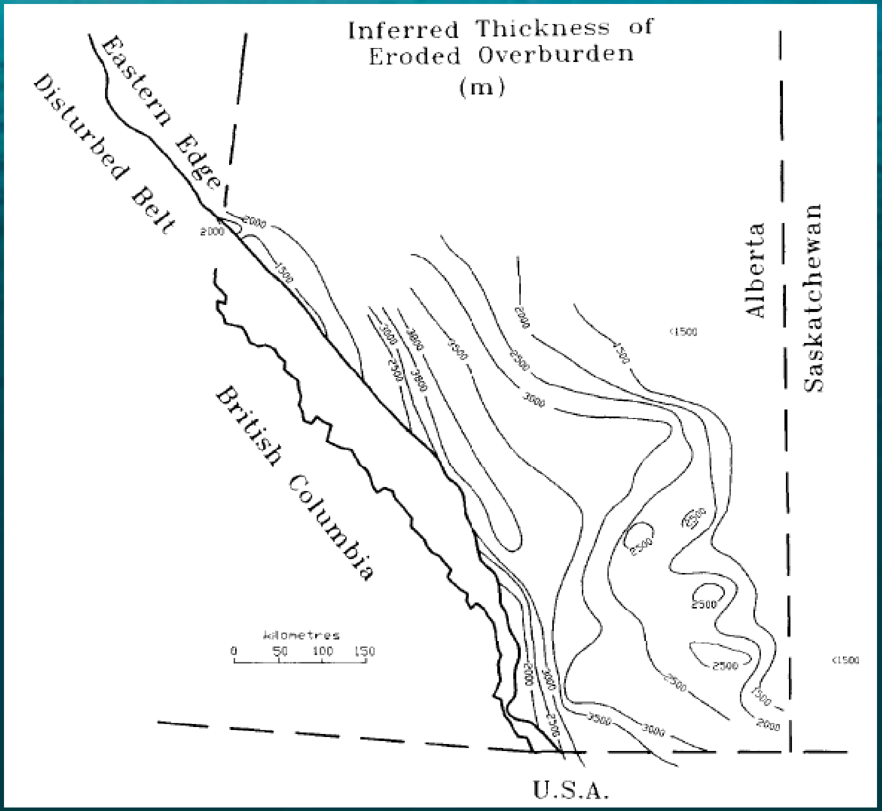


Bachu, 1999

Sub-Hydrostatic Regime in SW Alberta



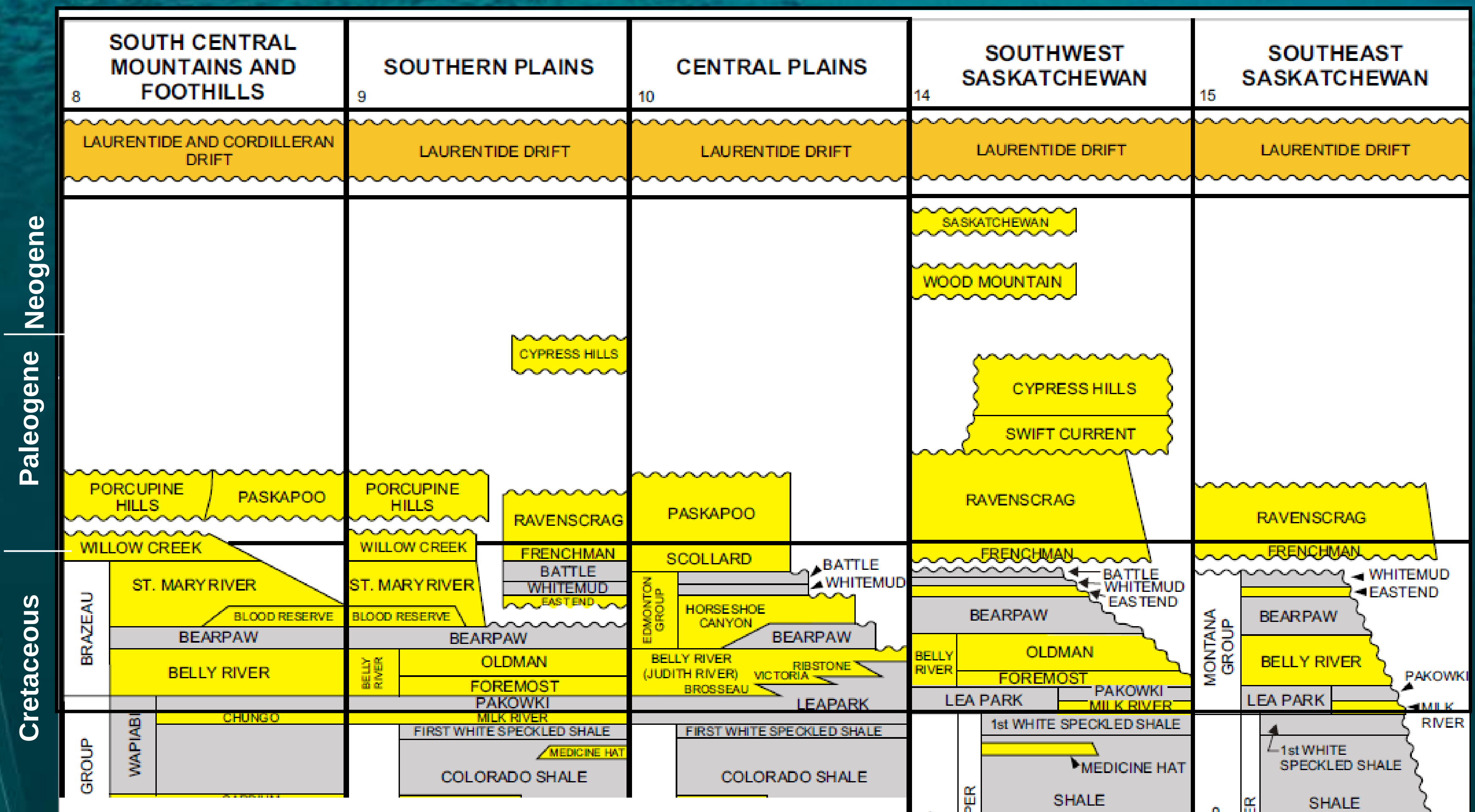
Distribution of freshwater hydraulic heads in the Horseshoe Canyon aquifer (Bachu and Underschulz, 1995)



Bustin, 1991

Net unloading effect (combination of erosional and glacial processes) has been interpreted as the main mechanism for the sub-hydrostatic regime

Stratigraphy of the Western Canada Sedimentary Basin
(Alberta and SE Saskatchewan)



conceptual model contd.

SARGS Model Layers

Hydrostratigraphic Layers	Hydraulic Property	Source
Recent	Depends	ERCB/AGS
Paskapoo	Aquifer	
Scollard	Aquifer	ERCB/AGS
Battle	Confining	ERCB/AGS
Horseshoe Canyon	Aquifer	
Bearpaw	Confining	Hamblin (GSC) picks / AGS/ Saskatchewan Data / Outcrops
Belly River*	Aquifer	ERCB/AGS & SWA
Lea Park (Top of Colorado Group)	Confining	ERCB/AGS & SWA

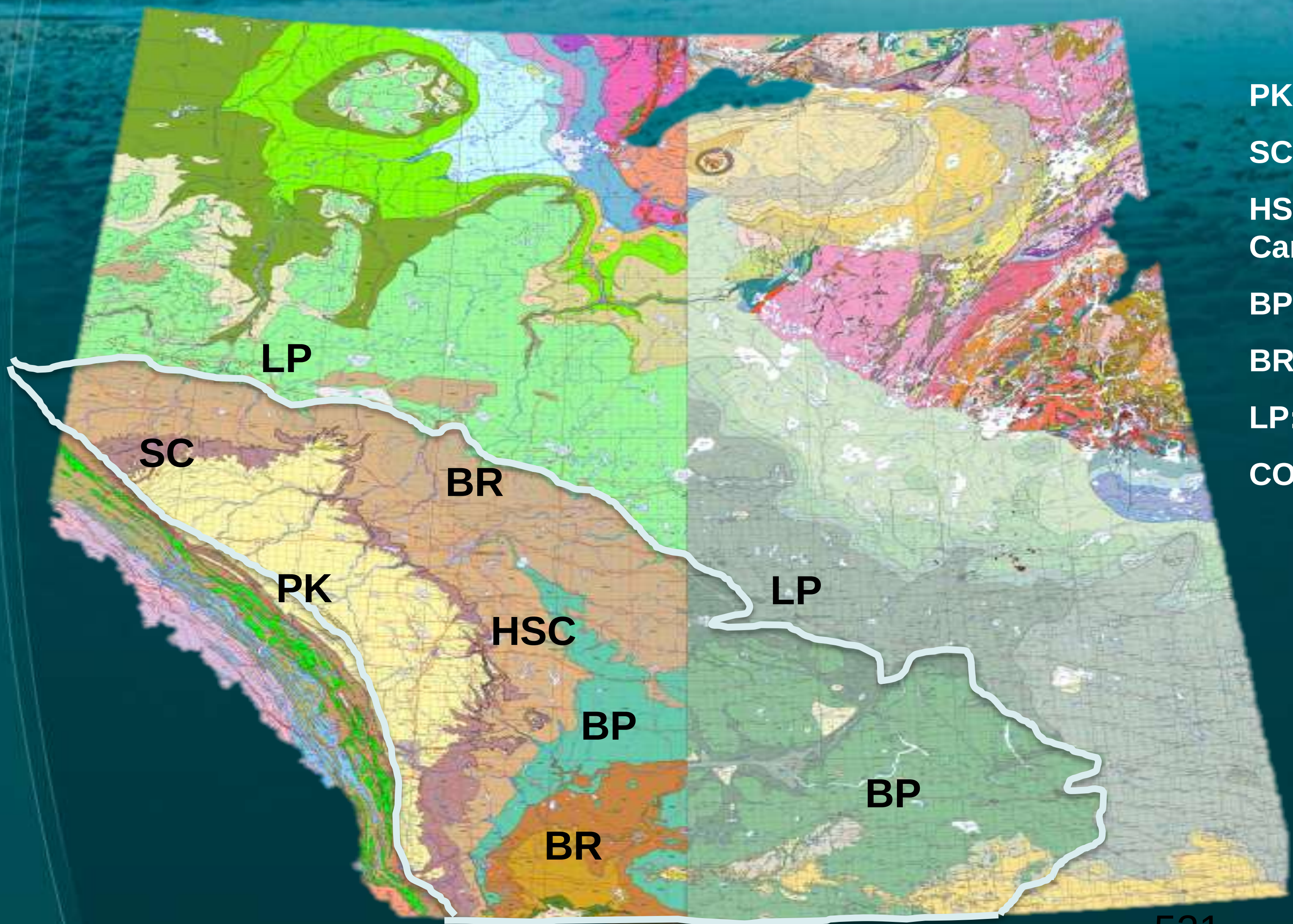
For modeling purposes

•Belly River and Horseshoe Canyon have same hydraulic properties.

*•*Belly River divided into to two sub-layers Belly River and Basal Belly River .*

conceptual model contd.

Bedrock sub-crop Map



PK: Paskapoo

SC: Scollard

HSC: Horseshoe Canyon

BP: Bearpaw

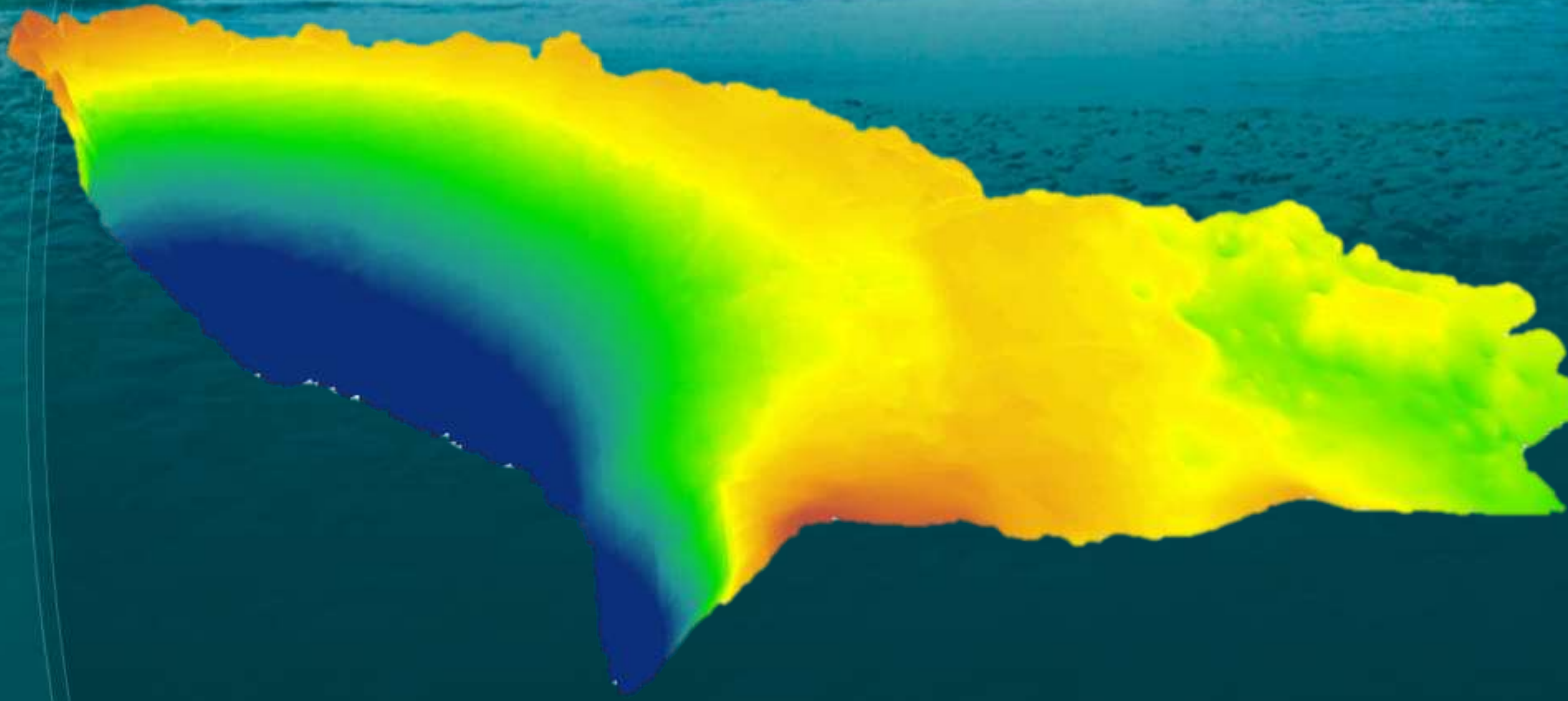
BR: Belly River

LP: Lea Park

COL: Colorado

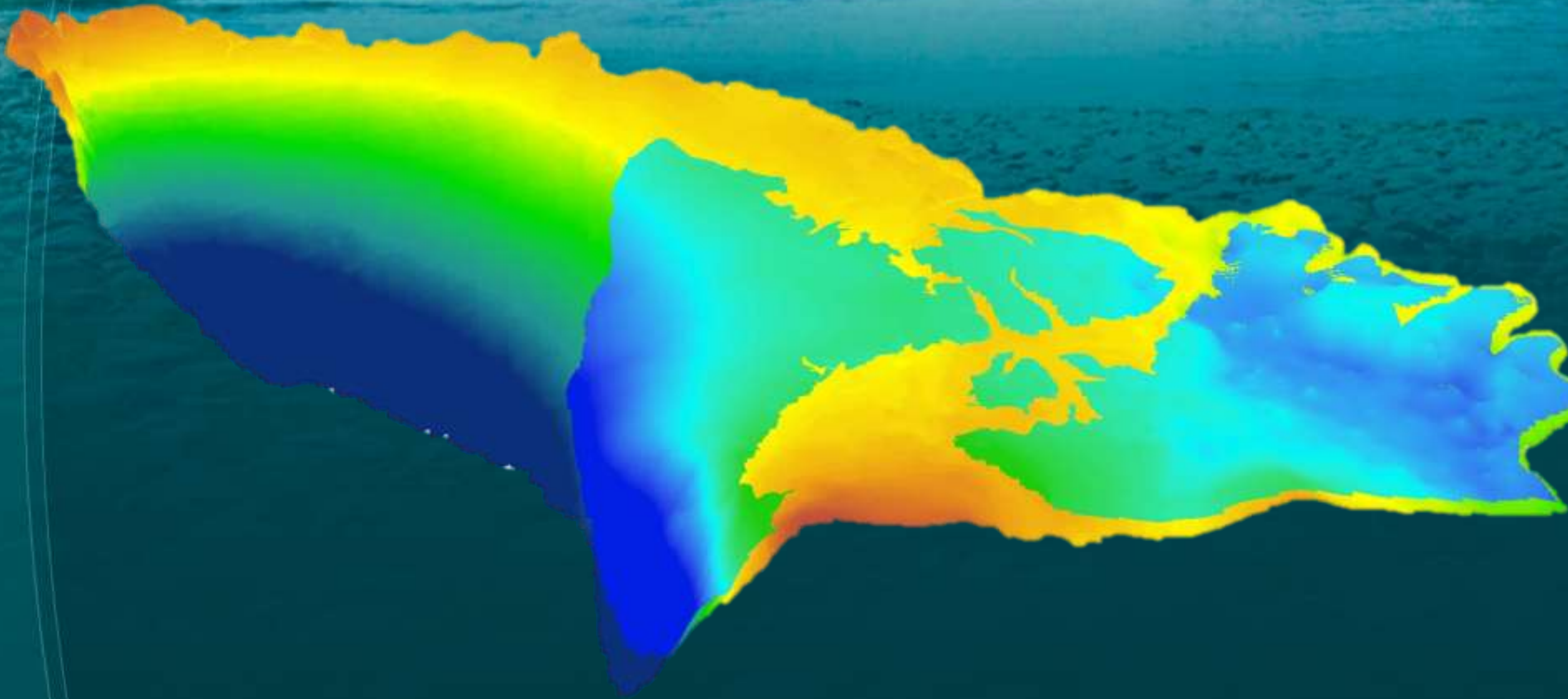
conceptual model contd.

Conceptual Model



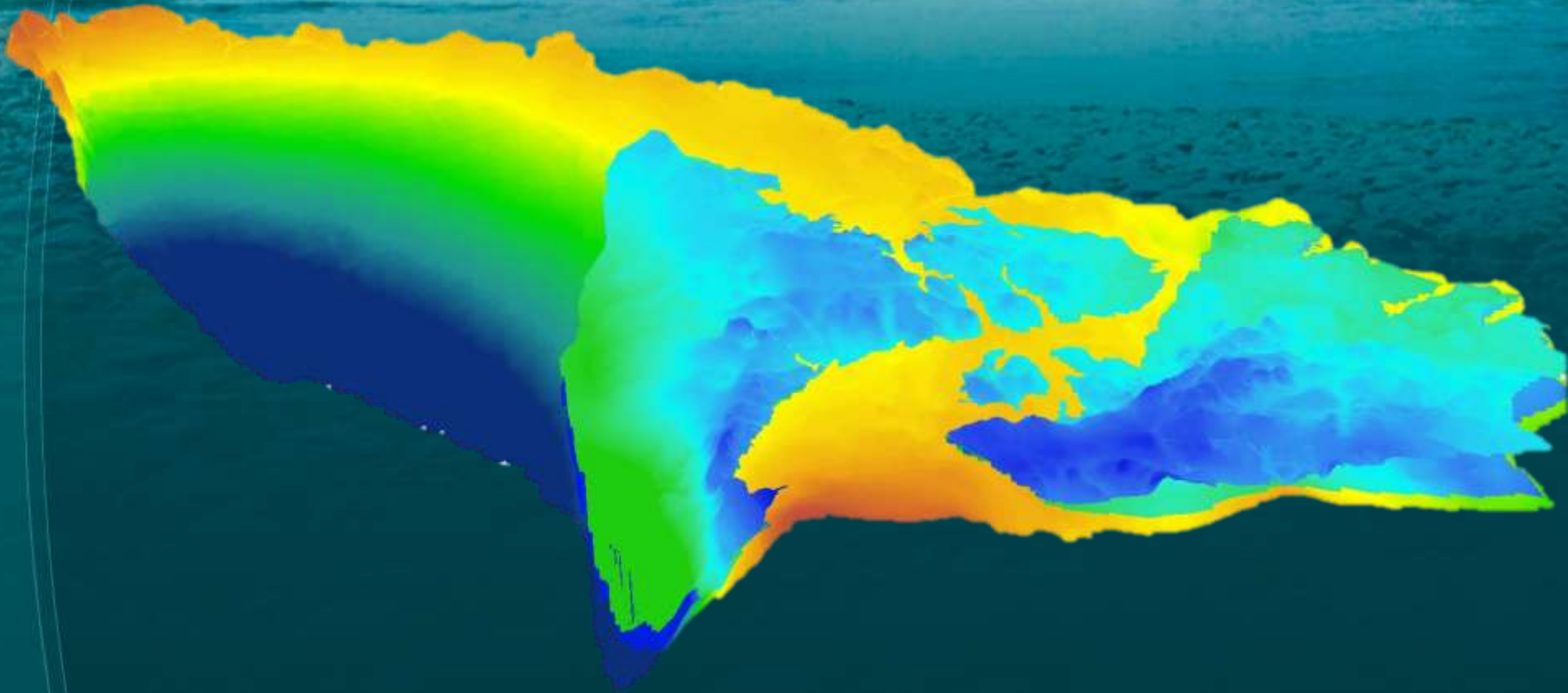
Lea Park

Conceptual Model



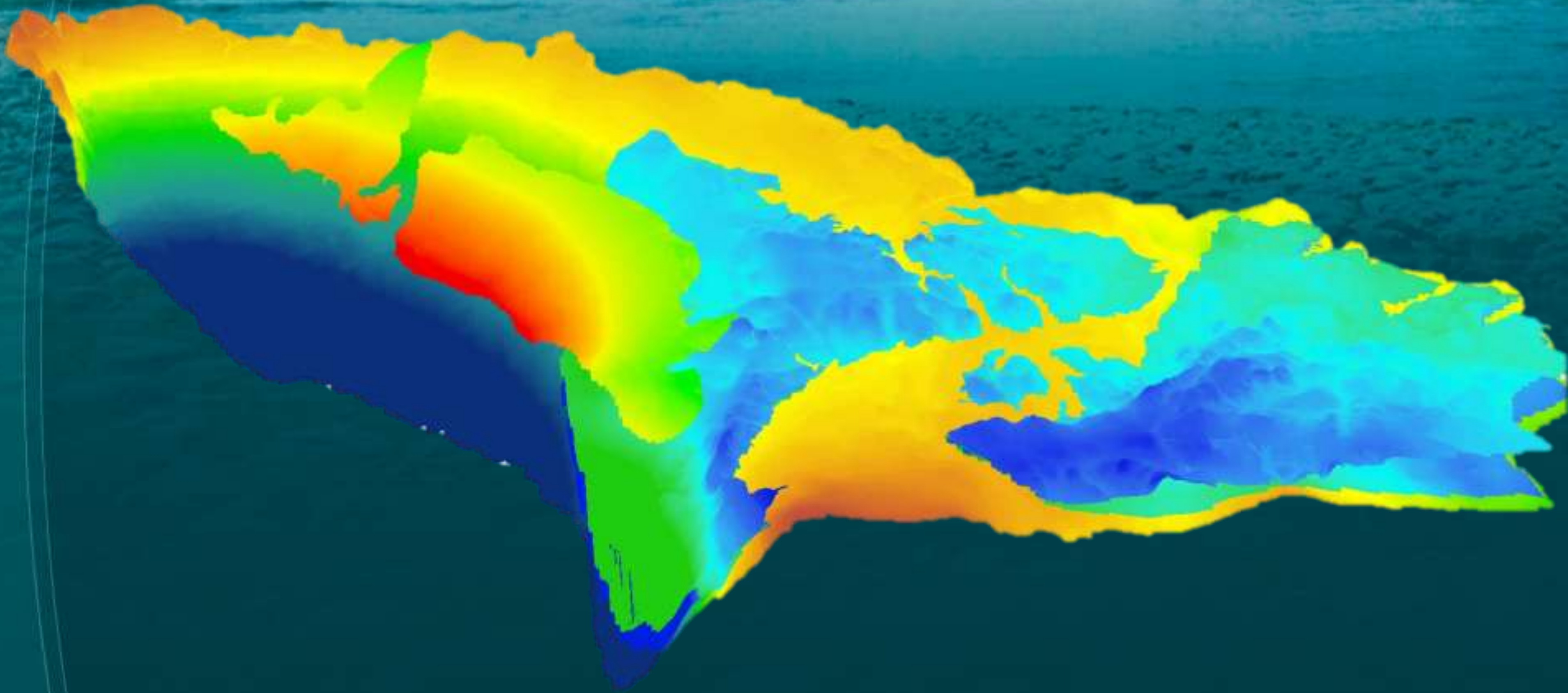
Belly River

Conceptual Model



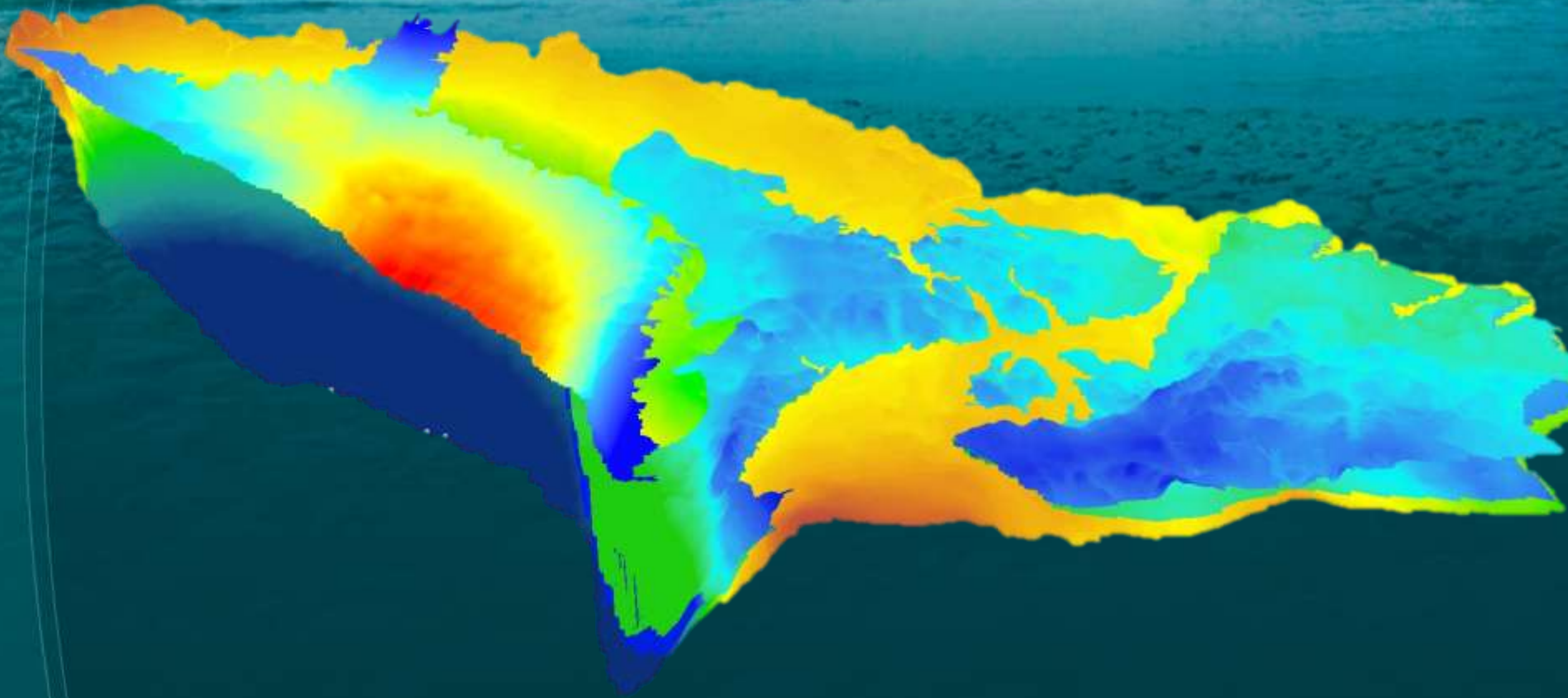
Bearpaw

Conceptual Model



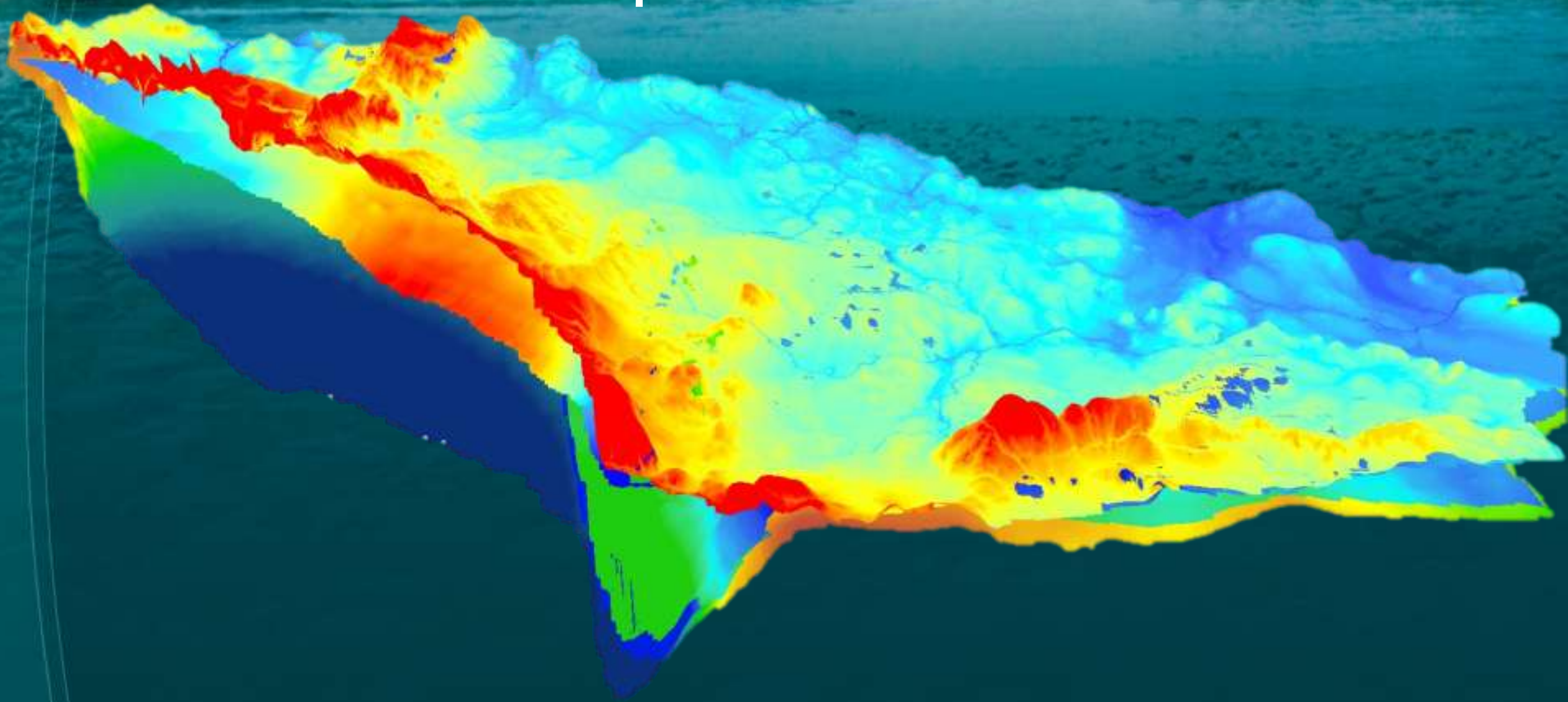
Battle

Conceptual Model



Scollard

Conceptual Model



Model Domain

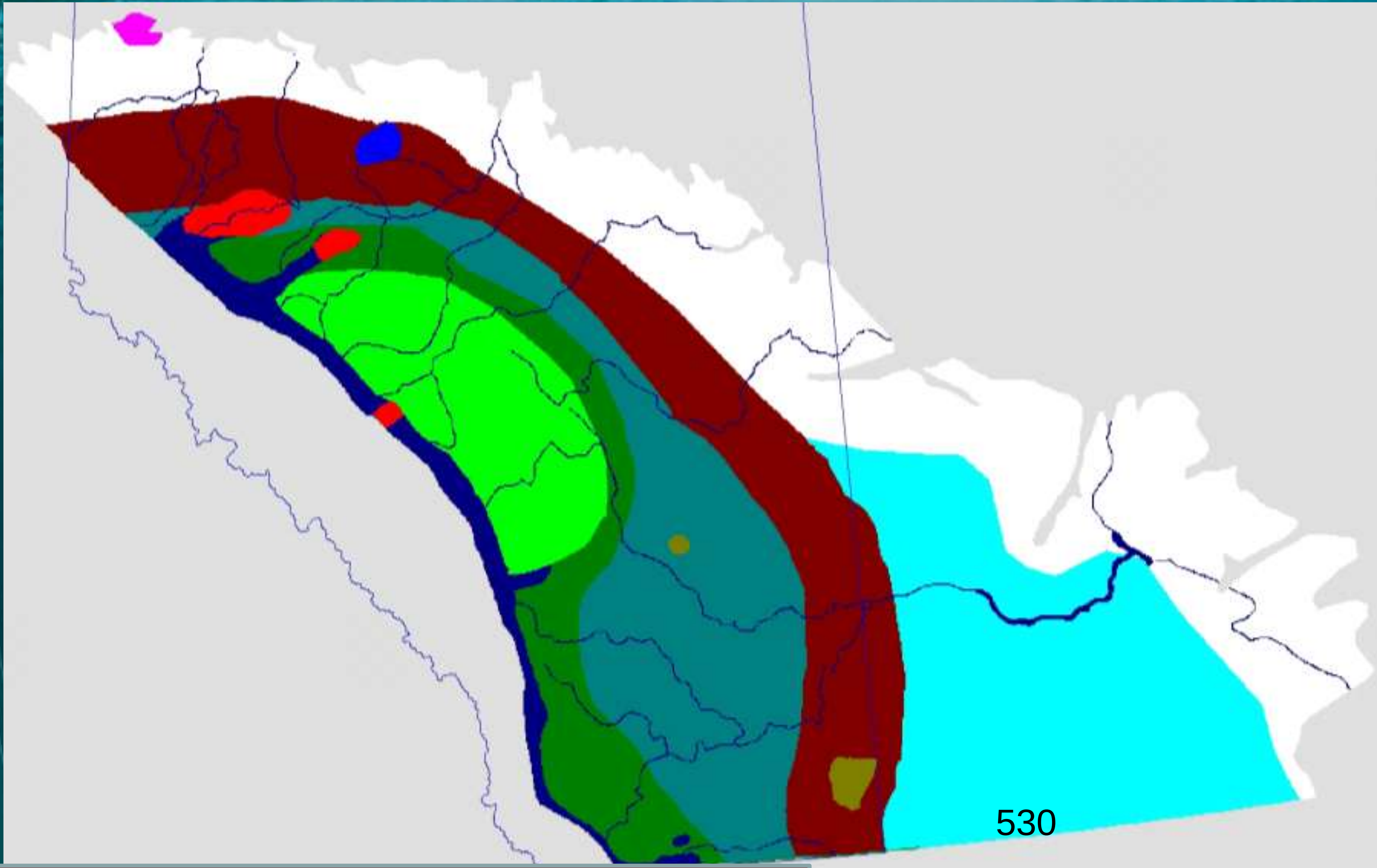
NUMERICAL MODEL

- Model domain : 610 X 1000 X 8 (approx. 3 x 10^6 active cells)
- Present grid size (approx) : 1250 (m) X 1250 (m)

Numerical Model (contd.)

- **Pseudo Underpressuring**
  - Generalized Head Boundary at the bottom (Lea Park)
  - The size of above mentioned underpressured zone based on DST measurements and earlier work
  - Drill stem test (DST) measurements are error prone hence a rigorous data culling procedure was undertaken that included identifying samples affected by production-induced drawdown
- **Major River Systems (along with major tributaries)**
  - North Saskatchewan River
  - South Saskatchewan River
  - Peace River
  - Athabasca River
- **Recharge is implemented as a combination of precipitation, ET, etc.**

Recharge and River Systems



Calibration

- Automated Calibration
  - Dynamically Dimensioned Search (DDS[1])

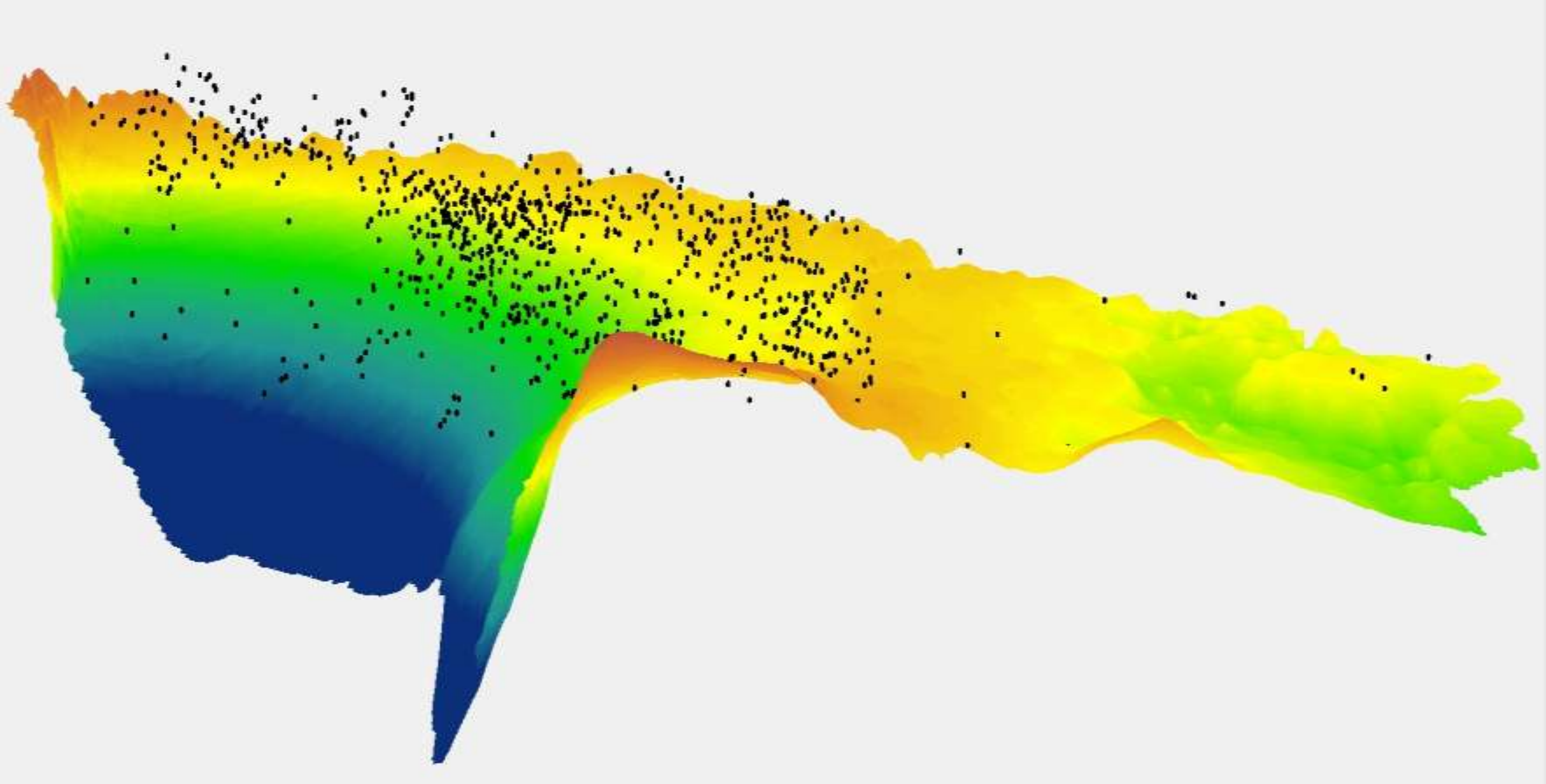
- Calibration targets
  - ESRD Observation wells
  - Water wells
  - DST measurements (cleaned for production influence)

  - Calibration Targets (820)
    - Drift = 61
    - Paskapoo = 241
    - Scollard = 68
    - Belly River / Horseshoe Canyon = 450 (200 DSTs)

- Initial hydraulic parameters estimated from aquifer test results

  - [1]Tolson, B. A., and C. A. Shoemaker (2007, WRR), Dynamically dimensioned search algorithm for computationally efficient watershed model calibration

Calibration

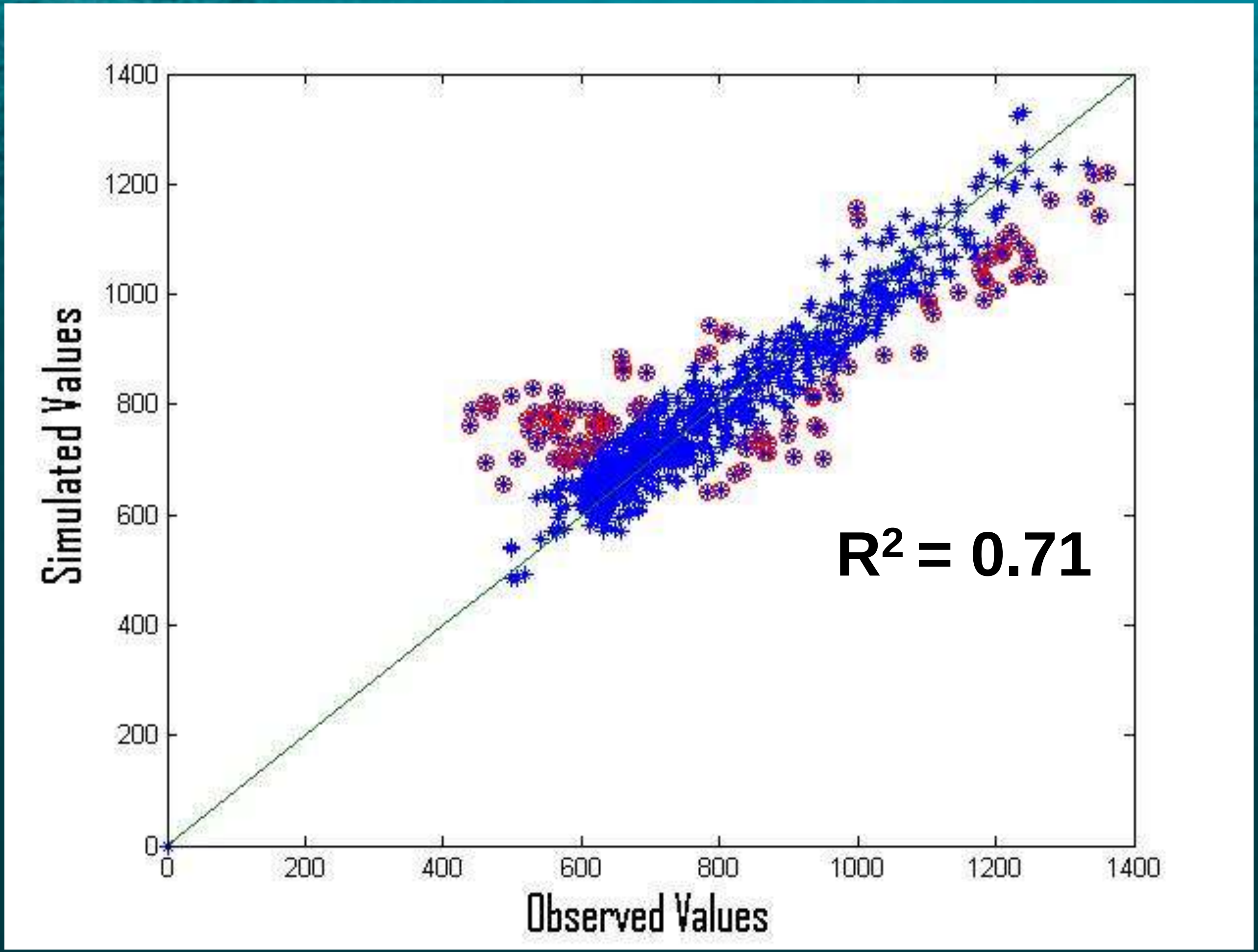


Results

- Quality of results / uncertainty
  - Plot of simulated head vs. observed head
  - Error plot
  - Spatial distribution of errors

- Hydraulic head maps
  - Paskapoo
  - Scollard
  - Belly River

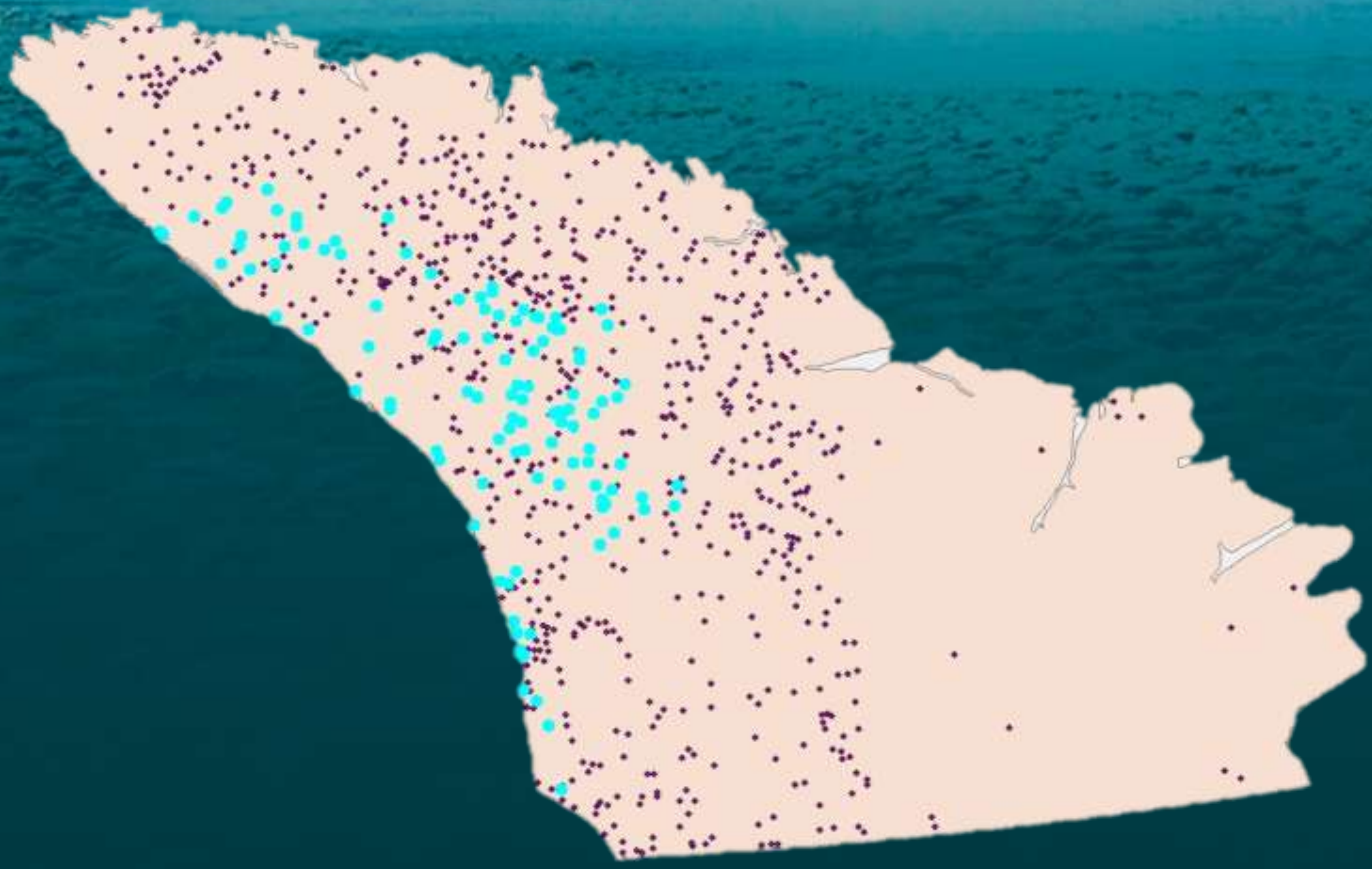
Results



1400
1200
1000
800
600
400
200
0
Simulated Values
0
200
400
600
800
1000
1200
1400
Observed Values
R2 = 0.71

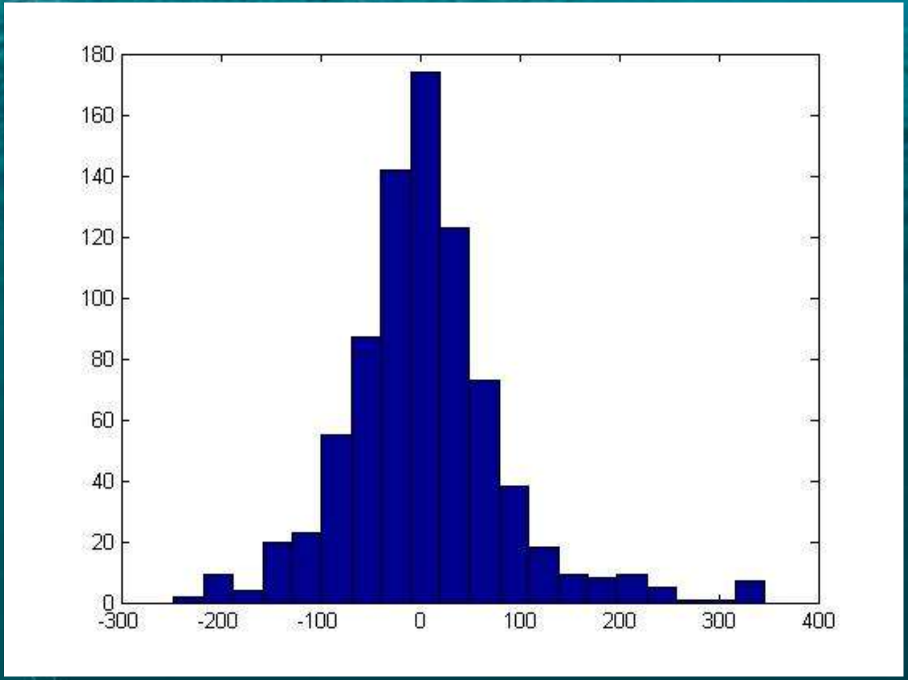
ERCB Energy Resources Conservation Board | AGS Alberta Geological Survey

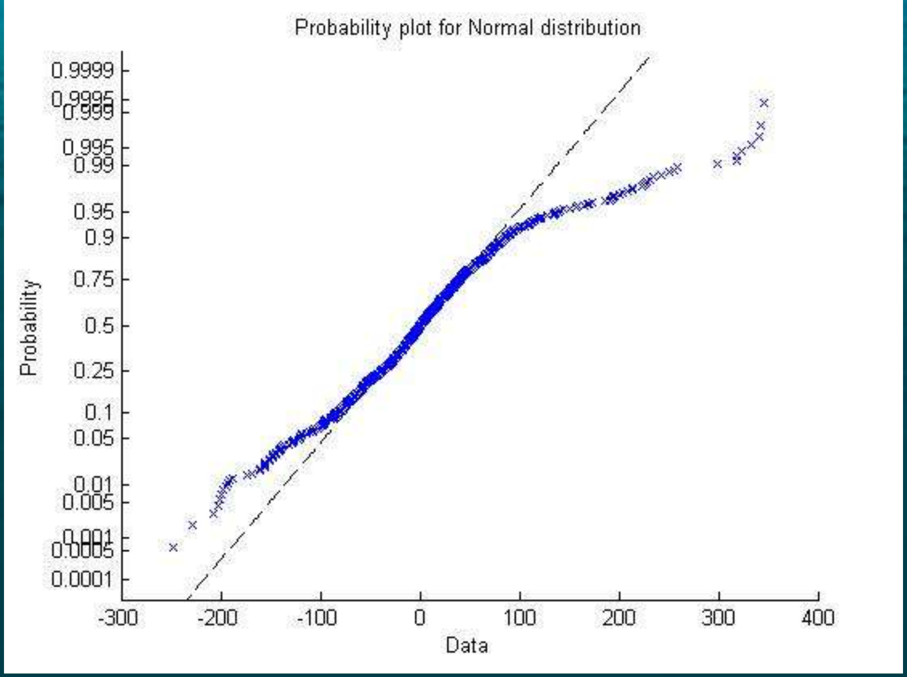
Results



Spatial Distribution of Highlighted (previous slide) Errors

Results

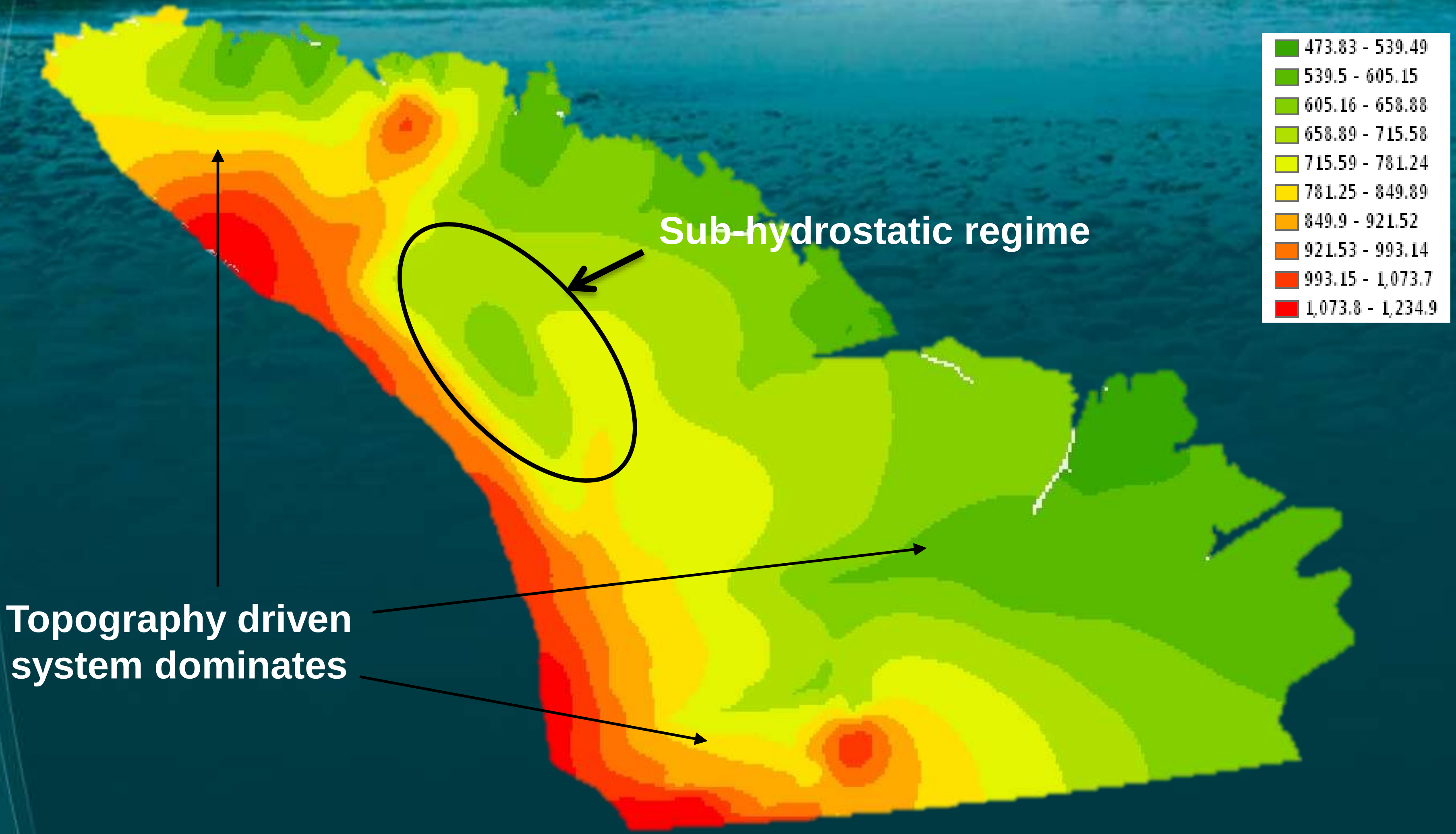




Error Distribution

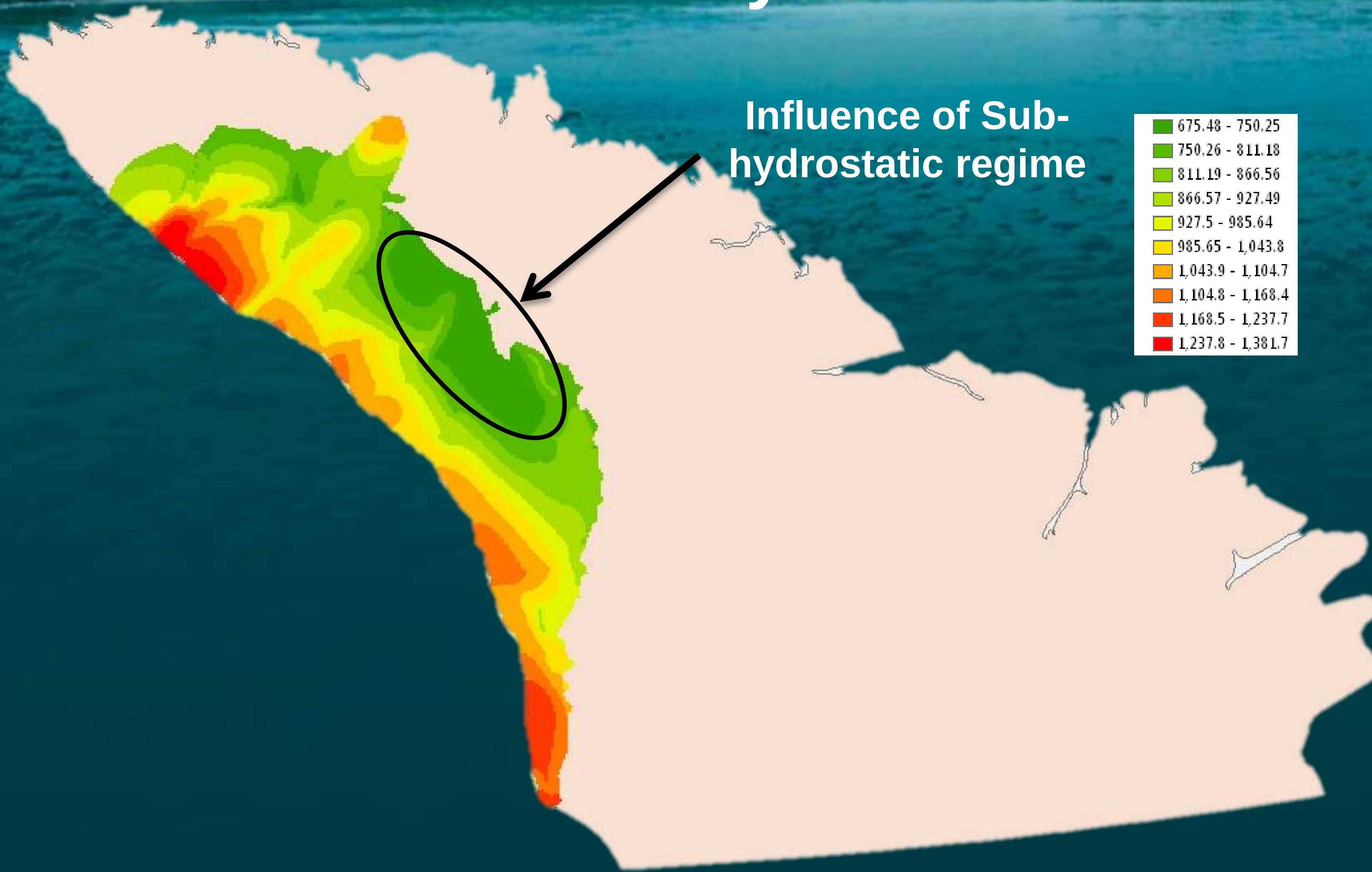
Probability Plot

Distribution of Hydraulic Heads



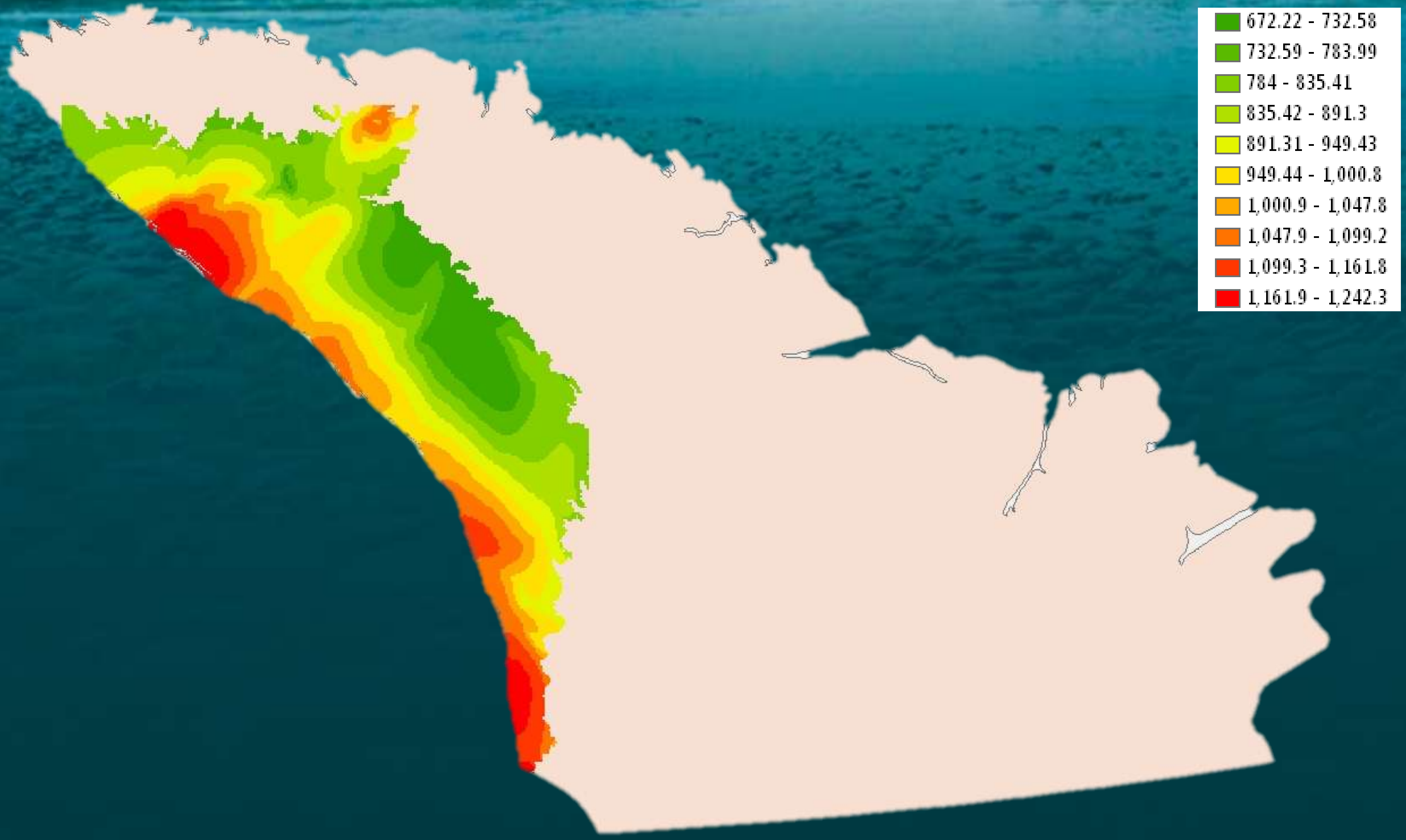
Belly River aquifer

Distribution of Hydraulic Heads



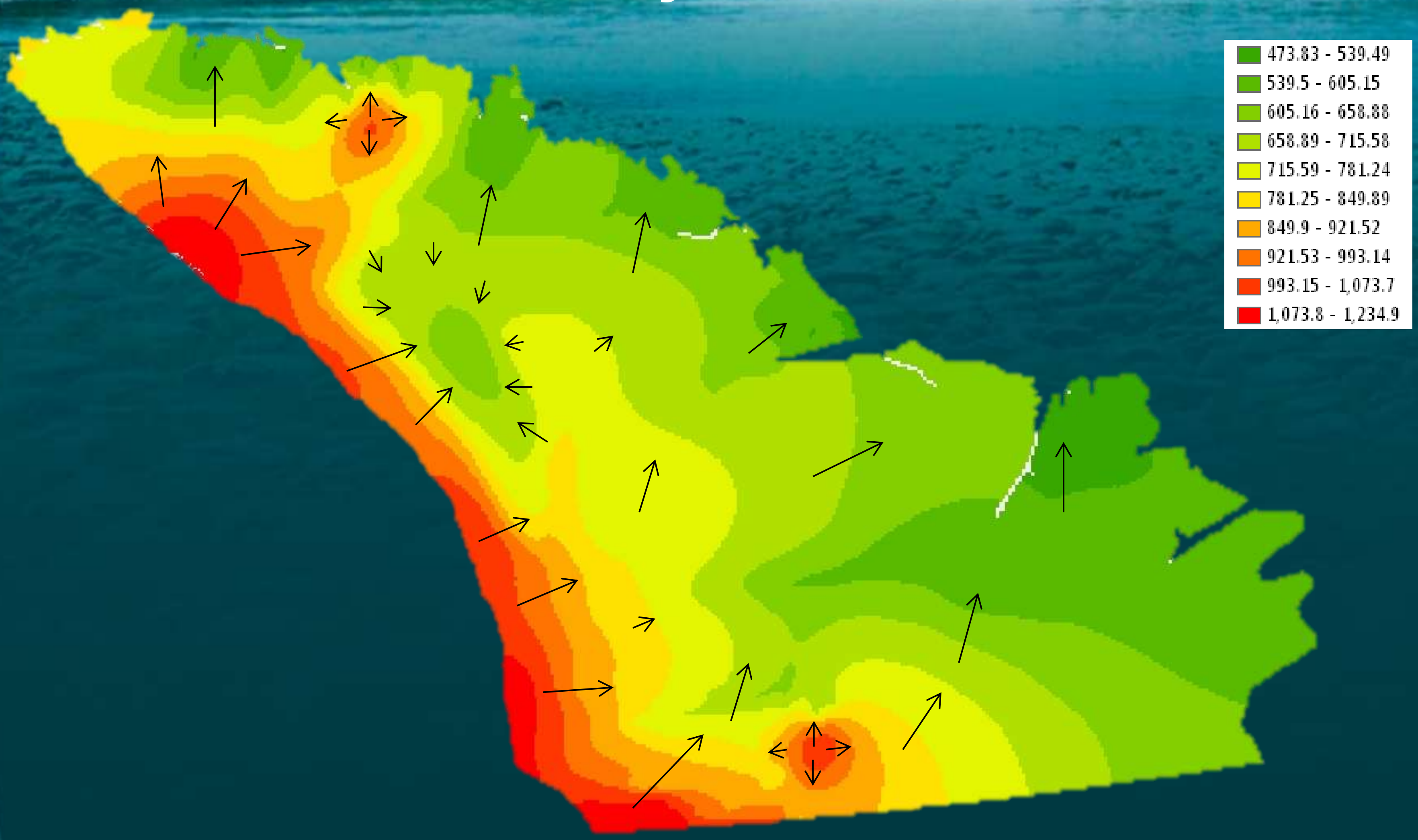
Paskapoo aquifer

Distribution of Hydraulic Heads



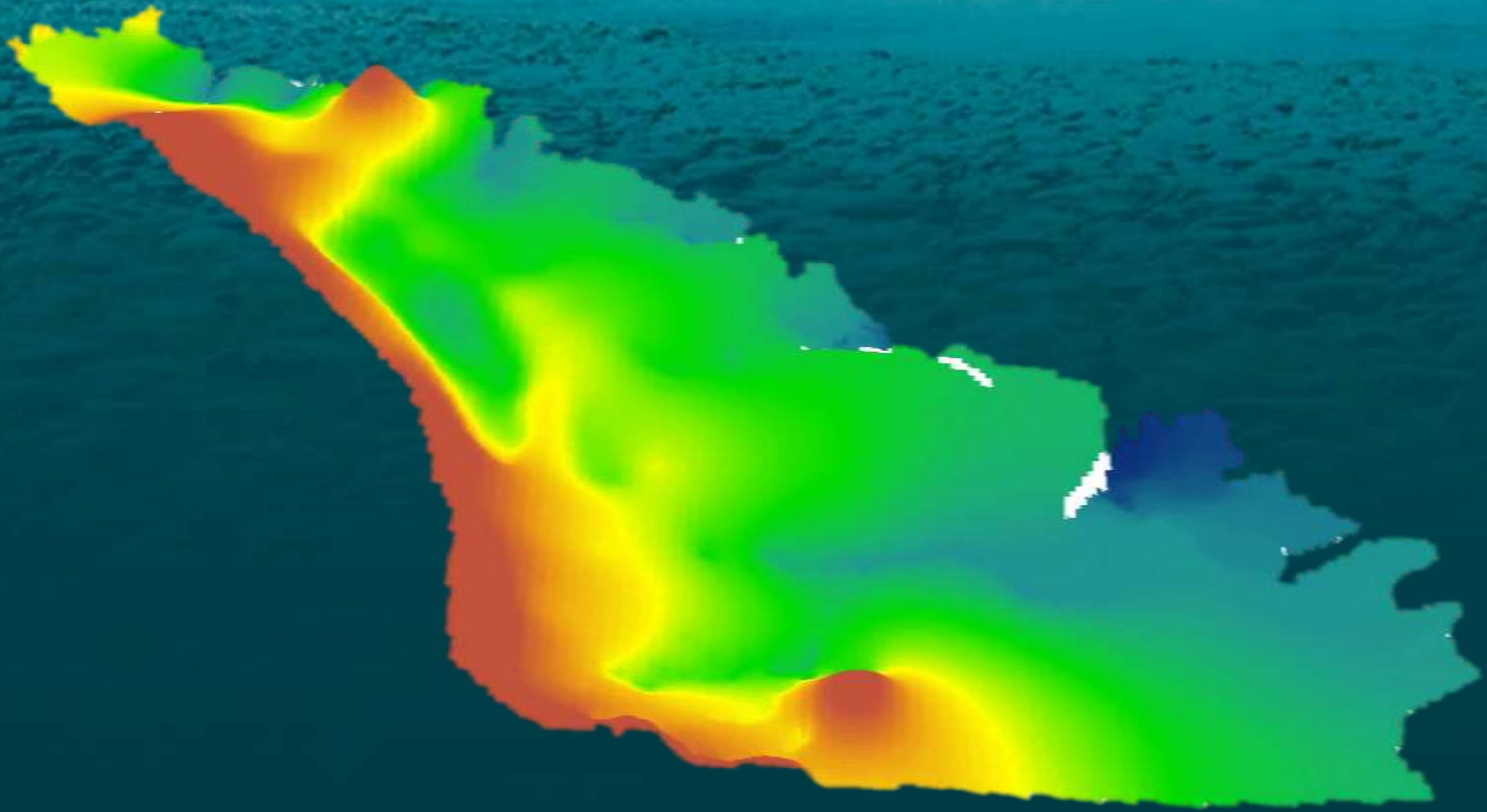
Scollard aquifer

Distribution of Hydraulic Heads



Belly River aquifer

Distribution of Hydraulic Heads



Belly River aquifer

Summary

- **Developed regional numerical model to provide a reliable set of boundary conditions (water budget analysis) for sub-basin modelling.**
- **The nested approach for sub-basin models ensures continuity at a variety of scales.**
- **Results show that topography-driven, local- to intermediate-scale flow systems dominate in the upper hydrostratigraphic units (i.e. Quaternary, Paskapoo, Scollard) but are influenced (relatively small) by sub-hydrostatic conditions in deeper units.**
- **Flow paths in the Horseshoe Canyon Formation and Belly River Group hydrostratigraphic units are controlled by regional scale topography-driven flow systems and sub-hydrostatic pressure regimes.**

Acknowledgments

ERCB Energy Resources Conservation Board | AGS Alberta Geological Survey

- Colleagues in the Groundwater section, and Bedrock and Quaternary geology sections at the AGS

Alberta Environment and Sustainable Resource Development

Water Security Agency

Day 2 – Session 3

Mervyn Davies - Stantec

BIOGRAPHY

Mervyn Davies is a Senior Principal with Stantec and has 35 years of air quality consulting experience in western Canada. He has prepared source and emission inventories; supervised specialized field studies; reviewed and interpreted ambient air quality data; and developed, evaluated and applied air quality simulation models. Mervyn has been the discipline lead for numerous air quality assessments that required cumulative, multimedia assessments on an air shed basis. Mervyn has worked with industry, regulatory and third-party stakeholder clients; has provided air quality training programs to industry; and has provided expert testimony at ERCB hearings. He is the author of ‘Air quality Modelling in the Athabasca Oil Sands Region’ chapter in the recently published book *Alberta Oil Sands: Energy, Industry and the Environment.*

Day 2 – Session 3

Mervyn Davies - Stantec

ABSTRACT

Air quality simulation models provide the linkage between sources that discharge gases and particles to the atmosphere, and the resulting ambient concentrations and deposition experienced by human and environmental receptors. The models provide this linkage by simulating transport, dispersion, chemical transformation, and deposition processes in the atmosphere. Even though air quality simulation models are well established, there are a number of challenges that can influence the outcome of these models. This presentation discusses some of these challenges in the context of the models being used in a multimedia/pathway context.

Air Quality Modelling for Multimedia Assessments and Associated Challenges

Mervyn Davies

March 14th 2013

One Team. Infinite Solutions

Stantec

What is an Air Quality Model?

- Provides a scientific link between an emission source and associated ambient concentrations and deposition.
- Uses mathematical relationships to simulate transport, dispersion, chemical transformation, and wet and dry deposition processes in the atmosphere.
- Air is one of the key pathways from sources to receptors.

Why Air Quality Models?

- **Past Conditions**
  - Forensic analysis
- **Existing Conditions**
  - Fill in the gaps between monitoring stations
  - Provide predictions for parameters not monitored
  - To discriminate source contributions
- **Future Conditions**
  - Examine air quality changes before a facility is built
  - Examine future year changes
  - Examine the effects of management actions

Spatial Scales

- **Single facility**
  - 20 by 20 km to 50 by 50 km
- **Air Shed**
  - 100 by 100 km
- **Regional (e.g., NE Alberta)**
  - 300 by 700 km
- **Provincial**
  - 700 by 1200 km
- **Western Canada**
  - 1500 by 2500 km

Temporal Scales

- **Seconds to minutes**
  – Unplanned toxic and flammable releases
  – Quantitative risk and odour assessments
- **Short-term (Acute)**
  – 1-h to 24-h
  – Vegetation/human health
- **Long-term (Chronic)**
  – Annual to five-year modelling
  – Lifetime exposure
  – 100 year

Status of Air Quality Models

- **Air quality simulation models are mature**
  - Have been around since the mid 1970s
  - Continue to evolve
- **Alberta benefiting from the US generosity**
  - Public domain model codes, documentation, performance studies, and user groups are available
- **Alberta models**
  - Replaced by US EPA models due to resource challenges
  - Provides guidance on the application of these models
- **Environment Canada Models**
  - Not in public domain

Past Provincial Efforts

GLCGEN/FRQDTN

- An Alberta air quality model developed in 1981.
- Provided an internal weighting function to reduce/remove contribution when receptor sensitivity was reduced.
- Never really used on an operational basis due to computer platform complexities.

GASCON2

- An Alberta model to evaluate hazards and risks associated with unplanned sour gas releases.
- One copy was sold.

Air Quality Model Inputs

- Source and emission inventory
  – From industry, ESRD, EC and consultant databases
- Hourly meteorological data
  – From surface measurements and meteorological models
- Topographical data
  – From digital elevation models
- Land cover properties
  – From land use class models.
- Ambient concentration data
  – From ambient air quality monitoring stations

Air Quality Model Outputs

- Ambient concentrations
- Wet deposition
- Dry deposition
- Total deposition
- Primary emissions
- Secondary pollutants
- 1-h, 24-h, month, annual averages
- Hourly time series
- Frequency of exceeding a threshold

Receptor locations

- **Coordinate system**
  - UTM NAD 83
  - Lambert conformal conic projection
- **Nested Cartesian grid systems**
  - Spacing
- **Discrete Locations**
  - Monitoring stations
  - Community locations
  - Identified lakes
- Can examine 10,000 to 20,000 receptors

Human Exposure Assessments

- **Hazard and QRA modelling for land use planning**
  - Setbacks between industry and residences
- **Endpoints:**
  - Nuisance(e.g., odours)
  - Mild irritation
  - Respiratory
  - Neurological
  - Reproduction and development
  - Imunotoxicity
- **Acute and chronic exposures**

Environmental Assessments

- Vegetation: direct
- Livestock and wildlife: direct
- Soils: deposition
  - Vegetation
- Water bodies: deposition
  - Fish
- Food chain
  - Relates back to human exposures

Technical Challenges

- **Model Input**
  - Emission inventory
- **Model Assumptions**
  - Northern latitudes/Cold winters
    - Is the chemistry still valid?
    - Gas/particle phase distribution still valid?
  - Extrapolation of default parameters
    - Land cover properties
    - Seasonal variations

Ambient Monitoring

Modelling and monitoring complement one another; one is not a replacement for the other.

- Monitoring provides a gauge of model performance.
- Desirable to have concentration and deposition data.
- No one wants to locate ozone monitors downwind of large emission sources.
- Gaps in deposition monitoring. Recommendations have been put forward; does not appear to be any action.

Technical Challenges

- **Source and emission inventory**
  - Data not well documented
  - Industry data for existing operations often difficult to obtain
  - Industry data for future operations incorporate conservative assumptions
  - Emission databases often treated by industry and regulators as proprietary
  - Biogenic sources often not included

Process Challenges

- **Environmental zones in Alberta defined by river/drainage basis**
  - Do not fit into an airshed definition
  - CASA airsheds and provincial regions do not match
- **Divergence of regulatory application and land-use planning model approaches**
  - May lead to conflicting predictions
  - Want consistency from a public record perspective

Communication

“**Functional** multidisciplinary communication is essential”

- Is the overall objective defined?
- Have the end users defined what is required?
- Have receptor locations been defined?

- Have model limitations been communicated to end-user?
- Has end-user had discussions with the modeller to confirm appropriate assumptions?

CMO Scope?

- What “air” models will be addressed by the CMO?
  - Computational Fluid Dynamic models?
  - Hazard and quantitative risk models?
  - Visibility/haze models?
  - Odour models?
  - Noise models?
  - Light trespass models?
  - EMF from power lines?
- What’s included, what’s excluded?

CMO Scope?

- Will the CMO only address models if there is an "integrated environmental" component?
- Will the CMO include human health as well as environmental modelling endpoints?
- Will the CMO address local, regional and provincial scale issues where modelling can be adopted to resolve issues?
- Linkages to other tools (e.g., monitoring)?

CMO Scope?

- Does the CMO have a model and modeller inventory for the province?
  - Regulatory, academic, and private sectors?
  - Regulatory and no-regulatory applications?
- How will the CMO determine the appropriate selection and application of models?
  - Regulatory, academic, and private sector inputs?
  - Alberta and non-Alberta inputs?
- How will the CMO promote and support model use?
  - Regulatory, academic, and private sectors?
  - Workshops, websites, publications?

CMO Scope?

- How will the CMO act as a warehouse for models?
  - Public domain vs. commercial models?
  - Model guidance or directives re the application?
    - Will future AQMG come from the CMO?
  - Common input data?
    - How will ensure these are updated on a timely manner?
    - How will you ensure they are Alberta specific?
- How will CMO obtain feedback on modelling applications?
  - What is the indicator that the modelling is being done appropriately?
  - Review regulatory applications?
  - Review industry association assessments?

CMO Scope?

- Will the CMO be setup as a support AESRD department like RMD was? Or will it be at arm's length like CASA?
- Will the CMO resources have sufficient resources to be functional?
- Will the CMO activities be <u>open and transparent</u>?
  - Never trust a breakfast cereal box that says "nutritious"!
- Recipe for success (?):
  - Communication!
  - Communication!
  - communication!

Day 2 – Session 3

Sarah Depoe - AESRD

BIOGRAPHY

Sarah is a Cumulative Effects Assessment Specialist with Alberta Environment and Sustainable Resource Development. In her position she provides scientific support for the Regional Strategic Assessment of the South Athabasca Oil Sands project. Sarah has 10 years experience in government, working primarily in water quality, environmental stewardship and land use policy roles. Sarah is a Professional Biologist with a BSc in Aquatic Biology from the University of Manitoba; her graduate research is in Environmental Biology at the University of Alberta.

Day 2 – Session 3

Sarah Depoe - AESRD

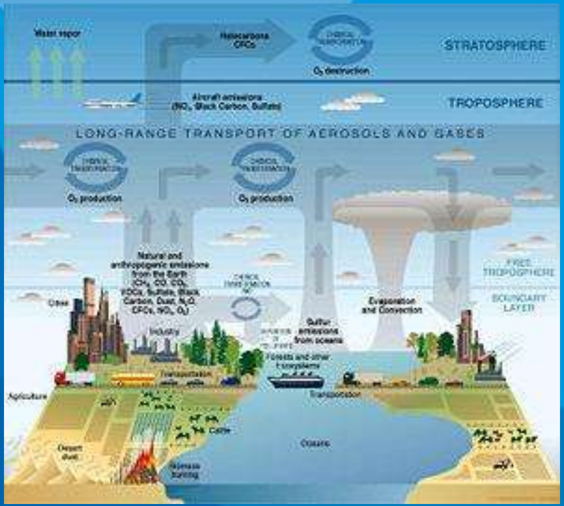
ABSTRACT

The Government of Alberta is currently conducting a Regional Strategic Assessment (RSA) in the South Athabasca Oil Sands (SAOS) Area. In situ oil sands development is expected to account for a significant amount of development in the SAOS area in the Lower Athabasca region over the next several decades. The RSA project aims to develop an understanding of the cumulative effects of a growing energy sector and use this knowledge to inform the development of high-level management strategies, including a sub-regional plan under the Land Use Framework. To support this assessment, empirical models will be used to examine the environmental (air, land, surface and ground water, biodiversity) over a 50 year time horizon. The purpose of this presentation will be to introduce the various environmental models used in the assessment (CALPUFF/CMAQ, FEFlow, Mike SHE/Mike11 and ALCES), cross-media integration efforts and the challenges and opportunities of linking environmental, economic and social outcomes.

Alberta Government

Cumulative Effects Modelling in the South Athabasca Oil Sands

Environmental Modelling Workshop
March 14, 2013
Sarah Depoe – ESRD



Presentation Outline

- Policy direction for the South Athabasca Oil Sands (SAOS) Regional Strategic Assessment (RSA)
- What is Regional Strategic Assessment (RSA)?
- Cumulative Effects Approach in the SAOS RSA
- Environmental Models and Integration
  - Air Quality
  - Surface and Ground Water
  - Land and Biodiversity
  - Environmental Health Risk Assessment
- Lessons Learned

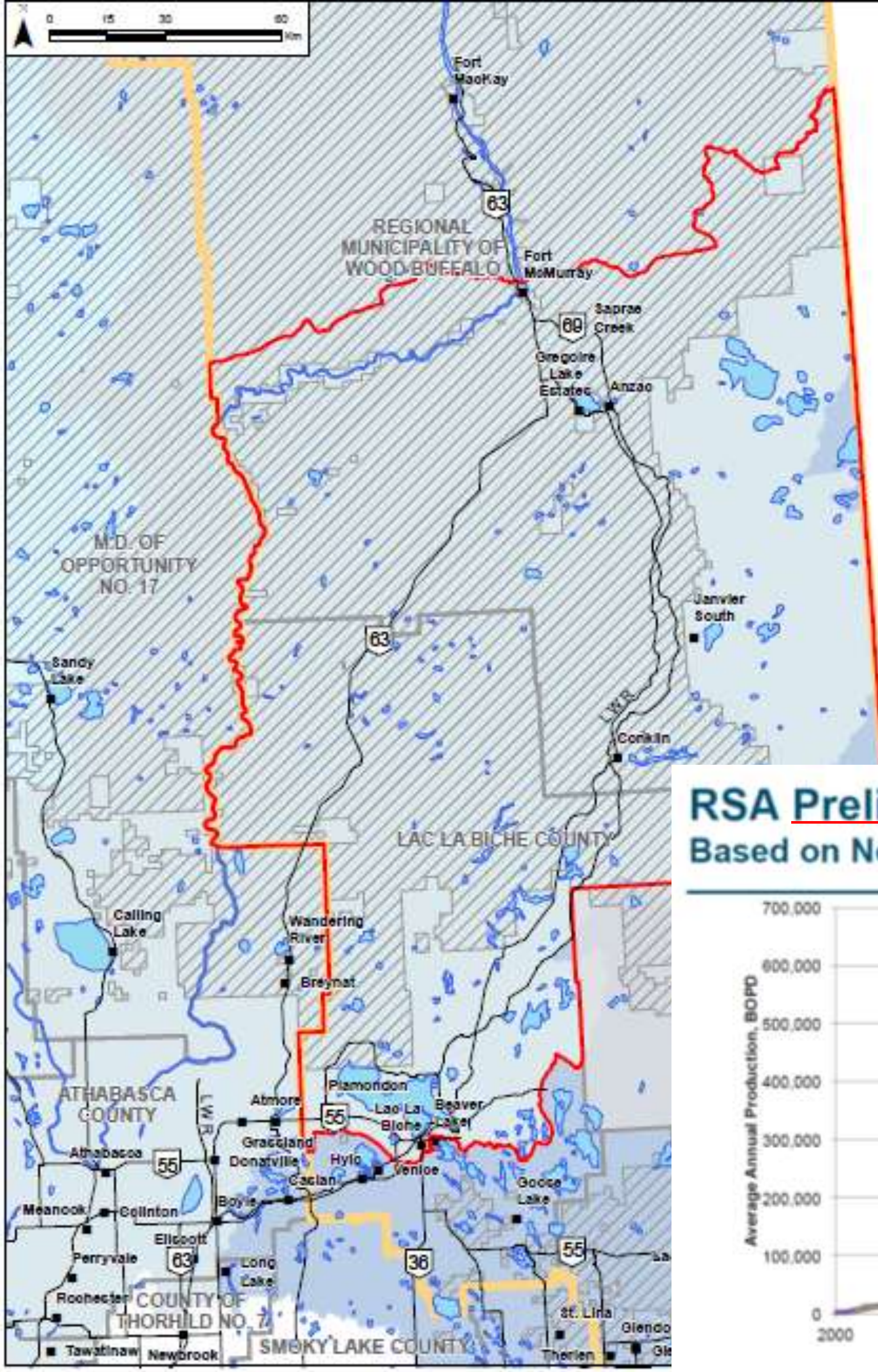
Policy direction

Outcome 1:
The economic potential of the oil sands resource is optimized

Strategies:

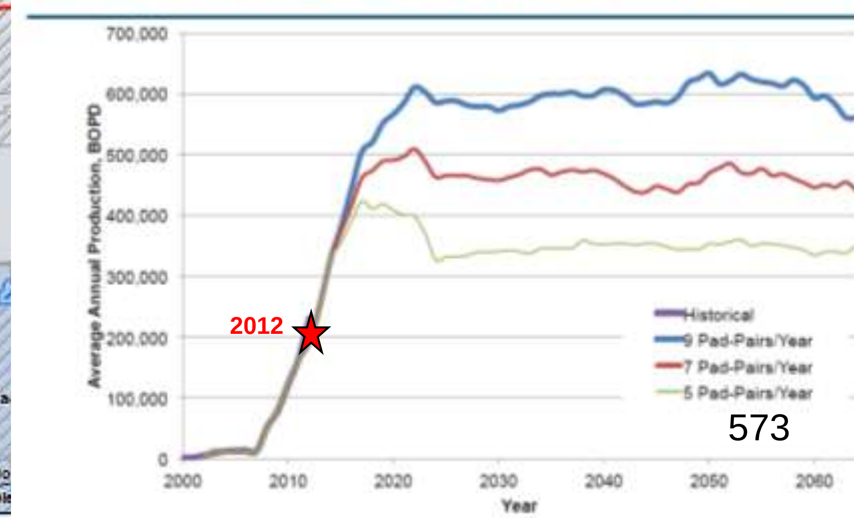
Development of a sub-regional plan using a strategic environmental assessment approach for the south Athabasca oil sands area. Undertaking this assessment at a sub-regional scale will contribute to the management of cumulative effects and support efficiencies in the regulatory review process for in-situ oil sands operations.

Alberta



South Athabasca Oil Sands Regional Strategic Assessment Study Area

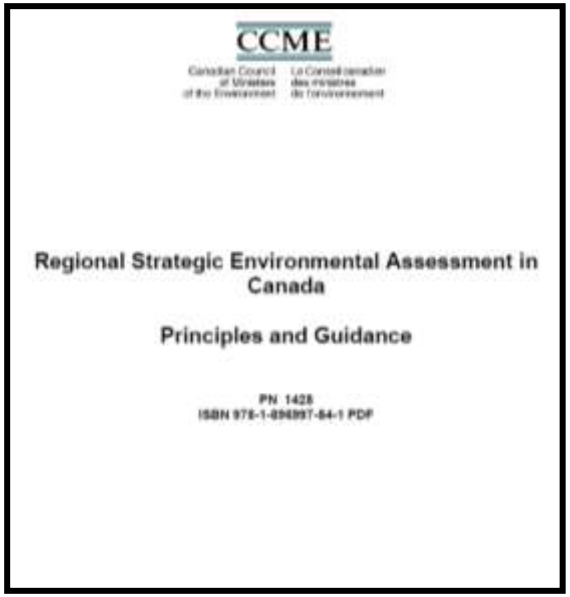
RSA Preliminary Production Scenarios
Based on No. of SAGD Pad-Pairs Added Annually



Regional Strategic Assessment (RSA): Definition

‘ A process designed to systematically assess the potential environmental effects, including cumulative effects, of alternative strategic initiatives, policies, plans or programs for a particular area’.

Canadian Council of Ministers of the Environment (CCME), 2009


CCME

Regional Strategic Environmental Assessment in Canada

Principles and Guidance

PN 1428
ISBN 978-1-896997-84-1 PDF

Regional Strategic Assessment (RSA)

RSA merges the concepts of regional cumulative effects assessment and strategic environmental assessment.

It is valuable when:

- Rapid development of the regional area is anticipated
- Government wants to provide greater public confidence that decisions are being made with full consideration of the environmental impact.

RSA is intended to:

- Inform decision-making to ensure the sustainability of the region at a desired level of environmental quality (both biophysical and socio-economic)


Human footprint on landscape
Air emissions
Groundwater extraction
Habitat for species at risk (e.g. caribou)
Wetland loss
Environmental health effects
Traditional land use
© 2013 Cnes/Spot Image
©2010 Google
In Situ Oil Sands Development
Seismic Exploration
© 2013 Google
Image Regional Municipality of Wood Buffalo
© 2013 Cnes/Spot Image
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©2010 Google

RSA for the South Athabasca Oil Sands Area

Purpose:

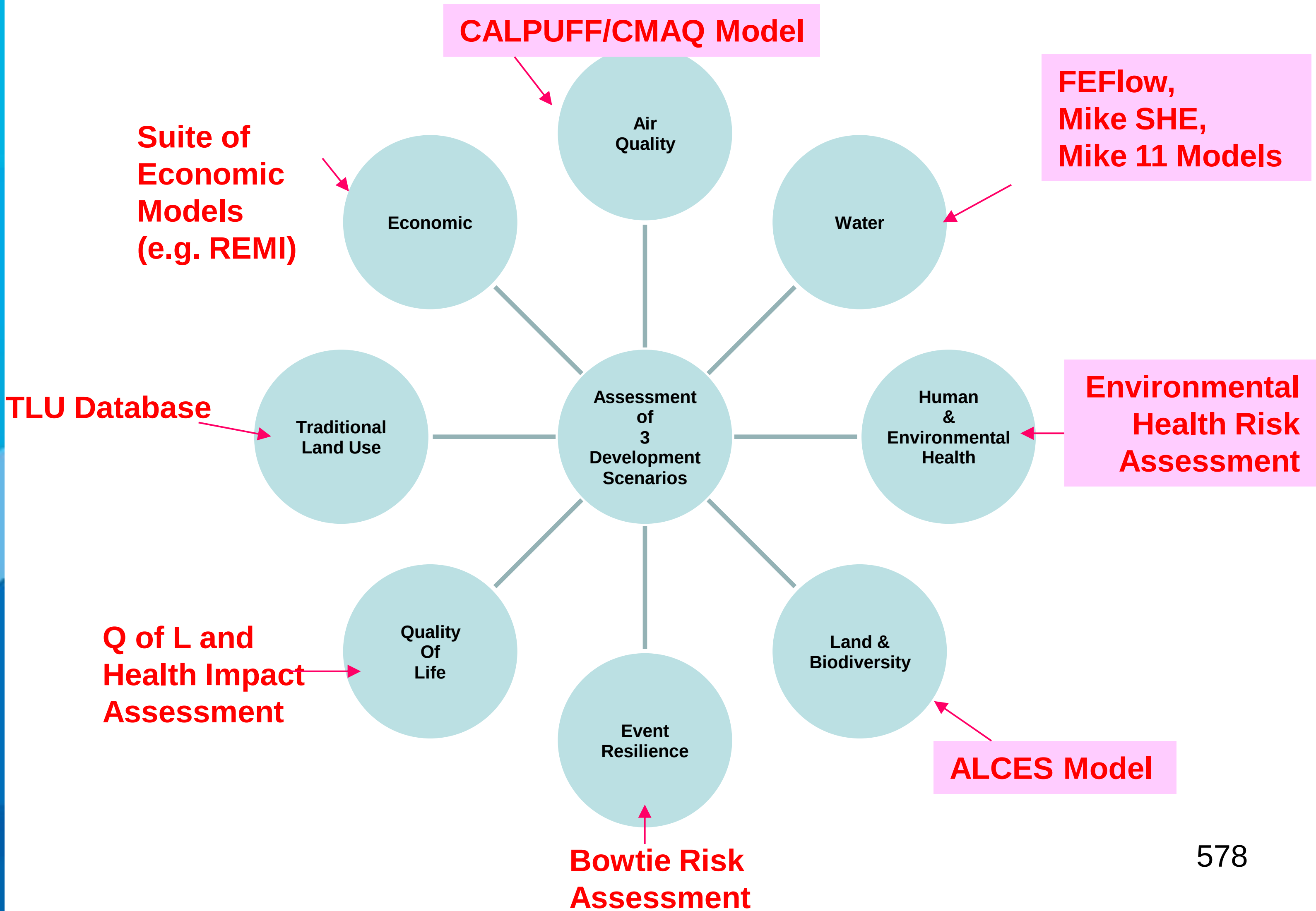
To inform decision-makers, planners, and stakeholders about:

(i) Cumulative effects of potential future development activities and other events and processes (e.g. demographic changes, natural events such as forest fires and floods)

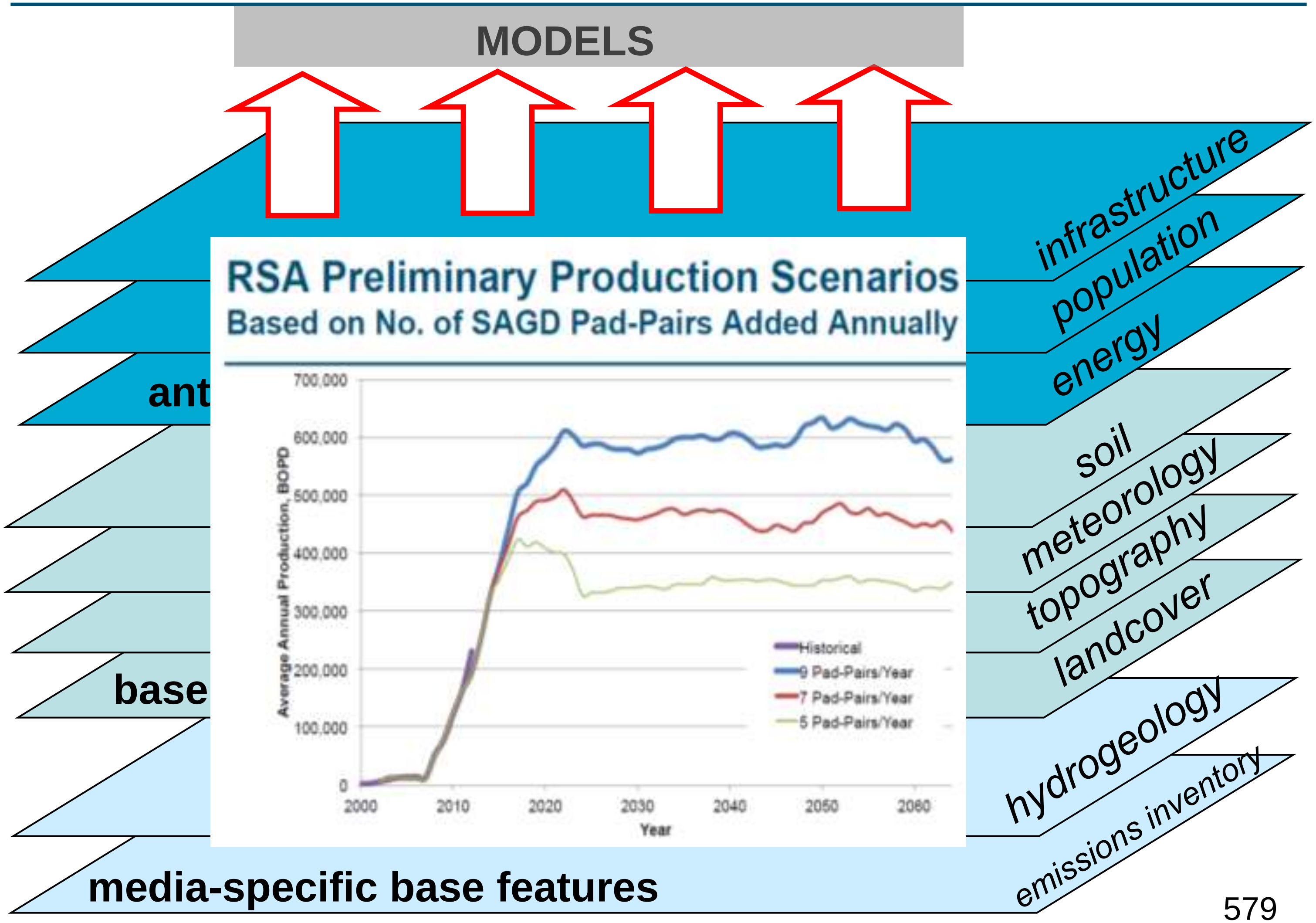
(i) Options for managing these effects such that desired outcomes are optimally achieved

(ii) Opportunities for regulatory enhancement

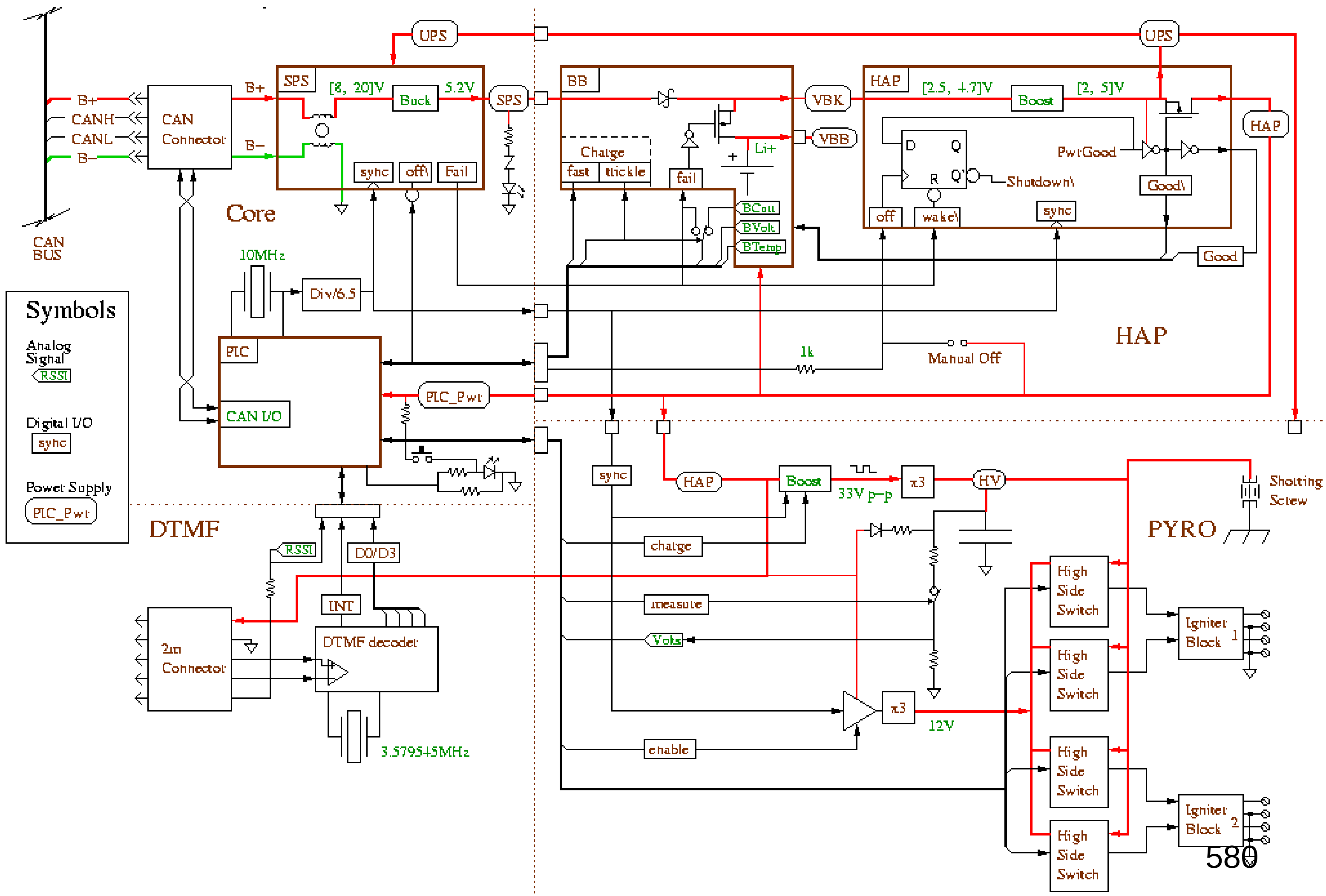
Regional Cumulative Effects Assessment



Integration: Same data inputs and scenario analysis



Air Quality: CALPUFF



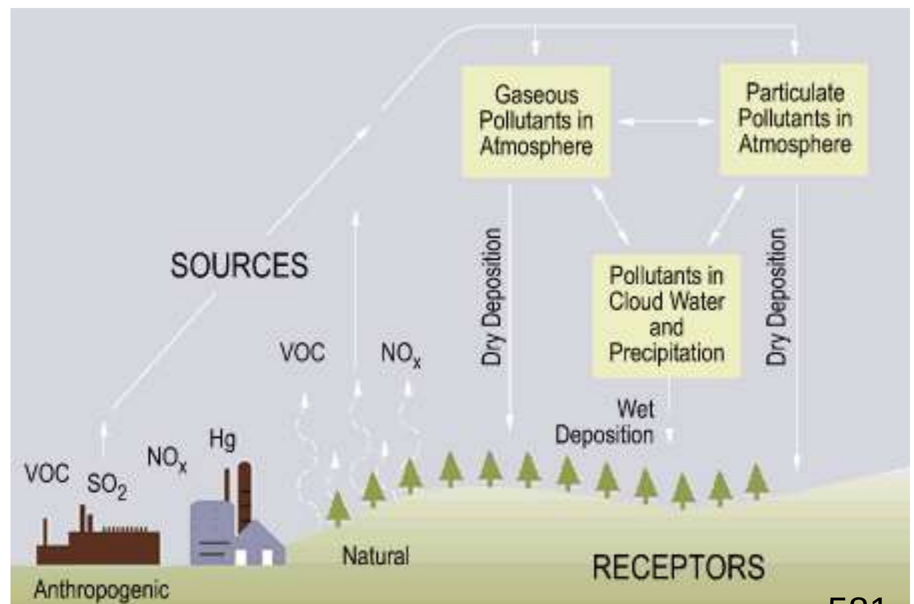
Air Quality Modelling

Currently using two models:

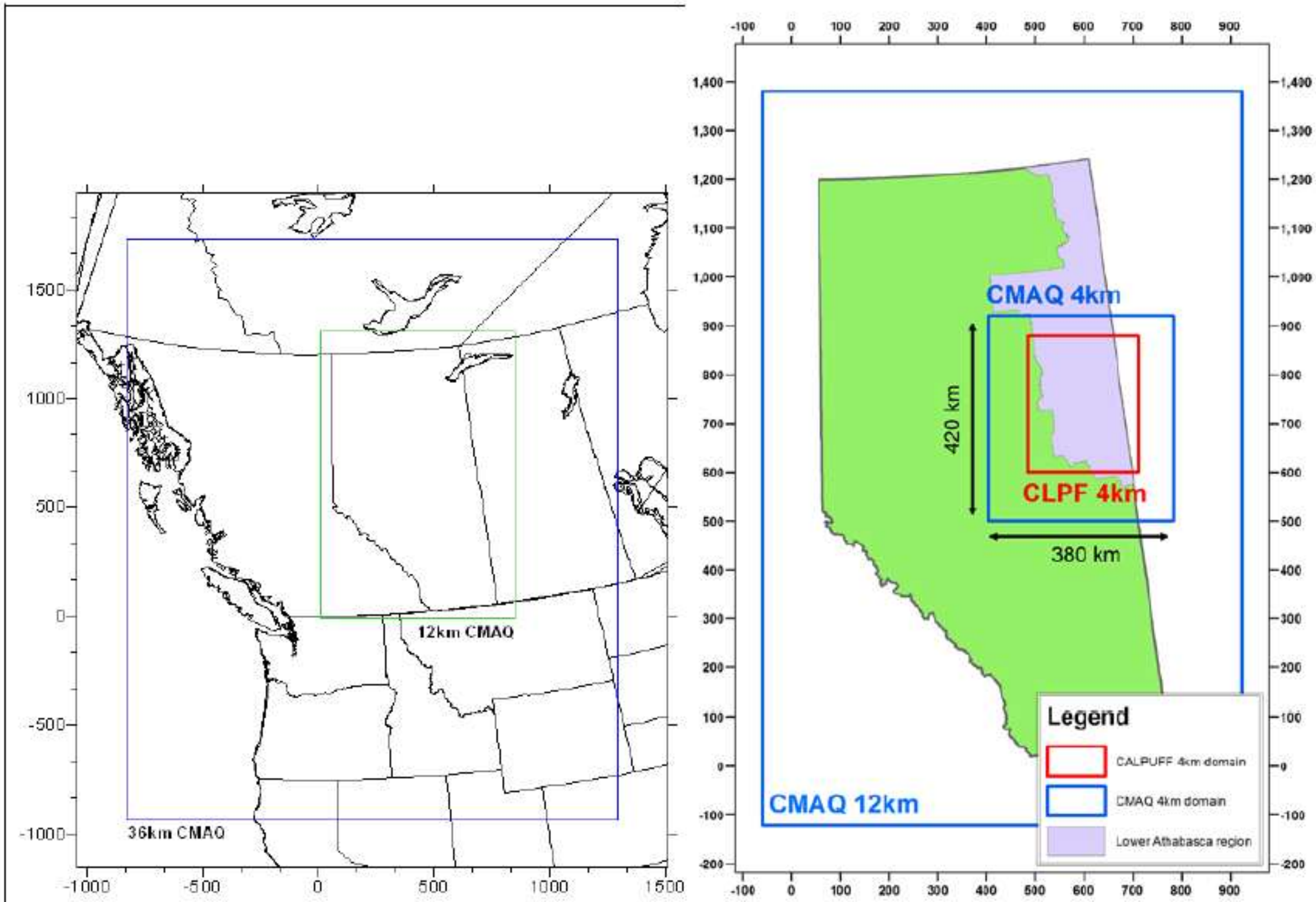
- CALPUFF modelling approach - transport and dispersion model
- CMAQ modelling approach - simulates multiple tropospheric air quality issues

We are using updated emissions inventories:

- TPM, $PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, NH_3, TRS (e.g. carbon disulphide), acidic deposition, metals, PAHs, VOCs



Source: USEPA



SW Corner: (-828, -936) 59 x 74 cells 36 km
SW Corner: (-60, -12) 82 x 125 cells 12 km
SW Corner: (404, 500) 95 x 105 cells 4 km (CMAQ)
SW Corner: (484, 600) 57 x 70 cells 4 km (CALPUFF)

Figure 4-1. 36/12/4 km CMAQ modelling domains for the SAOS Region.

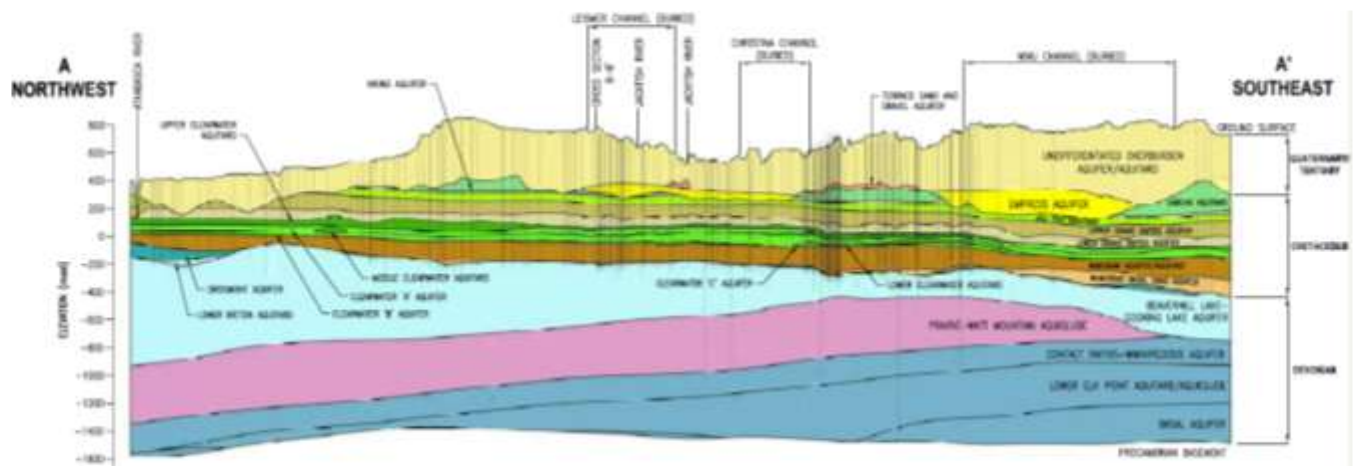
Water Modelling

Currently using three models:

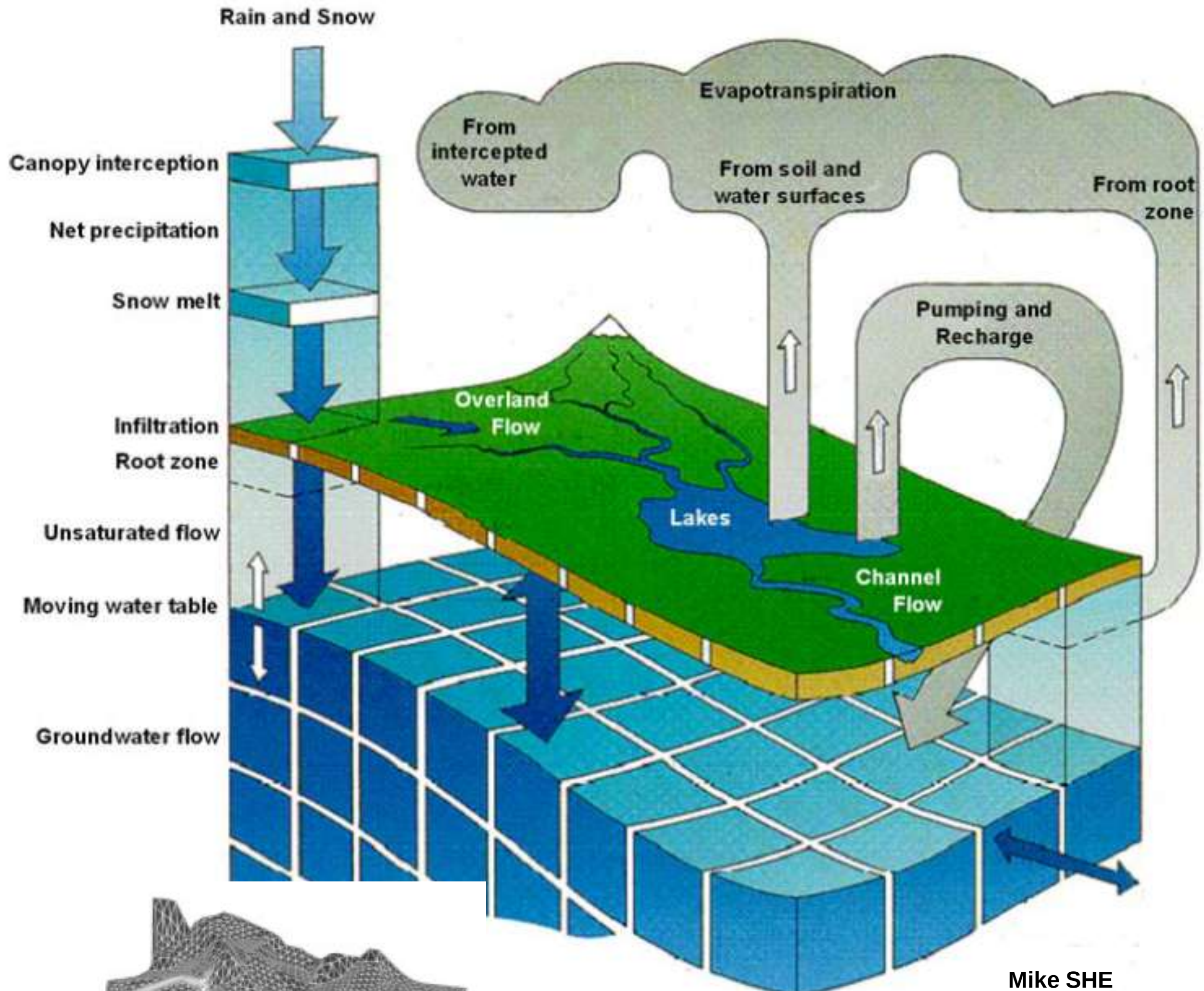
- FEFLOW – Advanced Groundwater Modelling
- Mike SHE – Integrated Catchment Modelling
- Mike 11 – River Modelling

Building on:

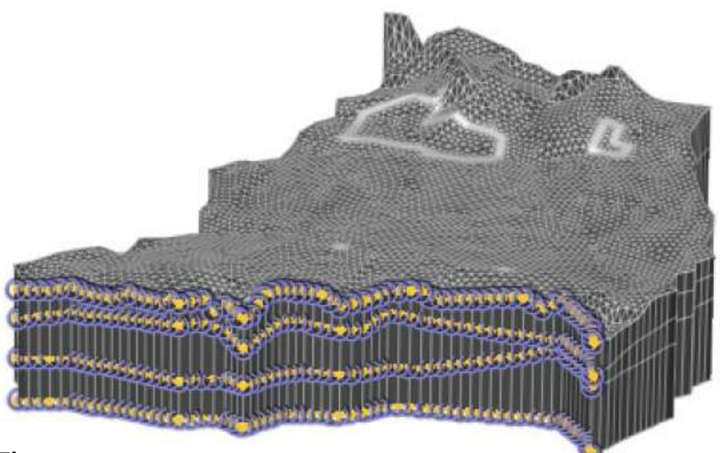
- Groundwater Flow Model for the Athabasca Oil Sands (In Situ) Area South of Fort McMurray (Worley Parsons, 2010)



Source: Worley Parsons (2010)



Mike SHE



FE Flow

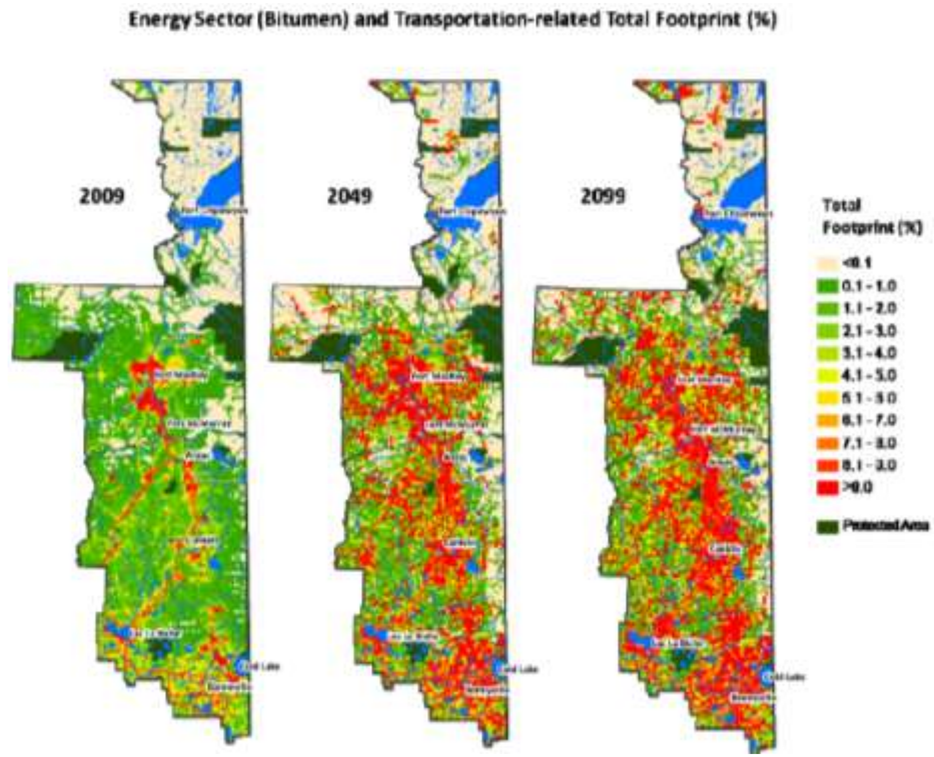
Land and Biodiversity

Modelling Approach

- ALCES/ ALCES Mapper
- Other spatially explicit modelling tools

Building on:

- Models developed to support the LARP



Source: LARP Report (ALCES Group, 2009)

Alberta

Environmental Health Risk Assessment

EPA United States Environmental Protection Agency

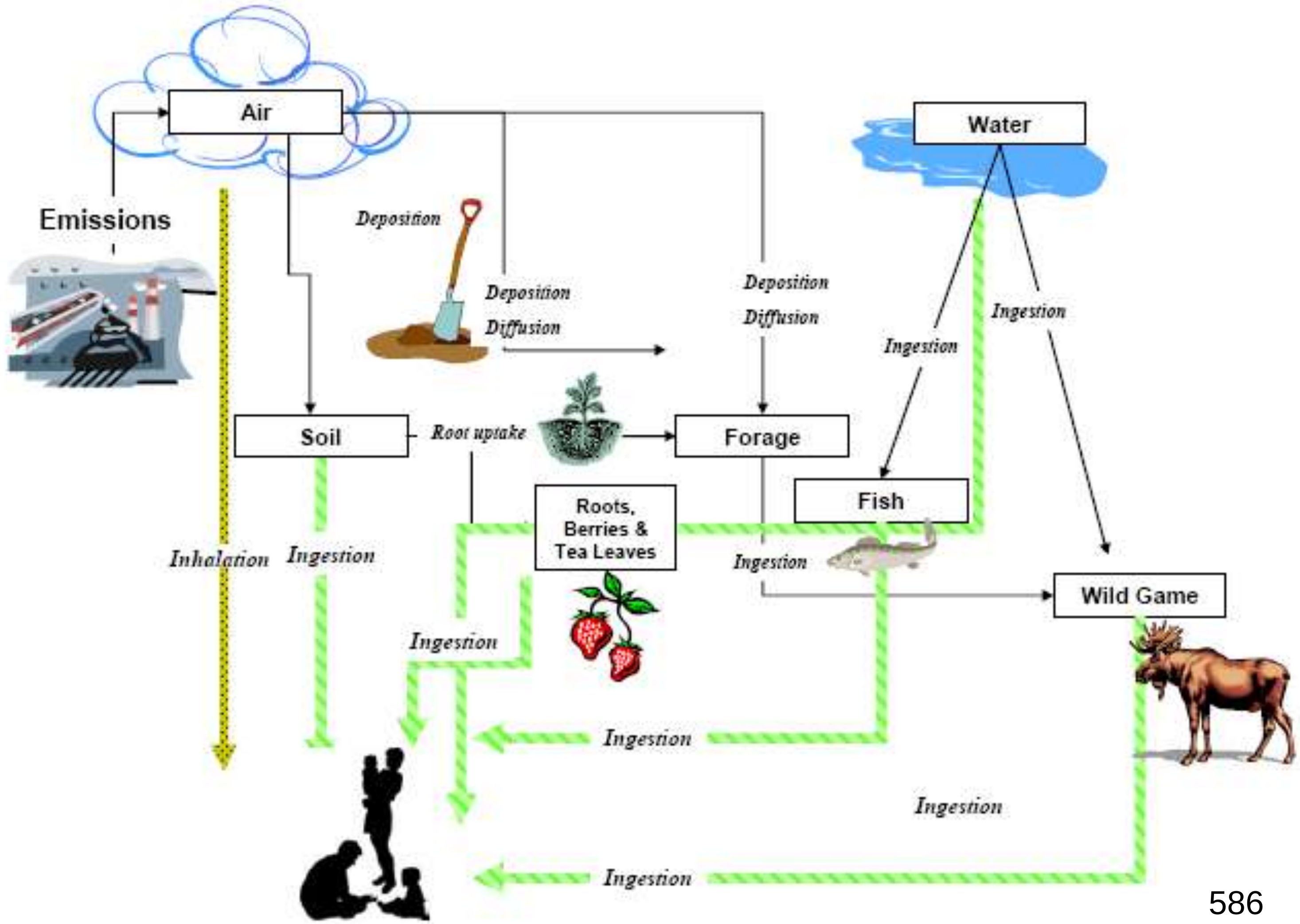
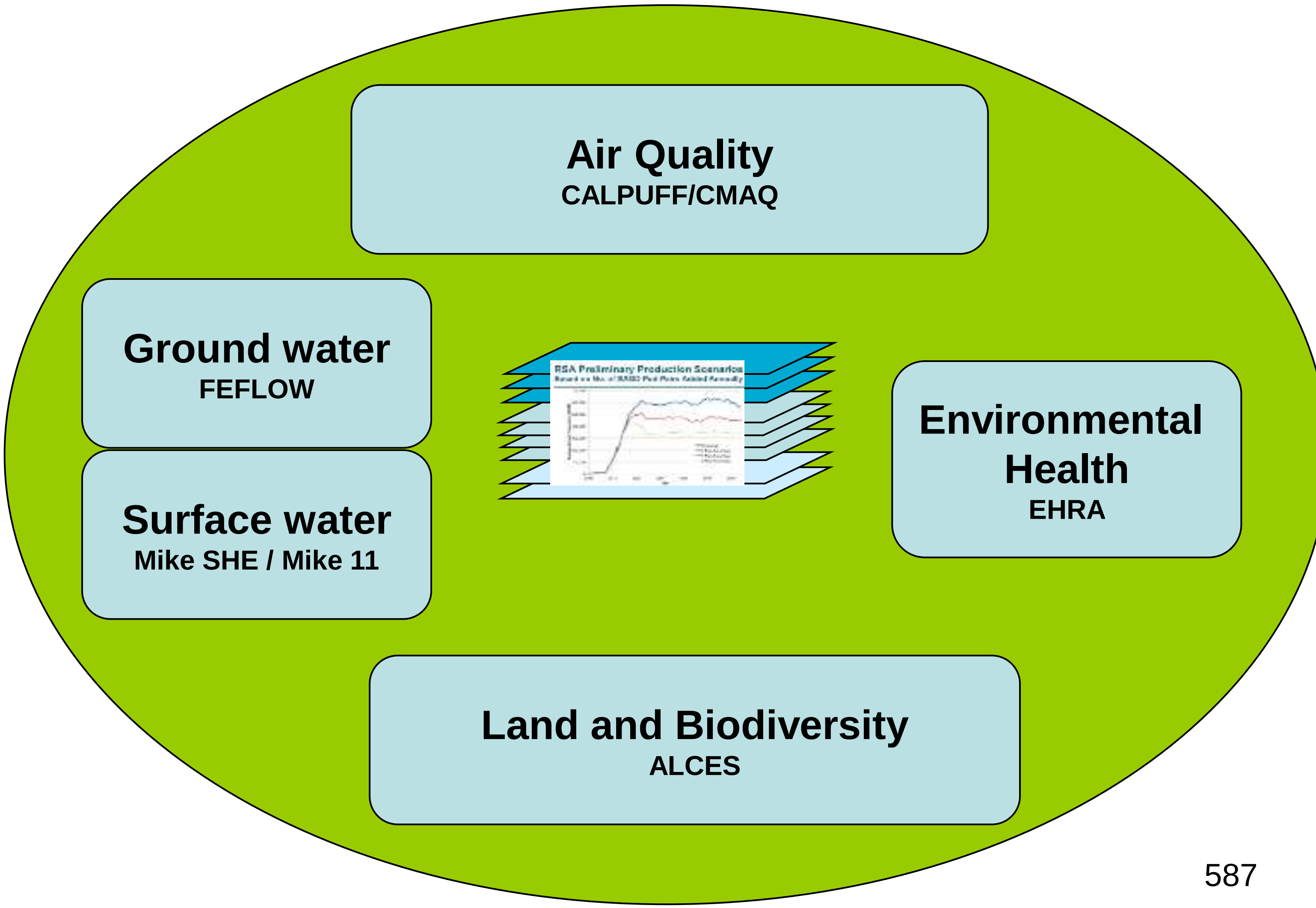
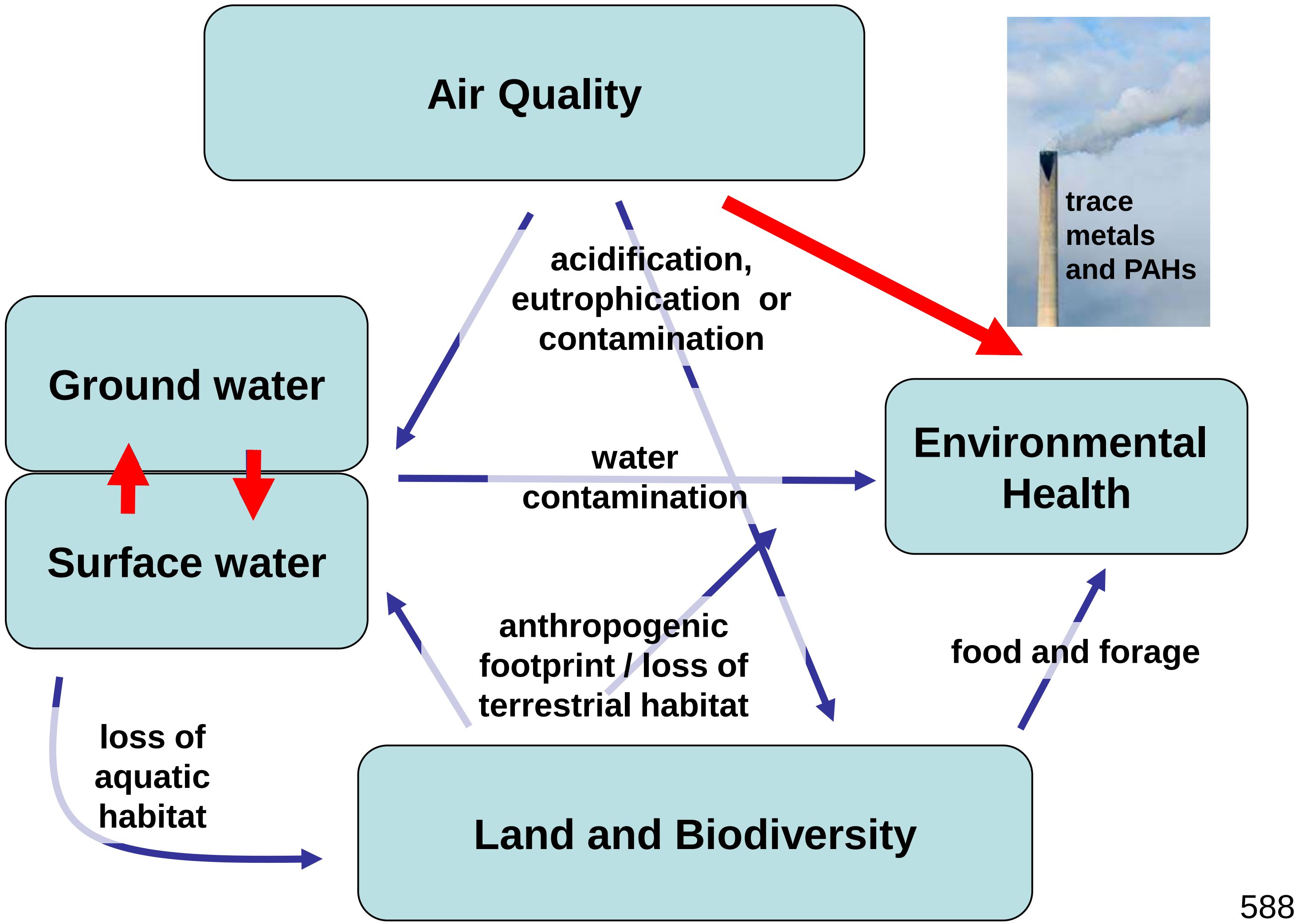


Image source: EIA Report

Model Integration



Linking various model outputs in the assessment



Lessons Learned

- Large data requirements to run models at this scale and complexity
- Time constraints
  - Computational time requirements
  - Integration among models hampered in part by the need to work in parallel versus in series
- Assumptions
  - The need to make assumptions around factors that may have significant impact on model outputs (e.g. reclamation rates of linear disturbance features)
- Data input quantity/quality
  - A lack of field data in certain cases, no data, or data with poor spatial and temporal representation.
- Inherent uncertainties about changes in climate, technology and demand for resources

Summary

- Models will provide valuable information to support decision making
- Environmental models are one aspect of the cumulative effects assessment
  - The SAOS RSA will include expert review, stakeholder engagement and other qualitative or quantitative assessment methods
- Use of information from each tool will be based on a foundation of knowledge of their limitations
- Cumulative effects assessments are complex
  - Continued efforts are needed to integrate and enhance our abilities to do it well
  - Reliant on good thinking

Major Outputs of the SAOS RSA

Profile of the SAOS Area Report

Spring 2013

- Present **general baseline** information regarding the condition of indicators related to **valued social, environmental and economic (SEE) components** within the area.
- **Form a chapter in the RSA report**
- **Articulate,** where information is available, the current issues, trends, drivers and pressures influencing conditions of SEE components.

SAOS Regional Strategic Assessment Report

December 2013

- **Present the cumulative effects assessment of three energy production scenarios** in the SAOS on the SEE components
- Explore potential **management options**
- **Provide guidance** for further scenario analysis that will support the development of an **SAOS sub-regional plan**

Acknowledgments

RSA Teams members that contributed to the content of the presentation (AESRD in-house modellers)

- Brian Kolman
- Cecilia Ferreyra
- Chantelle Leidl
- Dallas Johnson
- **Debra Hopkins**
- Gustavo Hernandez
- Judy May-McDonald
- Kevin Williams
- **Sillah Kargbo**
- **Wen Xu**
- **Yaw Okyere**

Cumulative Effects and People

Day 2 – Session 3

Margaret Scott – WorleyParsons Canada Ltd.

BIOGRAPHY

Margaret Scott is an Environmental Engineer with WorleyParsons Canada Ltd. in the Burnaby office. She has over six years of consulting experience. Her area of expertise is in groundwater modelling where she has worked on a variety of projects including integrated surface-water/groundwater interaction flow models and numerous local and regional-scale groundwater flow and transport models for various clients including Alberta Environment and Sustainable Resource Development, Origin Energy (Australia), Arrow Energy (Australia), USACE, Niagara Peninsula Conservation Authority, and the South West Florida Water Management District. Margaret received her Bachelor of Applied Science in Environmental Engineering-Civil Specialization with Water Resource Option at the University of Waterloo. She completed a Master's of Applied Science in Civil Engineering at the University of Waterloo focusing on regional-scale numerical modelling for watershed management and source water protection.

Day 2 – Session 3

Margaret Scott – WorleyParsons Canada Ltd.

ABSTRACT

The unprecedented growth of oil sands activity in the Athabasca region has raised concerns that mining and in-situ oil sand extraction processes may negatively affect groundwater quantity and quality. In 2010, the Royal Society of Canada, the Oil Sands Advisory Panel, and the Pembina Institute released reports highlighting the need to better characterize groundwater water resources within the Athabasca Oil Sands region, and to develop numerical modelling tools to better project potential cumulative effects of oil and gas development on water quantity and quality during bitumen development over the next decades and into the far-future (effectiveness of mine reclamation). Simultaneously, Alberta Environment and Sustainable Resource Development has developed a Groundwater Management Framework (GMF) which outlines an approach to identify and manage potential cumulative environmental effects of oil sands activities (and other related disturbances) on the environment. The GMF is predicated on the integration of decision-support tools such as modelling, monitoring, and management. The implementation of this framework will challenge groundwater users in the region to respond to adaptive and cooperative management principles in order to achieve the intended goals and outcomes.

Our presentation will focus on the development of the groundwater modelling decision-support tools for the mineable area north of Fort McMurray (NAOS model) and the in-situ region south of Fort McMurray (SAOS model). Within the GMF, the purpose of these models are to facilitate understanding of potential cumulative effects of groundwater extraction, injection, and diversions (i.e. mine dewatering) on water quantity and quality. In addition, the numerical model developments incorporate a consistent interpretation of the regional geologic and hydrogeologic setting (conceptual model), in alignment with Royal Society of Canada recommendations. The conceptual and numerical models can also be used in future Environmental Impact Assessments, to provide decision-support for expanding the regional groundwater monitoring network, and for establishing groundwater management targets within the GMF. Model development and calibration will be presented as well as associated challenges with representing the complex hydrogeologic setting and development history of the region. Possible future groundwater model refinements and potential applications for addressing the concerns highlighted by the independent research institutes will also be discussed.

WorleyParsons
resources & energy

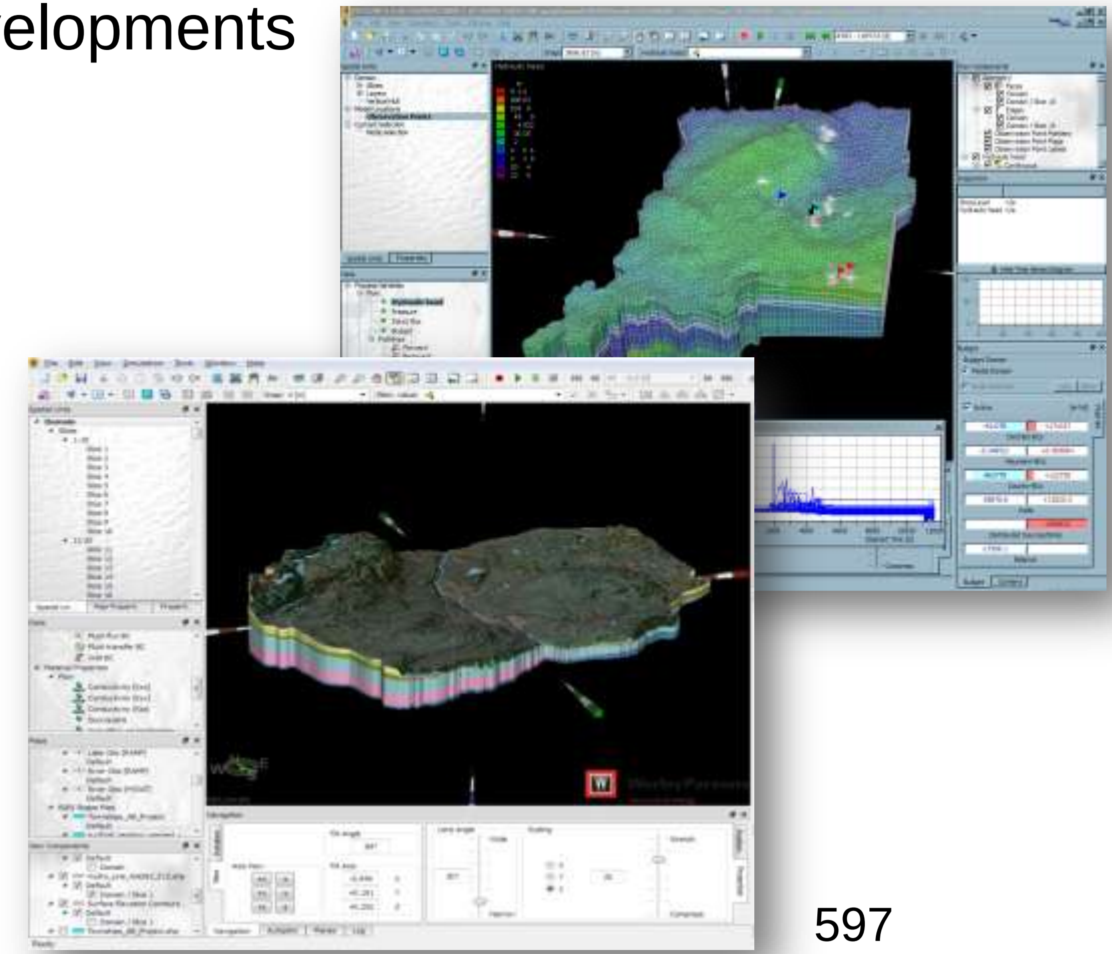
Groundwater Flow Model Development for Cumulative Effects Management within the Athabasca Oil Sands

Margaret Scott, MASc, EIT
Jos Beckers, PhD, P Geoph
Matthew Webb, MSc

EcoNomics

Overview

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



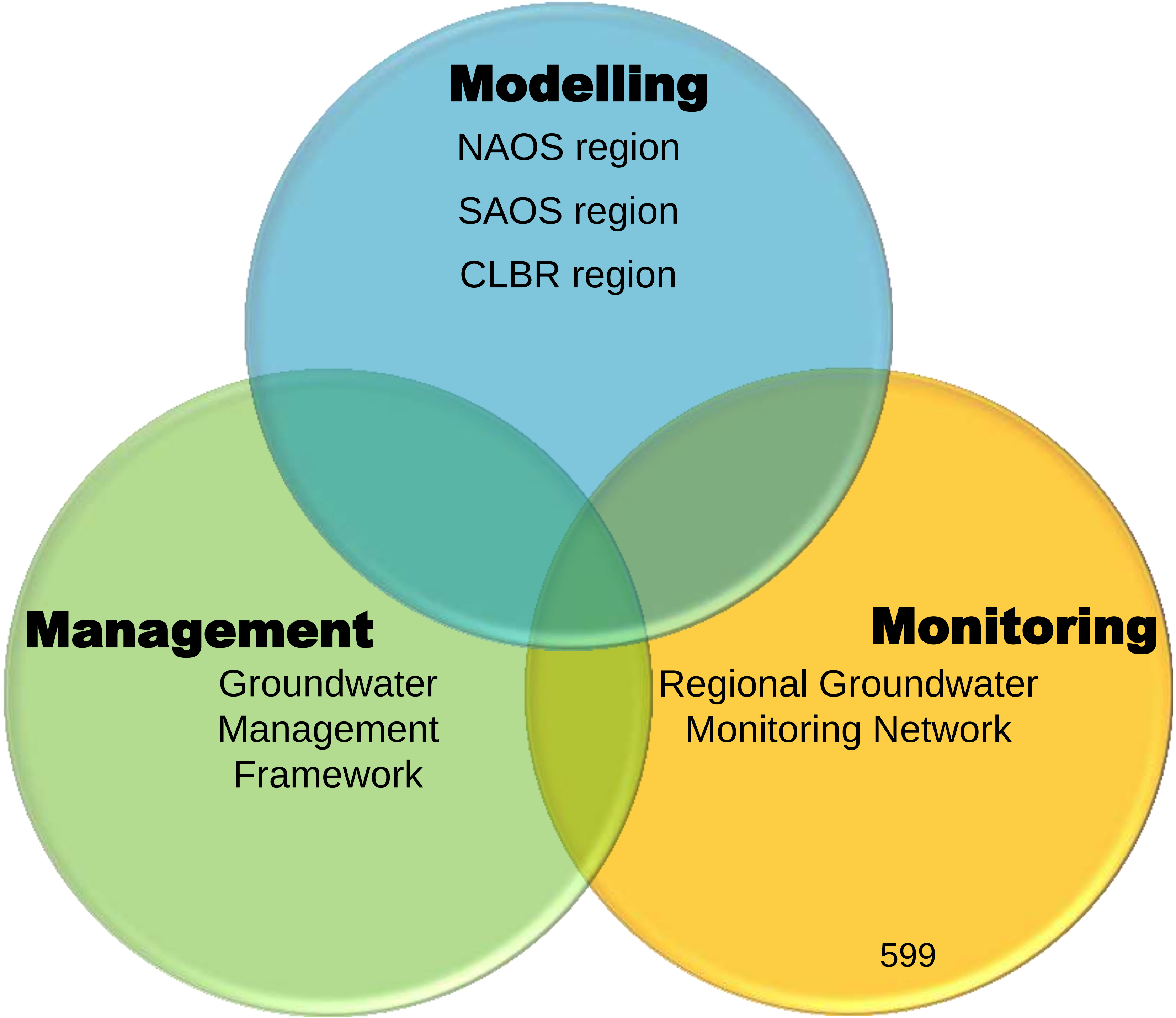
Groundwater Management Framework Tools

Develop
& Integrate Tools

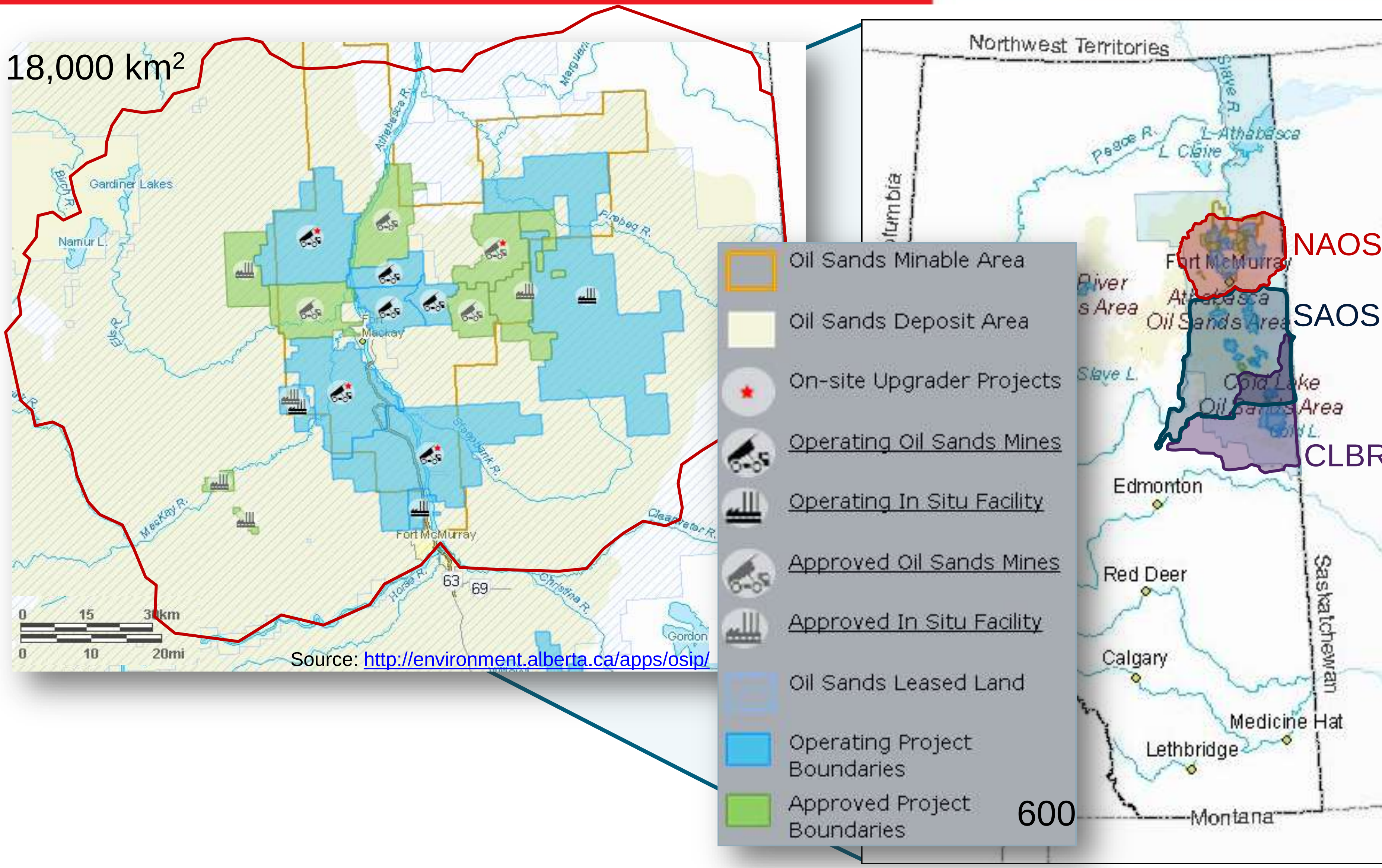
Modelling

Management

Monitoring

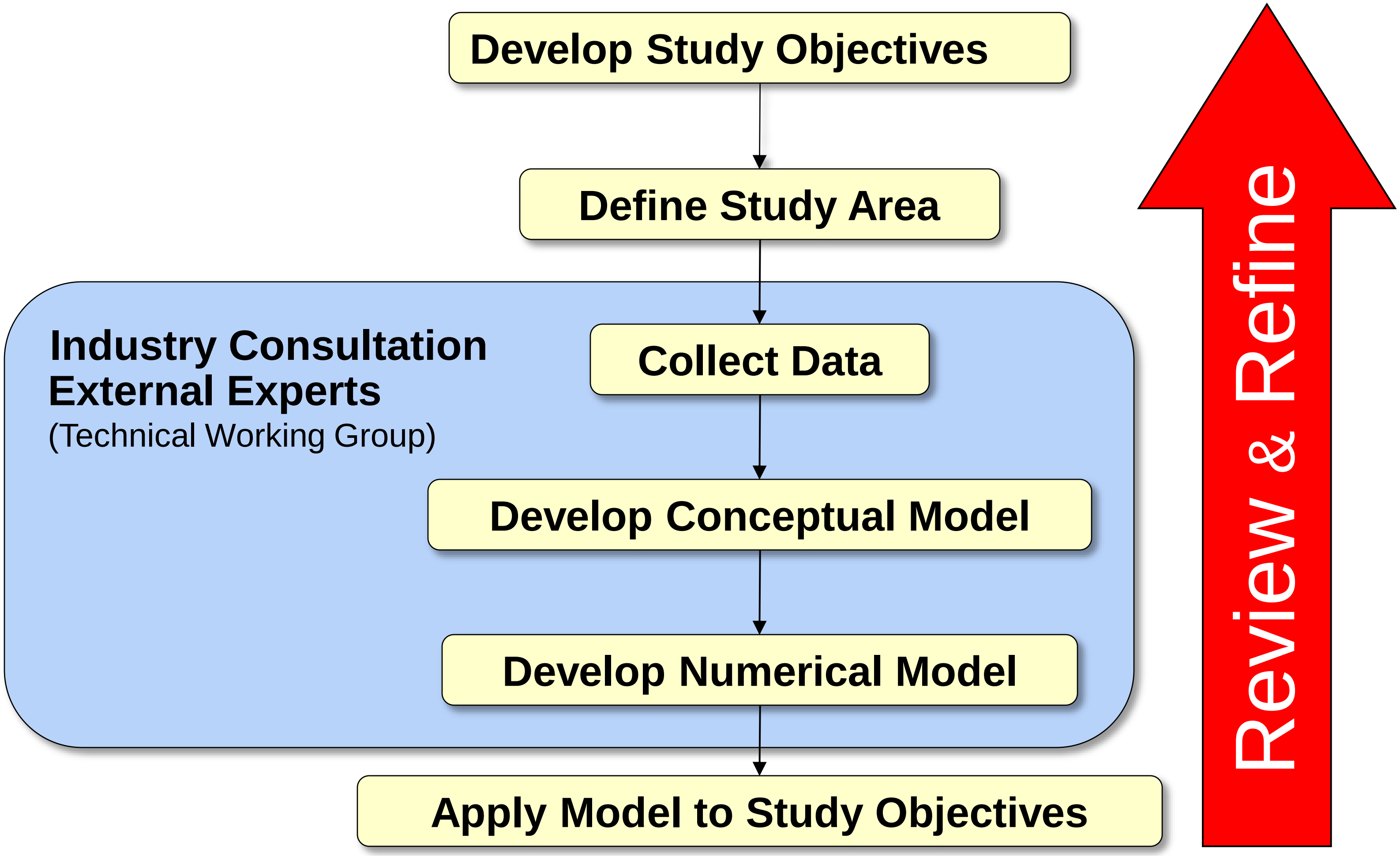

Modelling
NAOS region
SAOS region
CLBR region
Management
Groundwater
Management
Framework
Monitoring
Regional Groundwater
Monitoring Network

NAOS Region



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

Methodology



Industry Participants

ATHABASCA OIL SANDS CORP.

cenovus ENERGY

Esso Imperial Oil

Syncrude Securing Canada's Energy Future

SUNCOR ENERGY

TOTAL

Husky Energy

DOVER Operating Corp.

Canadian Natural

External Experts

Alfonso Rivera Canadä

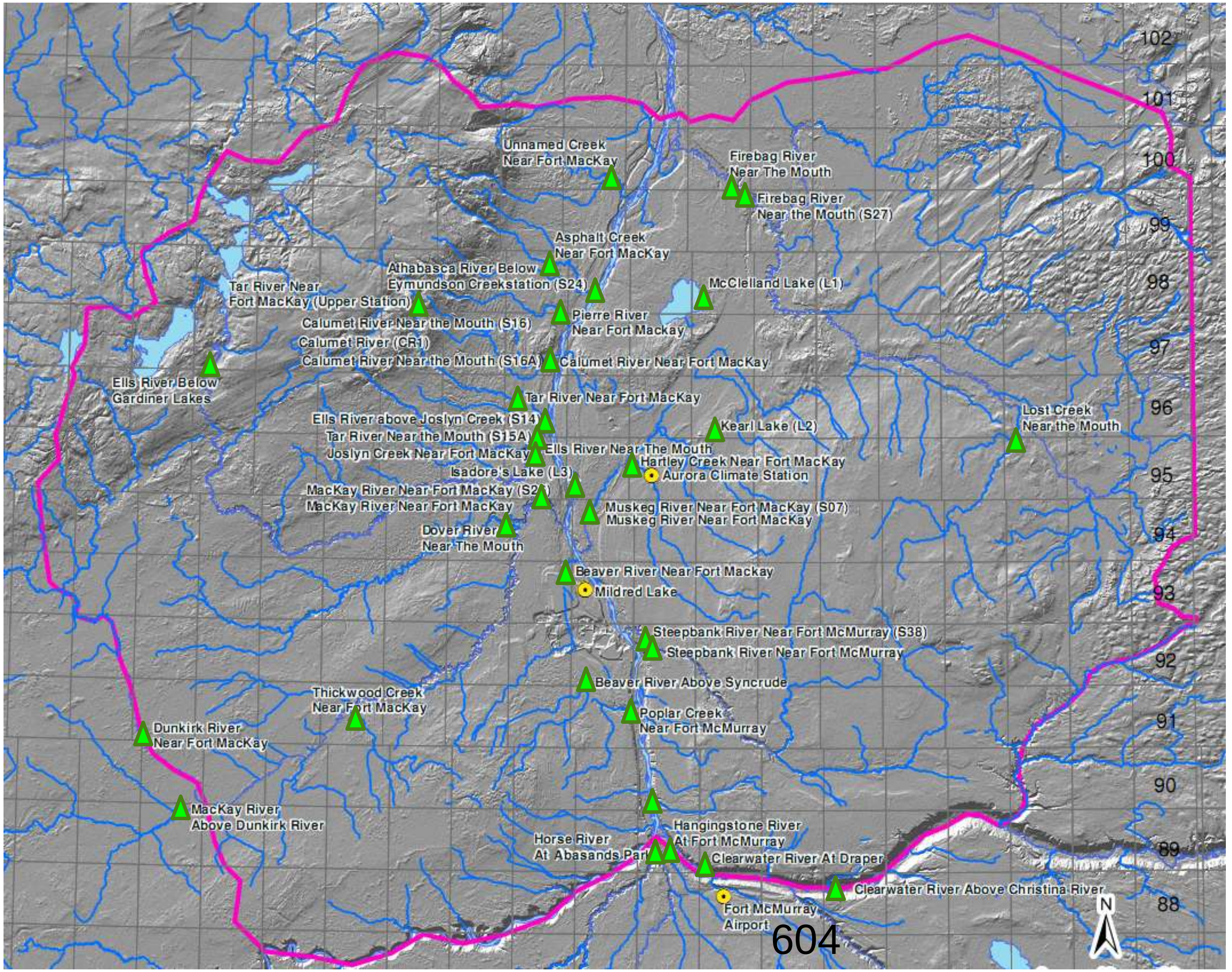
- Director of Geoscience for the Geological Survey of Canada
- Member of expert panel that reviewed the NAOS Groundwater Management Framework

René Therrien

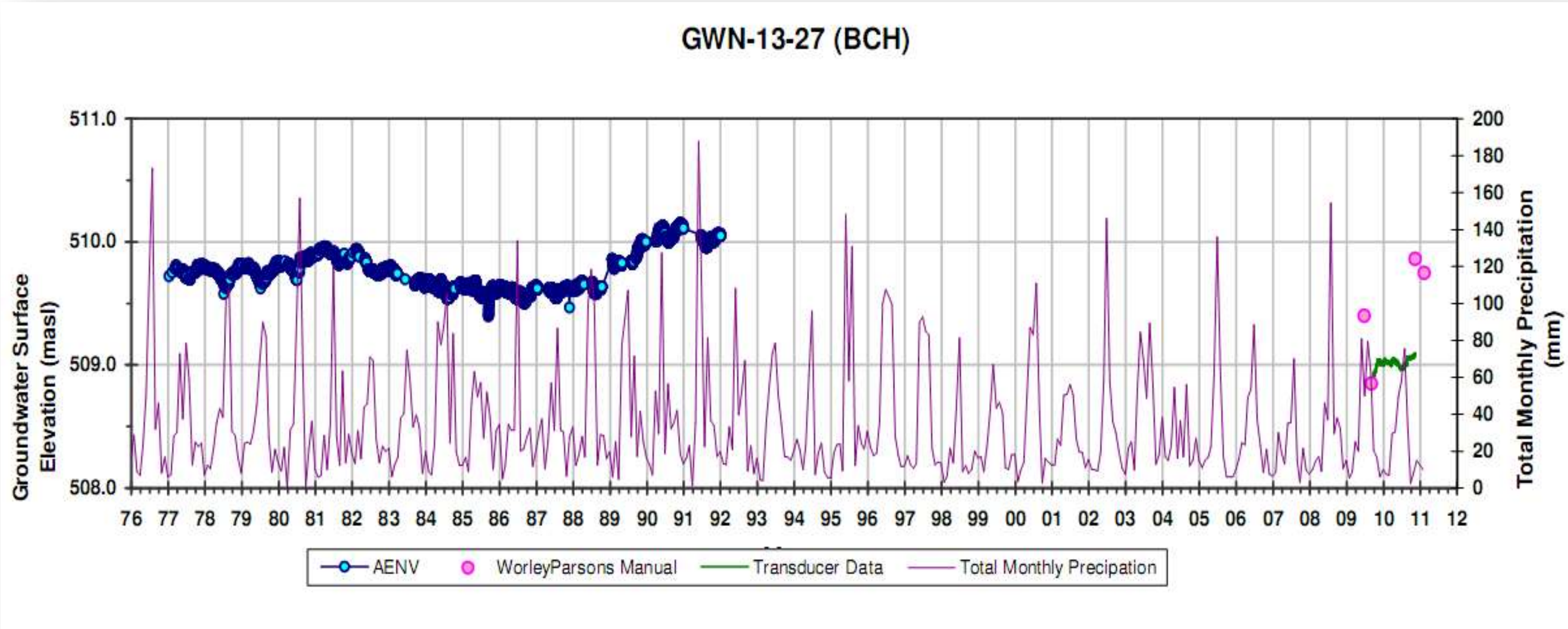
- Chair, Department of Geology and Geological Engineering at Université Laval
- Member of the Royal Society of Canada Expert Panel

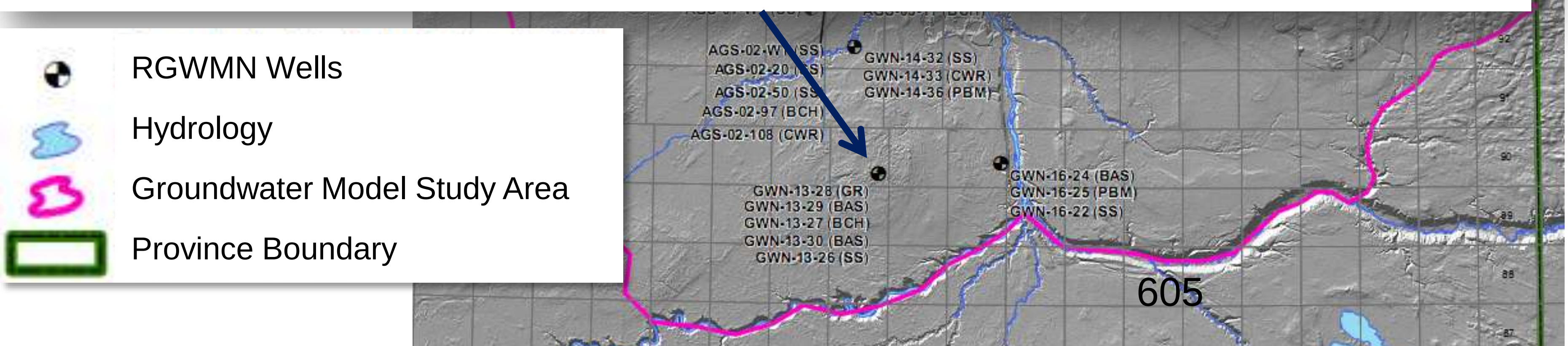
Hydrology

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



Hydrogeology





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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	

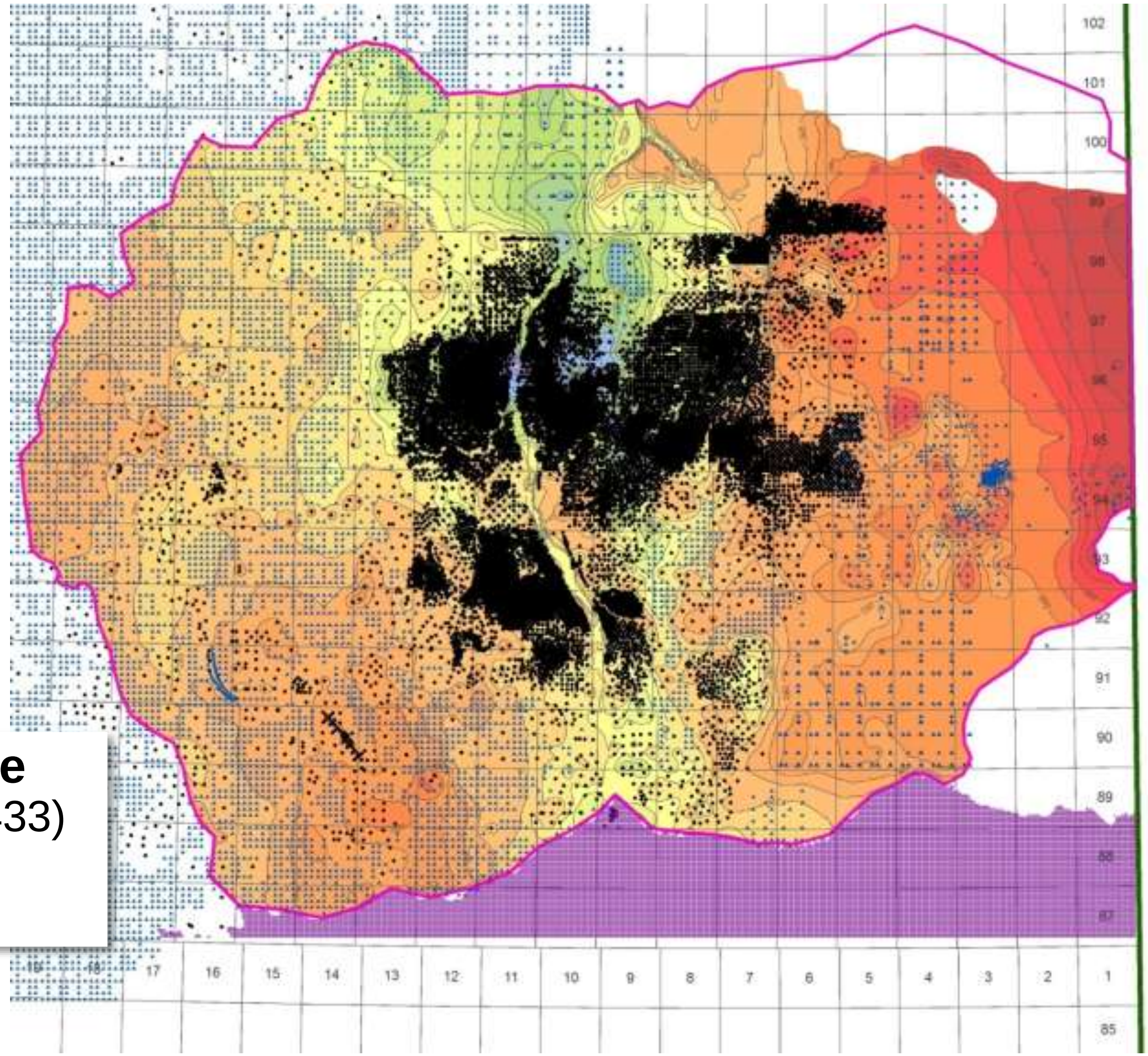
Continued

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

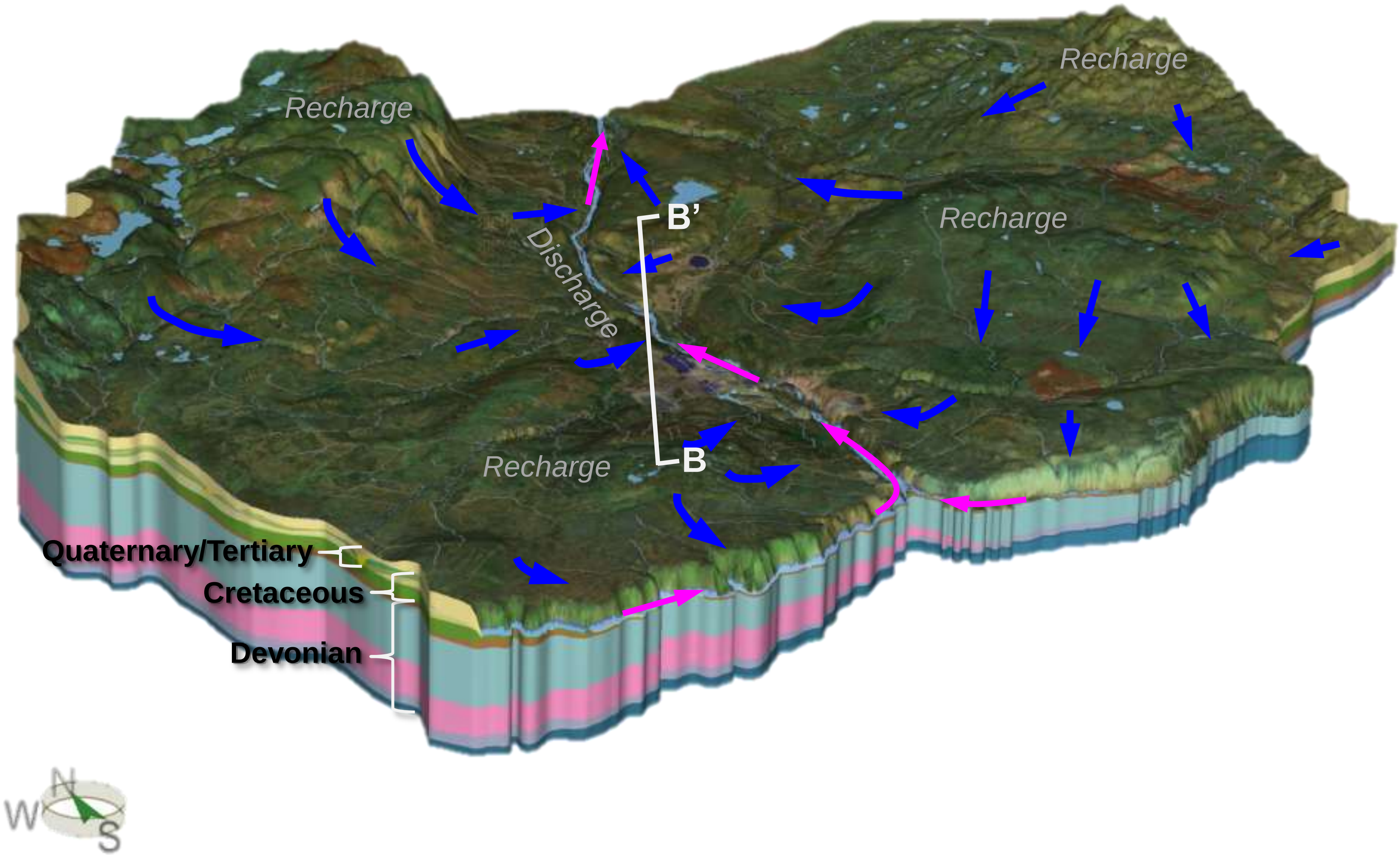
Surface & Isopach Development

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

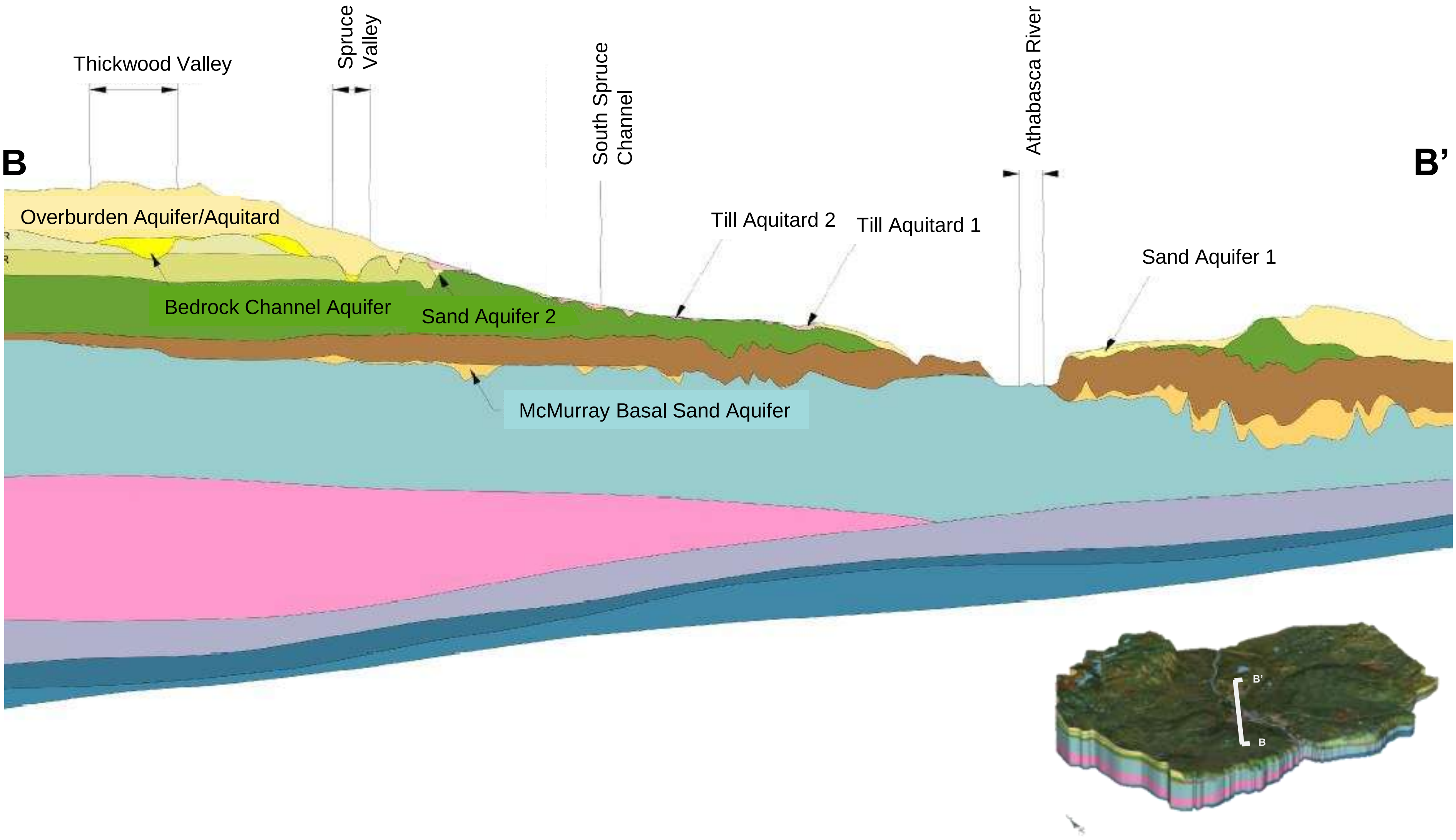


Devonian Surface
Operator Tops (50,433)
Grid Data (10,485)
Control Points (5)

Conceptualization



Conceptualization

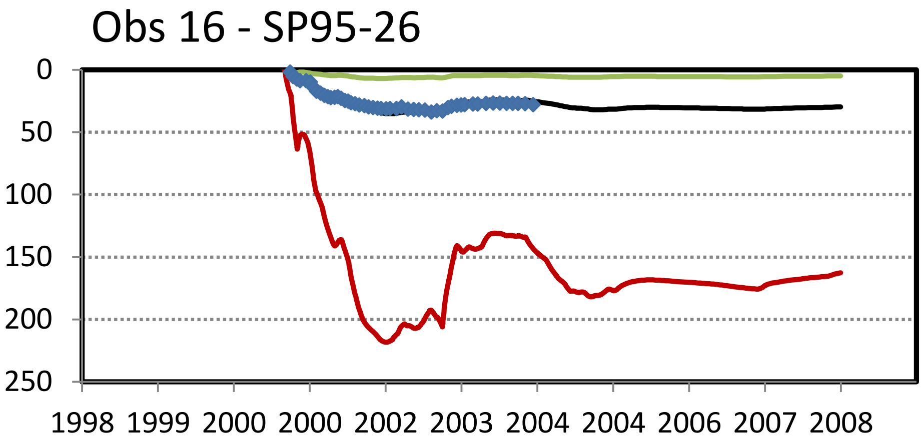


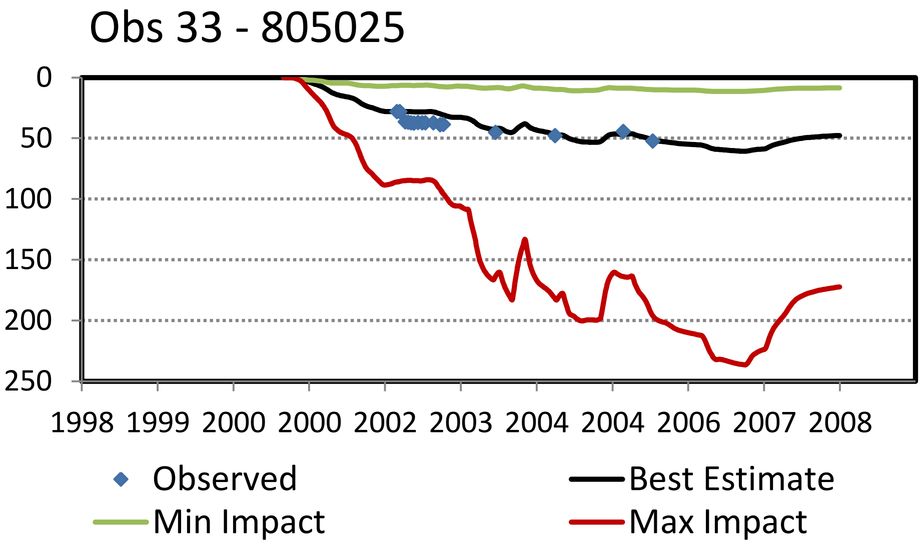
Model Design & Calibration

21 layer FEFLOW model (3.0 million elements)

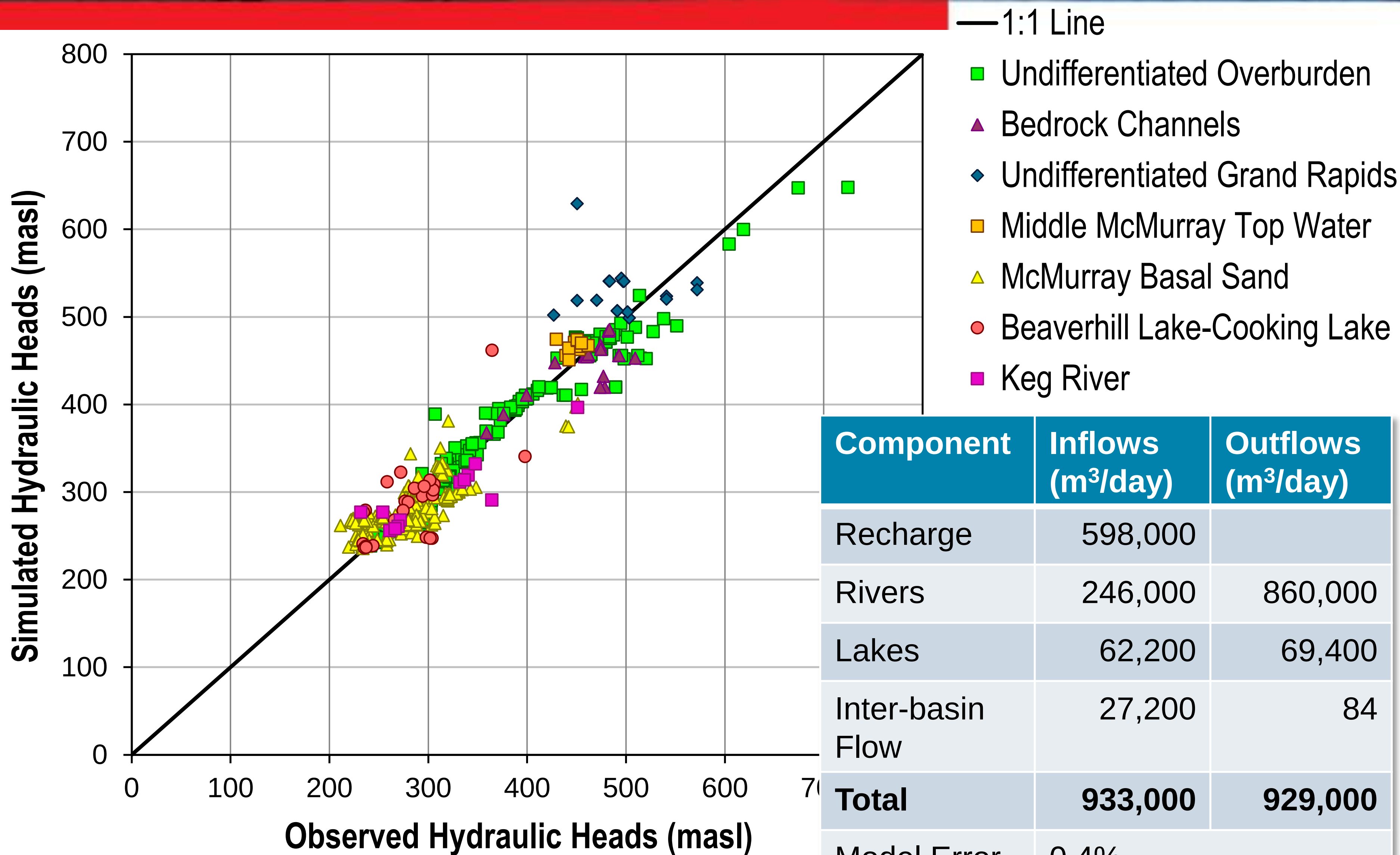
Calibration Methodology

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



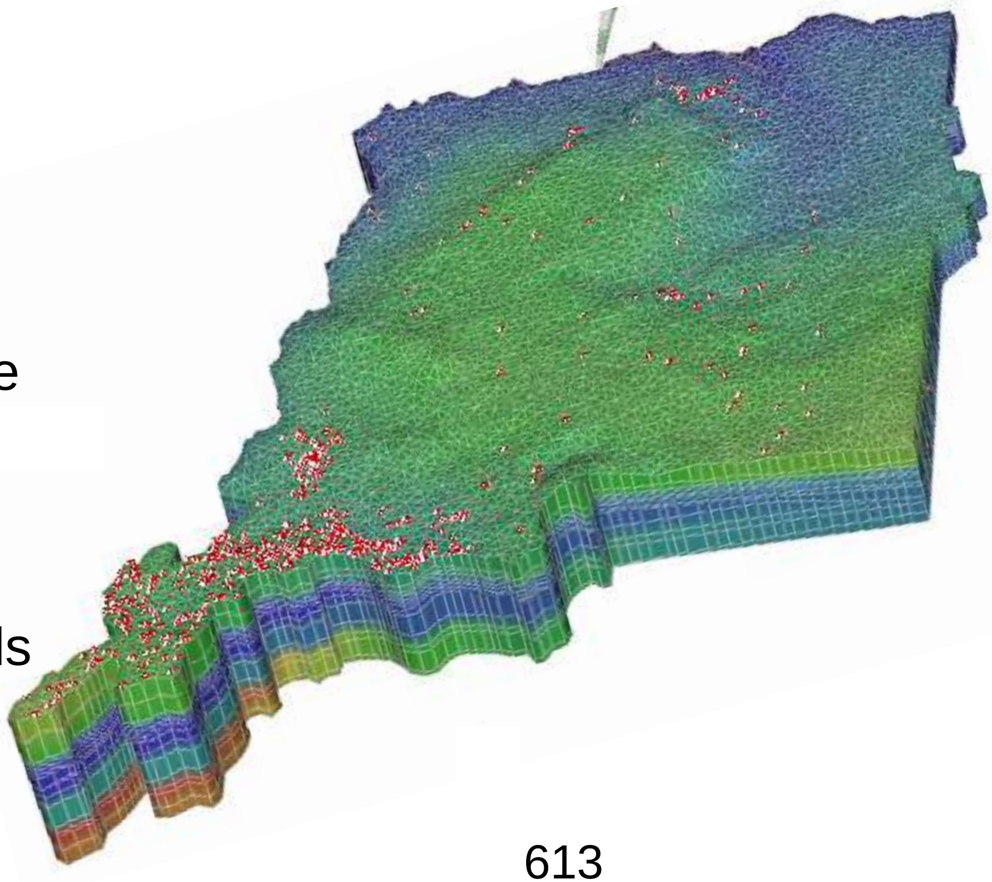
Component	Inflows (m^3/day)	Outflows (m^3/day)
Recharge	598,000	
Rivers	246,000	860,000
Lakes	62,200	69,400
Inter-basin Flow	27,200	84
Total	**933,000**	**929,000**
Model Error	0.4%	

Model Design

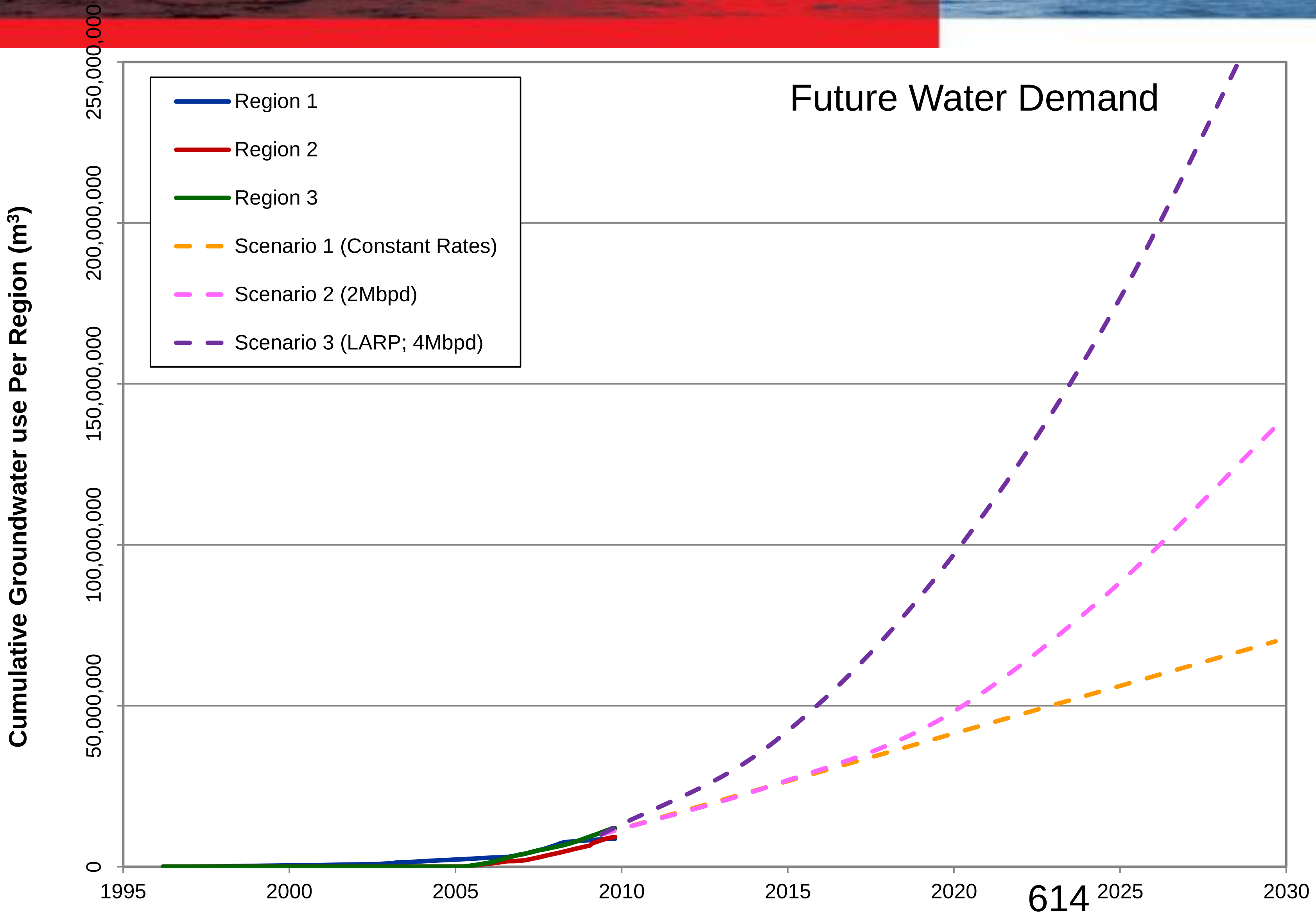
25 layer FEFLOW model (292,075 elements)

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



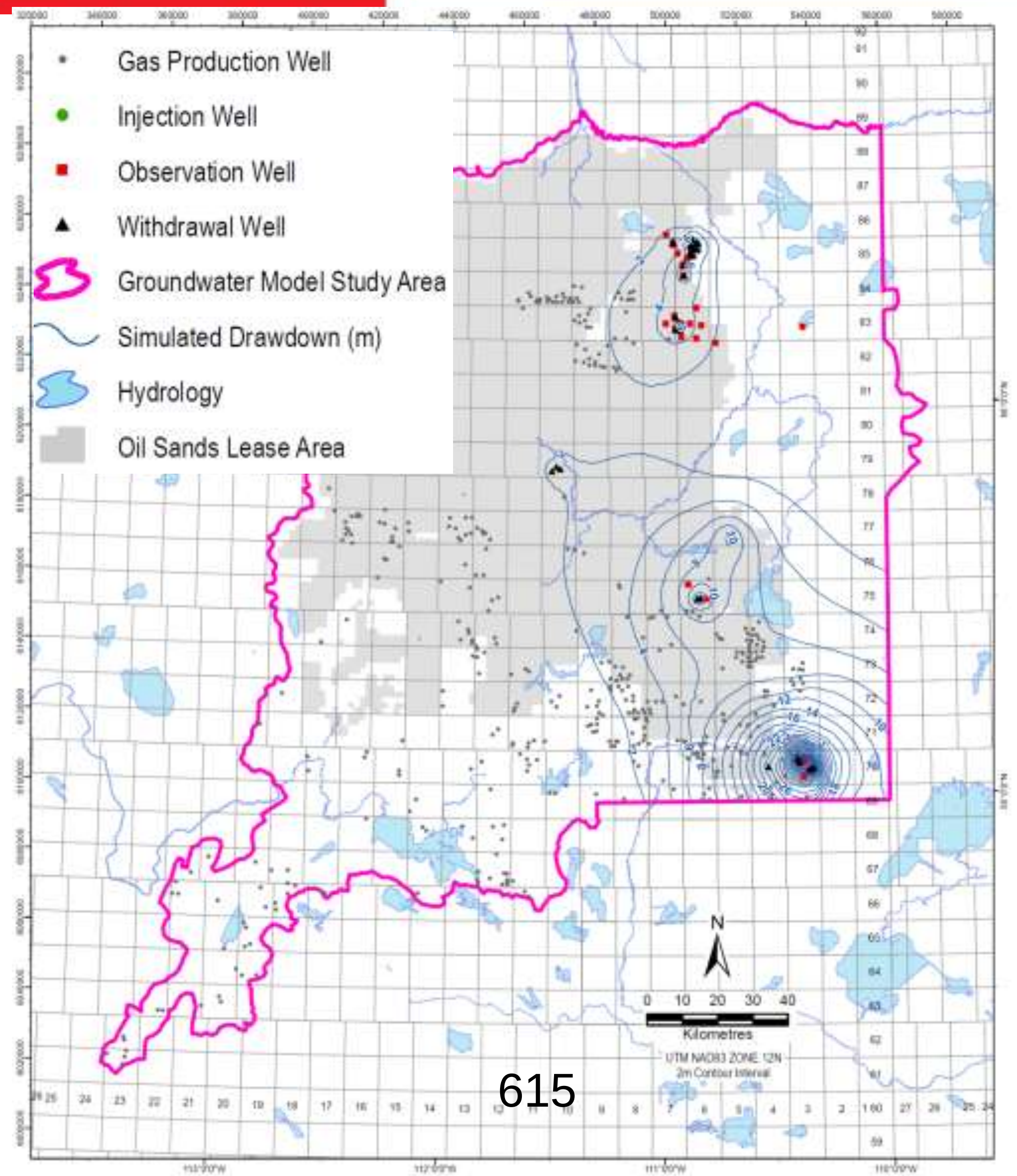
Predictive Scenarios



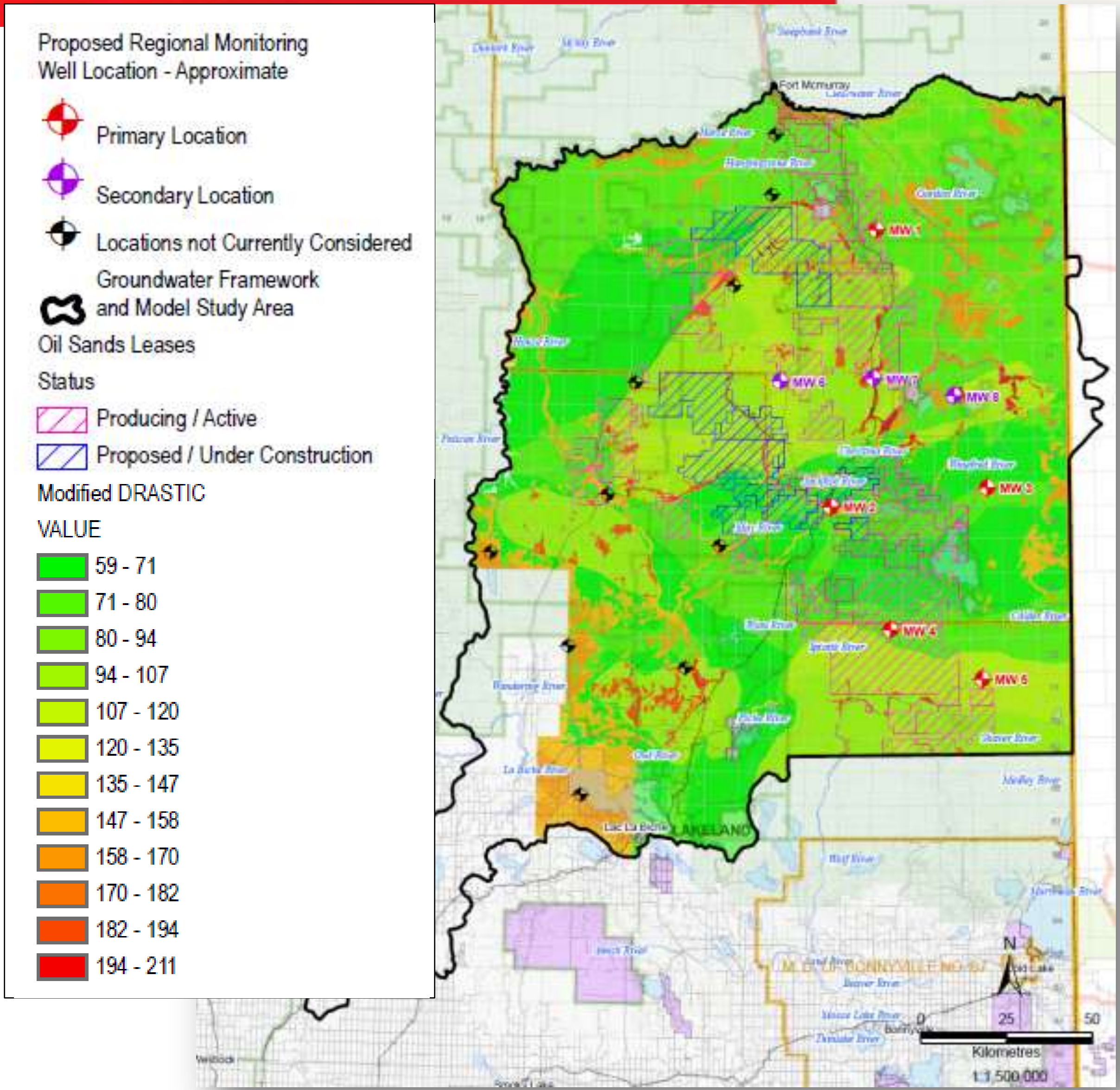
Scenario 1 Results

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



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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