Alberta Government

Environmental Modelling Workshop

A Compilation of All Presentations
March 2013

Conference Organizing Committee

The organizing committee is proud to host the first Environmental Modelling Workshop in Edmonton, Alberta. It is our hope that registered delegates will leave the workshop with an appreciation of how modelling can provide government and industry with the information and tools to best achieve monitoring, planning, and management objectives. Delegates will learn how modelling is used across government ministries and within industry. National speakers will provide expertise on a myriad of topics including air and water management, cumulative effects, biodiversity management, land-use planning, data integration, and climate variability.

The organizing committee wishes to thank Alberta Environment and Sustainable Resource Development for hosting the 2013 Environmental Modelling Workshop.

Name	Organization / Group
Anil Gupta	AESRD (CMO)
Ben Arril	AESRD
Benjamin Adei	AESRD (CMO)
Crystal Kushneryk	AESRD
Deepak Muricken	AESRD
Edwin Rodriguez	AESRD (CMO)
Eric Anderson	AESRD (CMO)
Janelle Lane	AESRD
Jannette Wombold	AESRD
John Diiwu	AESRD
Laura Lee Billings	AESRD
Richa Sharma	AESRD
Sillah Kargbo	AESRD
Sunny Cho	AESRD
Terry Vaughan	Ministry of Culture, GOA
Werner Herrera	AESRD, Chairman

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Keynote

Day 1 - Keynote Speech

Anil Gupta – Central Modelling Office

ESRD - Central Modelling Office

Reaching Our **Full Potential**

Integrated Environmental Modelling

Anil Gupta, Ph.D., P.Eng.

Manager, Central Modeling Office
Policy Division
Environment and Sustainable Resource Development

Outline

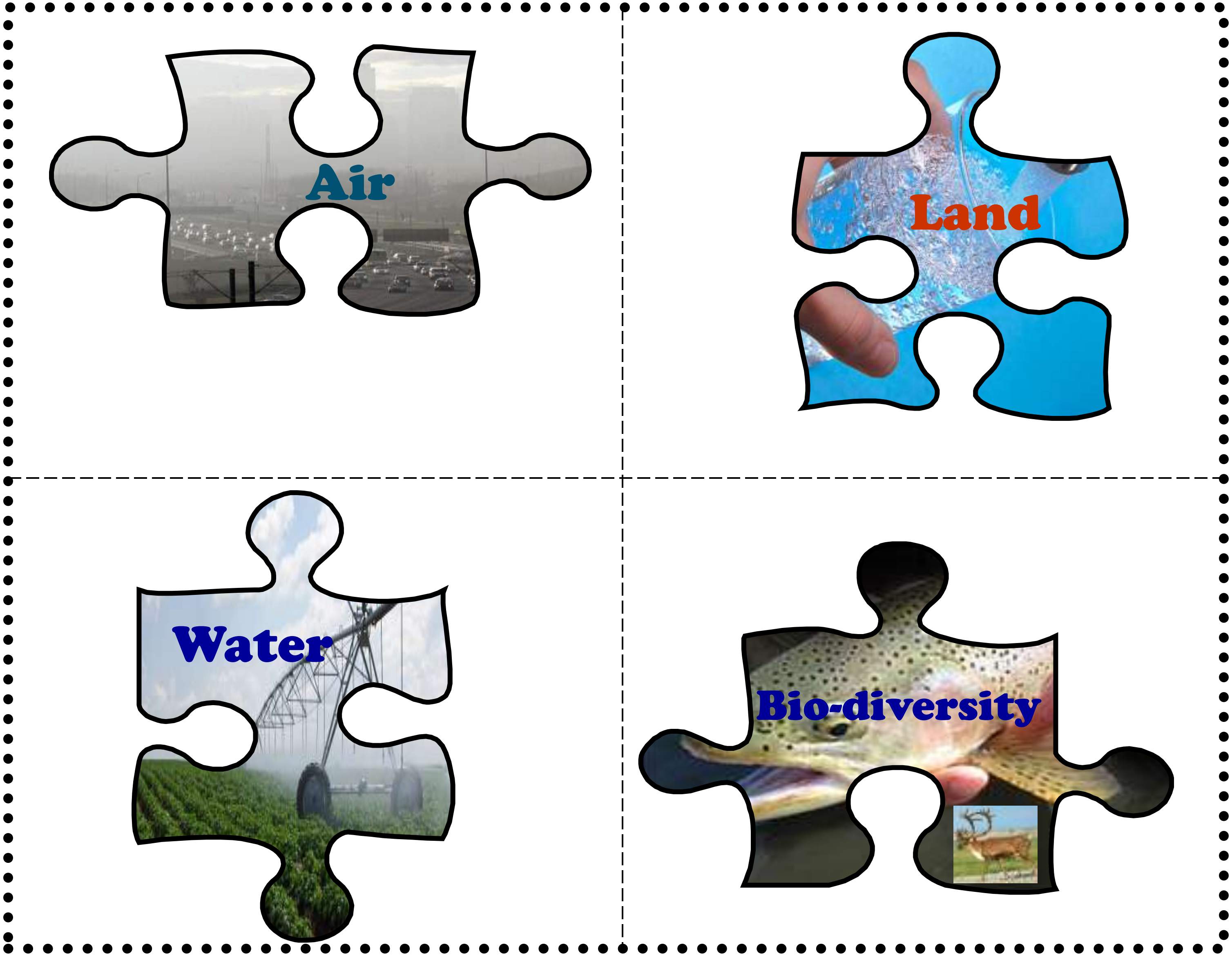
Integrated Modelling

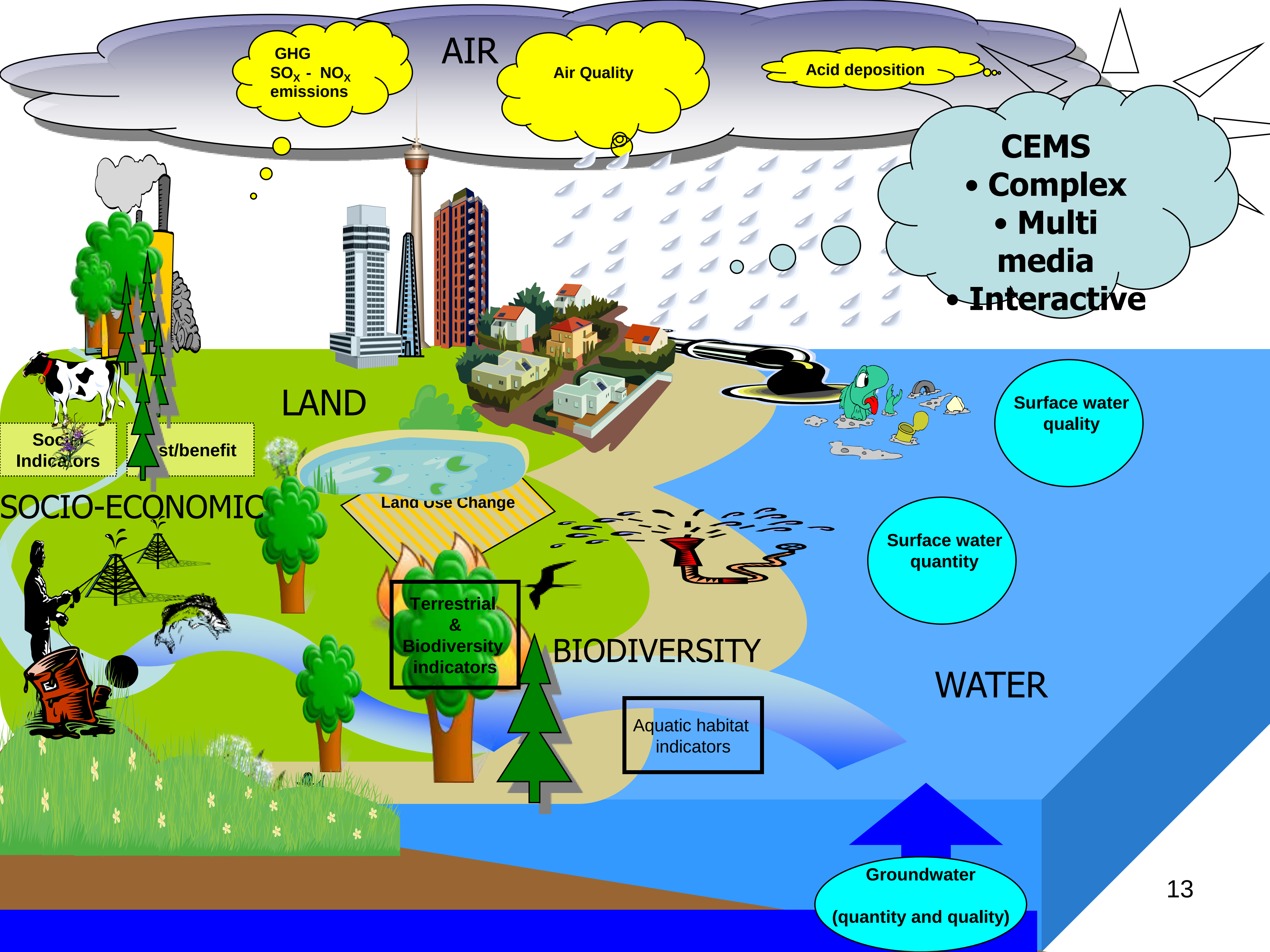
- Integrated modelling – what does it mean?
- Integration efforts – some examples
- What else is being done to address?

Central Modelling Office/ESRD/GOA

- ESRD Modelling Context
- Why do we model? – a regulatory perspective.
- Current modelling practices in ESRD
- Challenges and opportunities
- CMO structure and role in supporting/enhancing modelling in ESRD

Environment



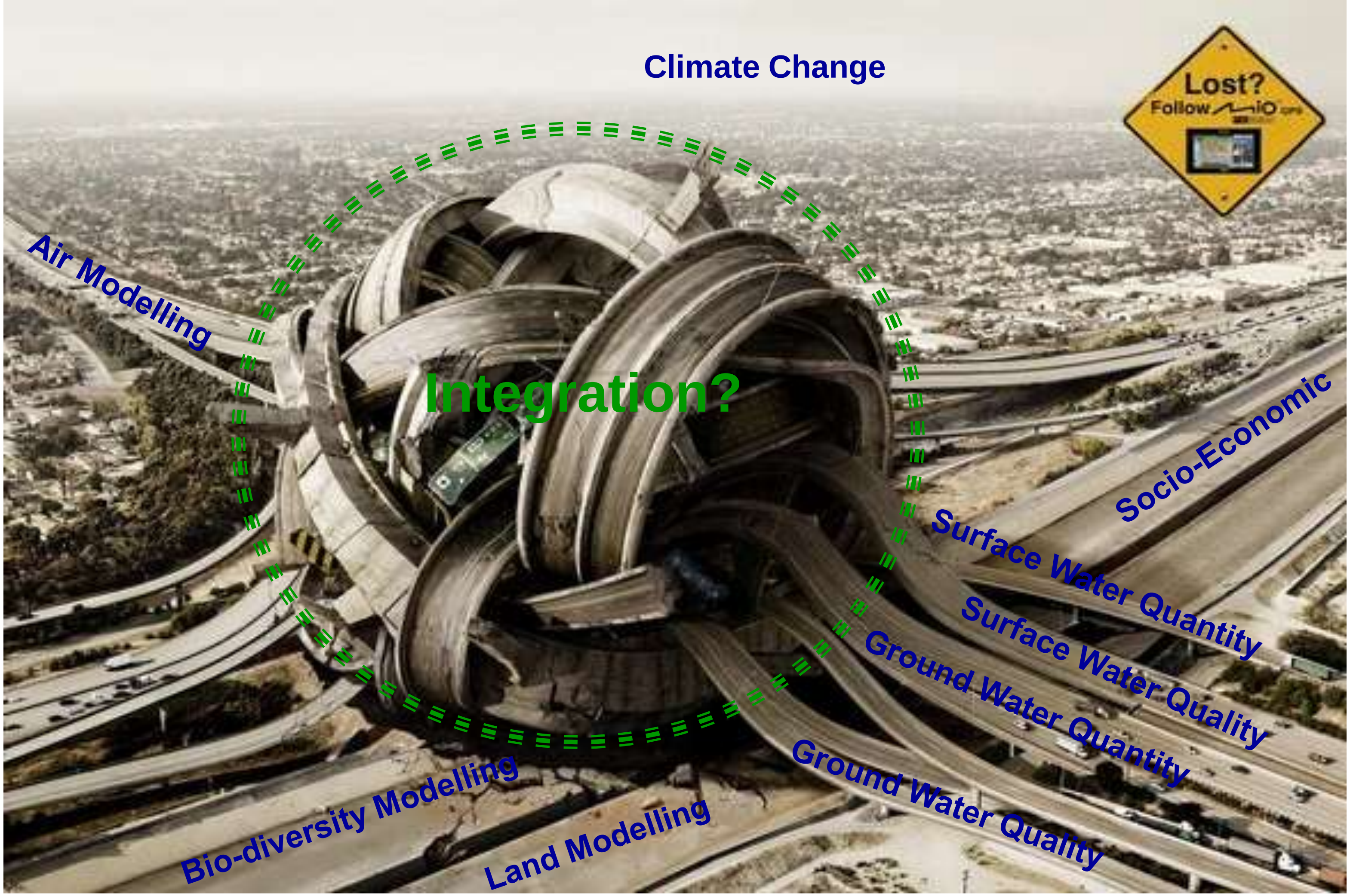

AIR
GHG
SO_X - NO_X
emissions
Air Quality
Acid deposition
CEMS
• Complex
• Multi media
• Interactive
LAND
Socio Indicators
st/benefit
SOCIO-ECONOMIC
Land Use Change
Terrestrial & Biodiversity indicators
BIODIVERSITY
Aquatic habitat indicators
Surface water quality
Surface water quantity
WATER
Groundwater
(quantity and quality)

Isolated (sector or media based) vs. Integrated

• In past - modelling efforts were either <u>sector based or media specific</u> (e.g., land, air, water and biodiversity).

They lacked the ability to consider how these landscape components interact with each other.

The Problem


Climate Change
Lost?
Integration?
Air Modelling
Socio-Economic
Surface Water Quantity
Surface Water Quality
Ground Water Quantity
Ground Water Quality
Bio-diversity Modelling
Land Modelling

Isolated (sector or media based) vs. Integrated

•CEMS Approach – ESRD/GOA is moving towards Cumulative Effect Management (CEM).

One of the critical aspect to moving toward CEM is to create an **integrated, versatile multi-media environmental modelling system**, which can also encompass climate change adaptation to support policy and decision making. (plus linkages with, **socio-economics and energy** side of modelling).

The Solution

Integrated Modelling System

Alberta

Common understanding is important

What does it mean by IEM?

Integrated environmental modeling, often requires to integrate (spatial) data and computational models from a variety of disciplines (e.g., related to physical, biotic, social, and economic environments) and at different scales, to understand and to solve complex societal problems that arise from the interaction of humans and environment, and to contribute in this way to establishing the foundation of sustainable development, to inform policy and to support decision-making.

(Rothman, 1997, Parker, 2002)

•Parker, P., et al., Progress in Integrated Assessment and Modelling. *Environmental Modelling & Software*, 3(17): 209–217, 2002.

•Rothman, Dale S., Robinson, John B., Growing Pains: A Conceptual Framework for Considering Integrated Assessments. *Environmental Monitoring and Assessment*, 46(1): 23–43, 1997.

- No single agency or model has the capability to address complex interdisciplinary environmental issues (e.g., cumulative effects management, climate change, etc.)

- Collaborative approaches are required to pool resources and provide consistent direction, while allowing flexibility to address different issues.

(Integrated) Environmental Modelling – Models & Modelers

A collaborative teamwork

- Integration efforts – some examples

ESRD/GOA Modelling Context

Increased reliance on models (modelling) to support CEMS, LUF-regional plans, evaluation & reporting, operations (approval & compliance), emergency management and other ESRD strategies including policy development and environmental monitoring.

•Why do we do modelling? (regulatory perspective)

- is a proven way of providing decision support to performance-driven, outcome based processes.
  - To diagnose and examine causes and precursor conditions of events that have taken place
  - To forecast outcomes and future events
- Modelling informs policy (MIP)
- Modelling compliments monitoring (MCM)
- Modelling ~ a proven tool for evaluation and reporting

Modelling use in ESRD

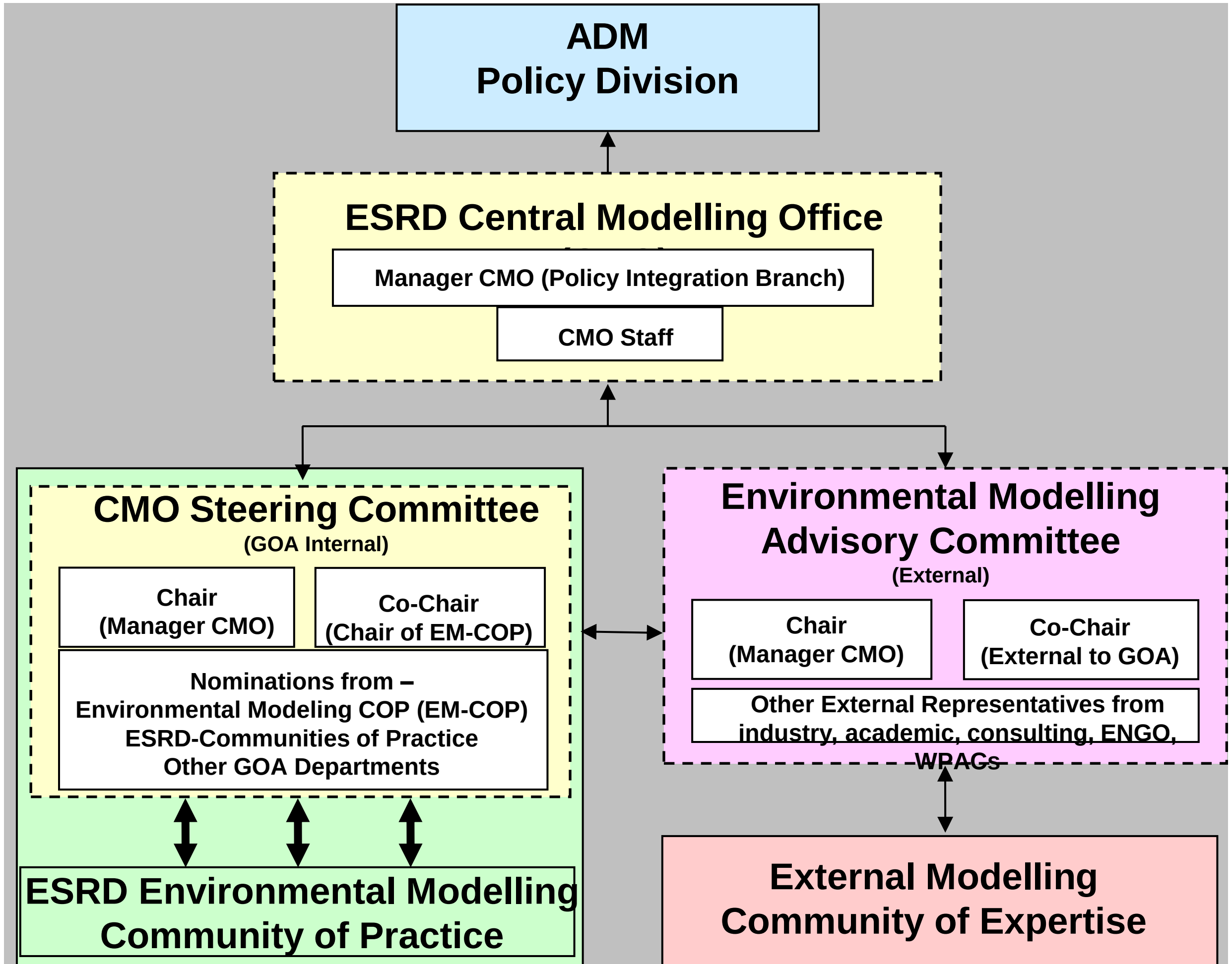
- Policy – development and analysis (what if)
- Regulatory decision making (approval, licensing etc.)
- Implementation applications (enforcement, compliance etc)
- Emergency management
- Routine operations – water supply, dam operations, effluent discharge, emissions,
- Planning
- Monitoring (compliments)
- Cumulative effects (of multiple projects/activities and/or across various media)
- Performance indicator – identify, triggers/limits
- E&R - Performance evaluation of management practices
- Predictions – short term and long term

ESRD Modelling Capacity

- Land Use Modeler
- Surface Water Modelers/Hydrologist
- Water Allocation Modelers
- Water Quality Modeler/Limnologists
- GW Modelers/Hydrogeologists – quantity & quality
- Air Quality Modelers
- Riparian Modelers
- Bio-diversity Modelers
- Forest Management
- Forest Fire
- Wildlife

Opportunities brings Challenges

CMO Structure



COP: Communities of Practice
ENGO: Environmental Non Government Organizations;
WPAC: Watershed Planning Advisory Committees

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Pro-active Approach

Role of CMO in Enhancing/supporting Modelling Work at ESRD

- Coordination (oversight, guidance and support)

- Provide assurance to stakeholders (internal & external) that ESRD modelling adheres to standard guidelines and criteria and is done in a cumulative effects based manner with acceptable science rigour, credibility and transparency that is sustainable in the long term.

- Promote a cumulative effects based approach to modelling where strategic/regional and multi-media modelling efforts are integrated to best achieve environmental management objectives.
- Assess departmental modelling needs, funding priorities and resourcing needs and champion those needs on behalf of ESRD modelling community.
- Promote collaboration and information exchange between model developers and users.
- Promote Integration of socio-economic, energy and climate change modelling with environmental modelling.

What is being done by CMO?

- Alberta Modelling Guidelines – best modelling practices (BMP), standards, criteria, protocols...
- Evaluation of Modelling Tools
- Modelling Expert System
- Modeling Toolbox
- Centralized Modelling Repository
- Modelling Capacity - Computing Centre – high end hardware, software & version mgt
- Centralized Modeling Data Warehouse
- Annual/Bi-annual Environmental Modelling Workshops
- CMO - Steering Committee (GOA wide – internal): Charter
- CMO - Environmental Modelling Advisory Committee (External – include all sectors)
- Integrating socio-economic,energy and climate change modelling
- Modelling Center of Excellence

Strategic Modelling (RSA)

- energy flow / development scenarios
- policy cost / benefit
- climate change / GHG emission scenarios
- human health risk
- others

Strategic / Spatial Integration

(Vertical Integration)

Enablers

-communication

-collaboration

Regional / Operational Modelling

Water

Surface Water

-quality / quantity
-Infrastructure/storage feasibility
-scenario / policy assessment
-Risk assessment (License approvals/transfers)
-EIA decision support
-others

Groundwater

-impact studies
-infrastructure / storage
-SW/GW interaction
-EOR support
-others

Air

- regional plan support (airsheds)
- NOx/Sox
- acid deposition
- PM & Ozone (target loads/ management framework/ emission caps)
- AAAQ
- evacuation zones
- others

Land & Biodiversity

-climate change / reclamation
-biodiversity risk
-Acid Deposition Management Framework support
-others

Multimedia Integration

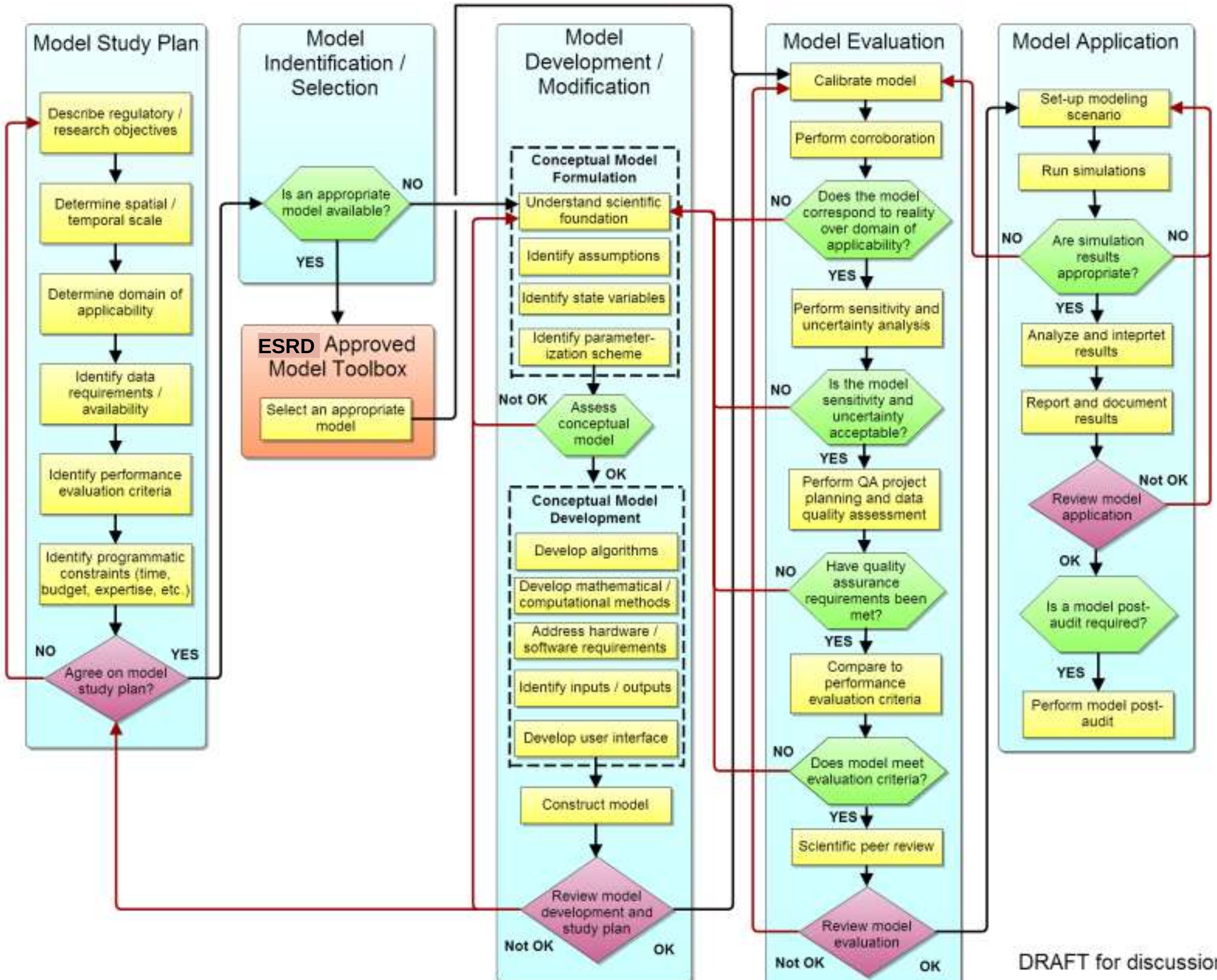
(Horizontal Integration)

Enablers

-research
-expert network
-collaboration
-common data

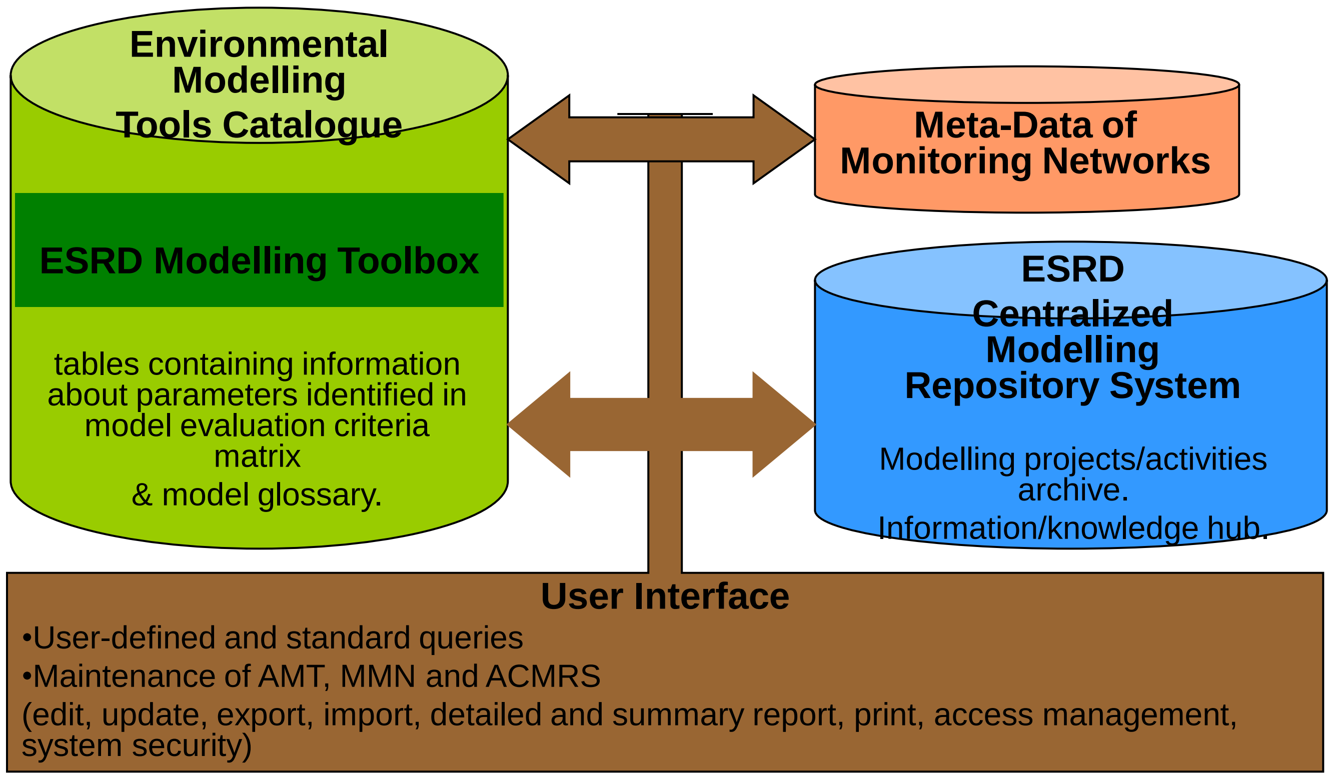
Model Integration

ESRD **Modelling Process**

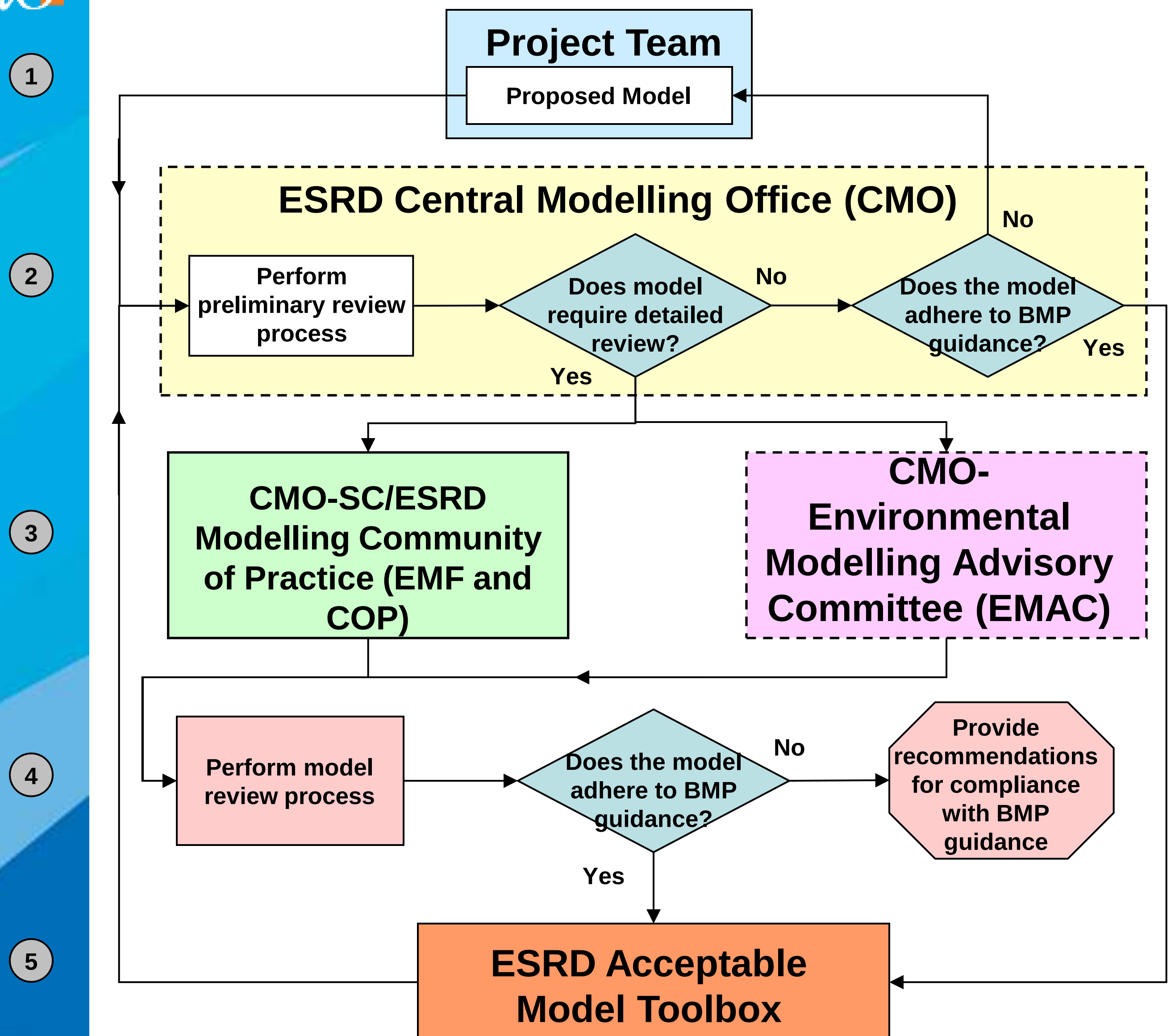


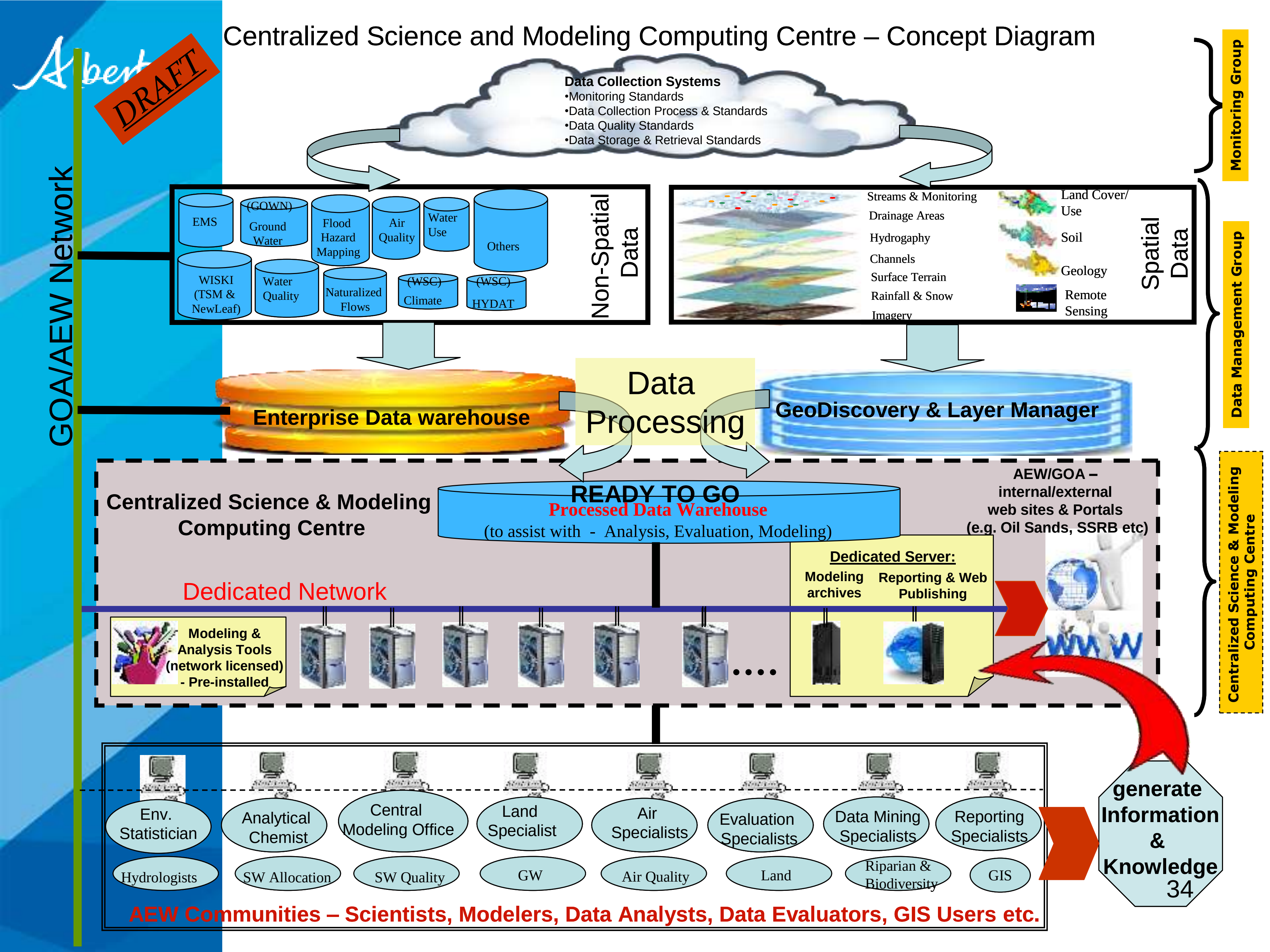
•ESRD Modelling Expert System (EMES)

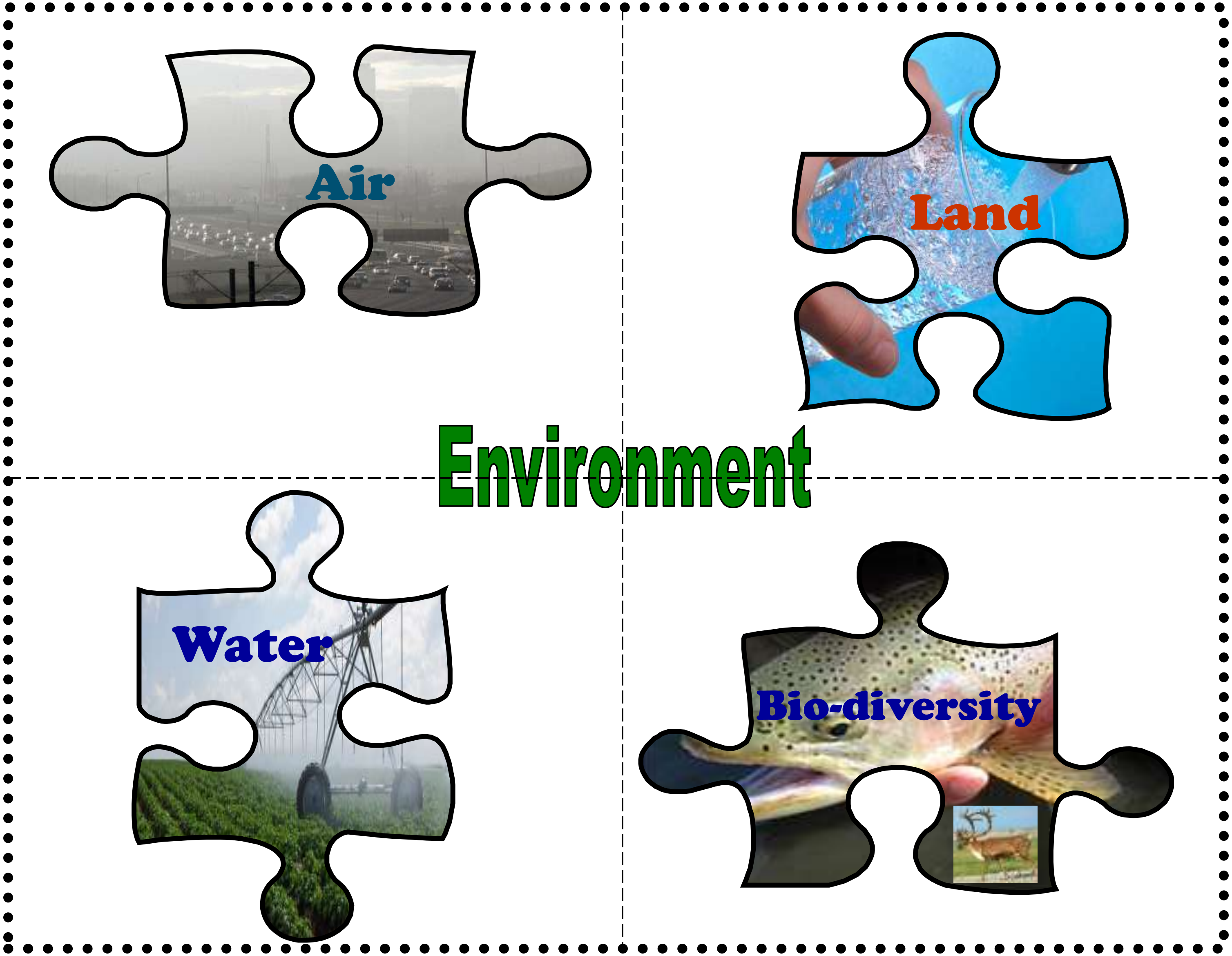
•Concept Diagram



ESRD Model Approval Process




Centralized Science and Modeling Computing Centre – Concept Diagram
Alberta
DRAFT
GOA/AEW Network
Monitoring Group
Data Management Group
Centralized Science & Modeling Computing Centre
Data Collection Systems
•Monitoring Standards
•Data Collection Process & Standards
•Data Quality Standards
•Data Storage & Retrieval Standards
EMS
(GOWN) Ground Water
Flood Hazard Mapping
Air Quality
Water Use
Others
WISKI (TSM & NewLeaf)
Water Quality
Naturalized Flows
(WSC) Climate
(WSC) HYDAT
Non-Spatial Data
Streams & Monitoring
Drainage Areas
Hydrography
Channels
Surface Terrain
Rainfall & Snow
Imagery
Land Cover/ Use
Soil
Geology
Remote Sensing
Spatial Data
Enterprise Data warehouse
Data Processing
GeoDiscovery & Layer Manager
Centralized Science & Modeling Computing Centre
READY TO GO
Processed Data Warehouse
(to assist with - Analysis, Evaluation, Modeling)
AEW/GOA – internal/external web sites & Portals (e.g. Oil Sands, SSRB etc)
Dedicated Server:
Modeling archives
Reporting & Web Publishing
Dedicated Network
Modeling & Analysis Tools (network licensed) - Pre-installed
....
Env. Statistician
Analytical Chemist
Central Modeling Office
Land Specialist
Air Specialists
Evaluation Specialists
Data Mining Specialists
Reporting Specialists
Hydrologists
SW Allocation
SW Quality
GW
Air Quality
Land
Riparian & Biodiversity
GIS
AEW Communities – Scientists, Modelers, Data Analysts, Data Evaluators, GIS Users etc.
generate Information & Knowledge
34


Air
Land
Environment
Water
Bio-diversity


Land
Air
Integrated
Environment
Environmental
Water
Biodiversity
Modelling

Once upon a time, a student once went to his teacher.

He asked his teacher a question: "Sir, is there any good in talking a lot?"

The teacher replied: "Toads and frogs croak night and day,
but no one pays any attention to them.
But the cock crows at a certain time of night and wakes up everyone."

The teacher smiled at his student and said,
"This proves that no good is achieved by talking a lot.
What is important is to say the right thing at the right time.

This is the right time. **Timing can not be better!**

The province is implementing CEMS to continue the economic development while safe guarding the environment.

Modelling, indeed pays a significant role:

- In policy development
- In implementation of CEMS through Regional Plans (LUF)

Modelling Integration:

- Horizontal (across media)
- Vertical (geospatial scale)
- Social dimension
- Economics
- Energy development
- Climate Change

What is the ultimate GOAL?
What is being done?
Why?
How is being done?
Are we on right track?

If we keep on doing what we are doing >> will this take us to where we want to be?

Do we need to change/adjust or align the things?

Enhanced Collaboration? What does it mean? How?

Develop a road map!

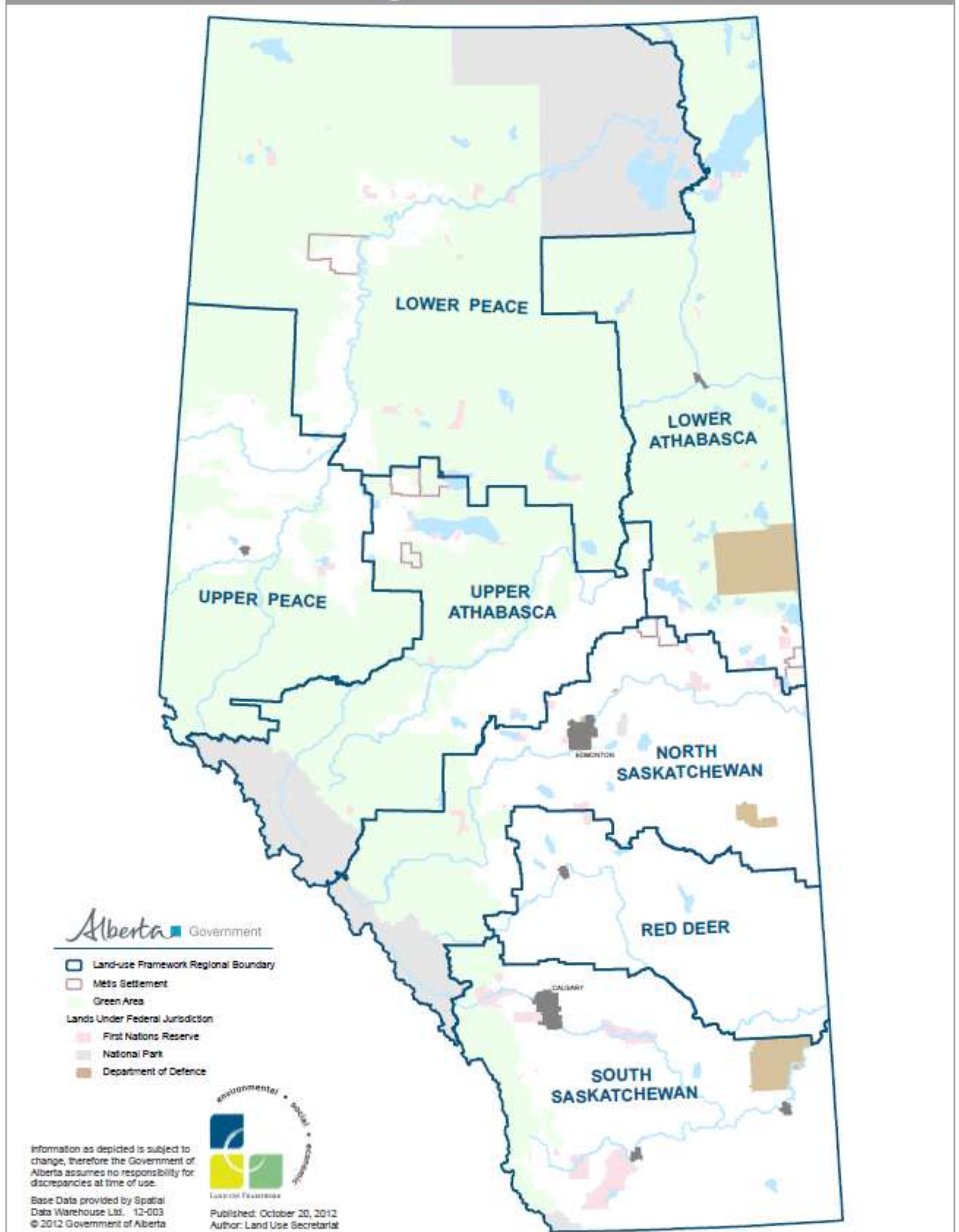
Workshop provides opportunity to showcase current practices and expand you understanding related to other media modelling.

I see this is the group that will **Walk the Talk**.

I have full confidence that together we can take the challenge!

The End

Alberta Land-use Framework Regions



Session 1

Day 1 – Session 1

Tim Wool – USEPA

BIOGRAPHY

Tim Wool is a National TMDL expert with the United States Environmental Protection Agency (USEPA), Region 4 office. Tim has over 25 years of experience in the development and application of water quality models. Tim has supported USEPA with the development of numeric nutrient criteria for the State of Florida. Tim has numerous experiences in developing and reviewing TMDLs for bacteria, nutrients, metals, dissolved oxygen, and mercury.

Day 1 – Session 1

Tim Wool – USEPA

ABSTRACT

This presentation will focus on the use and utility of using mechanistic models for making water quality management decisions. The strengths and weaknesses of using mechanistic models to make water quality management decisions will be presented. An overview of the Water Quality Analysis Simulation Program (WASP) will be given, high lighting the advantages of using a dynamic model. A modelling scenario will be given where a suite of mechanistic models were used to make a TMDL decision.

The Use of Mechanistic Models for Water Quality Management

Tim A. Wool
US EPA – Region 4
Atlanta, GA

Utility of Mechanistic Models

- Simplistic Representation of Reality
  - Cannot Simulate "Everything"
  - All Models are Wrong . . . .
- Interpolate
  - Known and Unknown
- Provides Linkage between
  - Loads and Response Variables
  - Can Determine Important Processes
    - Nutrients/DO/Algae/Light
- Management Strategies
  - Determine Load Reductions to meet WQS
    - Never to Exceed
    - X% Exceedence
    - Duration, Frequency and Magnitude
  - Evaluate Best Management Practices

Mechanistic Models

- Mathematical models based on fundamental equations that produce physical responses to temporal and spatial inputs
- Process-based, time-variable representation of processes
  - Watershed – rainfall/runoff, topography, land use, infiltration
  - Hydrodynamics - circulation, transport, deposition
  - Water Quality – algal growth/death, decay, nitrification, SOD
- Both graphical comparisons and statistical tests are required in model calibration and validation

Types of Mechanistic Models

- Landscape/Loading models
  - Runoff of water and dissolved materials on and through the land surface
  - Erosion of sediment and associated constituents from the land surface
- Receiving water models
  - Flow of water through streams and into lakes and estuaries
  - Transport, deposition, and transformation in receiving waters
- Linked models
  - Combination of landscape and receiving water models

Mechanistic Models -- Linked

Input — **Algorithms** — **Output**

Input

Time series
Meteorology
Streamflow
WQ sampling

Spatial/Landscape
Soils
Topography
Land cover
Pollutant characteristics

Receiving Waters
Physical data
Kinetics data
Fate & transport

Algorithms

Landscape/ Watershed Models
Hydrology
Buildup
Washoff
Erosion
Overland transport
Fate & transport

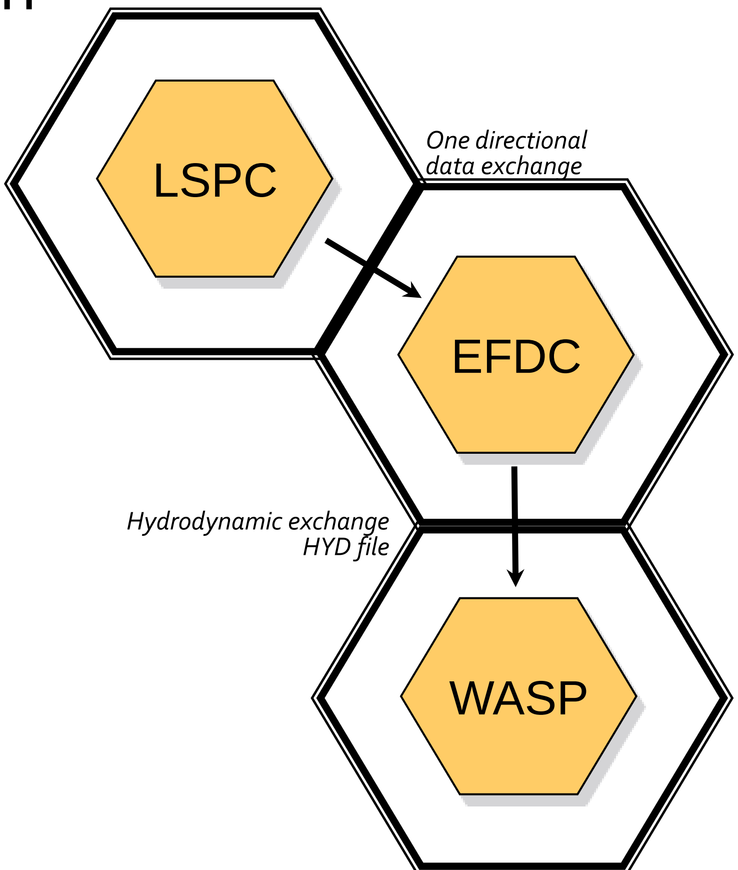
Receiving Water Models
Hydraulics
Hydrodynamics
Fate & transport
Scour & deposition
Chemical interactions

Output

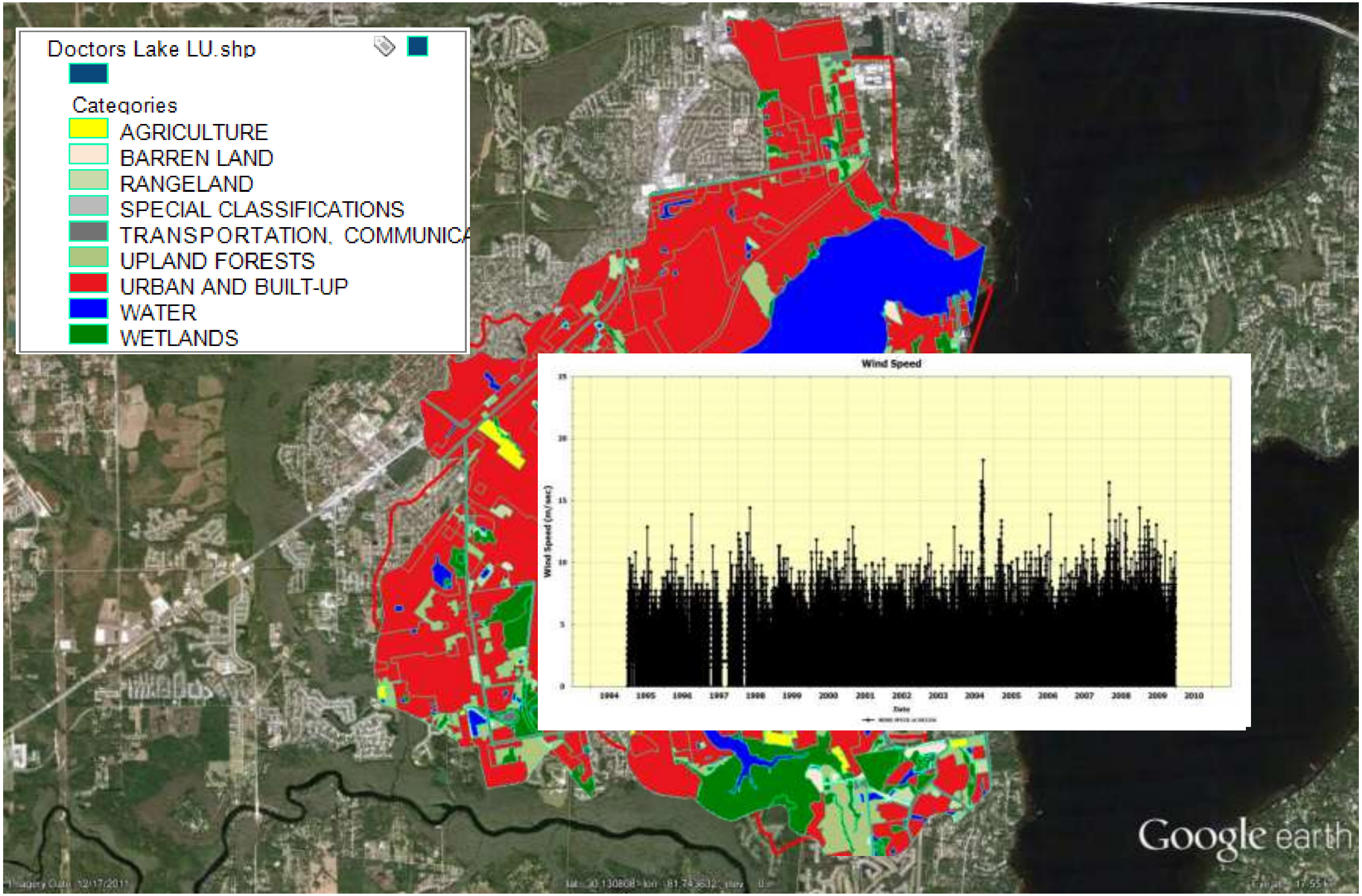
Time series
Summary statistics
% change/Improvement
Violations
Classification maps
Impact maps

Mechanistic Models -- Linked

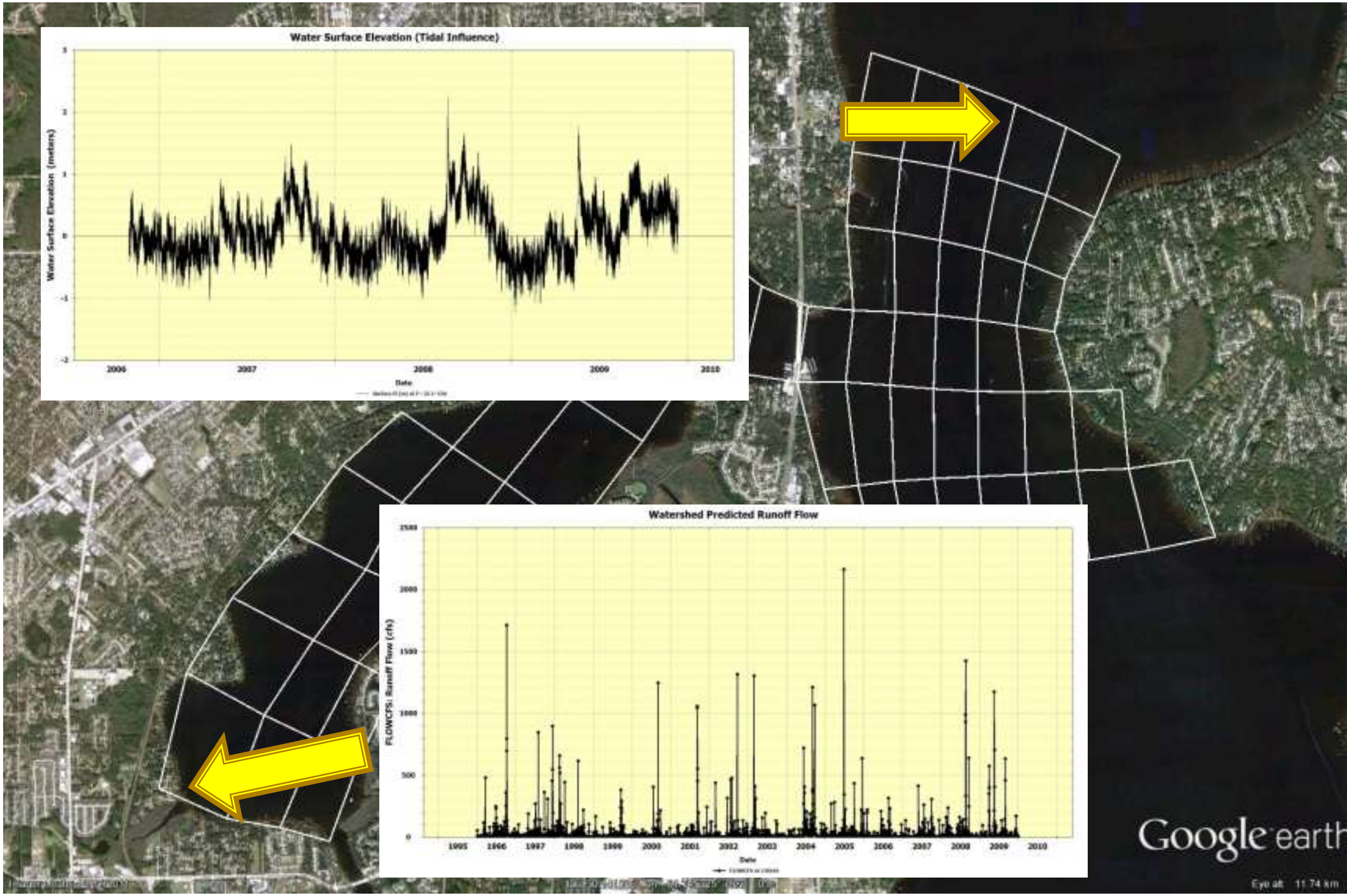
- LSPC – Loading Simulation Program C++
  - Simulates watershed loadings delivered to the estuary
- EFDC – Environmental Fluid Dynamics Code
  - Simulates the hydrodynamics within the estuary
- WASP – Water Quality Analysis Simulation Program
  - Simulates the water quality response within the estuary



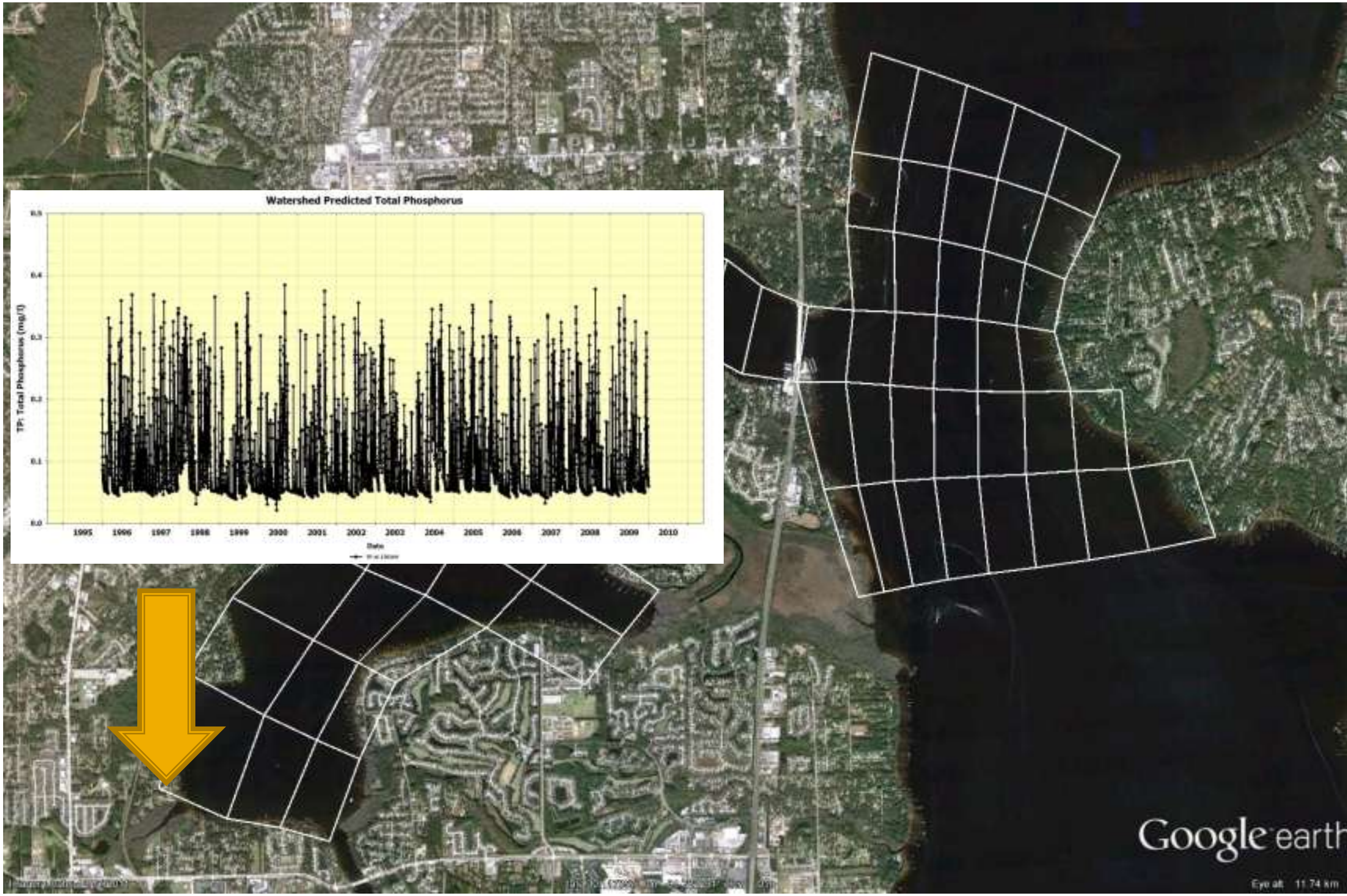
Example of Linked Models


Doctors Lake LU.shp
Categories
AGRICULTURE
BARREN LAND
RANGELAND
SPECIAL CLASSIFICATIONS
TRANSPORTATION, COMMUNICA
UPLAND FORESTS
URBAN AND BUILT-UP
WATER
WETLANDS
Wind Speed
Wind Speed (m/sec)
1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Date
Google earth

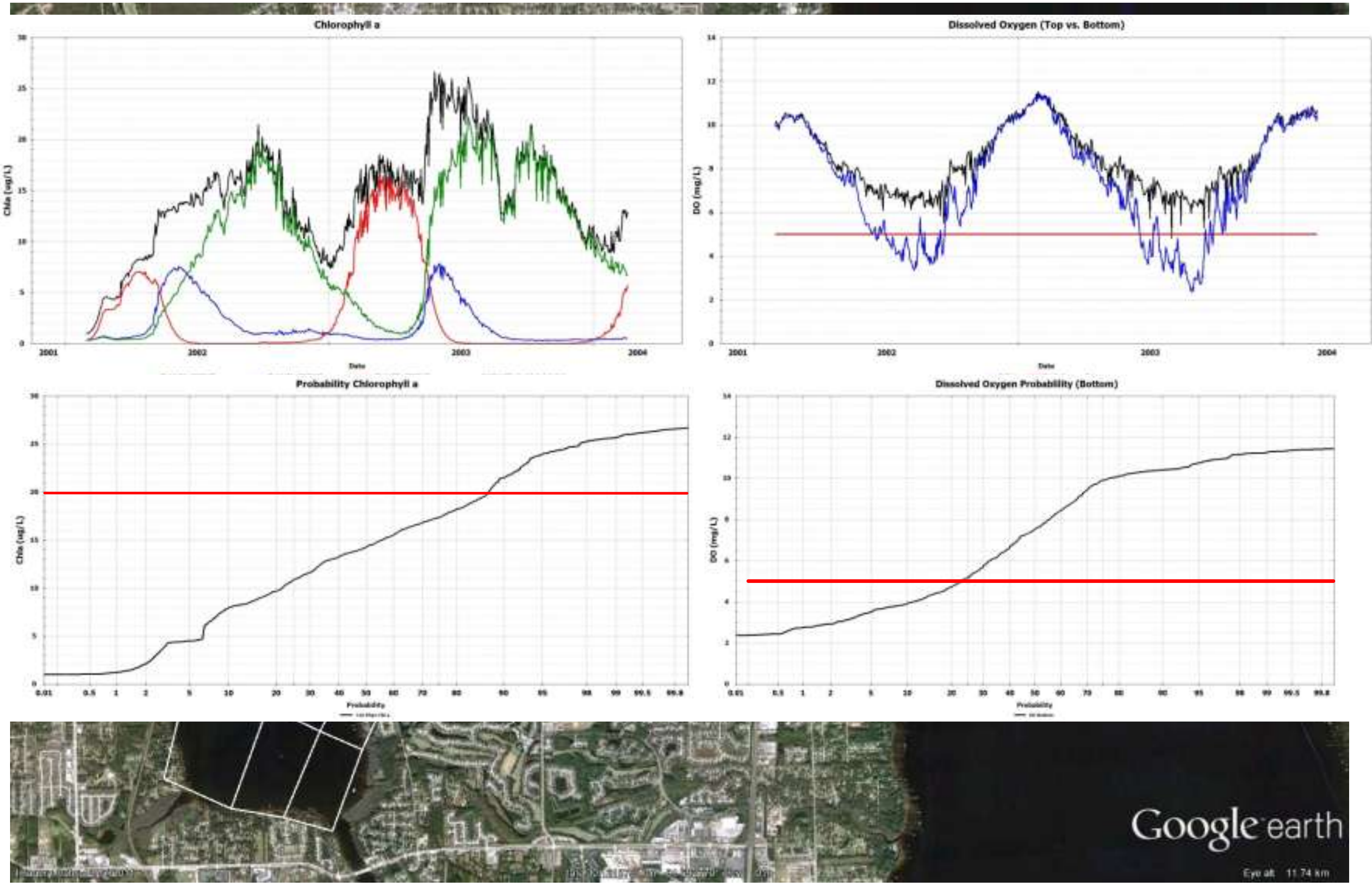
3 Dimensional Hydrodynamic Model



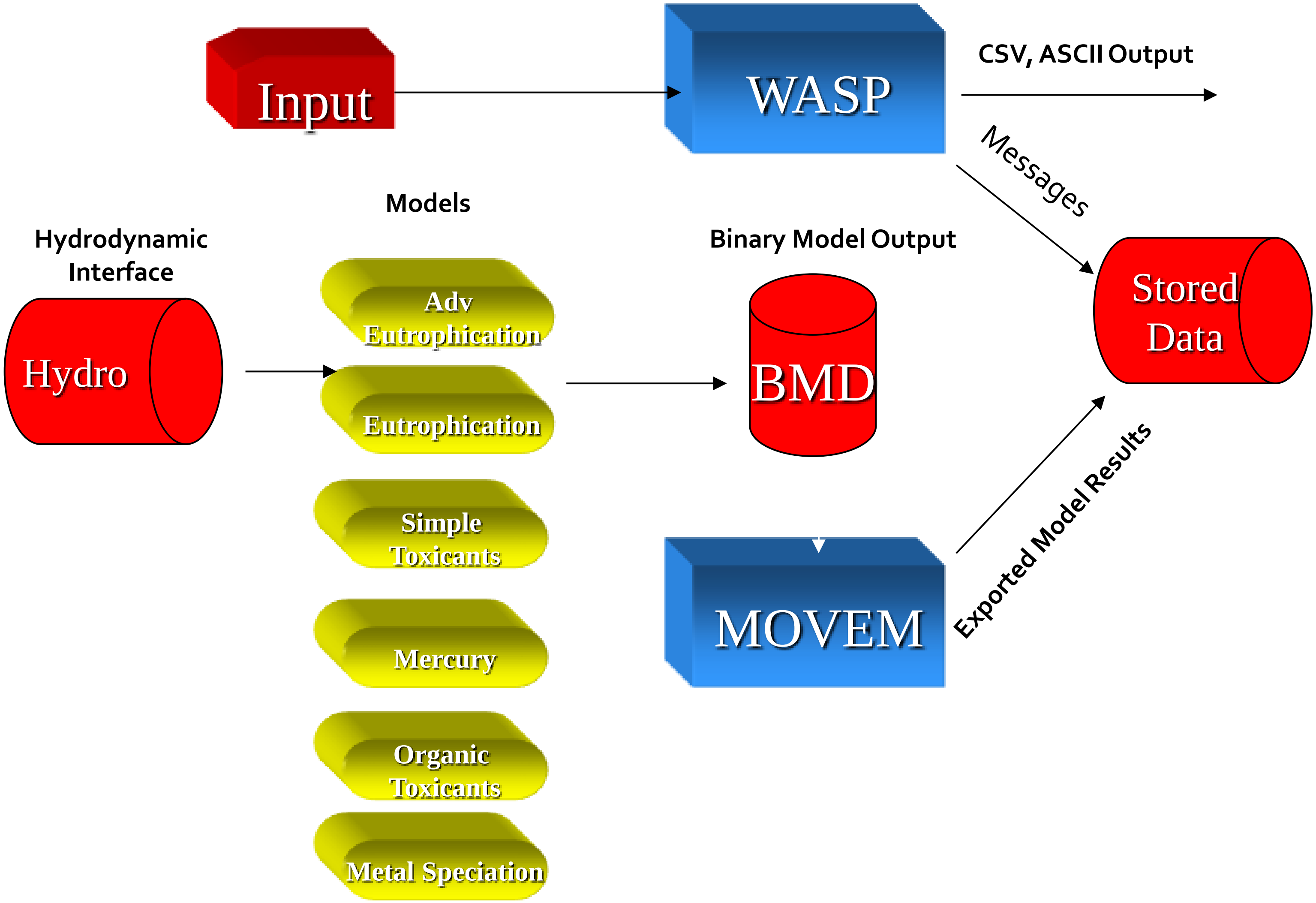
Water Quality Model



Water Quality Model

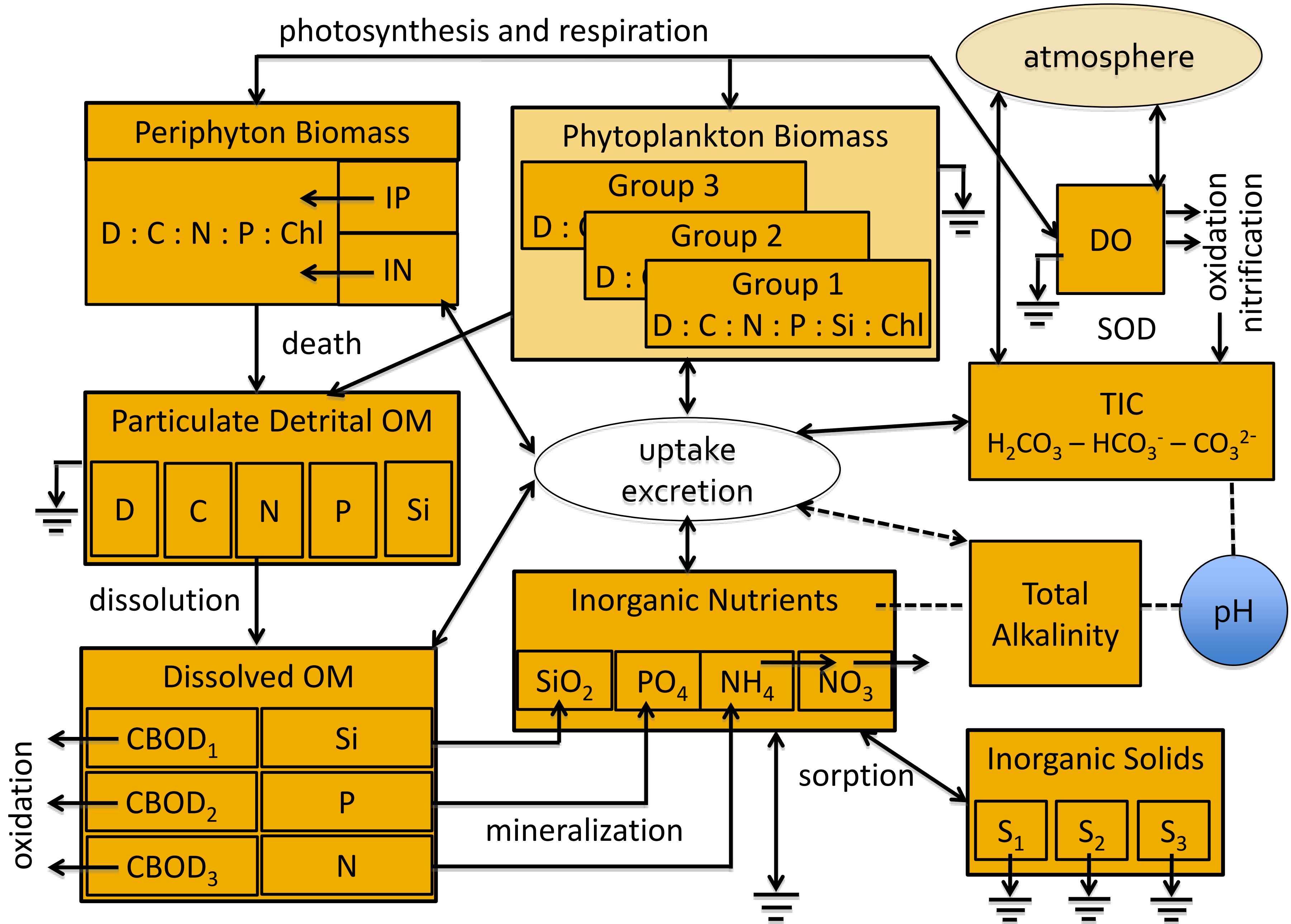


WASP Modeling Framework



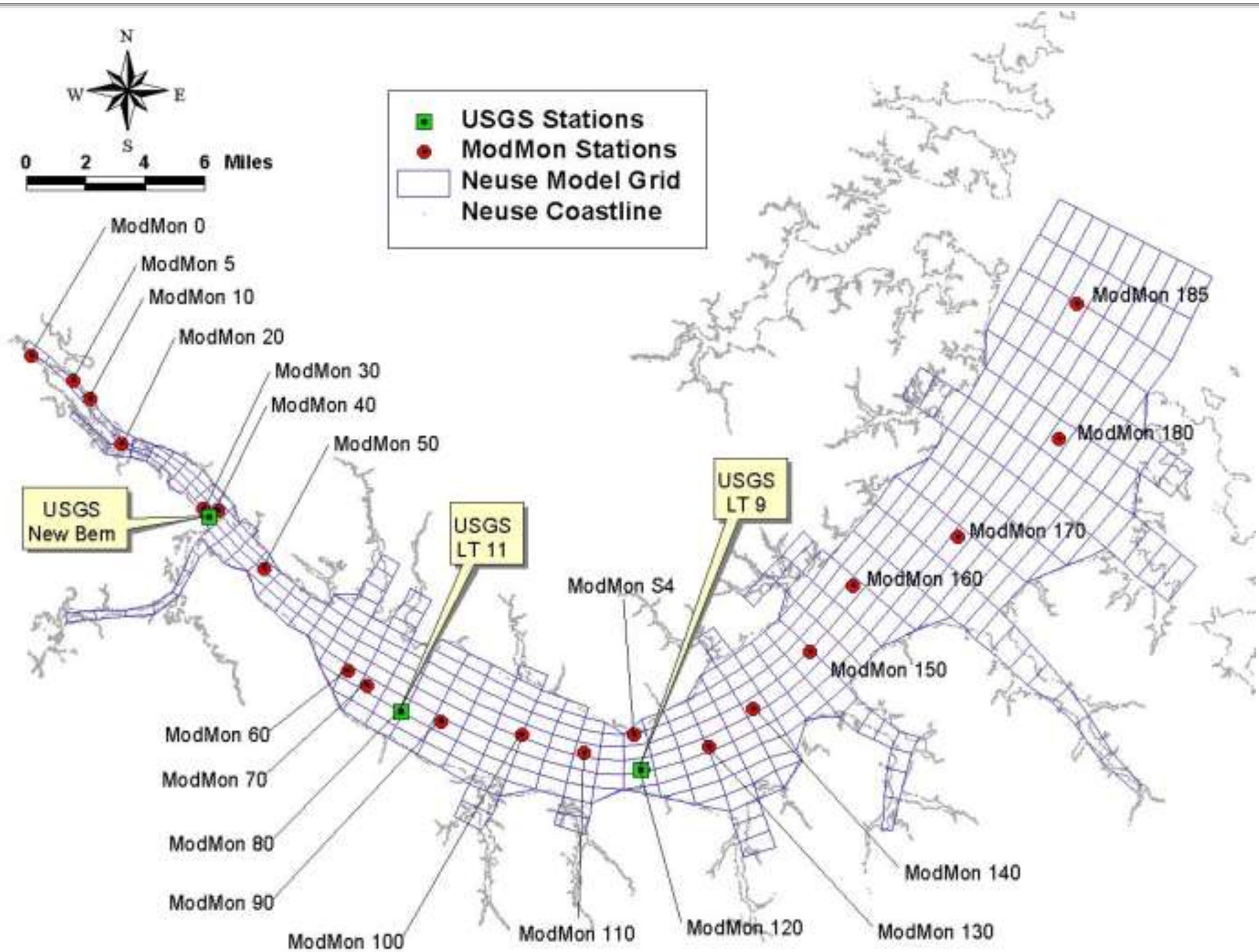
Conventional Water Quality

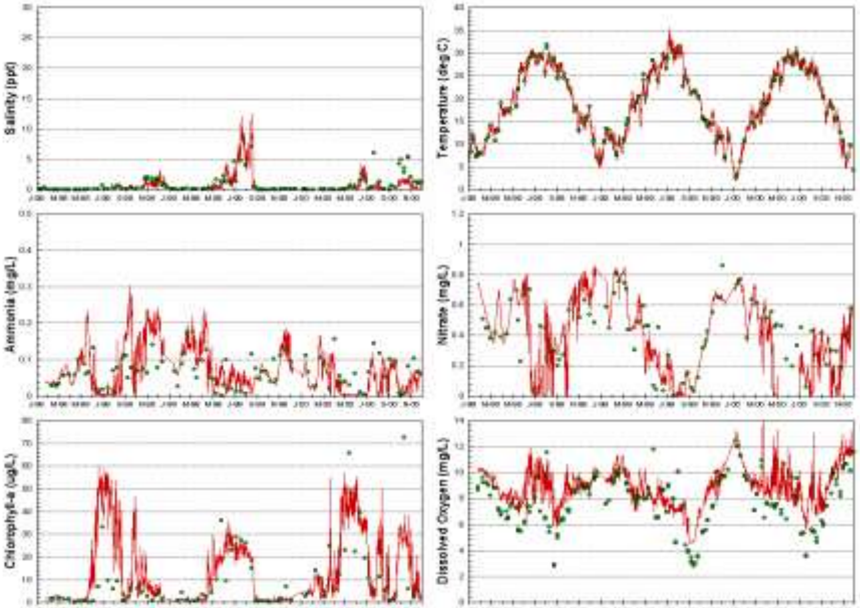
- Important Processes
  - Nutrient Dynamics
    - Nitrogen (Ammonia, Nitrate, DON, PON)
    - Phosphorus (Orthophosphate, DOP, POP)
    - Silica (Dissolved, Particulate)
  - Algal Dynamics
    - Multiple Algal Groups (Green, Blue Green, Diatoms)
    - Light (Algal Self Shading, DOC, TSS)
  - Dissolved Oxygen Dynamics
    - Multiple BOD (Slow, Med, Fast or Biotic, Watershed, WWTP)
    - Reaeration (Wind, Hydraulic)
    - Sediment Diagenesis (Oxygen Consumption, Nutrient Fluxes)

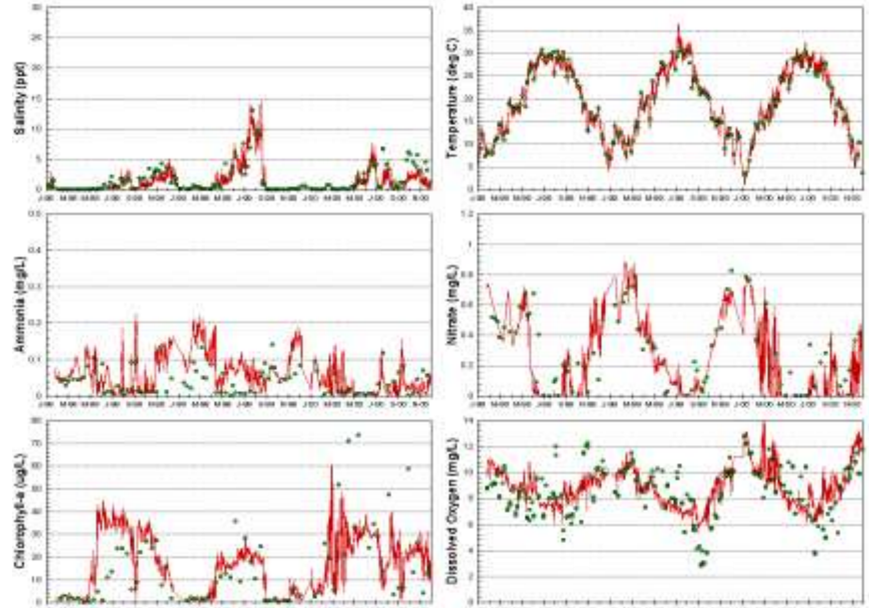


photosynthesis and respiration
atmosphere
Periphyton Biomass
IP
D : C : N : P : Chl
IN
Phytoplankton Biomass
Group 3
D : C
Group 2
D : C
Group 1
D : C : N : P : Si : Chl
DO
oxidation
nitrification
SOD
death
Particulate Detrital OM
D
C
N
P
Si
uptake
excretion
TIC
$H_2CO_3 – HCO_3^- – CO_3^{2-}$
Total
Alkalinity
pH
dissolution
Inorganic Nutrients
SiO_2
PO_4
NH_4
NO_3
Dissolved OM
$CBOD_1$
Si
$CBOD_2$
P
$CBOD_3$
N
oxidation
mineralization
sorption
Inorganic Solids
S_1
S_2
S_3

Nitrogen TMDL -- Neuse River/Estuary North Carolina




Salinity (ppt)
Temperature (deg C)
Ammonia (mg/L)
Nitrate (mg/L)
Chlorophyll-a (ug/L)
Dissolved Oxygen (mg/L)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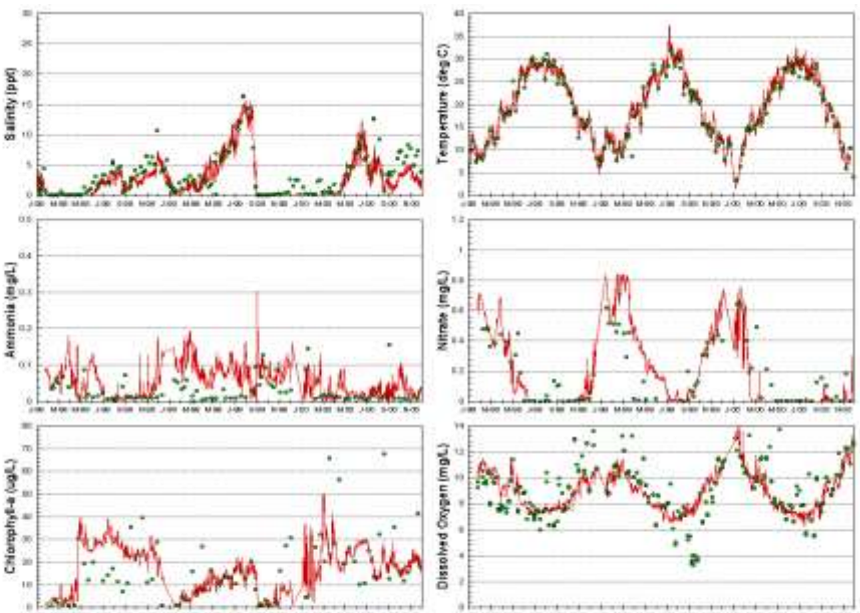
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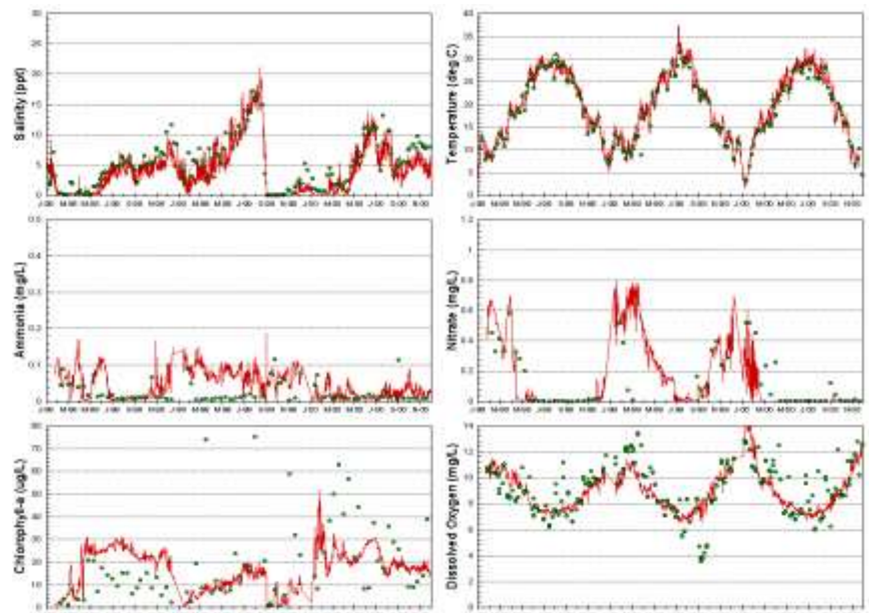
Salinity (ppt)
Temperature (deg C)
Ammonia (mg/L)
Nitrate (mg/L)
Chlorophyll-a (ug/L)
Dissolved Oxygen (mg/L)

Questions ?

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Day 1 – Session 1

Danielle Marceau – University of Calgary

BIOGRAPHY

Dr. Danielle Marceau is a professor in the Department of Geomatics Engineering at the University of Calgary and holds a Schulich Research Chair in GIS and Environmental Modelling. Her research program focuses on developing spatial simulation models, namely cellular automata (CA) and agent-based models (ABMs) to study the dynamics and interactions of natural and human systems. These models are integrated with Geomatics technologies to create intelligent computer-based information systems to guide decision making in environmental resource management. She applies her research in domains that are of particular relevance in Alberta and elsewhere in Canada: water and energy, land use and spatial planning, wildlife-human interactions, and disease propagation. Due to the interdisciplinary nature of her research, she works with scientists in different disciplines in collaboration with government agencies, industries, and non-for-profit organizations.

Day 1 – Session 1

Danielle Marceau – University of Calgary

ABSTRACT

Coupled natural/human systems are systems in which human activities interact with natural landscape components, raising complex issues of environmental resource management. To address this complexity, new modelling approaches are required to study the reciprocal interactions and feedback mechanisms that characterize these systems. Spatial simulation models such as cellular automata (CA) and agent-based models (ABMs) are increasingly used as laboratories to understand the rules that govern the interaction and evolution of these systems, and explore the future paths they can take through the testing of alternative scenarios. When combined to Geomatics technologies as components of spatial decision support systems, they become powerful tools to understand how human decisions are made, how these decisions affect the environment over which they are made, and which measures could be implemented to achieve a sustainable usage of environmental resources.
This presentation provides an overview of current research projects undertaken to address resource management issues in domains that are of high relevance in Alberta: land use and spatial planning, water and energy systems, and wildlife/human interactions including wildlife responses to human disturbances and disease propagation. Three common aspects to these projects will be highlighted: the necessity of an interdisciplinary approach, the benefits of spatial simulation models, and the importance of involving stakeholders in the modelling process.

Modeling coupled natural/human systems for environmental resource management

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Web site: www.ucalgary.ca/gcl

First Annual Environmental Modelling Workshop, CMO
University of Alberta, March 13-14, 2013

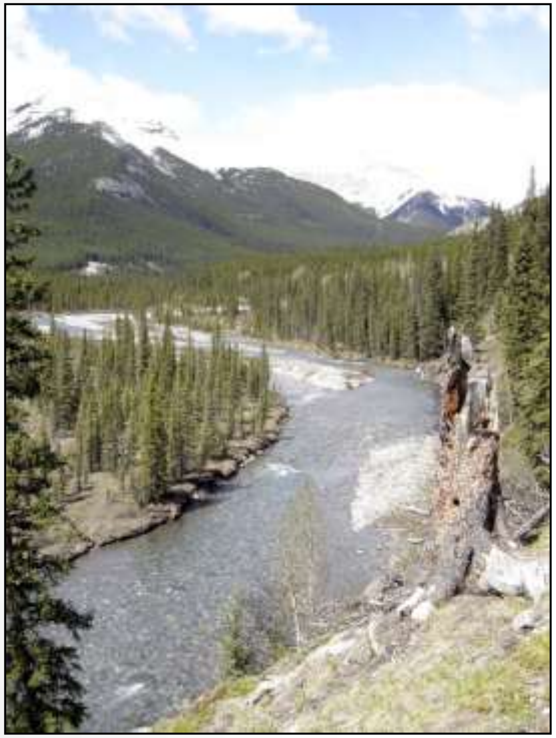
Research program objective

To develop spatial decision support systems using Geomatics technologies and simulation models to study complex coupled natural/human systems

- Coupled natural/human systems:
  - Systems in which human activities interact with natural landscape components, raising complex issues of environmental resource management

- Focus on (current projects):
  - Land-use change
  - Water resources
  - Spatial planning
  - Wildlife response to human disturbances
  - Disease propagation

The Elbow River watershed project



Dr. Danielle Marceau, Geomatics Eng., UofC

Nishad Wijesekara, Majeed Pooyandeh, Babak Farjad, Ph.D. students

Dr. Shawn Marshall, Geography, UofC

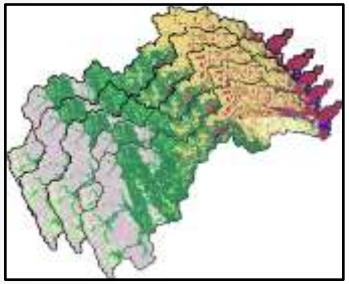
Dr. Anil Gupta, AESRD

Patrick Delaney, DHI Water and Environment, Canada

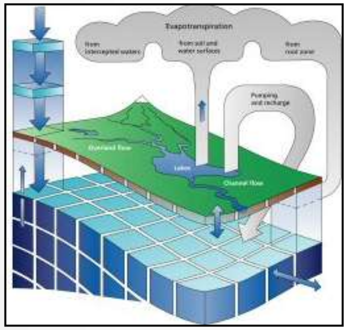
Several stakeholders

Objective

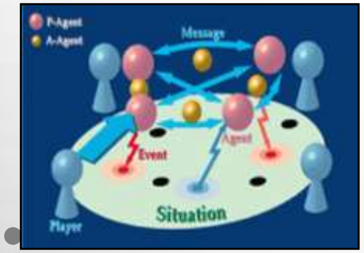
To study the impact of land-use and climate change on the hydrology of the watershed while considering the perspective of stakeholders



- This is achieved through the development of an integrated modeling system that includes:
  - A cellular automata (CA) to simulate scenarios of land-use change

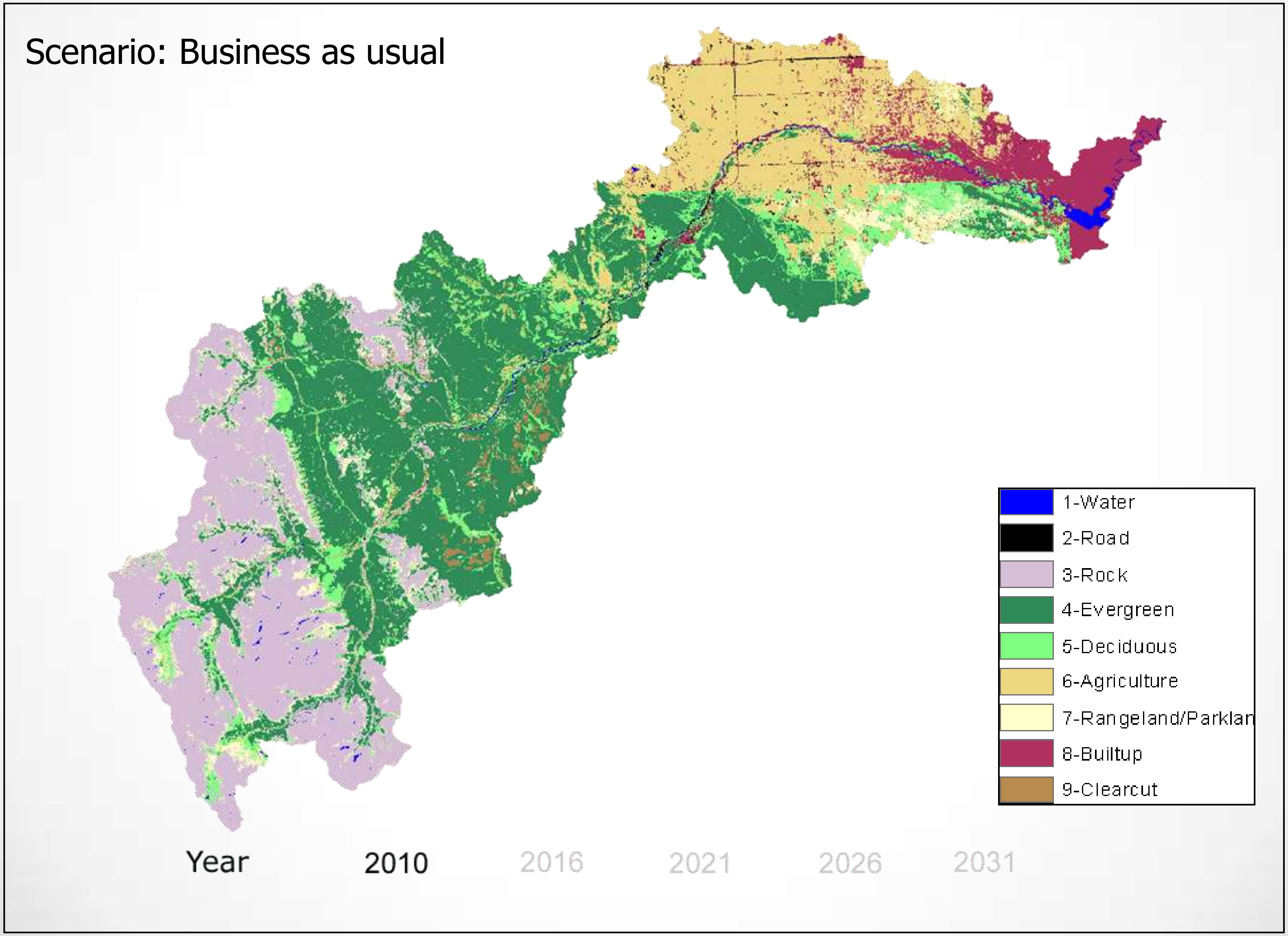


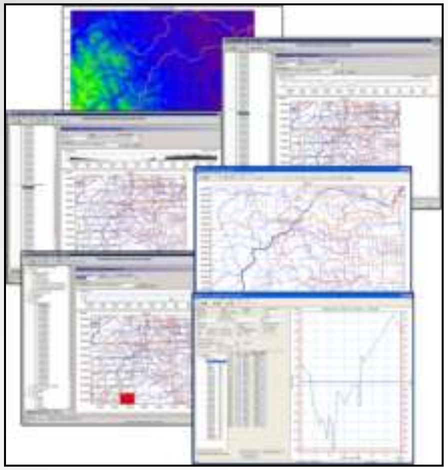
  - A spatially-distributed hydrological/climate model (MIKE SHE)



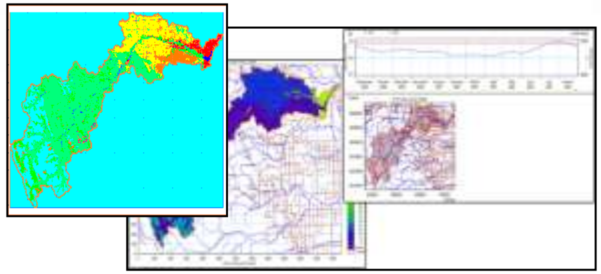
  - A web-based agent-based model (ABM) to support the negotiation of stakeholders concerned by land development and water resources

Land-use change CA modeling

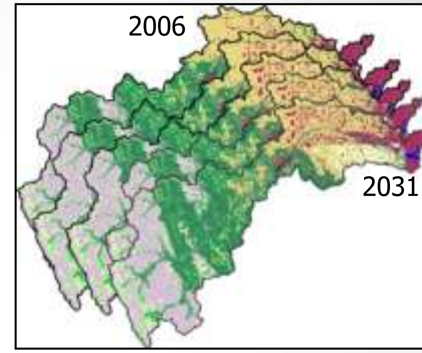




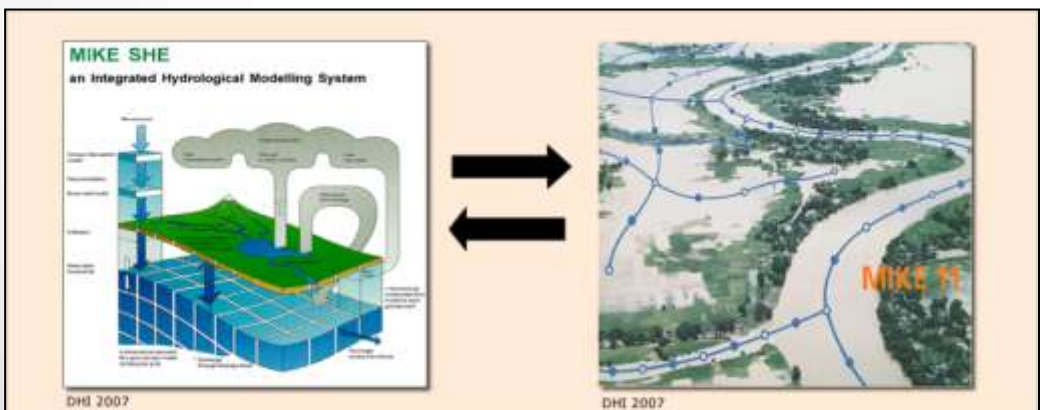
- Topography
- Climate data
- River channel data
- Ground water table

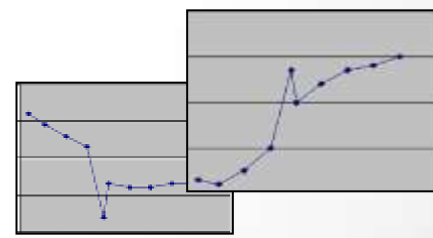


- Surface roughness
- Leaf area index
- Root depth



MIKE SHE simulations





- Total water balance
- Total overland flow
- Evapotranspiration

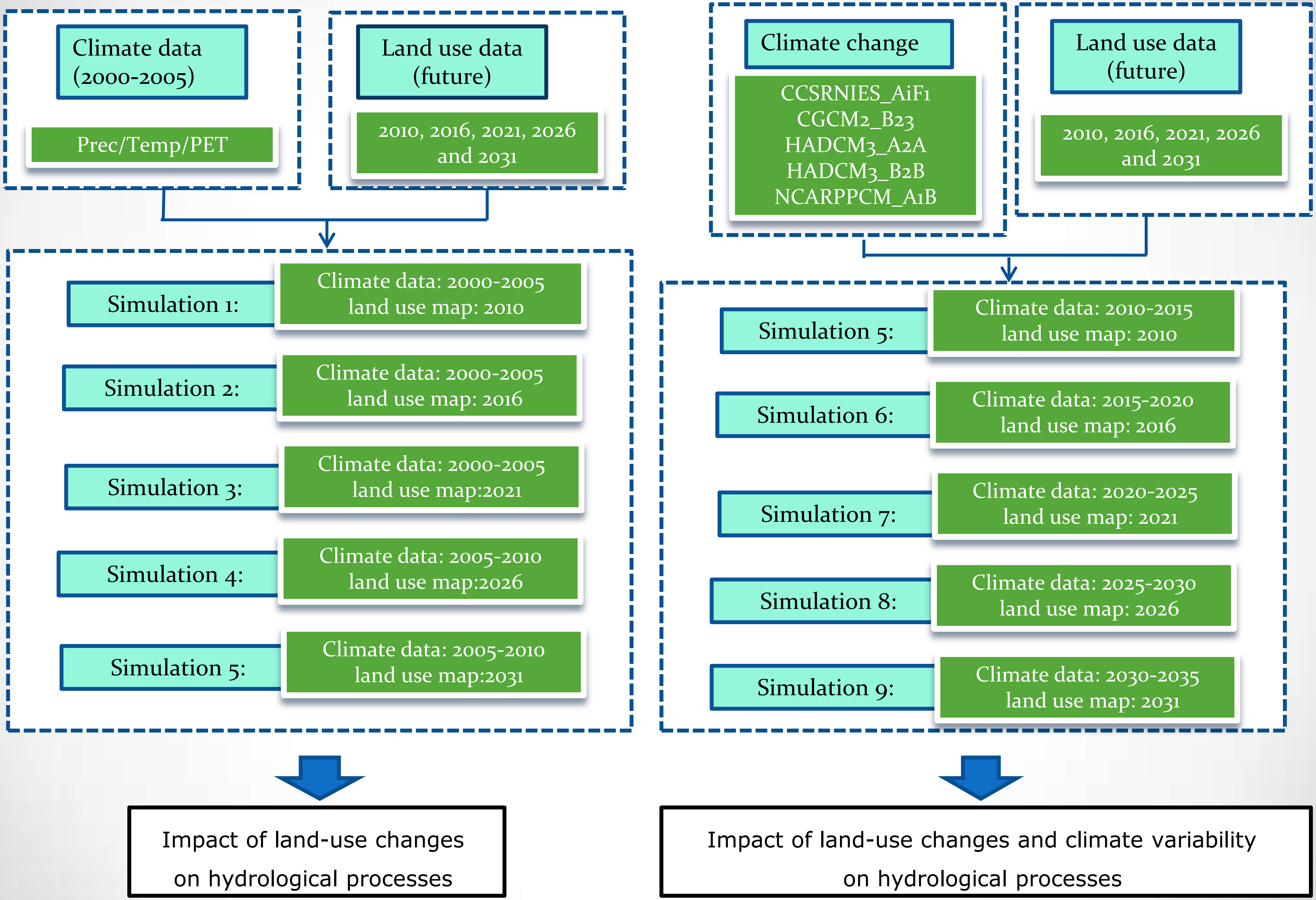
(Wijesekara and Marceau, 2012)

Impact of land-use scenarios on hydrology

Scenario	OL (mm)	BF (mm)	ET (mm)	Inf (mm)
BAU	454.0	110.0	1809.3	276.1
RV-LUC	445.4	109.9	1779.6	318.0
BC-LUC	440.3	115.7	1795.9	306.6
P-LUC	584.1	110.0	1669.4	243.3

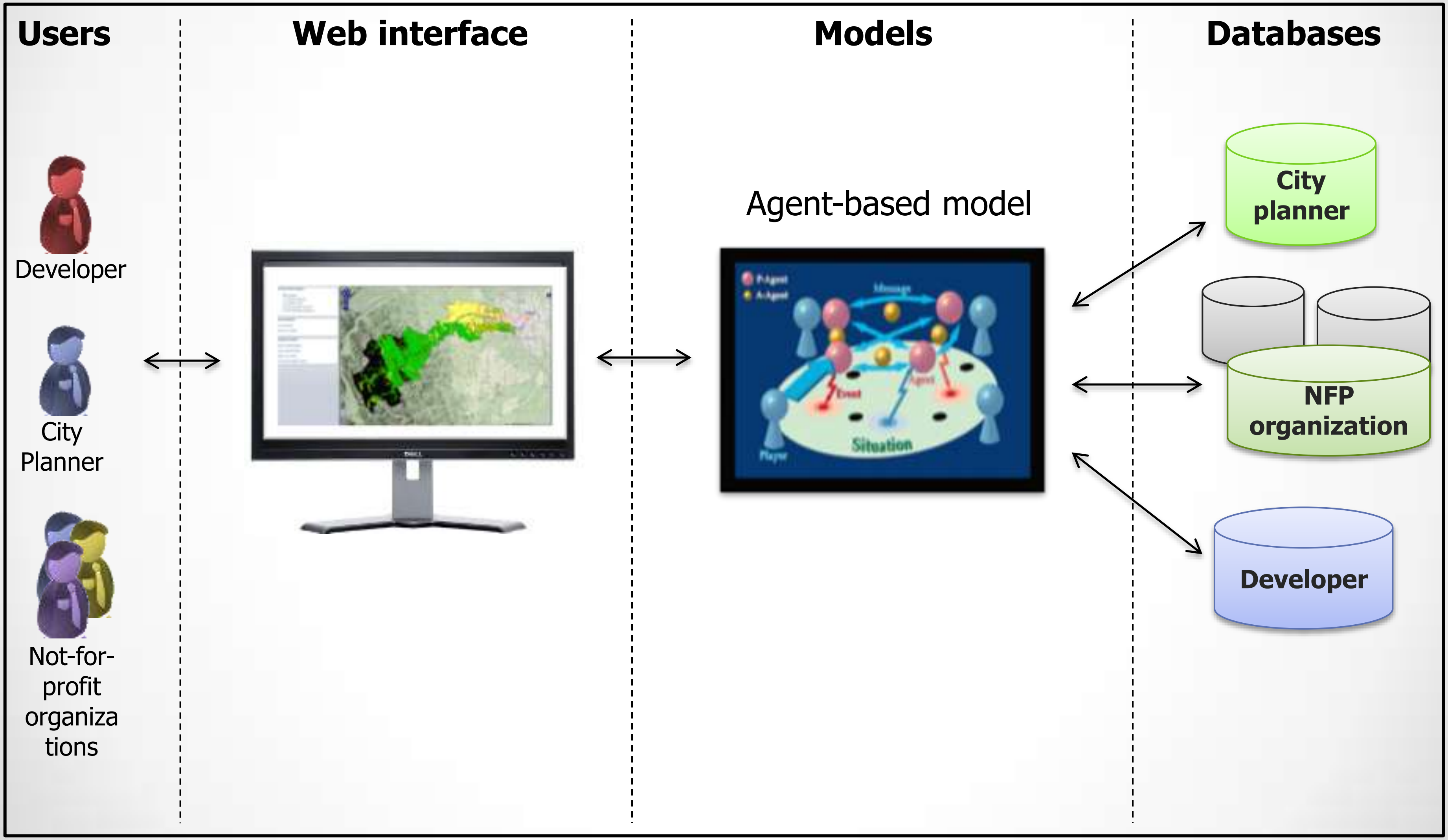
(Wijesekara et al., 2013)

- BAU: business as usual
- RV-LUC: new development concentrated in the Rocky View County
- BC-LUC: new development concentrated in Bragg Creek
- P-LUC: development based on projected population growth


Climate data (2000-2005)
Prec/Temp/PET
Land use data (future)
2010, 2016, 2021, 2026 and 2031
Simulation 1:
Climate data: 2000-2005 land use map: 2010
Simulation 2:
Climate data: 2000-2005 land use map: 2016
Simulation 3:
Climate data: 2000-2005 land use map:2021
Simulation 4:
Climate data: 2005-2010 land use map:2026
Simulation 5:
Climate data: 2005-2010 land use map:2031
Impact of land-use changes on hydrological processes
Climate change
CCSRNIES_A1F1
CGCM2_B23
HADCM3_A2A
HADCM3_B2B
NCARPPCM_A1B
Land use data (future)
2010, 2016, 2021, 2026 and 2031
Simulation 5:
Climate data: 2010-2015 land use map: 2010
Simulation 6:
Climate data: 2015-2020 land use map: 2016
Simulation 7:
Climate data: 2020-2025 land use map: 2021
Simulation 8:
Climate data: 2025-2030 land use map: 2026
Simulation 9:
Climate data: 2030-2035 land use map: 2031
Impact of land-use changes and climate variability on hydrological processes

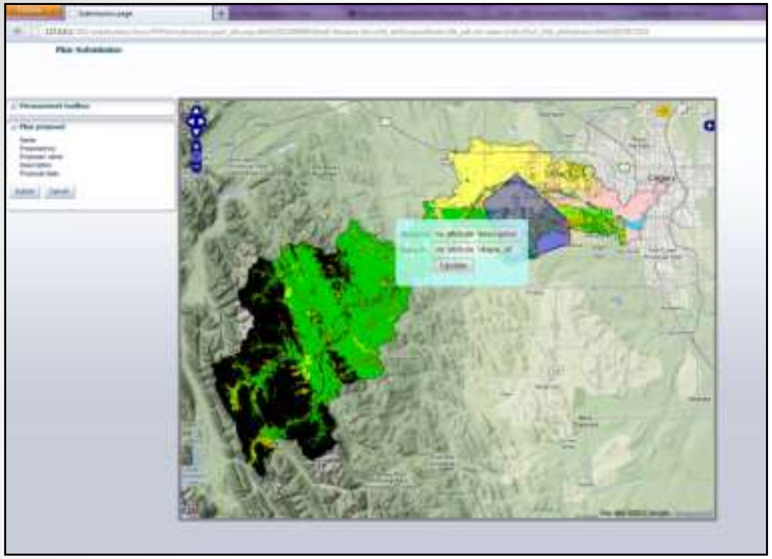
(Farjad, 2012)

Representing stakeholder' perspectives

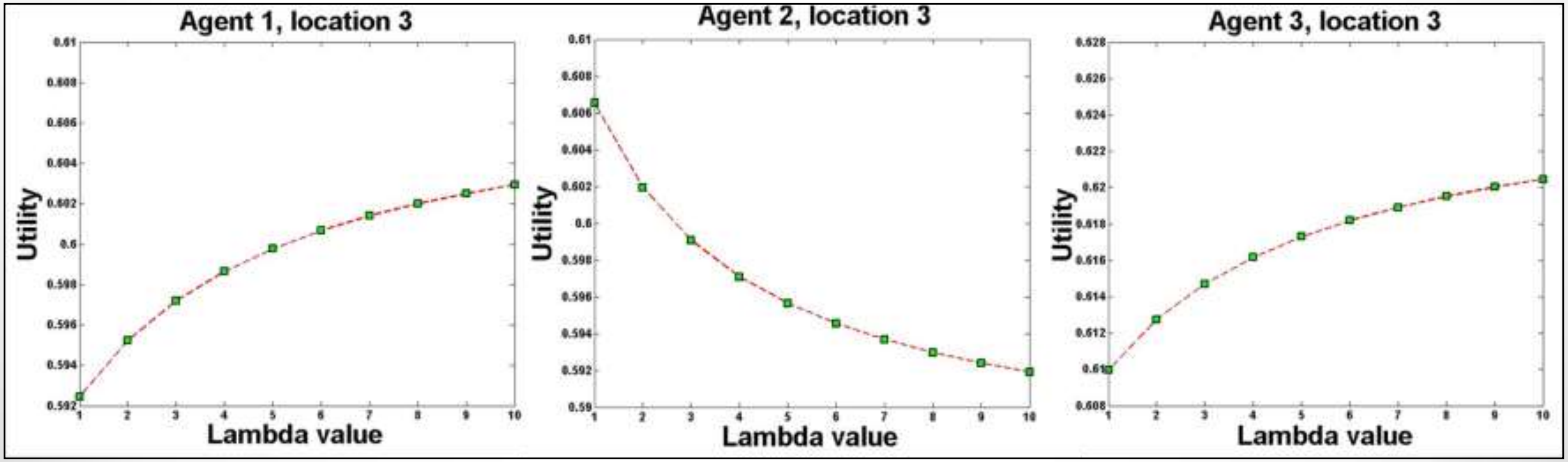


(Pooyandeh and Marceau, 2012)

Agents' negotiation

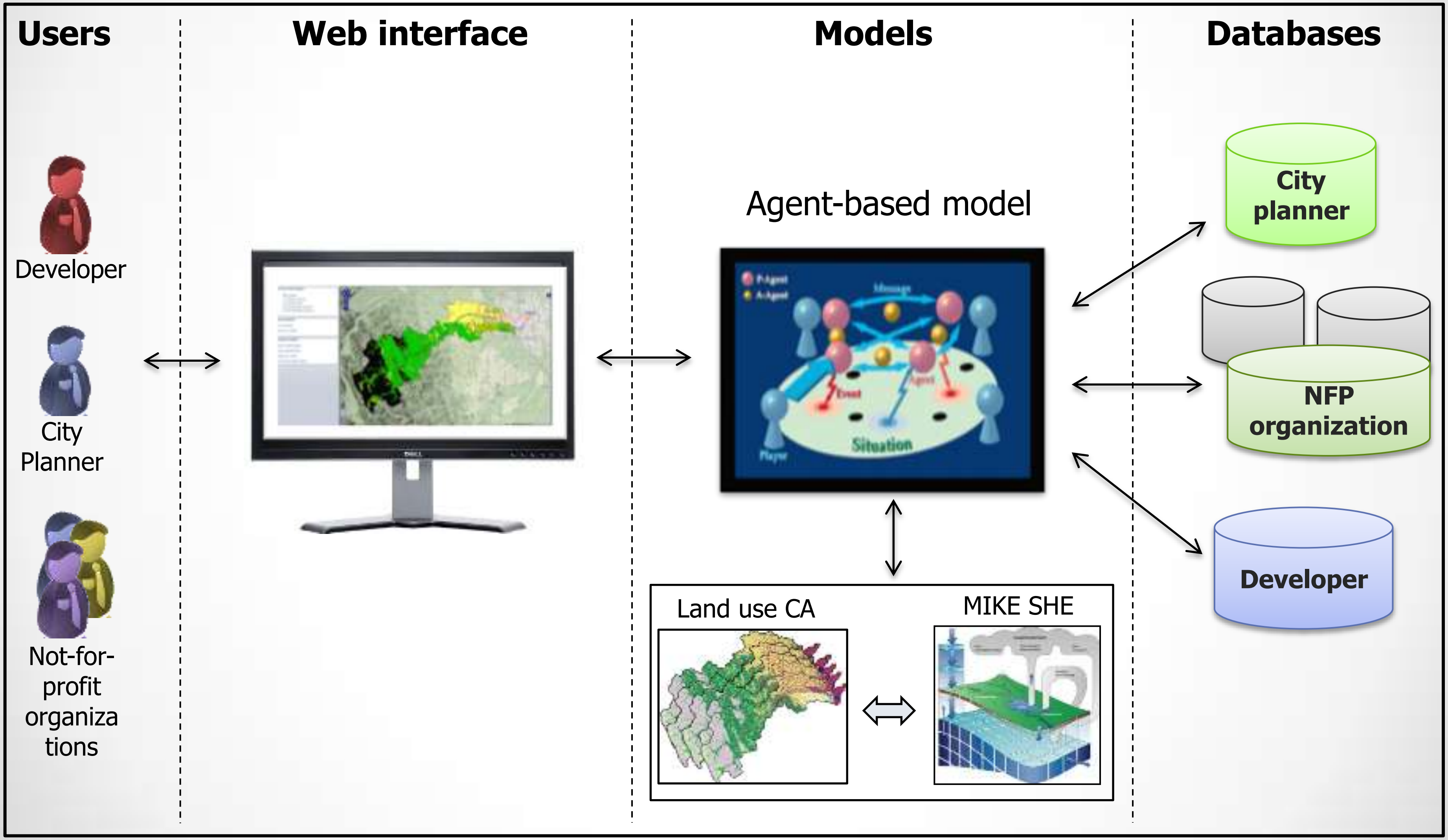


- Utility: objective (satisfaction) of the agent
- Lamba value: weights adjusted by each agent during the negotiation
- An agreement is reached when each agent is satisfied at a minimum level of 0.6



(Pooyandeh and Marceau, 2013)

Representing stakeholder' perspectives

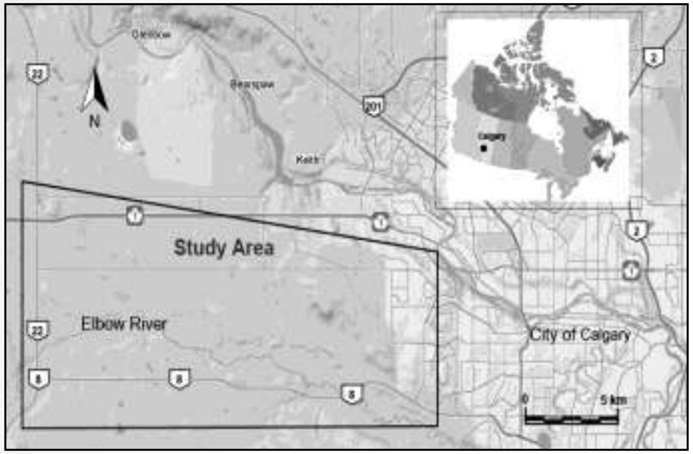


(Pooyandeh and Marceau, 2012)

Calgary/Rocky View land-use dynamics

Dr. Danielle Marceau, Geomatics Eng., UofC
Fang Wang, Ph.D. student
Colleen Sheppard, Calgary Regional Partnership
Rocky View County

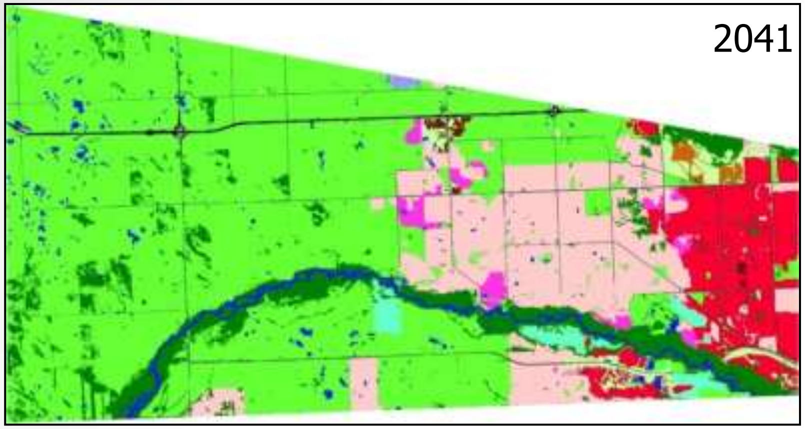
Objective and Method

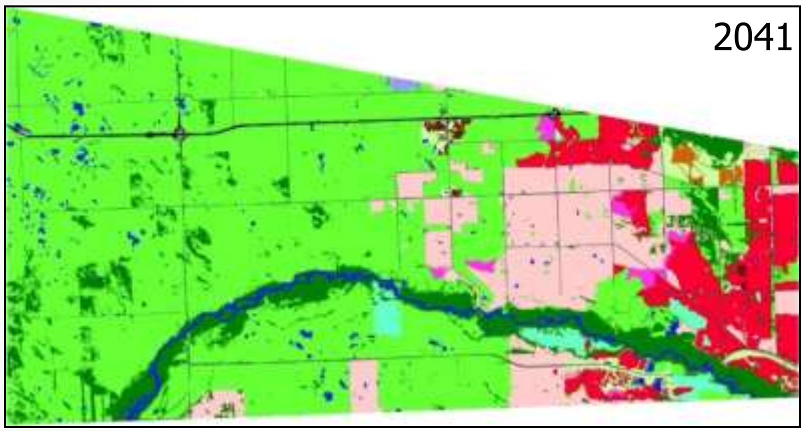


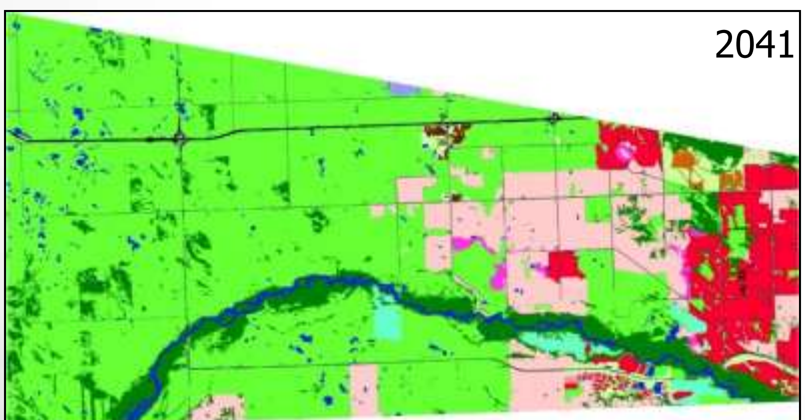
(Wang and Marceau, 2012)

- Objective:
  - To explore scenarios of land-use change in a dynamic area of Calgary/Rocky View at very fine spatial scale (5 m)
- Method:
  - A patch-based CA model was developed to take into account the internal spatial heterogeneity of the land-use classes
  - e.g.: a residential area composed of houses, streets, and green spaces

Simulated scenarios

1.


2.


3.


1. Business-as-usual Scenario

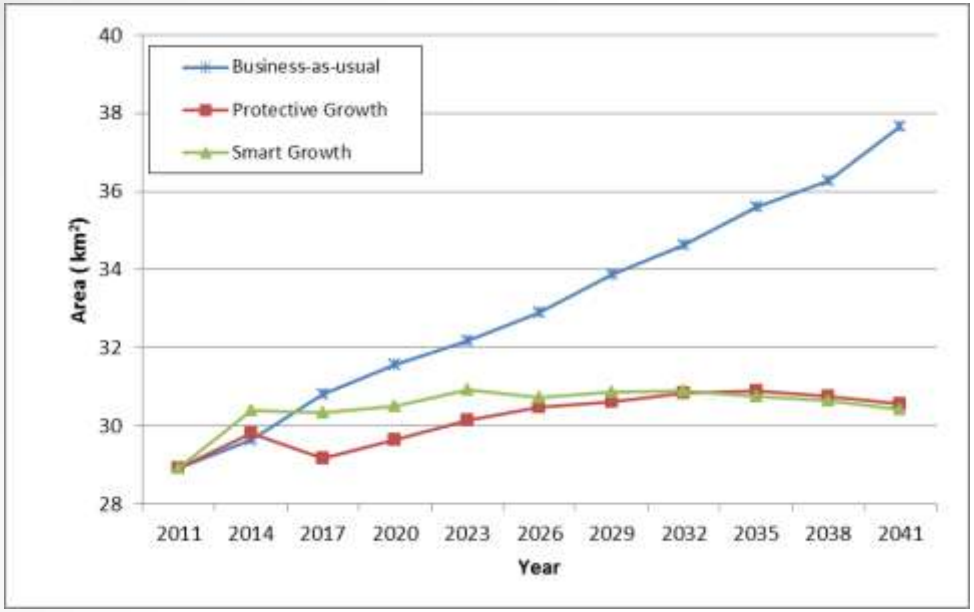
2. Protective Growth Scenario

3. Smart Growth Scenario

- 0:No Data
- 1:Commercial/Institutional
- 2:Industrial
- 3:Airport
- 4:Urban Residential
- 5:Country Residential
- 6:Road Level 1
- 7:Road Level 2
- 8:Road Level 3
- 9:Golf Course
- 10:Agriculture
- 11:Water
- 12:Forest
- 13:Green Area
- 14:Under Development

Result: Sustainability

1.



1. Projected area for country residential
2. Land consumption in 2041

2.

Class	Business-as-usual Scenario (km^2)	Protective Growth Scenario (km^2)	Smart Growth Scenario (km^2)
Country Residential	37.67	30.56	30.43
Urban Residential	18.69	19.83	16.55
Agriculture	139.13	144.42	148.13
Forest	25.05	27.13	27.16

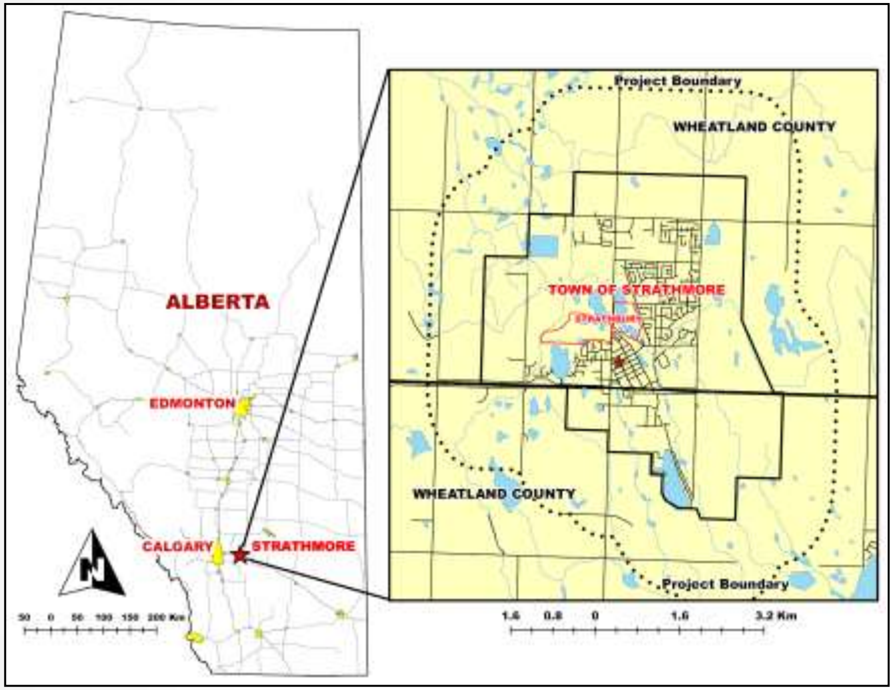
(Wang and Marceau, 2012)

Spatial planning in Strathmore

(Town of Strathmore web site)

Dr. Danielle Marceau, Geomatics Engineering, UofC
Michael Kieser, M.Sc. student
Stakeholders in Strathmore

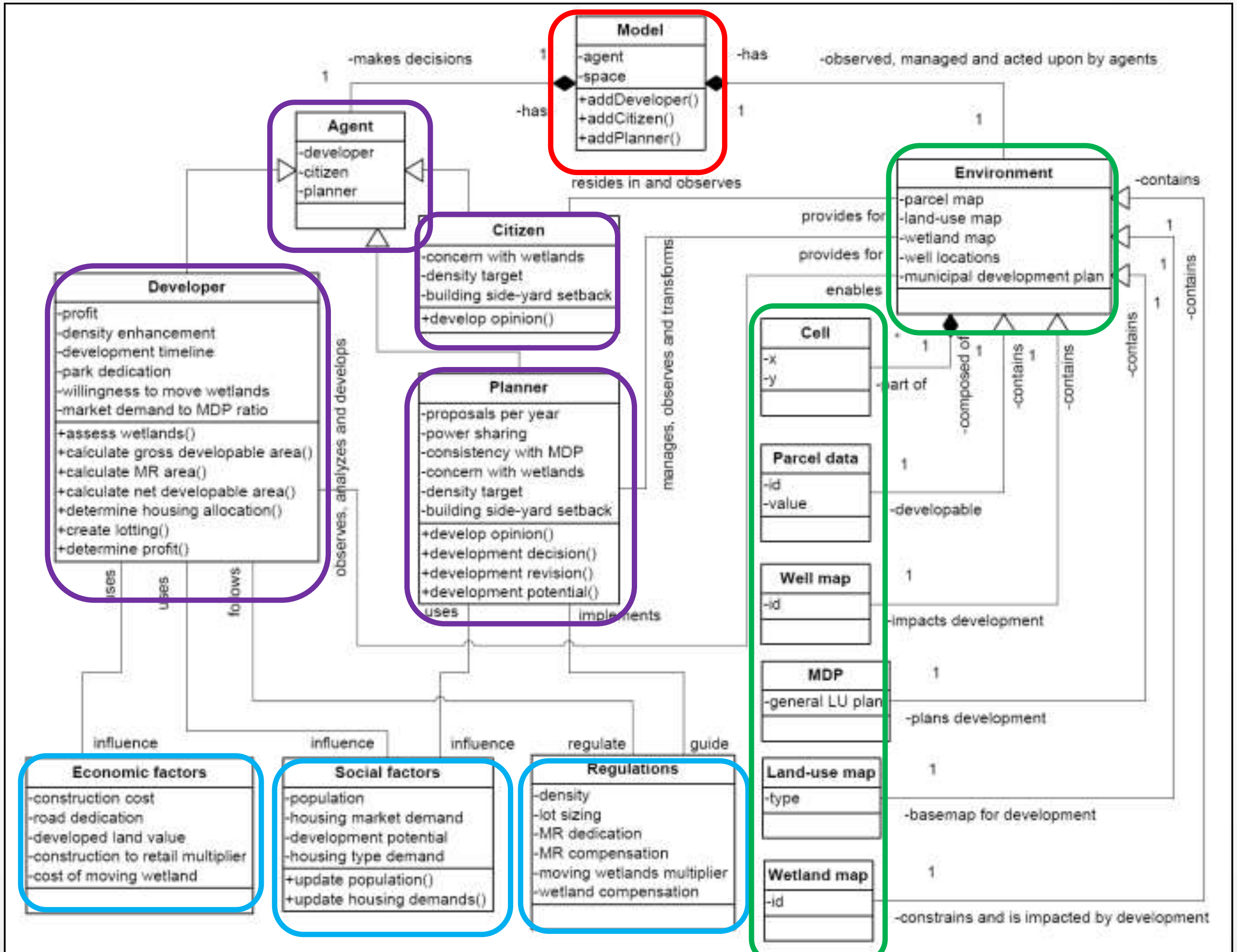
Objective and Method



(Kieser and Marceau, 2011)

- Objective:
  - To simulate the land development process in a proposed residential subdivision in Strathmore
  - To evaluate the impact of five scenarios over 10 years
- Method:
  - An agent-based model was developed to take into account the stakeholders' perspectives along with government regulations, planning policies and design standards

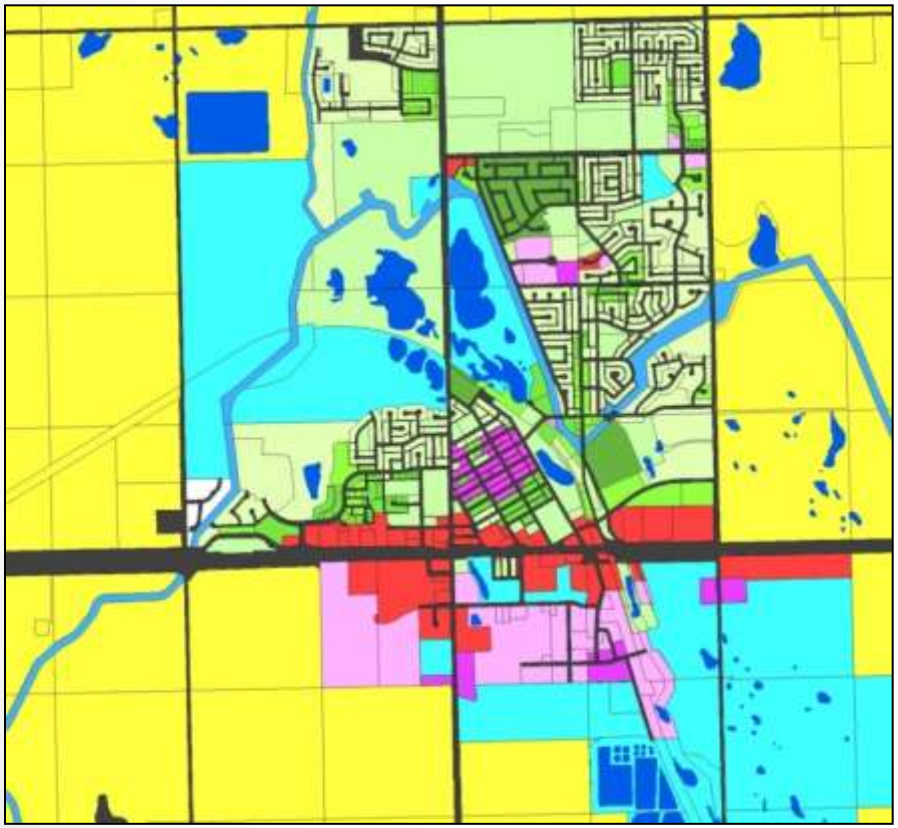
Conceptual model



(Kieser and Marceau, 2011)

Land use in 2007

Spatial resolution: 4 m



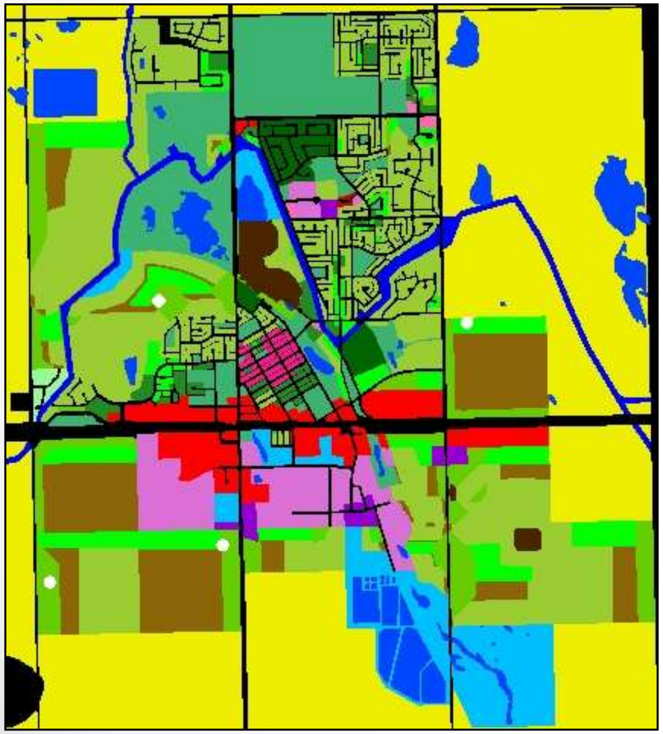
(Kieser and Marceau, 2011)

Legend

- Wetlands
- C1 - Commercial
- CB - Central Business
- CHWY - Highway Commercial
- DC3 - Direct Control
- P1 - Public Service
- M1 - Restricted Light Industrial
- M2 - Light Industrial
- CR1 - Country Residential
- R1 - Single Detached Residential
- R2 - Mixed Housing
- R2X - Medium Density Attached
- R3 - Apartment District
- MHP - Mobile Home Park
- MR - Municipal Reserve
- ER - Environmental Reserve
- OS - Open Space
- AG - Agriculture
- UR - Urban Reserve
- WID Canal
- Roads

Scenario 1: Business as usual

This scenario projects current development goals into the future

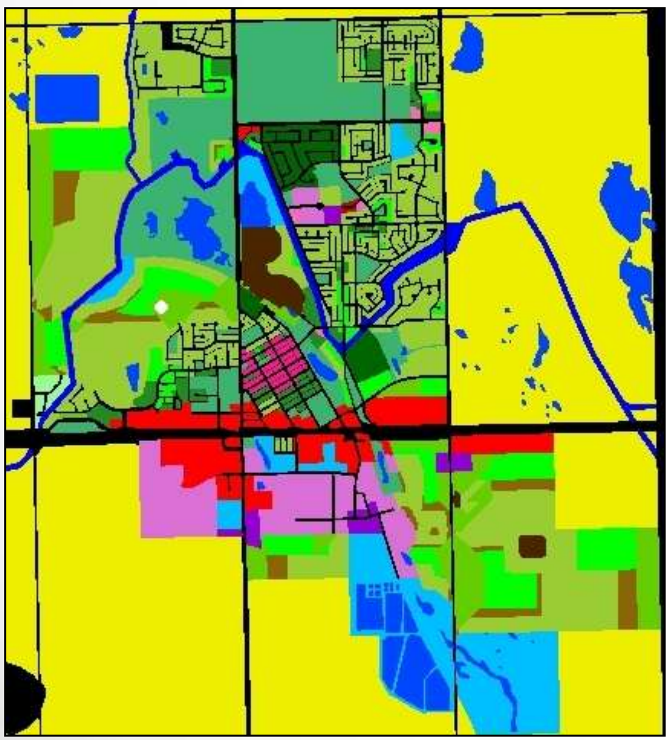


(Kieser and Marceau, 2011)

- By year 9, the development potential has surpassed the housing demand (170%)
- After 10 years, land-use change has occurred over 280 ha contained within 17 land parcels

Scenario 2: Change in the market

This scenario simulates an adaptation to the market demand for smaller housing types

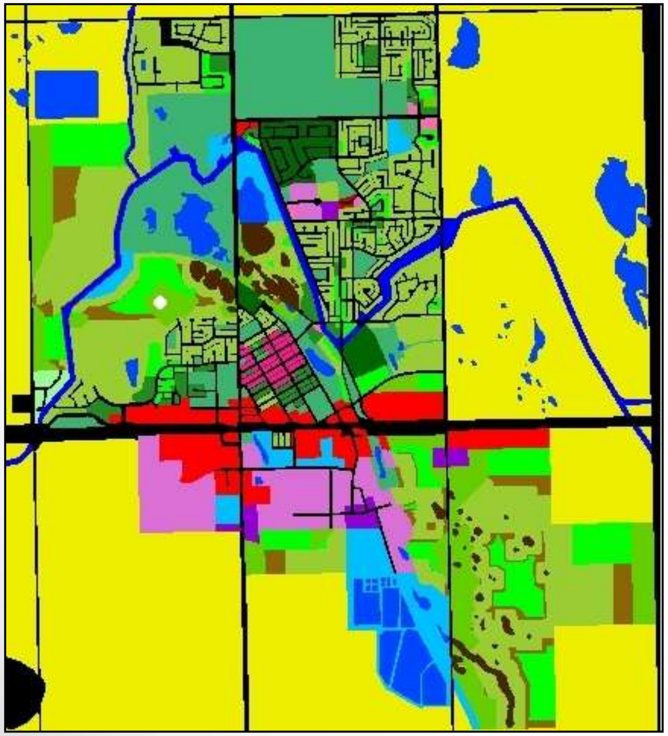


(Kieser and Marceau, 2011)

- This scenario results in the development potential being 30% greater than the housing demand
- After 10 years, land-use change occurs on 176 ha contained within 11 land parcels

Scenario 3: Sustainable development

This scenario controls development rate, gives preference to smaller housing types, decreases the road infrastructure, does not disturb wetlands



(Kieser and Marceau, 2011)

- Land-use change occurs on 198 ha contained within 11 land parcels
- This scenario creates more intricate patterns and presumably a more interesting community

The woodland caribou project
(*Rangifer tarandus caribou*)

Dr. Danielle Marceau, Geomatics Eng., UofC
Dr. Christina Semeniuk, PDF
David Birkigt, Researchc Associate
Dr. Marco Musiani, EVDS and Veterinary Medecine, UofC
Dr. Greg McDermid, Geography, UofC
Dr. Mark Hebblewhite, University of Montana
Scott Grindal, ConocoPhillips Canada

Objective

To determine how the industrial activities influence woodland caribou habitat selection and use in the study area

- An ABM/CA model was developed to:
  - Simulate and recreate the movement behaviors of caribou to explore how they select and use their winter habitat
  - Determine the relative impact of different industrial features on caribou habitat selection strategies in winter
  - Assess how caribou adapt to their changing environment

Modeling approach

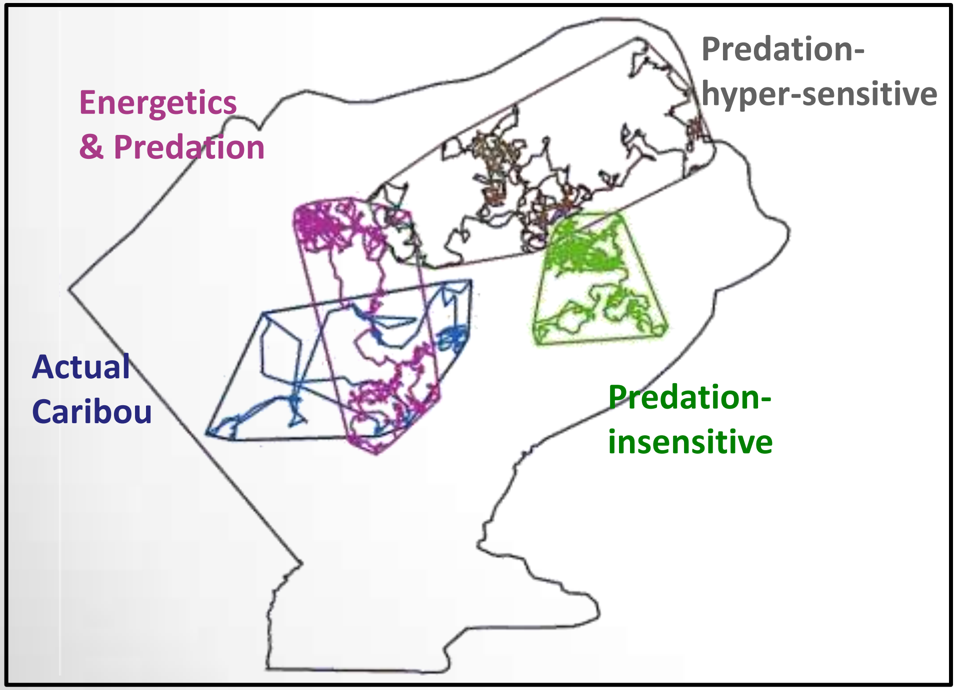
Our modeling approach combines movement ecology with behavioural ecology within an ABM/CA framework

- The ABM simulates caribou as individual agents that:
  - Are capable of making trade-off decisions to maximize their survival and reproductive success
  - Are spatially aware of their surrounding environment
  - Have a memory
  - Can learn where to forage, while concurrently avoiding predators and habitat disturbance

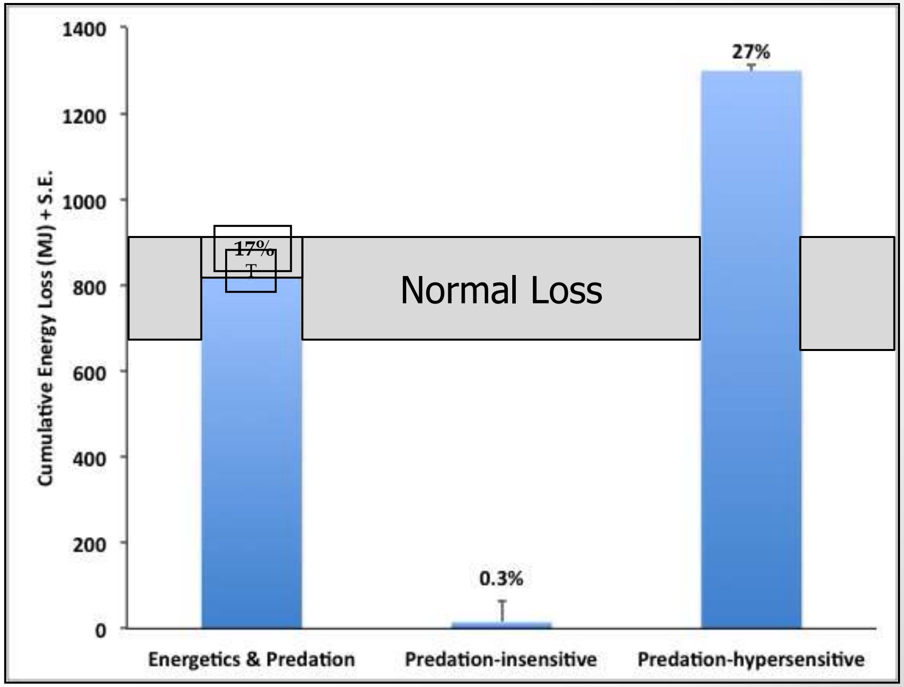
Result: Strategy for habitat use

The Energetics and Predation scenario in which the caribou agent must trade-off its daily energy requirement, minimize its reproductive energy loss, and minimize the predation risk is the best-fit scenario

Representative paths and home ranges



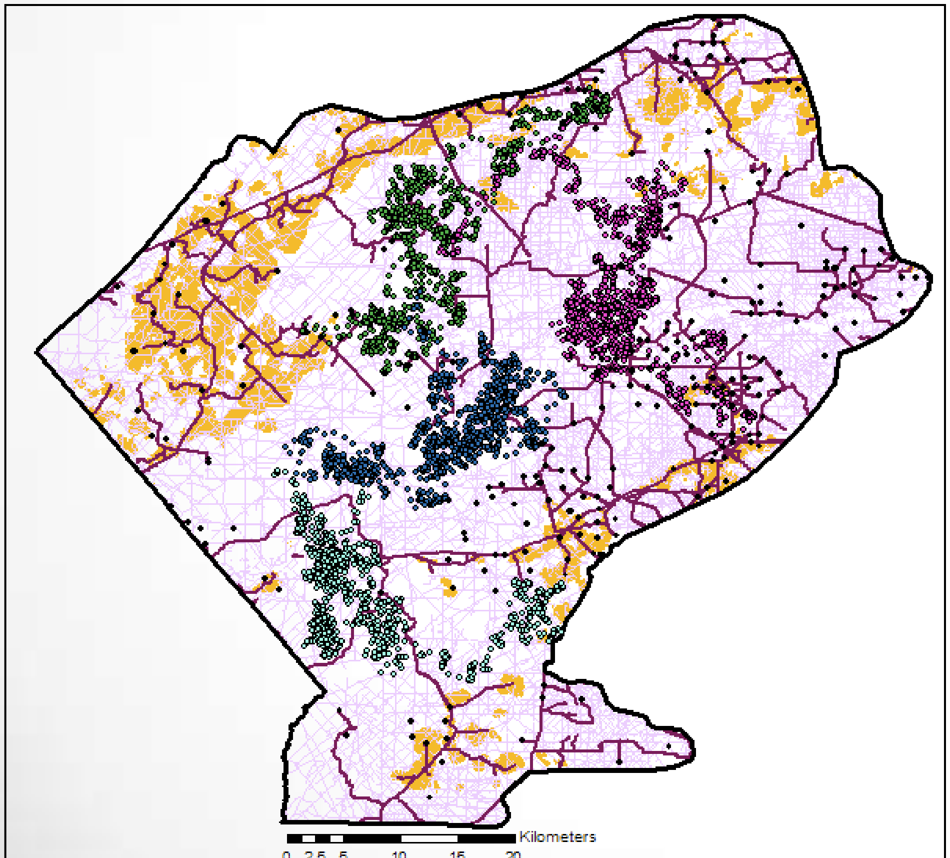
Cumulative energy loss



(Semeniuk et al., 2012)

Result: Sensitivity to industrial activities

Forestry and oil and gas features distinctly affect the spatial and energetic responses of caribou



- Caribou are most sensitive to the presence of linear features
- They are sensitive to a minor extent to cutbloc density and active wellsites

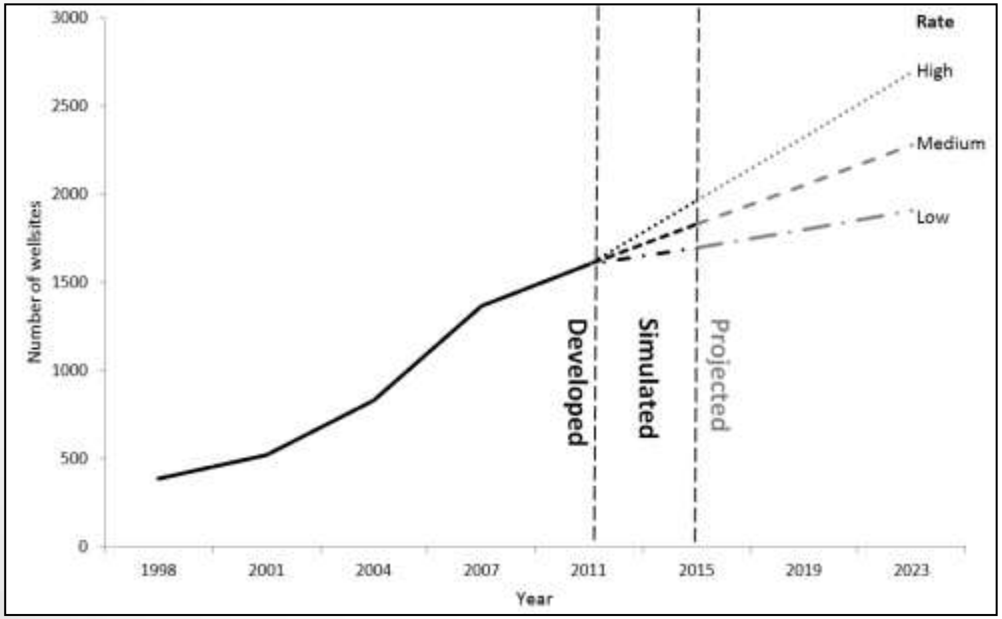
Legend

- infrastructure
- seismic lines
- cutblock density
- active wells
- sample agent locations

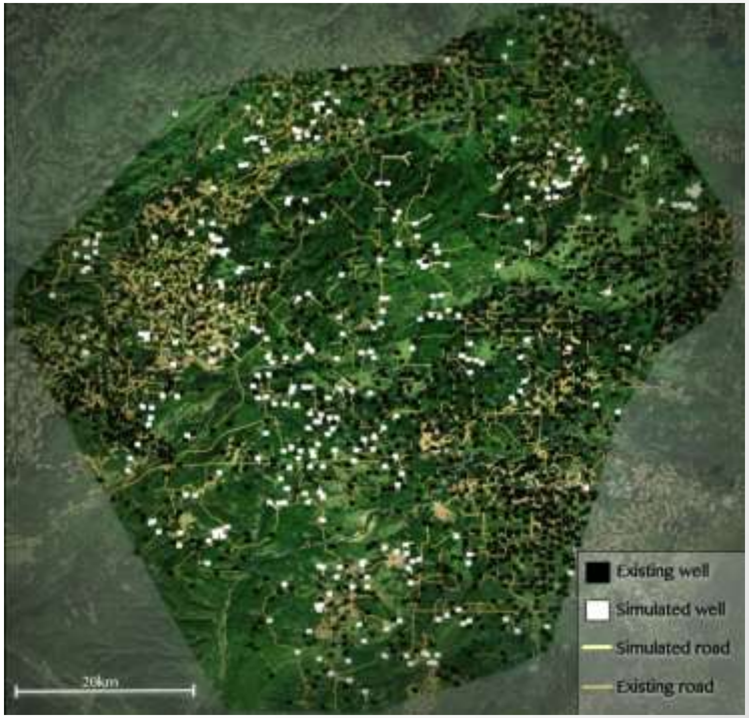
(Semeniuk et al., 2013)

Projecting in the future

A cellular automata was developed to simulate three scenarios of upstream development over the next 10 years



2015: medium development rate



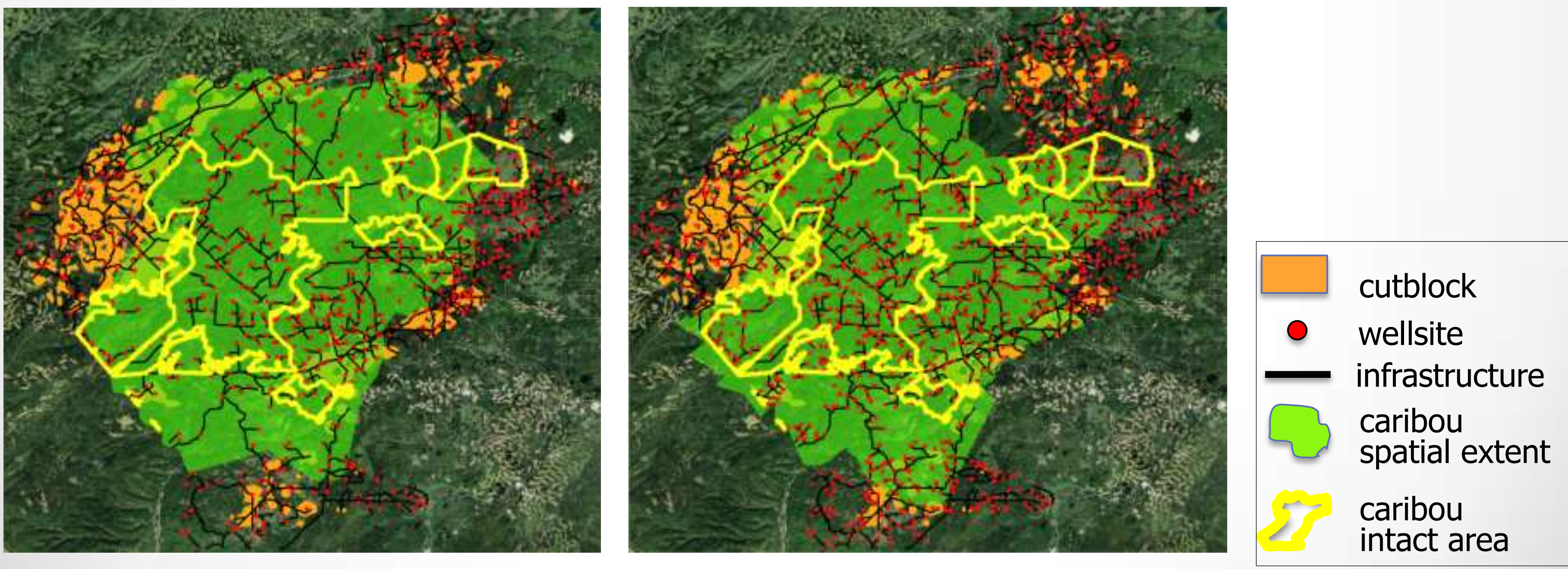
(Birkigt et al., 2013)

Result: Adaptation to projected conditions

Projected environmental conditions up to 2023 using a cellular automata reveal how caribou adapt to the changes in their habitat

2011: Intact area: 63%

2023: Intact area: 53%



(Semeniuk et al., 2013)

Modeling disease propagation with ABMs

Wildlife - Cattle

Dr. Karen Orsel, Veterinary Medicine, UofC
Dr. Ale Massolo, Veterinary Medicine, UofC
Dr. Danielle Marceau, Geomatics Eng., UofC
Dr. Aaron Reeves, PDF
Mathieu Provost, Ph.D. Student
Ranchers

Coyote – Dog - Human

Dr. Ale Massolo, Veterinary Medicine, UofC
Dr. Danielle Marceau, Geomatics Eng., UofC
Ken Mori, M.Sc. Student, Geomatics Eng.
City of Calgary

Conclusion

Understanding the complex interactions between human and natural systems is essential for environmental resource management

- It requires an interdisciplinary scientific approach
- It requires a flexible and comprehensive modeling approach to investigate multiple scenarios
- It requires the involvement of stakeholders as they are key actors in the process of identifying and implementing sustainable management measures

Acknowledgements

- Funding for these projects is provided by:
  - GEOIDE
  - MITACS
  - NSERC
  - ConocoPhillips Canada
  - Tecterra
  - Alberta Environment Sustainable Resource Development (AESRD)
  - DHI (in-kind)
  - Calgary Regional Partnership
  - Alberta Innovates (scholarship)
  - University of Calgary (Internal awards)

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Day 1 – Session 1

Richard Leduc – AirMet Science Inc.

BIOGRAPHY

Richard Leduc's, Ph.D., work is related to meteorology and air quality. He actively works (private sector) in modelling, network development and data analysis. He published the Québec Guidelines on dispersion modelling and authored sections of Québec Air quality regulation. He also works as an Associate Professor (volunteer) at Laval University with graduate students.

Day 1 – Session 1

Richard Leduc – AirMet Science Inc.

ABSTRACT

A simple technique to obtain wind field in urban areas was implemented and coupled to a stochastic lagrangian particle model. The main features of these approaches will be outlined along with some practical problems. Examples of applications in urban areas will be presented. Some ongoing and future work will conclude the presentation.

APPLICATION OF LAGRANGIAN MODELLING IN URBAN AREAS

Richard Leduc, Ph.D.
Environmental Modelling Workshop
Edmonton, March 13 2013

SPECIAL THANKS

- Thanks to Jesse Thé, Lakes Environmental, and Yann Contratto, Olfactoexpert for their continual support

Lakes Environmental

olfactoexpert inc.

PLAN

- Introduction
- Wind field
- Particle model
- Examples

BASE REFERENCE

- H.C. RODEAN, 1996
- ***STOCHASTIC LAGANGIAN MODELS OF TURBULENT DIFFUSION***
- American Meteorological Society, Meteorological Monograph , Volume 26
- <u>JD Wilson Alberta University works are significative</u>

Introduction

- Basic motivation:
  - how to calculate and illustrate in a simple way the wind field around an industrial complex to help in some occasions to refine results of AERMOD
  - and show how a plume could behave
- Everything done here is based on published litterature

Introduction

- 2 blocs are necessary:
  - obtain wind field solution in built areas – industrial complex or urban center
  - resolve the equations for lagrangian transport of parcels

WIND FIELD

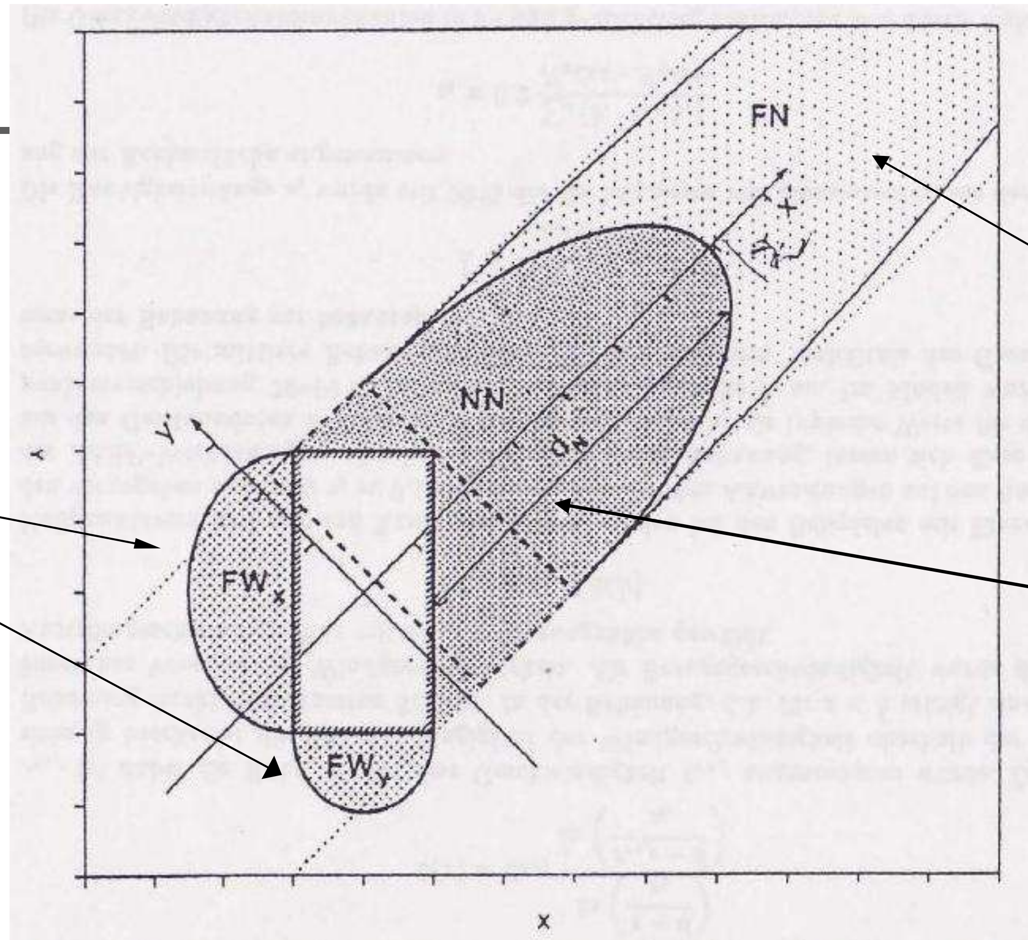
- Options
  - CFD model: solve basic movement equations
    - interesting, precise
    - longer execution time
  - parameter model
    - simplified building effects
    - quite fast

AIRFLO MODEL

- Based on Rockle (1990), Kaplan et Dinar (1996), Los Alamos (2003 and others) following Hosker (1984)

- Wind field parametrized according to influence zone around a building
  - base on one building not too excentric form (cubic or rectangle)

parametrized zones



upfront cavities

	FX	FY
a_x	$L_f \sin^2\theta\sqrt{1-\left(\frac{z}{0.6H}\right)^2}$	$\frac{L}{2}$
a_y	$\frac{W}{2}$	$L_f \cos^2\theta\sqrt{1-\left(\frac{z}{0.6H}\right)^2}$
vent initial	$u_0=0$	$v_0=0$

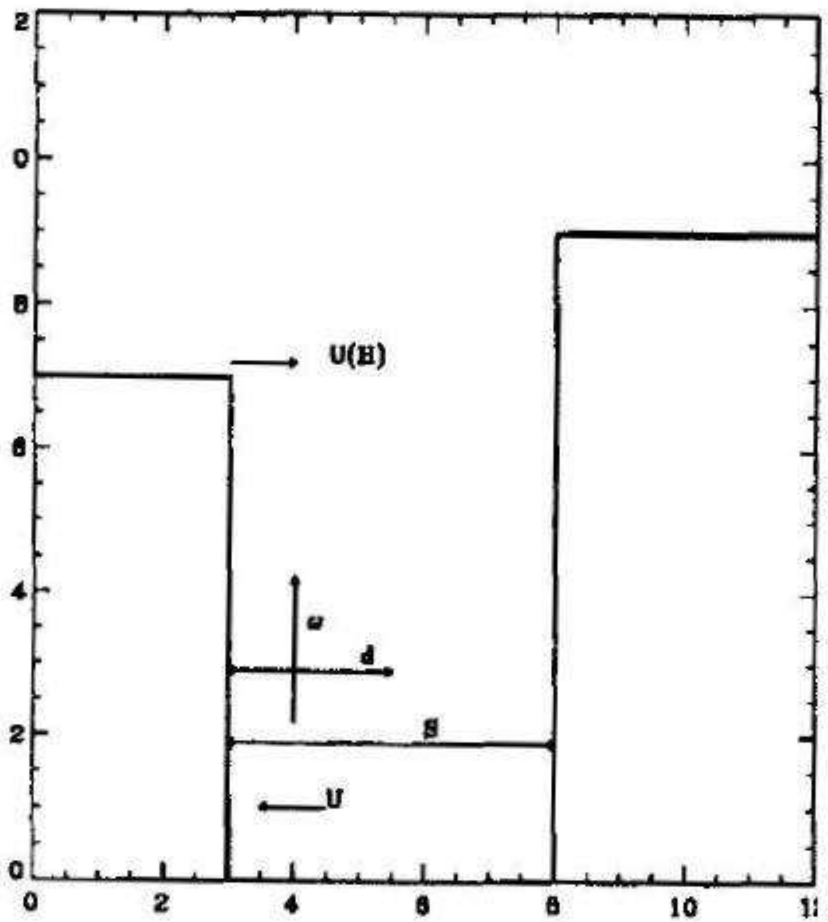
$$\frac{L_f}{H}=\frac{2(W/H)}{1+0.8W/H}$$

rear cavity and wake

¤	N¤	F¤
a_x,¤	¶ $L_r\sqrt{1-\left(\frac{z}{H}\right)^2}$ ¶ ¤	¶ $3L_r\sqrt{1-\left(\frac{z}{H}\right)^2}$ ¤
a_y,¤	$\frac{b_e}{2}$ ¶ ¤	$\frac{b_e}{2}$ ¤
composante x¤	$u_0=-u(H)\left(1-\frac{d_l}{d_N}\right)^2$ ¶ ¤	$u_0=u(z)\left(1-\frac{d_N}{d_l}\right)^{1.5}$ ¤
composante y¤	$v_0=-v(H)\left(1-\frac{d_l}{d_N}\right)^2$ ¶ ¤	$v_0=v(z)\left(1-\frac{d_N}{d_l}\right)^{1.5}$ ¤

$$\frac{L_r}{H}=\frac{1.8W/H}{(L/H)^{0.3}(1+0.24W/H)}$$

street canyon



si S < S**

$$\frac{S^{**}}{H} = \begin{cases} 1.25 + 0.15\,W/H & W/H < 2, \\ 1.55 & W/H \geqslant 2. \end{cases}$$

¶

$$U = -U(H)\frac{d}{0.5S}\left(\frac{S-d}{0.5S}\right) \cdot\cdot\cdot\cdot\, W = -\left|\frac{U(H)}{2}\left(1-\frac{d}{0.5S}\right)\right|\left(1-\frac{S-d}{0.5S}\right)$$ ¶

¶

S: street width

d: distance from grid point to upwind building

U(H) wind on roof of upwind building

for non perpendicular wind to canyon axis wind is decomposed in parallel and perpendicular components

- Buildings are defined
  - 4 corners, height
  - for industrial complex, take BPIP
- Each grid point is determined
  - free
  - inside a building
  - in zone: upfront, cavity, wake, canyon
  - search for street canyons is tedious
    - grid points in street canyons are saved in a file for further applications

Initial wind field

- MOST profile according to the weather conditions (wind, temperature, cloud ect) and local variables (roughness, albedo ect)
- Each grid point is attributed an initial wind field depending on its position with respect to building zones

Wind field solution

- Initial wind field is the start up wind for the application of a mass conservation model on the modelling domain (divergence minimization)

- the function E is minimize over the whole domain
- (u_0, v_0, w_0): initial wind field: wind attributed in various zones
- (u, v, w): final wind field

$$E(u,v.w) = \int_V \left[\alpha_1^2 \left(u - u_0 \right)^2 + \alpha_2^2 \left(v - v_0 \right)^2 + \alpha_3^2 \left(w - w_0 \right)^2 \right] dV$$

- with a zero divergence constraint on the final wind field

$$\nabla \bullet V = 0$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

- is the same as to minimize J

$$J(u,v,w;\lambda)=\int_V \begin{bmatrix} \alpha_1^2(u-u_0)^2+\alpha_2^2(v-v_0)^2+\alpha_3^2(w-w_0)^2+ \\ \lambda\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}\right) \end{bmatrix} dV$$

- and λ(x,y,z) is subjected to the following identity and is solved numerically; R is called the source term (divergence)

$$\frac{\partial^2\lambda}{\partial x^2}+\frac{\partial^2\lambda}{\partial y^2}+\left(\frac{\alpha_1}{\alpha_2}\right)^2\frac{\partial^2\lambda}{\partial z^2}=R$$

then the final wind field (u,v,w) is obtained as a function of (x,y,z) with λ(x,y,z)

$$u = u_0 + \frac{1}{2\alpha_1^2}\frac{\partial\lambda}{\partial x}$$

$$v = v_0 + \frac{1}{2\alpha_1^2}\frac{\partial\lambda}{\partial y}$$

$$w = w_0 + \frac{1}{2\alpha_2^2}\frac{\partial\lambda}{\partial z}$$

- The λ equation is discretized as

$$R_{i,j,k}=\frac{\lambda_{i+1,j,k}-2\lambda_{i,j,k}+\lambda_{i-1,j,k}}{\Delta x^2}+\frac{\lambda_{i,j+1,k}-2\lambda_{i,j,k}+\lambda_{i,j-1,k}}{\Delta y^2}+$$

$$\left(\frac{\alpha_1}{\alpha_2}\right)^2\frac{\lambda_{i,j,k+1}-2\lambda_{i,j,k}+\lambda_{i,j,k-1}}{\Delta z^2}$$

$$R(I,J,K)=-2\alpha_1^2\,DIV(I,J,K)$$

- At solid surfaces such as wall and roofs the wind and the derivatives are null

$$\frac{\partial \lambda}{\partial x} = 0 \; ou \; \frac{\partial \lambda}{\partial y} = 0 \; ou \; \frac{\partial \lambda}{\partial z} = 0$$

- At points where there are solid surfaces discretized λ equation is adjusted to have zero derivatives. For example for a solid surface to EAST and one SOUTH

$$\frac{\partial^2 \lambda}{\partial x^2} = \frac{\partial}{\partial x}\left(\frac{\partial}{\partial x}\right) = \frac{1}{\Delta x}\left(\left.\frac{\partial \lambda}{\partial x}\right|_{i+1/2} - \left.\frac{\partial \lambda}{\partial x}\right|_{i-1/2}\right)$$

$$= \frac{1}{\Delta x}\left(0 - \left.\frac{\partial \lambda}{\partial x}\right|_{i-1/2}\right) = \frac{1}{\Delta x}\left(-\left.\frac{\partial \lambda}{\partial x}\right|_{i-1/2}\right)$$

$$= \frac{\lambda_{i-1} - \lambda_i}{\Delta x^2}$$

$$\frac{\partial^2 \lambda}{\partial y^2} = \frac{\lambda_{j+1} - \lambda_j}{\Delta y^2}$$

- which is put back in the discretized equation

$$R_{i,j,k}=\frac{\lambda_{i-1,j,k}-\lambda_{i,j,k}}{\Delta x^2}+\frac{\lambda_{i,j+1,k}-\lambda_{i,j,k}}{\Delta y^2}+\left(\frac{\alpha_1}{\alpha_2}\right)^2\frac{\lambda_{i,j,k+1}-2\lambda_{i,j,k}+\lambda_{i,j,k-1}}{\Delta z^2}$$

- to obtain a value for $\lambda_{i,j,k}$

$$\lambda_{i-1,j,k}-\lambda_{i,j,k}+A\left(\lambda_{i,j+1,k}-\lambda_{i,j,k}\right)+B\left(\lambda_{i,j,k+1}-2\lambda_{i,j,k}+\lambda_{i,j,k-1}\right)=\Delta x^2 R_{i,j,k}$$

$$\lambda_{i,j,k}=\frac{-\Delta x^2 R_{i,j,k}+\lambda_{i-1,j,k}+A\lambda_{i,j+1,k}+B\left(\lambda_{i,j,k+1}+\lambda_{i,j,k-1}\right)}{2\left(0.5+0.5A+B\right)}$$

$$A=\Delta x^2/\Delta y^2\quad B=\Delta x^2\left(\alpha_1/\alpha_2\right)^2$$

- Every point has its own equation depending on where is the solid surface (example wall to the NORTH, wall to WEST, roof UNDER)
- $\lambda_{i,j,k}$ field is then obtained iteratively according to the procedure given by Press (Numerical Recipes in FORTRAN)
- Final wind (u,v,w) is then obtained for all grid points
- Wind field for downtown Montréal (170 structures) calculated in 2 minutes: 1 min for initial search of canyon, 1 min for wind calculation, 4 millions grid points

AIRLAG MODEL

- Moves particules in the wind field (U,V,W) from AIRFLO
- Same spatial discretization
- Wind, buildings and other infos imported from AIRFLO output

Few equations

- Speed increments of a parcel moving in a wind field (U_1,U_2, U_3) are shown in Rodean, based on Thomson; these have a tensor form. The terms contain a deterministic part and a stochastic part to mimic turbulence

$$du_i = a_i(\vec{x},\vec{u},t)dt + b_{ij}(\vec{x},\vec{u},t)dW_j(t)$$

$$a_i = -\left(\frac{C_0\varepsilon}{2}\right)\lambda_{ik}(u_k - U_k) + U_j\frac{\partial U_i}{\partial x_j} + \frac{1}{2}\frac{\partial \tau_{ij}}{\partial x_j}$$

$$+\left[\frac{\partial U_i}{\partial x_j} + \frac{\lambda_{lj}}{2}\left(U_m\frac{\partial \tau_{il}}{\partial x_m}\right)\right]\left(u_j - U_j\right)$$

$$+\left[\frac{\lambda_{lj}}{2}\frac{\partial \tau_{il}}{\partial x_k}\right]\left(u_j - U_j\right)\left(u_k - U_k\right)$$

- expressing the tensors as summations

$$a_i = \sum_{k=1}^{3}\left(-\left(\frac{C_0\varepsilon}{2}\right)\lambda_{ik}(u_k - U_k)\right) \qquad T1$$

$$+\sum_{j=1}^{3} U_j \frac{\partial U_i}{\partial x_j} \qquad T2$$

$$+\sum_{j=1}^{3} \frac{1}{2}\frac{\partial \tau_{ij}}{\partial x_j} \qquad T3$$

$$+\sum_{j=1}^{3}\left[\frac{\partial U_i}{\partial x_j}\right]\left(u_j - U_j\right) \qquad T4a$$

$$+\sum_{l=1}^{3}\sum_{j=1}^{3}\sum_{m=1}^{3}\frac{\lambda_{lj}}{2}U_m\left(\frac{\partial \tau_{il}}{\partial x_m}\right)\left(u_j - U_j\right) \qquad T4b$$

$$+\sum_{l=1}^{3}\left(\frac{\lambda_{lj}}{2}\right)\sum_{j=1}^{3}\sum_{k=1}^{3}\left(\frac{\partial \tau_{il}}{\partial x_k}\right)\left(u_j - U_j\right)\left(u_k - U_k\right) \qquad T5$$

τ is the shear stress matrix

λ is inverse of τ

- and for a_1 !!!!

$$a_1 = -\frac{C_0\varepsilon}{2}\left(\lambda_{11}\left(u_1-U_1\right)+\lambda_{12}\left(u_2-U_2\right)+\lambda_{13}\left(u_3-U_3\right)\right)$$

$$+U_1\frac{\partial U_1}{\partial x_1}+U_2\frac{\partial U_1}{\partial x_2}+U_3\frac{\partial U_1}{\partial x_3}+\frac{1}{2}\left(\frac{\partial \tau_{11}}{\partial x_1}+\frac{\partial \tau_{12}}{\partial x_2}+\frac{\partial \tau_{13}}{\partial x_3}\right)$$

$$+\frac{\partial U_1}{\partial x_1}\left(u_1-U_1\right)+\frac{\partial U_1}{\partial x_2}\left(u_2-U_2\right)+\frac{\partial U_1}{\partial x_3}\left(u_3-U_3\right)$$

$$+\frac{1}{2}\left(U_1\frac{\partial \tau_{11}}{\partial x_1}+U_2\frac{\partial \tau_{11}}{\partial x_2}+U_3\frac{\partial \tau_{11}}{\partial x_3}\right)\left(\lambda_{11}\left(u_1-U_1\right)+\lambda_{12}\left(u_2-U_2\right)+\lambda_{13}\left(u_3-U_3\right)\right)$$

$$+\frac{1}{2}\left(U_1\frac{\partial \tau_{12}}{\partial x_1}+U_2\frac{\partial \tau_{12}}{\partial x_2}+U_3\frac{\partial \tau_{12}}{\partial x_3}\right)\left(\lambda_{21}\left(u_1-U_1\right)+\lambda_{22}\left(u_2-U_2\right)+\lambda_{23}\left(u_3-U_3\right)\right)$$

$$+\frac{1}{2}\left(U_1\frac{\partial \tau_{13}}{\partial x_1}+U_2\frac{\partial \tau_{13}}{\partial x_2}+U_3\frac{\partial \tau_{13}}{\partial x_3}\right)\left(\lambda_{31}\left(u_1-U_1\right)+\lambda_{32}\left(u_2-U_2\right)+\lambda_{33}\left(u_3-U_3\right)\right)$$

$$+\frac{1}{2}\Bigg(\left(\lambda_{11}\left(u_1-U_1\right)+\lambda_{12}\left(u_2-U_2\right)+\lambda_{13}\left(u_3-U_3\right)\right)\left(\frac{\partial \tau_{11}}{\partial x_1}\left(u_1-U_1\right)+\frac{\partial \tau_{11}}{\partial x_2}\left(u_2-U_2\right)+\frac{\partial \tau_{11}}{\partial x_3}\left(u_3-U_3\right)\right)$$

$$+\left(\lambda_{21}\left(u_1-U_1\right)+\lambda_{22}\left(u_2-U_2\right)+\lambda_{23}\left(u_3-U_3\right)\right)\left(\frac{\partial \tau_{12}}{\partial x_1}\left(u_1-U_1\right)+\frac{\partial \tau_{12}}{\partial x_2}\left(u_2-U_2\right)+\frac{\partial \tau_{12}}{\partial x_3}\left(u_3-U_3\right)\right)$$

$$+\left(\lambda_{31}\left(u_1-U_1\right)+\lambda_{32}\left(u_2-U_2\right)+\lambda_{33}\left(u_3-U_3\right)\right)\left(\frac{\partial \tau_{13}}{\partial x_1}\left(u_1-U_1\right)+\frac{\partial \tau_{13}}{\partial x_2}\left(u_2-U_2\right)+\frac{\partial \tau_{13}}{\partial x_3}\left(u_3-U_3\right)\right)\Bigg)$$

- Expressions are complex
- In a simple case without buildings one can use a reference system aligned with the mean wind i.e. with $U_2=0$, $U_3=0$ also (no vertical movement in the mean flow) and so many terms go to 0

- With buildings U_3 (vertical wind) may be non zero; but a moving doubly rotated system can have $U_2=0$ and $U_3=0$
- This was developped; but this requires continual change in reference frame following the particle and complex calculations (much time consuming) and interaction with buildings is difficult to follow
- Ordinary reference frame (x,y,z) is used

- To improve calculation speed all variables that could be computed before start are done (position dependent values are attributed to matrices)

Solid surfaces

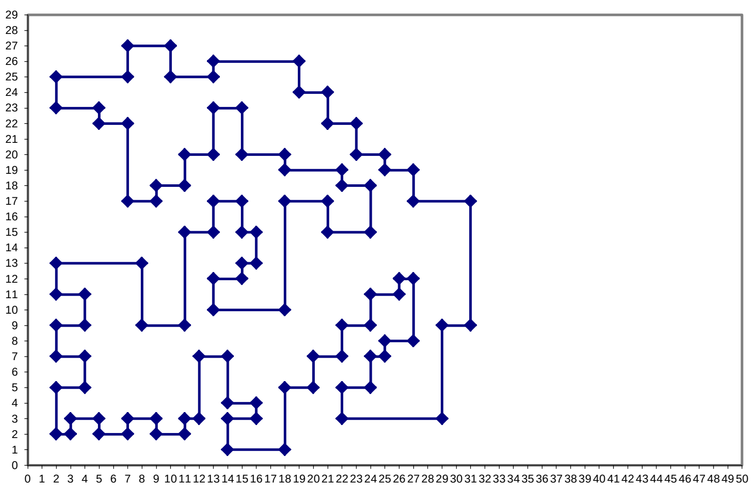
- Parcels are reflected on solid surface and on ground
- Tennis ball refection in 3d
- Special cases as ground to building, building corners, roof to wall ect are considered

Examples

- Only qualitative results examples are shown here
- Model validation will be undertaken

- A short anecdote....☺!
  - Rockle parametrization is based on rectangular forms
  - non-rectangular buildings are thus approximated as superposition of rectangles
  - one would like to have some procedure to get rectangles from polygonal buildings; defined for example as in AERMOD VIEW with BPIP file

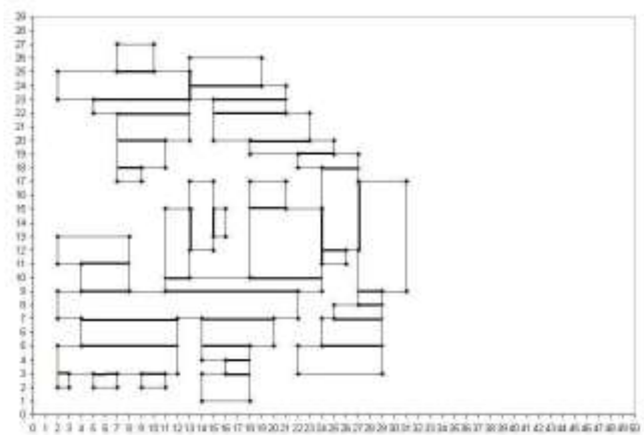
- efforts were devoted to program an algorithm to decompose concave rectilinear polygons in a minimum number of rectangles that superpose or do not superpose
  - what a job ☹☹.....
  - program will be made available on internet



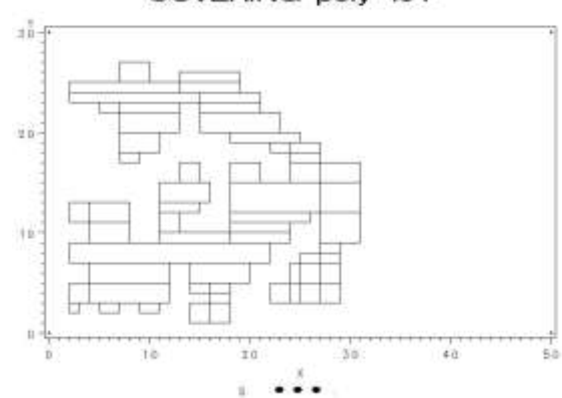
original 104 vertex

juxtaposition

superposition



COVERING poly 104



Québec, summer 2012: legionela episod
13 deads
origin: one cooling tower ; identified 20 september

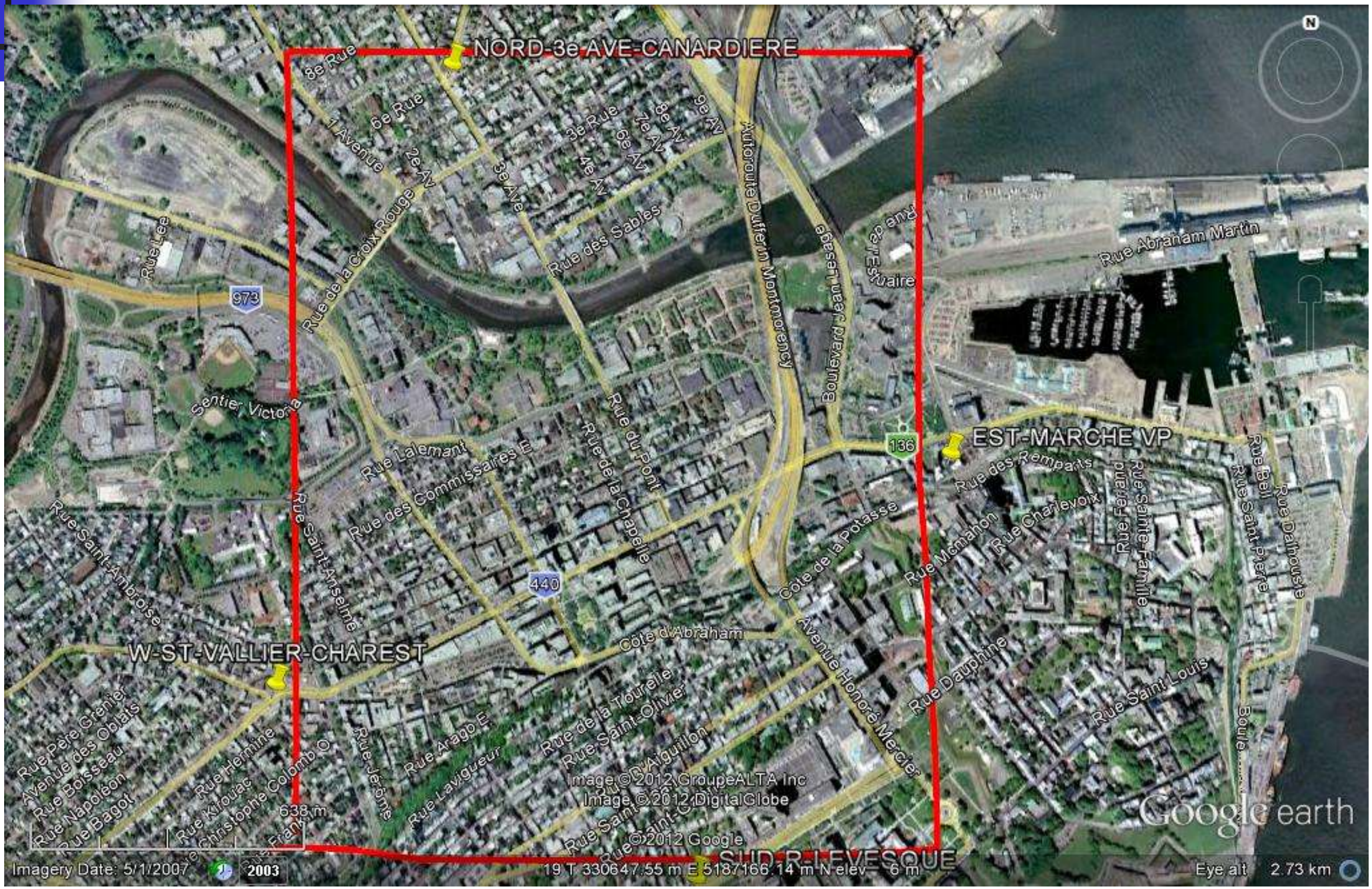
27/08/2012 news

a try for AIRLAG

as a volounteer test

the problem region were search was made

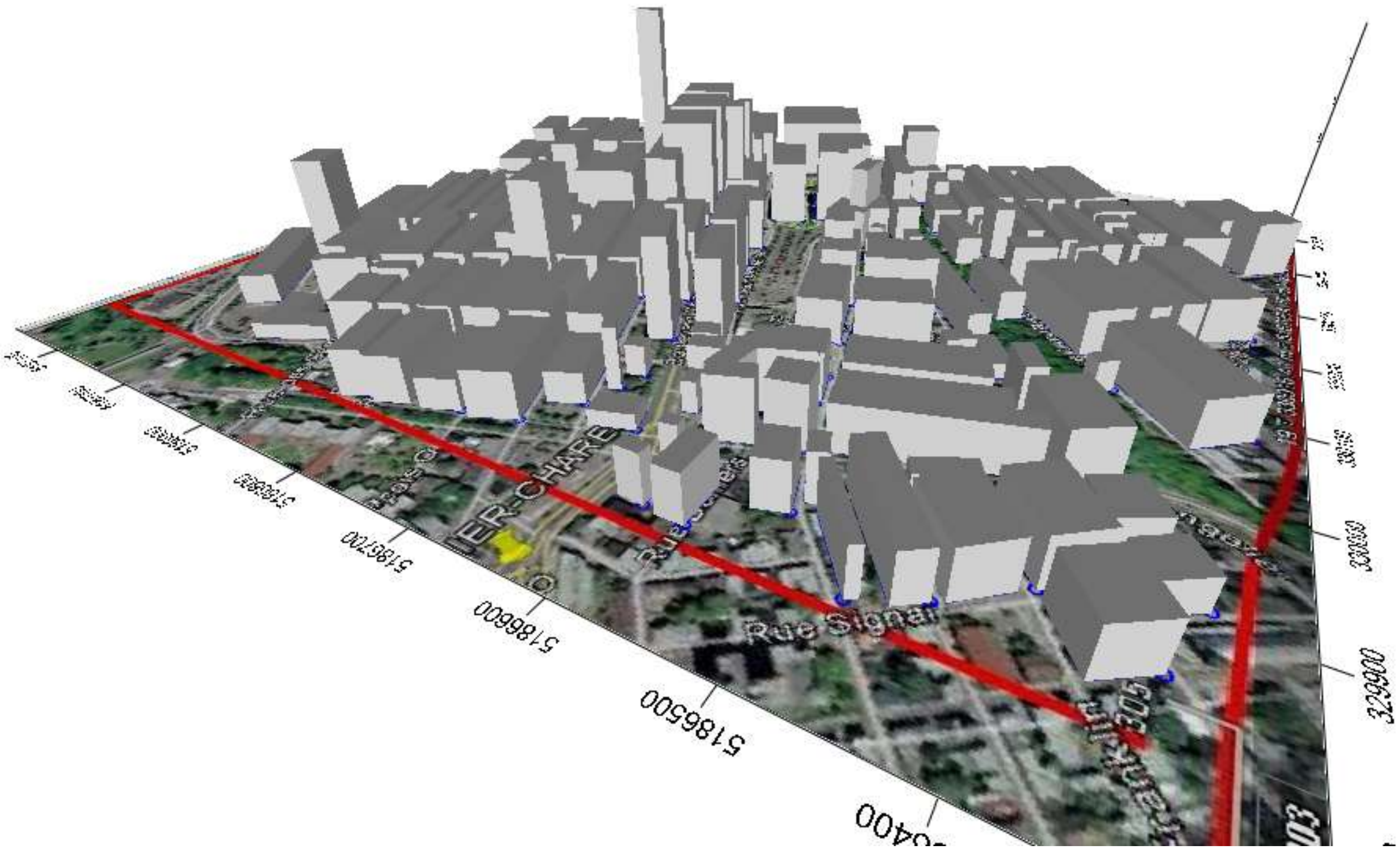
470 structures individual or joined (hand worked-no interface to municipal building data base yet) were input to AIRFLO/AIRLAG



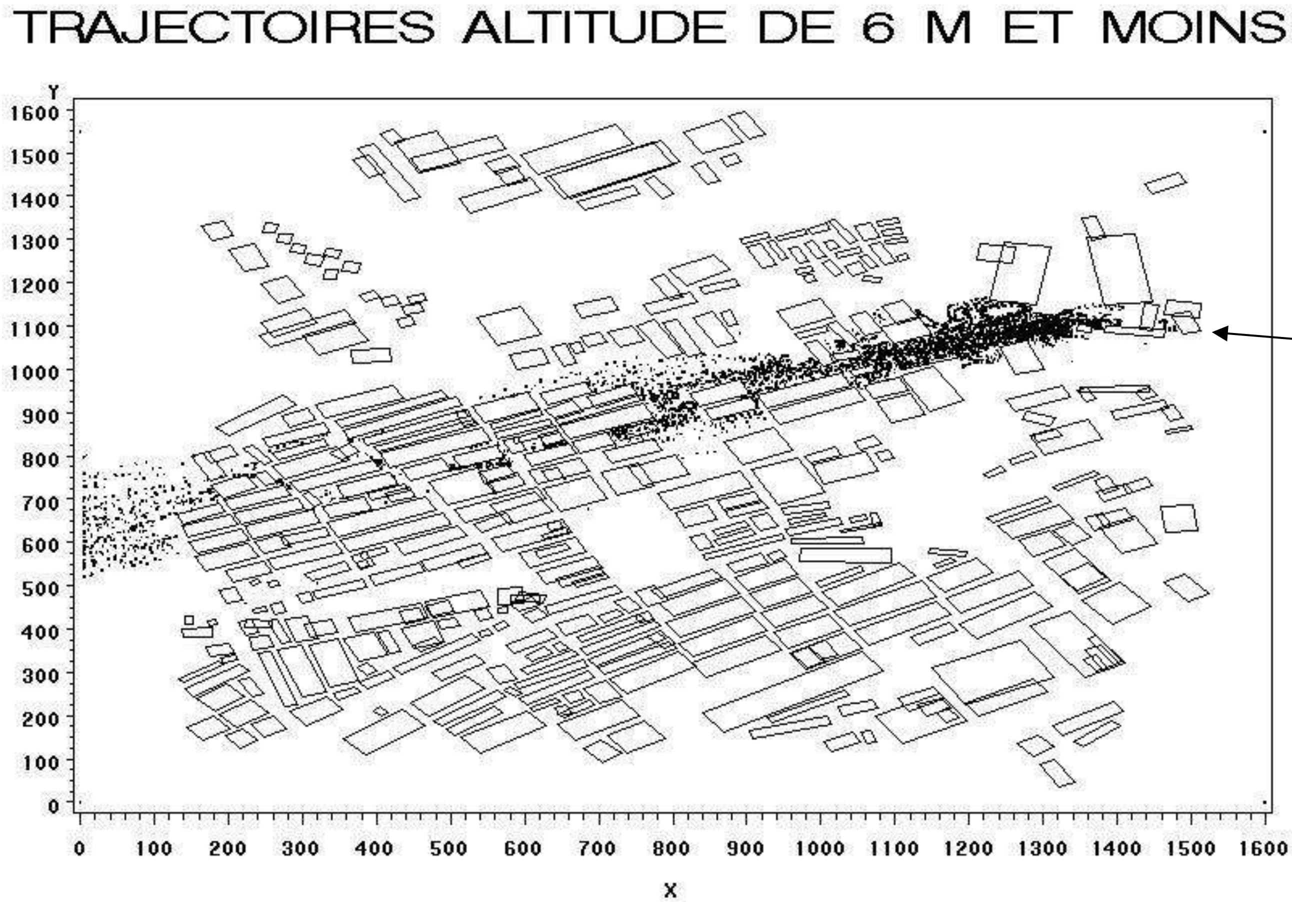
one part of the region, view towards NE

domain 1.5 km x 1.5 km

3D buildings view from AERMOD View



one place was suspected
trial: EAST wind, summer daytime

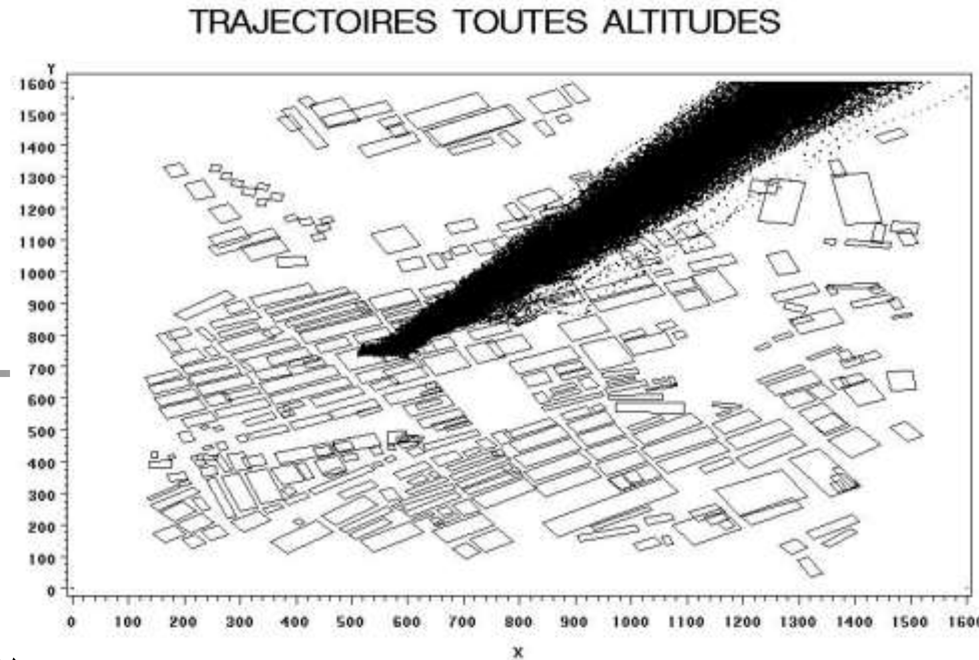


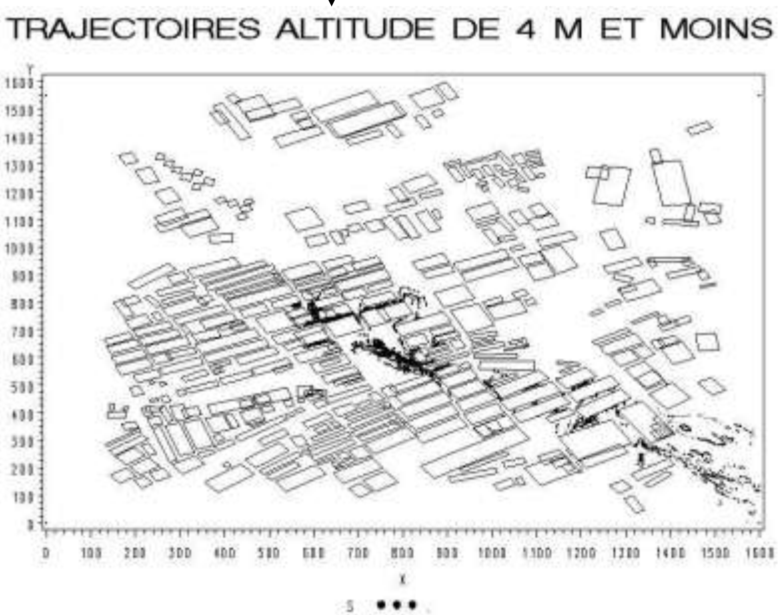
probable origin

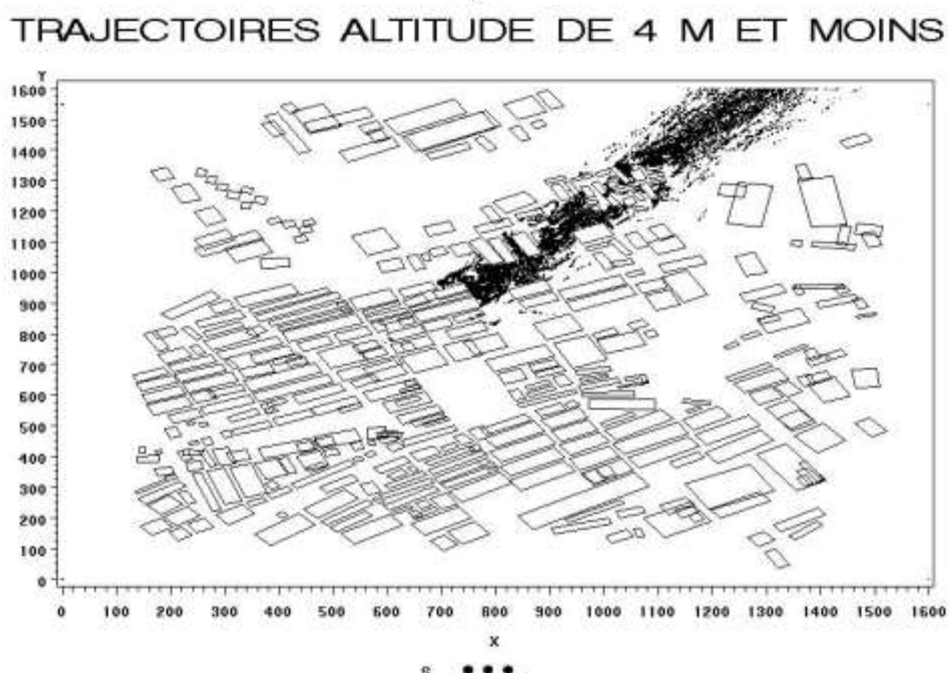
identified source roof

wind SW

wind NW

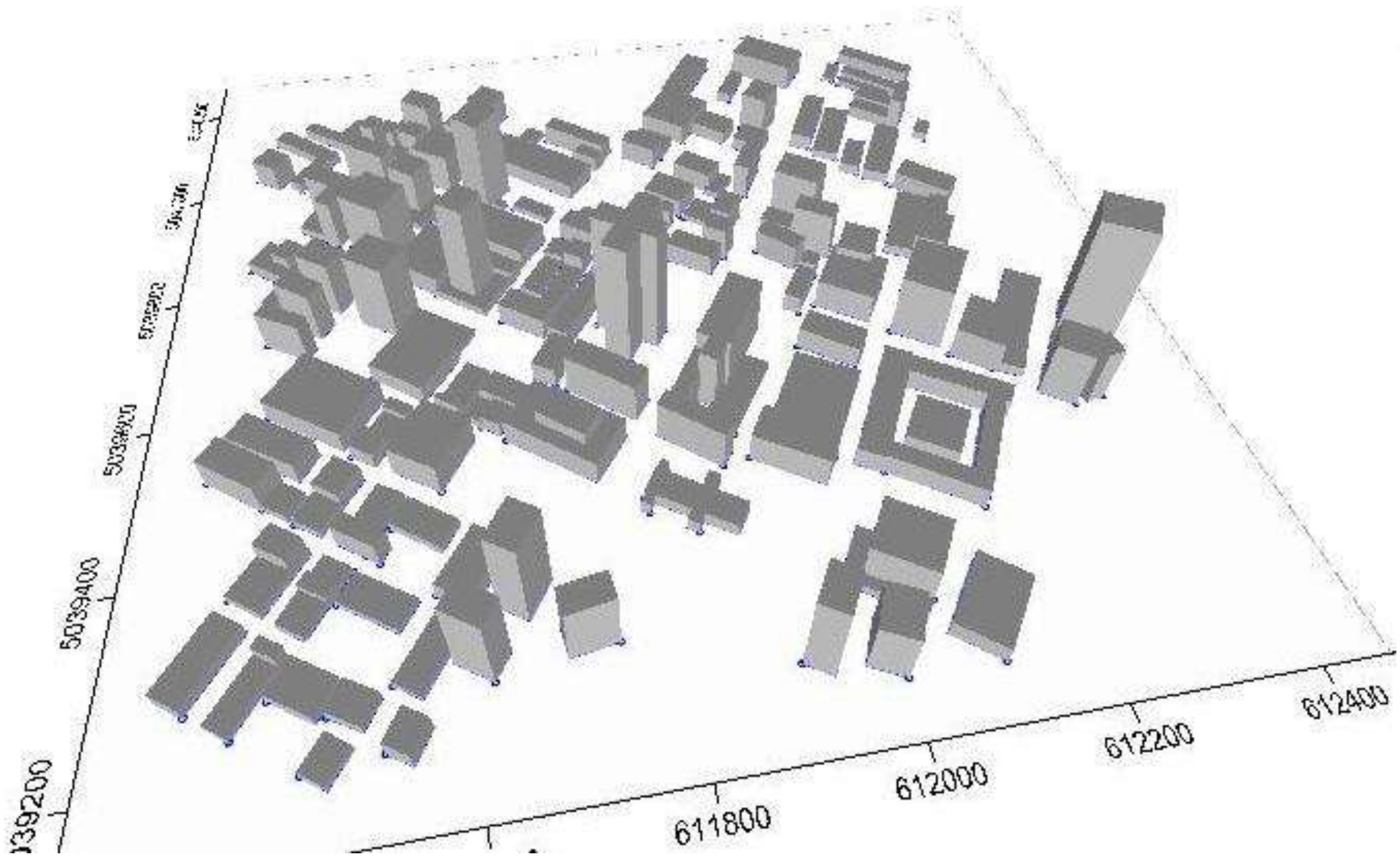


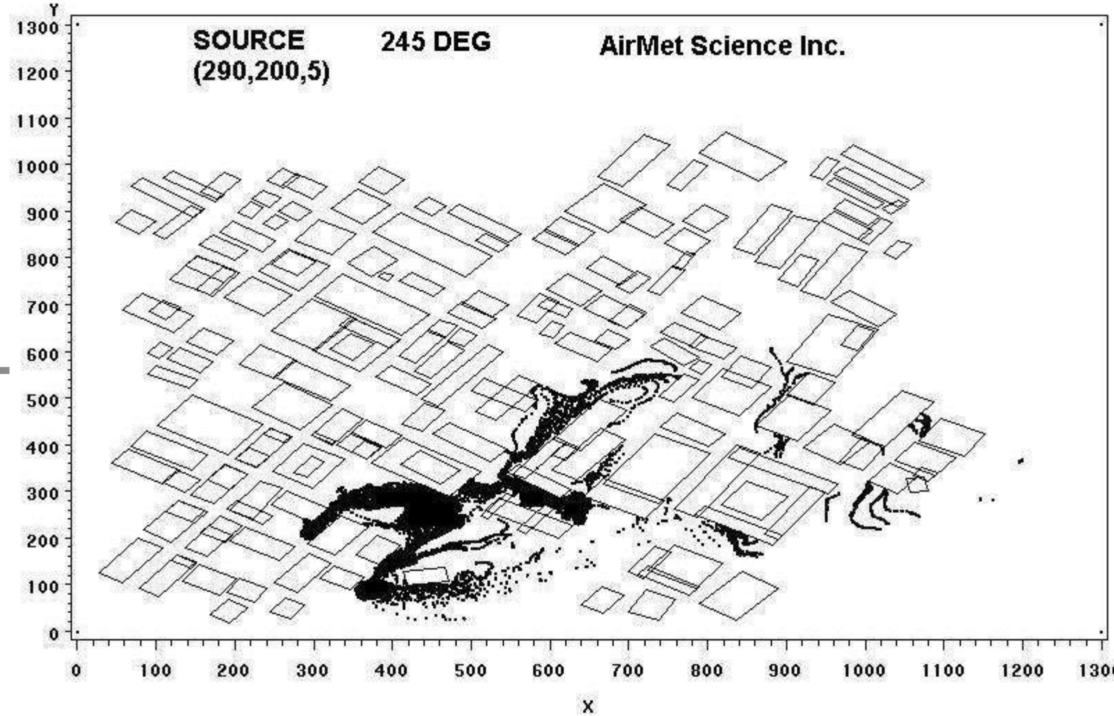


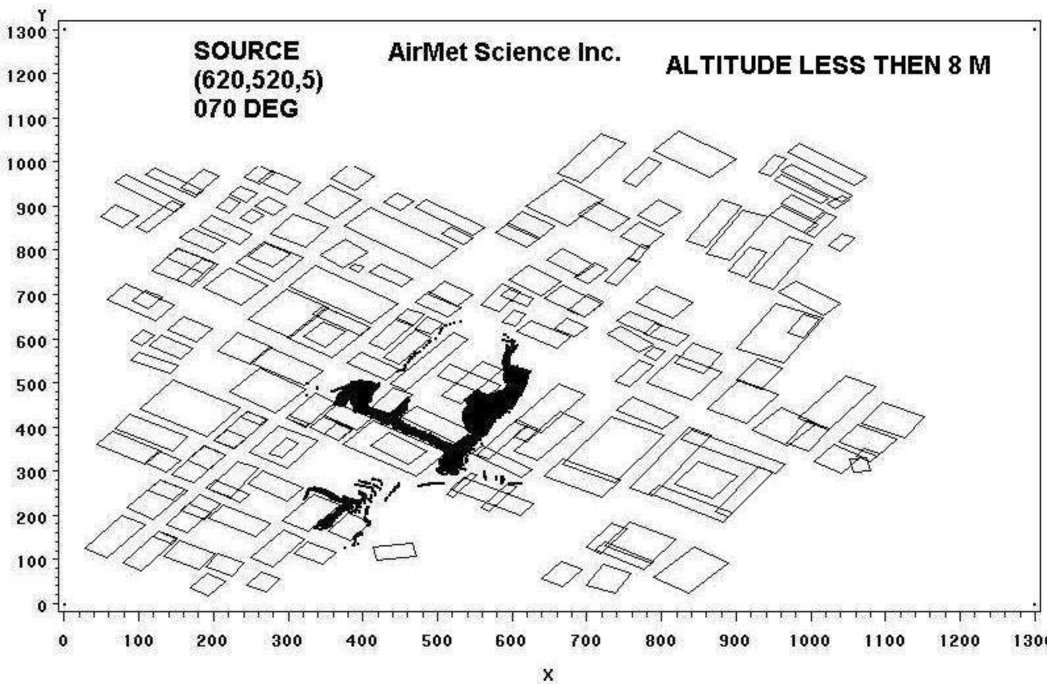


bacteria can reach people and go far

Montréal, part of downtown (170 structures) 3D from AERMOD View







complex circulation patterns

Ongoing and future works

- Vegetation effect
- Lagrangian fluctuations to calculate exceedances probabilities
- Topography
- Roof circulation
- Validation with wind tunnel experiments
- Improve code performance
- Migration to a better performing FORTRAN compiler
- Visual interface
- Wind field solution is still under questionning (CFD?)

Conclusion

- Development of this model (up to this point) required non negligeable efforts
- Further development appears interesting

THANKS

Day 1 – Session 1

Andrew Parker – Tetra Tech Inc.

BIOGRAPHY

Mr. Parker is a Vice President with Tetra Tech's Water Resources Group. He supervises a team of engineers and scientists focusing on watershed planning and management, environmental model development and application, and environmental monitoring and assessment. In his 16 years with Tetra Tech, he has managed more than 50 water resources management and modelling projects in Alberta, over 25 of the United States, Korea, and the Caribbean. He has extensive experience implementing a range of models for planning and regulatory purposes including TMDLs, Implementation plans, climate change studies, Environmental Impact Statements, NPDES permitting, mixing zone analyses, and criteria development. Recent projects include: Chesapeake Bay Total Maximum Daily Load (TMDL) and Watershed Implementation Plan (WIP) development; national scale climate change modelling; and basin-wide modelling studies for the North Saskatchewan River (Canada), Klamath River (USA), Nakdong River (Korea), and Lake Champlain (USA/Canada).

Day 1 – Session 1

Andrew Parker – Tetra Tech Inc.

ABSTRACT

Modelling is an effective tool for supporting water resources management. A wide range of models have been developed and applied in the public and private realms to evaluate surface hydrology, groundwater, hydrodynamics, sediment transport, and water quality. Models are generally designed to focus on a limited aspect of the built or natural environment; however they are frequently coupled to support water management and planning. Indeed, linked models take full advantage of models' individual strengths and avoid oversimplification.

Different models are coupled depending on the primary objectives of a study. Watershed and receiving water models are commonly coupled to support Cumulative Effects, Total Maximum Daily Load (TMDL), and comprehensive watershed management studies. These studies take advantage of the strengths of the different modelling platforms. Watershed models predict time-variable hydrology and water quality conditions throughout a variety of land surface categories, typically for surface and groundwater. They enable land-based, climate change, and other scenarios to be evaluated, as well as determination of source-based load distribution. Receiving water models focus only on water bodies, such as rivers, streams, lakes, and reservoirs, and typically simulate hydrodynamics and/or water quality processes. Commonly coupled non-proprietary watershed models include the Loading Simulation Program in C++ (LSPC), Hydrologic Simulation Program Fortran (HSPF), Soil and Water Assessment Tool (SWAT), and Storm Water Management Model (SWMM), while receiving water models include the Environmental Fluid Dynamics Code (EFDC), CE-QUAL-W2, and the Water quality Analysis Simulation Program (WASP).

In recent years, a focus on watershed implementation has resulted in linkage of watershed and BMP models. Advanced BMP models, such as System for Urban Stormwater Treatment and Analysis IntegratioN (SUSTAIN), simulate combinations of structural management practices and enable users to optimize selection and placement of these practices based on hydrology, water quality, and economic targets. Linked watershed-BMP modelling applications have become a powerful tool to evaluate the potential benefits of costly infrastructure before spending limited resources to construct them.

This presentation will explore a number of coupled watershed-receiving water and watershed-BMP model applications in Alberta and the United States, including the North Saskatchewan River LSPC-EFDC modelling system.

TETRA TECH

Water Resources Management Using Coupled Models in Alberta and the U.S.

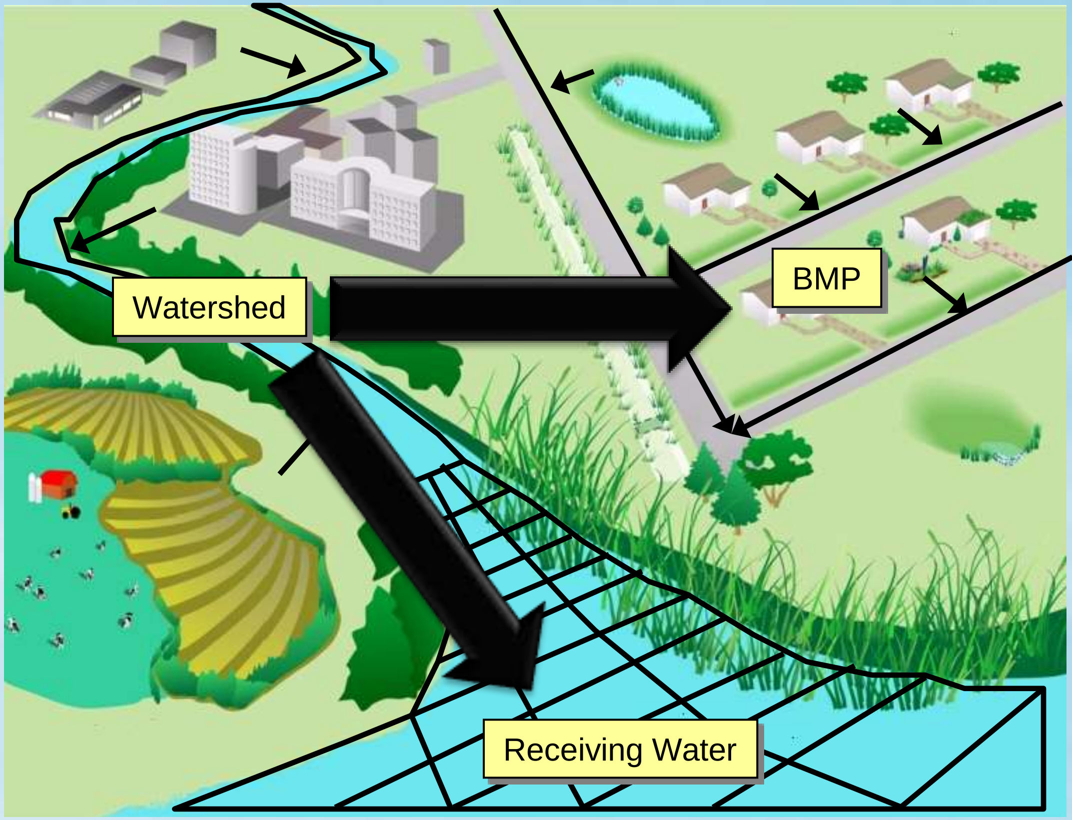
Andrew Parker

Water Resources Modeling Group

Fairfax, Virginia, USA

Environmental Modelling

- Effective tool for water resources management
- Coupling takes advantage of individual model strengths
- Focus on:
  - Watershed-Receiving Water
  - Watershed-BMP



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Watershed-Receiving Water Models

- Cumulative Effects, Total Maximum Daily Load (TMDL), and comprehensive watershed management studies
- Watershed models
  - Predict time-variable hydrology and water quality for various land surface categories (typically surface and groundwater)
  - Evaluate land-based, climate change, and other scenarios
  - Determine source-based load distribution
  - Non-proprietary examples include LSPC, HSPF, SWAT, and SWMM
- Receiving water models
  - Simulate hydrodynamics and/or water quality processes in water bodies
  - Non-proprietary examples include EFDC, CE-QUAL-W2, and WASP

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Watershed-BMP Models

- Watershed implementation driven
- Advanced BMP models
  - Simulate combinations of structural management practices
  - Enable users to optimize selection and placement of practices based on hydrology, water quality, and economic targets
  - Example: System for Urban Stormwater Treatment and Analysis IntegratioN (SUSTAIN)
- Evaluate potential benefits of costly infrastructure before spending limited resources on construction

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Commonly Coupled USEPA Models

- ► LSPC (Watershed)
  - Snow, flow, temperature, sediment, water quality (HSPF routines)
  - Object-oriented environment and relational database
  - Tailored for large-scale watershed modelling and TMDLs
- ► EFDC (Receiving Water)
  - Fully integrated hydrodynamics, sediment, and water quality
  - 1, 2, or 3-dimensional simulation of rivers, lakes/reservoirs, estuaries
- ► SUSTAIN (BMP)
  - Implementation planning framework
  - Determine cost-effective mix of BMPs to meet flow/load goals
- ► All are public domain – freely available at http://www.epa.gov

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Case Studies

LSPC → EFDC

- ▶ Watershed Management and Cumulative Effects Assessment
  - *North Saskatchewan River*

LSPC → EFDC

- ▶ Reservoir Management
  - *Lake Lanier, Georgia*

LSPC → SUSTAIN

- ▶ Optimal Implementation Planning
  - *Milwaukee, Wisconsin Metropolitan Sewer District*

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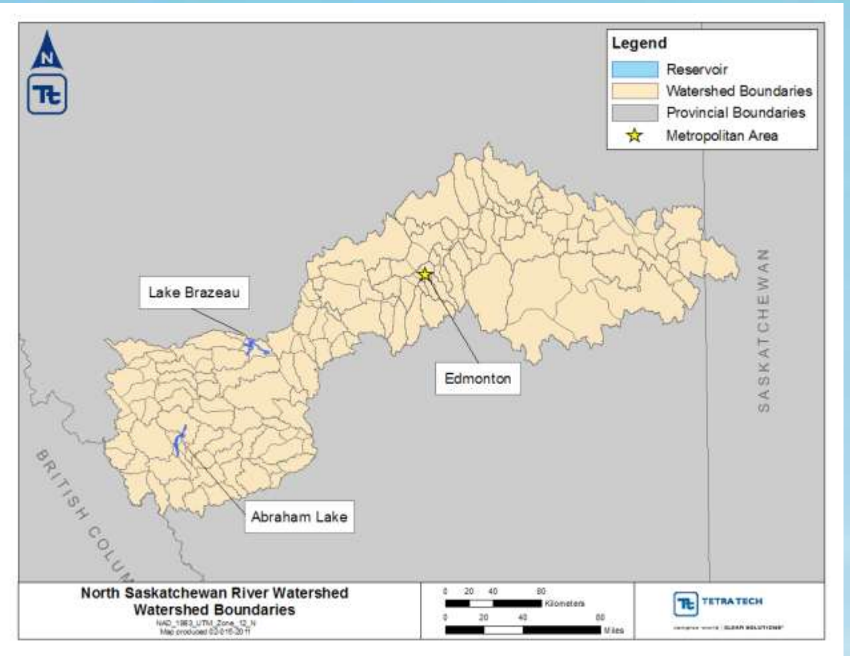
North Saskatchewan River

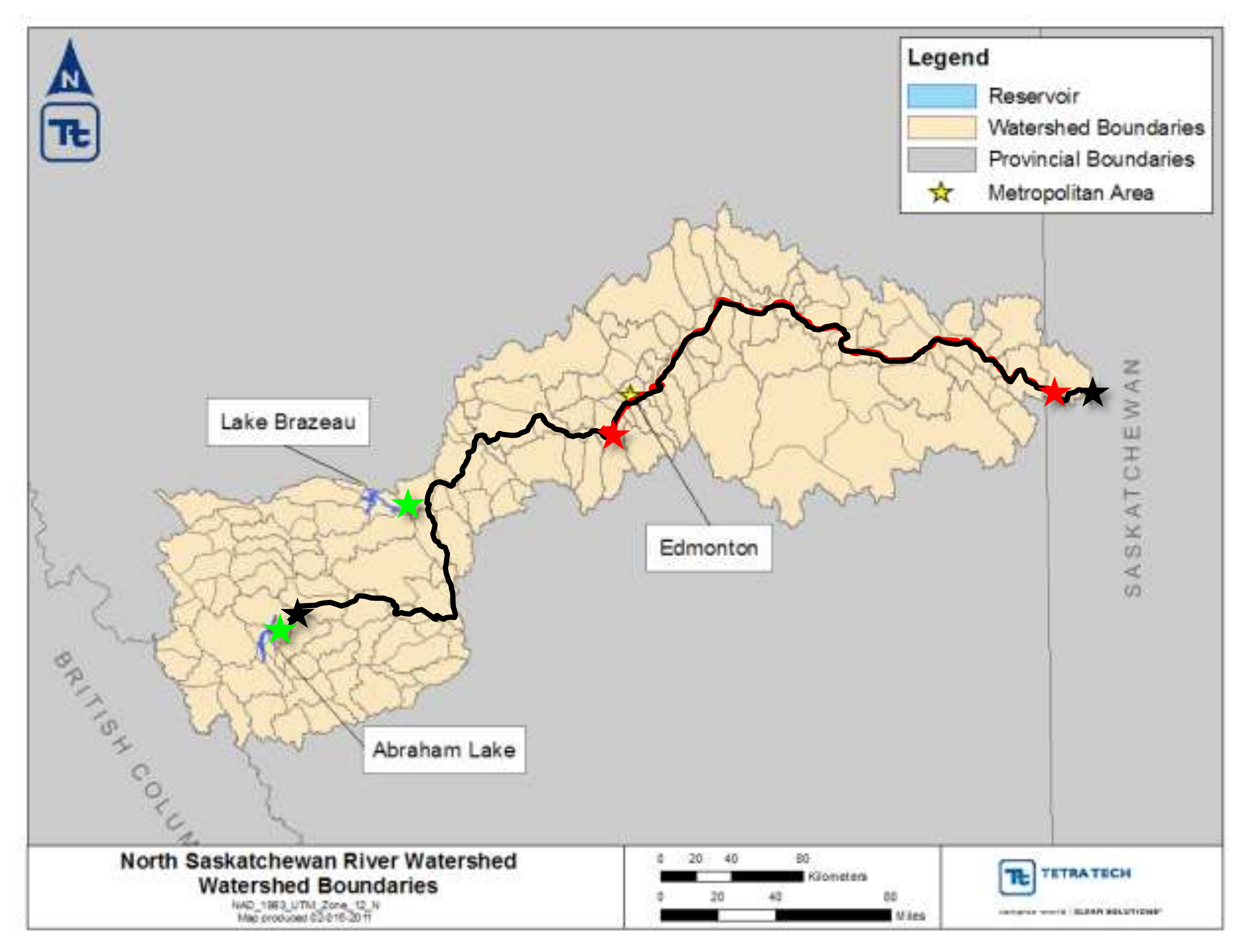
LSPC → EFDC



- ► Developed coupled watershed-receiving water models for AESRD
- ► Hydrology, hydrodynamics, and water quality
- ► LSPC for basin-wide simulation
- ► EFDC for main-stem river, Lake Brazeau, and Abraham Lake

Phased Modelling Process

- 2D/1D model of NSR
  - Devon to Saskatchewan
- 1D model of NSR
  - Abraham Lake to Saskatchewan
- Watershed model
- 3D models of lakes
  - Abraham Lake
  - Lake Brazeau
- Watershed model enhancements



complex world | CLEAR SOLUTIONS™

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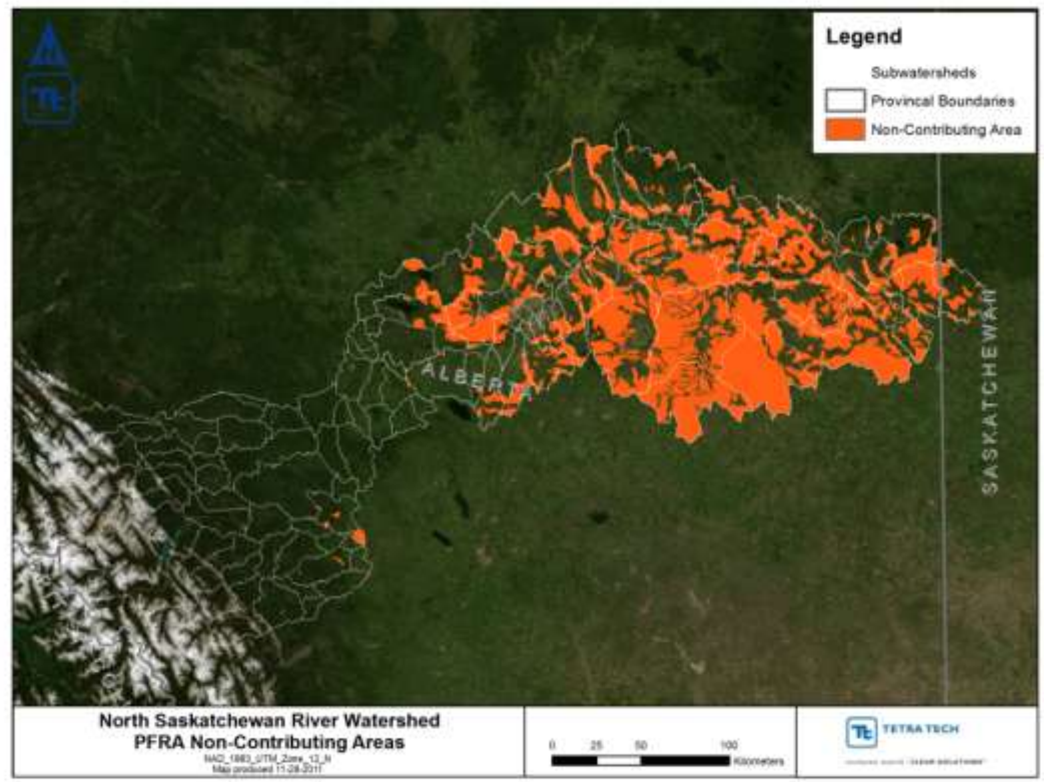
LSPC Enhancements

- ► Improved meteorological input data/snow representation
- ► Increased number of calibration locations
- ► Quantified impact and modelled behavior of hydrologically non-contributing areas
- ► Multi-faceted water quality calibration



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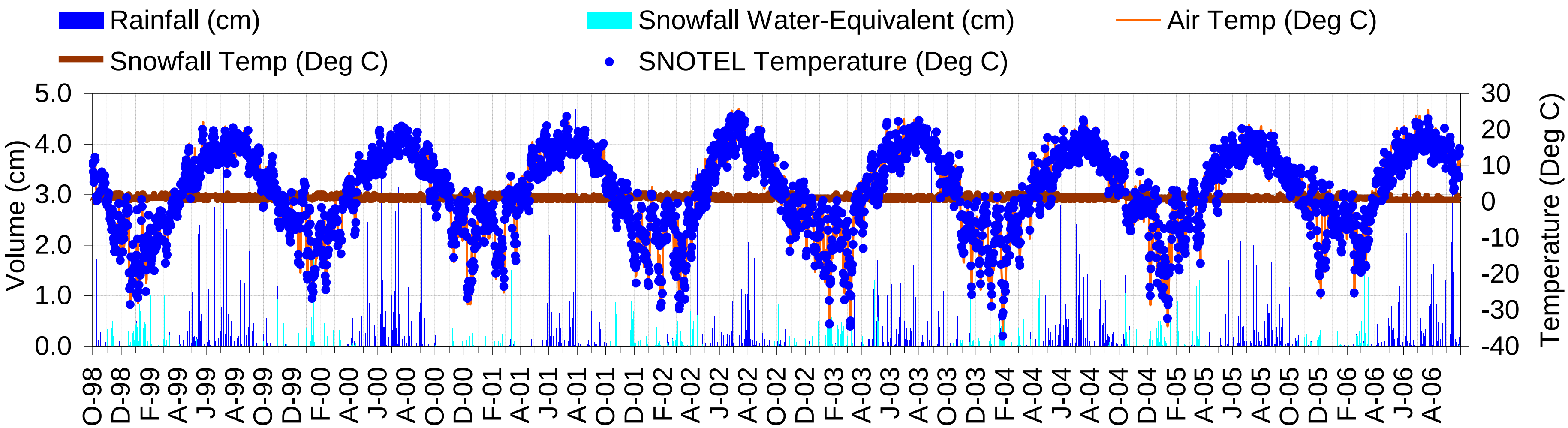

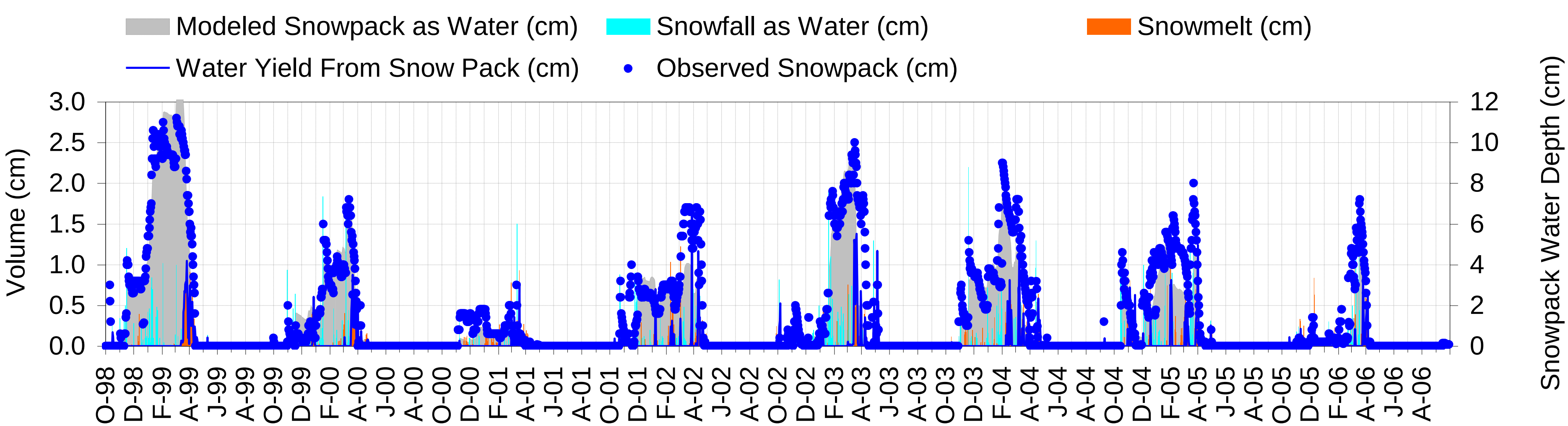

LSPC snow calibration at Edmonton Woodbend (10/1/1998 to 9/30/2006)

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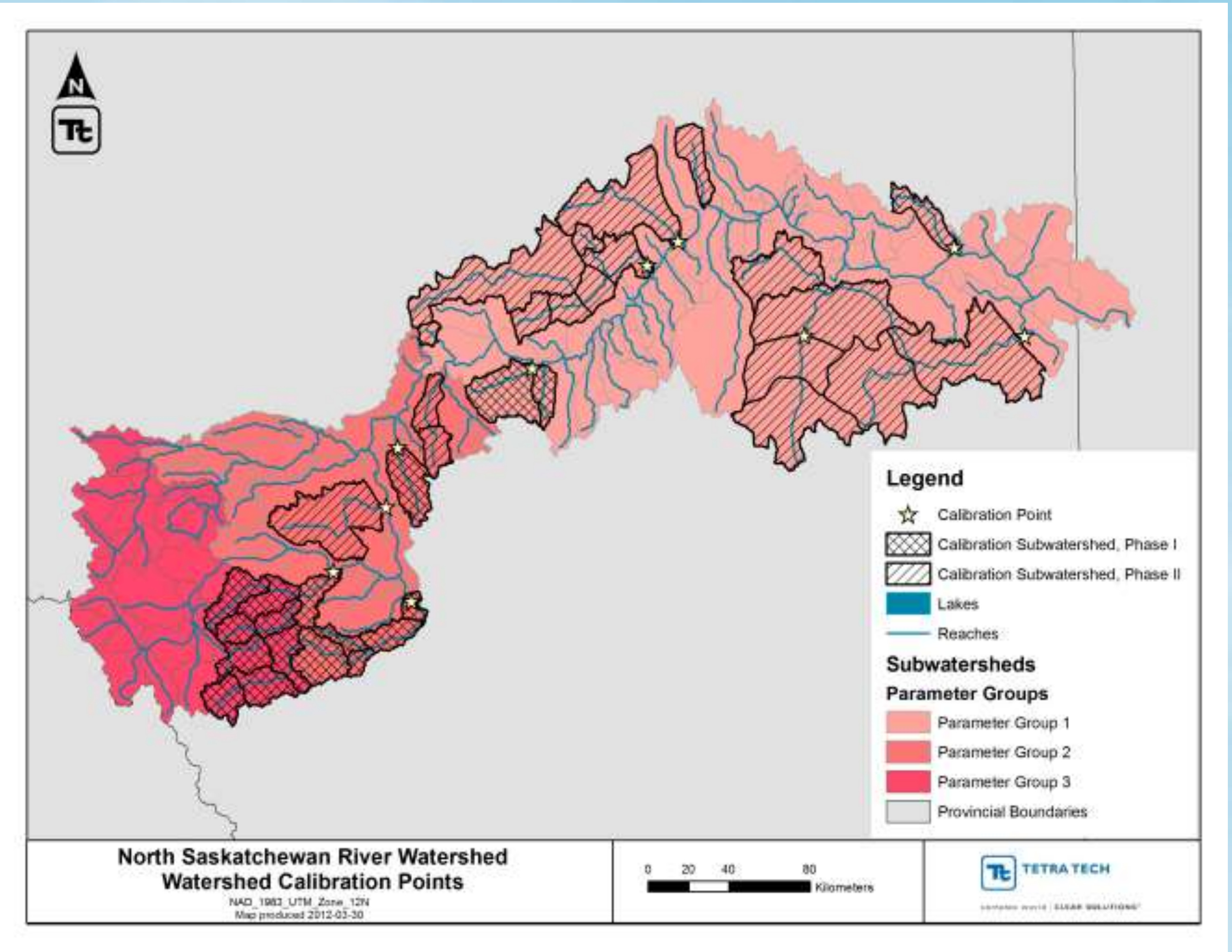
Calibration Locations



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Summary of Seasonal Flow Patterns in NSR Basin

NSR Tributary		Average Elevation (m)	Percent NCA	Peak Flow Month	Percent of Observed Annual Flow	
Name	Gage ID				March-**April**-May	May-**June**-July
Ram River	05DC006	1,807	0.0%	June	20%	61%
Clearwater River	05DB006	1,731	0.0%	June	19%	51%
Baptiste River	05DC012	1,106	0.010%	June	30%	58%
Rose Creek	05DE007	974	0.004%	May	49%	62%
Modeste Creek	05DE911	893	0.0%	April	63%	50%
Tomahawk Creek	05DE009	799	0.0%	April	72%	41%
Strawberry Creek	05DF004	798	0.19%	April	71%	47%
Sturgeon River	05EA001	715	27%	April	82%	37%
Vermillion River	05EE009	673	77%	April	84%	41%
Vermillion River	05EE007	666	74%	April	96%	17%
Waskatenau Creek	05EC002	664	37%	April	92%	14%
Redwater River	05EC005	661	26%	April	90%	34%

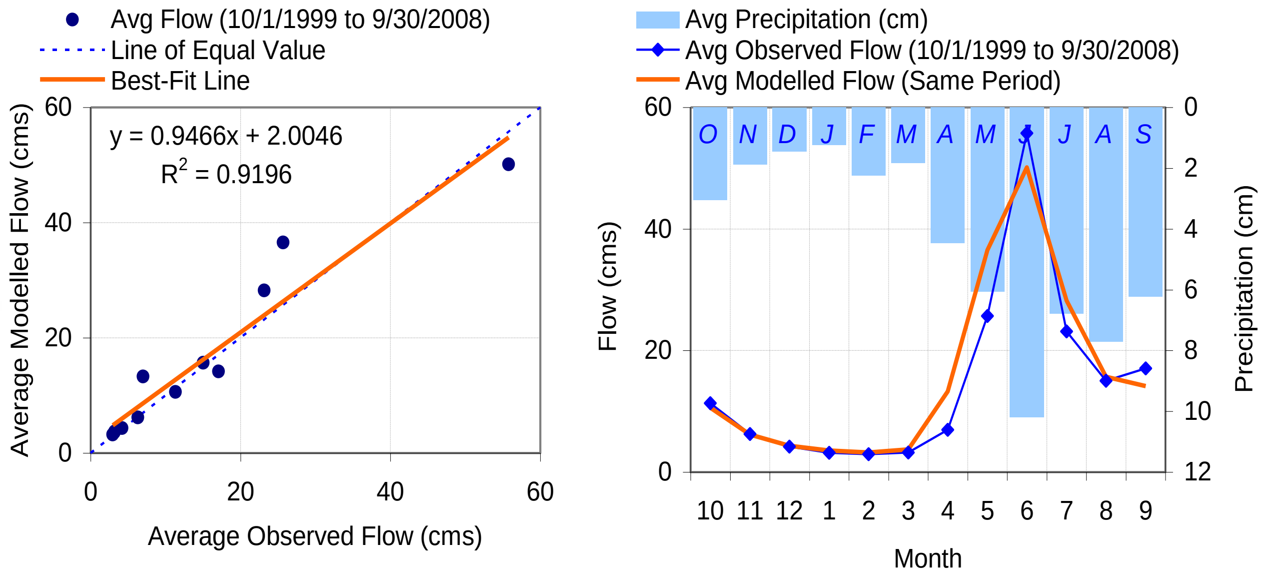
NCA – Evaluation of Physical Processes

- Frozen Ground
  - Spring: runoff occurs because ground acts impervious
  - Summer: surface depressions contain most runoff when ground thaws
- Deep Aquifer Recharge
  - Summer/fall: baseflow in streams dissipates
  - Performed full mass balance
    - Maximum potential evapotranspiration had little effect
    - Groundwater recharge was most effective

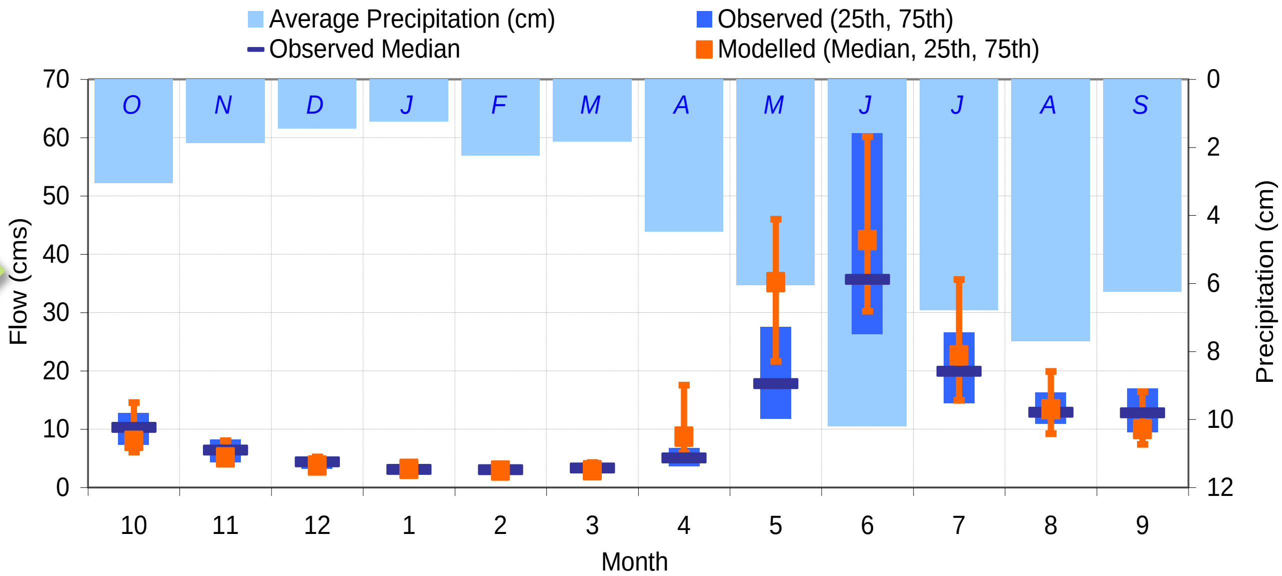
Ram River Gage (05DC006)

Streamflow Observed vs. Modelled

seasonal / monthly flow



quartile variation



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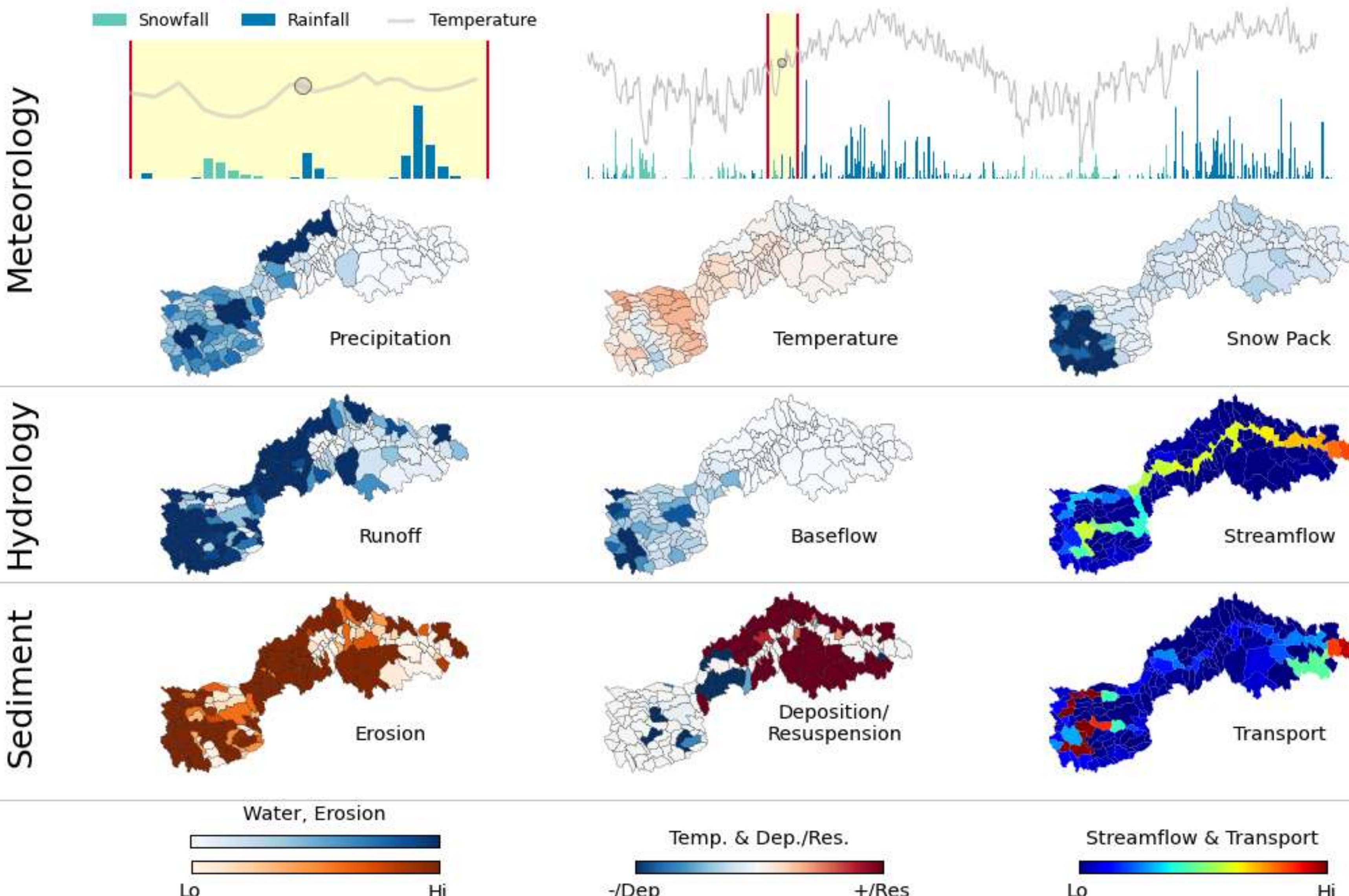
Error Statistics: Ram River (LSPC)

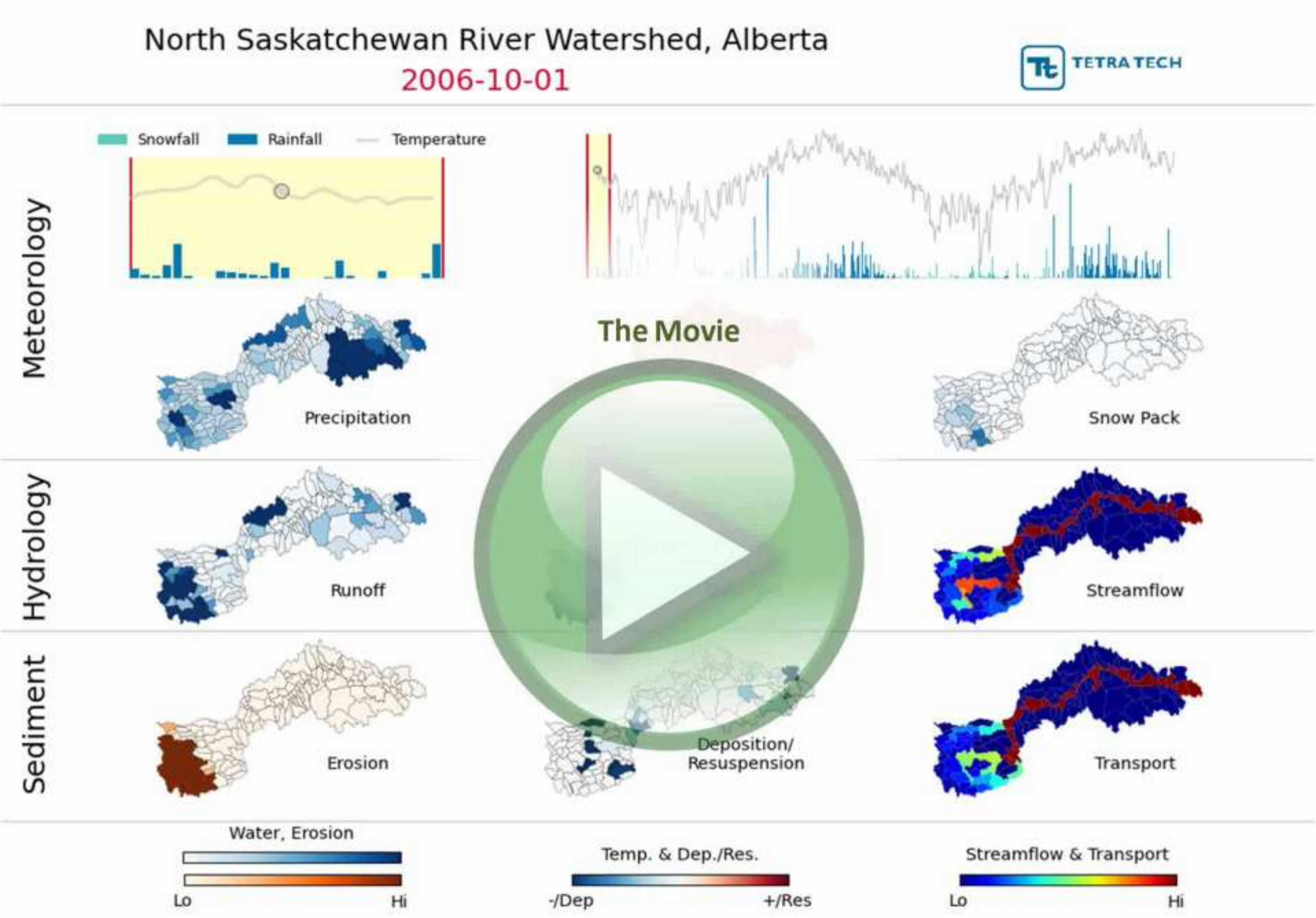
Hydrologic Indicator	Observed (cm/year)	Simulated (cm/year)	Error Statistics	
			Error (%)	Goal (%)
Total In-stream Flow:	24.34	26.43	8.60	±10
Total of lowest 50% flows:	3.35	3.60	7.51	±10
Total of highest 10% flows:	10.90	10.41	-4.55	±15
Summer (months 7-9):	7.75	8.16	5.31	±30
Fall (months 10-12):	3.06	2.96	-3.21	±30
Winter (months 1-3):	1.29	1.45	12.50	±30
Spring (months 4-6):	12.24	13.86	13.22	±30
Total Storm Volume:	5.18	4.56	-11.89	±20
Summer Storm Volume (7-9):	1.16	1.20	3.43	±50
Nash-Sutcliffe Coefficient of Efficiency, E:		0.54	Model accuracy increases as E or E' approaches 1.0	
Baseline adjusted coefficient (Garrick), E':		0.44		

Metrics: HSPEXP, Nash-Sutcliffe, Garrick

North Saskatchewan River Watershed, Alberta

2007-04-09




North Saskatchewan River Watershed, Alberta
2006-10-01
TETRA TECH
Snowfall
Rainfall
Temperature
Meteorology
Hydrology
Sediment
Precipitation
Snow Pack
The Movie
Runoff
Streamflow
Erosion
Deposition/
Resuspension
Transport
Water, Erosion
Lo
Hi
Temp. & Dep./Res.
-/Dep
+/Res
Streamflow & Transport
Lo
Hi

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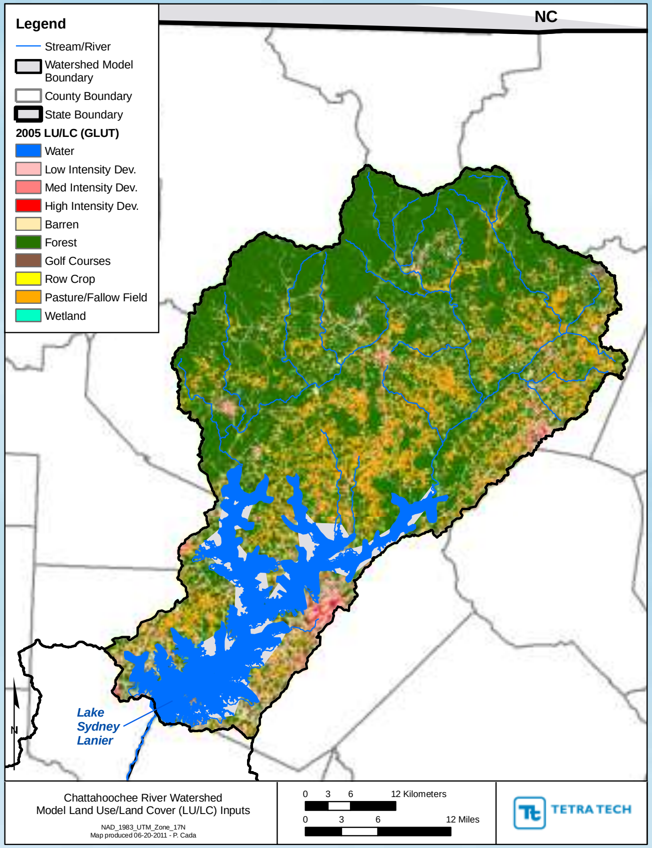
Lake Lanier

LSPC → EFDC

- ▶ Multi-purpose application
- ▶ Reservoir operations (Army Corps of Engineers)
- ▶ TMDL and wasteload allocations (Georgia EPD and USEPA)
- ▶ Landuse management for development



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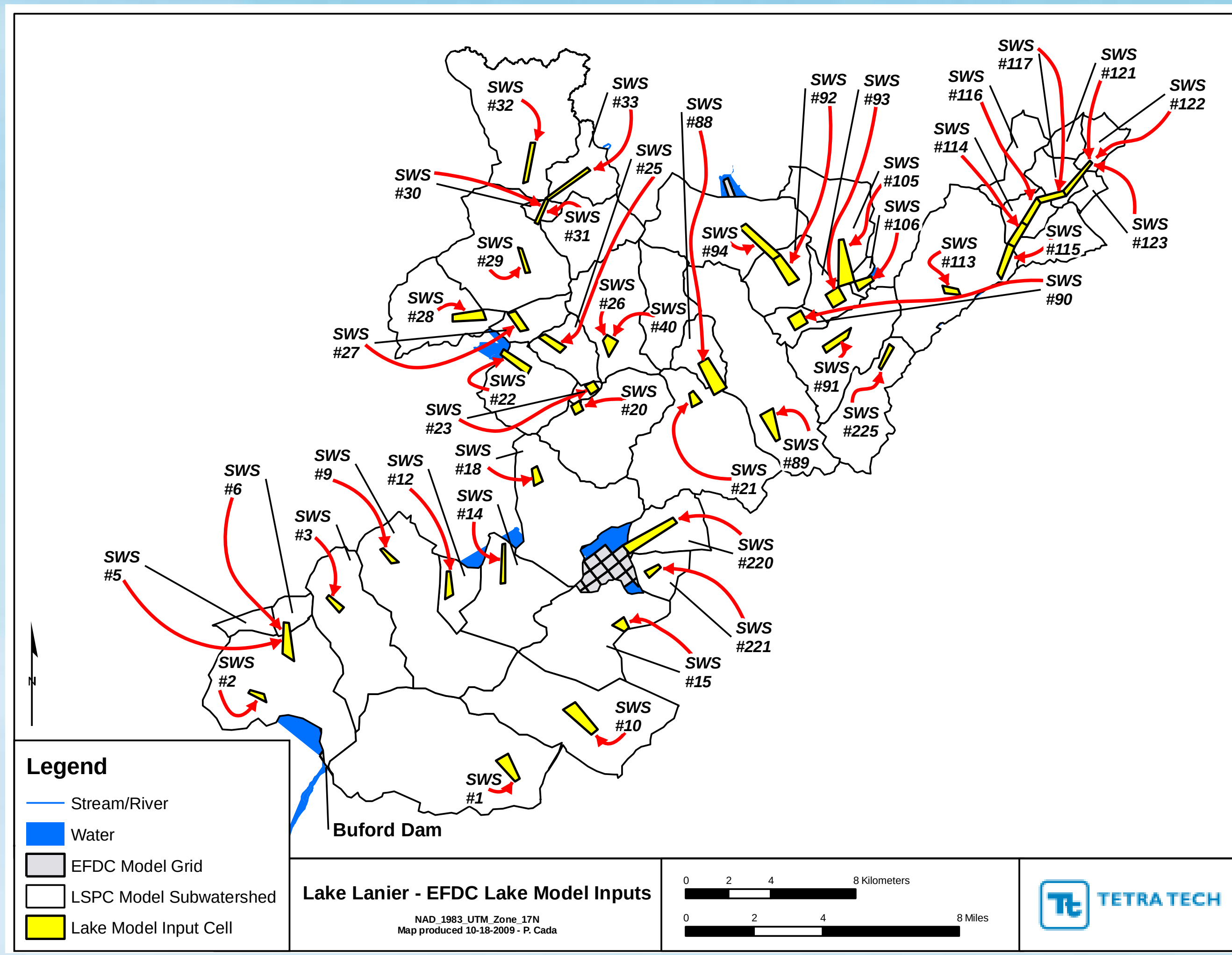
Concentrations:
Chl-a, TN, NH_3, NOx, OrgN, TP, PO_4, OrgP, BOD, DO, Temp, TSS, Fecal

LSPC

Flows
Temperatures
Concentrations

EFDC

Lake/Harbor – Water Surface
River/Lakes – Temperatures
River/Lake/Harbor Concentrations:
(Chl-a, TN, NH_3, NOx, OrgN, TP, PO_4, OrgP, BOD, DO, Temp)



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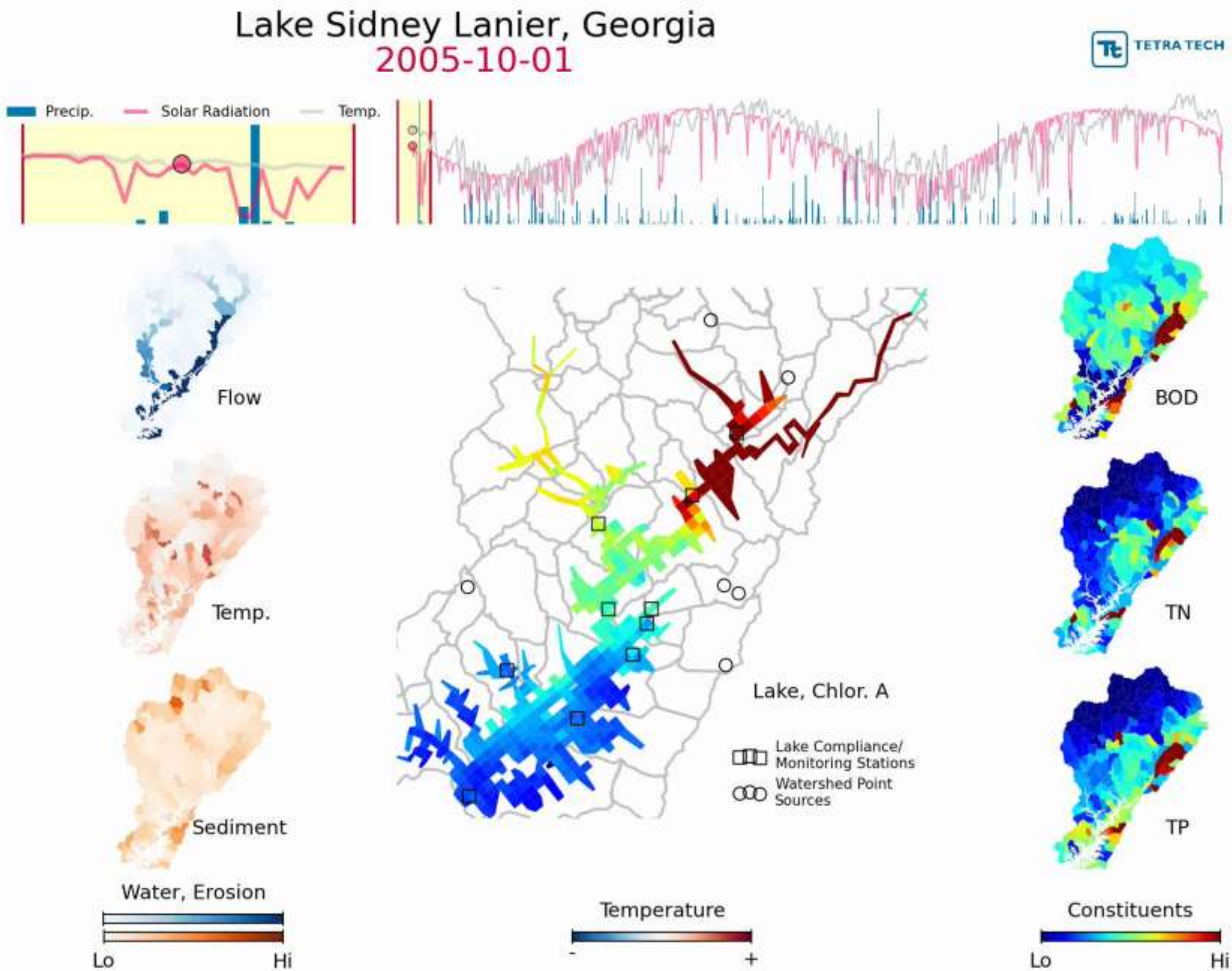
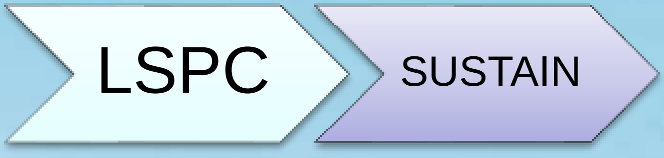
Scenarios

- Historical and current conditions
- Current conditions with allowable permits
- Current conditions w/ point sources/withdrawals removed
- All forested/natural
- Future land use full build-out
- Future land use w/ point sources/withdrawals removed
- Nonpoint source management practices
- TMDL to meet water quality criteria
  - Landuse and point source-specific reductions
- Reservoir operational changes



Lake Sidney Lanier, Georgia
2005-10-01
TETRA TECH
Precip.
Solar Radiation
Temp.
Flow
Temp.
Sediment
Lake, Chlor. A
Lake Compliance/ Monitoring Stations
Watershed Point Sources
BOD
TN
TP
Water, Erosion
Lo
Hi
Temperature
-
+
Constituents
Lo
Hi

Milwaukee Metropolitan Sewer District



- Explored ability of green infrastructure to reduce combined sewer overflows
- Benefits measured by:
  - Environmental outcomes (pollution reductions)
  - Economic and social outcomes (triple bottom line)
- Applied SUSTAIN linked to LSPC

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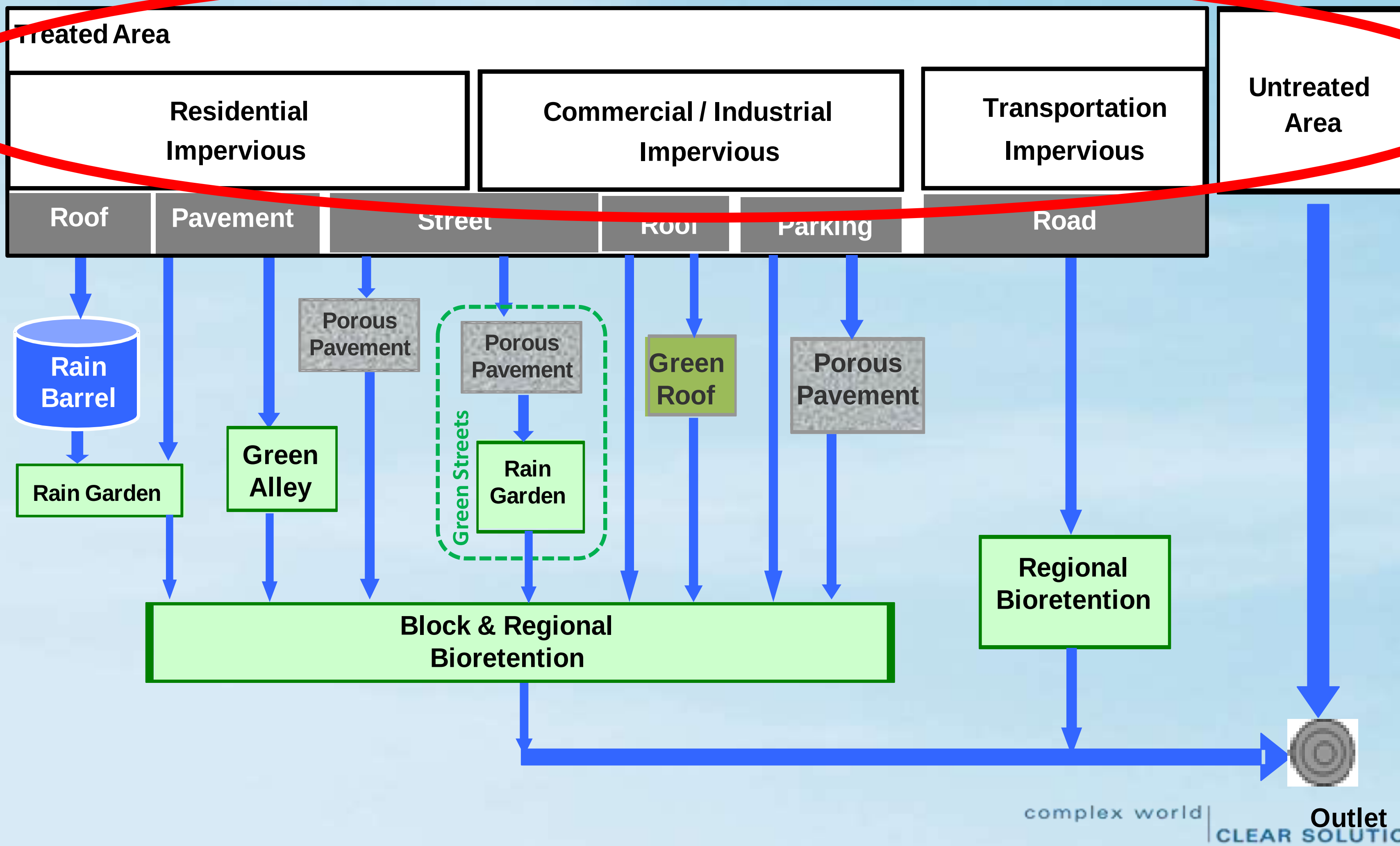
Potential Types and Locations

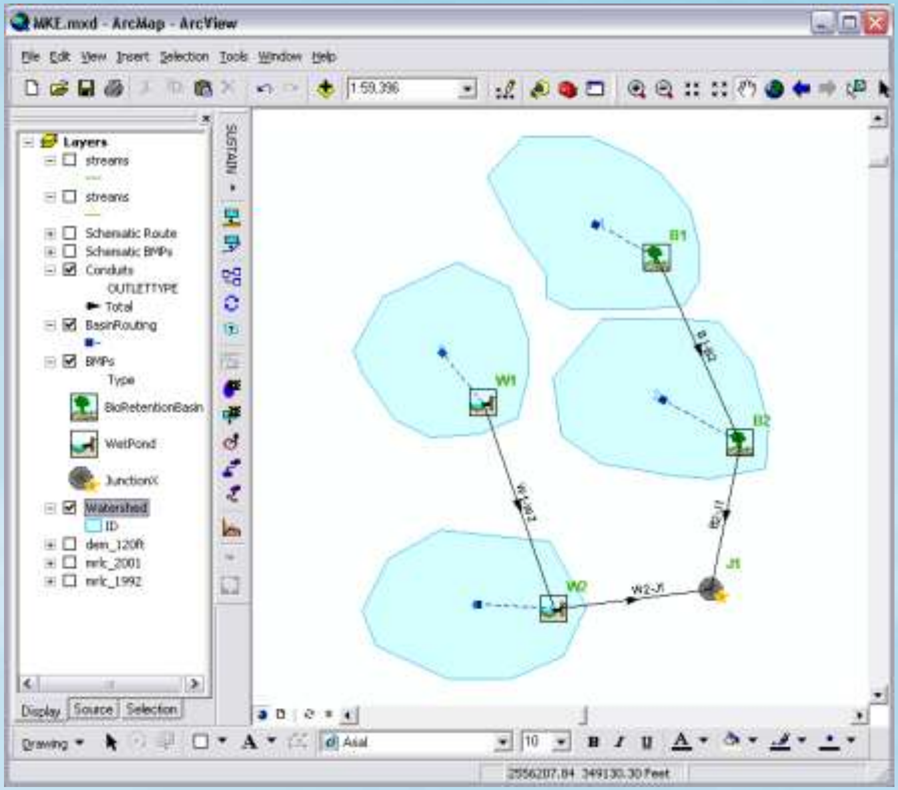
BMP Configuration:
Aggregate BMP Network

From LSPC model



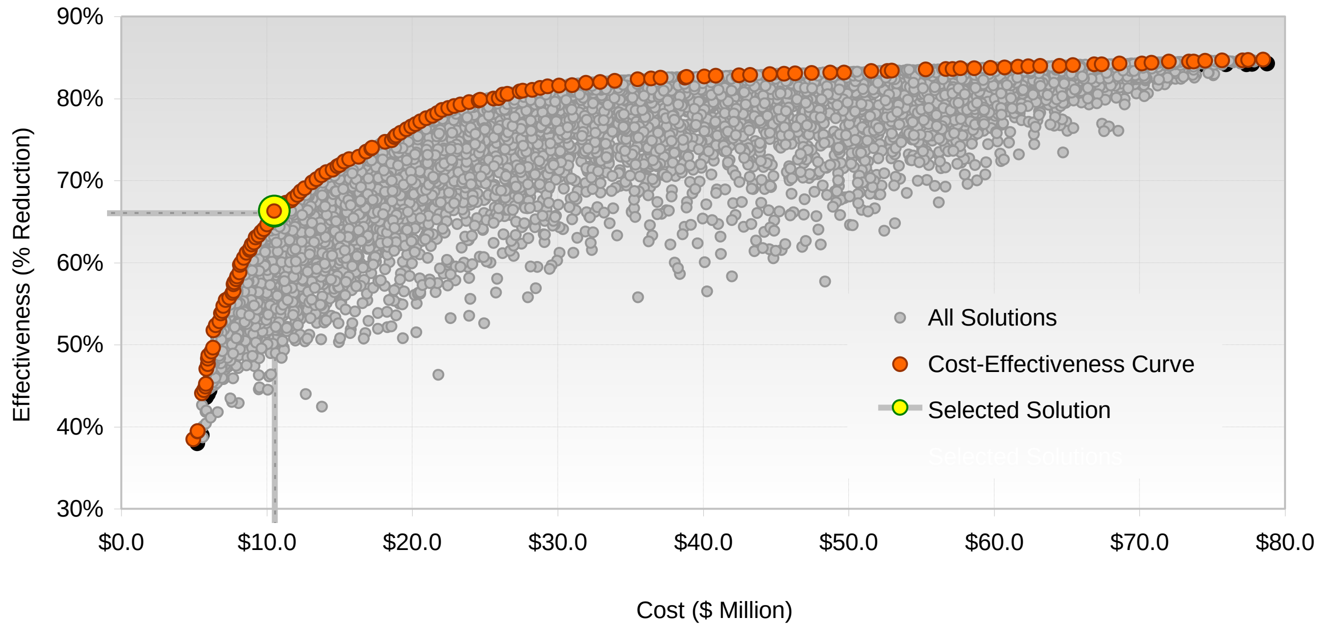
Selection and Placement Optimization

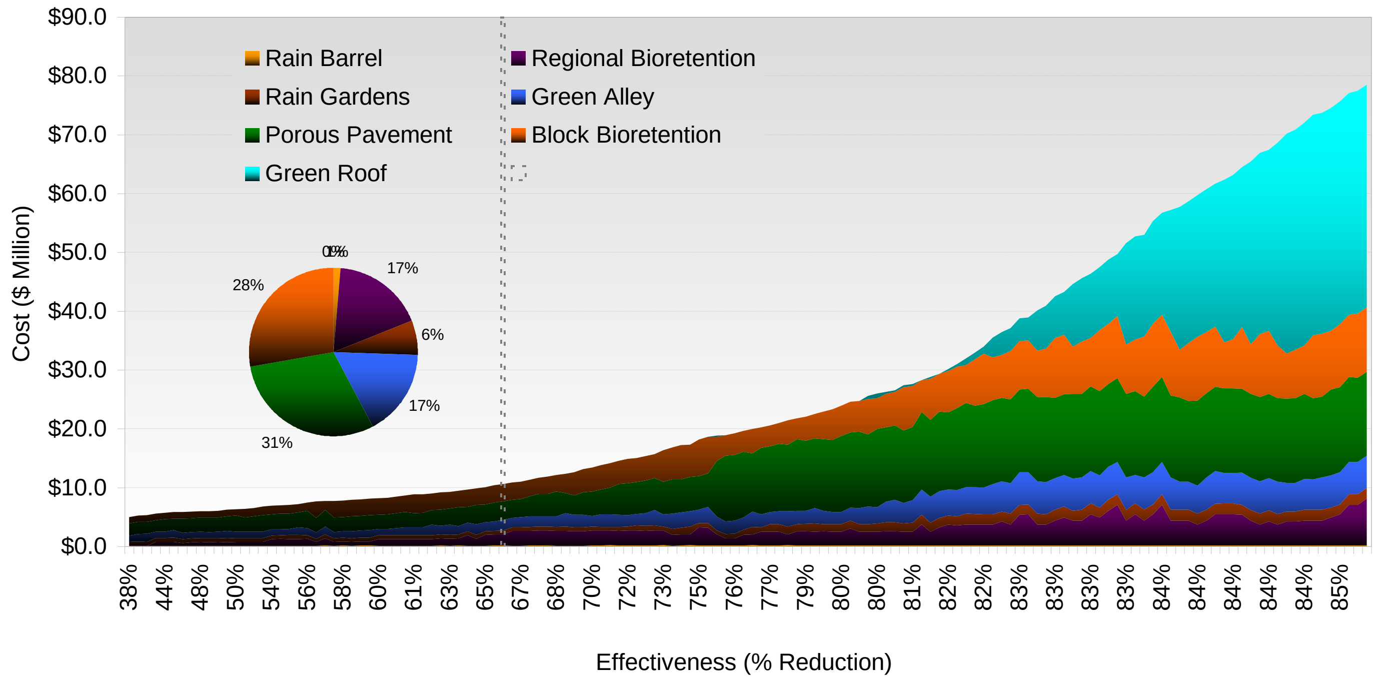
- ► BMP Configuration
  - Map all potential locations
  - Typical routing configuration
  - Unit cost (scalable)
- ► Decision Variables
  - BMP Size (0 to maximum)
  - BMP Location (on or off)
- ► Objectives
  - Minimize Cost
  - Maximize Volume Reduction



Cost-effective Solutions

- Reduction:
  66.0%
- Cost:
  $10.6 Mil





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Thank you!

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Ryan Murphy

John Riverson

Brian Watson

Brandon Wood

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Day 1 – Session 1

Dan Sheer – Hydrologics

BIOGRAPHY

Dan Sheer earned his Ph.D. at the Johns Hopkins University in 1975. At the Interstate Commission on the Potomac River Basin, he helped resolve the long standing water supply dispute between Maryland, Virginia, The District of Columbia, and the U.S. Government concerning Washington Metro Area water supply. He developed and applied a range of water resources systems techniques, including collaborative modelling and gaming, to achieve this award winning success. In 1985 he left his position as Technical Director to found HydroLogics, in order to expand the application of those techniques to other basins. HydroLogics now helps manage water in river basins containing about 20% of the US population. The firm has been instrumental in the resolution of some of the most complex water disputes of the last 30 years, and has worked internationally, particularly in China and Canada. Clients include the Delaware and the Susquehanna River Basin Commissions, the South Florida Water Management District, the Southern Nevada Water Authority, many states and cities, The Nature Conservancy, several hydropower utilities, and many others. HydroLogics OASIS software is one of the most widely used water management planning and management tools.

Day 1 – Session 1

Dan Sheer – Hydrologics

ABSTRACT

Water management is about obtaining the most appropriate and beneficial mix of multiple types of benefits from water resources. Social and governmental values determine what constitutes an appropriate benefit and how the achievement of those benefits should be balanced to provide the best mix. Science cannot determine what values are appropriate nor how they should be balanced.

Science, largely through the use of management models, can predict with some limited accuracy and precision the effect that existing and proposed management actions will have on benefits derived from water resources. The focus of this presentation will be on how models can be designed or chosen and then used for this function, and how modelling results can be made most useful and informative to water managers, decision makers, and the public. The talk will draw on examples from the author’s long experience in the field.

It will cover:

· developing performance metrics
· designing models and post-processors to display those metrics
· ensuring model credibility
· ensuring that models can evaluate all candidate alternatives
· the modeler’s responsibility to ensure that, in so far as possible, alternatives that provide the most effective (non-inferior) mixes of possible benefits are identified

HYDROLOGICS

Advancing the management of water resources

Using Models in Water Management:
Philosophy, Principles and Practice

Daniel P. Sheer, Ph.D., P.E.

President, HydroLogics Inc.

March 13, 2013

Presenter

Daniel P. Sheer

June 24, 2002

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919-856-1288

1851 Heritage Lane, Ste. 130
Sacramento, CA 95815
916-920-1811

Management is about Values

- We manage to achieve the things we want, i.e. to advance our VALUES
- “What do we WANT?” is NOT a scientific question
- “What can we GET by managing” IS a scientific question
- MODELS can help determine what we can GET and HOW we can get it

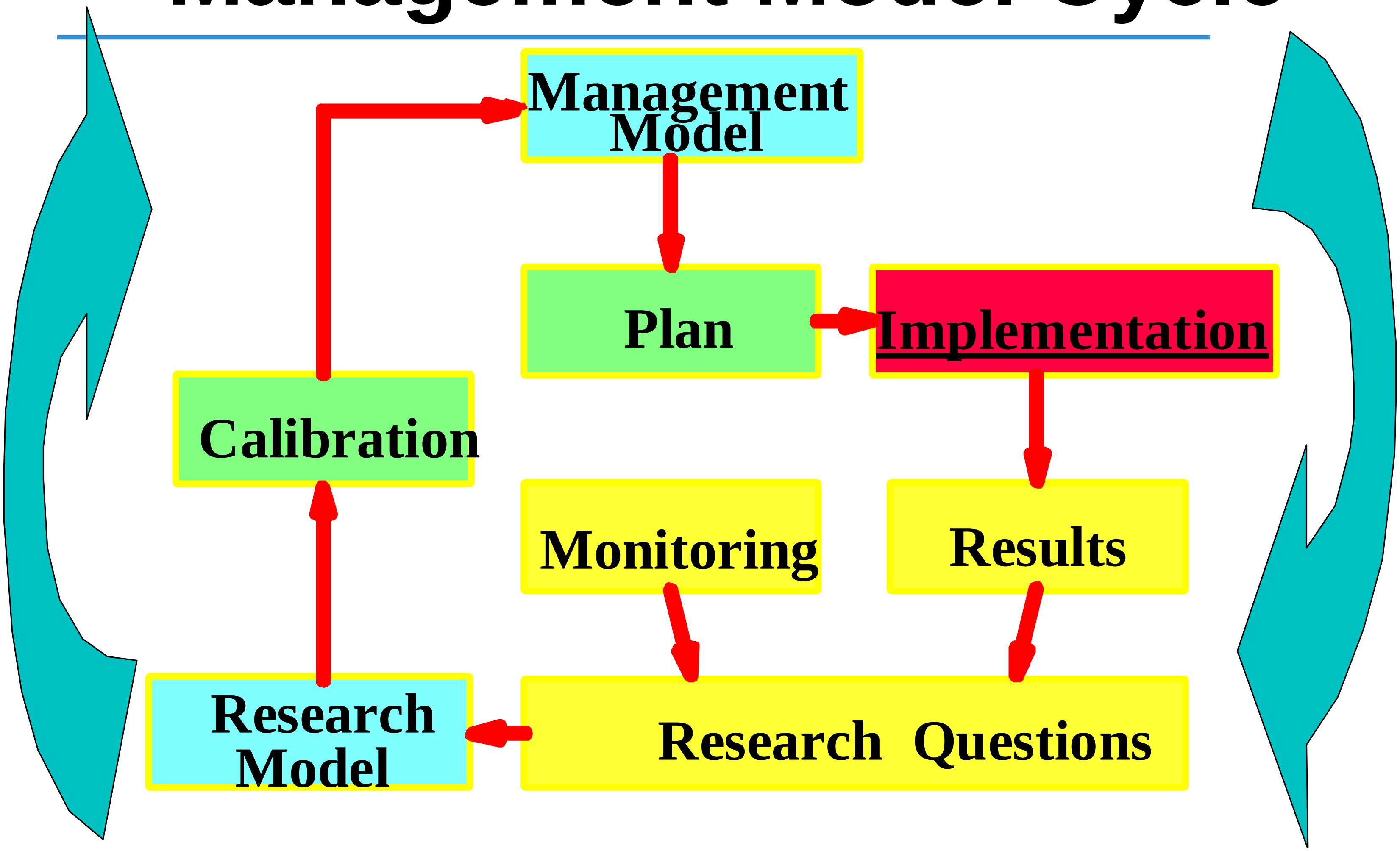
Management Models:

- Predict the likely OUTCOME of human actions
- Produce output that relates the outcome to human VALUES
- Use scientific cause and effect or empirical relationships to make the predictions and to produce the output

Management Models vs. Research Models

- Research models try to simulate history in order to determine how the world works
- Management models assume that we know how the world works, and try to evaluate the impacts of actual and potential human actions on the future

The Research Model - Management Model Cycle



Models are “Needy Beasts”

- Models require care and feeding
  - Data
  - Methods
  - This must be provided
- Models need the ability to simulate different kinds of human behavior
  - Users can’t give this to models – they have to be born this way

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Management is a Form of Human Behavior

- Rational (linking actions to desired outcomes), one would hope
- Management models must let us test alternative human behaviors
  - Different operating policies
  - Building and operating new things
  - Changing values
  - Leaving things alone

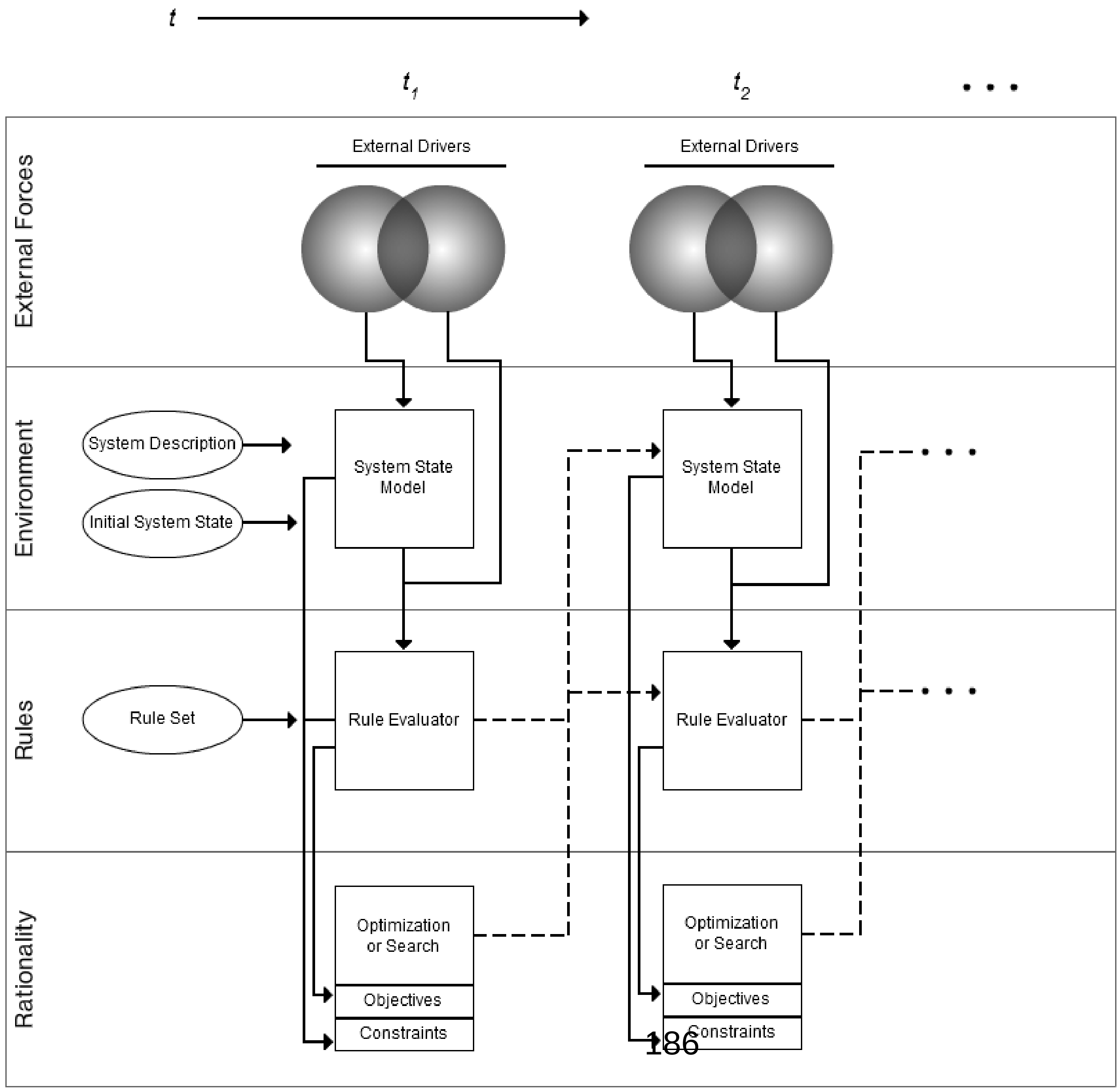
A “Model” of Human Behavior

- Short-term objectives and constraints
  - Determined by current factors
- Rules set short-term objectives and constraints
- Rules evolve (or are designed) to obtain long-term objectives
- Actions affect the environment which then determines current factors……..

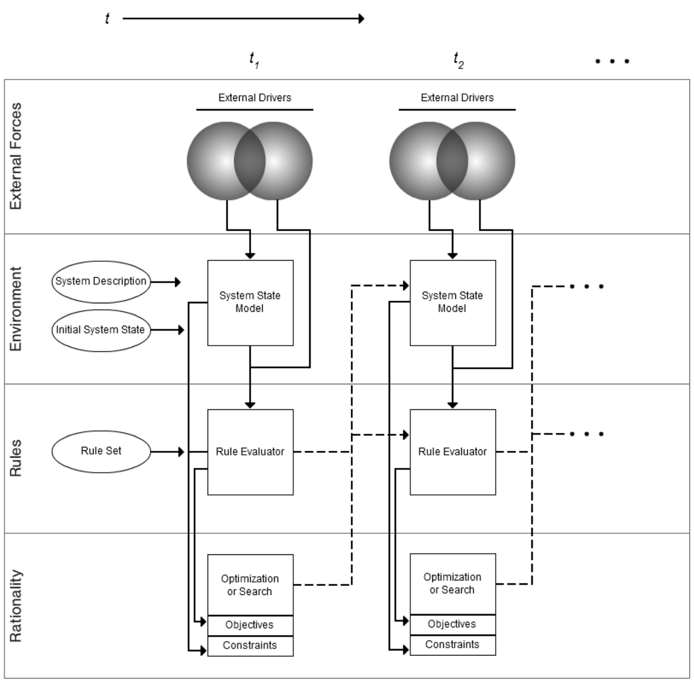
A Management Model Has

- Time series of external data that “drive” the model (boundary conditions)
- Science that links the drivers and human responses to determine what happens (system state)
- Rules that dictate human reactions, including short-term optimization

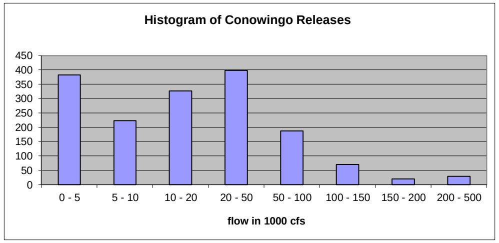
Generalized Management Model Schematic

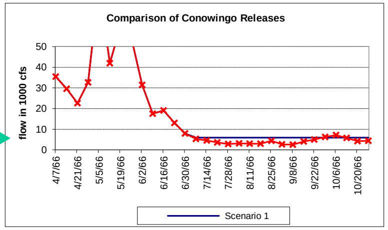


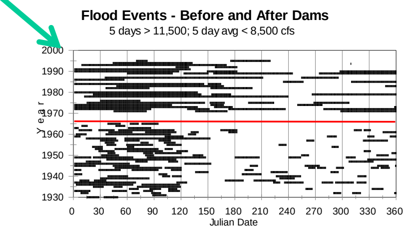
Post-Processors Convert Model Output to PMs Based on Science



Post-Processor







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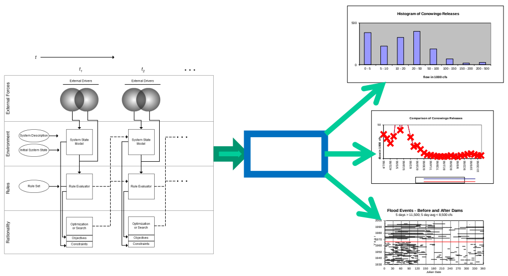
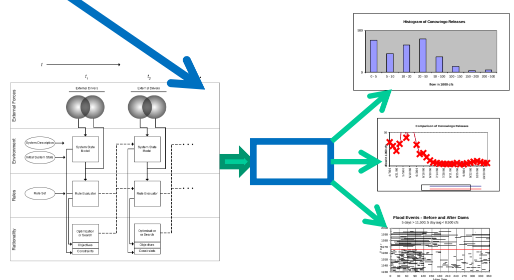
Using Management Models

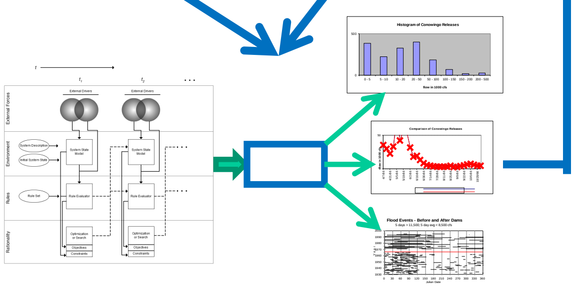


1. Evaluate natural/current base case(s)

2. Evaluate alternative that improves PMs



3. Lather, rinse and repeat until satisfied (or exhausted)



Rule Inputs

- Rules have both forms and parameters
- Rules can be static or dynamic
    - FITFIR
    - Reservoir Rule Curves
    - Minimum Flows
    - Conservation practices
    - Habitat creation
    - Objectives and constraints for optimization

New Rule Forms are Important

- Imagination is limited by tools
- Models should accommodate the widest reasonable range of rule forms
- Dynamic rules depend on system state and external drivers
- Optimization rules require an optimizer
- Some sort of scripting language is needed to change the forms of rules

Management Model Output (PMs)

- Surrogates for short- and long-term objectives
- Most management PMs long-term, but not all
- Most benefits from water resources are local, so PMs for water resources are unique to locale

Human Behavior Targets Values (Performance Measures)

- PM design is the most intellectually demanding part of the modeling process
- Management Models must produce PMs
- Managers generally try to achieve short term PMs as surrogates for improving long term performance

What Is A Performance Measure?

- A display
- Compares alternatives for one management objective
- Needs only to distinguish "better" and "worse"
- Water management is multi-objective
- Multiple performance measures are required

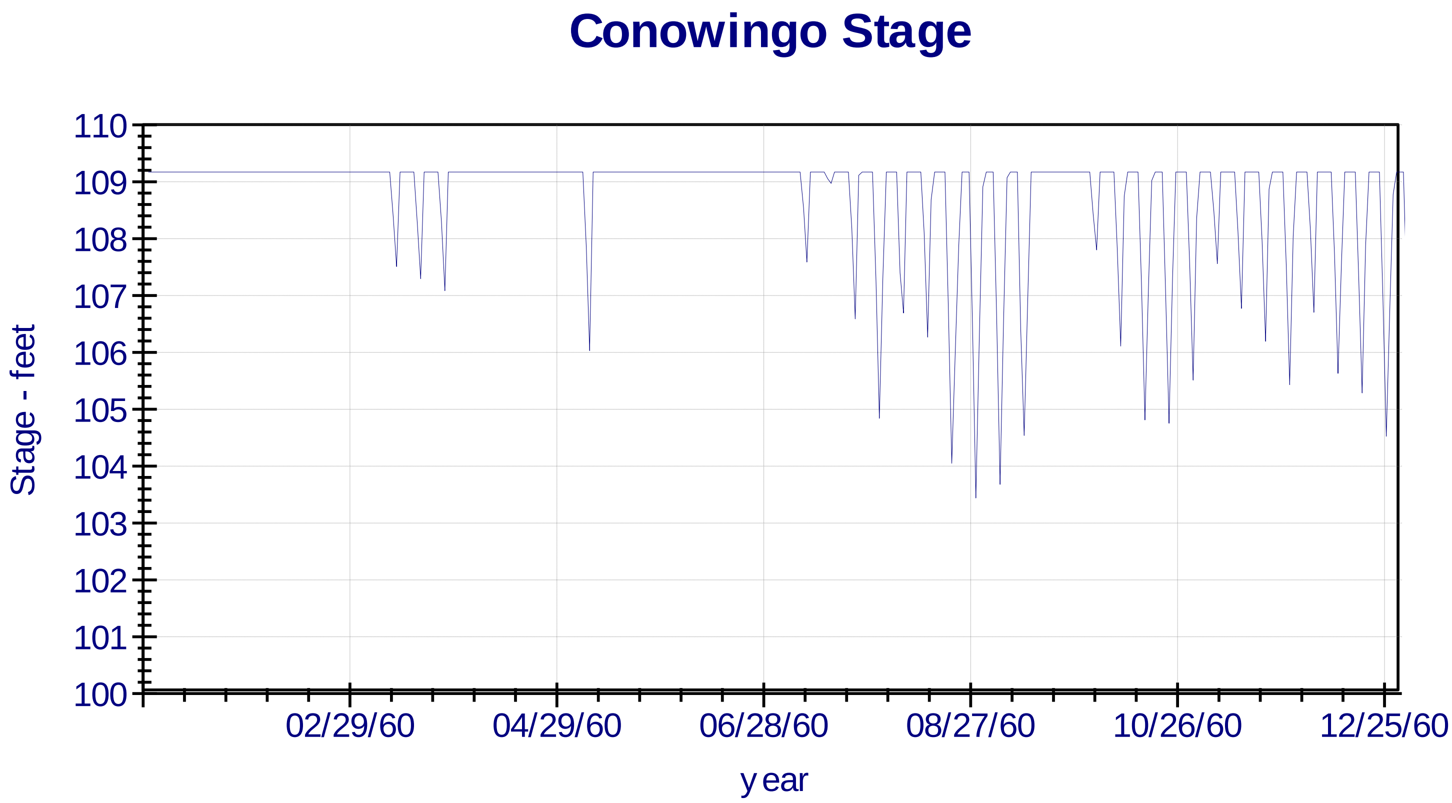
Performance Measures Must Be:

- Meaningful and Understandable
- Credible
- Reproducible

Performance Measures

- Providing meaningful ways to compare alternatives is very challenging
- Biological issues are often the most difficult
- HydroLogics has a process for producing such displays

Performance Measures



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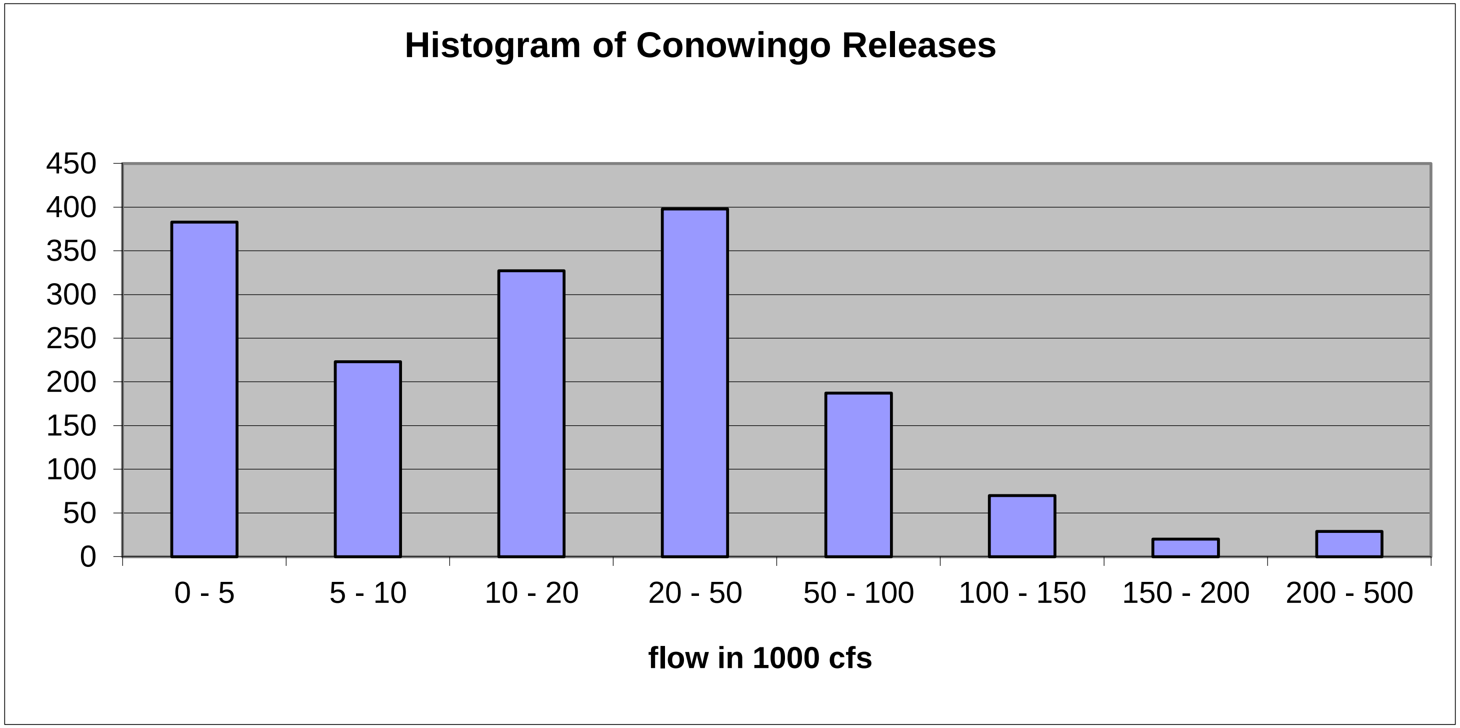
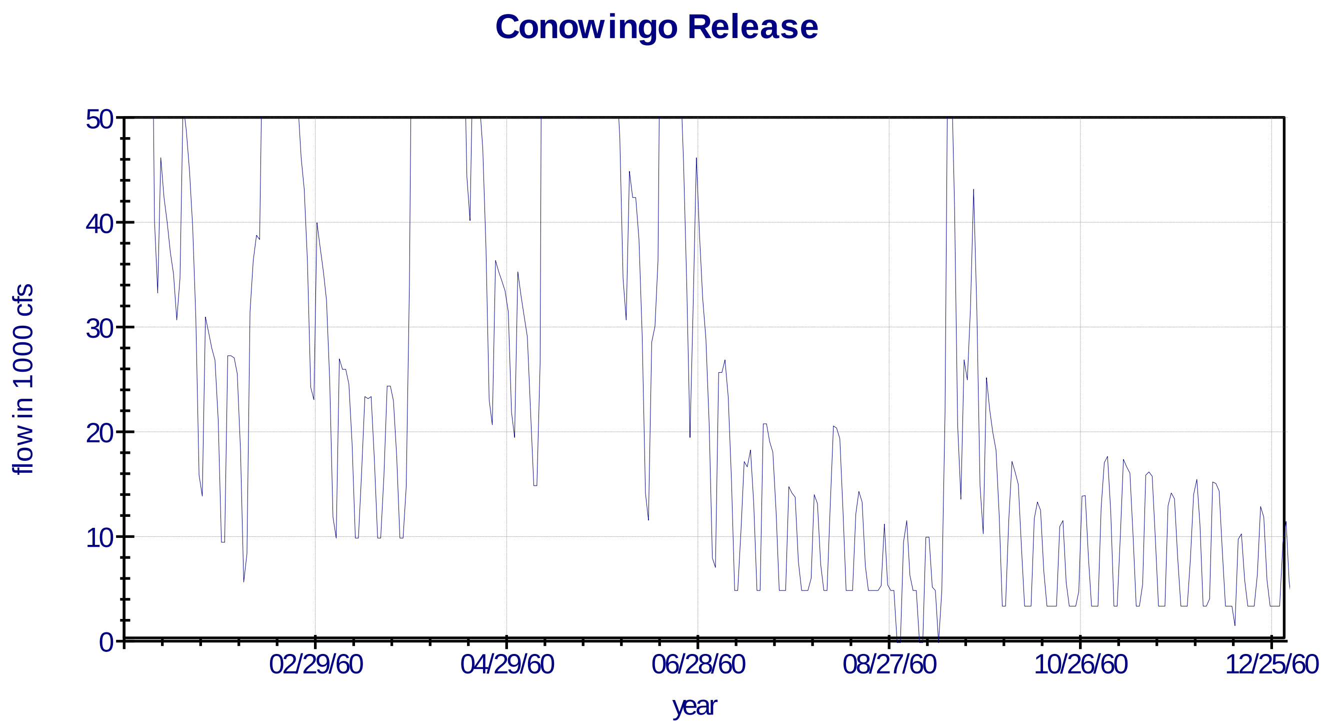
Performance Measures



Performance Measures



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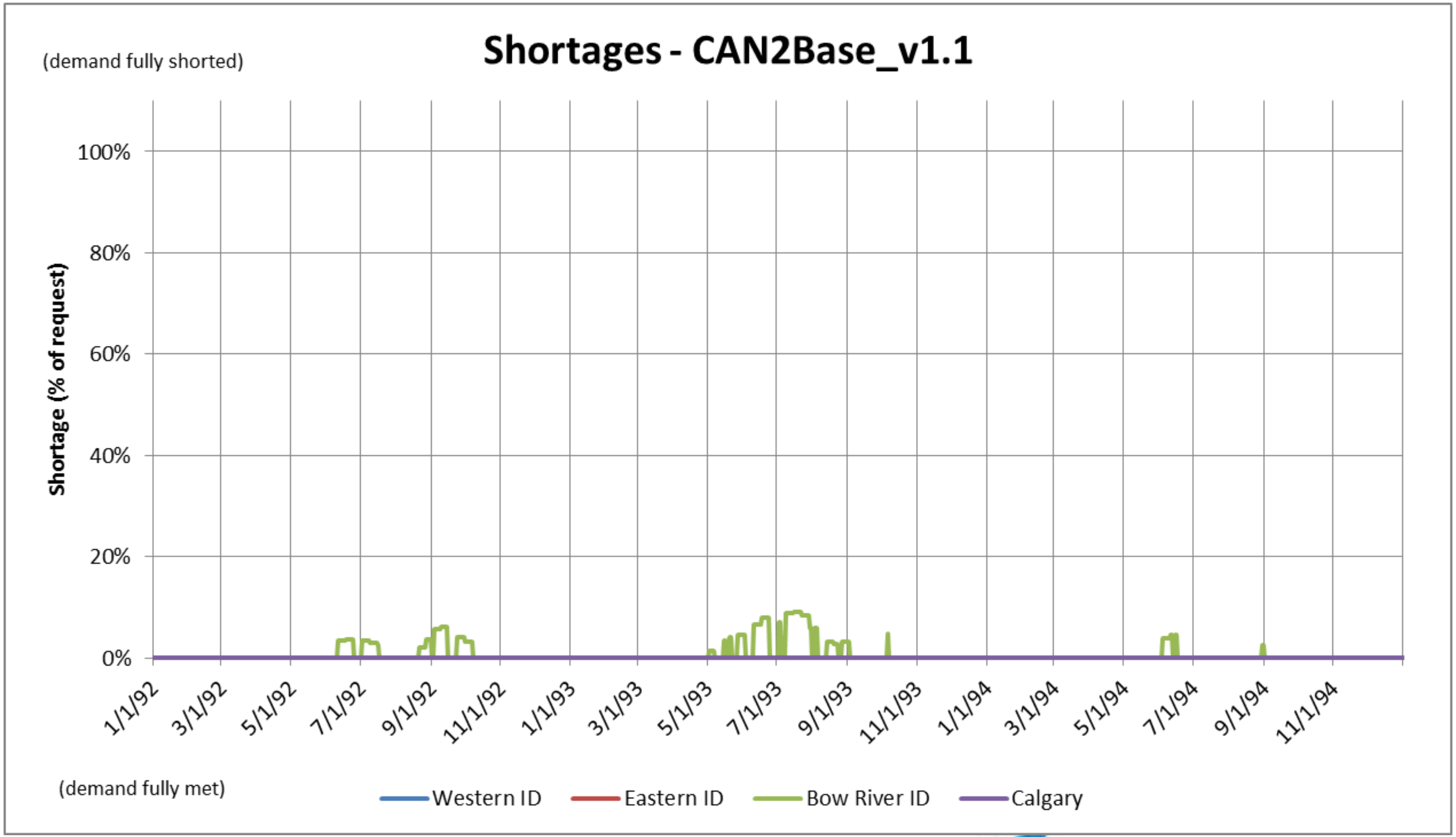
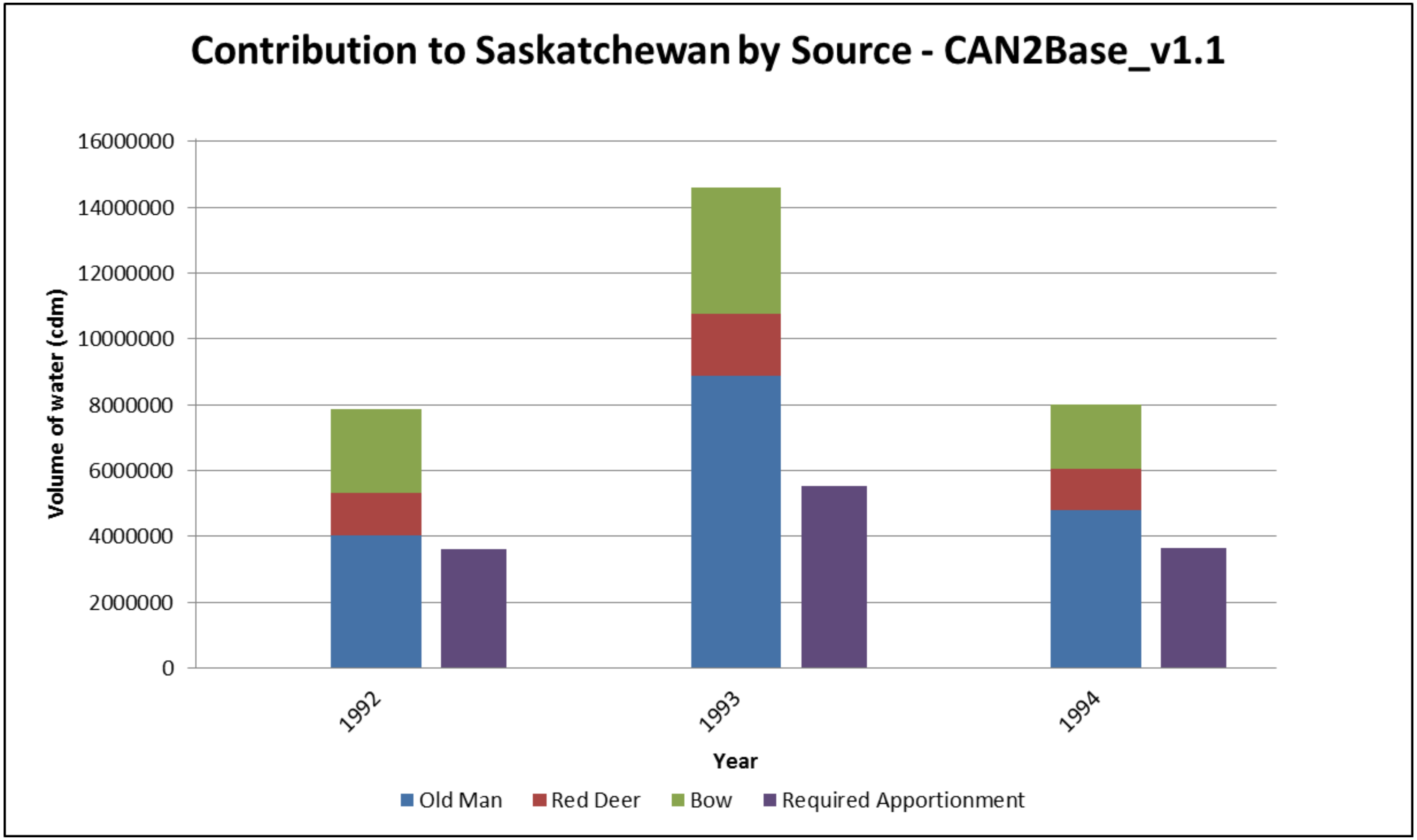
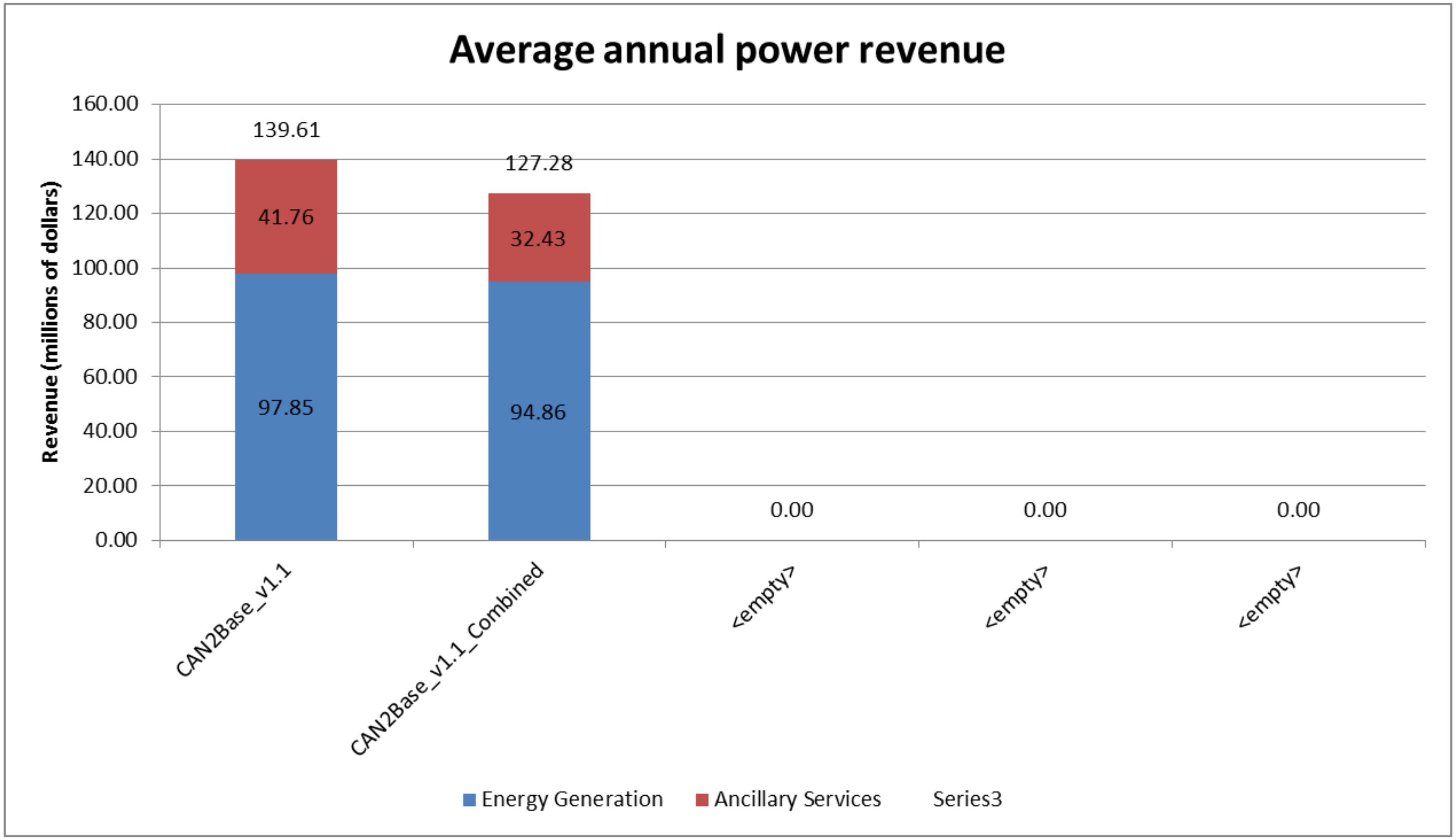
Performance Measures



Performance Measures



Performance Measures



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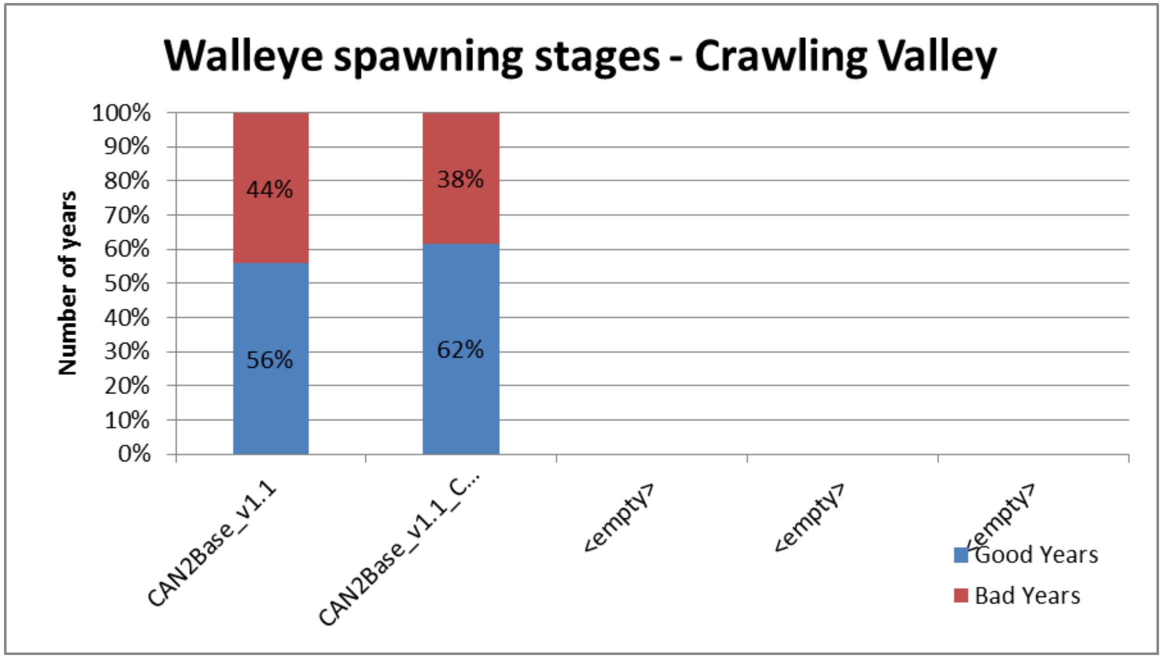
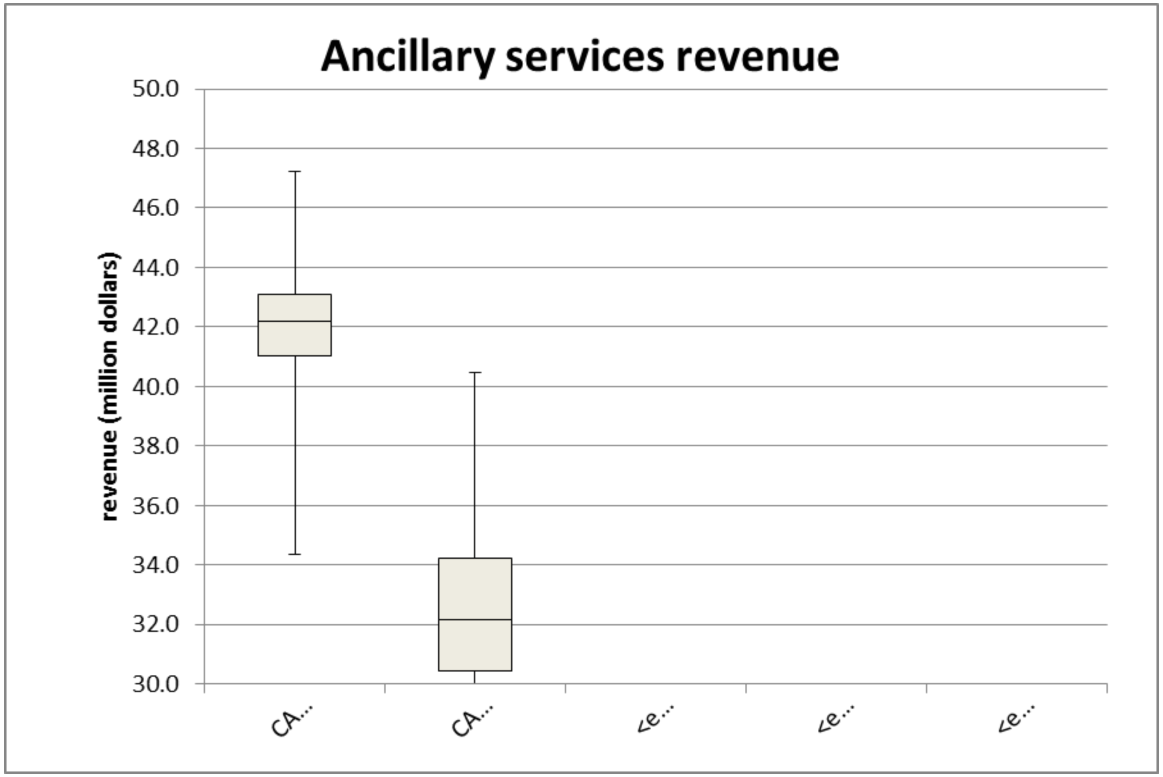
Performance Measures



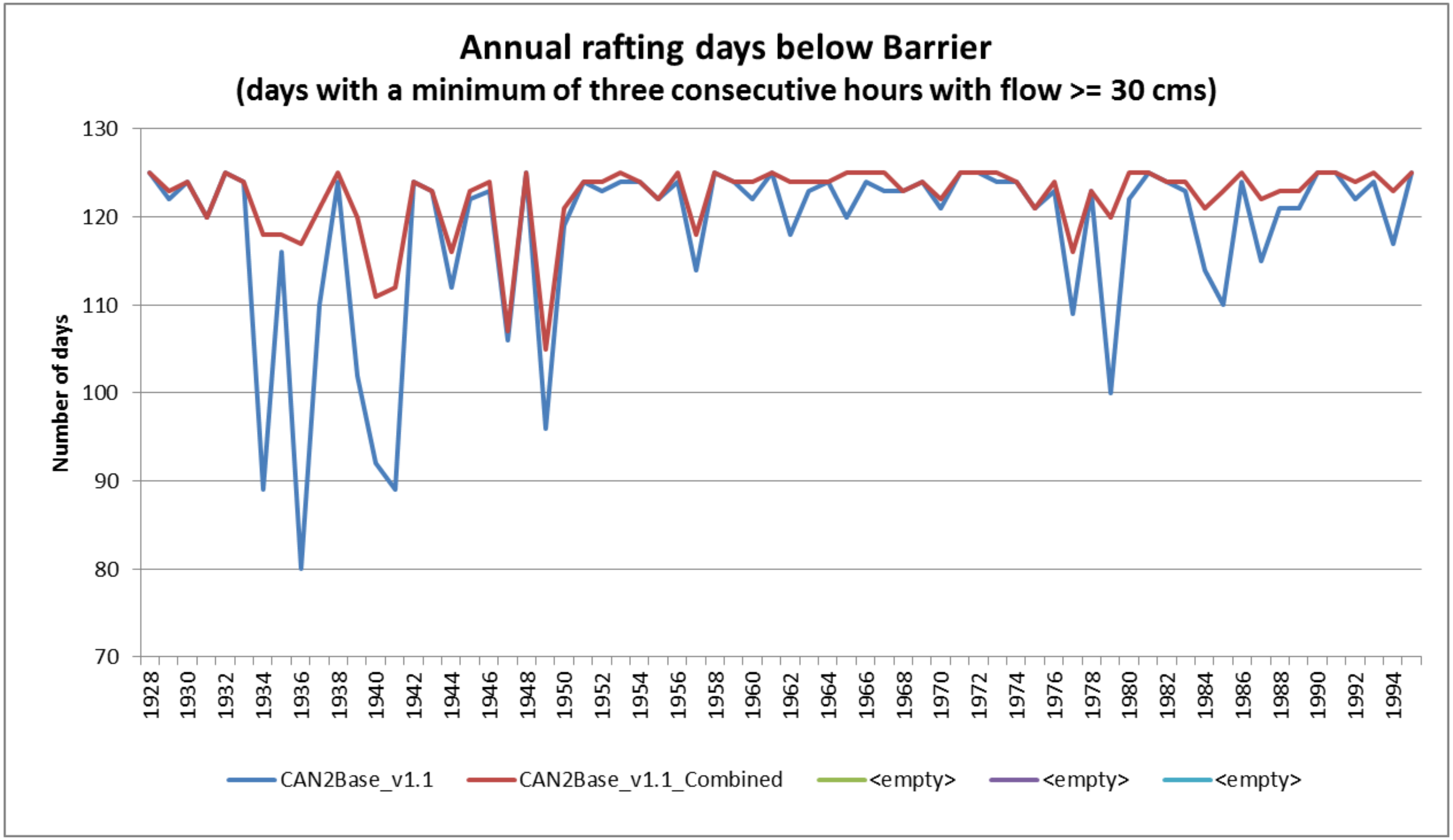
If the stage on June 1 is lower than that on April 1 then the walleye eggs have not been protected and the year is considerd bad for walleye spawning. Pike spawning needs are similar to walleye.

HYDROLOGICS

Performance Measures



Performance Measures - Surrogates



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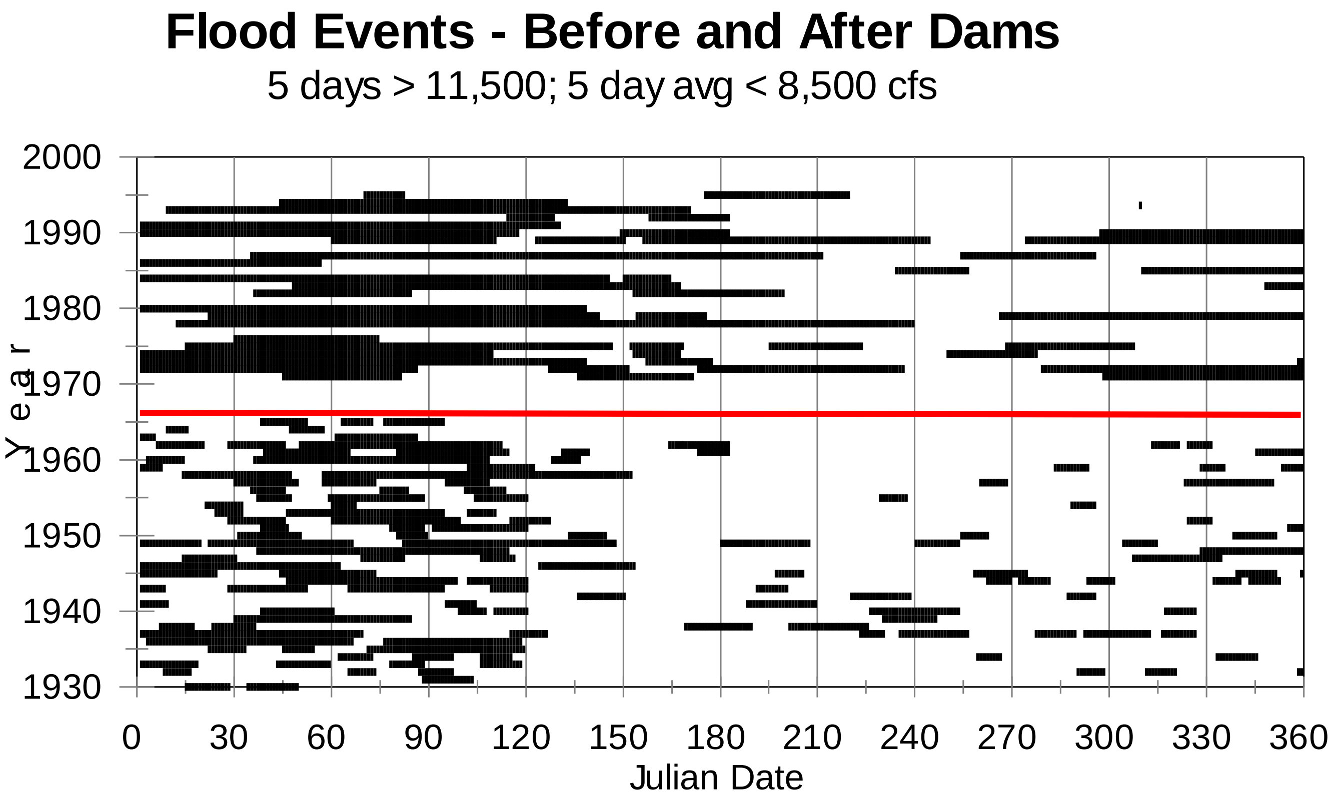
Performance Measures - Surrogates



Performance Measures

Scenario	Number of Days in Water Restriction	Number of Years with Water Restrictions	Volume of Water Not Delivered (million gallons)
1	10	1	25
2	16	3	30
3	5	5	5
4	25	3	140
5	30	6	130
6	18	2	65

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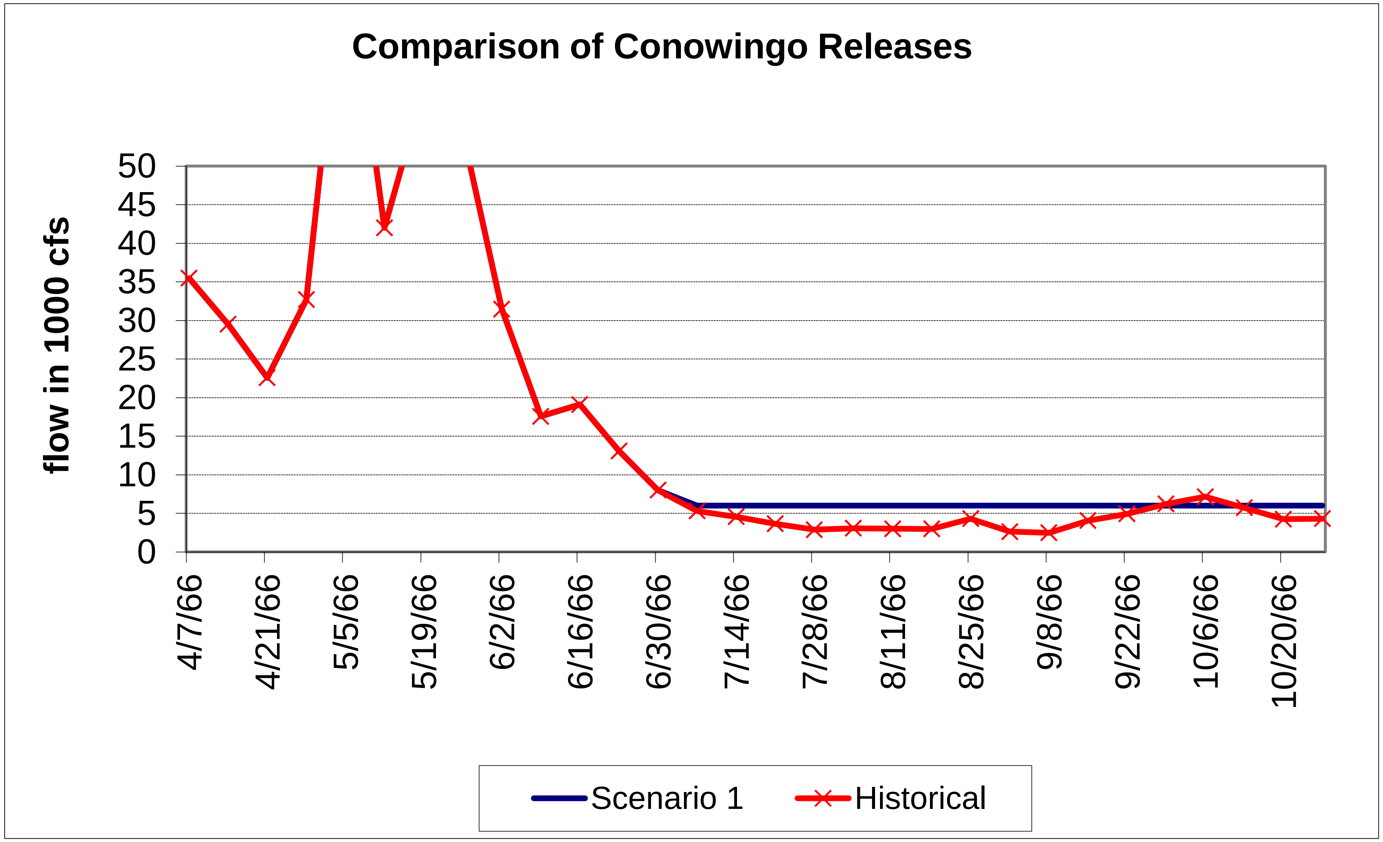
Performance Measures - Surrogates

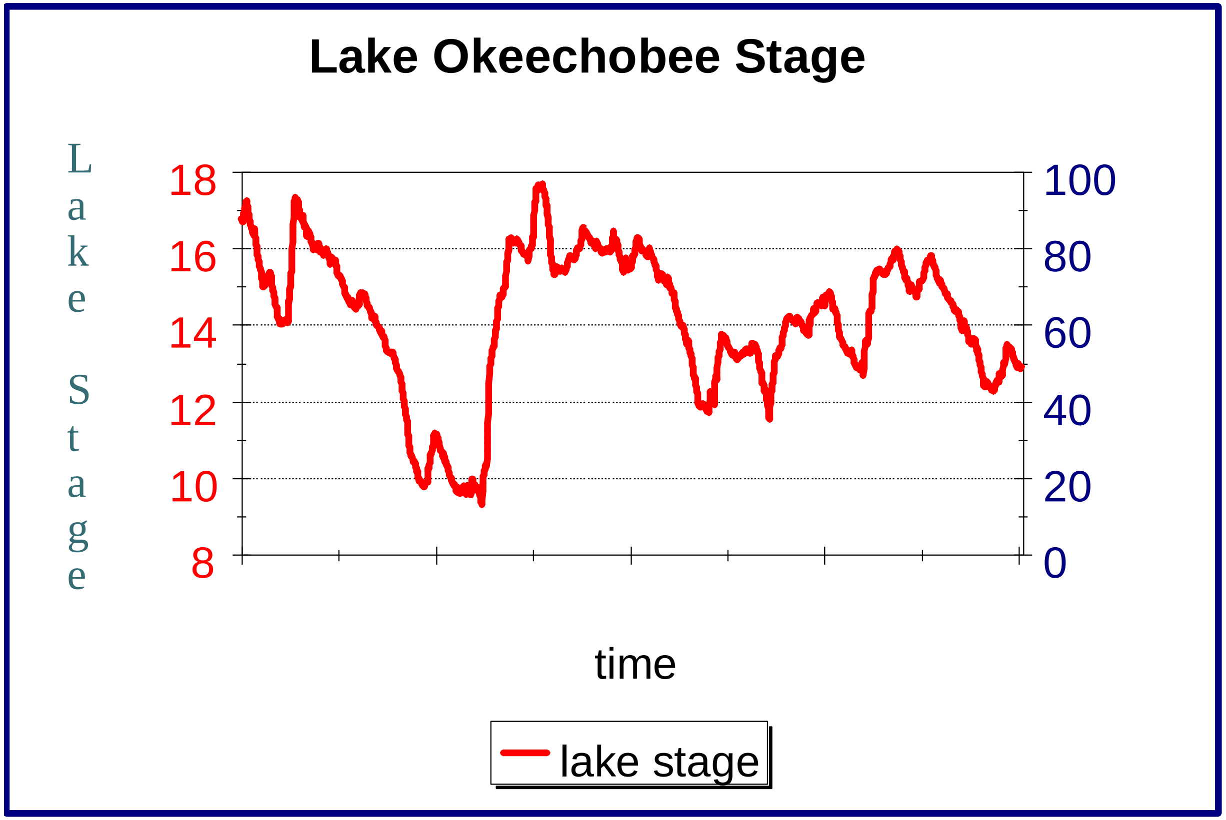


Planning and Operations Measures

- Planning Measures - Long term performance, statistics, historical "worst case," expected duration
- Operations Measures - Given "current conditions" - shorter term performance, statistical measures, conditional "worst case" and duration

Performance Measures - Operations

Process for Developing Performance Measures



8 1997 Water Resources Management Inc.

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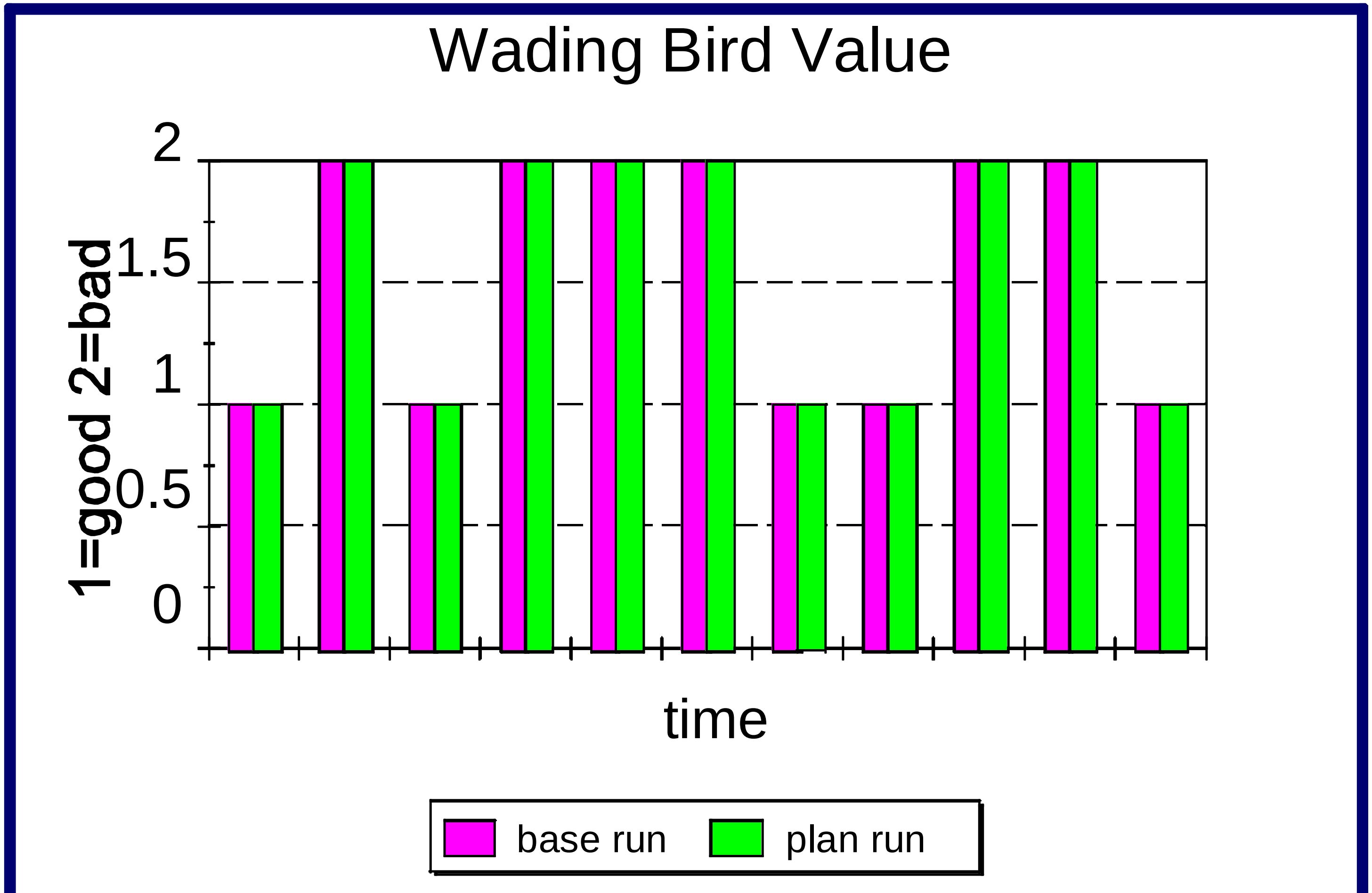
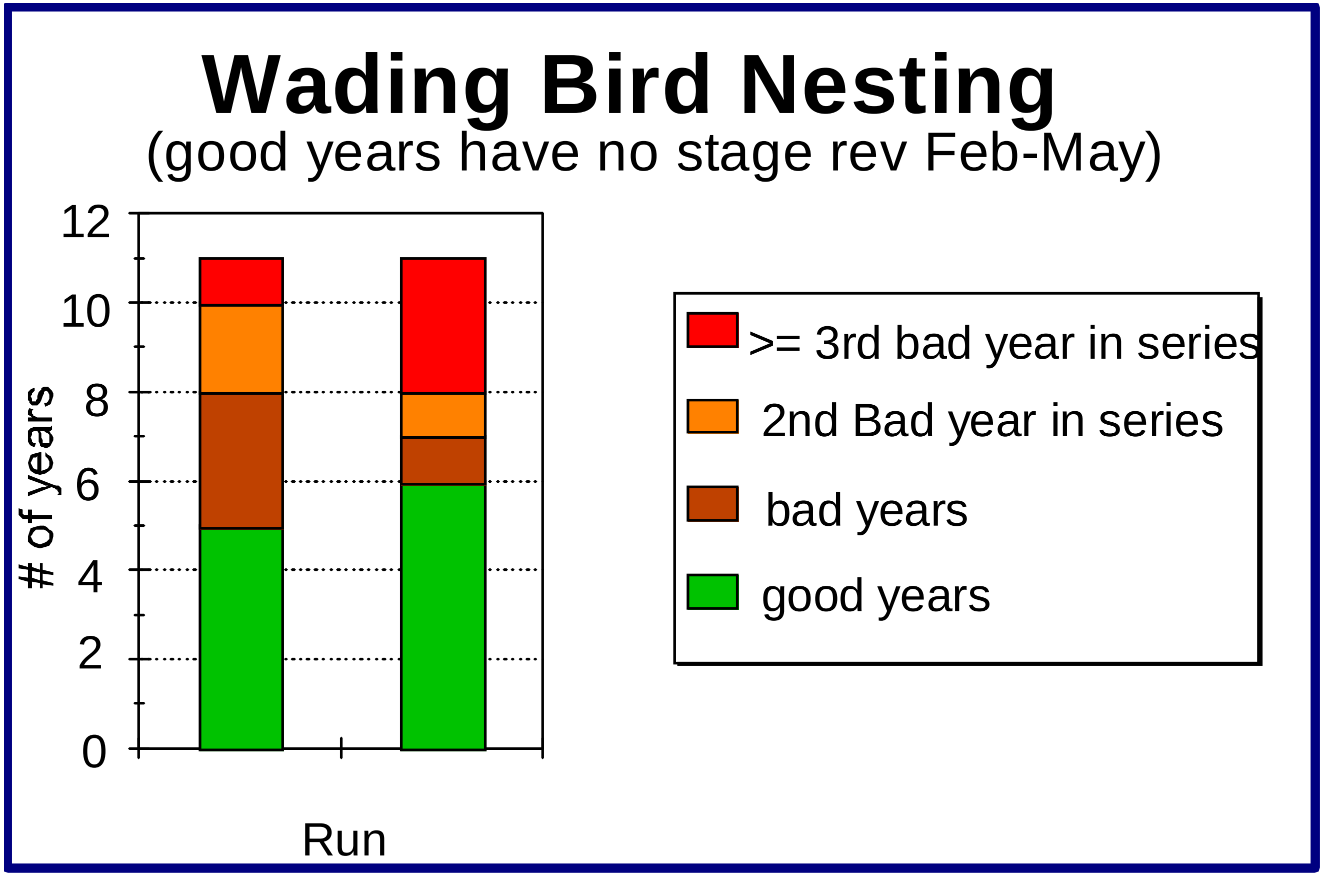
Scientific Rationale

- No habitat if lake stage exceeds 15 feet
- No forage if lake stage reverses by more than 6 inches

Performance Measure First Attempt



Performance Measure Revised



Model Care and Feeding

- Models must be updated to reflect new data, science, and values, to add functionality and to upgrade technology
- Scientific models get updated immediately
- Management models, particularly regulatory models update infrequently- provide a stable regulatory environment

Making Models Public

- Advantages
  - Reduced agency workload for permitting
  - Free model review
  - Better public understanding of requirements
  - Transparency
- Disadvantages
  - Maintenance
  - Transparency

Conclusions

- Management is about values
- Management uses rules
- Management models make it possible to use science to evaluate the performance of rules in terms of values
- Management models must be flexible in terms of rules
- Output must show results in terms of values (PMs)

Day 1 – Session 1

Chiadih Chang – AESRD

BIOGRAPHY

Dr. Chiadih Chang has been working for Alberta Environment and Sustainable Resource Development (ESRD) since 2004. He is currently the Section Head of Evaluation and Reporting, Policy Division. Chiadih is a Professional Engineer as well as a GIS Professional. Chiadih obtained his Ph.D. degree in Water Resources Engineering (Hydrology) from the University of Calgary in 1992. Over the past 25 years, Chiadih has had a passion for developing GIS-based decision support tools by coupling GIS technology with environmental modelling, especially in the area of water resources. Before joining ESRD, Chiadih worked as a regional hydrologist for Ontario Ministry of Natural Resources for 10 years, a post-doctoral research fellow for Environment Canada for 2 years, and a water resources engineer for the Taiwanese Government in 1986 before he came to Canada for his Ph.D. study.

Day 1 – Session 1

Chiadih Chang – AESRD

ABSTRACT

Spatial assets and technologies to support the environmental modelling are required to be implemented and delivered within an enterprise maturity model. The objective of this presentation is to share a vision and demonstrate a prototype of an enterprise environmental spatial system for Alberta that integrates the following components:

Data access from multiple internal and external sources,

· Automation of thematic mapping at different scales

· Enabling/facilitating the use of spatial environmental evaluation applications, simulation models, and tools

· A spatially-searchable information and knowledge management superstore utilized by multidisciplinary environmental analysts and evaluators

· A web-based, spatial-enabled, open and transparent reporting system

The proposed integrated spatial system would allow regulatory agencies to manage the environment and natural resources in an effective, efficient, responsible, and transparent manner, which leads to the achievement of desired environmental outcomes and sustainable development of natural resources.

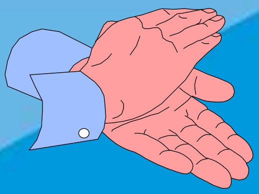
A Vision of Enterprise Environmental Spatial System $(ES)^2$ for Supporting Environmental Modelling

"Leadership is the capacity to translate vision into reality."(Warren G. Bennis)

Chiadih Chang, Ph.D., P.Eng., GISP
Science, Evaluation & Reporting
Policy Division, AESRD

Environmental Modelling Workshop 2013
Edmonton, March 13, 2013

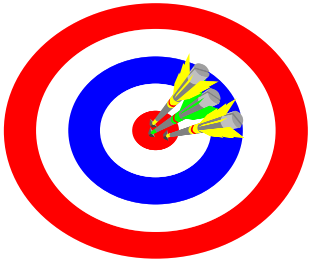
Acknowledgements



- Anil Gupta
- Barry Northey
- Brian Sawyer
- Bob Barraclough
- Curt Romaniuk
- Daryl McEwan
- Dave Junor
- Derek Nalder
- Don Page
- Geniene Sabila
- James Greengrass
- Jordan Erker
- Judy Heilman
- Justin Wilkes
- Kelsey Ayton
- Lee George
- Matthew Lynch
- Moses Bitew
- Patrick Vacca
- Phil Mackenzie
- Ray Keller
- Scott Kilborn
- Stuart Cruikshank
- Tom Davis
- Vernon Remesz
- More…

Purposes of the Presentation

- Share the $(ES)^2$ vision
- Receive your feedback
- Explore future engagement and collaboration opportunities



Presentation Outlines

1. Background
2. Challenges
3. $(ES)^2$ vision
4. Conceptual demo
5. Summary

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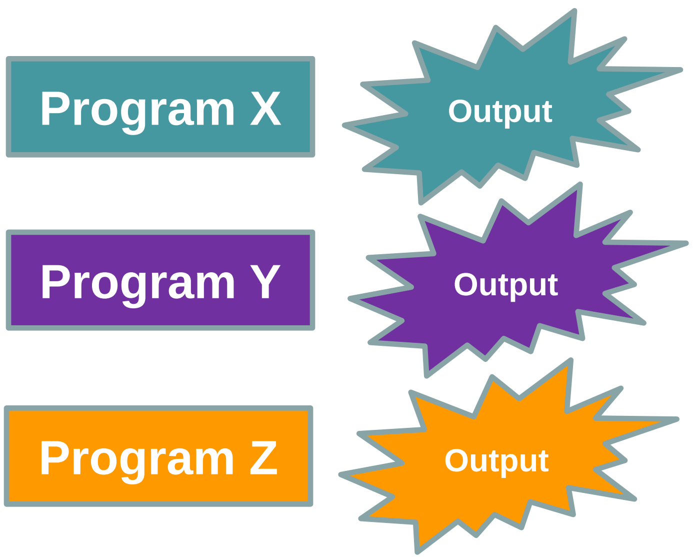
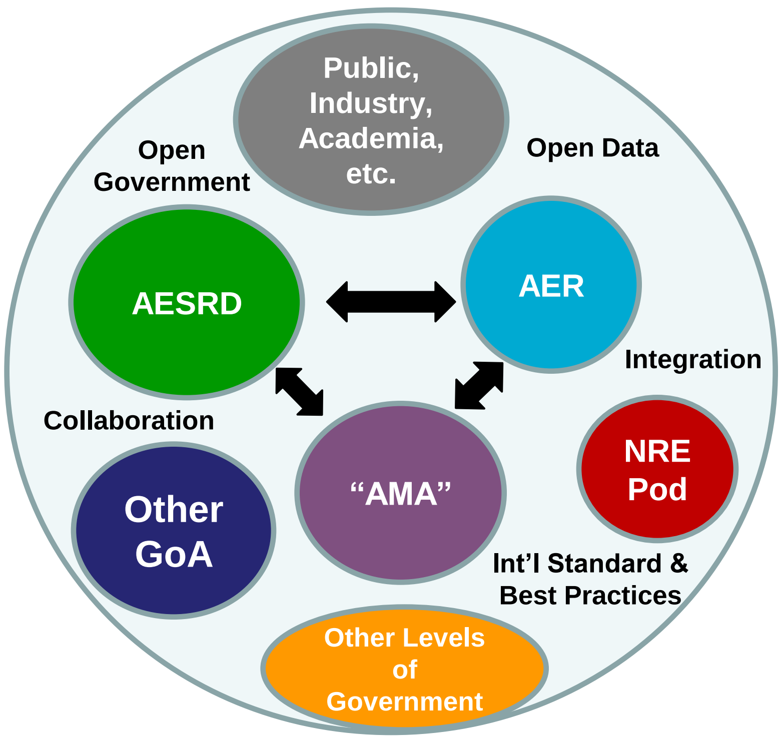
Old Paradigm vs. New Reality

The Old Paradigm



Program-centric with little to no perceived requirement for coordination or alignment between programs or departments.

The New Reality



A "System of Systems" delivering the <u>outcomes</u> of Integrated Resource Management (IRM) and Cumulative Effects Management (CEM).

* Modified based on ESRD draft informatics Program Governance (2013)

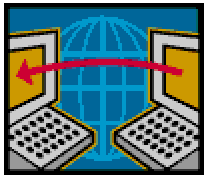
Data → Information → Knowledge

- “We are drowning in data and thirsting for information” (John Naisbitt, Megatrends, 2000)

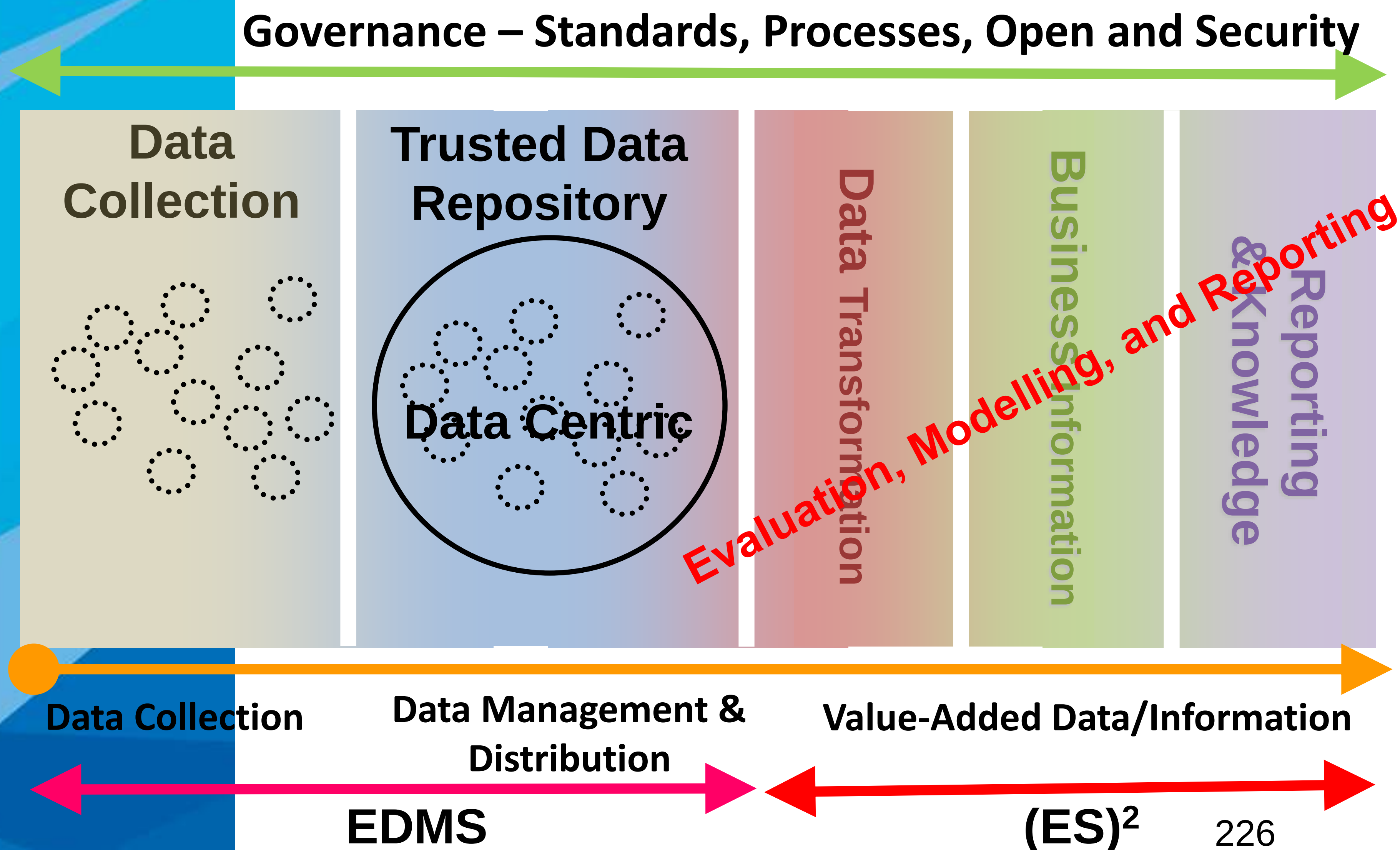
- 80% of all data contains some reference to geography (Franklin and Hane, 1992)

- Use a GIS to manage, visualize, explore, synthesize, and analyze the spatial data; and turn data into information into knowledge.

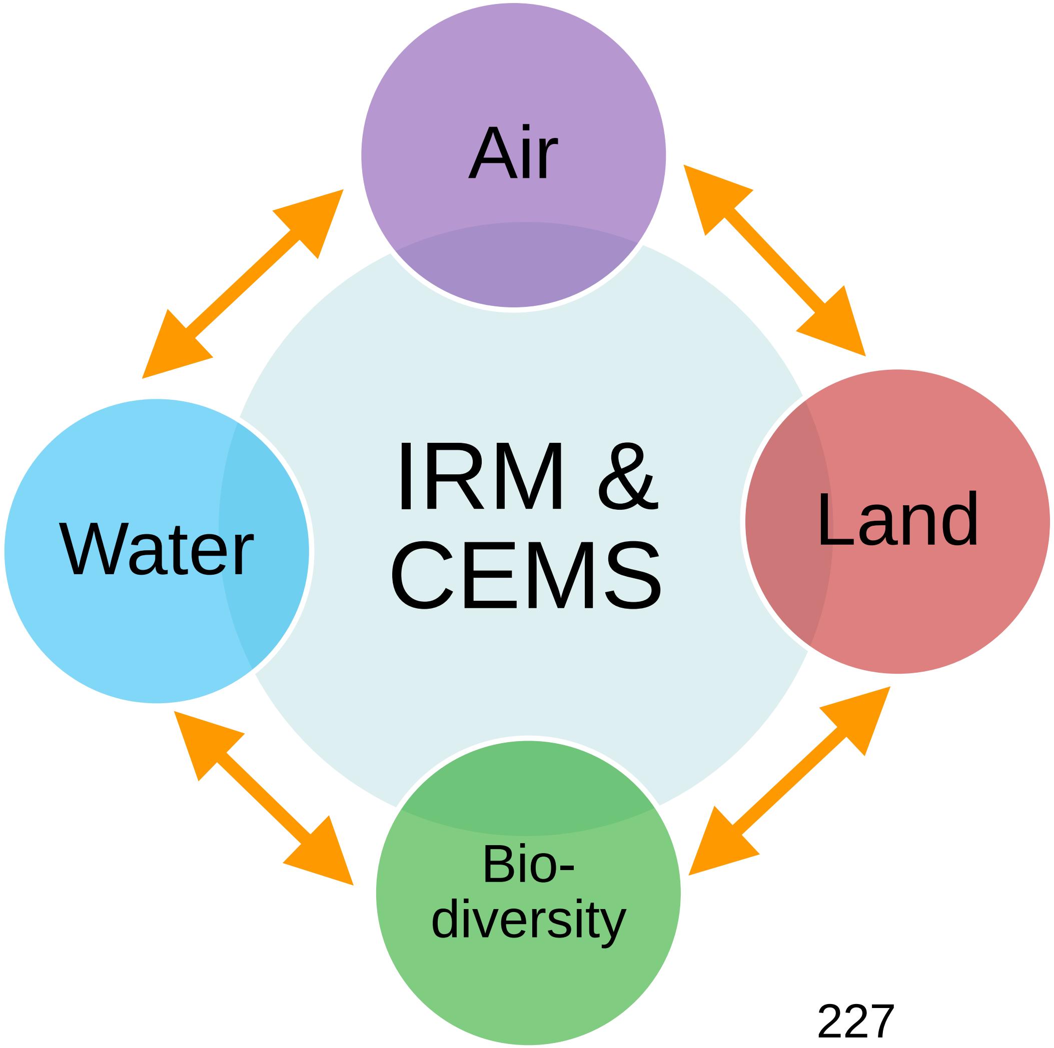
- Put the right data/information/knowledge, in the right format, in the right hands, at the right time - Informatics.



Enterprise Data Management System (EDMS) & $(ES)^2$



Need More Integrated and Collaborative Approach…



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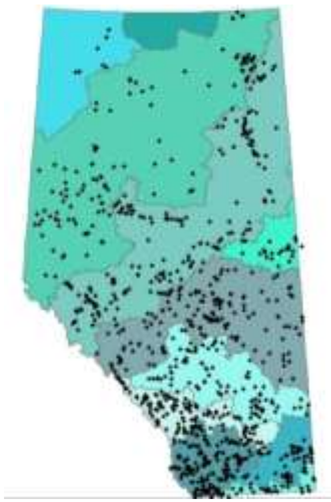
Challenge #1: Data Availability

Data are often unavailable or insufficient for the area of interest. We simply cannot afford to monitor everything in everywhere, for example:



1,100 Hydrometric Stations

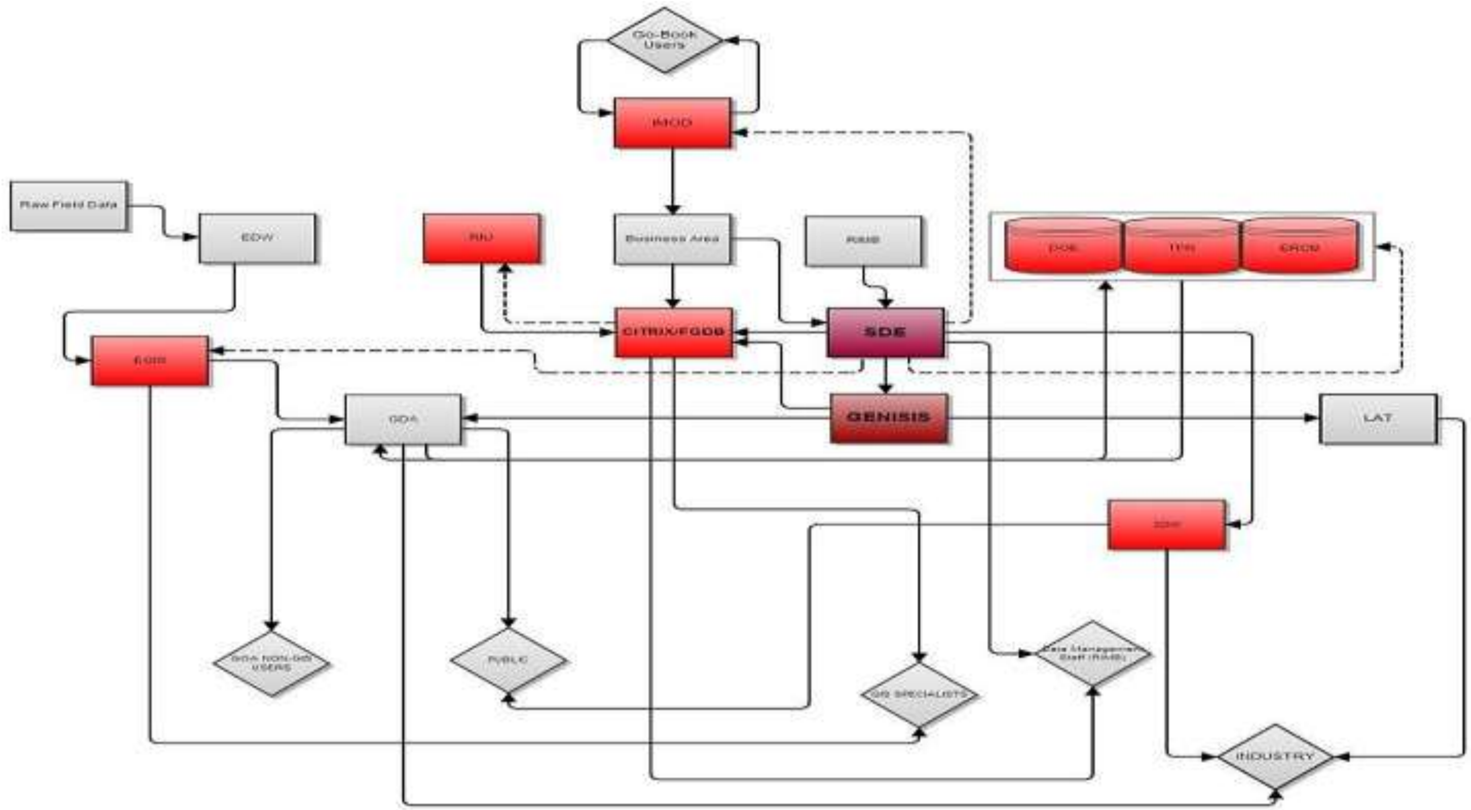
140 'Suitable' Hydrometric Stations

Water Management 'Challenge'

Need for environmental modelling

Challenge #2: Access to Authoritative Data Sources

The current status of GIS data in ESRD:



Need for accessing authoritative data sources

Challenge #3: Data Preparation

60 - 80% of the time spent on data analytics projects is spent preparing the data for analysis, which often is:

- Repetitive
- Time consuming
- Laborious
- Costly
- Error prone

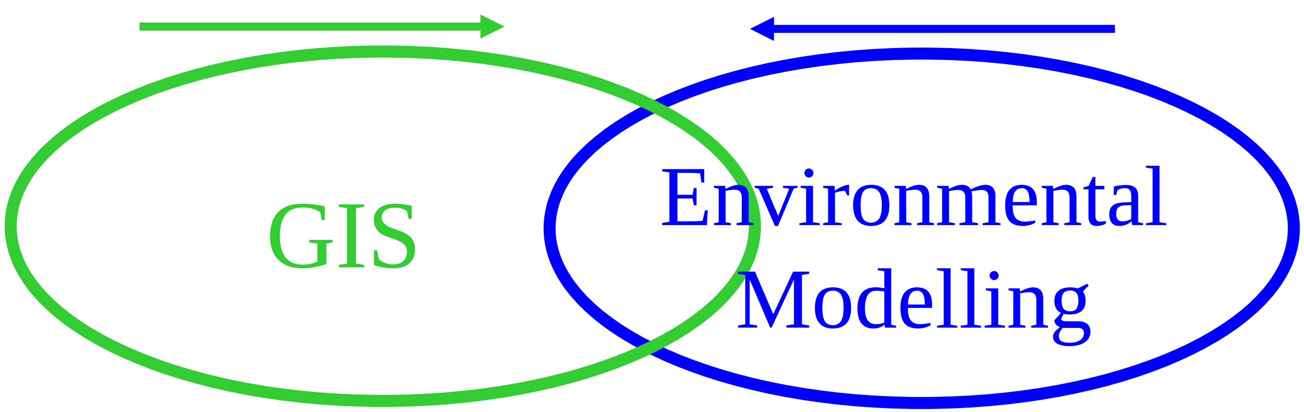
e.g. Watershed Modelling

Need for automation of data preparation

Challenge #4: Integration with GIS

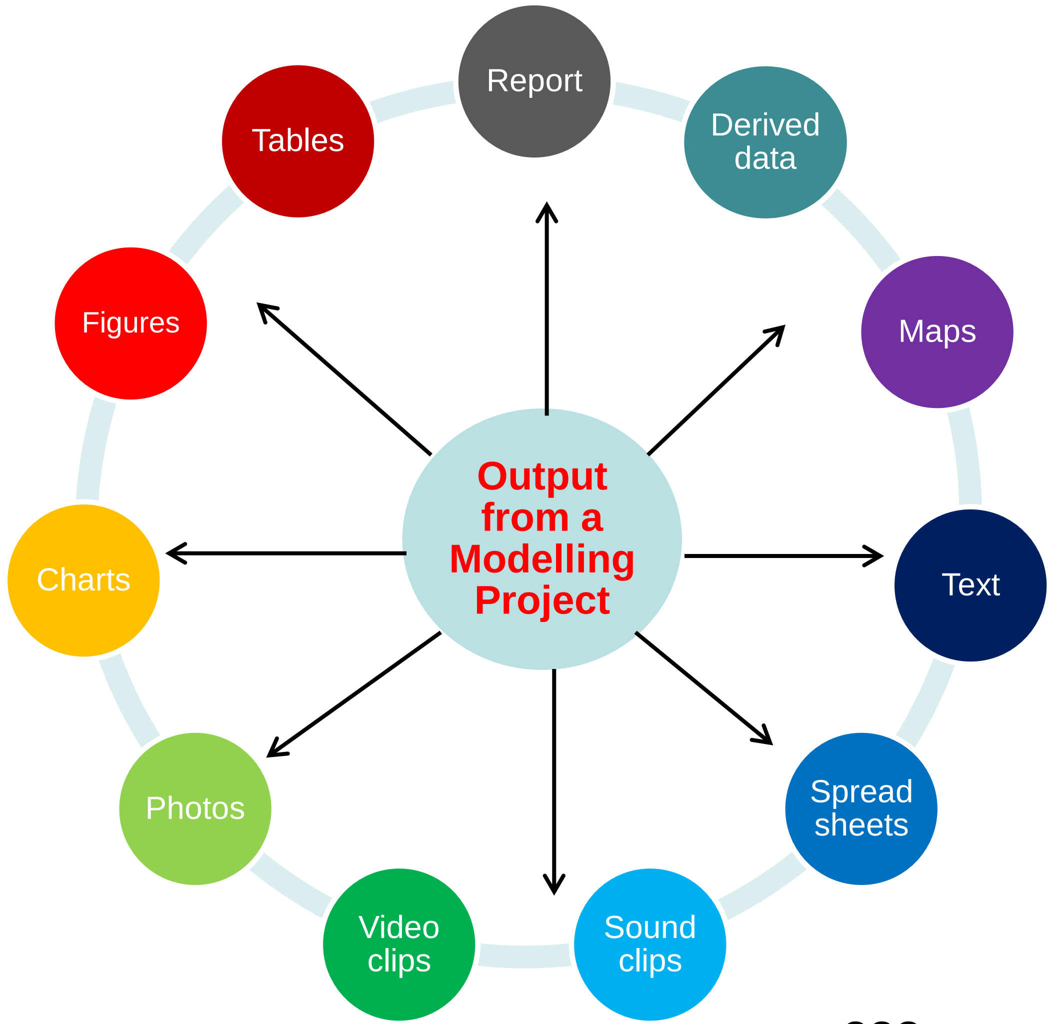
- There are trends in interfacing GIS with predictive water resource models. However, neither technology was initially developed to interact with the other (Martin et al., 2005).

- Lack of integration between spatial and temporal data/information.



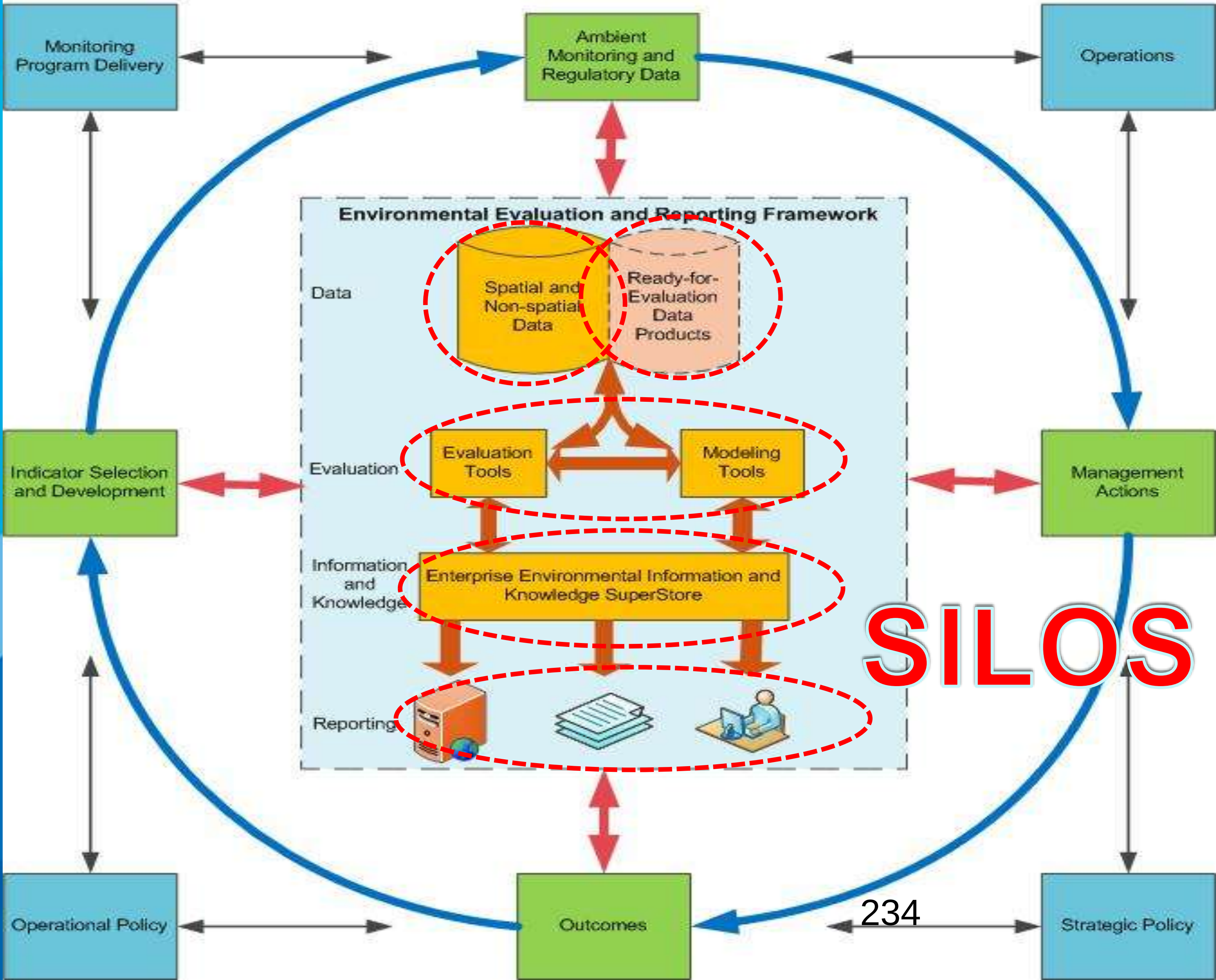
Need for GIS-Modelling Framework

Challenge #5: Is Information and/or Knowledge Generated from a Project Readily Available/Accessible to Others?



Need for Information & Knowledge Management

Challenge #6: Fragmented Silos



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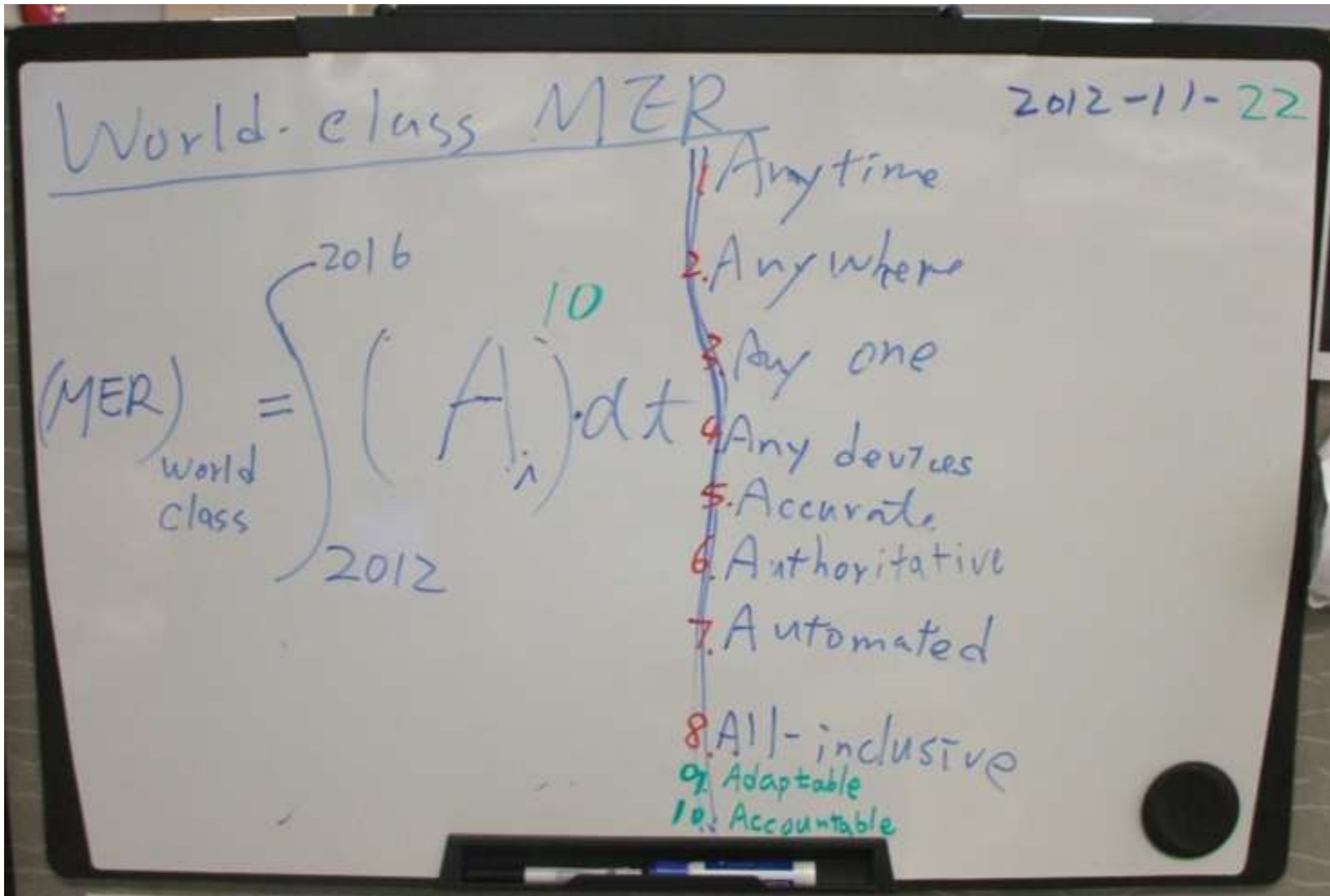
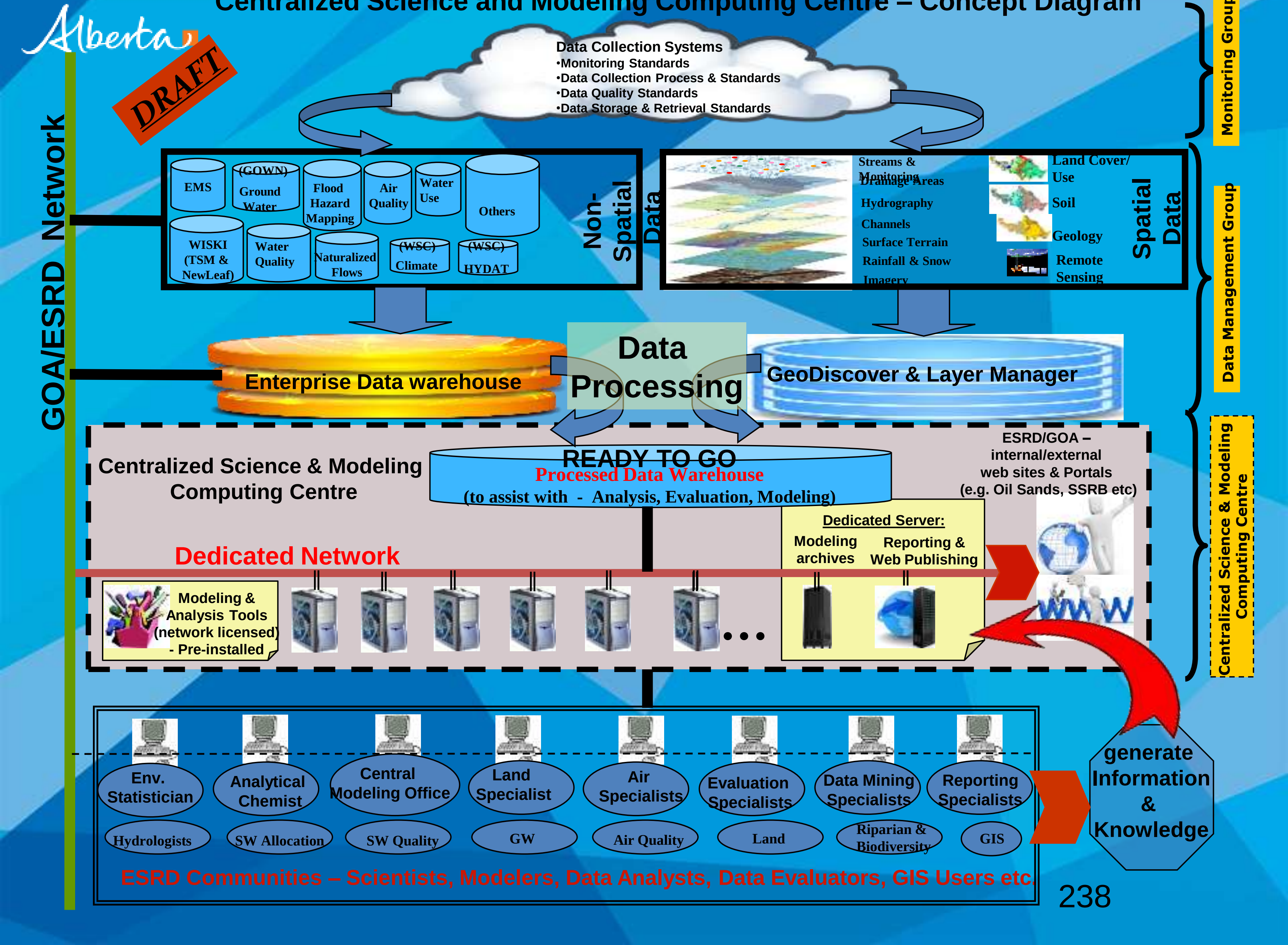
World-Class Monitoring, Evaluation and Reporting (MER)

1. Anytime
2. Anywhere
3. Anyone
4. Any devices
5. Accurate
6. Authoritative
7. Automated
8. All-inclusive
9. Adaptable
10. Accountable

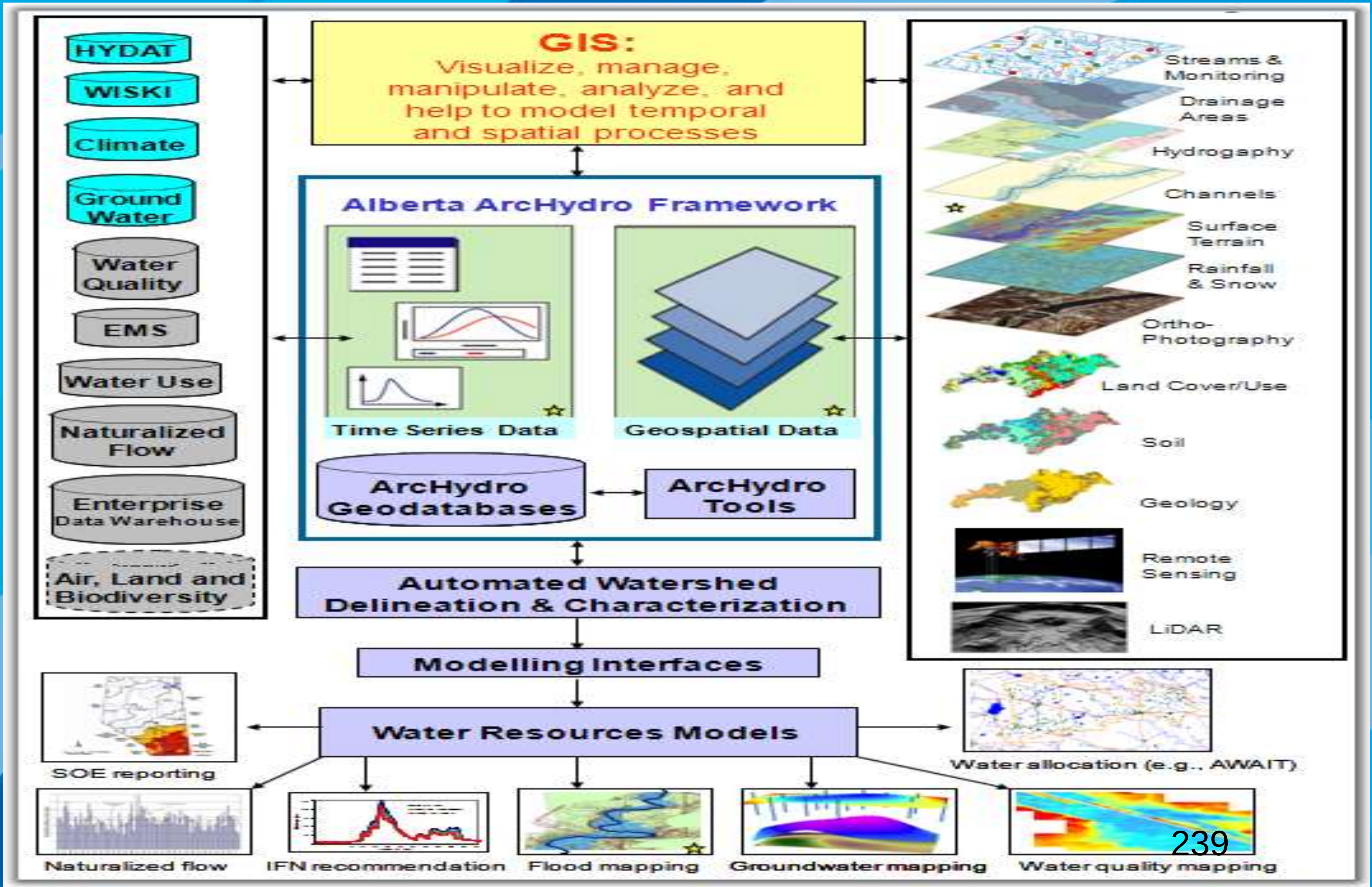


Walk the Talk!

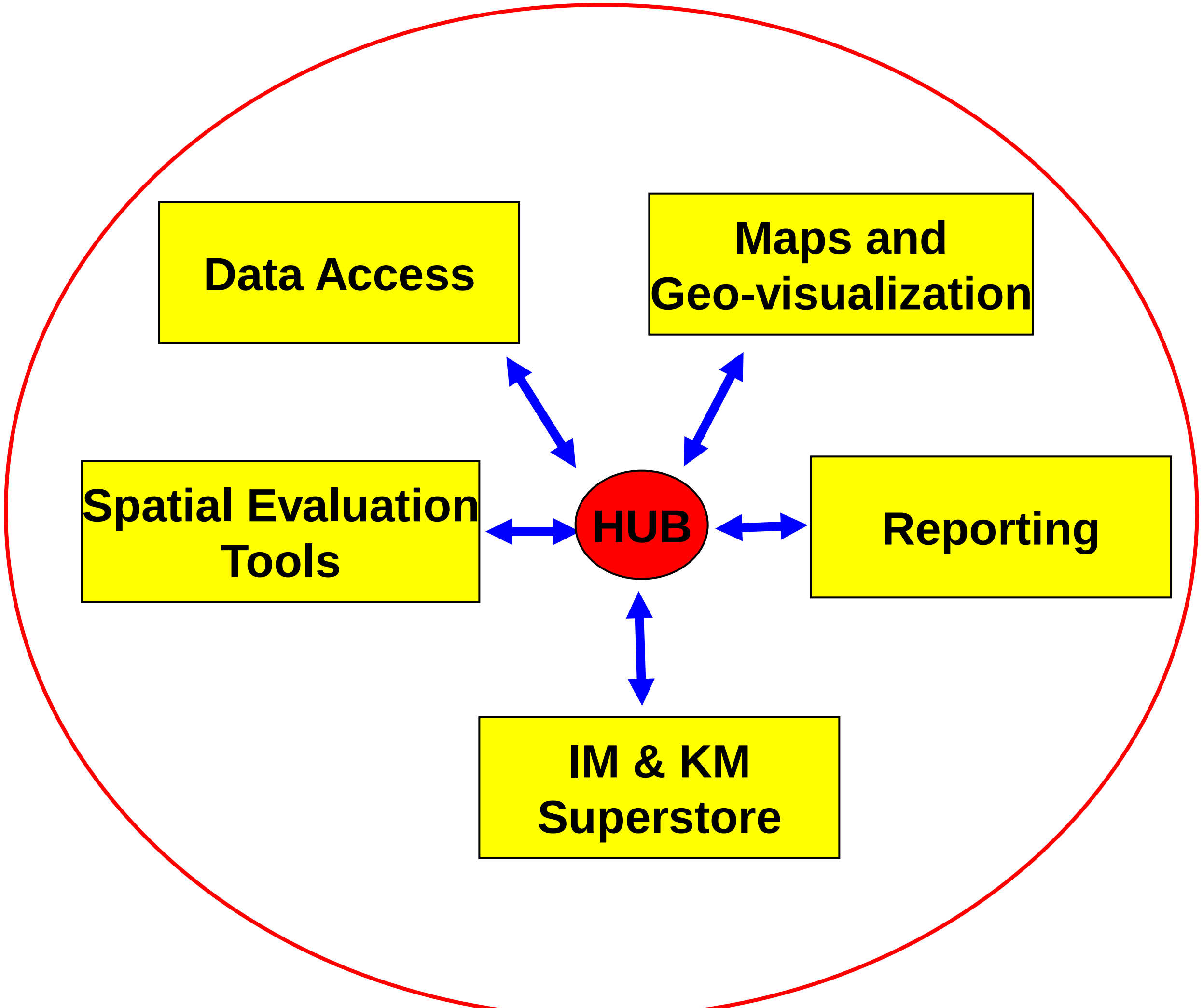
Centralized Science and Modeling Computing Centre – Concept Diagram



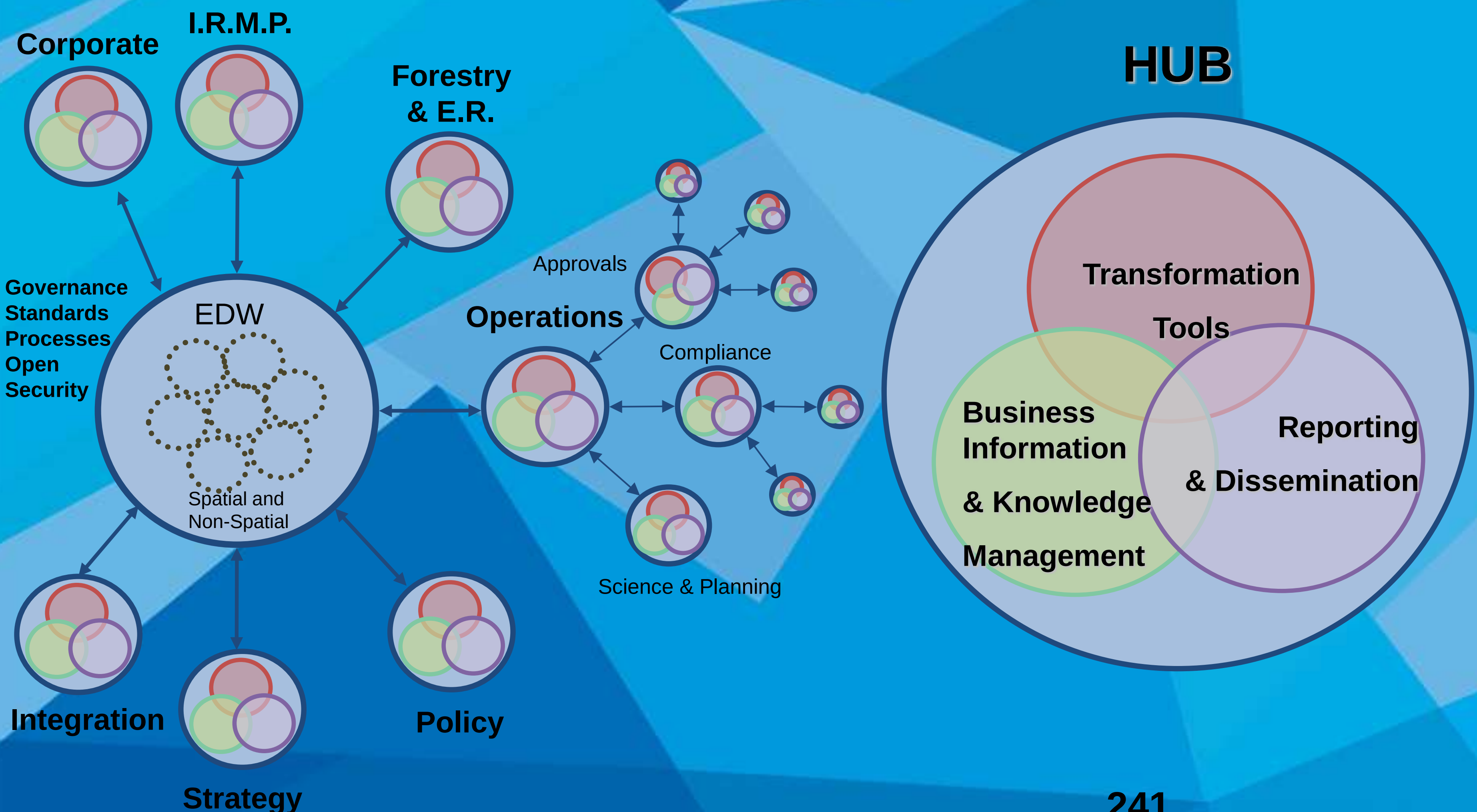
ArcHydro as a Ready-To-Go Data Framework for Water Resource-Related Models



Vision of (ES)^2

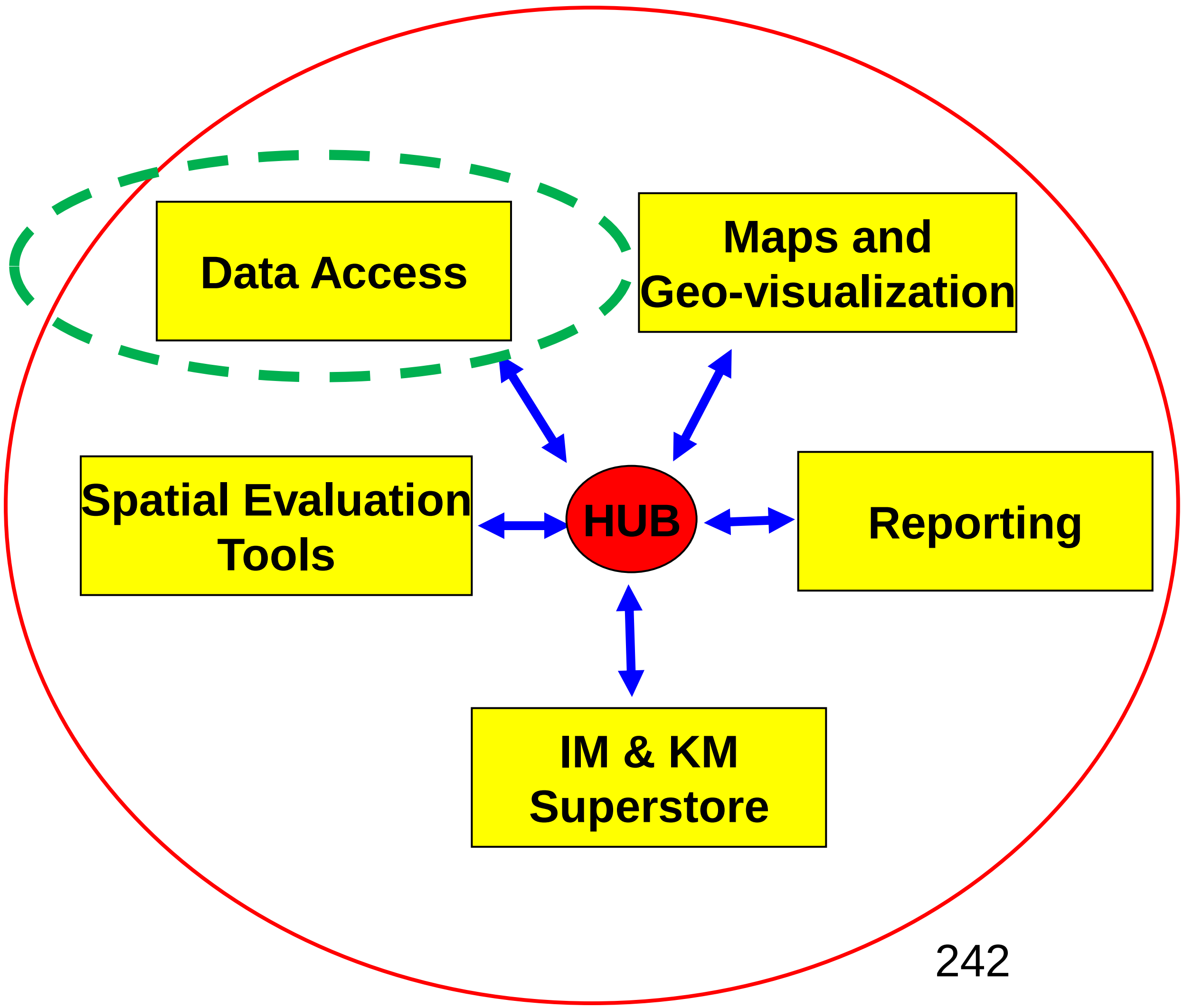


$(ES)^2$ HUB



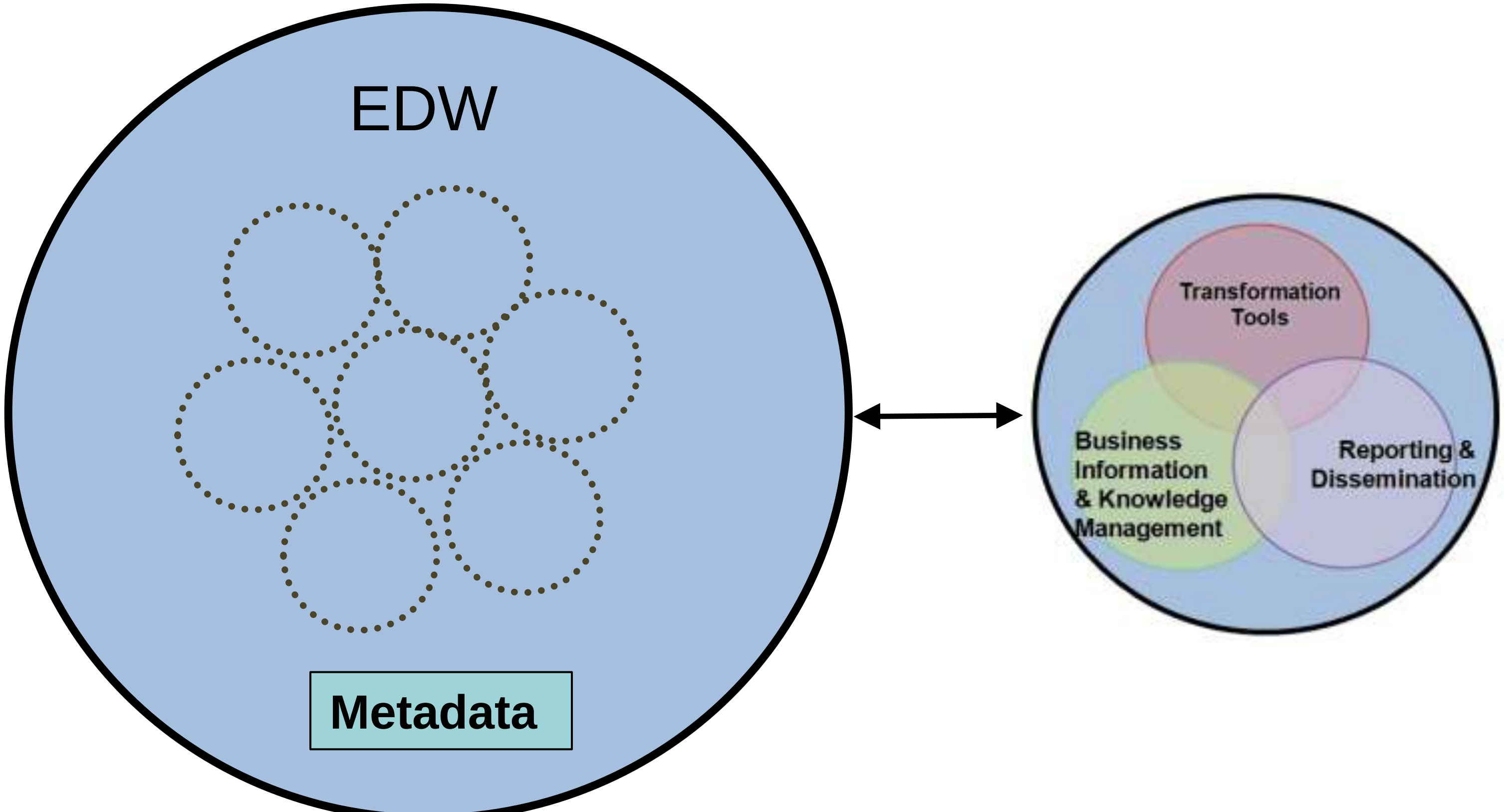
Corporate
I.R.M.P.
Forestry & E.R.
Governance
Standards
Processes
Open
Security
EDW
Spatial and Non-Spatial
Approvals
Operations
Compliance
Science & Planning
Integration
Strategy
Policy
HUB
Transformation
Tools
Business Information
& Knowledge
Management
Reporting
& Dissemination

Vision of (ES)^2

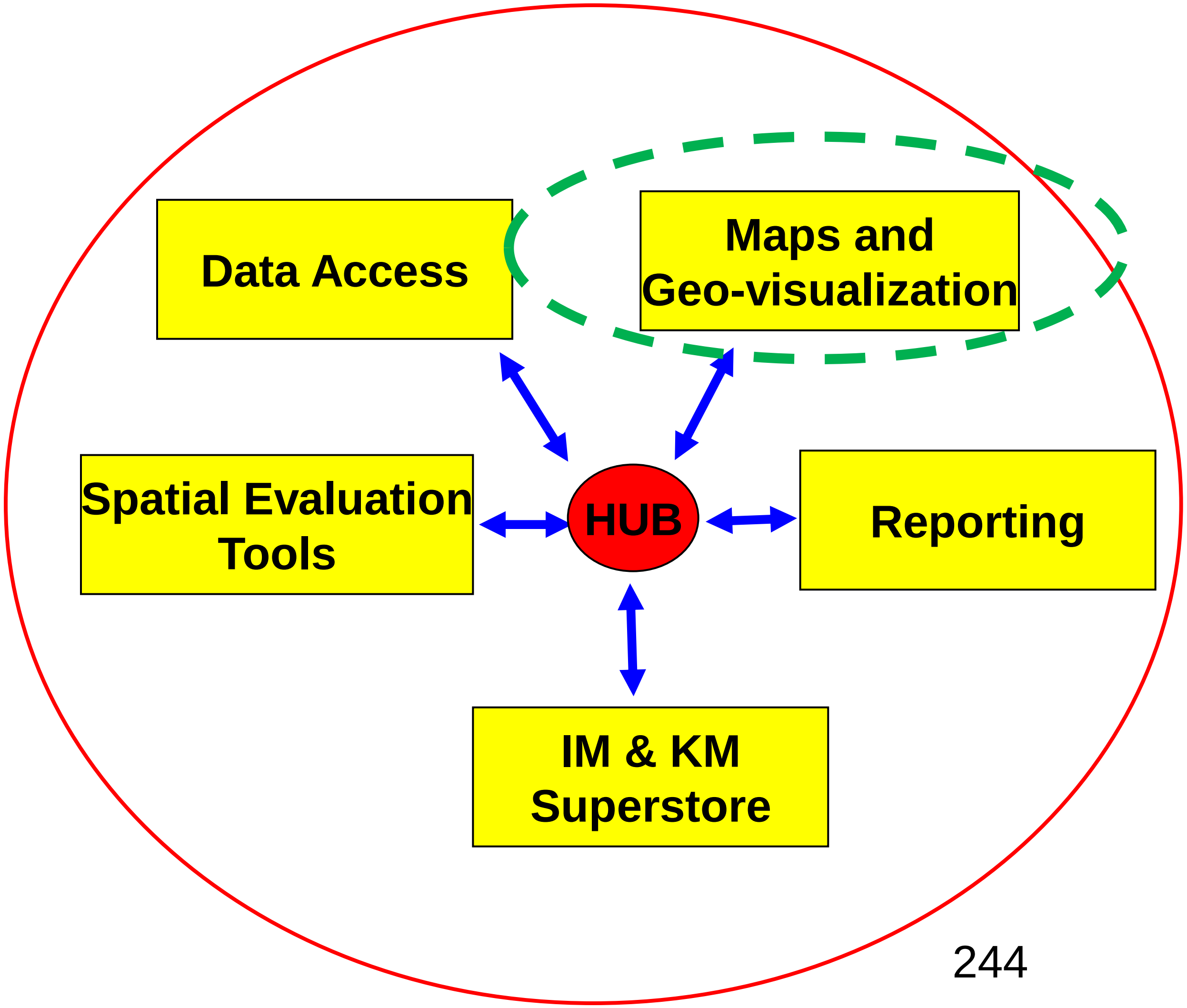


Data Access: Access to all the available data layers from various authoritative sources, including ESRD, GDA, NRE Pod, and partners

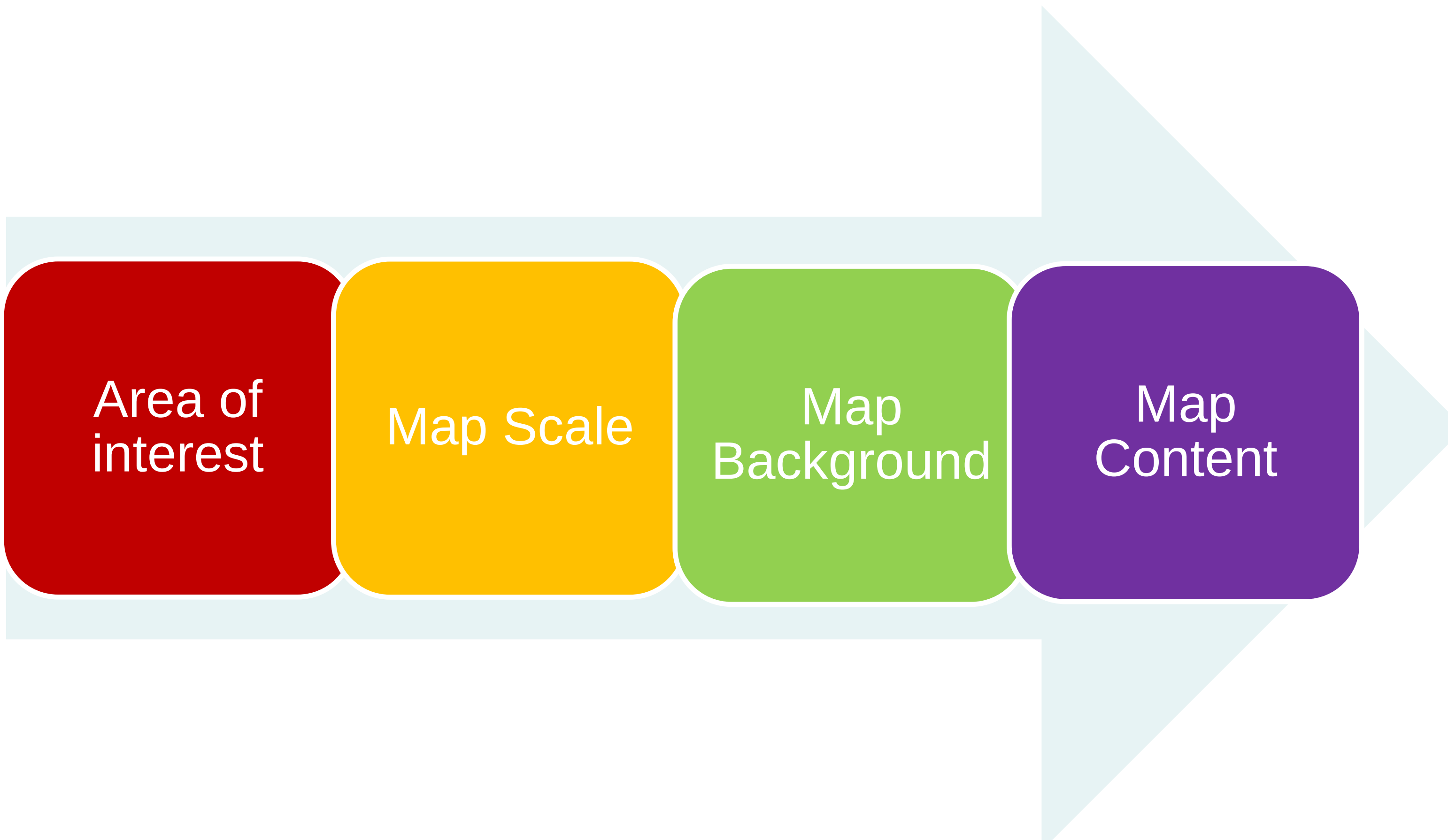
Data Centric: Access to Authoritative Data, Spatial and Non-Spatial



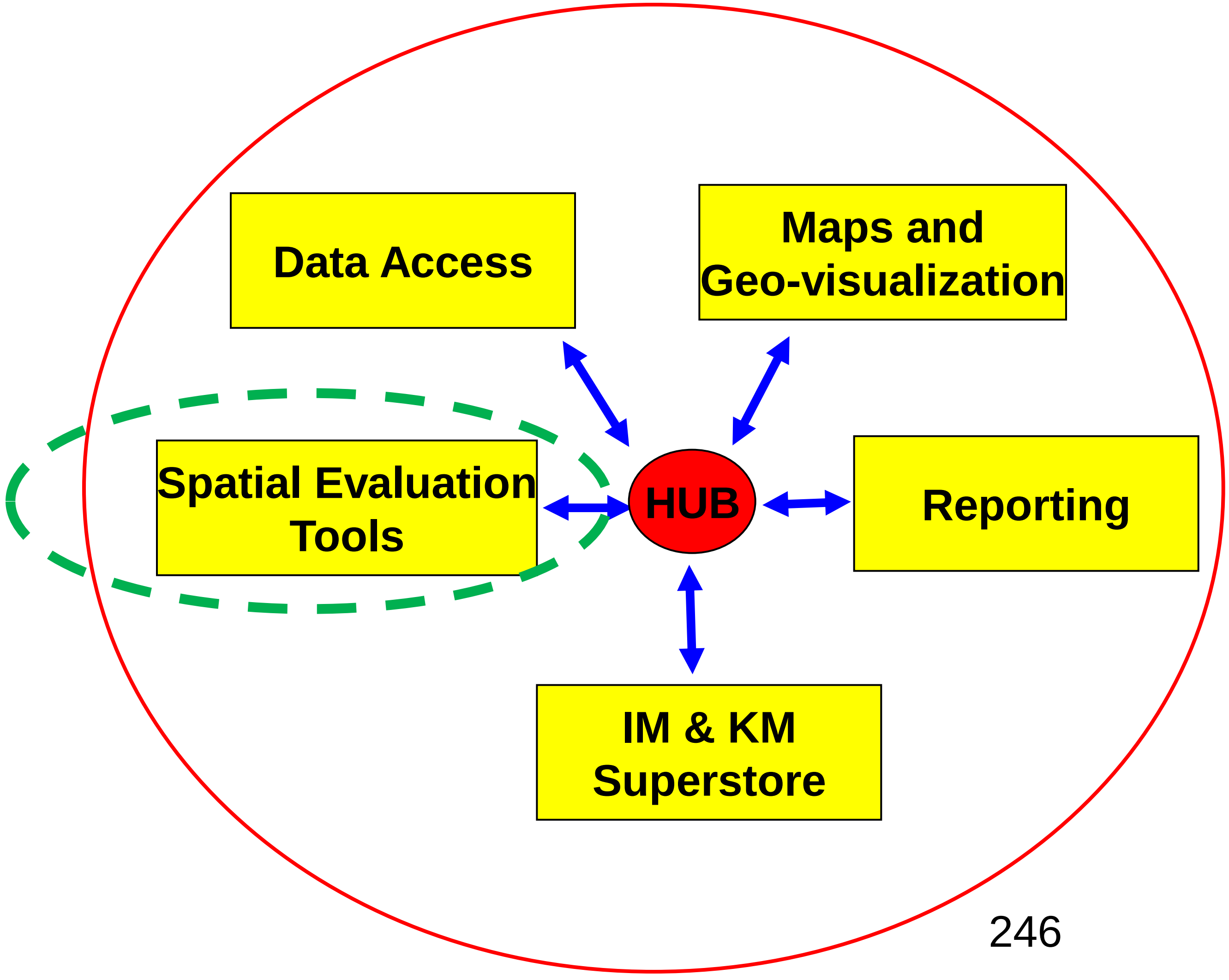
Vision of (ES)^2



Map and Geo-visualization: Automation of consistent cartographic, thematic maps at different scales

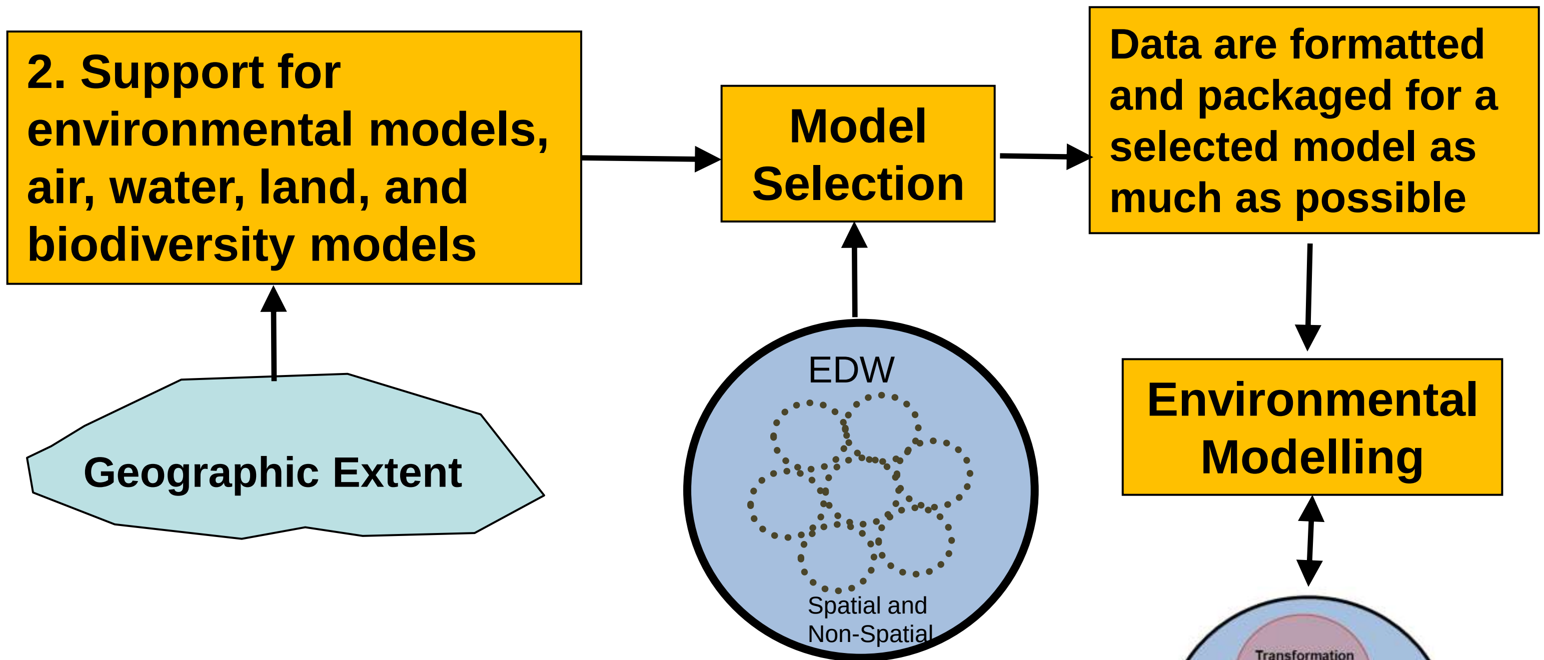


Vision of (ES)²



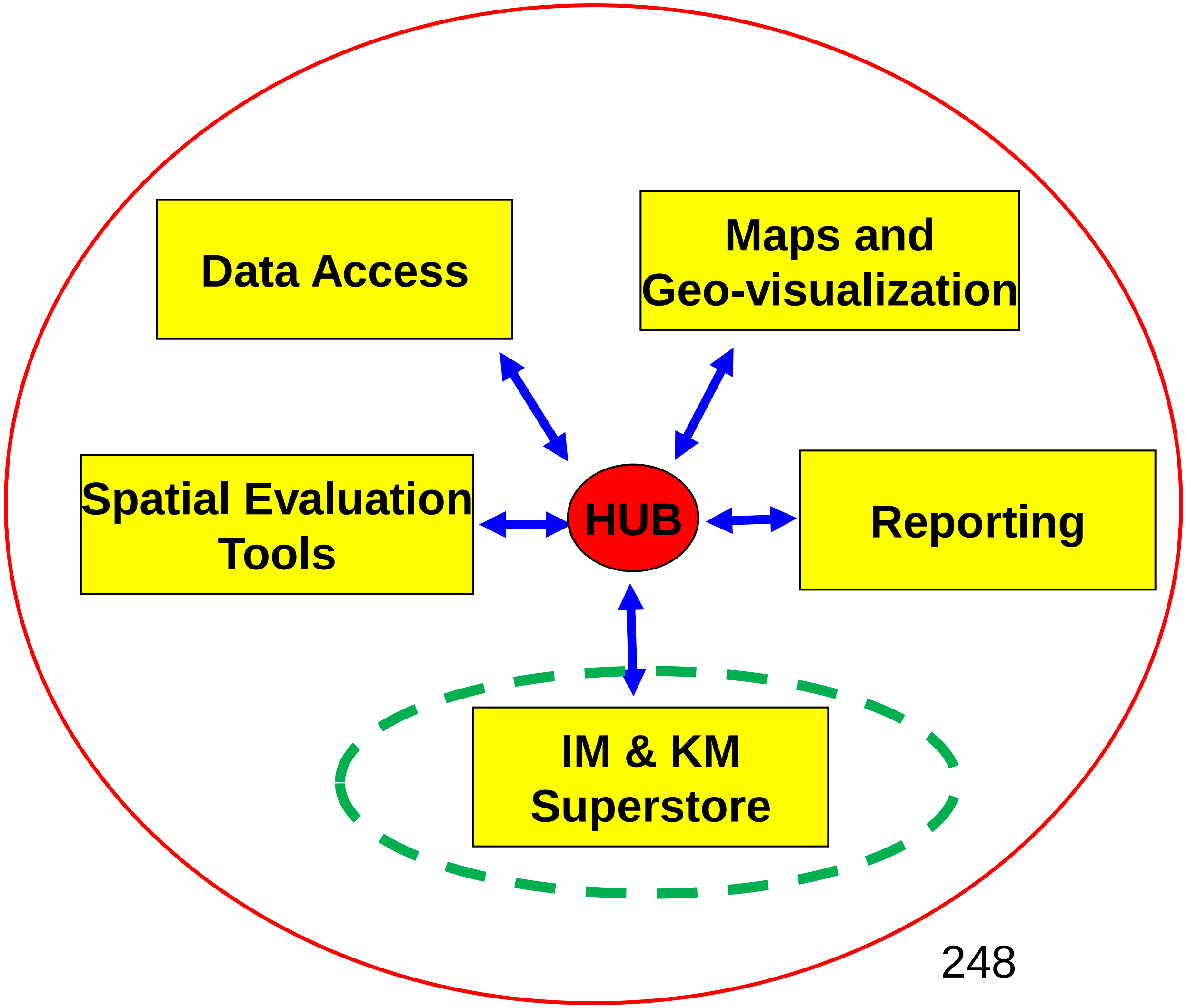
Spatial Evaluation: Access to (1) business spatial evaluation applications, (2) support for spatial analytical models, and (3) generic spatial tool sets

1. Business Spatial Evaluation Applications, e.g., AWAIT, Mikisew, WESPAB , etc.

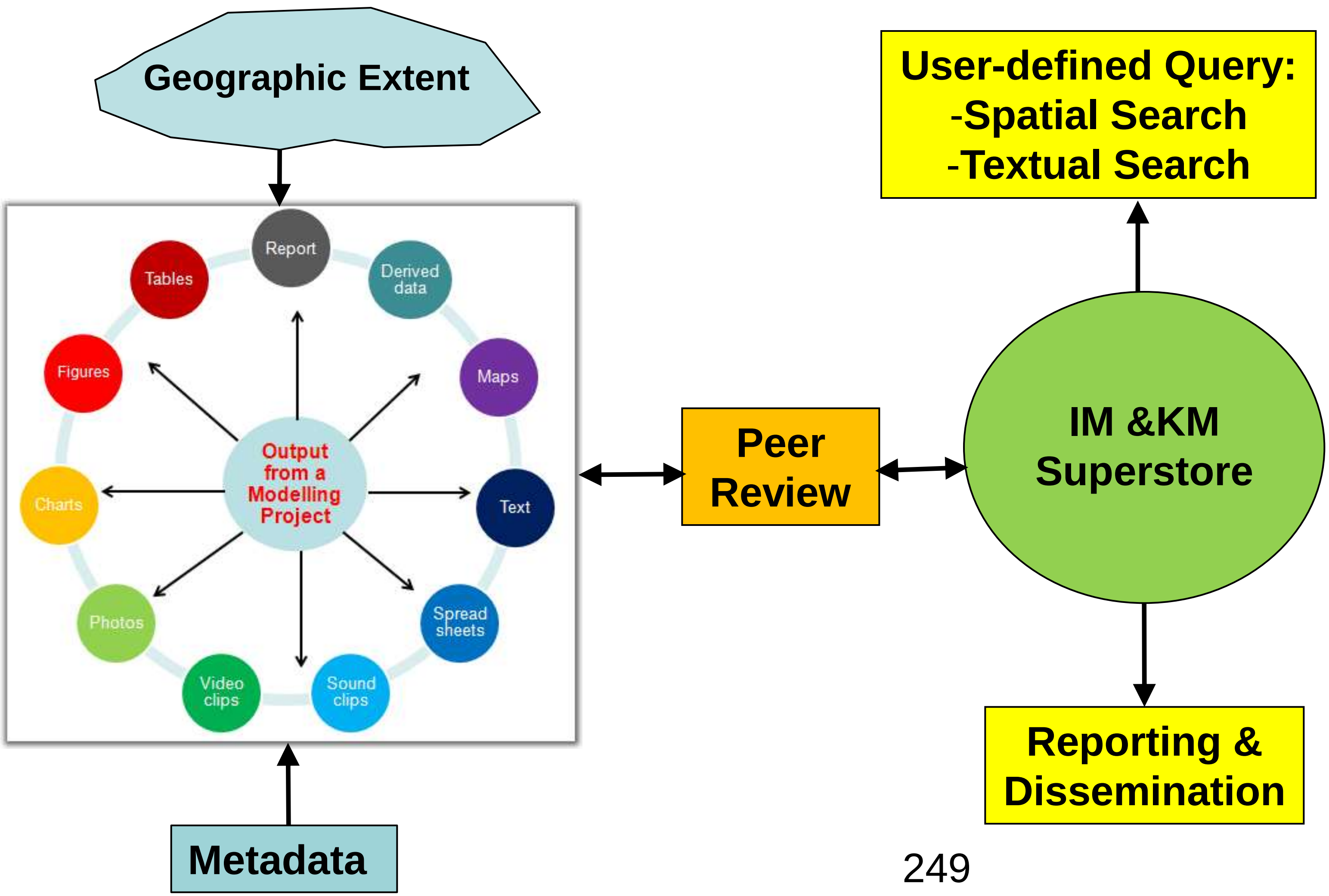


3. Generic Spatial Tool Sets, e.g., Zoom to Township, Place Name, etc.

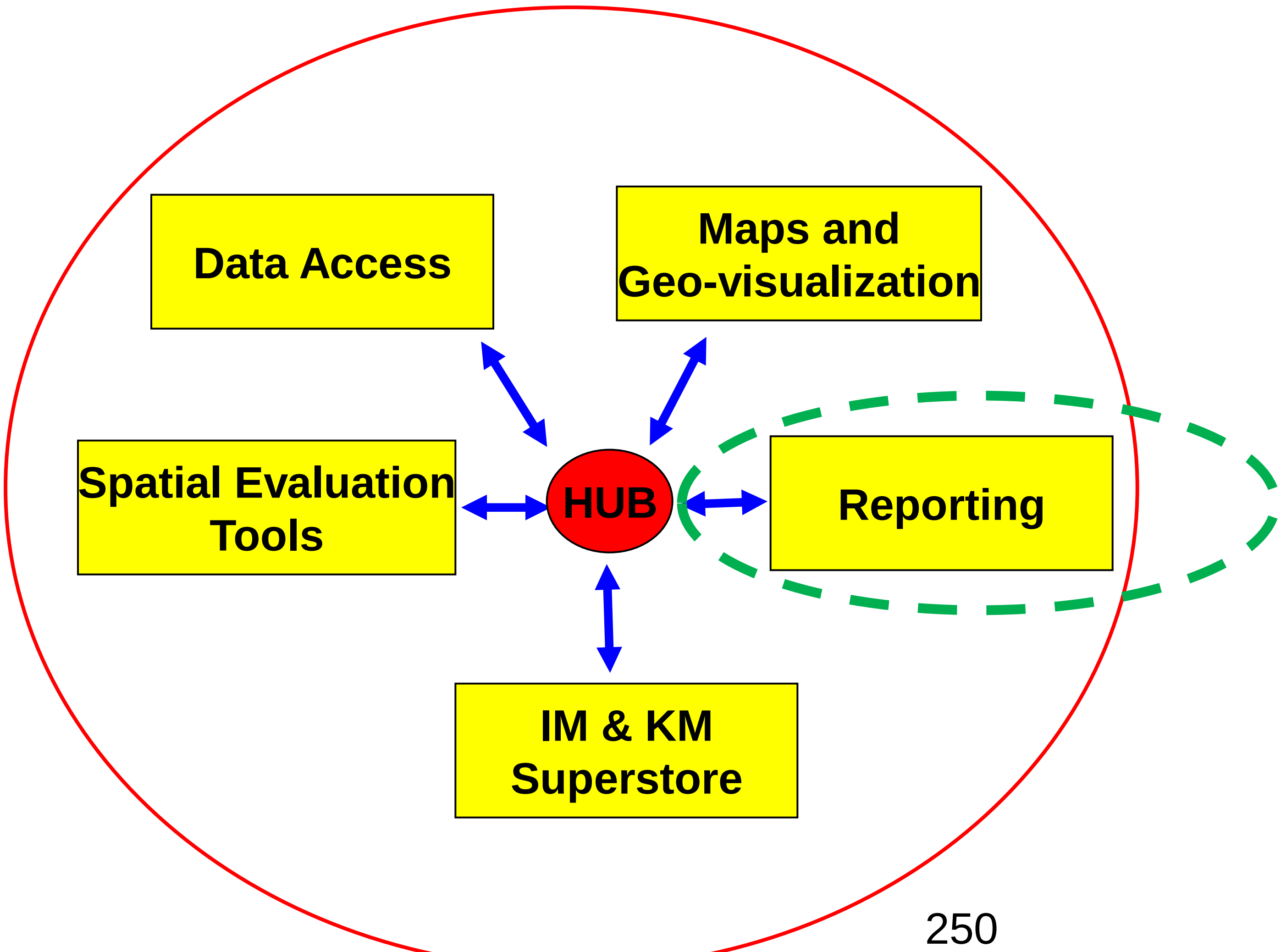
Vision of $(ES)^2$



IM & KM Superstore: Spatially/Textually-searchable catalog to manage/store/access project-based derived information and expert knowledge (derived databases, maps, text, reports, spreadsheets, graphics, pictures, audio files, video clips, etc.)



Vision of $(ES)^2$



Reporting: A spatially-searchable, open & transparent reporting system (a Story Teller) with an option for downloading relevant data and information

Benefits of $(ES)^2$

- Support business processes and management activities within CEMS, IRM, LUF.
- Support scientifically rigorous and defensible data, information and knowledge, i.e., putting the right data/information/knowledge, in the right format, in the right hands, at the right time.
- Support open data.
- Integrate various GIS functions.
- Align with the world-class Monitoring, Evaluation & Reporting vision.
- Support Alberta Monitoring Agency and Alberta Energy Regulator.
- Align with EDMS, including GeoDiscover Alberta.
- Achieve the goal of enterprise GIS (BPIT, 2011).

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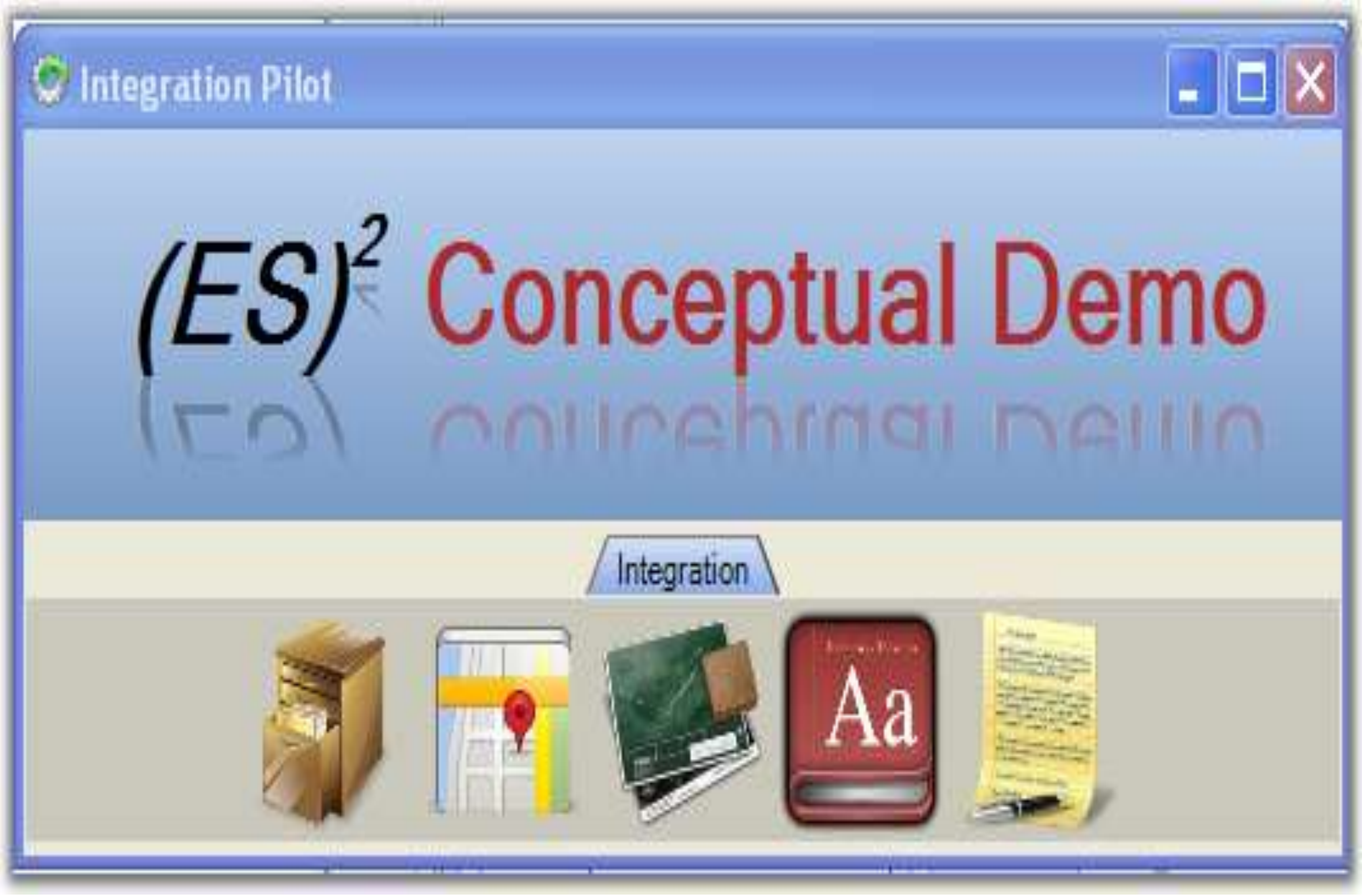
Conceptual Demo



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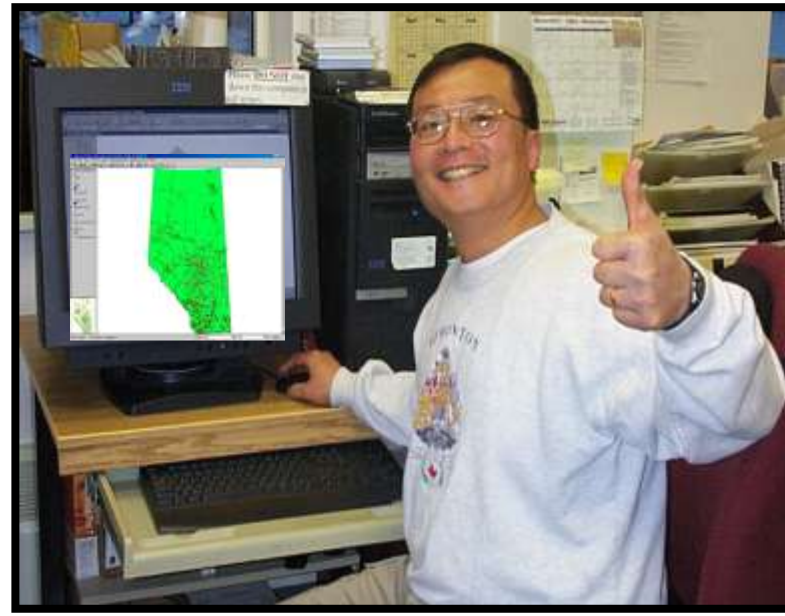
(ES)^2 Can Make a Difference!

Without **(ES)^2** versus With **(ES)^2**



Stressful and frustrated modeler due to inaccessible data/tools and laborious, inconsistent, time-consuming, non-transparent**,** fragmented, and silo work.

Happy & productive modeler who are making meaningful contributions as a result of an efficient, effective, innovative, timely, informed, open, transparent, and credible enterprise spatial system.

Summary

- We have a vision to create a world-class Enterprise Environmental Spatial System $(ES)^2$ for Alberta.

- We are excited and passionate to do the right thing, and we will strive to do it right through a journey of learning (and making mistakes!)

- We need your support and engagement. By working together, we can make a difference!

Thank You!

Q&A, Comments and Discussions

"A journey of a thousand miles begins with a single step. Just do it!"

Session 2

Day 1 – Session 2

Stefan Kienzle – Univesity of Lethbridge

BIOGRAPHY

Stefan is a hydrologist and GIS analyst at the Department of Geography, University of Lethbridge, with over 25 years of experience in watershed modelling. Stefan is also Adjunct Professor at the University of Regina (Saskatchewan, Canada) and the University of South Africa (Pretoria, South Africa). He has worked in government research institutes, consulting, and various Universities in Africa, Europe, and Canada. Stefan has been working with, and further developing, the ACRU agro-hydrological modelling system since 1990, and applied the model for watershed impacts analysis in South Africa, New Zealand, the USA and Canada. His current research focus is using the ACRU agro-hydrological modelling system to simulate the impacts of environmental change on watershed hydrology in many watersheds in the Province of Alberta.
In order to enable his work, Stefan is in the process of establishing a digital hydro-climatological Atlas of Alberta with a high spatial resolution. Dr. Kienzle maintains a strong research lab with research assistants and graduate students, and has published widely in international journals, including Journal of Hydrology, Hydrological Processes, Water Resources Management, Climatic Change, and the Hydrological Sciences Journal. Stefan is co-author of several book chapters. He was expert witness on hydrological issues in numerous court cases, including oil sands hearings in 2003 and 2006.

Day 1 – Session 2

Stefan Kienzle – Univesity of Lethbridge

ABSTRACT

Sustainable environmental management requires the knowledge of the envelope of expected water availability, both in rivers and in the soil. The ACRU agro-hydrological modelling system is a model than can provide this information under a range of environmental conditions.

ACRU is a multi-purpose, multi-level, integrated physical-conceptual model that is designed to simulate total evaporation, soil water and reservoir storages, land cover and abstraction impacts, snow water dynamics and streamflow at a daily time step. As is the case with every integrated/multipurpose hydrological modelling system applied to simulate hydrological responses in large and heterogeneous watersheds, ACRU requires considerable spatial information, inter alia, on topography, a wide range of climatic parameters, soils, land cover, reservoirs, and streams. The spatial organization of sub-units in ACRU is flexible, and includes sub-watersheds, square grid cells, and hydrological response units (HRUs). For example, the 20,000 km2 upper North Saskatchewan River watershed was subdivided into 1528 HRUs, each having a unique combination of elevation, land cover, and climate. The output of the ACRU model consists of daily time series of 52 variables for each spatial modelling unit, including streamflow, groundwater flow, groundwater recharge, soil water deficit and surplus, irrigation requirements, water use by vegetation, and evaporation from wet surfaces. From the time series, risk analyses on any variable can be carried out using exceedance probability plots, which provide information on the percentage of time a certain value, e.g. flood, soil moisture, or low flow is exceeded.

Current work on the Hydro-Climatological Atlas of Alberta is also briefly presented, including the calculation of climate trends based on the instrumental record 1950 – 2010.

Environment and Sustainable Resource Development

Environmental Modelling Workshop 2013

Simulating Hydrological Behaviour Under Environmental Change in Alberta

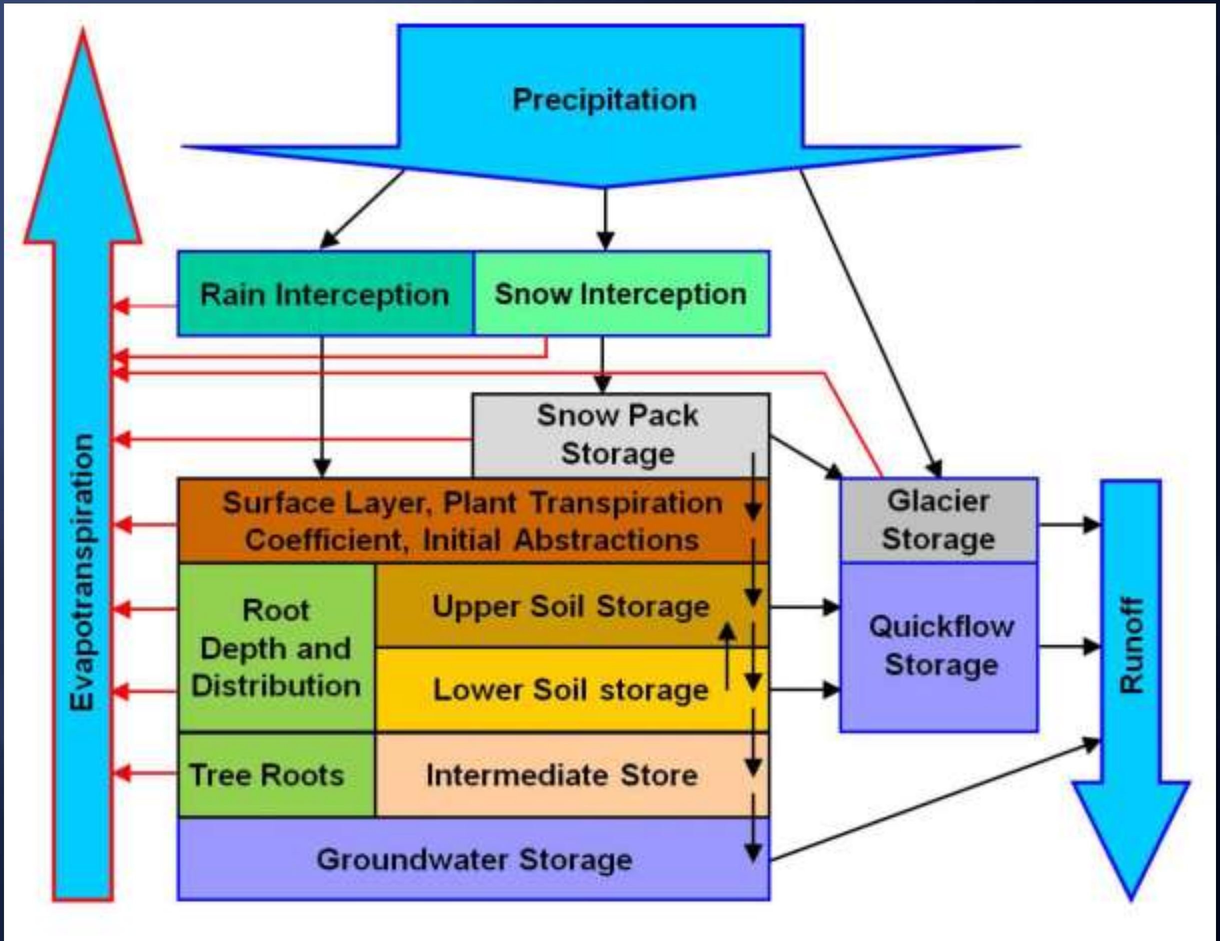
Stefan W Kienzle

University of Lethbridge

Department of Geography

Watershed Modelling Lab

ACRU agro-hydrological modelling system

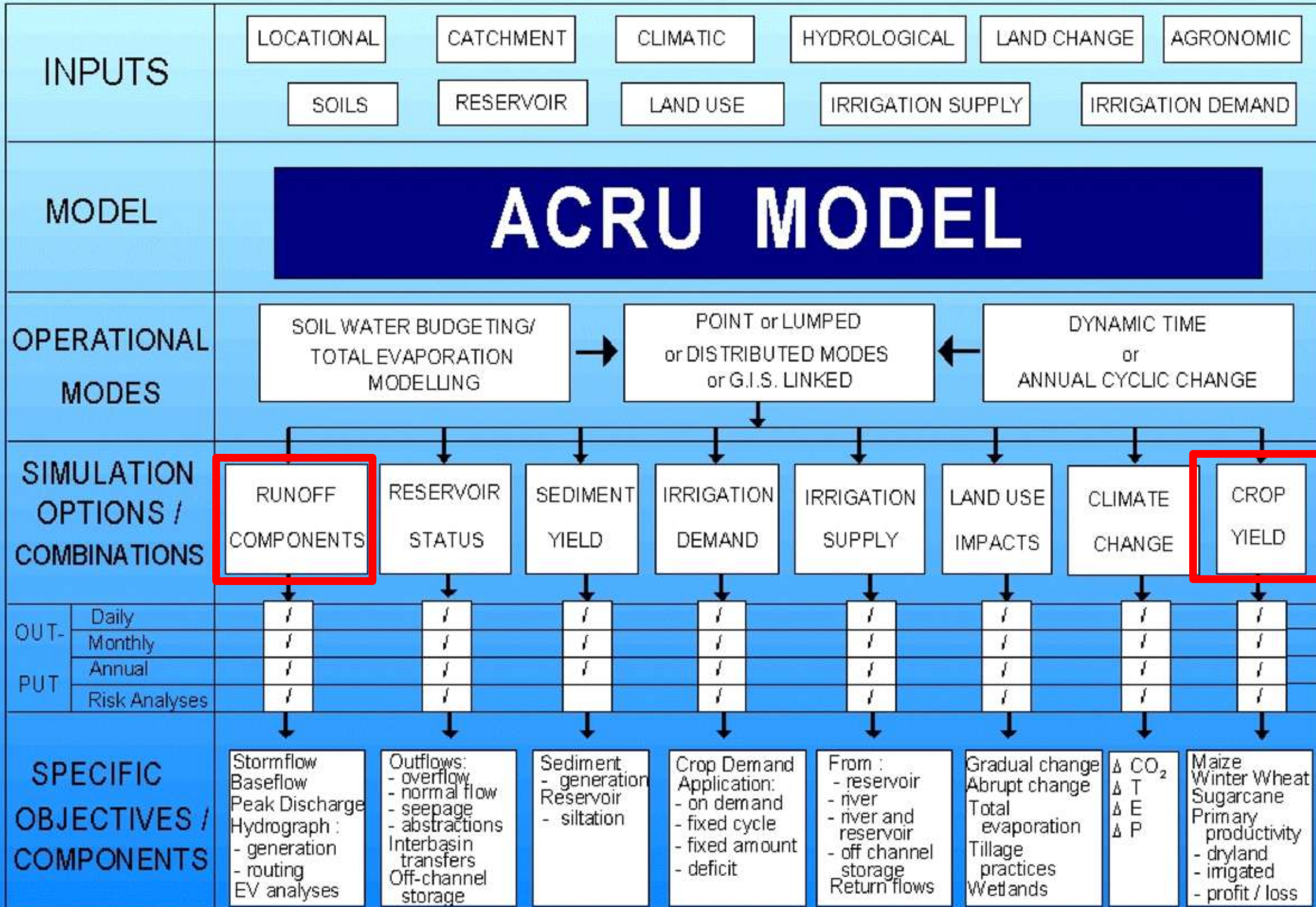


Multi-purpose

Multi-level

Integrated physical model

- Actual evaporation
- Soil water and groundwater storages
- Snow
- (Glaciers)
- Land cover and abstraction impacts on water resources
- Streamflow at a daily time step.


INPUTS
LOCATIONAL
CATCHMENT
CLIMATIC
HYDROLOGICAL
LAND CHANGE
AGRONOMIC
SOILS
RESERVOIR
LAND USE
IRRIGATION SUPPLY
IRRIGATION DEMAND
MODEL
ACRU MODEL
OPERATIONAL MODES
SOIL WATER BUDGETING/ TOTAL EVAPORATION MODELLING
POINT or LUMPED or DISTRIBUTED MODES or G.I.S. LINKED
DYNAMIC TIME or ANNUAL CYCLIC CHANGE
SIMULATION OPTIONS / COMBINATIONS
RUNOFF COMPONENTS
RESERVOIR STATUS
SEDIMENT YIELD
IRRIGATION DEMAND
IRRIGATION SUPPLY
LAND USE IMPACTS
CLIMATE CHANGE
CROP YIELD
OUT-PUT
Daily
Monthly
Annual
Risk Analyses
SPECIFIC OBJECTIVES / COMPONENTS
Stormflow
Baseflow
Peak Discharge
Hydrograph :
- generation
- routing
EV analyses
Outflows:
- overflow
- normal flow
- seepage
- abstractions
Interbasin transfers
Off-channel storage
Sediment
- generation
Reservoir
- siltation
Crop Demand Application:
- on demand
- fixed cycle
- fixed amount
- deficit
From :
- reservoir
- river
- river and reservoir
- off channel storage
Return flows
Gradual change
Abrupt change
Total evaporation
Tillage practices
Wetlands
Δ CO_2
Δ T
Δ E
Δ P
Maize
Winter Wheat
Sugarcane
Primary productivity
- dryland
- irrigated
- profit / loss

ACRU agro-hydrological modelling system

Applications in:

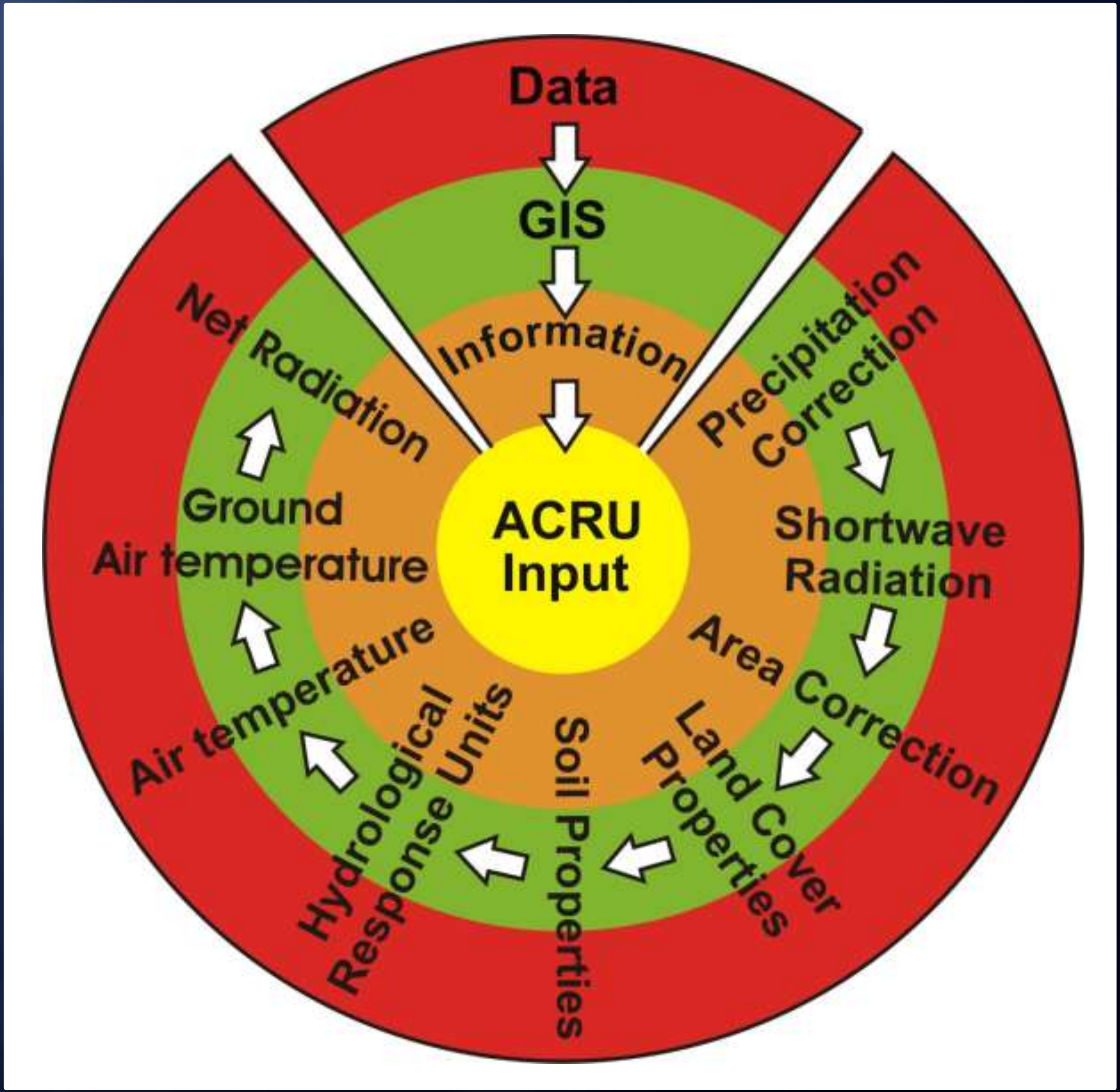
- Water resource assessments
  - (Everson, 2001; Kienzle *et al*, 1997; Schulze *et al.*, 2004)
- Flood estimation
  - (Smithers *et al.*, 1997; 2001; 2012)
- Land use impacts
  - (Kienzle and Schulze, 1991; Tarboton and Schulze, 1993, Kienzle, 2008)
- Climate change impacts
  - (New, 2003; Schulze *et al.*, 2004; Forbes *et al.*, 2011; Nemeth et al., 2012; Kienzle et al., 2012)
- Irrigation supply & demand
  - (Dent, 1988; Kienzle, 2008)

Actual Evapotranspiration

Monthly values for

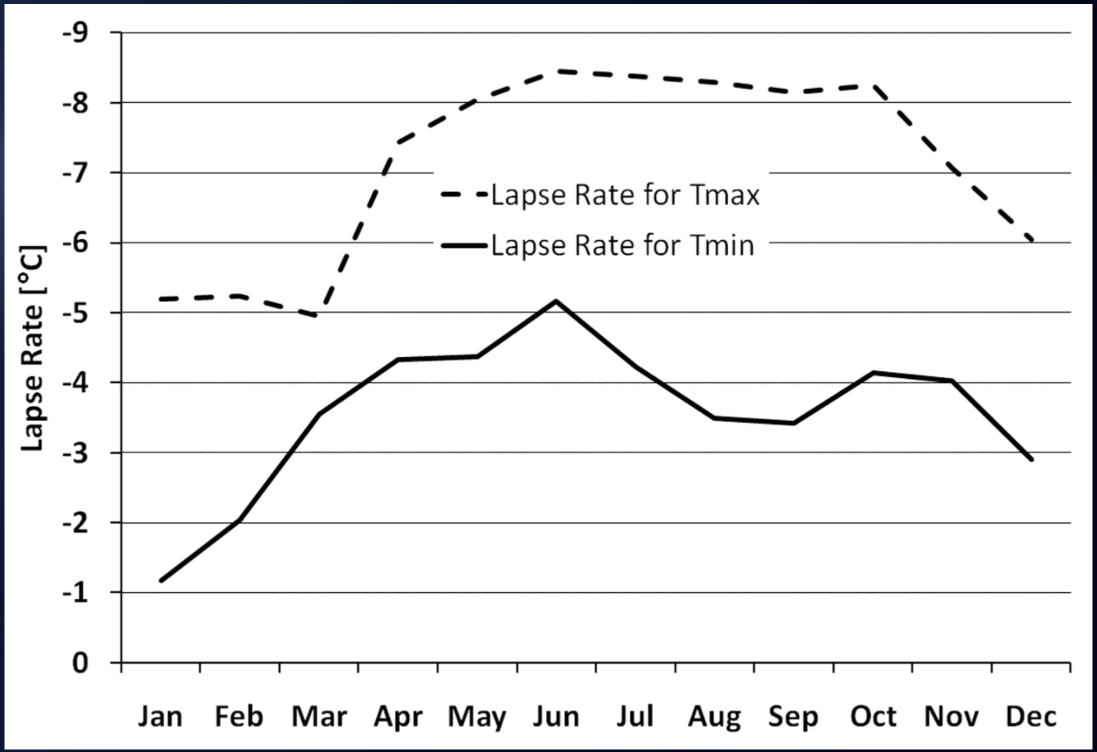
- Plant Transpiration Coefficient
  - = crop coefficient
- Stress threshold
- Interception
- Root distribution
- Initial abstractions

Extensive Data Pre-processing



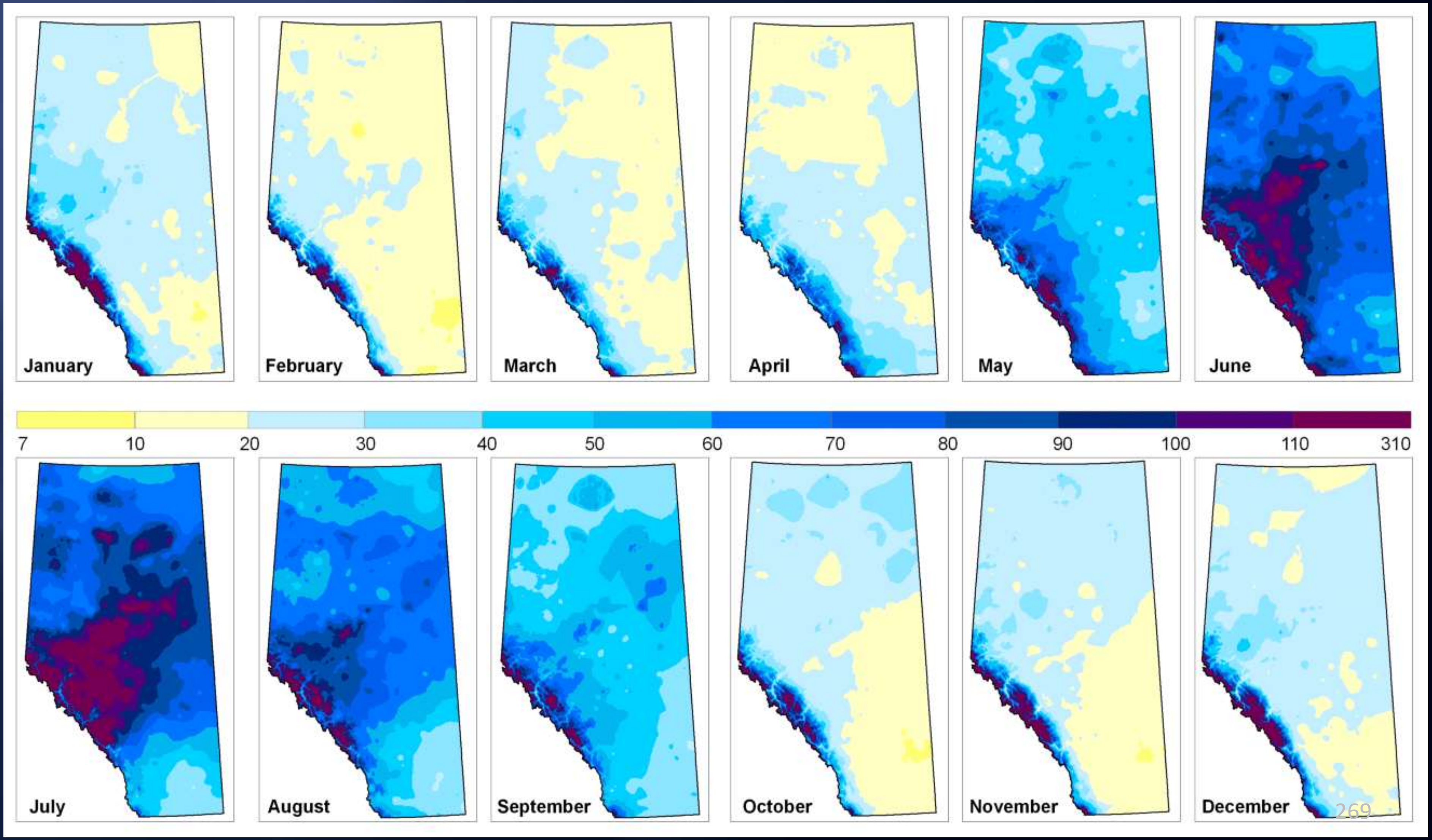
Seasonality of many variables

- Lapse rates
- Wind speed
- Relative humidity
- Albedo
- Radiation
- Sunshine hours

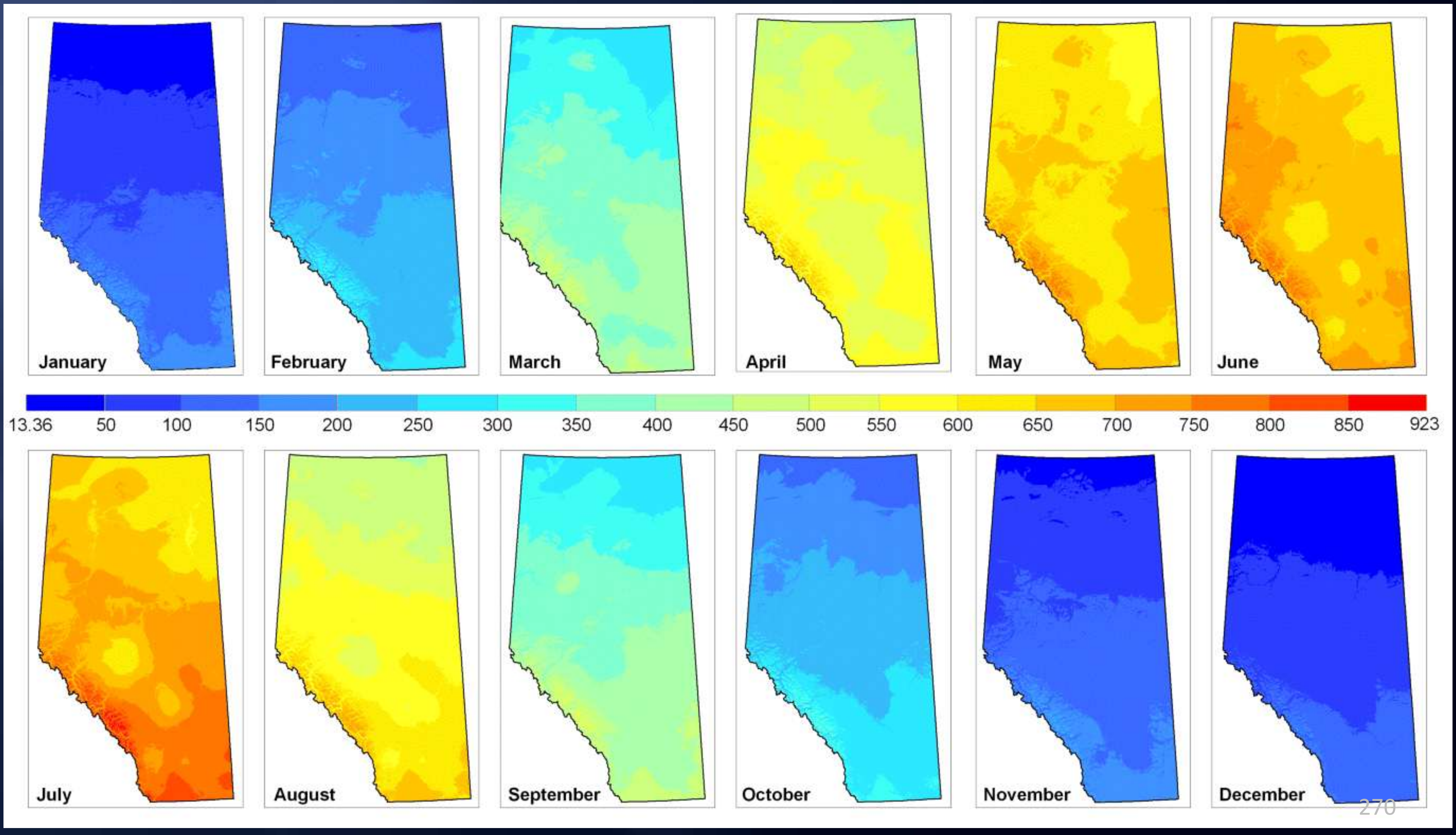


PRISM Mean Monthly Precipitation (1971-2000)

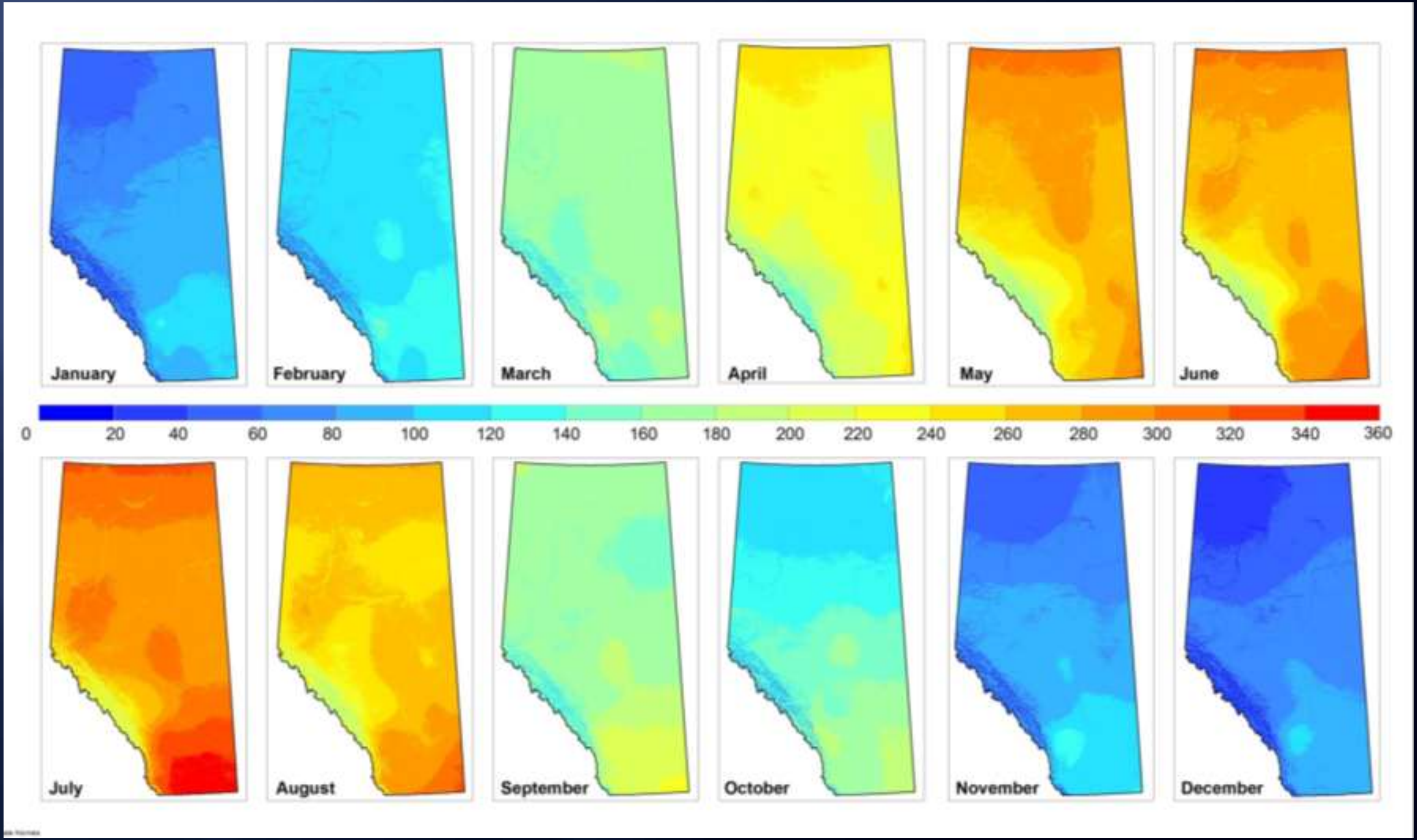
[mm month-1]



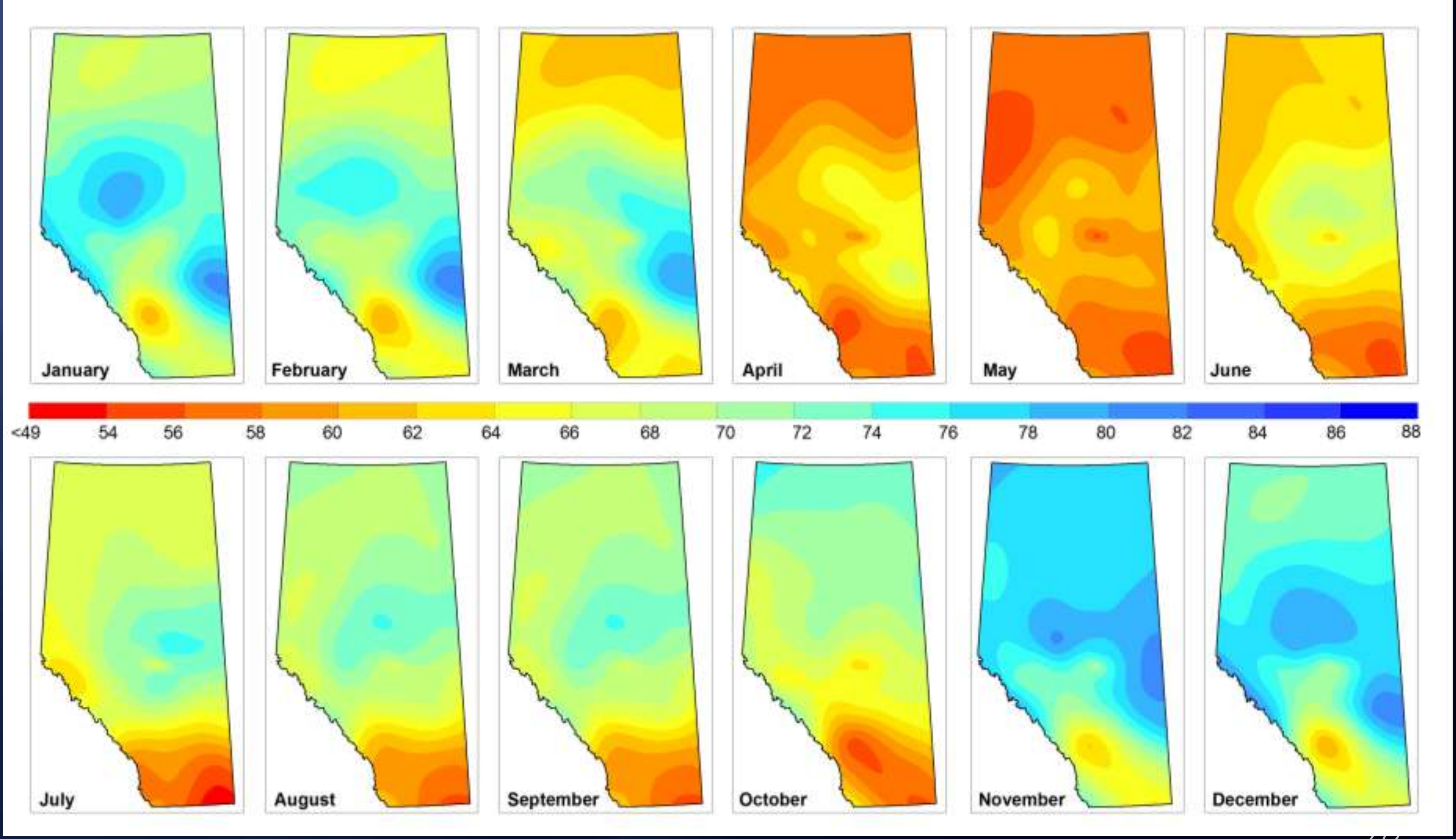
Mean Monthly Incoming Solar Radiation
[MJ m-2 month-1]



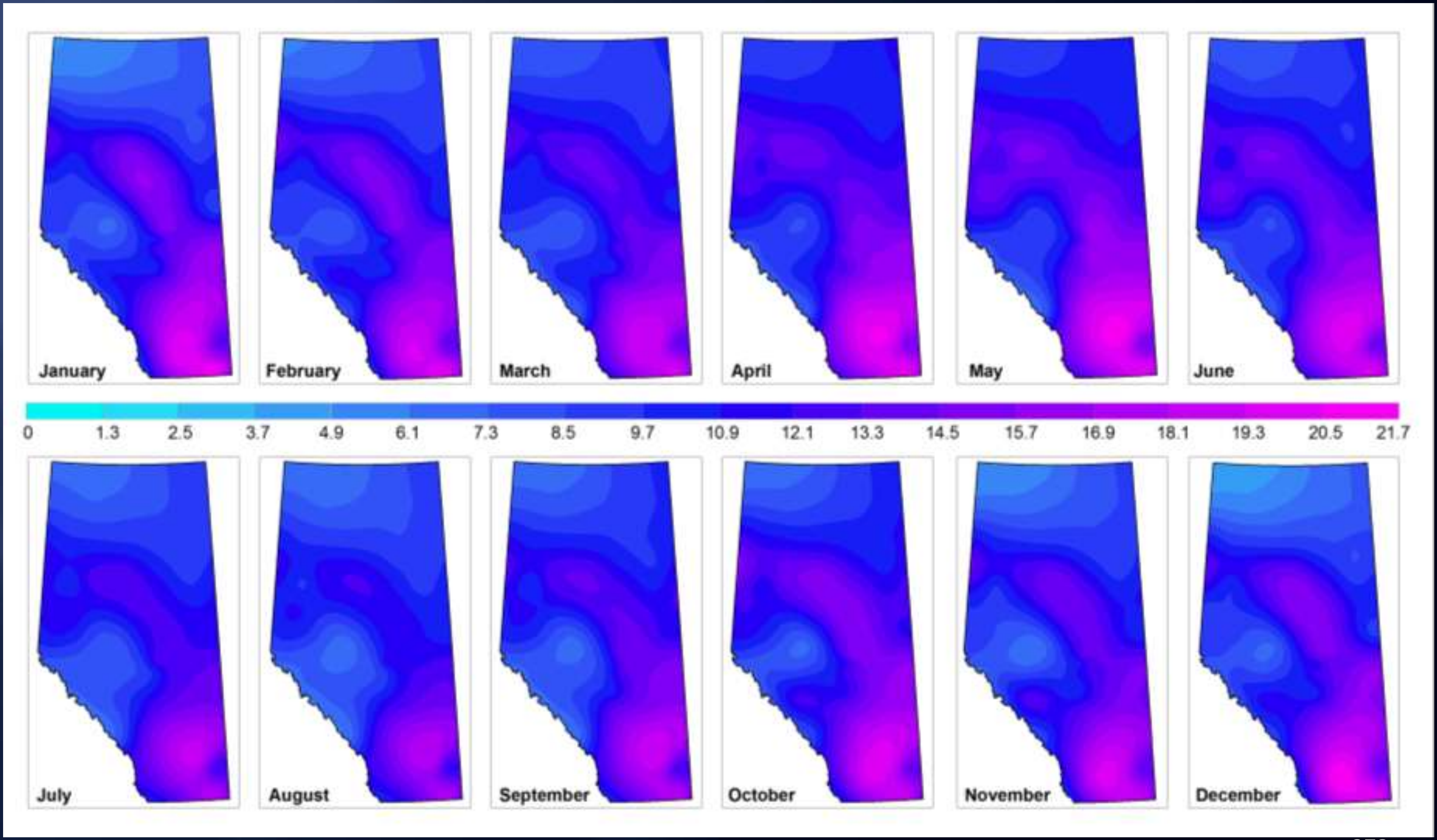
Mean Monthly Sunshine Hours



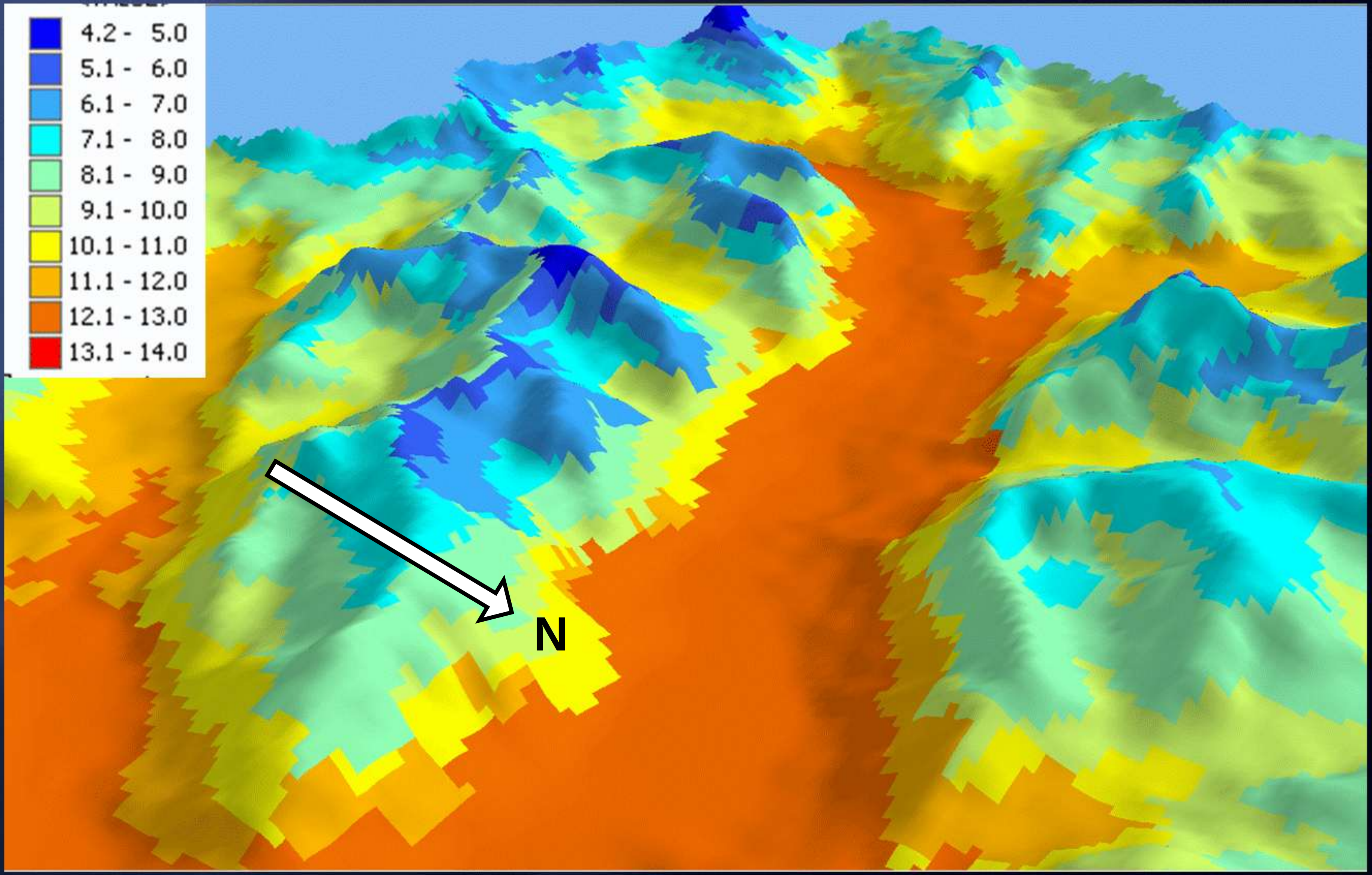
Mean Monthly Relative Humidity [%]



Mean Monthly Wind Speed [km/hr]



MEAN ANNUAL MAX. TEMPERATURE – ADJUSTED



Example Application: Impacts of Climate Change Modelling Approach

1. Setup of all input variables for the physical-based hydrological model

2. Verify baseline (1961-1990) output against observations
   - Air temperature
   - Snow pack (SWE)
   - Streamflow
     - – calibrate within physically meaningful boundaries

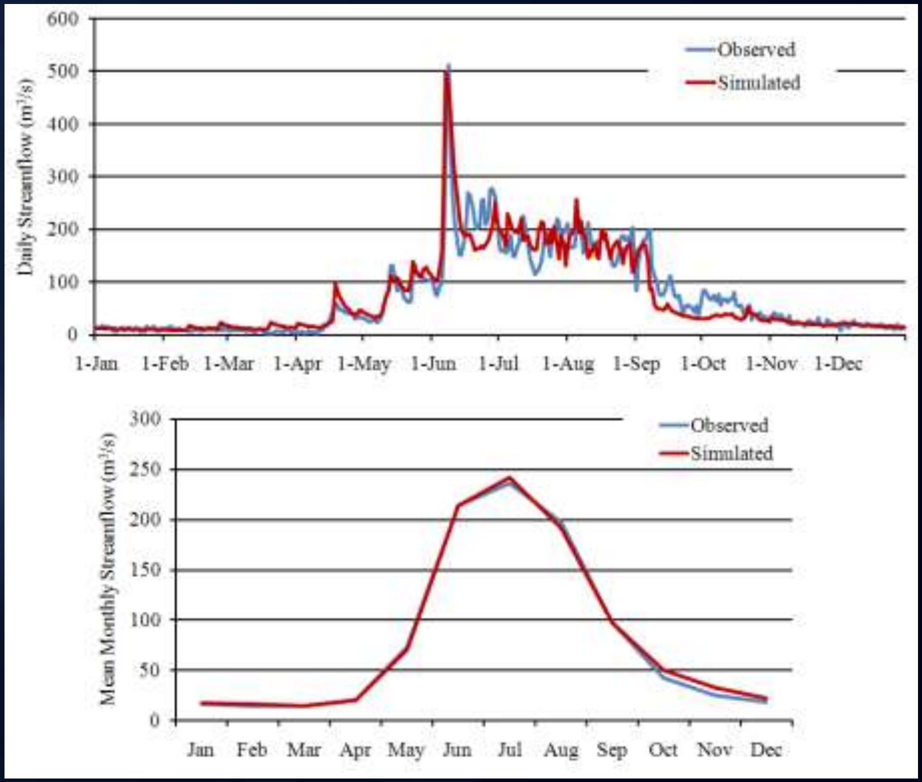
3. Simulate hydrology under environmental change

- Risk analysis for operational hydrology

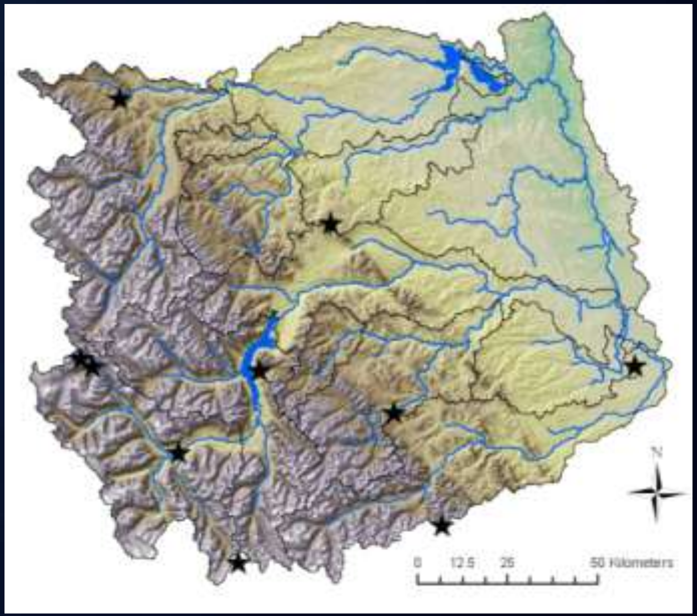
Simulation Objectives: Operational Hydrology

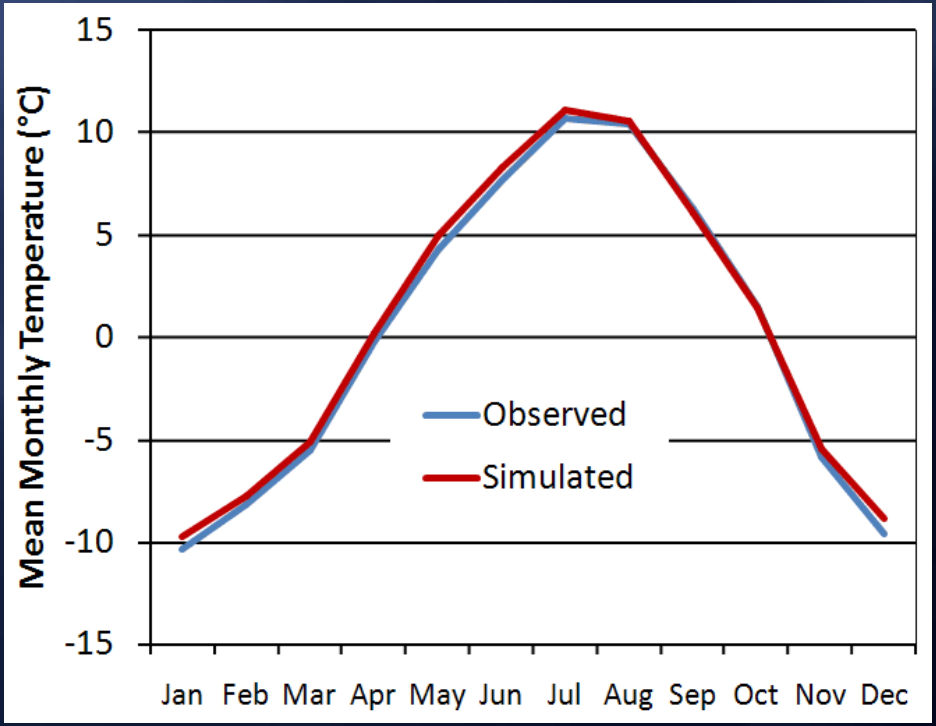
Simulate streamflow for the base period 1961-1990 to replicate these characteristics:

- Annual water yield
- Seasonality
- Shape of hydrographs
- Timing of snowmelt
- Peak flows
- Low flows
- Variance



Temperature Verification

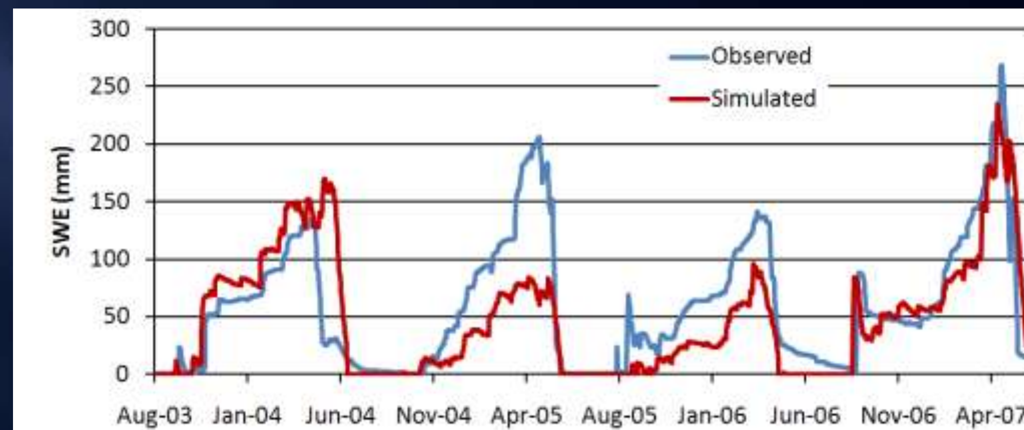


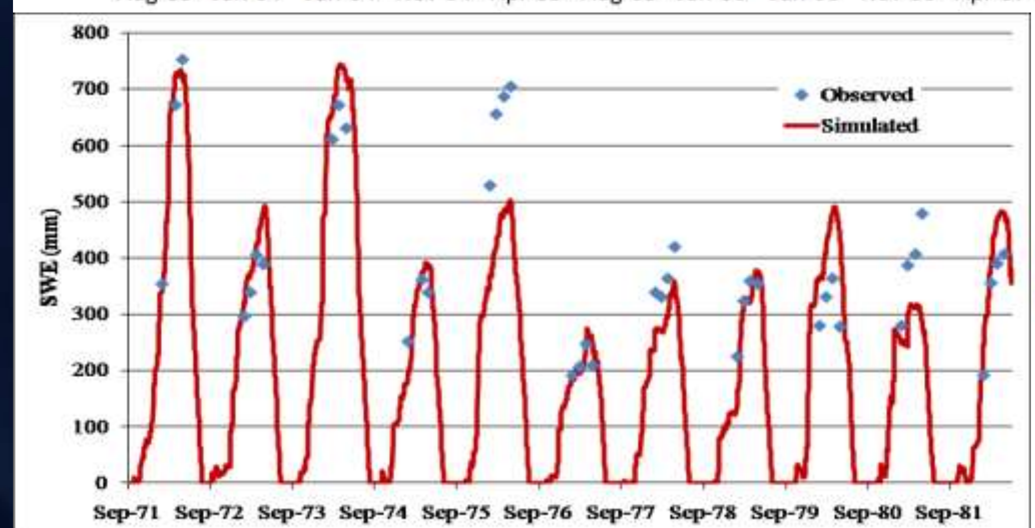


	Daily	Monthly
N	37402	499
Observed Mean (°C)	3.30	0.40
Simulated Mean (°C)	3.67	0.77
P(T<=t) two-tail	0.00	0.46
Observed Variance	78.98	67.04
Simulated Variance	75.48	64.59
% Difference	-4.64	-3.79
Coefficient of Determination (r^2)	0.88	0.98
Regression Coefficient (Slope)	0.92	0.97
Regression Intercept	0.75	0.39

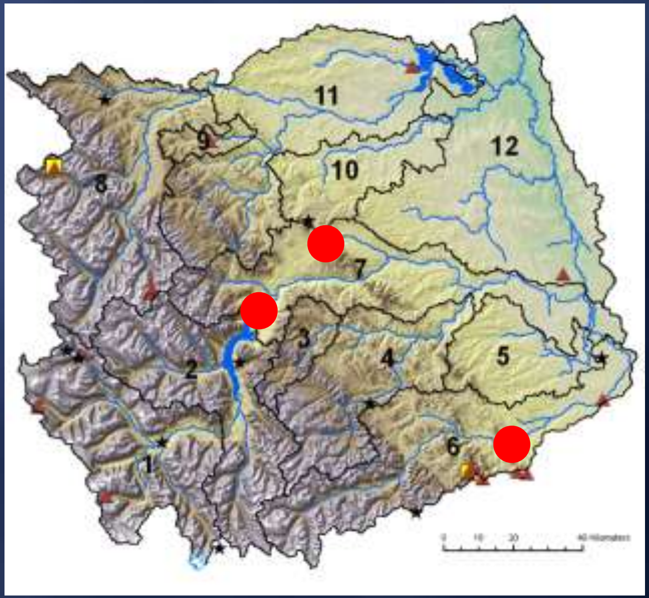
Snow Verification

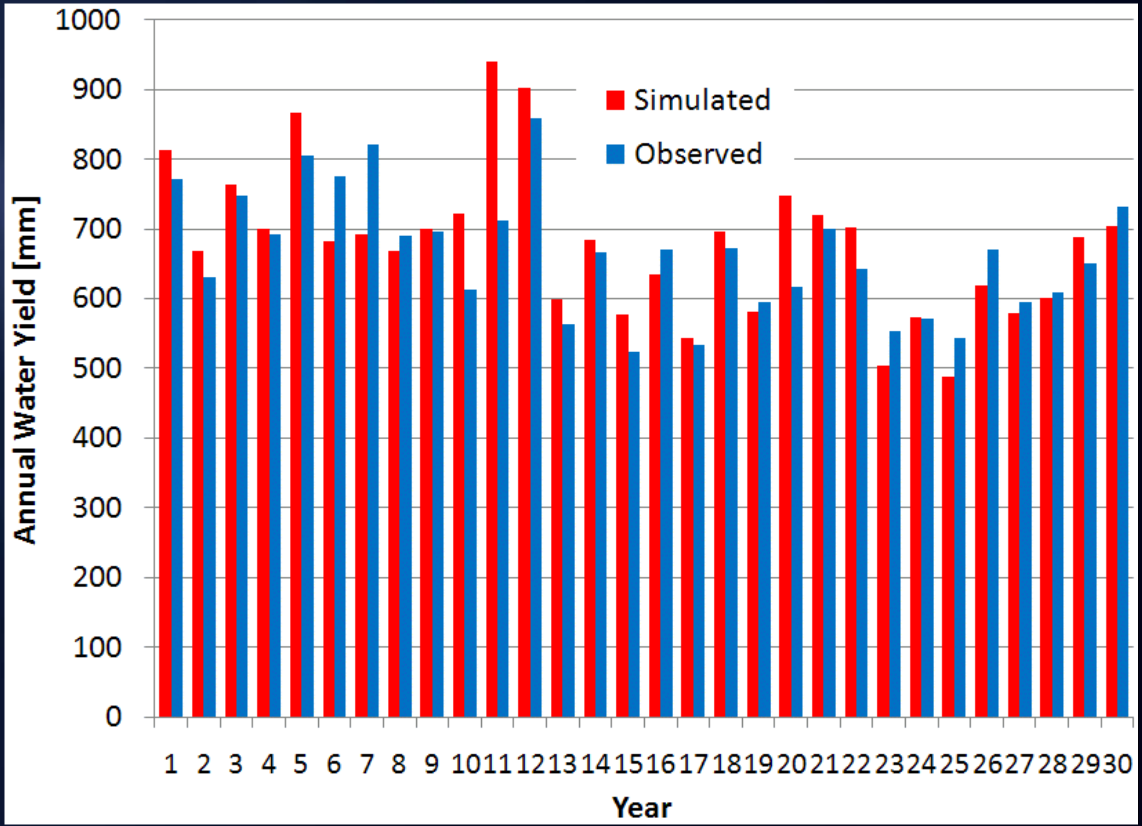
- Average conditions and their variance are simulated successfully.



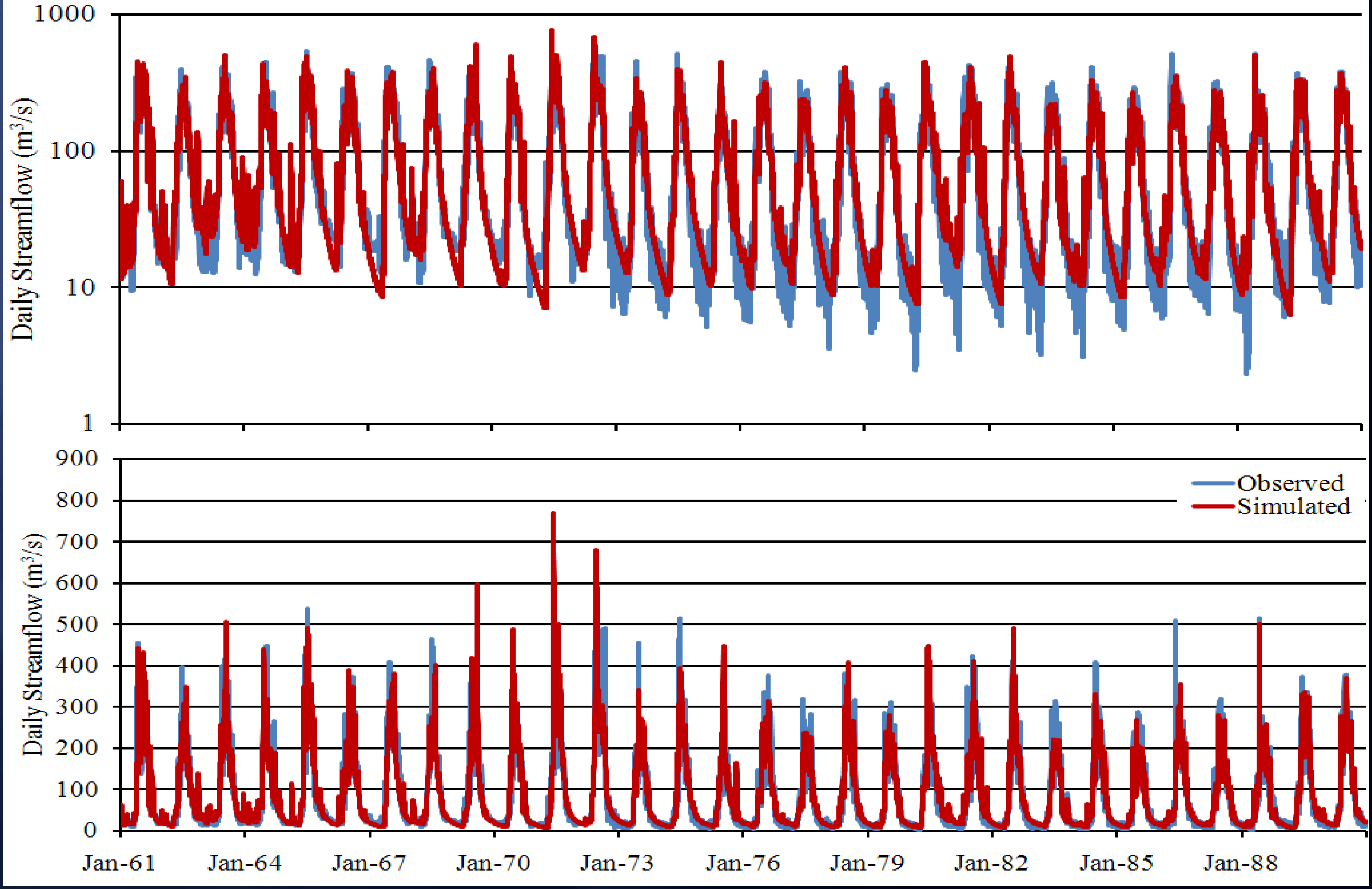


Simulated and Observed Annual Streamflow





Simulated and Observed Daily Streamflow

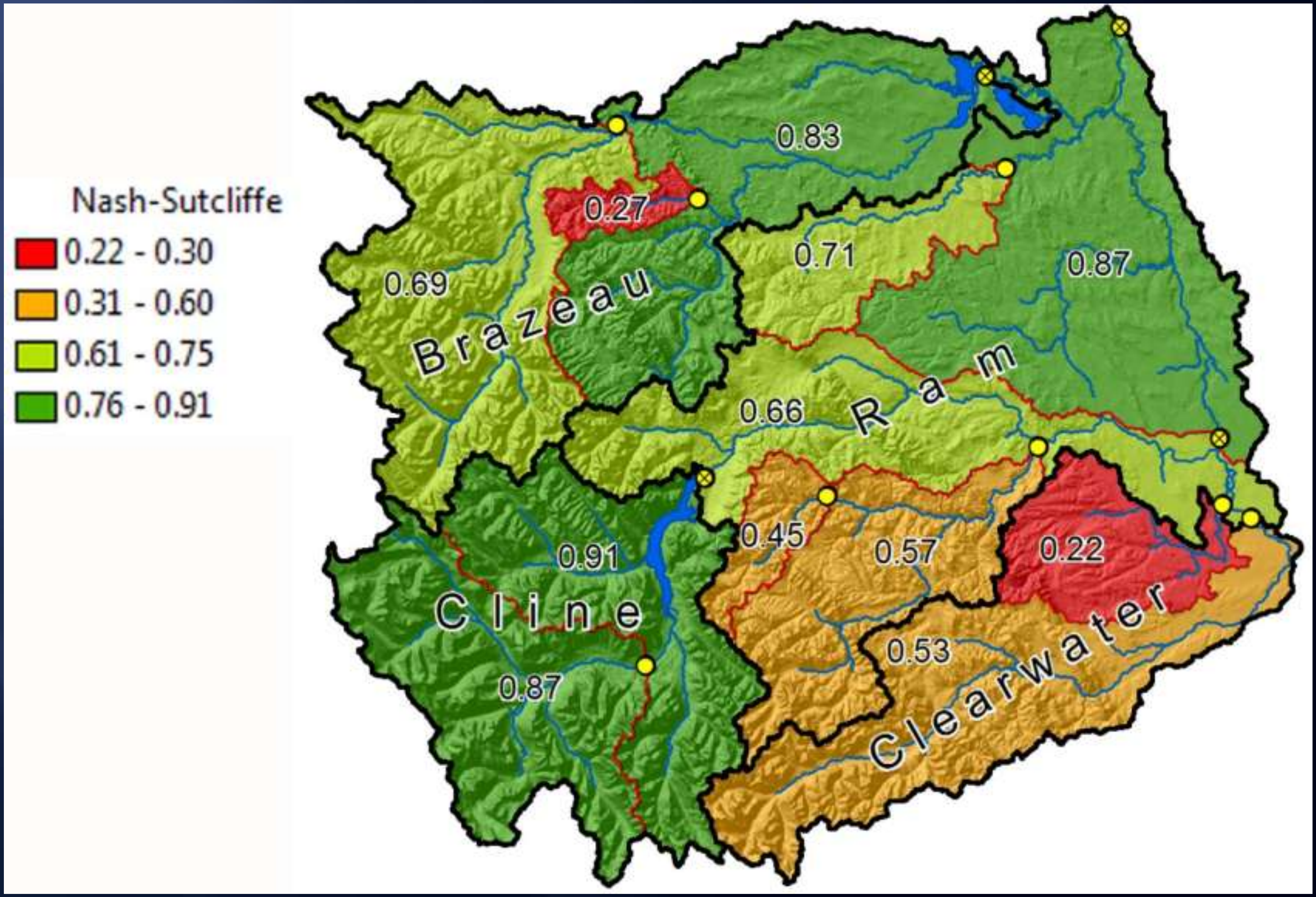


Cline River: Simulated and observed streamflow

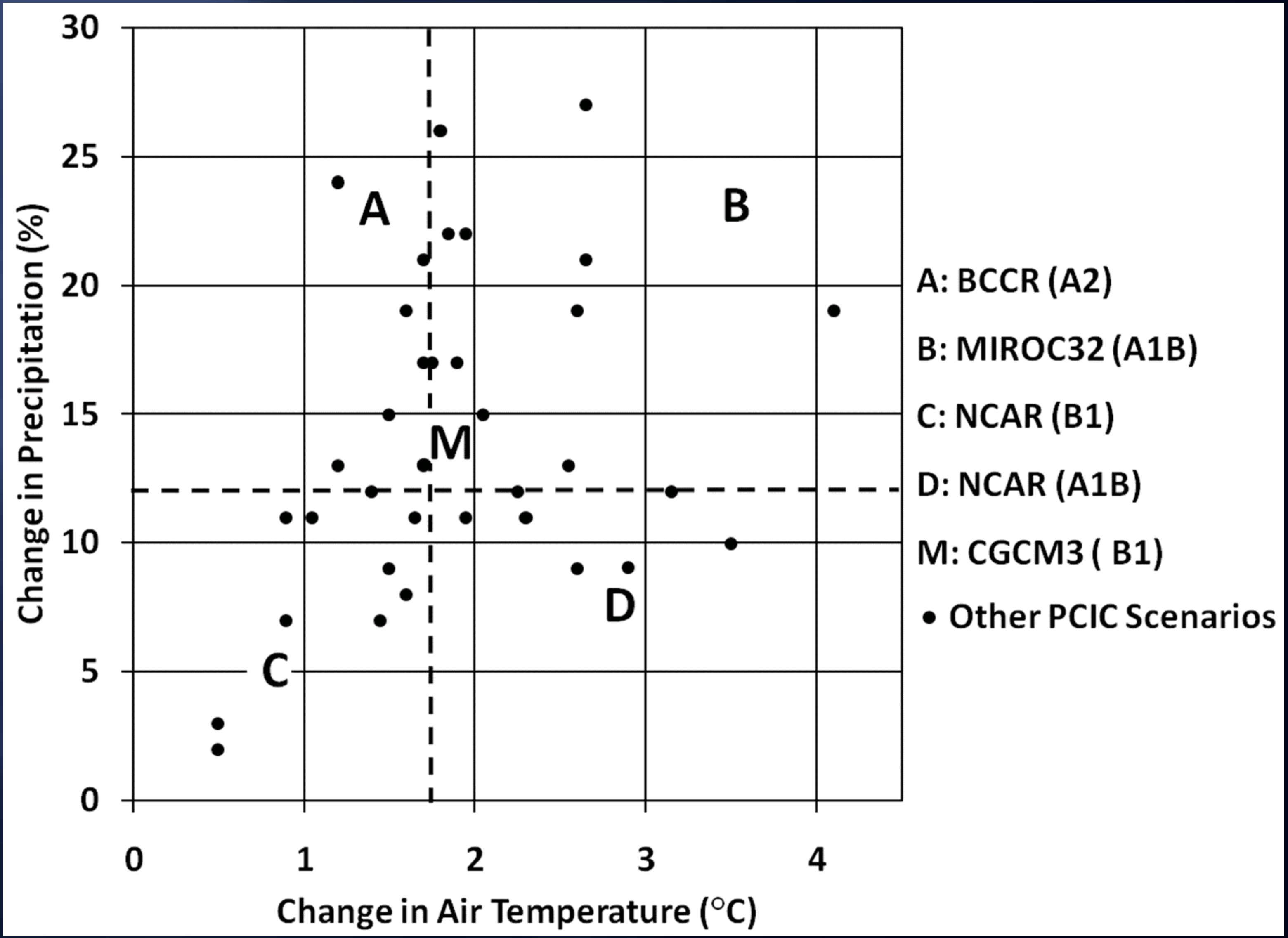
	1961-90	
	Daily	Monthly
Observed Sample Size (Days/Months)	10957	360
Simulated Sample Size (Days/Months)	10957	360
Observed Mean (m^3/s)	81.18	80.77
Simulated Mean (m^3/s)	82.95	82.54
% Difference	2.13	2.14
P(T<=t) two-tail	0.16	0.78
Observed Variance	8756.30	7419.40
Simulated Variance	8445.30	7401.60
% Difference	-3.68	-0.24
Observed Standard Deviation	93.58	86.14
Simulated Standard Deviation	91.90	86.03
% Difference	-1.82	-0.12
Coefficient of Determination (r^2)	0.83	0.92
Regression Coefficient (Slope)	0.89	0.96
Regression Intercept	0.23	0.11

Upper North Saskatchewan River Simulation

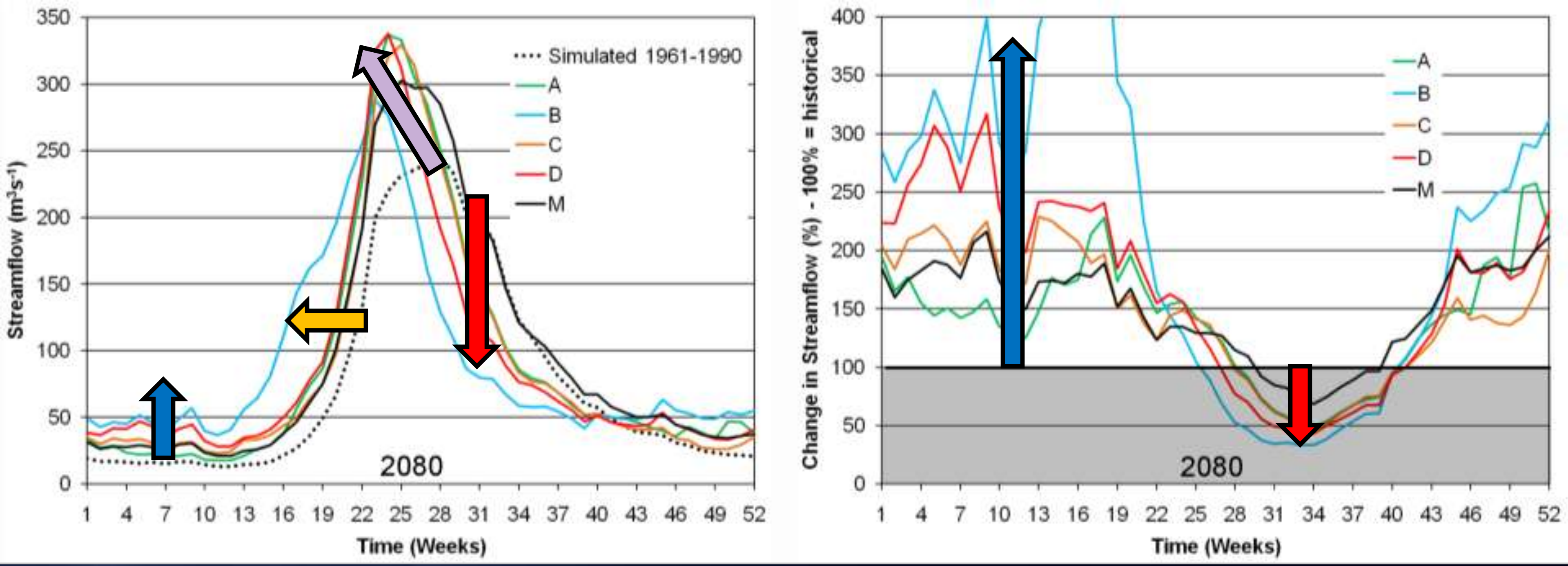
Nash-Sutcliffe Efficiency coefficients for 12 sub-watershds



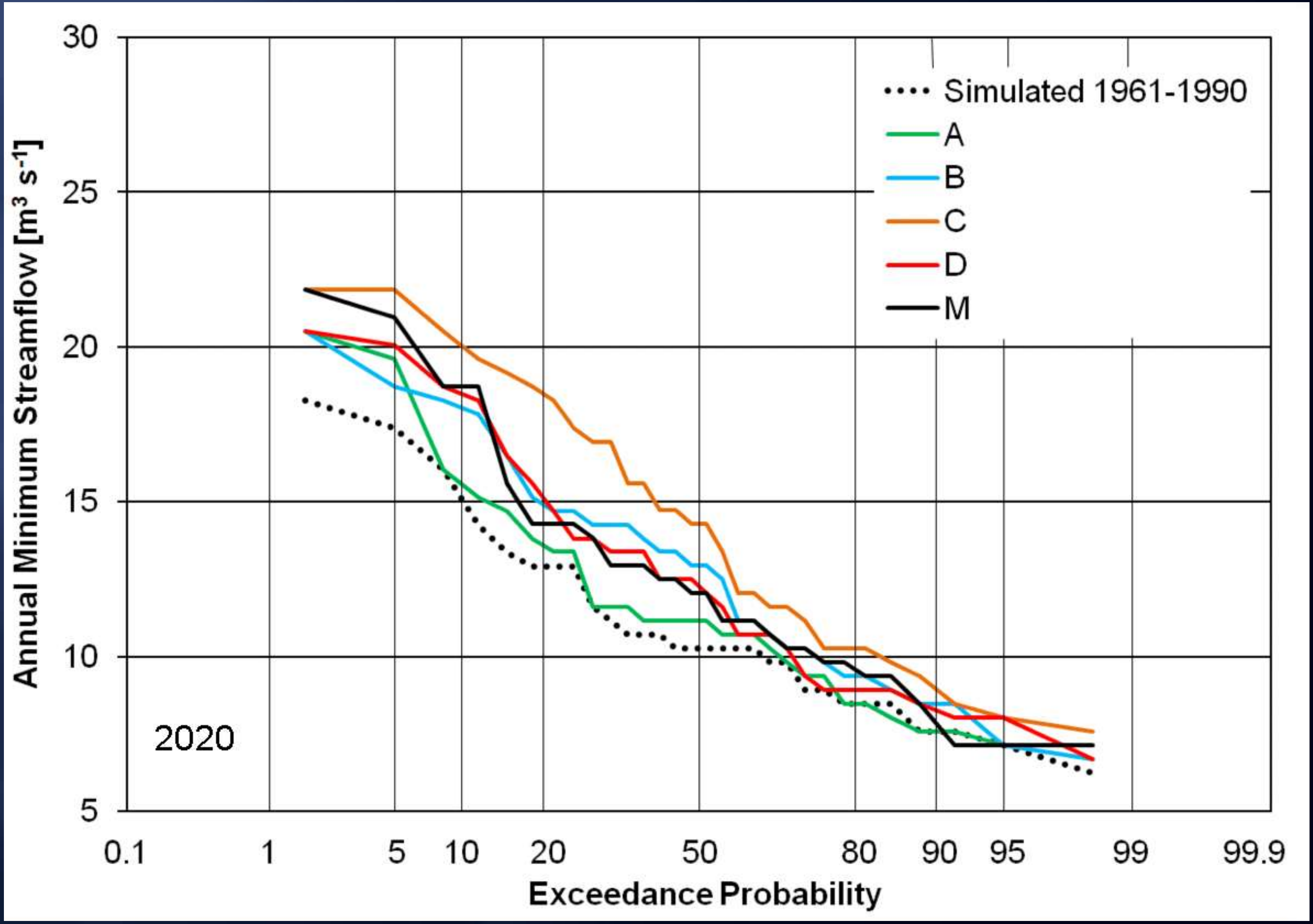
Selection of Climate Scenarios



Cline River: Streamflow Impacts 2040-2069



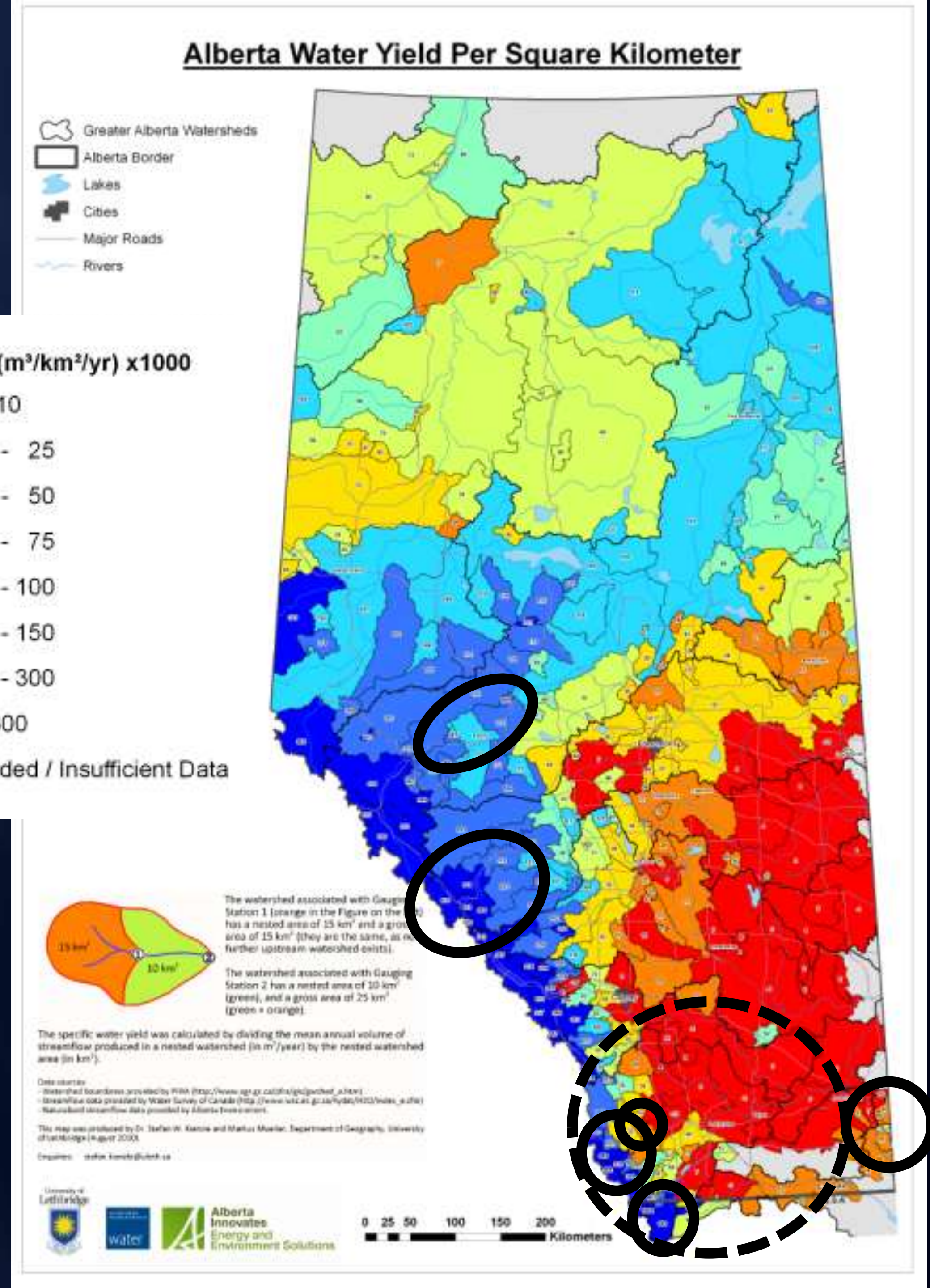
Cline River: Annual Minimum Streamflow Exceedance Probability: 2020

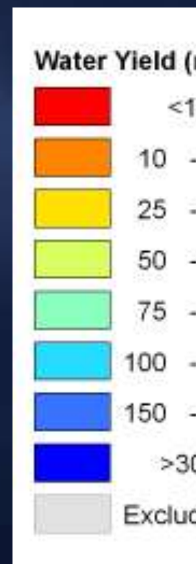


Many hydro-climatological variables

- Daily time series for each HRU:
  - 52 variables
    - Streamflow
    - Groundwater contribution
    - Potential evapotranspiration
    - Actual evapotranspiration
      - Evaporation
      - Transpiration
    - Soil water storage
      - Soil water deficit
      - Groundwater recharge
      - Irrigation demand
    - .....

Water Yield in Alberta





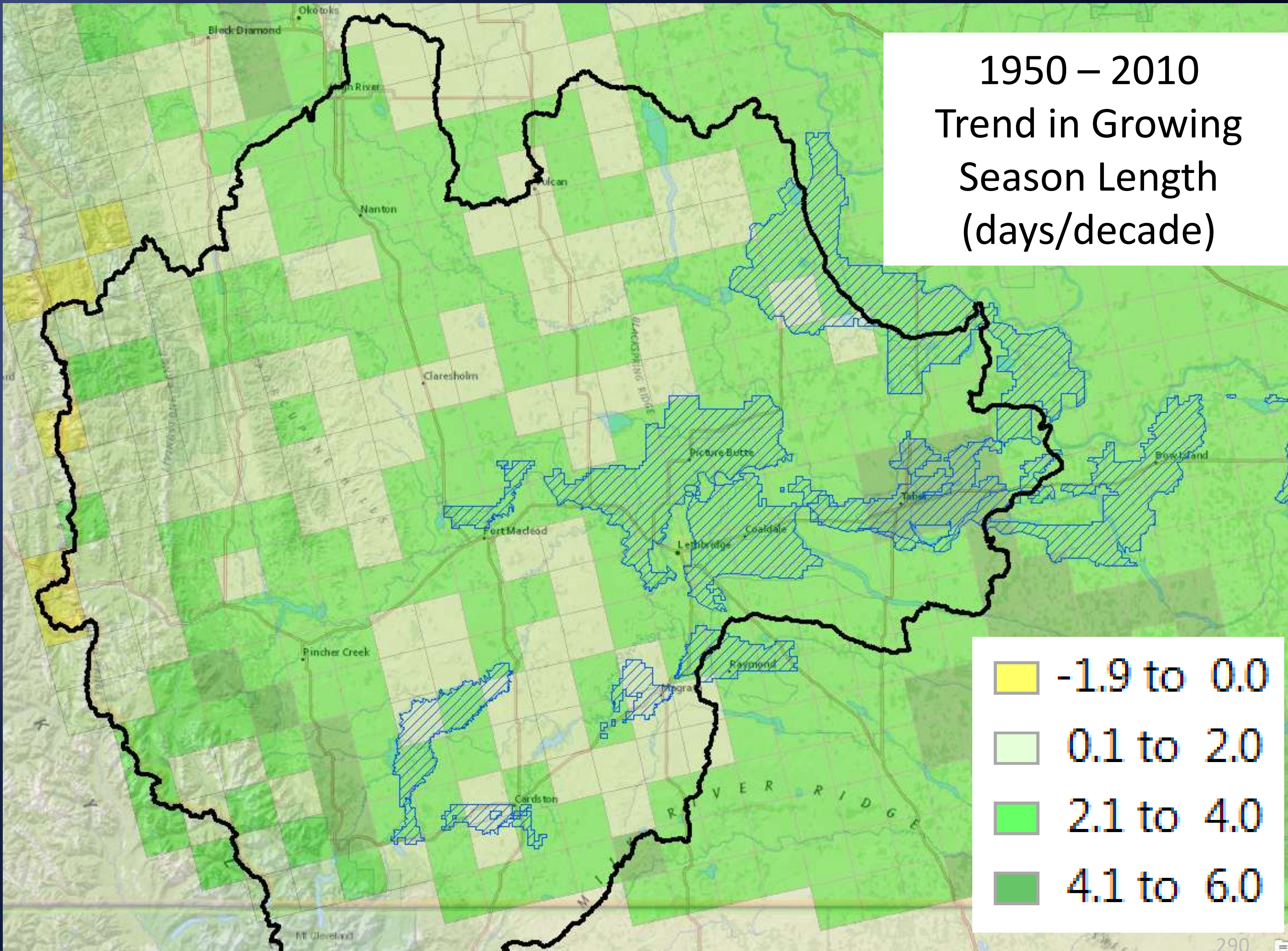
ACRU Simulations in:

- Upper North Saskatchewan River
- Castle River
- St. Mary’s River
- Beaver Creek
- Swift Current Creek
- Oldman River
- McLeod River

The ACRU model is used as a translator of climate change and land cover scenarios into hydrological responses.

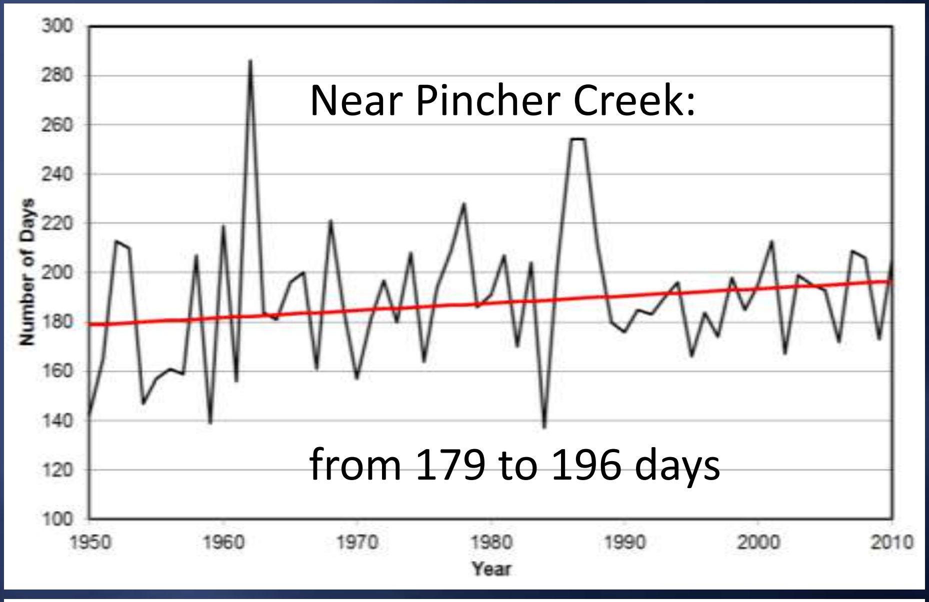
Land Use Impacts on Streamflow
Mgeni Watershed

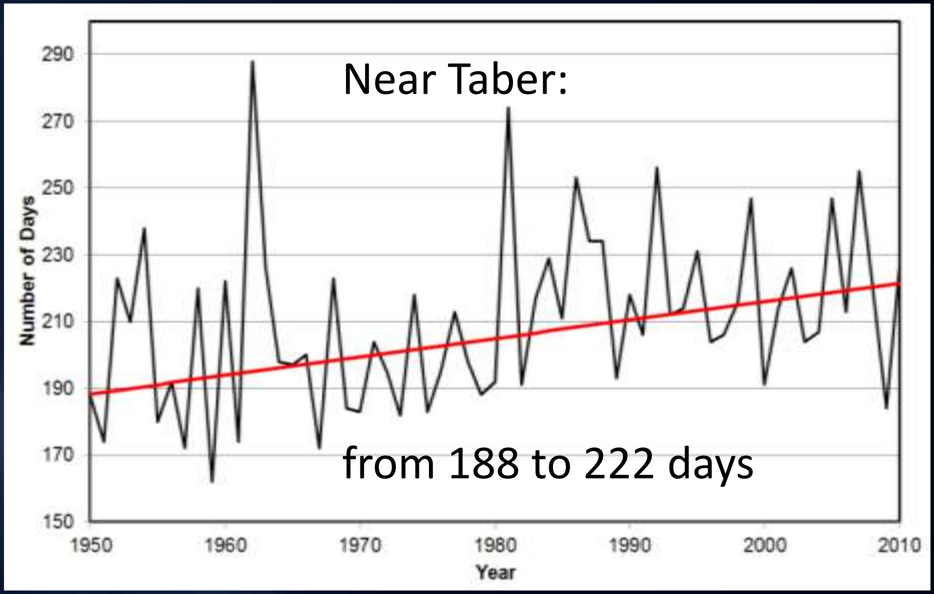
Scenario		Mean annual runoff (mm)			
		Lions MC (MAP = 979 mm)		Karkloof MC (MAP = 1 081 mm)	
A	Baseline land cover	233.4		345.6	
B	Present land use	204.5	(–12.4%)	277.6	(–19.7%)
C	Baseline + irrigation	180.2	(–22.8%)	319.7	(–7.5%)
D	Baseline + afforestation	192.9	(–17.4%)	272.0	(–21.3%)
E	Baseline + 2 × afforestation	178.4	(–23.6%)	241.6	(–30.1%)

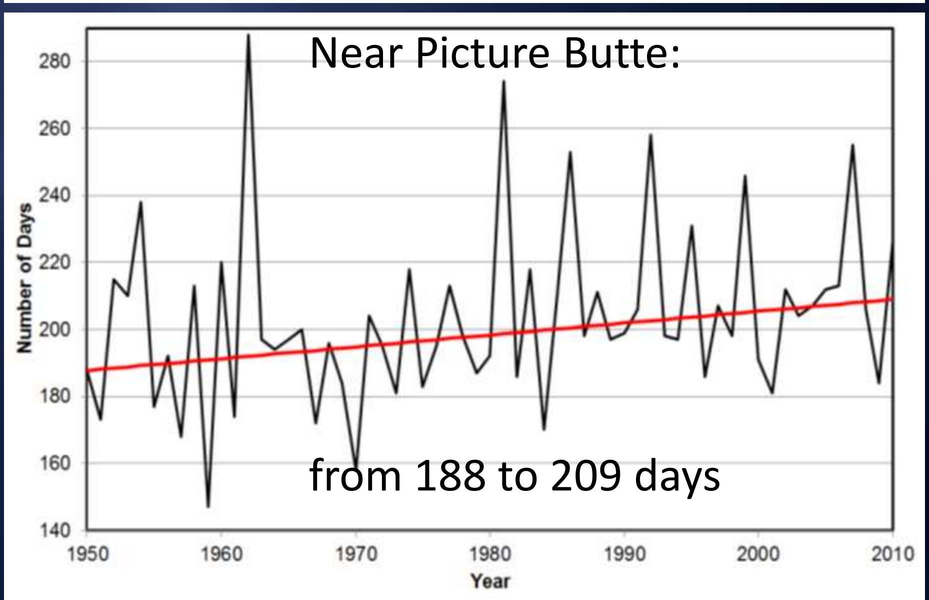


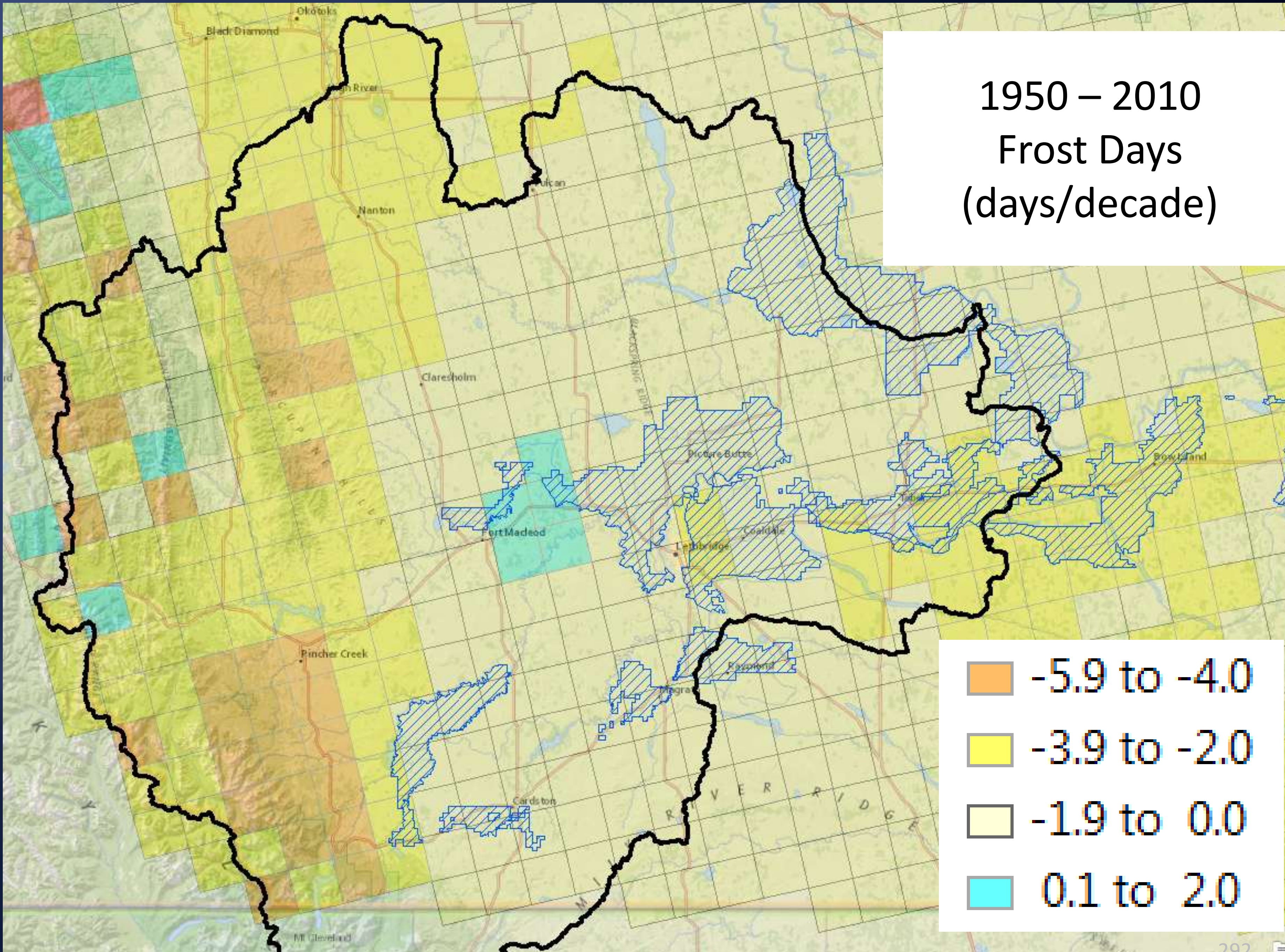
1950 – 2010
Trend in Growing
Season Length
(days/decade)
-1.9 to 0.0
0.1 to 2.0
2.1 to 4.0
4.1 to 6.0
Okotoks
Black Diamond
Nanton
Claresholm
Fort Macleod
Picture Butte
Coaldale
Lethbridge
Taber
Pincher Creek
Raymond
Cardston
Mt Cleveland

Historical Trend in Growing Season Length

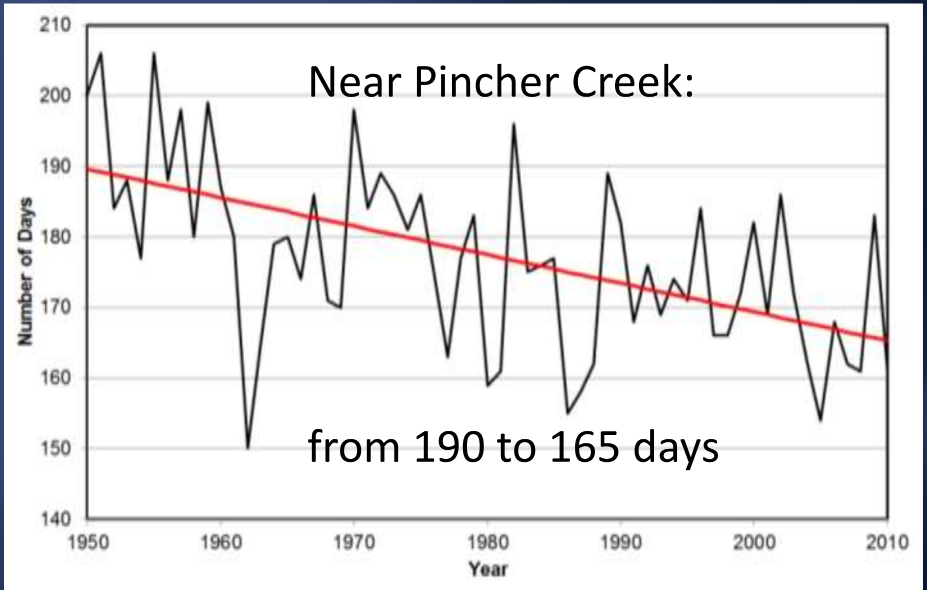


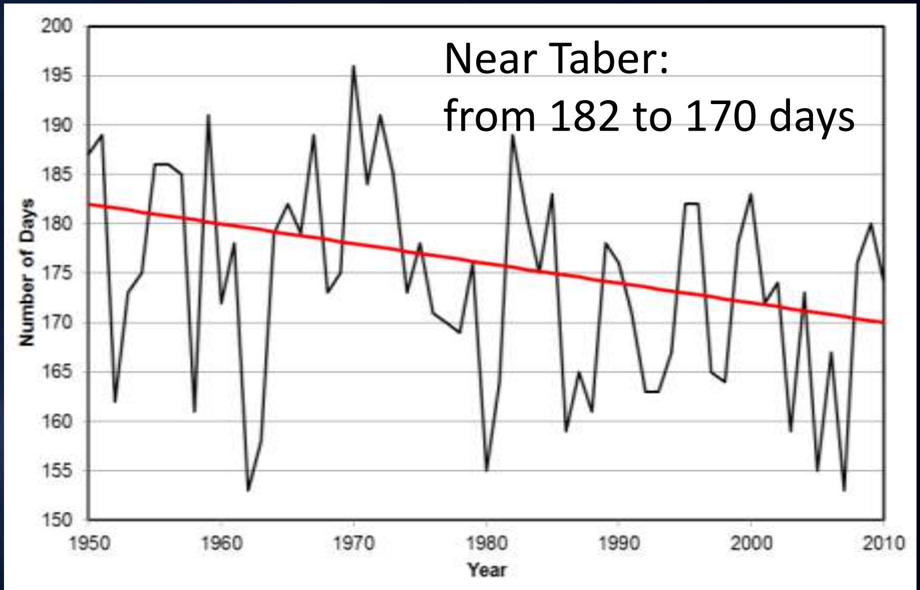


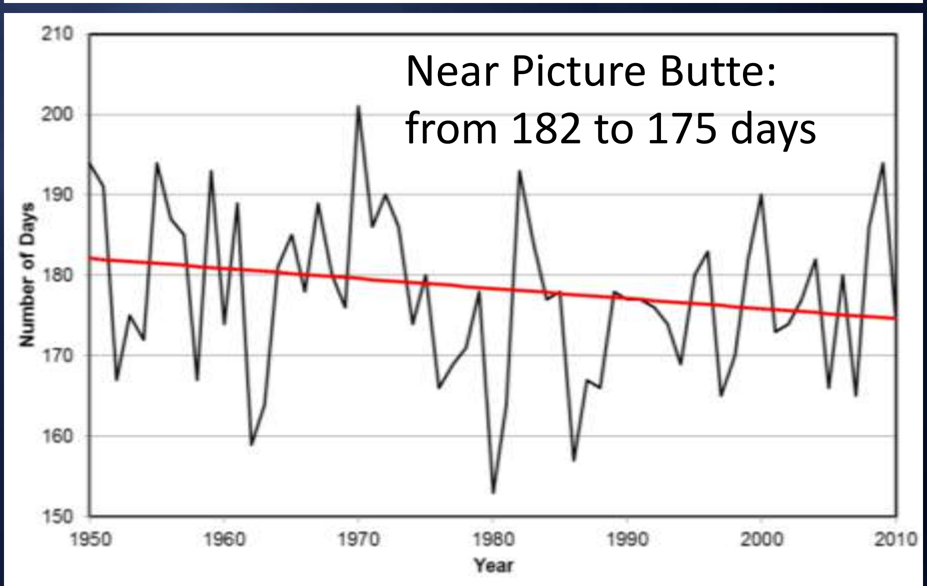



1950 – 2010
Frost Days
(days/decade)
-5.9 to -4.0
-3.9 to -2.0
-1.9 to 0.0
0.1 to 2.0
Okotoks
Black Diamond
Nanton
Claresholm
Fort Macleod
Picture Butte
Coaldale
Lethbridge
Pincher Creek
Raymond
Cardston
Taber
Bow Island
Mt Cleveland

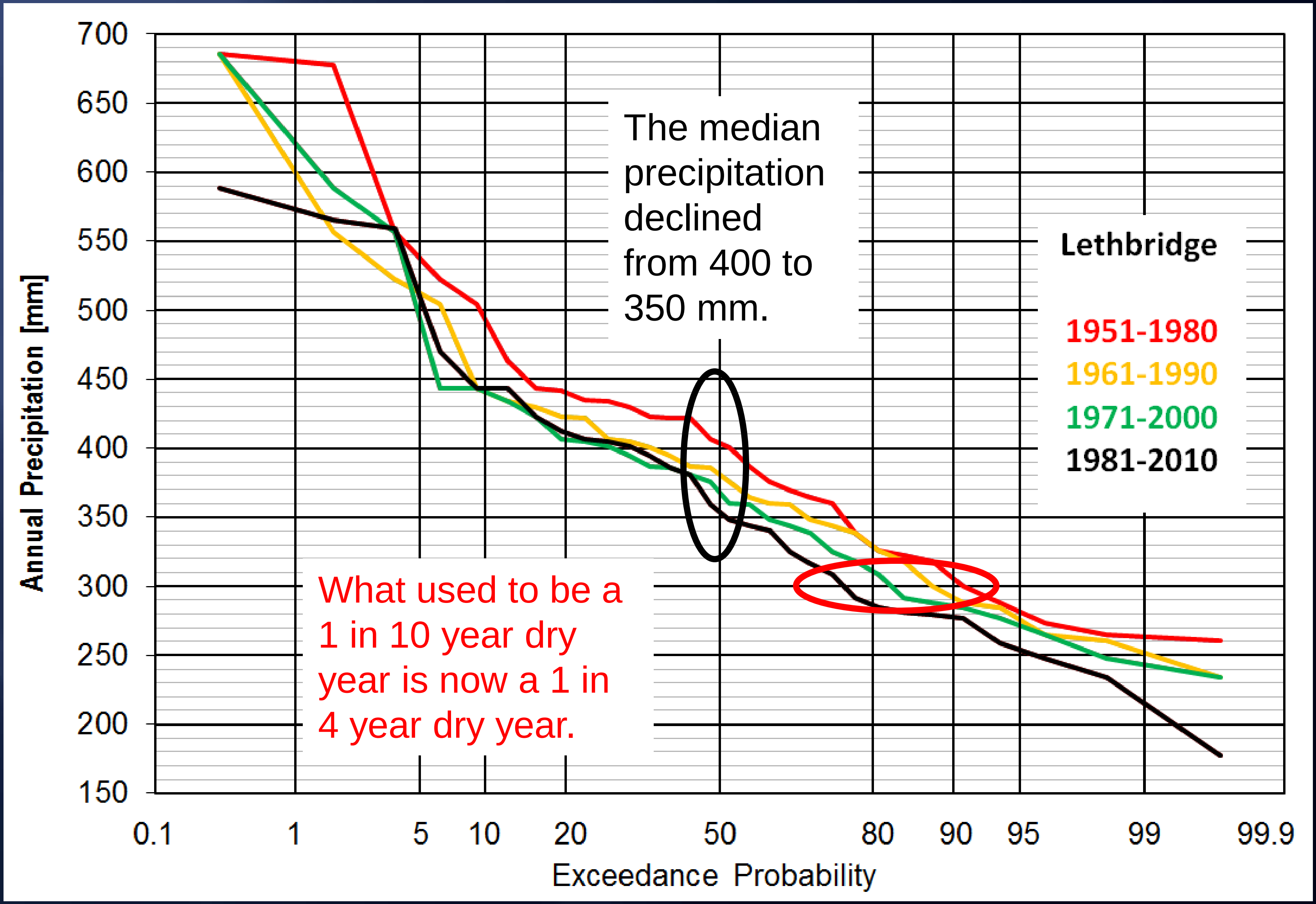
Historical Trend in Number of Frost days







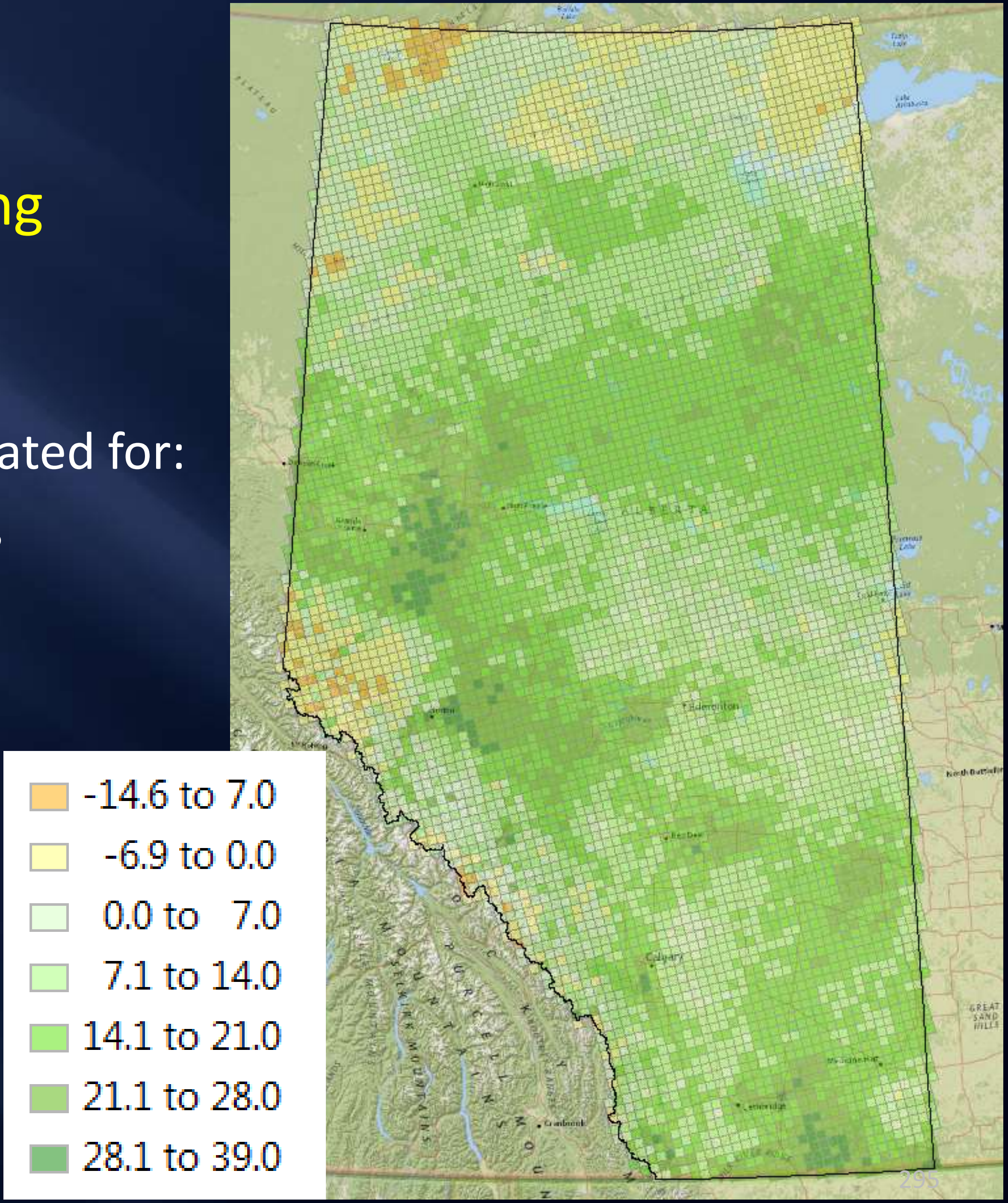
What is the chance of annual precipitation being over a certain value in Lethbridge?



Alberta 1950-2010 Change in growing season length [in days]

Alberta maps will be created for:

- Many climate indices
- PET
- Future climates
- Drought indices
- Crop yields



Day 1 – Session 2

Krish Vijayaraghavan – ENVIRON

BIOGRAPHY

Krish Vijayaraghavan has over 15 years of experience in air quality modelling and analysis, with particular expertise in linkages with watershed models and emissions models. He has published over 30 peer-reviewed papers in scientific journals and directed modelling studies of photochemical air pollution (ozone, particulate matter), exposure to air toxics such as mercury and arsenic, and atmospheric deposition of sulfur, nitrogen, mercury and other gases to watersheds. These have included studies on diverse topics such as the effect of motor vehicle emissions standards on ambient ozone and PM, the contributions of oil sands emissions in Alberta to acidic deposition and ozone, the long-range transport of atmospheric mercury, and the development of a interface between two advanced air quality and watershed models.

Day 1 – Session 2

Krish Vijayaraghavan – ENVIRON

ABSTRACT

Atmospheric deposition is often a major component of pollutant loading to sensitive watersheds and ecosystems. However, the models used to track the fate of pollutants in the atmosphere and in watersheds have different features and are run at varying spatial and temporal scales with diverse chemical constituents and model inputs. This paper discusses the issues that need to be considered when integrating information from air quality and watershed/ecosystems models to address the impacts of sulfur, nitrogen and mercury deposition on ecosystems.

Linking Air Quality and Watershed Models

Krish Vijayaraghavan and Ralph Morris
ENVIRON International Corporation
Novato, California

AESRD Environmental Modelling Workshop
March 13-14, 2013
Edmonton, Alberta

ENVIRON

Acknowledgements

- Alberta ESRD
- Cumulative Environmental Management Association
- Electric Power Research Institute
- RTI International
- Southern Company
- Stantec
- Systech Water Resources
- Trent University
- U.S. EPA

Integrated Environmental Modelling

Cumulative Effects Management (CEM)

From the perspective of an air quality modeller

Air Quality Modelling	⟷	Water, Land and Biodiversity Modelling

Old Paradigm

Modellers operate in isolated spheres of expertise

New Paradigm

Two-way communication between modellers

Synergize modelling efforts and models where possible

Potential Needs Filled by Air Quality Models in an Integrated Modelling Approach

- Supplement measurement networks that are sparse in temporal and spatial extent and chemical composition
- Provide dry and wet deposition to aquatic and terrestrial models for critical loads exceedance and other impacts
  - Acid deposition
  - Nutrient deposition
  - Mercury and other air toxics deposition
- Source attribution – Current contributions of sources and effect of changes in air emissions on ecosystems
- Ambient air concentrations for vegetation and human exposure studies
  - Ozone
  - PM
  - Hazardous air pollutants
- Data for socio-economic cost/benefit models
  - PM etc.

Air Quality Models

- **Global 3-D:** GRAHM, GEOS-Chem, MOZART etc.
- **Regional 3-D**: AURAMS, CMAQ, CAMx, RELAD etc.
- **Local puff/plume:** CALPUFF, AERMOD, SCICHEM etc.
- **Local/regional plume-in-grid:** CMAQ-APT, CAMx-PiG

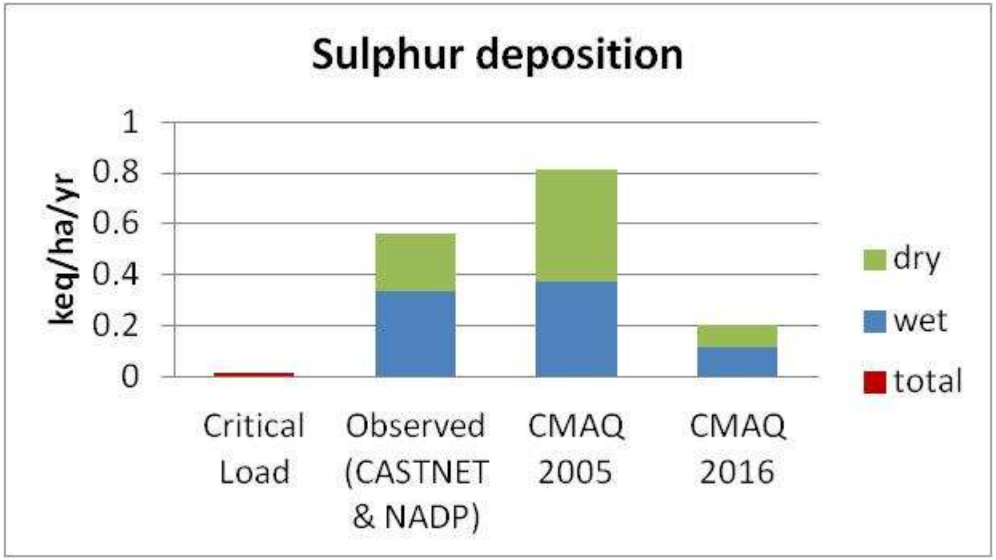
- Focus here on deposition modelled by CMAQ and its potential role in integrated modelling systems

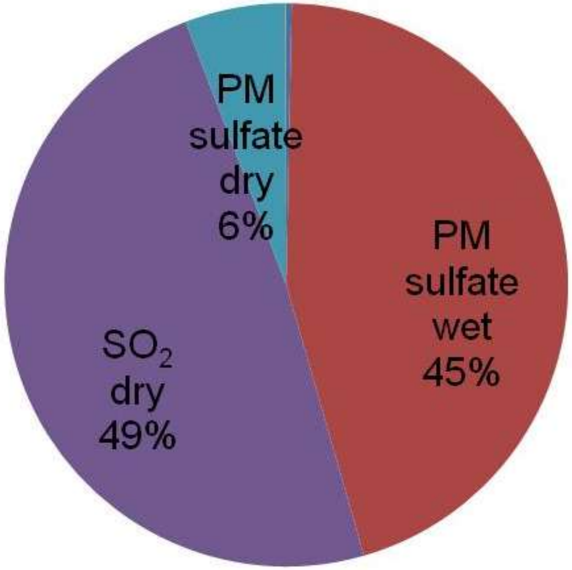
  CMAQ
  - Applied by Alberta ESRD and CEMA
  - Advanced multi-pollutant 3-D photochemical model
  - Developed by U.S. EPA with regular scientific updates from the community
  - Emissions from natural and anthropogenic sources, dispersion, chemical and physical transformations, dry and wet deposition of gases and particulate matter
  - Ozone, PM, acid deposition of N and S compounds, mercury and other air toxics
  - Base cations are modelled but emission inventories are uncertain

Sulphur Deposition in CMAQ

- Sulphur dioxide (SO_2)
- Particulate sulphate ($SO_4^{=}$)
- Sulphuric acid (gaseous H_2SO_4 quickly condenses on to PM sulphate)

Example of application to identify critical load exceedances of surface water acidity: Sulphur deposition at Shenandoah National Park in Virginia





Total = 0.8 keq/ha/yr in 2005
For comparison, levels in Alberta range approximately from 0.01 to >1 keq/ha/yr

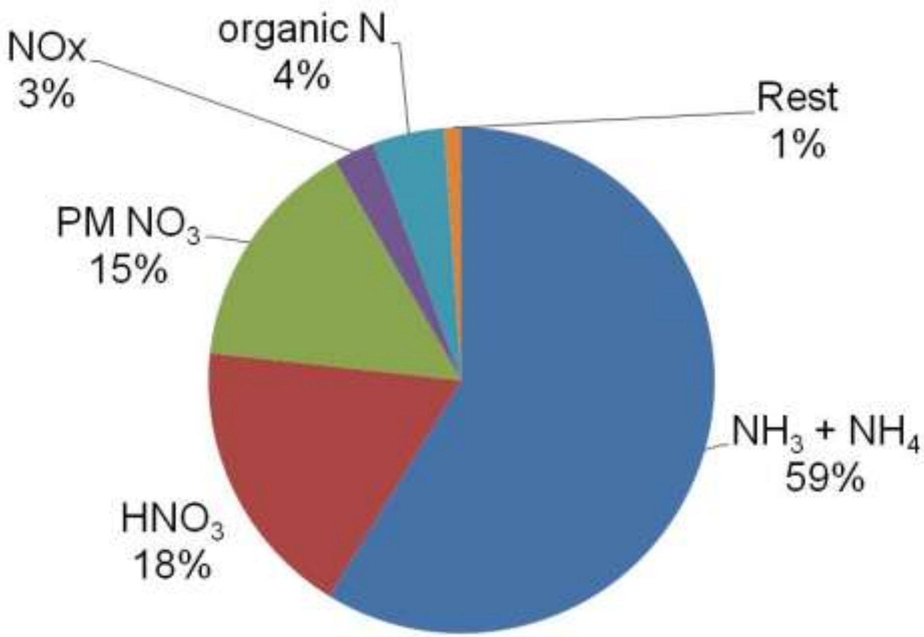
Source: Vijayaraghavan et al., 2012

Acknowledgement: U.S. EPA

Nitrogen Deposition in CMAQ

- NOx (NO, NO_2)
- Inorganic oxidized Nitrogen (HNO_3, N_2O_5, HONO, HNO_4, PM NO_3)
- Reduced Nitrogen (NH_3, PM NH_4^+)
- Organic Nitrogen (PAN, PANX, NTR)

Example: Components of nitrogen deposition at Shenandoah National Park



Total = 1.3 keq/ha/yr in 2005

Large fraction from NH_3 and NH_4

Potential in Alberta too

Source: Vijayaraghavan et al., 2012

Role of Ammonia/Ammonium Deposition

- Deposition of PM sulphate and nitrate associated with ammonium
- Reduced nitrogen itself can be a large fraction of total deposition
  - Gaseous ammonia dry deposition (wet smaller)
  - Particulate ammonium wet and dry deposition
- Eutrophication
- Acidification
  - Simpler air quality models assume constant ammonia concentrations and consider acidification due to only sulphate and nitrate
  - However, ammonia nitrification → acidification
- Alberta has one of the largest ammonia emissions inventories in Canada - large livestock population and fertilizer application
- Potential emissions from tailings, forest fires etc.
- Forest Service has measured high NH_3 (> 1 ug/m3) in remote areas in AB
- Air quality models used in integrated modelling in Alberta need to accurately characterize ammonia air concentrations and deposition

Deposition and Exceedances of Critical Loads (CL) of Surface Water Acidity

ENVIRON

- Unlike sulphur, some of the deposited nitrogen is retained in the terrestrial system and does not contribute to acidification.
- Potential acid input = S deposited + N deposited – N retained – BC
- CL of waters already includes BC. Methods for calculating exceedance:
  - EPA: Use measurements in surface streams to estimate net N loading to water

    Exceedance = S deposition + Measured N – Critical Load

    Cannot be applied for source attribution because modelled N is not used
  - Assessments in the oil sands region assume that 25% of the nitrogen compounds are acidifying when the N deposition is < 10 kg N/ha/yr

    Exceedance = Pre-development (loading estimated from measured S and N) + Post-development (modelled S dep + modelled N dep x retention factor) – Critical Load

    Simple approach for post-development but may be applied in emissions scenarios
  - Alternative advanced approach

    Apply mechanistic watershed model to estimate terrestrial retention of deposition from air quality model. Laborious but ideal for source attribution.

    Exceedance = S dep + Modelled N calibrated using measured N – Critical Load

Mercury Deposition

- Potential for dry deposition and wet deposition in rain and snow in Alberta

- Gaseous elemental mercury (HG)
  - negligible wet but undergoes dry deposition (bidirectional like NH3)

  Gaseous oxidized mercury (HGIIGAS)

  Substantial wet and dry deposition

  Particulate-bound mercury (PHG)
  - Intermediate wet and dry deposition

- Mercury deposition → Risk due to methyl mercury in fish and wildlife ?
  - Advanced Hg watershed/biocycling model, e.g., D-MCM or WARMF
  - Simpler approach - Human health risk assessment model such as HHRAP
  - Simplest approach – assume linearity

Examples of Air-Watershed Linkages

U.S. EPA's Watershed Deposition Tool

Schwede et al., 2009

- GIS-based tool that maps gridded deposition estimates from CMAQ to 8-digit hydrologic unit codes within a watershed or region.

- Deposition components:

  Total Nitrogen – Dry and Wet; Oxidized and Reduced
  Total Sulphur – Dry and Wet
  Total Mercury – Dry and Wet

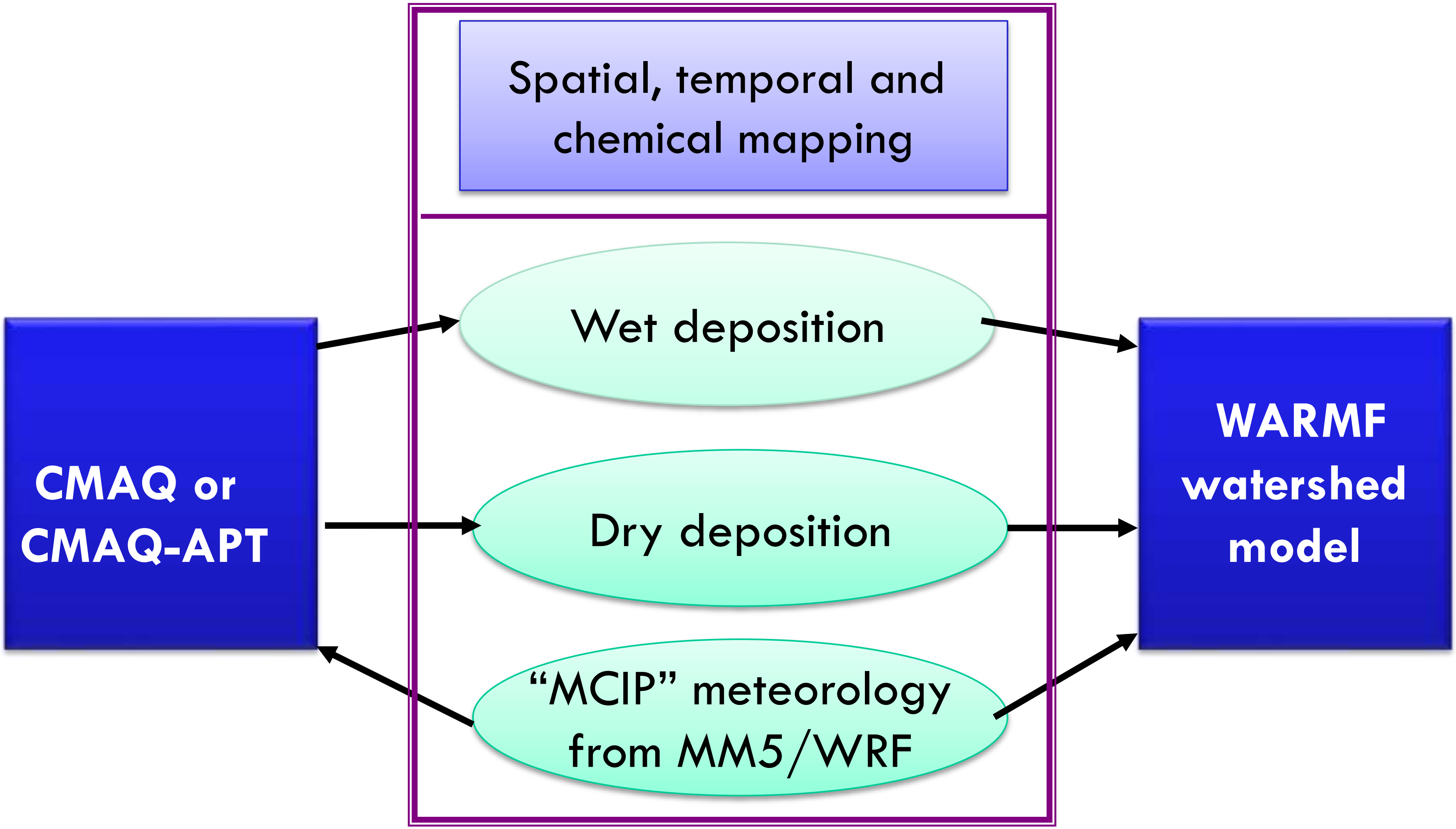
- Calculate the weighted average deposition over a HUC and the average change in a HUC between two different emission scenarios

- Advantage: Simple to use
  Disadvantage: Cannot use the deposition values to model within a watershed as values are averaged over watersheds

Examples of Air-Watershed Model Linkages

Linkage between CMAQ & WARMF and CMAQ-APT & WARMF

Herr et al., 2010; Vijayaraghavan et al., 2010

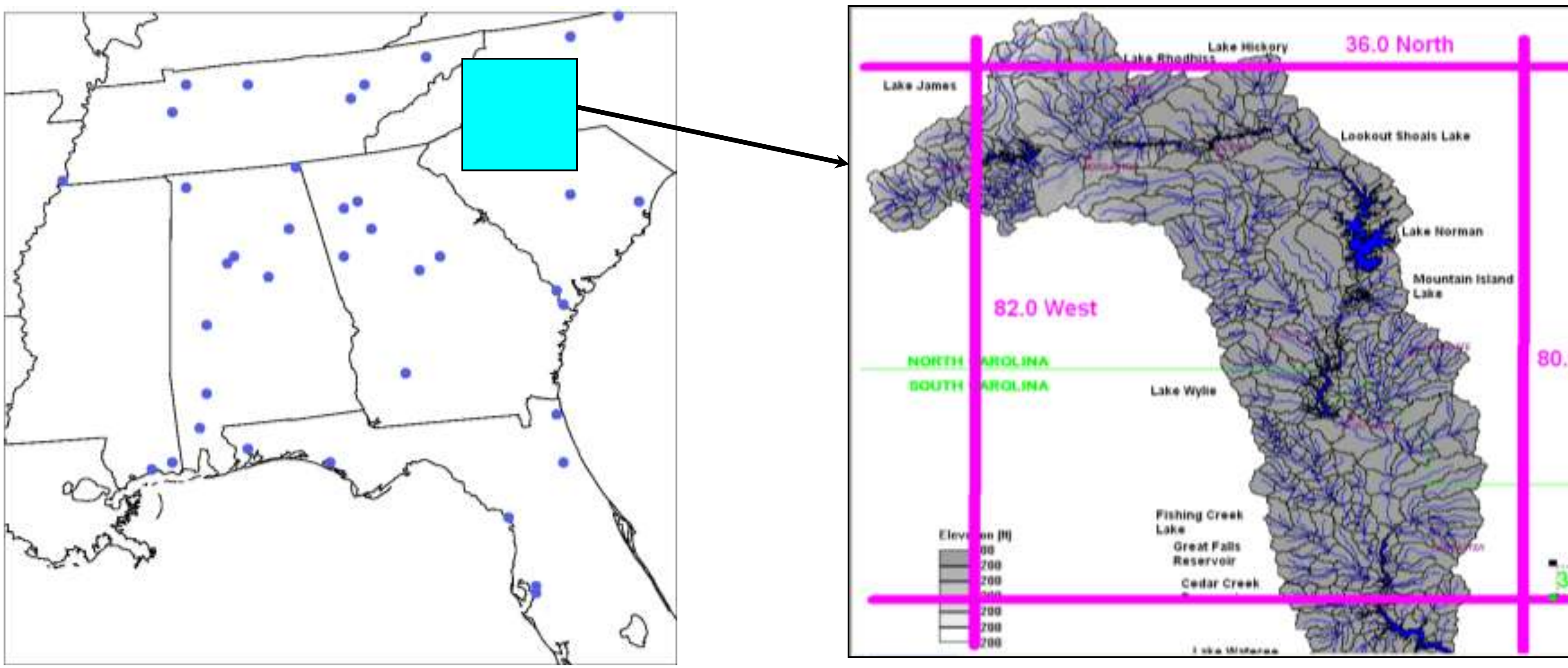


Acknowledgement: Systech Water Resources

CMAQ-WARMF Linkage
Application in Catawba River Basin, USA

Spatial Mapping

CMAQ-APT domain	**WARMF domain**
Southeastern USA	Catawba watershed
Rectangular grid:	Irregular catchments/ reservoirs
12 or 4 km resolution	~ 1 km^2 and larger



CMAQ-WARMF Linkage
Temporal Resolution and Extent

ENVIRON

- Temporal Resolution:

  CMAQ hourly temporal resolution → Daily totals for WARMF

  Match time zones
- Temporal extent:

  CMAQ 1-5 years → 50-100+ years for WARMF

  Important to model multiple years with air quality model to account for inter-annual variability in meteorology (e.g., precipitation)

  Model climatologically normal or “dry, wet and normal” years

  Communication important among modellers on extrapolating the AQ model deposition to the time period of the watershed model
- Important to identify key historical and planned future changes in emissions to get proper time record in the watershed model

CMAQ-WARMF Linkage
Chemical Species Mapping

WARMF species	Mapping from CMAQ species	Notes
SOX	SO2	as S
SO4	PM SO4	as S
NOX	NO + NO2	as NO2
NO3	Total NOz	Oxidized N other than NOx (as N)
NH4	NH3 + PM NH4	as N
CA, MG, K	Ca, Mg, K are not commonly modelled	Interpolate from NADP data
NA, CL	Use PM Na and Cl (however concentrations uncertain)	Interpolate from NADP data
HG0, HG2	HG, HGIIGAS	
HGP	PM Hg	

Examples of Air-Watershed Model Linkages

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Linkage between CMAQ & PLOAD and CMAQ & ReNuMa

Brandmeyer et al., 2007; Vijayaraghavan et al., 2010b

CMAQ or CMAQ-APT →

Mapping of dry and wet deposition

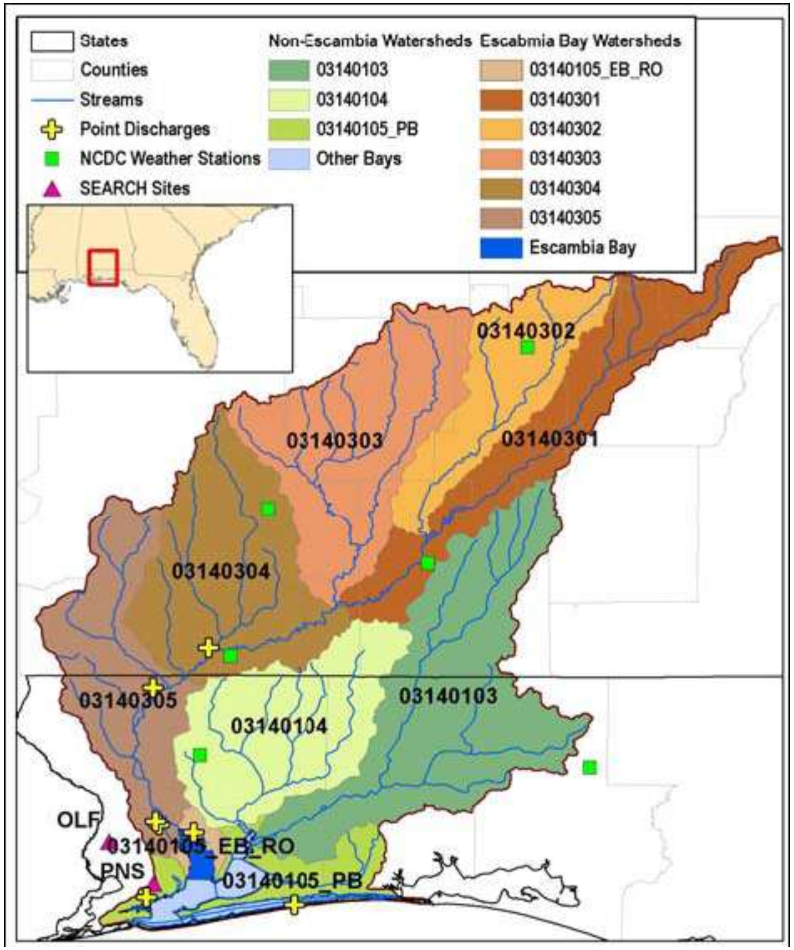
- Spatial mapping with GIS from grid to HUC8
- Hourly outputs summed to Daily for ReNuMa and Annual for PLOAD
- S species mapped to SO4
  N species → dissolved and particulate for ReNuMa and total N for PLOAD

→ **PLOAD screening model & ReNuMa mechanistic watershed model**

Acknowledgement: RTI International

Linkage between CMAQ & PLOAD and CMAQ & ReNuMa

Escambia Bay and Watershed in Alabama/Florida



1. Increase in NH_3 dry deposition after SO_2 and NOx reductions at local power plant and regionally → Dis-benefit

Change in NOy deposition (tons/yr N)	Change in NHx deposition (tons/yr N)	Change in Total N deposition (tons/yr N)
-2571	838	-1733

2. Calculated that approximately 10-18% of N deposition to the watershed reaches the Bay after terrestrial retention

Source: Brandmeyer et al., 2007; Vijayaraghavan et al., 2010b

Example of Air-Water Model Linkage

Proposed Work

- Link CMAQ deposition outputs to MAGIC model

- MAGIC: dynamic hydrogeochemical model of water acidification

- MAGIC Inputs:
  - Precipitation
  - Wet and Dry deposition of SO4, Cl, NO3, NH4, Ca, Mg, Na, K
  - MAGIC conventionally uses measured wet deposition and scales those to estimate dry deposition

- Use CMAQ to supplement measurements by providing wet and dry deposition at selected receptor locations: average deposition over each of the catchments modelled in MAGIC

- Important to select appropriate CMAQ emissions scenarios, i.e., identify when and where deposition changes due to changes in emissions (e.g., mines coming online) to specify historical and future break-points in MAGIC

Inconsistencies in Inputs of Different Model Components of an Integrated Modelling System

- **Precipitation**

  Problem

  Hydrology in water model driven by measurements

  Wet deposition in air model driven by modelled precipitation or modelled + measured precipitation

  Partial solution

  Scale wet deposition from air model by measured precipitation before handover to water model

- **Land use**

  Problem: Land use used to simulate dry and wet deposition in the air model often different from the land use in the land/water model

  Partial solution: Keep track of deposition in air model by land use type within a grid cell and handover to land/water model

Summary

- Frequent interactions between modellers in different disciplines are important for efficient integrated modelling efforts
- Advanced air quality models such as CMAQ can serve multiple needs for cumulative effects management
- Nitrogen species have different deposition characteristics and need to be modelled separately. In particular, important to model the impact of reduced nitrogen in Alberta
- Several approaches have been reported for linking air and watershed models
- Integrated models should resolve spatial, temporal and chemical differences in model configuration and inconsistencies in model inputs

Day 1 – Session 2

Kent Berg– AESRD

BIOGRAPHY

Kent Berg has a Bachelor of Science degree in Civil Engineering from the University of Calgary and is a professional engineer with AESRD. He has over thirty years experience with the department in water management and planning. Over the last twelve years, he has worked with the Water Resources Management Model that has been used by the department to support major water planning activities in southern Alberta since 1980.

Day 1 – Session 2

Tom Tang & Kent Berg– AESRD

ABSTRACT

Model developments and applications in the S. Region have been and are continuing to be driven by population growth and demand for safe and secure water supply. The emphasis of the modelling team in the Southern Region is primarily with water modelling. We work with specific water quality models and a water allocation model. The team supports regional delivery functions related to Water Act approvals, Water Management Operations and Watershed planning.

Our presentation describes the model development plan we are implementing to support two major initiatives in Southern Region:

· SSRB (South Saskatchewan River Basin Plan) implementation

· SSRP (South Saskatchewan Regional Plan)

The SSRB plan is an approved water management plan under the Water Act. The effect of the plan is closure of the Bow, South Saskatchewan, Oldman and related southern tributaries to new water allocation applications and introduction of the ability to transfer licences. Our water allocation model (WRMM) has and continues to be part of the plan development and implementation. We are in the process of updating the model to continue supporting the plan.

The SSRP is part of the provincial Land Use Framework initiative wherein a number of major overarching plans are being developed across the province. It is the second plan to be produced under the framework. Our team is working to build the capacity to develop new water quality models as well as land use modelling to support SSRP development and future implementation.

Southern Region Modelling Initiatives

Regional Science and Planning
Environmental Modelling Team

Southern Region

Drivers of Model development in the Southern Region

- Population Growth
- Water Scarcity
- Large water consumers

- Need for safe, secure water supply

Southern Region Modelling Team

Primarily Water Modelling

- Allocation
- Quality

Support to

- Approvals
- WMO
- Planning
- Apportionment negotiations

Development Plans

Supporting

- SSRB (South Saskatchewan River Basin) Plan
  - Approved water management plan
  - Basin closure to new applications (except Red Deer basin)
  - Updating of WRMM to support implementation
- SSRP (South Saskatchewan Regional Plan)
  - Land use framework planning
  - Building capacity for Water Quality and Land Use modelling

WRMM
Water Resources Management Model

The Water Allocation Problem

The Water Allocation Problem (in words)

How do you allocate a scarce resource (water) among competing demands in the most efficient way?

More than simple accounting

Constraints add complexity:

- Priorities.
- Instream objectives.
- Sharing agreements.
- Storage
- Variable flow from week to week , month to month, year to year

Origin of WRMM

Water scarcity in southern Alberta led to SSRB planning program

- WRMM was built for Alberta Environment.

To meet our ongoing needs

- WRMM models have grown in number and complexity over time.

Uses of WRMM

Major projects and studies

- SSRB planning program (1980’s, 2000’s)
- Meridian Dam analysis
- Highwood / Little Bow diversion plan
- Special Areas Water Supply Study
- Acadia Irrigation Proposal
- Negotiations with Siksika on Bassano dam claim
- Expansion of the Carseland Headworks
- Alberta/Montana sharing of flow in the St. Mary and Milk

Model Versions

WRMM (the original)

- Owned by Alberta ESRD
- Designed specifically for Alberta
  - Water Act
  - Instream objectives
  - Reservoir operating policy
- Runs quickly
- Proven itself in Southern Region Projects and GOA Studies
  - 30+ years history

Model Versions

Wrm-Dss (Wrmm version 2)

- New method of formulating solution
  - More optimal solution than WRMM
- No limitation on size of schematic
  - Commercial solver replaces built-in OKA solver
- No longer needs text files (uses databases)
  - Backwards compatible with existing model documents (can still use text files)

Model Versions

Wrm-Dss (cont'd)

- Includes Channel Routing features
  - For daily operational decision support

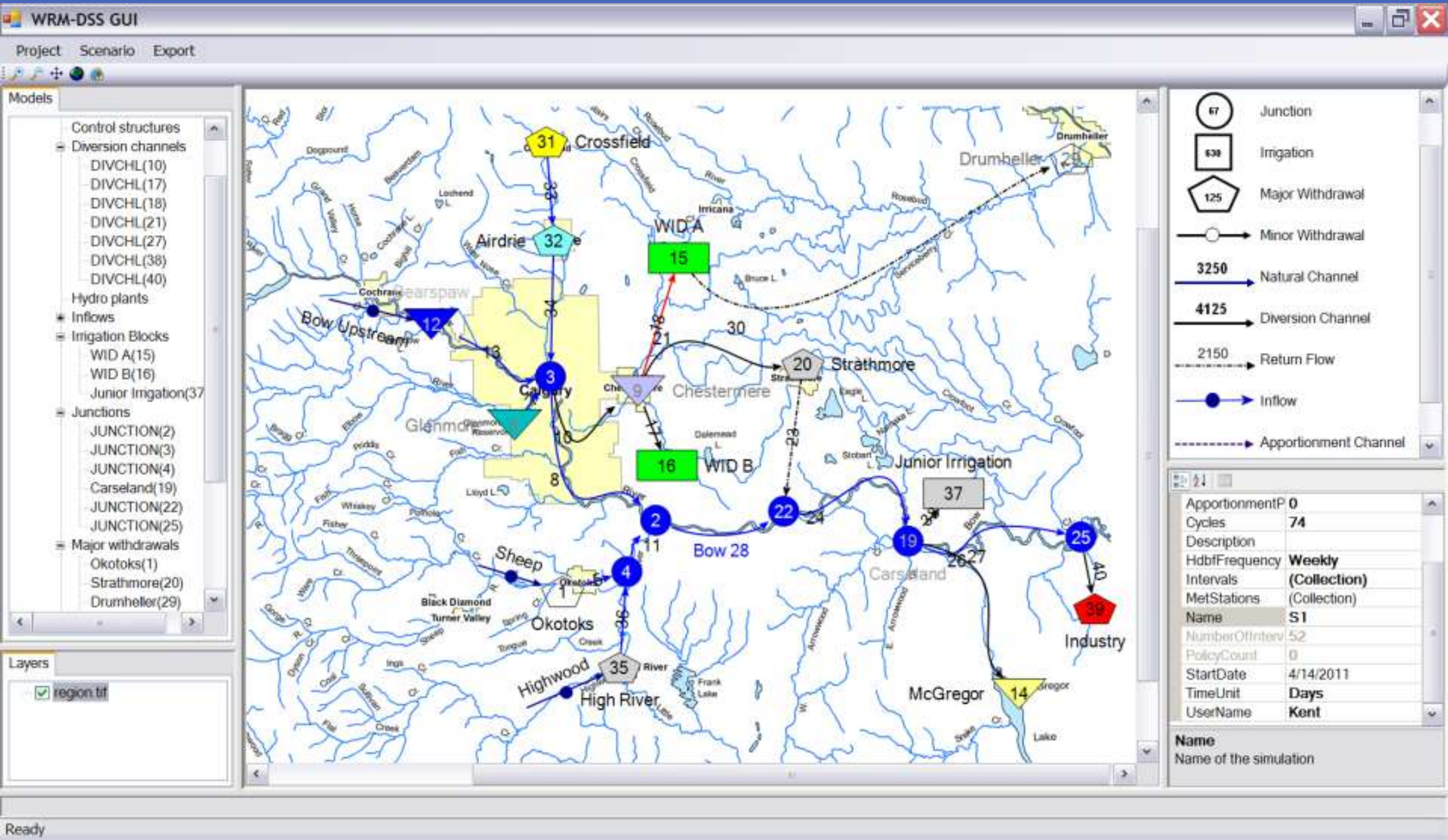
- State of the art programming for adaptation to other computing platforms

Alberta

Wrm-Dss Utility

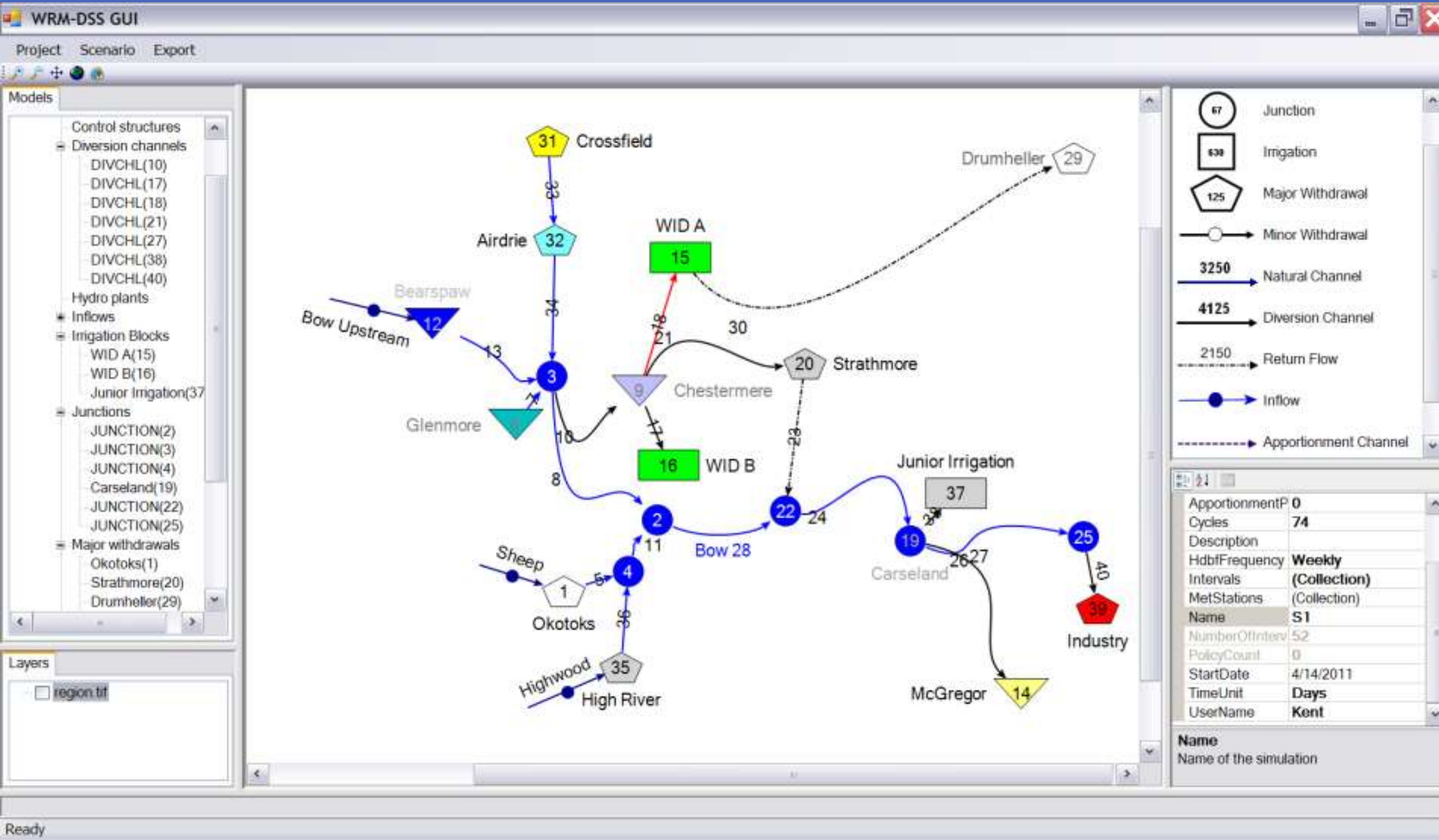
Graphical User Interface

- Makes model design visual
- Can use maps or images created in GIS applications as backgrounds
- State of the art industry standard programming
  - Potential to migrate to the Web
- Can be developed independently and in parallel to Wrm-Dss application
- No licencing / maintenance fees for dep't



WRM-DSS GUI
Project
Scenario
Export
Models
Control structures
Diversion channels
DIVCHL(10)
DIVCHL(17)
DIVCHL(18)
DIVCHL(21)
DIVCHL(27)
DIVCHL(38)
DIVCHL(40)
Hydro plants
Inflows
Irrigation Blocks
WID A(15)
WID B(16)
Junior Irrigation(37
Junctions
JUNCTION(2)
JUNCTION(3)
JUNCTION(4)
Carseland(19)
JUNCTION(22)
JUNCTION(25)
Major withdrawals
Okotoks(1)
Strathmore(20)
Drumheller(29)
Layers
region.tif
Crossfield
Airdrie
WID A
Bow Upstream
Calgary
Chestermere
Strathmore
WID B
Junior Irrigation
Bow 28
Sheep
Okotoks
Highwood
High River
Carseland
McGregor
Industry
Drumheller
Junction
Irrigation
Major Withdrawal
Minor Withdrawal
3250
Natural Channel
4125
Diversion Channel
2150
Return Flow
Inflow
Apportionment Channel
ApportionmentP 0
Cycles 74
Description
HdbfFrequency Weekly
Intervals (Collection)
MetStations (Collection)
Name S1
NumberOfInterv 52
PolicyCount 0
StartDate 4/14/2011
TimeUnit Days
UserName Kent
Name
Name of the simulation
Ready

Alberta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Okotoks(1)
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Layers
region.tif
31 Crossfield
Drumheller 29
Airdrie 32
WID A
15
Bearspaw
Bow Upstream
12
13
3
34
33
30
21
20 Strathmore
9 Chestermere
Glenmore
WID B
16
8
2
22
24
Junior Irrigation
37
19
25
40
Bow 28
Carseland
Sheep
4
11
1
Okotoks
39
Industry
Highwood
35
High River
McGregor
14
Junction
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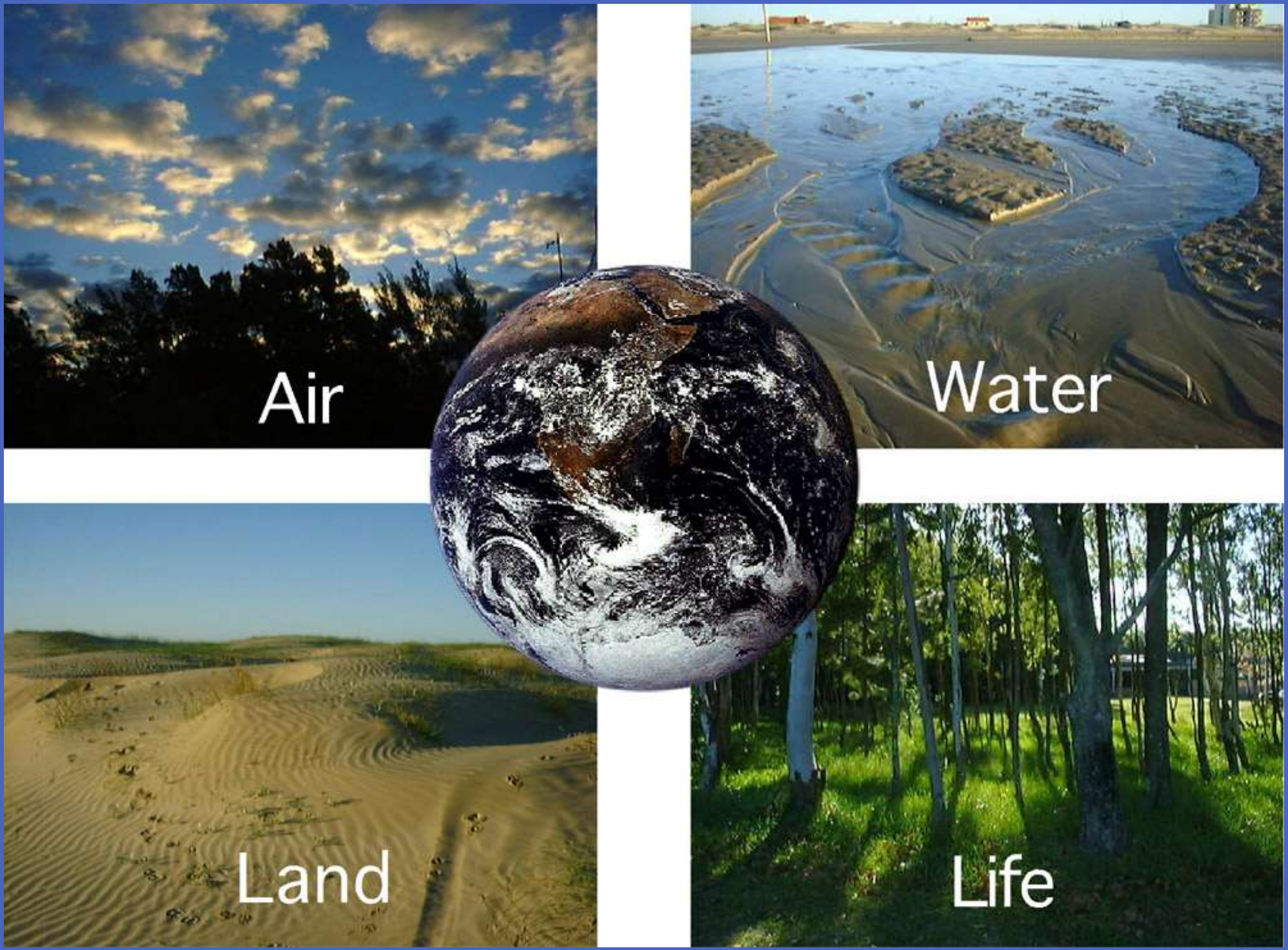
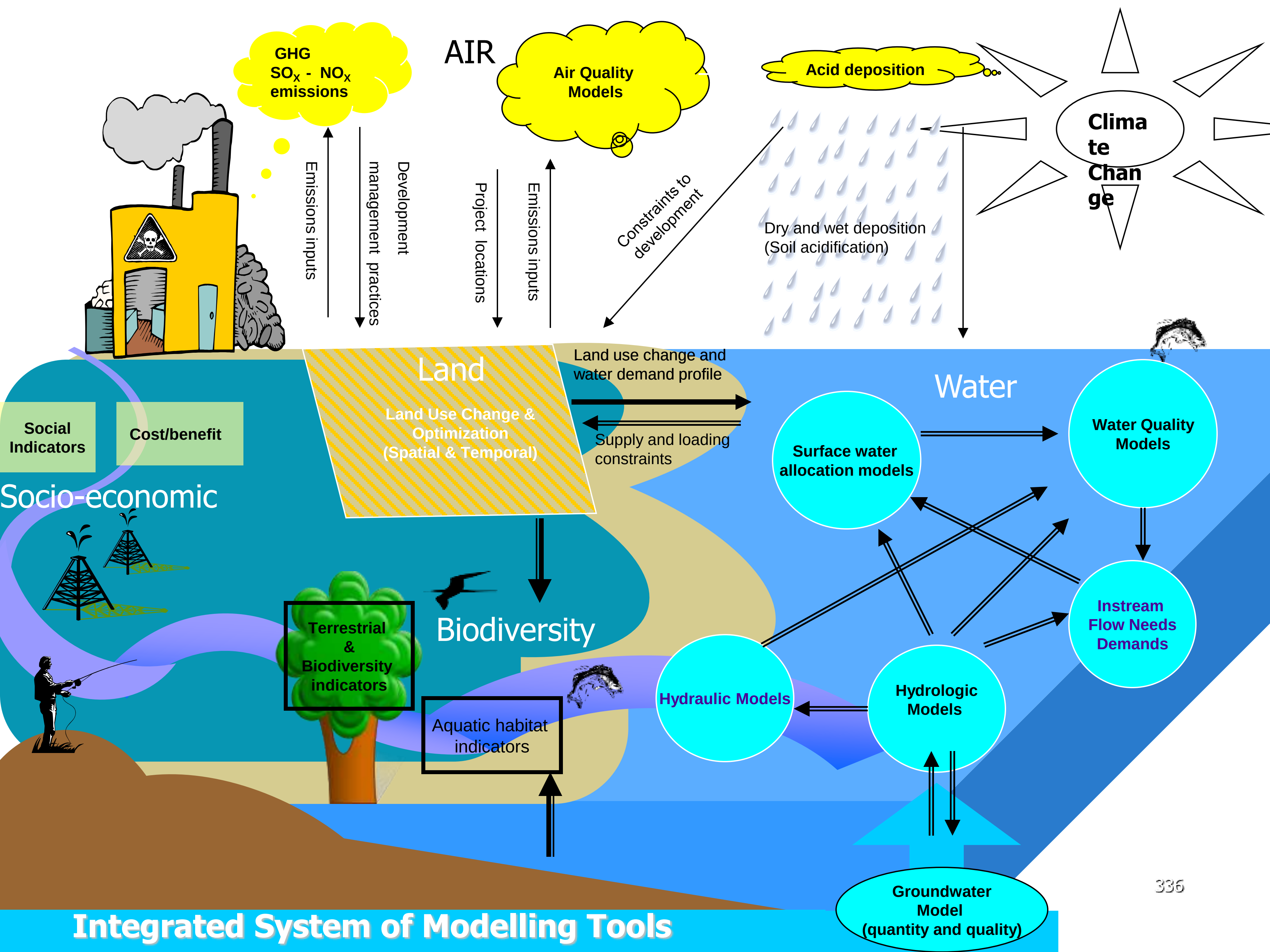
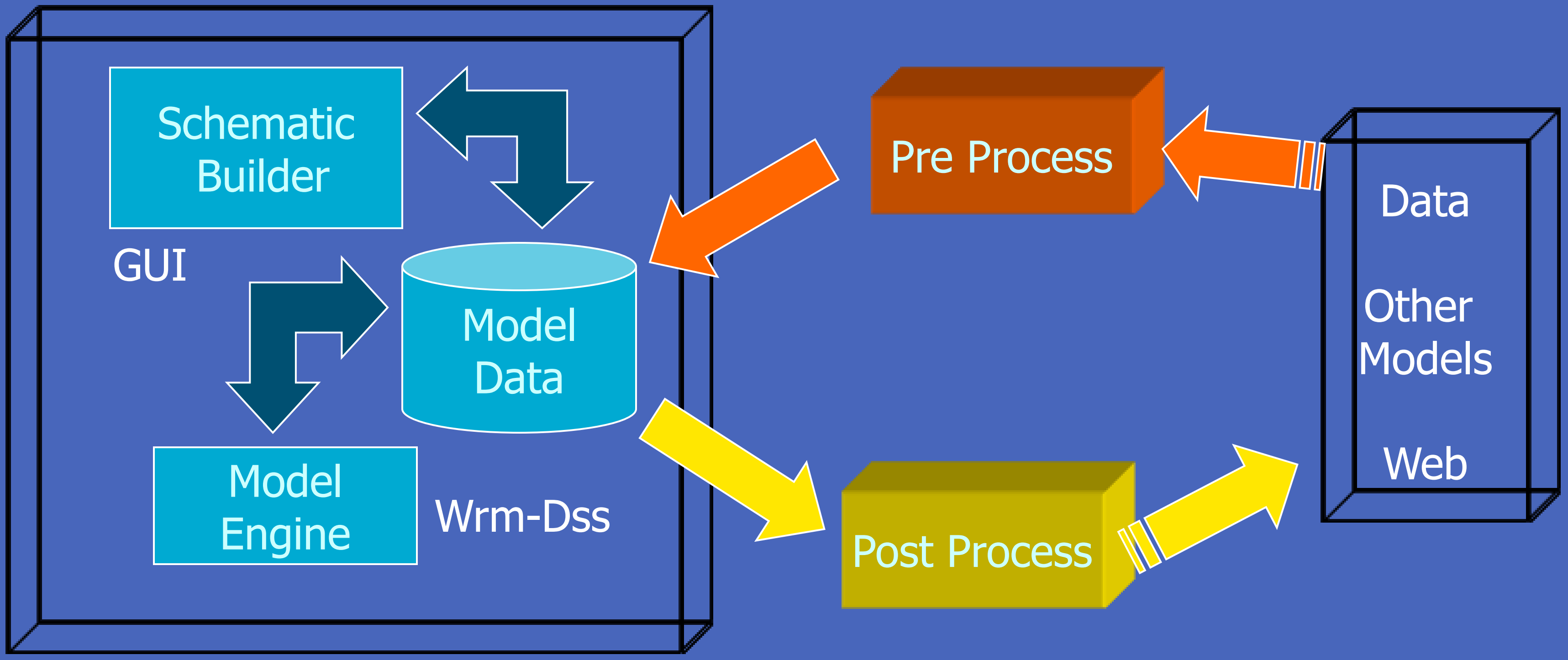


Cumulative Effects Management



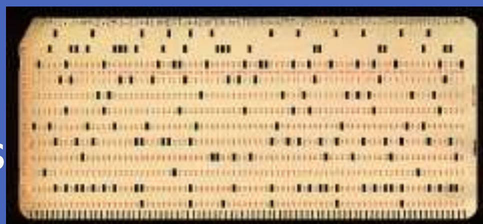
AIR
GHG
SO_X - NO_X
emissions
Air Quality Models
Acid deposition
Climate Change
Emissions inputs
Development management practices
Project locations
Emissions inputs
Constraints to development
Dry and wet deposition
(Soil acidification)
Land
Land Use Change & Optimization (Spatial & Temporal)
Land use change and water demand profile
Supply and loading constraints
Water
Surface water allocation models
Water Quality Models
Instream Flow Needs Demands
Hydraulic Models
Hydrologic Models
Groundwater Model (quantity and quality)
Social Indicators
Cost/benefit
Socio-economic
Terrestrial & Biodiversity indicators
Biodiversity
Aquatic habitat indicators
Integrated System of Modelling Tools

WRMM Linkages



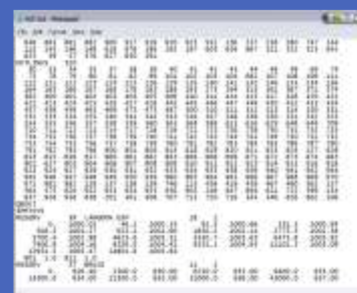
WRMM
Evolving with technology

1970's
to 90's



1990's
to 2010

Text files



Current to
Future

Database

Day 1 – Session 2

Tom Tang – AESRD

BIOGRAPHY

Tom Tang has a Master of Science degree in Civil Engineering from the University of New Brunswick. He is a professional engineer with AESRD currently leading the Environmental Modelling Team for the Southern Region. The team consists of water quality and water allocation modelling specialists supporting government projects ranging in scale from local to provincial and international. He possesses more than 30 years of experience in water resource management and modelling, including flood and water supply forecasting, water resources planning and operation. He has a strong expertise with hydrological and water allocation models.

Water Quality Model Development and Application

Alberta
Freedom To Create. Spirit To Achieve.

Government of Alberta

Modelling Plan and Priorities

Southern Region – South Saskatchewan and Milk River Basins

South Saskatchewan River Basin

- Bow River sub-basin including Highwood River
- Oldman River sub-basin
- South Saskatchewan River sub-basin
- Red Deer River sub-basin (TBD)

Milk River Basin

Modelling Focus

Model Development

Phase 1 - Data Scoping Study

Phase 2 –Data Collection

(Climate, Water Quality, Hydrometric, Bathymetric/Hydraulic, Sediment and Vegetation)

Phase 3 - Water Quality Models

- Non-point Source Watershed Model: characterize non-point sources
- In-stream Flow and Water Quality Model: characterize the fates of point and non-point sources in main water body

Model Applications

Data Scoping Study

SSRP Water Quality Data Scoping

- Identify, collect, and assemble existing data and knowledge
- Assess current water resources and water quality
- Identify data/knowledge gaps for model development
- Provide guidance for determining the approach and selecting appropriate models

Oldman/S. Sask., Milk, Highwood/L. Bow, Red Deer (Central Region)

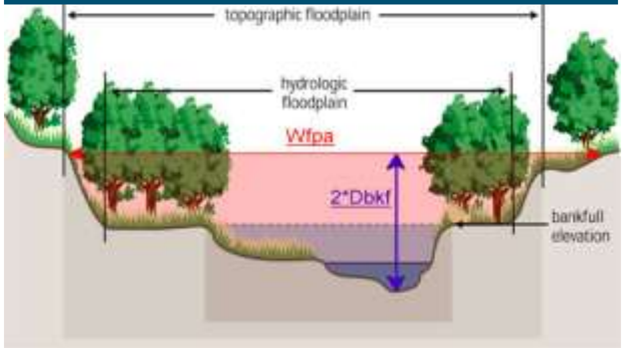
SSRP Land Use Land Cover (LULC) Data and Model Scoping

Potential Impact of Climate Change on Water Availability and LULC (Novus Environmental)

LULC Mapping for SSRP (U. of Calgary)

Address Data & Knowledge Gaps

Bathymetry



Lack of data at rural reaches for the 600 Km long of River

Sediment

Nutrients and organic matters; DO demands; Erosition/deposition

Ice

Ice development and its impact on water quality, sediment transport…

Macrophyte

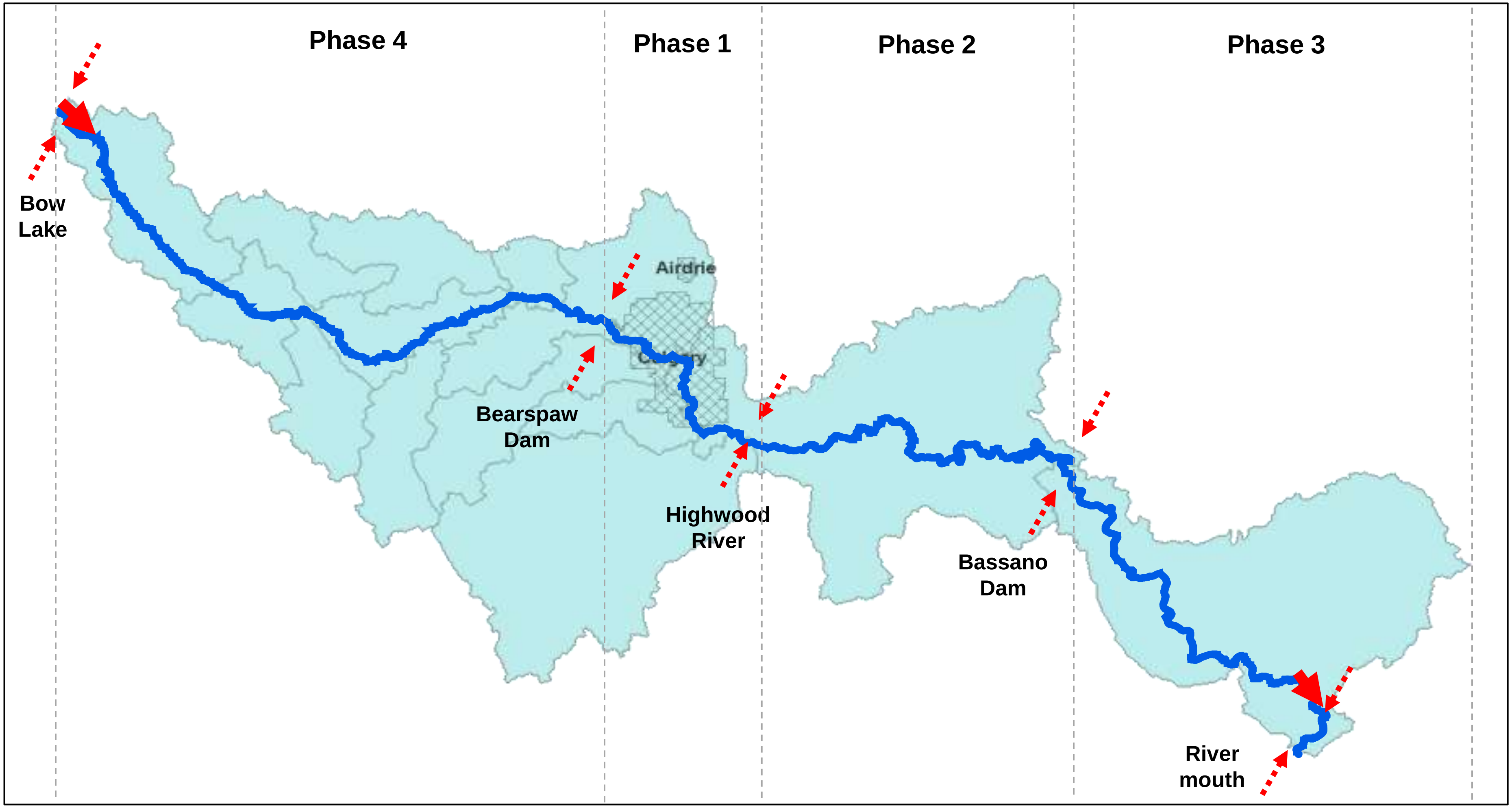
Lack scientific knowledge: kinetic rates, stoichiometry, community composition…

Address Data & Knowledge Gaps (cont'd)

Bow River Biosonic Vegetation/Sediment Study (4 phases)

- Joint Project (ESRD, City of Calgary and Golder Associates)
- Selected river reaches within the City of Calgary

Bow River Sub-Basin



Bow River Water Quality Model (BRWQM)

In-stream Flow and Water Quality Model (WASP/HECRAS)

Phase 1: Bearspaw Dam (U/S Calgary) to U/S Highwood Confluence
- owned by the City and enhanced by ESRD

Phase 2: Highwood Confluence to Bassano Dam

Phase 3: Bassano Dam – Mouth (Bow/Oldman Confluence)
– under development

Phase 4: Upper Bow River Water Quality Model (U/S Calgary)
-Develop prototype - incorporate Ice Dynamic Mechanism of RIVER1D into CE-QUAL W2

Stormwater Model (EPA SWMM under development**)**

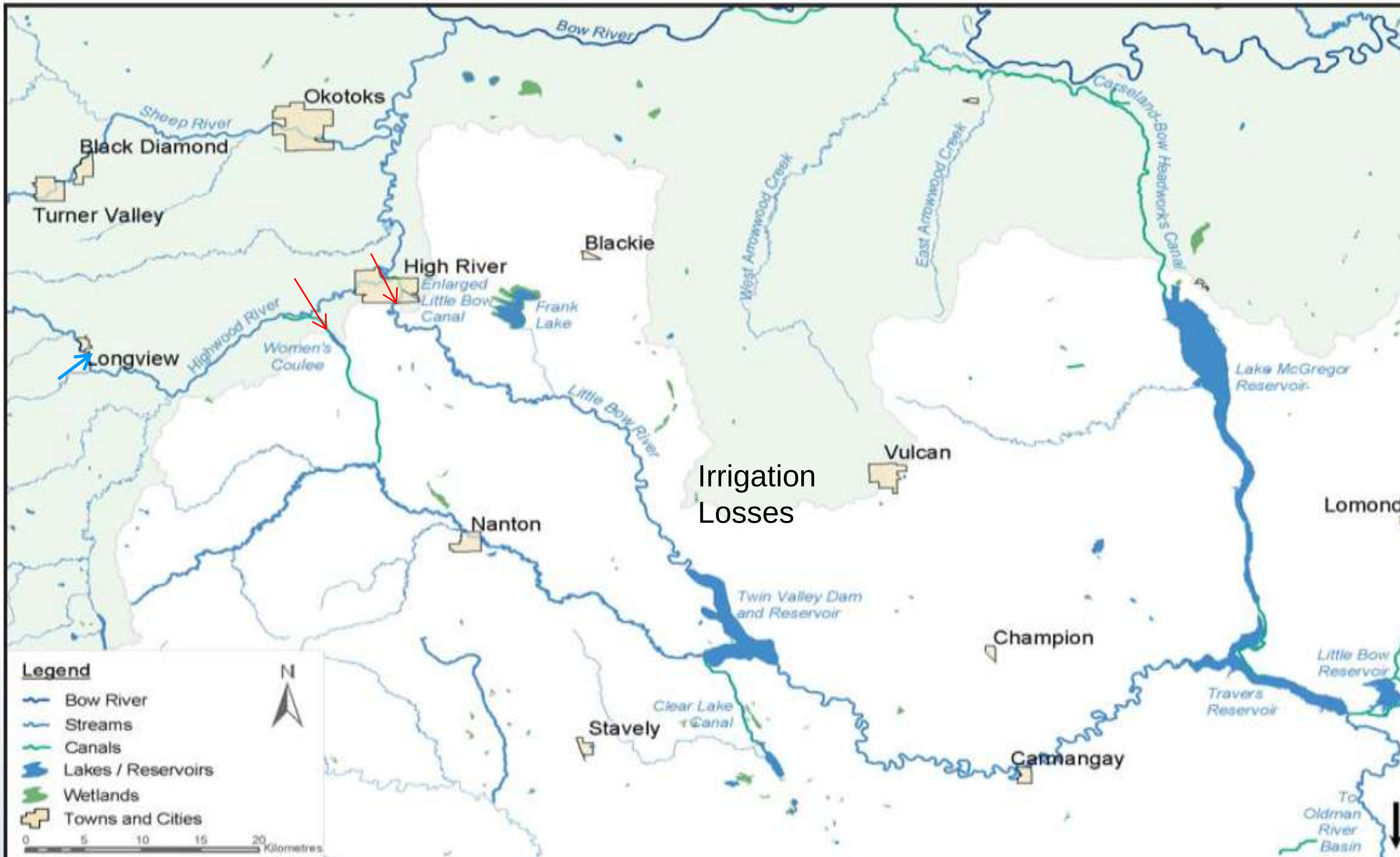
Phase 1: City of Calgary stormwater runoff (QHM)
-owned by the City

Non-point Source Watershed Model (SWAT)

Phase 2: Crowfoot Creek (WID Major Return Flow)

Phase 3: SWAT

Highwood/Little Bow System



Water Quality Models (cont'd)

Highwood/Little Bow System (2013 and beyond)

- Major Tributary and Non-point Source contribution to the Bow River

In-stream Flow and Water Quality Model

Phase 1
- *Highwood River*
- *Sheep River*
- *Frank Lake*

Phase 2
- Little Bow River
- Mosquito Creek
- Twin Valley Reservoir
- Other tributaries

Non-point Source Watershed Model

- Agricultural areas

Model Applications

BRWQM Application (Bearspaw Dam to Bassano)

LUF/Region Planning: SSRP – coupled WRMM with BRWQM

Regional Approval (Carseland effluent to the Bow River) - Wheatland County application (in progress)

Water Management Operations - Bow-Carseland Headworks (Travers Reservoir Enlargement EIA; and Bow-Carseland Canal Enlargement DFO approval)

Bow River Phosphorous Management Plan (P Plan) – model data update/extension to 2011, and model re-calibration (in progress)

Other Initiatives and Information

WRMM-CA Model Interface (Geomatic Journal) – in conjunction with U. of Calgary

SSRP Scenario Modelling Report – Modelling Team

Climate Change Impact Analysis (Research) – U. of Alberta; U. of Saskatchewan;

Bow River Biosonic Study on Sediment and Vegetation (CWRA National Conference) – in conjunction with Golder Associates and City of Calgary

Other Jurisdictions – Saskatchewan Water Security Agency etc

Day 1 – Session 2

David Hill – University of Lethbridge

BIOGRAPHY

In September 2012 David Hill was appointed as the inaugural Director of Centres and Institutes and Research Advocacy for the University of Lethbridge. In his role within the office of Research and Innovation Services, David assists university research institutes and centres to be successful in meeting their goals and objectives, in finding new opportunities for trans-disciplinary collaboration between centres and institutes and between the University of Lethbridge and other national and international research universities and organizations. He also seeks opportunities to mobilize knowledge and expertise so as to increase the impact of research outcomes to the community, businesses and the province. Prior to joining the university, David was the Executive Director for Water Resources with Alberta Innovates-Energy and Environment Solutions (AI-EES). He has almost 40 years of experience in water and natural resource management in Alberta, crossing the broadest spectrum of water issues and water companies. David has taken a lead role in the development of tools, policies and processes to promote increased water use efficiency in the agricultural sector, and has been a founding member of a number of regionally based water stakeholder organizations. He has led public-private sector research initiatives and has collaborated on international water research and policy.

David was a member of the Alberta Water Council from its inception in 2003 until joining the University of Lethbridge, representing the first irrigated agriculture and has been representing the science and research community since the fall of 2007. David is the Water Policy Co-Chair for the Pacific Northwest Economic Region, is a member of the Canadian Water Network's Canadian Municipal Water Consortium, a member of the Board of Directors of Inside Education, a member of the Board of Directors of the TEC Fund Limited Partnership (Edmonton) and has been a participant of the Rosenberg International Forum on Water Policy (University of California, Berkeley) since 2004. He is the Past-President of the Canadian Committee on Irrigation and Drainage and is a former member of national Board of Directors of the Canadian Water Resources Association. David has also served on Alberta's Endangered Species Conservation Committee, the Alberta Environmentally Sustainable Agriculture Council and was an advisory member of the Board of Directors for the Northwest Irrigation Operators Inc. in Boise, Idaho for 5 years. David is committed to finding proactive evidence-based solutions to priority issues in Alberta, with a focus on rapid step changes to allow Alberta to secure a world-leading position in the research, science and policy domains.

Day 1 – Session 2

David Hill – University of Lethbridge

Abstract

The status quo in integrated natural resource management no longer addresses Alberta's current needs and is ill suited to actively bring together the best of science, policy and practice in discovering new and adaptable solutions that can be readily implemented to meet Alberta's social, environmental and economic needs. Relationships and interdependencies between the management of air, land, water and bio-diversity are complex. It has often been difficult to resolve issues about perspective, data, information and knowledge and to visualize the opportunities that might exist to achieve improved and sustainable outcomes from these finite and ever-changing resources. This presentation will highlight some of the research and other activities that are ongoing at the University of Lethbridge. Emerging opportunities that exist to train students at the undergraduate and graduate levels alongside leading practitioners will be explored. The focus of these efforts is to develop and sustain the processes that Alberta needs to ensure that resource management decisions are well informed and that Alberta has the capacity for ongoing adaptive management.

Discovering the Possible:
Tools for Collaborative Learning and Improved Outcomes

Environmental Modelling Workshop 2013
Edmonton, Alberta

David F Hill, Director
david.hill@uleth.ca
Centres and Institutes and Research Advocacy
University of Lethbridge

University of Lethbridge | Office of Research and Innovation Services | 4401 University Drive | Lethbridge | Alberta | T1K 3M4 | www.uleth.ca

Background …

- Complexity of issues and decision-making … status quo is insufficient to deal with relationships between air, land, water and biodiversity
- Interests vs. Positions
- Engaging experience and real-world actors is key to success
- Tackling reality in a virtual world, not a theoretical world

Approach …

- Bring together the ‘best’ of science, practice and policy to discover and implement adaptable solutions to meet Alberta’s social, environmental and economic needs in response to ongoing change/uncertainty
- Develop a long-term view of the requirements for research, training, and the development/refinement of analytical tools to support informed decision-making

University Contributions ...

- Emerging increased focus on capitalizing on research findings to meet provincial priorities and to support economic development,
- Campus Alberta has a significant depth of expertise in teaching, research and working with communities, government and industry
- There is little appetite for duplication of activities, but heightened appetite for increased collaboration and added value

U of L Strengths …

- WISE, Water Institute for Sustainable Ecosystems
- ATIC, Alberta Terrestrial Imaging Centre
- Prentice Institute for Global Population and Economy
- ARRTI, Alberta RNA Research and Training Institute
- CSRM, Centre for Socially Responsible Marketing

5 of 9 existing U of L research organizations have water, land, biodiversity and community as research focus areas.

Capacity ...

- WISE ... Full range of water expertise, advanced and modern laboratory facilities designed to answer complex questions, complimented by physical geographers, economists, agrologists and policy expertise
- Long history in use of analytical tools (models) and visualization (GIS)
- Leading development of new modelling and monitoring approaches ... Functional environmental flows ... Riparian systems ...

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Capacity …

- ATIC … Single largest aggregation of hyper-spectral imaging scientists in western Canada, global experience in advanced remote sensing, on campus earth satellite receiving station, focussed on the development of tools and applications to support decision-making, excellent connections and collaboration with industry
- Developing expertise and tools for large landscape monitoring and reporting

Capacity ...

- Prentice Institute ... Trans-disciplinary global experience in addressing issues of population growth and economy with a focus on policy relevant outcomes
- ARRTI ... Leading advances in synthetic biology to address human health & industrial issues, undergraduate team developed petrochemical-eating bacteria, only Canadian team in 2011 at MIT iGEM competition, top 4 globally

Capacity ...

- Centre for Socially Responsible Marketing ... Focussed on supporting/training NGOs, community organizations, business in leading behaviour change for specific outcomes
- Other campus expertise focussed on aspects of the air, land, water & biodiversity space – chemistry, media arts, management, computing science, environmental education, etc
- Strong partnerships in the area of open, transparent access to data and commercial tool development

Experience/Opportunity ...

- Long history of collaboration with community, government and private sector in responsible natural resource management
- Specific interest in development of tools, models as key components of research and teaching/training
- Experience in use of ACRU, OASIS, SWAT, G-EPIC, I/O economic models and in development/piloting of new approaches

Experience/Opportunity ...

- Well developed collaborative relationships within Campus Alberta, Canadian Water Network, national and international organizations
- Going forward ... Development/deployment of trans-disciplinary, multi-institution undergrad and graduate student training focussed on integrated natural resource management with an emphasis on environmental modelling

Experience/Opportunity ...

- Going forward ... Initiation of specific on-line and on campus training resources for professional and executive training – extending research findings & opportunities into the workplace
- Going forward ... Fostering new approaches to research and knowledge mobilization, secondments, internships, fellowships

Closing Observations …

- U of L is well positioned to contribute to the development and refinement of evidence-based analytical tools across much or the air, land, water & biodiversity spectrum
- Collaborative processes that involve shared learning and making use of (capturing) experience will enhance research, training and realization of improved outcomes

Questions …

Research Info$ource Names University of Lethbridge, University of the Year 2012 (Undergraduate)
Accolades from Maclean's and Globe and Mail

Day 1 – Session 2

Hugh Norris – AESRD

BIOGRAPHY

Hugh Norris was born and raised in Alberta. Norris holds a BSc from U of C and a MSc from U of A. He has worked for Alberta Fish and Wildlife Division in the field (SW), HQ, field (Head of Fisheries Mgmt - NE Region), HQ (Head of Fisheries Allocation and Use), then 3 years as the F&W representative on Sustainable Resource Developments Land-use Framework Integration Team, and the last year continuing that work but through F & W. In the last four years his work included participating in the regional land-use planning processes, and developing the Biodiversity Management System and Biodiversity Management Frameworks.

With very recent reorganization, Norris is now the Biodiversity Section Head, Policy Integration Branch, Policy Division, Environment and Sustainable Resource Development.

Day 1 – Session 2

Hugh Norris – AESRD

ABSTRACT

Alberta's Land-use Framework (2008) defined a change to cumulative effects (CE) based management to deal with the competition that population increase and development activities were having for natural landscapes. The presentation is based on Alberta's Biodiversity Management System (BMS) which defines the steps necessary for bringing biodiversity into any cumulative effects based land-use planning to balance social, economic and environmental (SEE) values. Within this process, modelling is needed to approximate biodiversity indicator reference points; project CE based trajectories of biodiversity indicator outcomes into the future; test the tools that could be used to control effects of development; and likely in the future to help assess monitoring results.

The Importance of Modelling for Bringing Biodiversity into Land-use Planning.

March 13, 2013

Hugh Norris, AESRD

Alberta Land-use Framework, 2008

- 7 regional plans with GoA approved future outcomes.

- Complete a biodiversity strategy.

- Balance social, economic and environmental values.

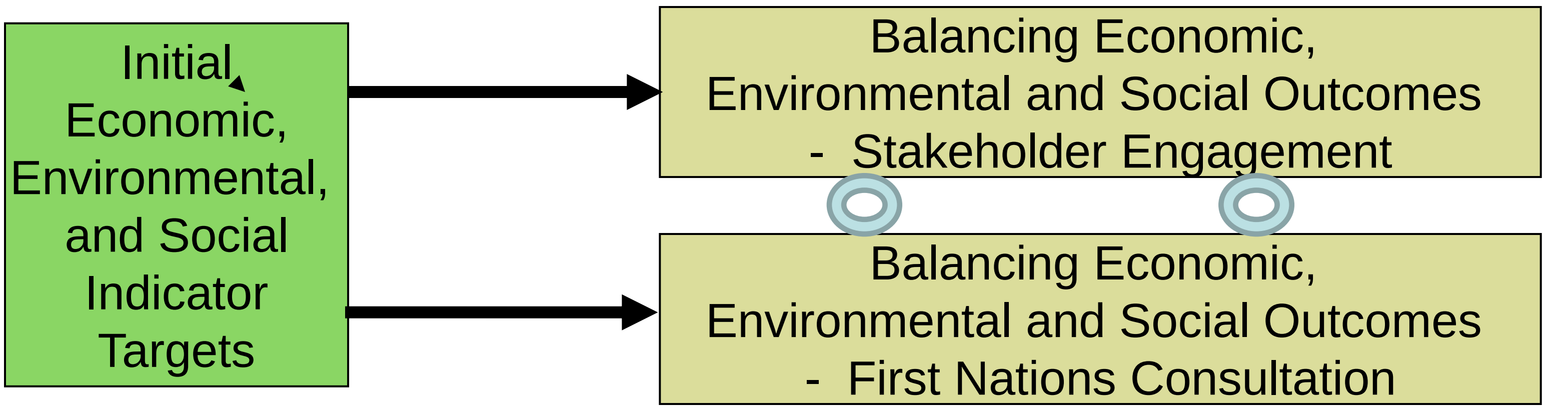
- New cumulative effects approach.

- GoA expectation to include Albertans in planning.

- LARP - build a Biodiversity Management Framework.

Planning - Building Plans and Management Frameworks

Cumulative effects – all values for one area considered at the same time.



GoA dept representatives will meet with a small but diverse group of stakeholders and with First Nations to try to optimize what everyone wants from the particular piece of land.

A Structured Recommendation Making process will be used to help the groups.

Recommendations go to the GoA who will finalize plans and Mgmt Frameworks.

Terrestrial Biodiversity Indicators

- Must represent breadth of biodiversity with:
  - coarse filters:
    - land-covers – 33, e.g., deciduous, white spruce, shrubland, fescue grassland, marsh,
    - habitat features – 11, e.g., amount of, seral stage, fragmentation, snags,
  - fine filters (often specific habitats):
    - guilds – 6, e.g., old forest birds, human associated birds, weedy vascular plants,
    - species – 16+, e.g., caribou*, moose, marten, barred owls, Canadian toad.

Aquatic Biodiversity Indicators

- coarse filters:

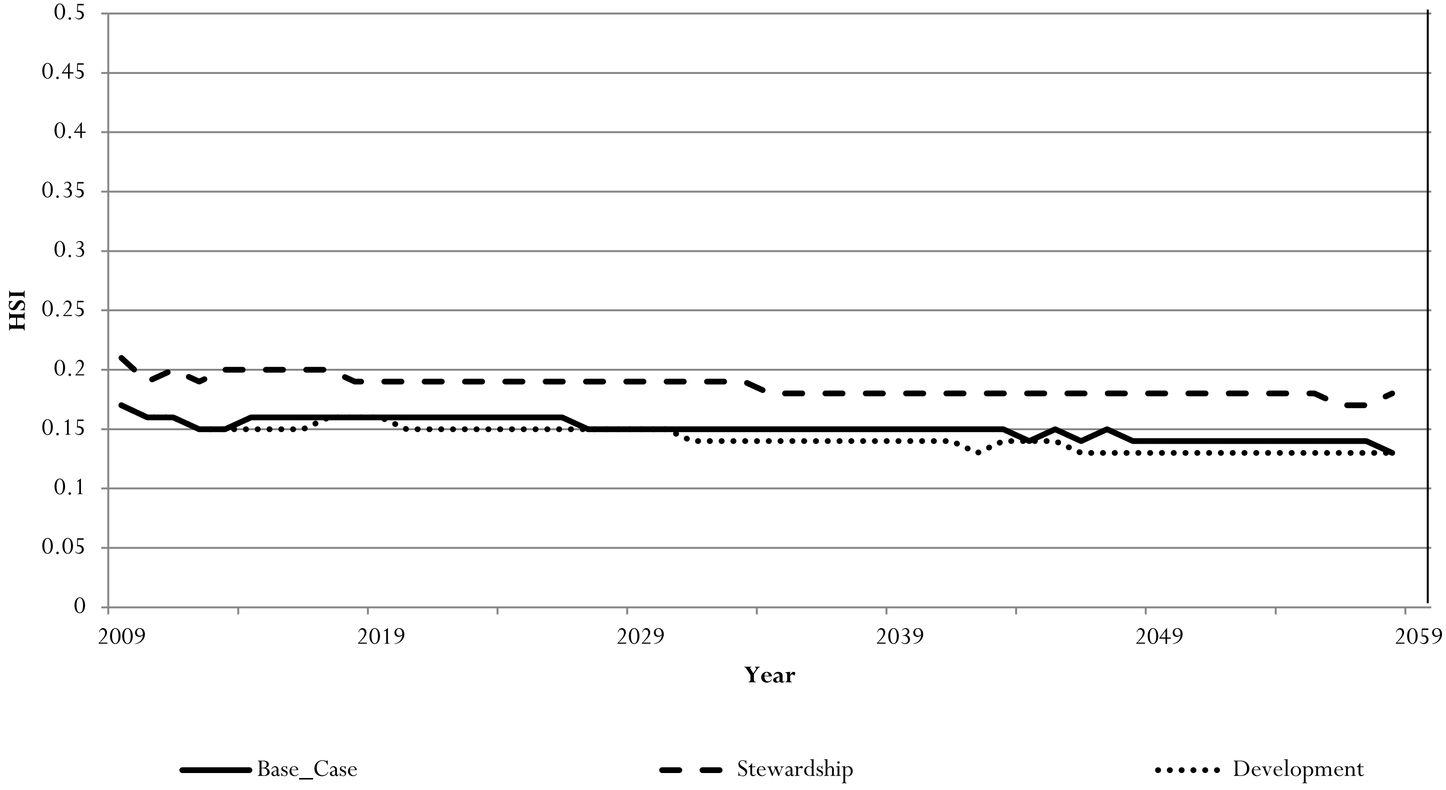
    - area of wetlands, standing water, flowing water,
    - habitat features – fishkill risk, stream continuity, riparian health,

- fine filters:

    - guilds – e.g., Index of Native Fish Integrity, wetland / riparian vertebrates,
    - species – Fish Sustainability Index.

- Must use models to project indicator status into the future.

Cumulative effects modelling provides indicator probable status trajectories under various land-use scenarios.



Results don't mean much to most people – need context.

Cumulative Effects

- Land-use Framework definition - combined effects of past, present and reasonably foreseeable future effects of land-use on the environment over time.

- Usually don't have data on changes in quantity and quality of habitats and populations from the "past".

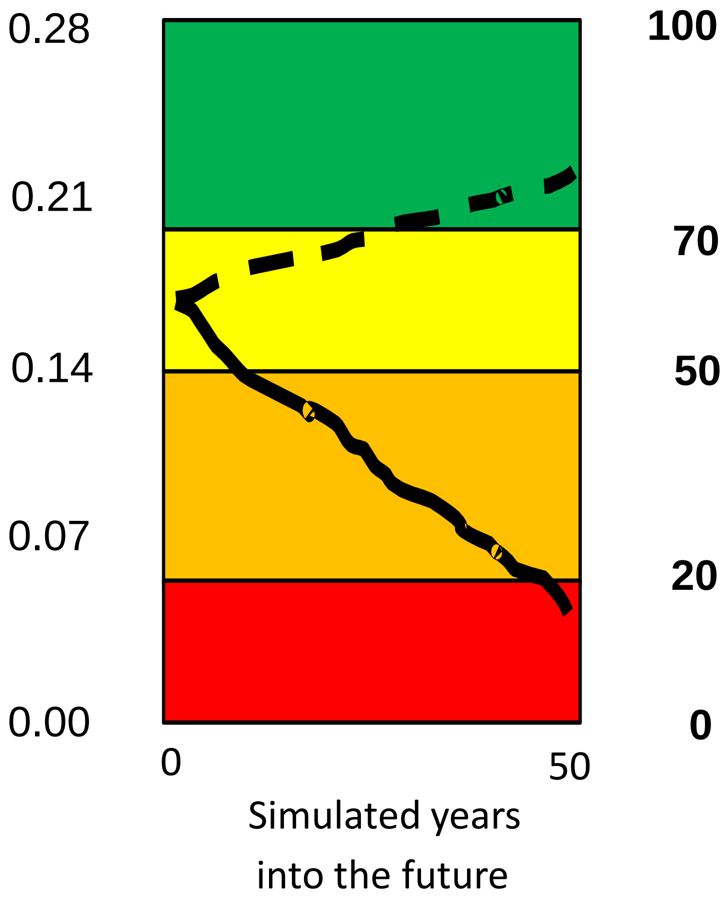
Range of Natural Variability

- Use modelling to project RNV of landscapes and indicators to pristine undisturbed by humans conditions, assuming no human footprint or introduced species, and assuming that natural disturbances occur as they did in the past.

- Repeating the modelling runs 50 or more times gives values to generate average, lower and upper limits of RNV.

Reference point = the average of RNV = 100%.
Risk assessment bands based on IUCN break-points.

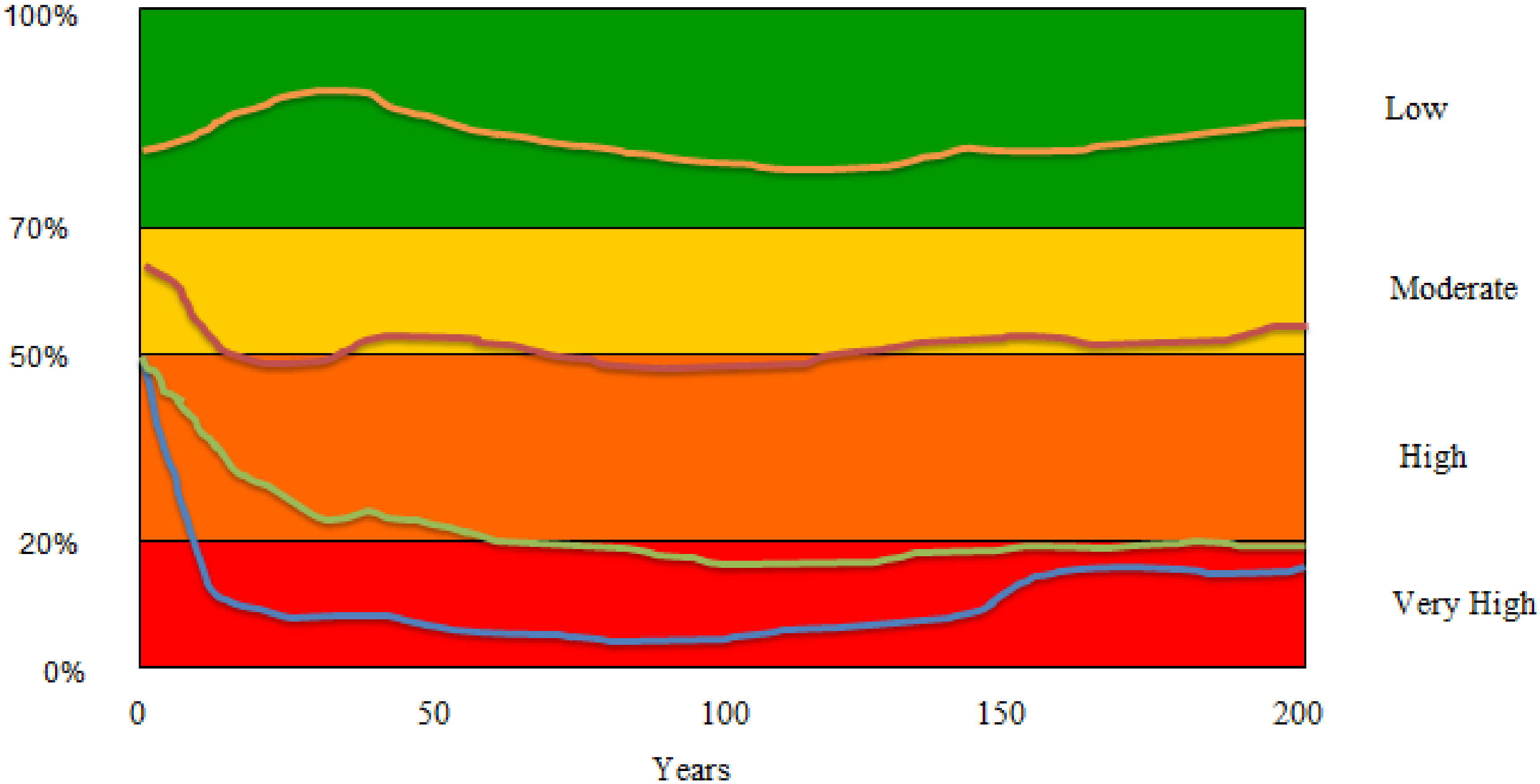
Indicator units (e.g., Habitat Suitability Index values for indicator X)



Proportion of native biodiversity indicator remaining compared to the pristine undisturbed by humans conditions

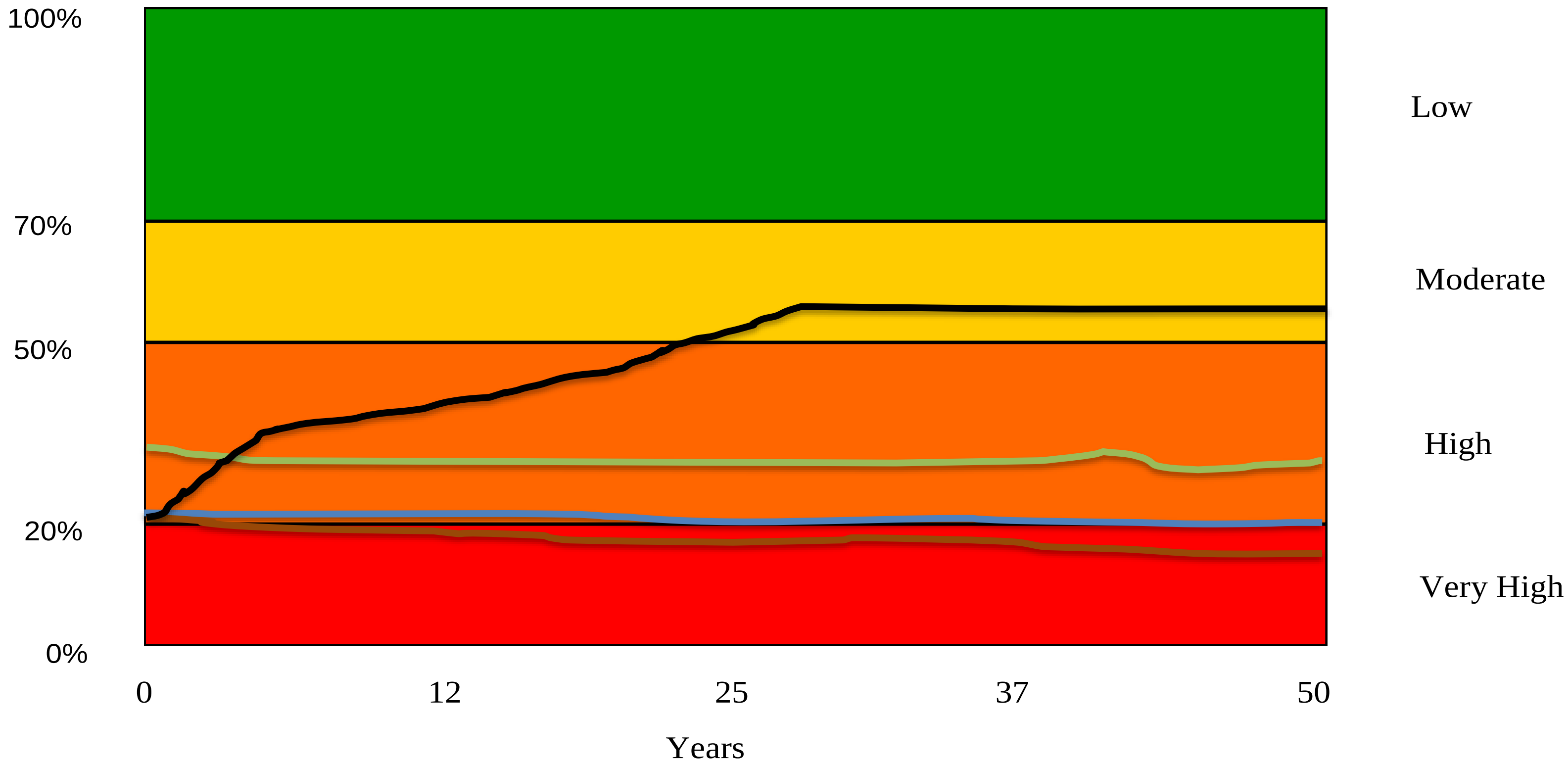
Within RNV is the preferred status from a biodiversity perspective.
Secondary preferred status outside RNV is in the green or high in the yellow risk levels. Ultimately GoA will decide acceptable level of risk.

Modelling facilitates comparisons of different land-use scenarios.



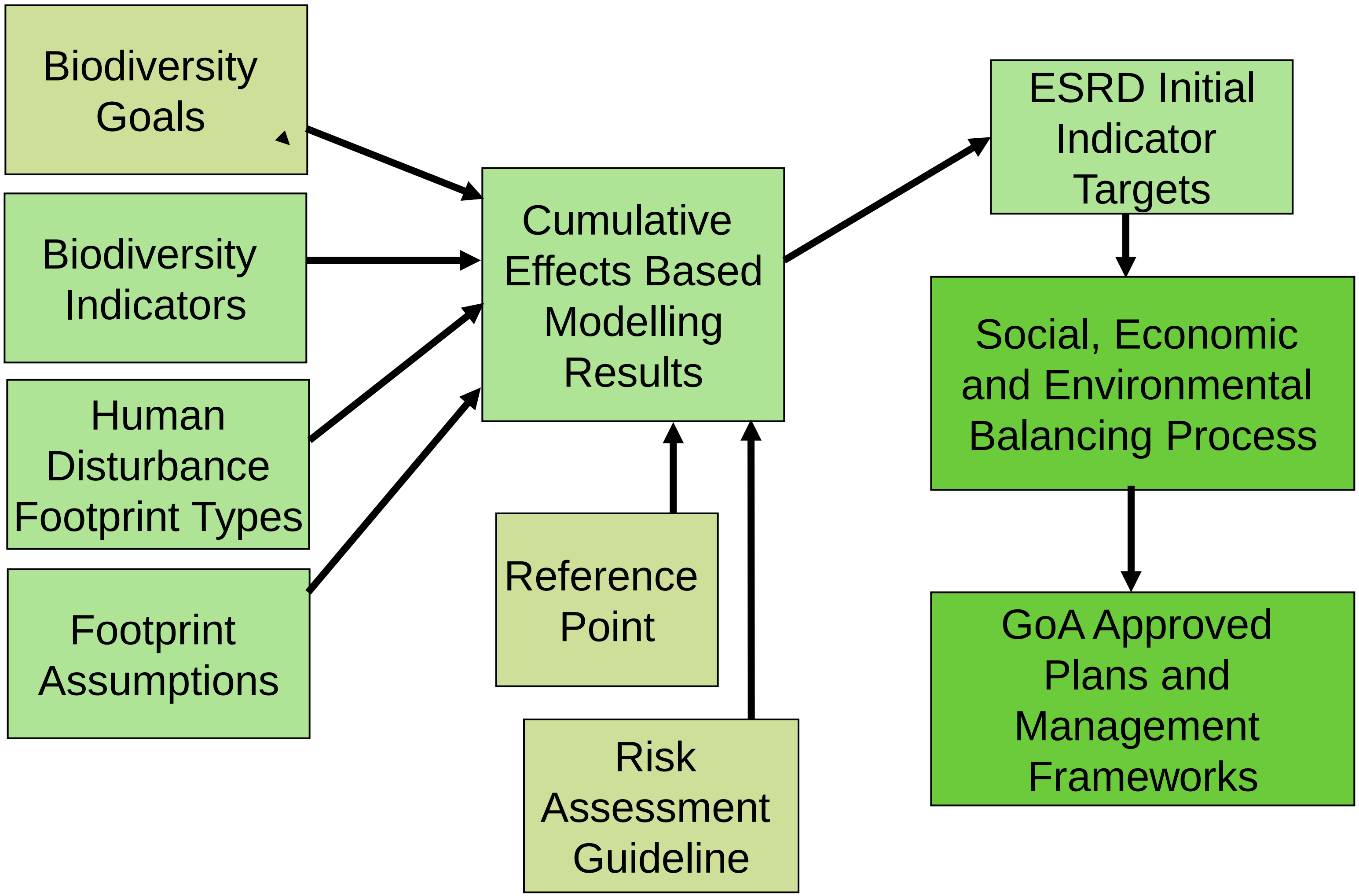
Proportion of a biodiversity indicator remaining compared to undisturbed (by humans) conditions and risk assessment bands. Example 1. Indicator model results: ---- **Base Case**; ---- **Best Practices**; ---- **Moderate Best Practices + Access Management**; ---- **High Best Practices + Access Management**

Reverse engineering of the model can be used to determine what land conservation and/or land-use controls would be needed to achieve specific targets.



Proportion of a biodiversity indicator remaining compared to undisturbed (by humans) conditions and risk assessment bands.
Example 4. Indicator model results: ---- Base Case; ---- Development; ---- Best Practices; ---- Approved Trajectory and Target.

Approach Needed for Bringing Biodiversity into Cumulative Effects Based Land-use Planning



Biodiversity Management Framework

- The GoA statement of integrated intent for managing biodiversity within a specific region or subregion.

- Determined by the GoA through the cumulative effects based land-use planning process to balance the economic, environmental and social values (3 pillars).

- Includes the GoA approved biodiversity indicator trajectories and targets to be achieved over a specified time-frame.

- Defines the means of achieving the targets through:
  - establishment of conservation areas,
  - controlling human disturbance footprints,
  - setting footprint reclamation rates and end-points, and
  - controlling public motorized use of the footprints.

Management Frameworks for CE

All MFs for a plan area should be built at the same time and through the same process so they are all fully integrated.

Water Quality and Quantity needs for people, industry and aquatic biodiversity will be different but the MFs should reflect the most sensitive need unless a trade-off has been made.

Air Quality also needs to reflect the needs of people as well as aquatic and terrestrial biodiversity.

A Contaminant MF could list the appropriate compounds known or likely to cause problems in the area and the concentrations of concern to humans and biodiversity.

Day 1 – Session 2

Nesa Ilich – Optimal Solutions Inc.

BIOGRAPHY

Dr. Nesa Ilich is a water resources engineer with over 20 years of consulting practice for various clients in the water resources sector, including Alberta Environment, TransAlta, Environment Canada and a number of international clients. He holds a Ph.D. from the University of Manitoba and M.Sc. from the University of Alberta. Dr. Ilich has significantly improved Alberta Environment's Water Resource Management Model (WRMM) through a series of contracts which started in 1988 and exported its use overseas. This model has been used in numerous multi-disciplinary basin management studies.
He has also recently developed and tested a unique method for multiple-site generation of stochastic hydrologic time series that was used successfully on several projects. Dr. Ilich has published numerous papers on computer modelling topics in river basin management and hydrology.

Day 1 – Session 2

Nesa Ilich – Optimal Solutions Inc.

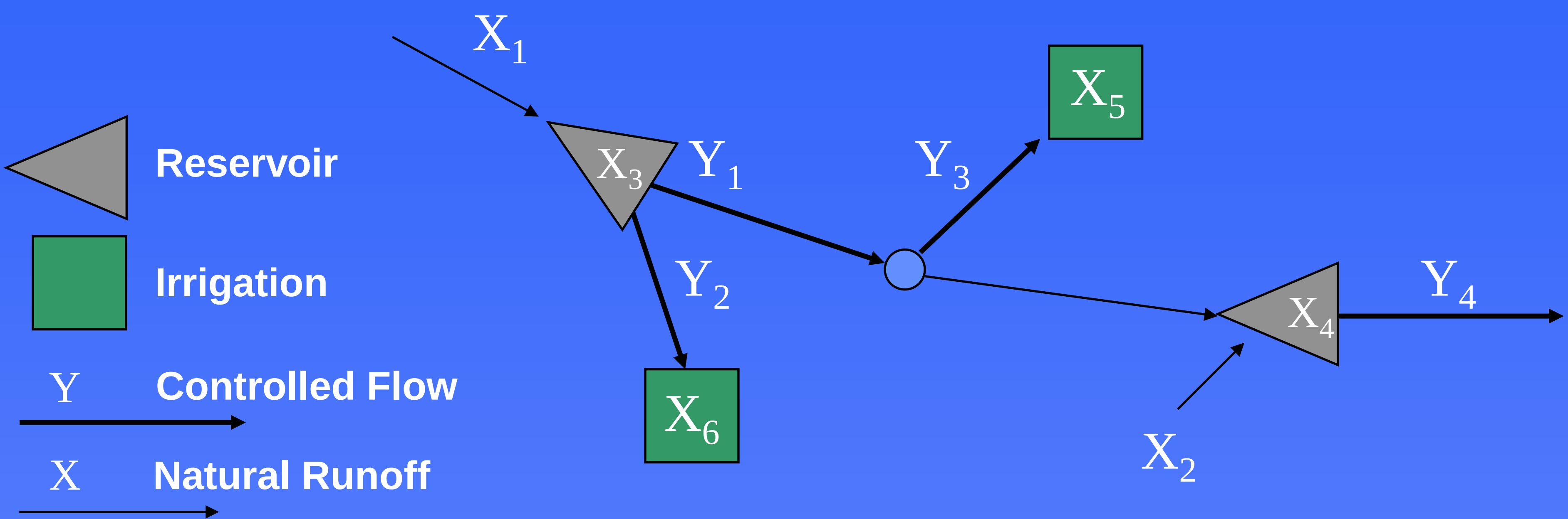
ABSTRACT

River basin management models differ substantially from simulation models, since they typically use some type of mathematical optimization to help address numerous options that decision makers face regarding basin-wide water allocation. New paradigms have emerged that provide substantial improvements to previous modelling. They include a combination of multiple time step optimization (MTO), which optimizes basin allocation at all nodes and for all relevant time steps, in conjunction with the new equal deficit sharing constraint, which de facto optimizes the amount of hedging applied to water demand in dry years, thus enabling firm supply at reduced rates as a function of the reduced hydrologic input and the priority of allocation. The new approach is flexible. When combined with stochastic hydrologic input, it can provide excellent basis for statistical inference of the model solutions, which is a valuable basis for building short term operating rules.

Conjunctive Optimization of Supply and Demand in River Basin Modeling

1. Introduction to Basin Management Models
2. Some Important Modeling Issues:
   - Current Modeling Practices
   - Simultaneous Optimization of Supply and Demand
   - Time Step Length
   - Need for agreement on minimum technical specifications and benchmarks
3. Conclusions and Recommendations

Introduction to Basin Management Models (BMM)



1. **BMM simulate decision making process**
2. **BMM are either:**
   - **Rule Based (rely on the use of "if-else" rules);**
   - **Optimization Based, e.g. Maximize** $\sum \sum Y_{i,t} P_i$

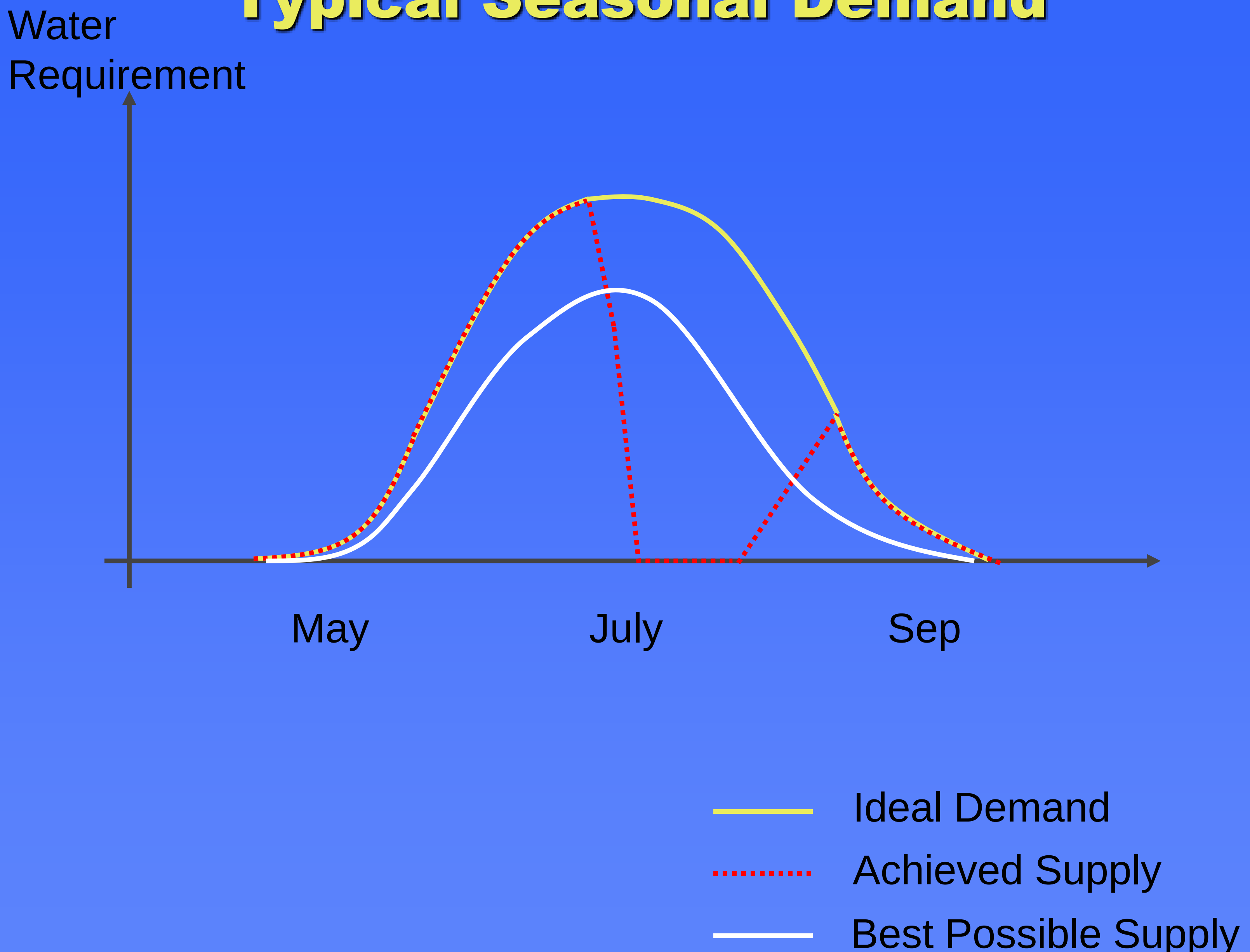
The Purpose and Typical Use of BMMs

The purpose of a BMM is to help us find the best operating regimes for various input scenarios

The use of BMM makes sense only if the obtained solution is better than the solution we would get using the rule of thumb (analogy with computer chess games)

The onus is on modelers to provide evidence that their model solutions are better than the rule of thumb

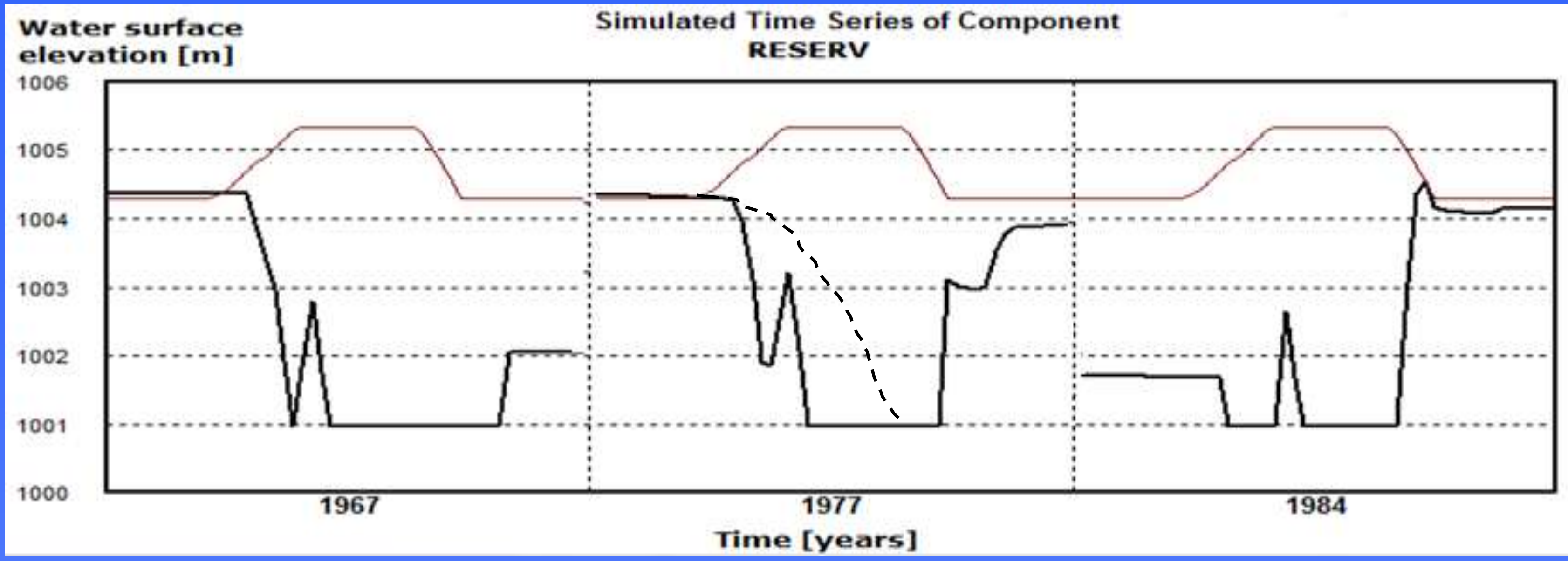
Typical Seasonal Demand

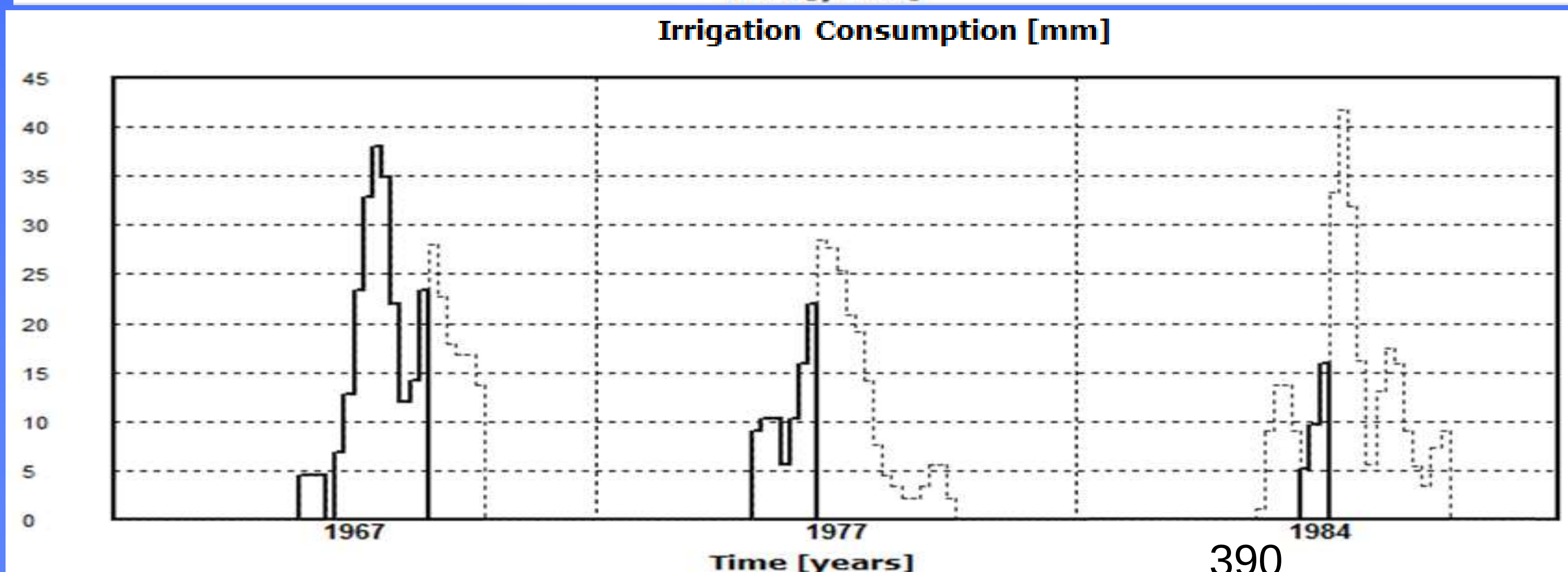


Current Modeling Practices

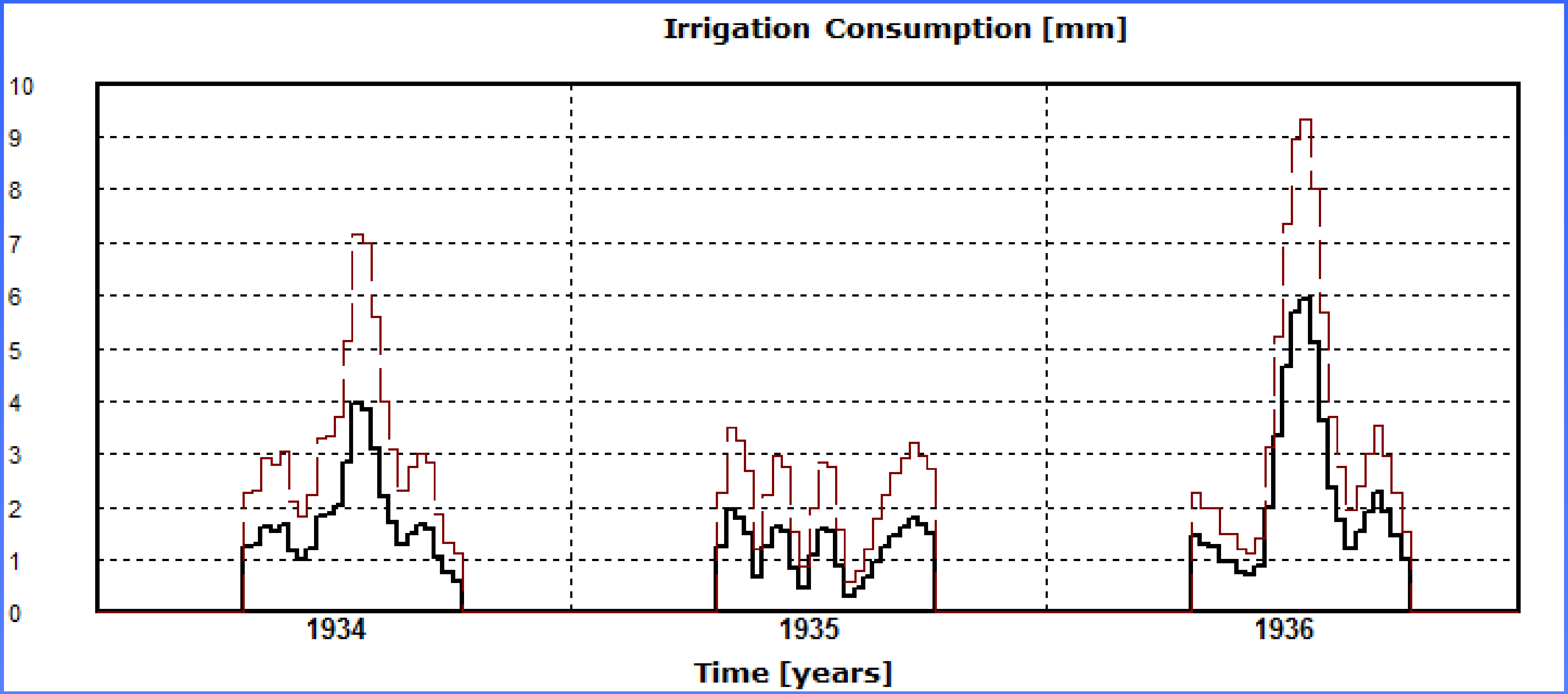
1. Reservoir operating rules are the same for every year, and they are arbitrarily defined by the modeler;
2. Model is typically run in single time step (STO) mode; and,
3. Water demands are based on full licenses (adjusted for precipitation) for each time step. There is no hedging of demands.

Modeling Results under STO Mode

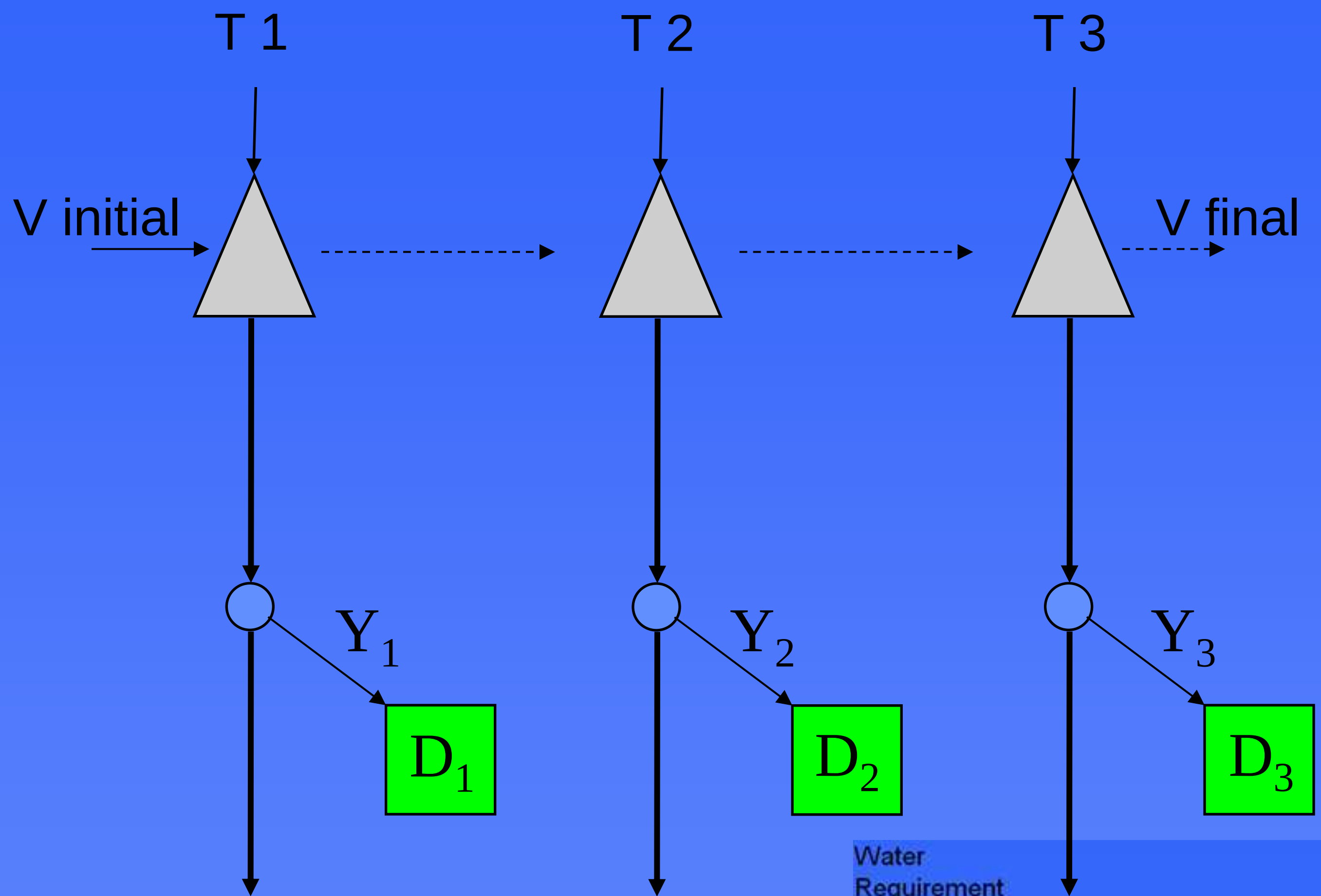




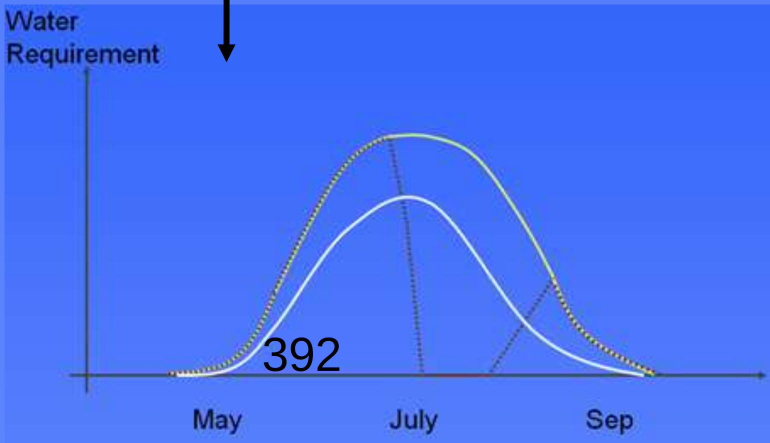
Modeling Results based on Demand Optimization



Multiple Time Step Optimization (MTO)



$$\frac{Y_t}{D_t} = \frac{Y_{t+1}}{D_{t+1}} \qquad for\ t = 0, n-1$$



Shortcomings of MTO

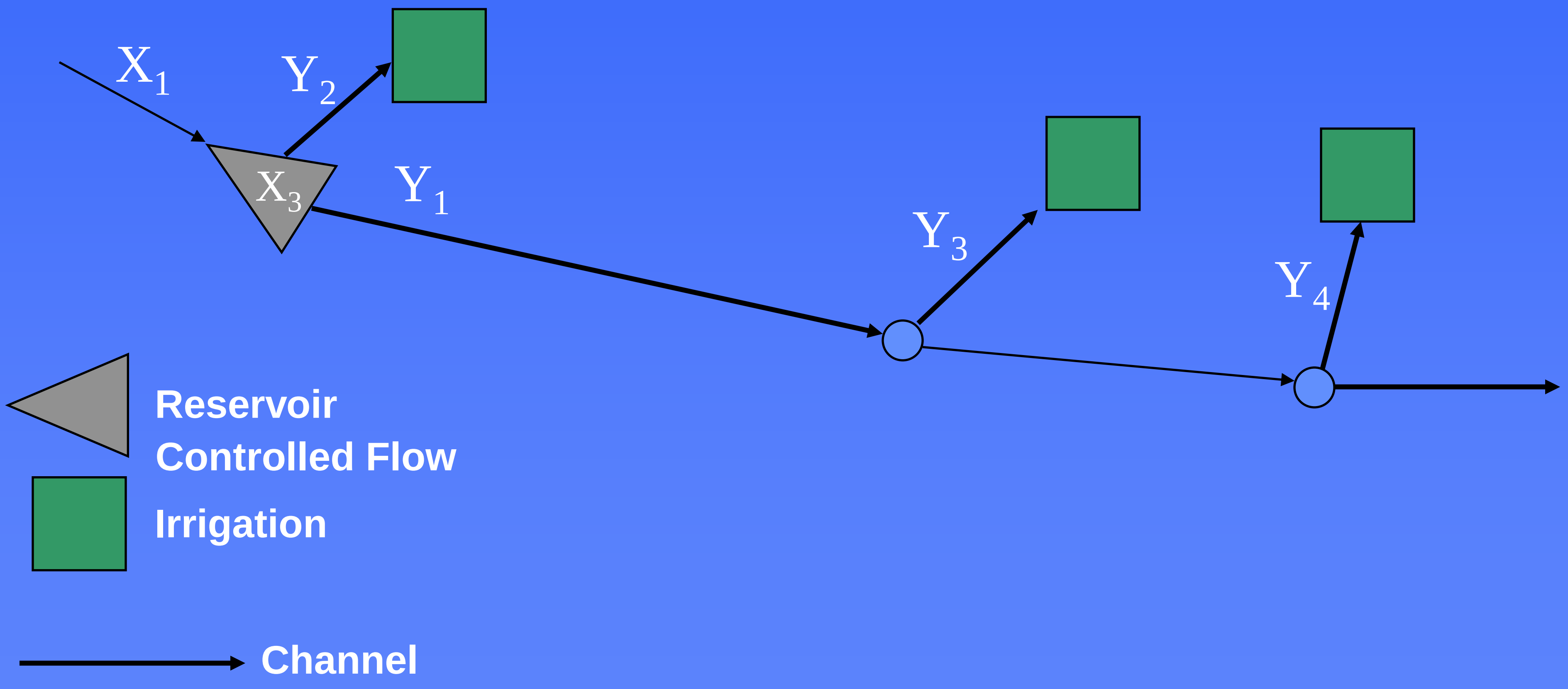
- Much larger solution networks with longer solution times;
- MTO runs are much more difficult to debug if something goes wrong; and,
- When used in combination with some constraints that require binary variables, the solution times may be prohibitive.

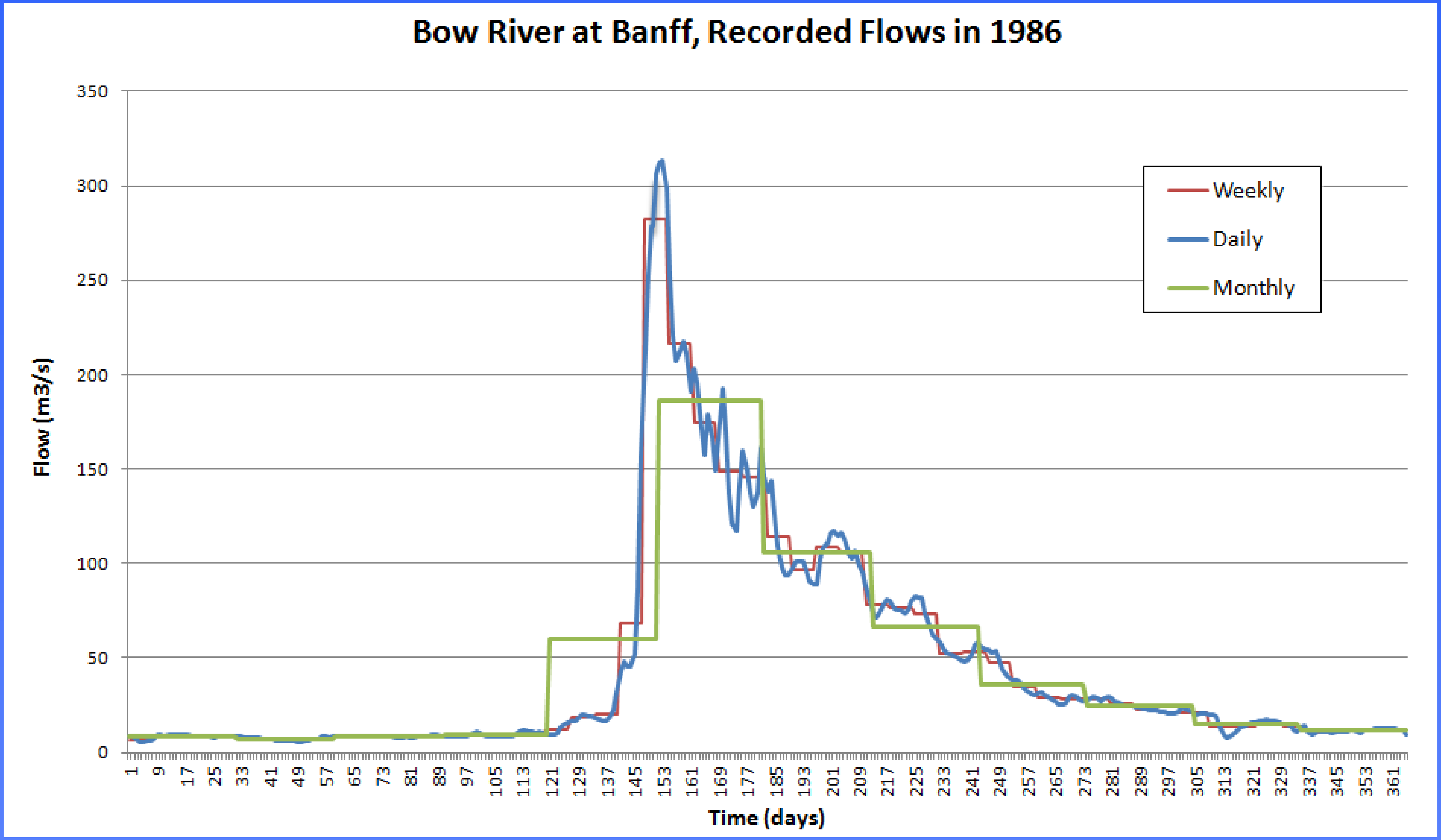
Benefits of MTO

- Solutions include perfect reservoir operating regime developed uniquely for each year by the model;
- Solutions include optimal demand reduction in dry years for all time steps within a year which is a better reflection of the actual management practices; and,
- Solutions over many years provide good basis for inferential development of seasonal operating rules

Time Step Length

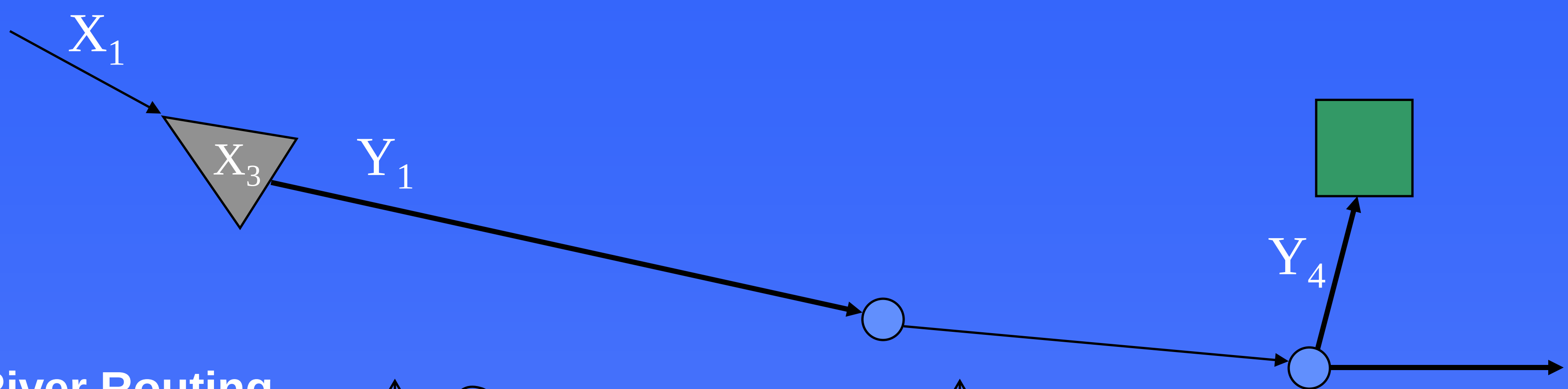
It is assumed that water can reach any user from the most upstream source within a time step. This restricts modeling of large basins to monthly time steps.



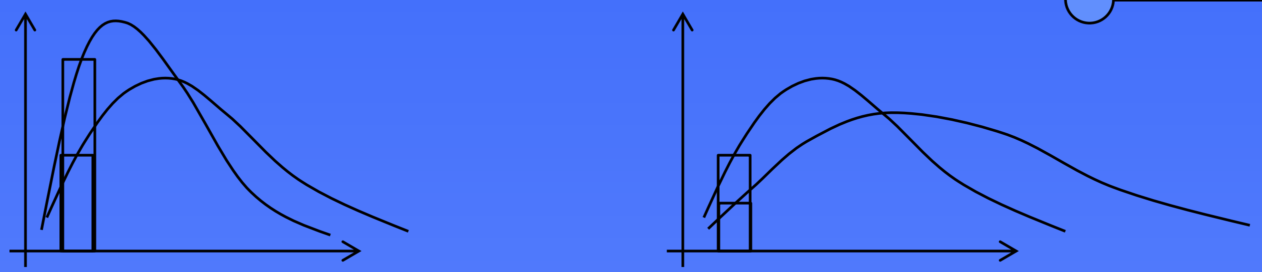


Monthly inflow hydrographs are much easier to manage. The same basins modeled with monthly and weekly time steps showed up to 28% difference in spills.

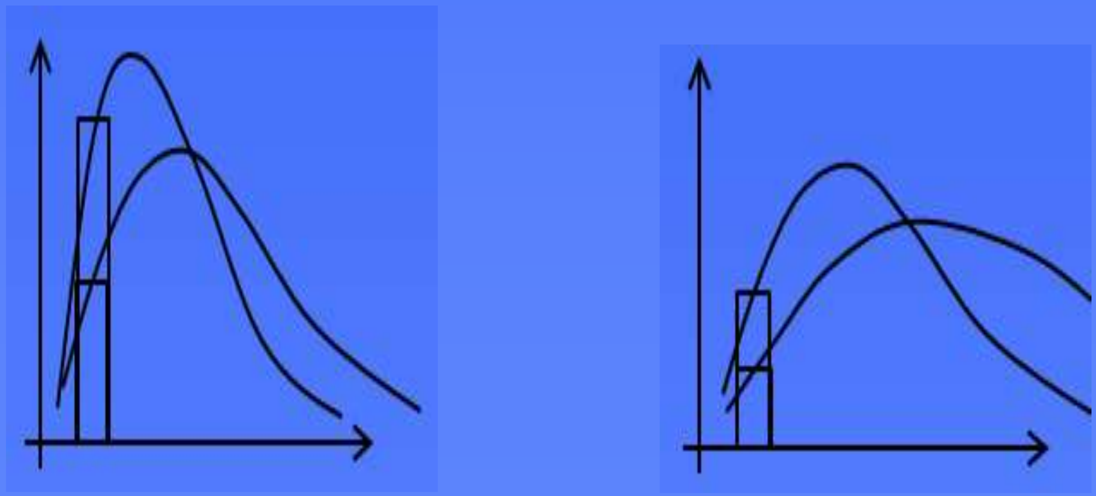
Problems with Channel Routing Constraints



River Routing Effects under normal reservoir release:



River Routing Effects under increased reservoir release:



Time Step Length

Inclusion of hydrologic channel routing as a constraint to optimization requires daily time steps, which introduces problems:

- model floods the river valley to reduce the downstream deficits[1];
- There is no published solution to this problem (which does not mean that there is no solution); and,
- Modeling of small (daily) time steps can be done by setting the storage outflow to a fixed user defined value, which turns off the powerful optimization engine that no longer drives the storage releases.

[1] *Ilich, N. 2008. Shortcomings of Linear Programming in Optimizing River Basin Allocation. Water Res. Research, Vol. 44.*

Time Step Length

There should be guidelines on:

- establishing the proper time step length (not too long to avoid problem with the spills, not too short to avoid problems with routing);
- how to model time steps which are shorter than the total travel time through the basin; and,
- how to model hydrologic river routing within the optimization framework, can it be done within the LP framework and if so, how? The routing coefficients do change with significant flow variations over the year.

$$O_i = C_0 I_i + C_1 I_{i-1} + C_2 O_{i-1}$$

Min Tech. Specifications: List of Constraints

- Storage outlet structure
- Diversion at a weir
- Net Evaporation on Reservoirs
- Return flow channels
- Diversion license volume limit per year
- Apportionment volume limit per year
- Channel routing (?)
- Equal deficit constraints

Model Constraints

There should be guidelines on:

- Establishing which constraints are important and by how much they affect the quality of solutions if they are not modeled;
- How individual constraints should be formulated and included in the model; and,
- Problems with constraints should be formulated as benchmark tests and their solutions should be published such that every model vendor can verify their results by re-running the benchmarks.

Model Objectives

Objective Function: $\sum \sum Y_{i,t} P_i$

A universally accepted algorithm that determines suitable priority factors *Pi* for a given system based on:

- **a) Network configuration**
- **b) Priorities**
- **c) Constraints**

has yet to be devised. It would be useful to the practitioners.

Summary of Desirable Research Objectives

Further research is needed to address the following issues:

a) How to model time steps that are shorter than the entire basin travel time

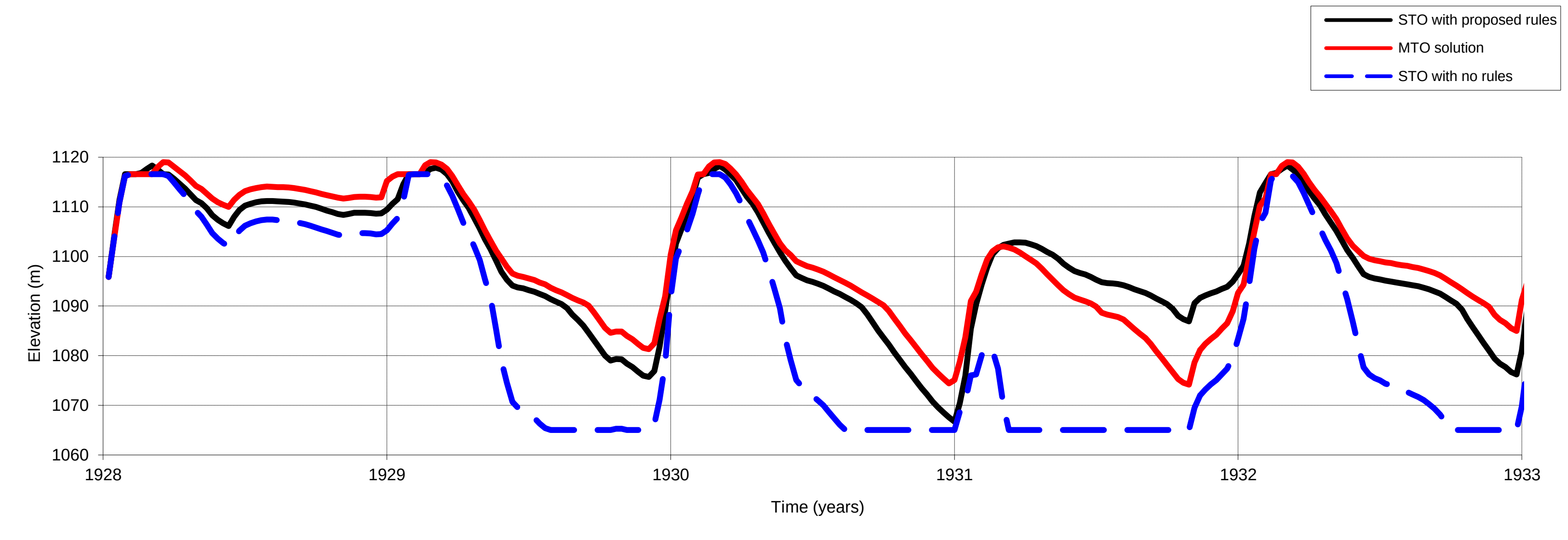
b) Importance of MTO solution framework

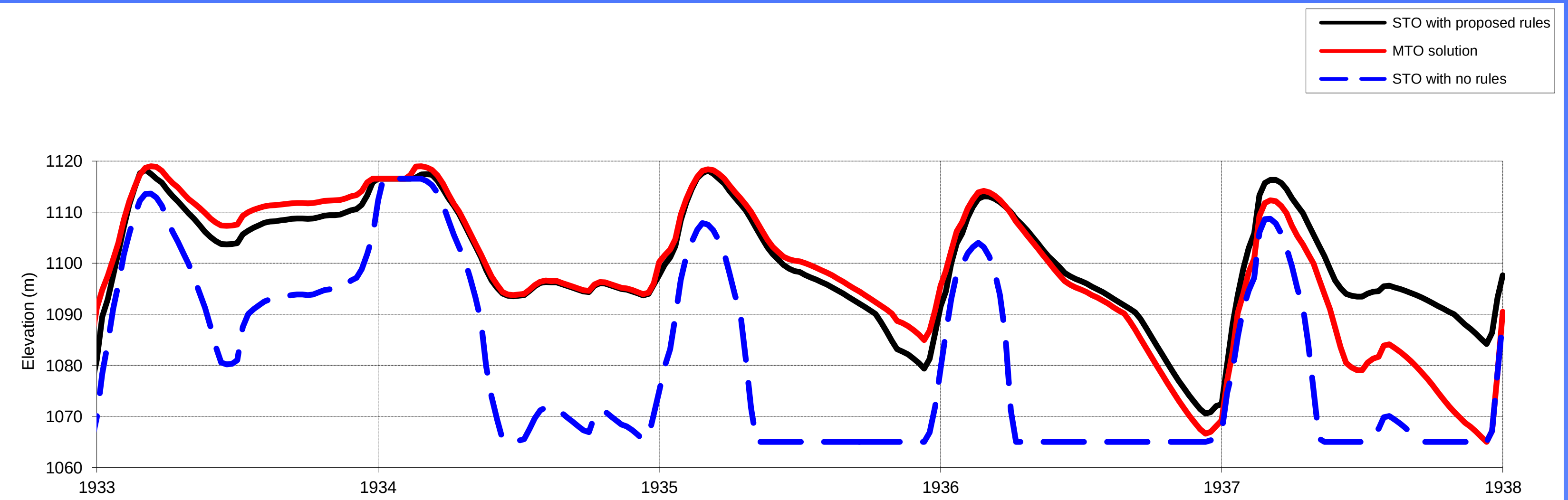
c) Agreement on which constraints are important and how they should be modeled

d) A universal algorithm that finds suitable payout (cost) factors based on network configuration and established priorities

e) General agreement on modeling approach aimed to derive short term operating rules that would be easy to understand and implement.

Use of MTO in Development of Rule Curves Storage Levels for three Scenarios (1928-1937)





The End

Alberta Government

Dinner

Day 1 – Dinner Key Note

John Pomeroy – University of Saskatchewan

BIOGRAPHY

Dr. John Pomeroy is the Canada Research Chair in Water Resources and Climate Change (Tier 1), Professor of Geography and Director of the Centre for Hydrology at the University of Saskatchewan, an Honorary Professor of the Centre for Glaciology, Aberystwyth University, Wales and Chinese Academy of Sciences, Lanzhou and an Institute Professor of the Biogeoscience Institute of the University of Calgary. He serves as President of the International Commission for Snow and Ice Hydrology, leads the Canadian Rockies Hydrological Observatory and was recently Chair of the IAHS Decade on Prediction in Ungauged Basins, Principal Investigator for the IP3 Cold Regions Hydrology Network and Co-Principal Investigator for the Drought Research Initiative. Dr. Pomeroy has authored over 200 research articles and several books. His current research interests are the impact of land use and climate change on cold and semi-arid region hydrology, snow physics, mountain hydrology, water security and hydrological predictions in Ungauged Basins including floods and droughts.

Day 1 – Dinner Key Note

John Pomeroy – University of Saskatchewan

ABSTRACT

The Canadian Prairie region has presented formidable challenges for hydrological models due to its many internal drainages, large depressional storage, variable contributing area, high infiltration rates, wind redistribution of snow, solar radiation dominated snowmelt, frozen soils and low evapo-transpiration rates. The Canadian Rockies have also presented widespread problems to many models because of many of the aforementioned processes and sublimation of intercepted snow, the impact of slope and aspect on the snowmelt energy balance and sub-canopy radiation effects. Realistic hydrological modelling in western Canada has been hampered by attempts to apply models that were developed for well-drained, temperate or humid regions in our often poorly-drained, cold and sub-humid environment. Such model applications often require setting parameters outside of their physically meaningful range in order to compensate for deficiencies in model structure, conceptualisation and parameterisation. The Cold Regions Hydrological Modelling Platform (CRHM) is a modular hydrological model development platform that was created to explore appropriate structural content, adapt model structure to specific process scales, and increase the physical basis of hydrological models. It has been developed based on western Canadian basin research. In CRHM the user assembles a hydrological model from a selection of hydrological process modules (parameterisations). CRHM's modularity provides the possibility to change process parameterisations from simpler to more complex ones and to emphasize prairie, forest or mountain processes. It is also possible to rapidly update parameterisations as advances in hydrological understanding occur, or to run models in parallel to compare the impact of differing parameterisations, parameter or driving data availability on model results. Recent CRHM advances include integration with the WISKI data management environment. The impact of these parameterisations on the predictive performance of models created with CRHM is discussed using case studies from the prairie and Rocky Mountains in Alberta. For some basins these are the first successful hydrological process simulations ever conducted and can be used to examine hydrological sensitivity to future land use, wetland drainage, drought, flood and climate change scenarios. The next steps are to apply models created from CRHM for these impact scenarios and to couple them to operational, climate and water resource models for a wider variety of applications from small to large scales.

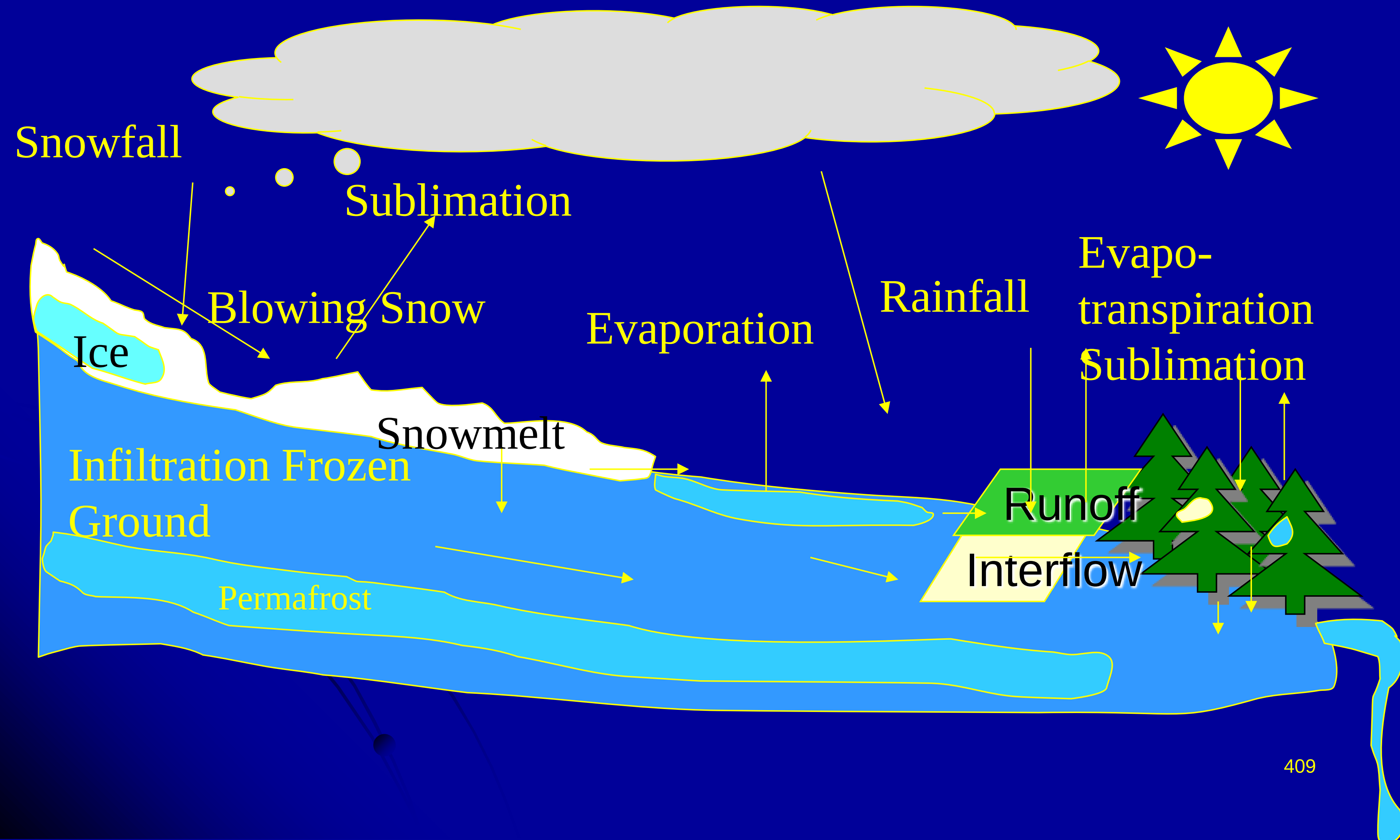
Multiscale Modelling of Mountain, Forest and Prairie Hydrology

John Pomeroy, Kevin Shook, Xing Fang, Tom Brown

Centre for Hydrology,
Univ. of Saskatchewan,
Saskatoon & Kananaskis (Coldwater Laboratory)

www.usask.ca/hydrology

Cold Regions Hydrological Cycle



Why Physically-based Hydrological Modelling?

- **Robust - can be more confidently extrapolated to different climates and environments and performs better in extreme situations (floods, droughts).**
- **Scientifically Satisfying - represents a compilation of what is understood about hydrology.**
- **Flexible – permits assessment of land use and climate change impacts on streamflow regime, soil moisture, wetlands, snowpack, groundwater, chemistry, etc.**
- **Can interface with chemistry and ecology - aquatic chemistry and hydroecological modelling require a sound hydrophysical base.**
- **Elevates hydrological *practice* to hydrological *science*.**

Information Needs to Design Models

- Identification of the principles governing the primary physical processes responsible for most water movement in basin (**processes**).
  - Governs model structure
- Fundamental boundary and initial conditions that affect these processes (**parameters**).
  - Governs model parameterisation
- Length scales for self-similarity and variability associated with the properties affecting these processes (**scale**).
  - Governs model spatial discretization.

Observations Clustered in Small Basins Improve Understanding






Appropriate Hydrological Modelling

- Model structural complexity needs to be appropriate for primary governing processes, parameter & meteorological data availability.
- Detailed parameter information is normally limited outside of research basins
- Basin discretization using hydrological response length scales found to be very useful
- Accurate interpolation of meteorological variables is critical.
- Structure, parameters and scale are informed by the results of process studies and distributed modelling at a network of research basins.

Cold Regions Hydrological Model Platform: CRHM

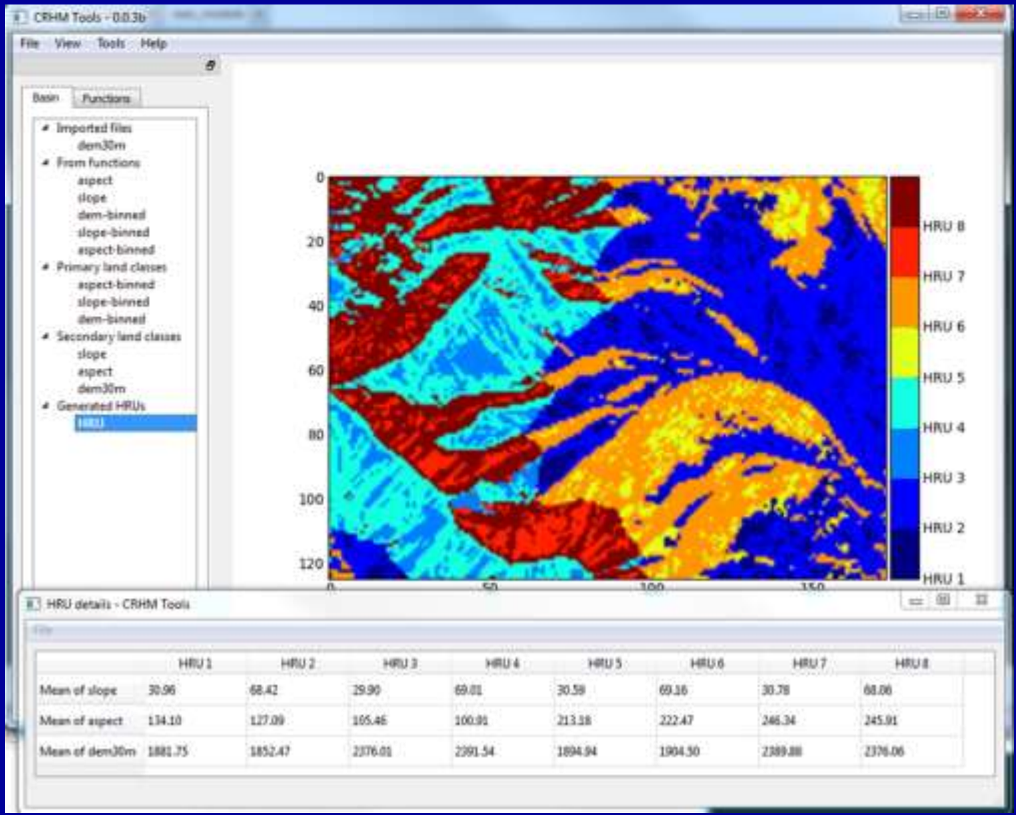
- Modular – purpose built from C++ modules
- Parameters set by knowledge rather than optimization
- Hydrological Response Unit (HRU) basis
  - landscape unit with characteristic hydrological processes/response
  - single parameter set
  - horizontal interaction along flow cascade matrix
  - Model tracks state variables and flows for HRU
- Coupled energy and mass balance, physically based algorithms applied to HRUs via module selection
- HRUs connected aerodynamically for blowing snow and via dynamic drainage networks for streamflow
- Flexible - can be configured for prairie, mountain, boreal, arctic basins
- Sub-basins connected via Muskingum routing
- Visualisation tools, GIS interface
- Model failure is embraced and instructive

Pomeroy et al., 2007 *Hydrol. Proc.*

Tom Brown, CRHM Modeller

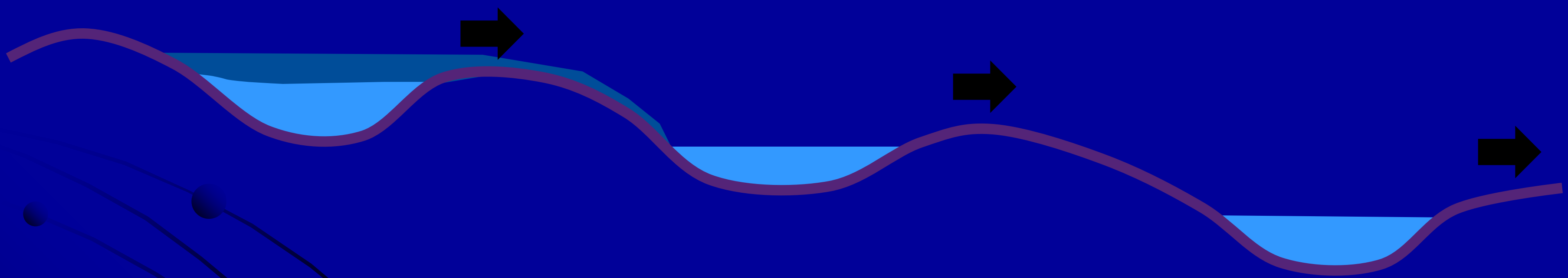
Hydrological Response Units (HRU)

- **A HRU is a spatial unit in the basin described by a single set of parameters, defined by**
  - **biophysical structure - soils, vegetation, drainage, slope, elevation, area (determine from GIS, maps)**
  - **hydrological state – snow water equivalent, internal energy, soil moisture, depressional storage, lake storage, water table (track using model)**
  - **hydrological flux - snow transport, sublimation, evaporation, melt discharge, infiltration, drainage, runoff. Fluxes are determined using fluxes from adjacent HRU and so depend on location in a flow sequence.**



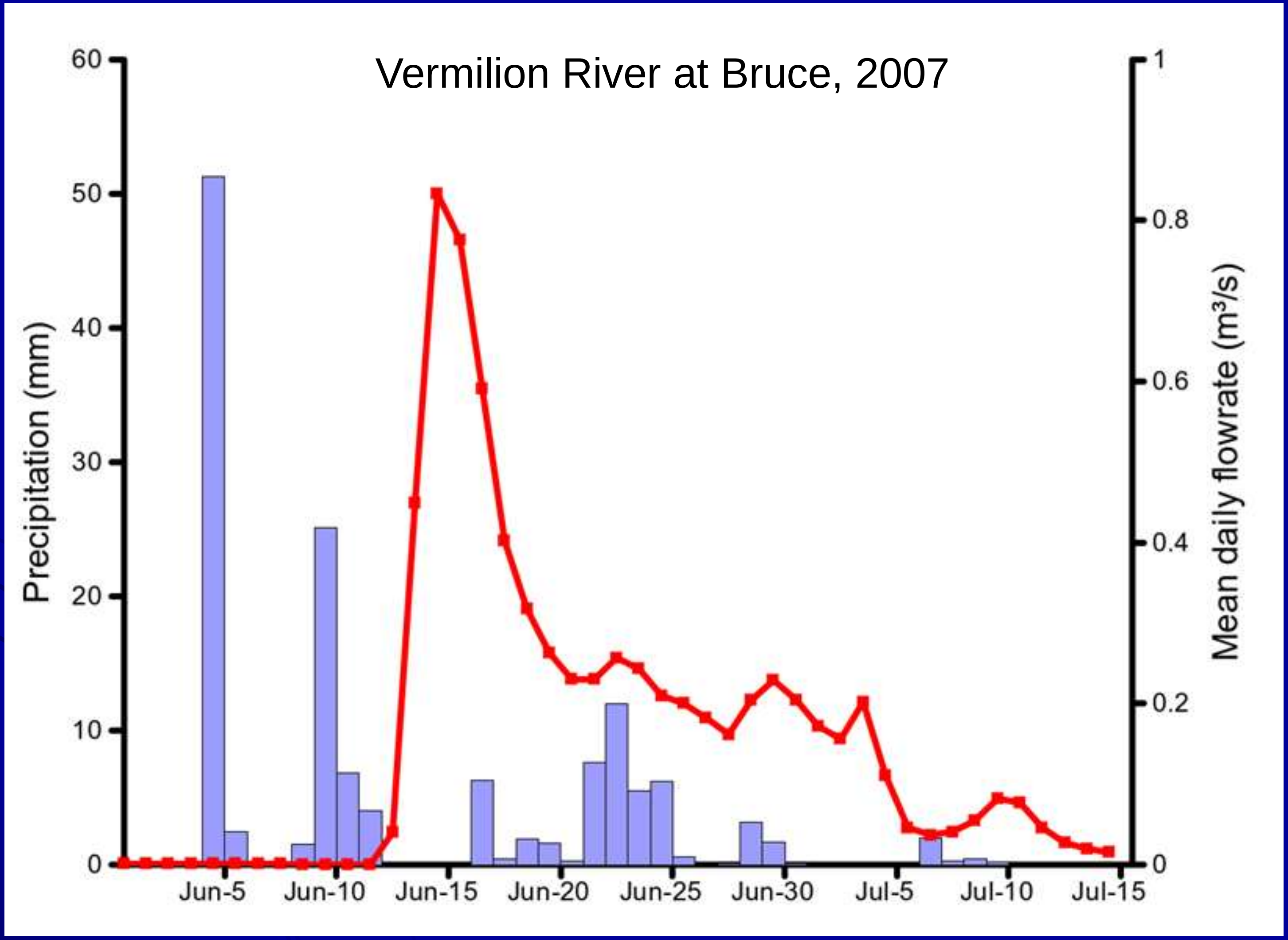
Prairie Hydrological Connectivity

The ‘fill and spill’ hypothesis



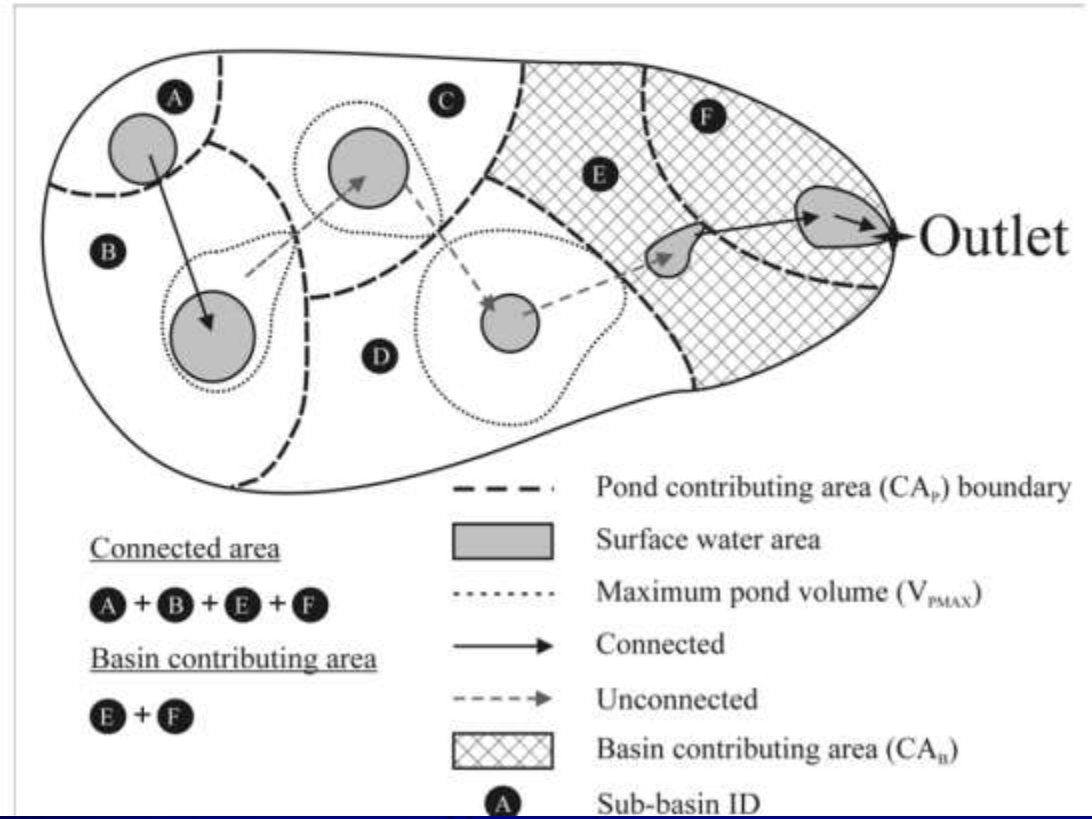
Lack of groundwater connections in this landscape – heavy tills

Impact of Fill and Spill on Hydrological Response to Precipitation

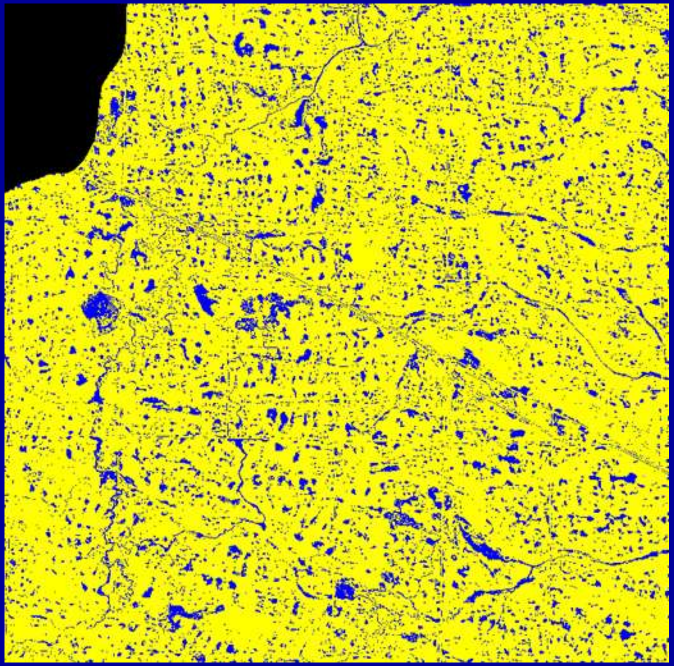


Fill and Spill Leads to Variable Contributing Area

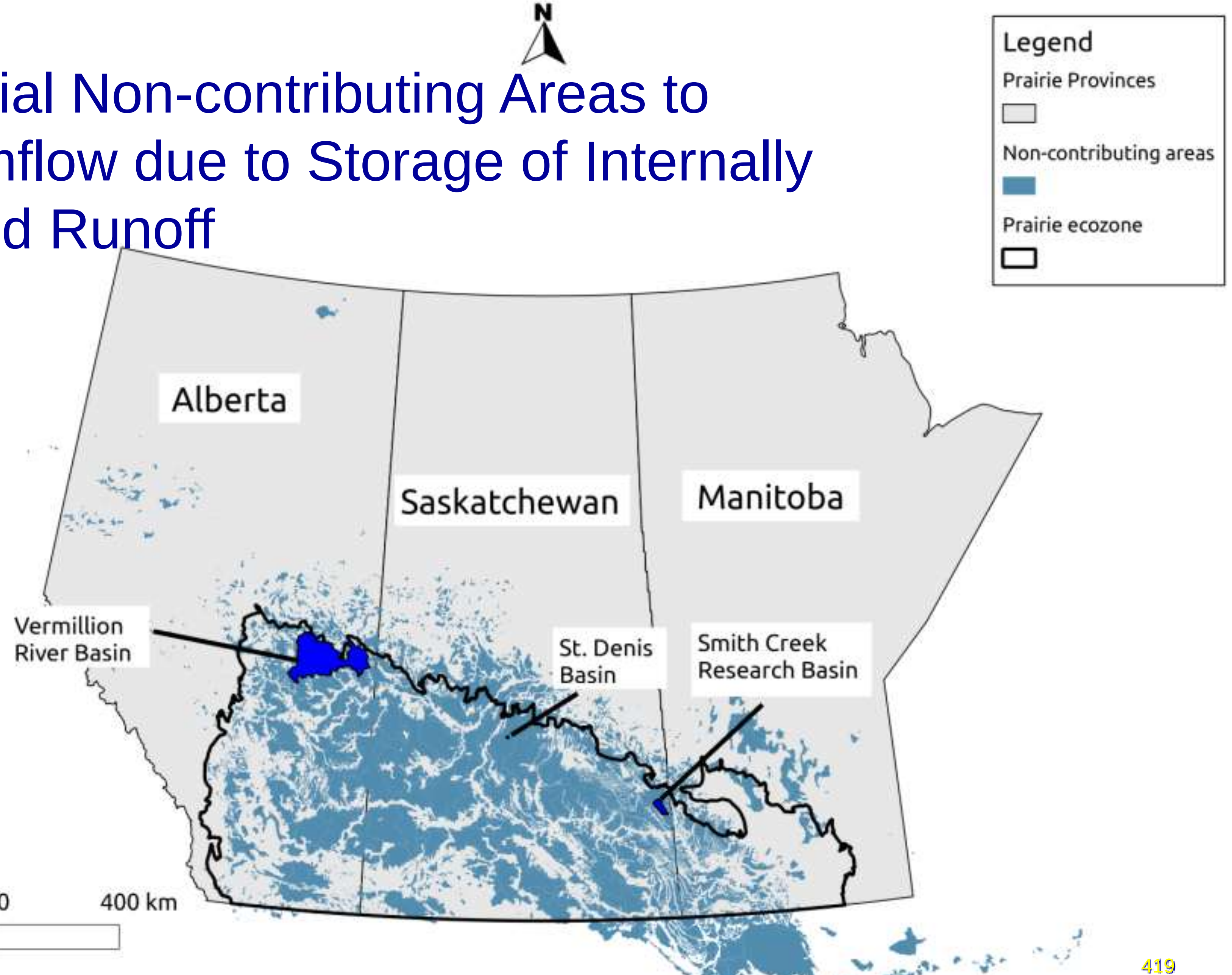
Conceptual View – Dean Shaw



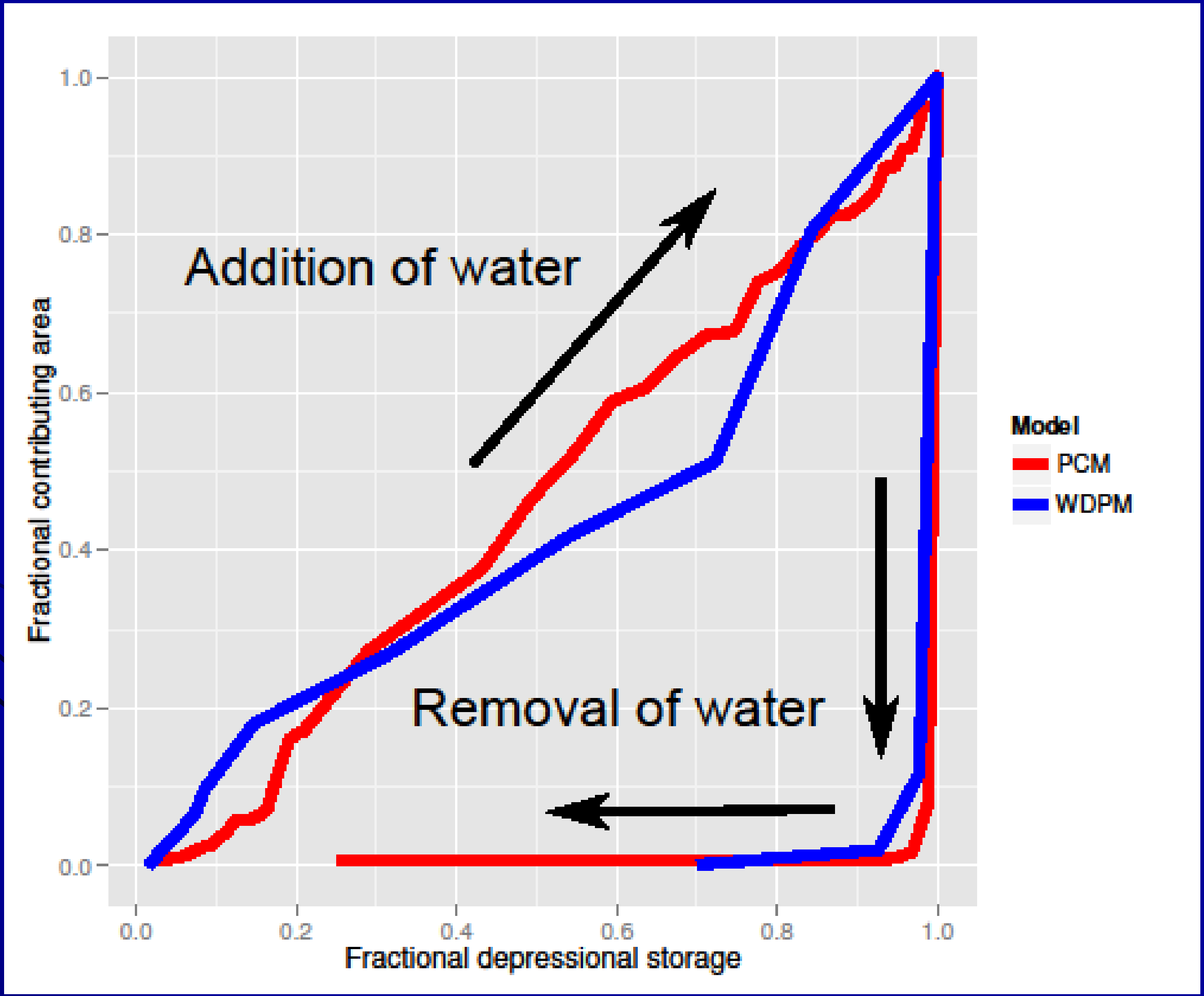
Real Wetlands, Vermilion River Basin



Potential Non-contributing Areas to Streamflow due to Storage of Internally Drained Runoff

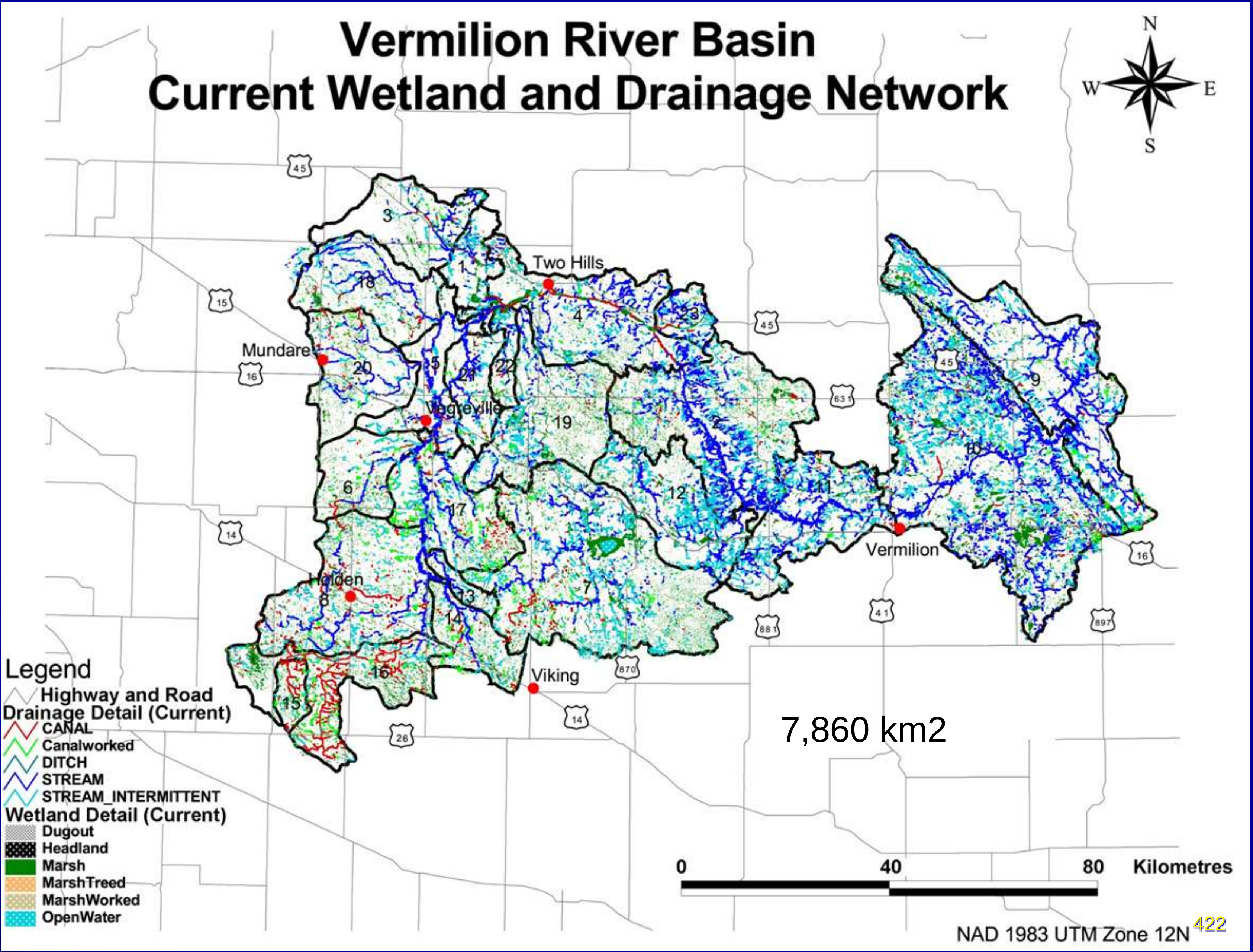


Depressional Storage – Basin Contributing Area Relationship

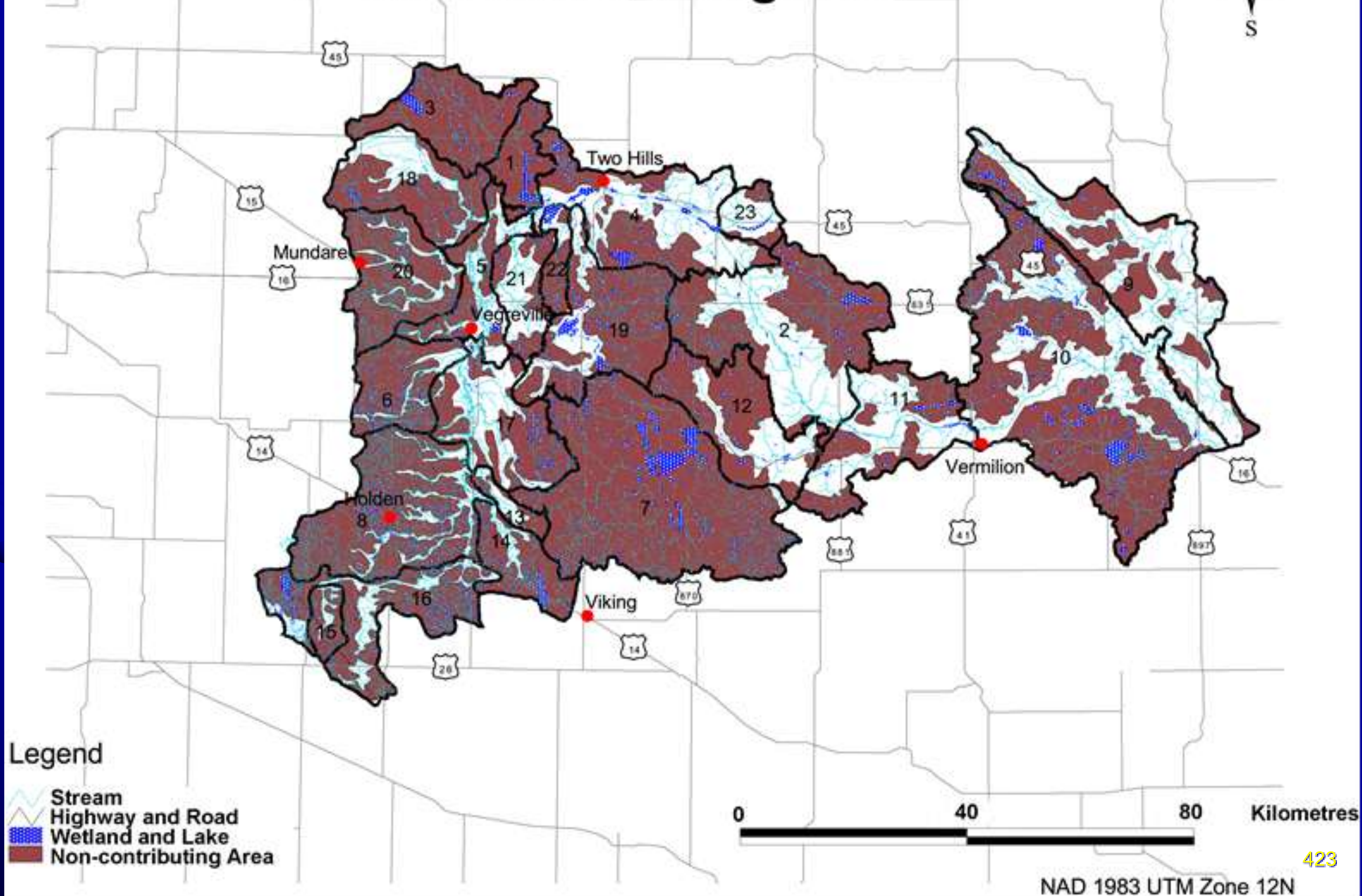


Objective

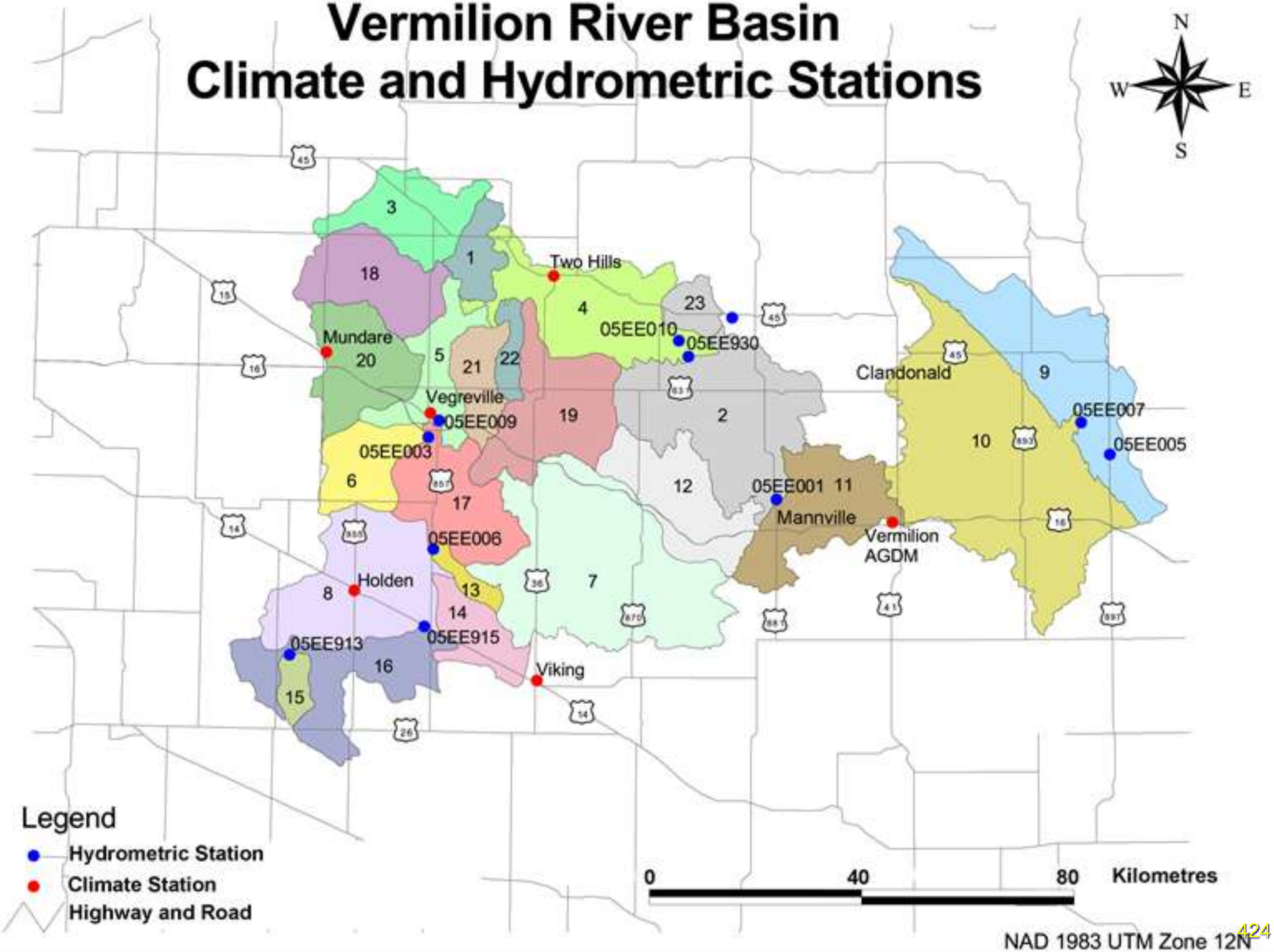
- Develop a model that can demonstrate the role of surface water storage on the hydrology of Prairie river basins.
- Apply the model to simulate streamflow.
- Modify the representation of wetlands in the model to show the impact of restoration and drainage on basin hydrology.


Vermilion River Basin
Current Wetland and Drainage Network
N
W
E
S
Two Hills
Mundare
Vegreville
Holden
Viking
Vermilion
Legend
Highway and Road
Drainage Detail (Current)
CANAL
Canalworked
DITCH
STREAM
STREAM_INTERMITTENT
Wetland Detail (Current)
Dugout
Headland
Marsh
MarshTreed
MarshWorked
OpenWater
7,860 km2
0
40
80
Kilometres
NAD 1983 UTM Zone 12N

Vermilion River Basin Non-contributing Area



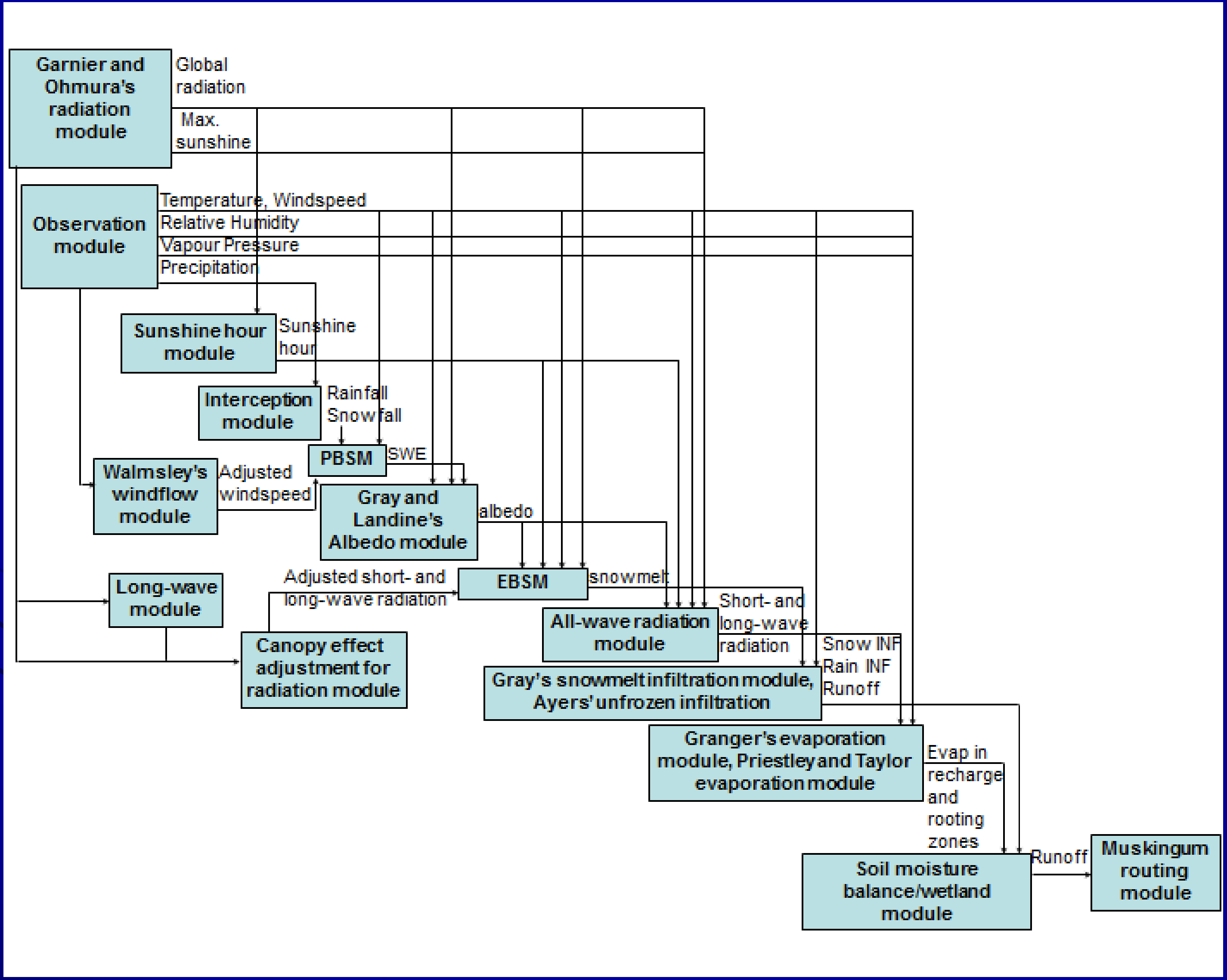
Vermilion River Basin Climate and Hydrometric Stations



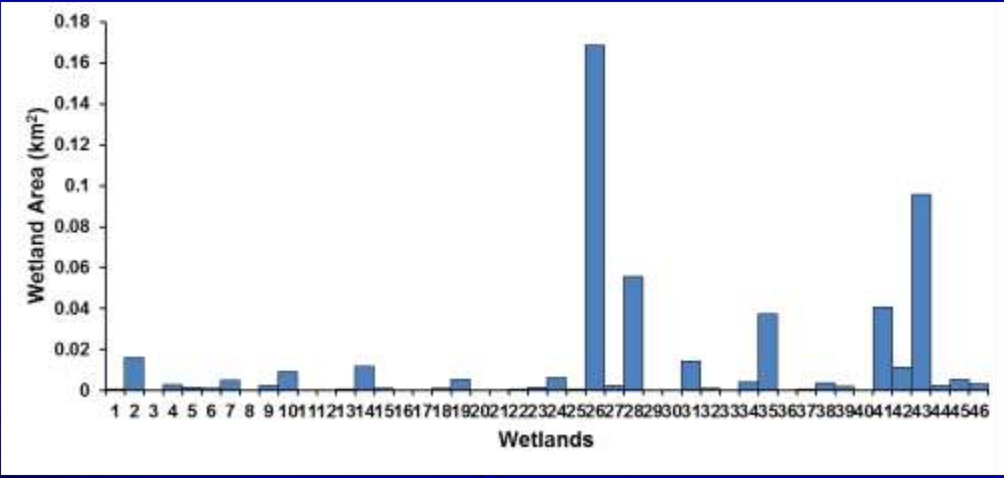
Model Setup

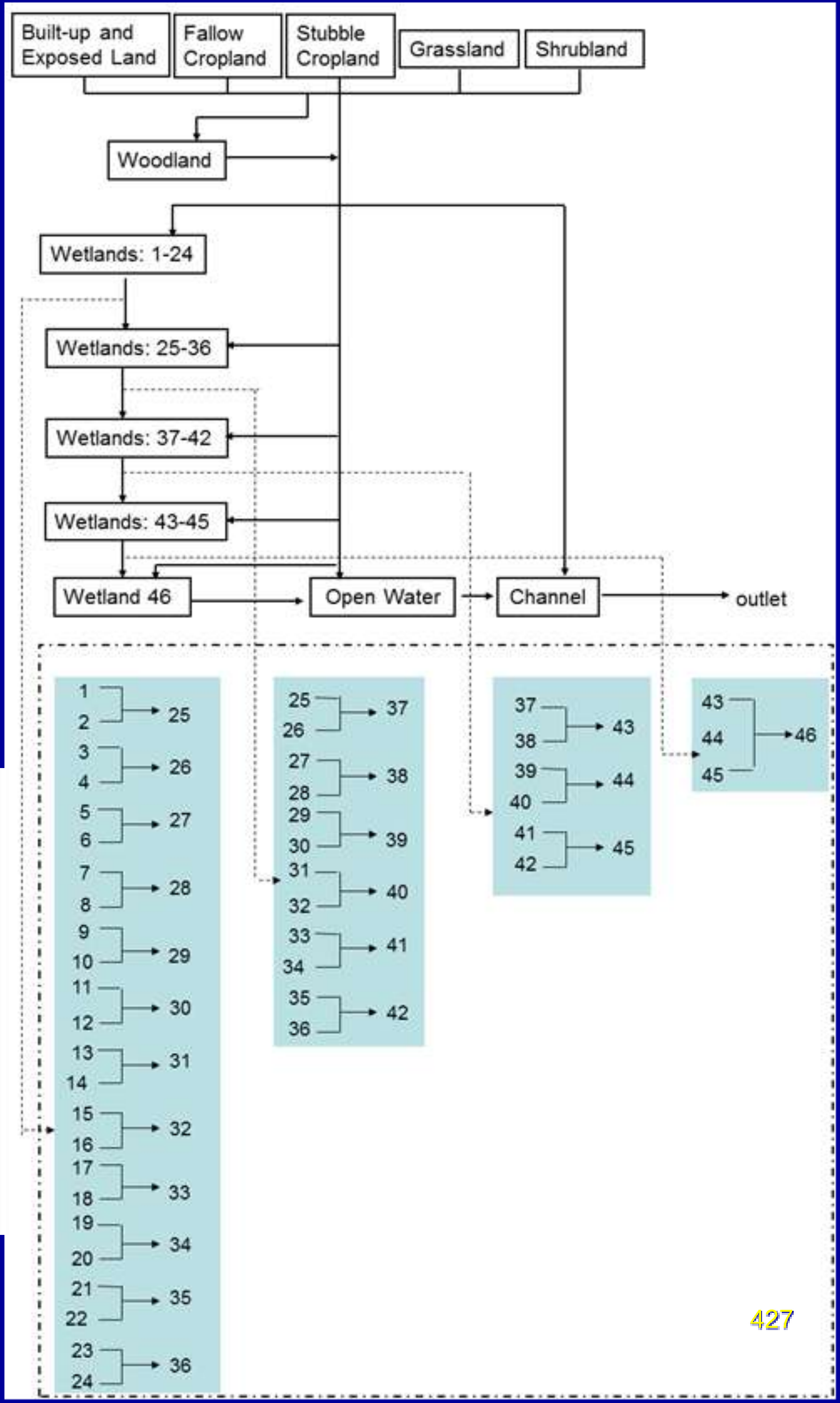
- Cold Regions Hydrological Modelling Platform (CRHM)
- Modules selected to describe hydrological processes operating in the basin.
  - Snow accumulation and melt
  - Wetland storage, drainage
  - Soil moisture storage, evapotranspiration and runoff
  - Stream routing
- Sub-basins broken into “hydrological response units” HRU corresponding to land use, drainage and soil zones.
- Sub-basins aggregated via routing module to describe total basin behaviour

Prairie Module Structure

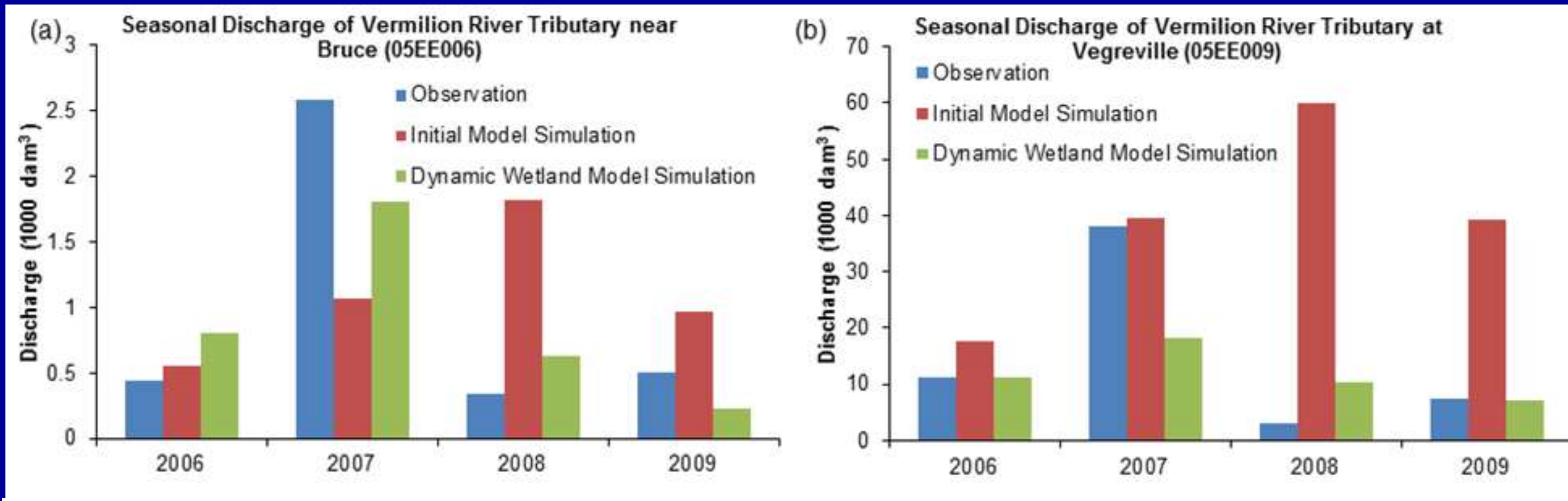


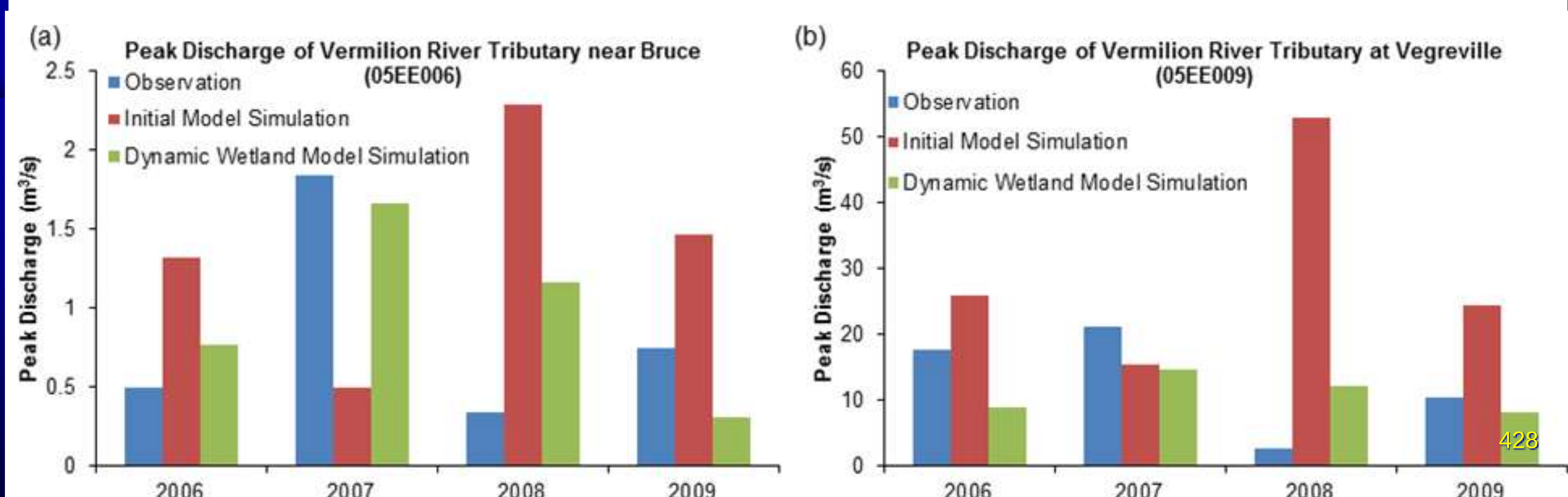
Basin and Wetland Representation





Dynamic Modelling of Wetlands Needed for Accurate Simulations

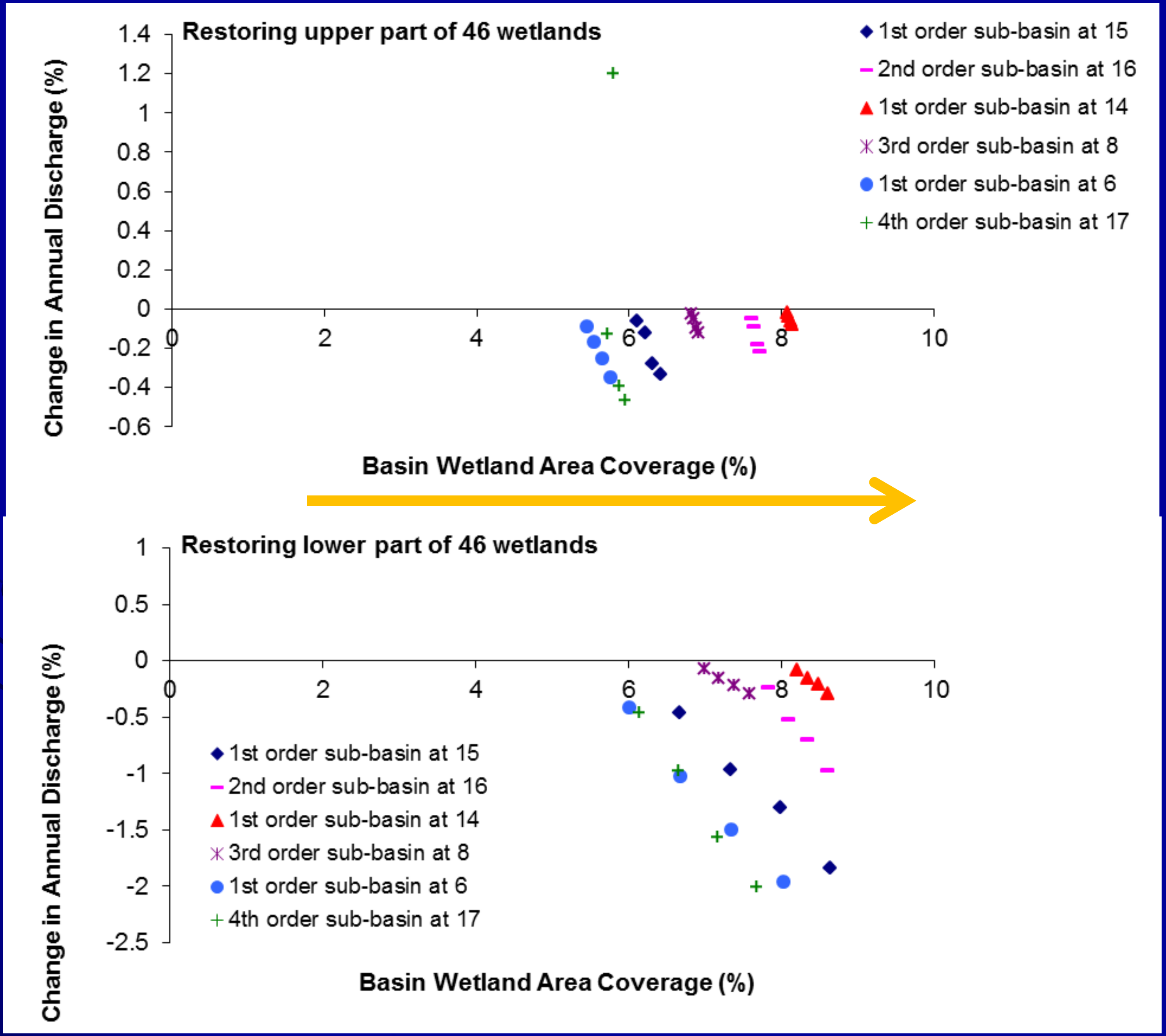




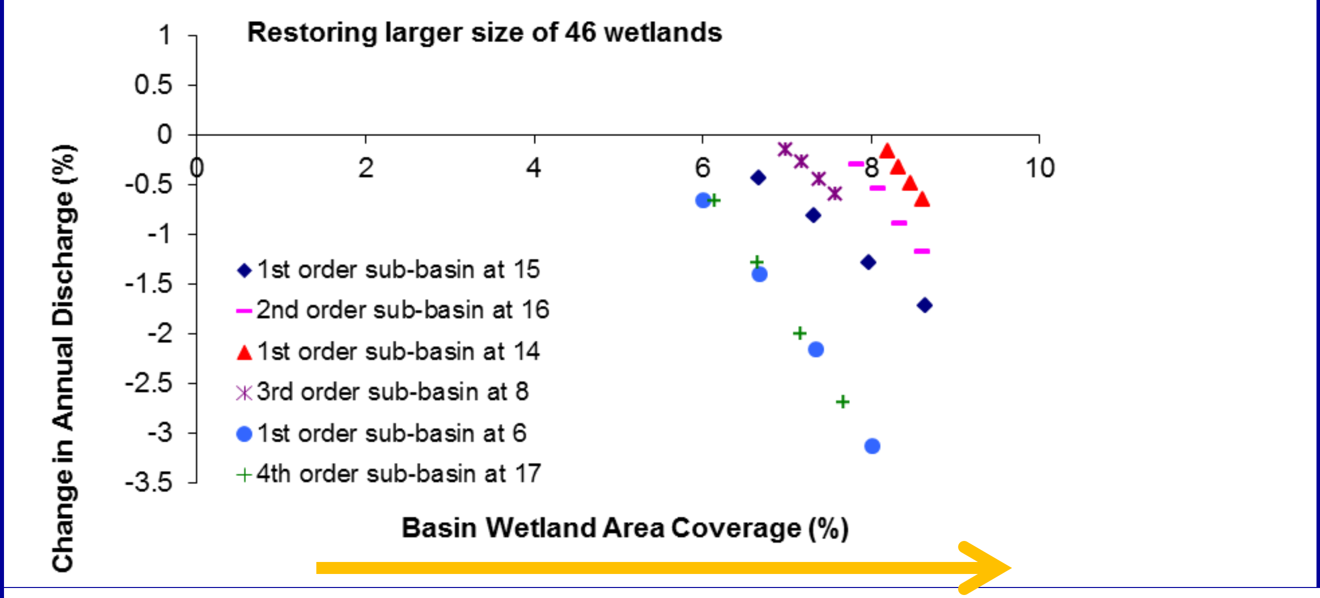
Sensitivity Analysis

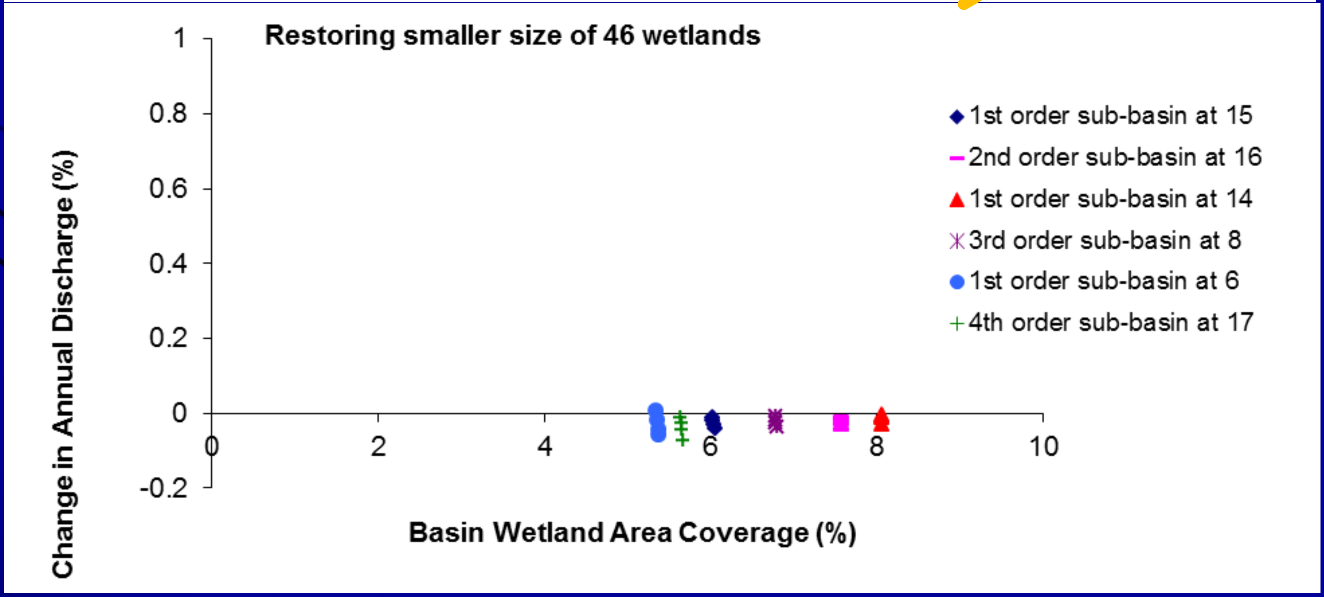
- Modelled sub-basins 6, 8, 13, 14, 15, 16, 17
- Years 2005-2009 with earlier spin-up years
- Wetland Restoration – all wetlands restored to 1949 levels
    - Spatial Wetland Restoration – upper vs lower basin
    - Wetland Size Restoration – large vs small
- Wetland Drainage – all wetlands drained
    - Spatial Wetland Drainage – upper vs lower
    - Wetland Size Drainage – large vs small
- Note relatively small area of wetlands (6%) and little apparent drainage since 1949 (then 7.4%)

Upper vs Lower Sub-Basin Location Wetland Restoration

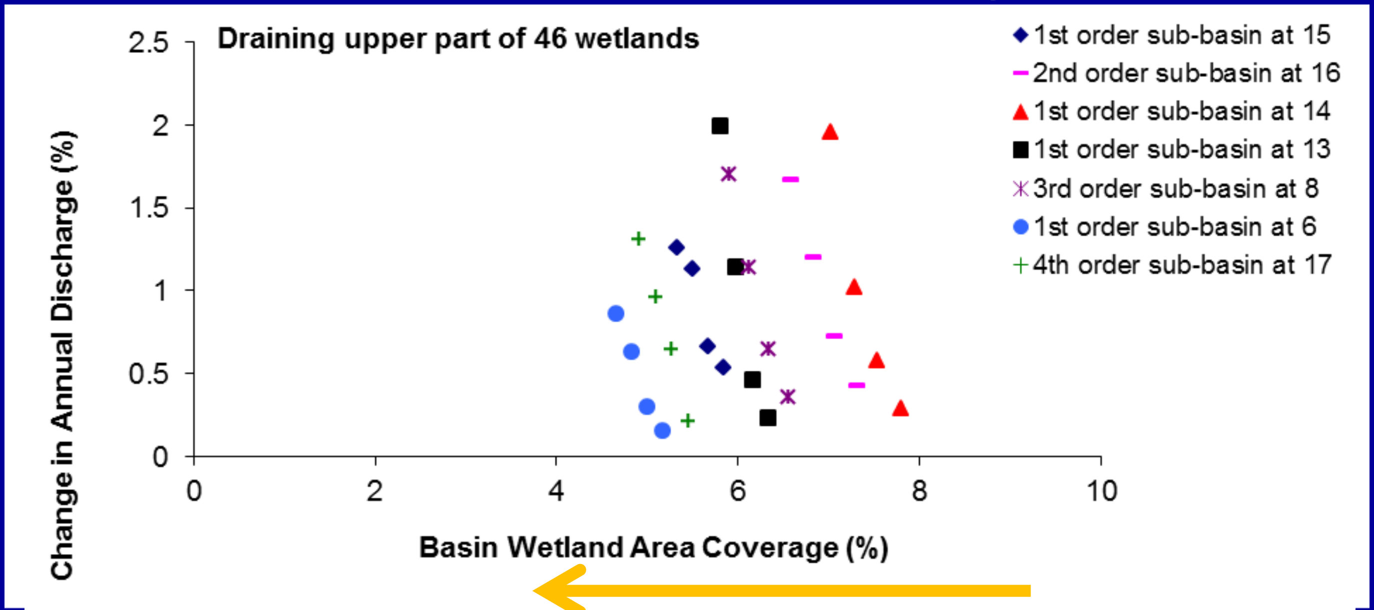


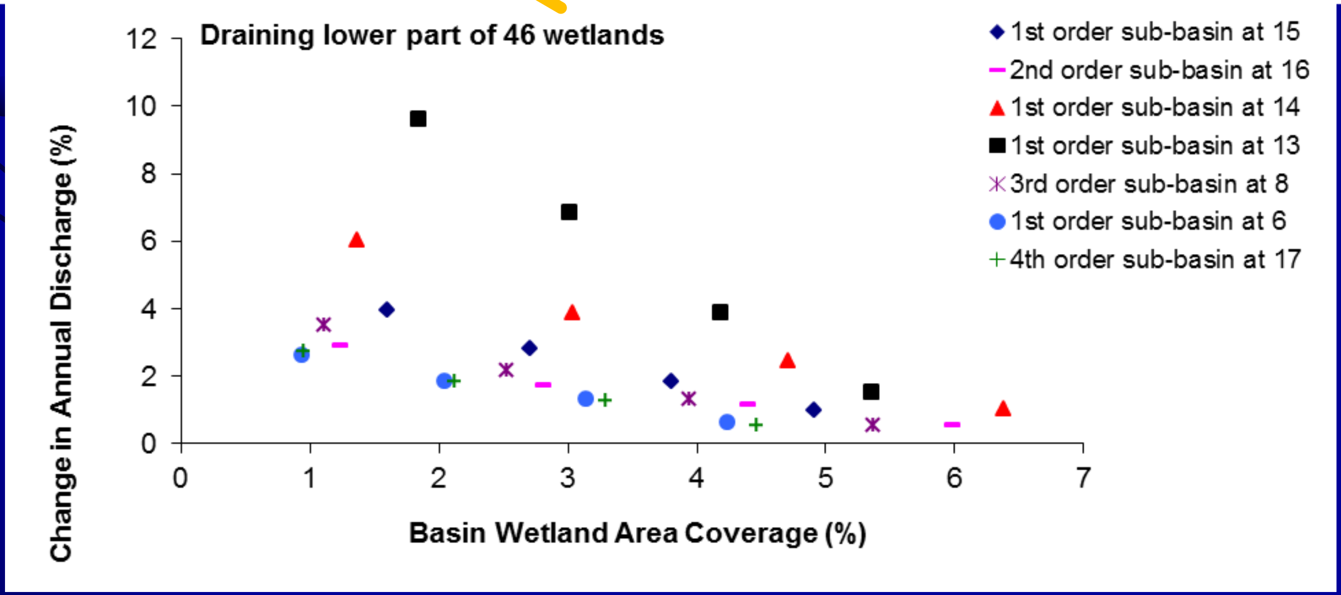
Large vs Small Size Wetland Restoration



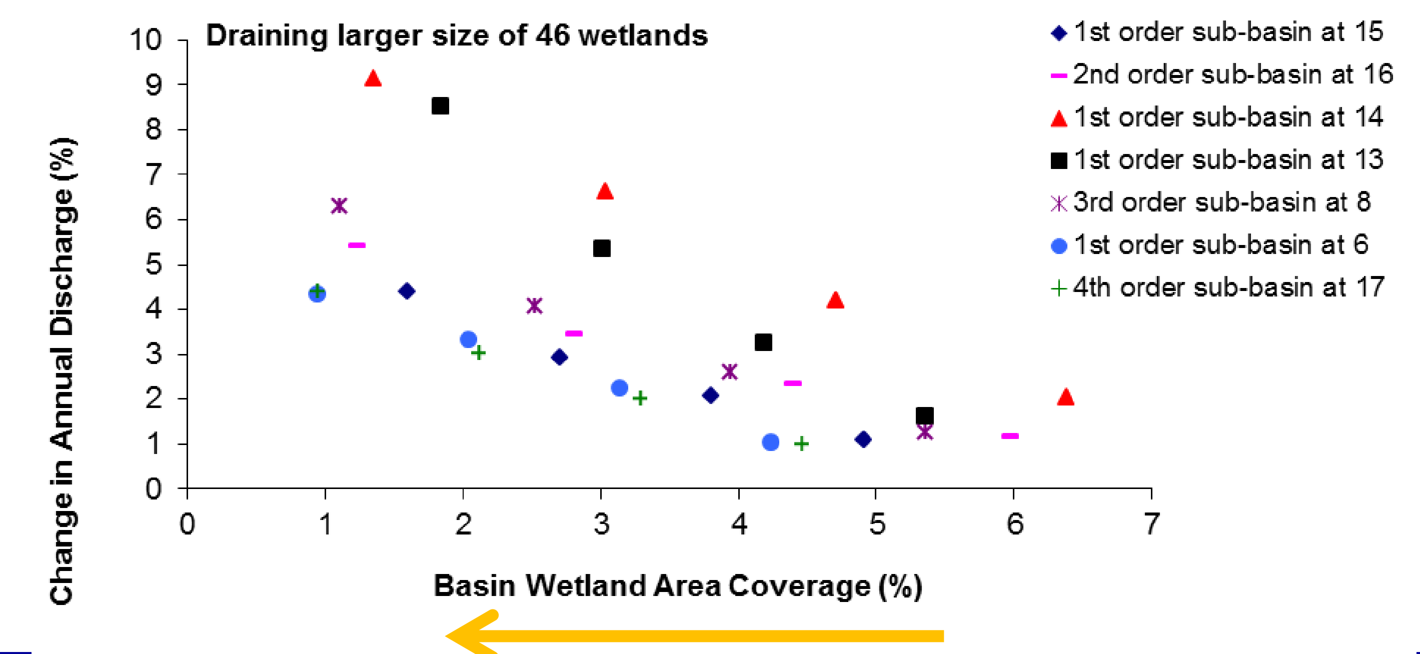


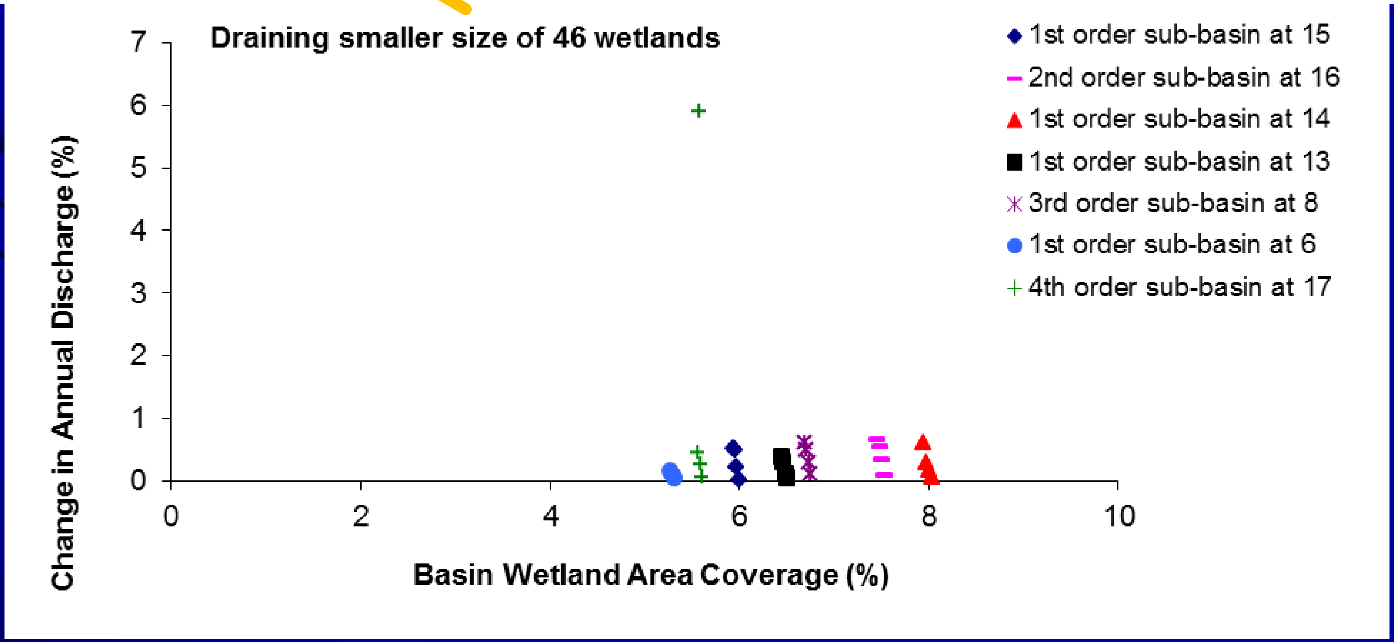
Upper vs Lower Sub-basin Location Wetland Drainage





Larger vs Smaller Wetland Drainage

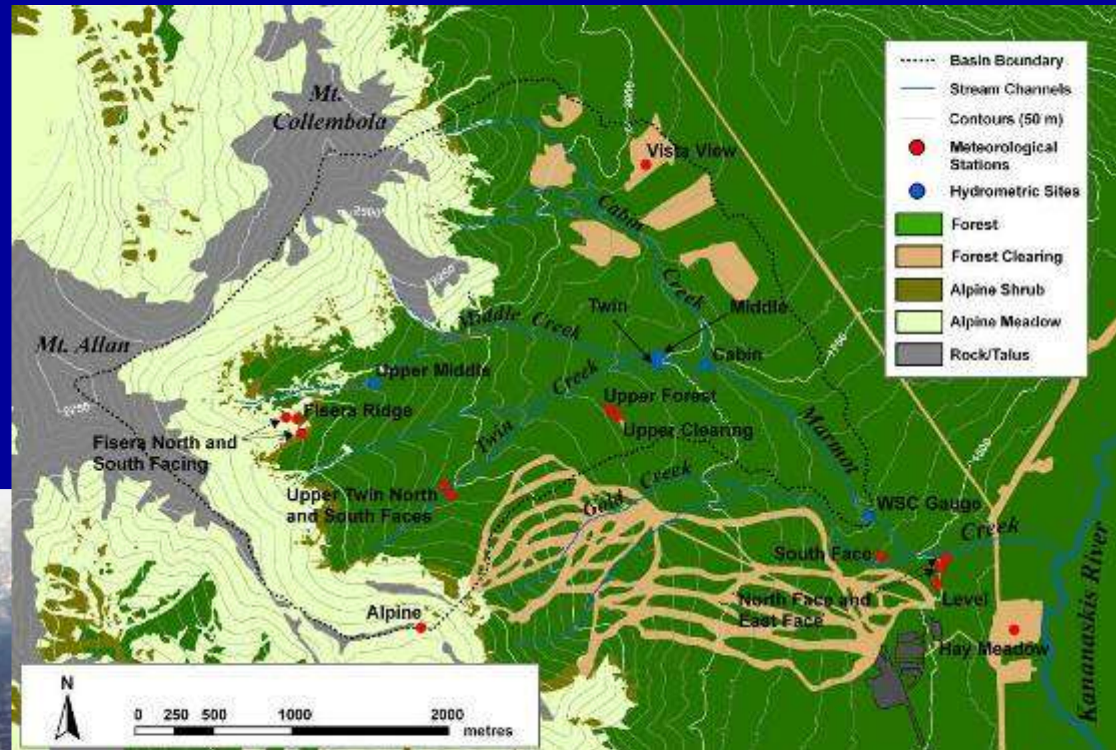


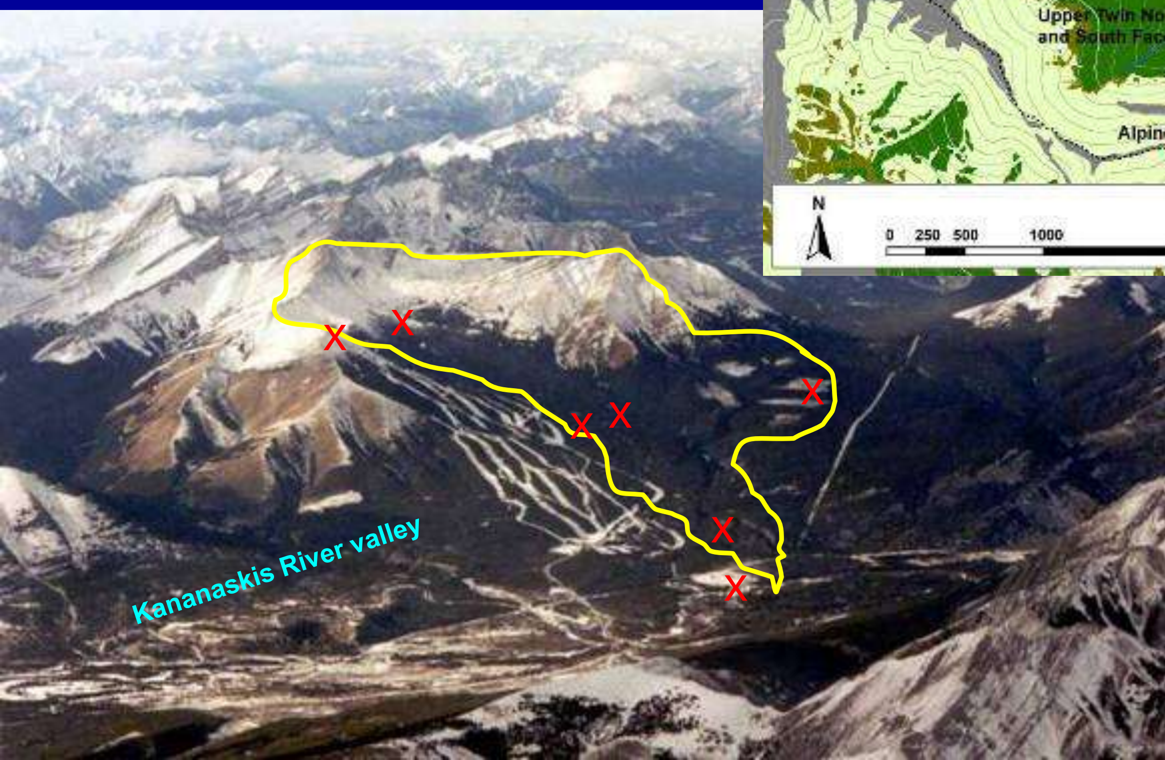


Vermilion River Basin Wetland Modelling Findings

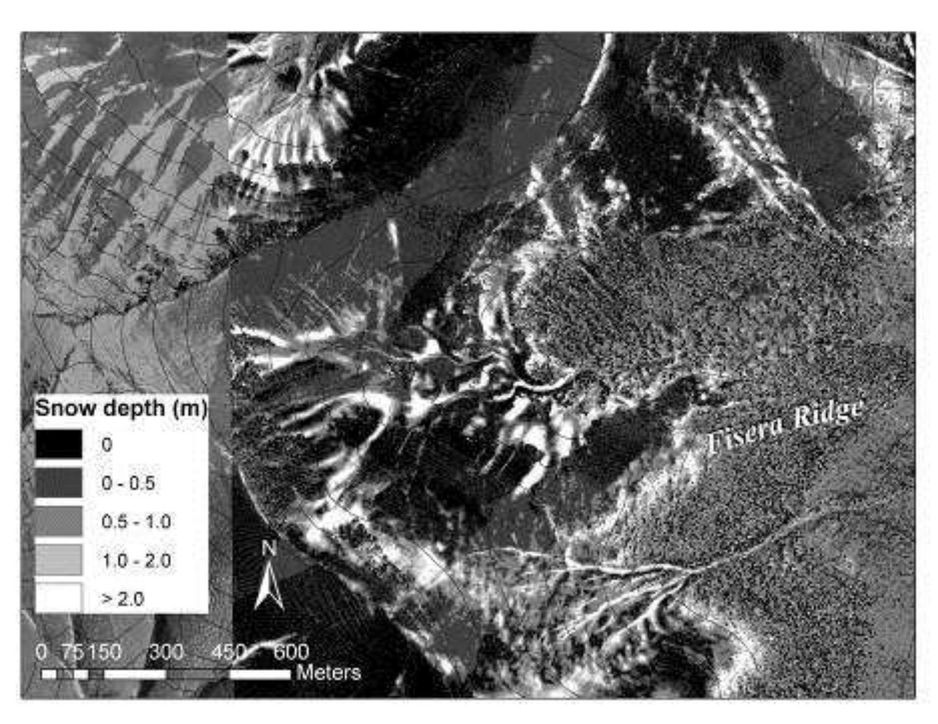
- Hysteresis affects the relationship between wetland water storage and contributing area, requiring explicit modelling of wetland dynamics in Prairie hydrology.
- Wetland restoration in the lower part of the sub-basins and for larger wetlands is most effective in reducing streamflows.
- Wetland drainage in the lower sub-basin and for larger wetlands is most effective in increasing streamflows.

Marmot Creek Research Basin

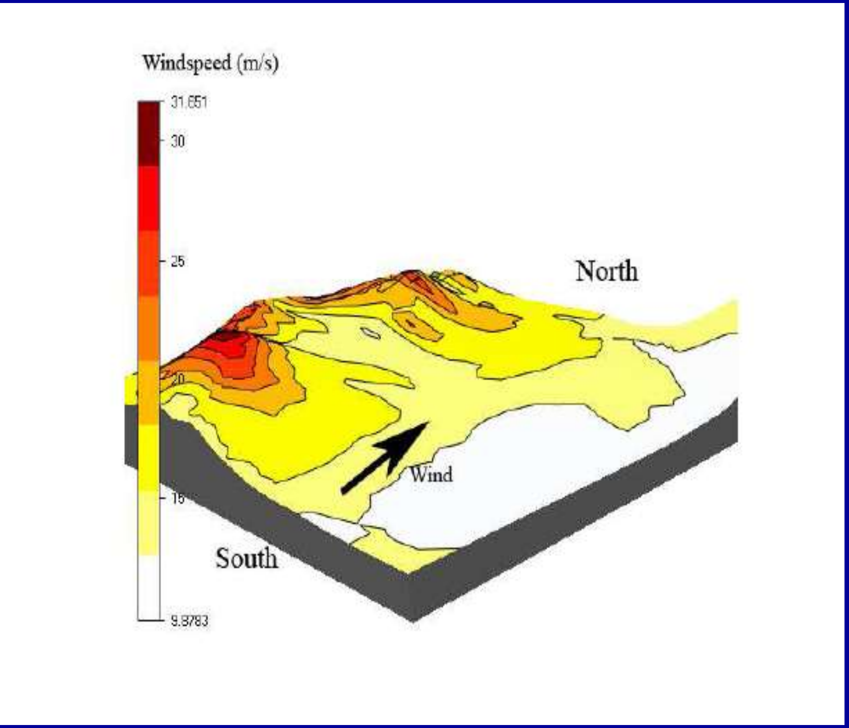




How to Determine HRU for Mountain Snow Redistribution?



LiDAR derived snow depth: subtraction of summer elevations from late winter elevations provides alpine snow depth

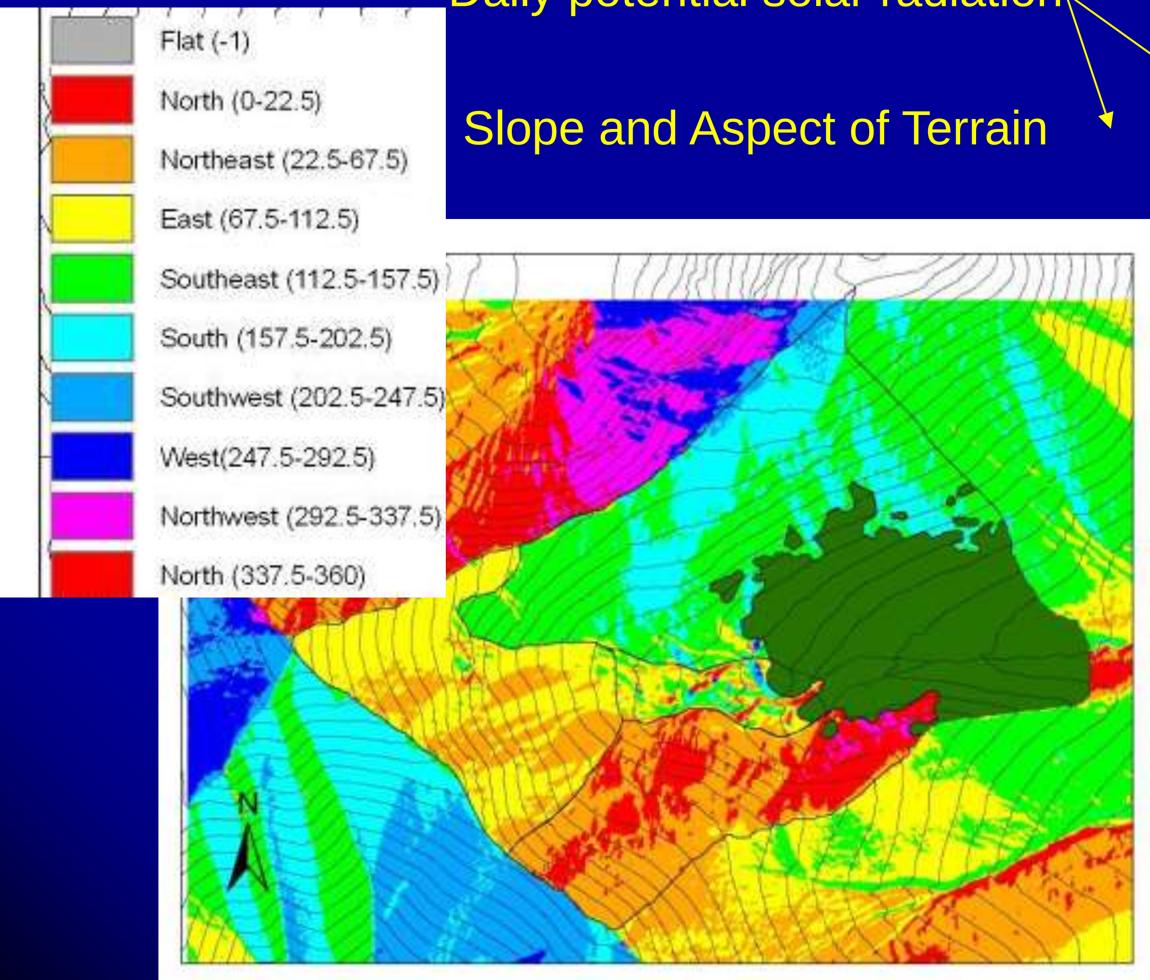


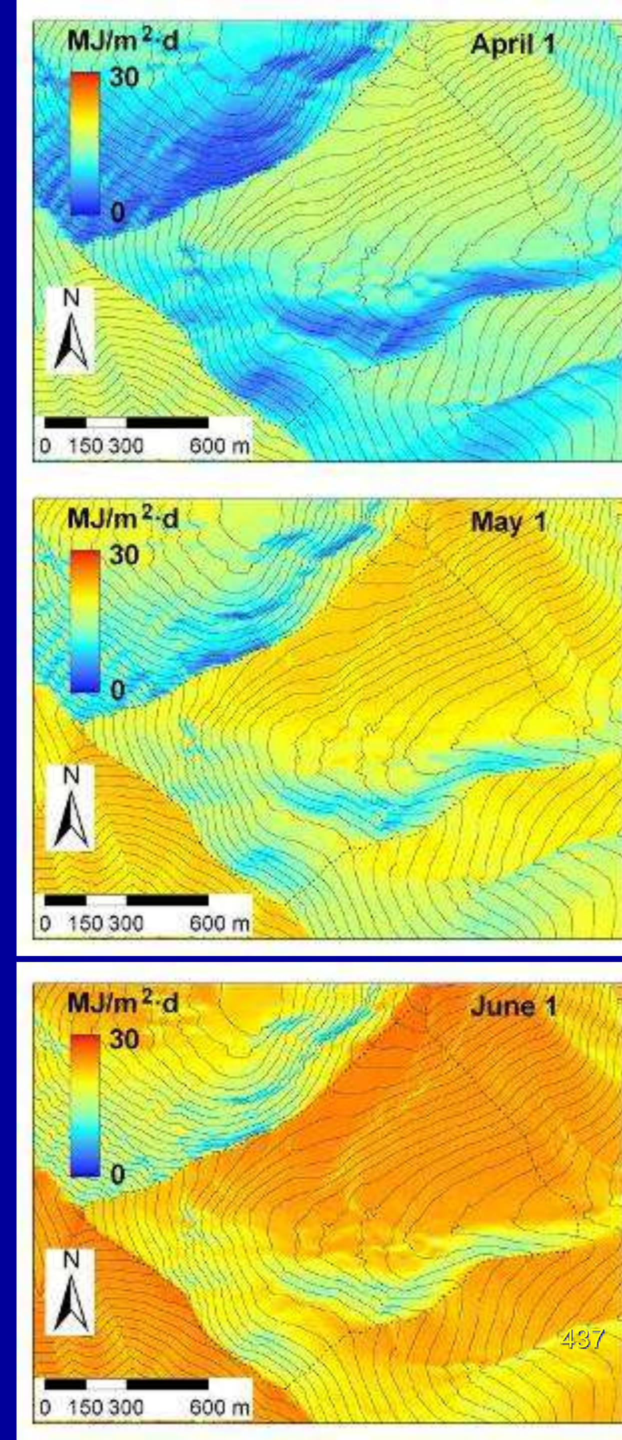
3D Reynolds averaged Navier-Stokes equations used for wind flow modelling over Marmot Creek topography (WindSim)

How to Determine HRU for Snow Melt?

Daily potential solar radiation

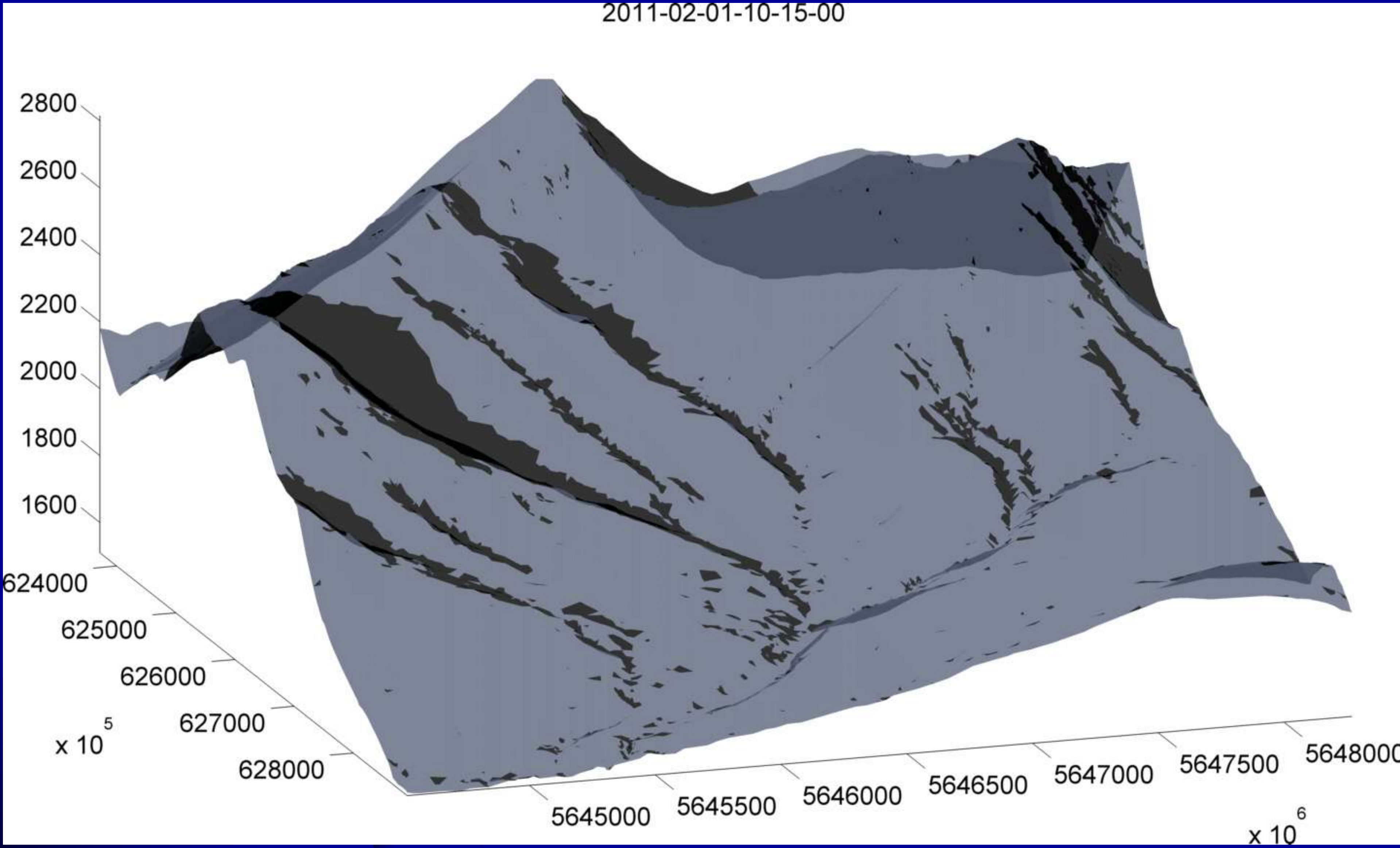
Slope and Aspect of Terrain





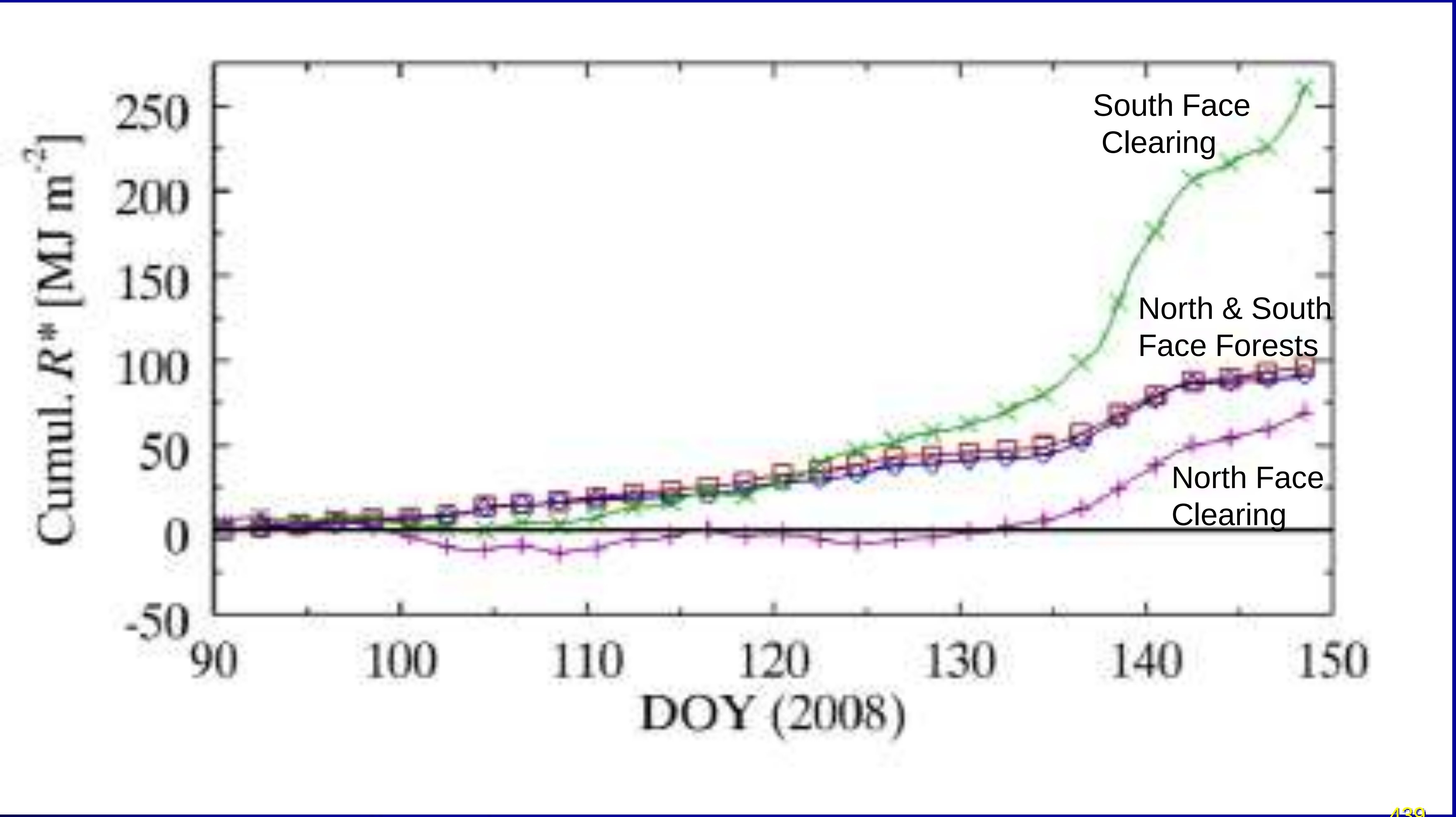
DeBeer

Shadow Migration Over a Day in Early Feb



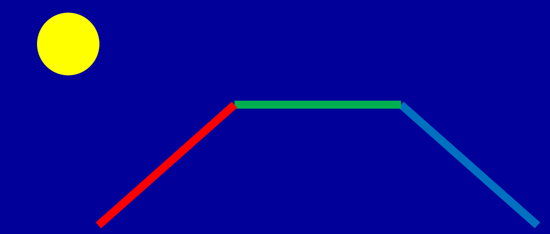
Chris Marsh, PhD

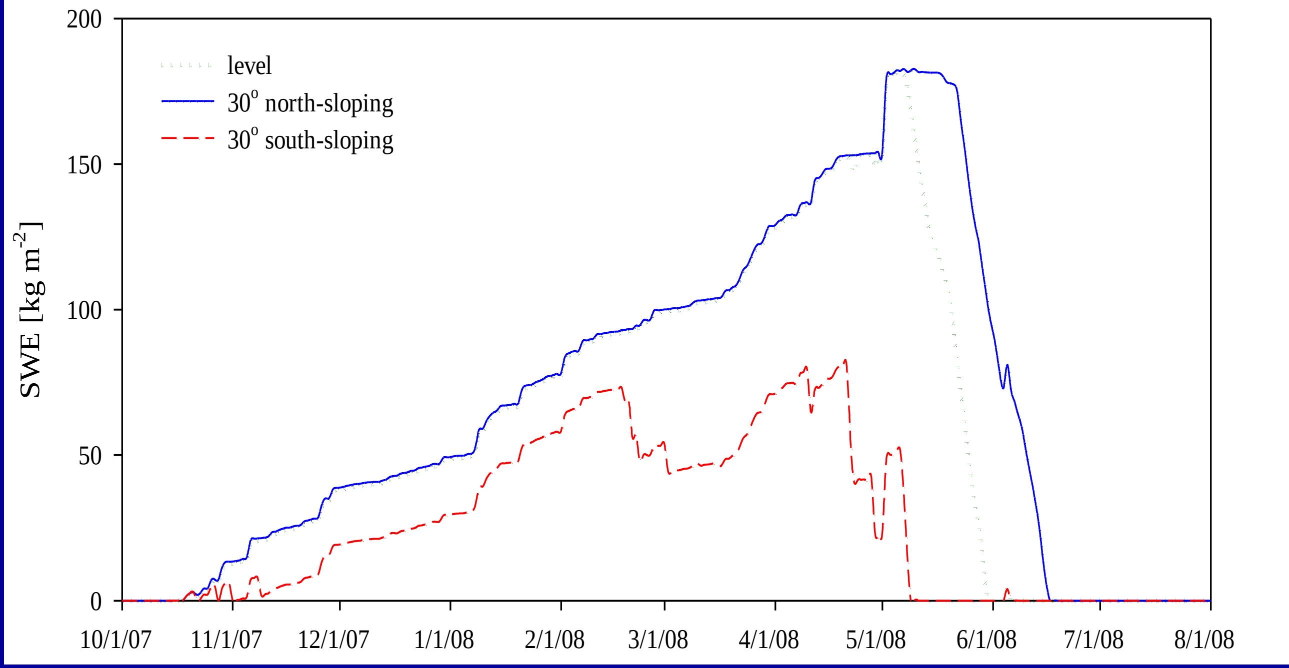
Net Radiation to Forests: Slope Effects



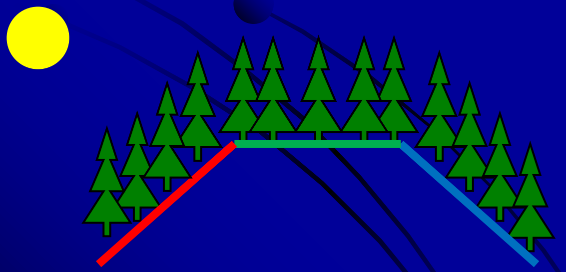
Ellis

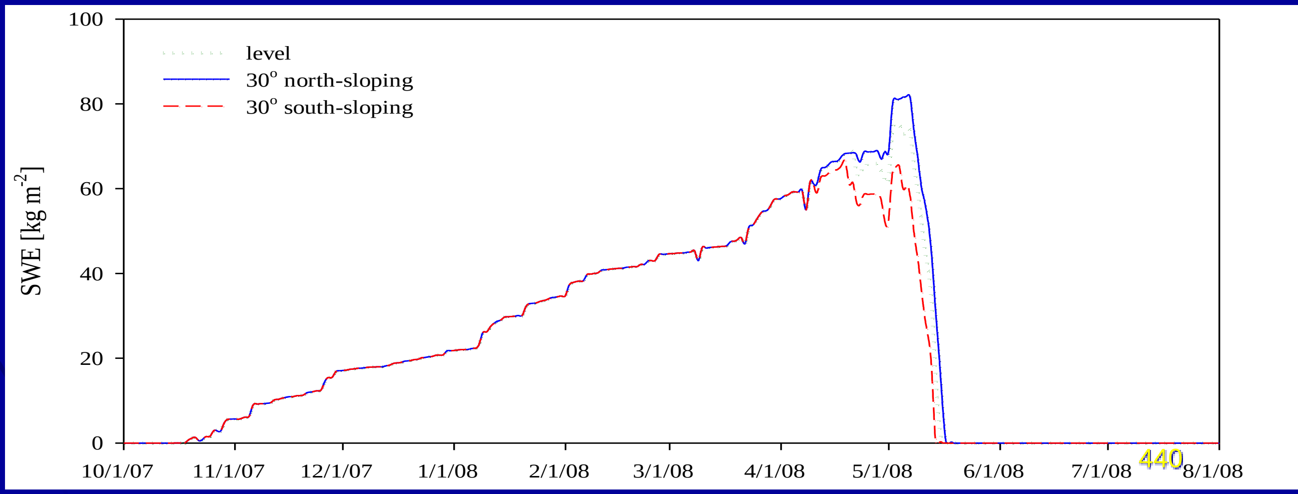
Forest Snow Regime on Slopes



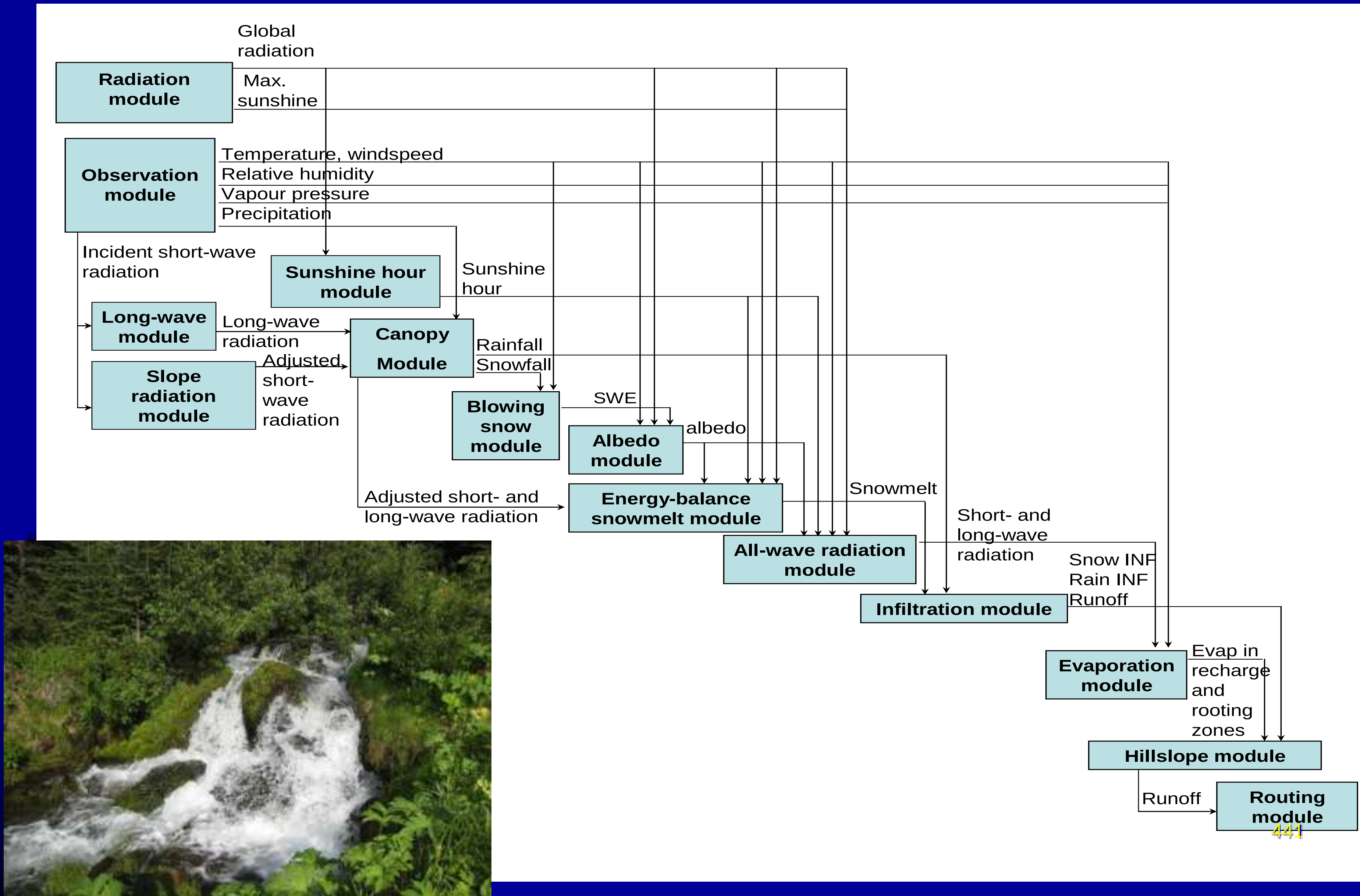


Open slopes highly sensitive to irradiation difference, forests are not

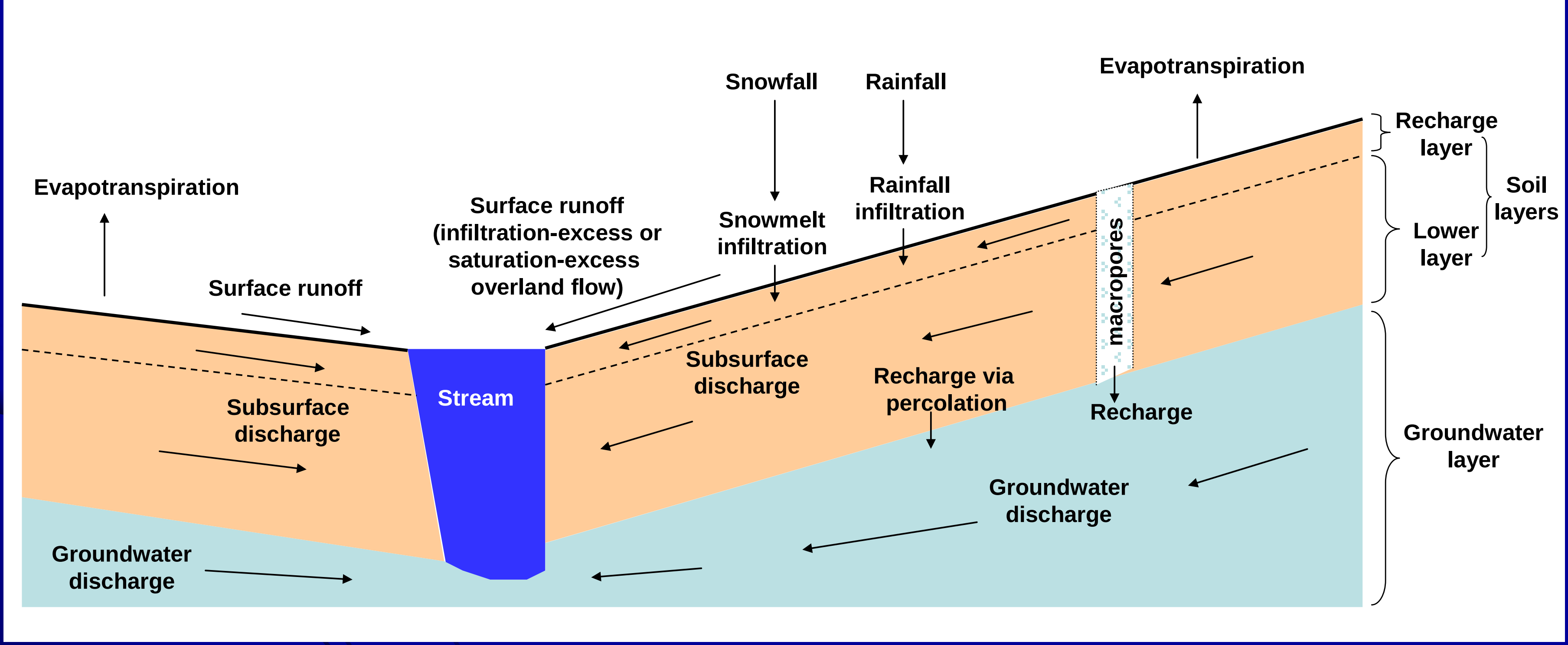




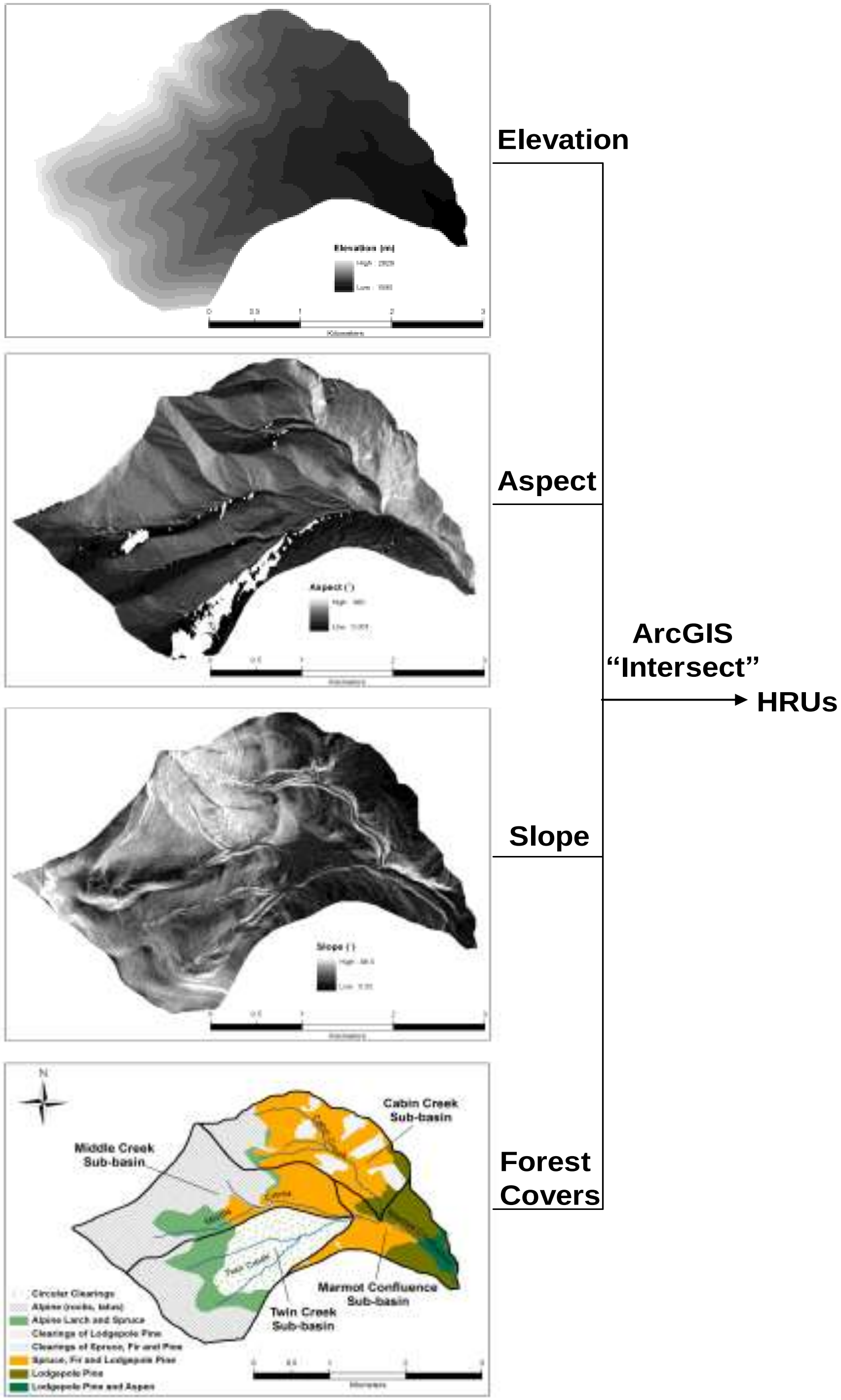
CRHM Mountain Structure



Mountain Hillslope Hydrology

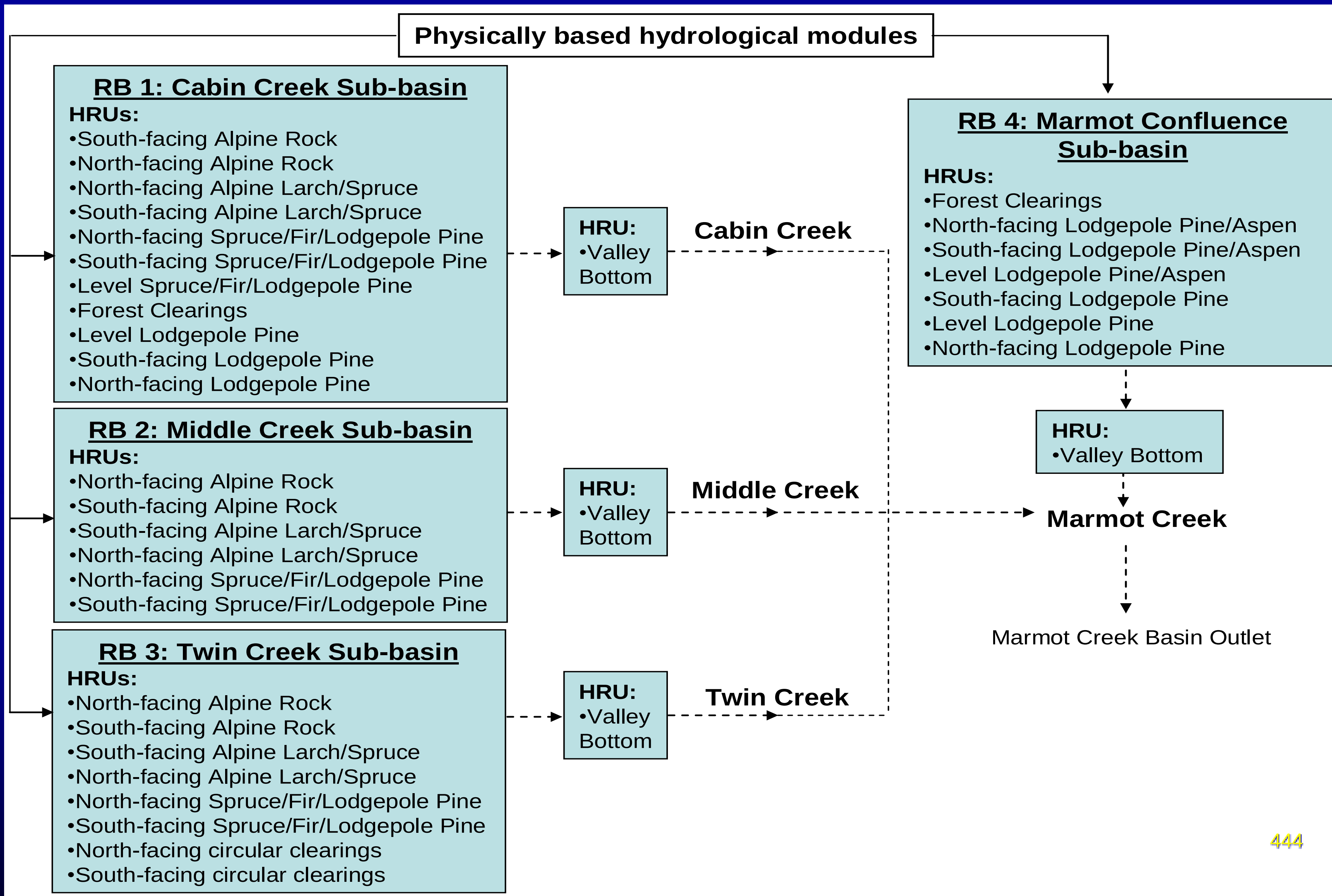


HRU Delineation

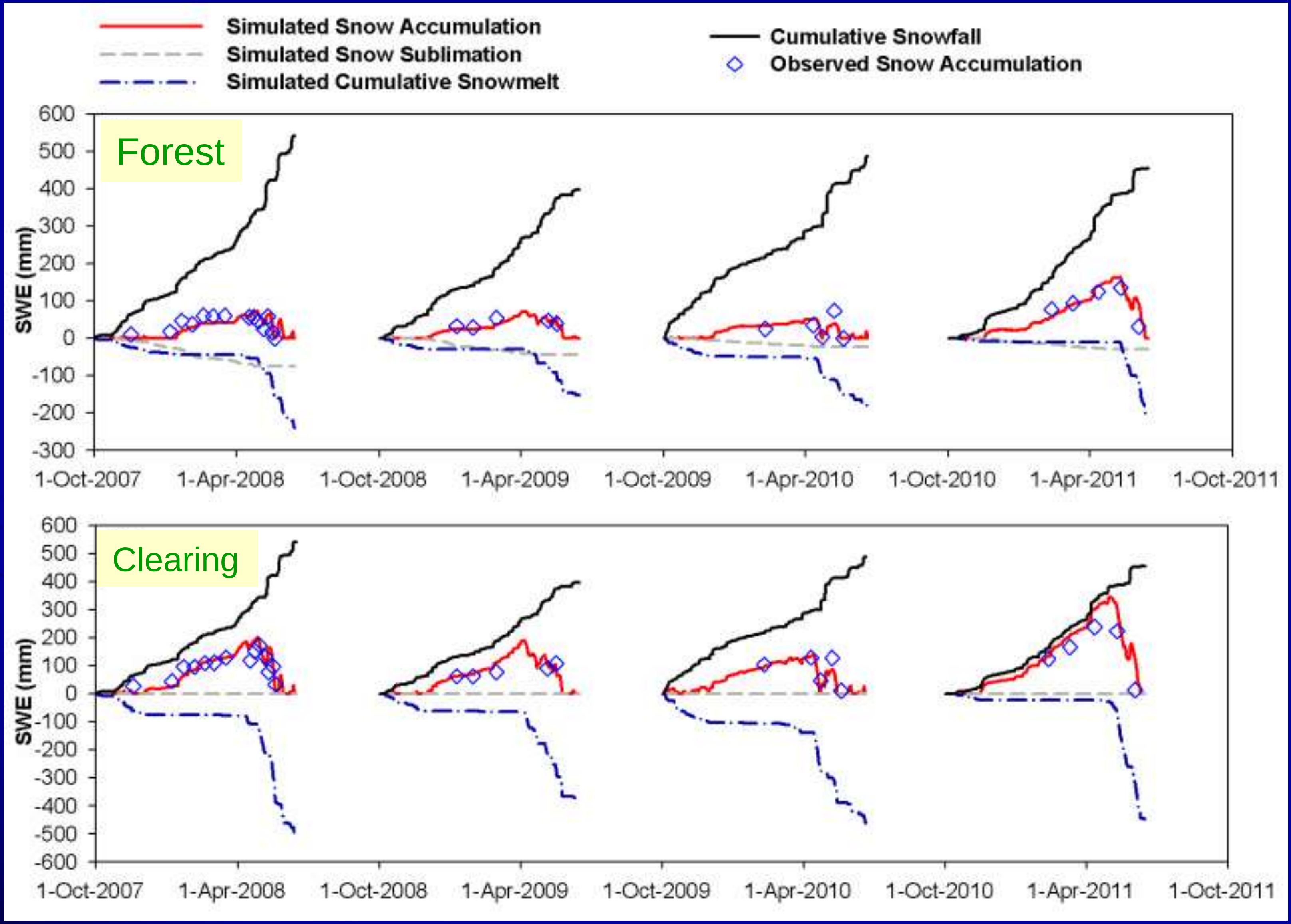


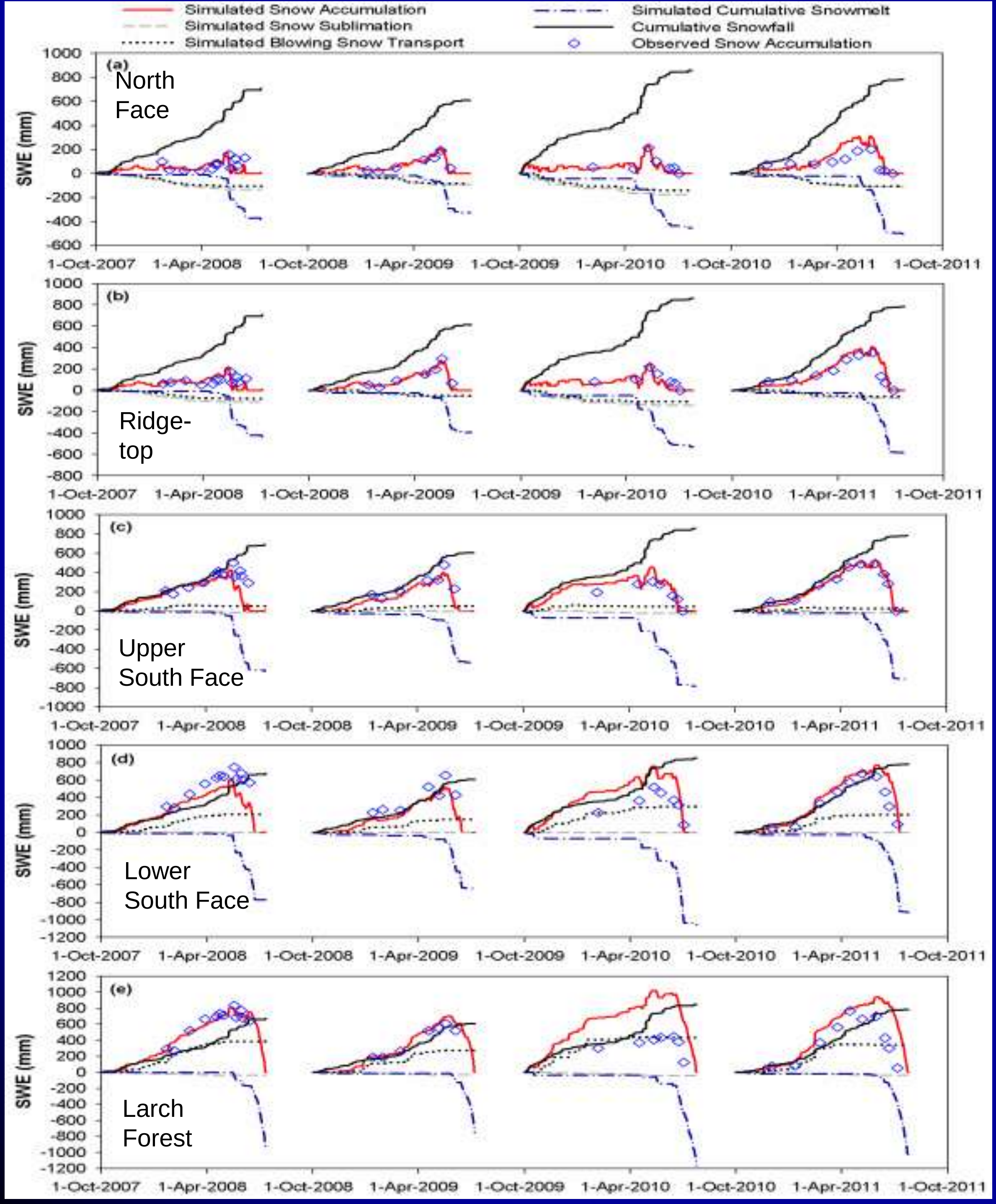
- Driving meteorology: temperature, humidity, wind speed, snowfall, rainfall, radiation
- Blowing snow, intercepted snow
- Snowmelt and evapotranspiration
- Infiltration & groundwater
- Stream network

Model Structure



Forest Snow Dynamics Simulations

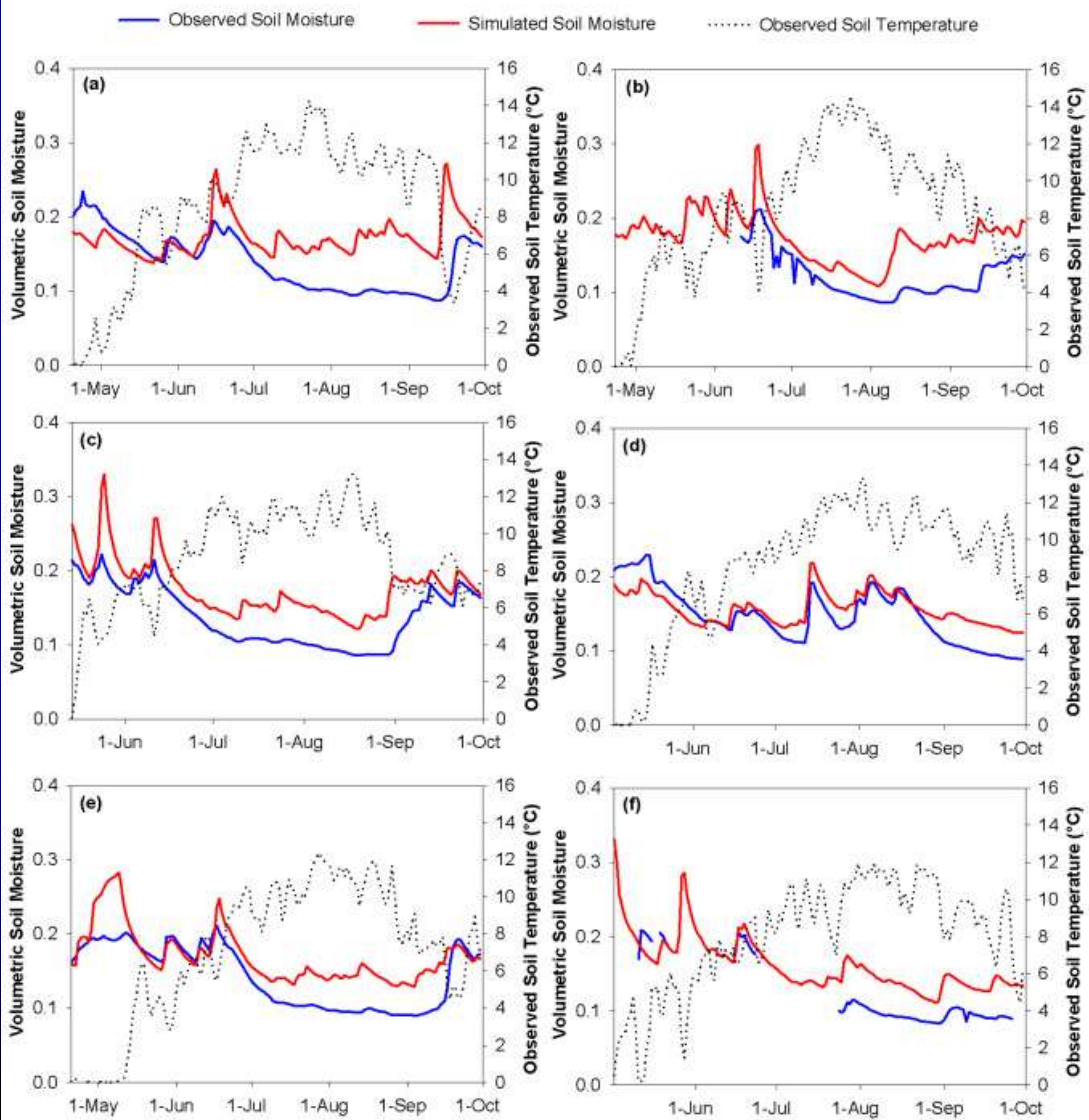




Alpine Snow Dynamics Simulations

Snow redistribution from north face and ridgetop to south face and larch forest

uncalibrated

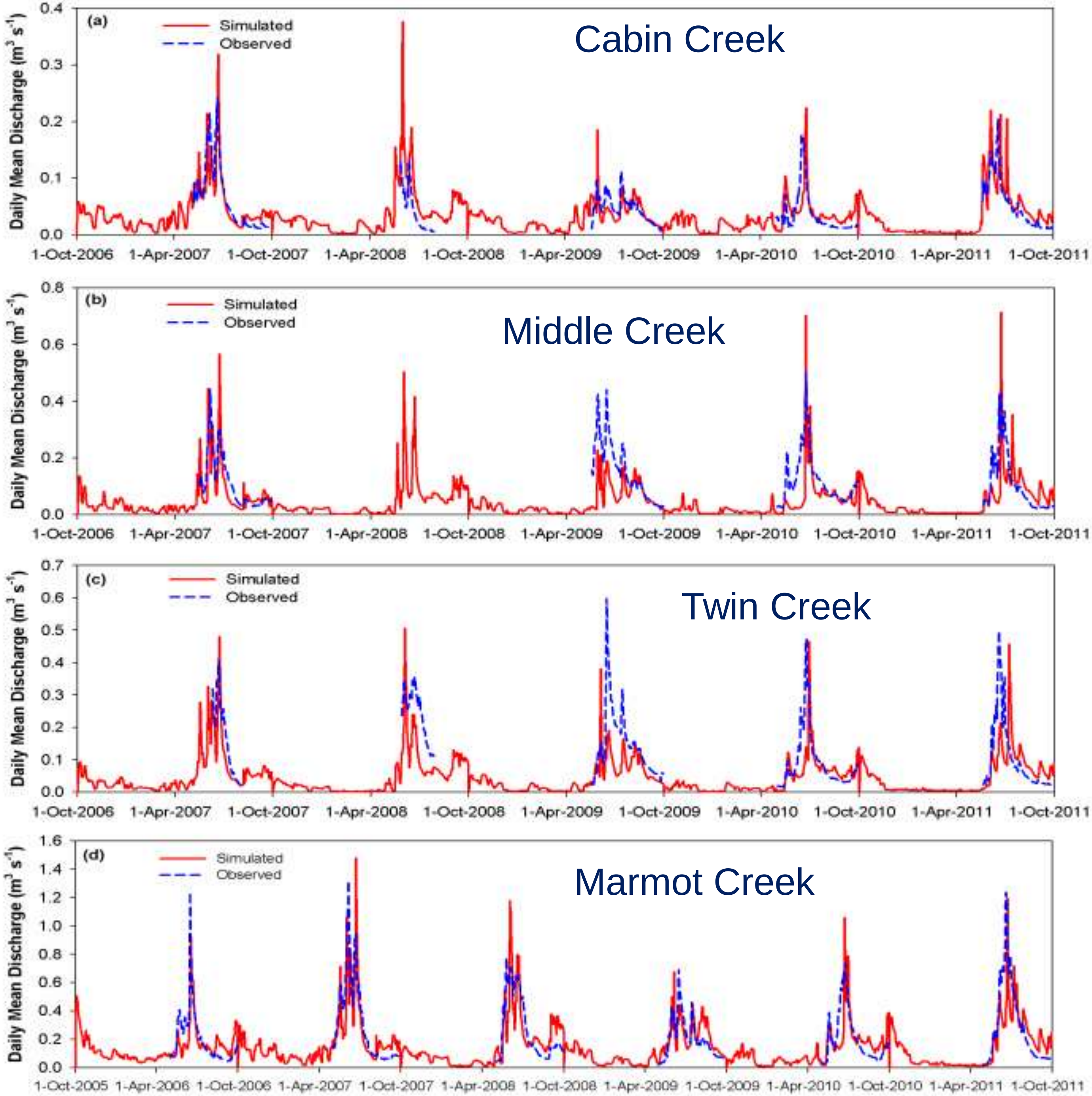


Model Tests: Soil Moisture

2006-2011

Level Forest Site

Uncalibrated



Uncalibrated Streamflow Simulation

N-S increases with basin scale to 0.58

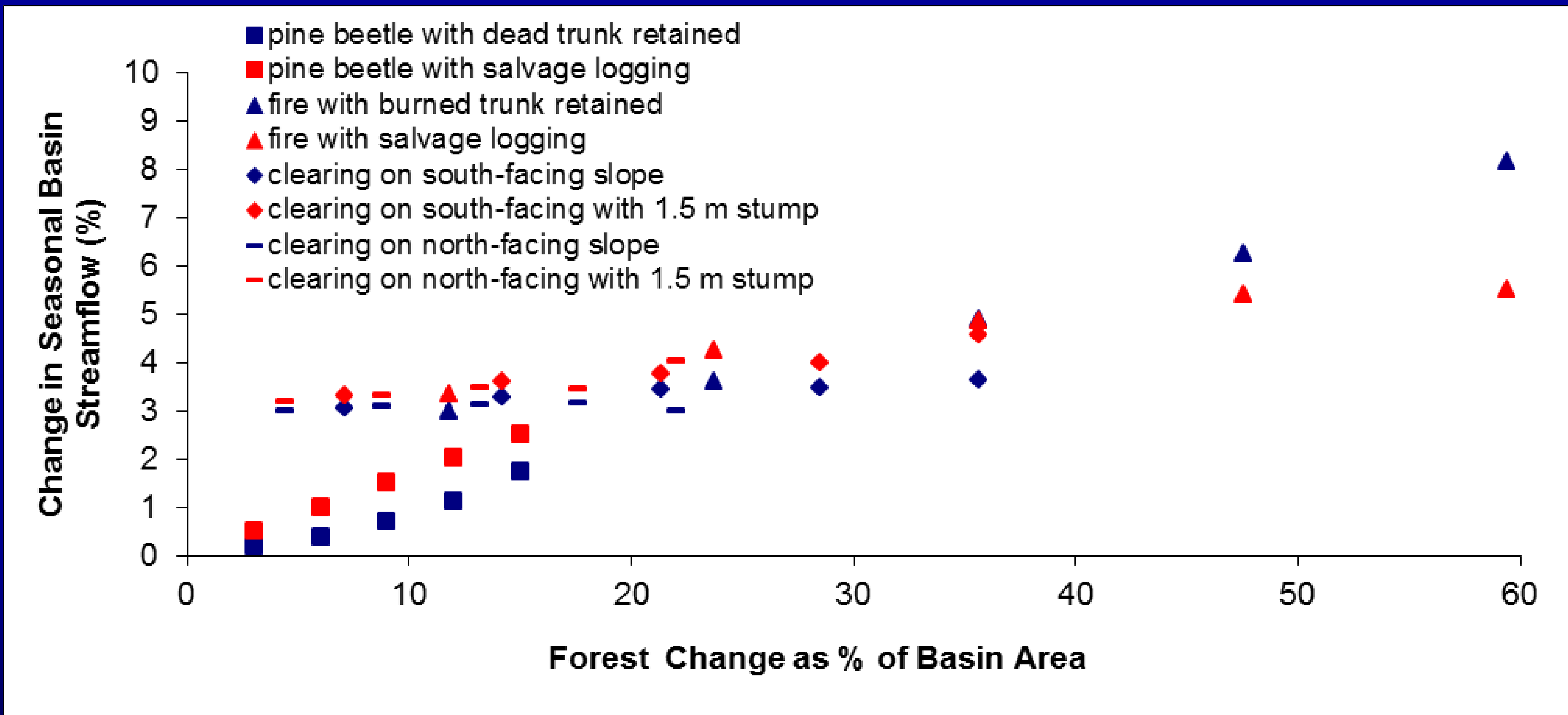
MB = 0.01 for Marmot Creek

Fang et al. HESS 2013 in review

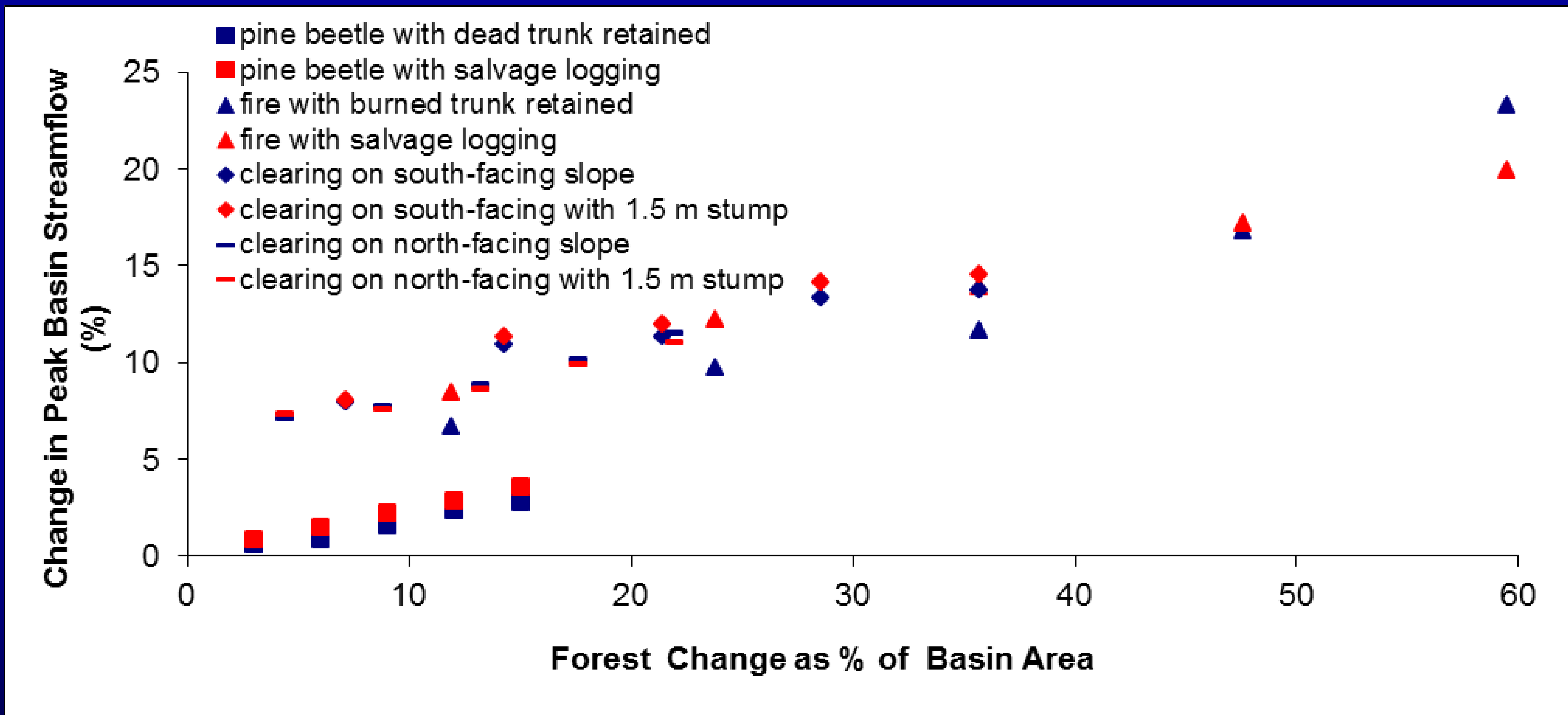
Application: Forest Cover & Climate Change

- Progressive canopy removal due to
  - Pine beetle removal of lodgepole pine canopy
  - Burning of all canopy, with and without salvage logging
  - Selective harvesting of canopy on north and south facing slopes, with and without 1.5 m trunk retention after harvesting
- Climate change: sensitivity analysis to rising air temperatures

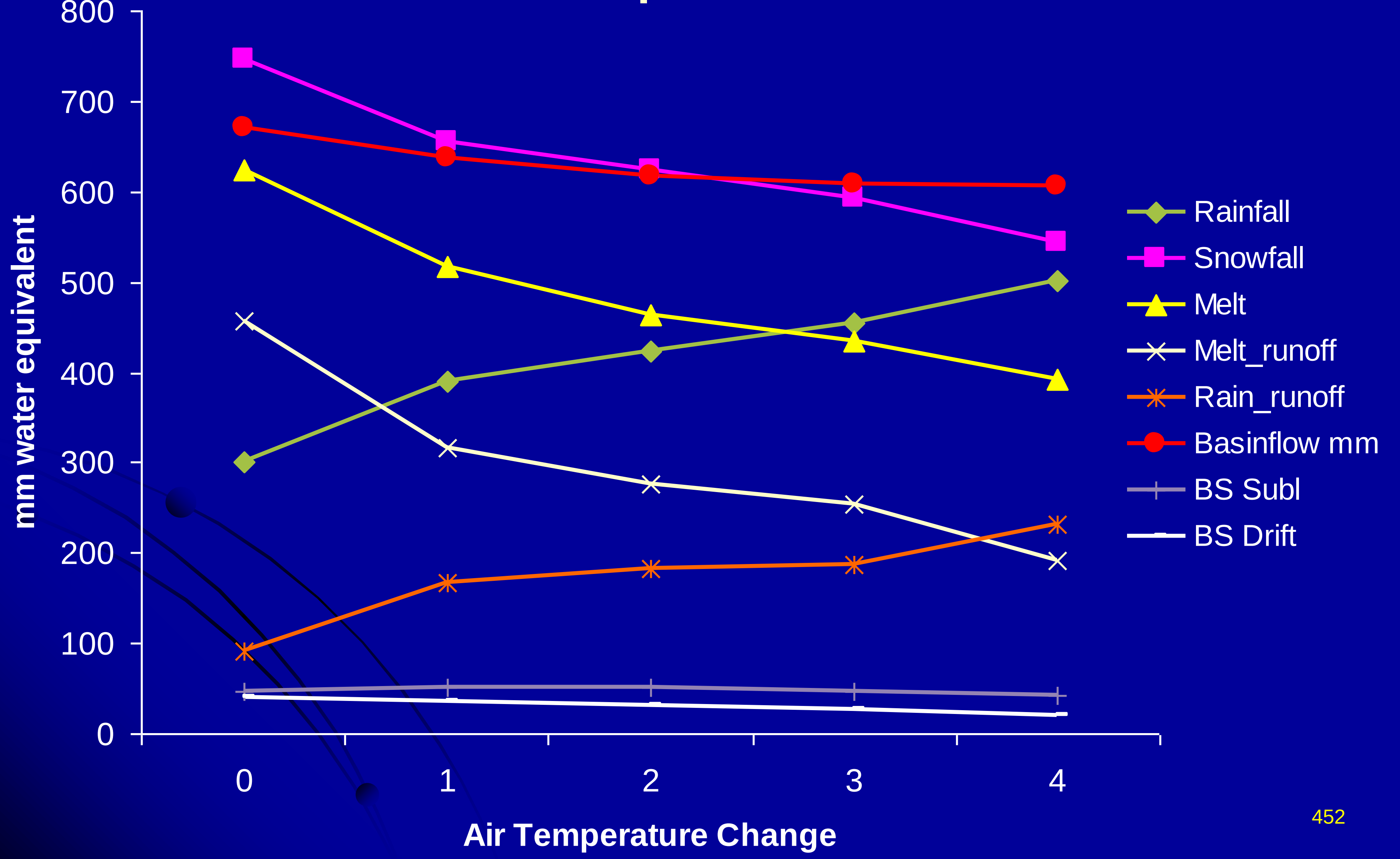
Forest Cover Disturbance Impact on Seasonal Streamflow



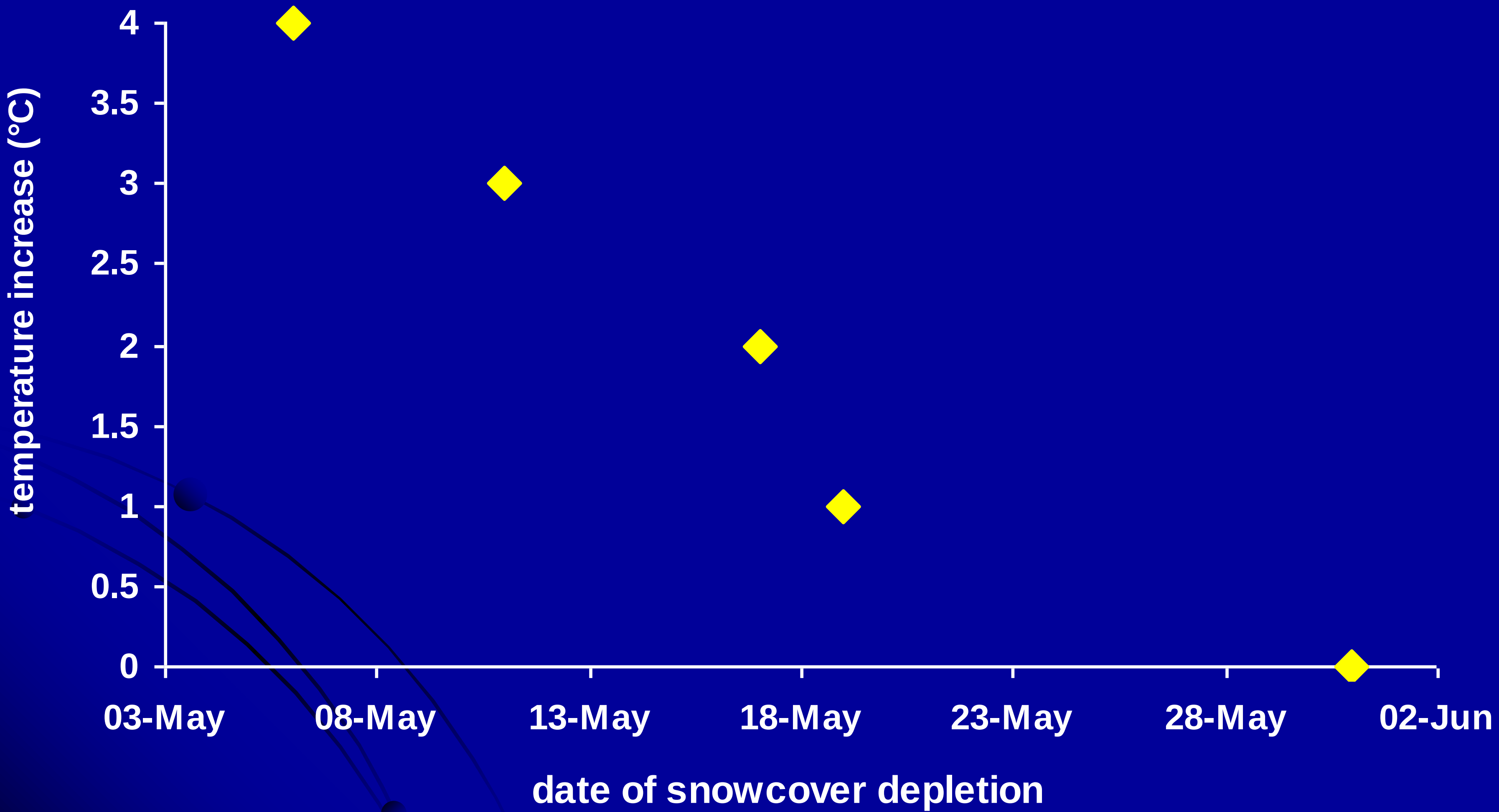
Forest Cover Disturbance Impact on Peak Streamflow



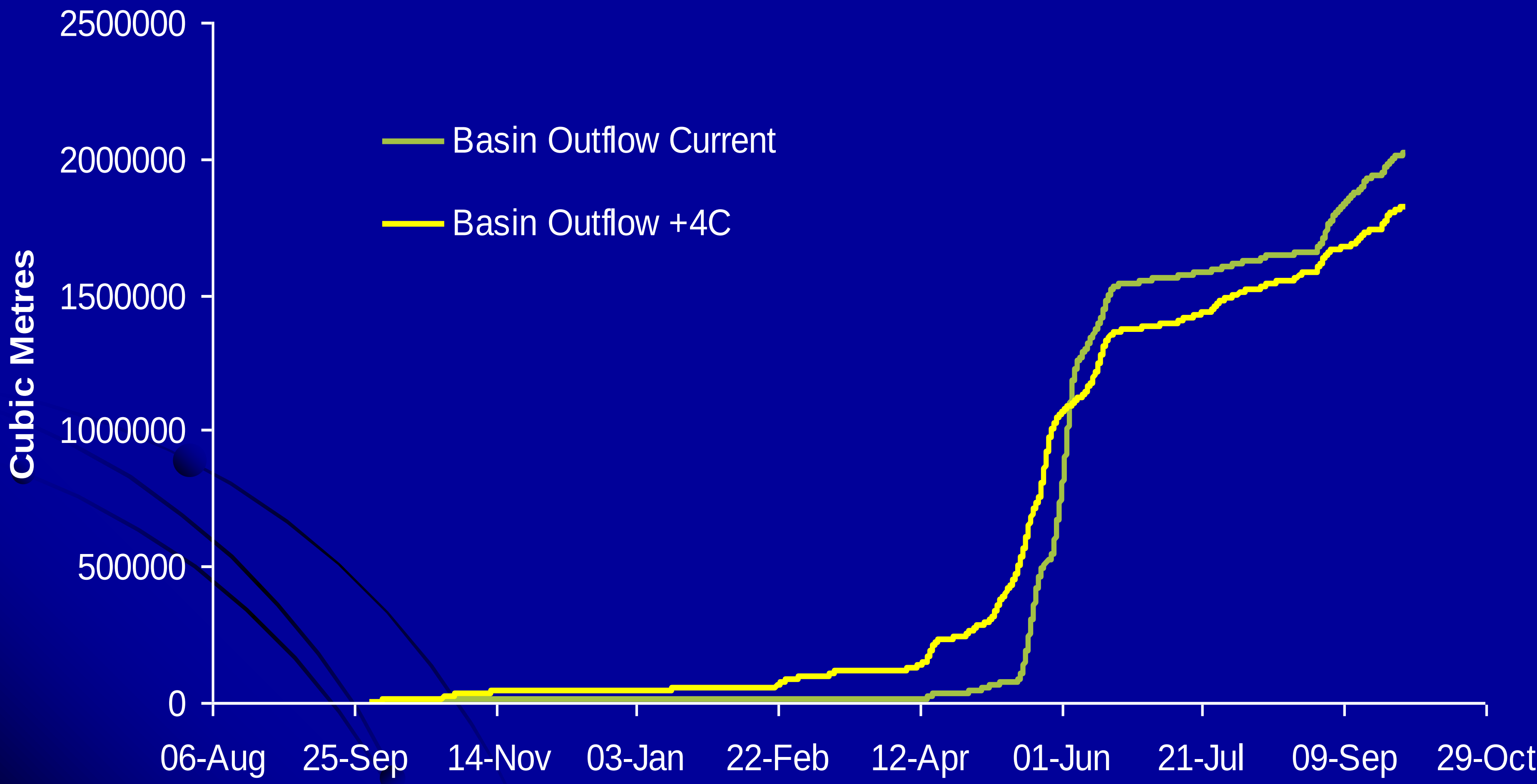
Alpine Hydrology Change with Rising Temperature



Impact of Winter Warming on Date of Snowpack Depletion



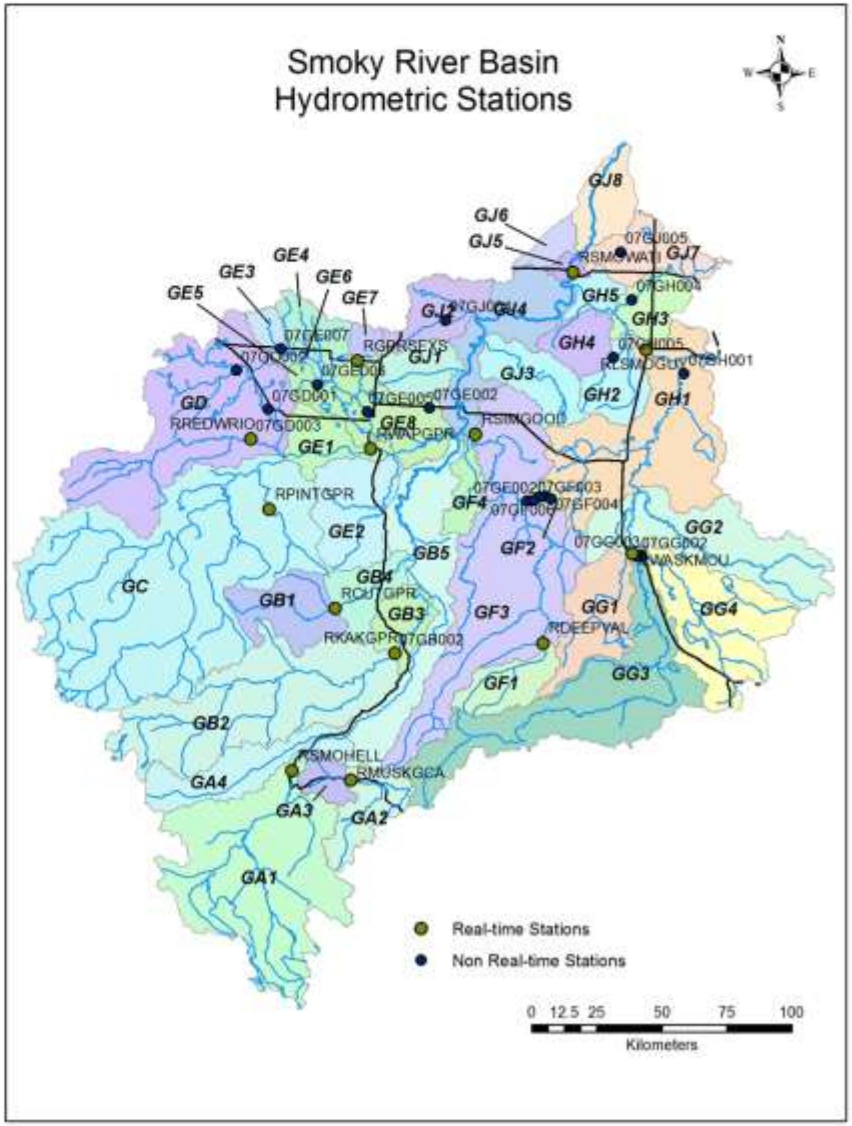
Change in Alpine Basin Discharge

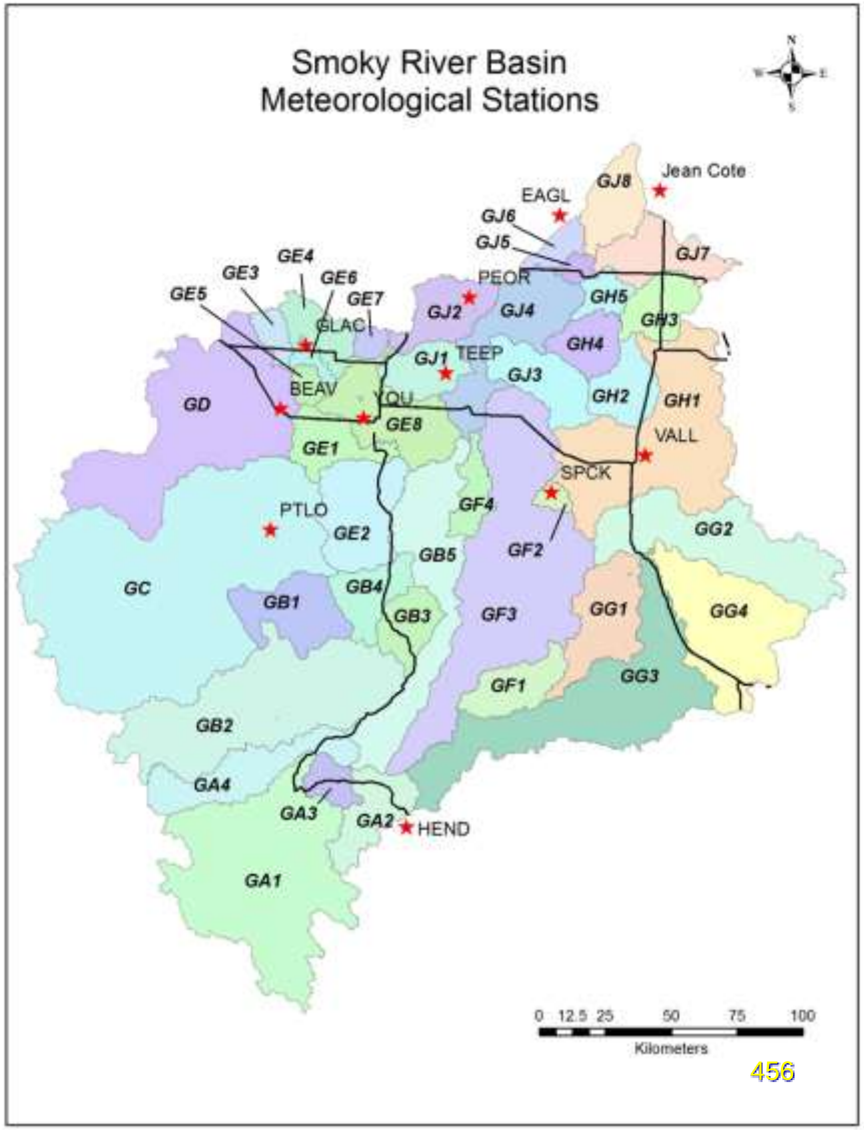


Application: Operational Forecasting of Ungauged Flows

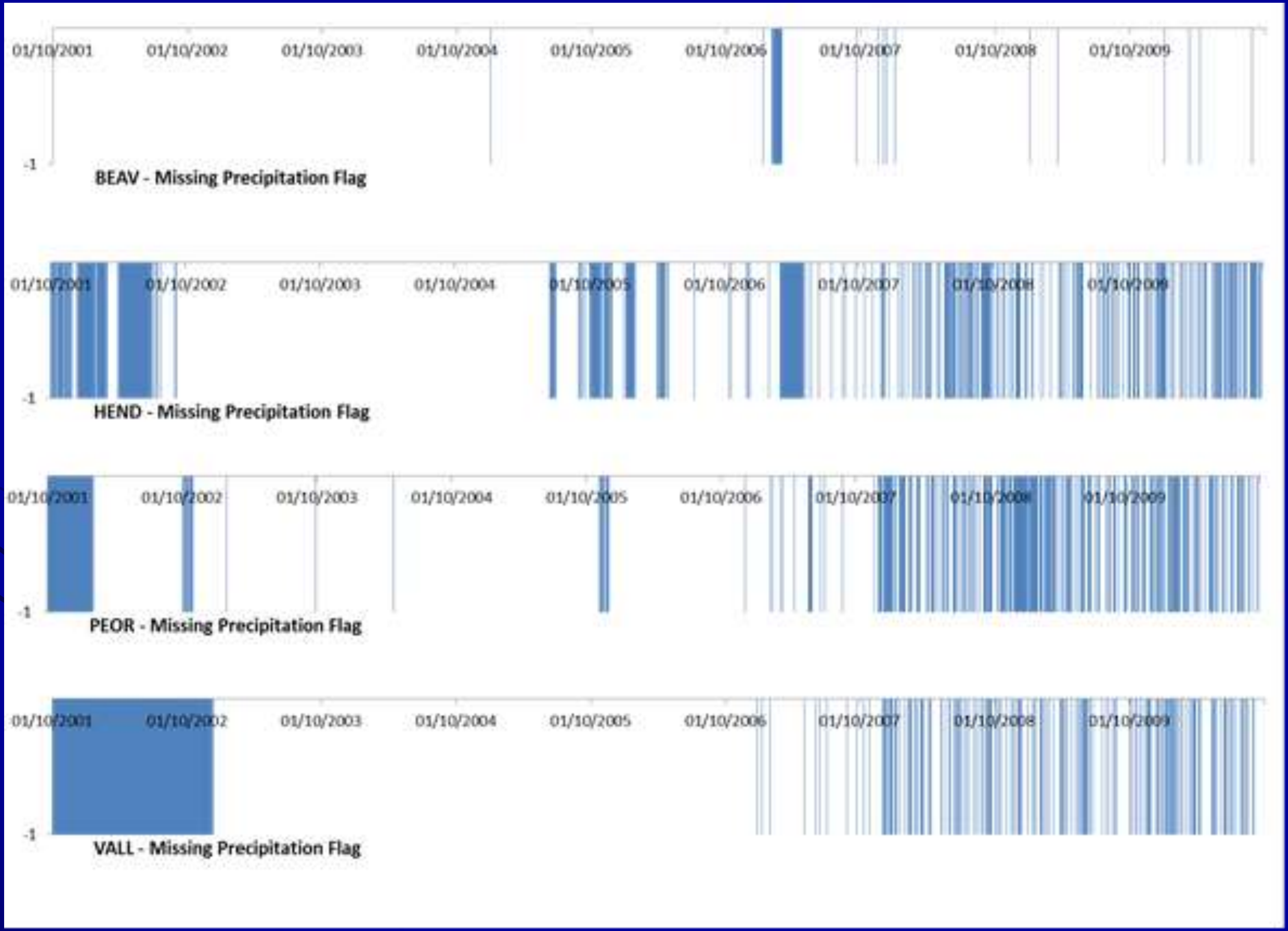
- Smoky River Basin is 46% ungauged
- Need to simulate spring streamflow from the ungauged basin area (23,769 km^2) in order to forecast Smoky River contribution to the Peace River
  - Run model on a daily basis during flood forecast period – update ungauged flows
  - Use daily updates of meteorological model forecast data to run for the future
  - Route ungauged with gauged flows for forecast

Smoky River Basin: 51,839 km^2



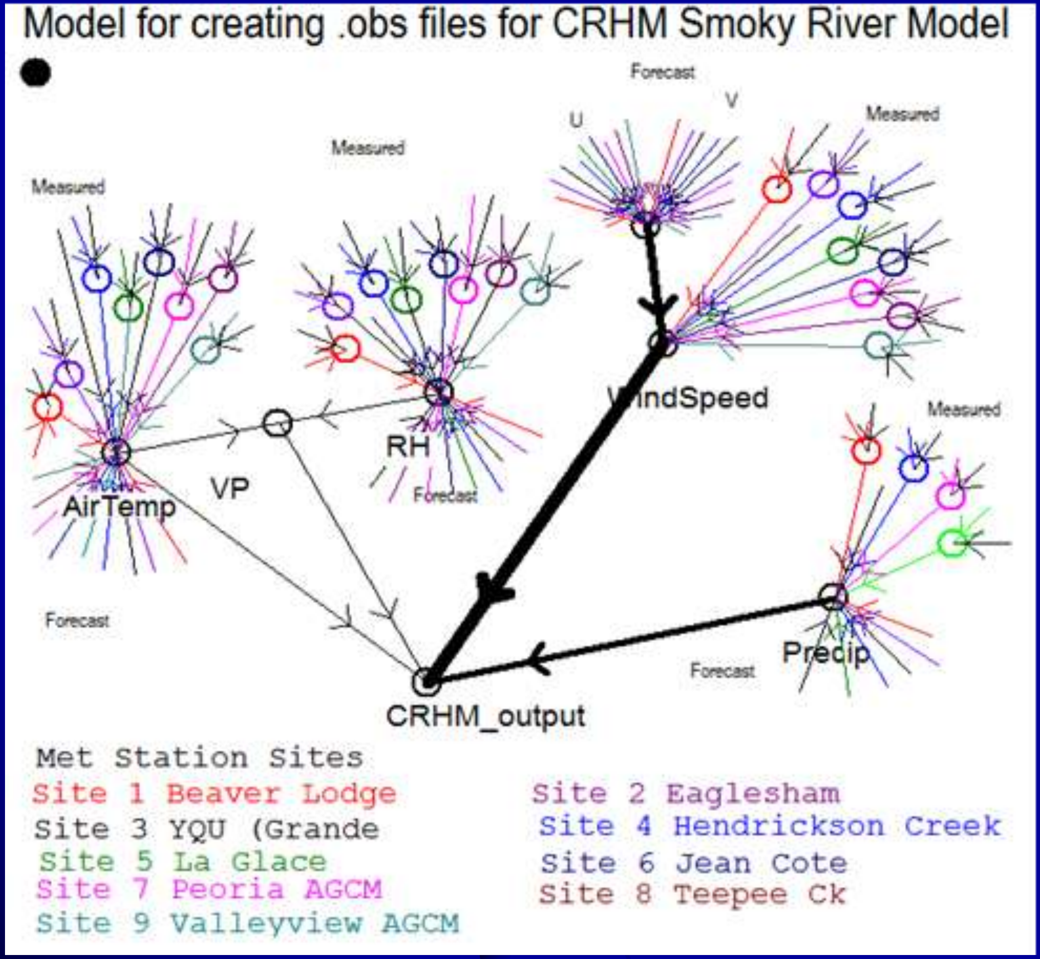


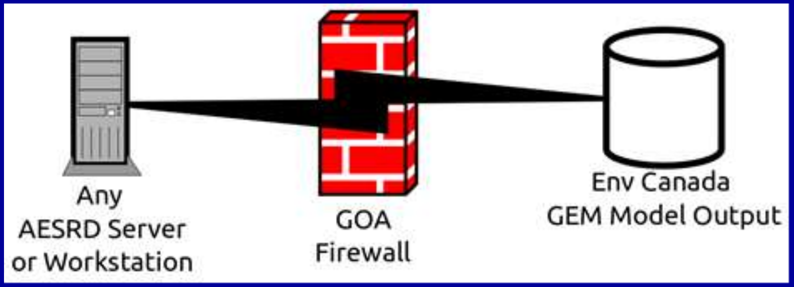
Challenge: Reliable Meteorological Observations and Forecasts

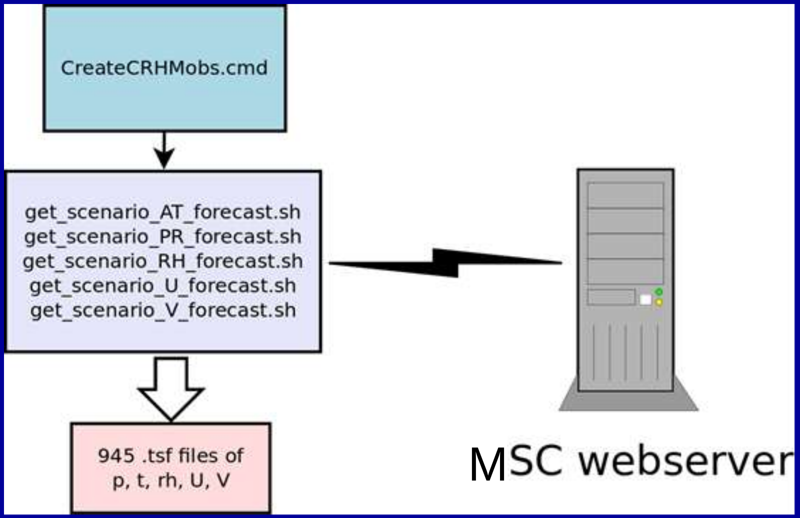


Interpolate and Predict

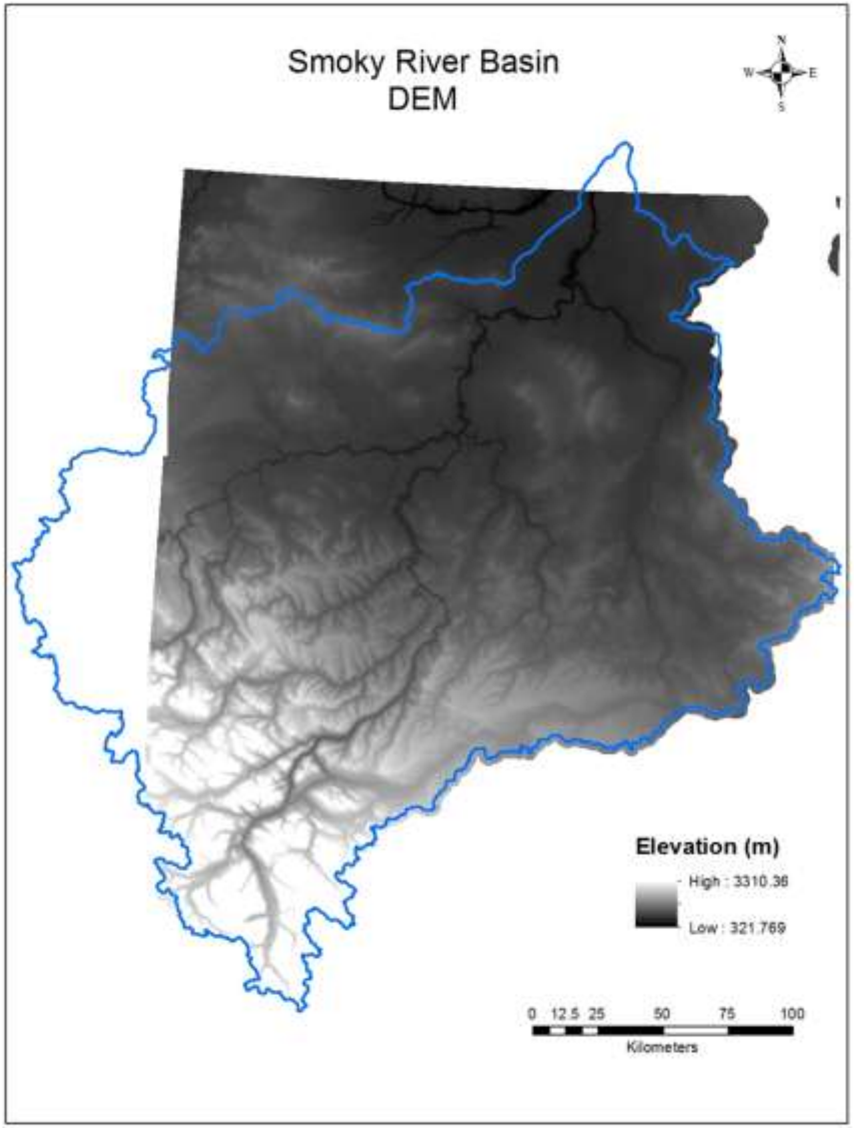
GEM-WISKI-CRHM

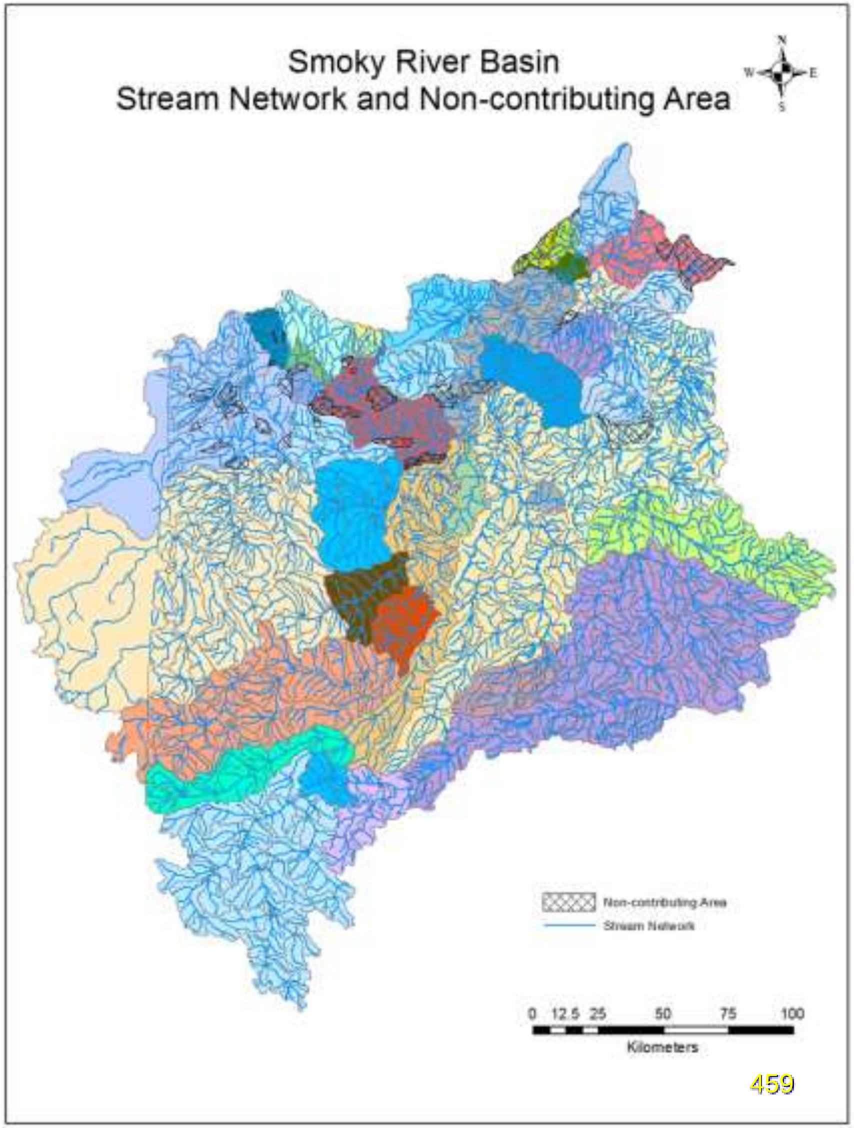




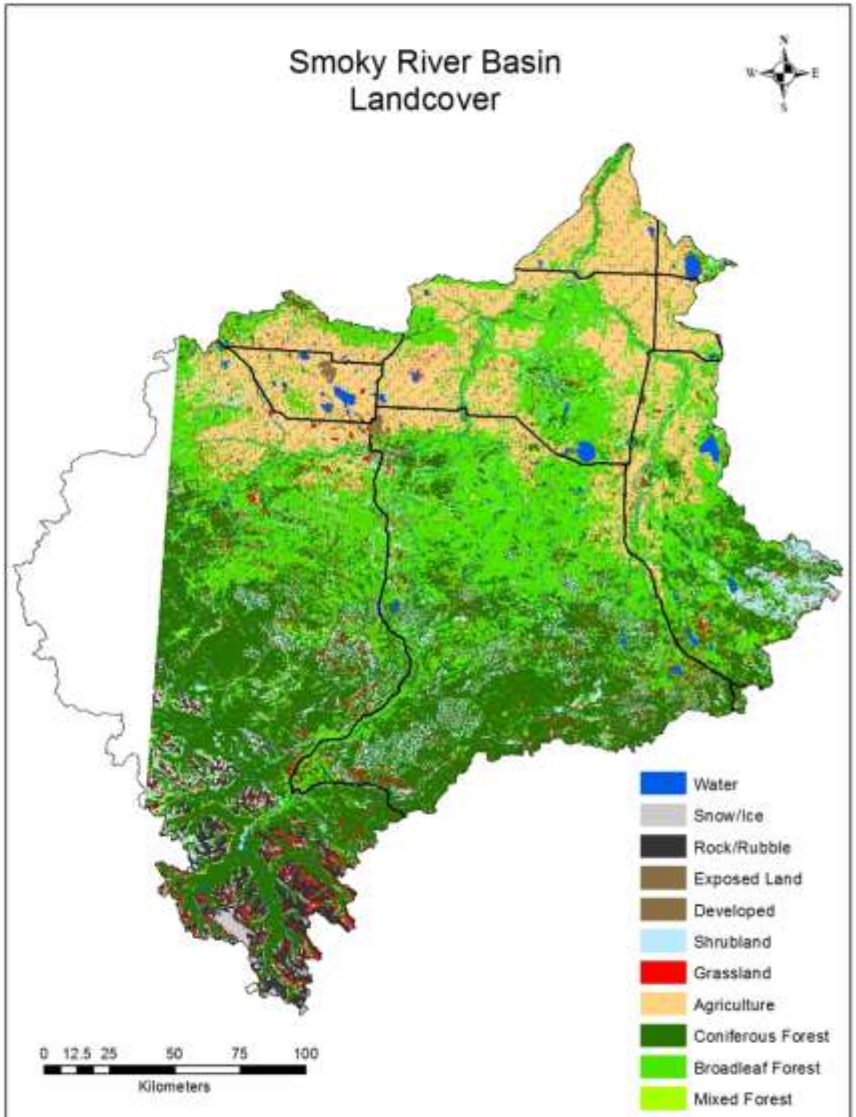


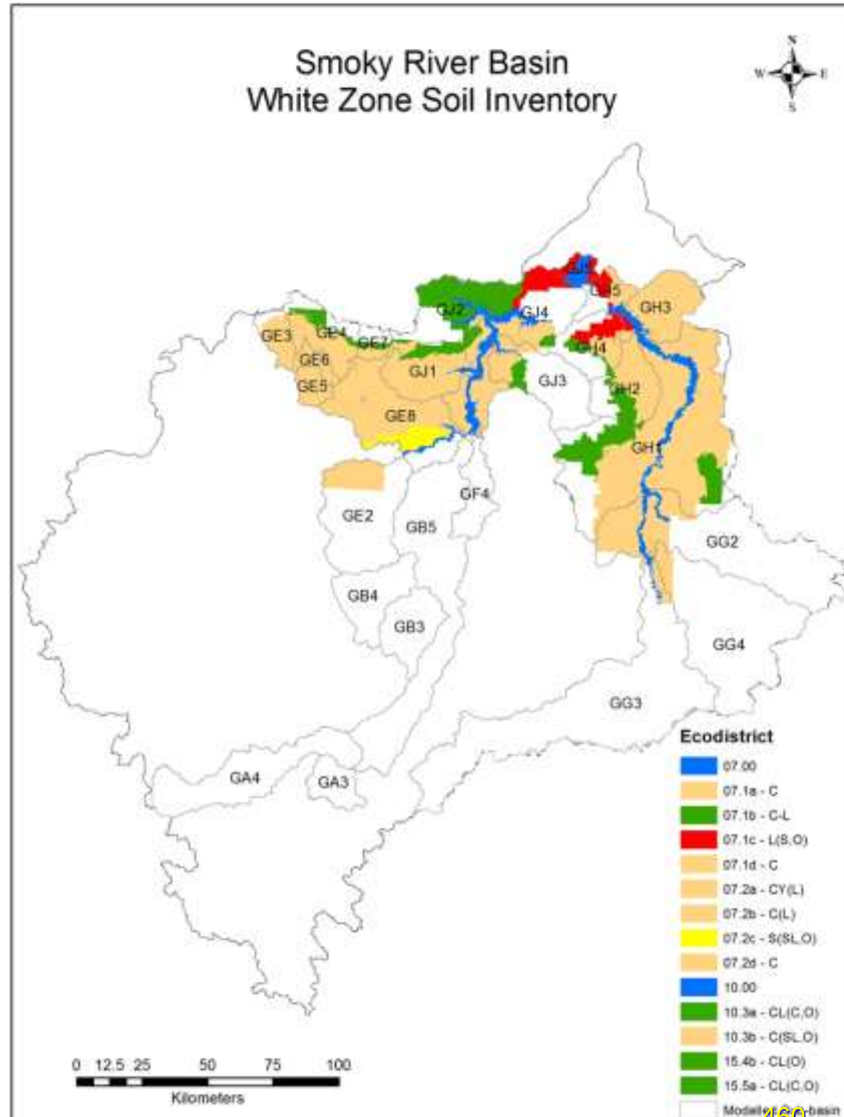
DEM and Derived Stream Network





Land Cover and Soils



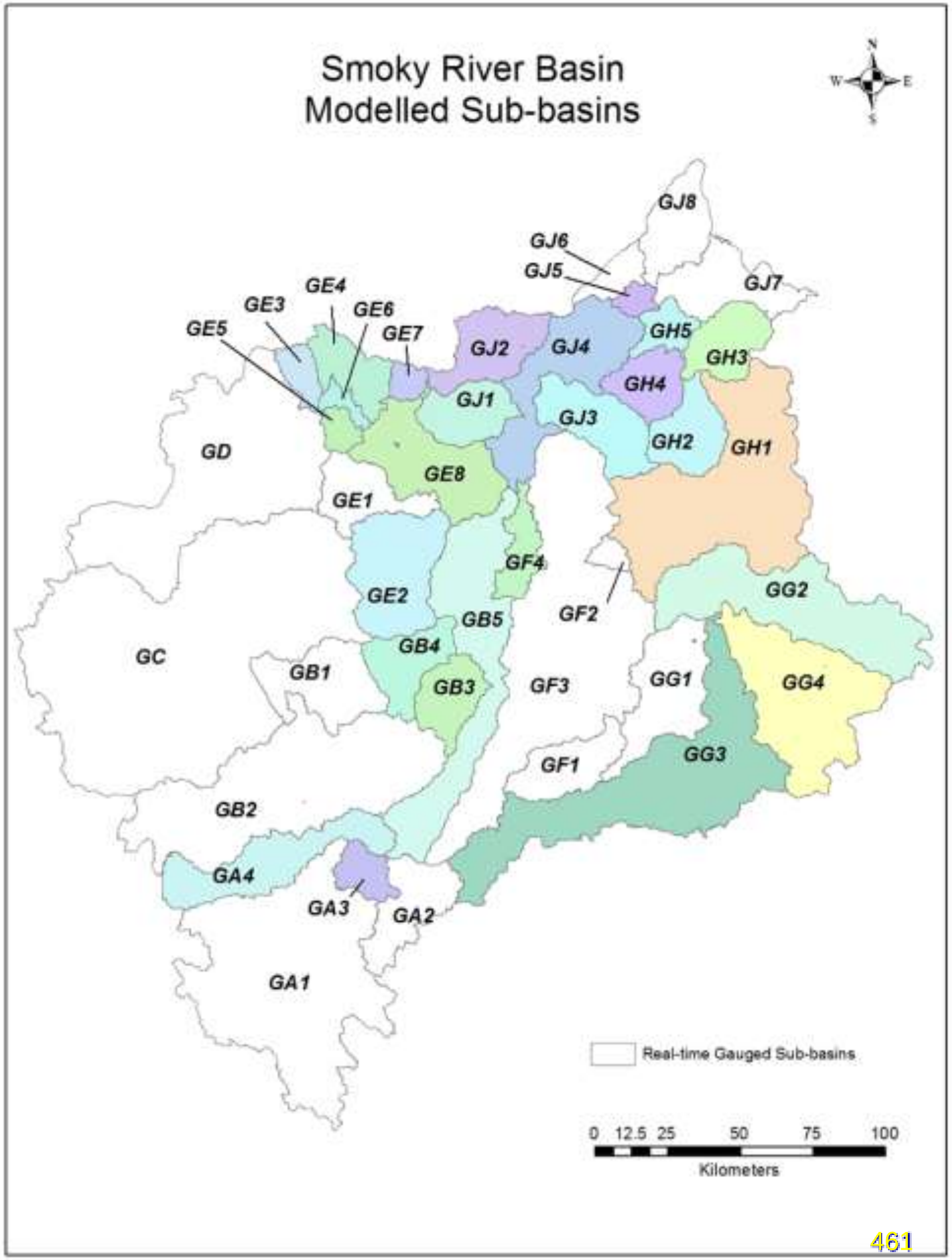


Sub-basins for Modelling

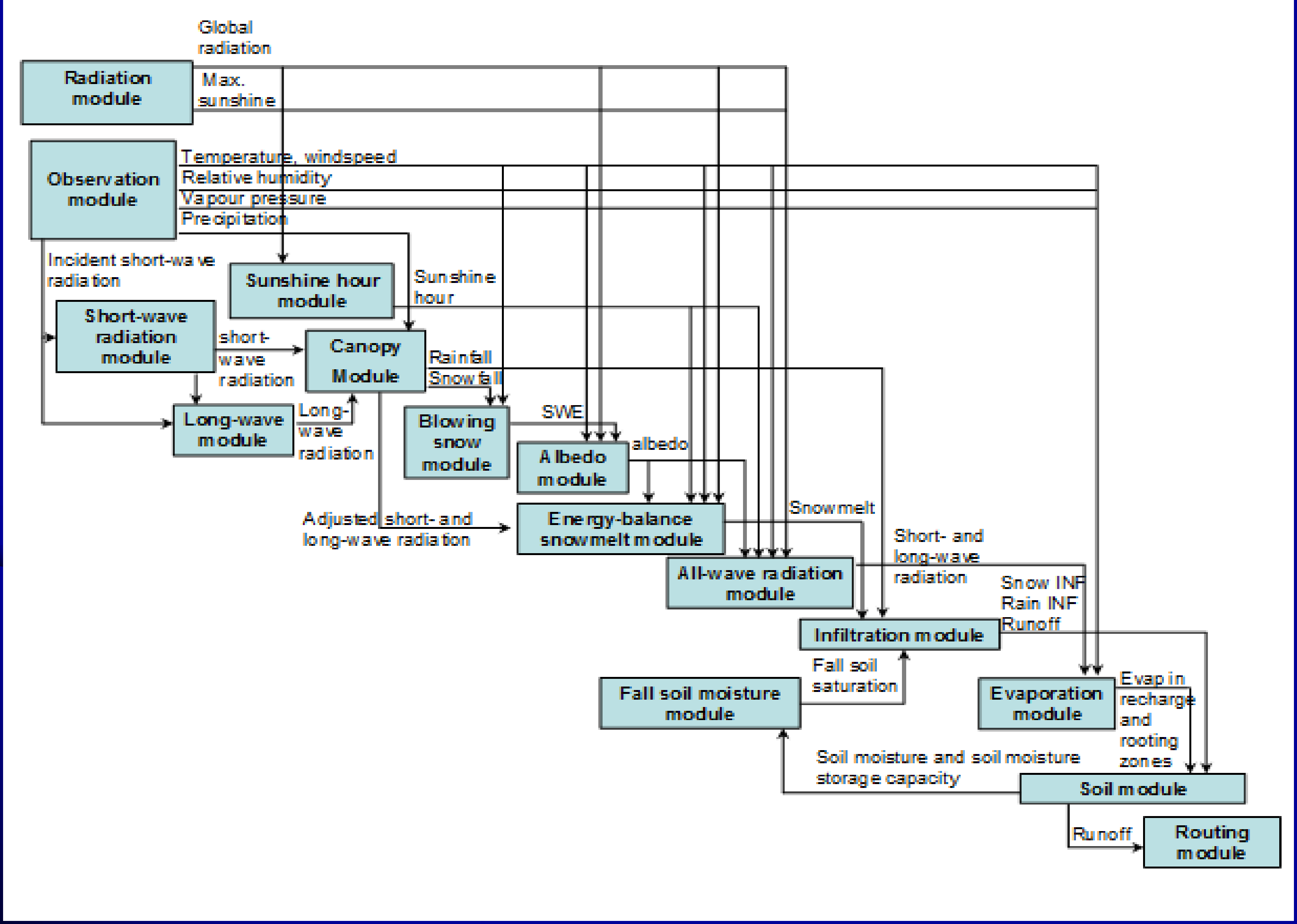
Modelled all ungauged and gauged basins without real time hydrometric stations

Sub-basins grouped into "types" based on ecoregion

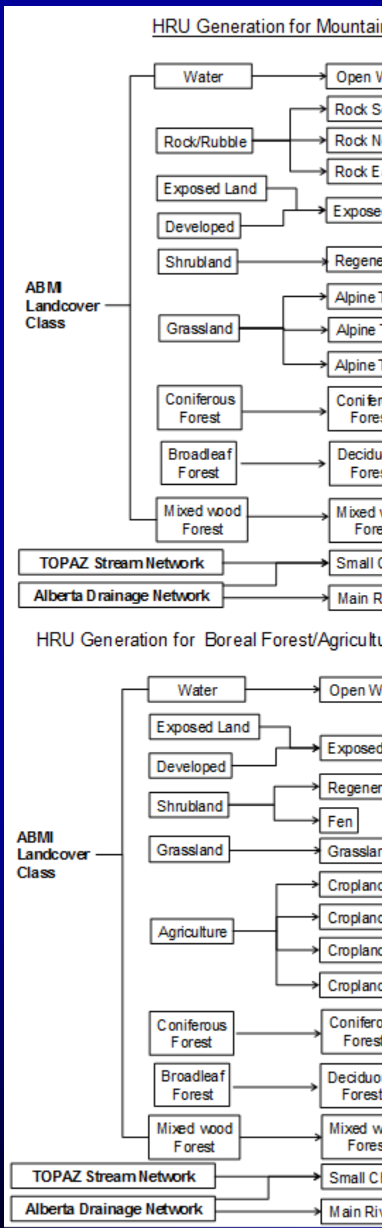
Real time gauged basins are estimated from gauge measurements and routed outside of CRHM using SSARR

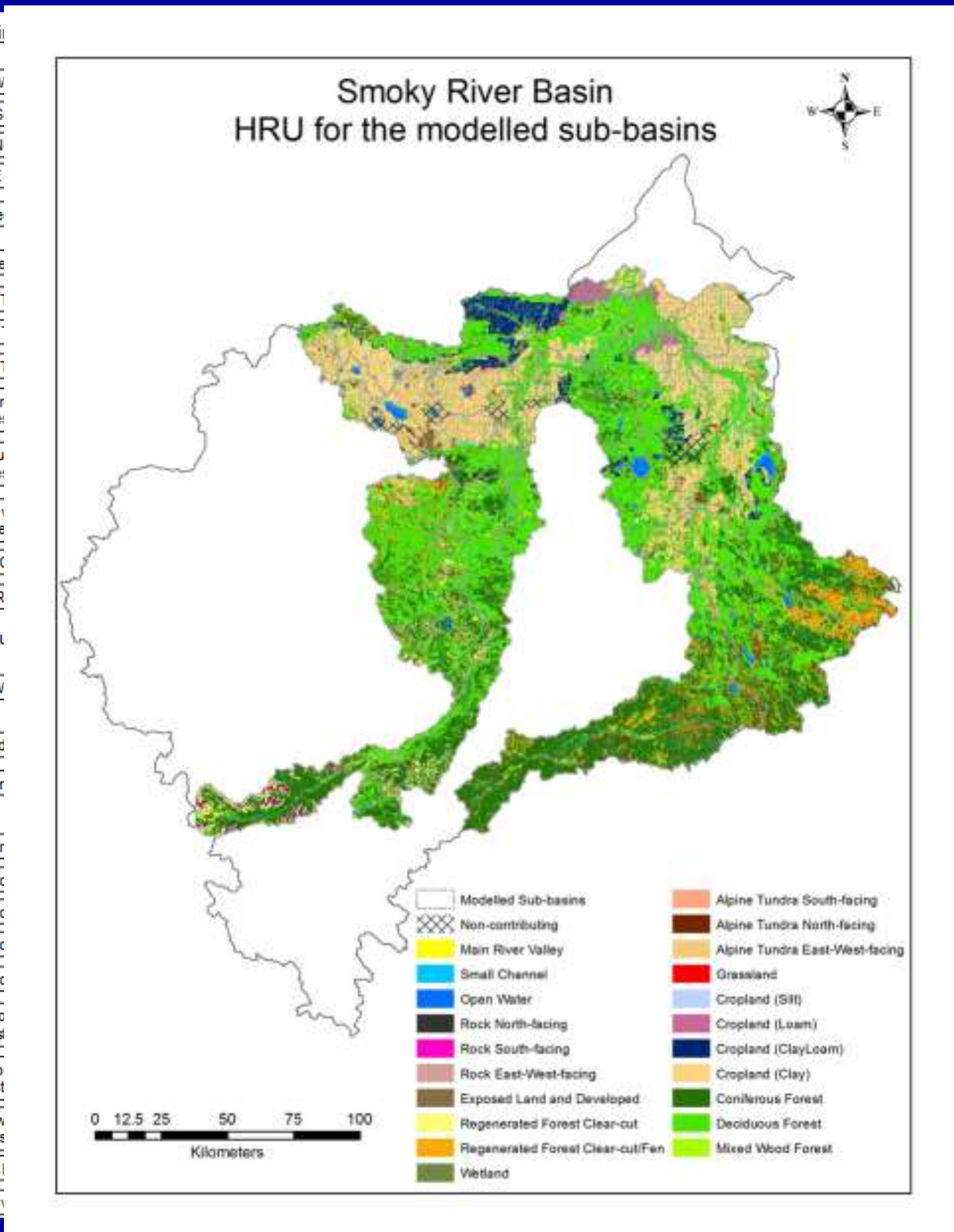


Module Structure within each HRU



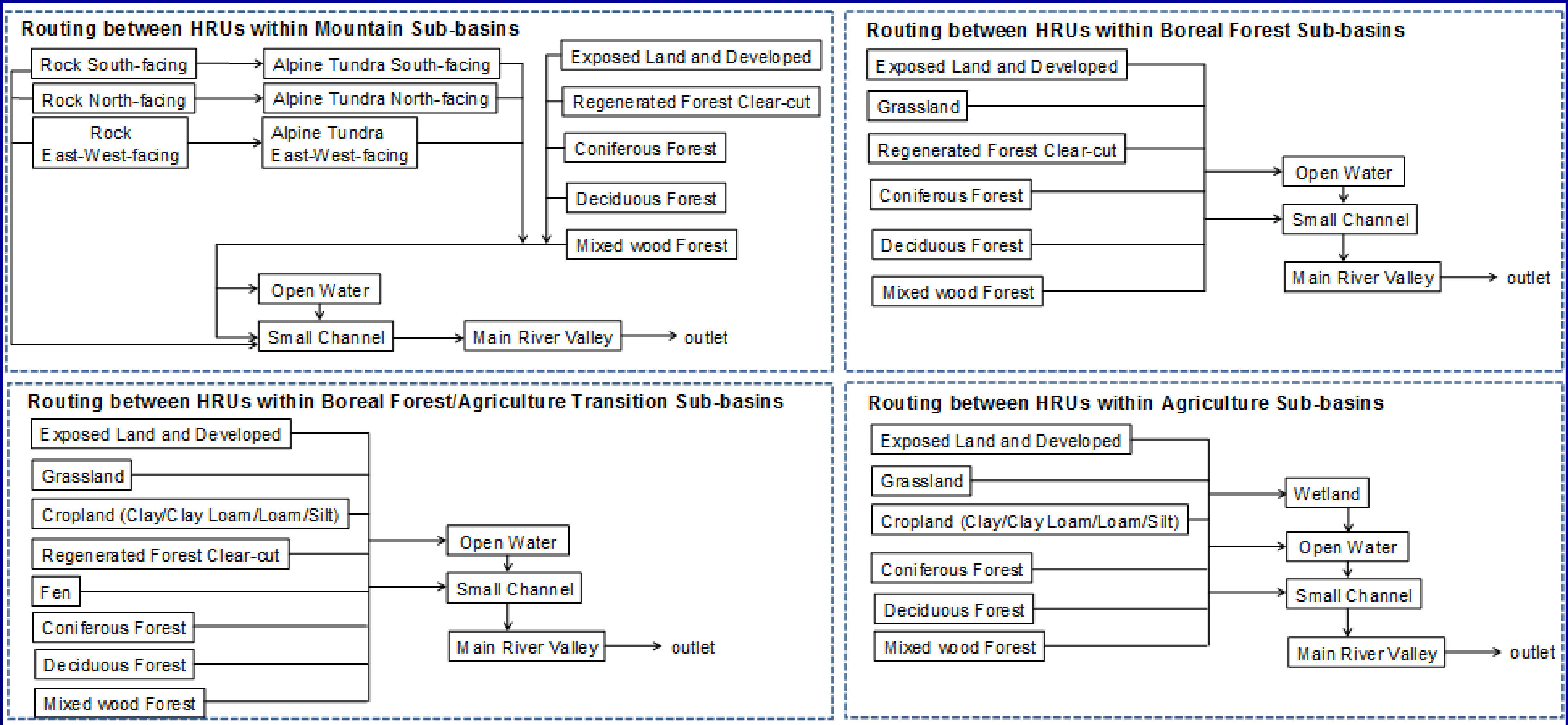
HRU Classification of Smoky Basin





HRU classification and interpretation of land cover, topography, drainage, soils to determine parameters was guided by sub-basin “type” which depended on ecoregion

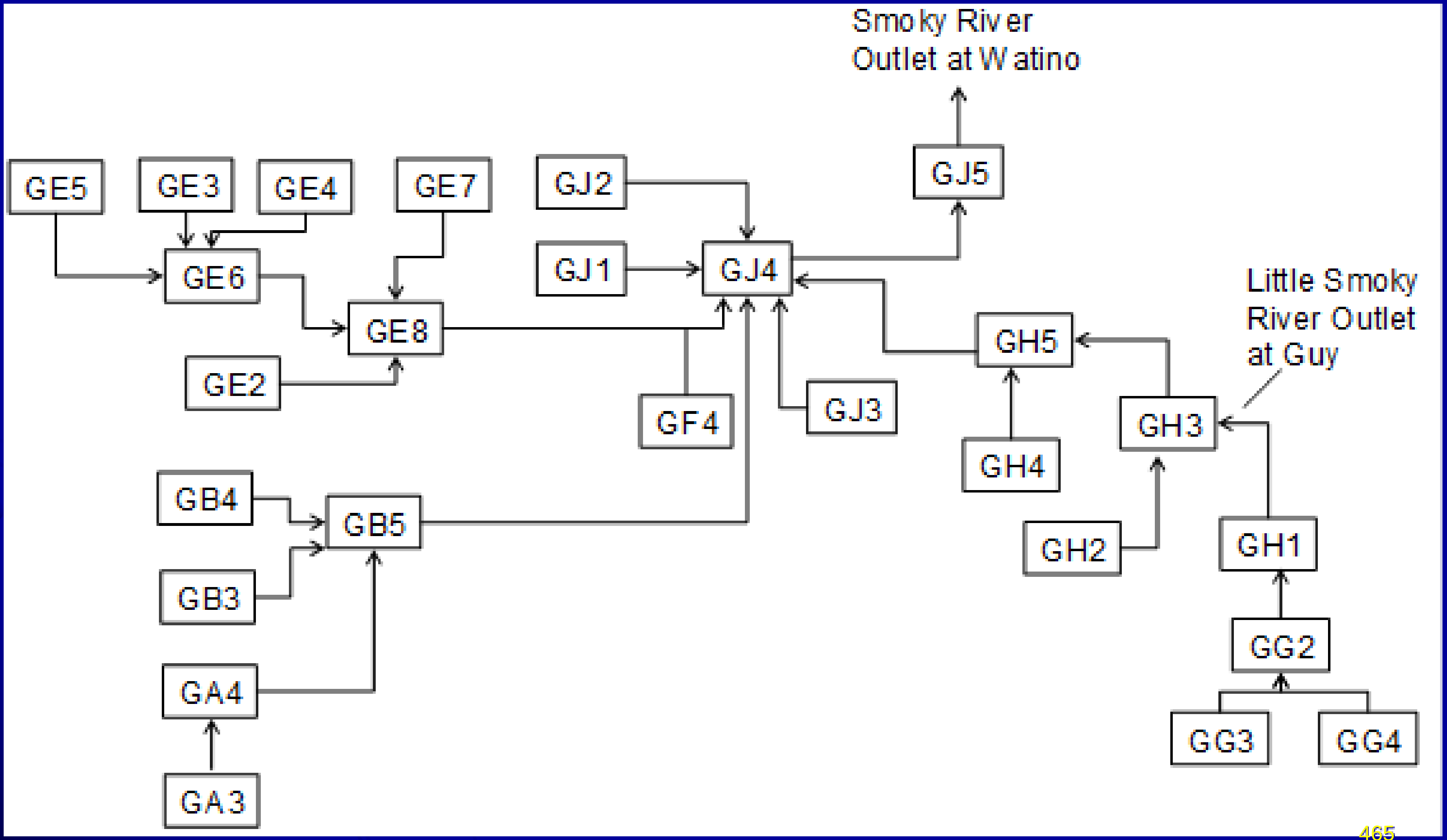
Routing between HRUs



Routing sequence depends on sub-basin type (ecoregion)

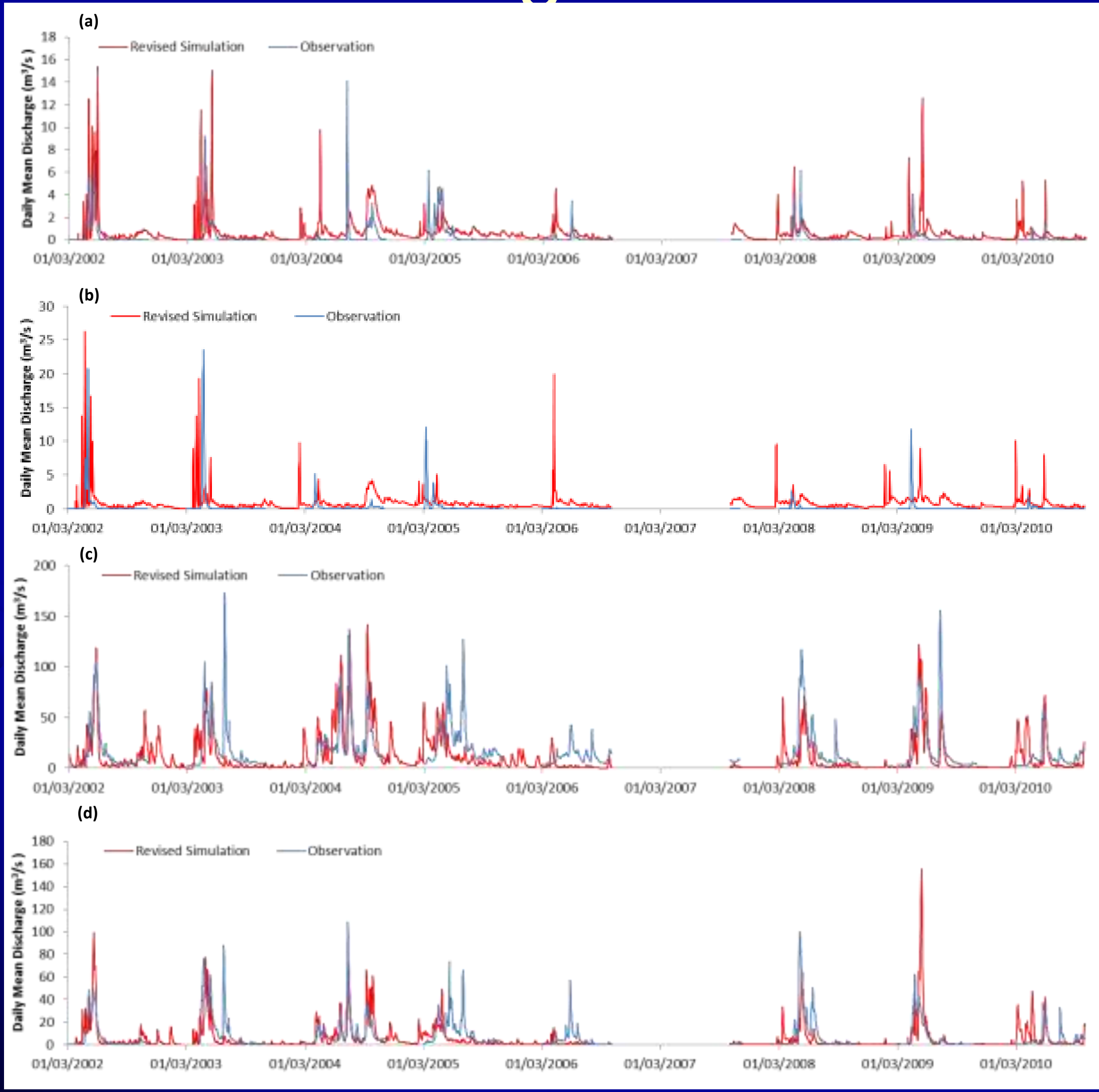
Routing between Sub-basins

Muskingum Routing used for river routing between sub-basins



Sub-basin Model Testing

Station Name	Station ID	Sub-basin
Grande Prairie Creek near Sexsmith	07GE003	GE7
Bear River near Valhalla Centre	07GE007	GE3
Little Smoky River at Little Smoky	07GG002	GG3
Iosegun River near Little Smoky	07GG003	GG4



Sub-basin

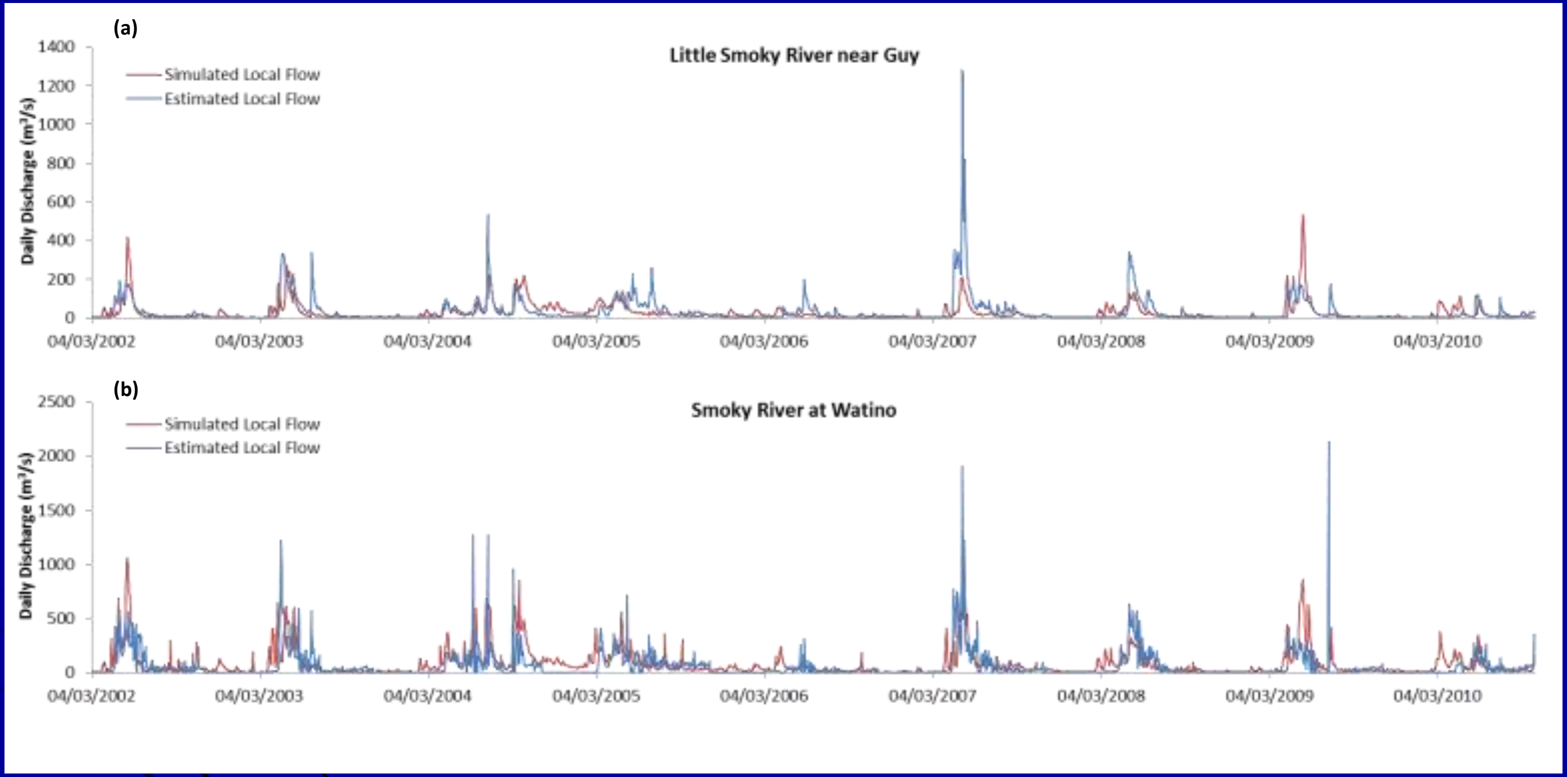
GE7

GE3

GG3

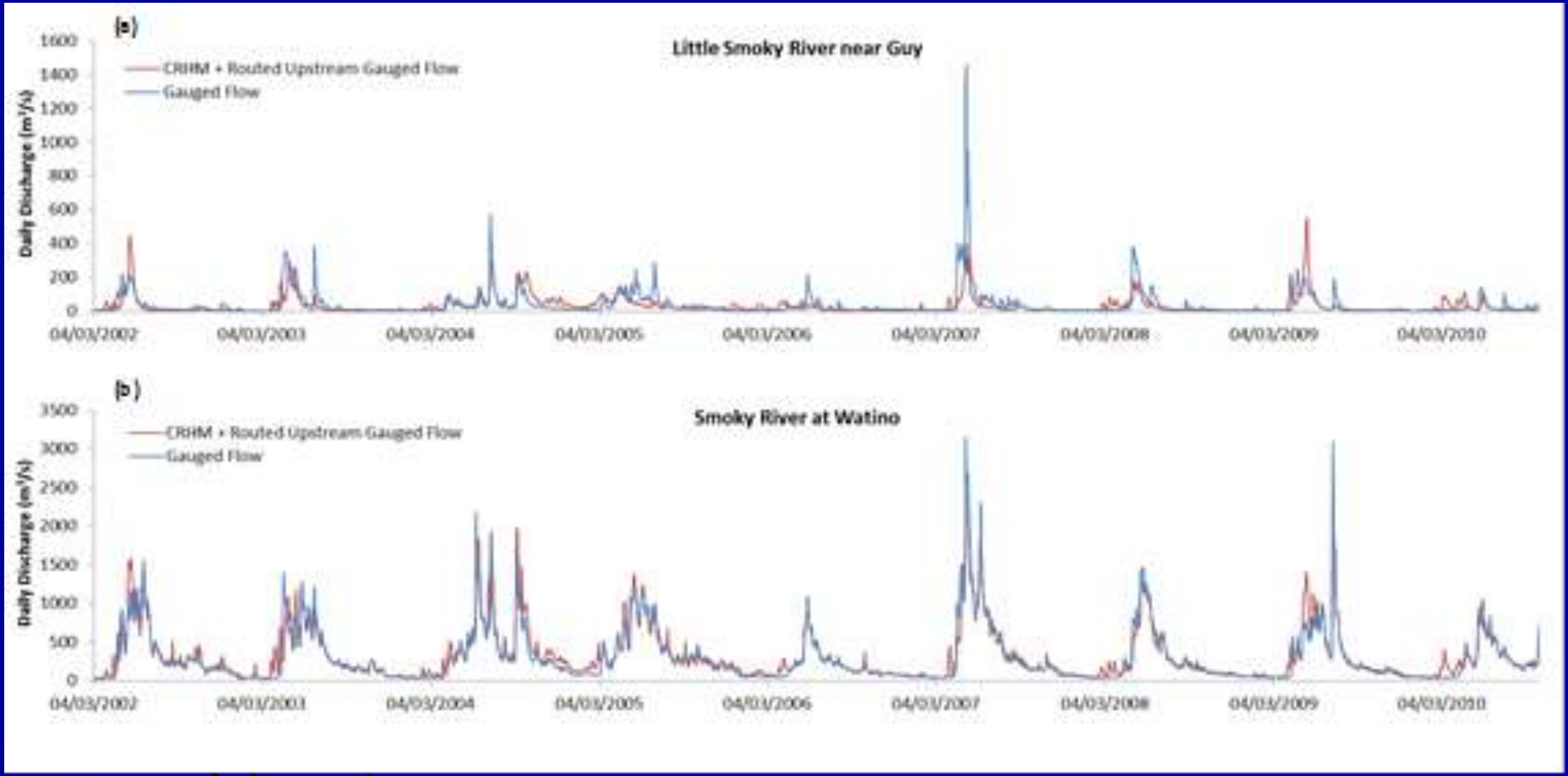
GG4

Basin Scale Local Inflow Evaluation



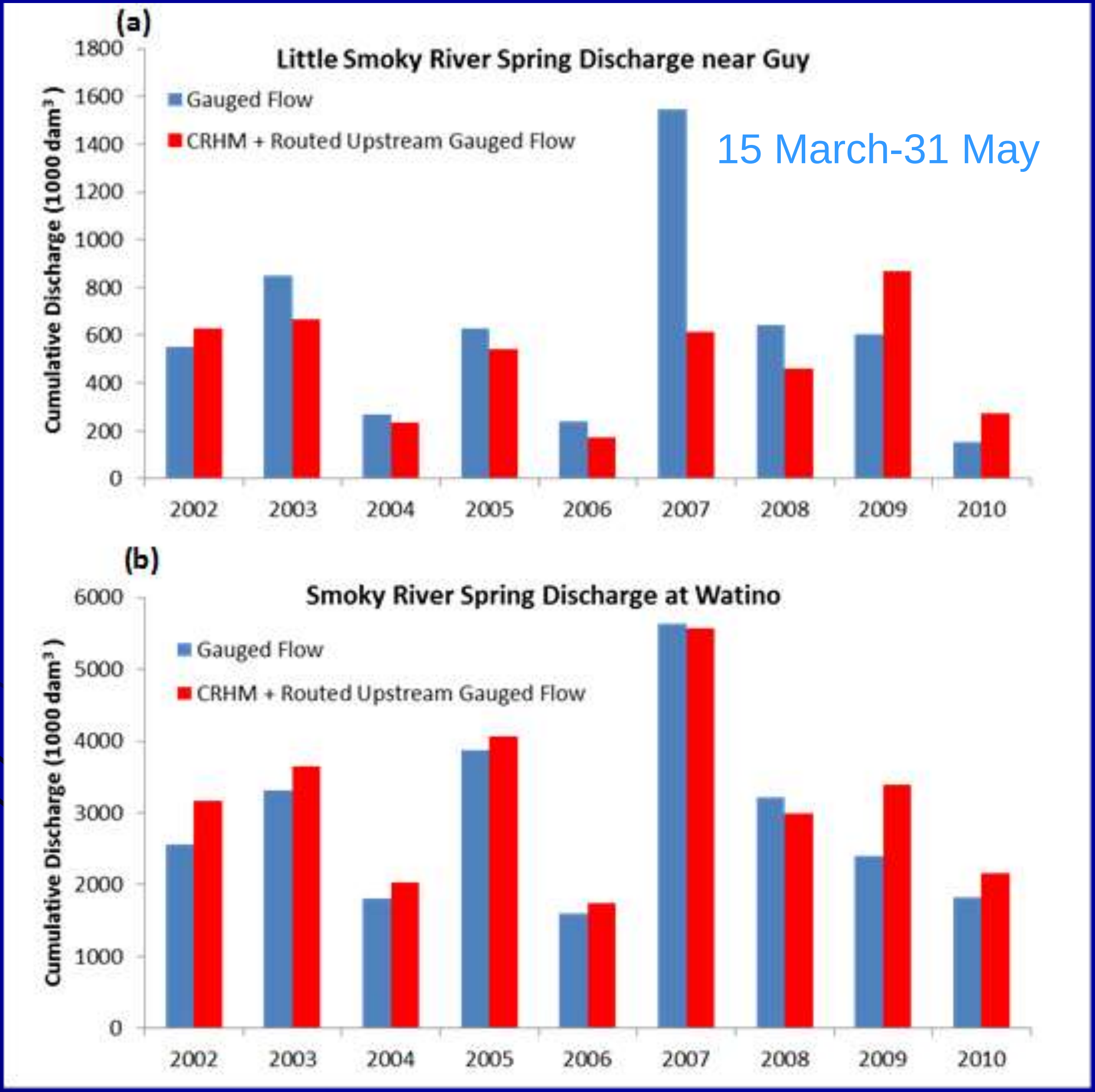
-Simulated local flows are only from CRHM hydrographs.
-Estimated local flows are gauged hydrographs minus routed upstream gauged hydrographs.

Basin-scale Prediction Evaluation

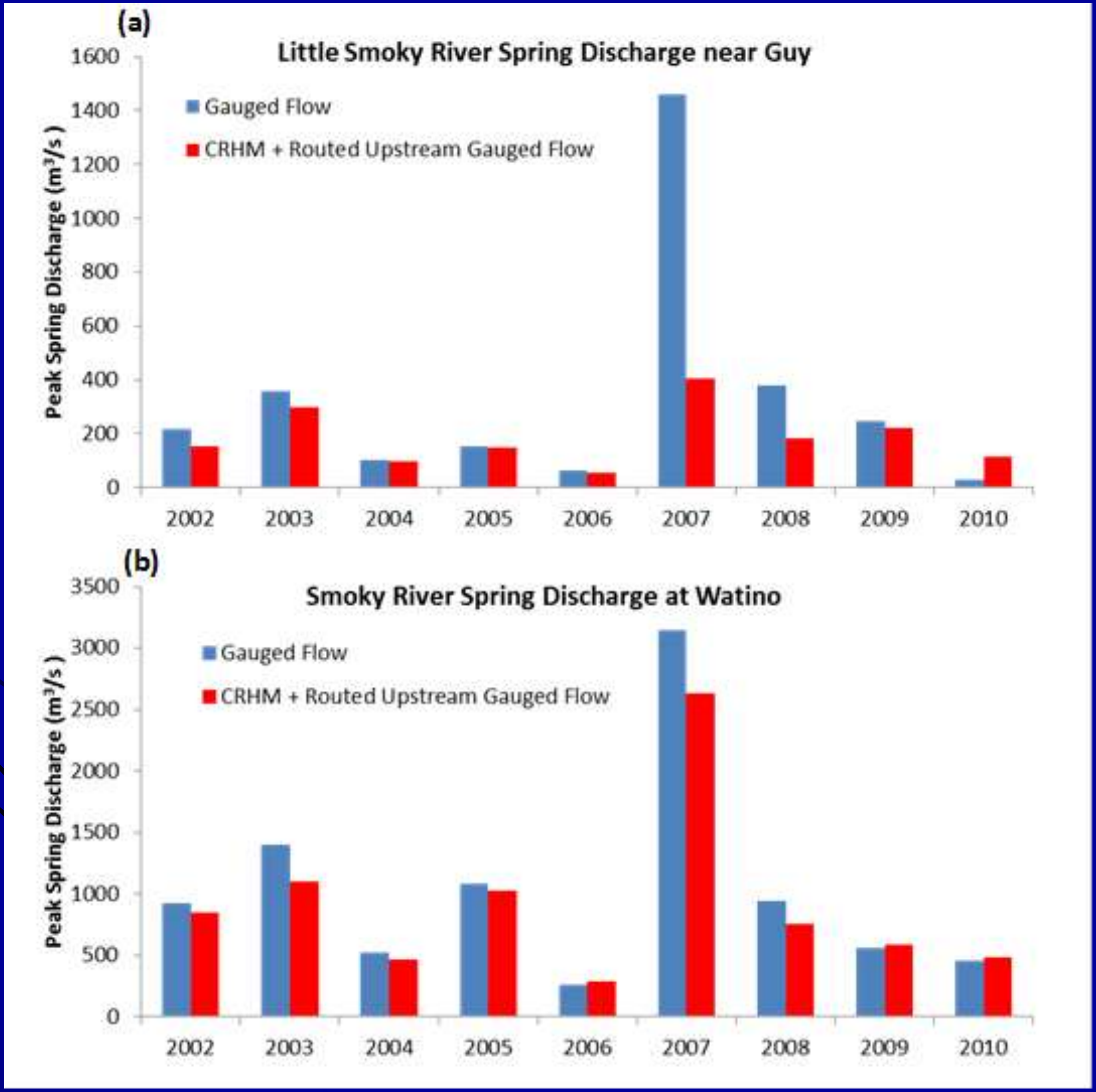


Predicted flows, Nash-Sutcliff Statistic: 0.41 (Little Smoky) and 0.87 (Smoky)

Predicted Spring Discharge



Predicted Spring Peak Discharge



Conclusions

- Better understanding of processes by intensive field study and detailed distributed modelling in research basins can be the basis for more realistic models and confident parameterisation.
- Using the results and understanding from research basins It is possible to simulate multiple hydrological states and fluxes in Alberta’s mountains and prairies without extensive calibration from streamflow observations.
- These models can be used to reliably show the sensitivity of Alberta’s river basins to climate change, drainage and land use change and provide new insights because of their strong physical basis.

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

Outline

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

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."

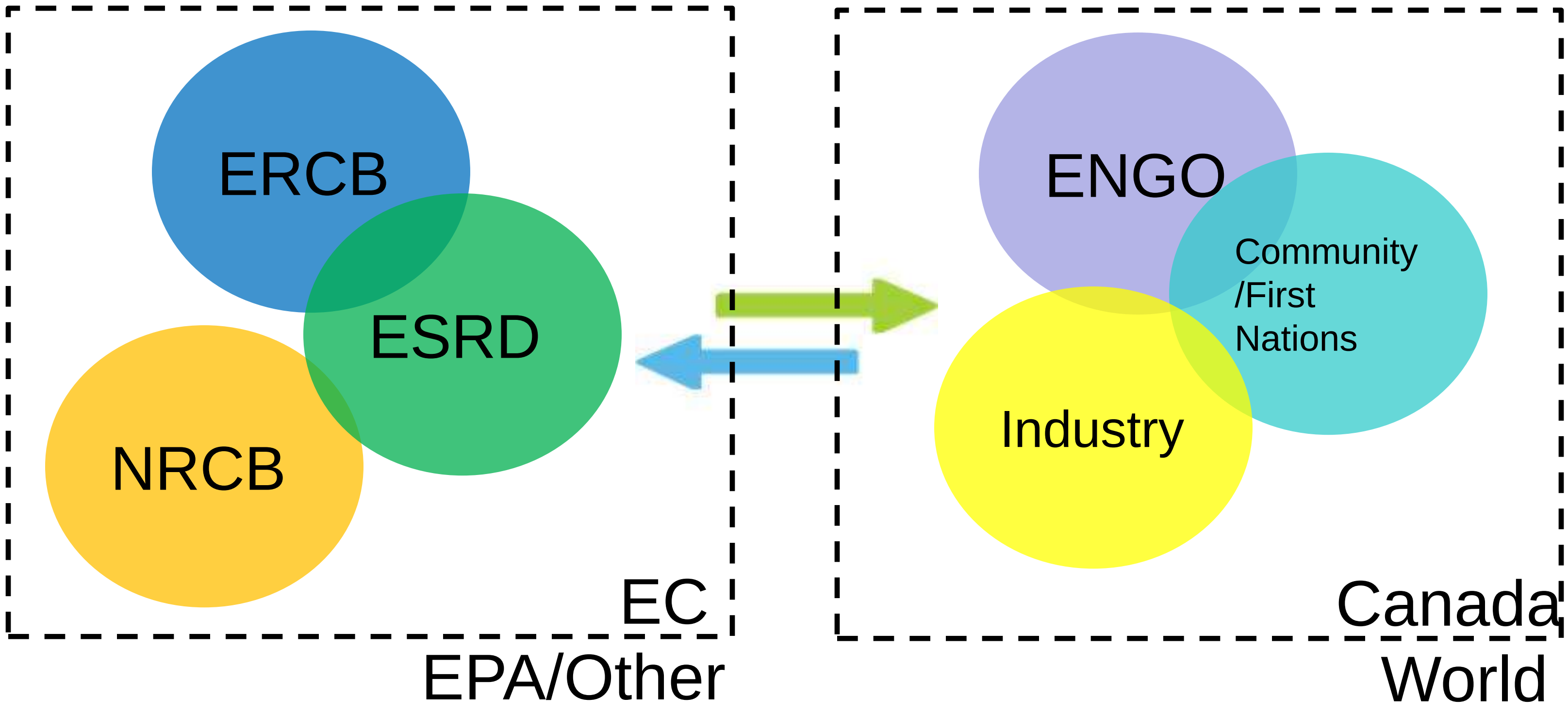
» **Alberta Environment Protection and Enhancement Act s.47(d)**

Regulatory Modelling

Who?

- **Regulators**

Non-Regulators



Regulatory Modelling

When?

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

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?

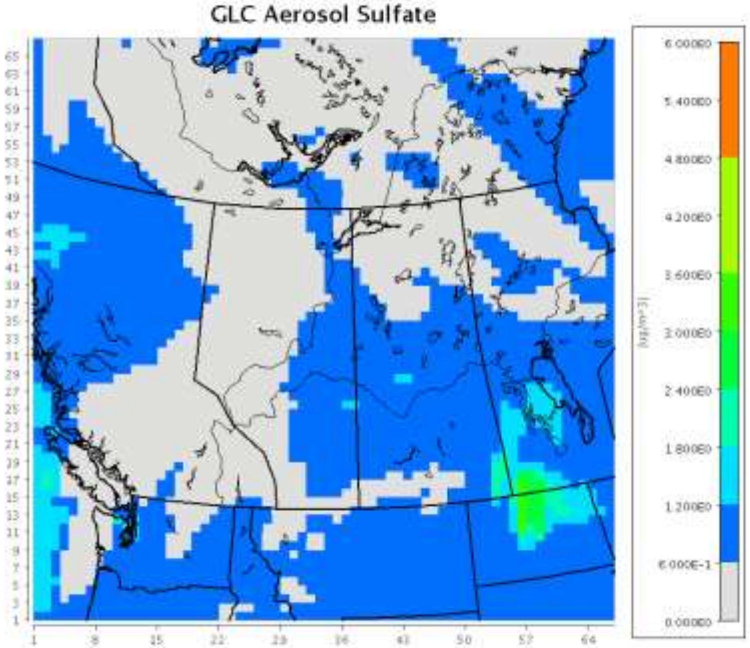
- Not currently tied to an EIA or permitting exercise
- May be tied directly into CEMS:
  - Frameworks
  - Regional/international initiatives
- Emergency response

Alberta Government

Non-Regulatory Modelling

Frameworks

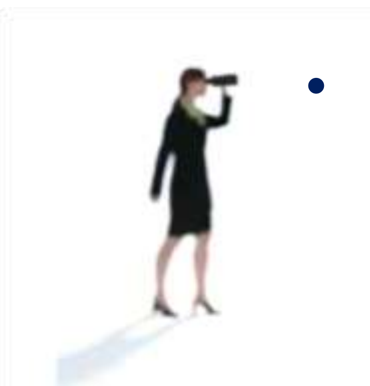
- **Acid Deposition Framework**
  - **Provincial/Western Canadian in scale**
  - **Non-regulatory data sets and models**

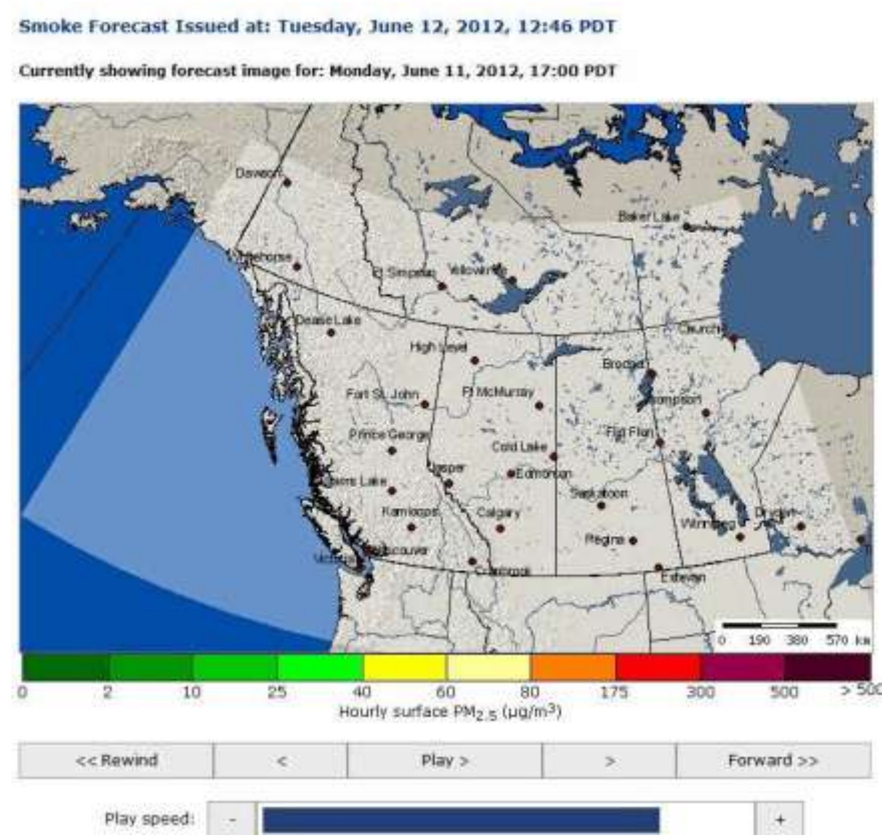


Non-Regulatory Modelling

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**

Alberta Government

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

Integration

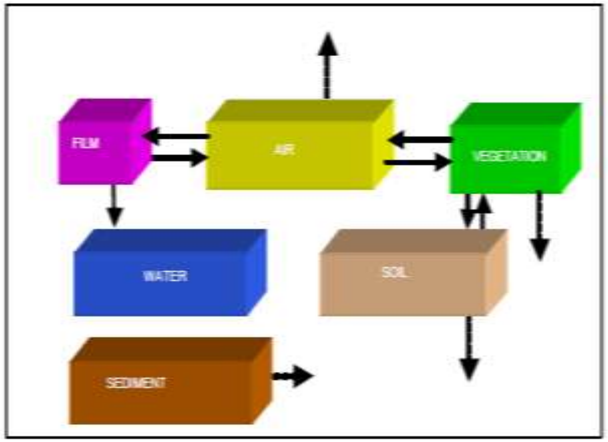
Air Integrated Models (Non-regulatory)

AirQUIS (Integrated air quality management system)

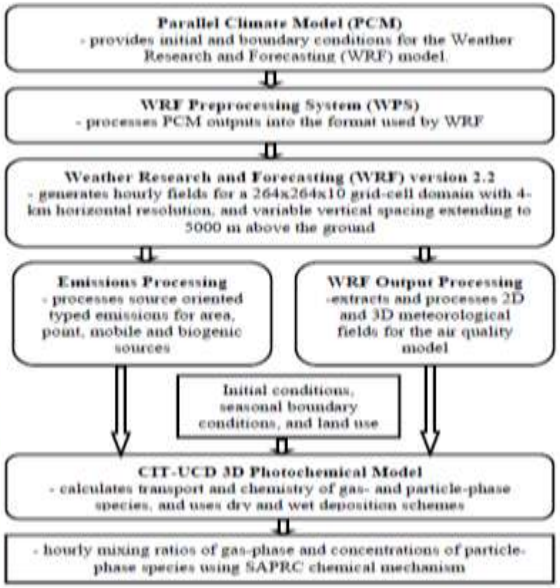
- An atmospheric transport model that produces atmospheric deposition fields for nutrients and other constituents
  - Community Multi-Scale Air Quality modelling system (US EPA)
  - GEM-MACH (EC)
  - AirQUIS (Norway)

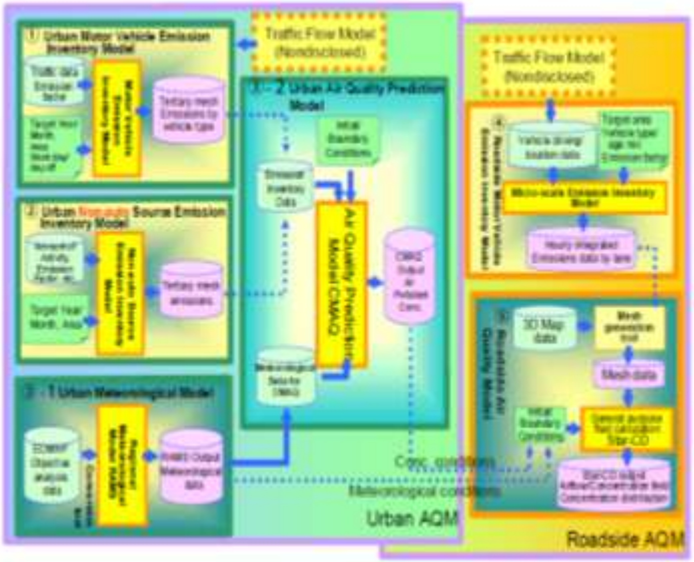
Integration

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



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

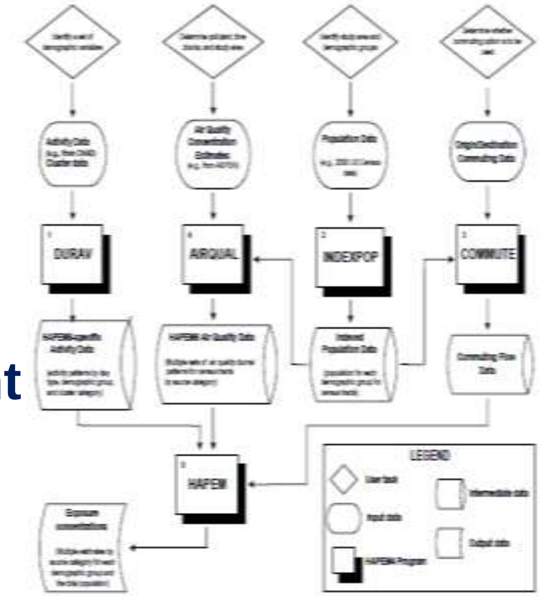


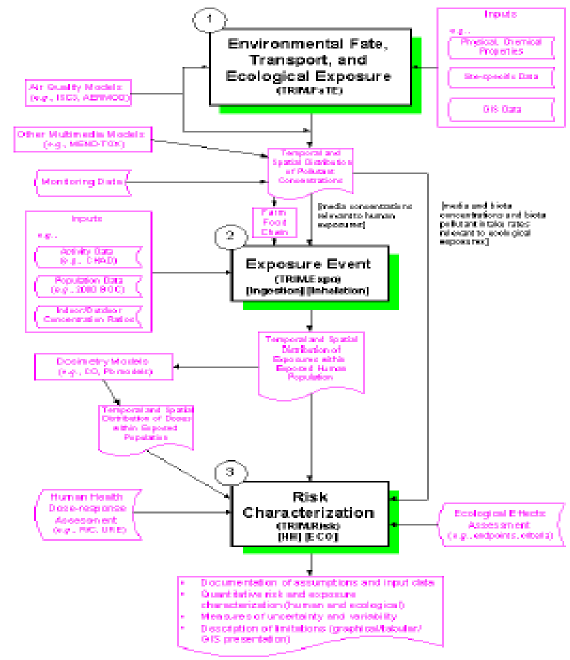


Integration

Air Integrated Models (Human Health & Risk Applications)

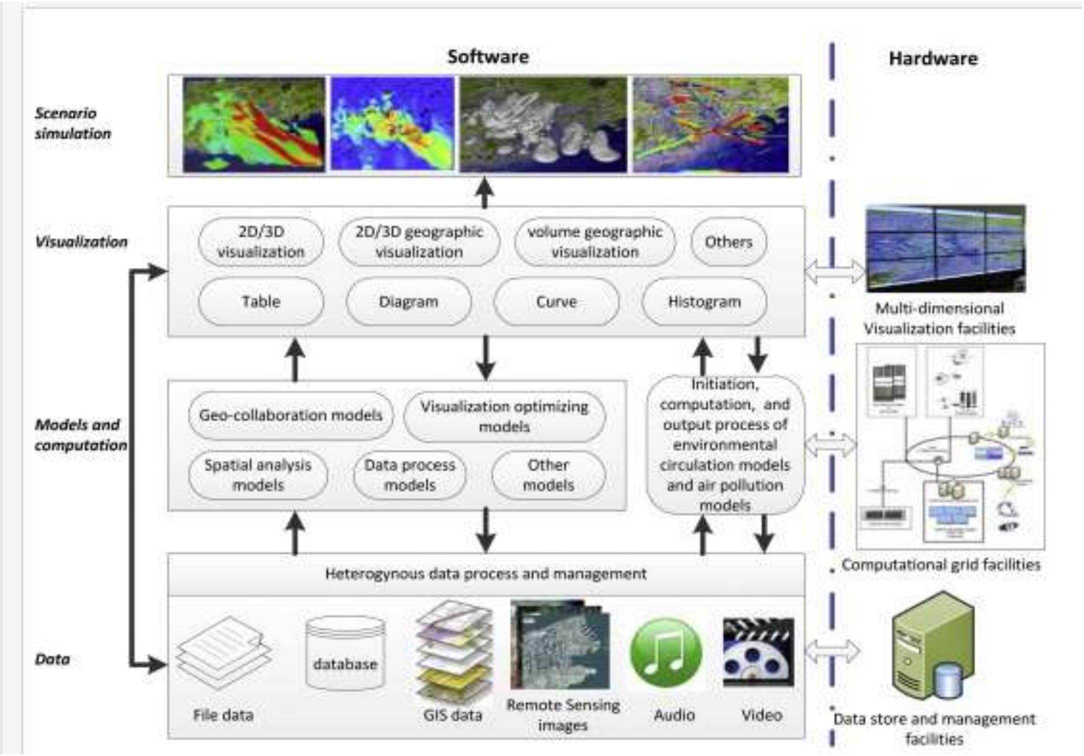
- Air Toxics Exposure Assessments
- Hazardous Air Pollutant Exposure
- Total Risk Integrated Multimedia





Integration

2nd Generation Integrated Modelling System



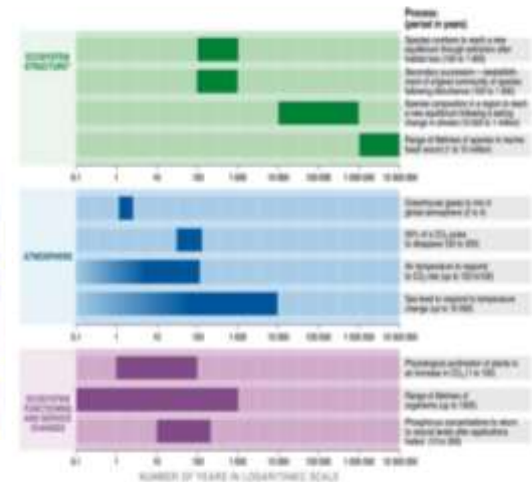
Software + Hardware

(Visualization GIS/ Data/Models/ Scenario)

Integration

Common Issues

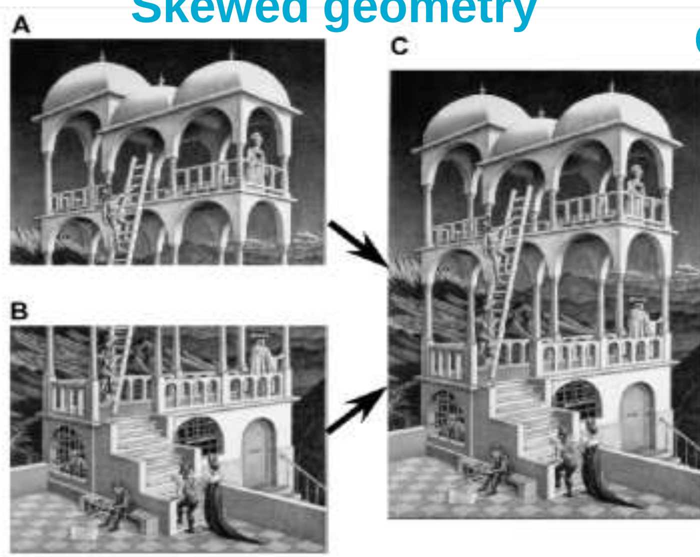
Temporal Dynamics



Ugly construct

Mismatched scales

Skewed geometry



Confusion of tongues

Overwhelming complexity

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

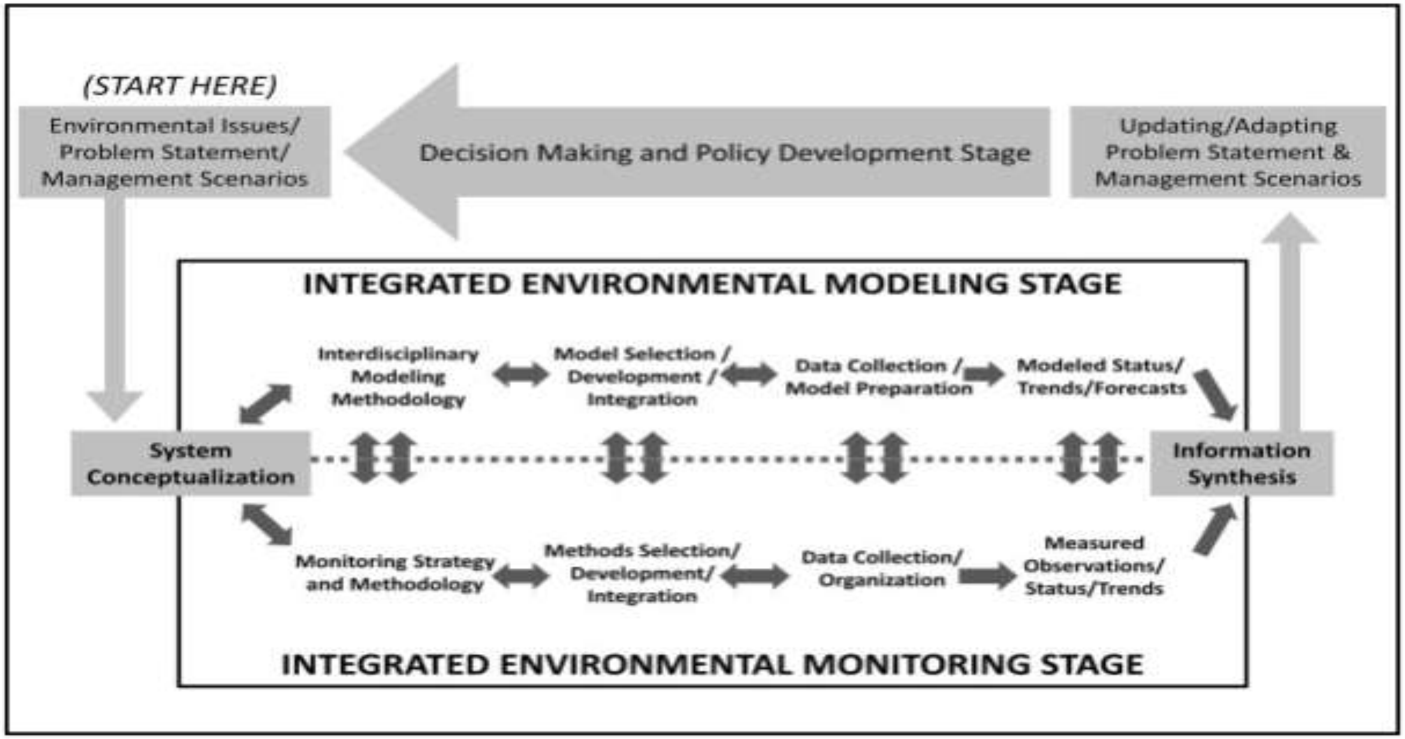
Integration

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

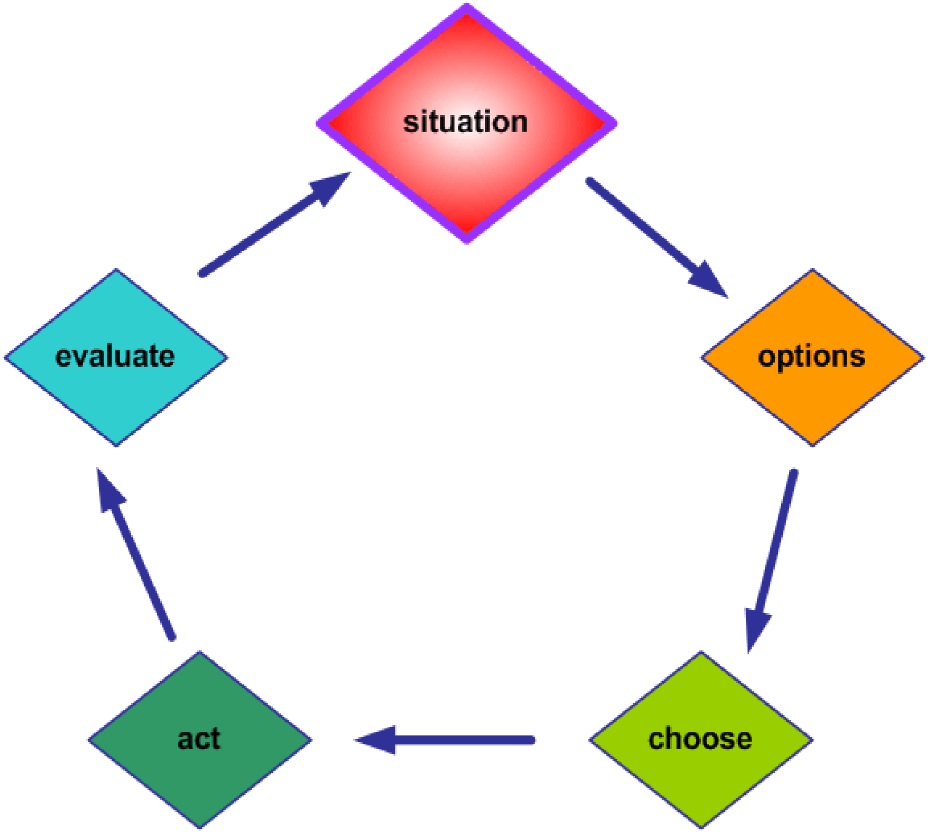
Decision Process (example)



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

Alberta Government

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

Freedom To Create. Spirit To Achieve.

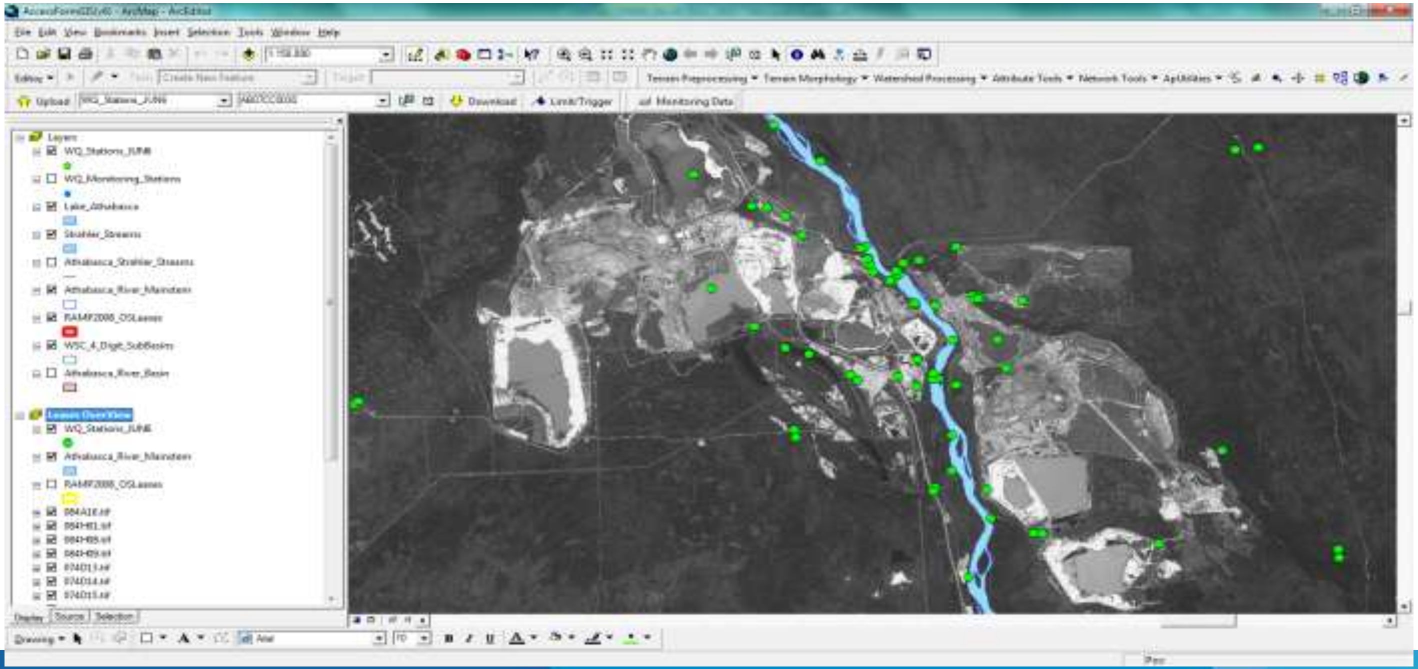
Government of Alberta

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

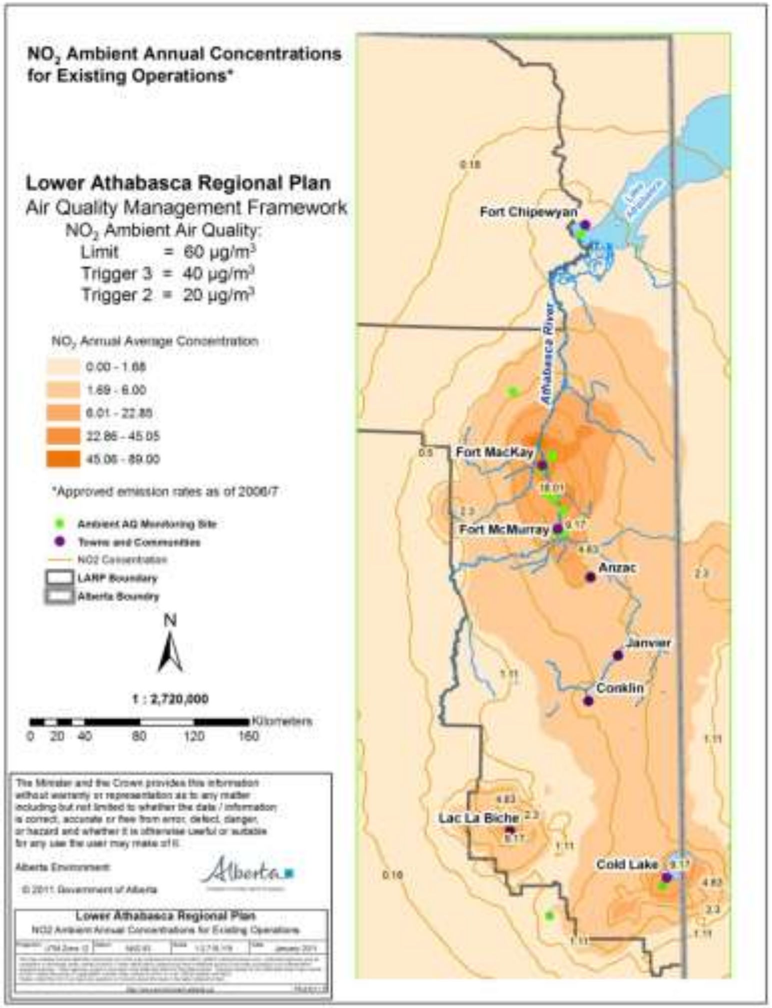
- Rationale for developing CEMTOOL
  - Regional plans require tools to develop thresholds, limits and outcomes.
    - Cumulative impacts are data intensive
    - Outcomes need to be measured and evaluated continuously
      - Data compilation and assessment in near real-time is critical
  - Management 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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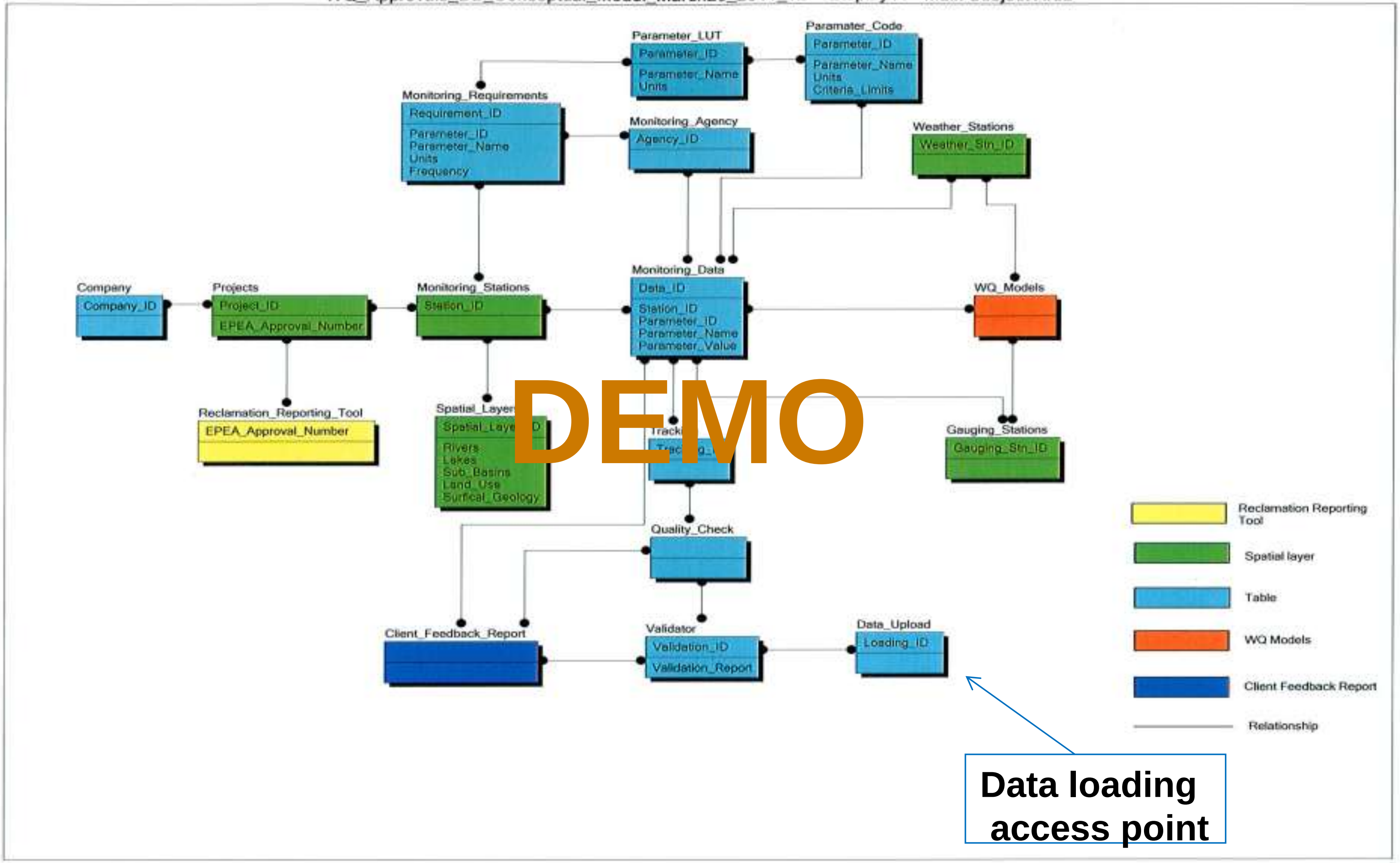

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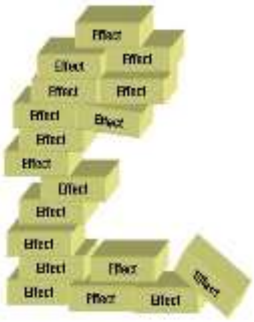
Cumulative Effects Management Tool

- 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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robert.magai@gov.ab.ca

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

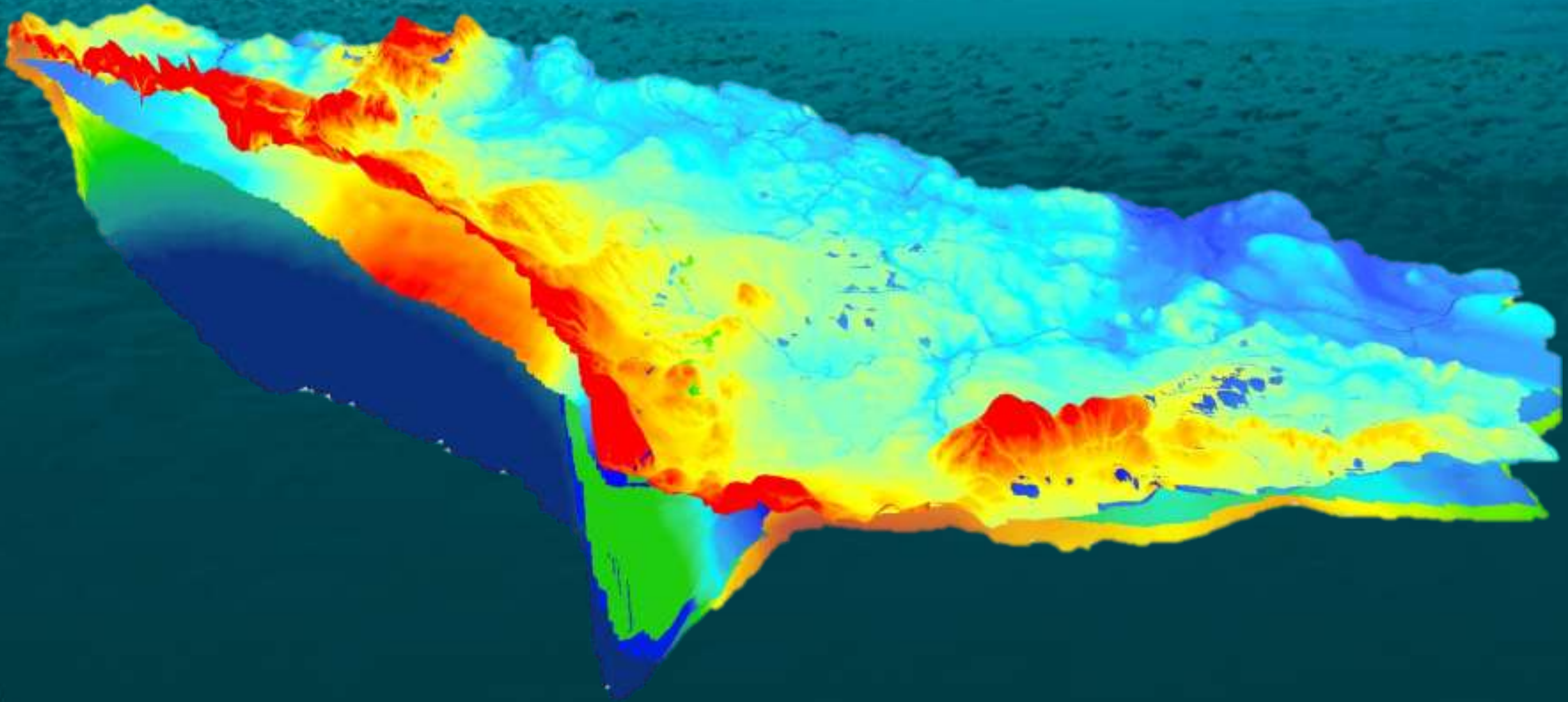
ABSTRACT

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

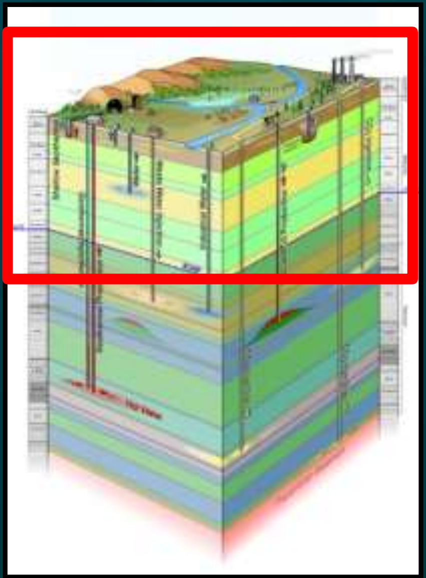
Environmental Modelling Workshop

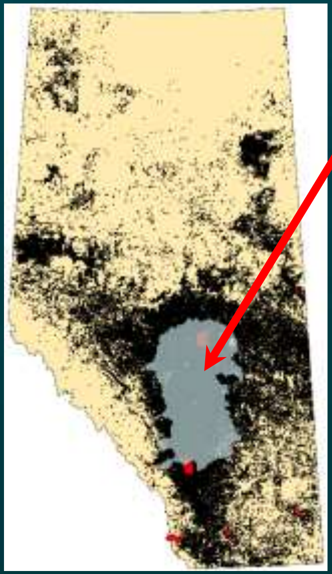
March 14, 2013

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

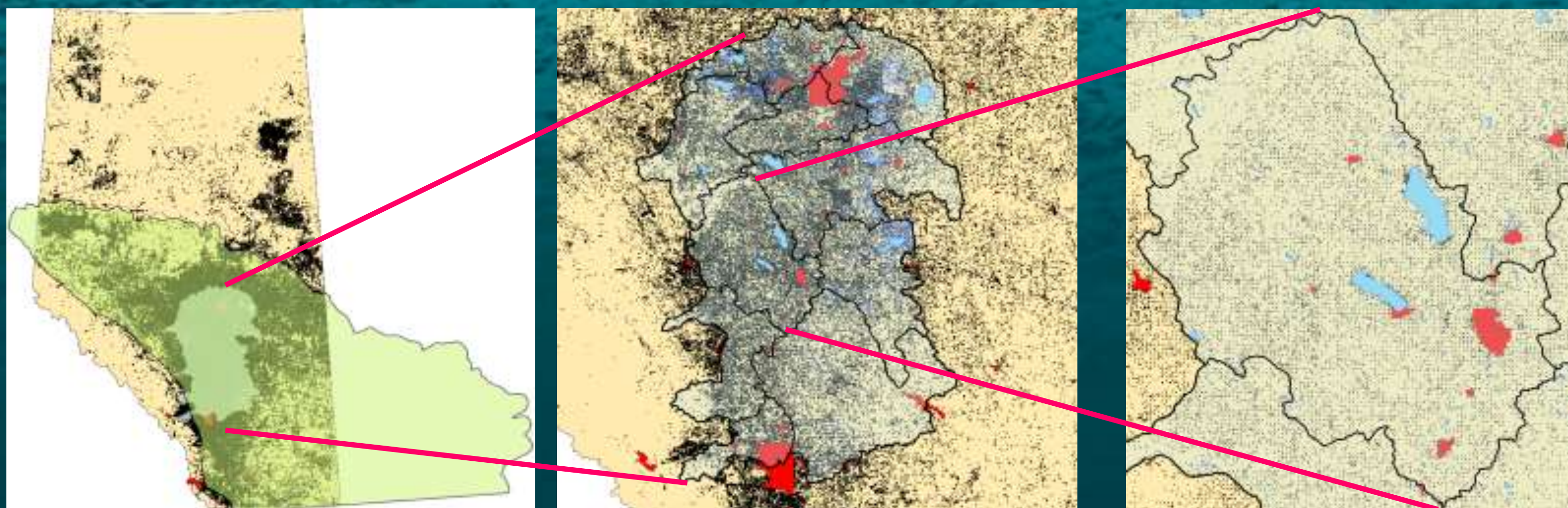
- Establish the **PURPOSE** of the model.
- Develop a **CONCEPTUAL MODEL** of the system.
  - Gather data
- **GOVERNING EQUATION** and **COMPUTER CODE**
- **DESIGN**
- **CALIBRATION**
  - Conduct a **CALIBRATION SENSITIVITY ANALYSIS**
  - Determine how the model responds to uncertainty in parameter values.
- **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 <u>Steady State</u> 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)

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
  - Reduces influence of BC's on management-scale model
- Accounts for groundwater flux between sub-basins

ALL MODELS ARE WRONG BUT SOME ARE USEFUL**

*For illustration only

Concept of Hydrostatic Pressure

$$h = z + \psi$$

Hydraulic head   Elevation head   Pressure head

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

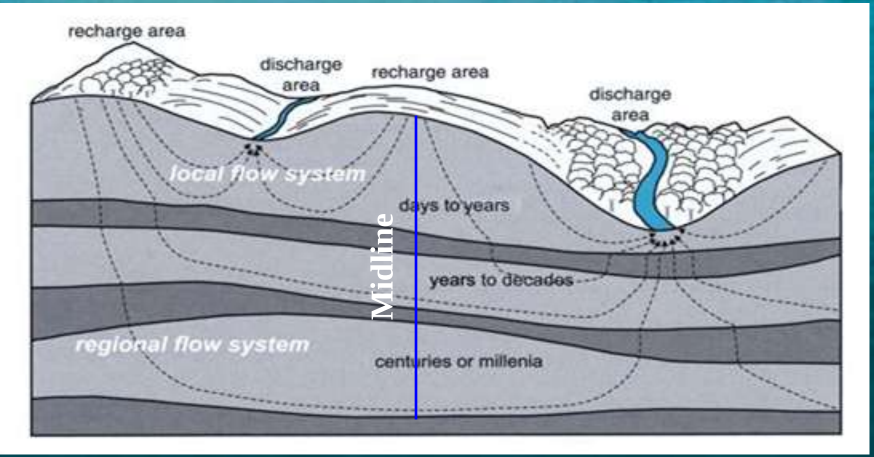
Formation fluid pressure

Density of fluid × Gravitational constant

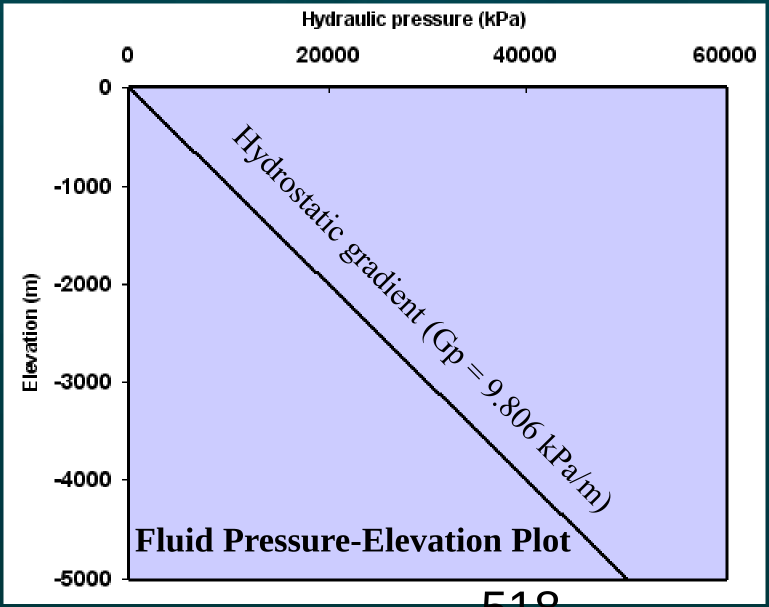
$$h = z + \frac{P}{\rho g}$$

i.e. <u>h remaining constant, P ∝1/z</u>

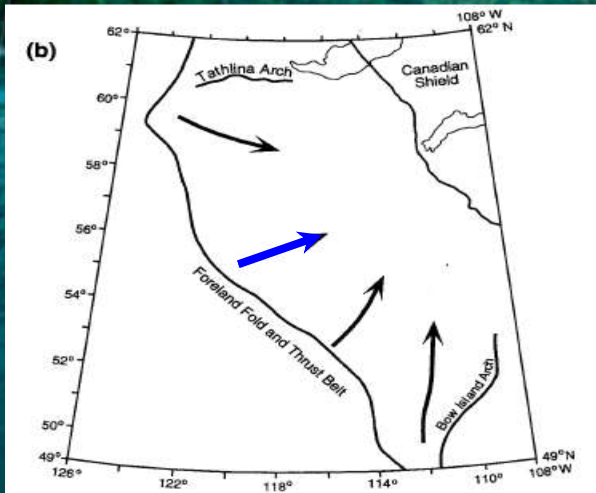
Under normal (hydrostatic) conditions, hydrostatic pressure increases by 9.8 kPa for every meter increase in depth



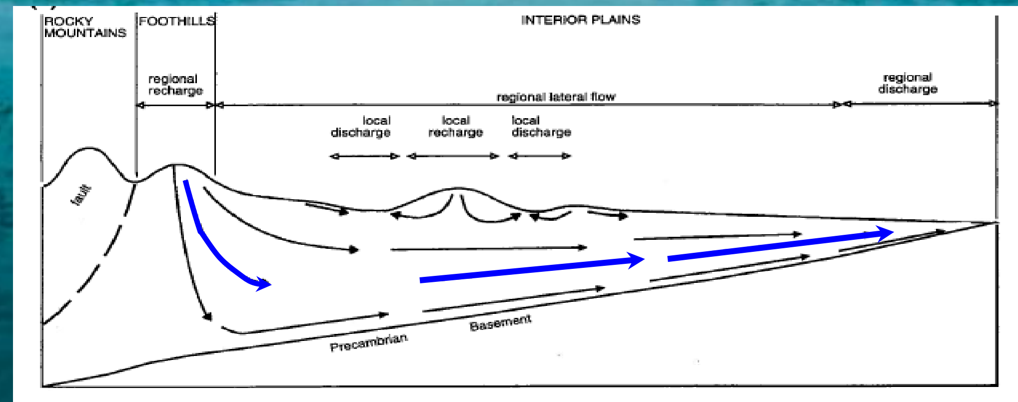
Groundwater flow systems (MAC education)**



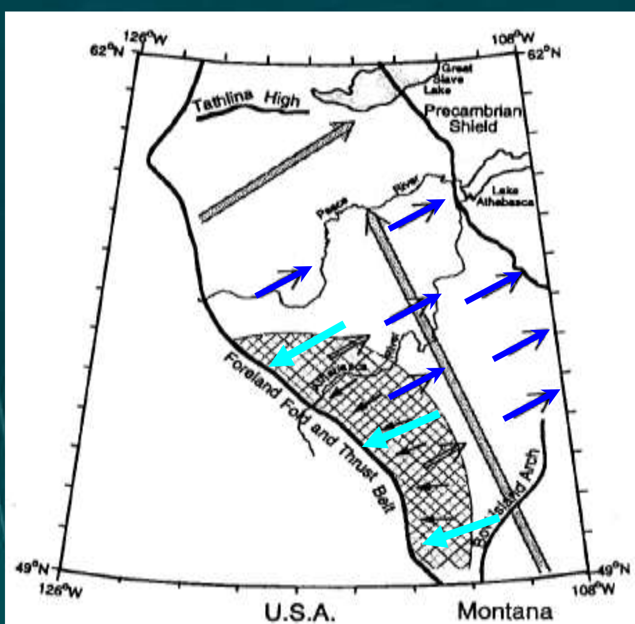
Existing knowledge of Basin-scale Flow in the Alberta Basin



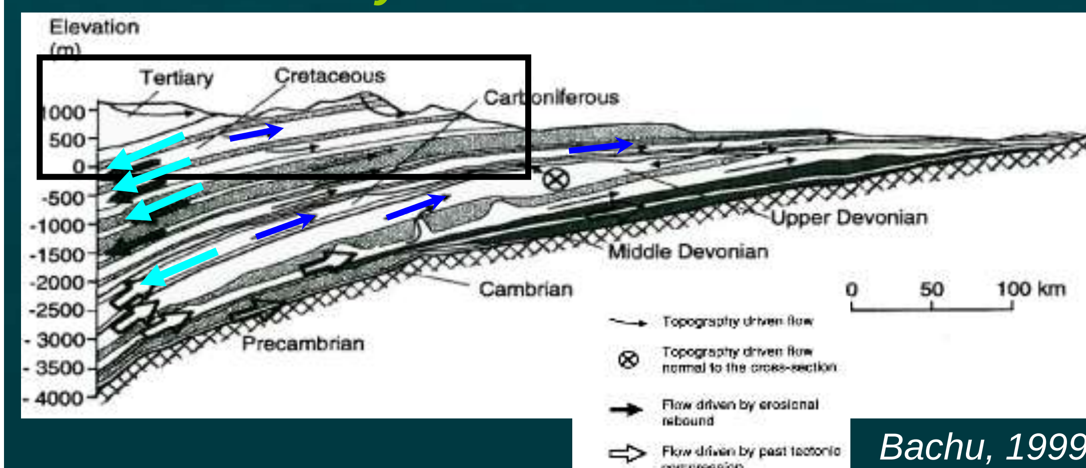
←BC Alberta SK→



Hitchon, 1984

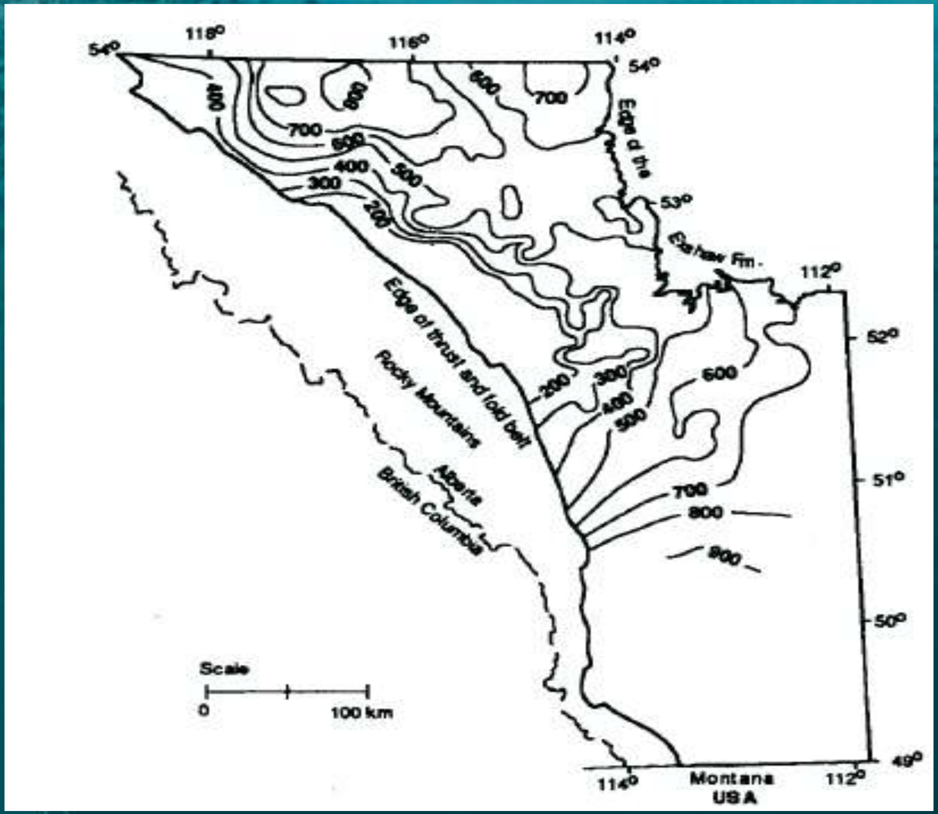


This study

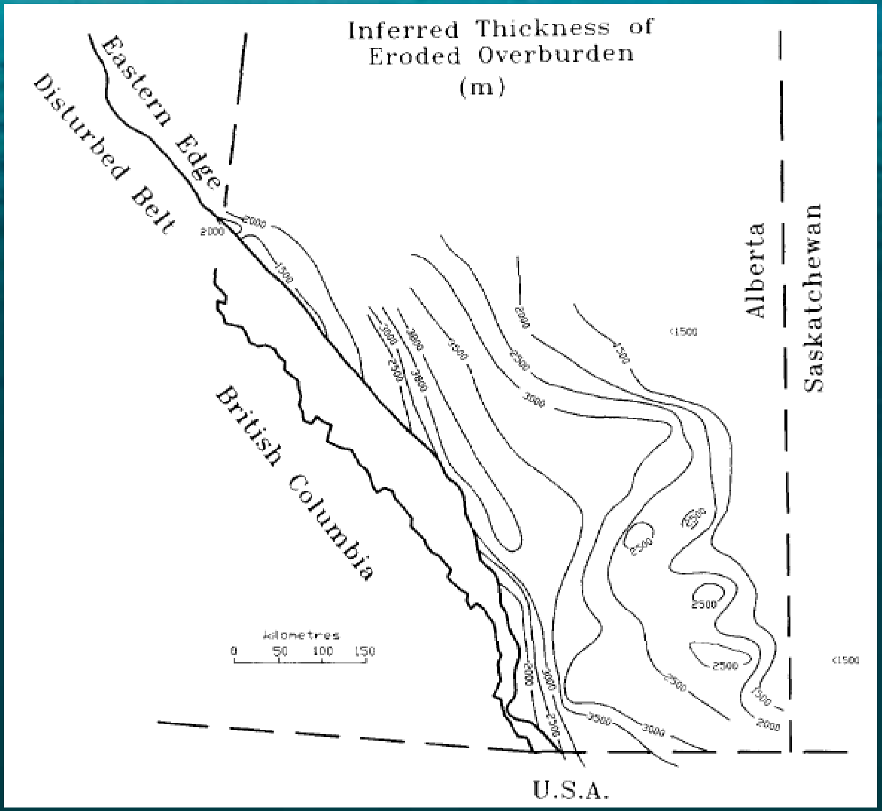


Bachu, 1999

Sub-Hydrostatic Regime in SW Alberta



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

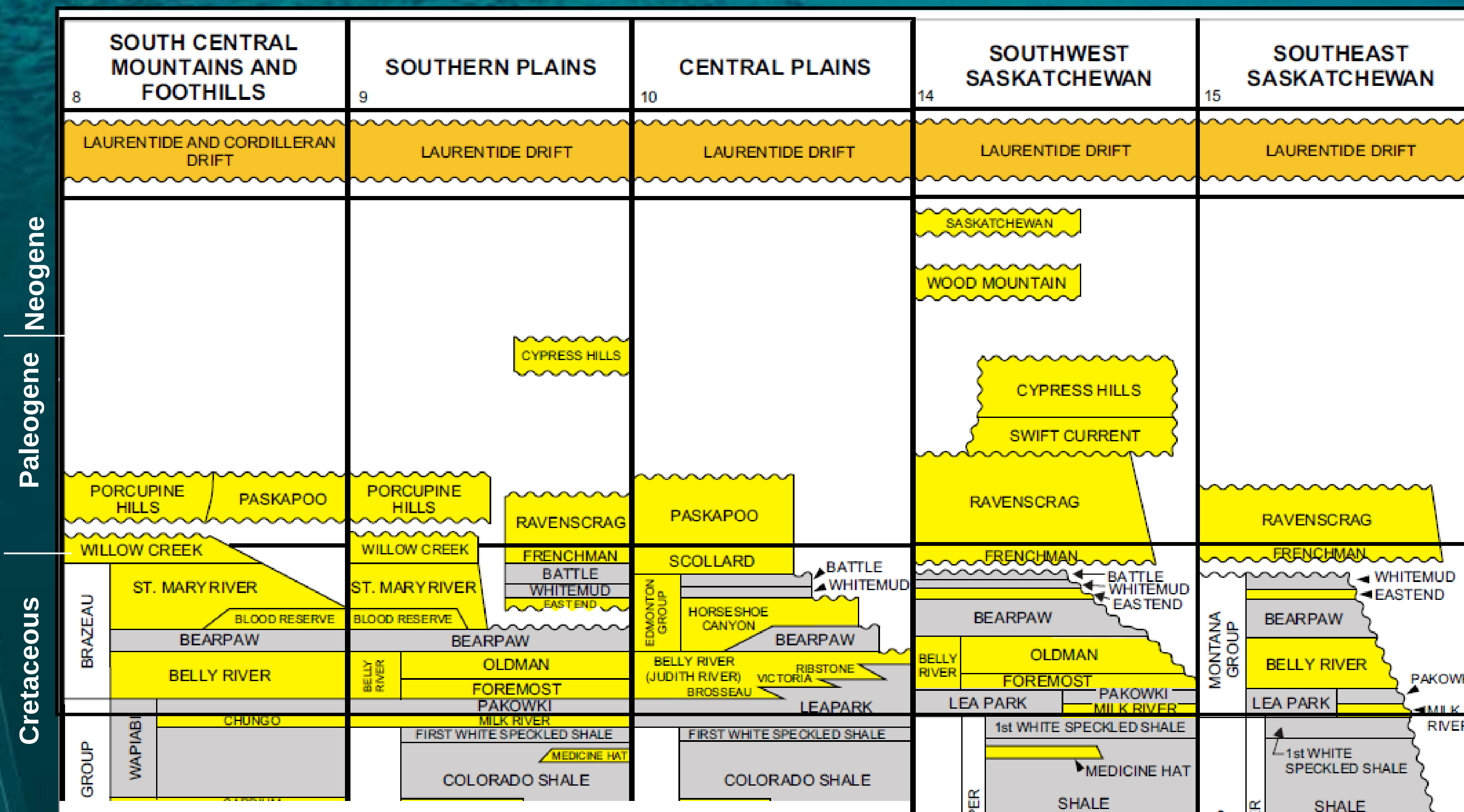


Bustin, 1991

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

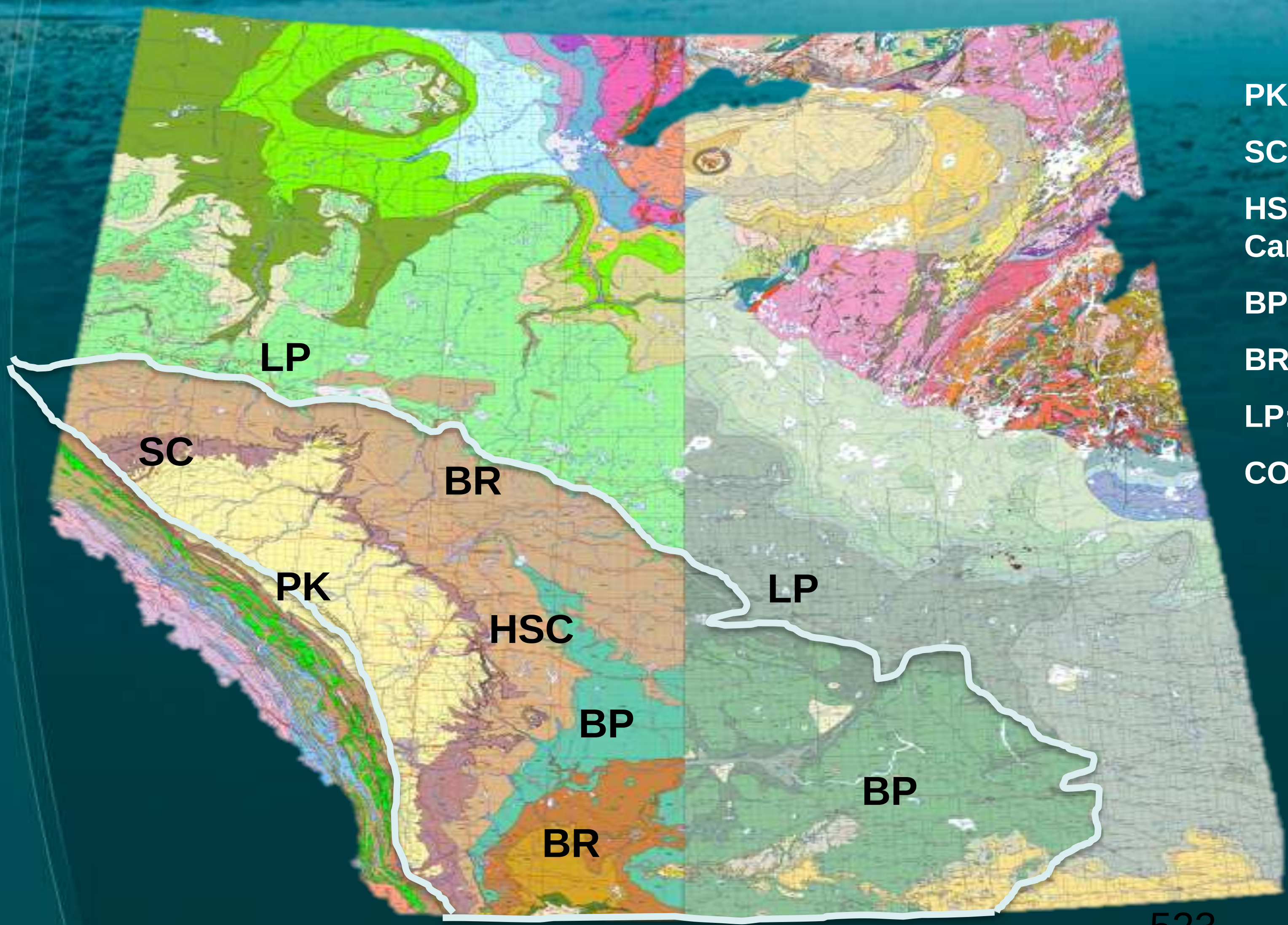
Hydrostratigraphic Layers	Hydraulic Property	Source
Recent	Depends	ERCB/AGS
Paskapoo	Aquifer	
Scollard	Aquifer	ERCB/AGS
Battle	Confining	ERCB/AGS
Horseshoe Canyon	Aquifer	
Bearpaw	Confining	Hamblin (GSC) picks / AGS/ Saskatchewan Data / Outcrops
Belly River*	Aquifer	ERCB/AGS & SWA
Lea Park (Top of Colorado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

<u>For modeling purposes</u>

- *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

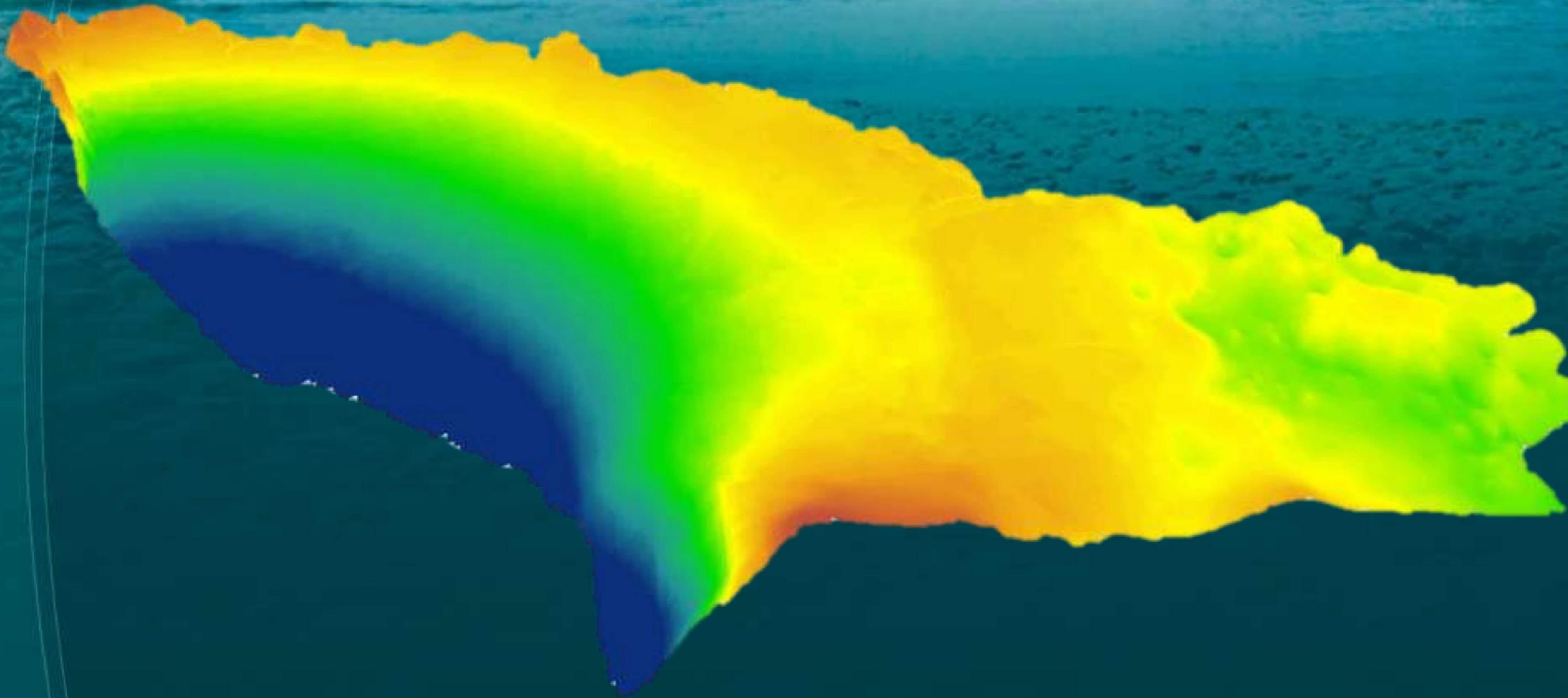
BR: Belly River

LP: Lea Park

COL: Colorado

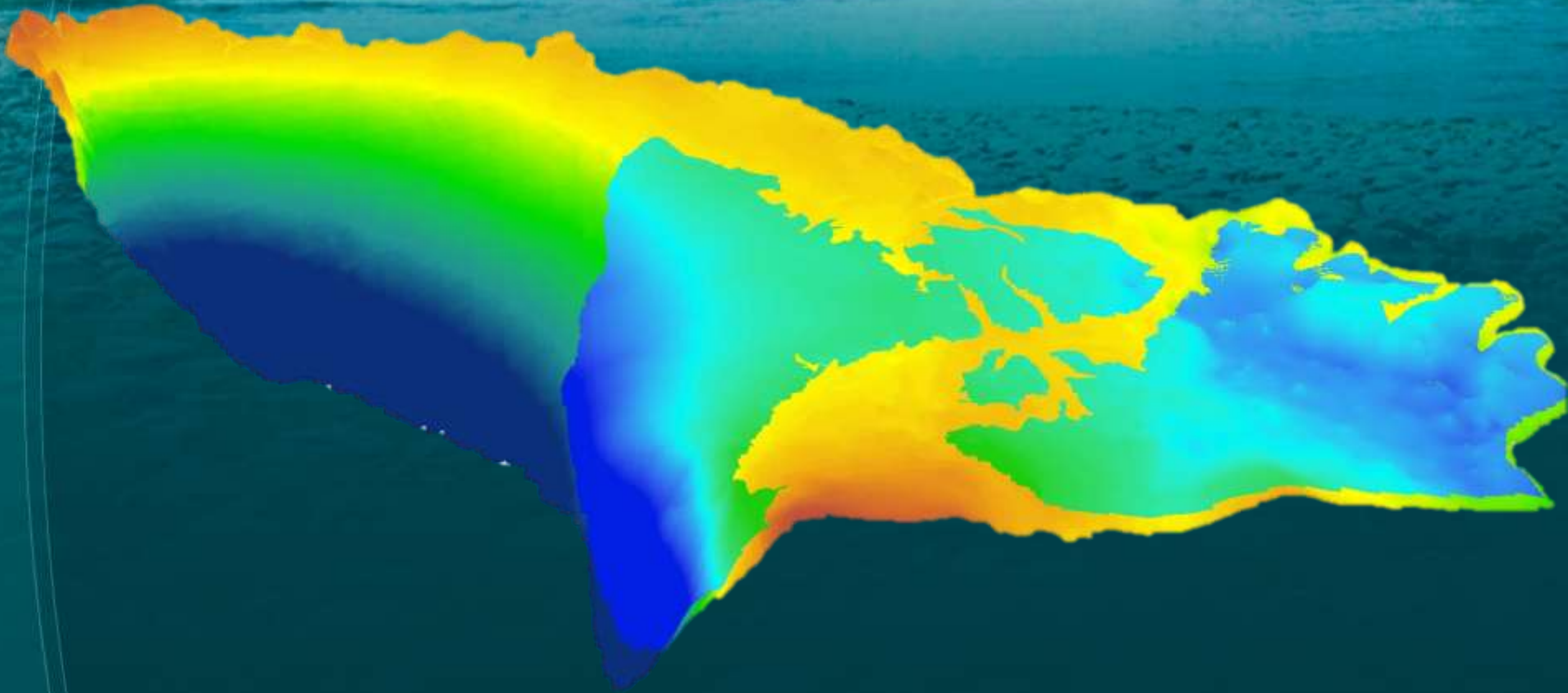
conceptual model contd.

Conceptual Model



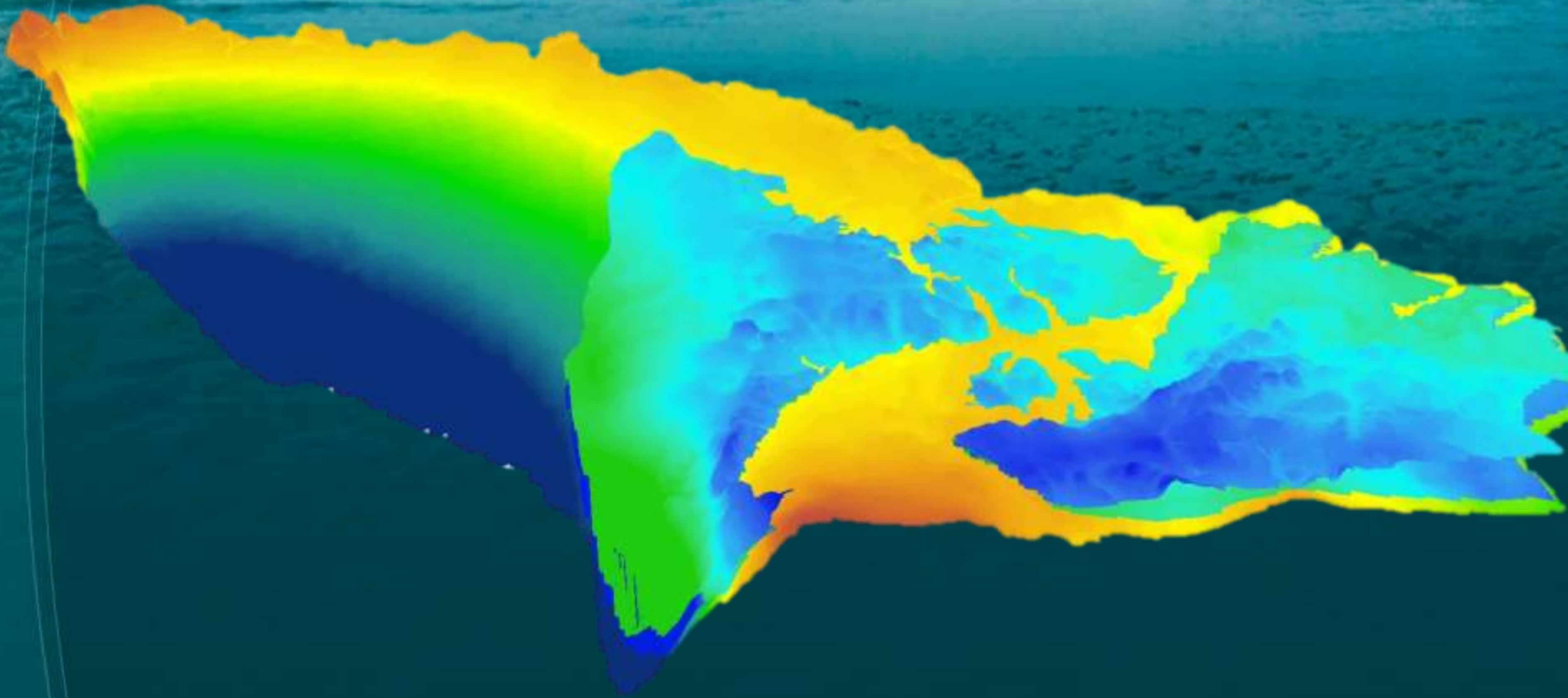
Lea Park

Conceptual Model



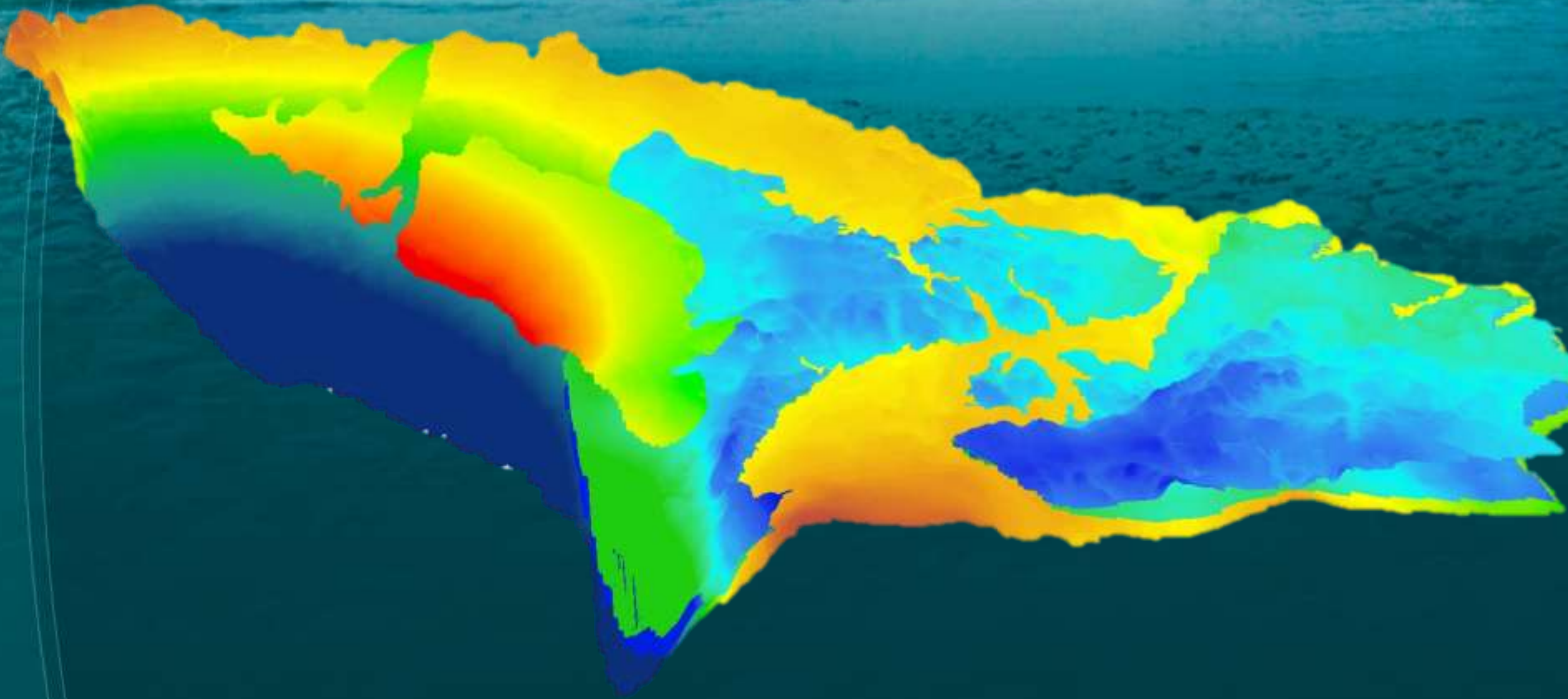
Belly River

Conceptual Model



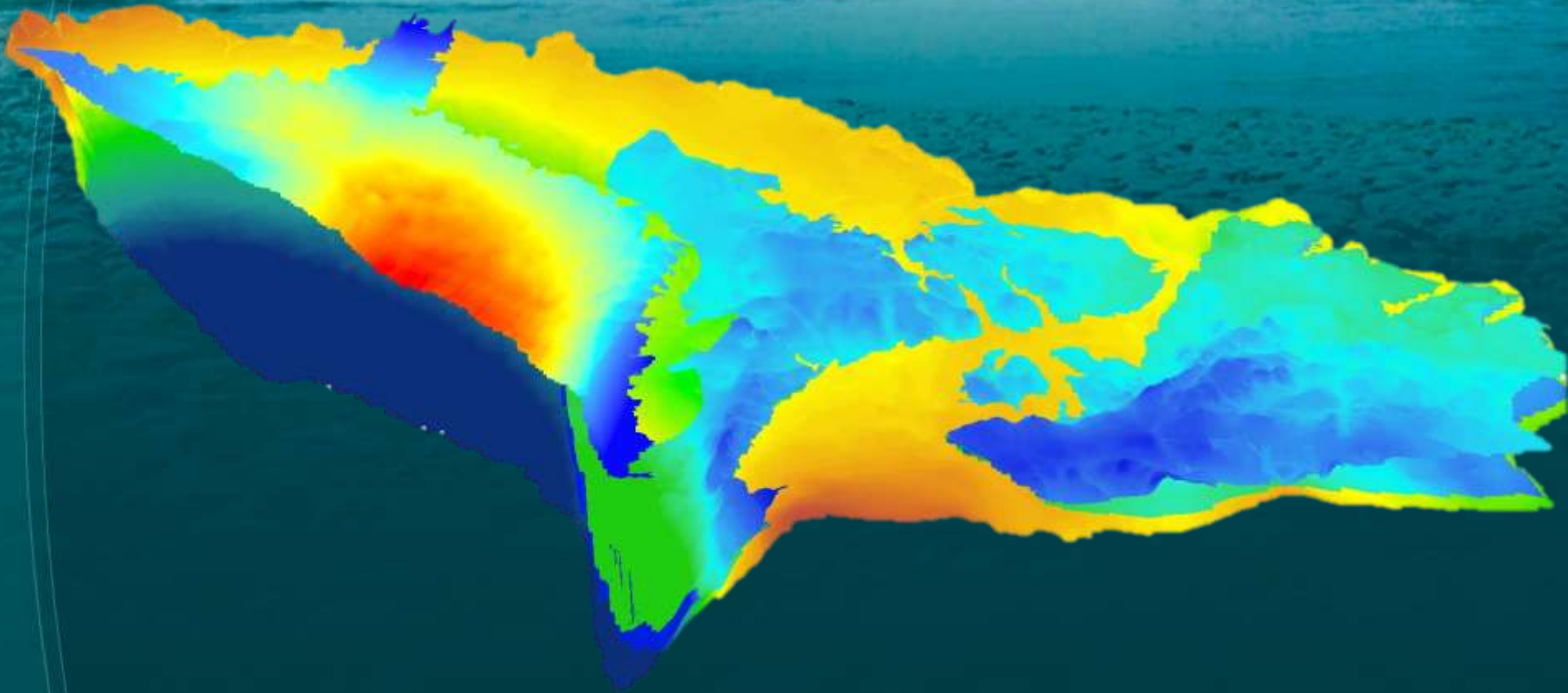
Bearpaw

Conceptual Model



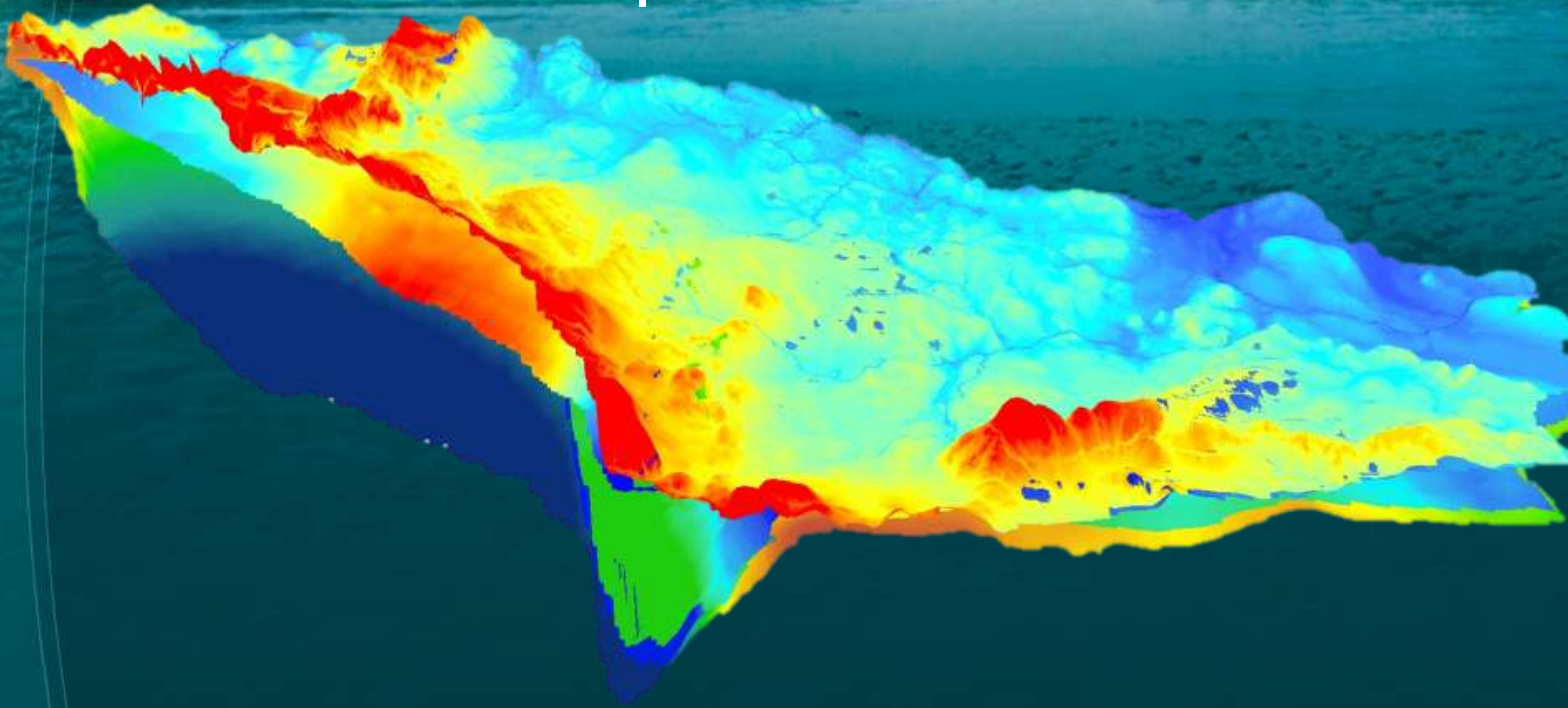
Battle

Conceptual Model



Scollard

Conceptual Model



Model Domain

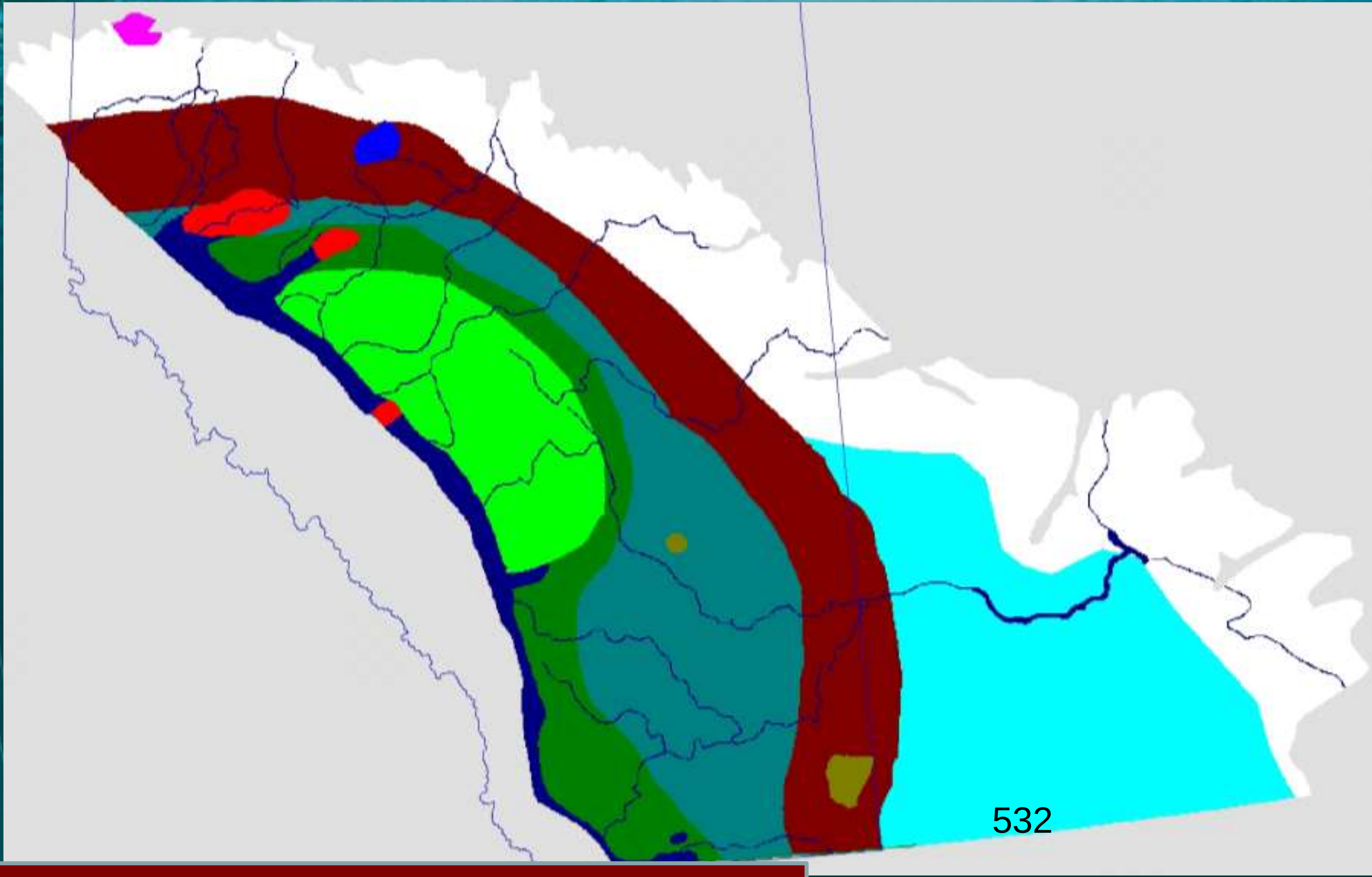
NUMERICAL MODEL

- **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])

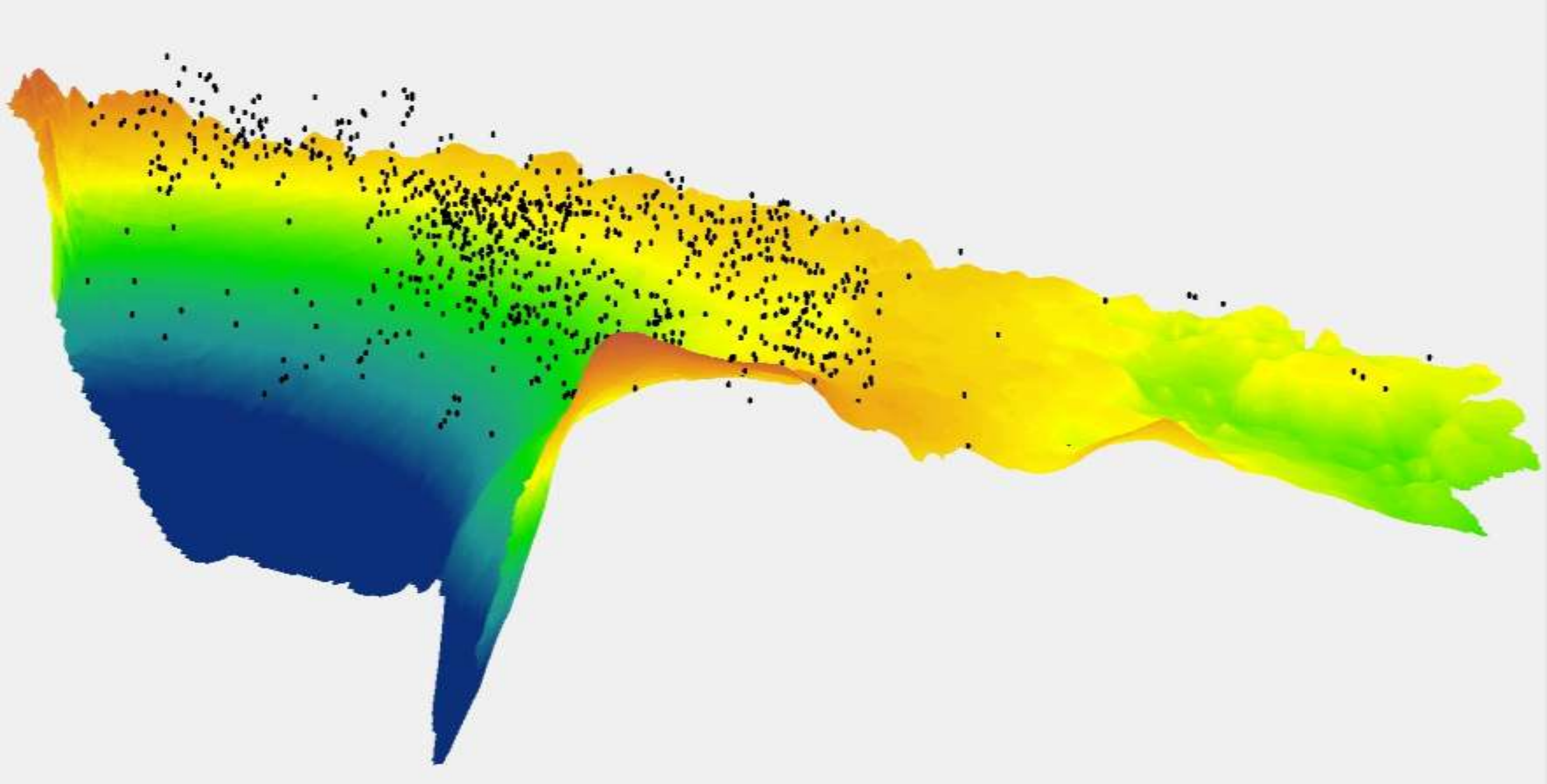
- Calibration targets
  - ESRD Observation wells
  - Water wells
  - DST measurements (cleaned for production influence)

  - 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

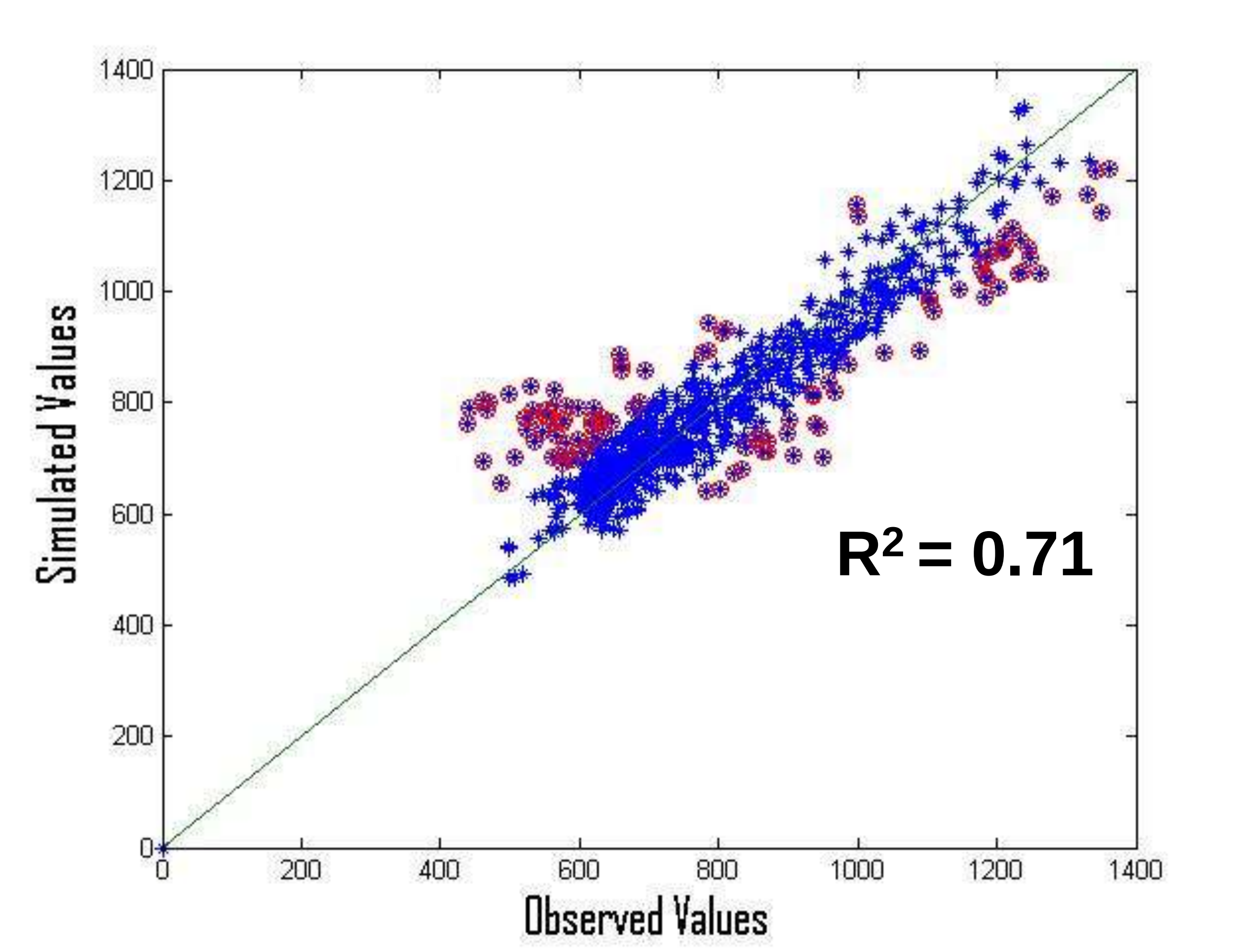


Results

- 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

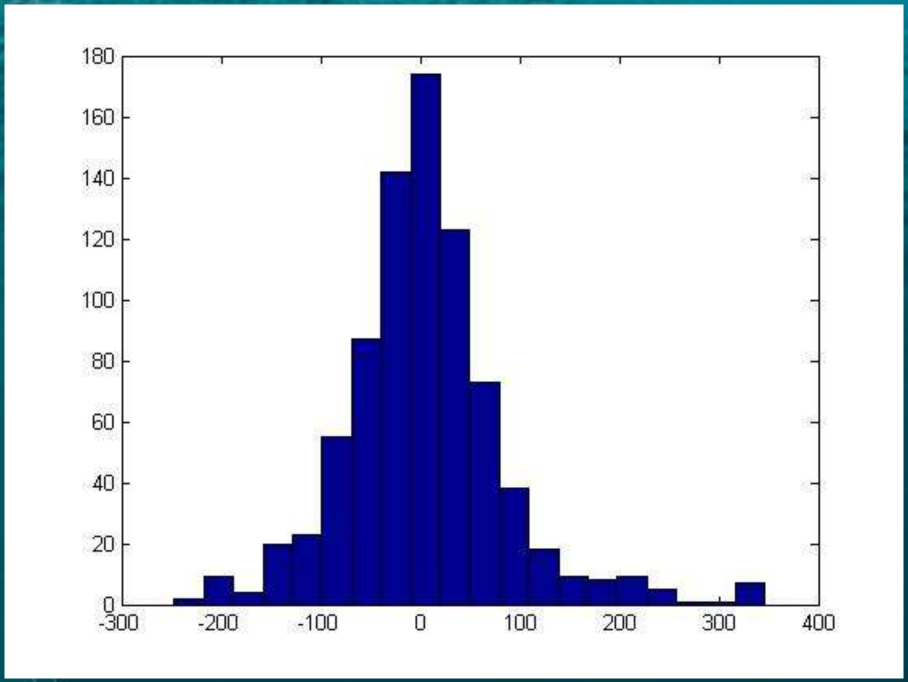


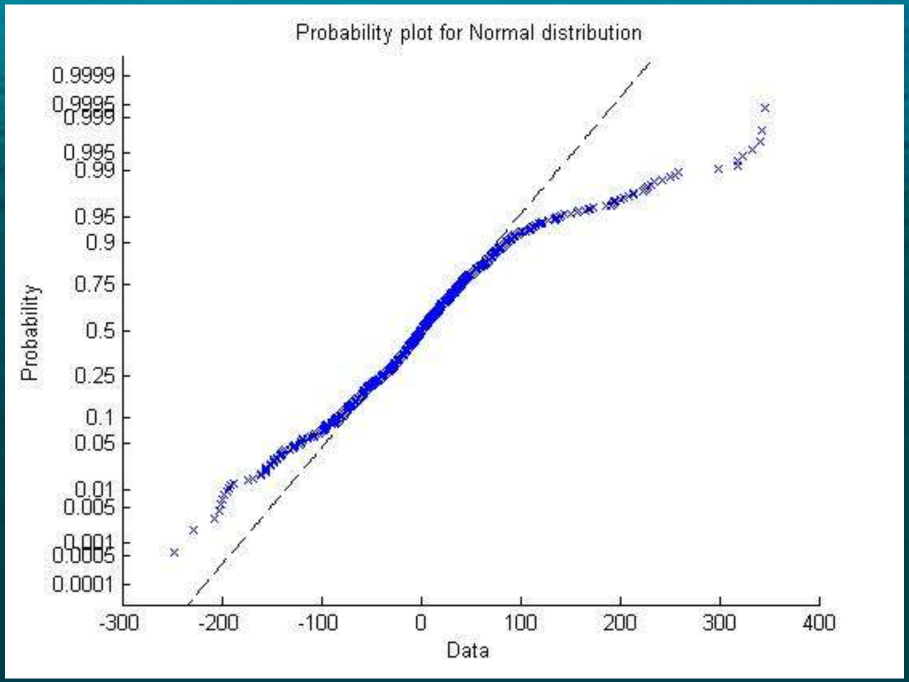
Simulated Values
Observed Values
0
200
400
600
800
1000
1200
1400
R² = 0.71

Results

Spatial Distribution of Highlighted (previous slide) Errors

Results

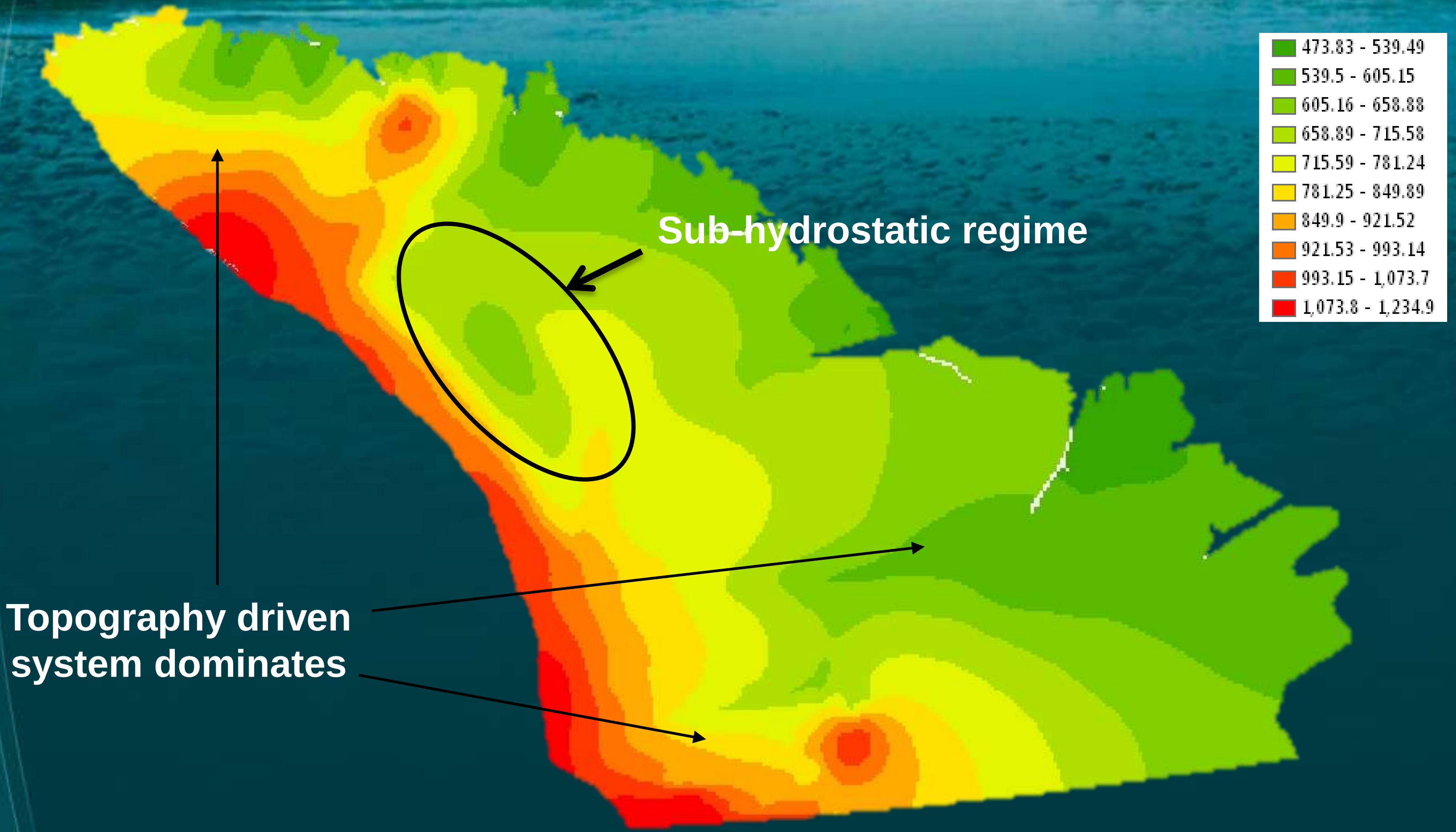




Error Distribution

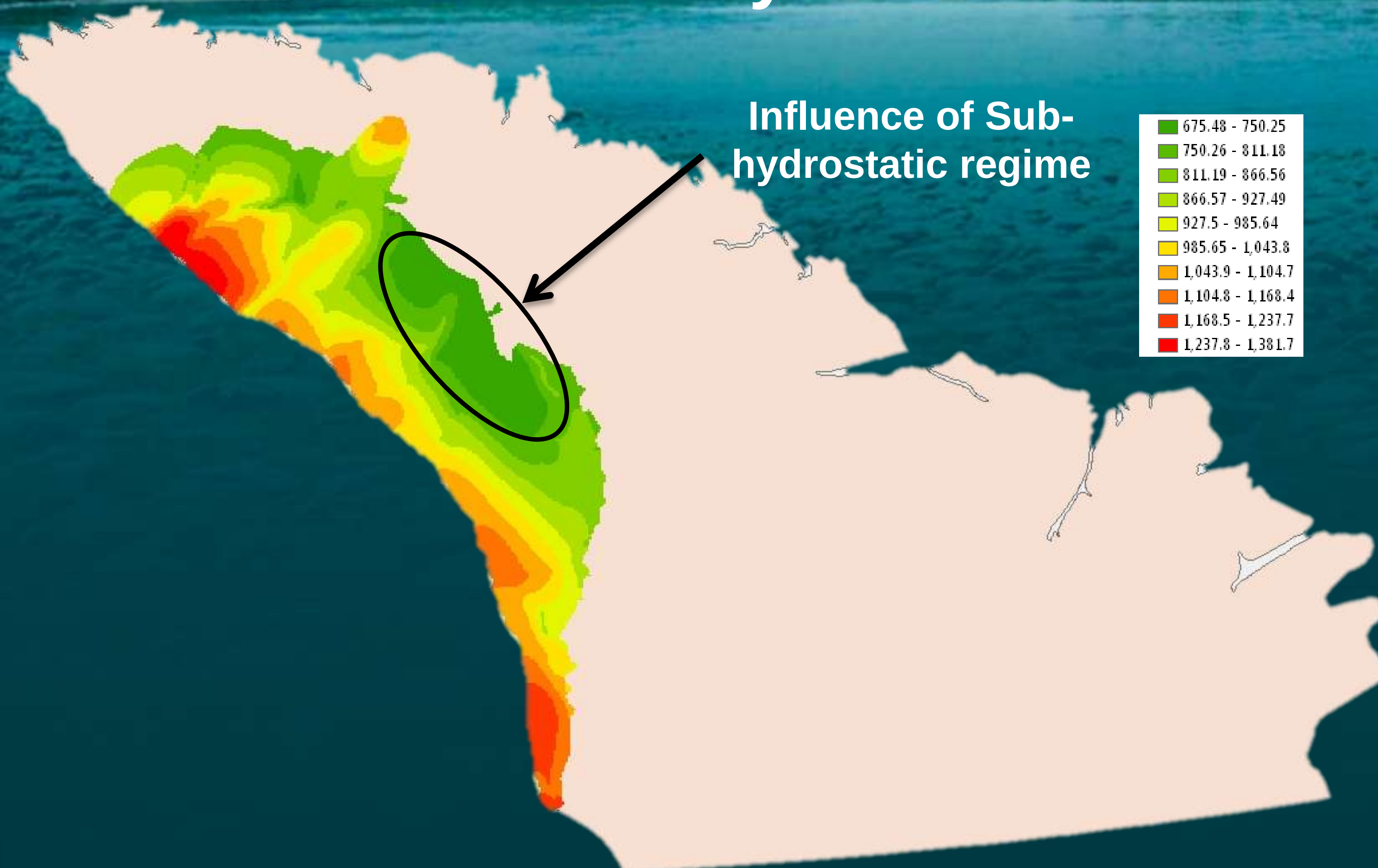
Probability Plot

Distribution of Hydraulic Heads



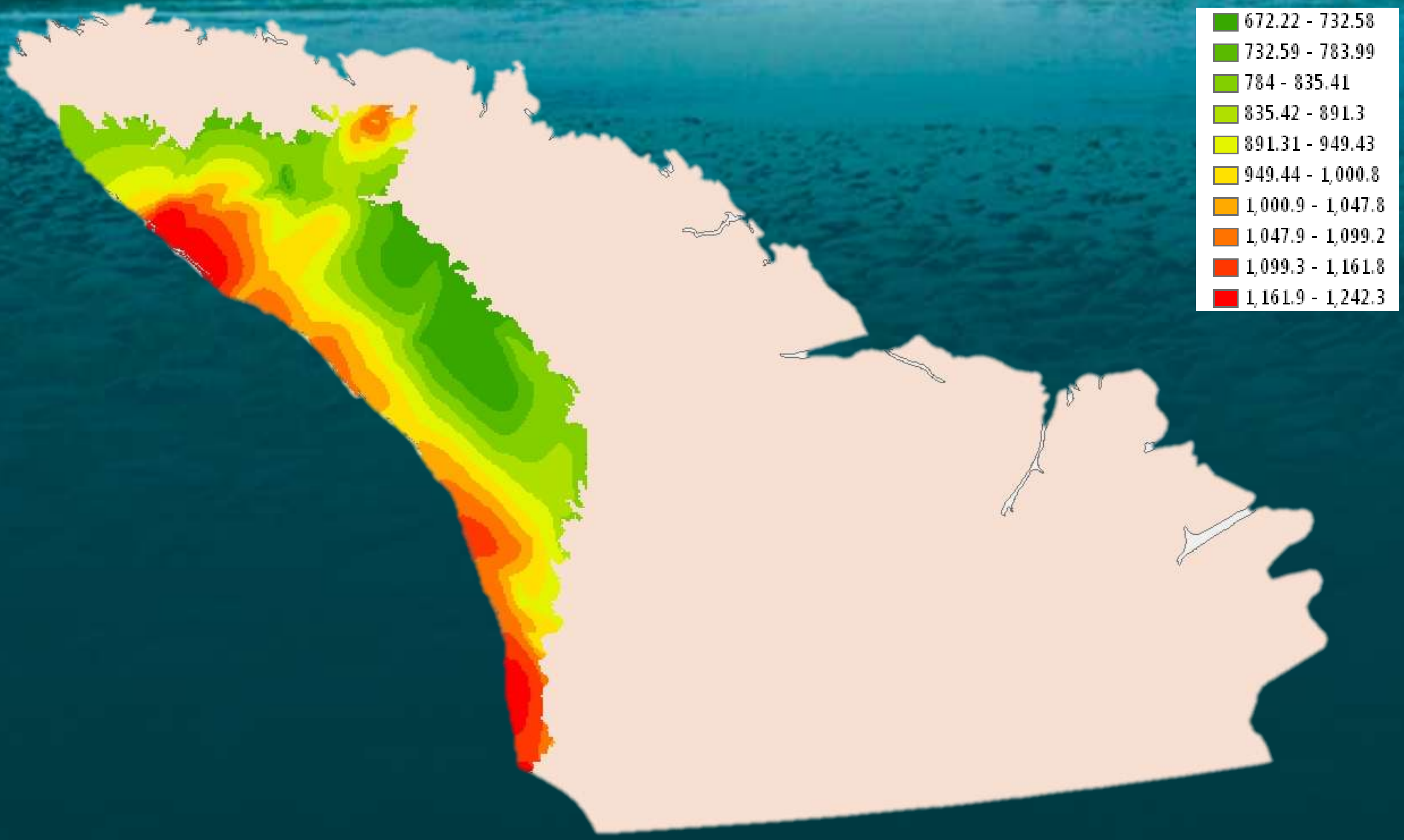
Belly River aquifer

Distribution of Hydraulic Heads



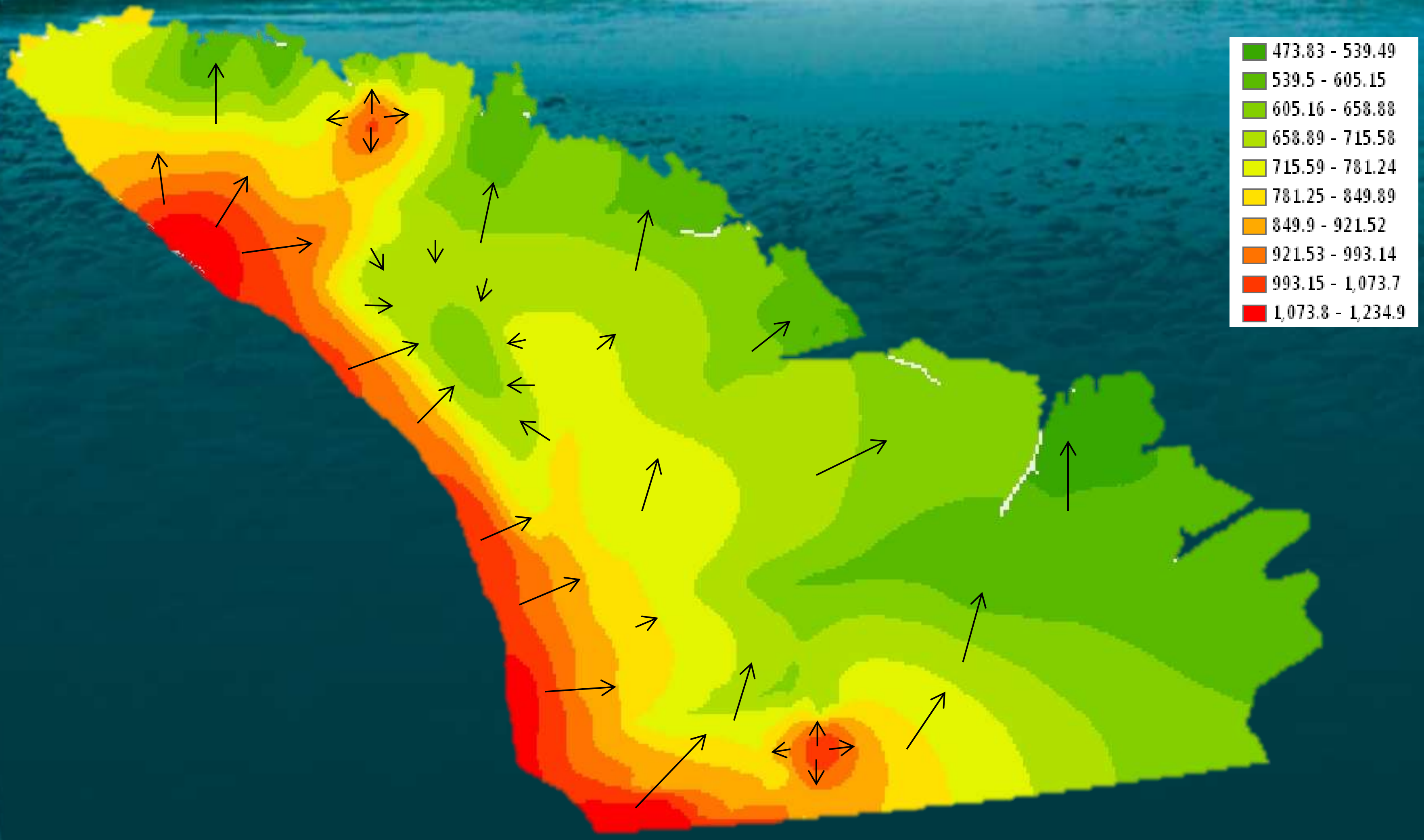
Paskapoo aquifer

Distribution of Hydraulic Heads



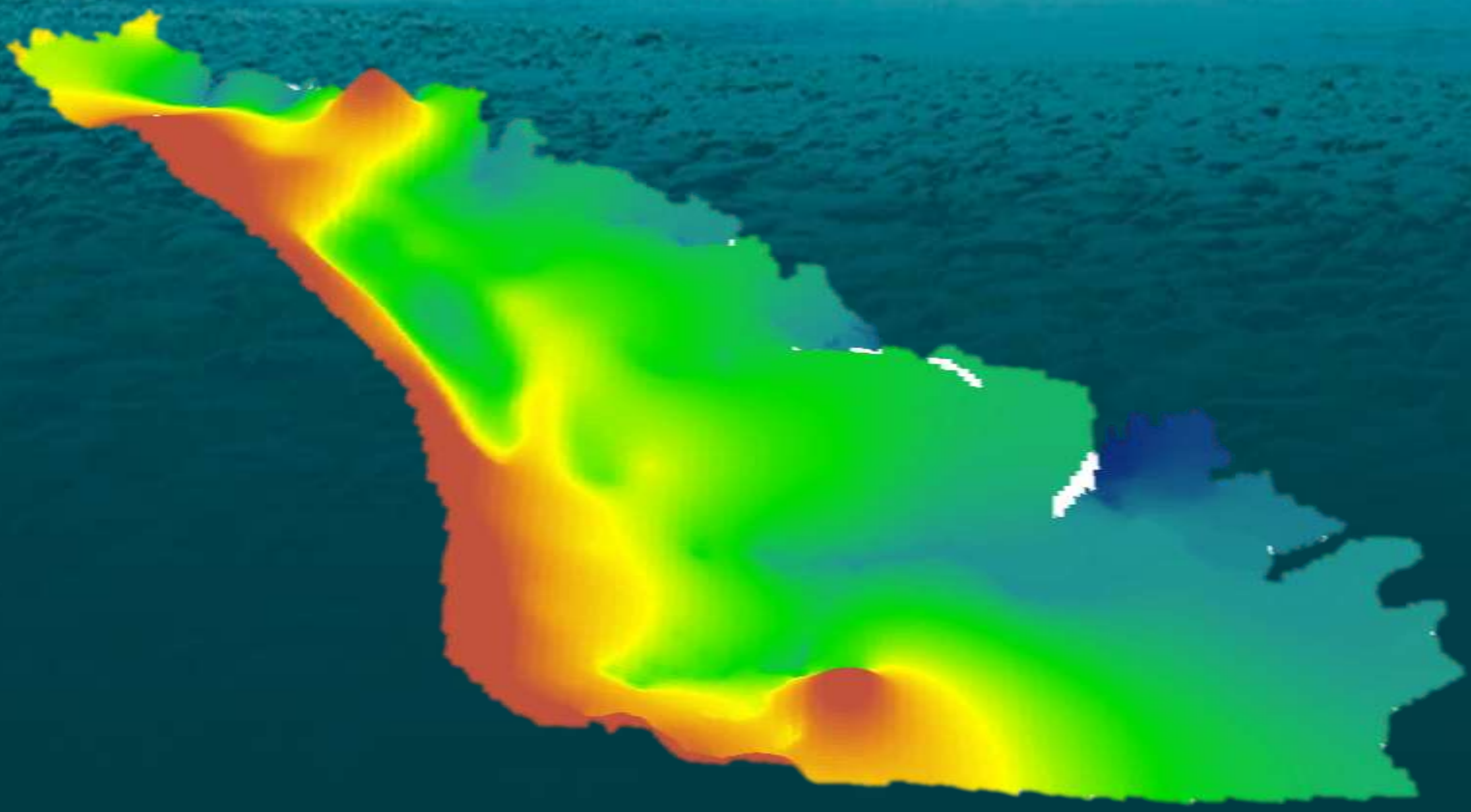
Scollard aquifer

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

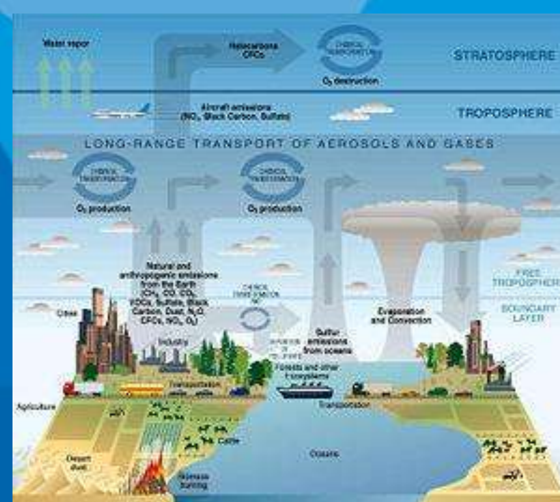
ABSTRACT

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

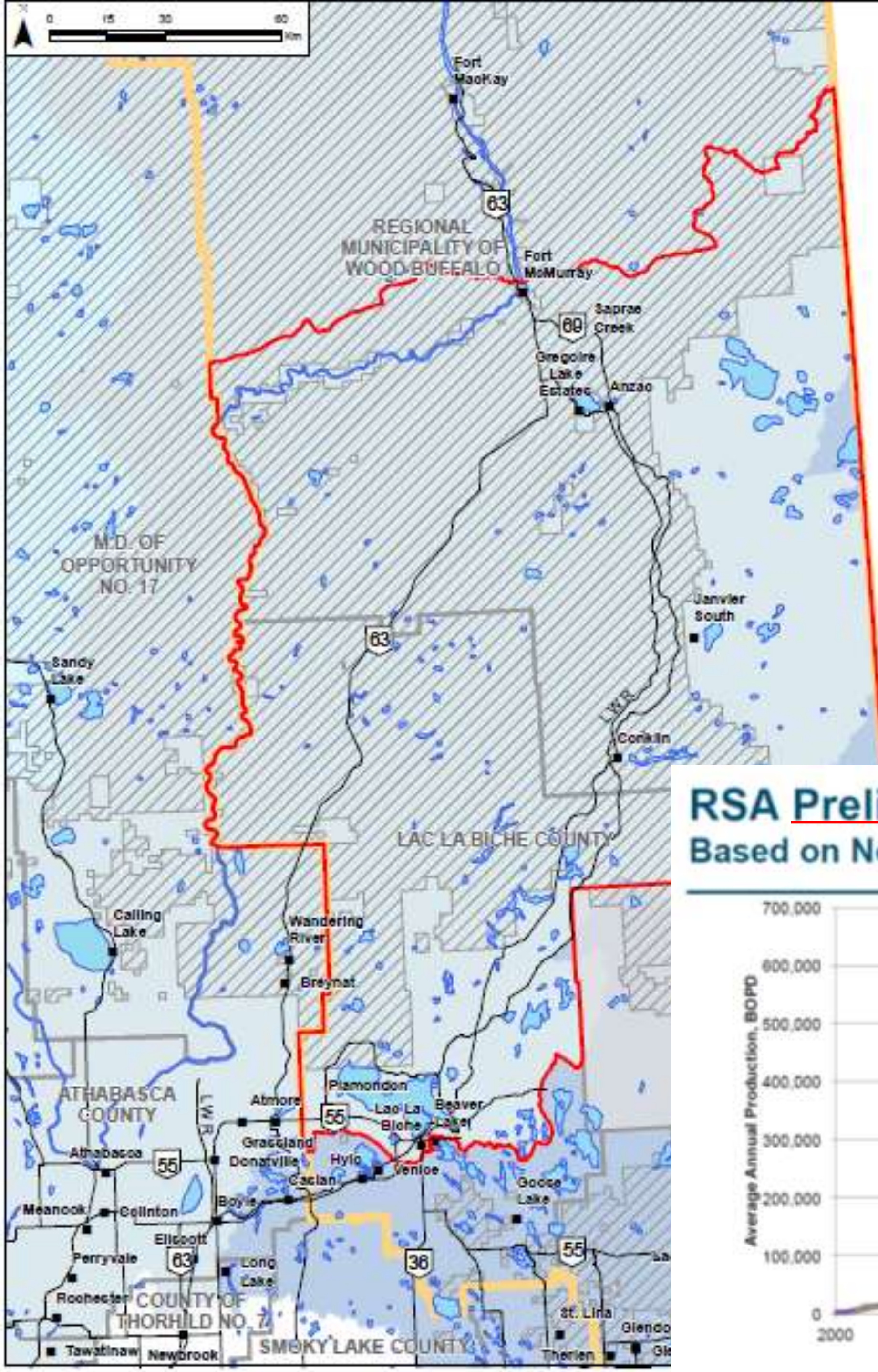
- Policy direction for the South Athabasca Oil Sands (SAOS) Regional Strategic Assessment (RSA)
- What is Regional Strategic Assessment (RSA)?
- Cumulative Effects Approach in the SAOS RSA
- Environmental Models and Integration
  - Air Quality
  - Surface and Ground Water
  - Land and Biodiversity
 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

Policy direction

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

Strategies:

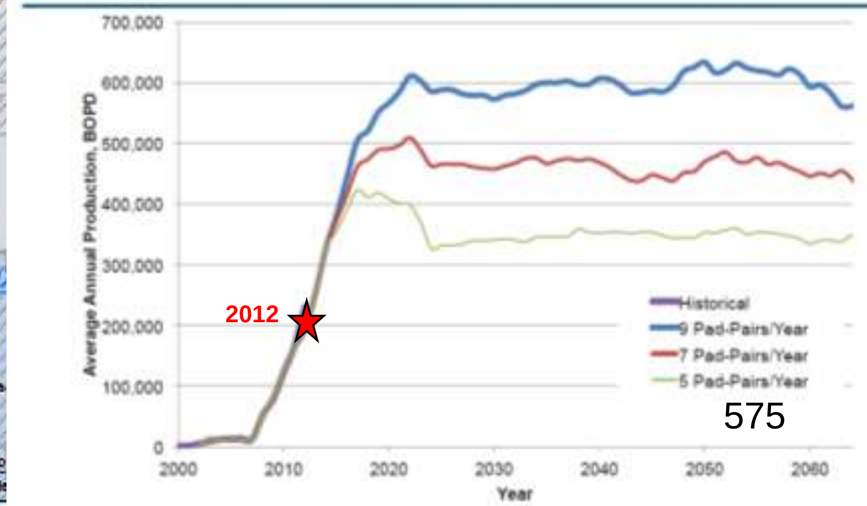
Development of a sub-regional plan using a strategic environmental assessment approach for the south Athabasca oil sands area. Undertaking this assessment at a sub-regional scale will contribute to the management of cumulative effects and support efficiencies in the regulatory review process for in-situ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



South Athabasca Oil Sands Regional Strategic Assessment Study Area

RSA Preliminary Production Scenarios

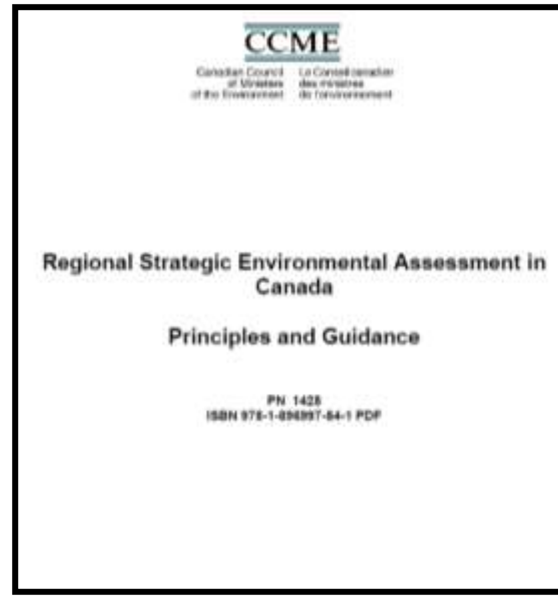
Based on No. of SAGD Pad-Pairs Added Annually



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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RSA for the South Athabasca Oil Sands Area

Purpose:

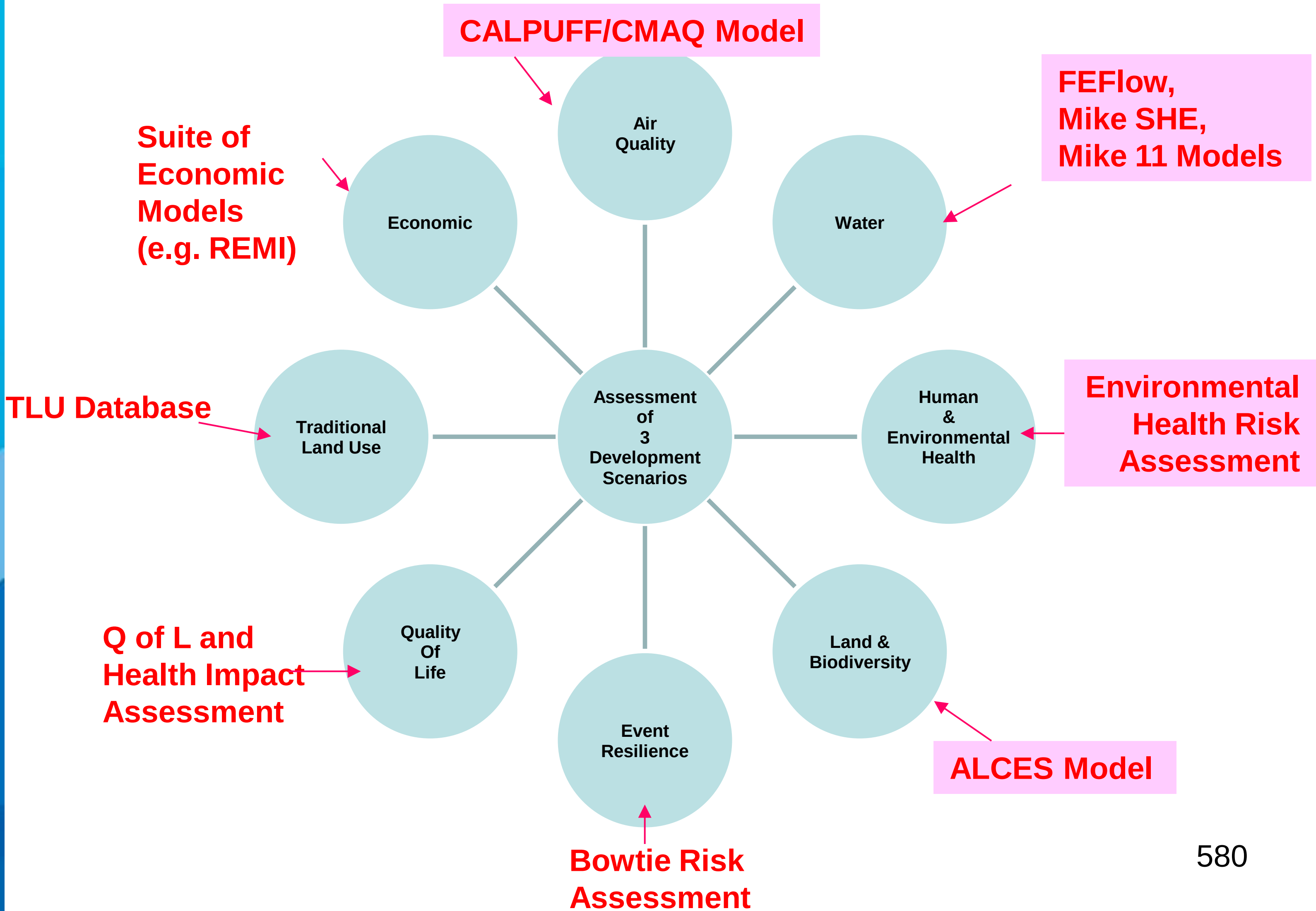
To inform decision-makers, planners, and stakeholders about:

(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)

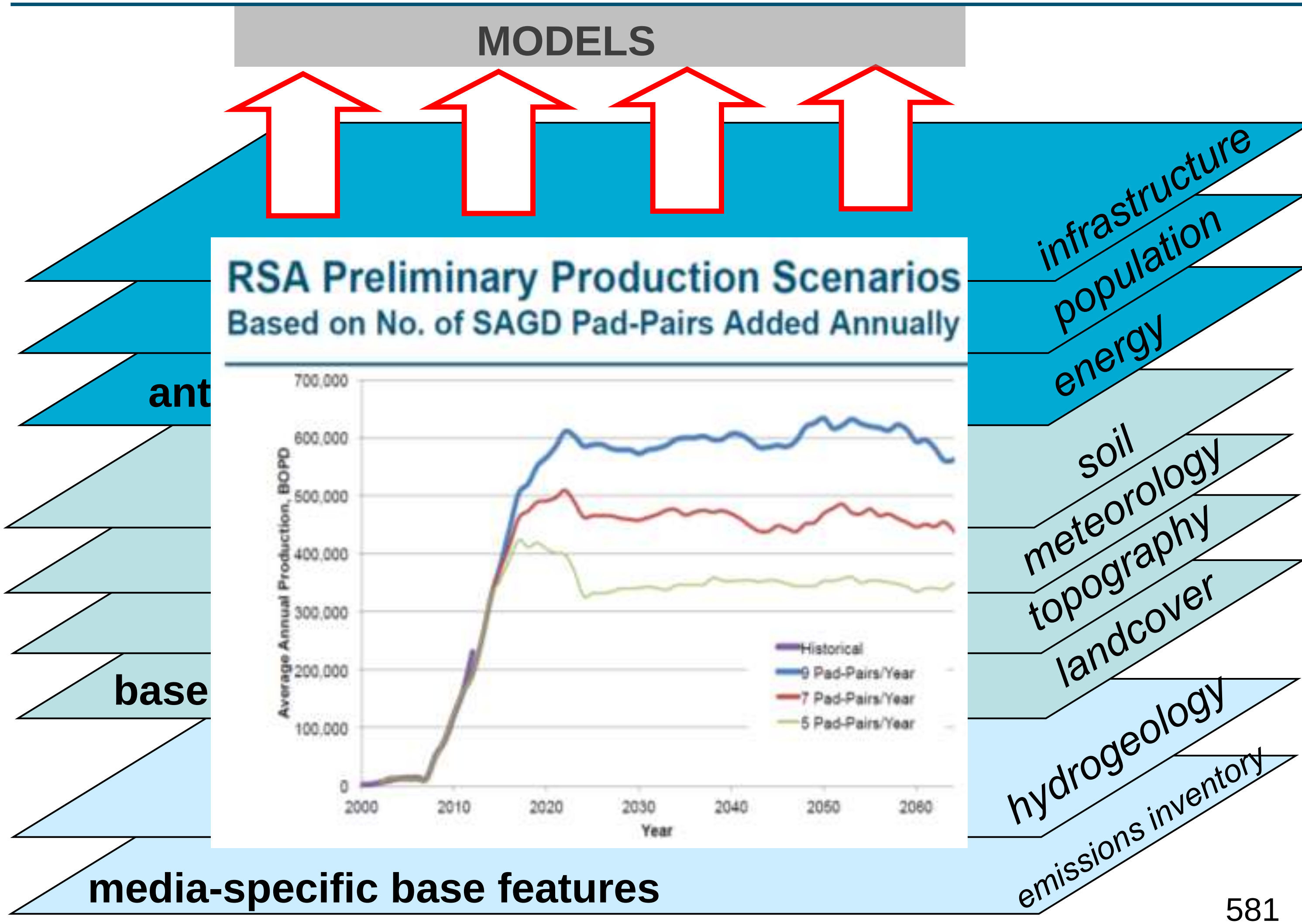
(i) Options for managing these effects such that desired outcomes are optimally achieved

(ii) Opportunities for regulatory enhancement

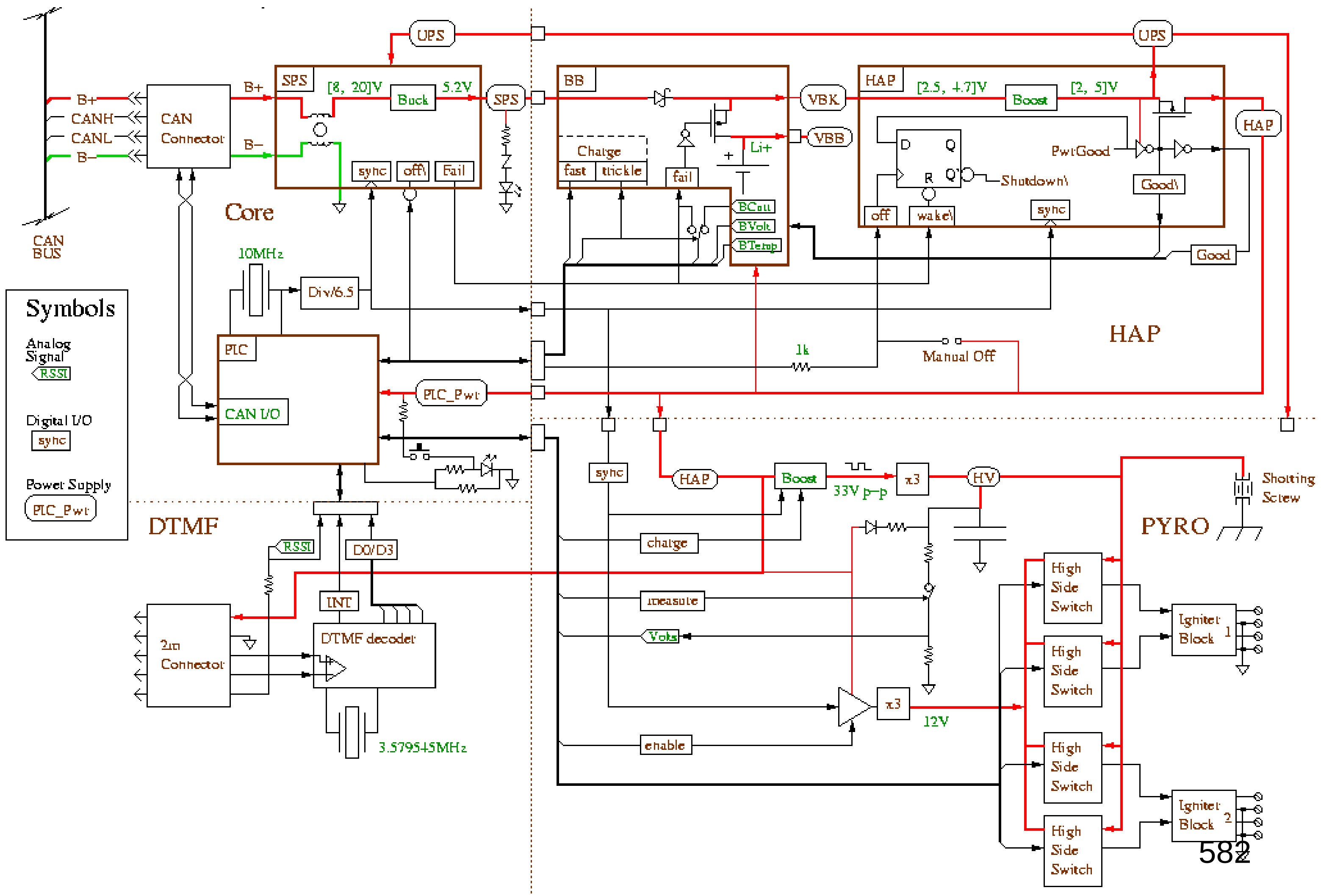
Regional Cumulative Effects Assessment



Integration: Same data inputs and scenario analysis



Air Quality: CALPUFF



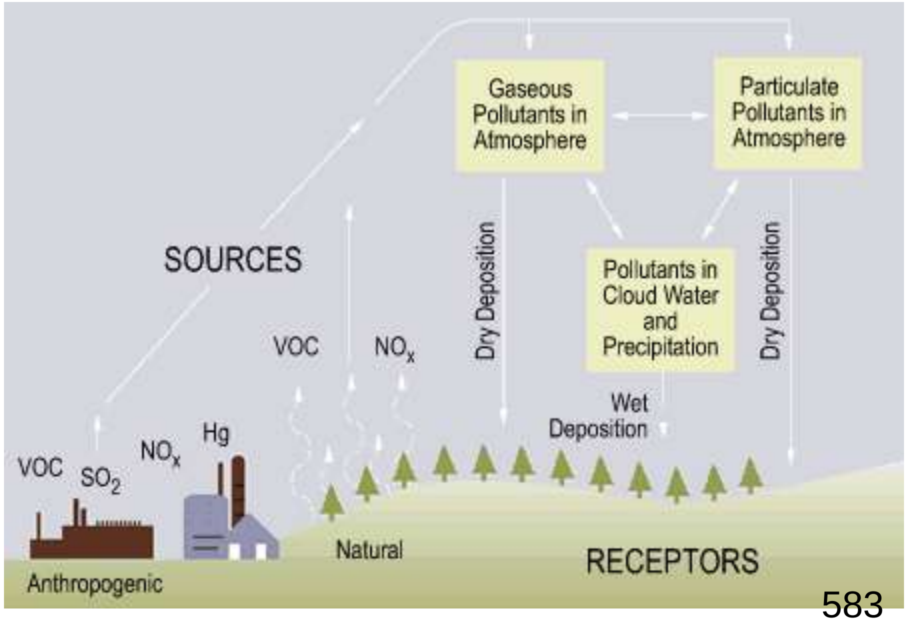
Air Quality Modelling

Currently using two models:

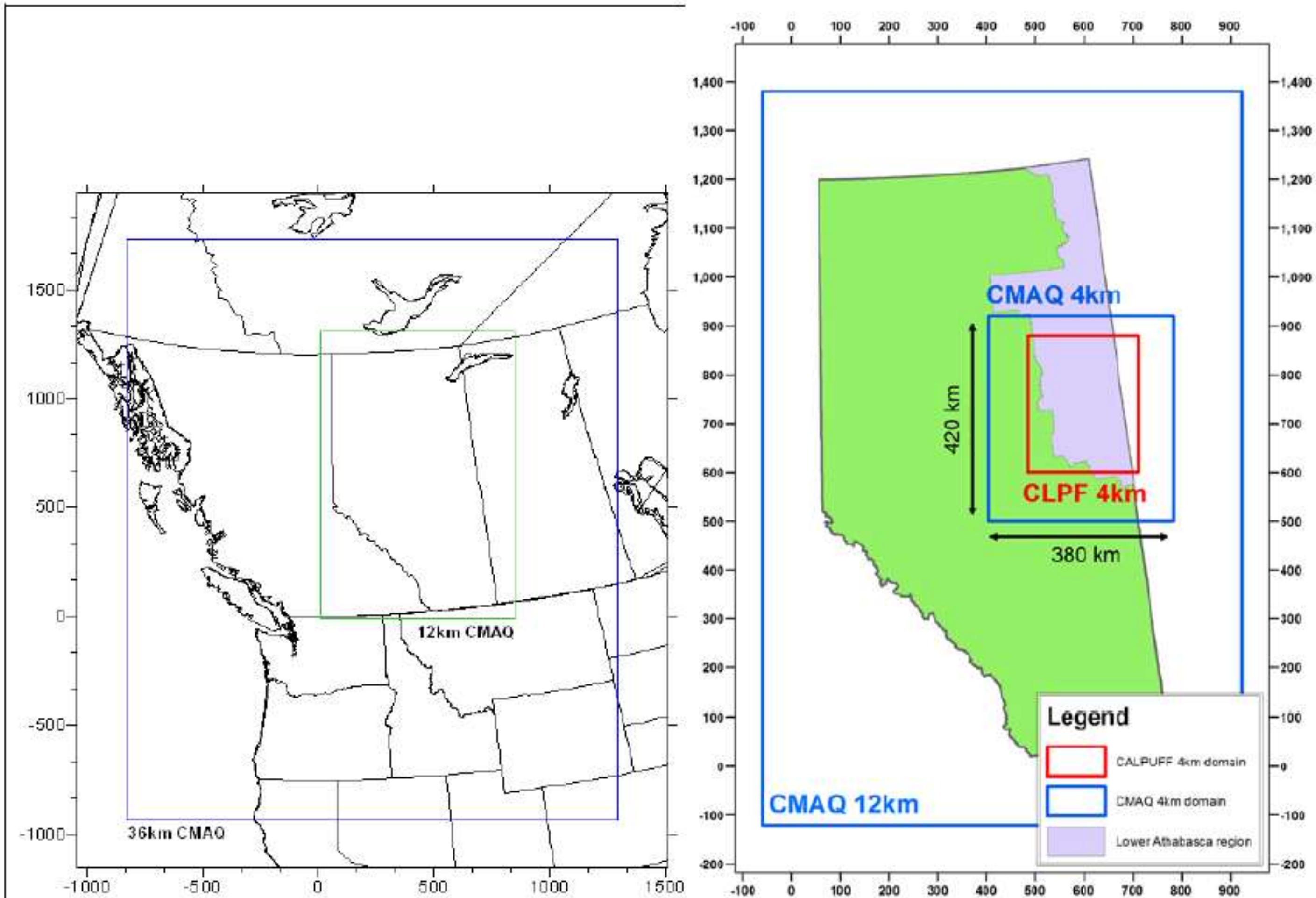
- CALPUFF modelling approach - transport and dispersion model
- CMAQ modelling approach - simulates multiple tropospheric air quality issues

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.

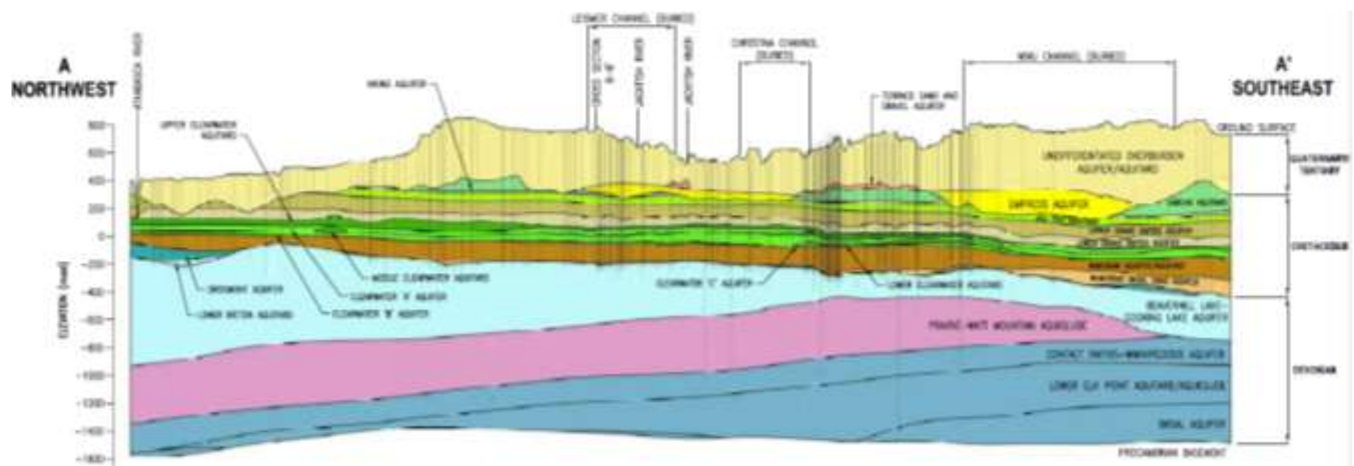
Water Modelling

Currently using three models:

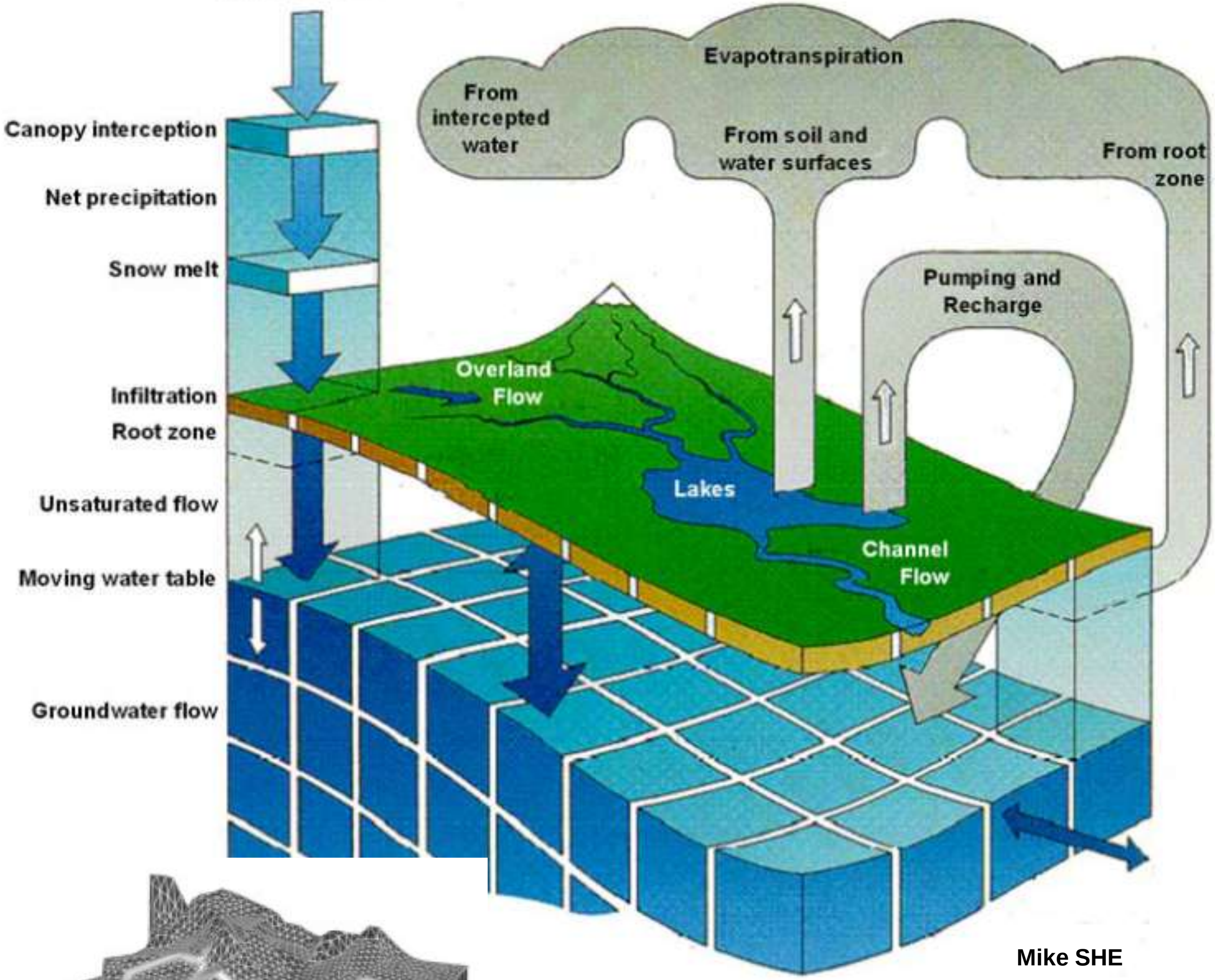
- FEFLOW – Advanced Groundwater Modelling
- Mike SHE – Integrated Catchment Modelling
- Mike 11 – River Modelling

Building on:

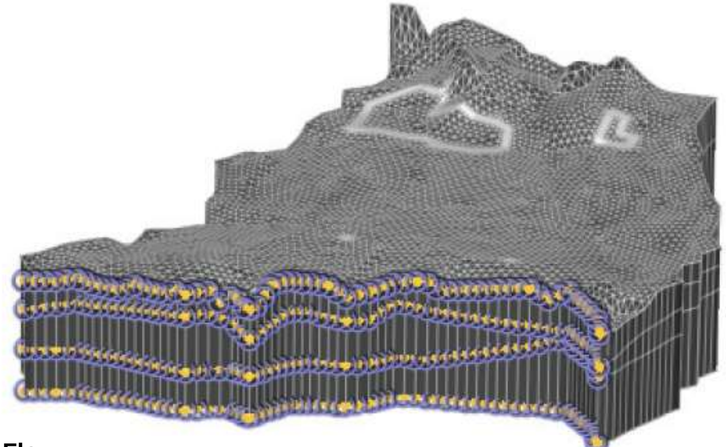
- Groundwater Flow Model for the Athabasca Oil Sands (In Situ) Area South of Fort McMurray (Worley Parsons, 2010)



Source: Worley Parsons (2010)



Mike SHE



FE Flow

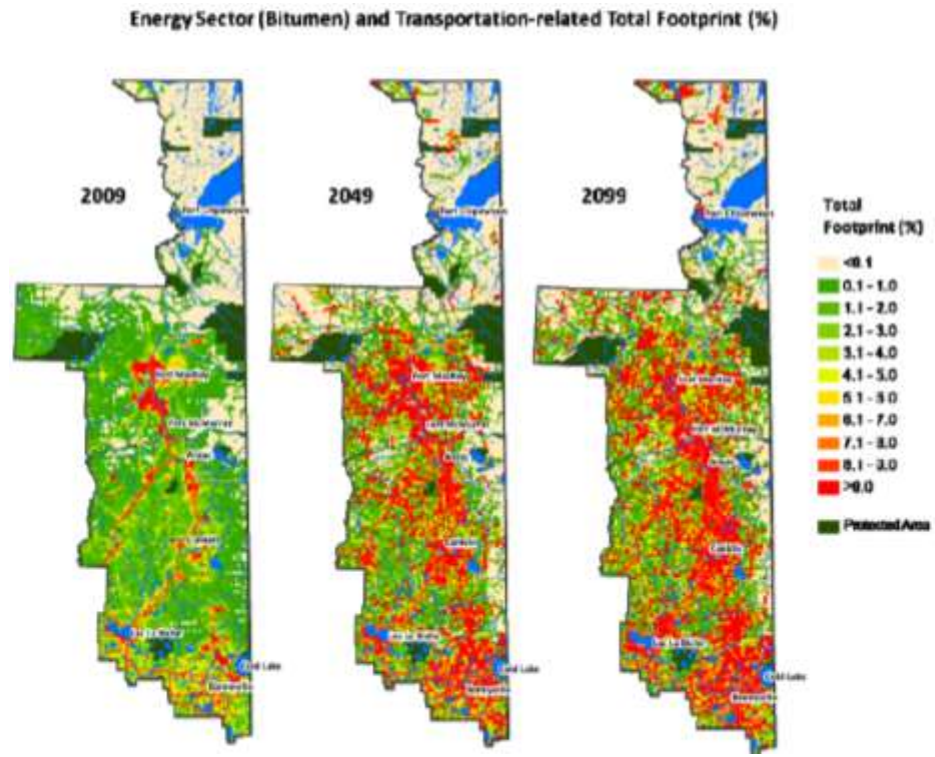
Land and Biodiversity

Modelling Approach

- ALCES/ ALCES Mapper
- Other spatially explicit modelling tools

Building on:

- Models developed to support the LARP



Source: LARP Report (ALCES Group, 2009)

Environmental Health Risk Assessment

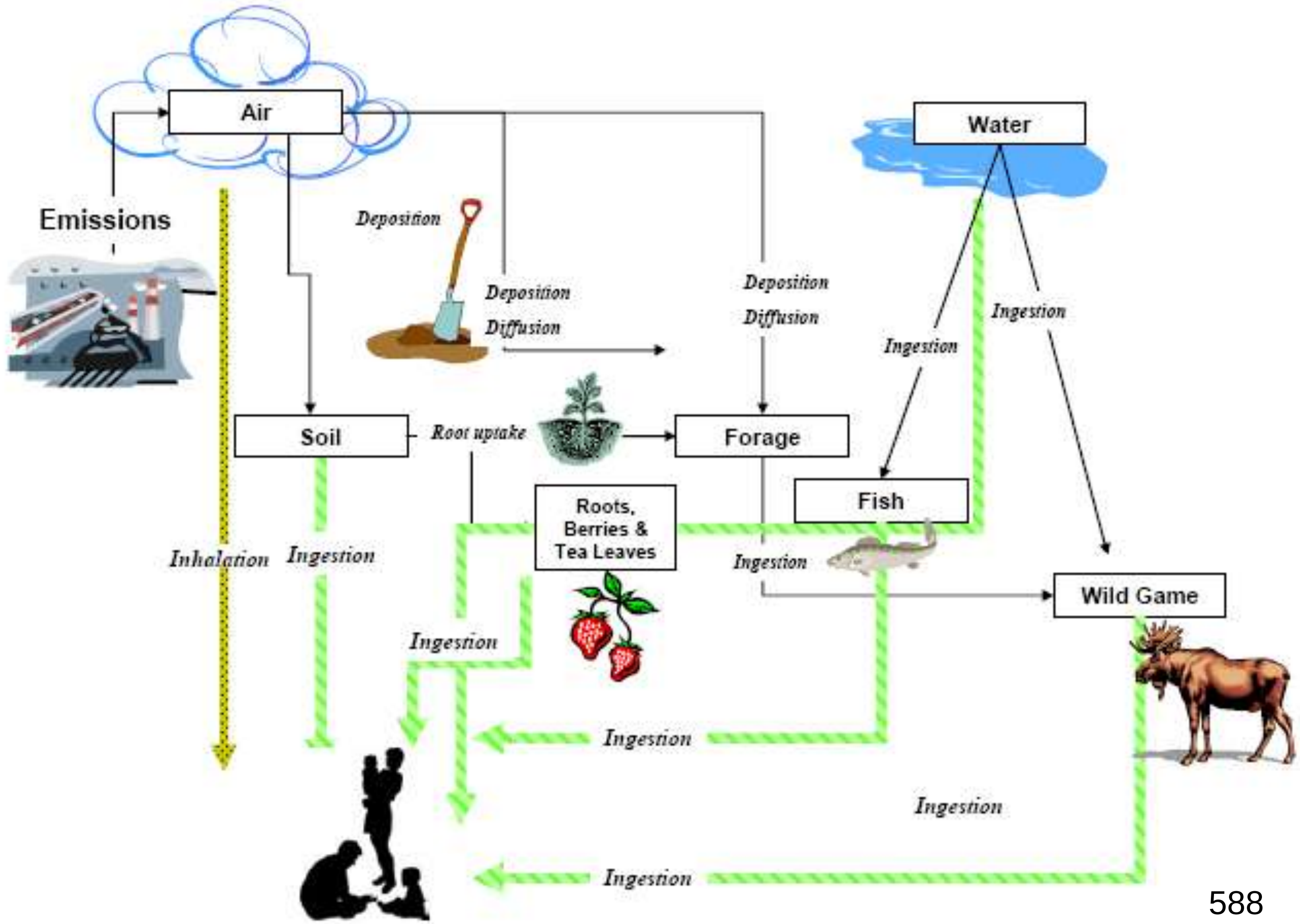


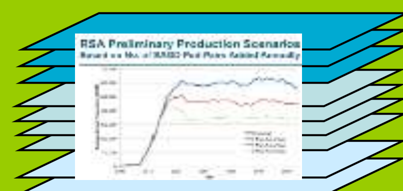
Image source: EIA Report

Model Integration

Air Quality
CALPUFF/CMAQ

Ground water
FEFLOW

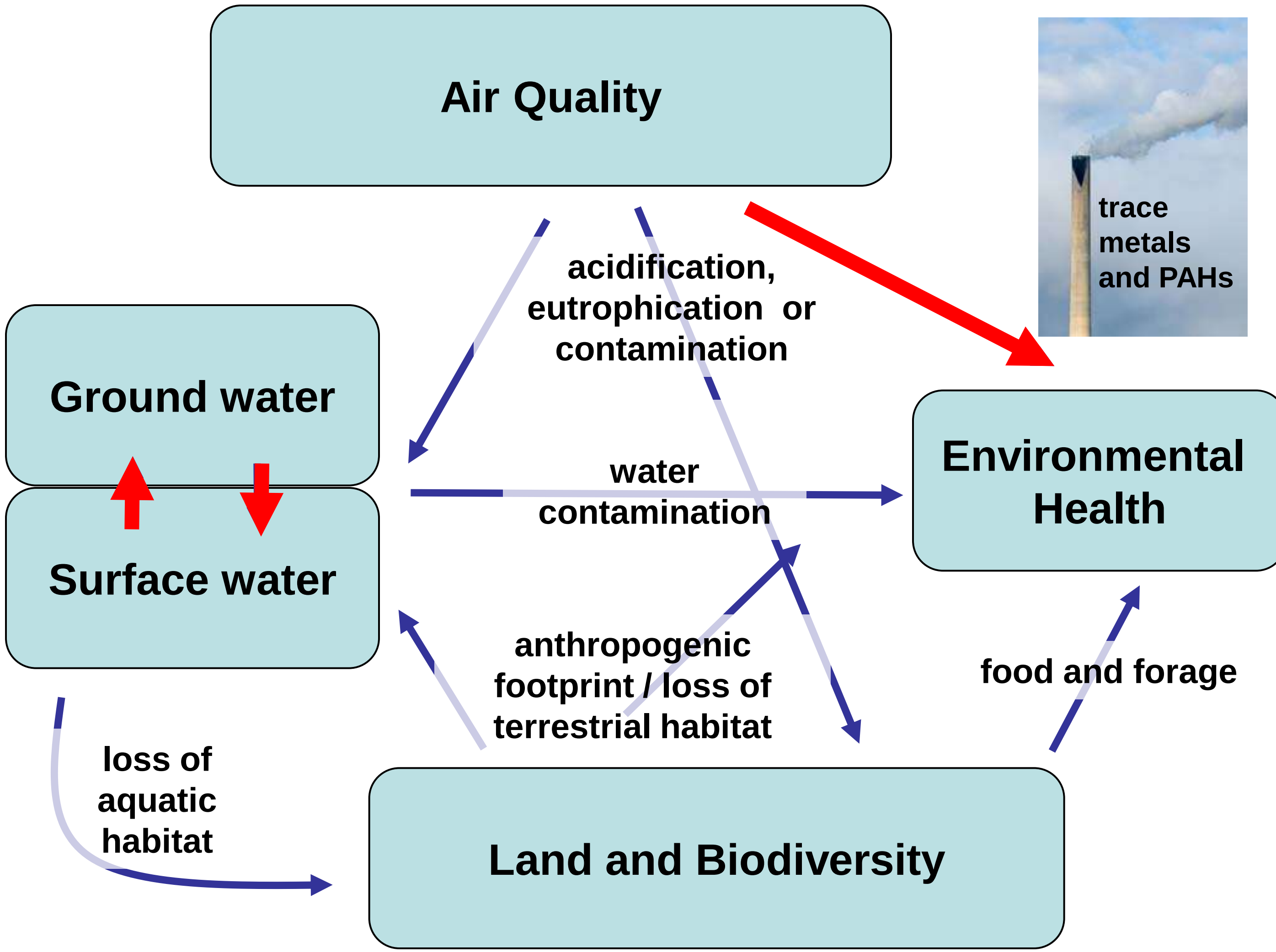
Surface water
Mike SHE / Mike 11



Environmental Health
EHRA

Land and Biodiversity
ALCES

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

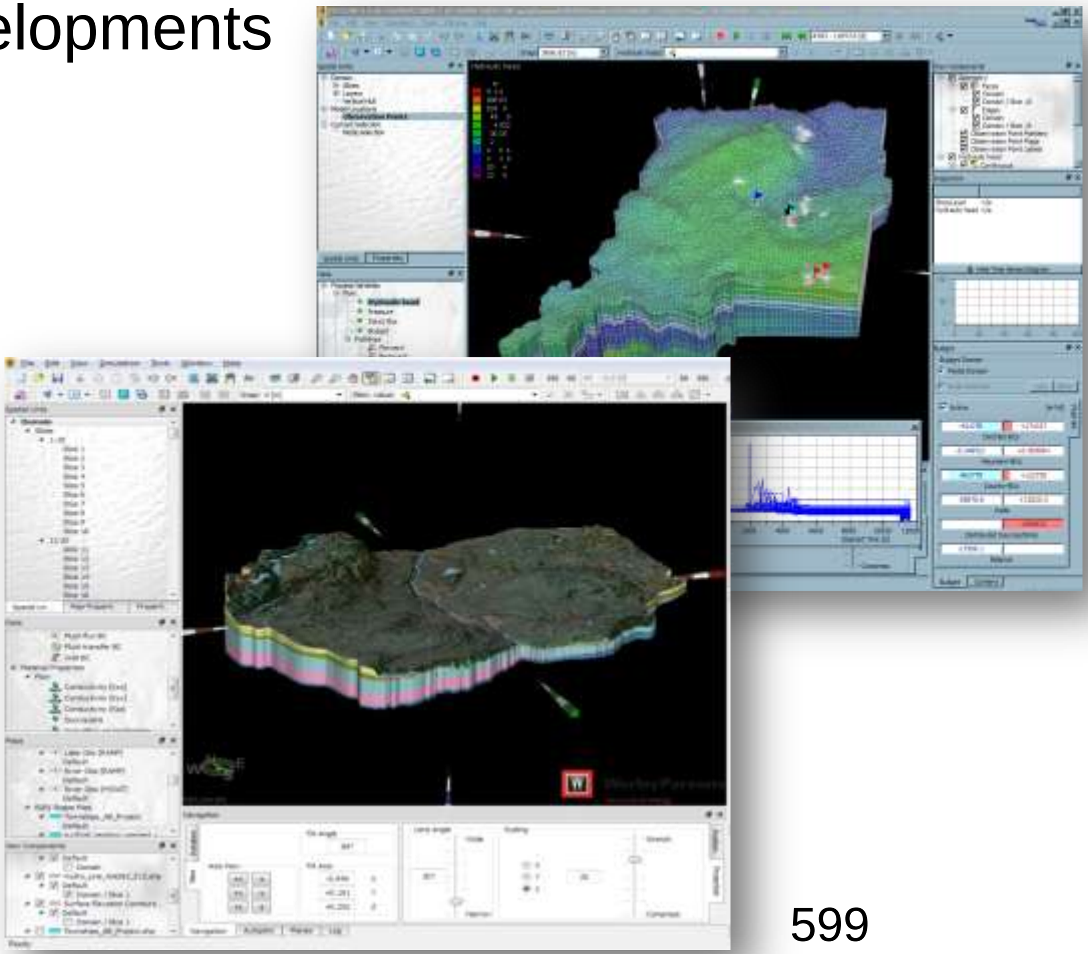
Jos Beckers, PhD, P Geoph

Matthew Webb, MSc

EcoNomics

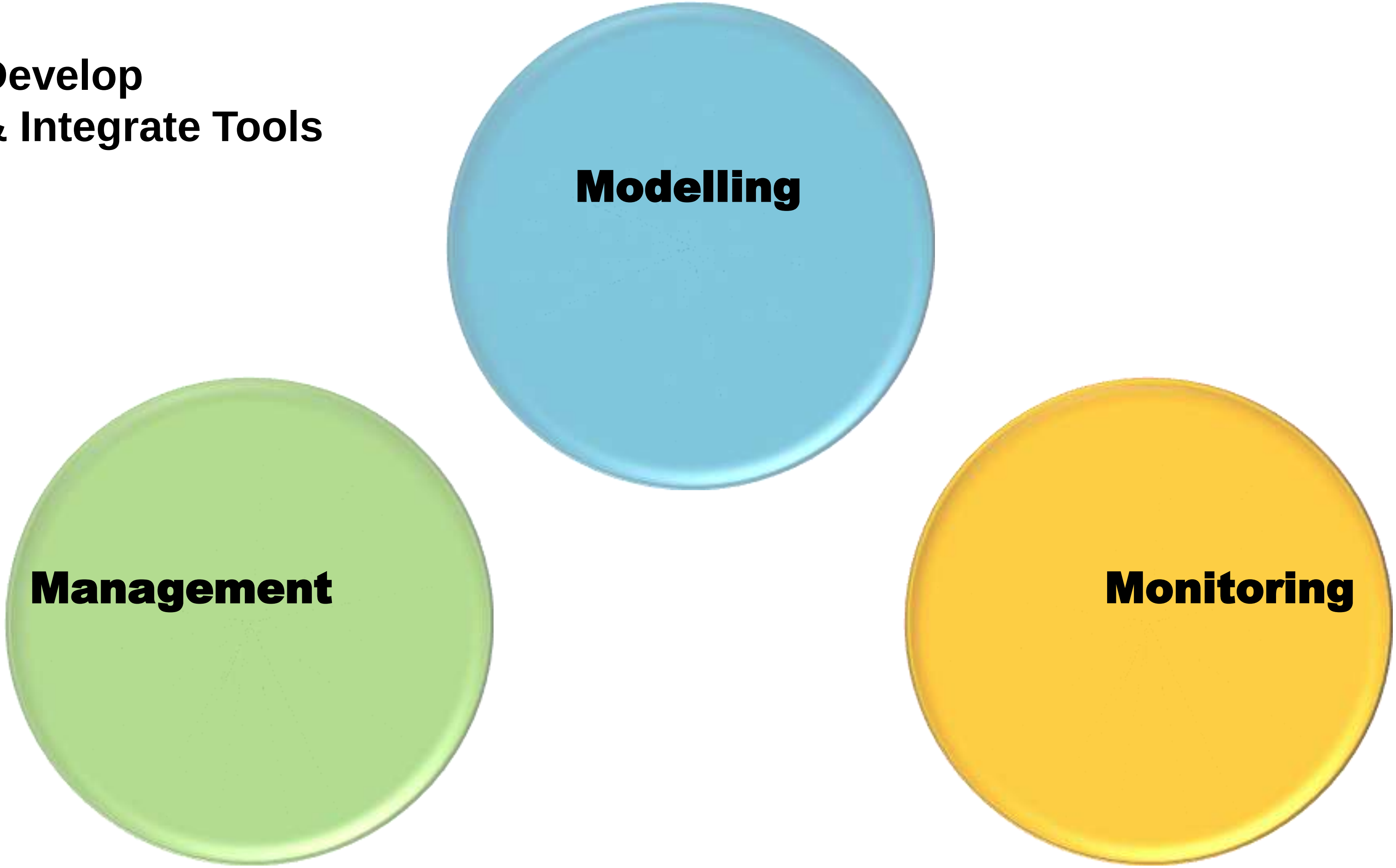
Overview

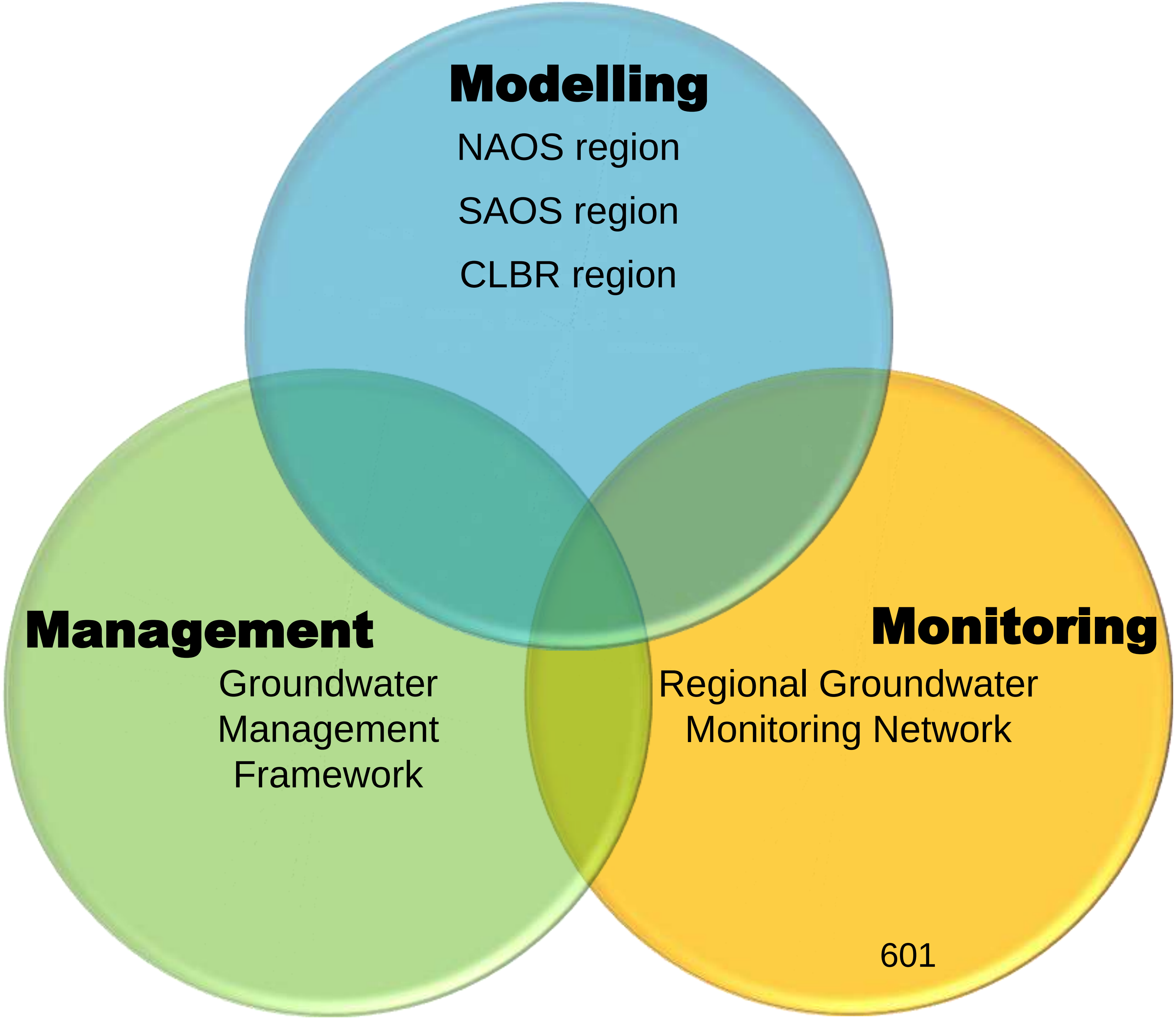
- Groundwater Management Framework Tools
- Modelling Tool Developments
  - Methodology
  - Conceptualization
  - Numerical Model
- Continued Work
- Challenges



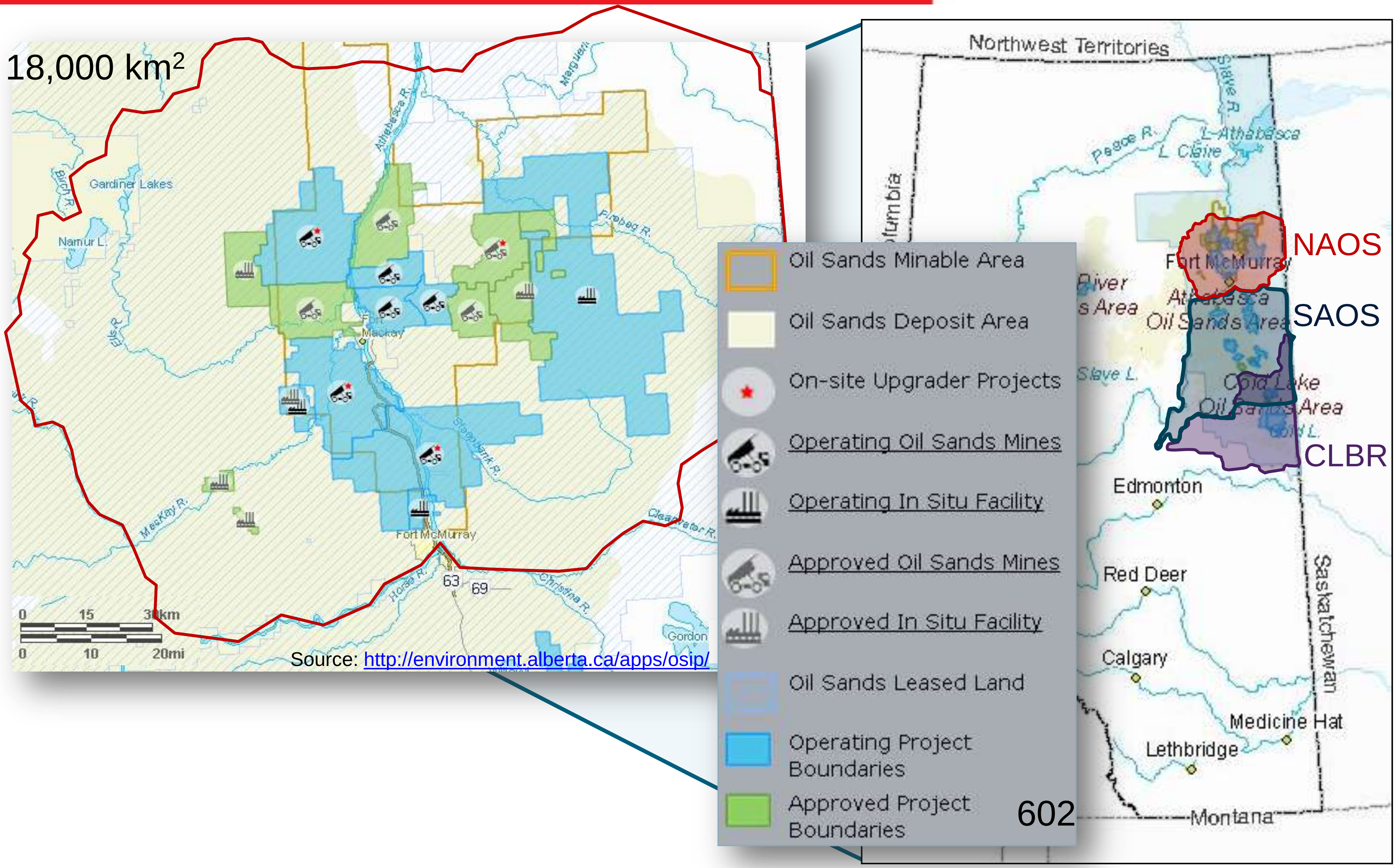
Groundwater Management Framework Tools

Develop
& Integrate Tools



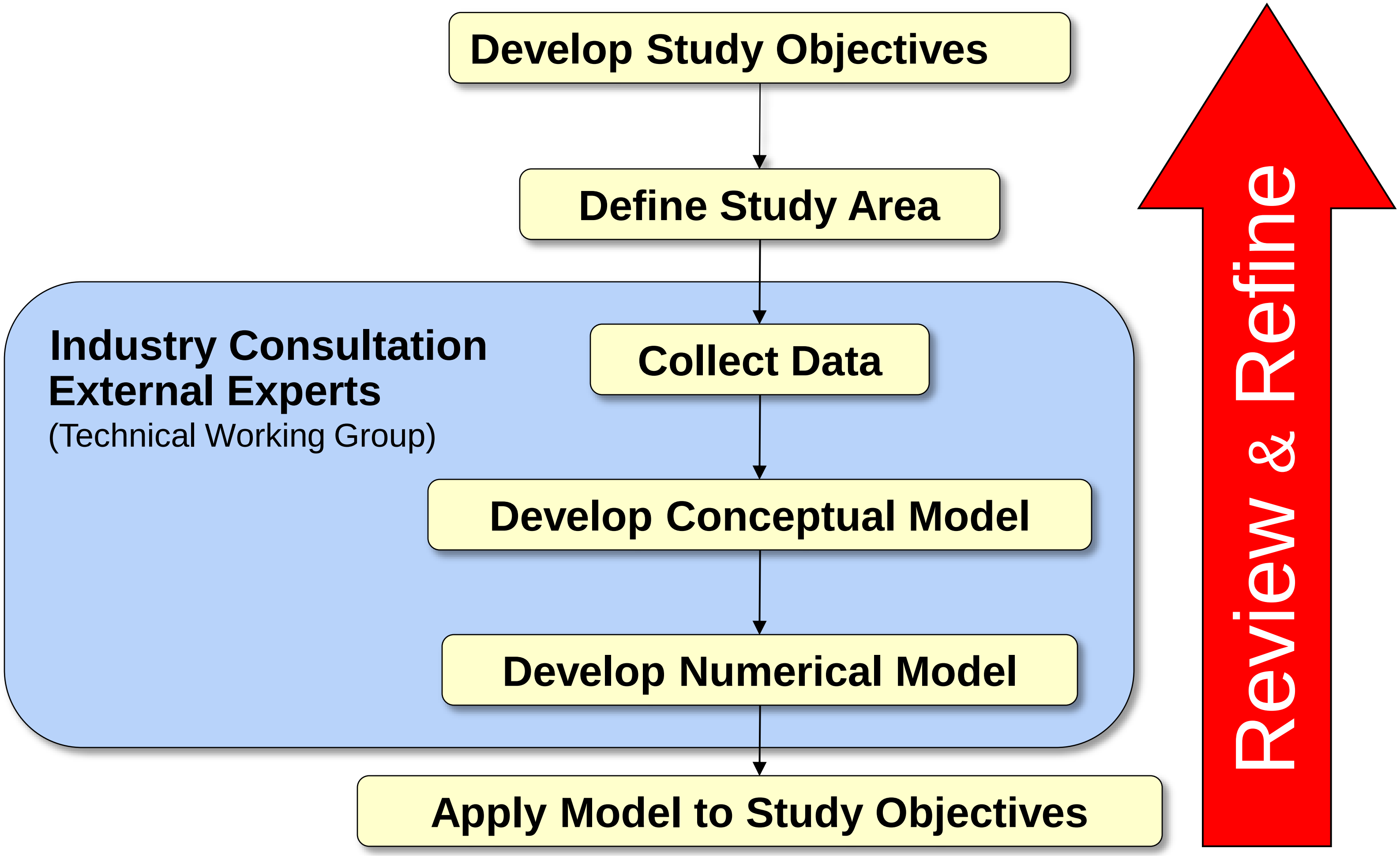

Modelling
NAOS region
SAOS region
CLBR region
Management
Groundwater
Management
Framework
Monitoring
Regional Groundwater
Monitoring Network

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

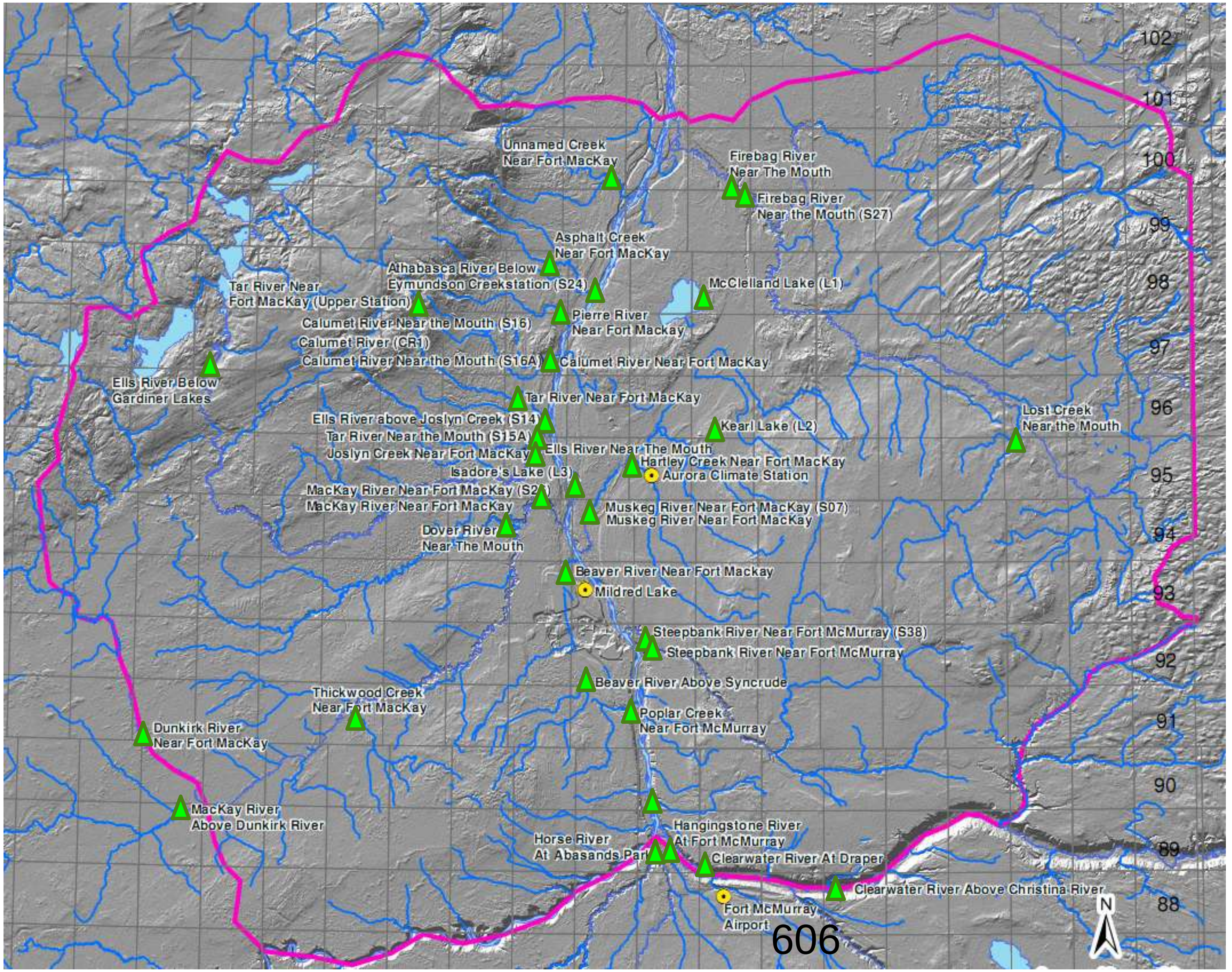
- Director of Geoscience for the Geological Survey of Canada
- Member of expert panel that reviewed the NAOS Groundwater Management Framework

René Therrien

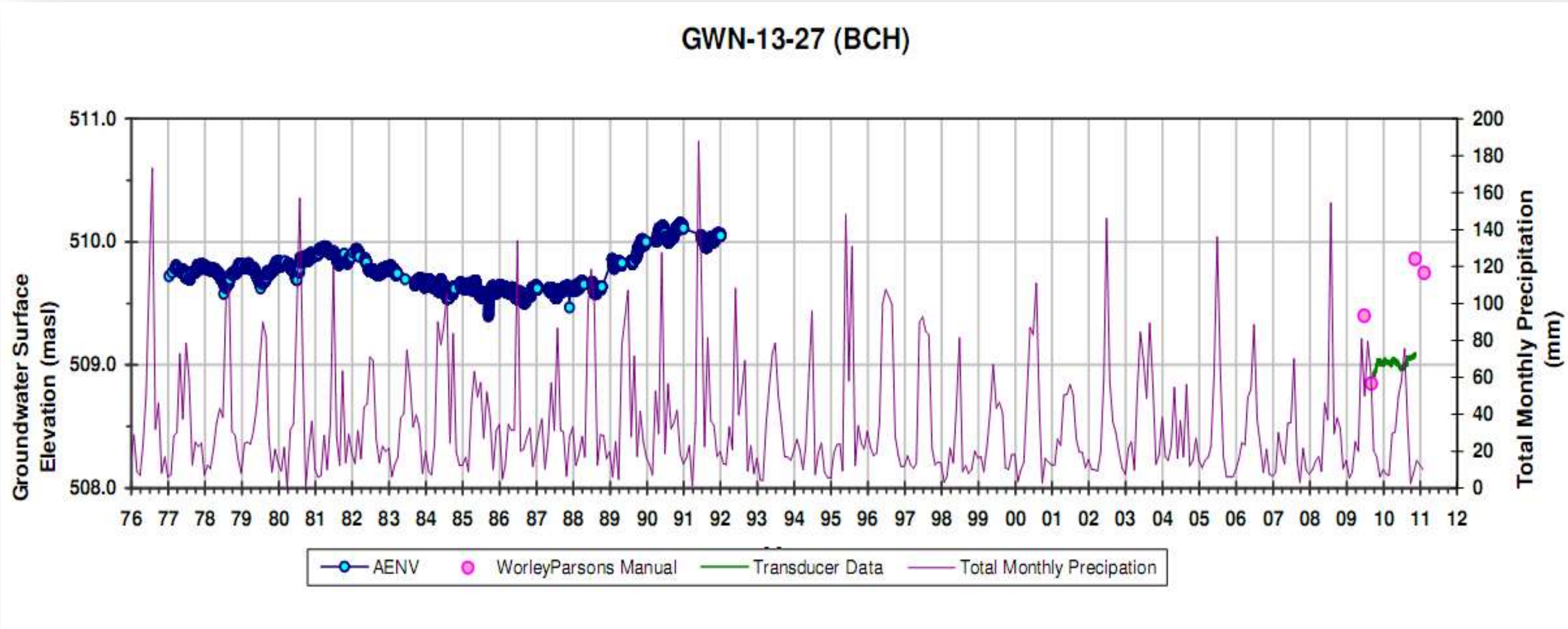
- Chair, Department of Geology and Geological Engineering at Université Laval
- Member of the Royal Society of Canada Expert Panel

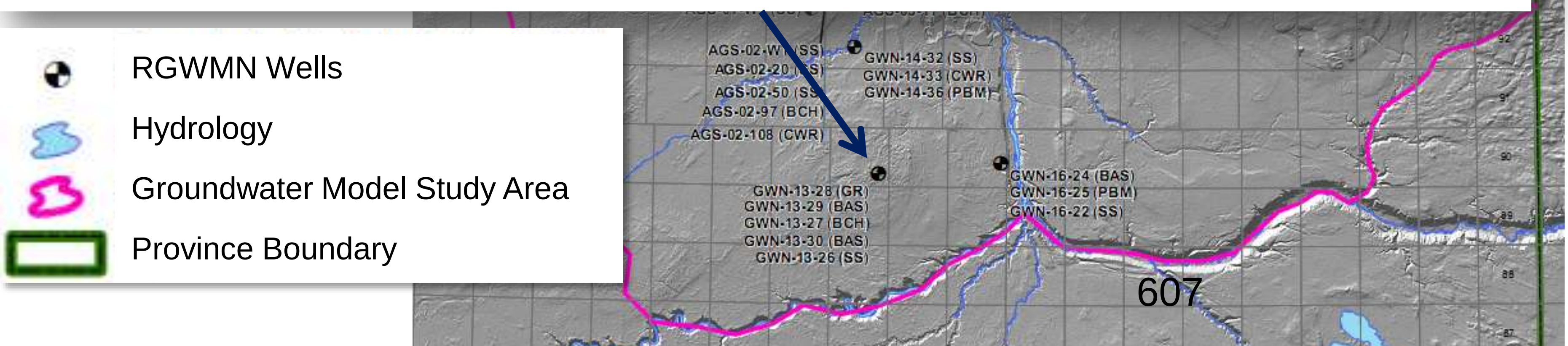
Hydrology

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



Hydrogeology





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	

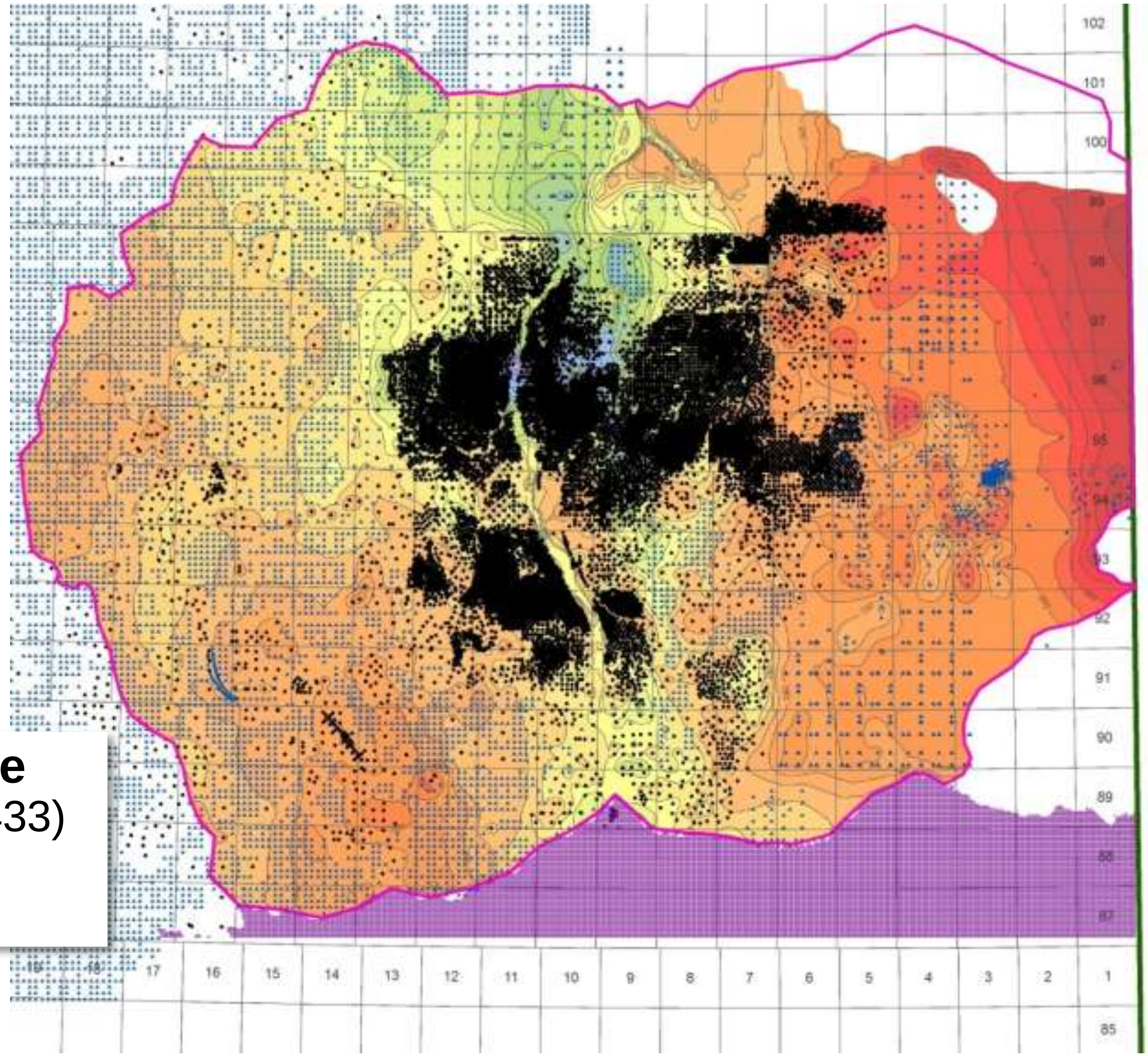
Continued

Hydrostratigraphy (continued)

<table>
<tr><th>Period</th><th>Group</th><th colspan="2">Formation</th><th>Hydrostratigraphy</th></tr>
<tr><td rowspan="6">Cretaceous</td><td rowspan="6">Mannville</td><td colspan="2">Clearwater</td><td rowspan="2">Clearwater Aquitard</td></tr>
<tr><td rowspan="5">McMurray</td><td>Upper</td></tr>
<tr><td>Middle (Top Water)</td><td>Middle McMurray Top Water Aquifer</td></tr>
<tr><td>Middle (Bitumen)</td><td rowspan="2">McMurray Aquitard</td></tr>
<tr><td>Lower (Bitumen)</td></tr>
<tr><td>Lower (Basal Sand)</td><td>McMurray Basal Sand Aquifer</td></tr>
<tr><td colspan="5">Sub-Cretaceous Unconformity</td></tr>
<tr><td rowspan="8">Devonian</td><td rowspan="3">Beaverhill Lake</td><td colspan="2">Waterways</td><td rowspan="4">Beaverhill Lake-Cooking Lake Aquifer/Aquitard</td></tr>
<tr><td colspan="2">Slave Point</td></tr>
<tr><td colspan="2">Fort Vermillion</td></tr>
<tr><td rowspan="5">Elk Point</td><td colspan="2">Watt Mountain</td></tr>
<tr><td colspan="2">Muskeg</td><td>Prairie Aquitard/Aquiclude</td></tr>
<tr><td colspan="2">Keg River</td><td>Keg River Aquifer</td></tr>
<tr><td colspan="2">Contact Rapids</td><td>Contact Rapids Aquitard</td></tr>
<tr><td colspan="2">Basal Red Beds/La Loche</td><td>Basal Aquifer</td></tr>
</table>

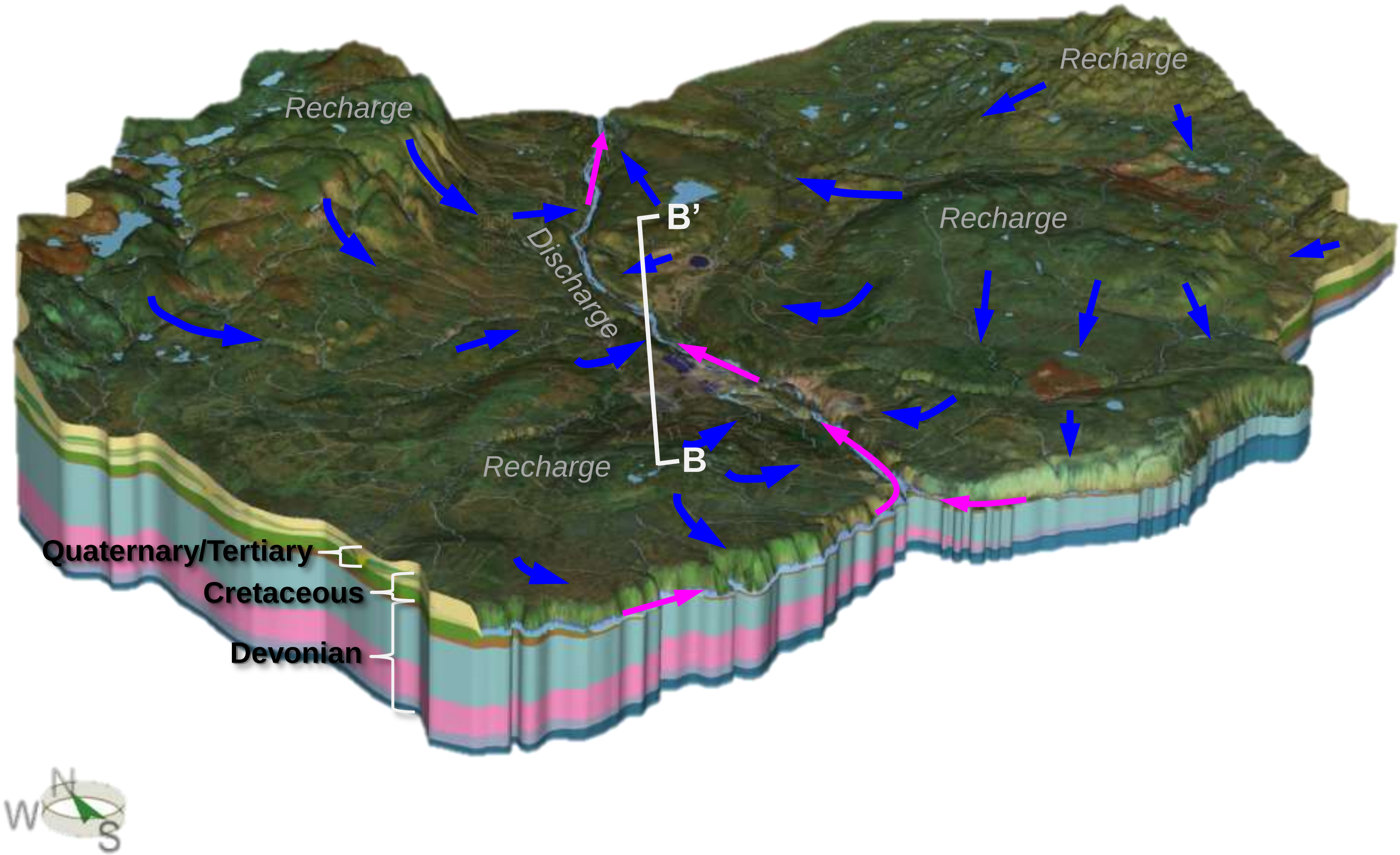
Surface & Isopach Development

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

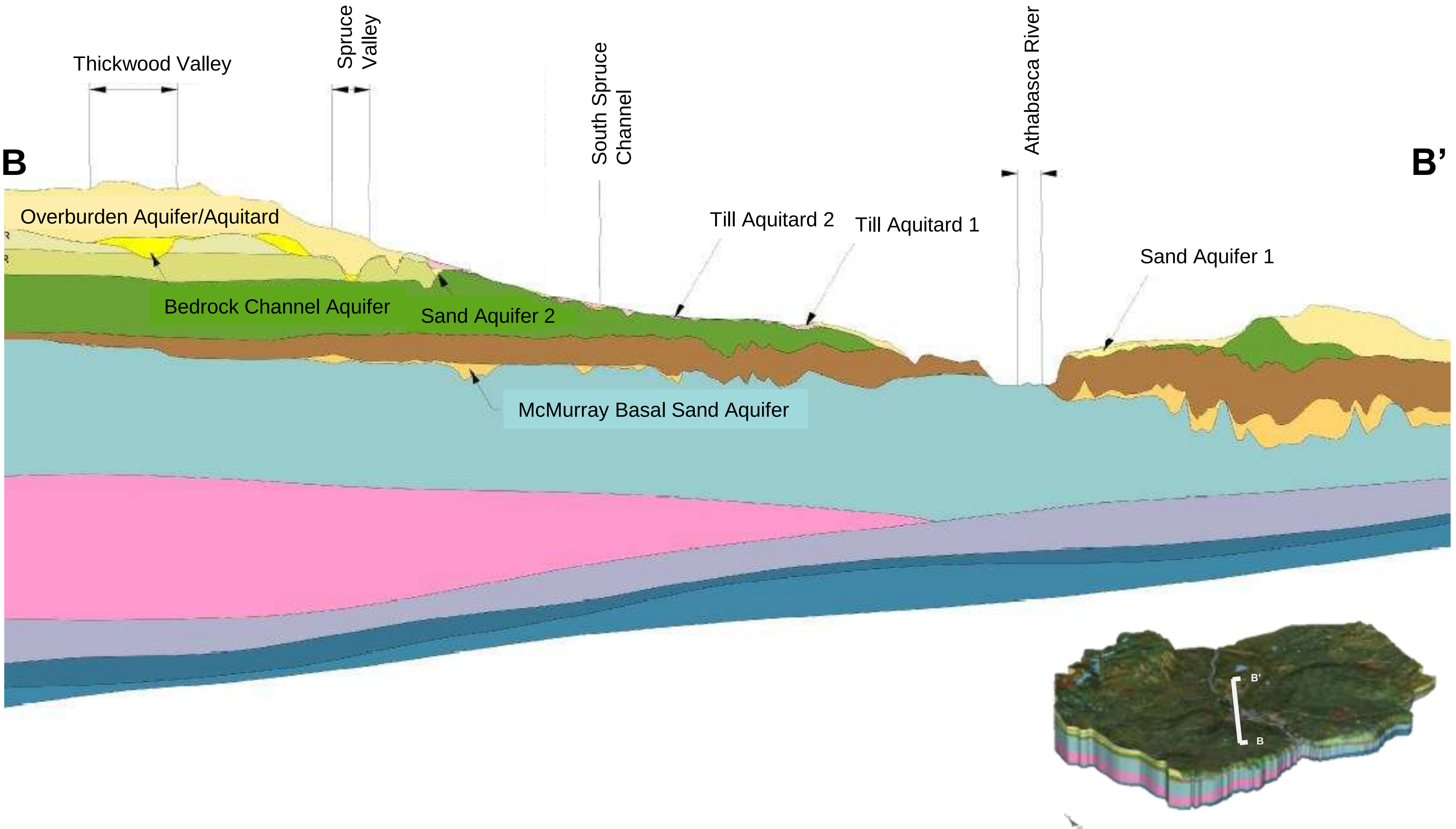


Devonian Surface
Operator Tops (50,433)
Grid Data (10,485)
Control Points (5)

Conceptualization



Conceptualization

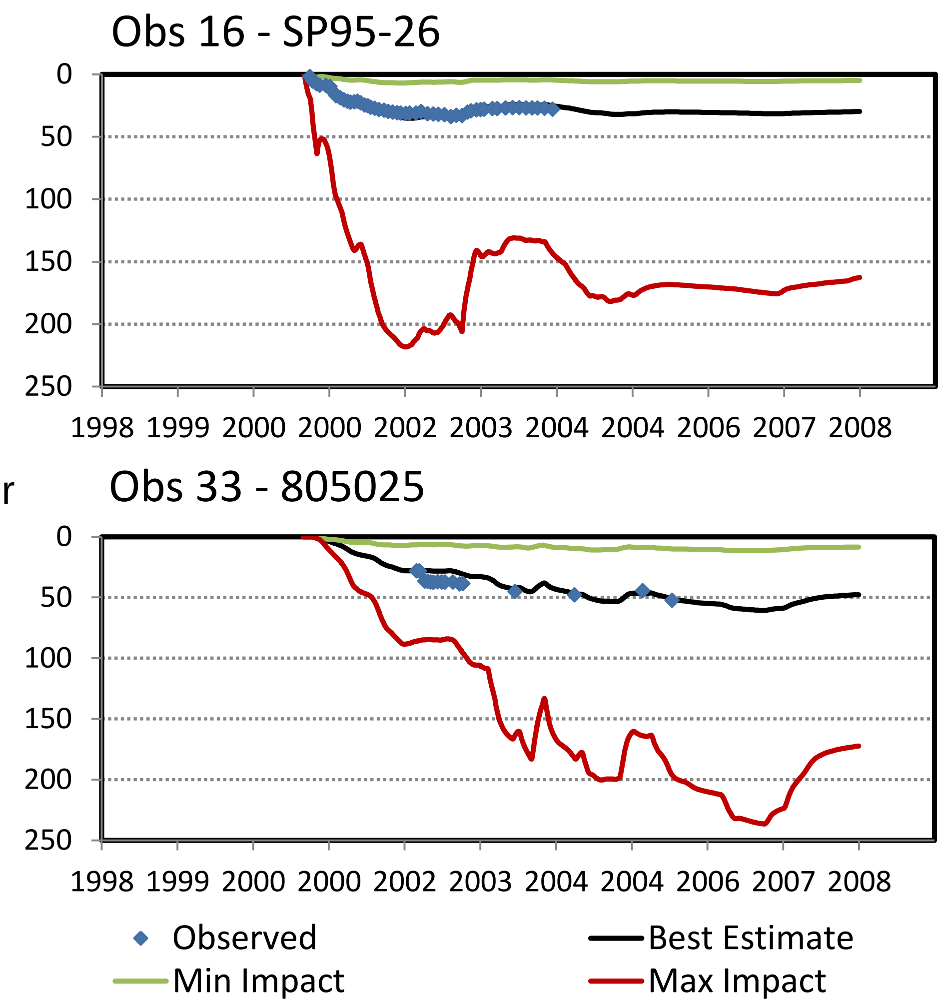


Model Design & Calibration

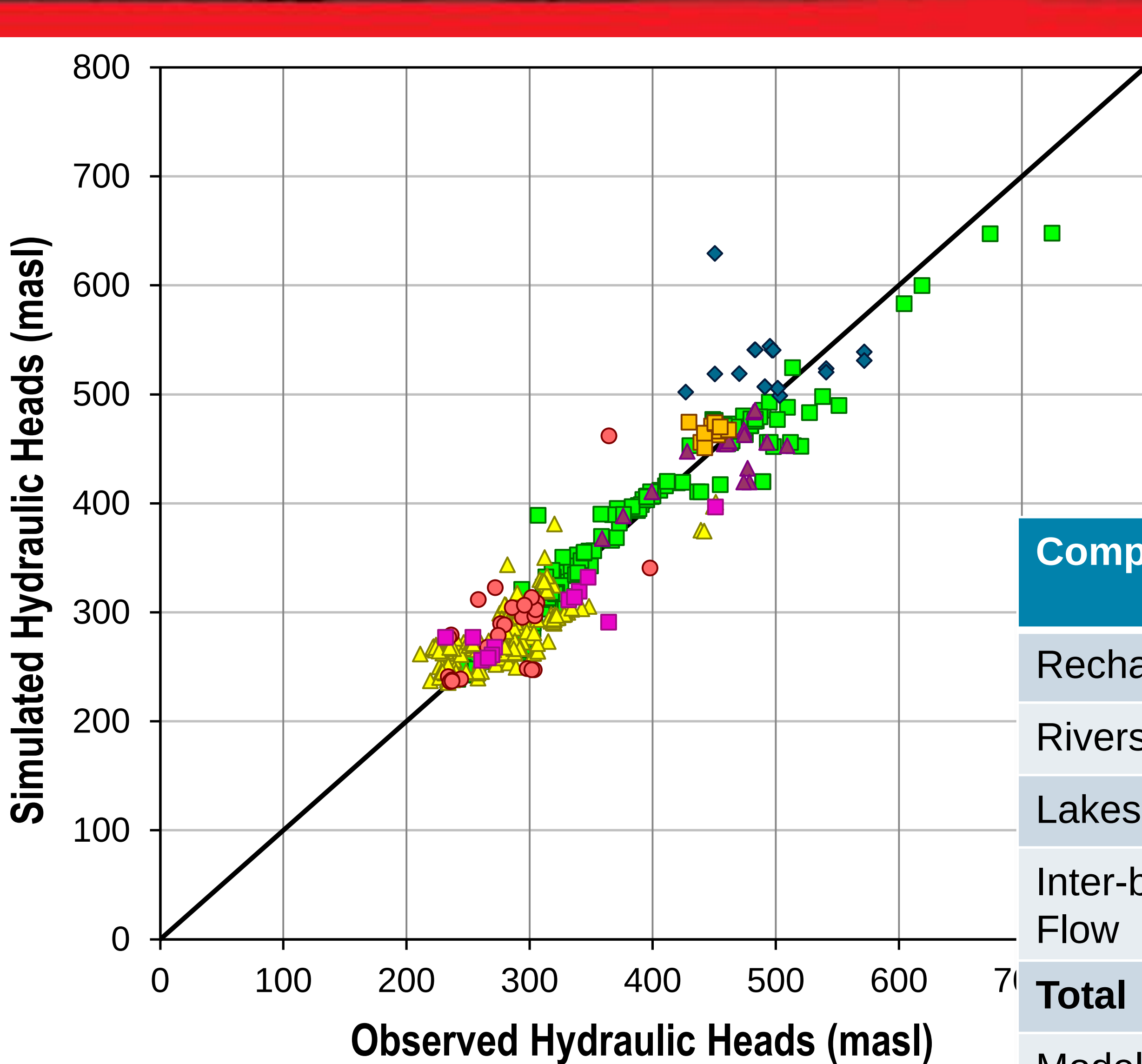
21 layer FEFLOW model (3.0 million elements)

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

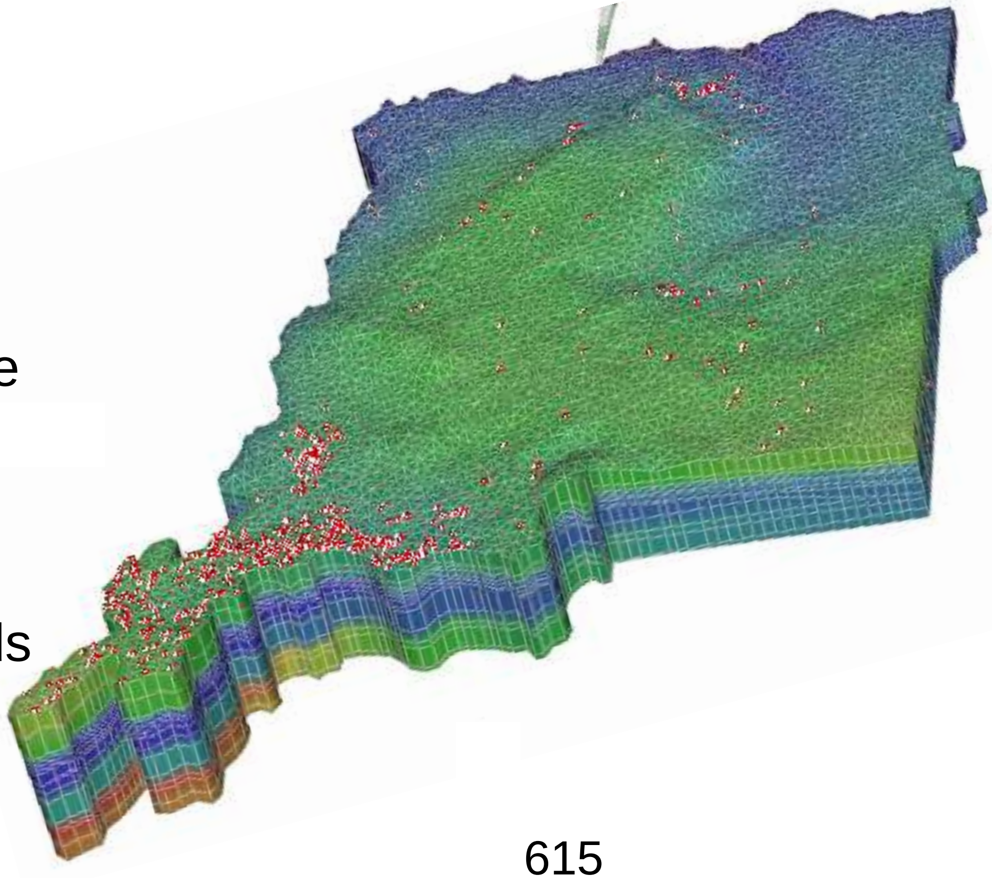


Component	Inflows (m^3/day)	Outflows (m^3/day)
Recharge	598,000	
Rivers	246,000	860,000
Lakes	62,200	69,400
Inter-basin Flow	27,200	84
Total	**933,000**	**929,000**
Model Error	0.4%	

Model Design

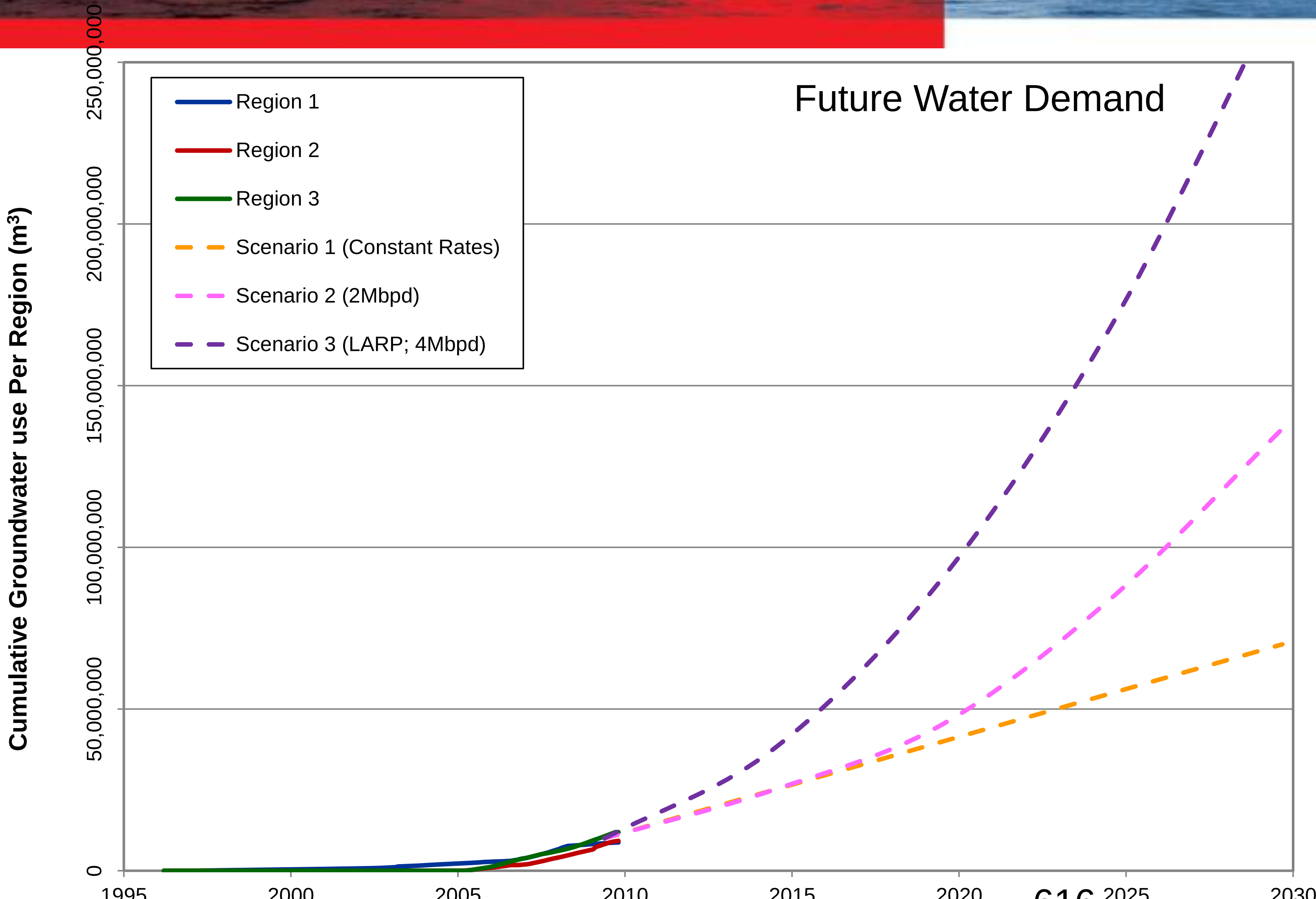
25 layer FEFLOW model (292,075 elements)

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

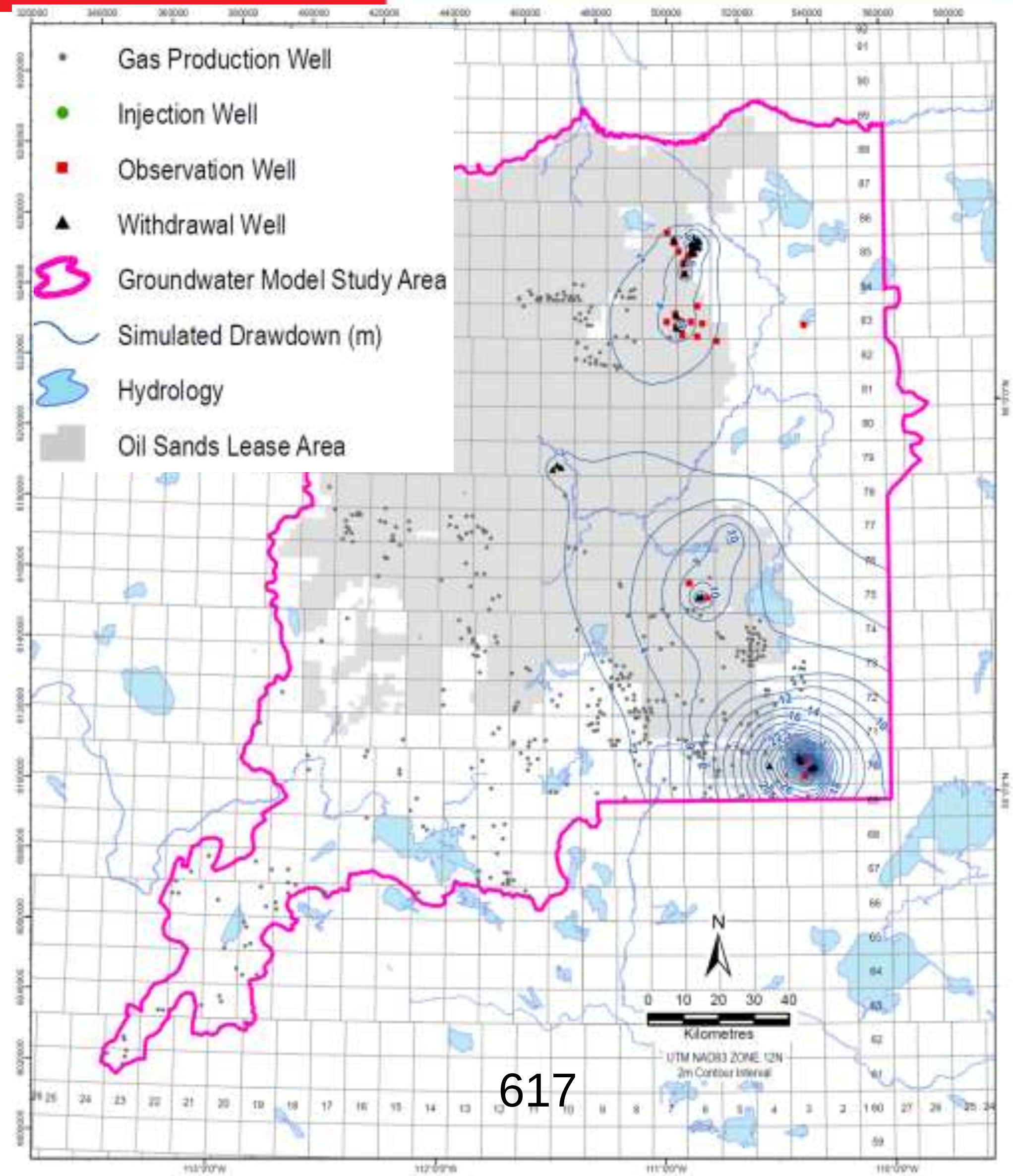
Predictive Scenarios



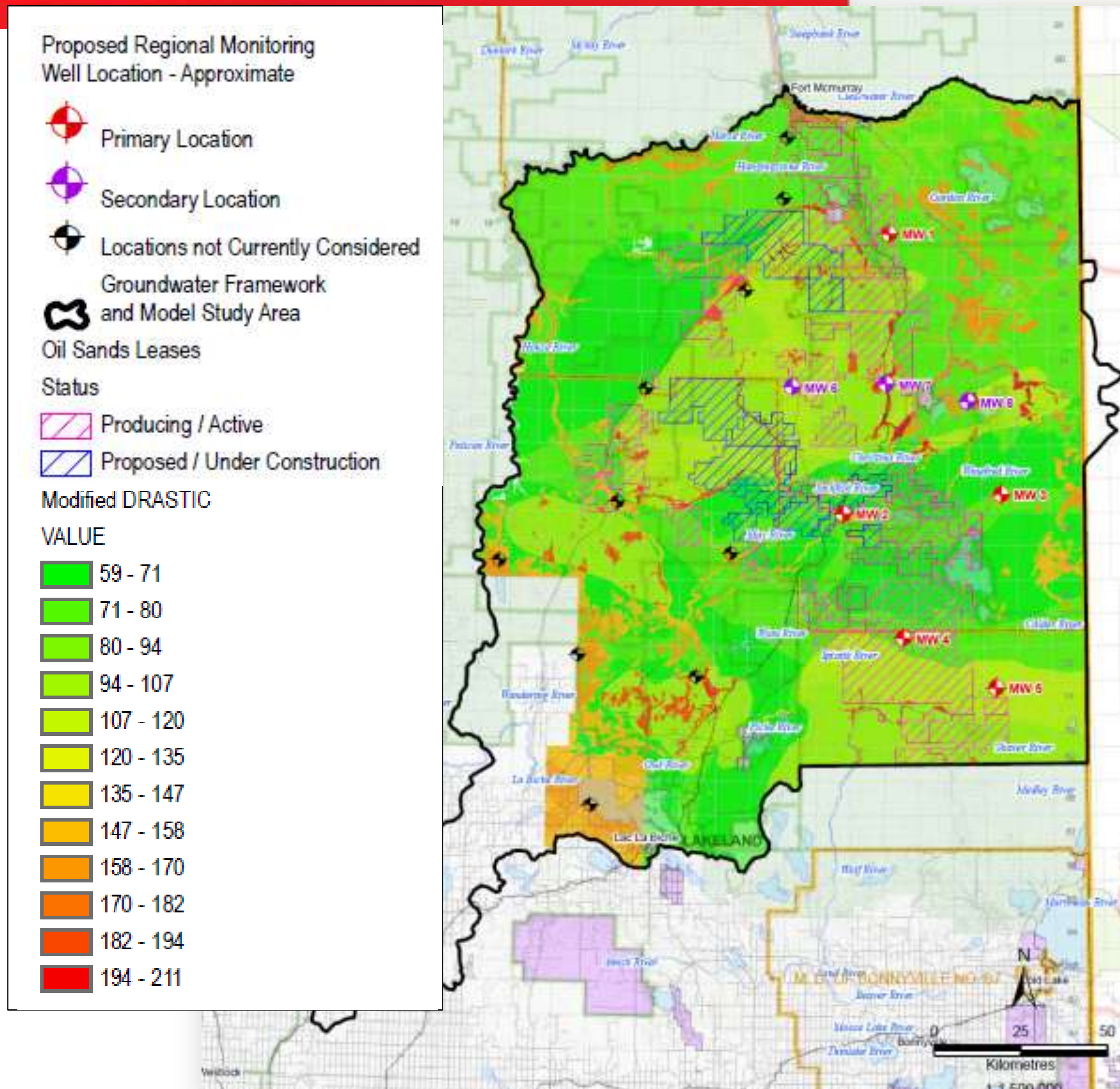
Scenario 1 Results

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?

Margaret Scott
Tel 778-945-5518 (Direct)
Fax 604-298-1625
margaret.e.scott@worleyparsons.com
www.worleyparsons.com

Alberta Government

Lunch

Day 2 – Lunch Presentation

Matthhijs Lemans – Deltares USA Inc.

BIOGRAPHY

Since January 2008, Matthijs Lemans is working for Deltares as a hydrologist in the Operational Water Management department. In 2007 he successfully finished his master Water Resources Management at the Technical University of Delft with a thesis about the application of control techniques to large water systems. Subsequently he worked for the Dutch national institute for inland water systems (RIZA). At Deltares, he gathered a lot of experience in developing and configuring (flood) forecast applications using the Delft-FEWS platform, for many national and international clients. Since June 2012, he works for the American daughter company, Deltares-USA, where he continues to work developing and implementing operational systems for government agencies, power authorities and private companies.

Day 2 – Lunch Presentation

Matthhijs Lemans – Deltares USA Inc.

ABSTRACT

The Delft Flood Early Warning System (Delft-FEWS) is model integration platform used around the world to support numerous operational needs. It grew up as a platform to support flood forecasting. Since its inception, it has been implemented for purposes well beyond flood forecasting. The popularity of the Delft-FEWS platform is derived from the very simple and flexible architecture it implements. Models are linked synchronously through time series, where a time series can be a scalar or a grid. Parameter storage, model connectivity, basin descriptions, operational work flows and predefined display configurations are all stored by FEWS. Any model that runs off a combination of states, parameters and time series can be linked to FEWS thus permitting forecasters to integrate favorite legacy models and newer experimental models side by side. In addition, Delft-FEWS supports uncertainty estimates via ensemble model runs and then calculations of probabilities from those ensembles. Data can be displayed in standard x-y plots, as profiles along a river, within a schematization of a system and in space as grids or basin averages with looping through time. Because there is a broad variety of users, the FEWS application supports a wide range of display functions.

One goal of the FEWS Development project at Deltares is the distribution of knowledge between the groups who conduct the various forms of operational hydrology whether it is flood forecasting or groundwater permitting. The U.S National Weather Service has recently implemented Delft-FEWS into a system they call the Community Hydrologic Prediction System (CHPS). The CHPS implementation offers an informative example of the technology transfer enabled by the FEWS application.

Delft-FEWS: An operational model integrator

Environmental Modelling Workshop, Alberta

March 13/14, 2013

Matthijs Lemans

Deltares USA

Presentation Overview

- Characteristics of any forecast system
- Description of FEWS, a multi-purpose forecast environment
- FEWS and model control
- FEWS Displays
- Example FEWS applications as model integrator

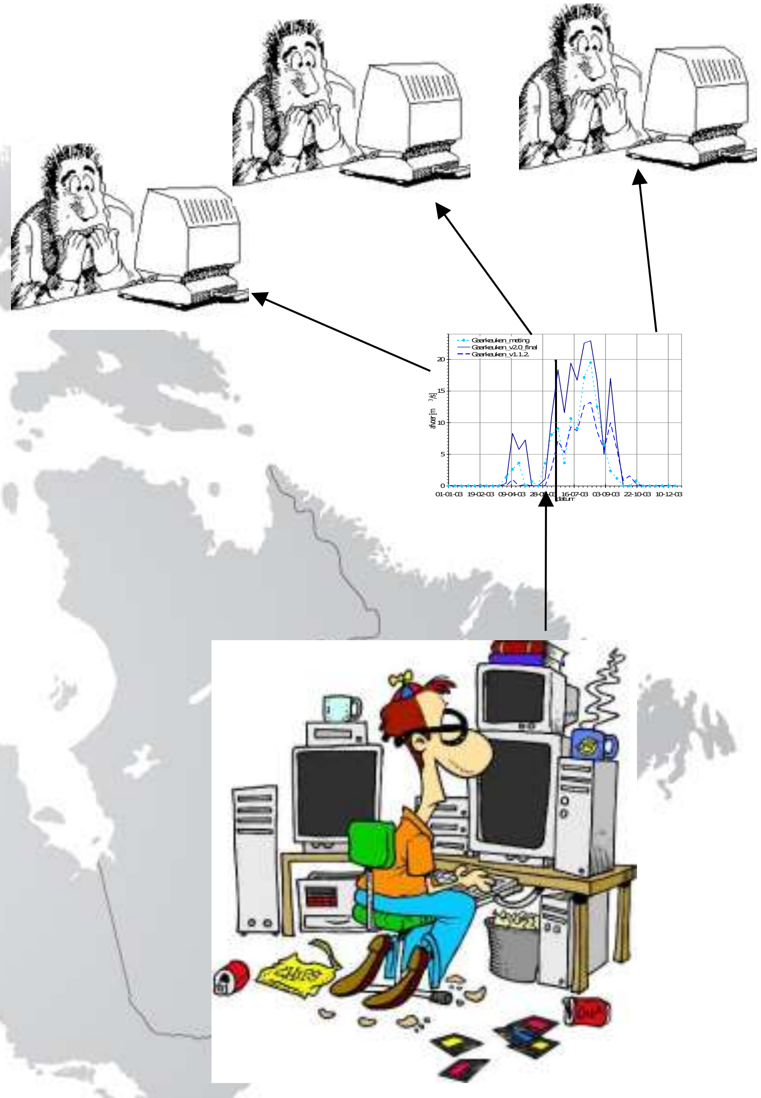
Forecast systems

Deltares

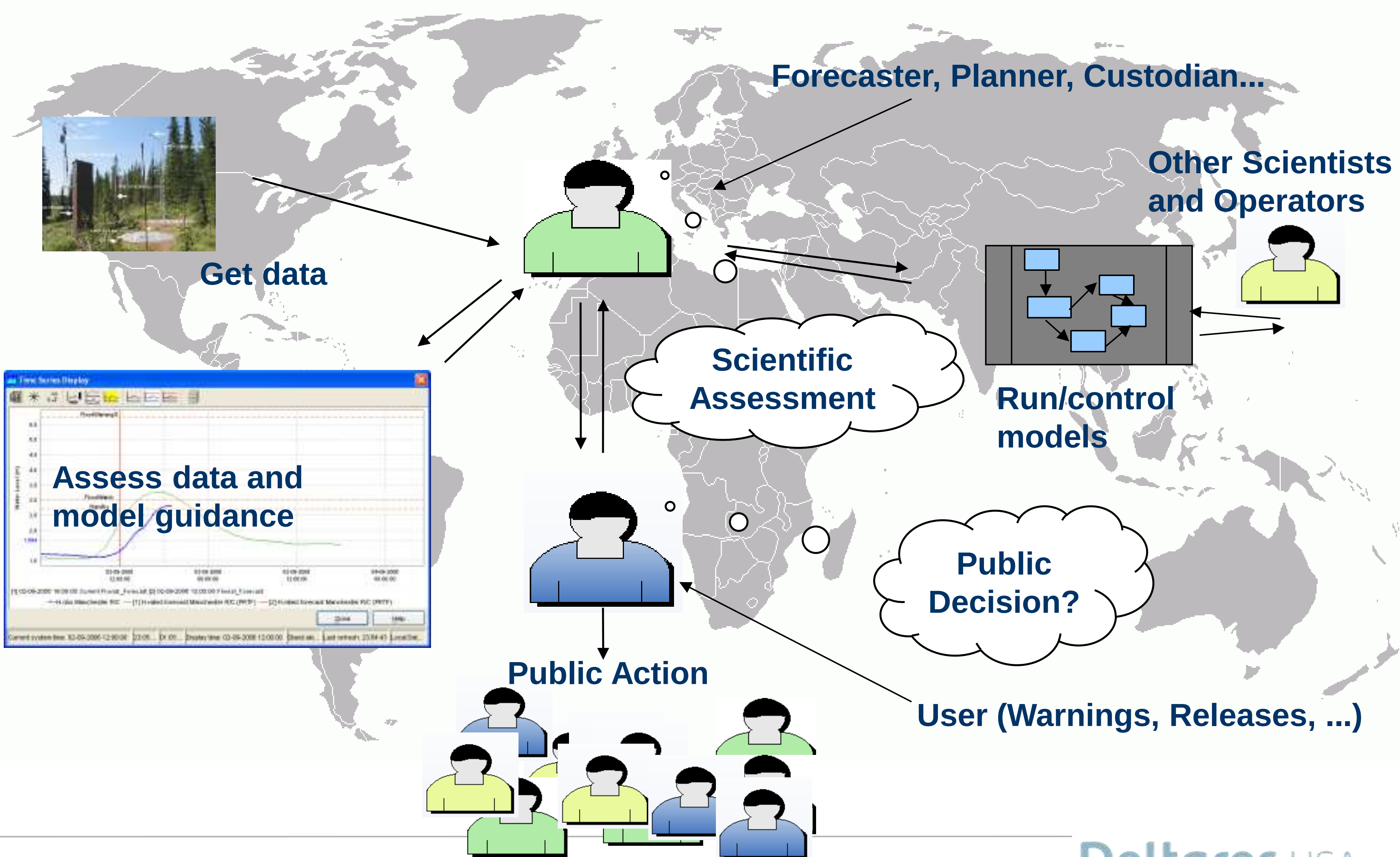
Operational Forecast System Purpose

Linking Forecasters, Regulators, Model Developers, Managers, and the Public

- **By making good science accessible to users**
- **By making models results understandable**
- **Presenting current and past observations**
- **With situational awareness highlighting areas of concern**
- **Generating Standard Reports**



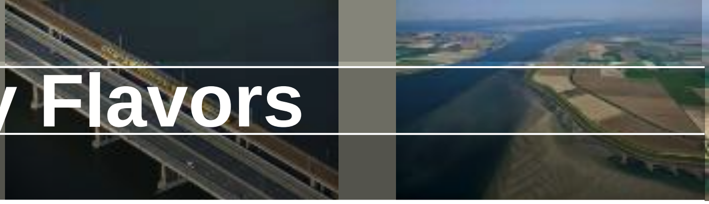
Elements of a Forecast System



FEWS: Introduction and Architecture

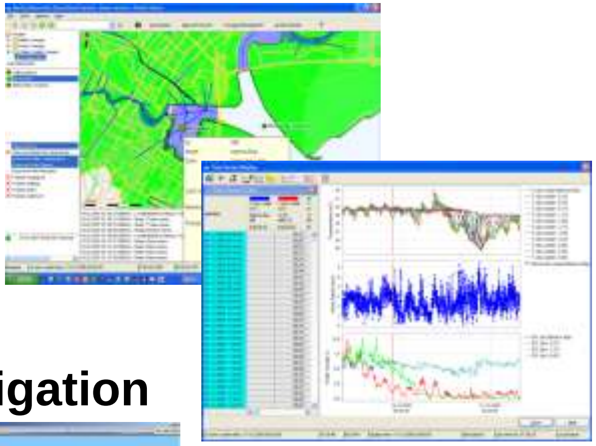
Delft – Flood Early Warning System

Delft-FEWS Systems Have Many Flavors

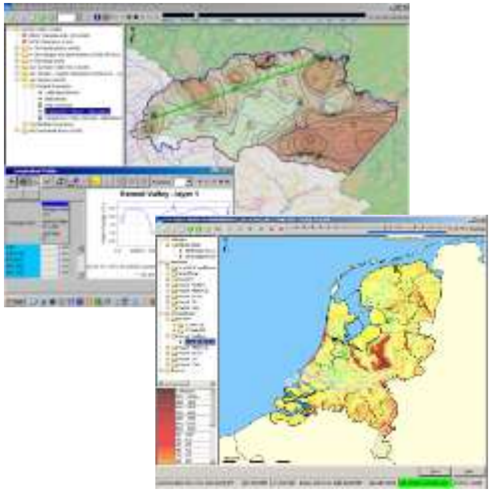


floods

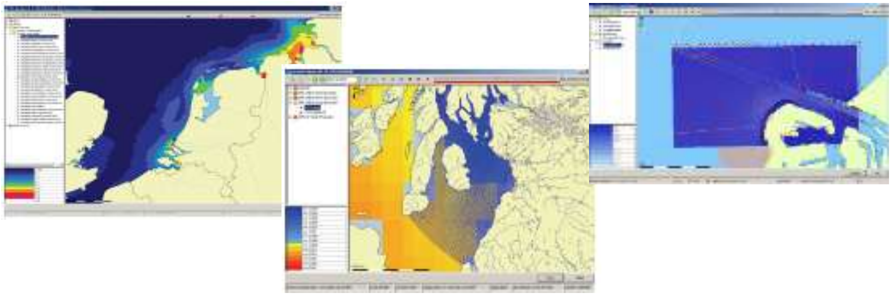
water quality



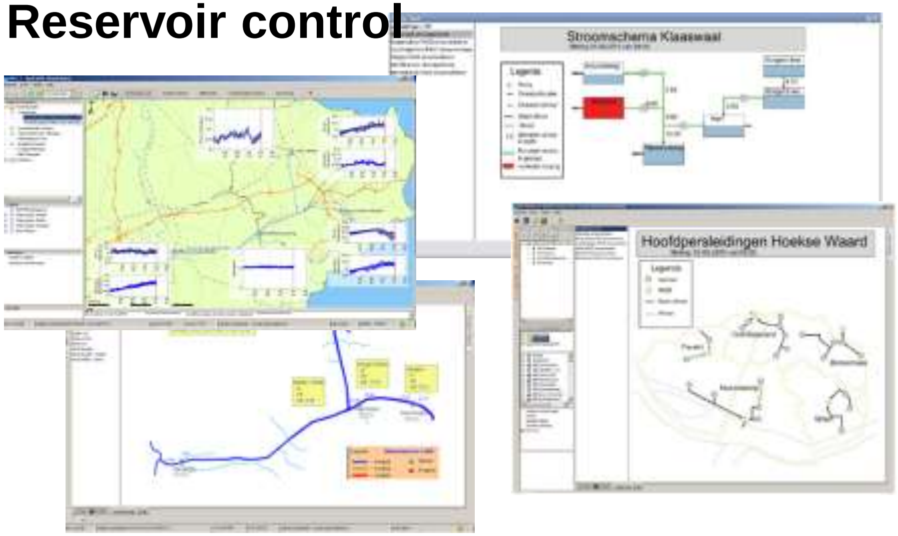
groundwater



coastal wq, storm surge, navigation

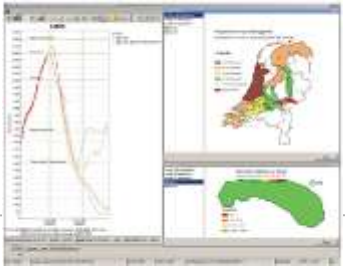


Reservoir control



lakes

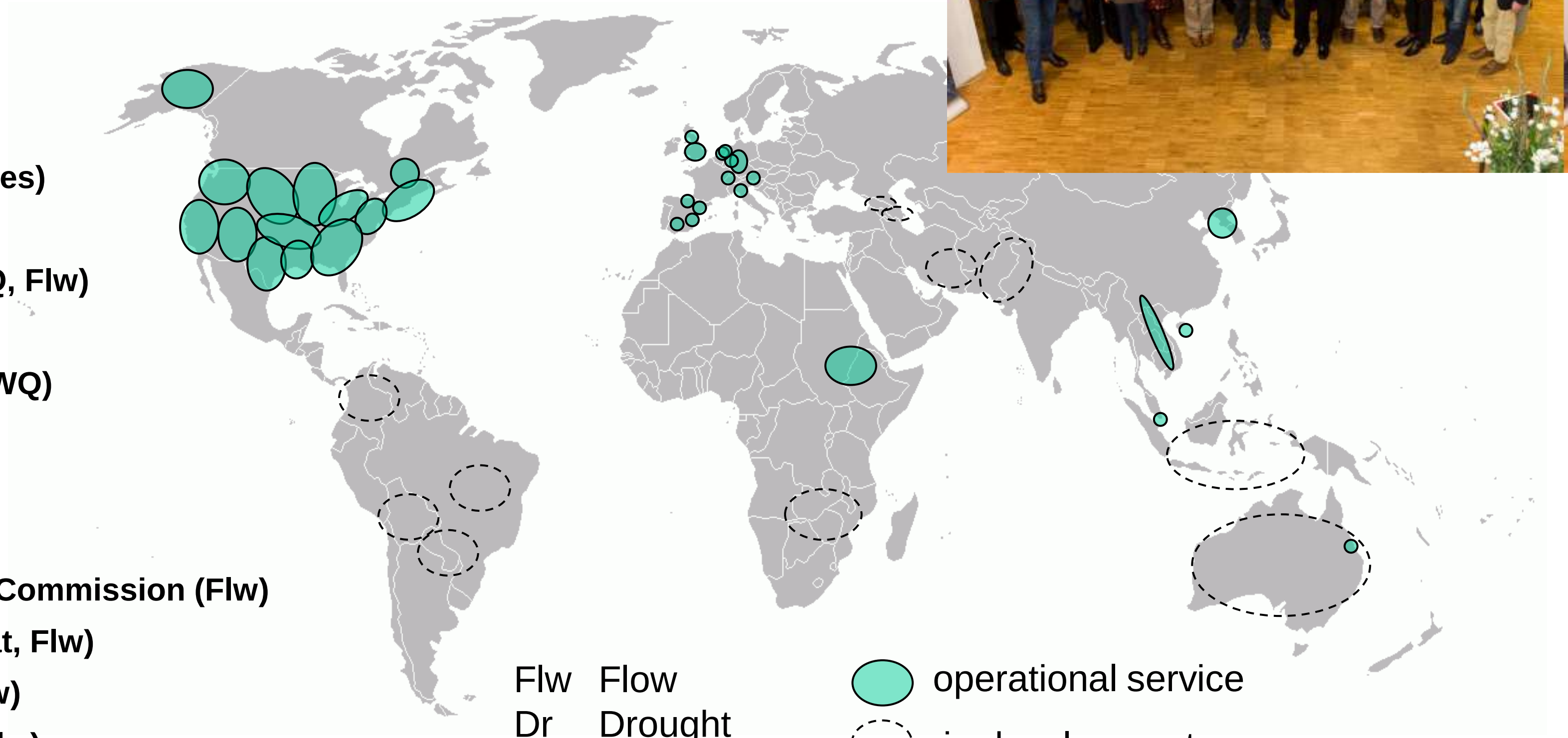
dike strength



Delft-FEWS User Community

- USA, NWS (Flw)
- USA, BPA (Flw, Res)
- Canada (Flw)
- UK (Flw, Gw)
- Netherlands (Dr, Flw, Wq, Ds)
- Germany (Flw)
- Suisse (Flw)
- Italy (Flw)
- Austria (Flw, Res)
- Spain (Flw)
- Singapore (WQ, Flw)
- Taiwan (Flw)
- South-Korea (WQ)
- Australia (Flw)
- Sudan
- Georgia
- Mekong River Commission (Flw)
- Indonesia (Peat, Flw)
- Azerbaijan (Flw)
- Zambezi (Dr, Flw)
- Colombia (Flw)
- Bolivia (Flw)
- Uruguay (Flw)
- Brazil (Flw, Res)

www.delft-fews.com



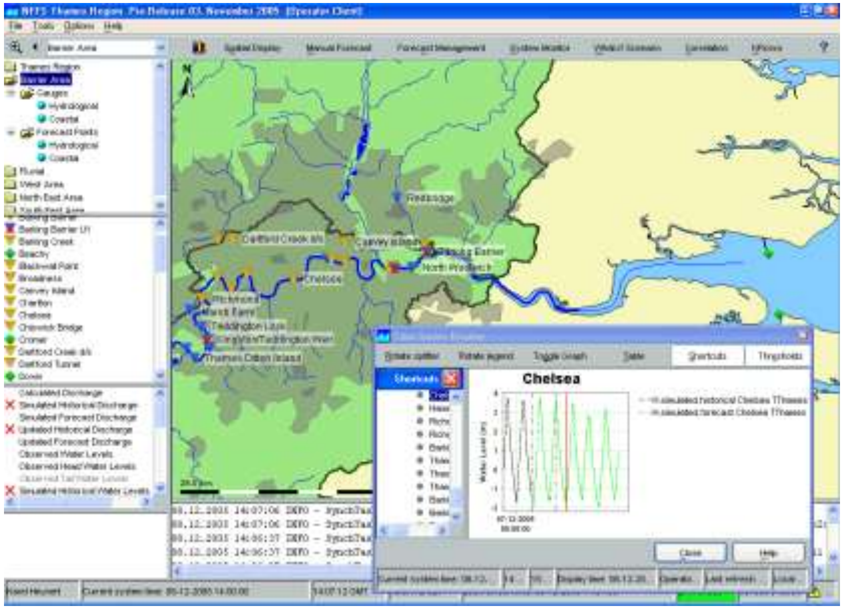
Flw Flow
Dr Drought
Wq Water Quality
Res Reservoir operation
Ds Dike strength
Gw Ground Water

operational service
in development

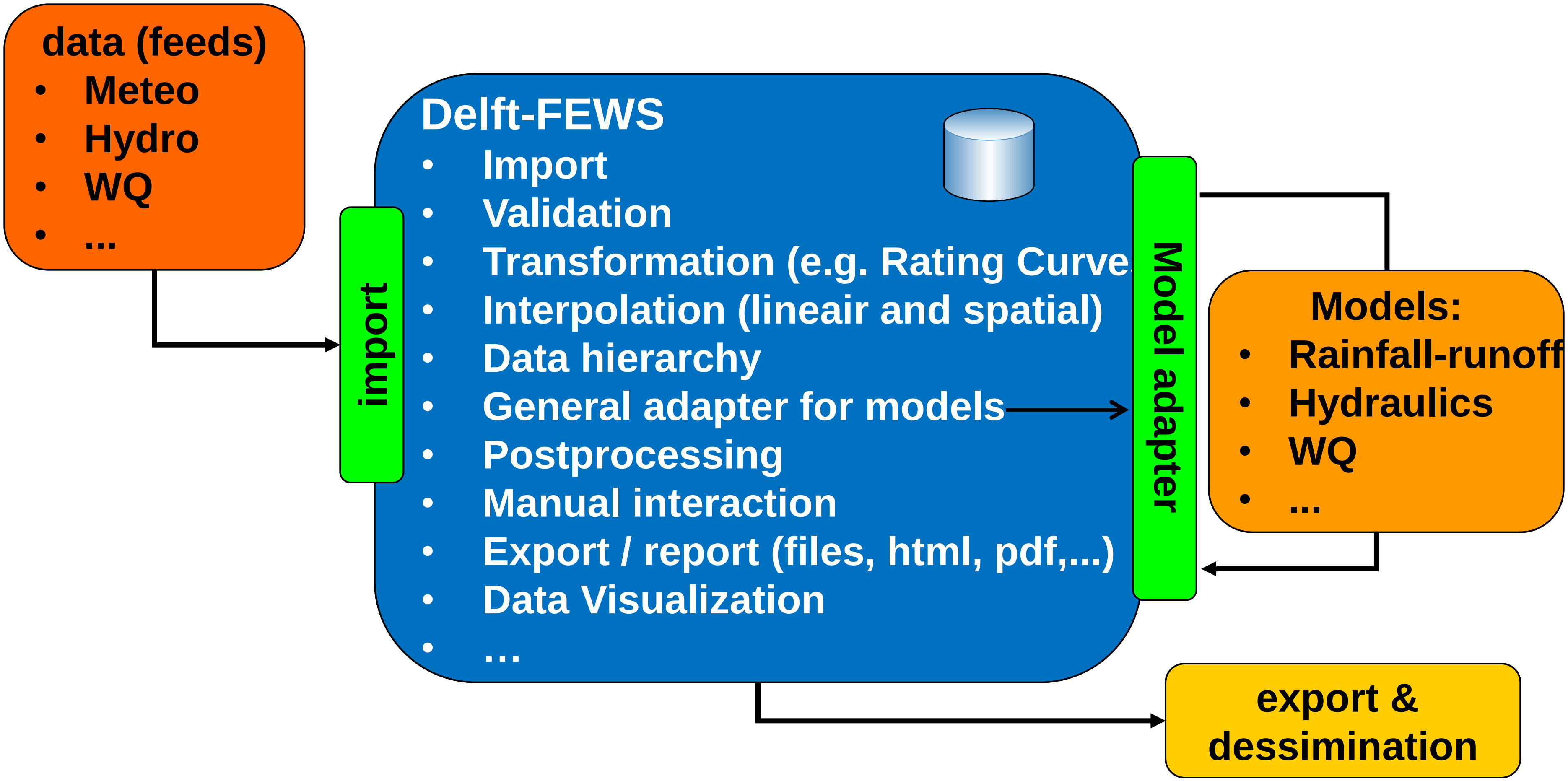
Deltares USA

Delft-FEWS Philosophy

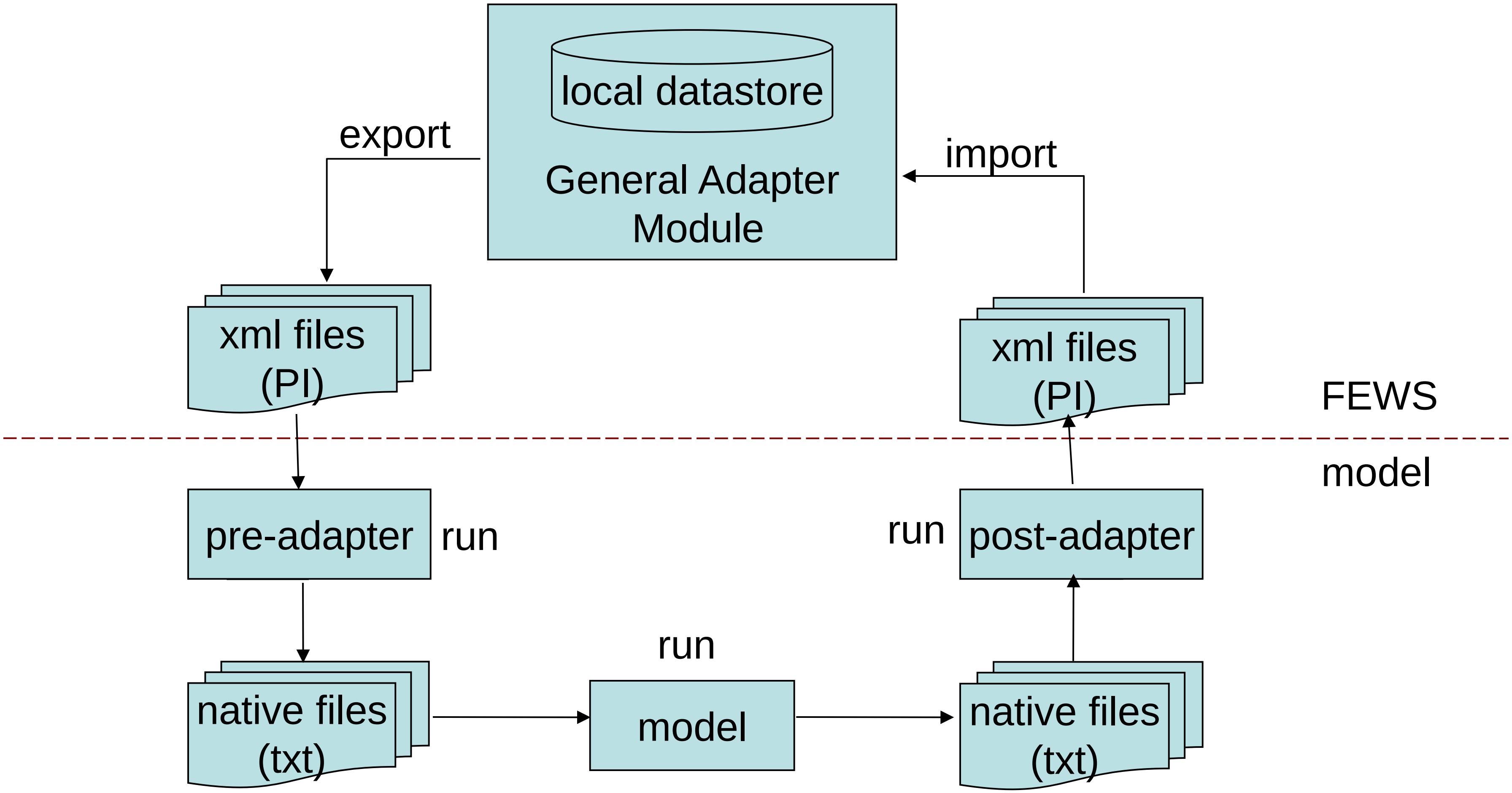
- FEWS is a data management system!
- Toolbox for development of forecasting systems
- Binding dataflows + models
- Fully ‘configurable’ by user
- Real-Time
- Rapid implementation, scalable & flexible
- High resilient & automatic / manual & stand alone



DELFT-FEWS Concept



Running models – how does it work



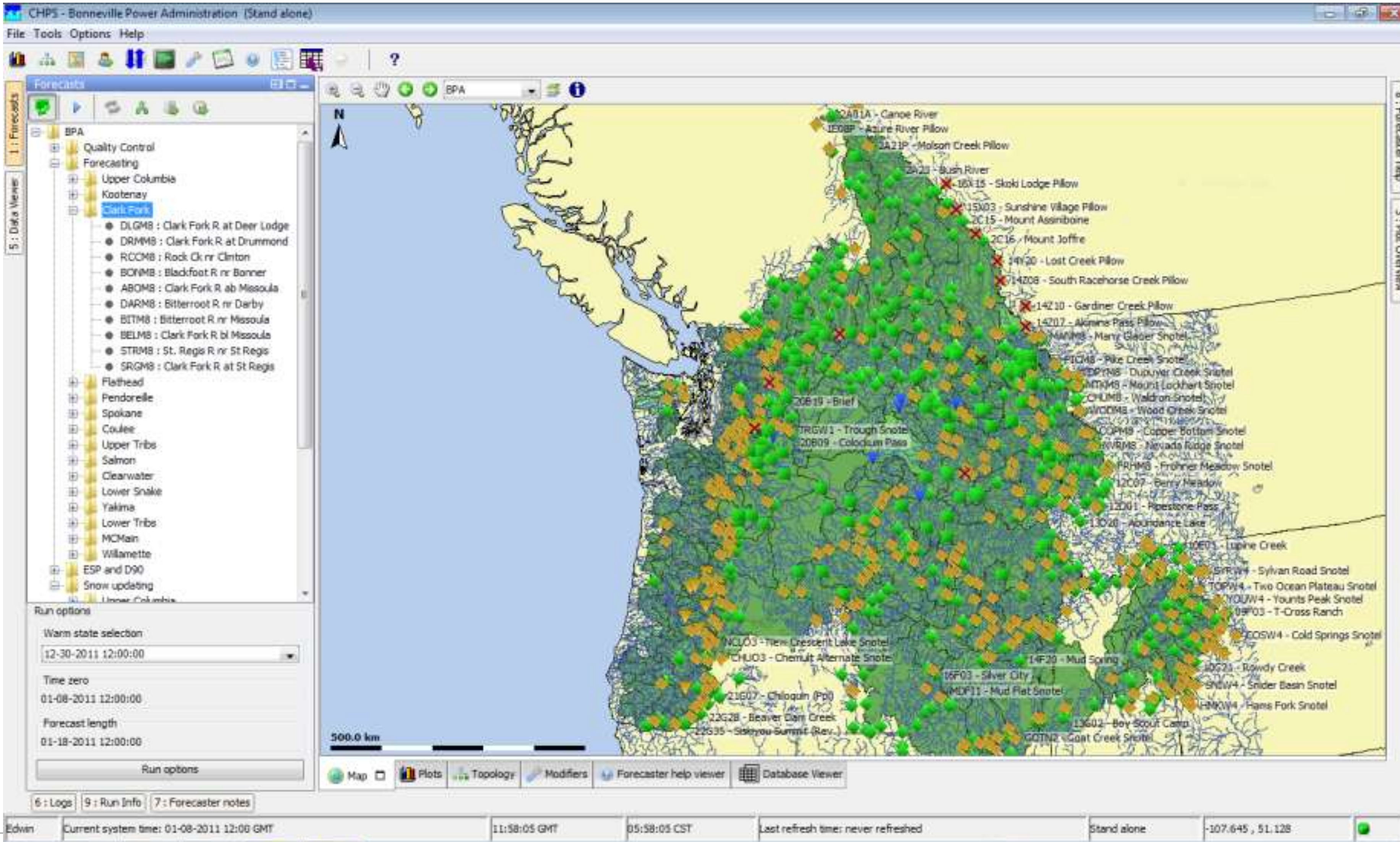
Delft-FEWS External Models – Model Adapters

- CEH Adapters (SNOWP, SNOW, PDM, KW, ARMA, TCM, HEC, GRID2GRID)
- HR (ISIS)
- PlanB Adapters (TRITON & PRTF)
- DHI Adapters (Mike11, NAM)
- Midlands Region (DODO, MCRM)
- Southern Region (STF)
- Northwest Region (NW TF – Common Adapter)
- Wales (SW Overtopping module - Common Adapter)
- SouthWest (Bruton/Holbeam Dam module – Common Adapter)
- **Deltares** (RTC Tools**,** Delft3D, SOBEK, RIBASIM, HYMOS, Sacrament, SSARR)
- SMHI (HBV)
- University of Karlsruhe (PRMS)
- JRC (Lisflood - PCRaster)
- NWS (SNOW17, SAC-SMA, UNIT-HG, LAG/K, SARRROUTE, SSARRESV, RESSNGL, BASEFLOW, CHANLOSS, APICONT, CONSUSE, GLACIER, LAYCOEF, MUSKROUT, RSNELEV, SACSMA-HT, TATUM)
- USACE (HEC-RAS, HEC-ResSim)
- University of Valencia (TETIS)
- EPA (EFDC, HSPF)

http://publicwiki.deltares.nl/display/FEWSDOC/Models+linked+to+Delft-Fews

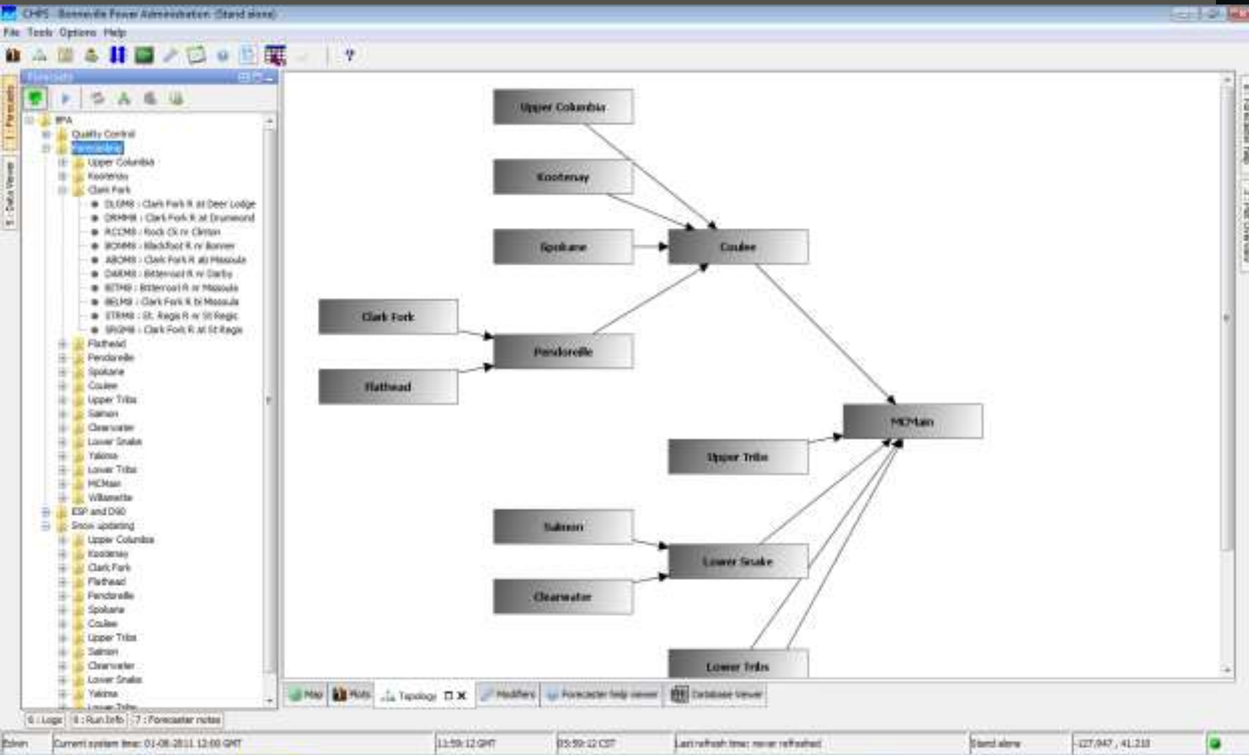
FEWS: Model Control

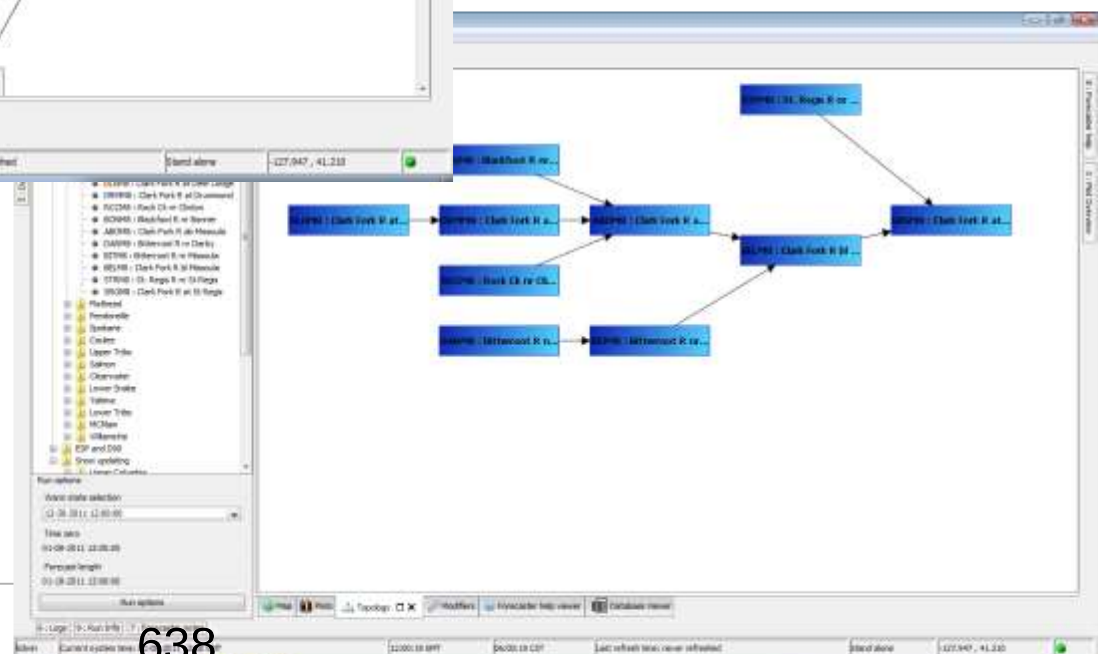
Situational Awareness



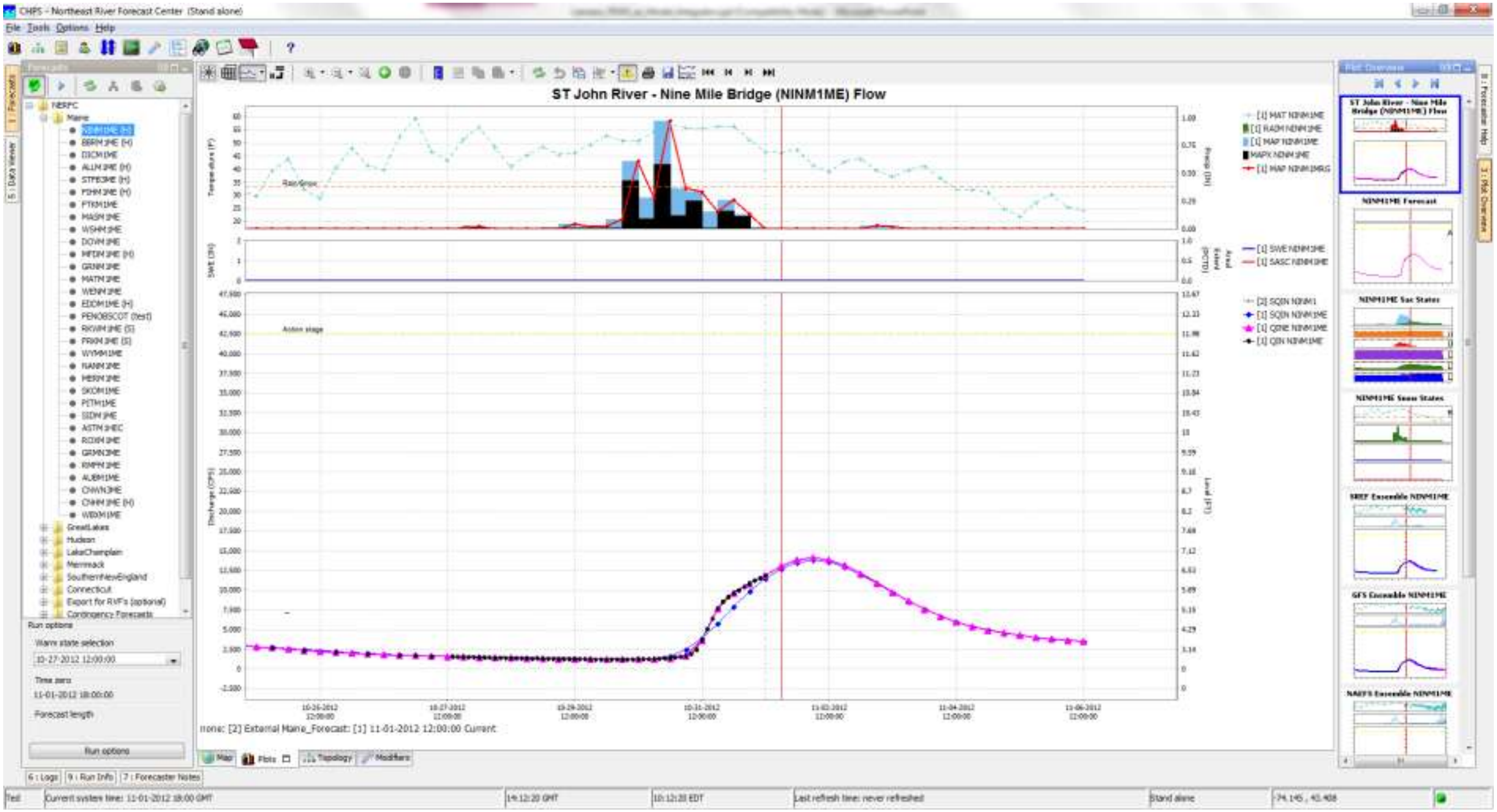
Deltares USA

Model Connectivity





Model Execution and Display



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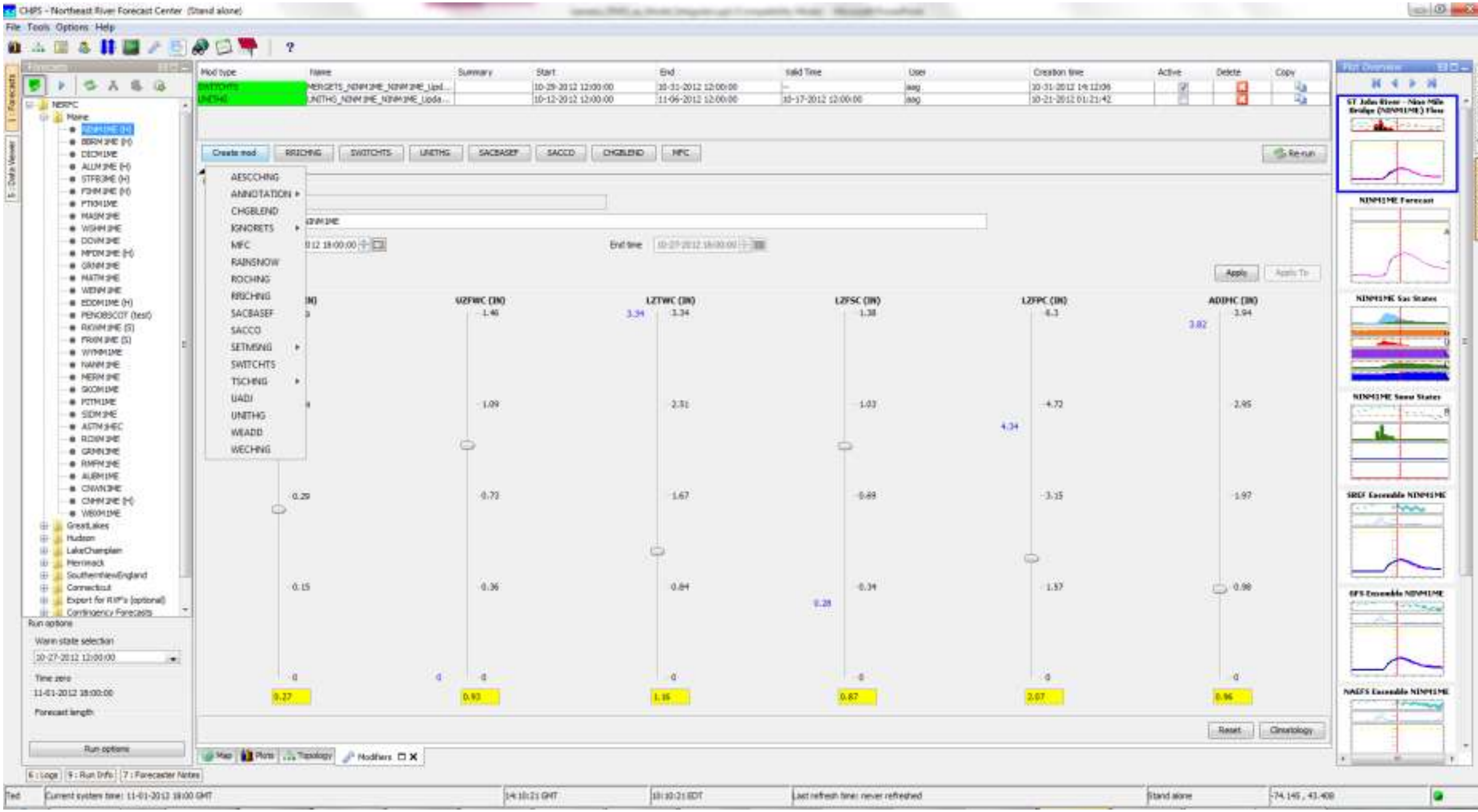
Control of Model Input, States, Options



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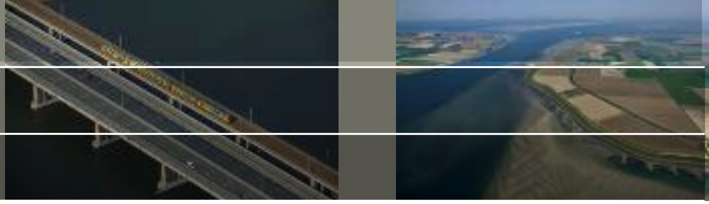
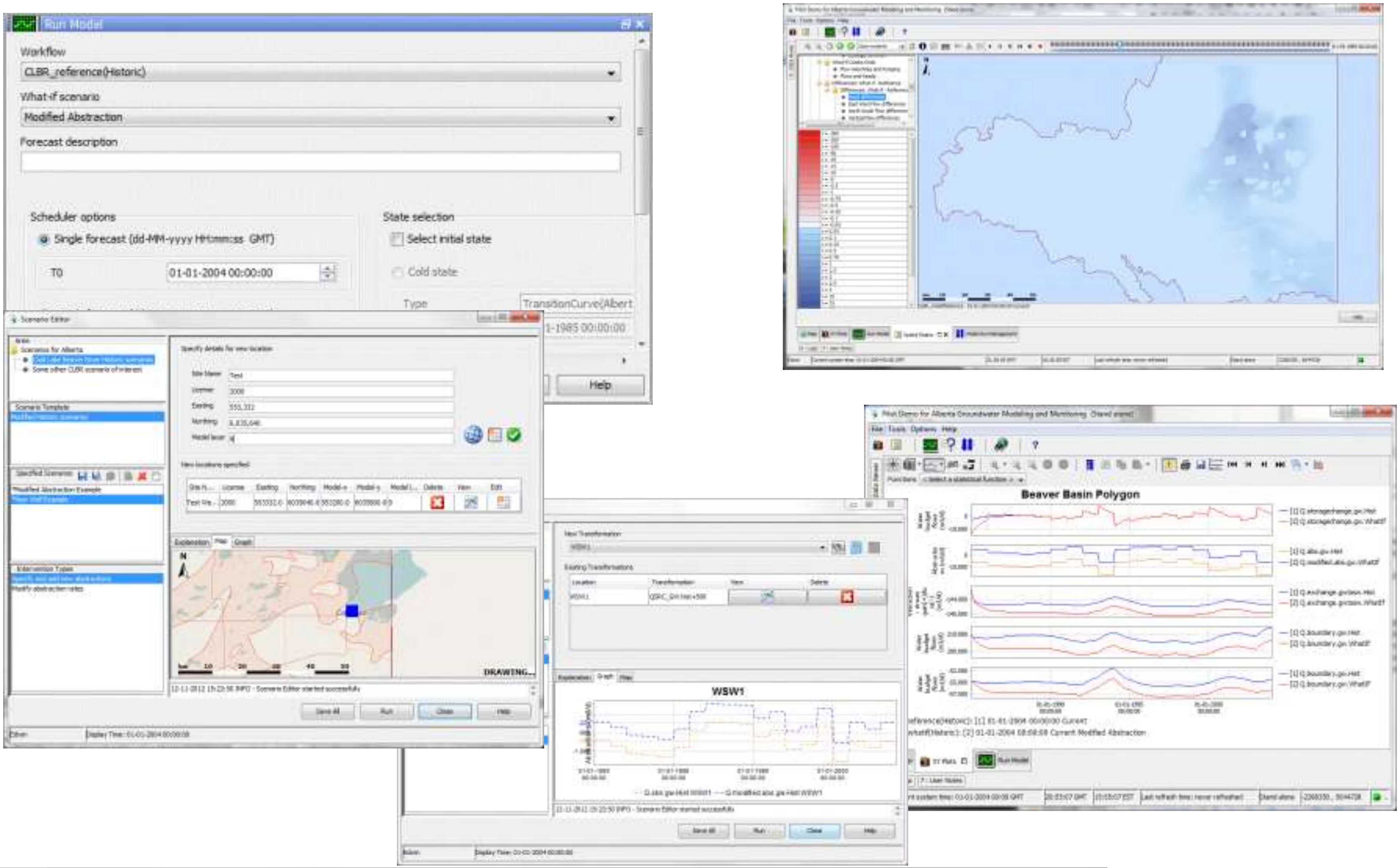
What if scenario's

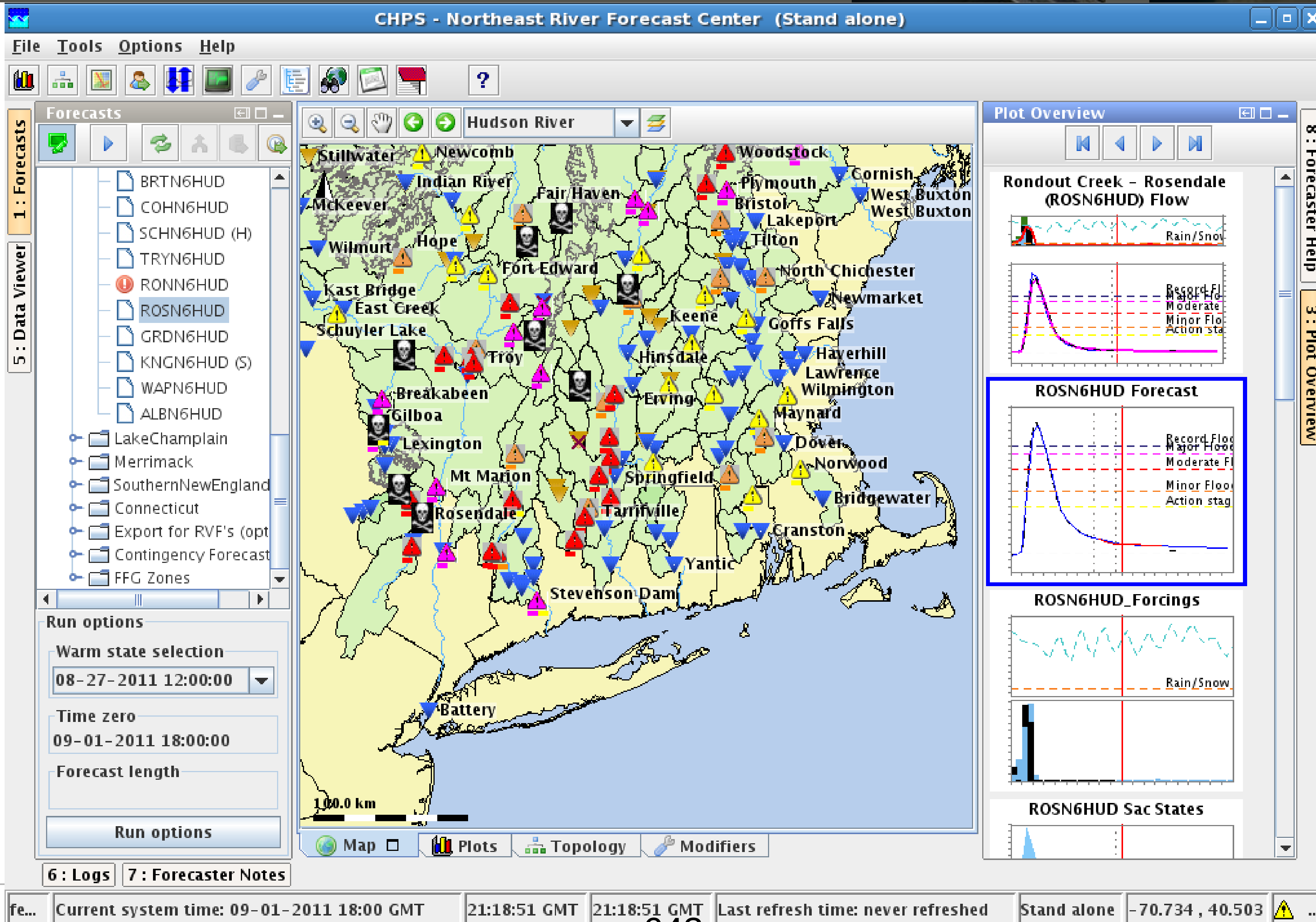




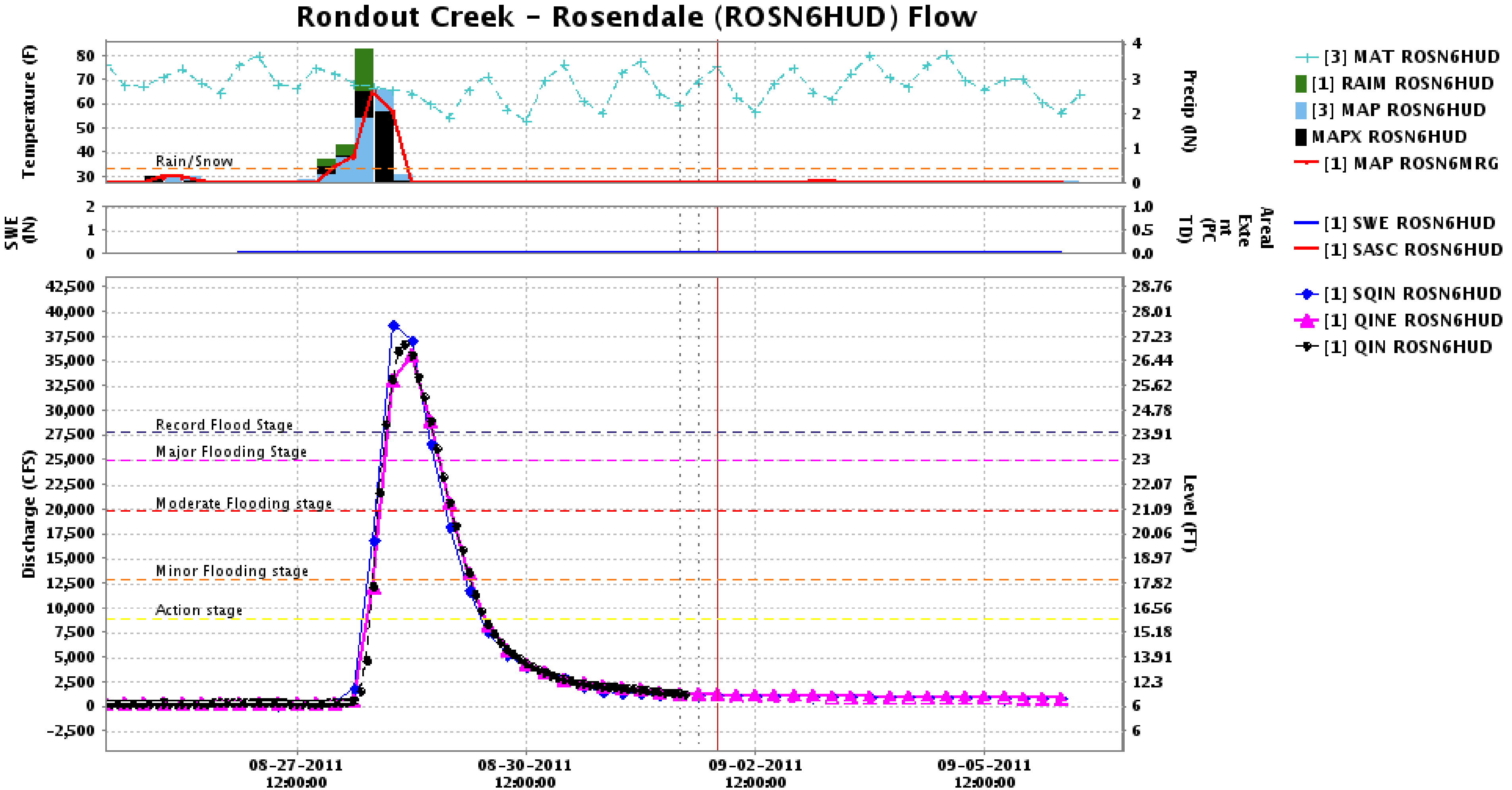
Deltares USA

FEWS: Displays

Customized Icons for the New England flood

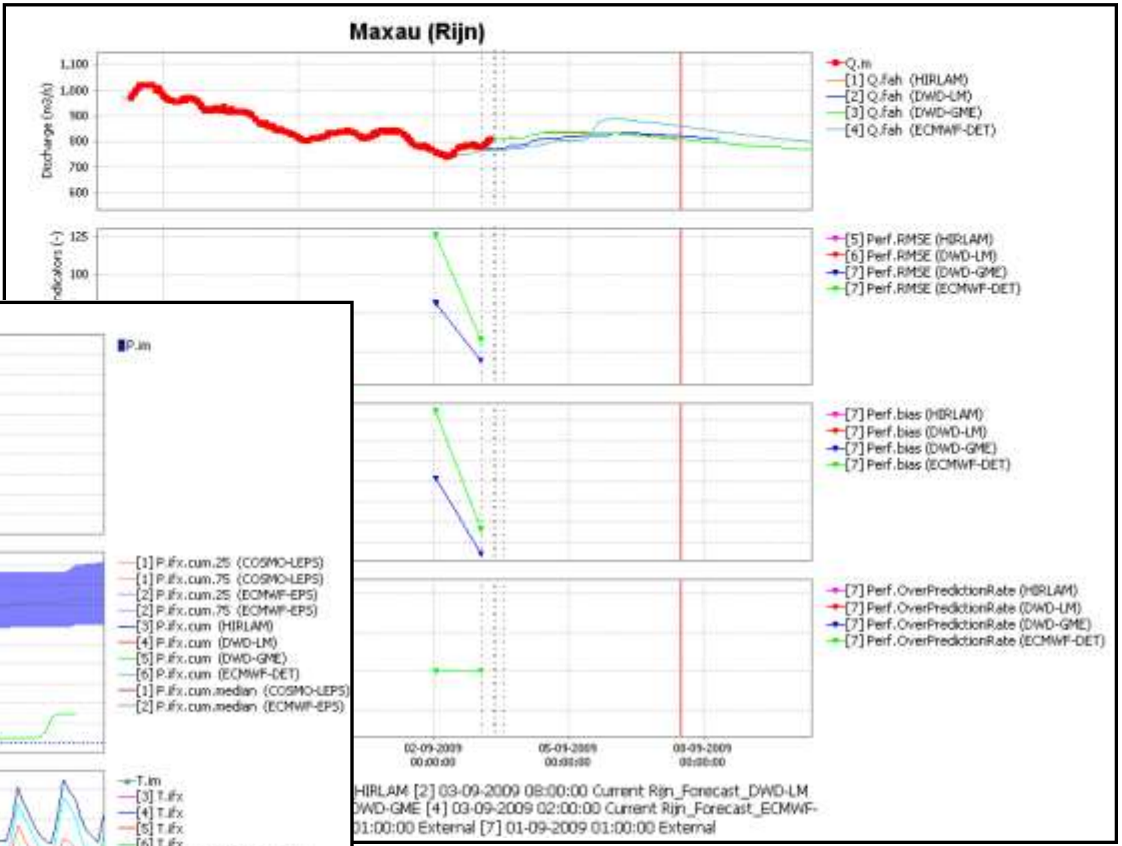


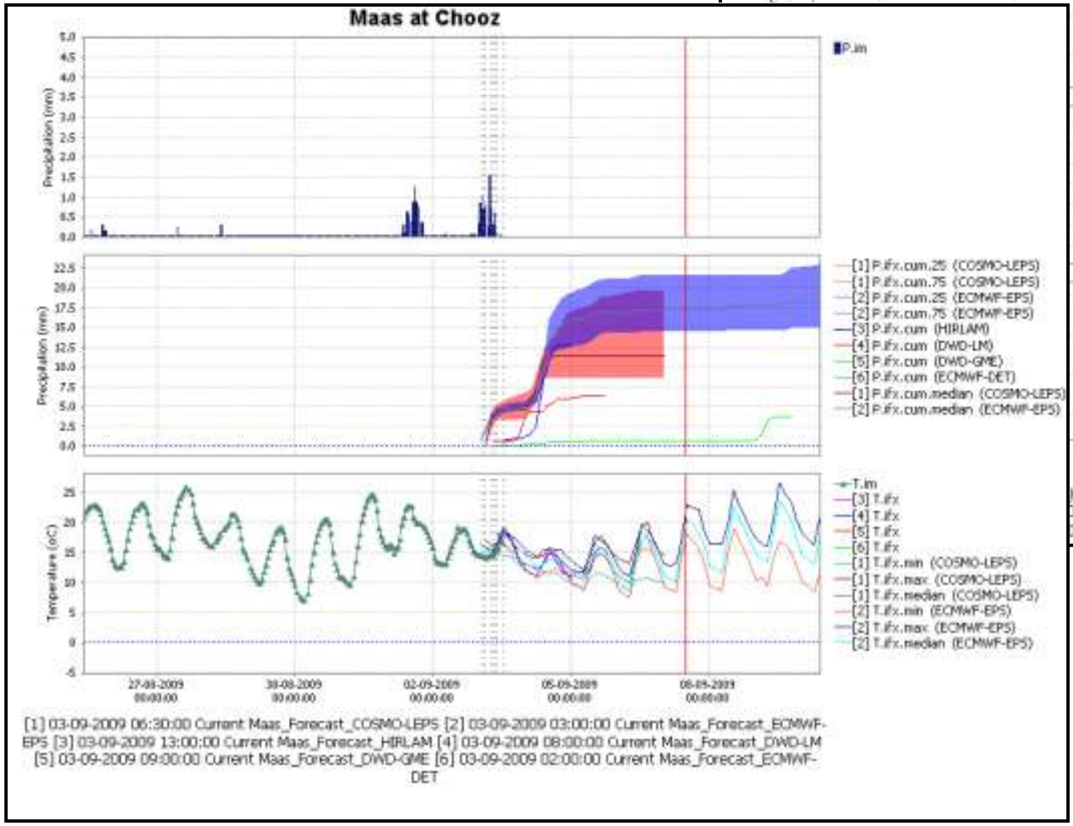
Threshold crossings



[1] 09-01-2011 12:00:00 Current FFG_FFH [2] 09-01-2011 18:00:00 Current MTRN6HUD_Forecast

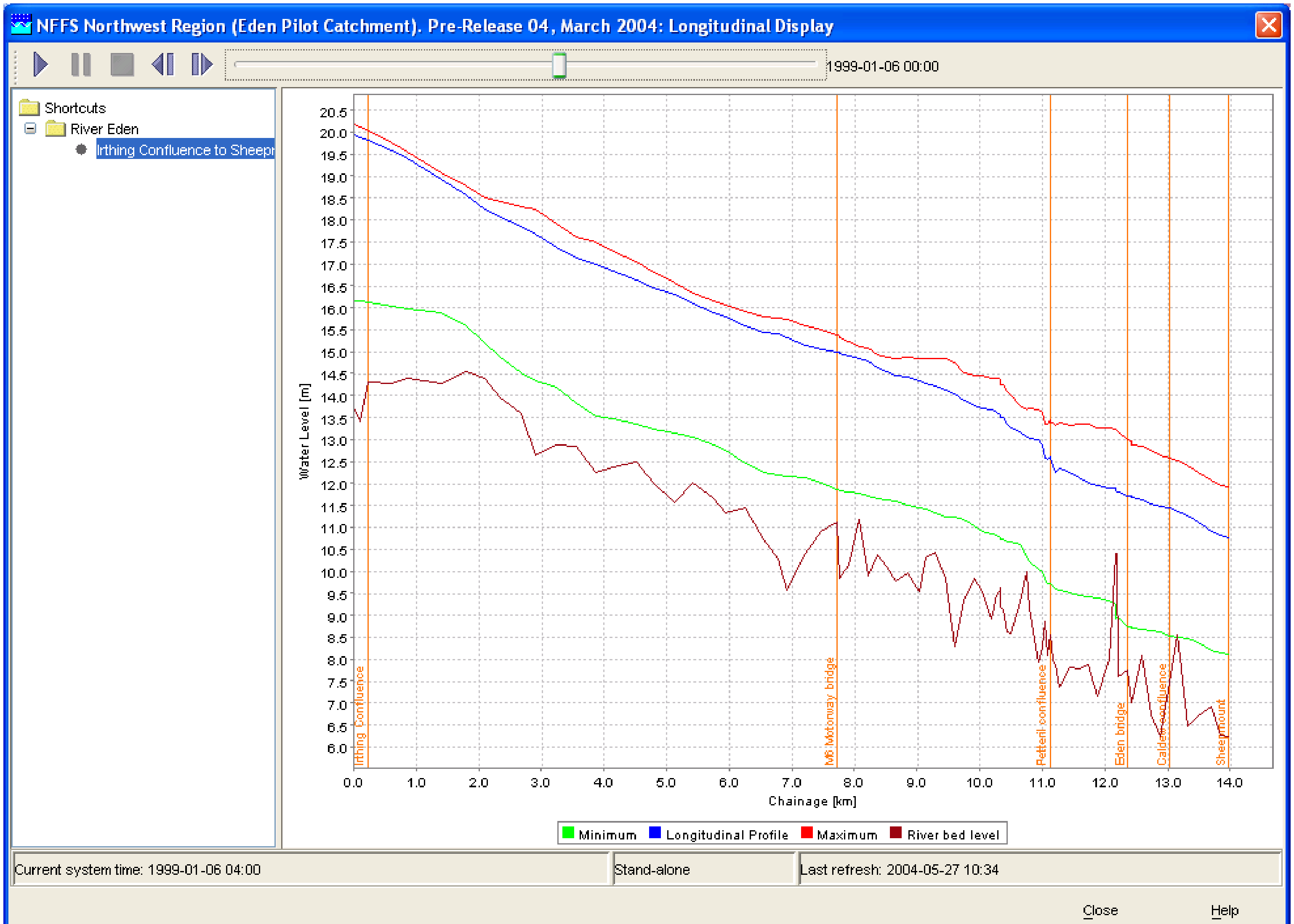
Uncertainty: Performance Indicators



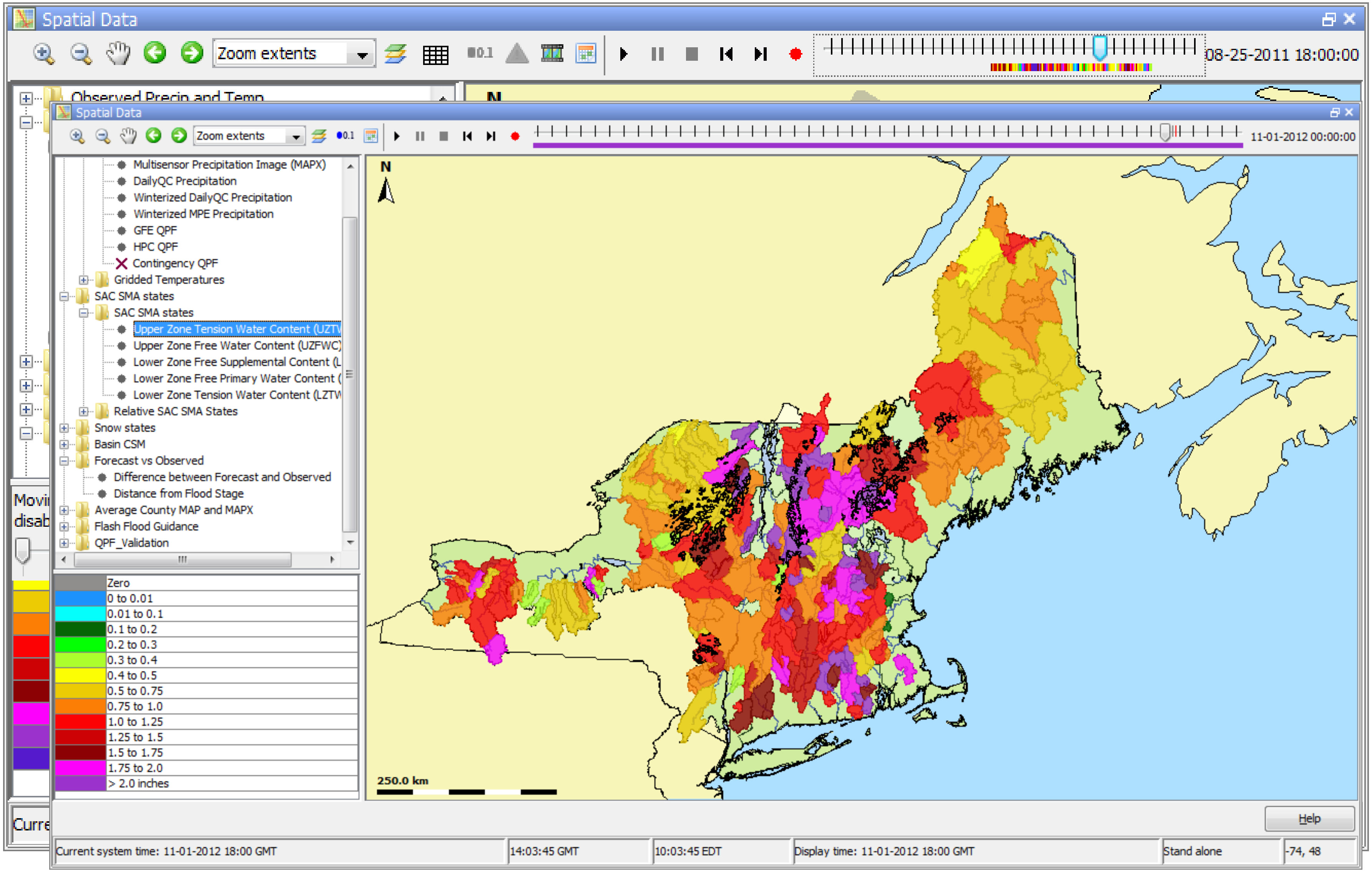


Deltares USA

FEWS: Longitudinal Display



Spatial data



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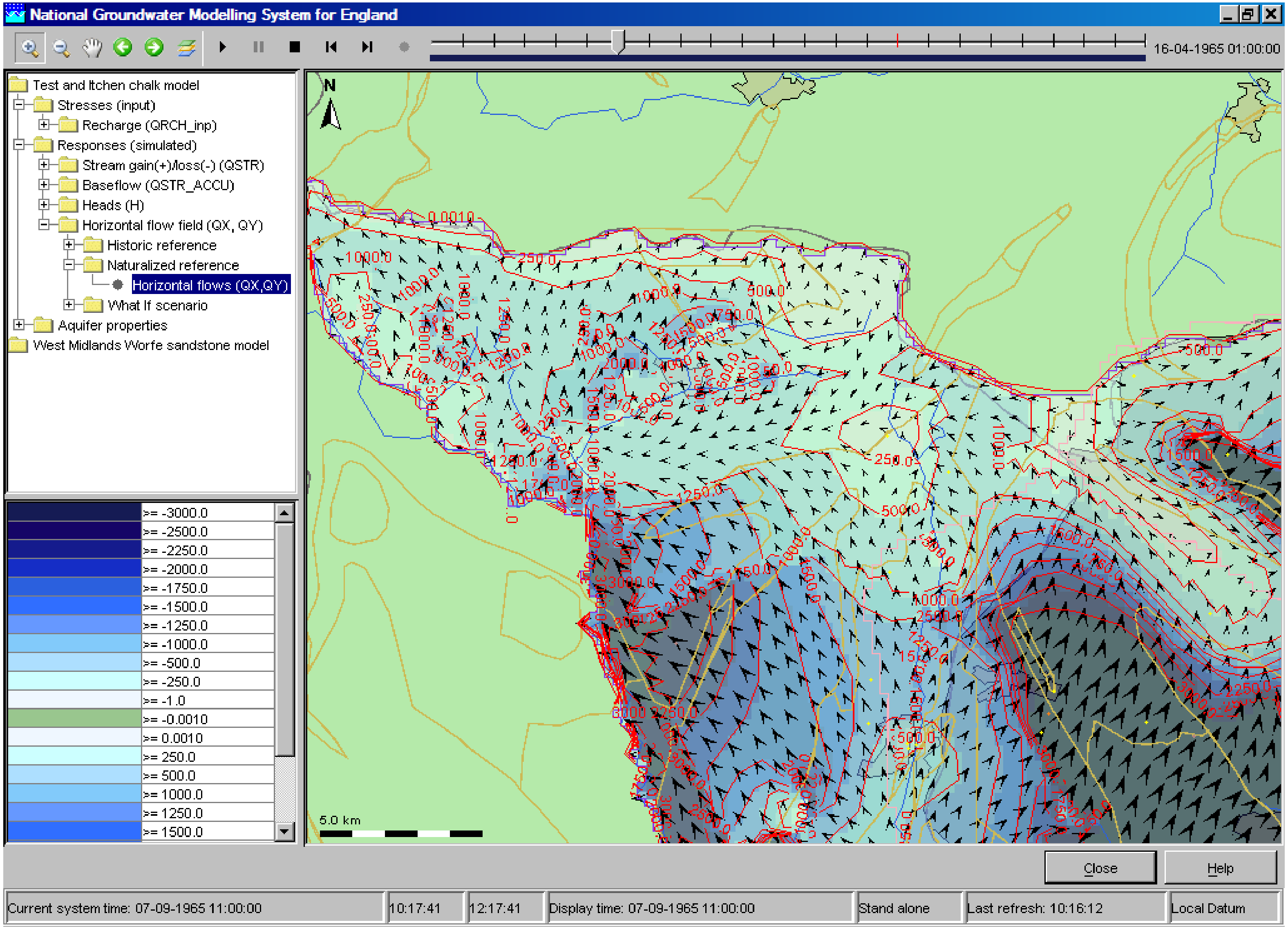
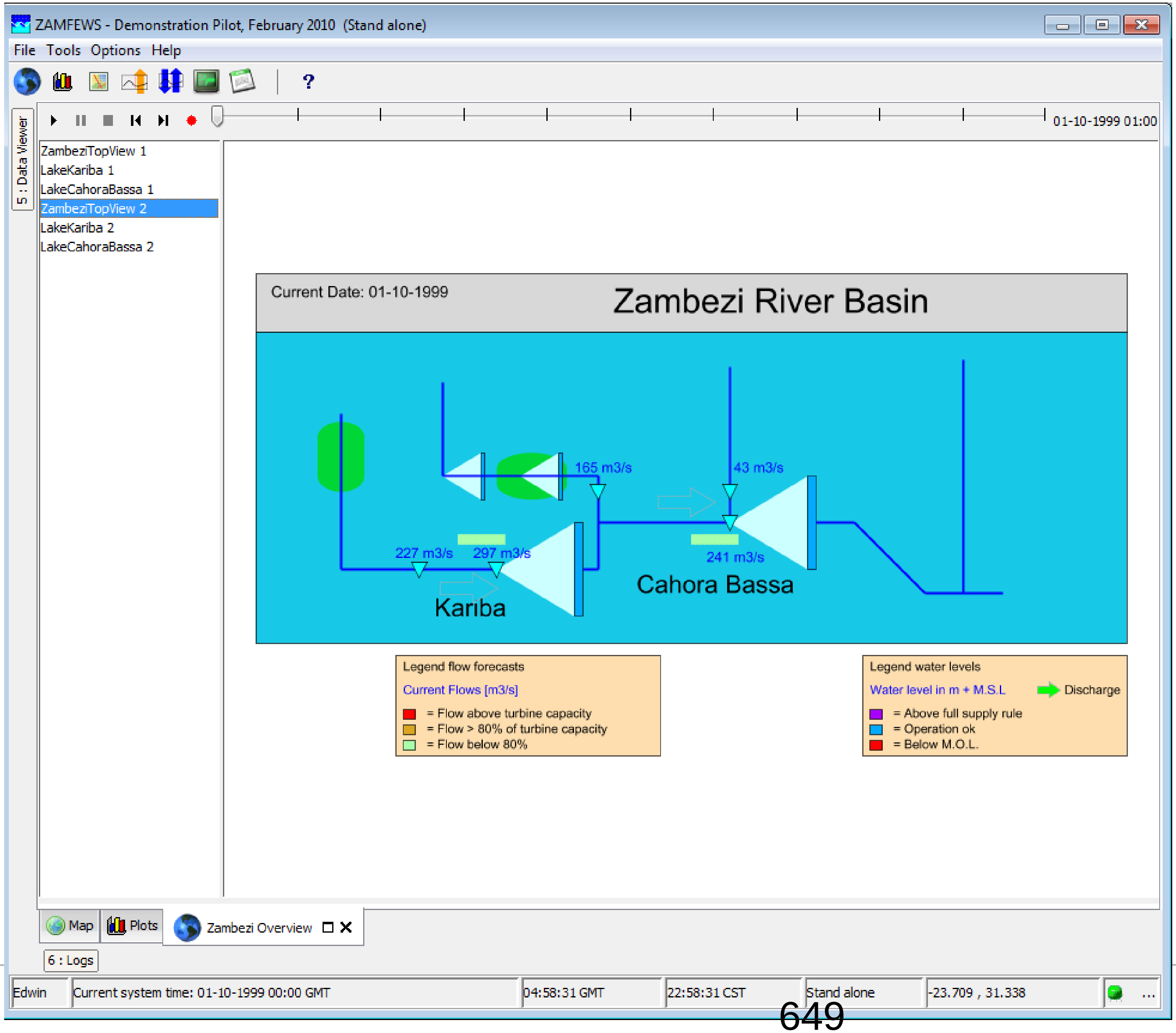
Animation of flow fields

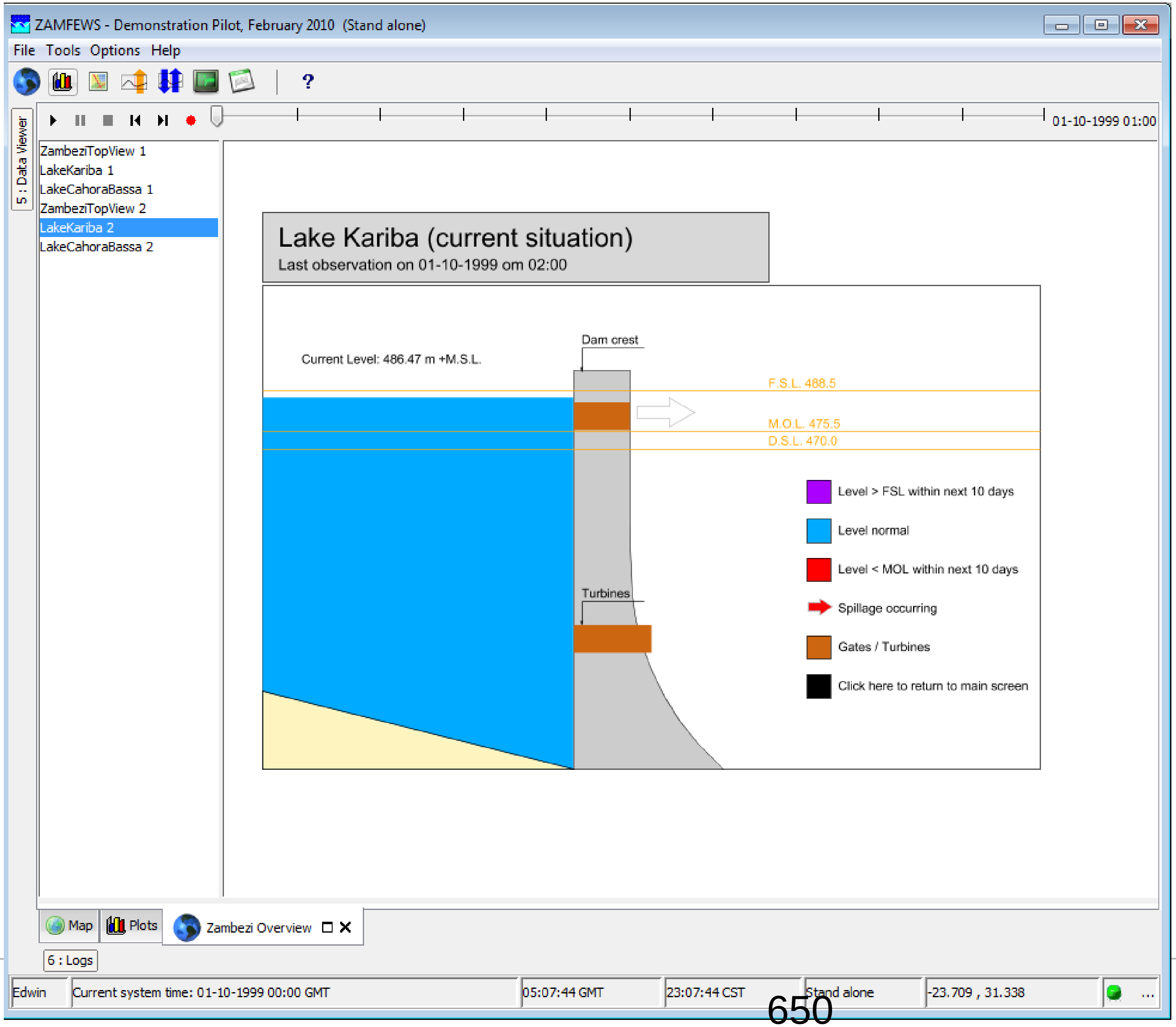


FEWS: System Display (1)

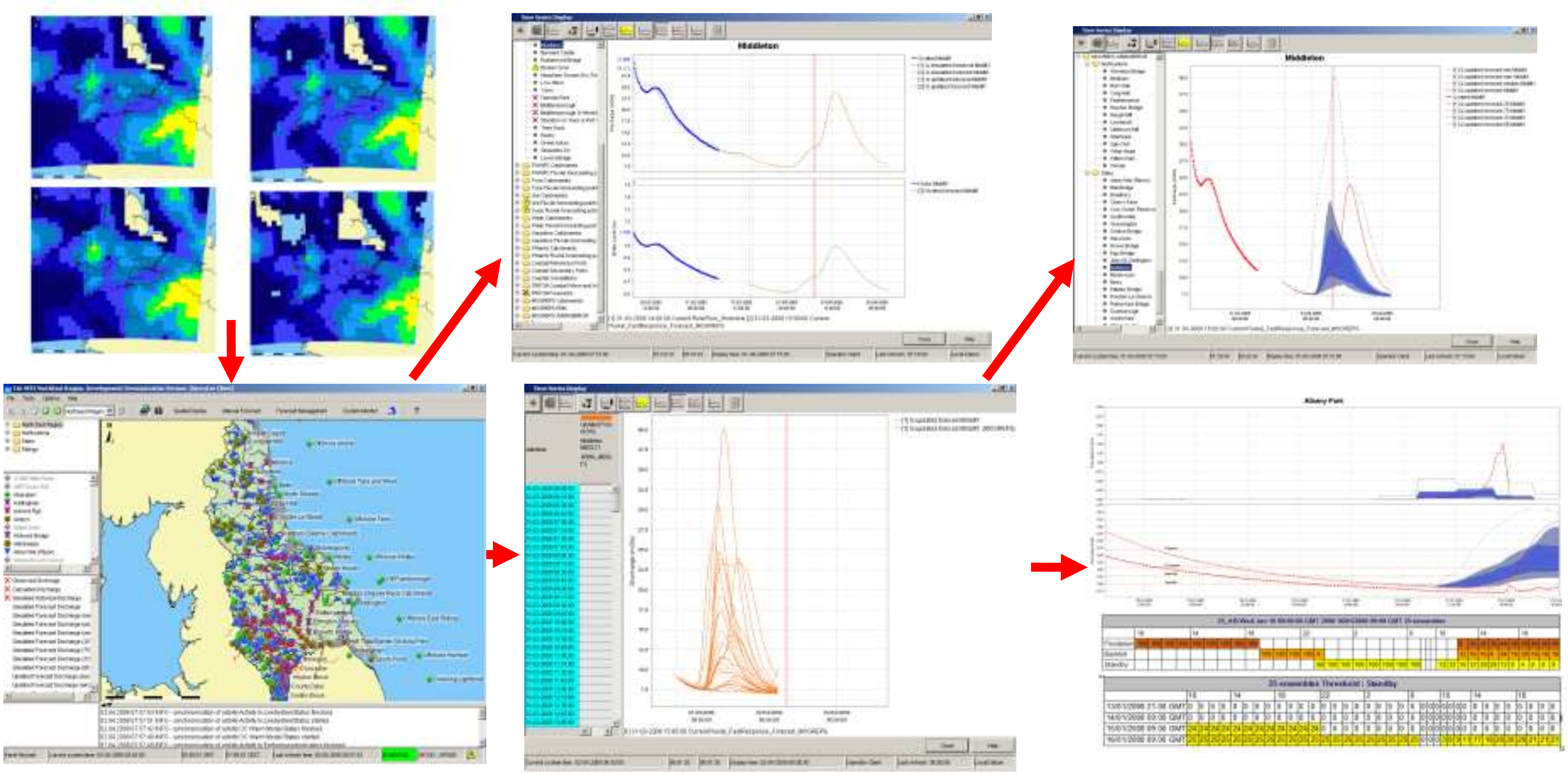


Deltares USA

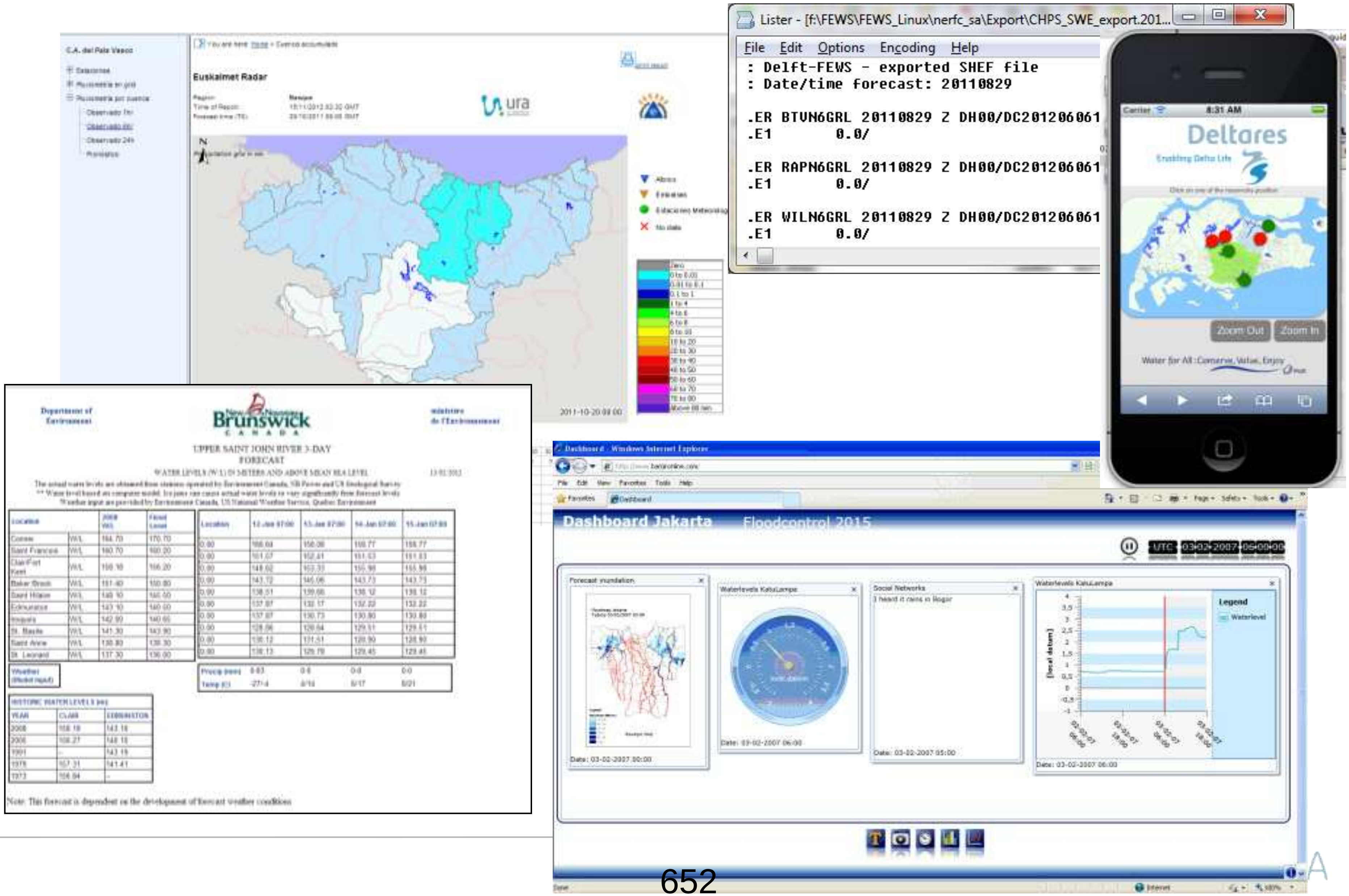
FEWS: System Display (2)



Ensemble forecasting in England & Wales



Exporting products



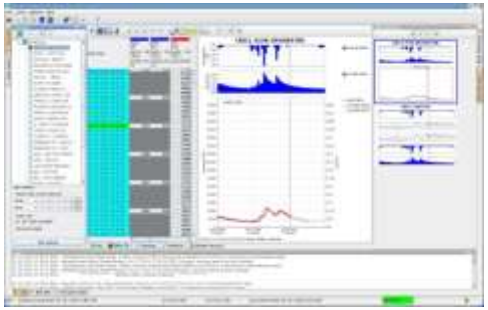
FEWS: Model integrator

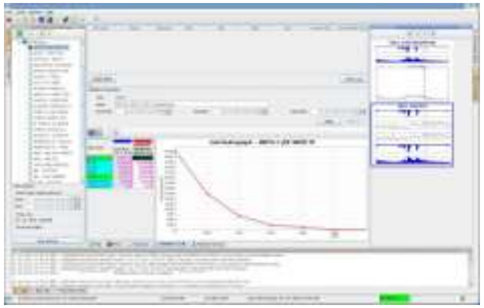
Deltares

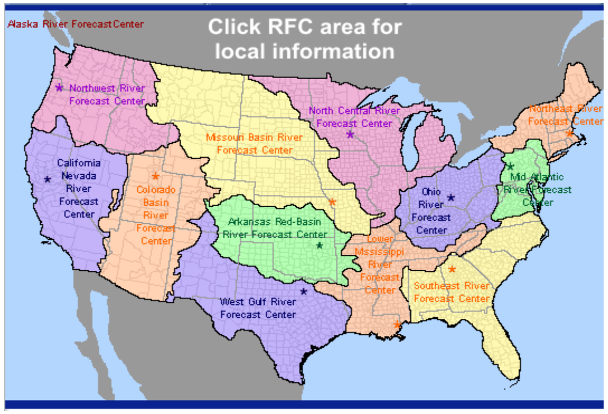
Community Hydrologic Prediction System (CHPS)

National River Forecasting System for National Weather Service (NWS / OHD), USA

- 13 River Forecast Centers (RFC)
- > 1000 models per RFC (snow, rainfall-runoff, routing, hydrodynamic)
- Interactive forecasting

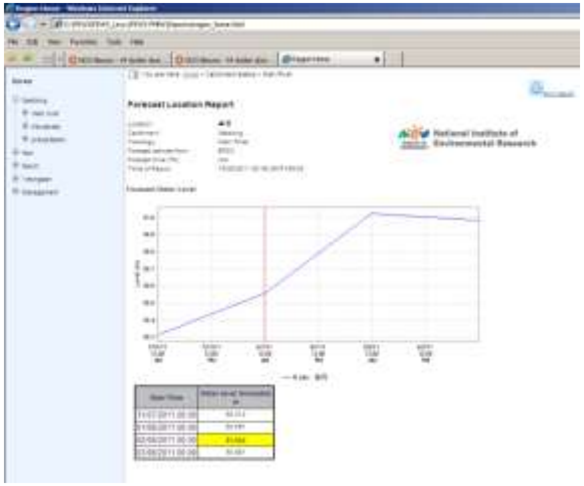




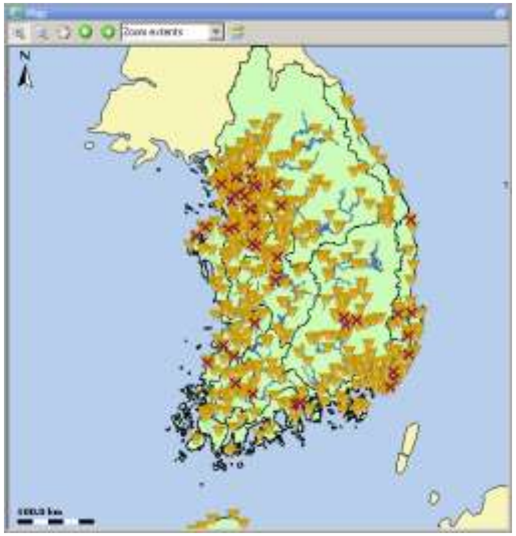


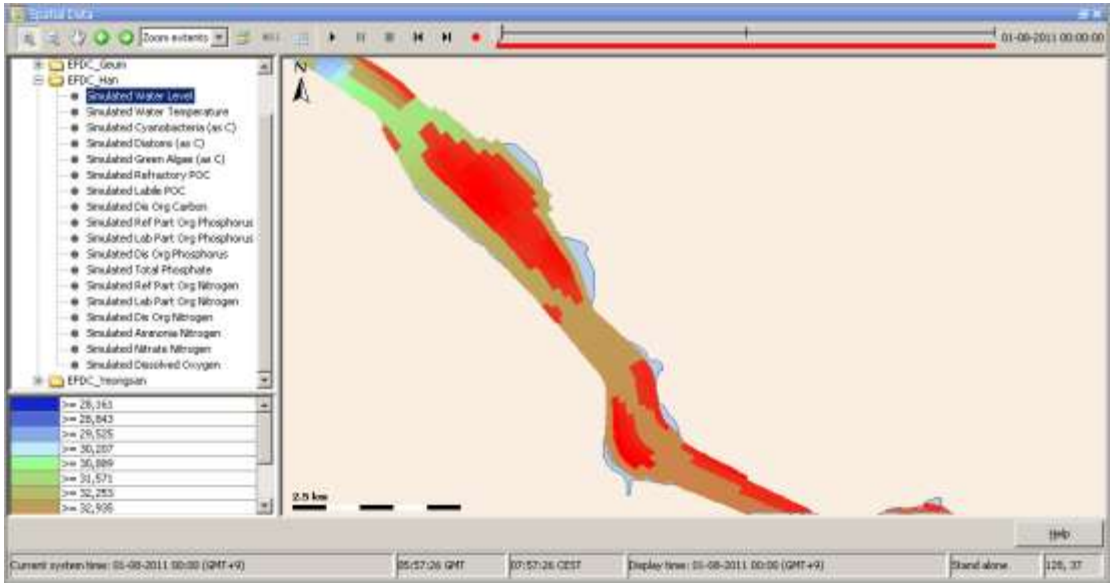
Deltares USA

Water Quality Forecasting System for the Four Major Rivers in Korea



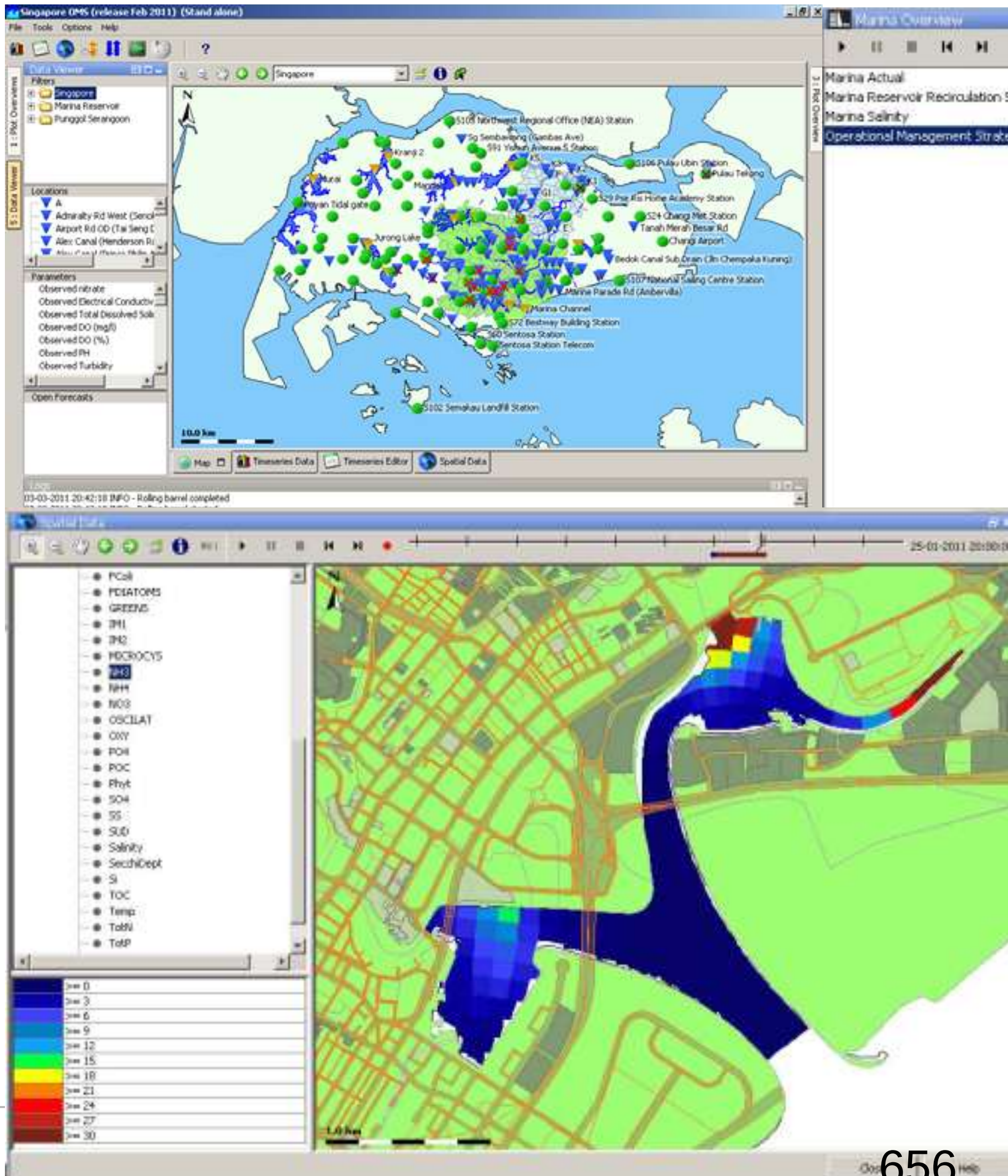
- Monitoring water quality in the river and reservoirs (including water temperature)
- 7 days forecast
- HSPF and EFDC 3D water quality modeling
- Better accuracy by using Data Assimilation through 'openDA'

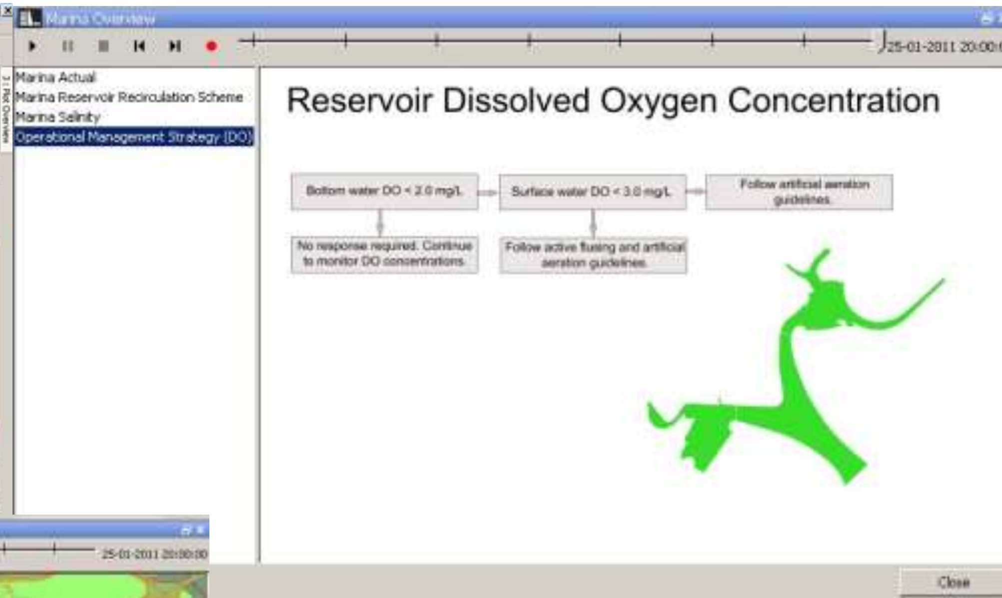




Deltares USA

Real time water quality management and forecasting for Marina Bay, Singapore



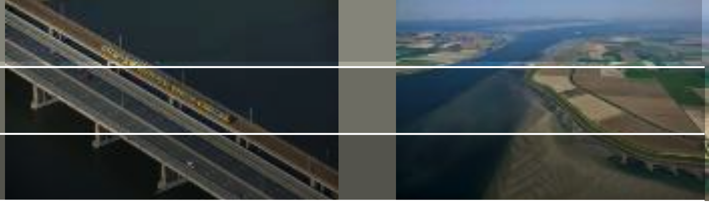


Integration of scientific knowledge in operational FEWS system:

- Hydraulic and hydrological models
- Water quality model DELFT3D
- RTC model for barrage
- Emission model

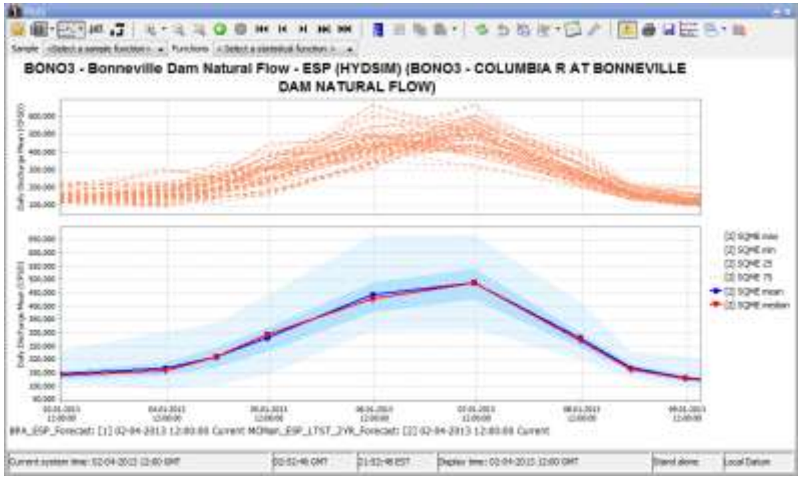
Deltares USA

Reservoir operations: BPA



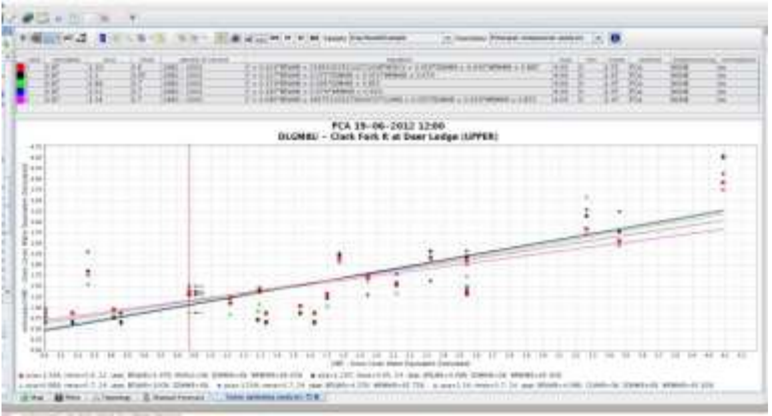
Streamflow (Ensemble) forecasting

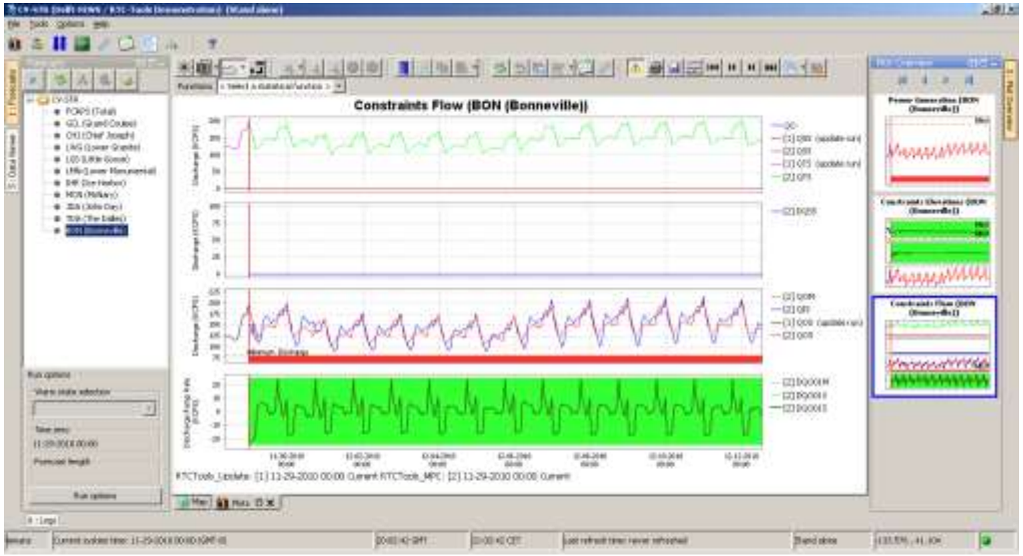
- Data Quality Control
- Snow Updating
- Hydrology and reservoir modeling
- Ensemble pre- and postprocessing



Reservoir system optimization

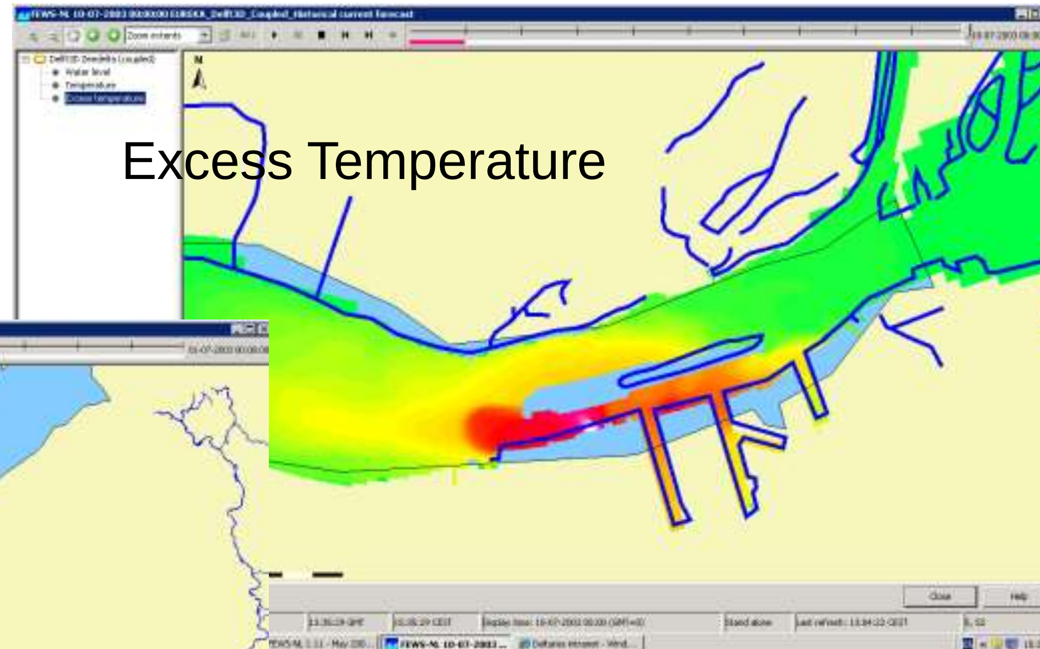
- RTC-Tools

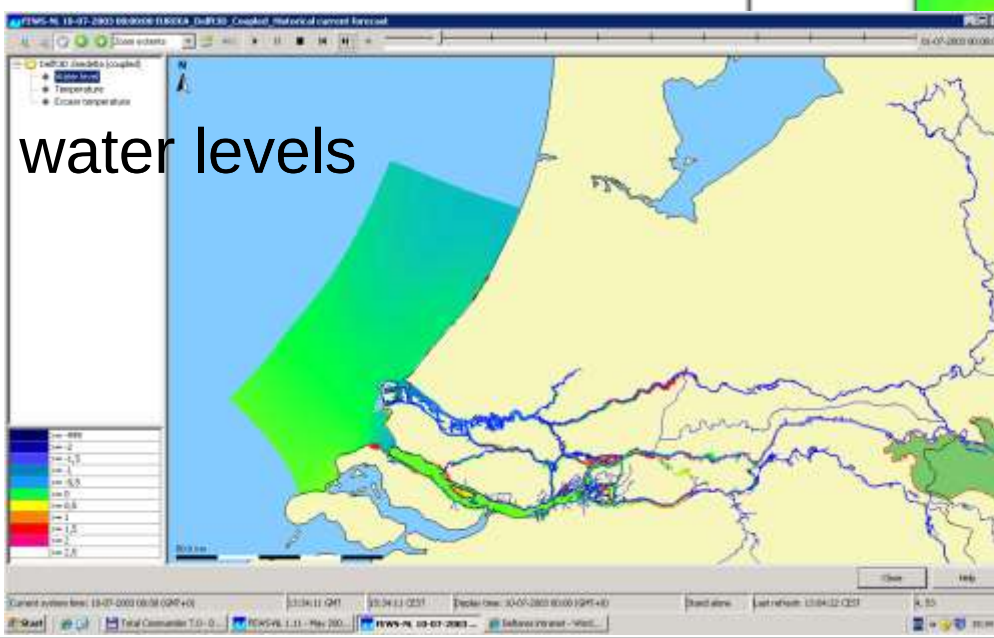




Prototype forecast system for cooling water

- From North Sea to Basel
- 3D in part of Hollandsch Diep estuary
- 2D till Hagestein and Dreumel
- 1D-2D-3D coupling under FEWS!





Can also model salinity with this setup

Deltares USA

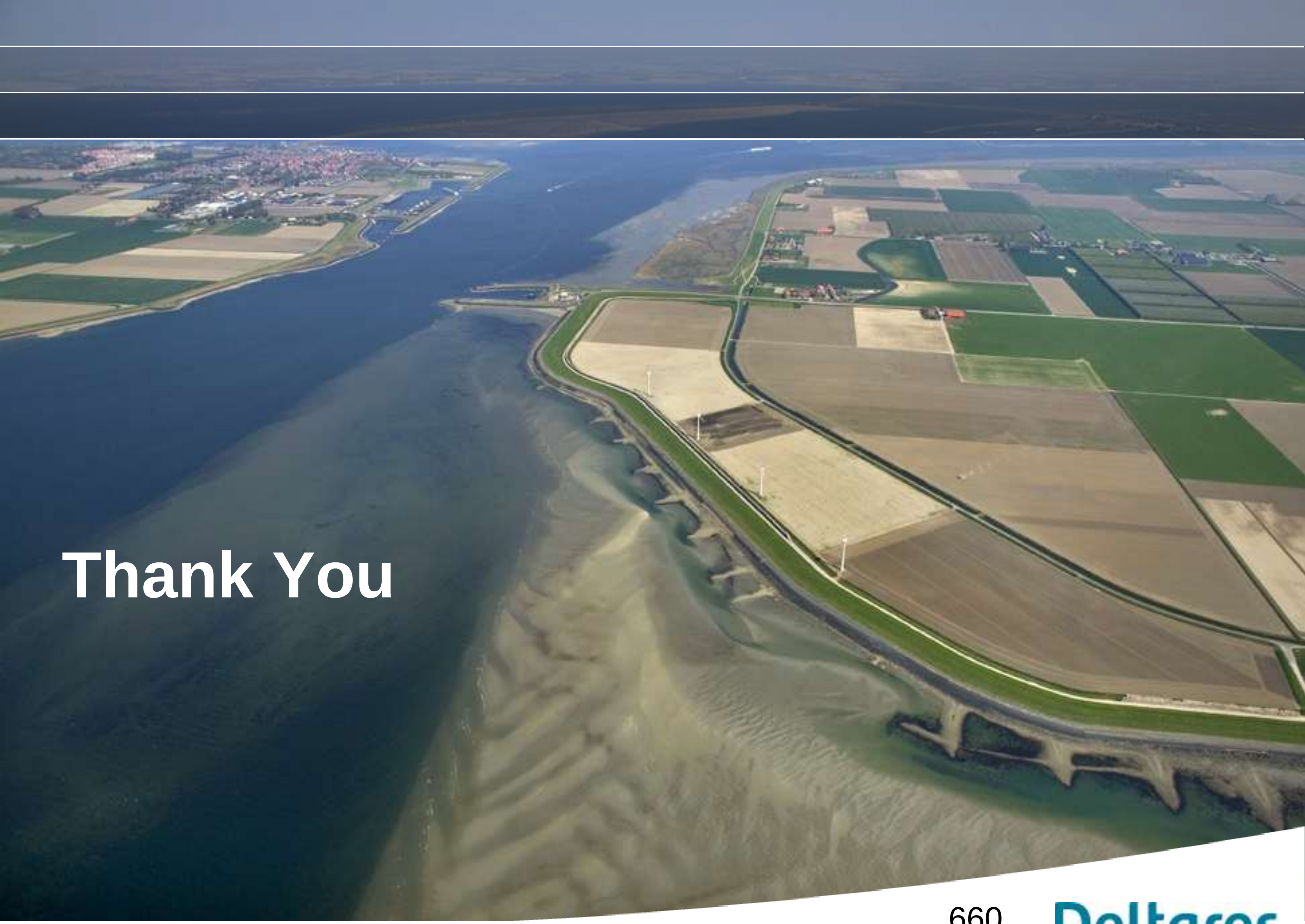
Conclusions

DELFT-FEWS:

- Is a world wide flexible forecasting tool
- Open to external data and models

- Creates collaboration
  - between forecasters and research groups
  - between forecast organizations

- Allows organizations to expand services and improve forecasts



Thank You

Session 4

Day 2 – Session 4

Paul Craig – Dynamic Solutions-International LLC (DSI)

BIOGRAPHY

Mr. Craig was a founding member of Dynamic Solutions-International LLC, which was started in 1998 in the United States. He is a registered Professional Engineer with over 34 years of experience in Water Resources and Environmental Engineering and is an expert in environmental hydrodynamics, hydrology, hydraulics and sediment transport.

Day 2 – Session 4

Paul Craig – Dynamic Solutions-International LLC (DSI)

ABSTRACT

A summary of the EFDC_DSI/EFDC_Explorer (EE) modelling system is presented along with how it is already being used by Alberta Environment for two river systems. An overview of the EE modelling system is presented with example plots and animations. The enhancements to EFDC are summarized with a focus on the model runtime speedup due to the implementation of openMP in the EFDC code.

EFDC_DSI/EFDC_Explorer Modeling System

Use and Applications for Alberta

ESRD Environmental Modelling Workshop

March 2013

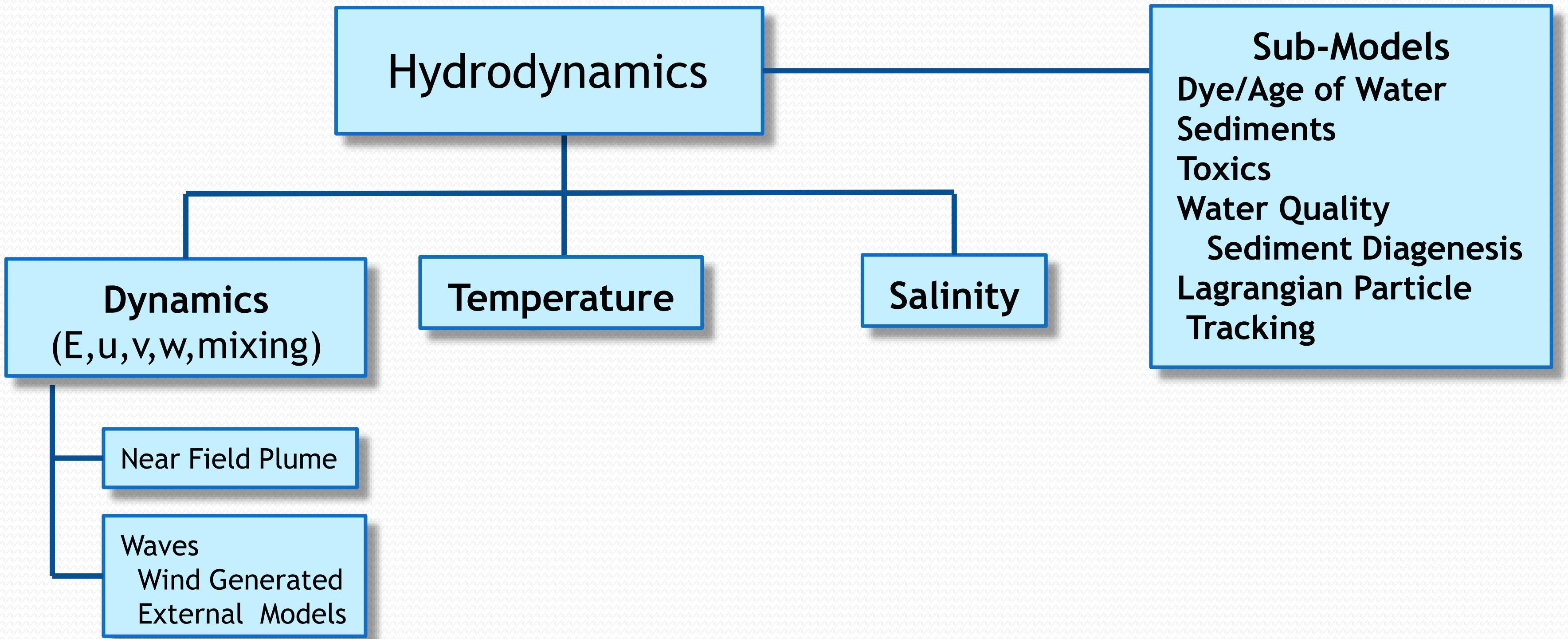
Dynamic Solutions International LLC

www.ds-intl.biz

The EFDC Model

- The Environmental Fluid Dynamics Code (EFDC) is a general-purpose hydrodynamic modeling package
- Simulates 1,2 & 3-D flow, transport, and biogeochemical processes in surface water systems (rivers, streams, lakes, estuaries, coastal waters and open ocean)
- EFDC model was originally developed at the Virginia Institute of Marine Science
- EFDC is a public domain model
- EFDC is a widely used and accepted model
- EFDC_DSI is Dynamic Solutions-International's enhanced and optimized version

EFDC Architecture



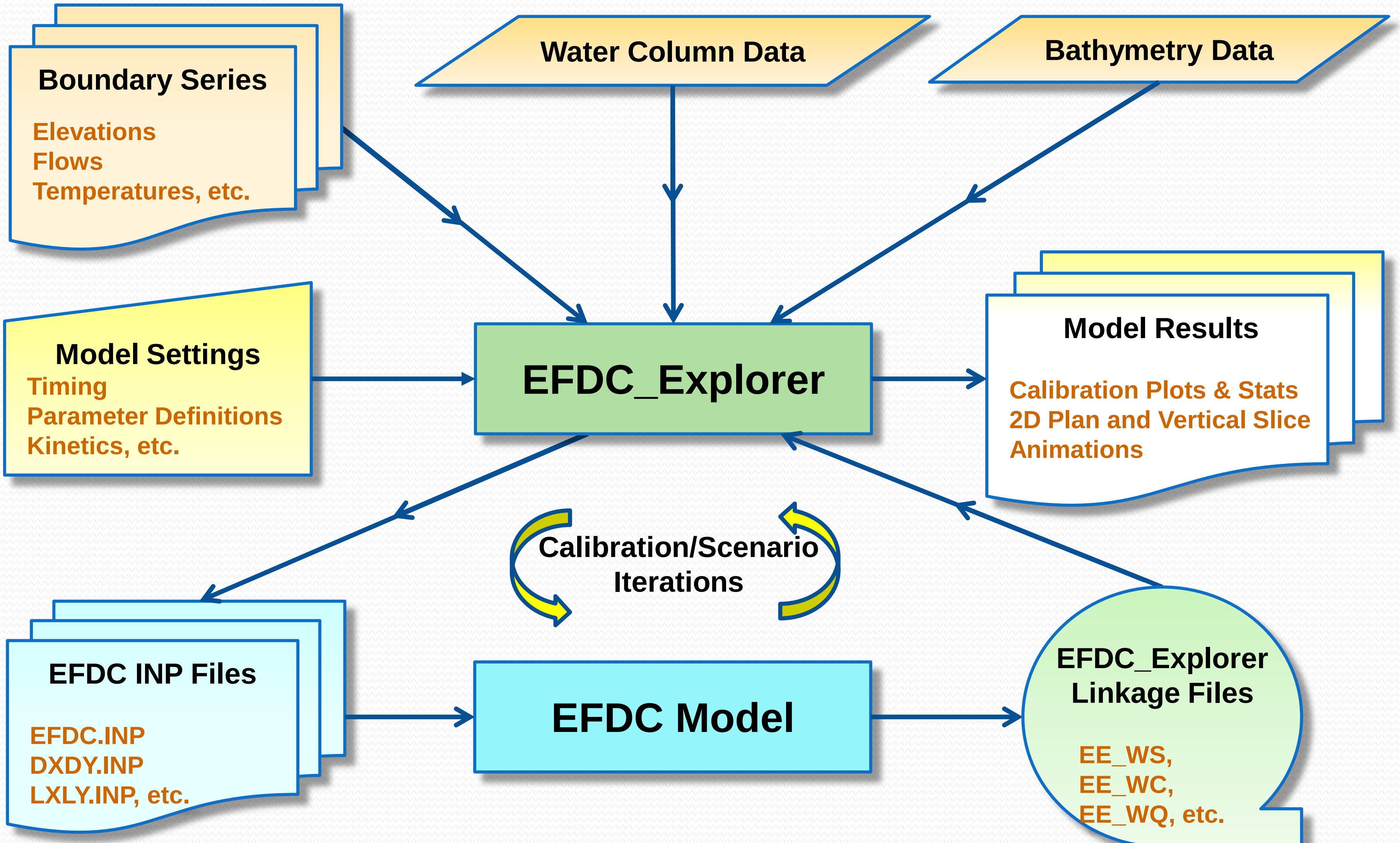
- EFDC's hydrodynamics are based on the 3D hydrostatic equations formulated in curvilinear-orthogonal horizontal coordinates and a sigma or stretched vertical coordinate system.
- EFDC is a coupled model eliminating model linkage issues

EFDC_DSI Enhancements

Dynamic Solutions-International (DSI) has developed an enhanced version the code (EFDC_DSI) which includes:

- Dynamic Memory Allocation
- Lagrangian Particle Tracking
- Improved/Simplified External Wave Model Linkage
- Internal Windwave Generation
- Added Dynamic Timestepping with WQ Model
- Age of Water/Residence Times
- Rooted Plant and Epiphyte Model (RPEM)
- OpenMP – Multi-Threading
- Upgraded all code to Fortran90 (EE7.1)

EFDC_Explorer/EFDC_DSI Modeling System



EFDC_DSI/EFDC_Explorer Uses

- Models of eutrophication and nutrient processes
- Water quality studies/planning
- Flood and inundation mapping
- Bridge scour analysis
- Oil spill tracking and planning
- Contaminated sediment/toxics analysis and planning
- Thermal discharge/impact studies and planning
- Aquatic vegetation studies
- Lakes/reservoir mixing and residence time studies
- Tailrace investigation for Hydropower
- Hydraulic structure design support

Applications in Alberta

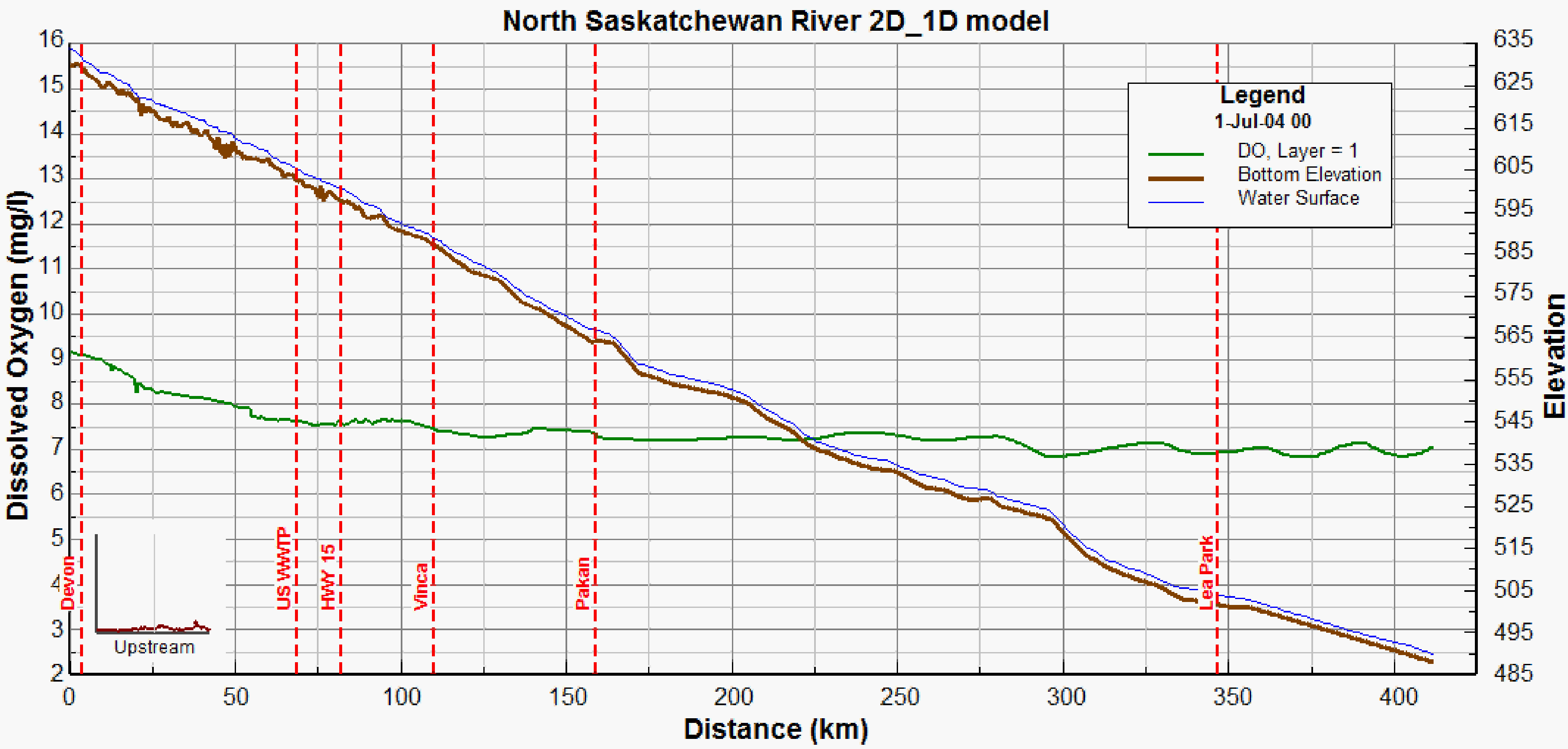
- North Saskatchewan River (NSR)
  - Water quality planning
    - 16 water quality constituents
  - DSI modified the EFDC_DSI model code to include the Rooted Plant and Epiphyte Model (RPEM)
- Lower Athabasca River (LAR)
  - DSI conducted a scoping study for hydrodynamics, water quality, sediments and toxics
  - Water quality planning
    - 15 water quality constituents
  - Contaminated sediments/toxics evaluation
    - DSI added sediment transport (4 classes)
    - DSI added toxics (24 classes)

North Saskatchewan River

- Number of Cells: 1776
- Number of Layers: 1
- Dimensions: 2D
- Duration: 1 to 10 years
- Area 9405 ha
- Length 412 km

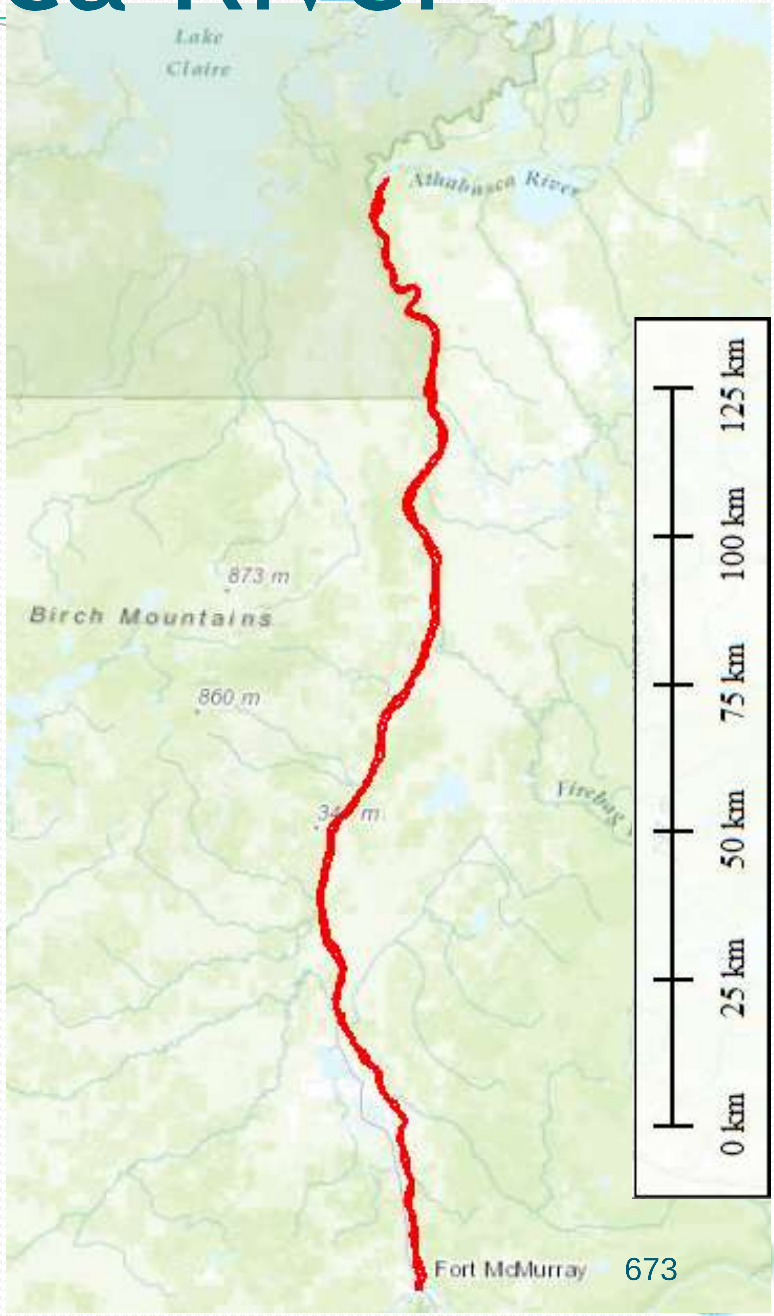
- Processes Modeled
  - Hydrodynamics
  - Temperature
  - Water Quality: 16
  - Sed Nutrient Fluxes: Fixed
  - RPEM

NSR Dissolved Oxygen Profile

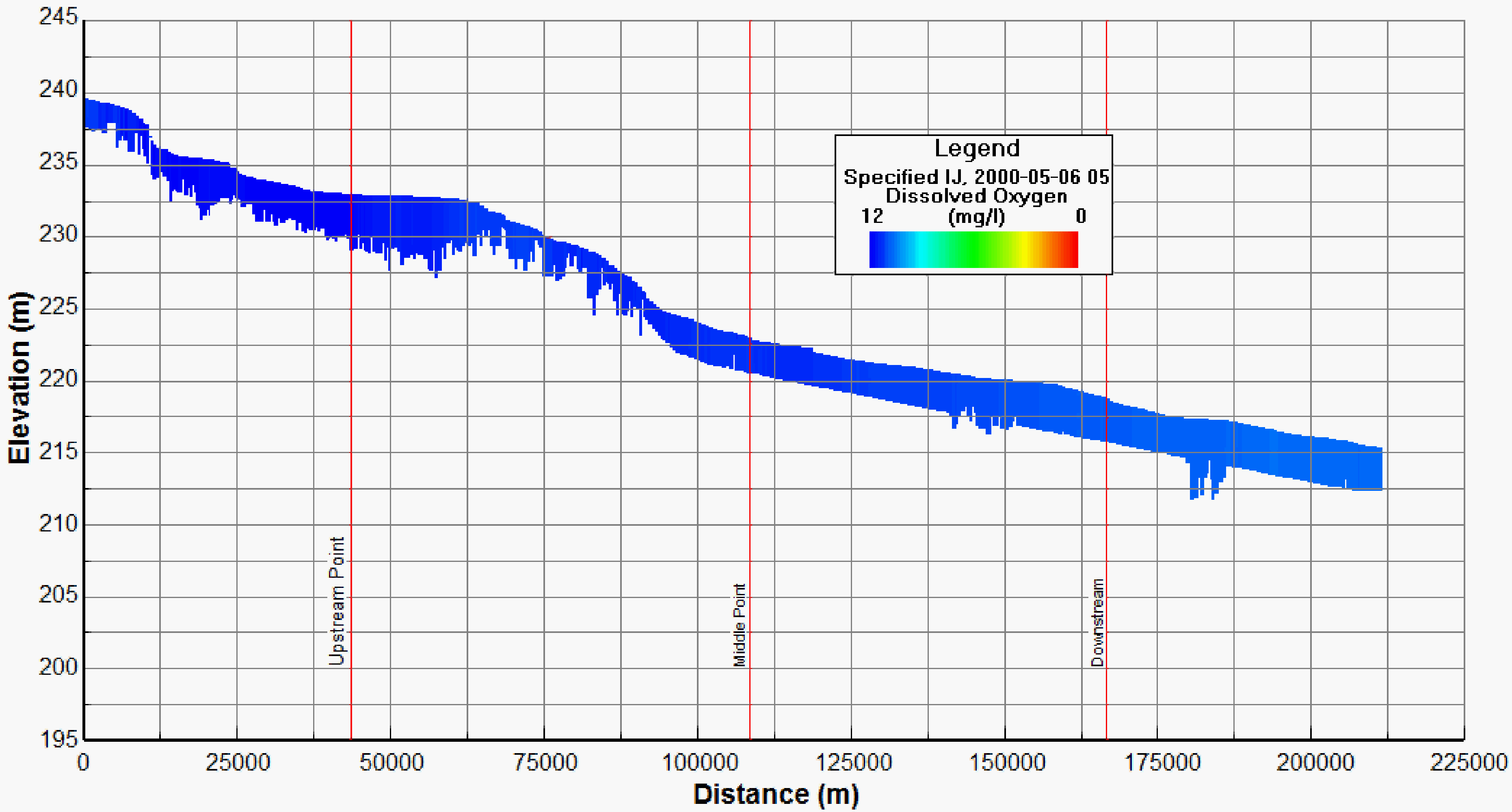


Lower Athabasca River

- McMurray to Old Fort
- Number of Horizontal Cells: 2257
- Number of Layers: 1
- Dimensions: 2D
- Duration: 1 to 10 years
- Area: 12,981 ha
- Length: 214 km
- Processes Modeled
  - Hydrodynamics
  - Temperature
  - Water Quality: 15
  - Sediment Nutrient Fluxes Fixed
  - Inorganic Sediments 4
  - Toxics
    - Metals 8
    - Organics 16

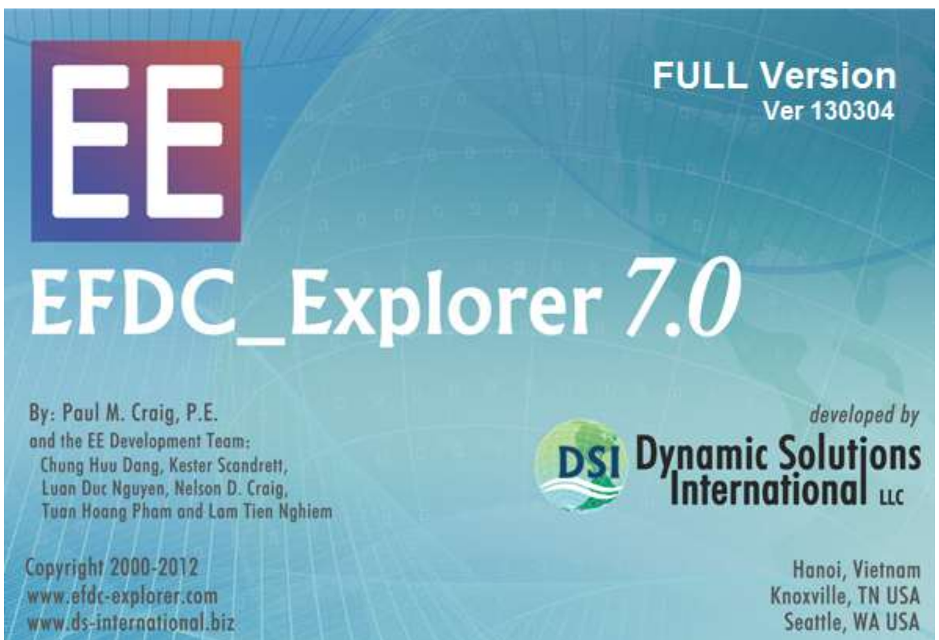


LAR Dissolved Oxygen Profile

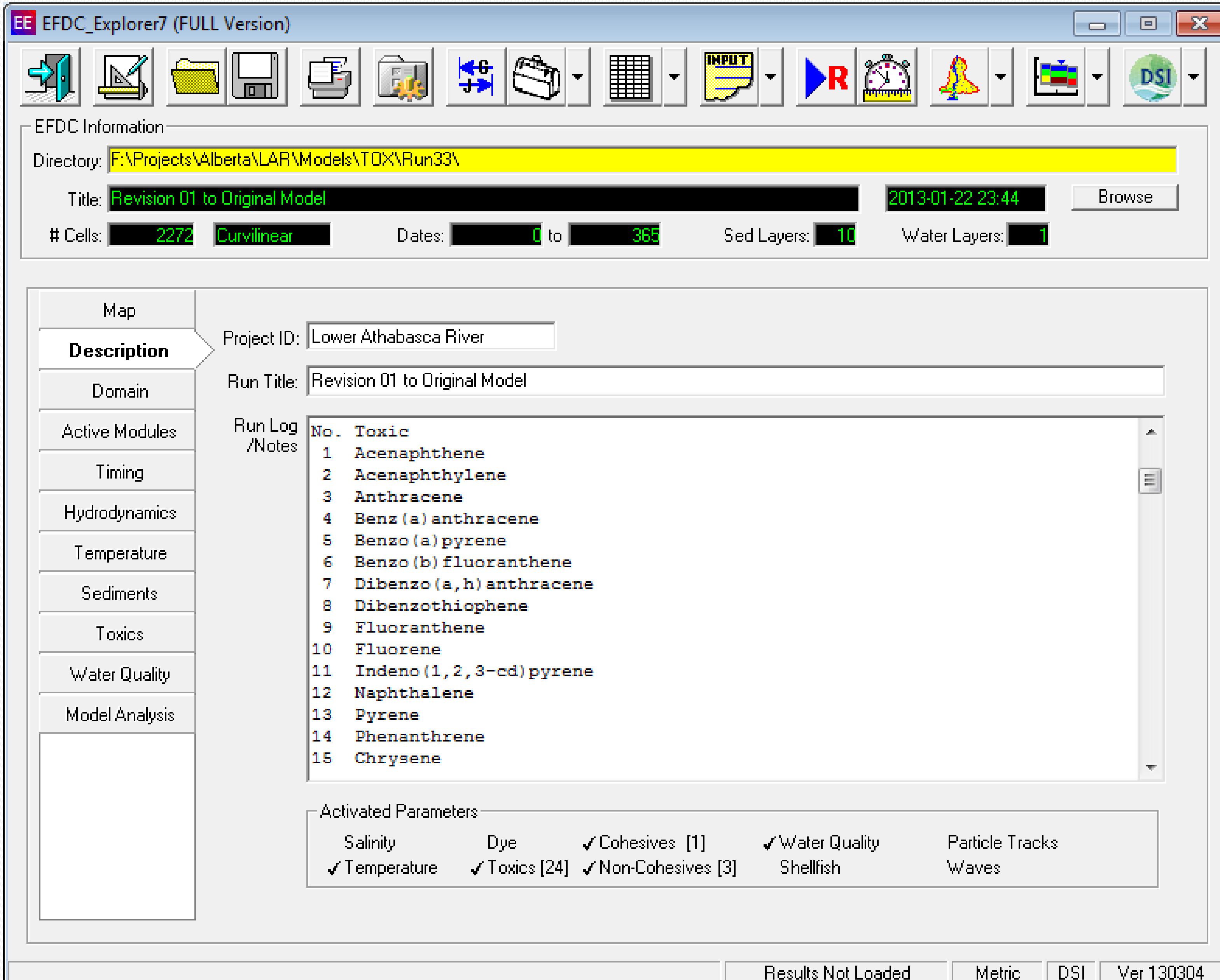


The Graphical User Interface for EFDC

EFDC_Explorer

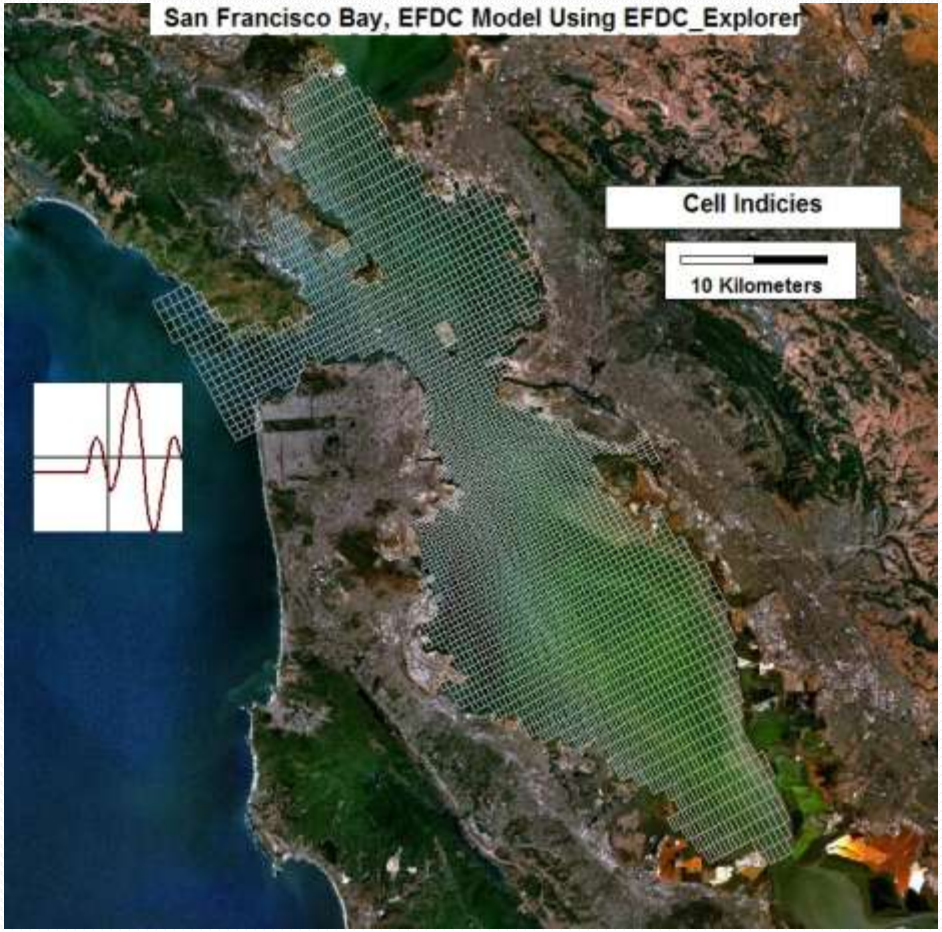


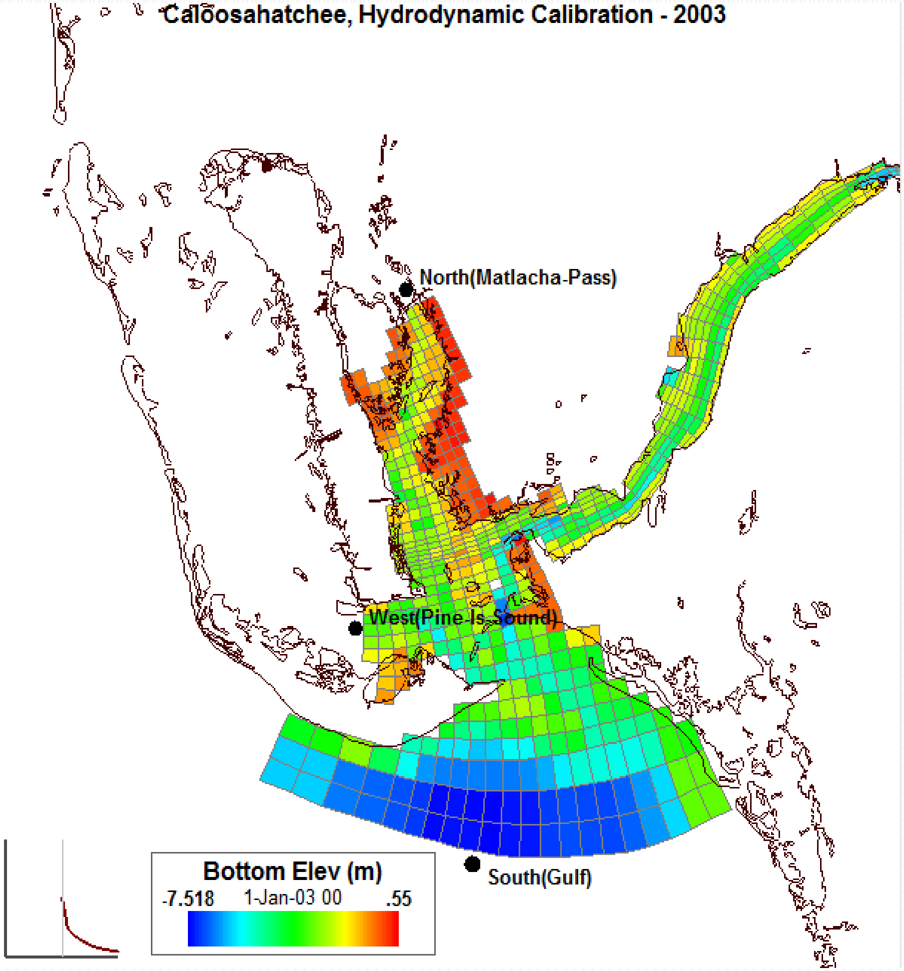
EFDC_Explorer Main Form



Example Grids

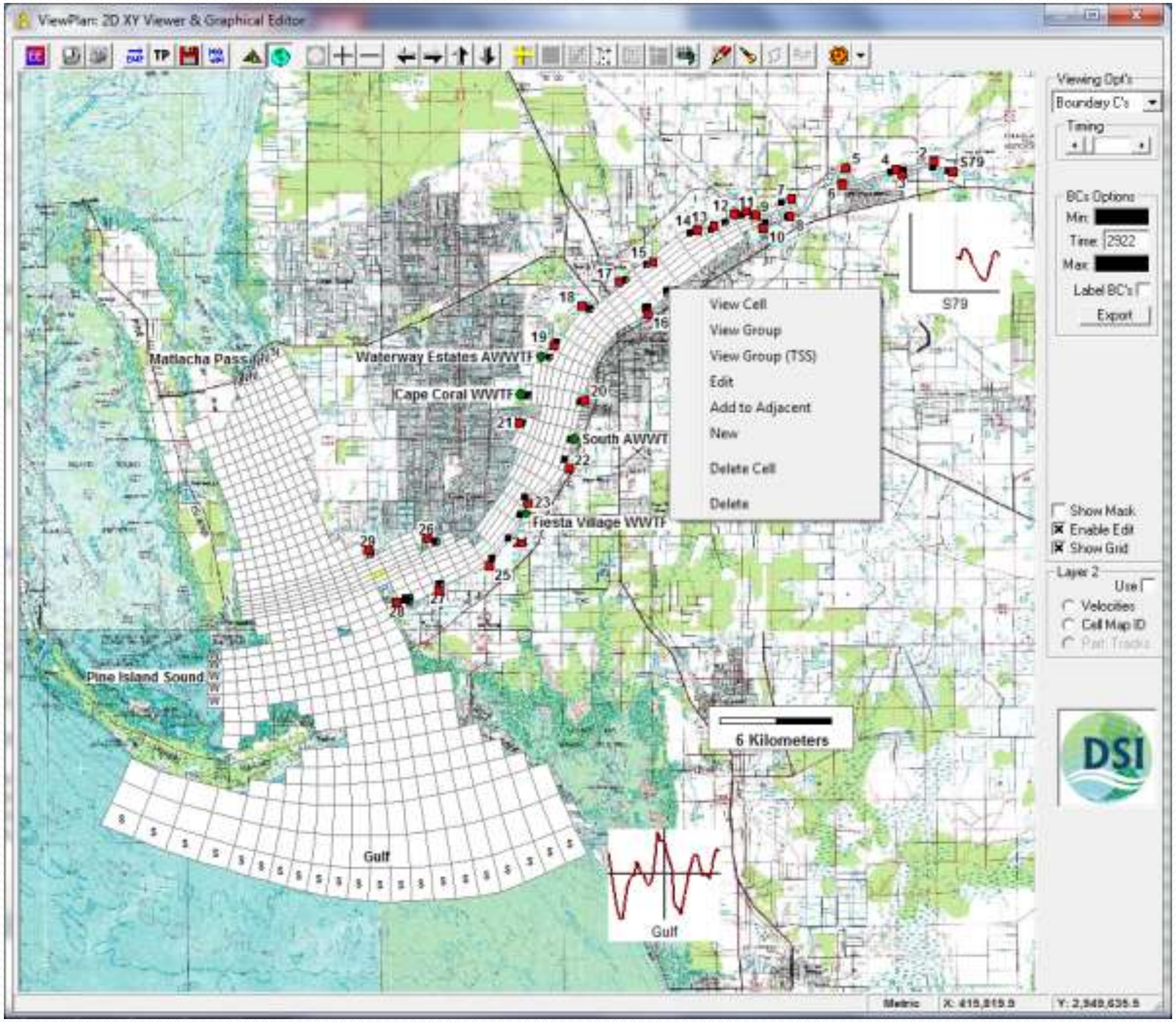
Rotated and Telescoping Cartesian Grids





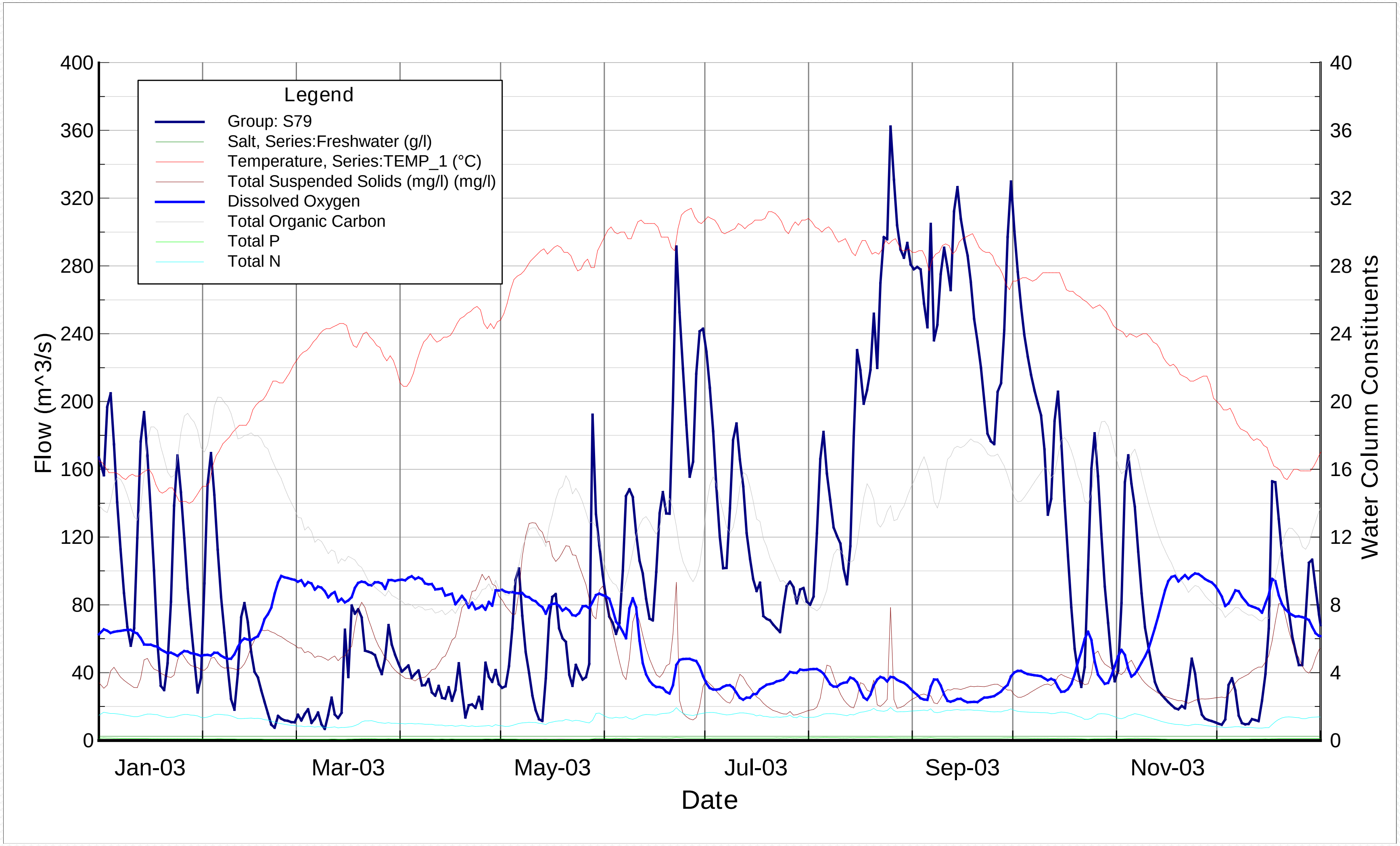
Orthogonal Curvilinear Grid

Boundary Condition Assignment



- Flow
- Withdrawal/ Return
- Open (EWNS)
- Hydraulic Structure
  - At Boundary
  - Internal
- EE Management
  - By Group

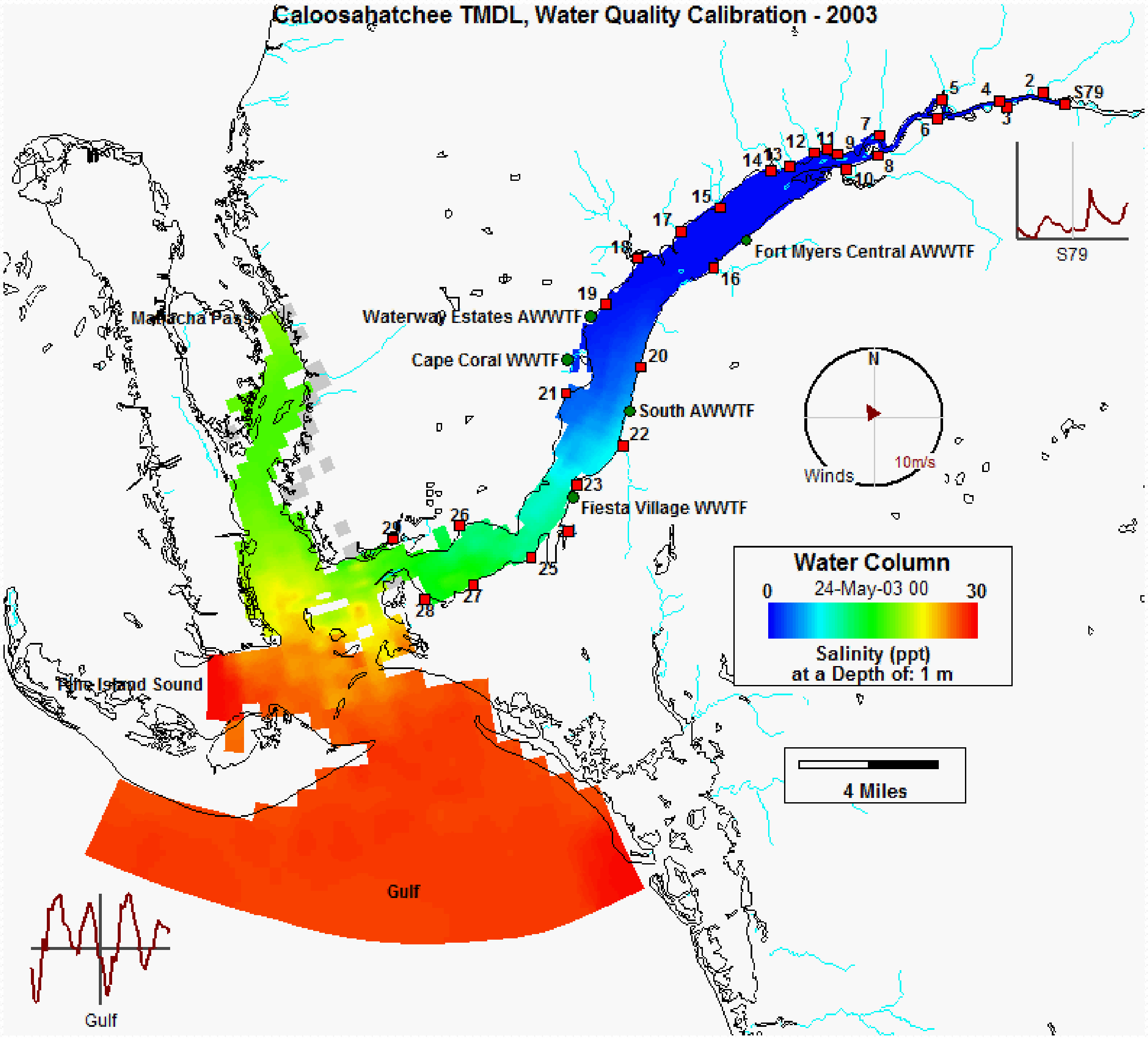
Boundary Condition Plots



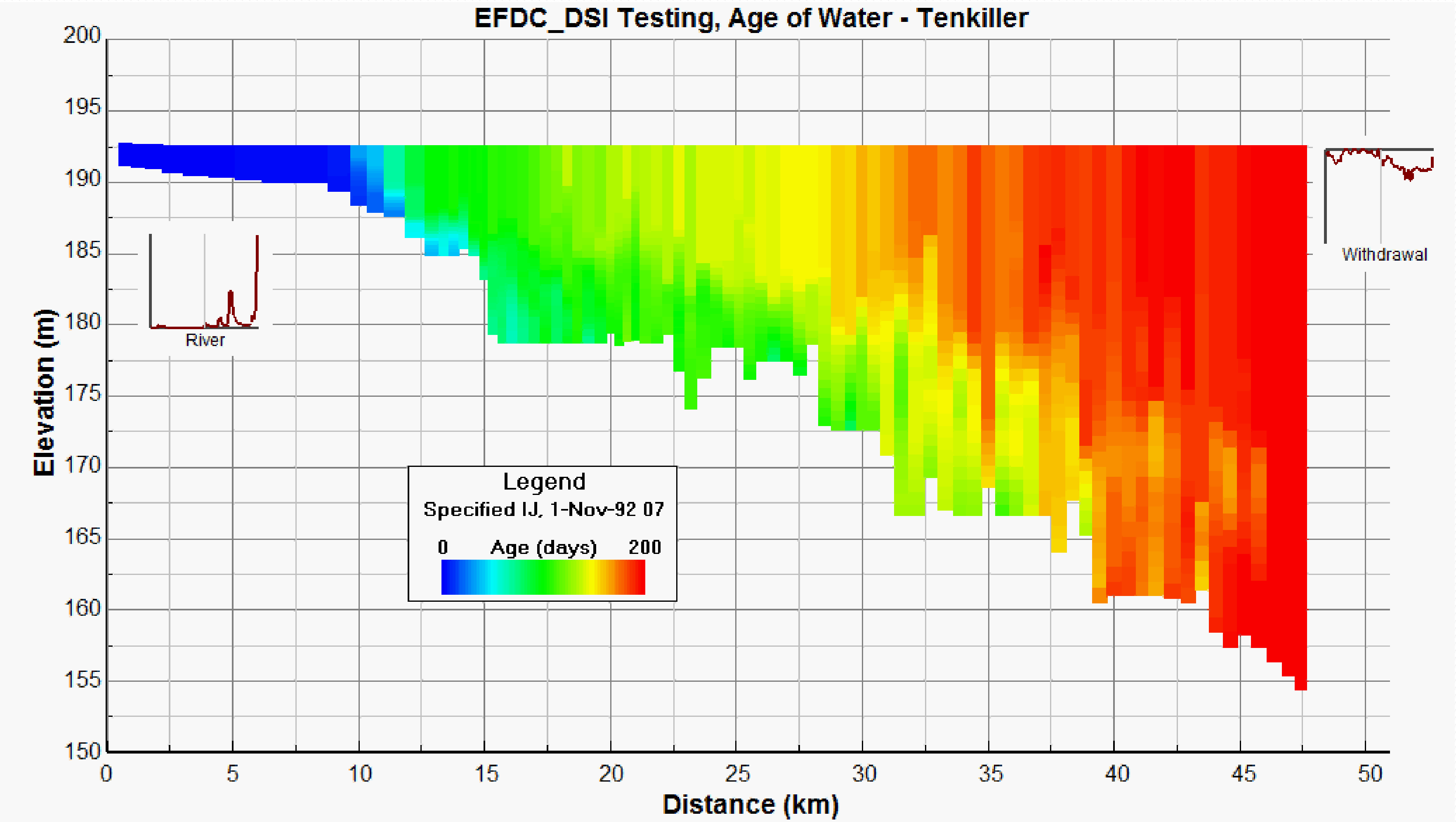
Model Calibration

- Plots
  - Time Series
  - Correlation Plots
  - Vertical Profiles
  - Plan View Overlays
- Statistics
  - Average
  - Relative
  - Absolute
  - Root Mean Square
  - Relative RMS
  - Nash-Sutcliffe
  - Model Bias
  - R-Squared (CP Only)

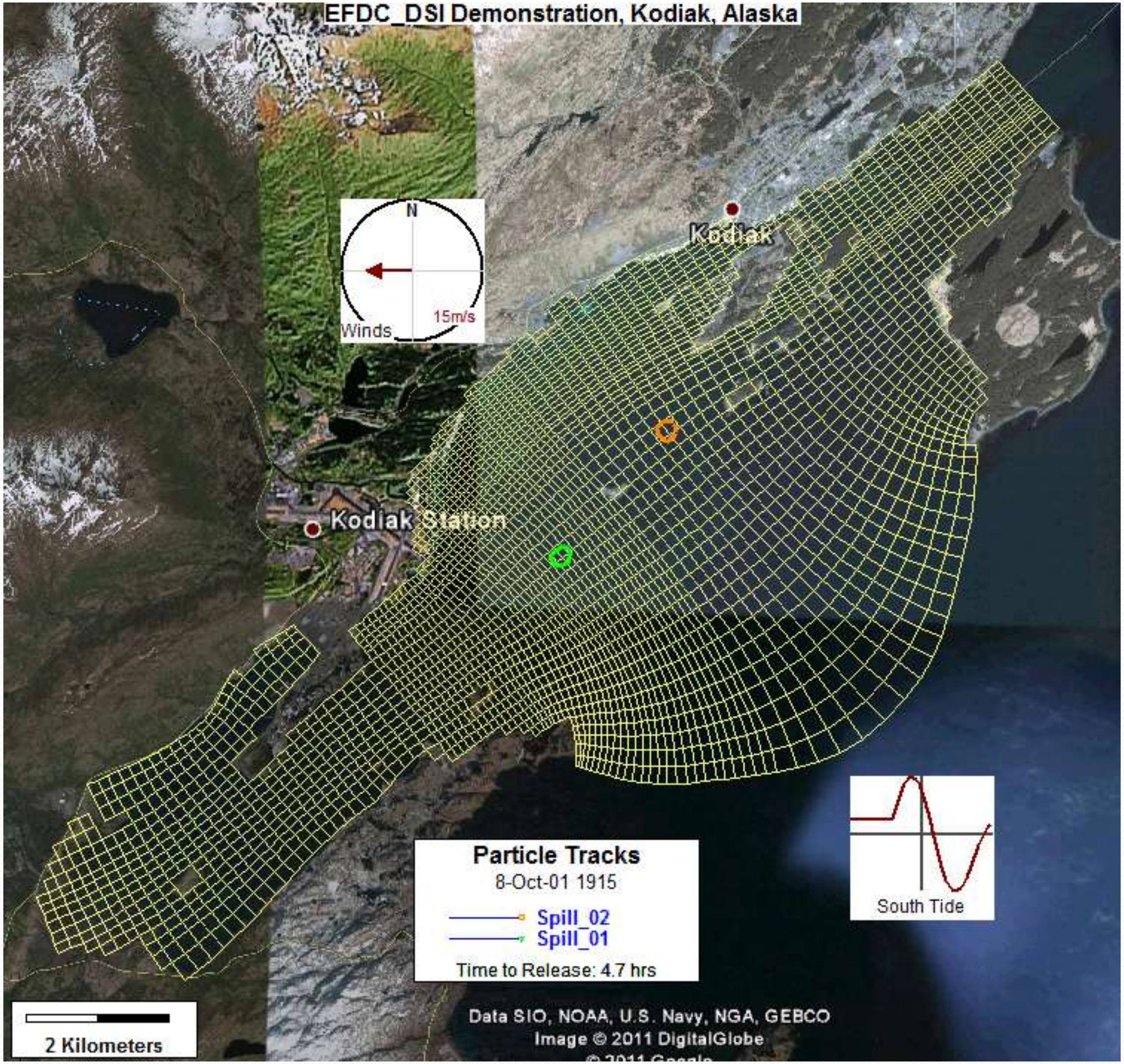
2D Plan View – Salinity



Age of Water – Reservoir



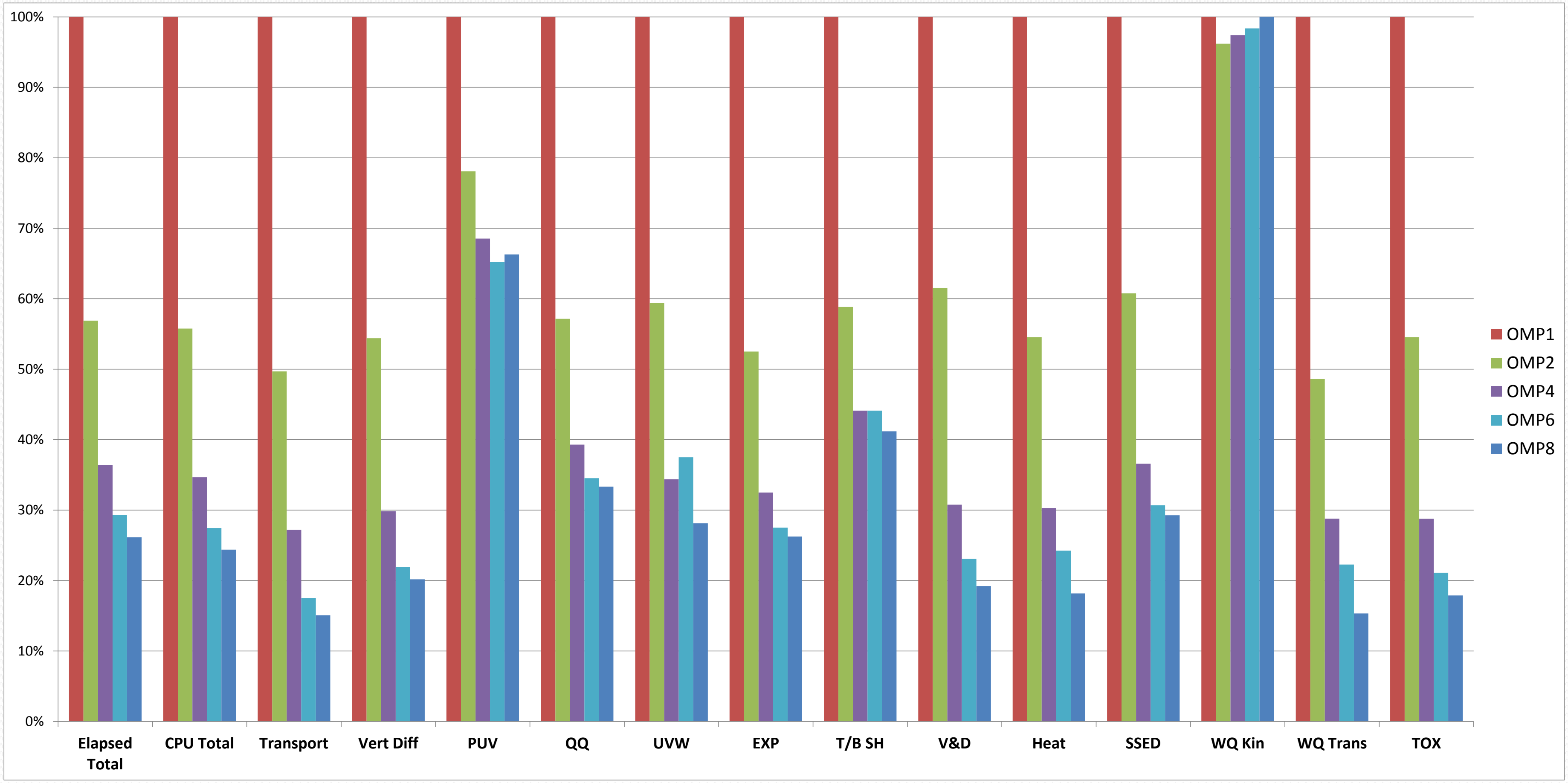
Hypothetical Oil Spill- Kodiak, AK



openMP
Multi-threaded EFDC_DSI

- Remarkably faster run times, proportional to the number of processors being used.
- Number of cores used fully configurable by the user.
- Run times up to 6 times faster on a eight core processor than the conventional single-threaded EFDC model.
- Working with Linux and Windows.

Time Saving with openMP for the Lower Athabasca Toxics Model



Testing and Quality Assurance

- All EFDC and EFDC_DSI features tested against text literature test cases
- Multiple example models available online for download on our website:
  - www.efdc-explorer.com
- EE has in-built pop-ups for user help, shortcut keys summaries, and a comprehensive user manual
- Pre-Run checks with more being added every month.

Recent Enhancements

- Automated calibration plots and tables
- Sediment grainsize core management tool
- Multiple Timing Frames
- Fixed depth and/or elevation extraction of model results:
  - 2D Plan view
  - Time series/calibration plots
- Write KML files for grid and model 2D fields, Read KML overlays
- Added DOC as one of the light extinction dependent variables
- Incorporated OMP for more of the sub-models
- 3D Perspective visualizations (EE7.1)

EFDC/EFDC_Explorer Packages

EFDC Model

Hydrodynamics	Water Quality	Sediment Transport	Toxics
• 1,2,3D Capable • Internal wind waves • Linked to many wave models • Vegetation • Lagrangian Particle Tracking • Wetting/Drying • Dye/Age of Water	• Eutrophication • 21 state variables • Sediment Diagenesis	• User specified number of sediment classes • Cohesive(s) • Non-cohesives • Bedload	• Metals • Persistent organic pollutants • 1-2-3 Phase adsorption

EFDC_DSI_SGL

EFDC_DSI_OMP (Optional)

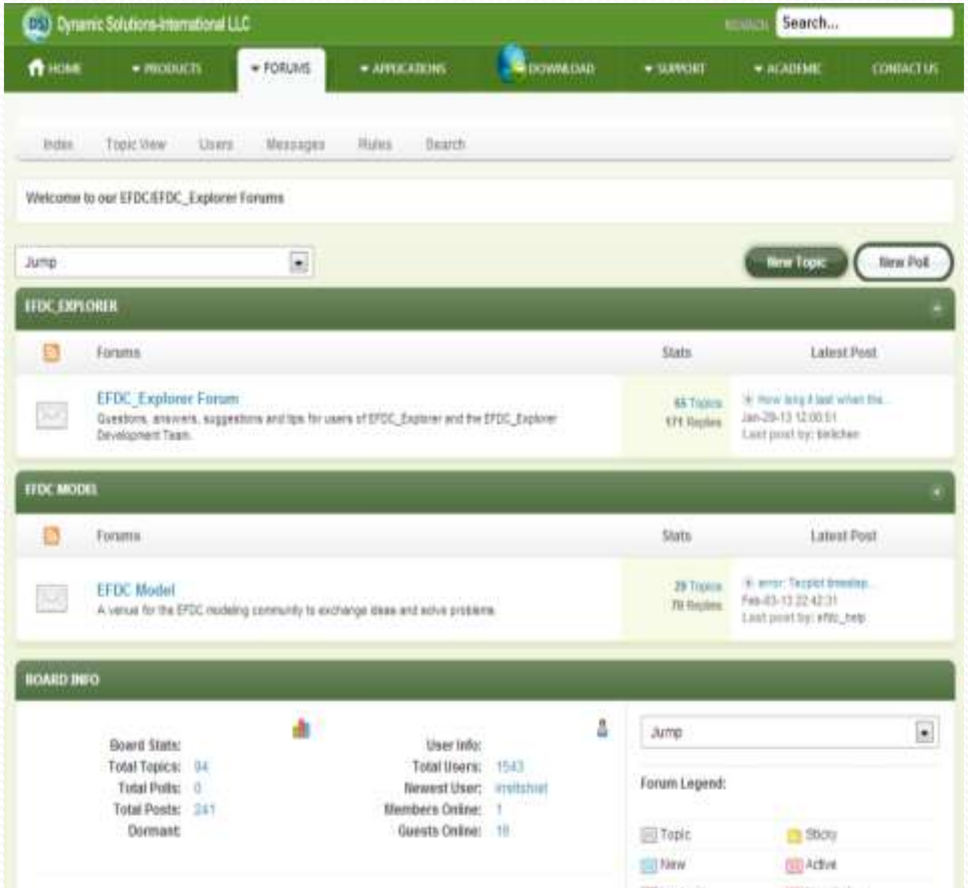
EE WEB Version

EE FULL Version

EFDC_Explorer

Web Site

www.efdc-explorer.com



EFDC_Explorer

EE User Community

www.efdc-explorer.com/forum

Contact Information

- www.ds-international.biz
- www.efdc-explorer.com
- Paul M. Craig, P.E.
  - pmcraig@ds-intl.biz
- EFDC_Explorer Development Team
  - ee_info@ds-intl.biz

Day 2 – Session 4

Darcy McDonald - AESRD

BIOGRAPHY

Darcy started the Government of Alberta (Environment) in 2000, as a limnologist and modeller (transplanted from work on coastal limnology and oceanography in BC). Darcy is presently a senior scientist at Alberta Environment (with the Northern Region (Science and Planning)), and has worked at both regional and provincial levels in AENV, conducting and managing monitoring, evaluation, and modelling programs.

Day 2 – Session 4

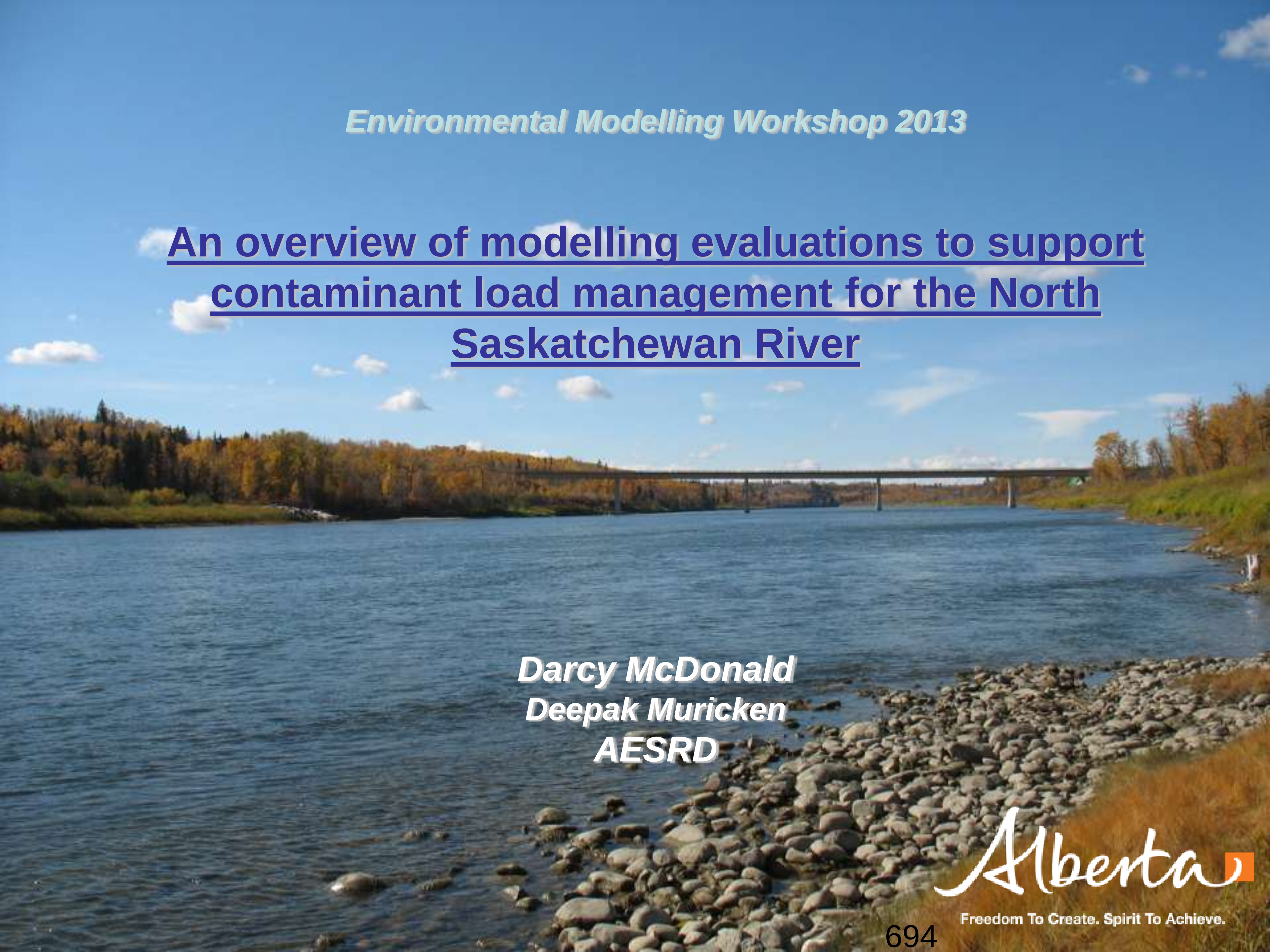
Darcy McDonald - AESRD

ABSTRACT

To support the management of water quality in the North Saskatchewan River (NSR), a number of monitoring and evaluation initiatives have advanced in recent years. Work has been undertaken to:

- Enhance information available for the NSR to enable better evaluation of river conditions
- Assemble available data on wastewater discharge and other pollutant sources
- Set appropriate water quality benchmarks that integrate the influence of variable flows
- Evaluate in stream pollutant loads and options for their management
- Enable evaluation of river conditions relative to water quality objectives

This presentation summarizes key aspects of this work, focusing on models and related tools developed for the NSR system in various domains, ranging from individual treatment facility to watershed scales.



Environmental Modelling Workshop 2013

An overview of modelling evaluations to support contaminant load management for the North Saskatchewan River

Darcy McDonald
Deepak Muricken
AESRD

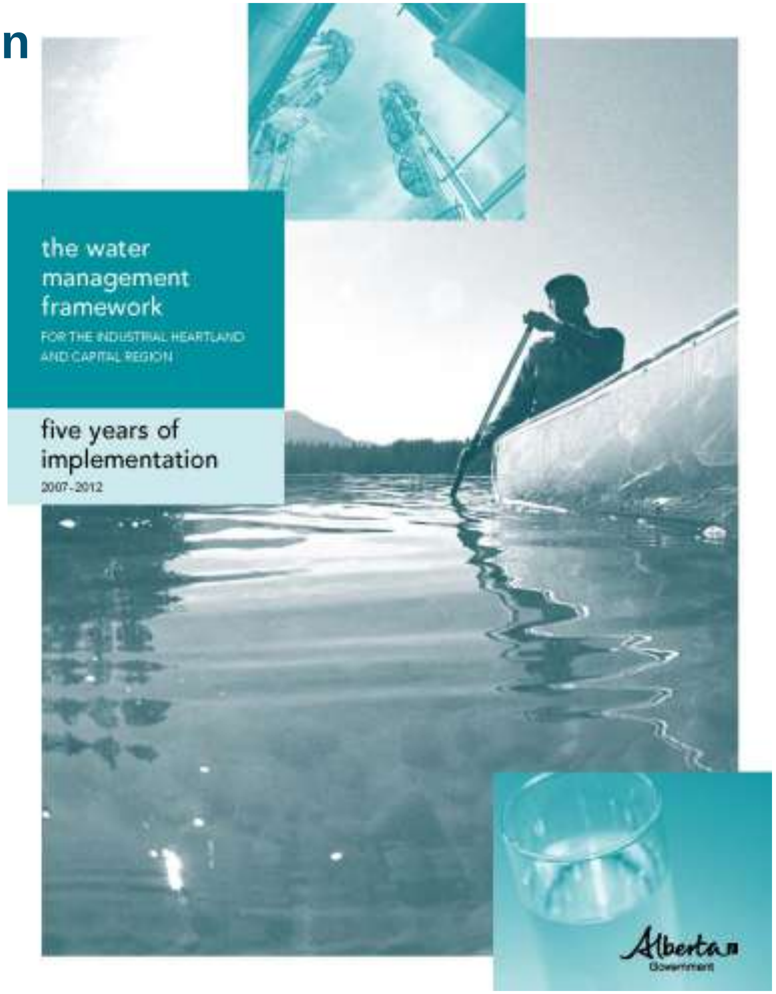
Alberta
Freedom To Create. Spirit To Achieve.

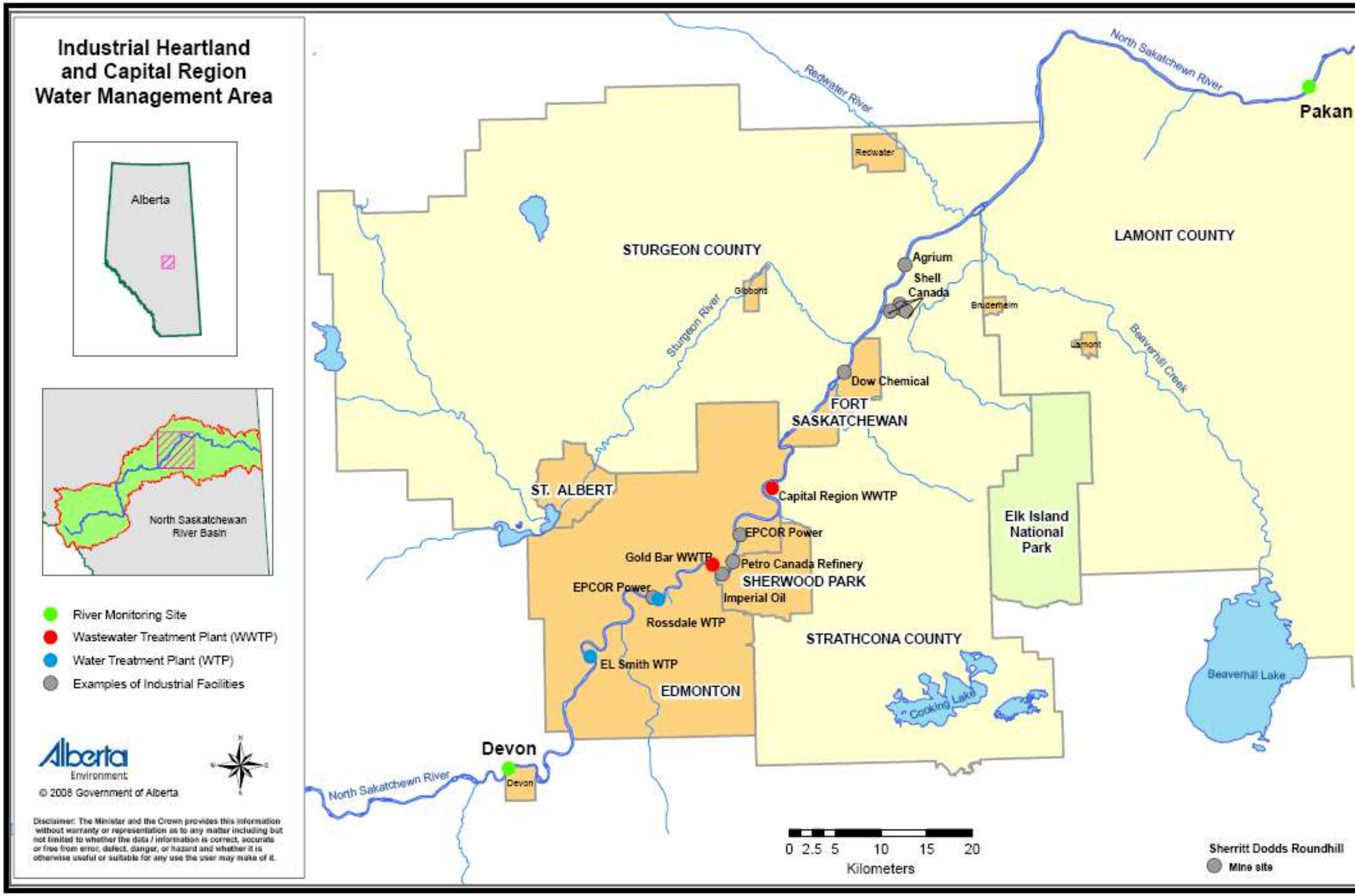
Background:

Water Management Framework
for the Industrial Heartland and Capital Region

- Framework describes:
  - Mandate
  - Vision
  - Strategic Objectives
  - Guiding Principles
  - Planning Horizon
  - Phases for implementation
  - Projects / Next Steps

http://environment.alberta.ca/01769.html





Industrial Heartland and Capital Region Water Management Area
Alberta
North Saskatchewan River Basin
River Monitoring Site
Wastewater Treatment Plant (WWTP)
Water Treatment Plant (WTP)
Examples of Industrial Facilities
Alberta Environment
© 2008 Government of Alberta
Disclaimer: The Minister and the Crown provides this information without warranty or representation as to any matter including but not limited to whether the data / information is correct, accurate or free from error, defect, danger, or hazard and whether it is otherwise useful or suitable for any use the user may make of it.
North Saskatchewan River
Redwater River
Pakan
Redwater
STURGEON COUNTY
LAMONT COUNTY
Agrium
Shell Canada
Gibbons
Bruderheim
Lamont
Sturgeon River
Beaverhill Creek
Dow Chemical
FORT SASKATCHEWAN
ST. ALBERT
Capital Region WWTP
Elk Island National Park
EPCOR Power
Gold Bar WWTP
Petro Canada Refinery
SHERWOOD PARK
EPCOR Power
Imperial Oil
Rossdale WTP
STRATHCONA COUNTY
EL Smith WTP
EDMONTON
Cooking Lake
Beaverhill Lake
Devon
Devon
North Sakatchewan River
0 2.5 5 10 15 20
Kilometers
Sherritt Dodds Roundhill
Mine site

To support the NSR/IH Water Management Framework, various monitoring and evaluation initiatives have advanced in recent years to:

- Enhance and assemble information available for the NSR and pollutant sources to enable better evaluation of river conditions;
- Set appropriate water quality benchmarks that integrate the influence of variable flows;
- Evaluate river conditions relative to water quality objectives.
- Evaluate instream pollutant loads and options for their management.

NSR Model Development and Implementation…
Why use models?

NSR Modelling Scope:

- Represent pollutant transport and related biological response in the river to assess management scenarios (e.g., wastewater management for the reach d/s of Devon).

=> Develop a suite of modelling tools to evaluate local and basin-scale pollutant loads and transport.

Goal:

Support informed management decisions on development in the NSR Basin

NSR Modelling Components:

1) Loading Calculation Tools
(conservative; e.g., LOADS, LOADEST, FLUX)

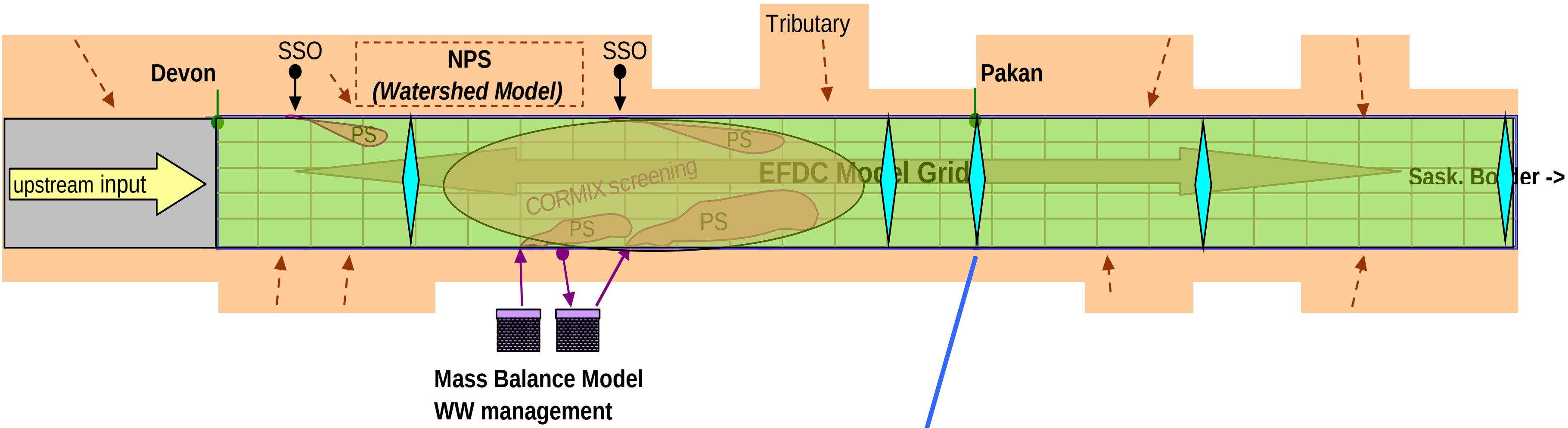
2) Wastewater Treatment Efficiency Model
(end-of-pipe; mass balance model)

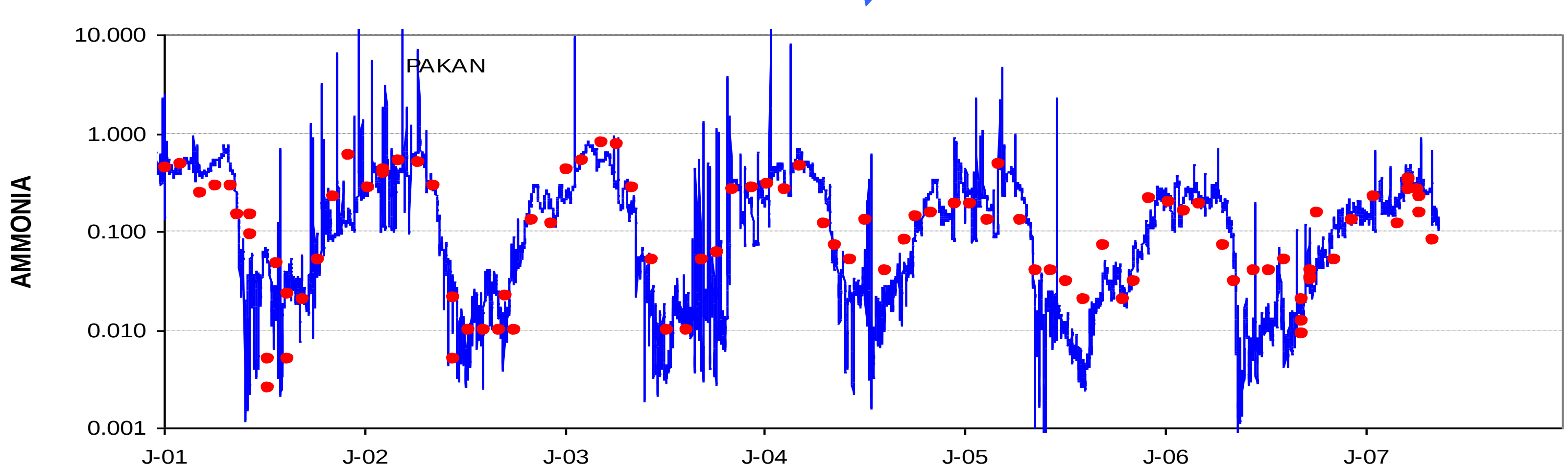
3) Near-Field (mixing zone) Model
(CORMIX)

4) Instream Hydrodynamic / Water Quality Model
(EFDC)

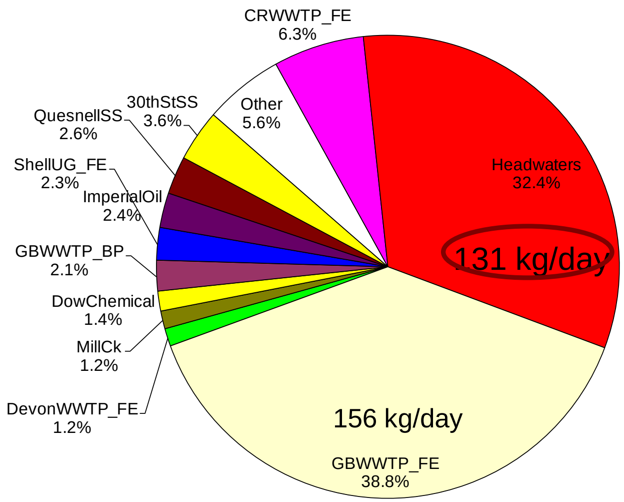
5) Watershed (basin-scale) Model (hydrologic / water quality)
(LSPC)

Diagram of instream NSR showing model domains

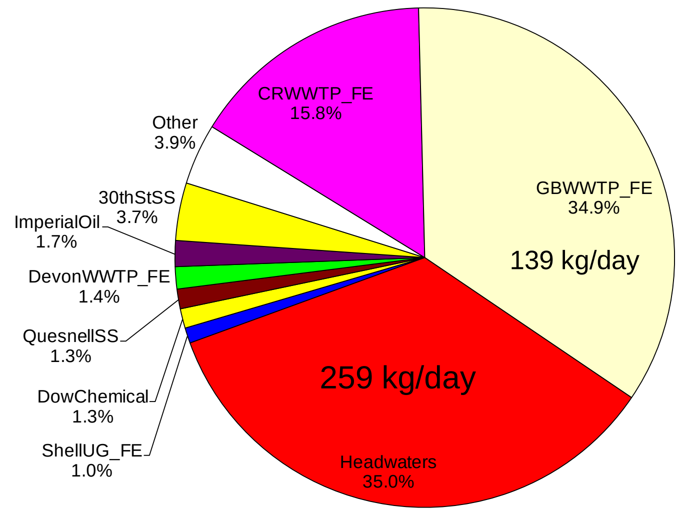




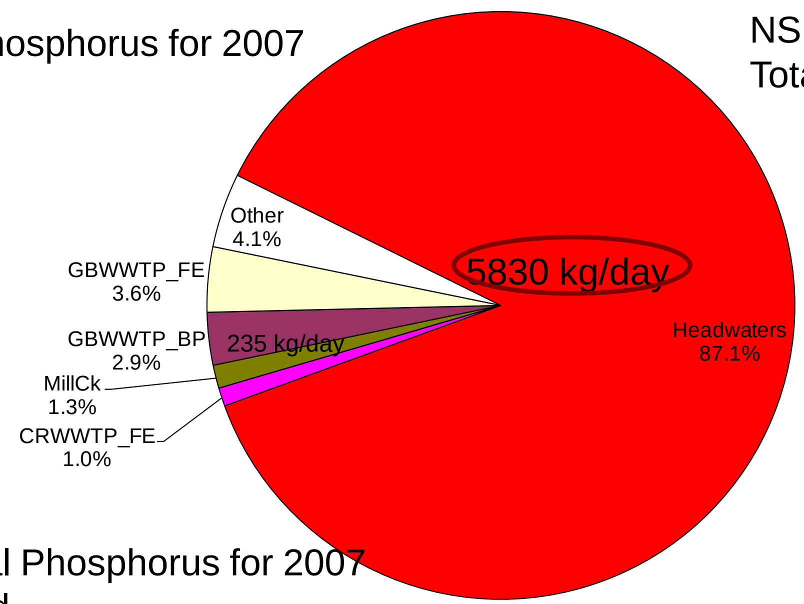
1). Contaminant Loading Calculations



NSR Fall Total Phosphorus for 2007
Total = 403 kg/d

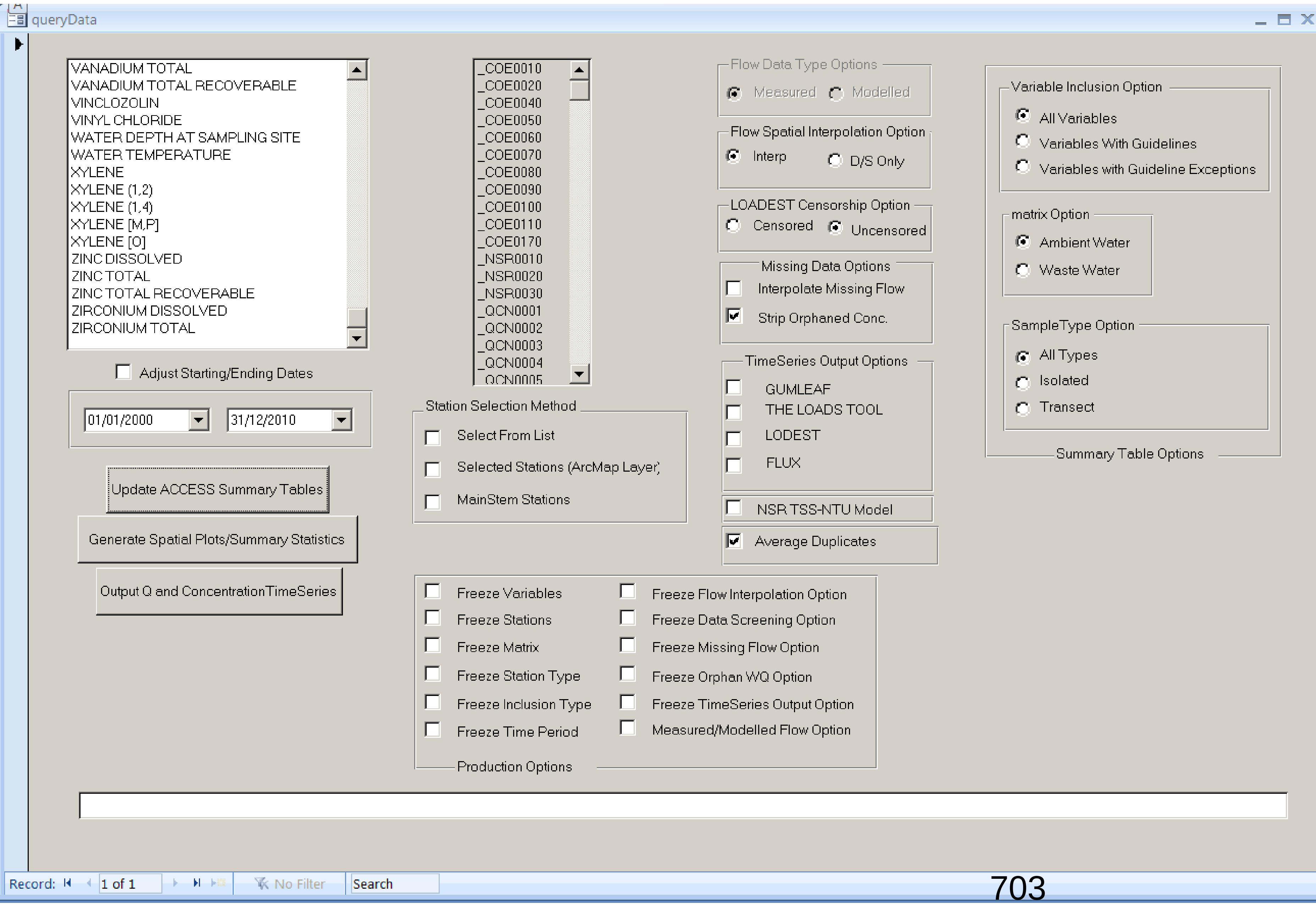


NSR Winter Total Phosphorus for 2007
Total = 398 kg/d



NSR Spring Total Phosphorus for 2007
Total = 6701 kg/d

NSR Load/Loading Calculations: Database User Interface



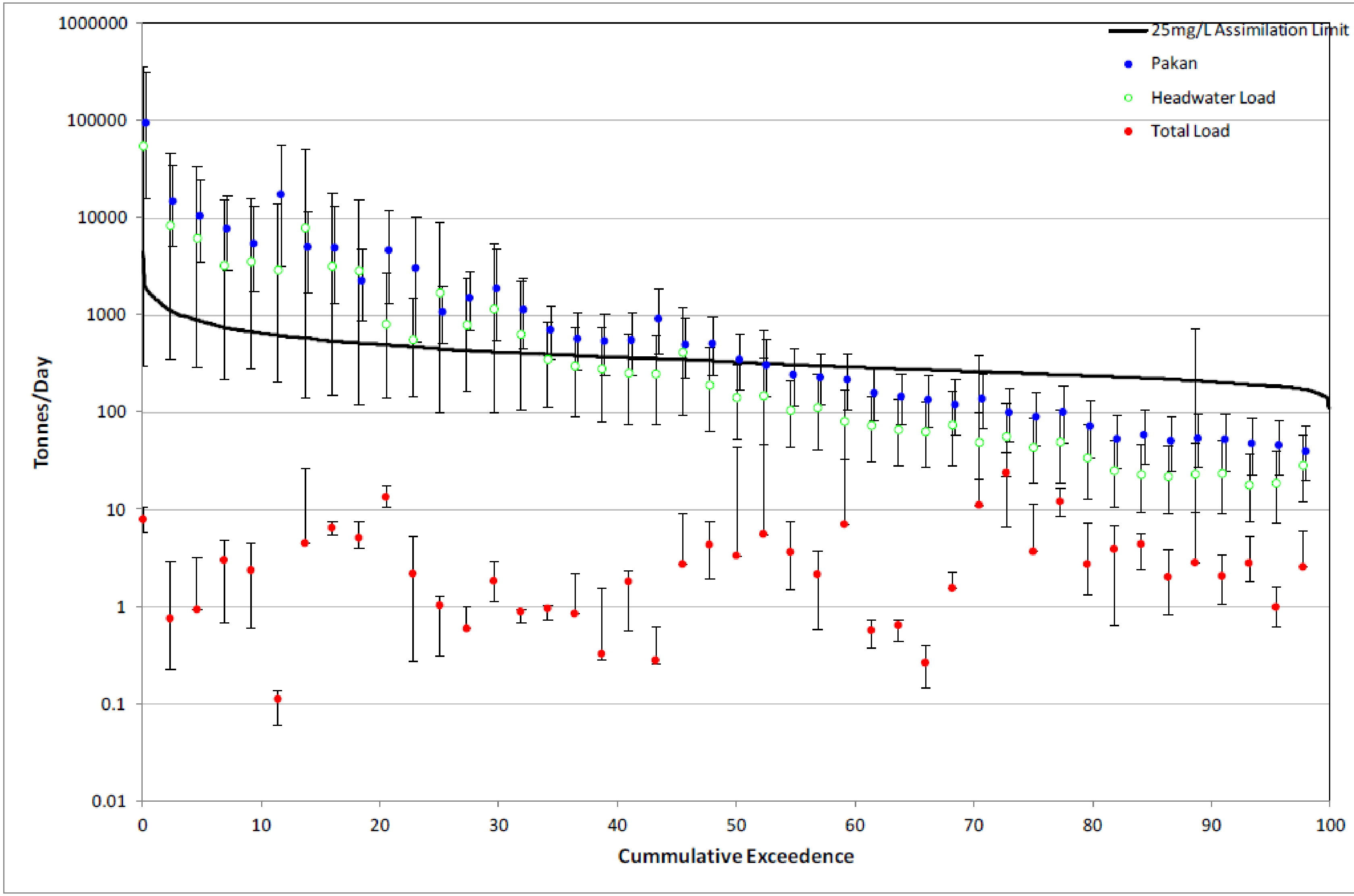
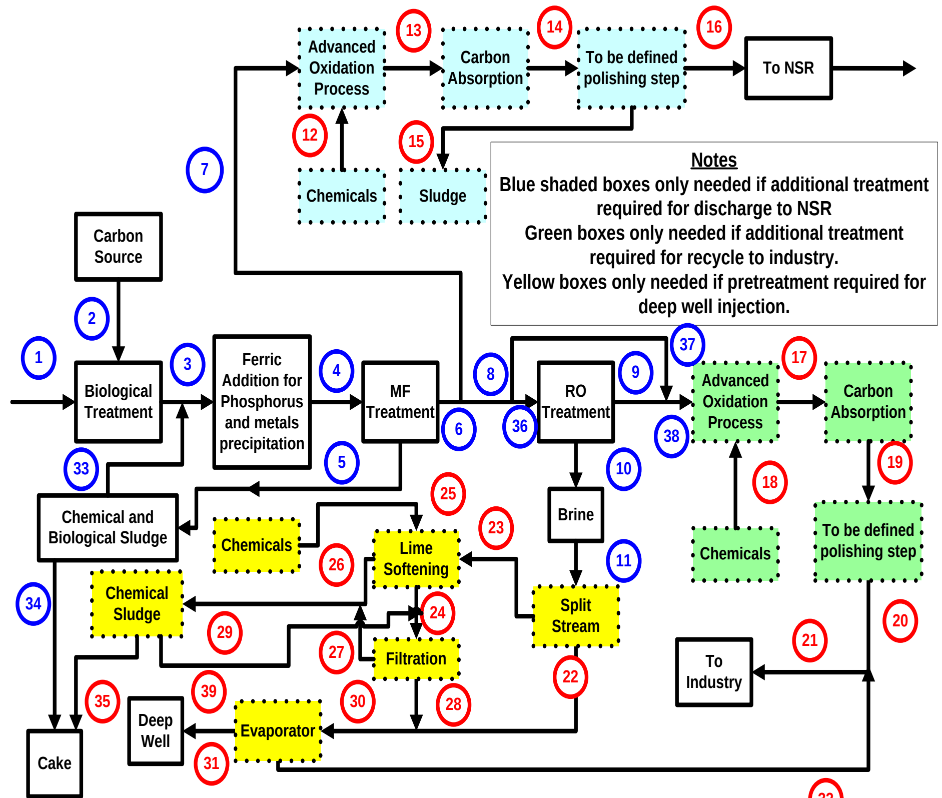


Figure 7 Example Load Duration Curve Based on Ambient Objective of 25 mg/L

2). Model for Evaluation of Industrial Water Supply and Wastewater Treatment.

- A Mass Balance Model (MBM) was developed to predict effluent loads discharged to the NSR for various wastewater management scenarios.
- The MBM applies optimal treatment processes to predict progressive reduction of contaminant load for the individual dischargers at a ten year time step.
- Output was incorporated in a TBL to evaluate socio-economic factors associated with various treatment scenarios.

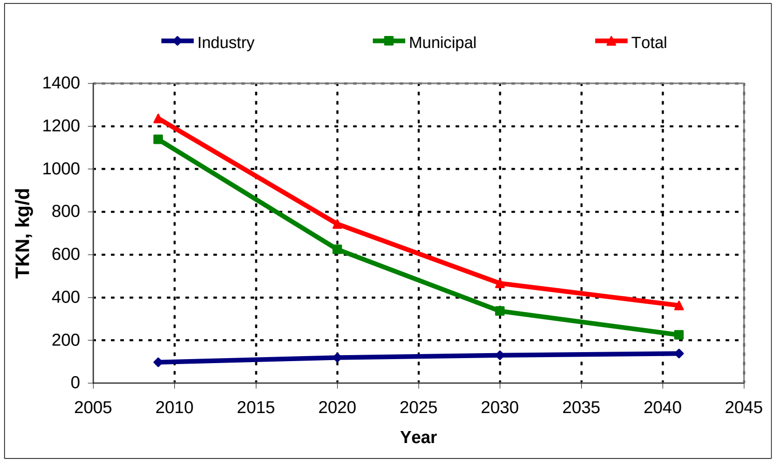


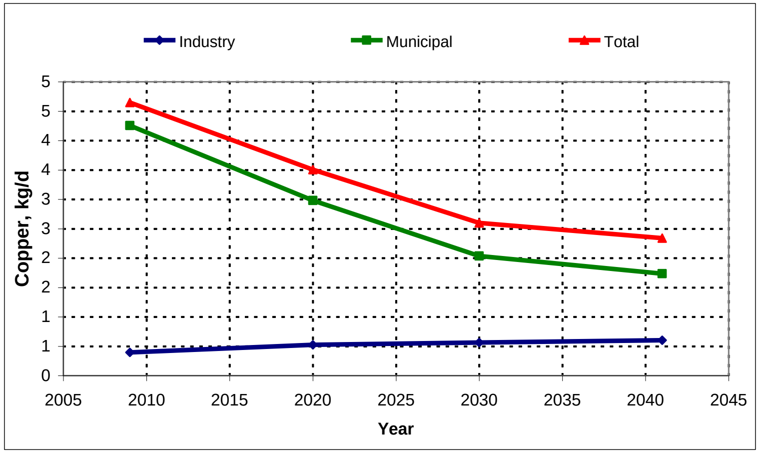
Industrial Wastewater Treatment Module

Mass Balance Model:

- Scenarios were selected based on TBL (triple bottom analysis) for assessment of load changes at temporal scale on the water quality of the North Saskatchewan River.

- The scenarios projected load reduction of nutrients and other constituents (e.g., metals, some organics) to the Year 2041.





3) CORMIX (Cornell Mixing Zone Expert System Model)

Why use a near-field model?

- **A long list of Variables of Concern (VOCs) was included in the Mass Balance Model (>100).**

- **To enable inclusion of a practical number of VOCs in river modelling and WQO development, CORMIX was applied to screen and optimize the list.**

- **Screening was based on:**

    - ***benchmark exceedences for WQ at mixing zone boundaries during 7Q10 flows, and:***

    - ***the occurrence of substantial differences between water quality values for Devon (u/s) and Pakan (d/s).***

    - ***effluent/ambient concentration ratios for various flow regimes***

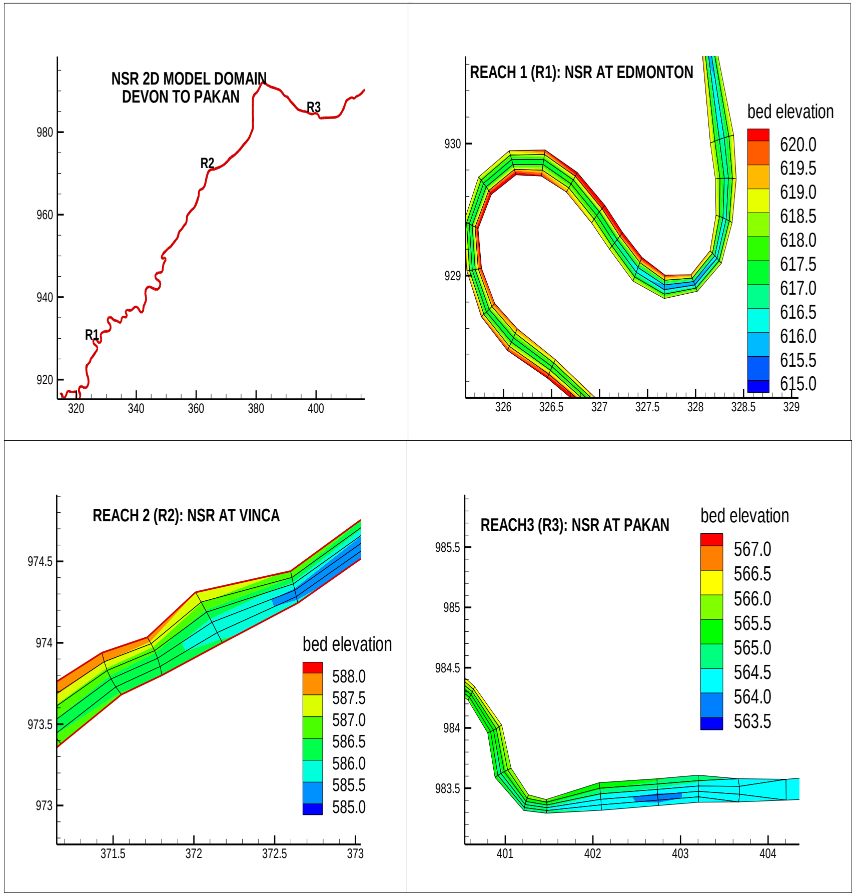
Near-field Screening Matrix: constituents flagged for further evaluation.

Benchmark Exceedence at Mixing Zone Boundary*

Variable	Scenario 1a	Scenario 1b	Scenario 2a	Scenario 2b	Scenario 3	Devon -> Pakan Δ median
Physical						
Total Suspended Solids	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.6
Nutrients and related						
Ammonia - N	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[ab],40[a]	10[ab],20[ab],30[ab],40[a]	2.8
NO2+NO3 - N	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	3.8
Phosphorus - Total	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	3.1
Total Organic Carbon	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.2
Bacteria						
E. coli	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	2.0
Salts						
Sodium	20[b],30[b],40[b]	20[b],30[b],40[b]	10[b]			2.1
Chloride	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[a]	3.8
TDS	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.1
Metals						
Aluminum	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.5
Antimony	20[b]	20[b]				1.5
Beryllium	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b]	20[b]	10[b],20[b]	0.9
Cadmium	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.6
Copper	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.4
Fluoride	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	1.2
Lead	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	1.7
Manganese			10[b]		10[ab]	1.6
Mercury	10[ab],20[ab],30[a],40[ab]	10[ab],20[ab],30[a],40[ab]	10[ab],20[a],30[a],40[a]	10[a],20[a],30[a],40[a]	10[ab],20[ab],30[a],40[a]	1.2
Molybdenum	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]			1.6
Nickel	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]	10[b]	10[b],20[b]	2.9
Selenium	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[a],30[ab],40[a]	10[ab],20[a],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	1.7
Silver	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab],30[ab],40[ab]	10[ab],20[ab]	20[ab]	10[ab],20[ab],30[ab],40[b]	1.9
Thallium	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]	10[b]	10[b],20[b]	1.4
Tin	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]		10[b]	2.4
Zinc	10[ab],20[ab],30[a],40[a]	10[ab],20[ab],30[a],40[a]	10[a],20[a]	10[a],20[a]	10[a],20[a]	1.6
Organics						
Chloroform	10[ab],20[ab],30[b],40[b]	10[ab],20[ab],30[b],40[b]	10[b],20[ab]	10[b],20[ab]	10[b],20[ab],30[b]	0.2
Phenol	10[ab],20[b],30[b],40[b]	10[ab],20[b],30[b],40[b]	10[b],20[b],30[b]	10[b],20[b],30[b]	10[b],20[b],30[b]	nd
Trihalomethanes	10[b],20[b],30[b],40[b]	10[b],20[b],30[b],40[b]	10[b]	10[b]	10[b],20[b],30[b]	0.1

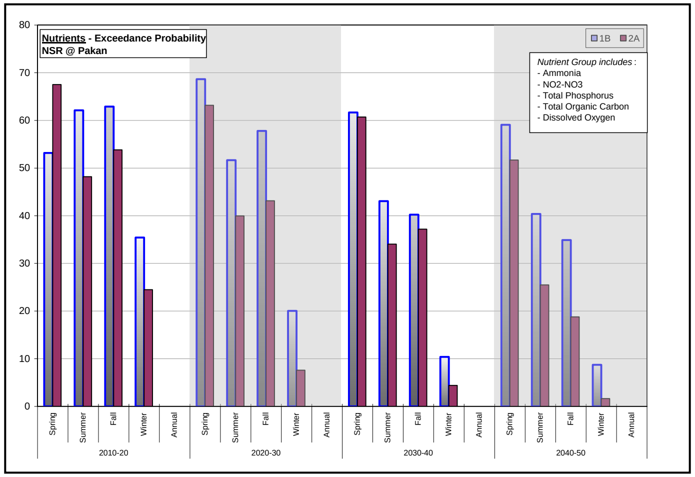
4). NSR River Water Quality and Hydrodynamic Model (EFDC)

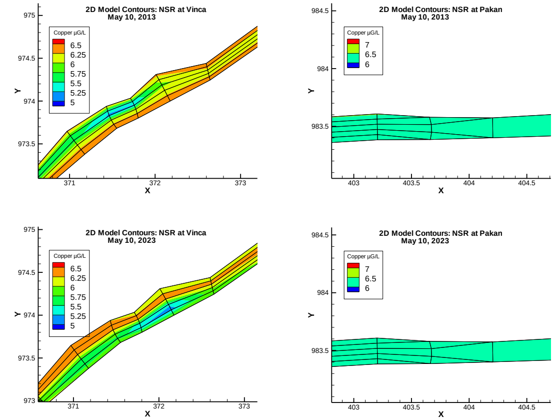
- Platform is “EFDC”, a hydrodynamic water quality model developed and supported by the USEPA/DSI.
- Represents lateral (cross channel) and longitudinal (along channel) processes and primary producer response (algae, macrophytes).
- The model includes tributary inflow, and all significant point discharges (WWTPs, CSOs, industrial facilities, and WTPs). There are ~ 40 discharges included.



Evaluation of Industrial Water Supply and Wastewater Treatment Scenarios (to 2041): Instream Modelling

- Model results were evaluated by:
  - Statistical comparison of model results, considering predicted departures from water quality benchmarks; and
  - Spatial plots of predicted concentration.
- The statistical comparison of model results is based on an exceedance score that includes scope, frequency and amplitude.
- Example spatial plots show the highest instream concentrations associated with effluent predicted at 7Q10 flows.



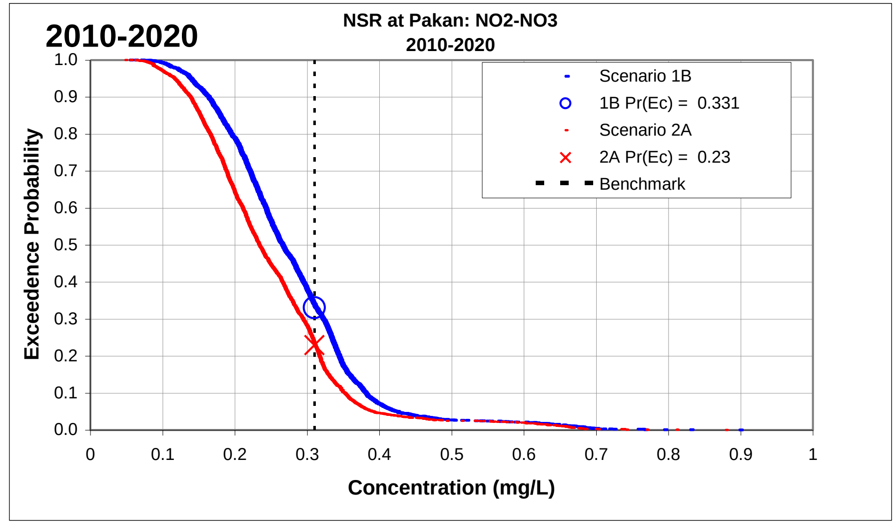


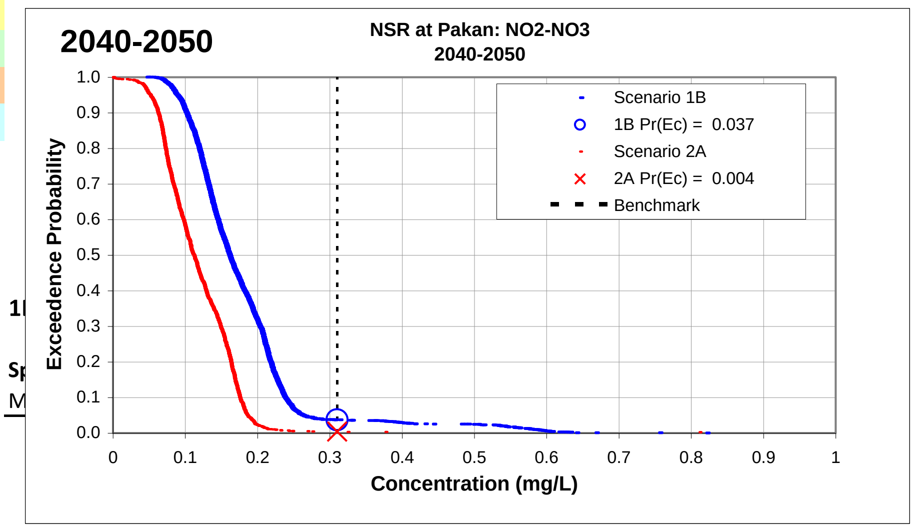
Exceedence Probability Calculation Sheet

Parameter: ***NO2-NO3 at Pakan*** mg/L

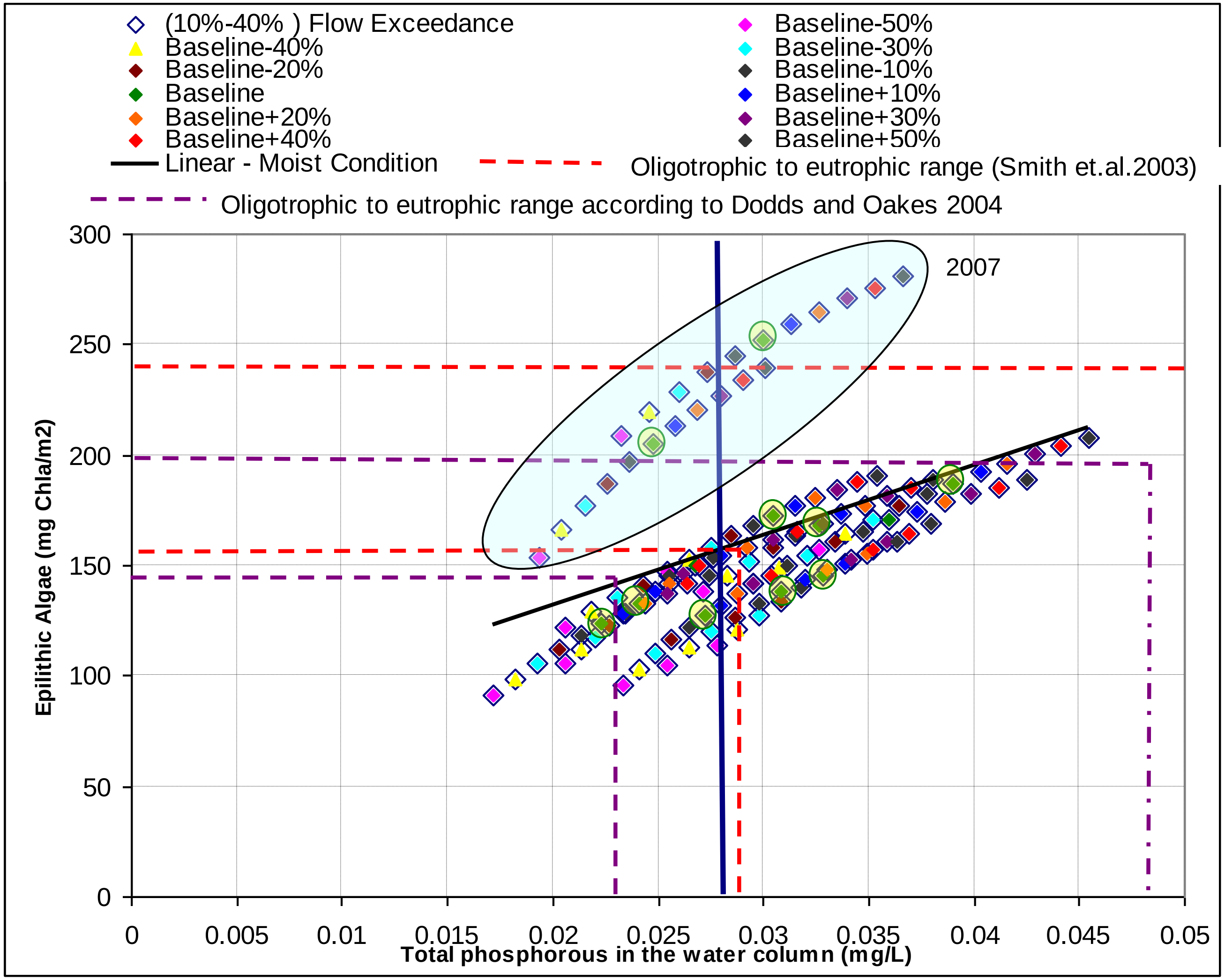
	Annual	Spring	Summer	Fall	Winter
Guideline Value =	0.31	0.098	0.098	0.098	0.31

Period	Season	1B	2A
2010-2020	Spring	**1B $Pr_{(Ec)}$ = 0.9**	**2A $Pr_{(Ec)}$ = 0.895**
	Summer	**1B $Pr_{(Ec)}$ = 0.878**	**2A $Pr_{(Ec)}$ = 0.823**
	Fall	**1B $Pr_{(Ec)}$ = 0.99600**	**2A $Pr_{(Ec)}$ = 0.98**
	Winter	**1B $Pr_{(Ec)}$ = 0.685**	**2A $Pr_{(Ec)}$ = 0.502**
	Annual	**1B $Pr_{(Ec)}$ = 0.331**	**2A $Pr_{(Ec)}$ = 0.23**
2020-2030	Spring	**1B $Pr_{(Ec)}$ = 0.893**	**2A $Pr_{(Ec)}$ = 0.878**
	Summer	**1B $Pr_{(Ec)}$ = 0.82600**	**2A $Pr_{(Ec)}$ = 0.693**
	Fall	**1B $Pr_{(Ec)}$ = 0.987**	**2A $Pr_{(Ec)}$ = 0.95**
	Winter	**1B $Pr_{(Ec)}$ = 0.143**	**2A $Pr_{(Ec)}$ = 0.026**
	Annual	**1B $Pr_{(Ec)}$ = 0.085**	**2A $Pr_{(Ec)}$ = 0.925**
2030-2040	Spring	**1B $Pr_{(Ec)}$ = 0.878**	**2A $Pr_{(Ec)}$ = 0.457**
	Summer	**1B $Pr_{(Ec)}$ = 0.73400**	**2A $Pr_{(Ec)}$ = 0.303**
	Fall	**1B $Pr_{(Ec)}$ = 0.95000**	**2A $Pr_{(Ec)}$ = 0.454**
	Winter	**1B $Pr_{(Ec)}$ = #N/A**	**2A $Pr_{(Ec)}$ = #N/A**
	Annual	**1B $Pr_{(Ec)}$ = 0.038**	**2A $Pr_{(Ec)}$ = 0.005**
2040-2050	Spring	**1B $Pr_{(Ec)}$ = 0.871**	**2A $Pr_{(Ec)}$ = 0.354**
	Summer	**1B $Pr_{(Ec)}$ = 0.672**	**2A $Pr_{(Ec)}$ = 0.063**
	Fall	**1B $Pr_{(Ec)}$ = 0.923**	**2A $Pr_{(Ec)}$ = 0.211**
	Winter	**1B $Pr_{(Ec)}$ = #N/A**	**2A $Pr_{(Ec)}$ = #N/A**
	Annual	**1B $Pr_{(Ec)}$ = 0.037**	**2A $Pr_{(Ec)}$ = 0.004**





Probability of Exceedence
= # failed tests/total number of tests



Modelled relationship between substrate algal abundance and TP (mean value of untransformed, response and explanatory variables, for incremental ten percentile flow exceedence), under moist conditions, for the North Saskatchewan River at Pakan (2005-2008).

5). NSR Watershed Model Development and application (LSPC):

- Work is ongoing to integrate with instream river model

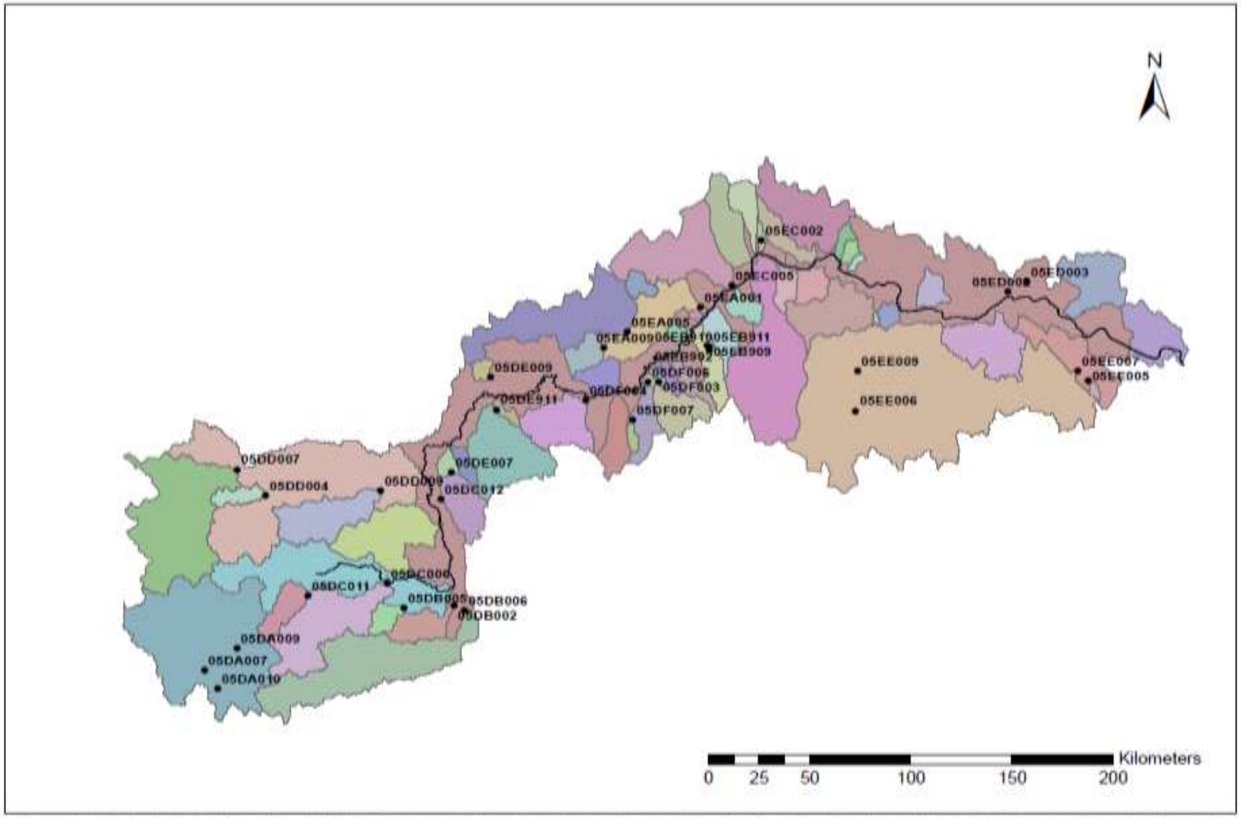


Figure 7. Model Calibration WSC Stream Gauging Locations. Black Line Indicates EFDC Instream Model Location

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Seasonal TSS synoptic sampling on the NSR for 2008

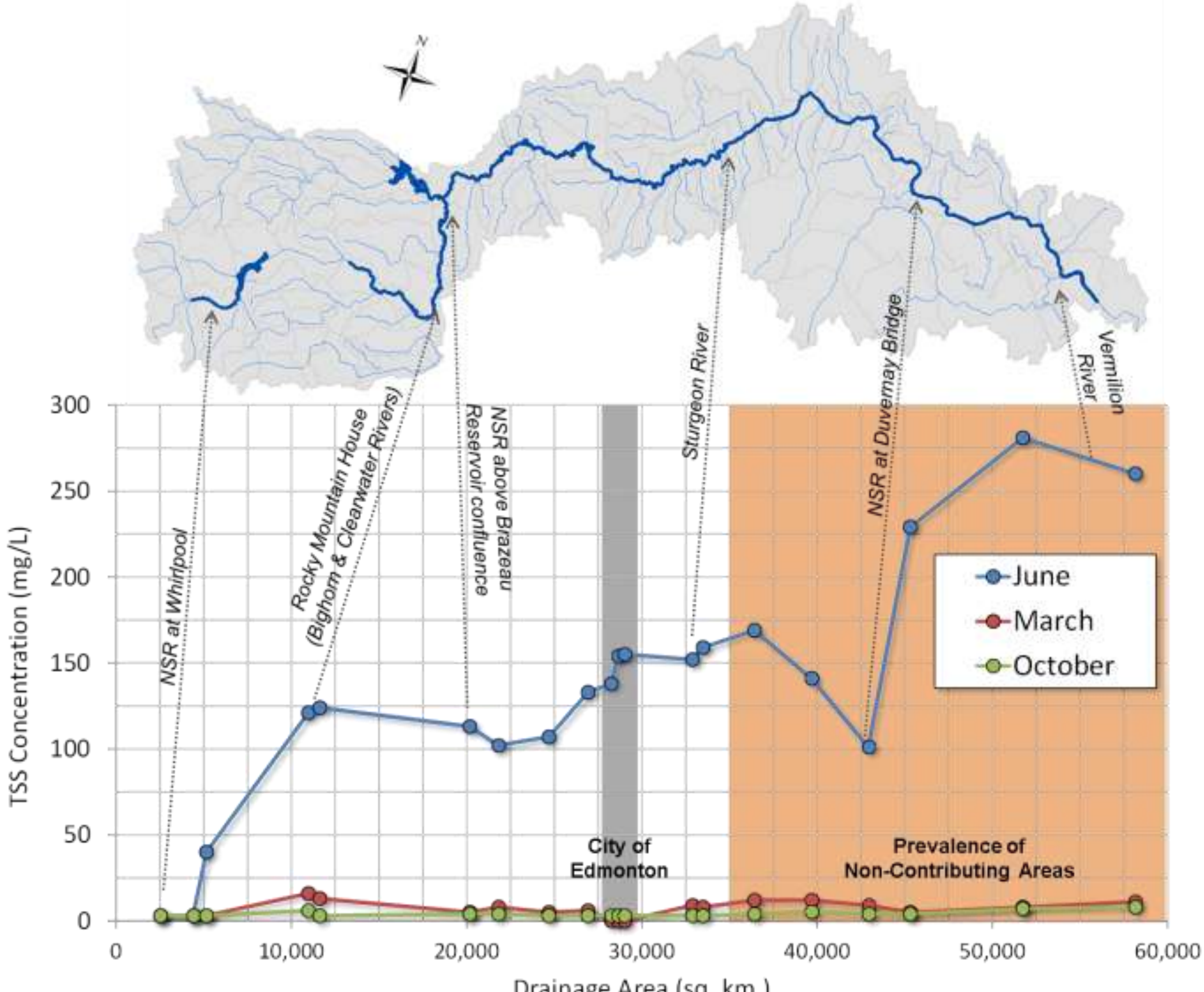
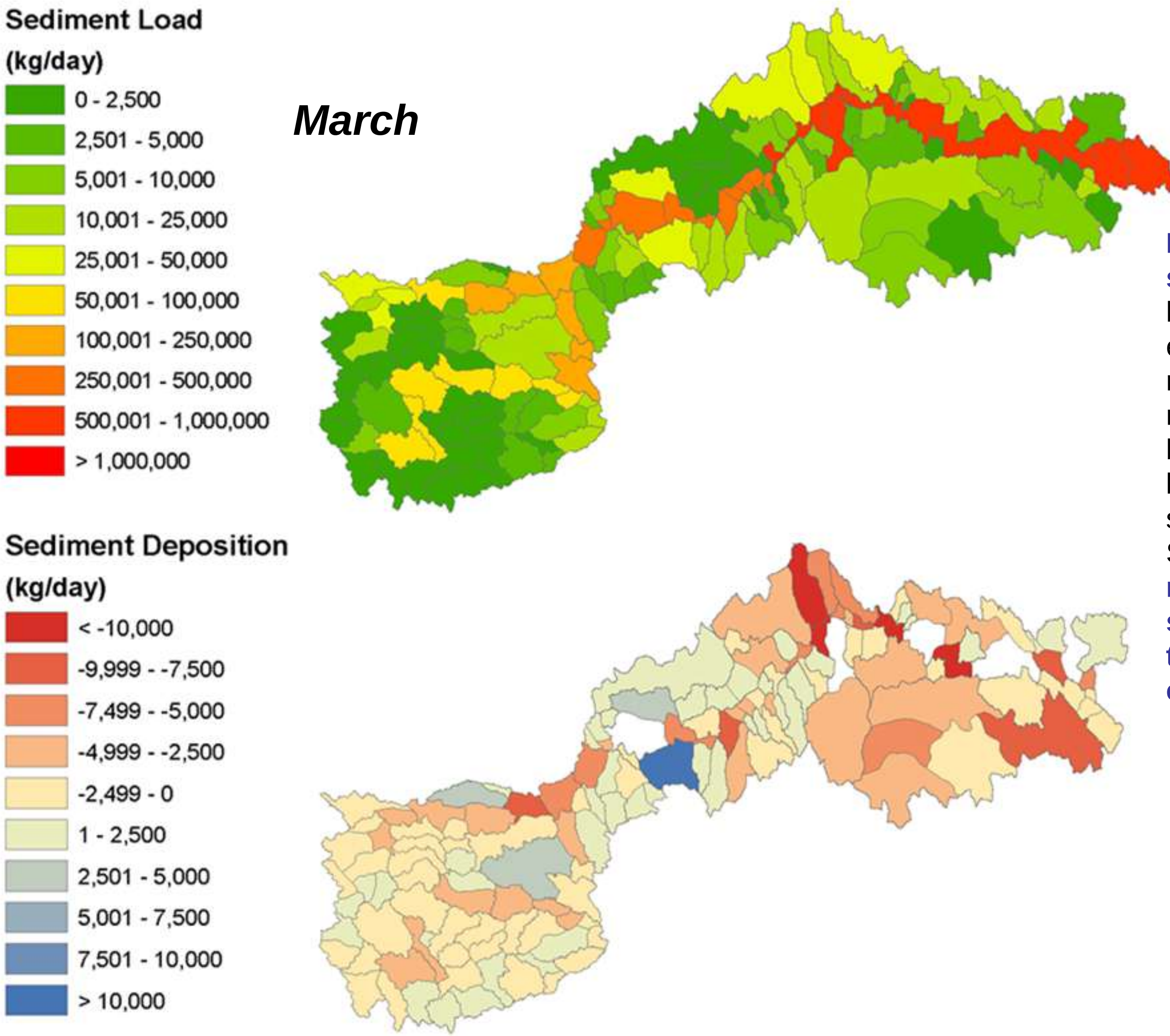


Table 3-4. Summary of seasonal flow patterns in NSR tributaries, sorted by average elevation

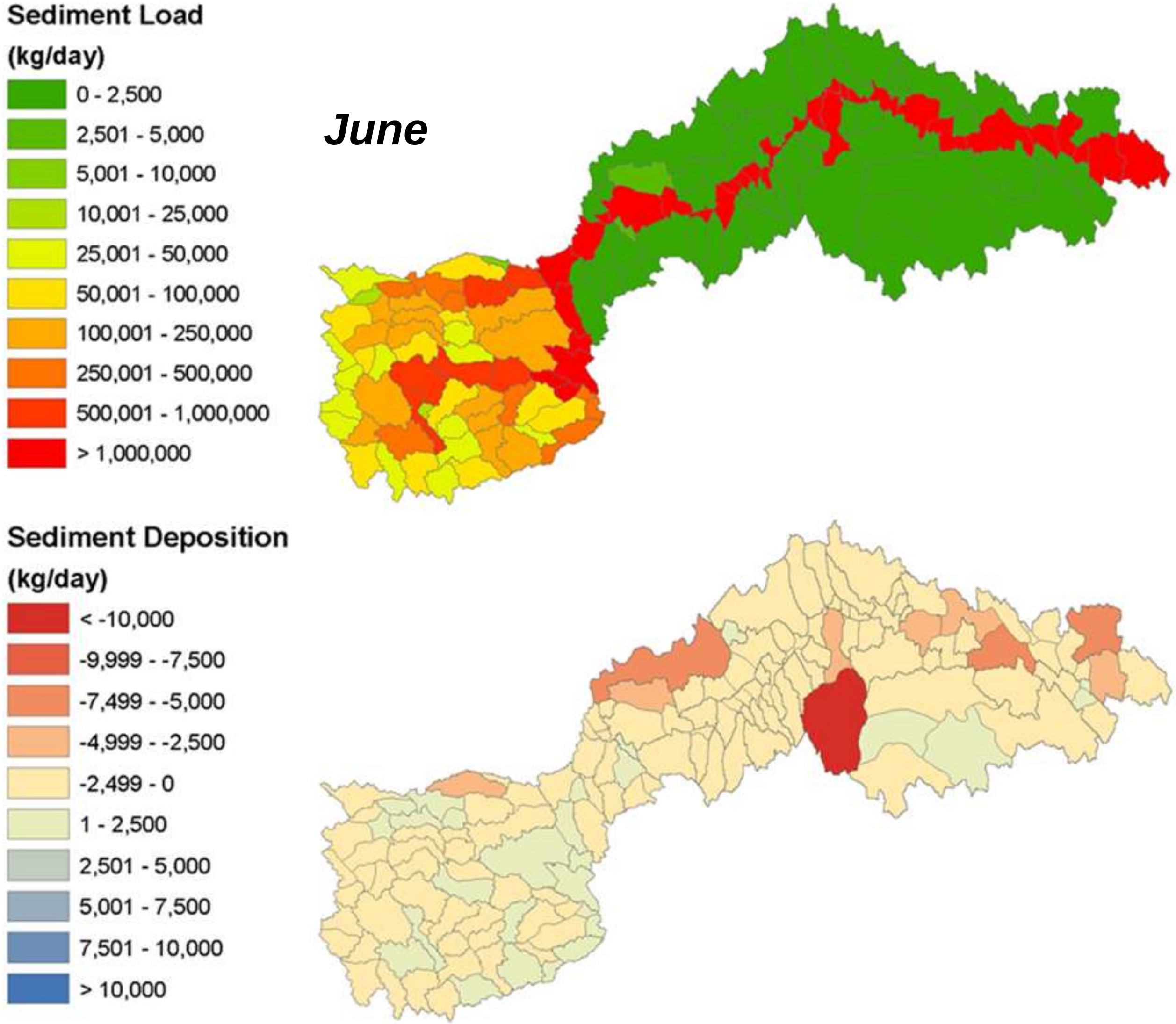
NSR Tributary		Average Elevation (m)	Percent NCA	Peak Flow Month	Percent of Observed Annual Flow	
Name	Gage ID				March-**April**-May	May-**June**-July
Ram River	05DC006	1,807	0.0%	June	20%	61%
Clearwater River	05DB006	1,731	0.0%	June	19%	51%
Baptiste River	05DC012	1,106	0.010%	June	30%	58%
Rose Creek	05DE007	974	0.004%	May	49%	62%
Modeste Creek	05DE911	893	0.0%	April	63%	50%
Tomahawk Creek	05DE009	799	0.0%	April	72%	41%
Strawberry Creek	05DF004	798	0.19%	April	71%	47%
Sturgeon River	05EA001	715	27%	April	82%	37%
Vermillion River	05EE009	673	77%	April	84%	41%
Vermillion River	05EE007	666	74%	April	96%	17%
Waskatenau Creek	05EC002	664	37%	April	92%	14%
Redwater River	05EC005	661	26%	April	90%	34%

Modelled sediment loads (LSPC)



March => beginning of the spring snowmelt; note slightly higher sediment loading in the eastern portion of the watershed relative to the higher elevation mountain regions. Also the beginning of a pronounced loading increase in the lower stretches of the NSR mainstem. Sediment deposition map shows **mobilization of sediment from some lower elevation tributaries to the NSR where early snowmelt begins.**

Modelled sediment loads (LSPC)



June => peak sediment loads. The model shows that sediment yield reduces in the lower elevation watersheds where NCA is prevalent, but increases in the higher elevation watersheds where snowmelt occurs in the later part of the spring. However, there are some notable differences in the amount of sediment that is being transported through the tributaries.

Mainstem shows the highest transported sediment loads; it is the main conduit that connects the western mountain regions to the eastern prairie regions. **Net deposition is clustered around zero** (i.e. relatively small deposition and/or resuspension) during the month of June. This is because energy associated with the higher flows generally tends to keep sediment in suspension as it is transported downstream.

What are we capable of doing now?

- represent past and present conditions for river water quality

- can identify relative point and non-point source contributions (e.g., loads) to water quality and instream response

- can run “hypothetical” or predictive simulations of potential flow and pollutant loading scenarios

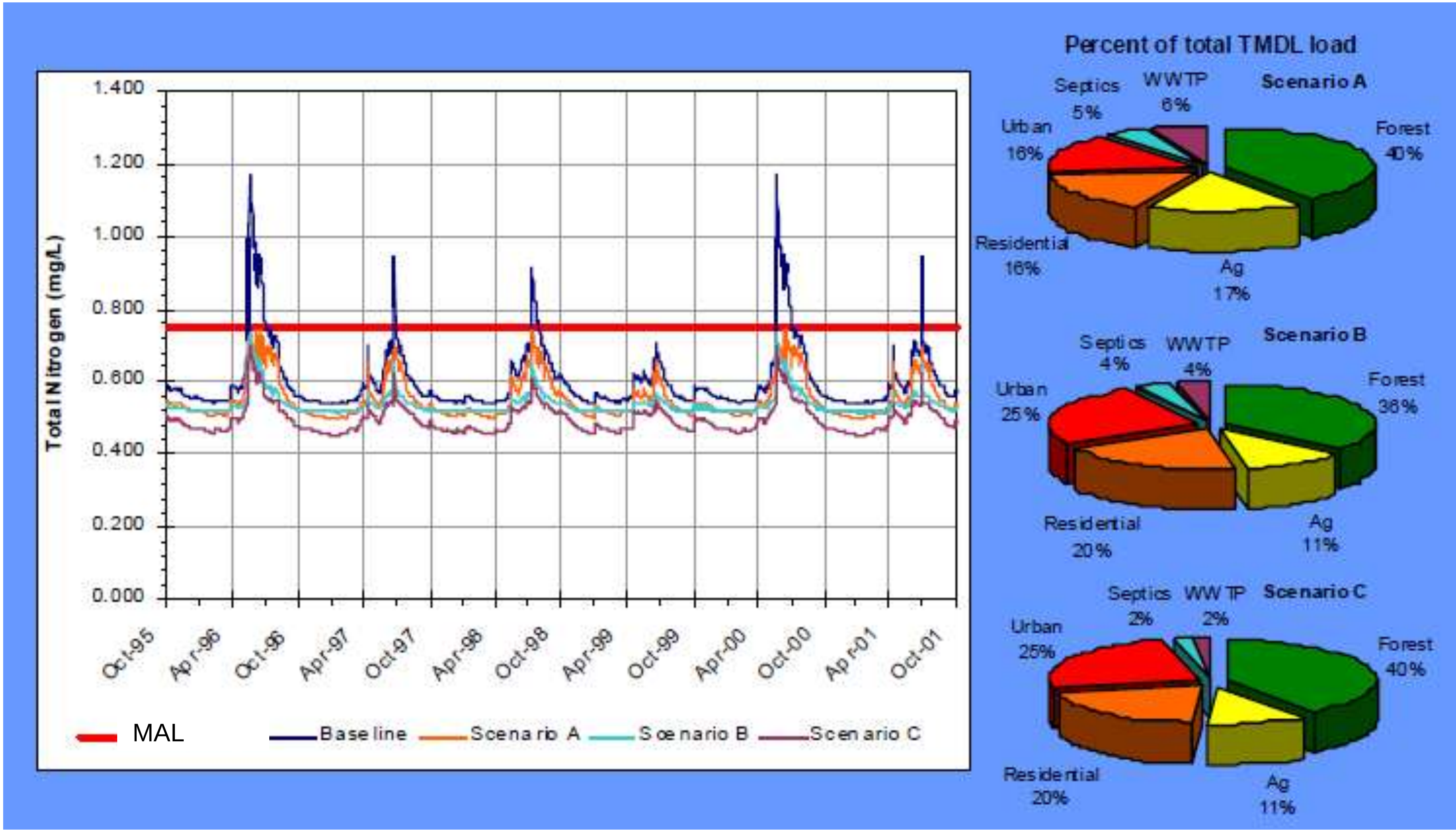
Ongoing Work and Next Steps:

- Continue to develop an integrated monitoring and reporting system (e.g., effluent: ambient) to better enable predictive evaluations in the NSR.
- Continue development of loading calculation tools, models, and related evaluations, for application in local and basin-scale assessment and future planning.
- Rationalize benchmarks (WQOs) with reference to effects.
- Watershed/regional planning initiatives will be able to use the model system, collaboratively.
- Test loading targets in the regulatory context (e.g., coordination of approvals).

Discussion

Allocation Scenarios

- Use modelling to represent different combinations of source reductions that meet water quality objectives



After TetraTech, 2009

Day 2 – Session 4

Brad Stelfox – ALCES Group

BIOGRAPHY

Dr. Brad Stelfox is an adjunct professor at the Department of Biological Sciences, University of Alberta and the Department of Environmental Design, University of Calgary. He and his family live in Calgary.
In 1995, Dr. Stelfox established FOREM Technologies, which focuses on the interface between human landuses and regional landscapes. The major development stream of Forem has been ALCES© (A Landscape Cumulative Effects Simulator) and ALCES© Mapper, programs gaining rapid acceptance by the governments, industry, the scientific community, and NGO's to explore issues between l andscapes, land uses (agriculture, forestry, oil and gas, mining, human populations, tourism, and transportation sectors), and ecological and economic integrity. In 2006, the ALCES Group was formed, a collection of landscape planners and resource analysts whose mission is to be a world leader in the delivery of land-use cumulative effects simulation modelling tools, strategic land-use planning advice, and the provision of practical strategies to assist governments, businesses, and society make balanced, informed decisions.
Dr. Stelfox received the William Rowan Award (The Wildlife Society; Alberta Chapter) in 2011, the Outstanding Leadership Award of the Canadian Boreal Initiative (2009), the Alberta Emerald Foundation Award (2004), and the Alberta Science and Technology Award (2003) for his contributions with the ALCES model in advancing understanding of land-use sustainability issues and in seeking solutions that balance economic, social, and ecological indicators.

Day 2 – Session 4

Brad Stelfox – ALCES Group

ABSTRACT

The presentation will focus on past, current and future land use trajectories in Alberta as quantified for the Alberta Land Use Framework using the ALCES Simulator and ALCES Mapper.

The role of both natural disturbance and anthropogenic disturbances in shaping performance of triple bottom line indicators (social, economic, ecological) will be discussed, as will the role in "beneficial management practices" in mitigating risk to air, land, and water metrics.

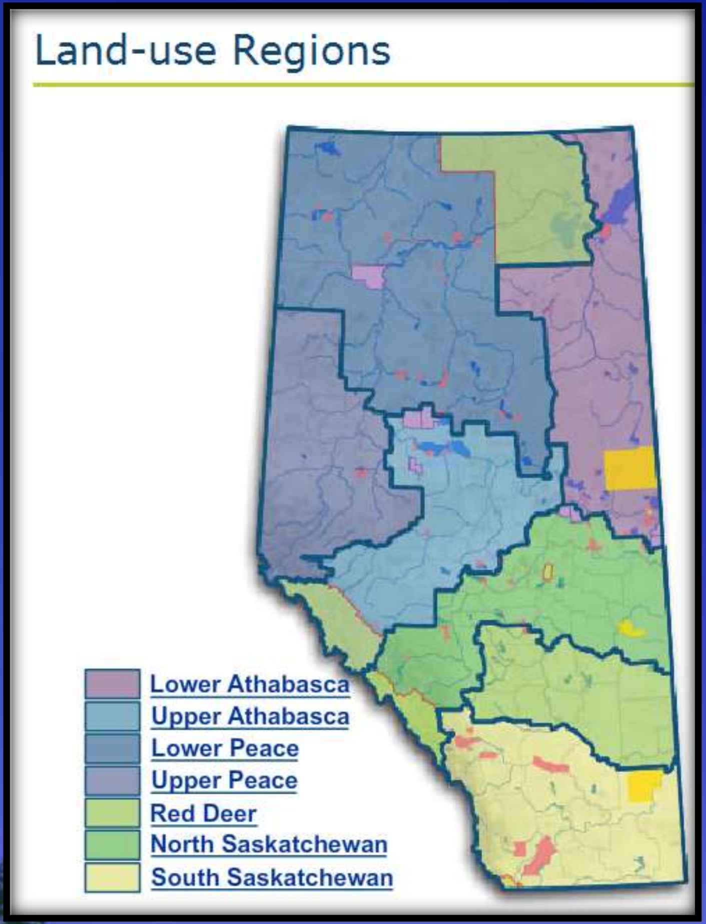
The analyses reveal that historic spatial growth patterns in land use, while instructive, are not necessarily predictive templates in understanding the key issues that will drive Alberta into the next 5 decades.

If Alberta is to achieve reasonable success in developing, defending, and implementing regional land use plans, a suite of complementary simulation products (educational, strategic, tactical) will be required to convey sustainability challenges to the "average" Alberta and the range of land use options (pace, tempo, geography) available to mitigate risk and optimize performance.

Assessing the Cumulative Effects of Alberta's Land Uses using ALCES

www.alces.ca

A Presentation to the
Central Modeling Workshop

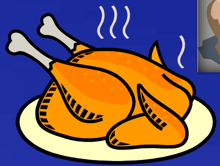


Why are we here? - an Awakening has Occurred

Alberta is Firing on All Land Use Cylinders

- 1-1.5 million head of cattle harvested
- 2-3 million head of swine harvested
- 100-120 million kg of poultry harvested
- 25-35 million tonne of crop harvested
- 20-25 million m^3 of timber harvested
- 150-160 billion m^3 of natural gas produced
- 25-35 million m^3 of conventional oil produced
- 60-80 million m^3 of bitumen produced
- 25-35 million tonne of coal produced
- 1200-1500 petajoules of electricity produced

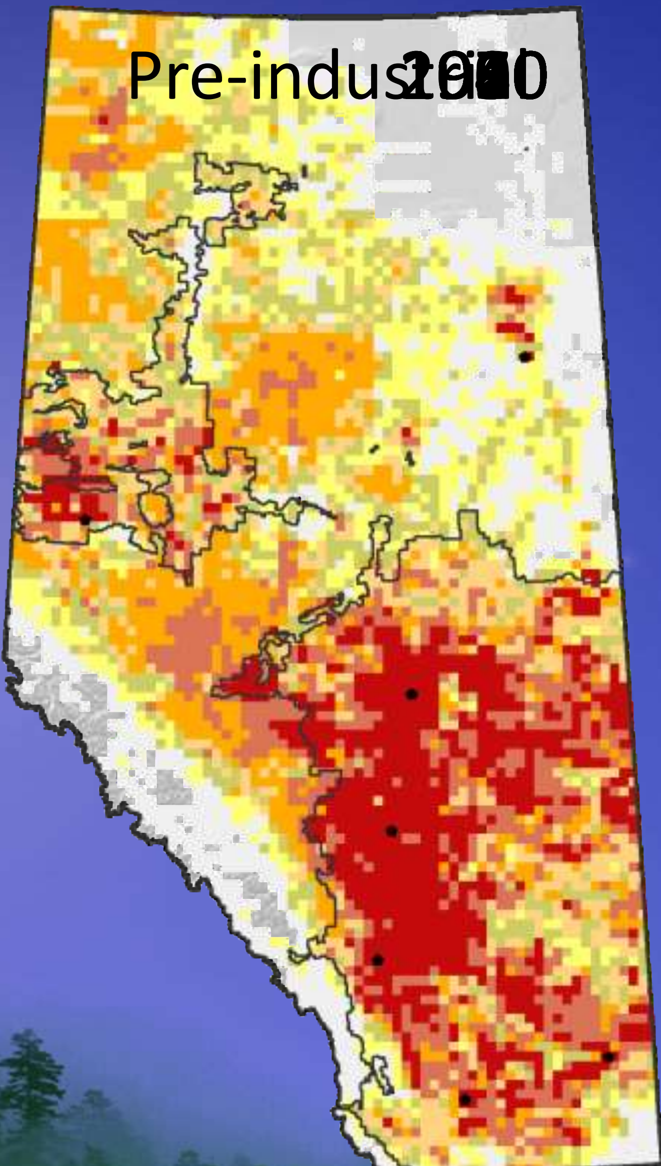




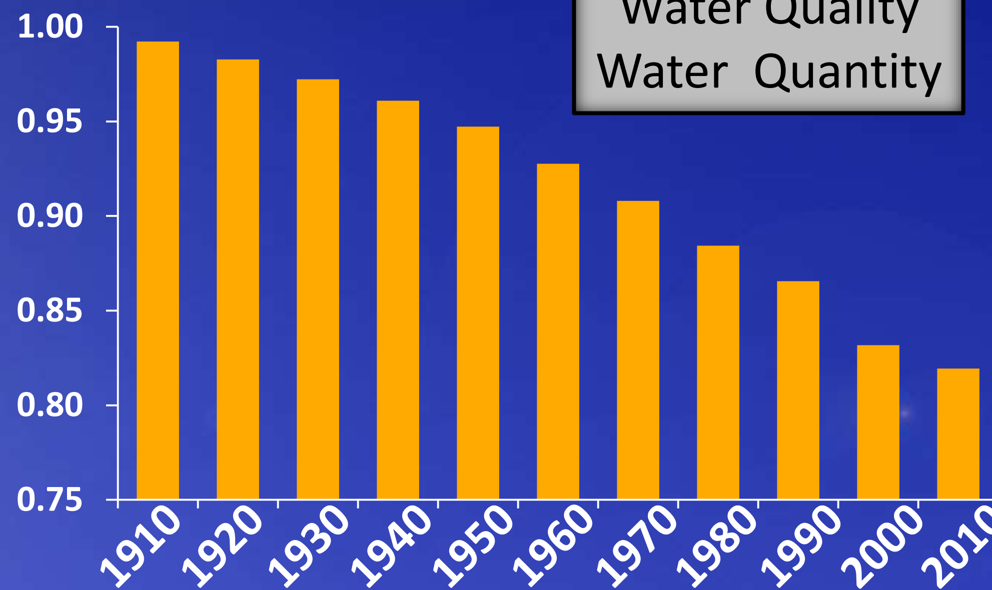




Reductions in Ecological Goods and Services



Biotic Carbon
Water Quality
Water Quantity



Land Use Index

- 0.935 - 0.999
- 0.874 - 0.934
- 0.808 - 0.873
- 0.748 - 0.807
- 0.726 - 0.747
- 0.678 - 0.725
- 0.325 - 0.677

Areas without a coloured grid cell have an index of 1 meaning no threat.

Multiple Communities, Multiple Demands

4.05

Balancing the Equation

Internalization of Natural Capital into Decision Making

An Integrated Approach; Management by Objective

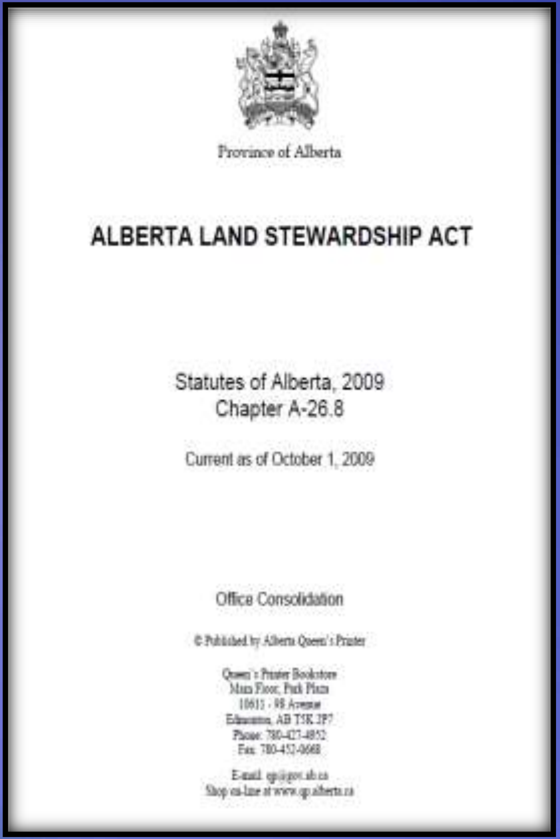
- Food
- Settlements
- Fuel
- Fiber
- Water Quantity
- Water Quality
- Carbon Stocks
- Air Quality

Trade-Offs
Limits
Thresholds
Risks
Knowledge

Alberta Land Stewardship Act (ALSA)

Alberta Land-Use Framework (ALUF)

Alberta Land Use Framework Regions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ALBERTA LAND STEWARDSHIP ACT

Statutes of Alberta, 2009
Chapter A-26.8

Current as of October 1, 2009

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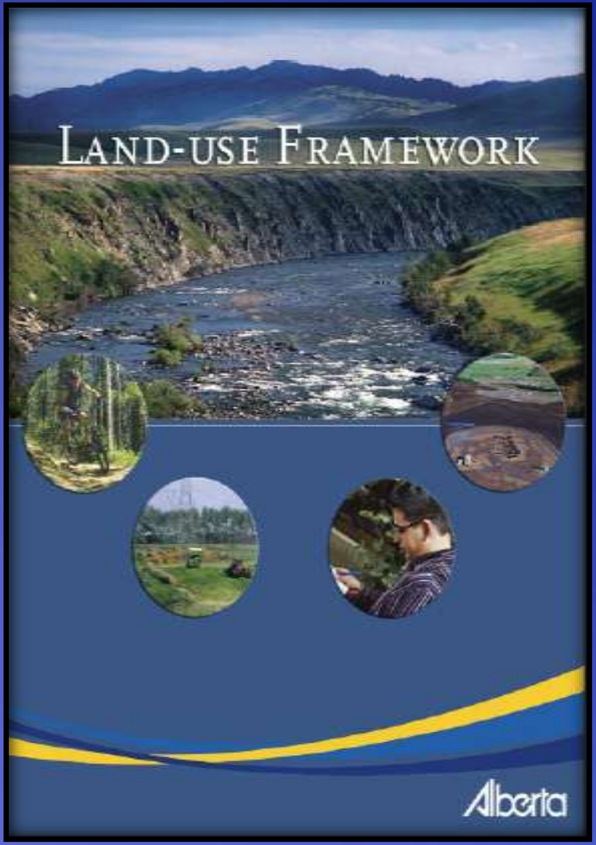
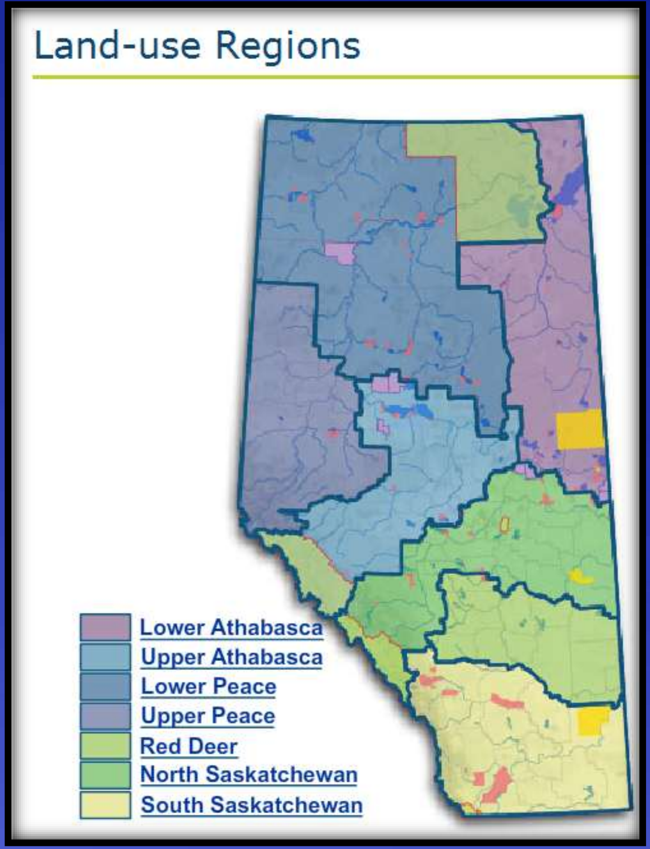




The ALCES Simulator Toolkit

- Several Tools in the Toolkit
- “What-If” Simulators
- Long-term (chronic = year DT) not acute (day DT) temporal domain
- Alberta has been the Geographic Focus
- Model Gradient from Simple to Comprehensive but focus has generally been more on shuttle architecture (focus on 1st and 2nd order dynamics)
- Educational Focus to Professional Grade
- Temporal Domain of Past, Current, and Future
- Triple Bottom Line Indicators
- Major Focus on Beneficial Management Practices
- Enable “Management by Objective” Solutions

ALCES ToolKit

Licensed
End User Computer

Licensed
End User Computer

Subscription and
Internet Delivered

Free and Internet Delivered

Free and Internet Delivered

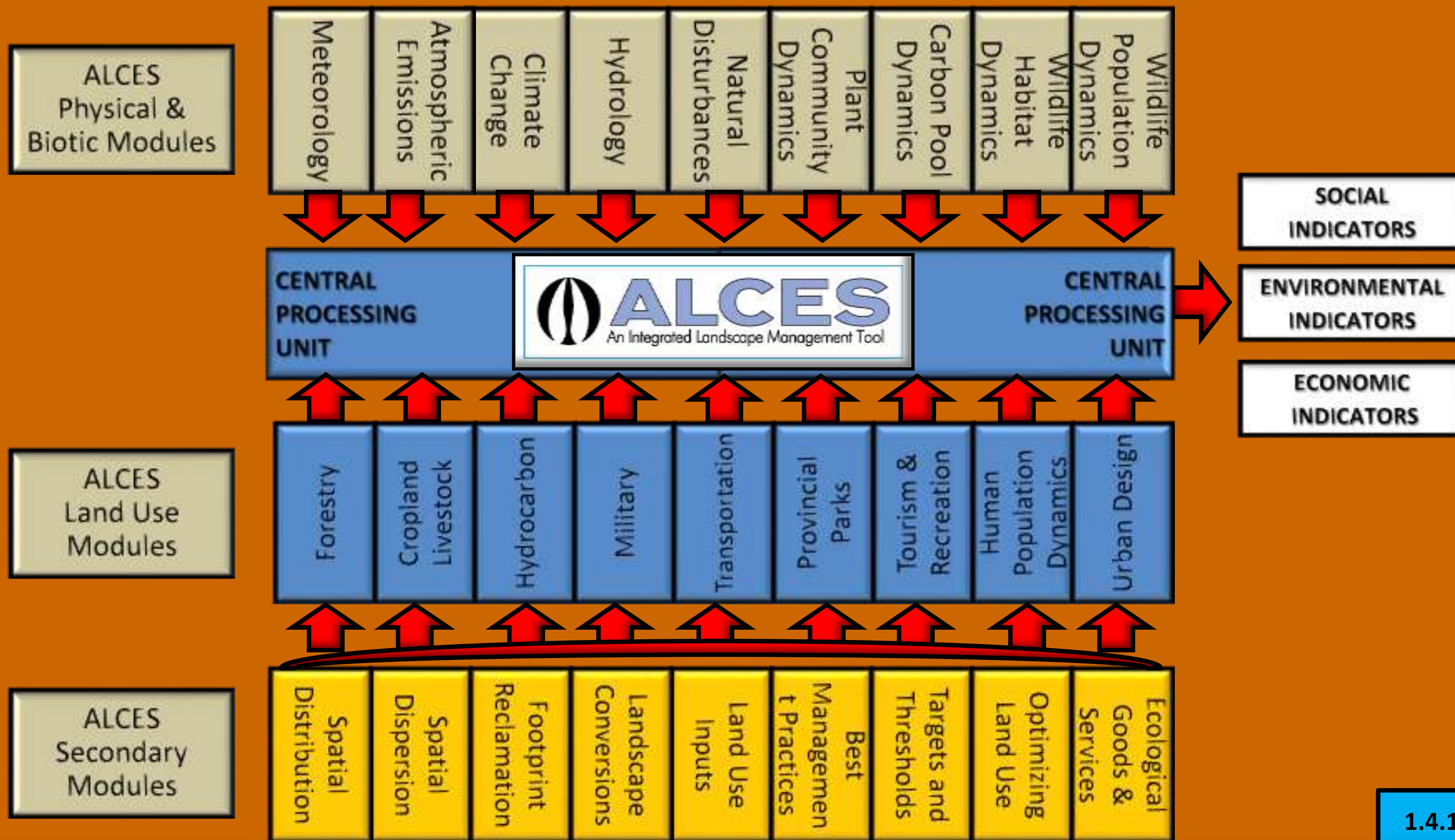
Free and Internet Delivered

Successful Assessment of Cumulative Effects of Land Uses requires Simulators to address:

- Air, Land, Water
- All Relevant Land Uses
- All Relevant Natural Disturbance Regimes
- Triple Bottom Line Indicators
- Temporal Domain of Past, Present, and Future
- Reference Points for Indicator Performance
- Uncertainty = Sensitivity Analyses
- “Beneficial Management Practices”
- Output that is Tabular, Graphic, and Maps
- Transparent Models where Users can readily see structure and Assumptions

Home | Back | Control Switches

Module Architecture of ALCES



1.4.1

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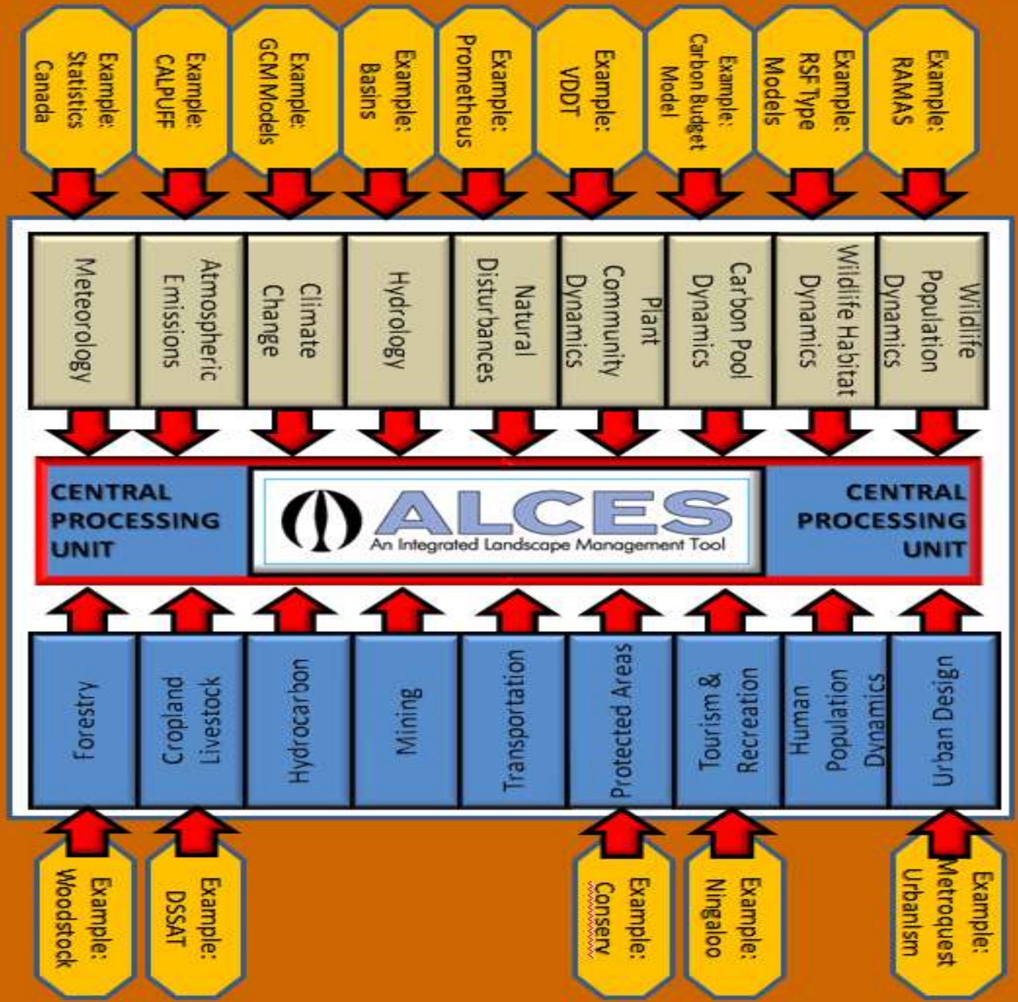
Multi-Model Integration with ALCES

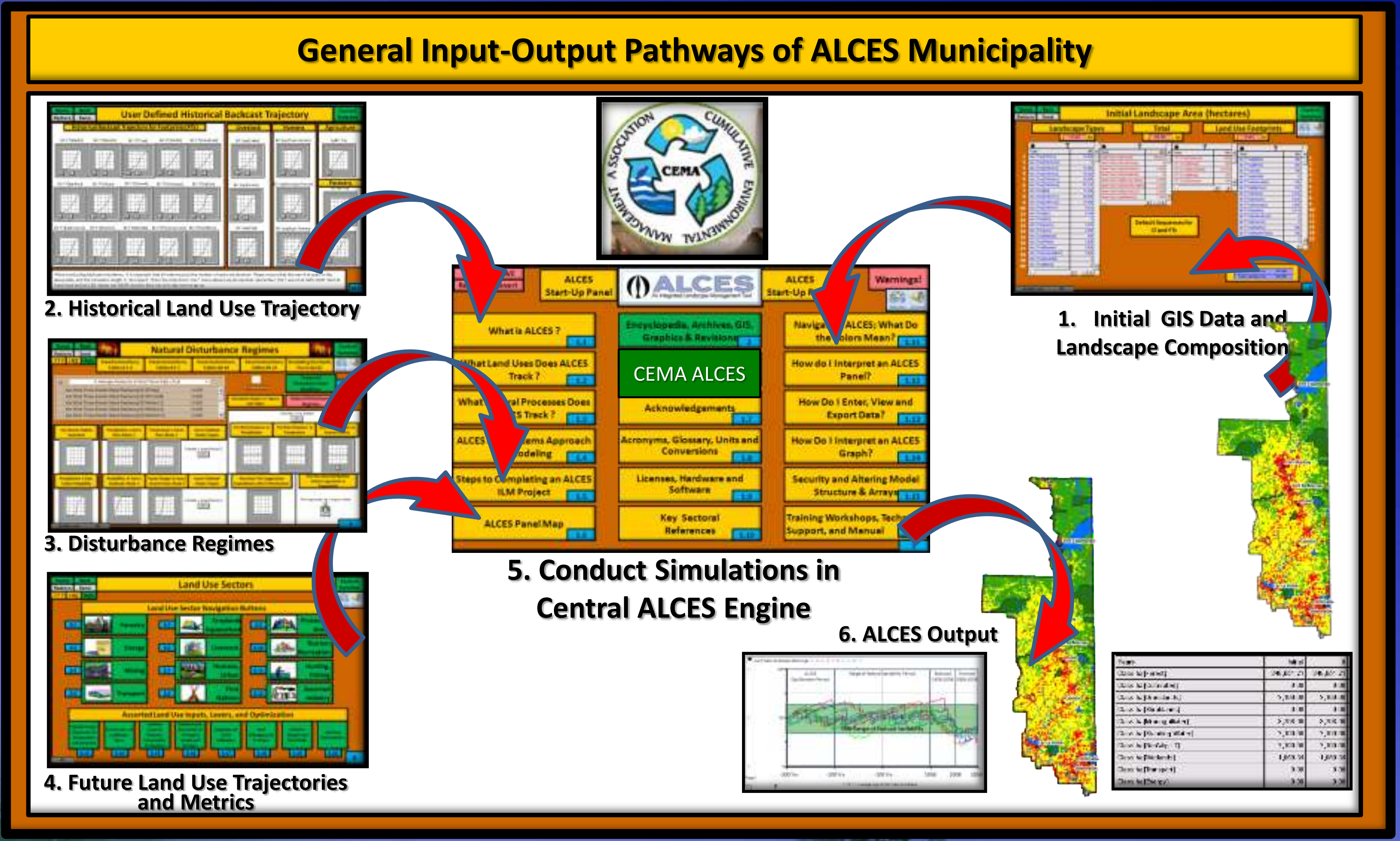
Control Switches

For Projects where detailed and mechanistic sectoral models have already been constructed, ALCES can be informed (receive input) from the output from these models



1.4.2

The basic steps of simulating land use in ALCES



Tracking Land Uses in ALCES

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What Land Uses Does ALCES Track?

8.1  Forestry

8.2 

Energy

8.3  Mining

8.4  Transport

8.5  Cropland Aquaculture

8.6  Livestock

8.7  Human Population Urban

8.8  First Nations

8.9  Protected Areas

8.10  Tourism Recreation

8.11  Hunting, Fishing Trapping

8.12  Assorted Industry

1.2

Tracking Natural Disturbances in ALCES

Home | Back

What Natural Processes Does ALCES Track?

Control Switches

1.3.1  Climate and Climate Change

1.3.2  Hydrological Cycle

1.3.3  Natural Disturbance Regimes

1.3.4  Plant Community Dynamics

Carbon Pool Dynamics  1.3.5

Wildlife Habitat  1.3.6

Wildlife Populations  1.3.7

Landscape Metrics  1.3.8

1.3

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Landscape Type (LT) Stratification; Alberta Example

Control Switches

LT1

Hardwood Forest

LT2

Mixedwood Forest

LT3

Mesic Spruce Forest

LT4

Hygric Spruce Forest

LT5

Pine Forest

LT6

Fen

LT7

Bog

LT8

Lentic (Lakes and Ponds)

LT9

Lotic (Streams and Rivers)

LT10

Native Grassland

LT11

Shrubland

LT12

Cereal Cropland

LT13

Forage Cropland

LT14

Alpine

LT15

Glaciers

LT16

Foothills

LT17

Beach

LT18

Prairie Potholes

LT19

Non-vegetated (dunes)

LT20

Shoreline

4.1

Footprint Type (FT) Stratification; An Alberta Example

FT1

Major Road (highway)

FT6

Air Strip

FT11

Recreational Feature

FT2

Minor Road

FT7

Recreational Trail

FT12

Seismic Lines

FT3

Railway

FT8

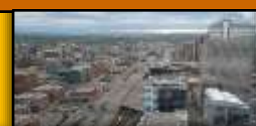
Golf Course

FT13

Wellpad

FT4

Inblock Road

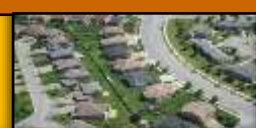
FT9

Downtown City

FT14

Pipeline

FT5

Transmission Line

FT10

Suburbia

FT15

Surface Mines

4.2

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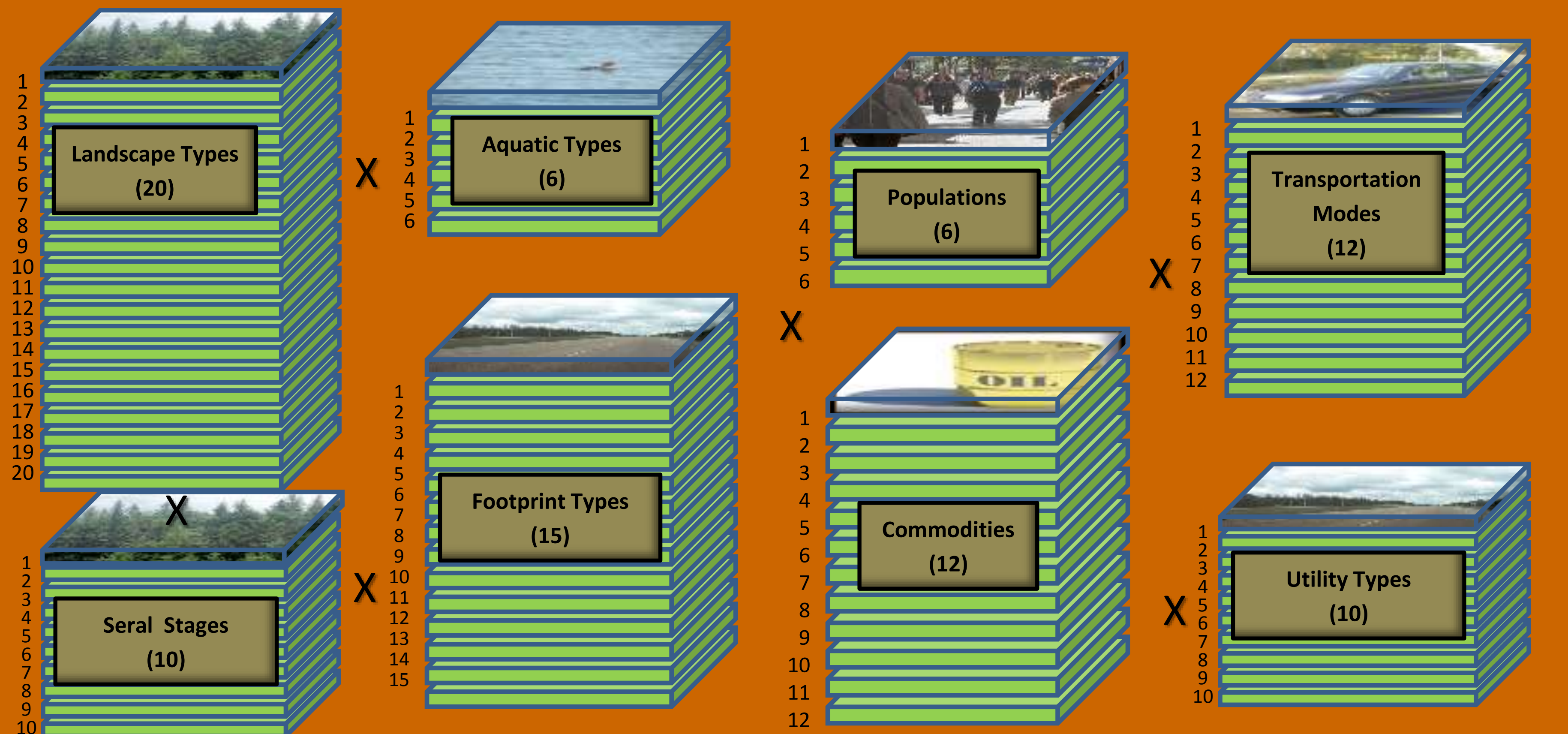
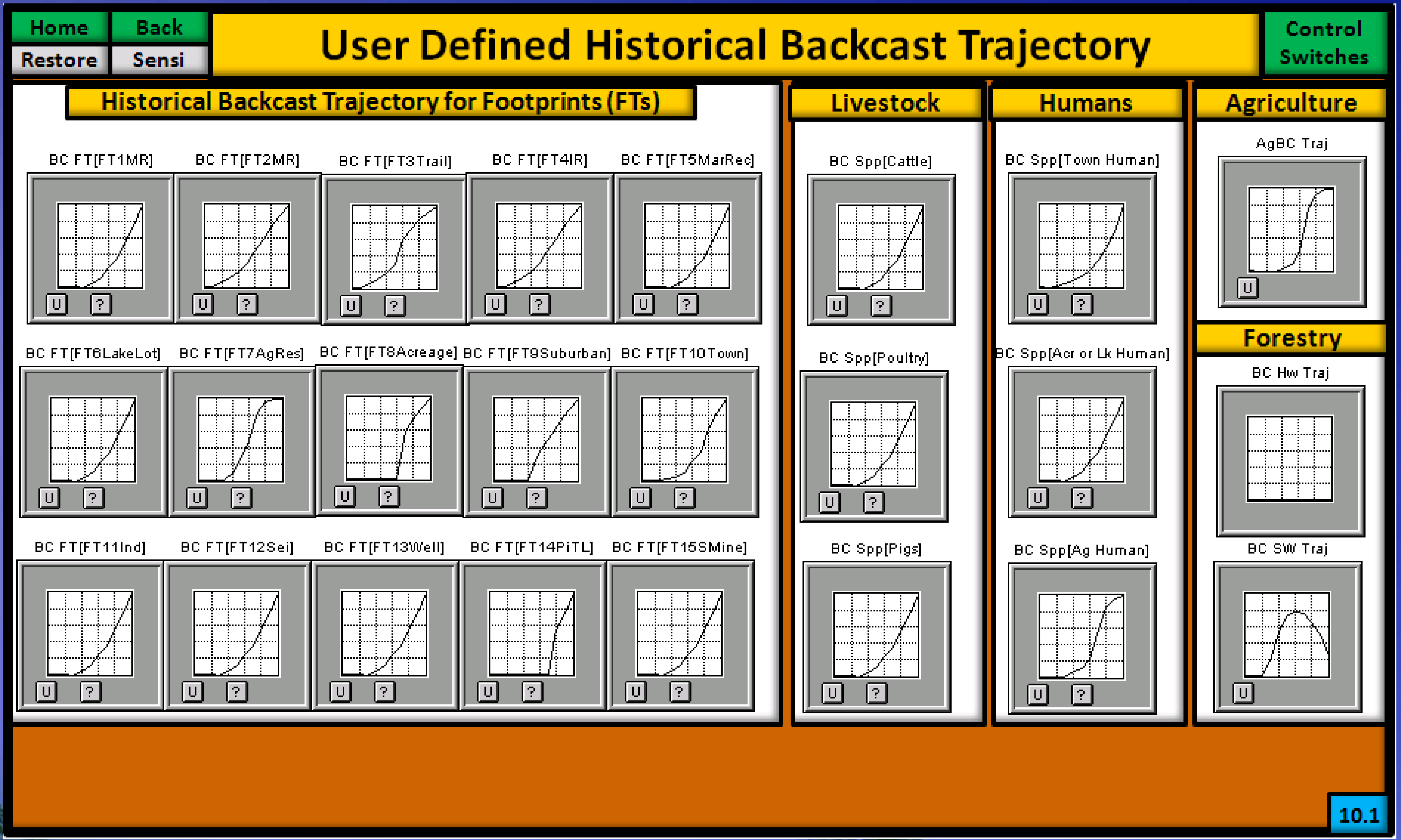
Permutations for Stratification Themes



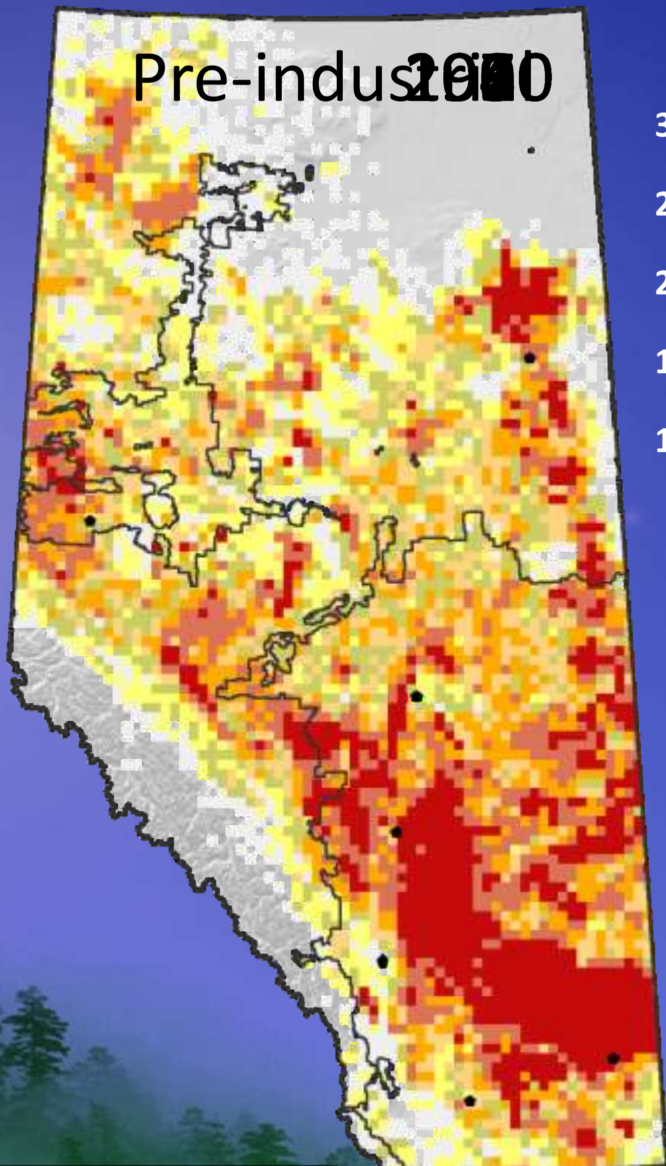
20 Landscape Types X 10 Seral Stages X 6 Aquatic Types X 15 Footprint Types X 6 Populations Types X 12 Commodities Types X 12 Transport Types X 10 Utility Types = 155,520,000 Combinations

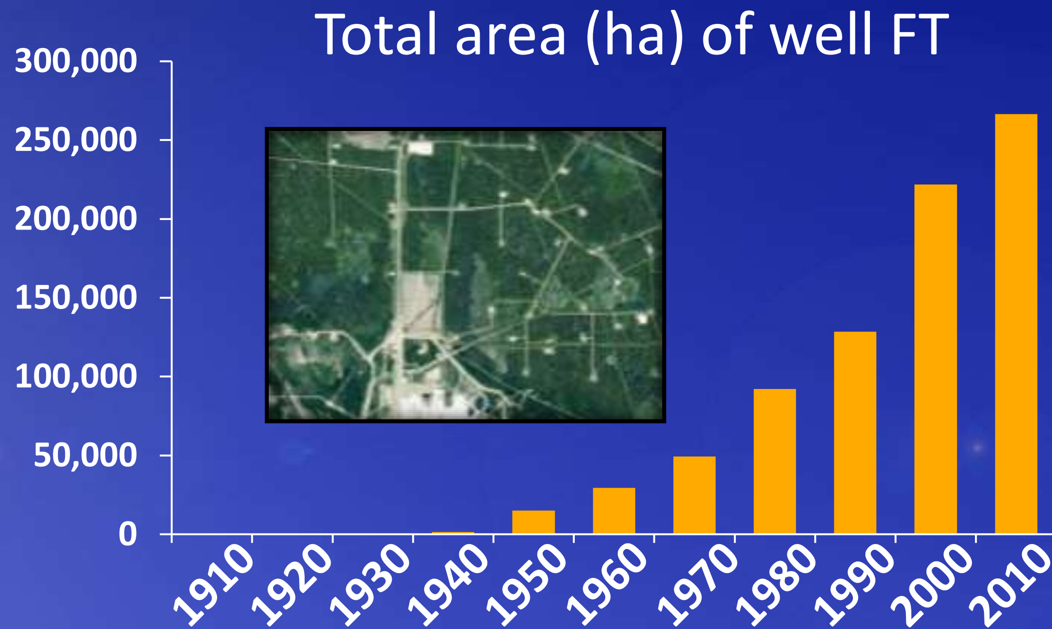
4.7

Reconstructing the History of Land Use Footprints

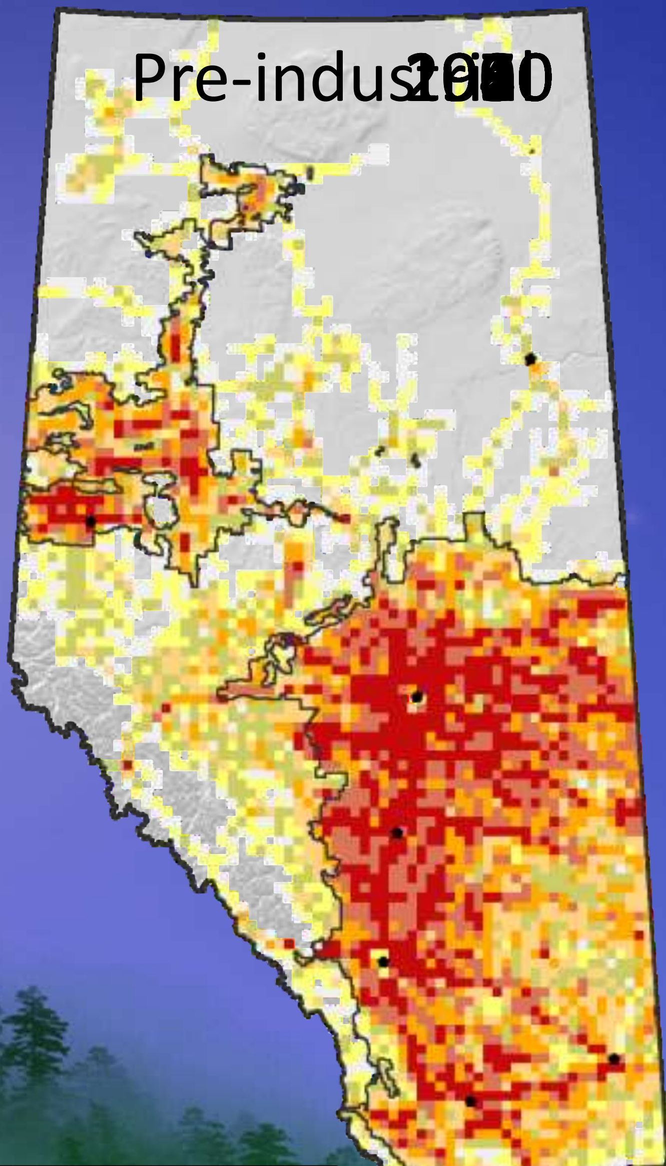


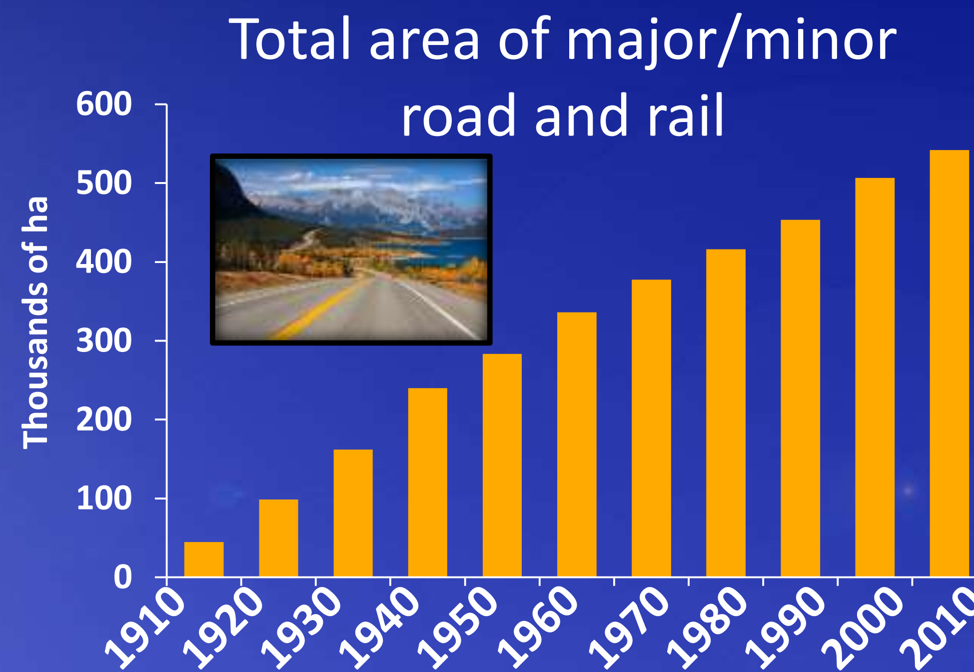
Hydrocarbon Well Footprint





History of Alberta’s Road Network

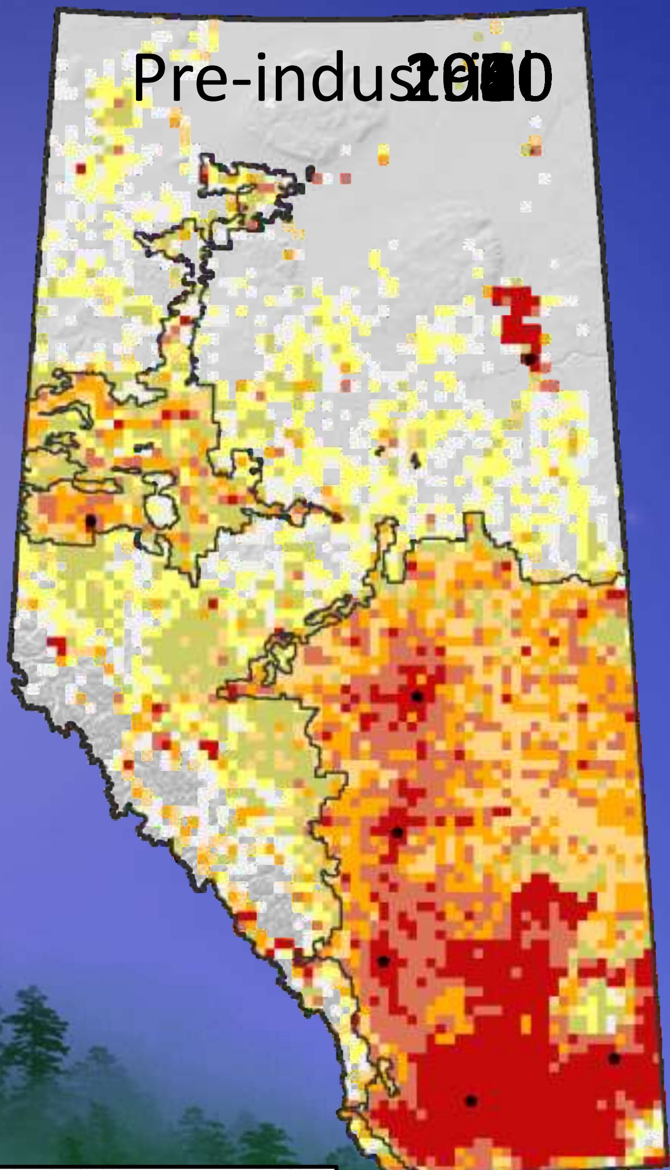


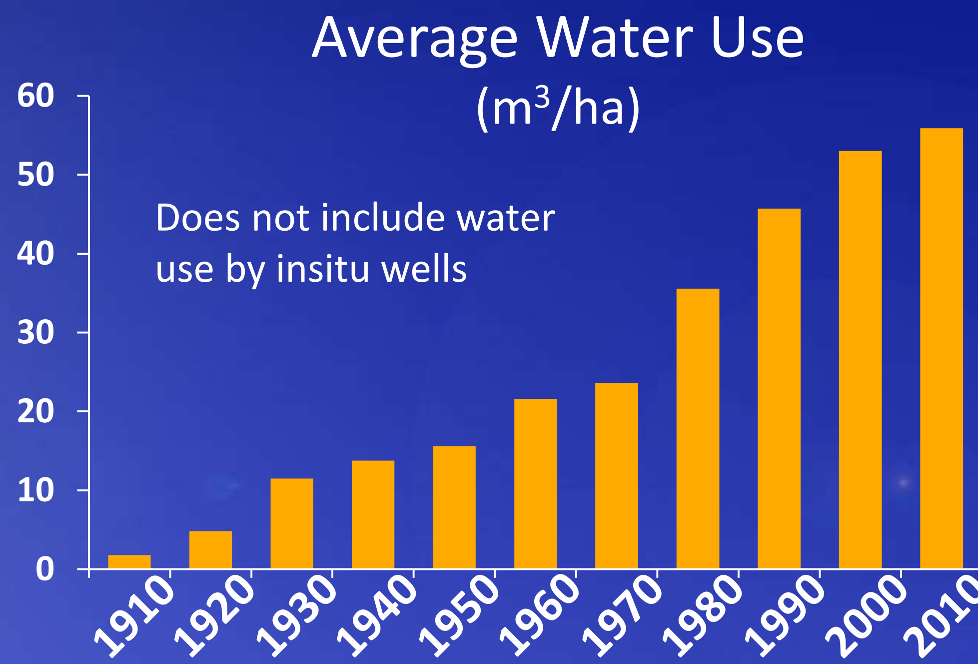


% Transportation FT

- 0.001 - 0.260
- 0.261 - 0.535
- 0.536 - 0.928
- 0.929 - 1.382
- 1.383 - 1.897
- 1.898 - 2.384
- 2.385 - 6.059

Water Demand





Water Use (m^3/ha)

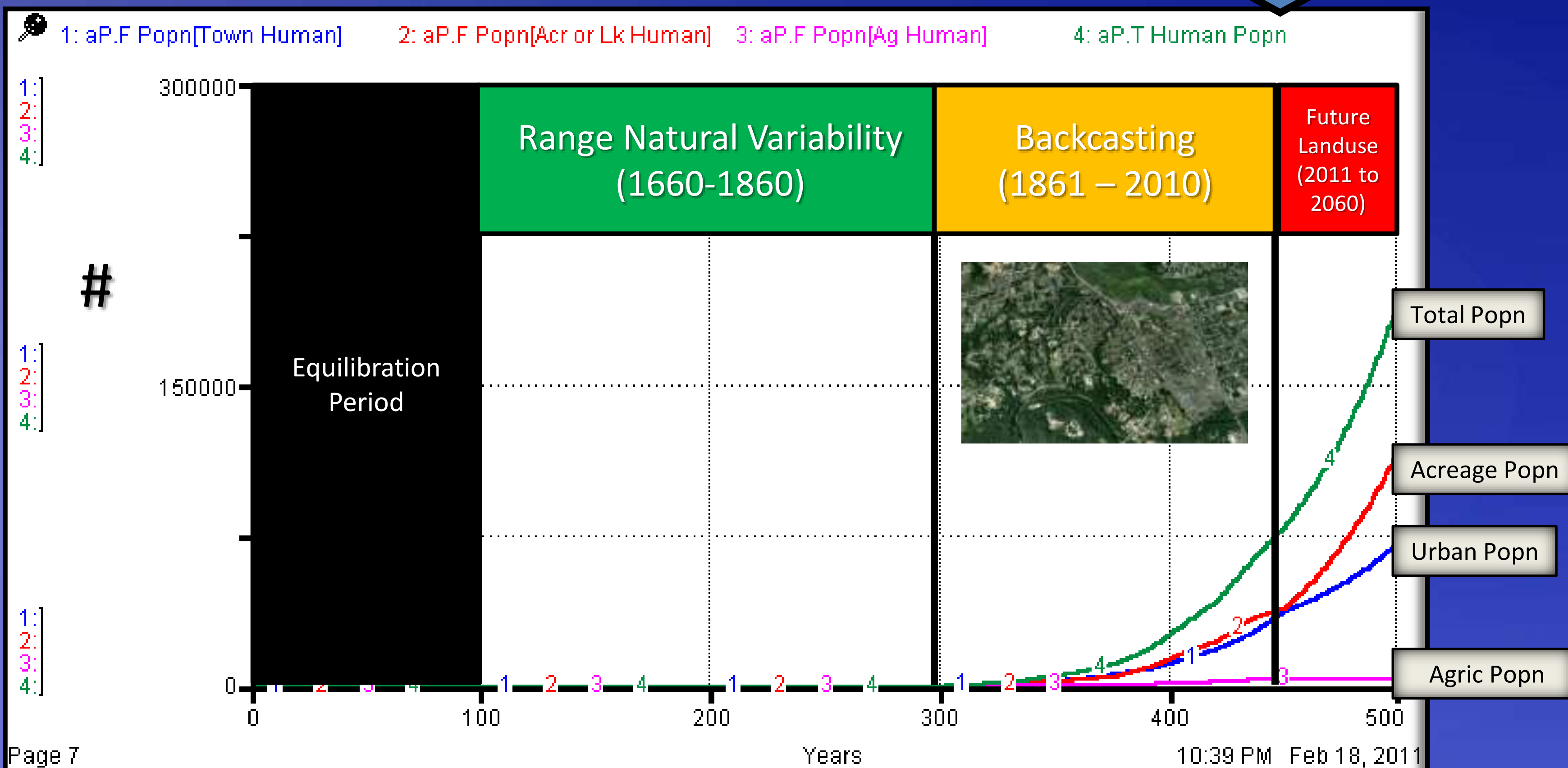
- 0.001 - 0.105
- 0.106 - 0.464
- 0.465 - 2.472
- 2.473 - 6.835
- 6.836 - 20.272
- 20.273 - 93.737
- 93.738 – 3,012.780

Exploring Alternative Futures

Define the House!!!!!

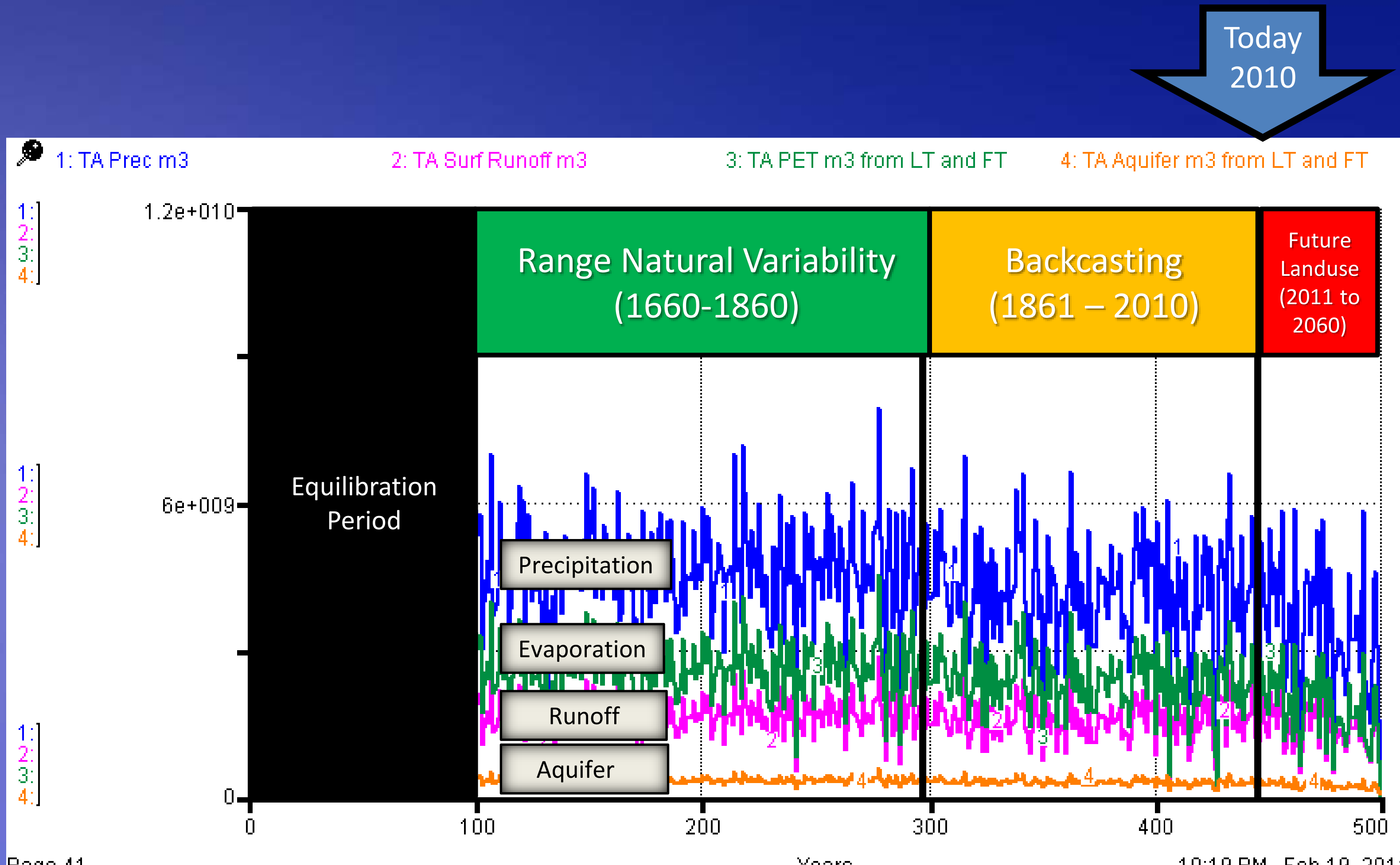
Graphic ALCES Output
Example: Human Population

Today
2010

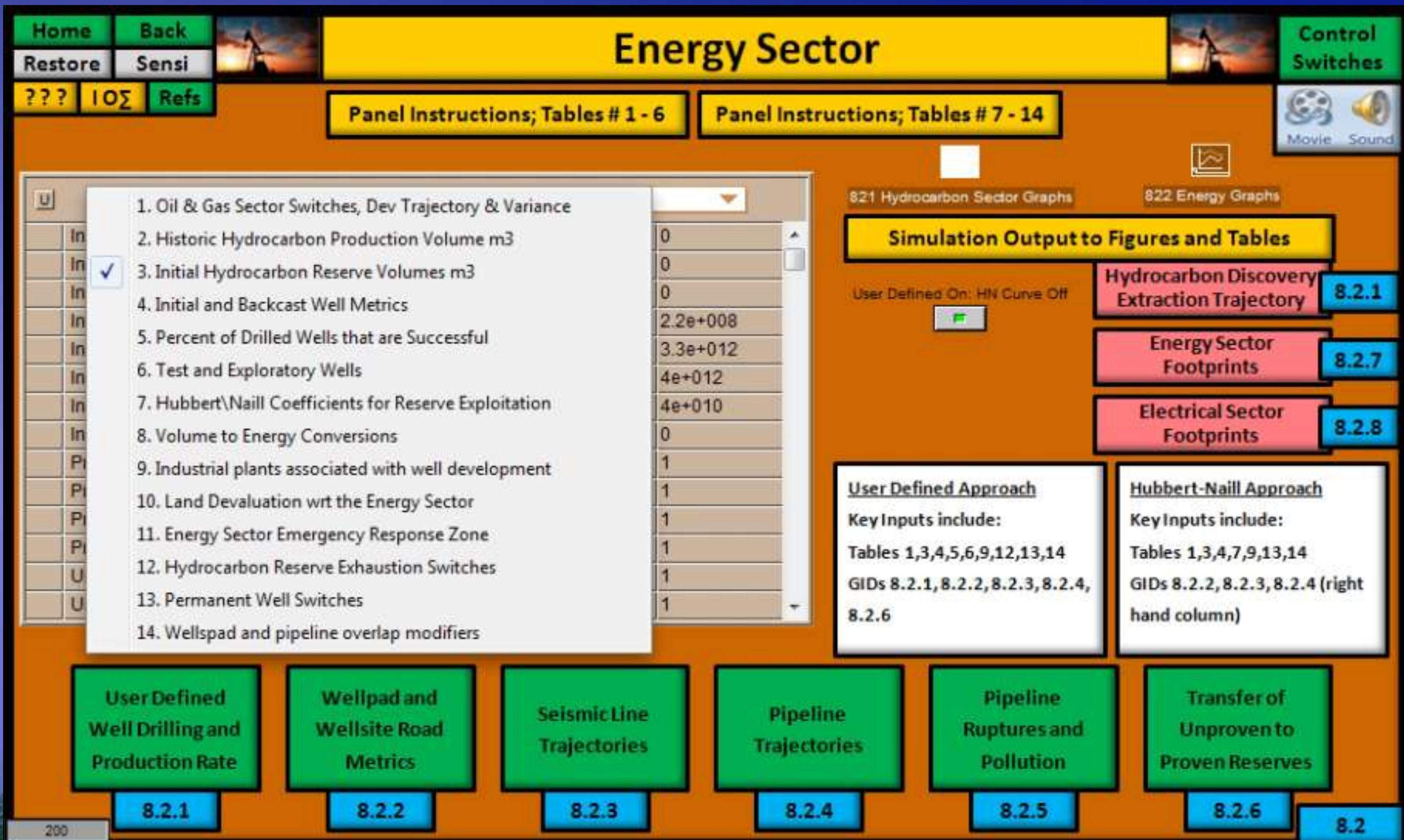


Simulation results from the CVRD ALCES Model are based on preliminary input coefficients.

Meteorology



Simulation results from the CVRD ALCES Model are based on preliminary input coefficients.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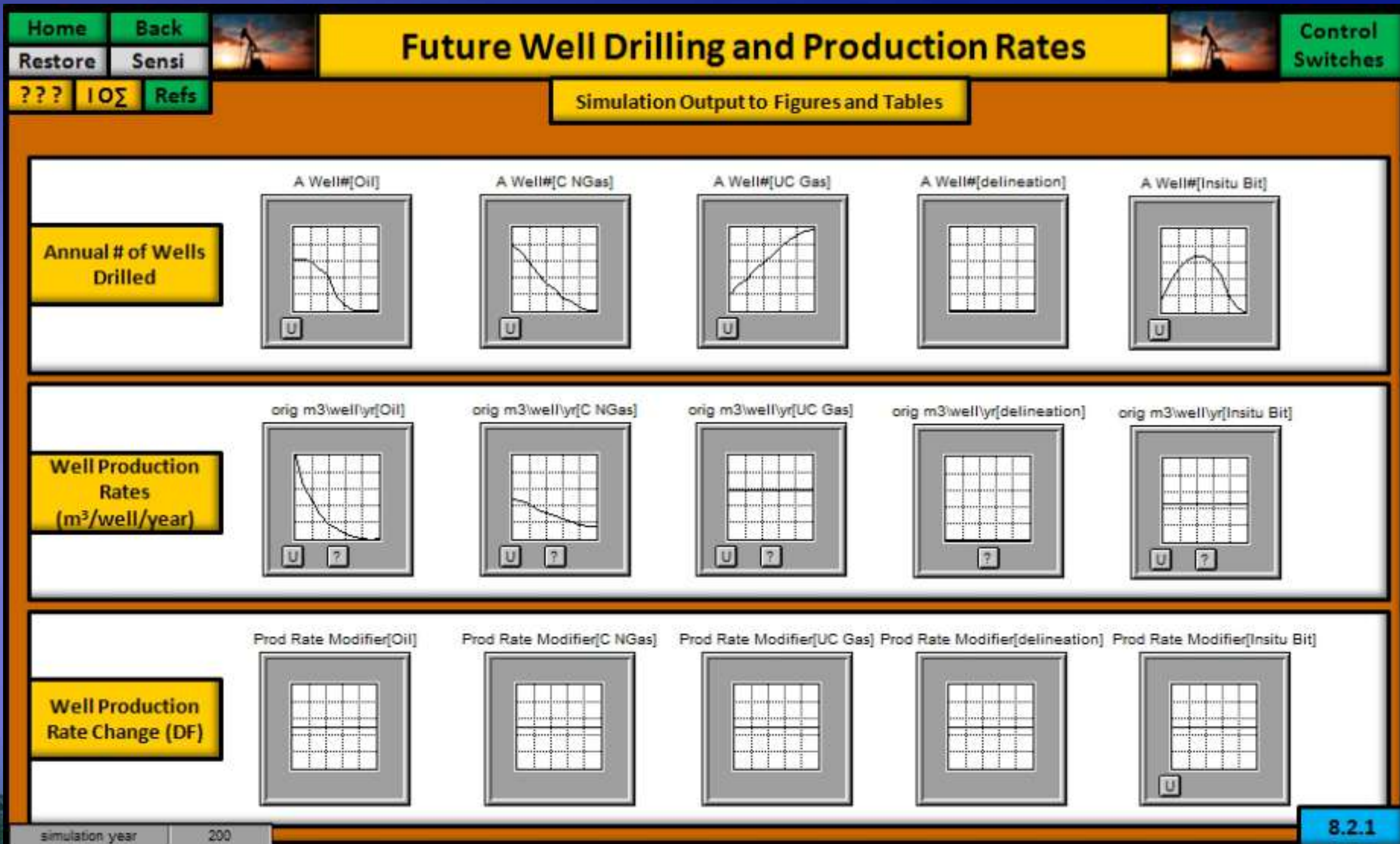
? ? ?
IOΣ
Refs
Energy Sector
Control Switches
Panel Instructions; Tables # 1 - 6
Panel Instructions; Tables # 7 - 14
Movie
Sound
821 Hydrocarbon Sector Graphs
822 Energy Graphs
1. Oil & Gas Sector Switches, Dev Trajectory & Variance
2. Historic Hydrocarbon Production Volume m3
3. Initial Hydrocarbon Reserve Volumes m3
4. Initial and Backcast Well Metrics
5. Percent of Drilled Wells that are Successful
6. Test and Exploratory Wells
7. Hubbert\Naill Coefficients for Reserve Exploitation
8. Volume to Energy Conversions
9. Industrial plants associated with well development
10. Land Devaluation wrt the Energy Sector
11. Energy Sector Emergency Response Zone
12. Hydrocarbon Reserve Exhaustion Switches
13. Permanent Well Switches
14. Wellspad and pipeline overlap modifiers
0
0
0
2.2e+008
3.3e+012
4e+012
4e+010
0
1
1
1
1
1
1
Simulation Output to Figures and Tables
User Defined On: HN Curve Off
Hydrocarbon Discovery Extraction Trajectory
8.2.1
Energy Sector Footprints
8.2.7
Electrical Sector Footprints
8.2.8
User Defined Approach
Key Inputs include:
Tables 1,3,4,5,6,9,12,13,14
GIDs 8.2.1, 8.2.2, 8.2.3, 8.2.4, 8.2.6
Hubbert-Naill Approach
Key Inputs include:
Tables 1,3,4,7,9,13,14
GIDs 8.2.2, 8.2.3, 8.2.4 (right hand column)
User Defined Well Drilling and Production Rate
8.2.1
Wellpad and Wellsite Road Metrics
8.2.2
Seismic Line Trajectories
8.2.3
Pipeline Trajectories
8.2.4
Pipeline Ruptures and Pollution
8.2.5
Transfer of Unproven to Proven Reserves
8.2.6
8.2
200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? ? ?
I O Σ
Refs
Future Well Drilling and Production Rates
Control Switches
Simulation Output to Figures and Tables
Annual # of Wells Drilled
A Well#[Oil]
A Well#[C NGas]
A Well#[UC Gas]
A Well#[delineation]
A Well#[Insitu Bit]
Well Production Rates (m³/well/year)
orig m3\well\yr[Oil]
orig m3\well\yr[C NGas]
orig m3\well\yr[UC Gas]
orig m3\well\yr[delineation]
orig m3\well\yr[Insitu Bit]
Well Production Rate Change (DF)
Prod Rate Modifier[Oil]
Prod Rate Modifier[C NGas]
Prod Rate Modifier[UC Gas]
Prod Rate Modifier[delineation]
Prod Rate Modifier[Insitu Bit]
simulation year
200
8.2.1

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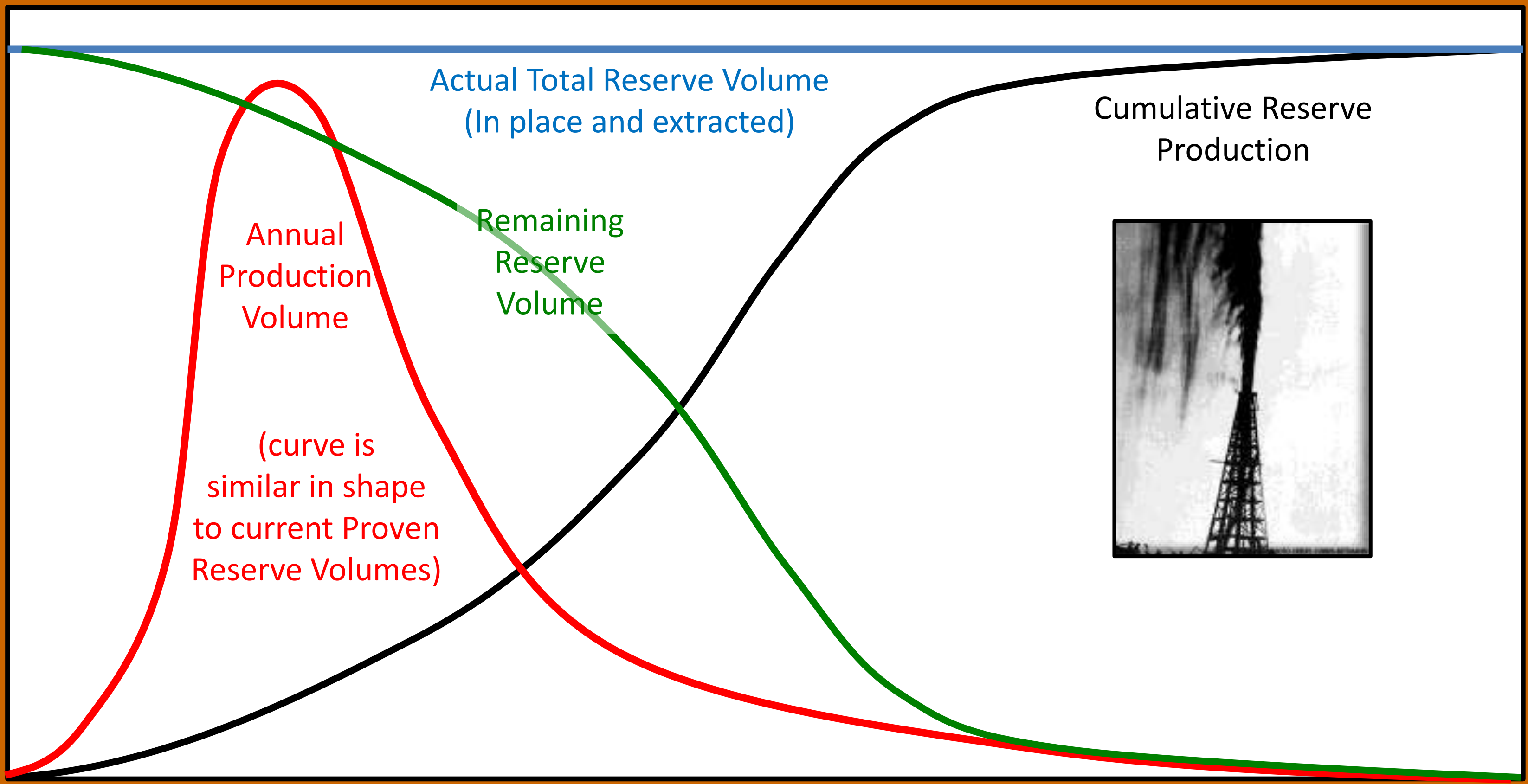
Generalized Hydrocarbon Discovery and Extraction Trajectory

Control Switches

m³

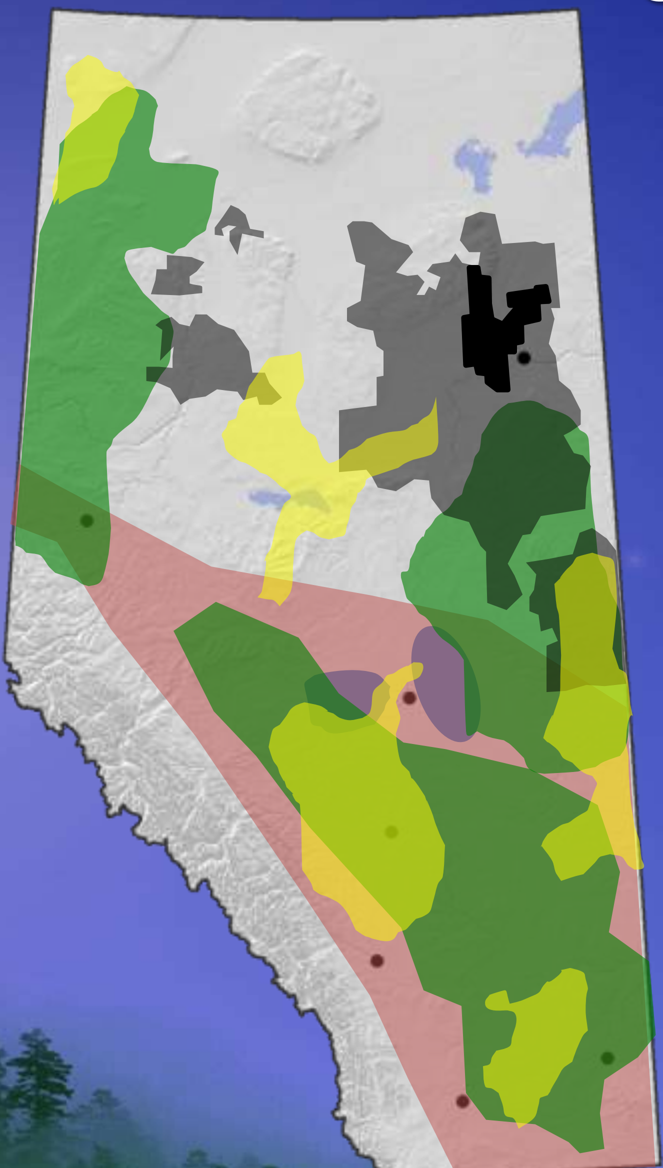
Annual Production not scaled to other variables



Time

8.2.5

An Example of Spatial Stratification of Future Hydrocarbon Growth Regions



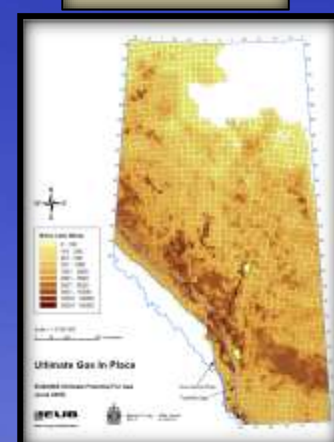
- Growth Area for Conv Oil
- Growth Area for Conv Gas
- Growth Area for Surf Bitumen
- Growth Area for Insitu Bitumen
- Growth Area for Coal Mining
- Growth Area for Unconv Gas (CBM, tight, shale)

Deep Gas and CBM Gas

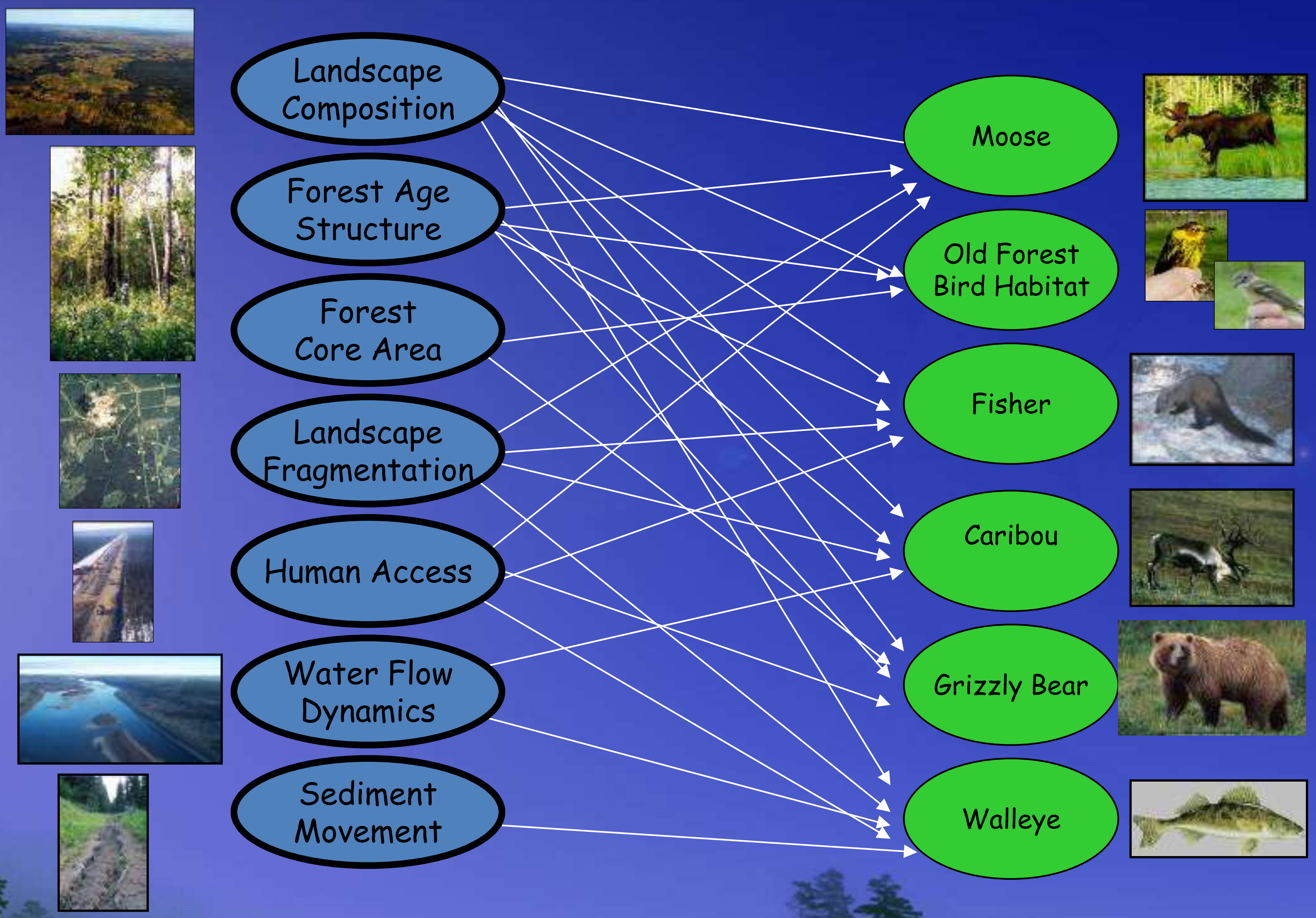
Oilsands and Oil

Unconventional Gas

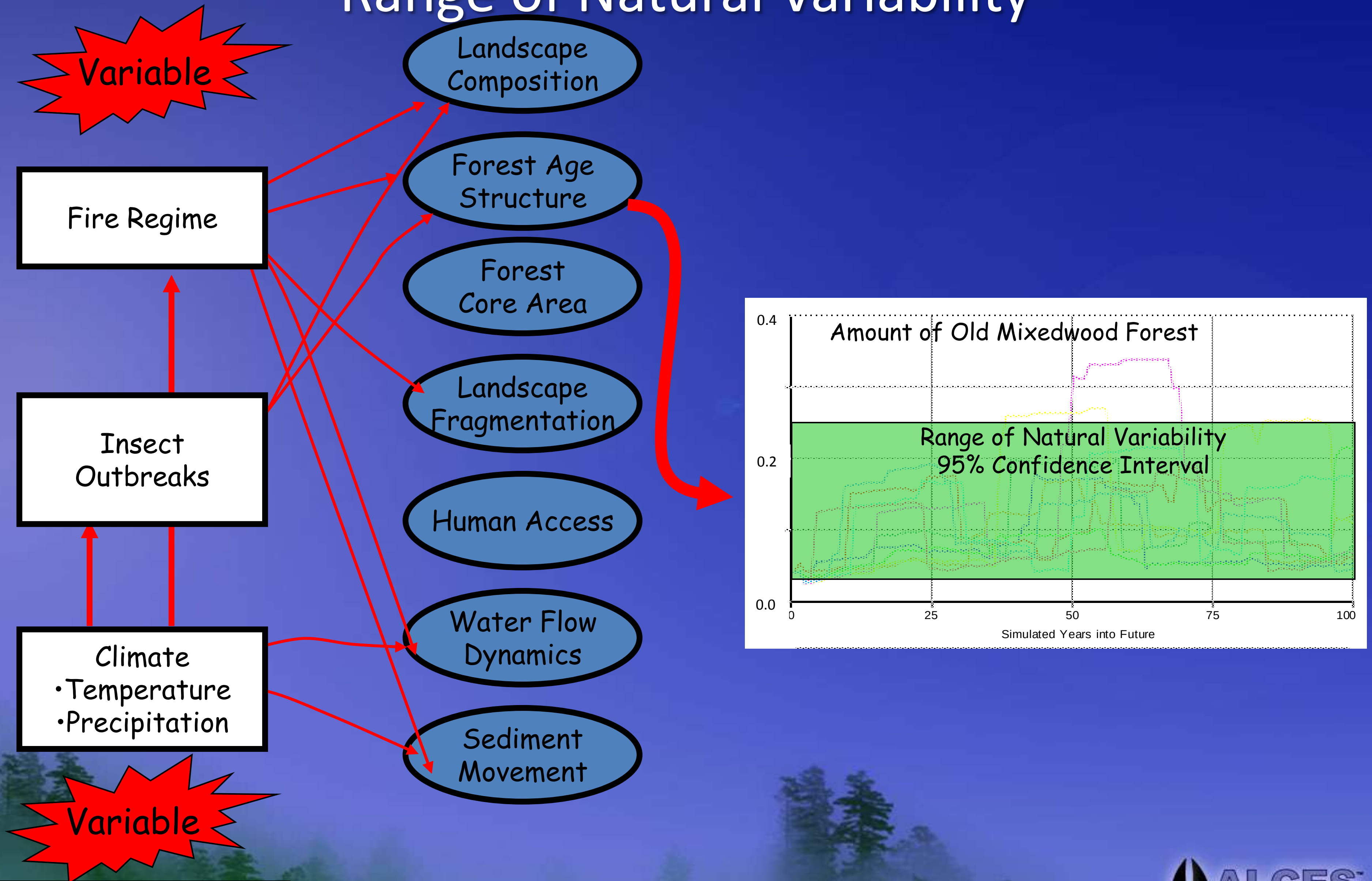
Remaining Gas Reserves



Ecological indicators and key ecosystem drivers

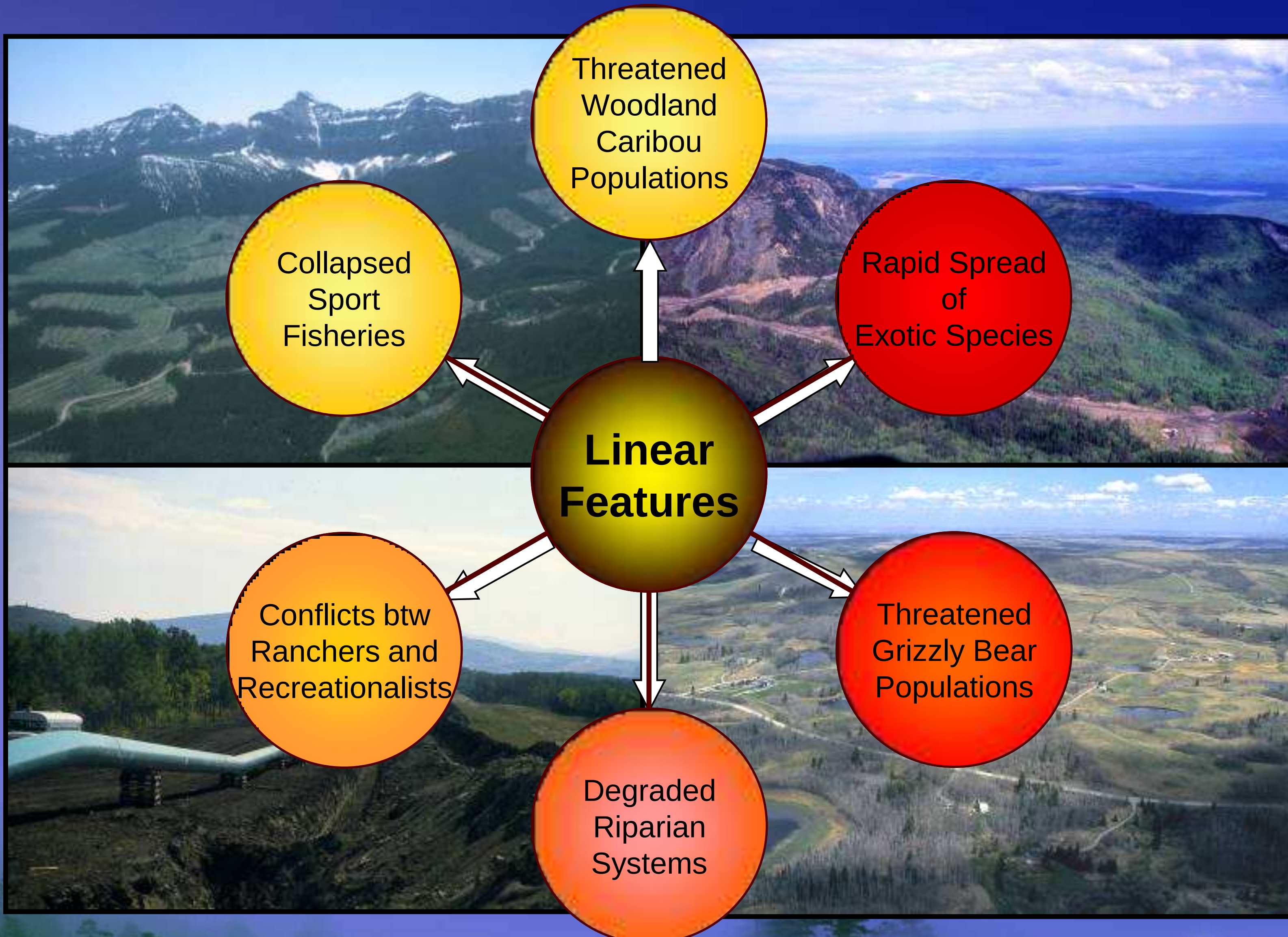


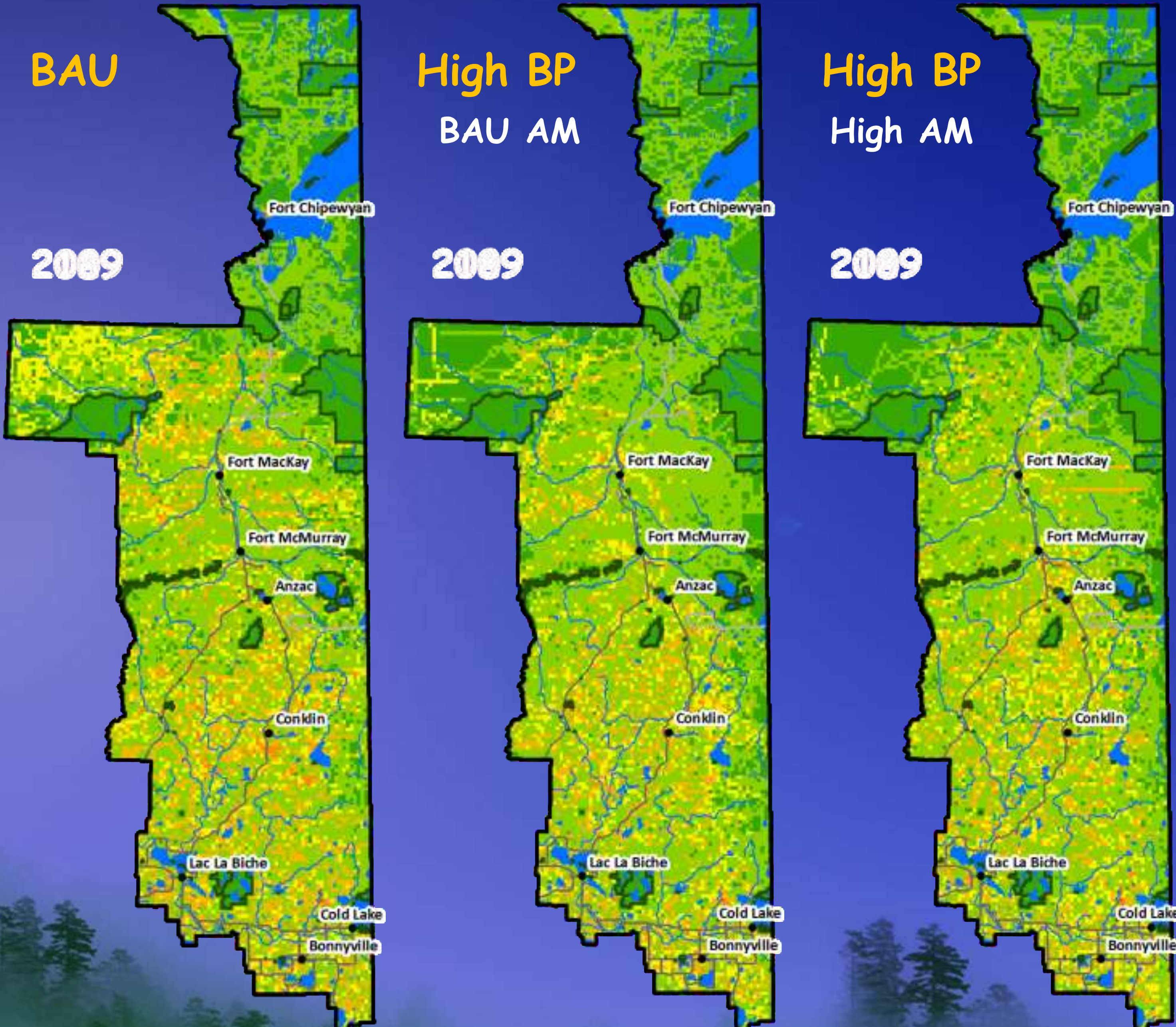
Ecological Drivers, Disturbance Regimes, & "Range of Natural Variability"



Linear Features and Access Management

A Common Thread





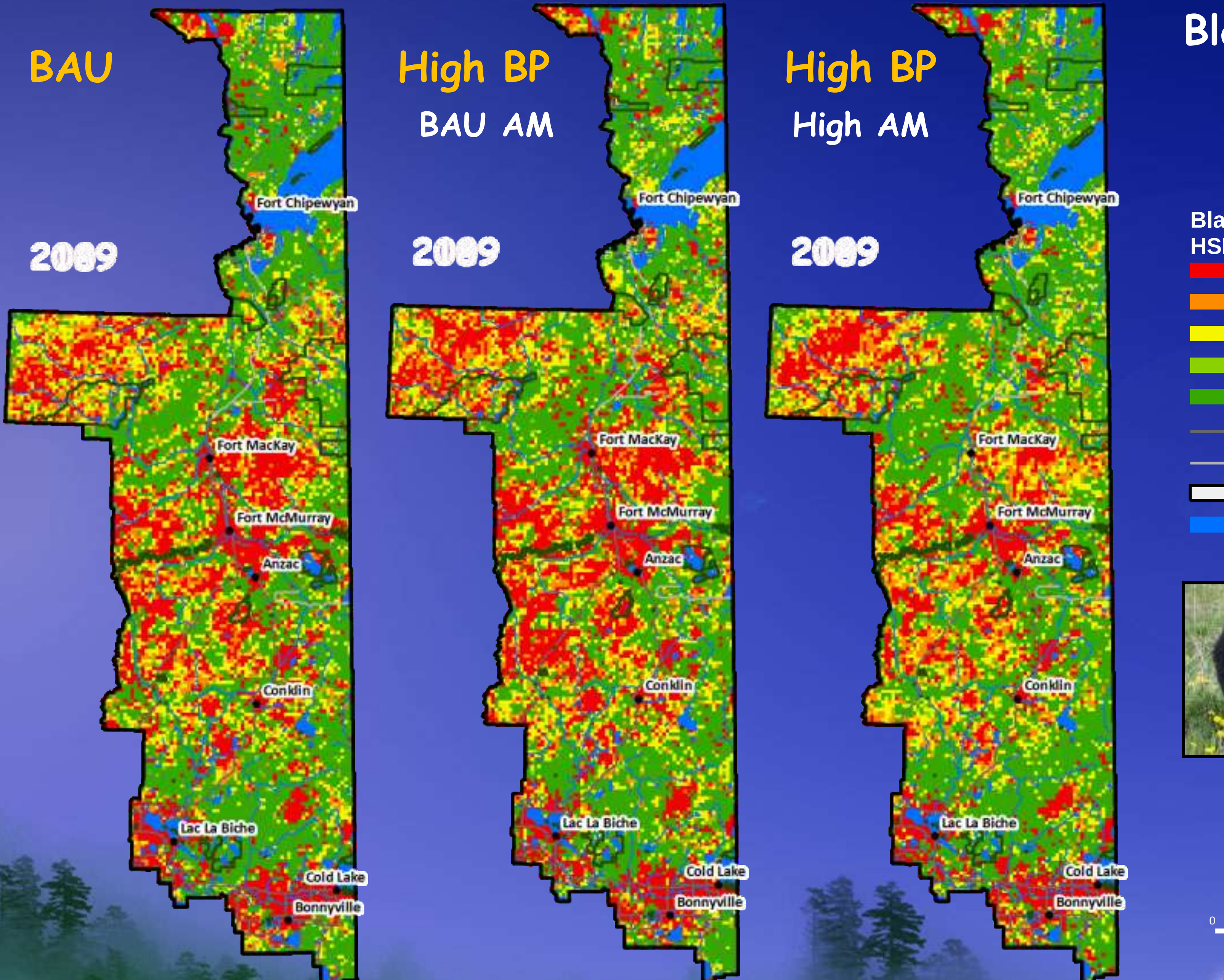
Linear Edge Density (km/km^2)

Linear Edge Density (km/km^2)

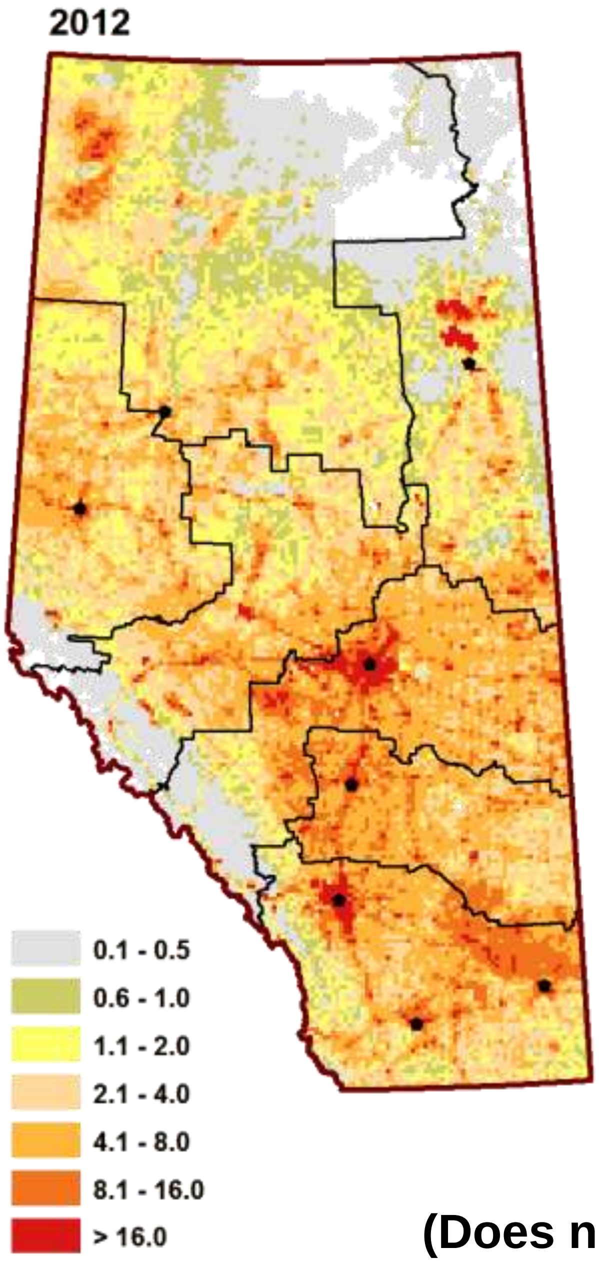
- 0
- 0 - 1.0
- 1.1 - 2.0
- 2.1 - 3.0
- 3.1 - 4.0
- 4.1 - 5.0
- >5.0
- Highway
- Winter road
- Protected area
- Hydrography

0 25 50 100
Kilometres

Black Bear HSI



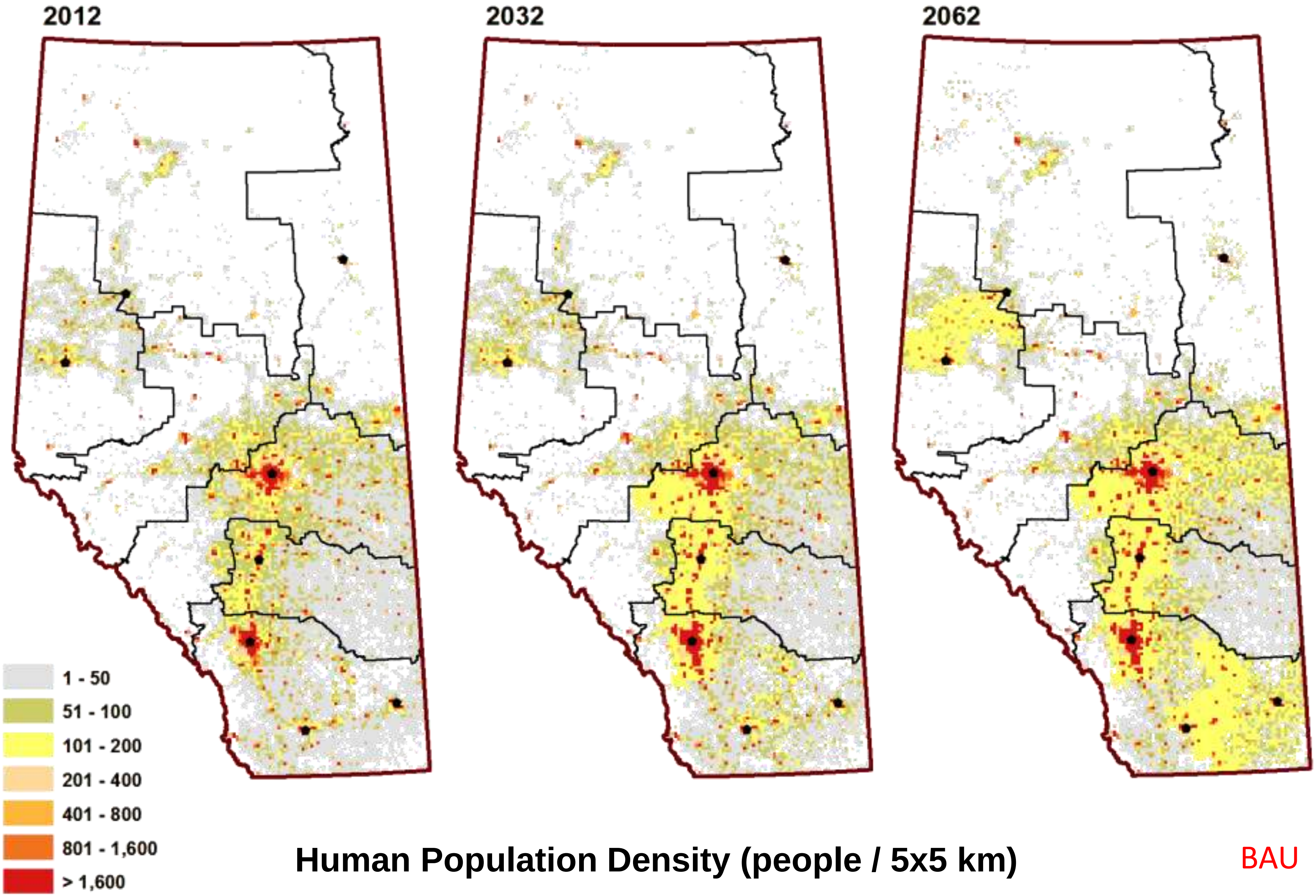
Black Bear HSI
- High Risk
- Moderate Risk
- Low Risk
- Stable
- RNV
- Highway
- Winter road
- Protected area
- Hydrography



Direct Footprint (%)
(Does not include Agriculture or Cutblocks)

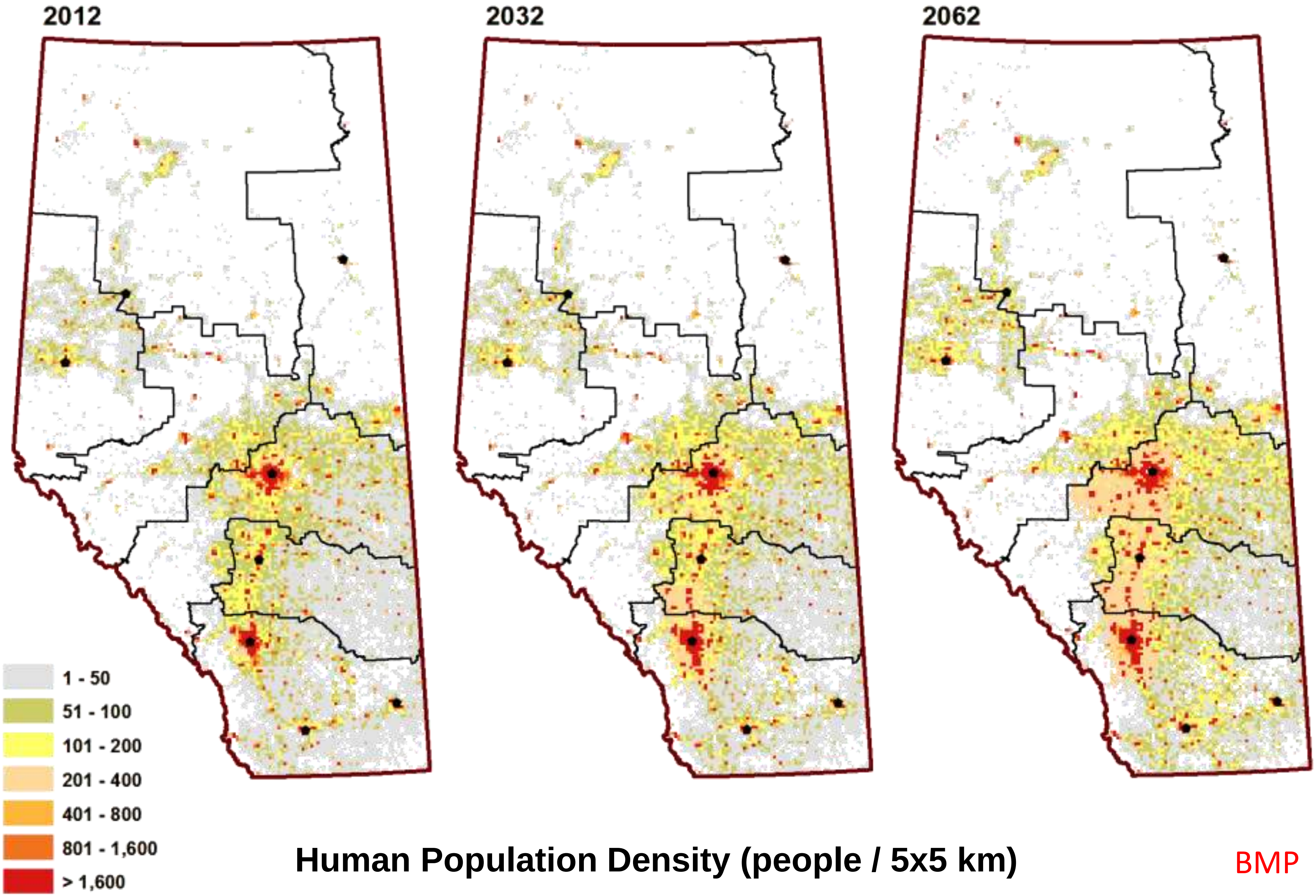
BAU

Central Modelling Office (CMO)



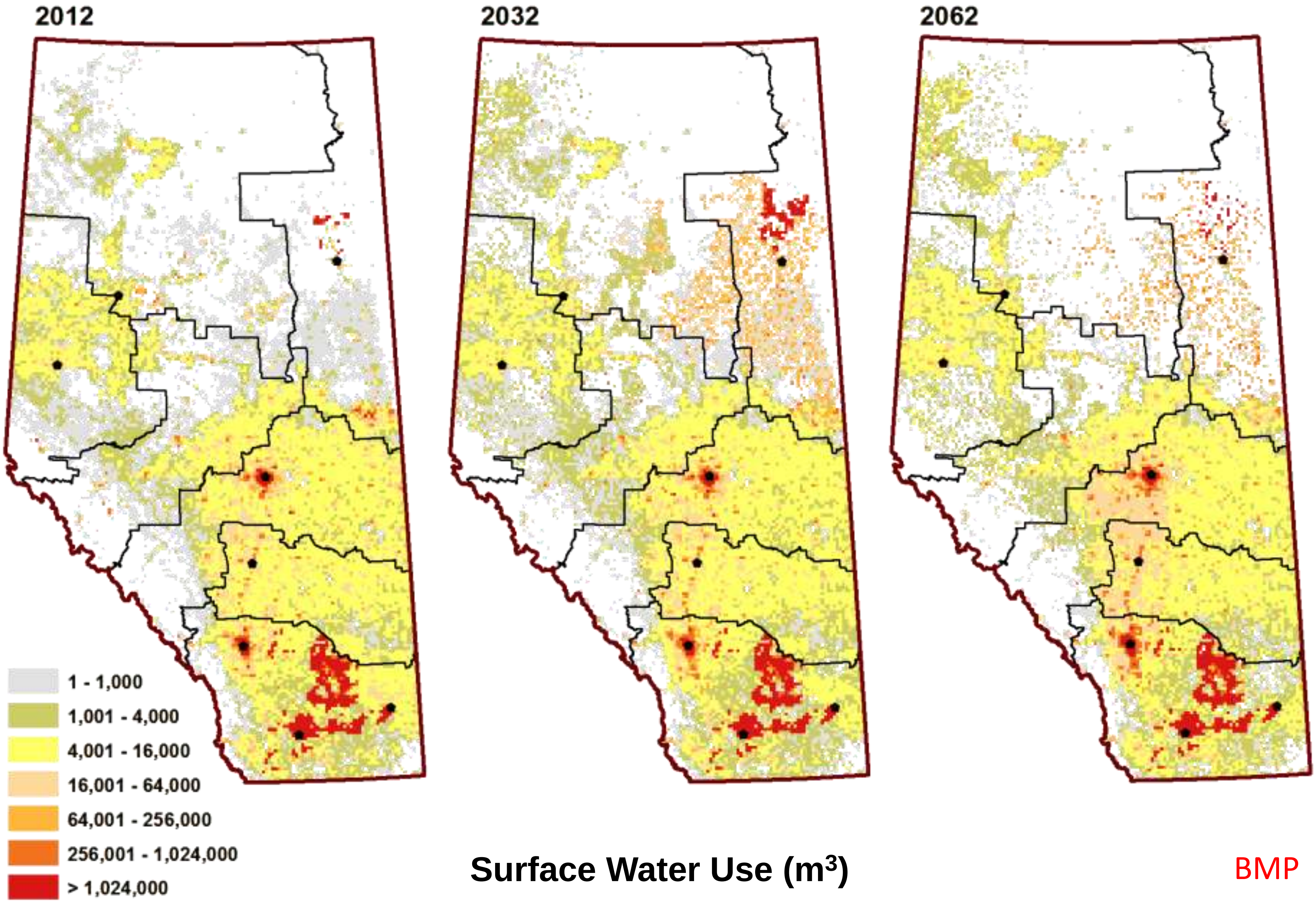
Human Population Density (people / 5x5 km)

BAU



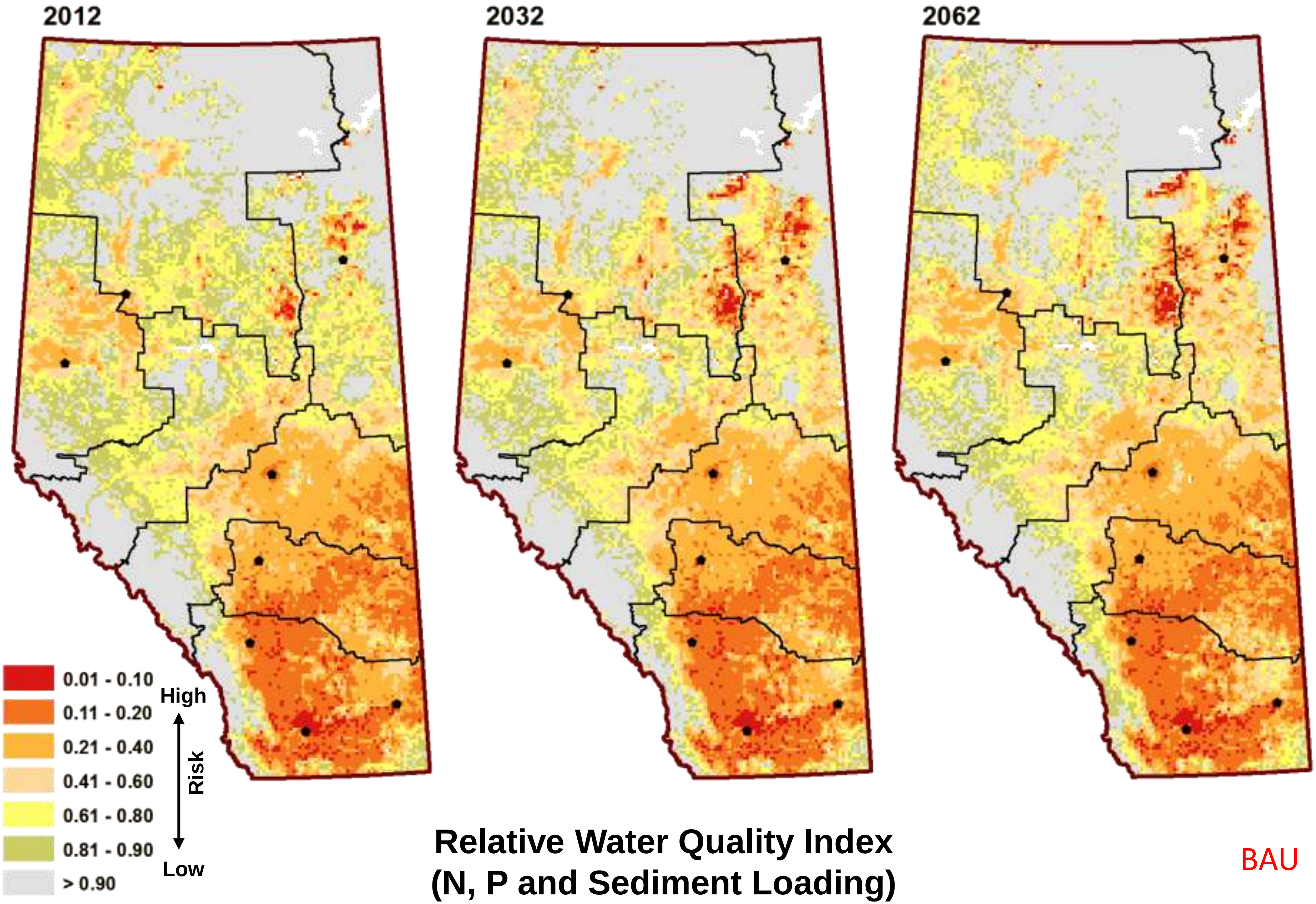
Human Population Density (people / 5x5 km)

BMP



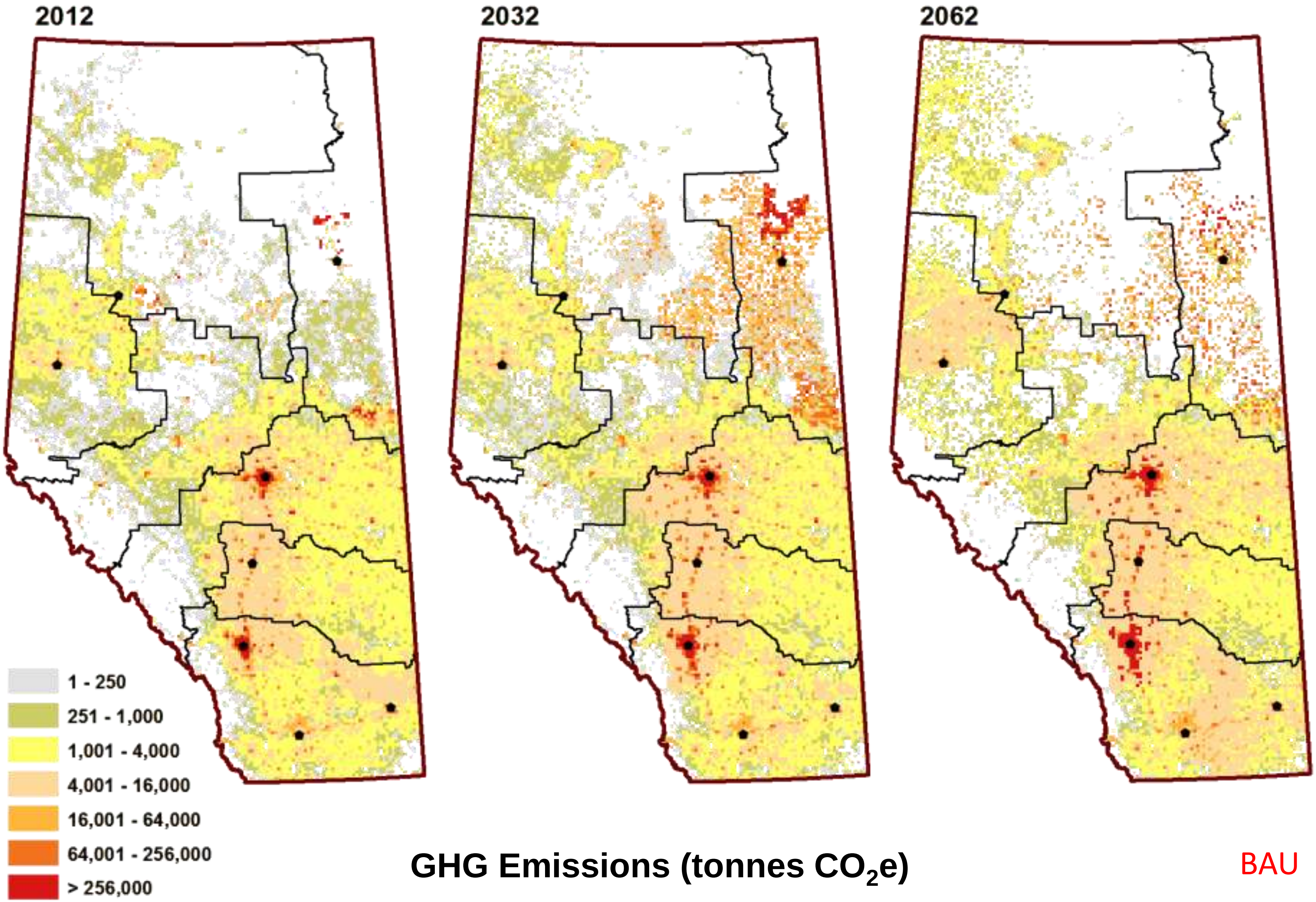
Surface Water Use (m^3)

BMP



Relative Water Quality Index
(N, P and Sediment Loading)

BAU

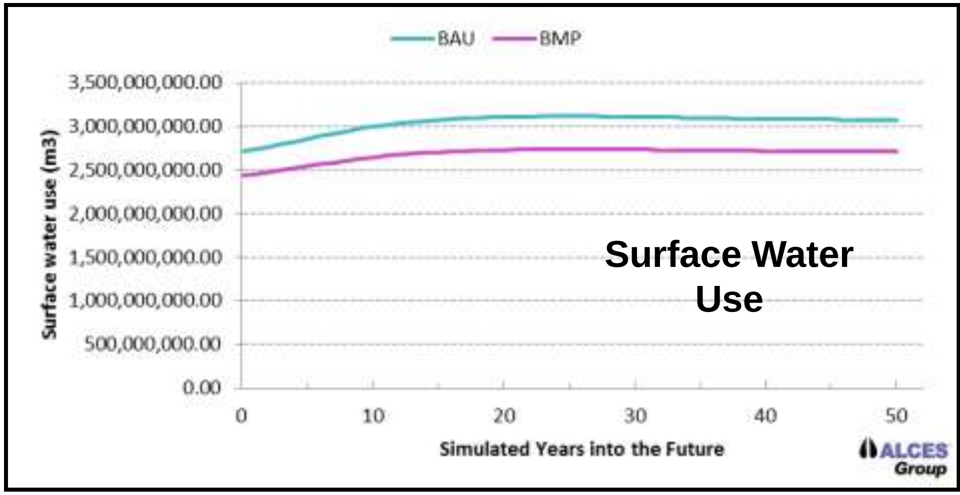


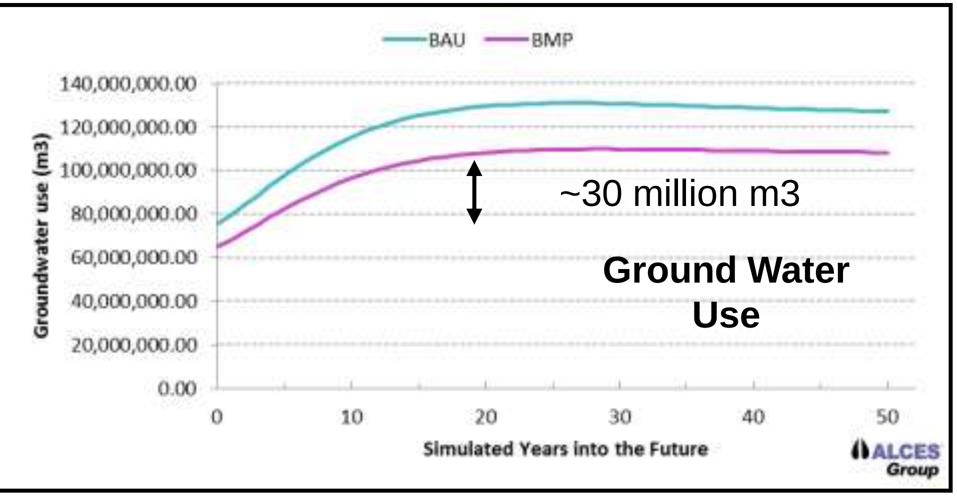
GHG Emissions (tonnes CO_2e)

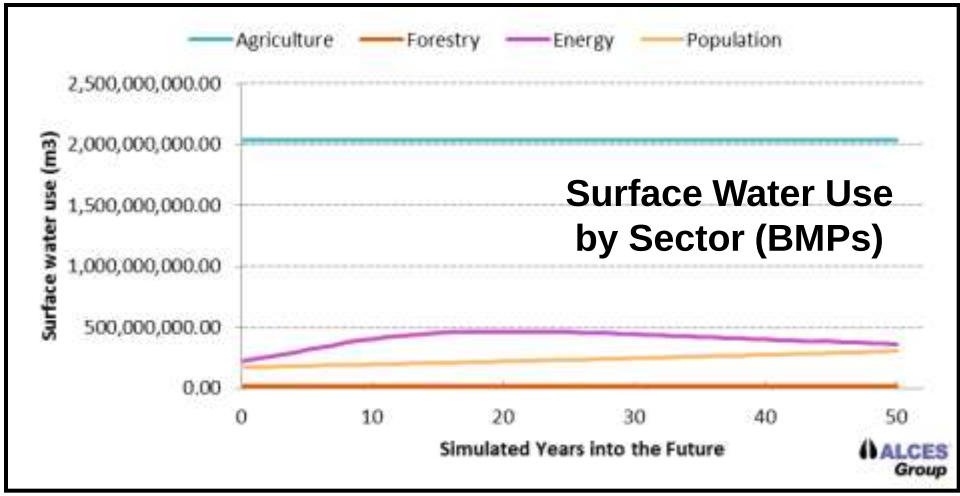
BAU

Environmental Future

- **Water Demand Best Practices**
  - More efficient water use
  - Result:
    - Increases still required in many regions







Relating Management Strategies to Inputs and Outputs

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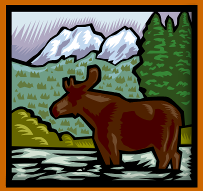
Input and Output Rates

Control Switches







Types	Landscapes/Footprints	Commodities	Human Populations	Livestock	Fish & Wildlife
Units	(ha)	(m^3)	(Individuals)	(Individuals)	(Individuals)

Input Rates

Landscapes/Footprints:
- Fuel (m3/ha/yr)
- Electricity (kHz/ha/yr
- Direct Labor (FTE/ha/yr)
- Indirect Labor (FTE/ha/yr)
- Natural Gas (m3/ha/yr)
- Water (m3/ha/yr)
- Nitrogen (tonne/ha/yr)
- Phosphorus (tonne/ha/yr)
- Herbicide (tonne/ha/yr)
- Insecticide (tonne/ha/yr)
- Manure Applications (tonne/ha/yr)
- Infrastructure Construction ($/ha/yr)
- Infrastructure Maintenance ($/ha/yr)

Commodities:
- Fuel (m3/m3/yr)
- Electricity (kHz/m3/yr
- Direct Labor (FTE/m3/yr)
- Indirect Labor (FTE/m3/yr)
- Natural Gas (m3/m3/yr)
- Water (m3/m3/yr)
- Operating Costs ($/m3/yr)

Human Populations:
- Fuel (m3/ind/yr)
- Electricity (kHz/ind/yr
- Direct Labor (FTE/ind/yr)
- Indirect Labor (FTE/ind/yr)
- Natural Gas (m3/ind/yr)
- Water (m3/ind/yr)
- Exercise (Calorie/ind/yr)

Livestock:
- Fuel (m3/ind/yr)
- Electricity (kHz/ind/yr
- Direct Labor (FTE/ind/yr)
- Indirect Labor (FTE/ind/yr)
- Natural Gas (m3/ind/yr)
- Water (m3/ind/yr)
- Nitrogen (tonne/ind/yr)
- Forage (tonne/ind/yr)
- Operating Costs ($/ind/yr)

Fish & Wildlife:
- Fuel (m3/ind/yr)
- Electricity (kHz/ind/yr
- Direct Labor (FTE/ind/yr)
- Indirect Labor (FTE/ind/yr)
- Natural Gas (m3/ind/yr)
- Water (m3/ind/yr)
- Nitrogen (tonne/ind/yr)
- Forage (tonne/ind/yr)
- Operating Costs ($/ind/yr)

Output

Landscapes/Footprints:
- Crop Production (m3/yr)
- Nitrogen Runoff (tonne/yr)
- Phosphorus Runoff (tonne/yr)
- Sediment Runoff (tonne/yr)
- Manure Production (tonne/yr)
- Direct Labor (FTE/yr)
- Indirect Labor (FTE/yr)
- Royalties ($/yr)
- Carbon Fixation (tonne/yr)
- Waste Water (m3/yr)
- Fuel Consumption (m3/yr)
- Greenhouse Gas Emission (Co2e/yr)
- Infrastructure Costs ($/yr)

Commodities:
- Conventional Oil (m3/yr)
- Natural Gas (m3/yr)
- Oilsand (m3/yr)
- Ore (m3/yr)
- Carbon Emissions (tonne/yr)
- Waste Water Emission (m3/yr)
- Sulfur Emission (tonne/yr)
- Acid Emission (tonne/yr)
- Direct Labor (FTE/yr)
- Indirect Labor (FTE/yr)
- Royalties ($)
- Electricity (kHz\yr)

Human Populations:
- Carbon Emissions (tonne//yr)
- Human Waste (tonne/yr)
- Water Consumption (m3/yr)
- Waste Water (m3//yr)
- Garbage (tonne/yr)
- Direct Labor (FTE/yr)
- Indirect Labor (FTE/yr)
- Anthro Footprint (ha/yr)
- Exercise (calories/yr)

Livestock:
- Methane Emissions (m3/yr)
- Manure Waste (tonne/yr)
- Waste Water (m3/yr)
- Meat Production (tonne/yr)
- Milk Production (tonne/yr)
- Direct Labor (FTE/yr)
- Indirect Labor (FTE/yr)
- Electricity (kHz\yr)

Fish & Wildlife:
- Methane Emissions (m3/yr)
- Manure Waste (tonne/yr)
- Waste Water (m3/yr)
- Meat Production (tonne/yr)
- Sport Harvest (tonne/yr)
- Aboriginal Harvest (tonne/yr)
- Direct Labor (FTE/yr)
- Indirect Labor (FTE/yr)

8.15.5

Energy Sector

Historical, Current and Future Alberta tracked in 27,200 cells that are each 5 x 5 km

Cost of Footprint:
- Construction
- Maintenance
- Reclamation

Inputs (amount, cost):
- Labour
- Fuel
- Materials
- Water

5 km

5 km

Outputs
- Commodity
- Revenue
- Royalties
- GDP
- Emissions

Landscapes
- Area
- Edge
- Forest Age
- Fragmentation
- Core Area

ALCES

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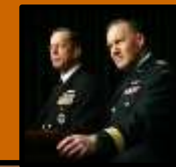
Multiple Demands and Domains






Energy Analyst | Economist | Mining Analyst | Ecologist | Soils Scientist | Military | Cropland Specialist

Hydrologist

What modeling architecture (structure, resolution, scale, integration) best communicates issues and opportunities for Alberta

Sociologist

Forester | Urban Planner | First Nations | Climate Scientist | Fire Ecologist | Transport Engineer | Ranching Specialist







4.05

end

Day 2 – Session 4

Patrick Delaney - DHI

BIOGRAPHY

Mr. Delaney is President of DHI Canada and is involved in all aspects of DHI's business including consulting services, software sales, technical support and training. Mr. Delaney manages consulting projects related to collection system modelling, integrated water resources management, river system flooding, and groundwater modelling. He has more than 15 years of experience in the development and application of water modelling tools and technologies for a variety of disciplines, and he has considerable experience in managing complex, inter-disciplinary water management projects. Mr. Delaney combines his technical expertise with a very practical approach to problem solving and the ability to communicate technical concepts in a clear and understandable language. He has led many professional training classes for groundwater modelling, integrated watershed modelling, urban flood modelling and river system flooding, and he has advised many clients working on local, regional, national, and international projects.

Day 2 – Session 4

Patrick Delaney - DHI

ABSTRACT

MIKE SHE is one of the only commercially available and widely-used integrated surface water/groundwater modelling tools available. MIKE SHE includes process models for overland flow, vegetation-based evapotranspiration, unsaturated flow, groundwater flow, and fully dynamic channel flow. It is a modular modelling system that includes both simple and advanced process models. This allows you to solve problems across the full hydrologic spectrum - i.e. from detailed wetland studies to basin-wide water resource management studies. This presentation will provide an overview of the integrated modelling approach and capabilities of MIKE SHE as well as highlighting some recent improvements that provide more support for cold-climate hydrology and some on-going research with the University of Calgary to integrate dynamic land-use planning considerations.

Opportunities and Challenges of Integrated Watershed Hydrology Modeling

Presented by
Patrick Delaney
President, DHI Canada

What is DHI?

- DHI is an independent, self-governing research and consultancy organisation (non-profit)
- DHI builds competence and promotes technological development relevant to the water and the environment
- DHI has ongoing activities world-wide
- DHI has a total staff of over 1100

MIKE by DHI SOFTWARE PRODUCTS

A Quick Review of the Land Use Framework

- The LUF is intended to bring about fundamental changes to the way that the Government of Alberta makes decisions about land and resource use.
- LUF "will provide a vision for land use in Alberta and the overall direction needed to manage growth and activities on Alberta's landscape.“
- "Cumulative effects management will be the instrument used at the regional level to manage the impacts of development on land, water and air.“
- LUF will provide the basis to identify appropriate limits for different types of development at regional levels and where appropriate at local levels

A Quick Review of the Land Use Framework

makes decisions

manage growth and activities

manage the impacts

identify appropriate limits

Environmental Modelling will play a critical role in the LUF process!

Environmental Modelling

Air

Water

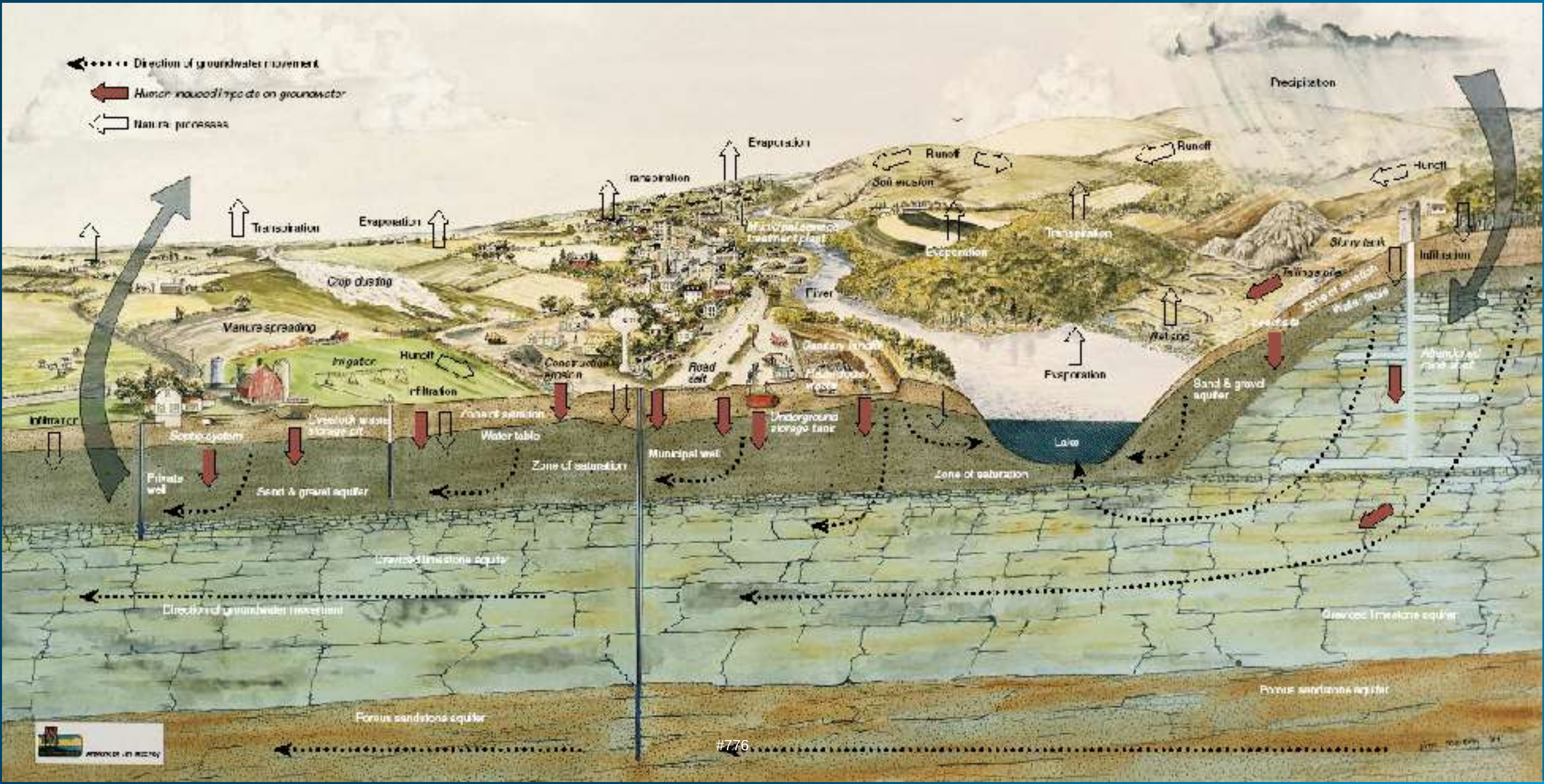
Land

Biodiversity

Environmental Modelling

Water Modelling –> Hydrologic Cycle

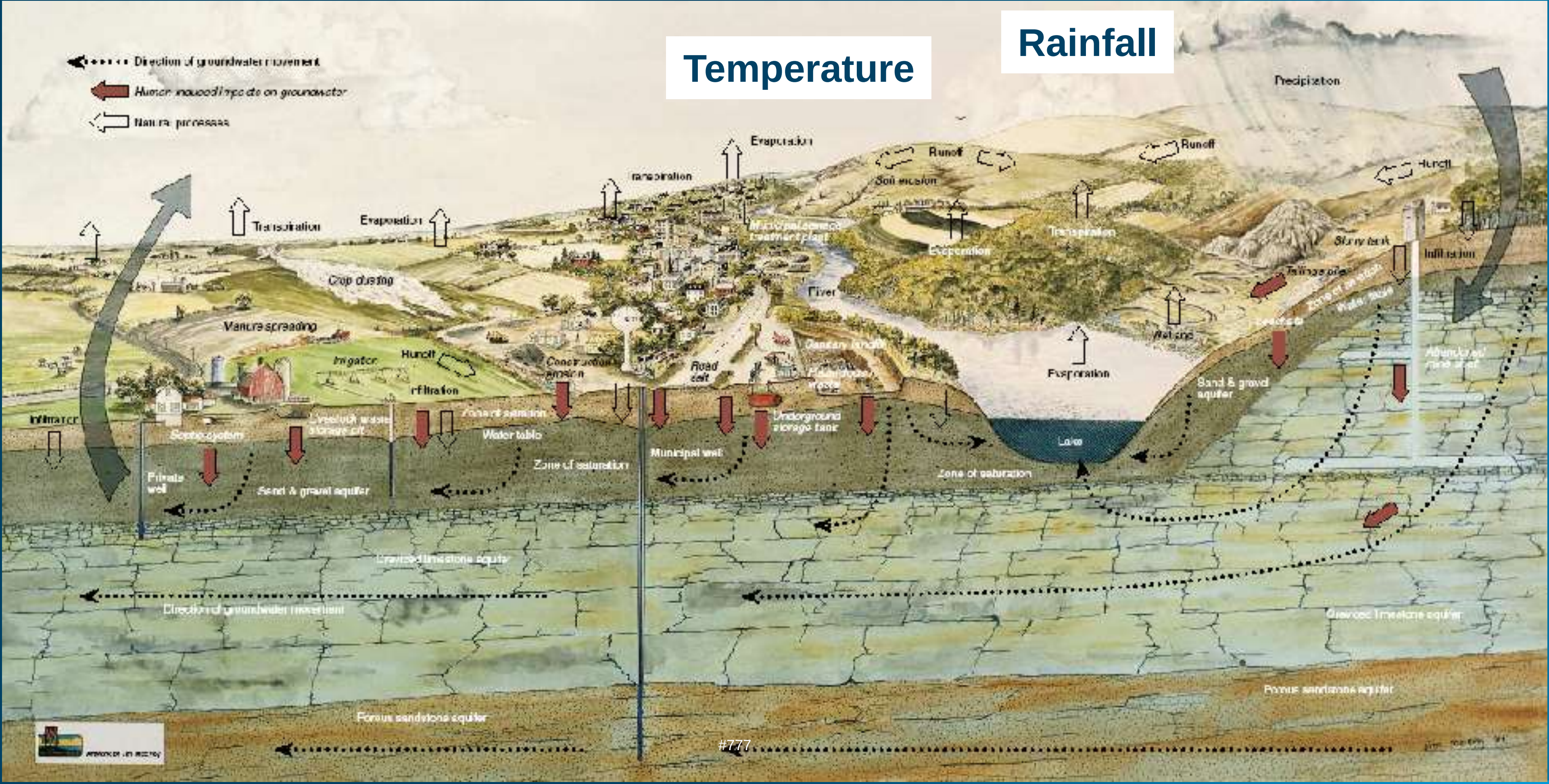
Climate, Surface Runoff, Infiltration, Evapotranspiration, Rivers, Groundwater



Environmental Modelling

Water Modelling –> Hydrologic Cycle

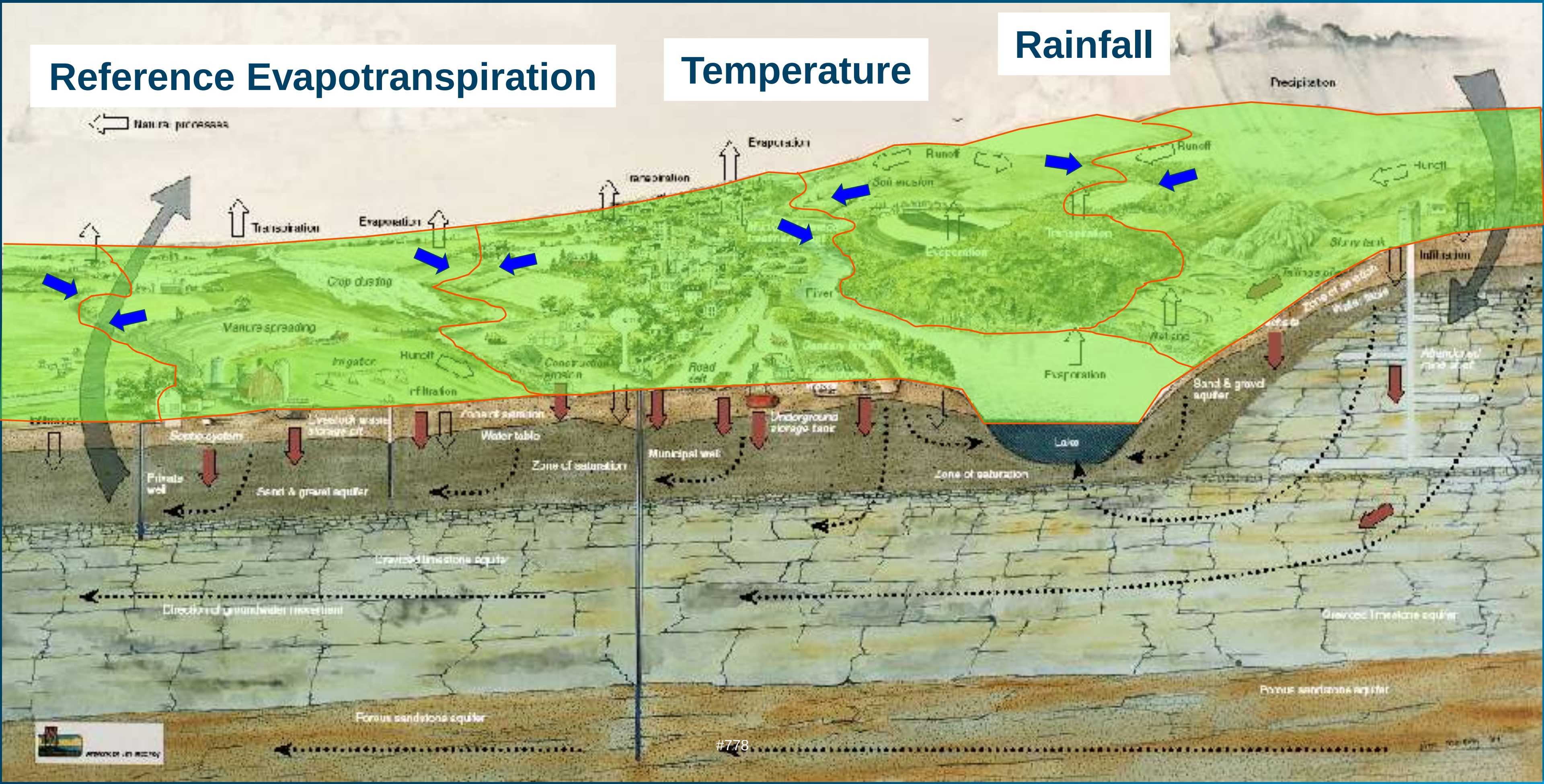
- Climate modeling - Well established models



Environmental Modelling

Water Modelling –> Hydrologic Cycle

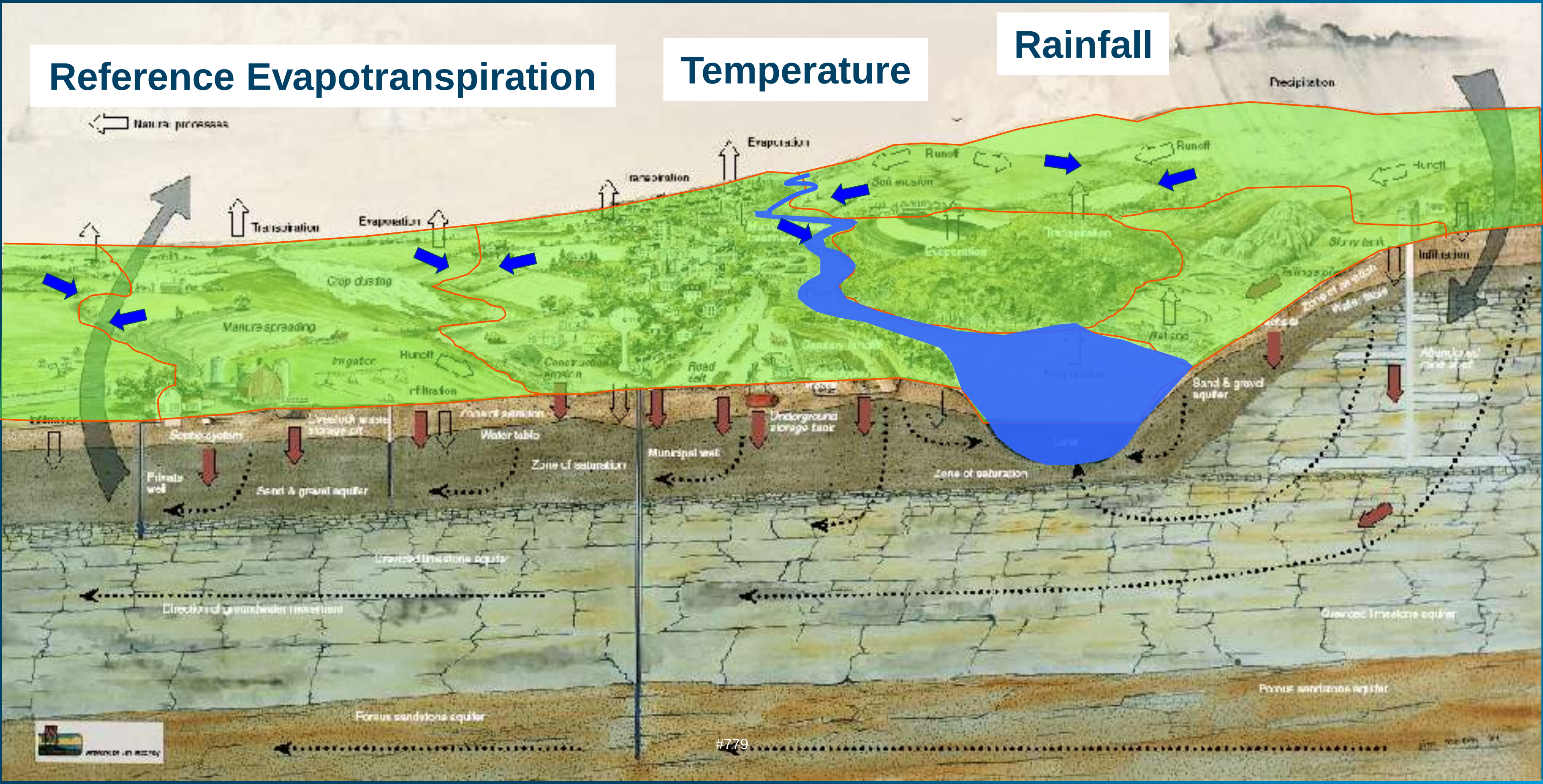
- Surface Runoff , Infiltration, Evapotranspiration - Well established models



Environmental Modelling

Water Modelling –> Hydrologic Cycle

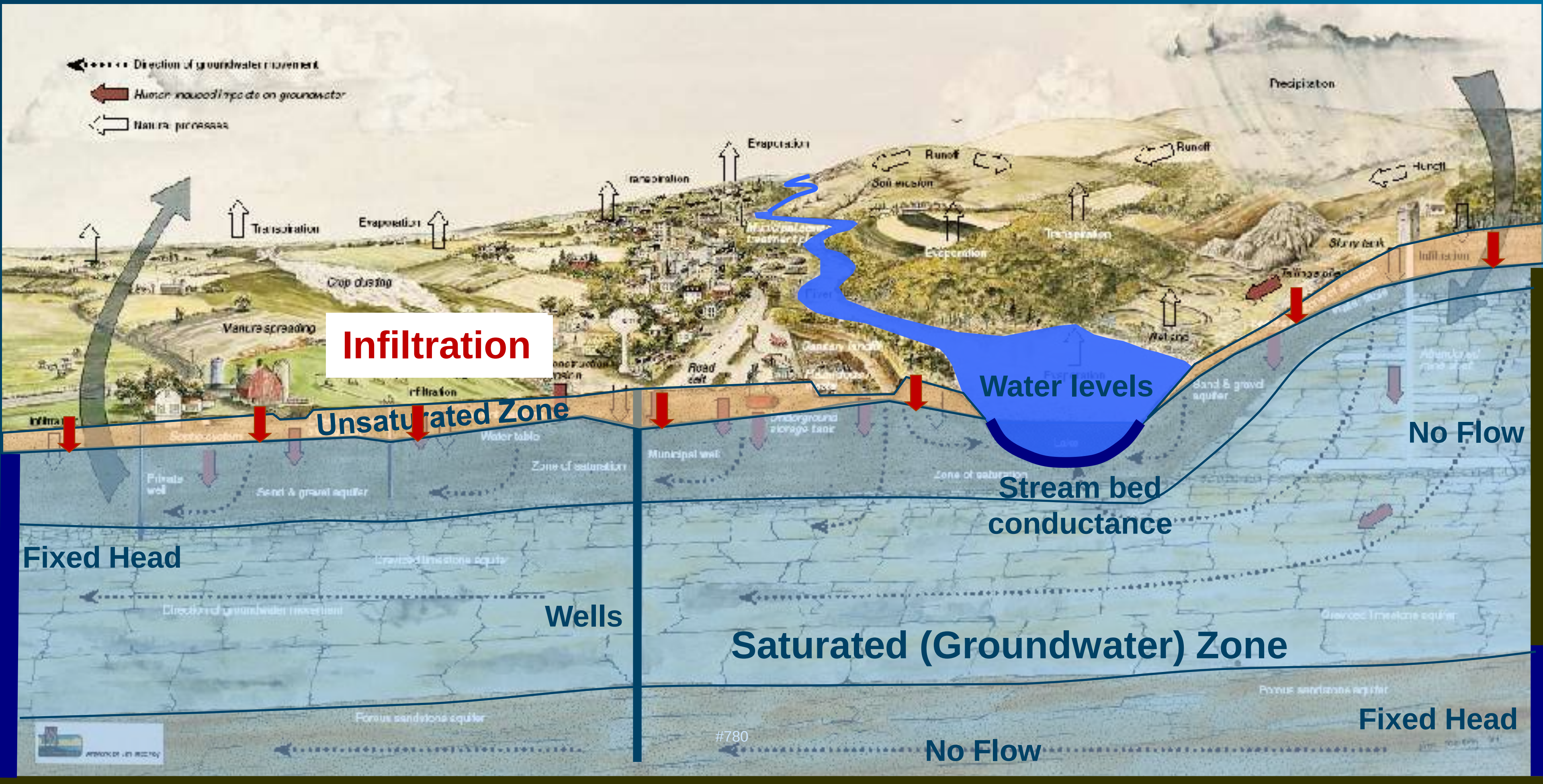
- Rivers and Lakes - Well established processes and models



Environmental Modelling

Water Modelling –> Hydrologic Cycle

- Groundwater - Well established processes and models



#780

Environmental Modelling

Success! We have all of the water models!

How do you manage Cumulative Effects?

How do you measure Cumulative Effects?

Climate model

+ Surface Runoff, Infiltration and Evapotranspiration model

+ Rivers and Lakes model

+ Groundwater model

~~= Cumulative Effects?~~

Where is the dynamic feedback?

Environmental Modelling

Why is dynamic feedback important?

Urbanization

Deforestation

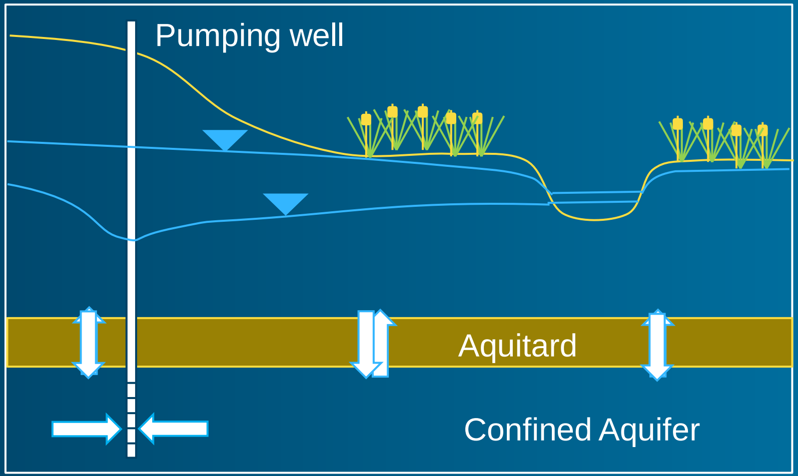
Urbanization

Increased runoff to low area

Wetland formation

Changes to vegetation and wildlife habitat

Groundwater Pumping



Install pumping well

Depressurize confined aquifer

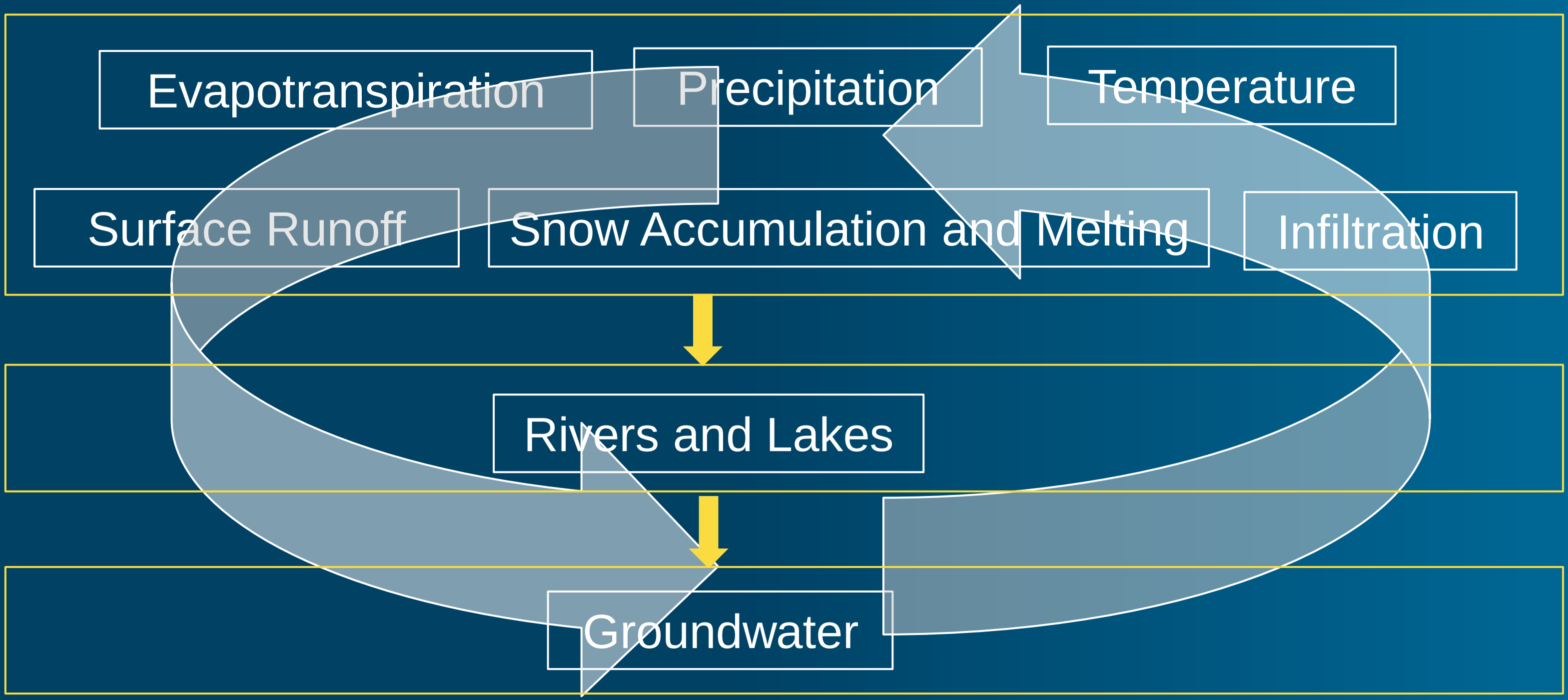
Dewater wetland and reduce baseflows to river

Changes to vegetation and aquatic habitat

Environmental Modelling

To measure and manage Cumulative Effects the models should not be run in sequence

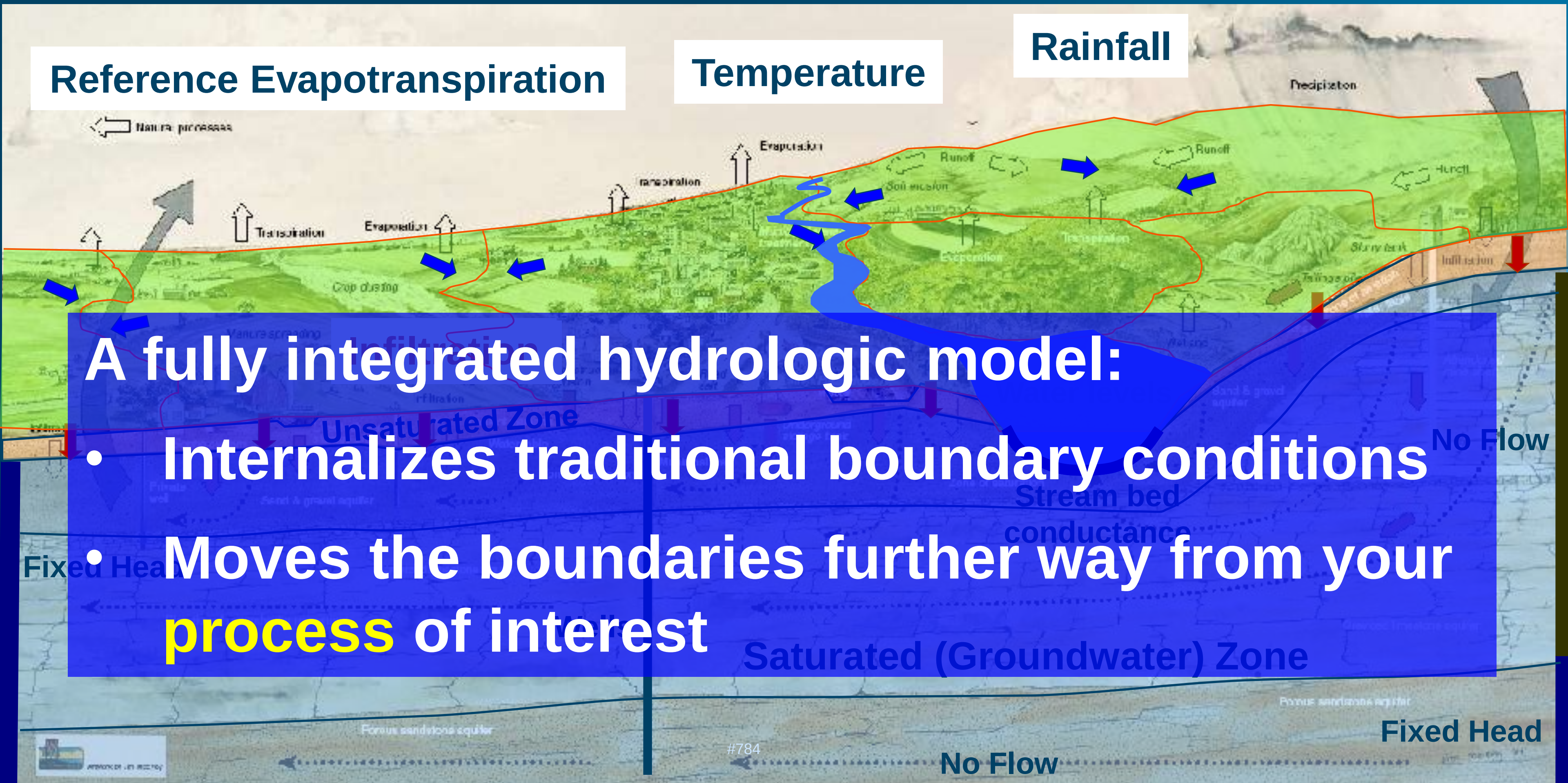
- they should be integrated



Integrated Environmental Modelling

To measure and manage Cumulative Effects the models should not be run separately

- they should be integrated together.



A fully integrated hydrologic model:

- **Internalizes traditional boundary conditions**
- **Moves the boundaries further way from your process of interest**

Integrated Environmental Modelling

Applications:

- **Wetland management**
- **Conjunctive water utilization**
- **Climate change impacts**
- **Land use change analysis**
- **Catchment nutrient balances**
- **Irrigation management**
- **Drought and flood planning**
- **Urban drainage**
- **Environmental river flows**

Basically:

How and where does ALL the water flow?

When will it get there and what will it be like?

MIKE SHE – Integrated watershed hydrology modelling

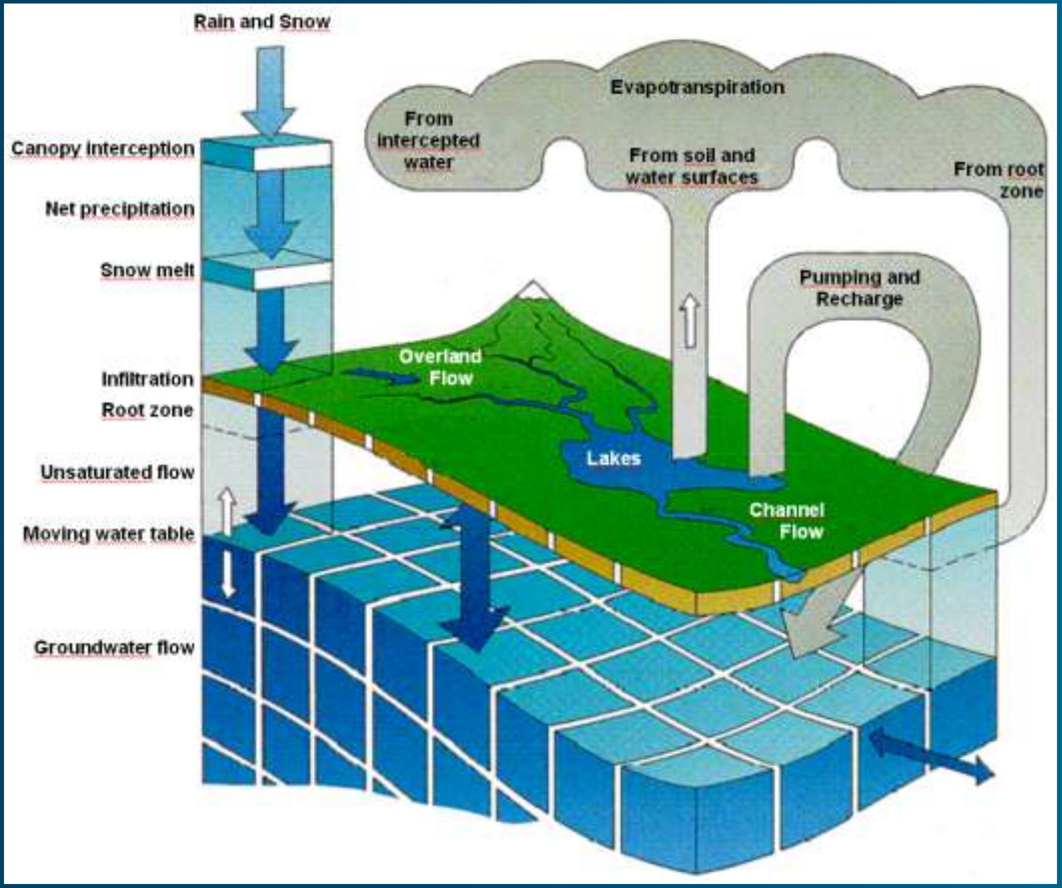
Groundwater and Surface Water
One Water — One Resource — One Model

Integrated water quality

Precipitation and snowmelt

Vegetation based evapotranspiration and infiltration

Unsaturated groundwater flow



Demand driven irrigation

Overland surface flow and flooding

Channel flow in rivers and lakes

(MIKE 11)

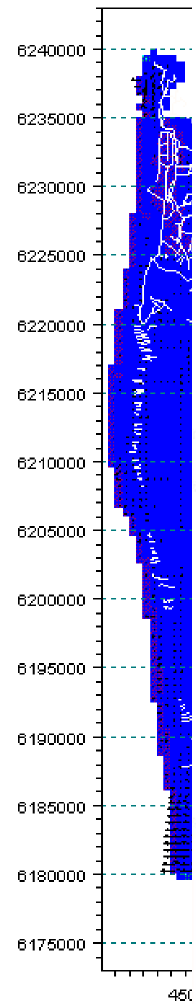
Saturated groundwater flow

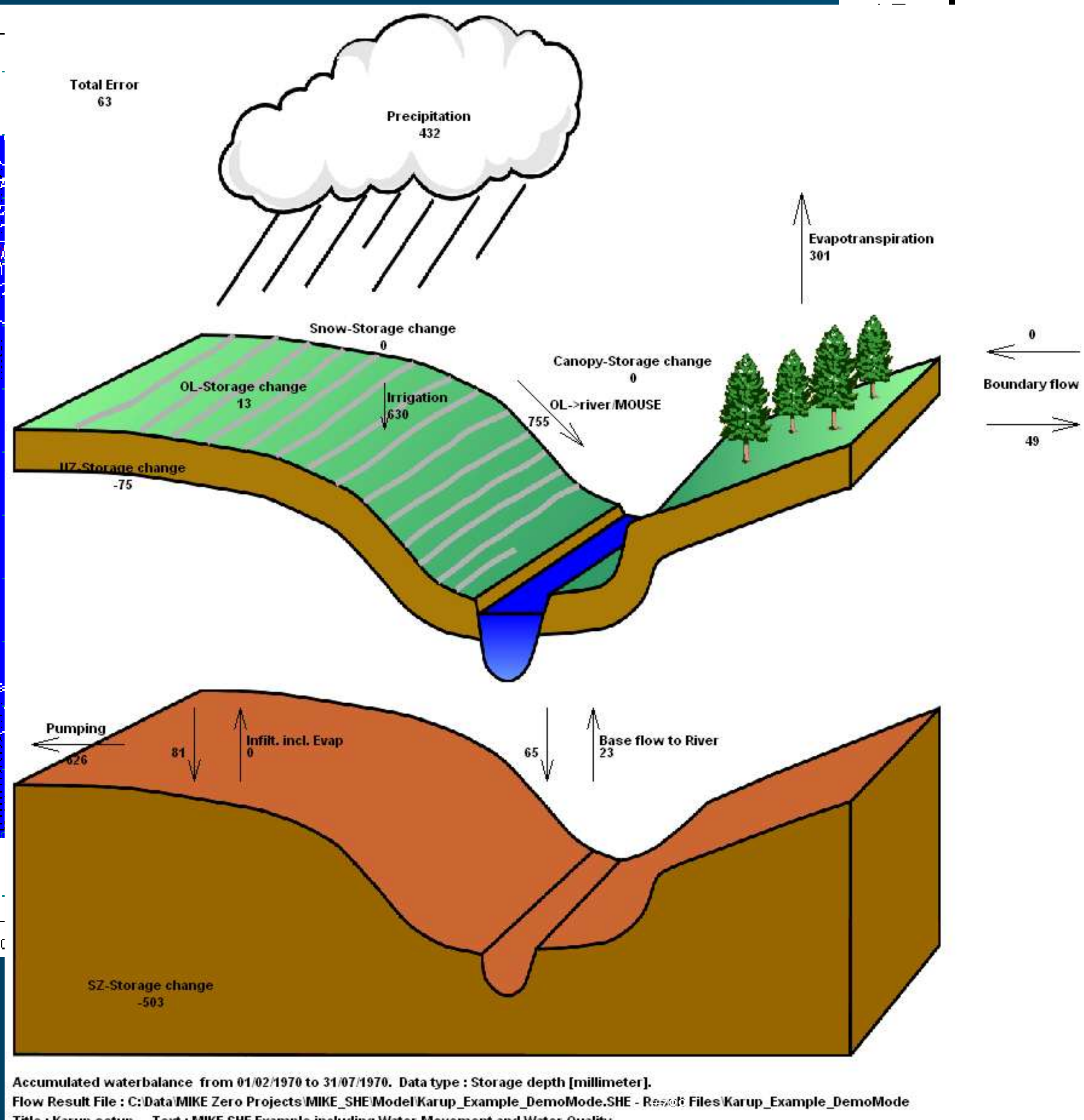
MIKE SHE – Integrated watershed hydrology modelling

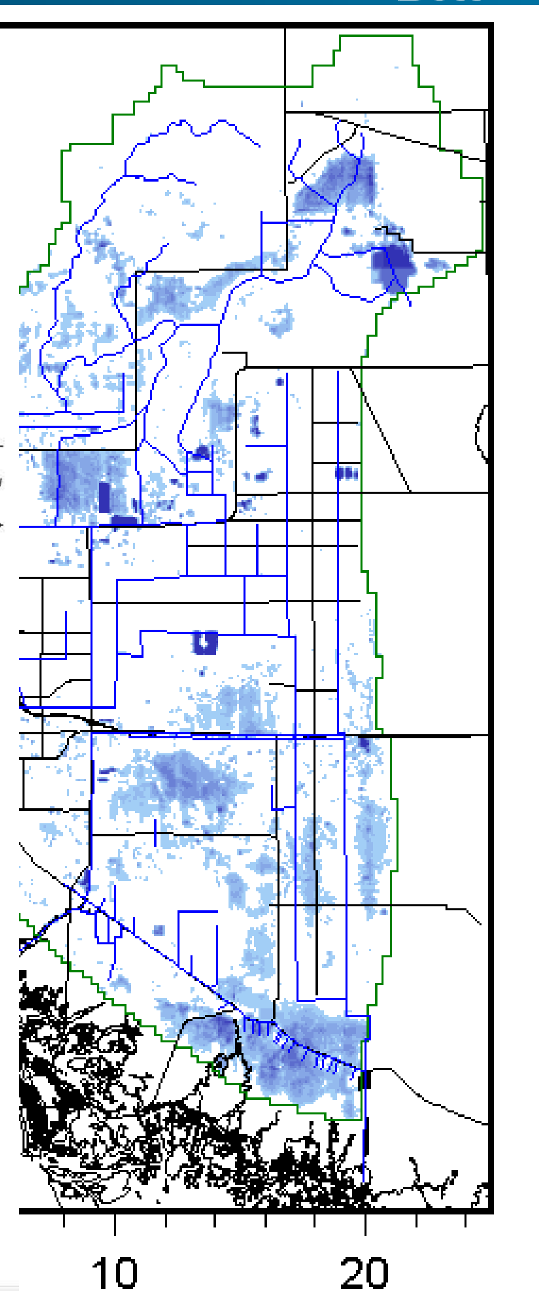
Supports:

- Grid independent data input and integration with GIS data sets
- Different spatial and temporal resolutions for input data
- Custom and adaptive solution time steps for each hydrologic process
- Rigorous and simplified process descriptions for each hydrologic process
- Time varying soil properties to accommodate winter hydrology (e.g. frozen soils)
- Time varying vegetation and surface roughness to accommodate seasonal changes as well as land-use changes
- Supports OpenMI for integration with other models and/or processes

Potential Outputs







Integrated Environmental Modelling

Advantages

- Inherent consistency between modelled surface and subsurface systems
- More robust solution because it uses all available data
- More reliable for predictive scenarios involving water budgets and potential modifications to land use, climate change, groundwater utilization, and river system operations
- Promotes and facilitates a better understanding of all hydrologic processes and their interdependencies

Groundwater discharge areas

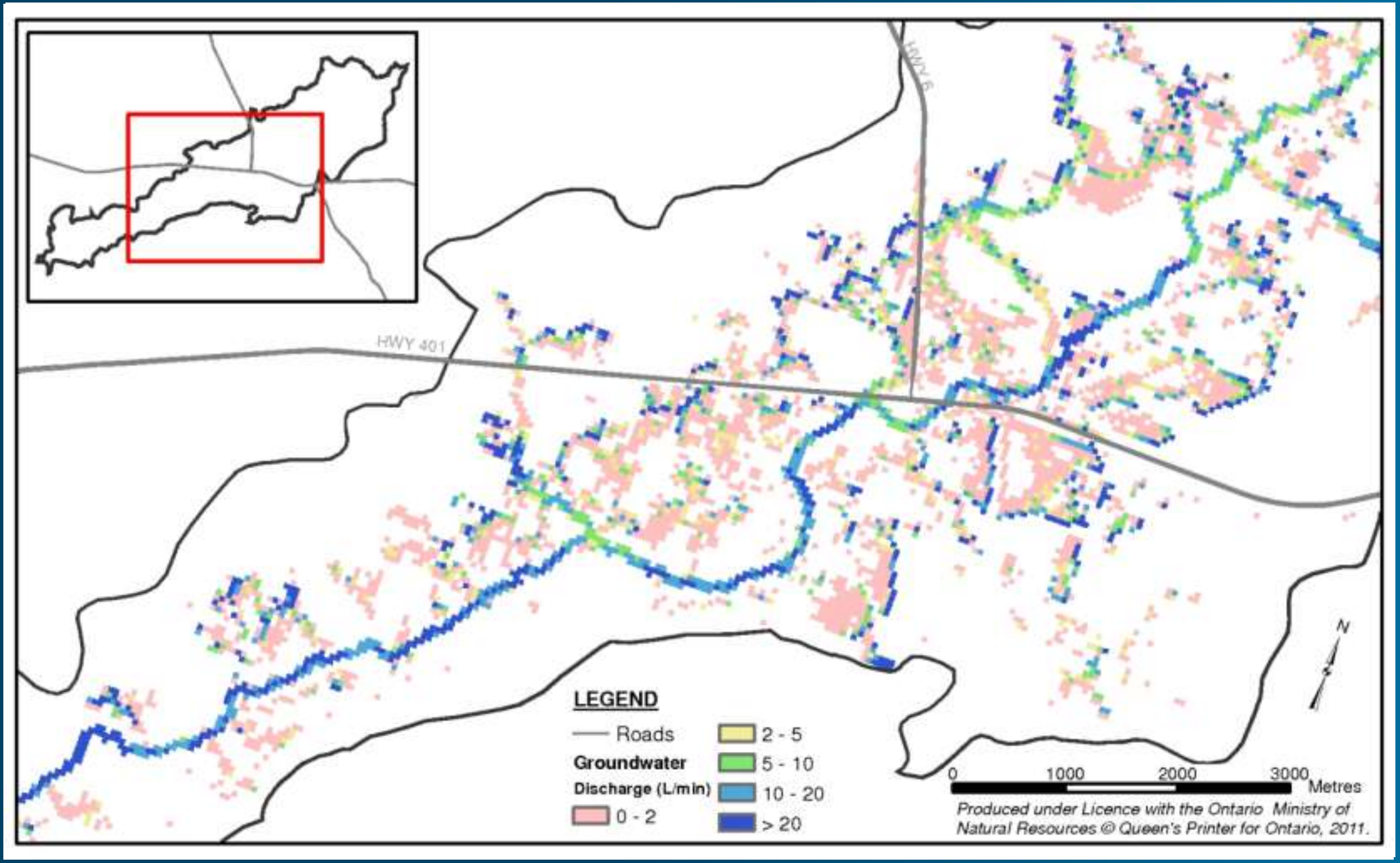


Image is provided courtesy of Matrix Solutions

Seasonal wetland delineation

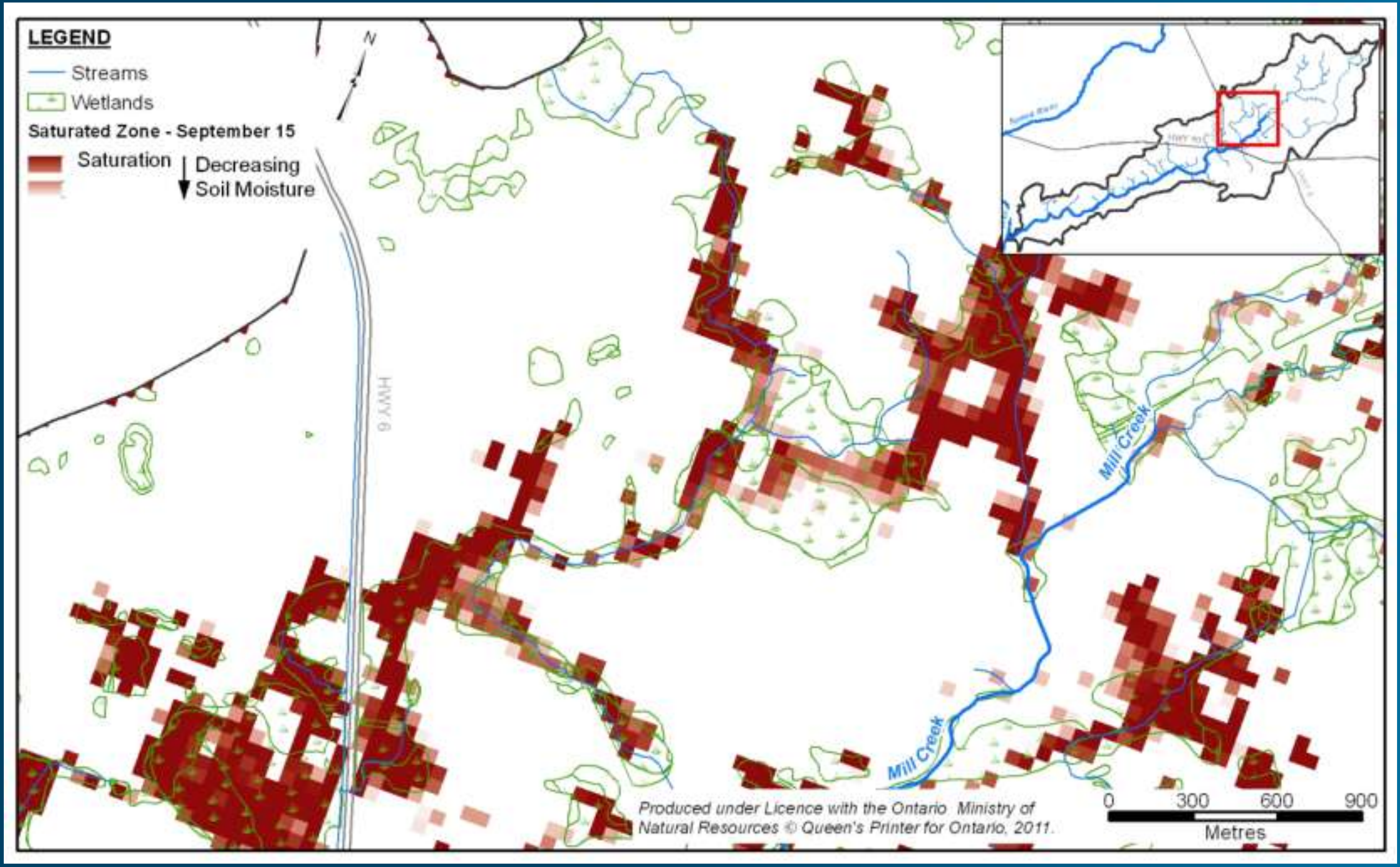


Image is provided courtesy of Matrix Solutions

Integrated Mine Water Management

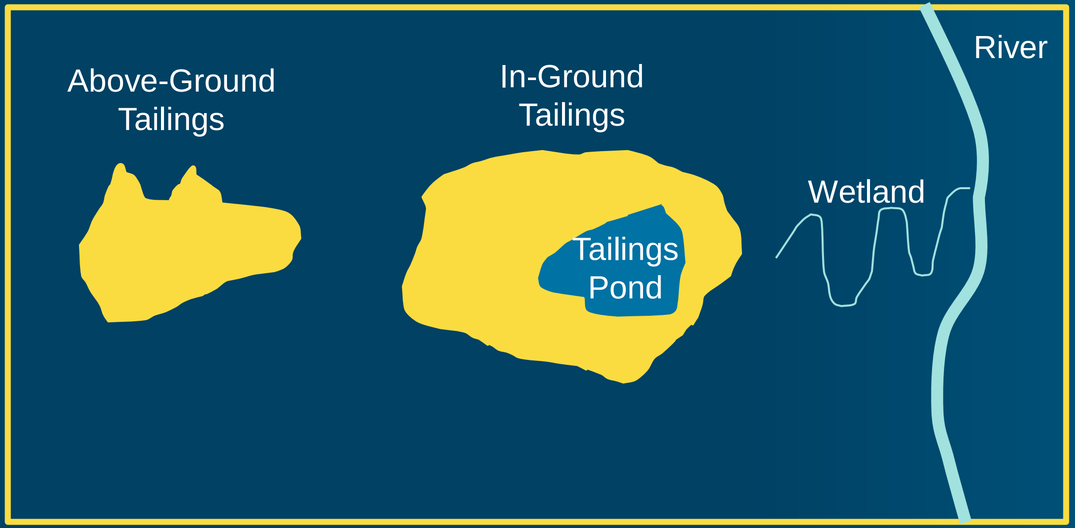
Water Management Issues of Concern

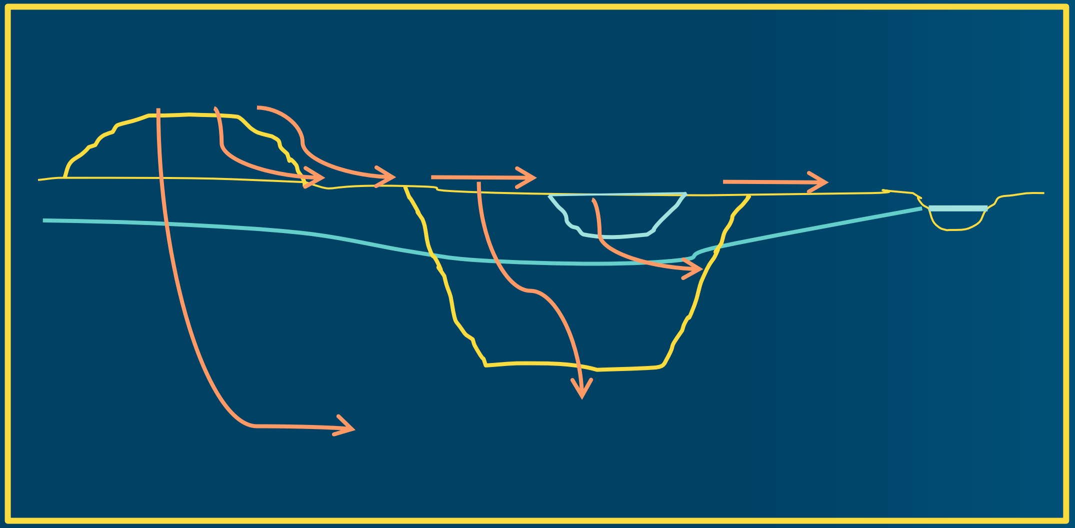
- Dewatering or aquifer depressurization
  - Disposal of extracted water
  - Impact on surrounding water supply wells
  - Impact on surrounding surface water bodies
- Product extraction/treatment
  - Water supply for processing/treatment
  - Process water management
  - Mine tailings management
- Stormwater management
  - Onsite flooding
  - Runoff water quality

Major issues:

- Managing water supply for sustainable mining operations
- Managing environmental risks associated with exposure to affected water

Integrated Mine Water Management



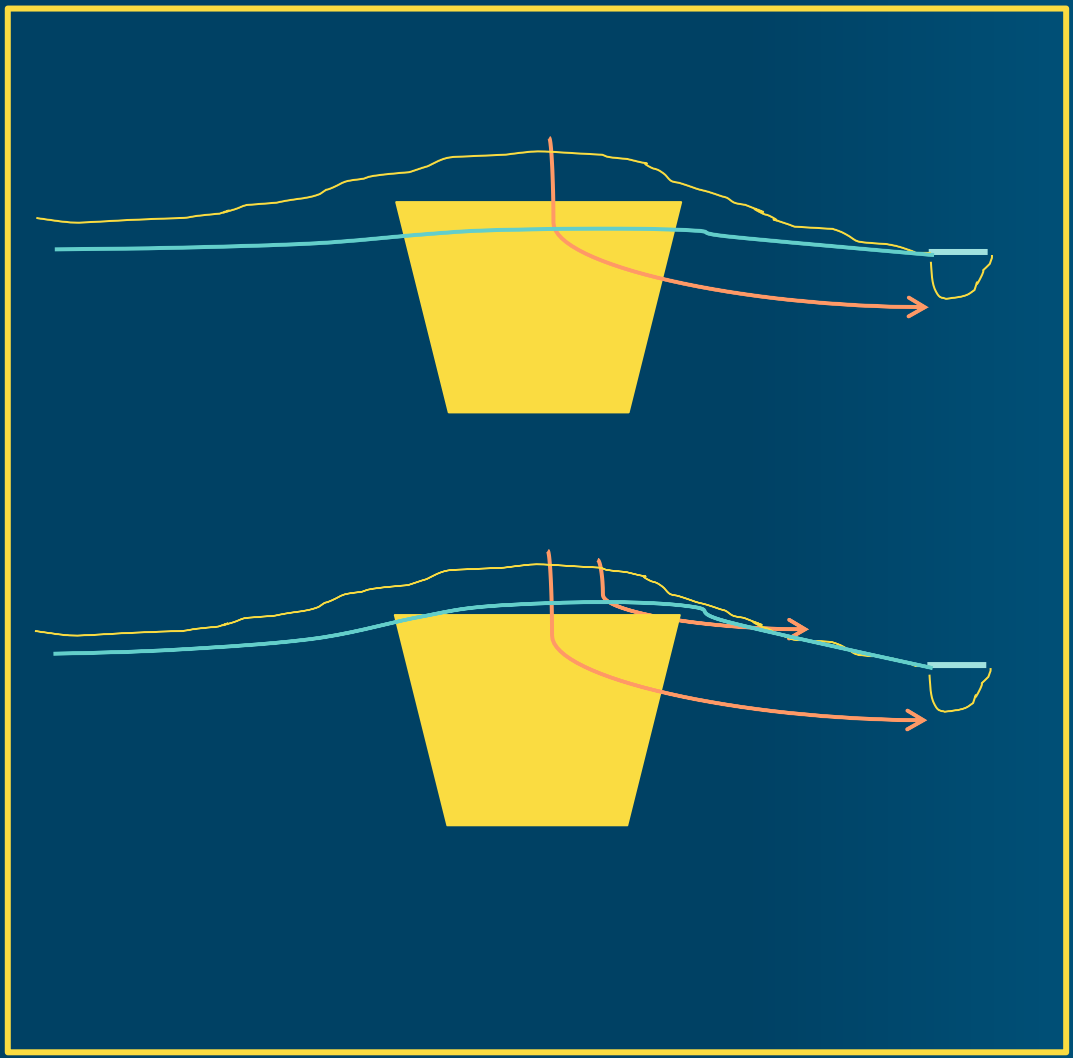


Operational Exposure

- Above-Ground Tailings
  - Stormwater runoff
  - Seepage and surface discharge
  - Seepage into groundwater
- In-Ground Tailings
  - Stormwater runoff
  - Seepage into groundwater
- Tailings Pond
  - Failure of impoundment
  - Seepage to groundwater

- Environmental Impacts
  - Surface water quality
  - Groundwater quality
  - Vegetation and habitat

Integrated Mine Water Management



Post Closure Exposure

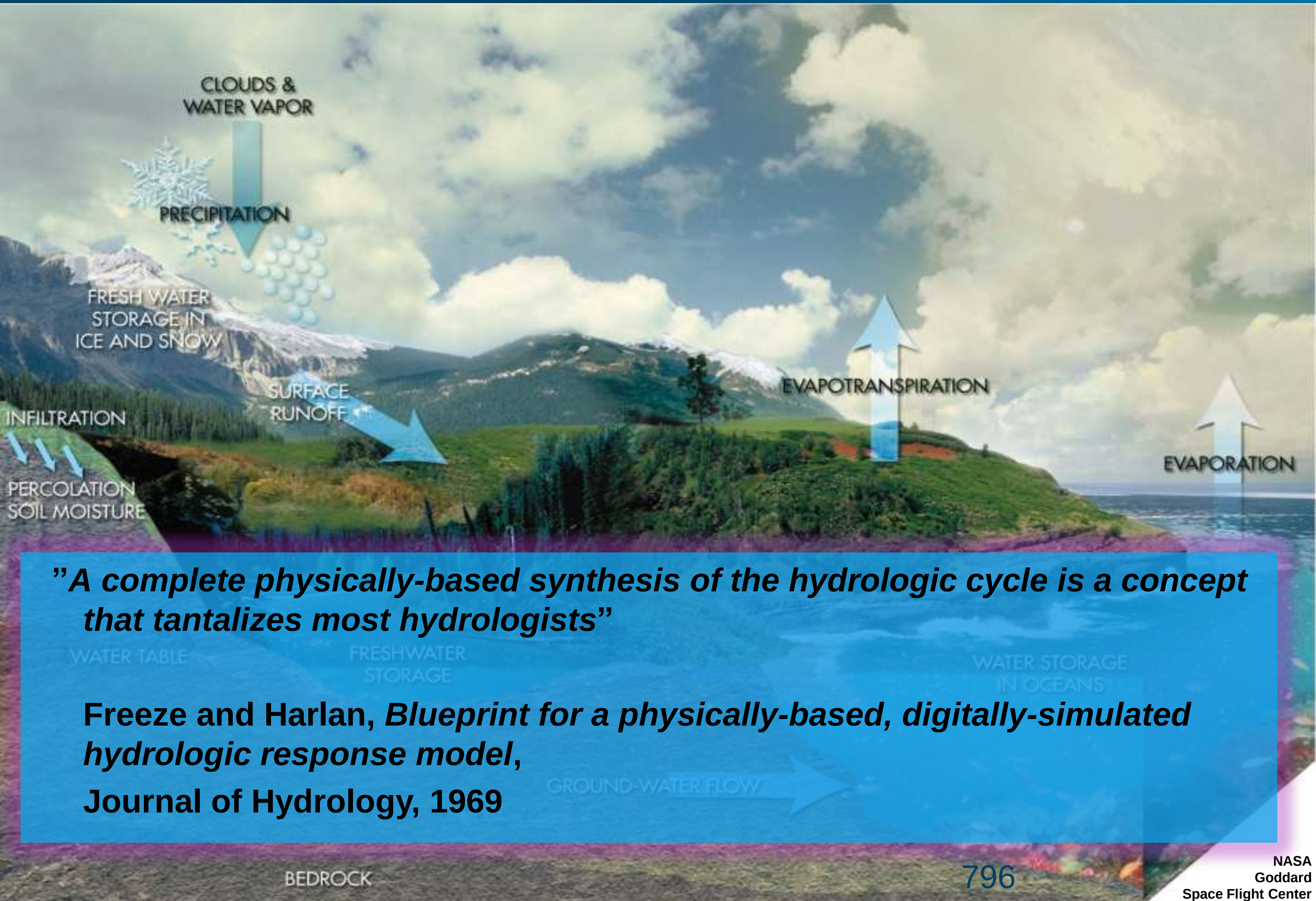
- In-Ground Tailings
  - Seepage into groundwater
  - Discharge to surface

- Environmental Impacts
  - Surface water quality
  - Groundwater quality
  - Vegetation and habitat

Integrated Mine Water Management

Why MIKE SHE?

- All exposure pathways can be modelled
  - Surface runoff, infiltration/seepage, groundwater, wetlands, channel flow, vegetation uptake
- Changing subsurface conditions can be accounted for
  - Time-varying hydraulic conductivity
- Seasonal hydrologic conditions are accommodated
  - Time-varying groundwater leakage term to handle frozen soils
- Integrated water quality is modelled through all flow processes
  - Reactive transport, biodegradation and transformations, geochemistry

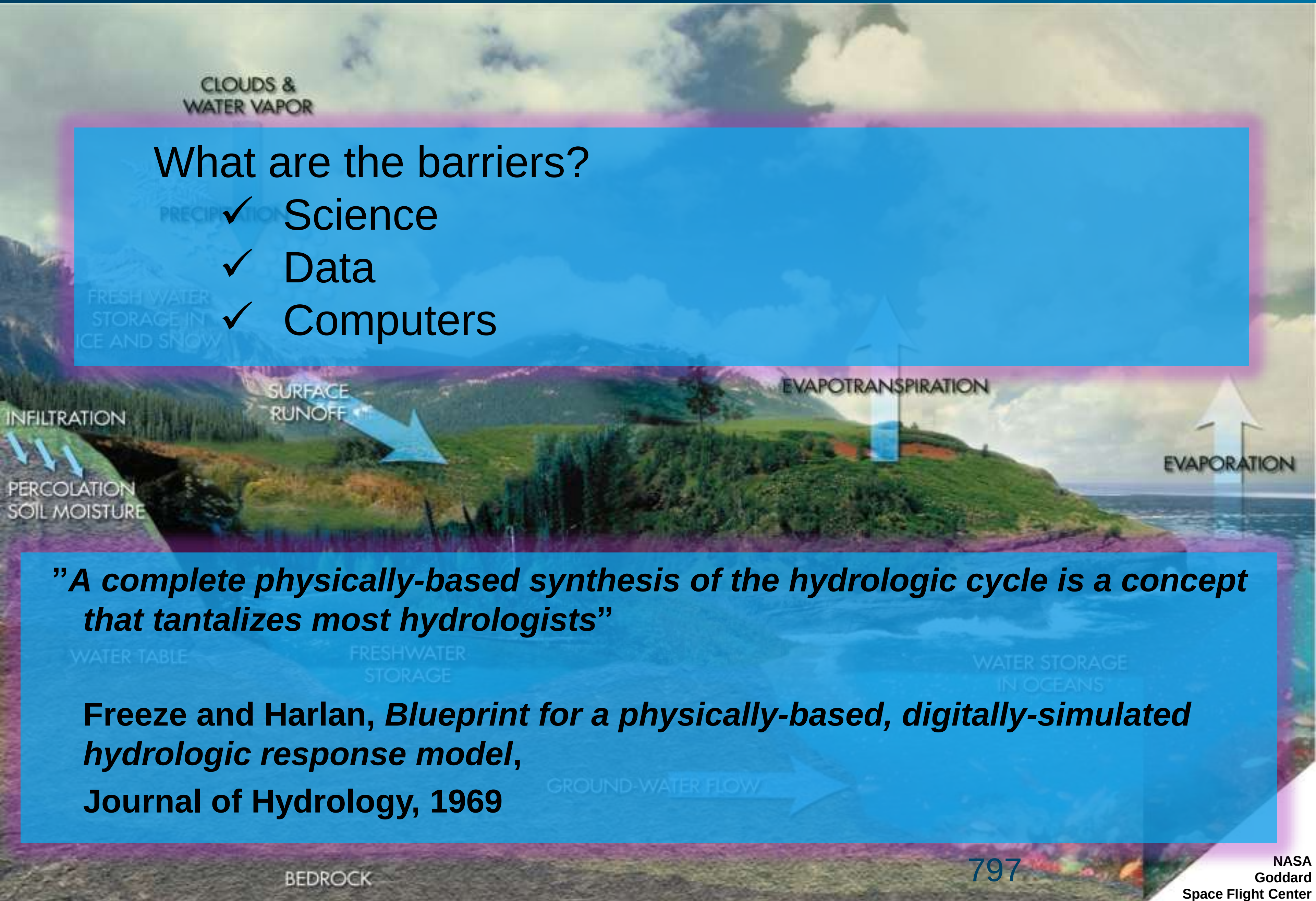


"A complete physically-based synthesis of the hydrologic cycle is a concept that tantalizes most hydrologists"

Freeze and Harlan, *Blueprint for a physically-based, digitally-simulated hydrologic response model*,

Journal of Hydrology, 1969

NASA
Goddard
Space Flight Center



What are the barriers?

- ✓ Science
- ✓ Data
- ✓ Computers

"A complete physically-based synthesis of the hydrologic cycle is a concept that tantalizes most hydrologists"

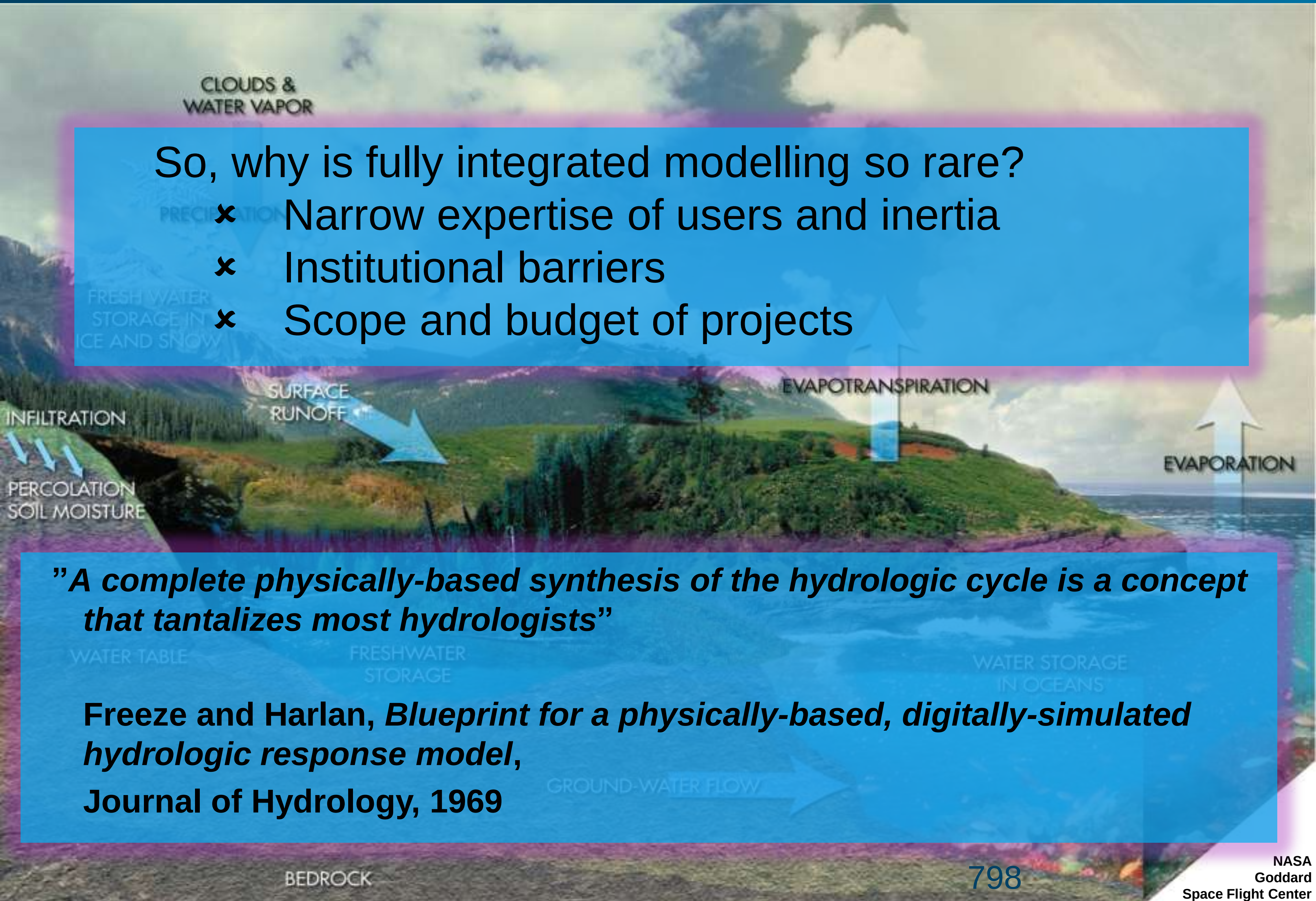
Freeze and Harlan, *Blueprint for a physically-based, digitally-simulated hydrologic response model*,

Journal of Hydrology, 1969

NASA Goddard Space Flight Center

So, why is fully integrated modelling so rare?

- Narrow expertise of users and inertia
- Institutional barriers
- Scope and budget of projects



NASA
Goddard
Space Flight Center

"A complete physically-based synthesis of the hydrologic cycle is a concept that tantalizes most hydrologists"

Freeze and Harlan, *Blueprint for a physically-based, digitally-simulated hydrologic response model*,

Journal of Hydrology, 1969

Elbow River Watershed Integrated Model

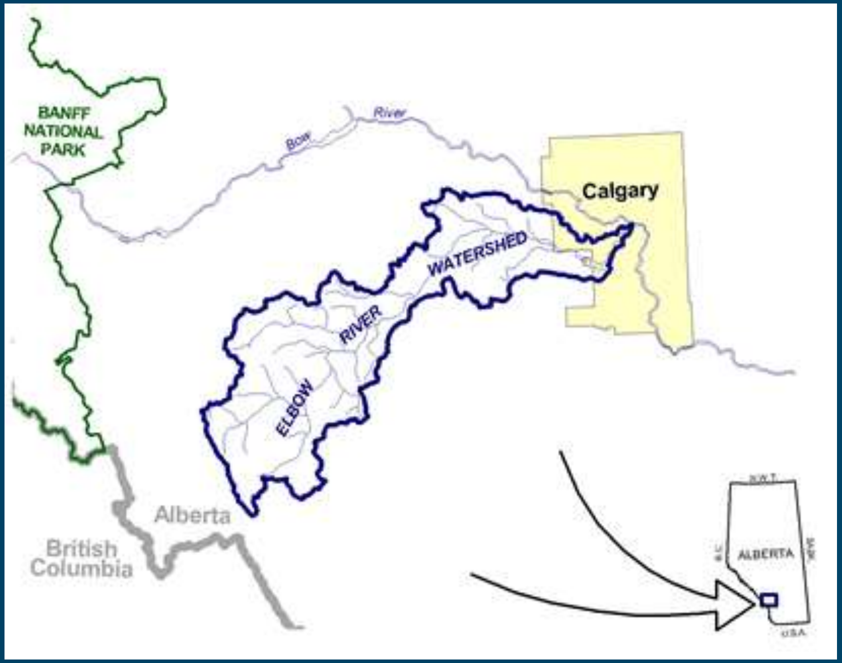
Research collaboration between University of Calgary, Alberta Environment and DHI

Objective:

- Assess the impact of potential land-use changes over the next 20 years on the hydrological processes in ERW by combining a land-use cellular automata (CA) model and the distributed physically-based MIKE-SHE hydrological model
- Develop a method for automating the updating of hydrologic parameters in MIKE SHE directly from the land-use CA model
- Evaluate combined hydrologic impacts of land-use changes and climate change

Elbow River Watershed Integrated Model

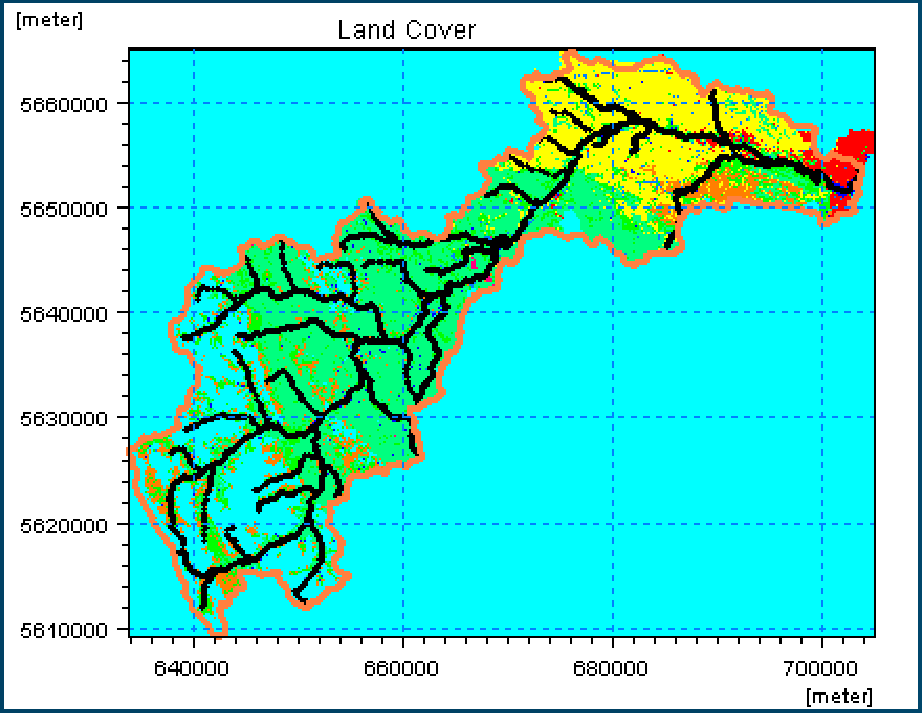
Model Overview



- Domain: Elbow River Watershed upstream above Glenmore Reservoir
- Area: ~1,273 km^2
- Calibration Period: 9/1/1981 – 12/31/1991
- Resolution: 200-m by 200-m square grid cells
- Coordinate system: NAD 1983 UTM Zone 11N projection, NAD 1983 datum

Elbow River Watershed Integrated Model

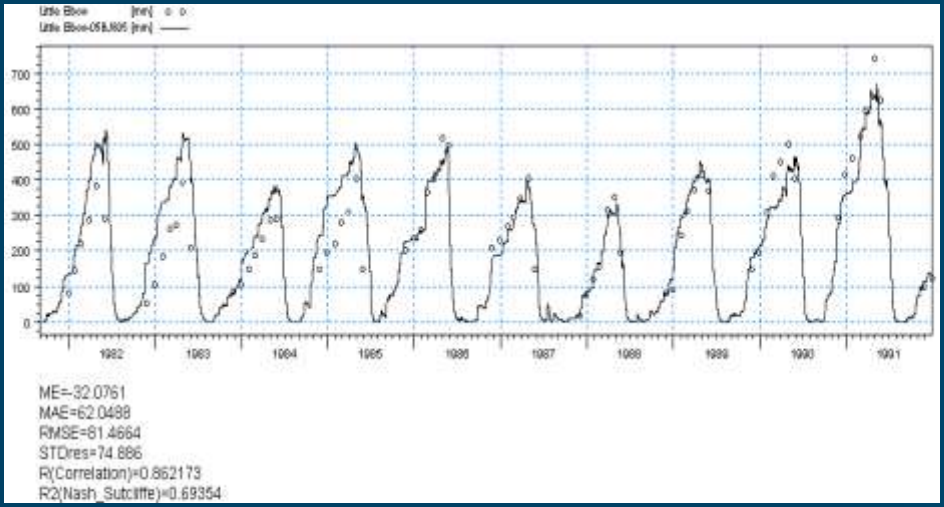
Model Overview

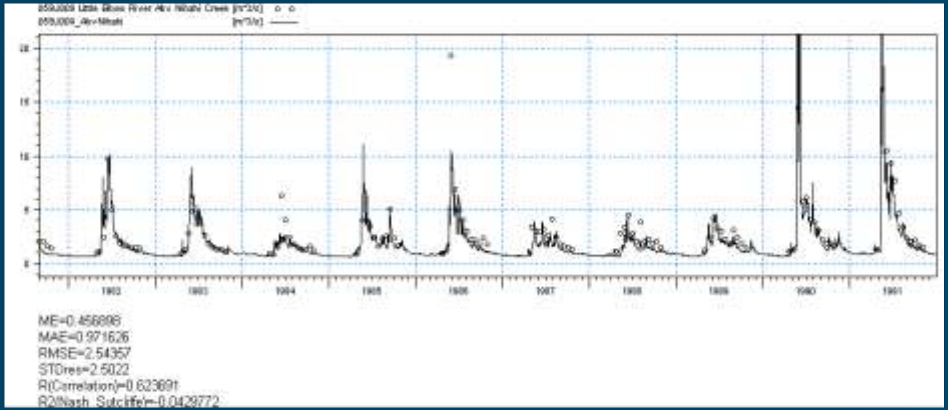


- Snowmelt – modified degree-day method
- Overland flow – 2D finite-difference diffusive wave
- Unsaturated flow and ET – 2-layer water balance approach
- Groundwater flow – 3D finite-difference method
- Channel flow – 1-dimensional hydrodynamic approach

Elbow River Watershed Integrated Model

Model Calibration





1961 – 2002

Subdivided into 5 separate intervals with known land-use distributions

- Overall Water Balance
- 1 snow station
- 5 streamflow monitoring stations
- Sporadic groundwater measurements

Elbow River Watershed Integrated Model

Results

- Research project is on-going
- Currently working on development of auto-feedback methodology between MIKE SHE and Land-use model.

Questions?

Patrick Delaney, pad@dhigroup.com

Day 2 – Session 4

David Sauchyn- University of Regina

BIOGRAPHY

Dave Sauchyn is Research Professor at the Prairie Adaptation Research Collaborative (PARC) at the University of Regina. His main research interests are the climate and hydrology of the past millennium in Canada's western interior and how knowledge of the past can inform scenarios of future climate and water supplies. He is Co-Director of the new 5-year project "Vulnerability and Adaptation to Climate Extremes in the Americas" (VACEA) involving research in Argentina, Colombia, Brazil, Chile and western Canada. Dave has been an invited expert witness on climate change in the Canadian Senate and House of Commons, and at forums hosted by provincial premiers and environment ministers. He is senior editor and co-author of the book *The New Normal: The Canadian Plains in a Changing Climate* published in fall, 2010.

Day 2 – Session 4

David Sauchyn- University of Regina

ABSTRACT

Conventional approaches to environmental modelling are based on the coupling of a dynamical model and “delta” scenarios of projected changes in mean climate. This standard practice has the advantage of the dynamical simulation of the biophysical and hydrological processes, but the disadvantage of requiring large amounts of data to calibrate and validate the model, limiting the domain to a few decades in terms of range of variability and extremes. Therefore the model outputs generally are restricted to projections of changes in mean states between past and future decades. Reconstructions of the climate and hydrology of the past millennium reveal fluctuations at time scales (multi-decadal) that exceed the length of most instrumental records. This scale of variability is important for our understanding of the stationarity of the regional climate regime, and for natural resource planning and management for extreme events in terms of magnitude to duration. We model streamflow as a function of the ocean-atmosphere oscillations (teleconnection indices) that drive the natural variability of the regional hydroclimatic regime. We then drive these regression models using output from an ensemble of global climate models (GCMs) that simulate spectral and geographic characteristics of relevant teleconnection patterns – the El Niño Southern Oscillation and Pacific Decadal Oscillation. This modelling approach captures the shift in climate variability that is forced by warming oceans and atmosphere. Conventional approaches to environmental modelling are based on the coupling of a dynamical model and “delta” scenarios of projected changes in mean climate. This standard practice has the advantage of the dynamical simulation of the biophysical and hydrological processes, but the disadvantage of requiring large amounts of data to calibrate and validate the model, limiting the domain to a few decades in terms of range of variability and extremes. Therefore the model outputs generally are restricted to projections of changes in mean states between past and future decades. Reconstructions of the climate and hydrology of the past millennium reveal fluctuations at time scales (multi-decadal) that exceed the length of most instrumental records. This scale of variability is important for our understanding of the stationarity of the regional climate regime, and for natural resource planning and management for extreme events in terms of magnitude to duration. We model streamflow as a function of the ocean-atmosphere oscillations (teleconnection indices) that drive the natural variability of the regional hydroclimatic regime. We then drive these regression models using output from an ensemble of global climate models (GCMs) that simulate spectral and geographic characteristics of relevant teleconnection patterns – the El Niño Southern Oscillation and Pacific Decadal Oscillation. This modelling approach captures the shift in climate variability that is forced by warming oceans and atmosphere.

Modeling for Climate Variability

Dave Sauchyn, Ph.D., P. Geo.
Prairie Adaptation Research Collaborative, University of Regina

AESRD Environmental Modeling Workshop, Edmonton, 13-14 March 2013

The **Prairie Adaptation Research Collaborative** (PARC) is a Research Institute based at the University of Regina. It was created as partnership of the governments of Canada, **Alberta**, Saskatchewan and Manitoba mandated to pursue climate change impacts and adaptation research in the Prairie Provinces.

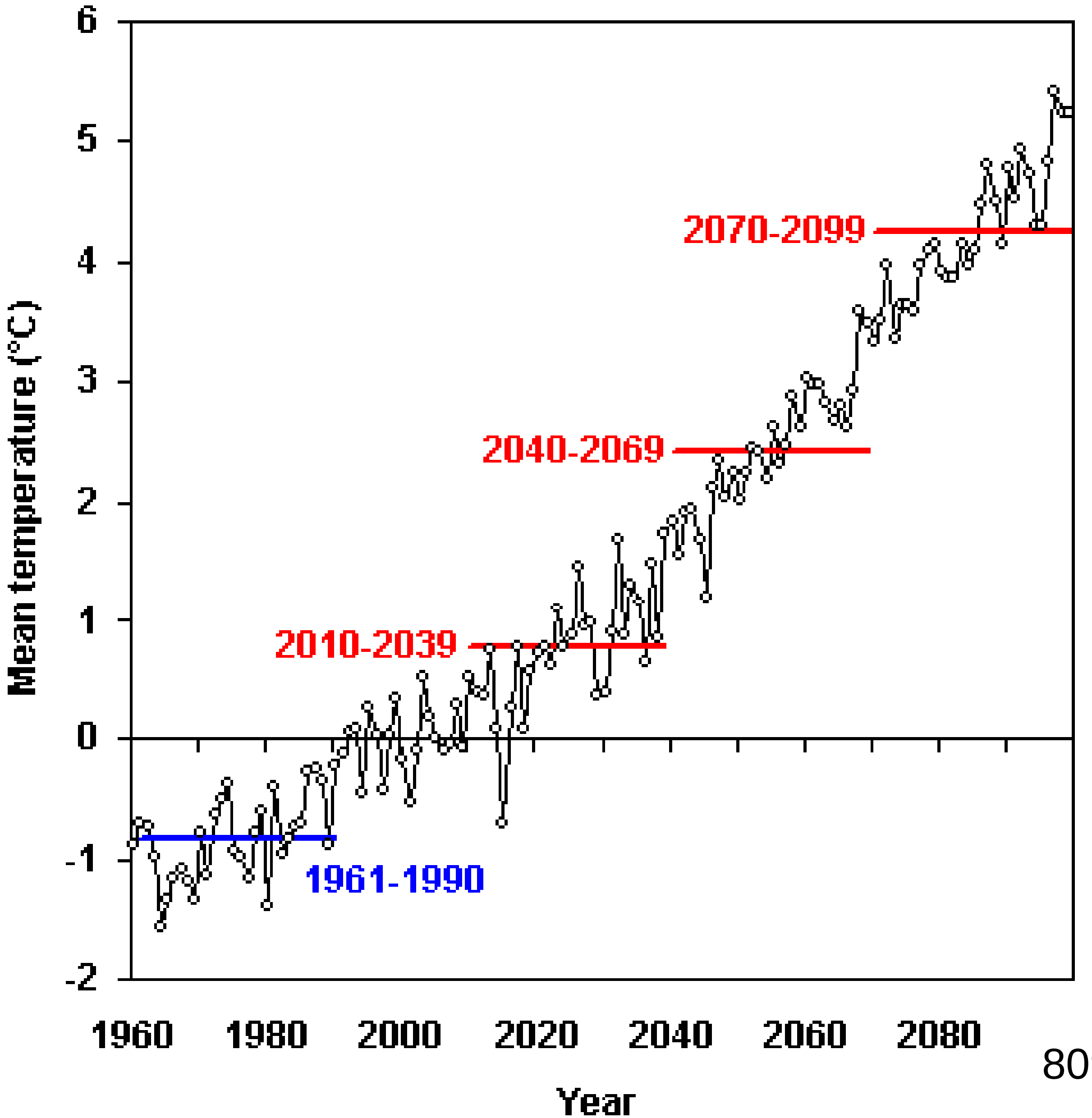
UNIVERSITY OF REGINA

PARC

Major Initiatives ($Ms)

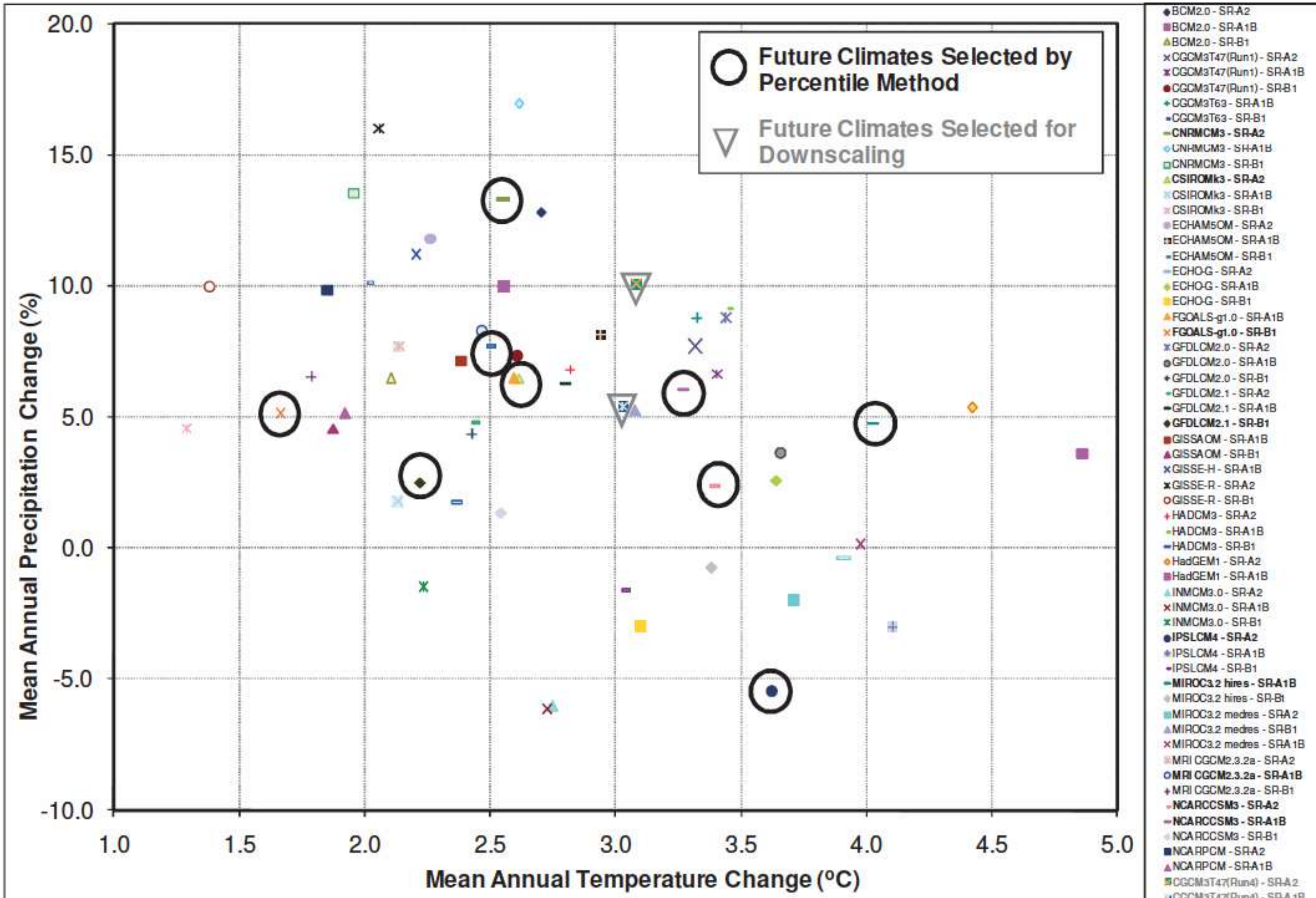
- 2000-2006: C-CIARN Prairies
- 2004-2008: Alberta Vulnerability Assessment Project, **AESRD**
- 2006-2010: Saskatchewan Climate Impact Assessment
- 2006-2008: Prairies Chapter, From Impacts to Adaptation
- 2008- 2011: Prairies RAC - **AESRD**
- 2011-2016: VACEA project – **Oldman River Basin**

Constructing Climate Change Scenarios



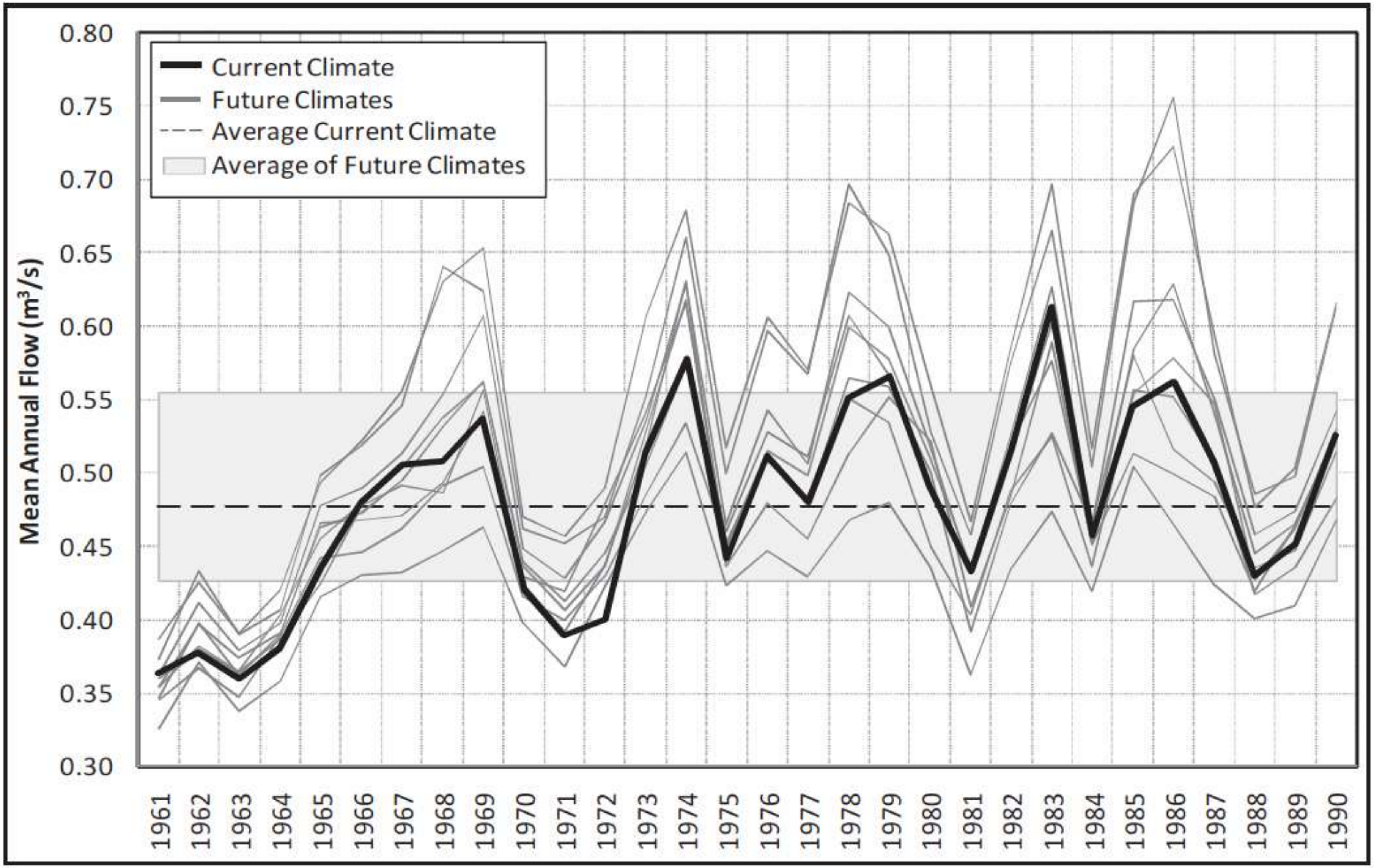
Source: Dr. Elaine Barrow

Selecting Future Climates



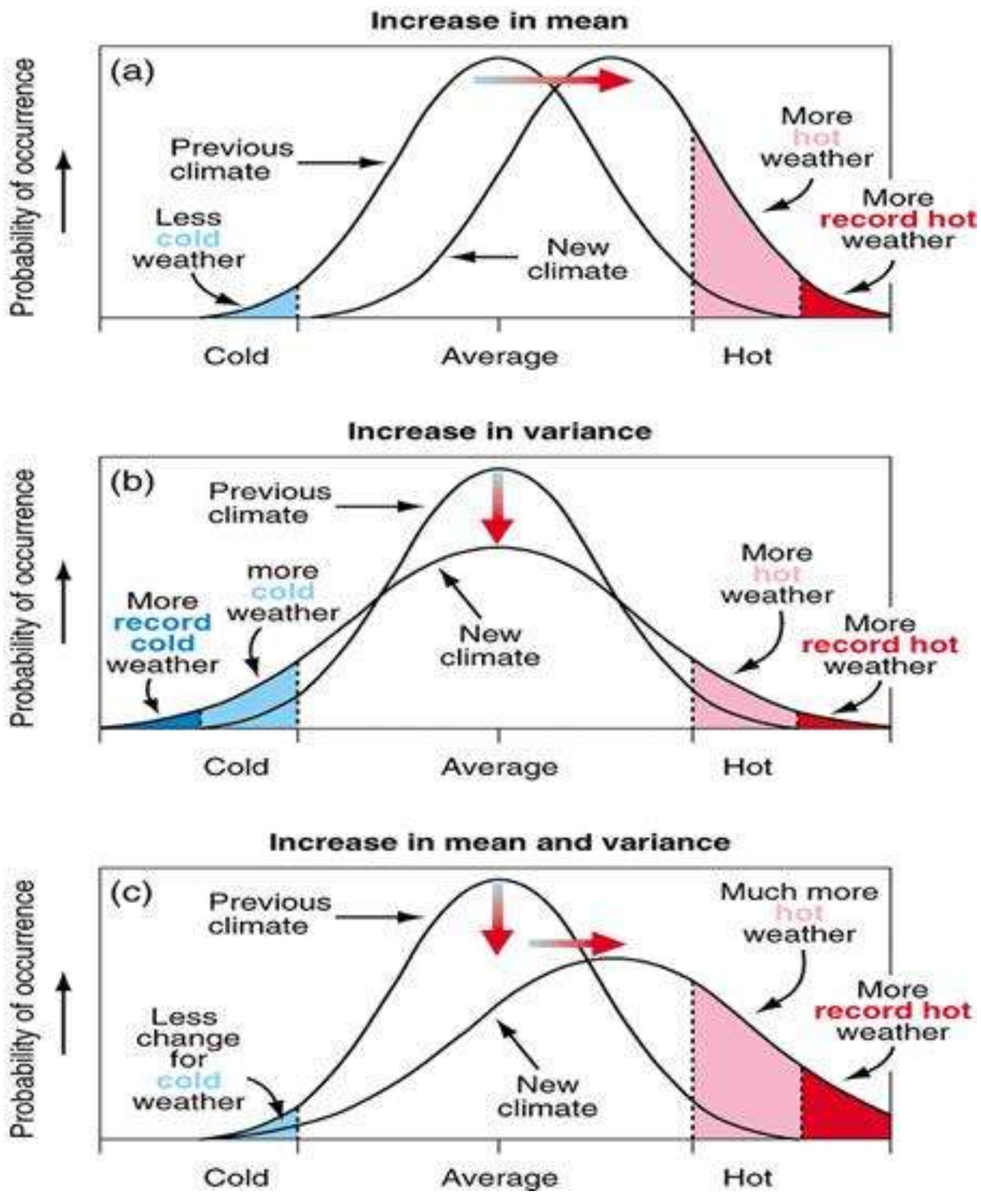
From: Guide for Assessment of Hydrologic Effects of Climate Change in Ontario

Annual streamflow with current (1961-90) and future (2041-2070) climate

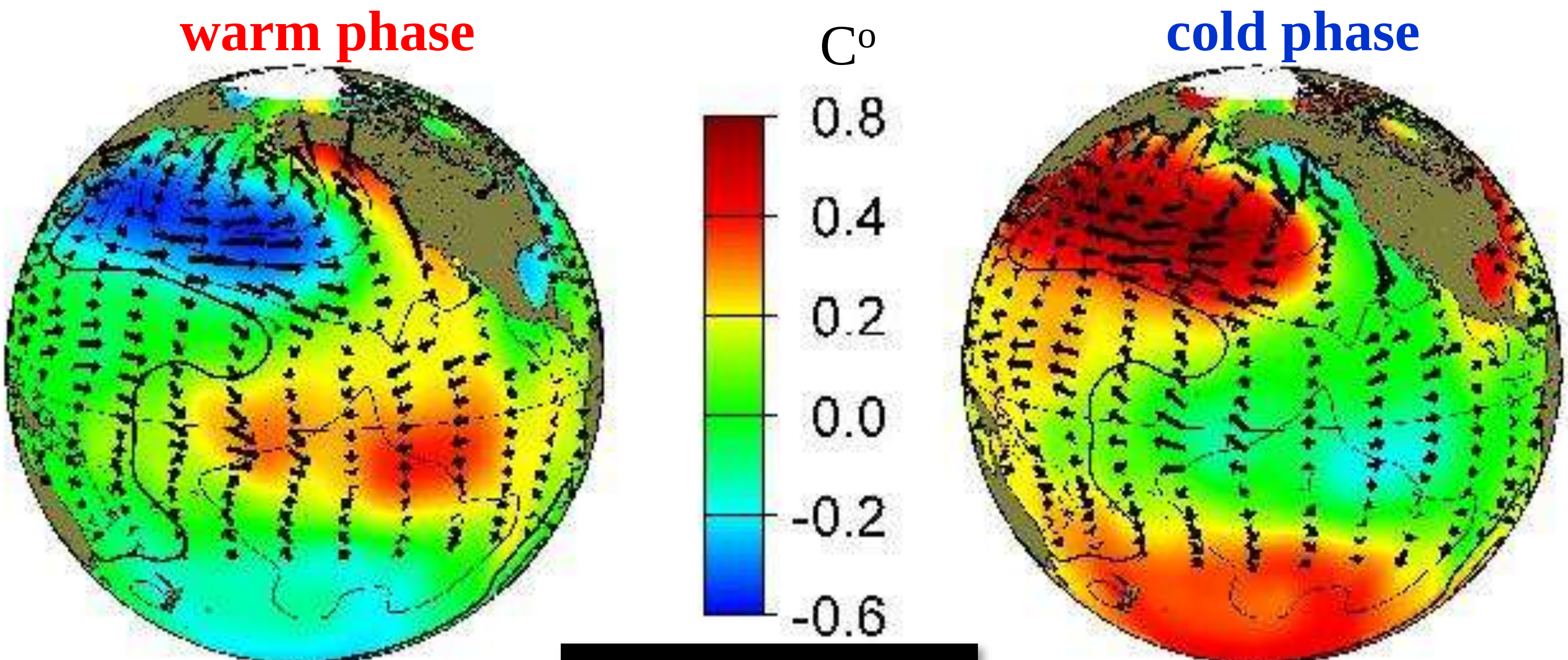


From: Guide for Assessment of Hydrologic Effects of Climate Change in Ontario

Climate Change

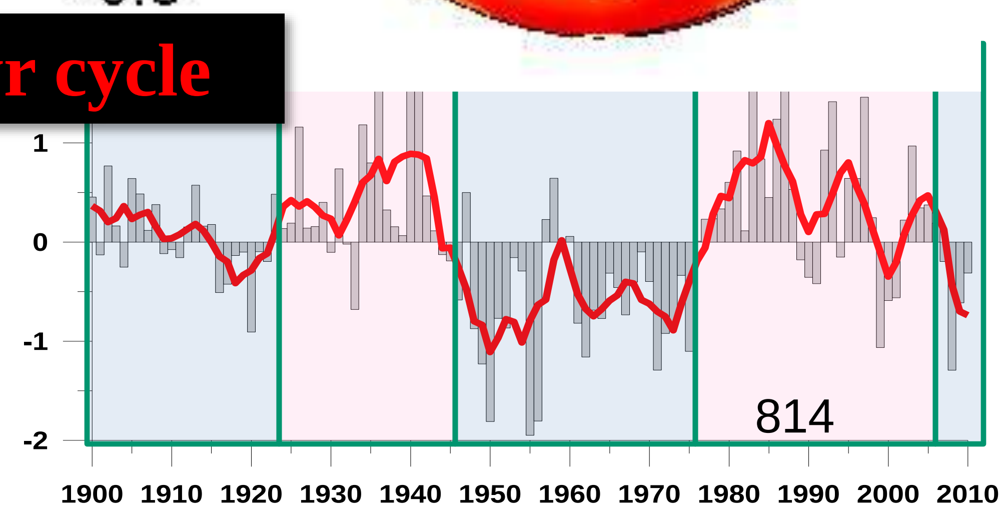


The Pacific Decadal Oscillation (PDO) is a major factor controlling Canadian Prairie precipitation and streamflow

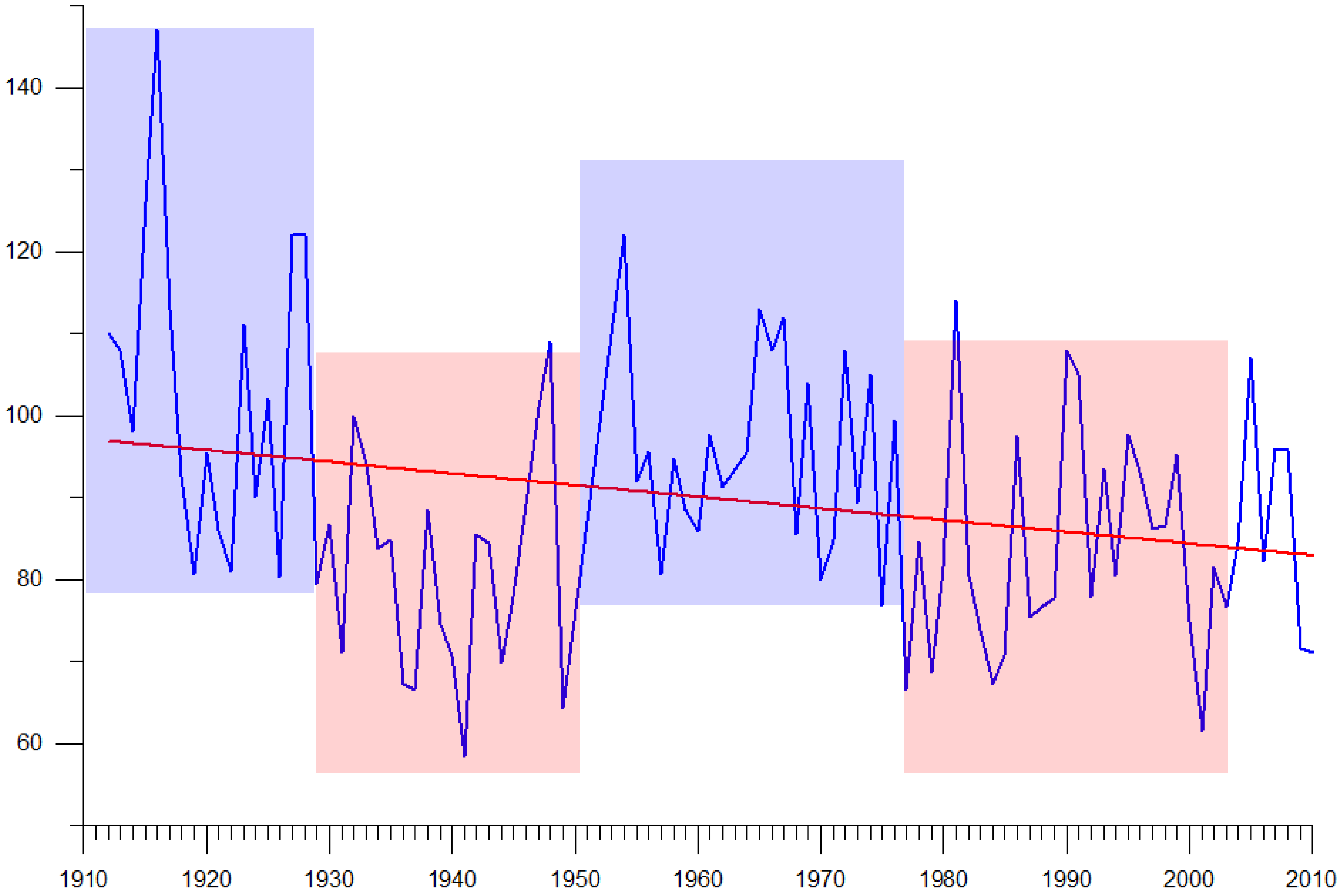


http://jisao.washington.edu/pdo/

Typical wintertime Sea Surface Temperature Anomalies (colors), Sea Level Pressure (contours) and surface wind (arrows) anomaly patterns during warm and cool phases of the PDO



Mean annual flow (m^3/sec), Bow River at Banff, 1911-2010



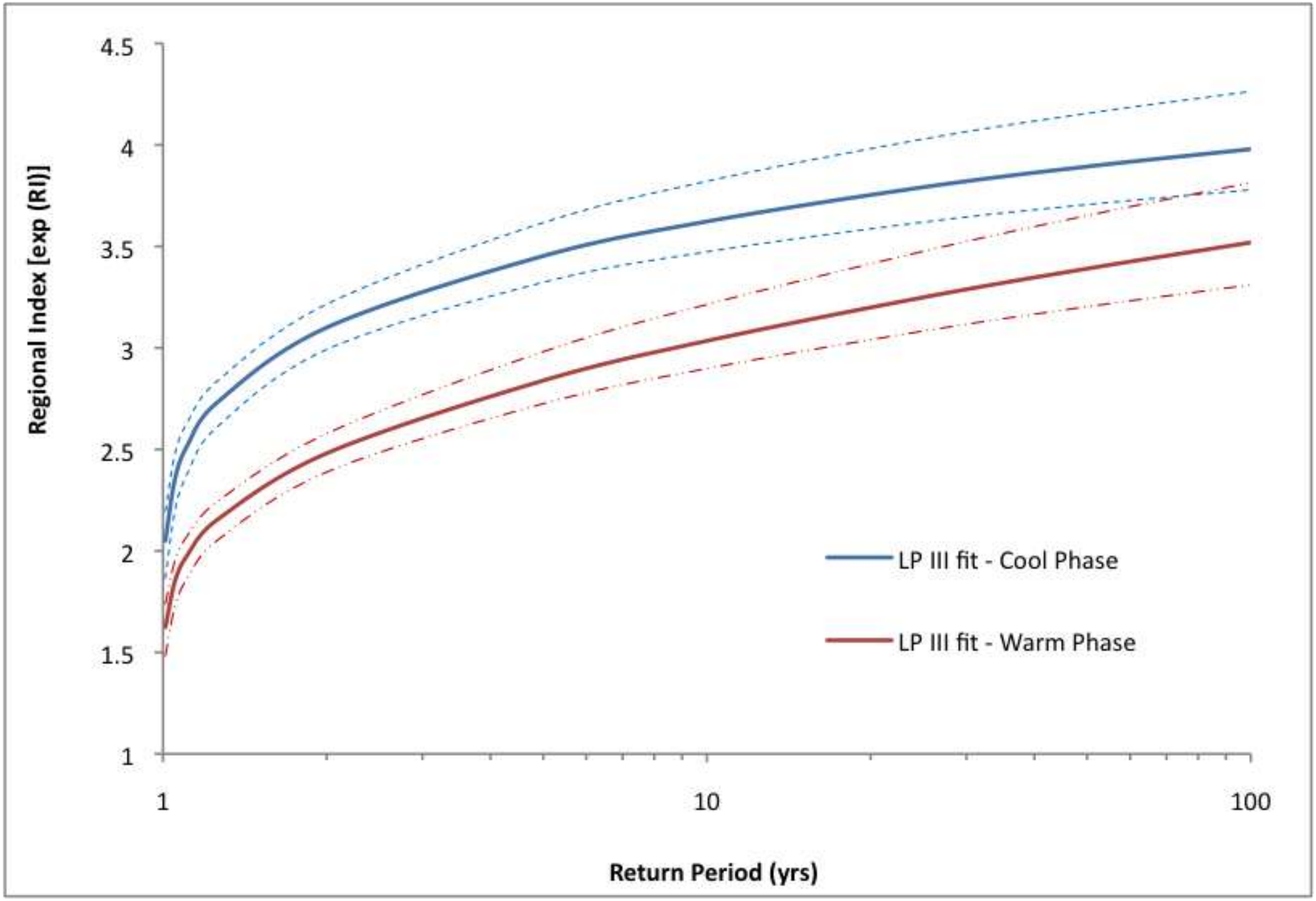
Cooking Lake, Alberta, 19 Sept 2008


Rosetown
Towing Inc.
CAA
ROAD
CLOSED

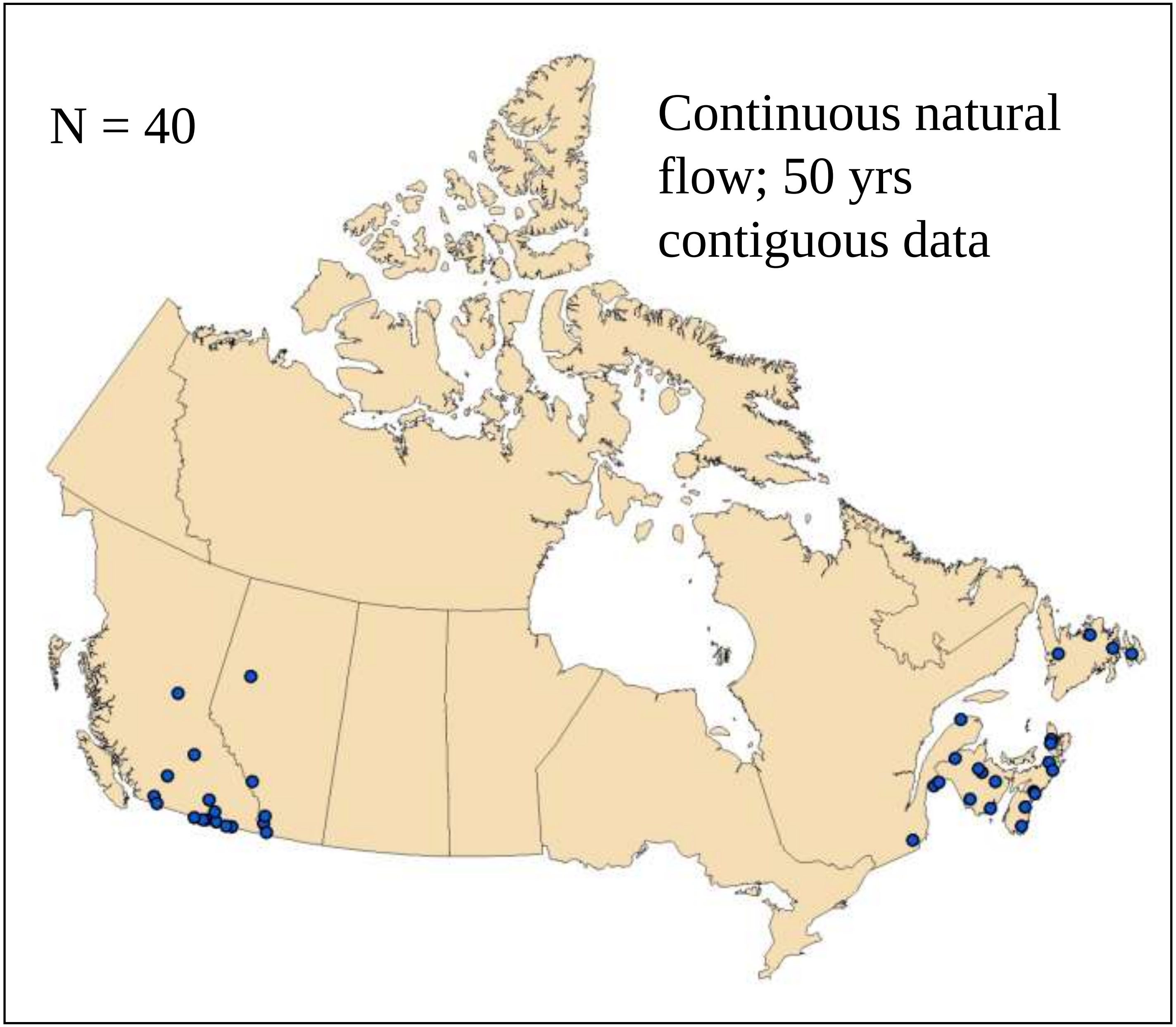
Probabilities of two consecutive years of 25th and 75th quartile flows by PDO phase - Saskatchewan River

Streamflow record	25th + PDO	25th – PDO	75th + PDO	75th – PDO
Actual Oldman R. near Lethbridge [05AD007]	0.196	0.000	0.020	0.146
Naturalized S. Saskatchewan R. at Medicine Hat	0.200	0.000	0.022	0.171
Actual S. Saskatchewan R. at Medicine Hat [05AJ001]	0.196	0.000	0.020	0.171
Naturalized Elbow R. below Glenmore Dam	0.200	0.000	0.044	0.146
Actual Elbow R. below Glenmore Dam [05BJ001]	0.176	0.048	0.059	0.190
Naturalized Bow R. at Calgary	0.178	0.000	0.044	0.195
Actual Bow R. at Calgary [05BH004]	0.176	0.024	0.039	0.195
Naturalized Spray R. at Banff	0.133	0.000	0.067	0.122
Naturalized N. Saskatchewan R. at Edmonton	0.118	0.024	0.098	0.119
Actual N. Saskatchewan R. at Edmonton [05DF001]	0.118	0.024	0.078	0.122
Actual N. Saskatchewan R. at Prince Albert, SK [05GG001]	0.137	0.049	0.039	0.122
Actual Saskatchewan R. at the Pas, MB [05KJ001]	0.137	0.025	0.059	0.175
Mean	0.149	0.015	0.043	0.135

Expected annual peak flow by PDO phase for 25 gauging stations

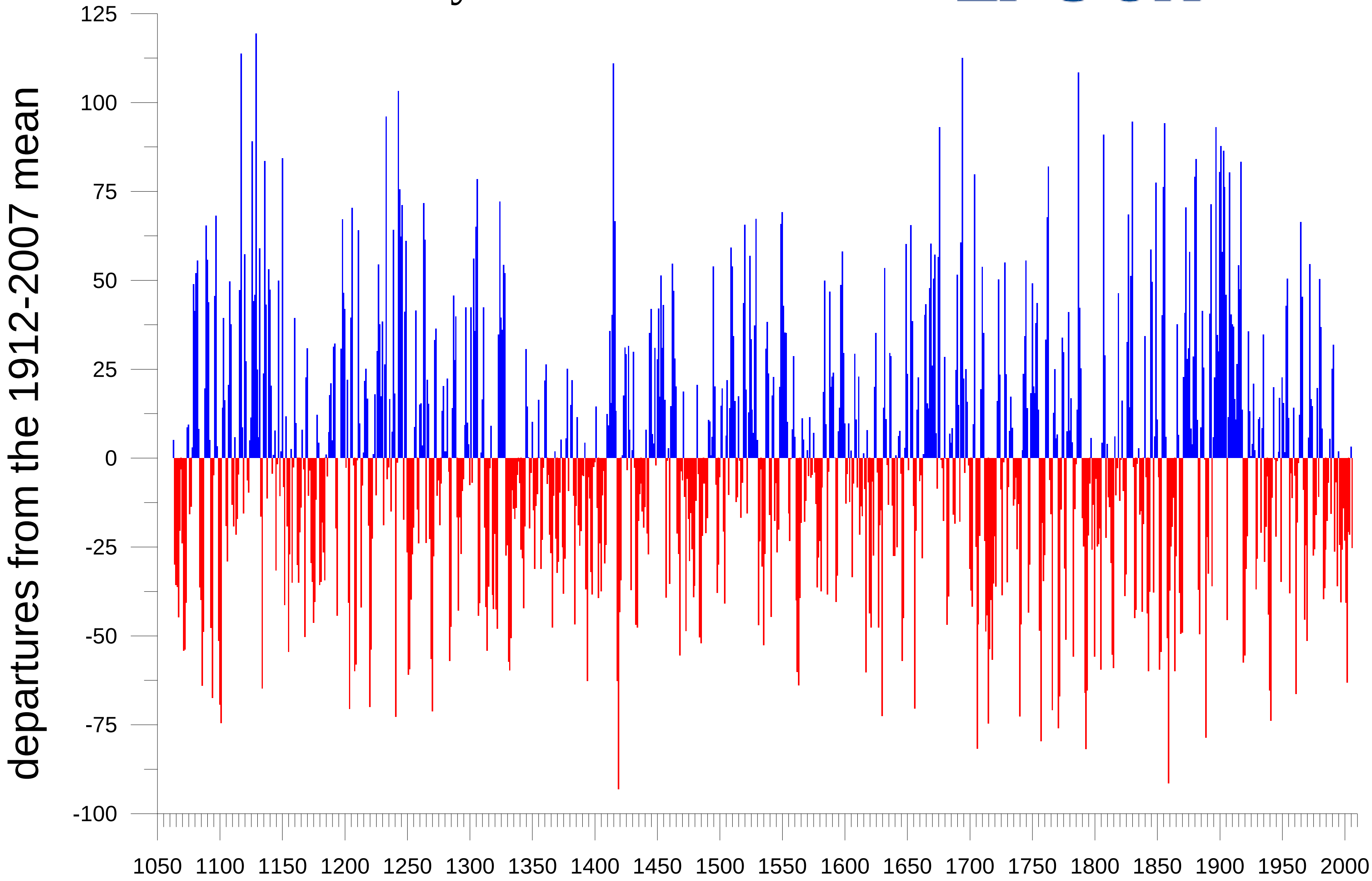


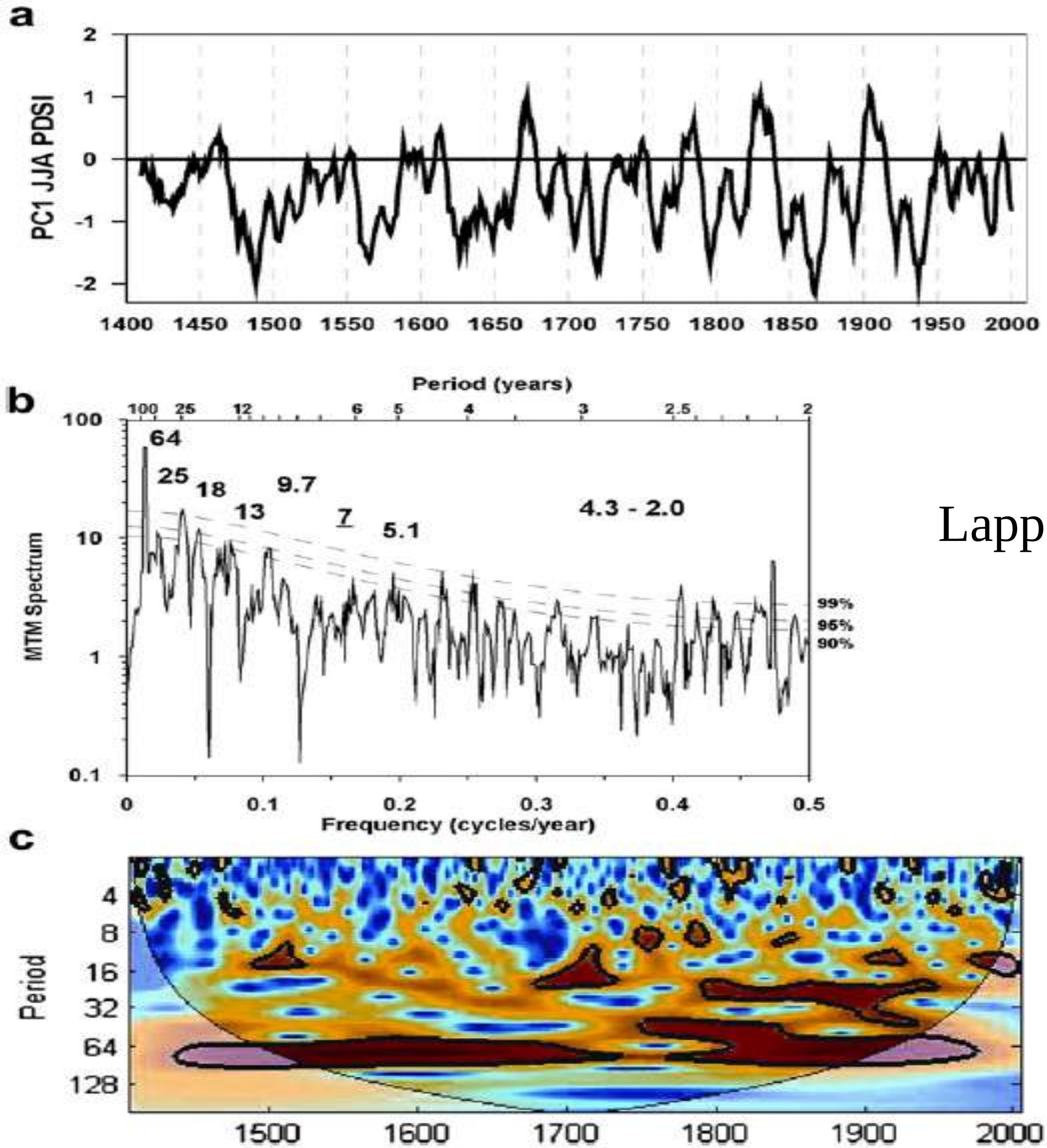
Gurrapu et al. 2012


N = 40
Continuous natural flow; 50 yrs contiguous data

Mean Annual Flow (m^3sec^{-1}) North Saskatchewan River, 1063-2006

Sauchyn *et al*. 2011

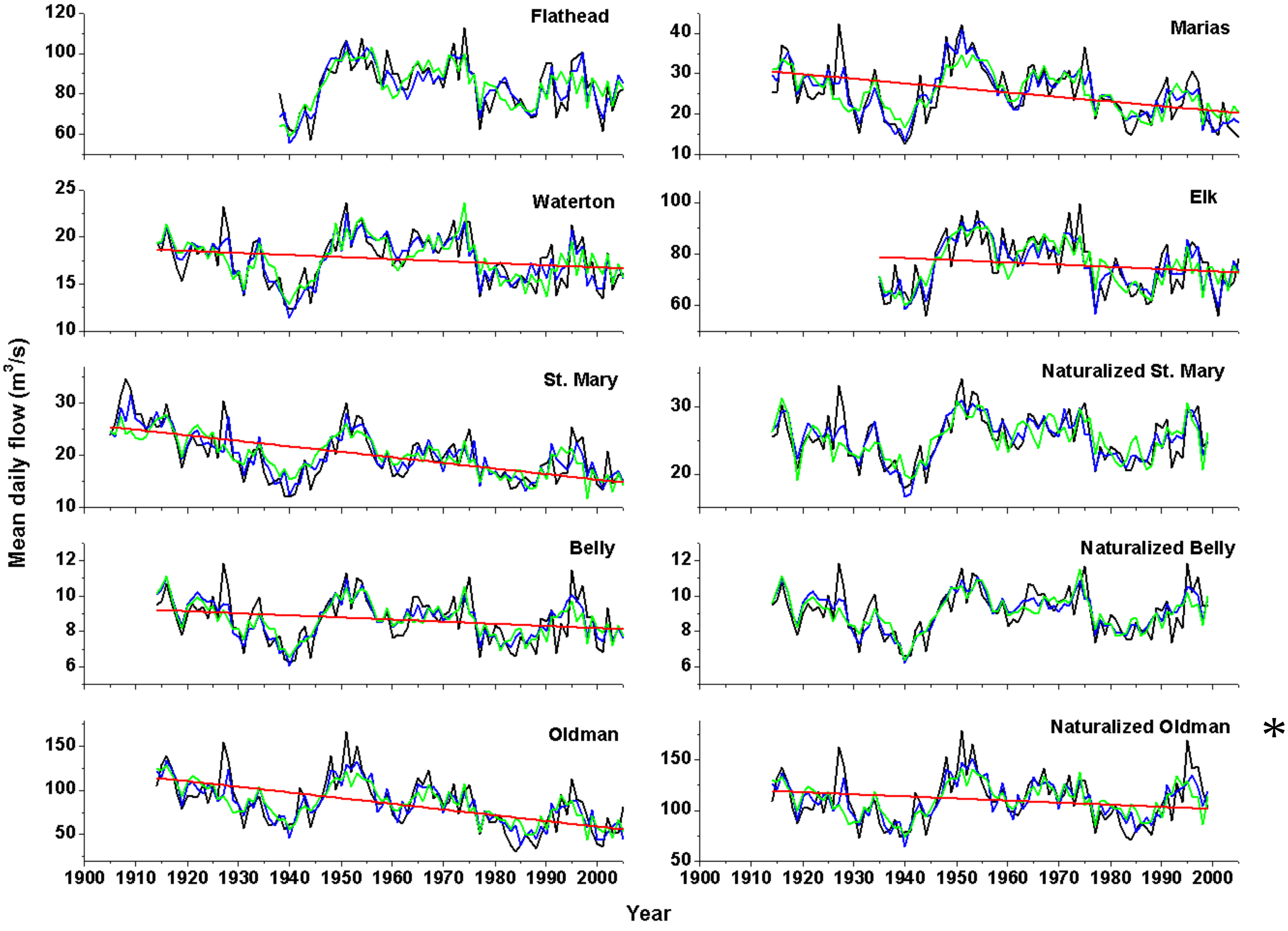




Lapp et al. 2012

St. Jacques et al. 2012

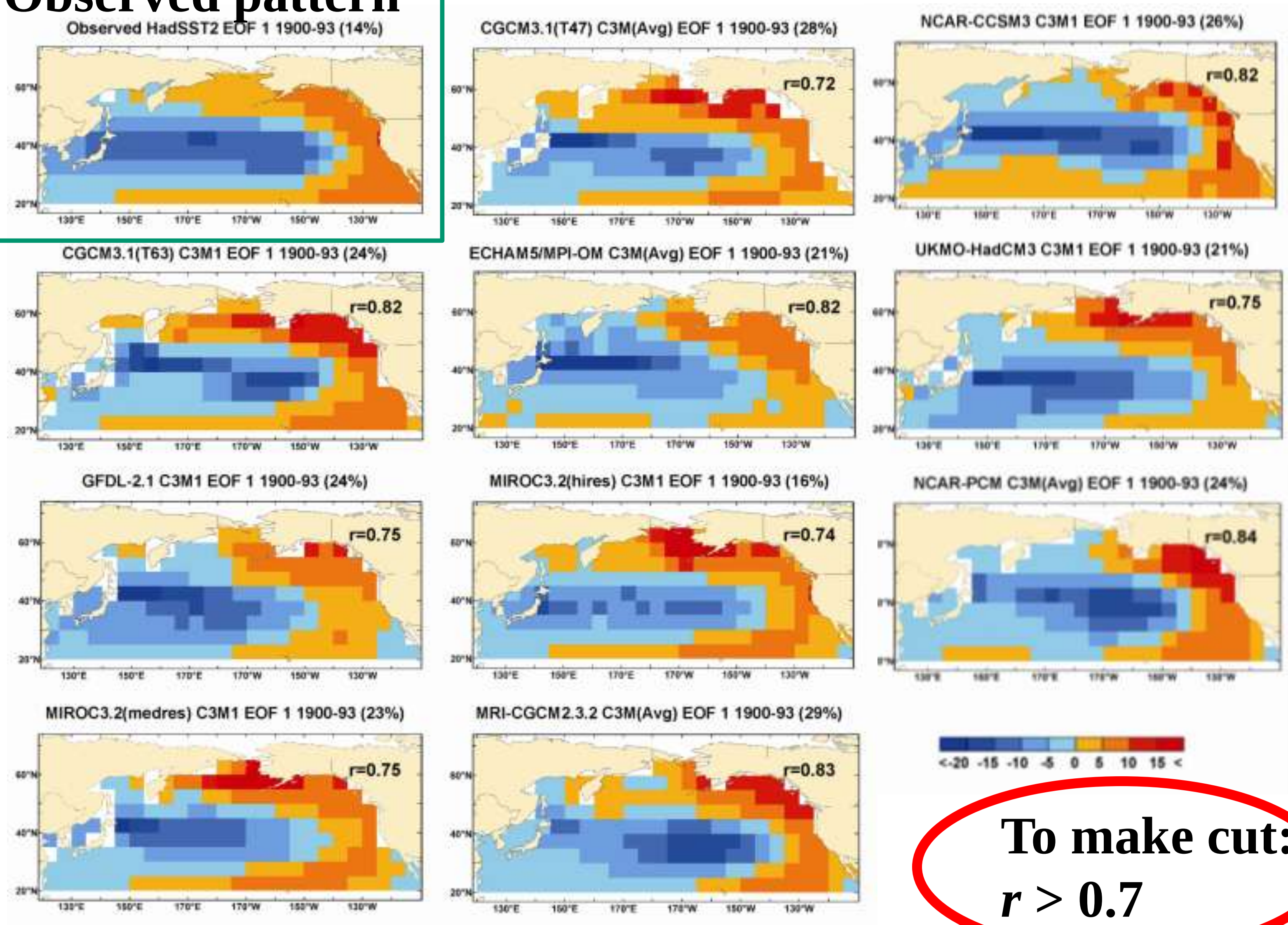
GLS Streamflow Models by Gauge



* e.g., $Qt = -0.24 - 5.16*trend - 8.38*PDO - 10.02*PDO_{P2} - 10.19*SOI_{P2}$

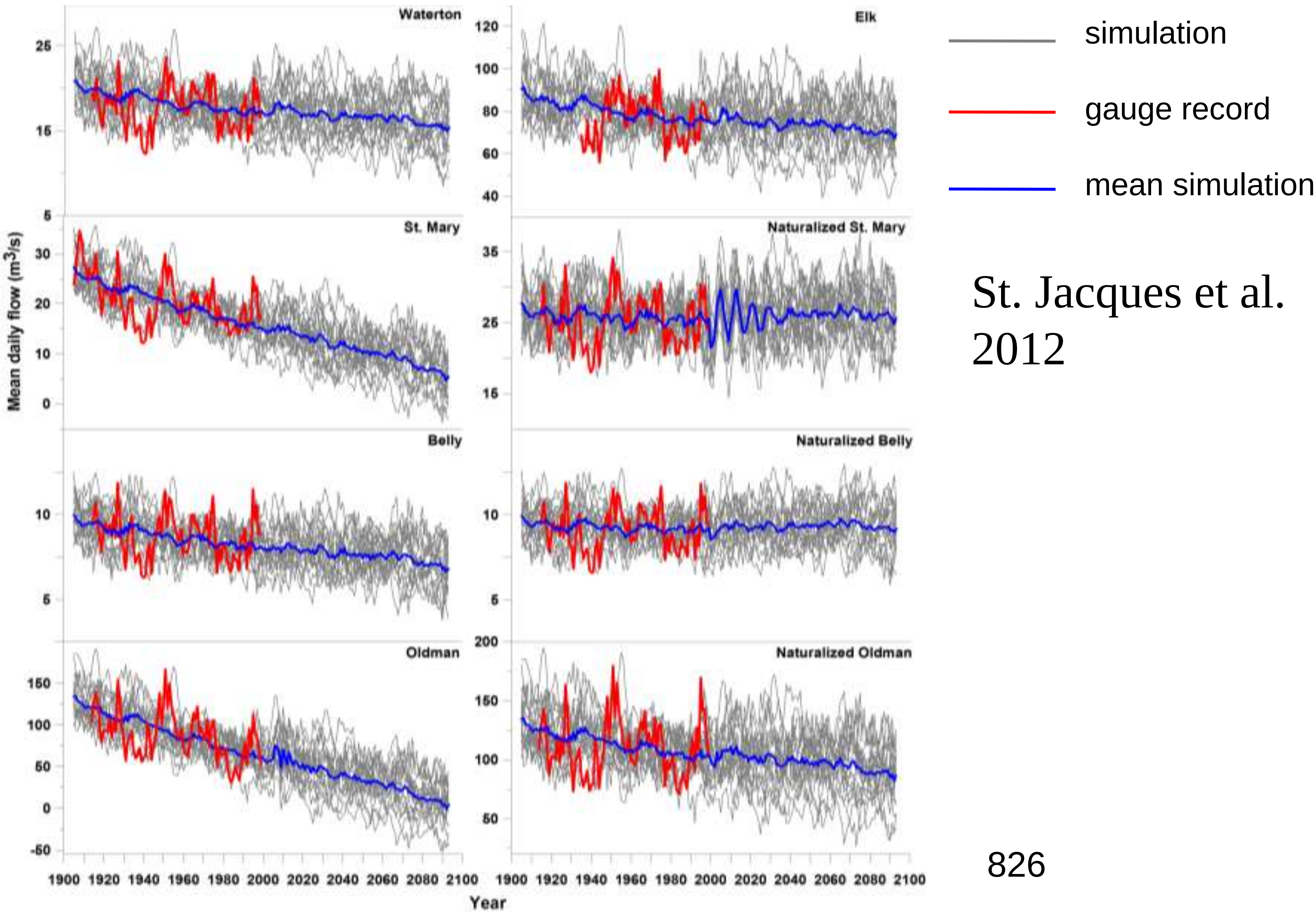
PDO: Observed versus 20th century simulations

Observed pattern



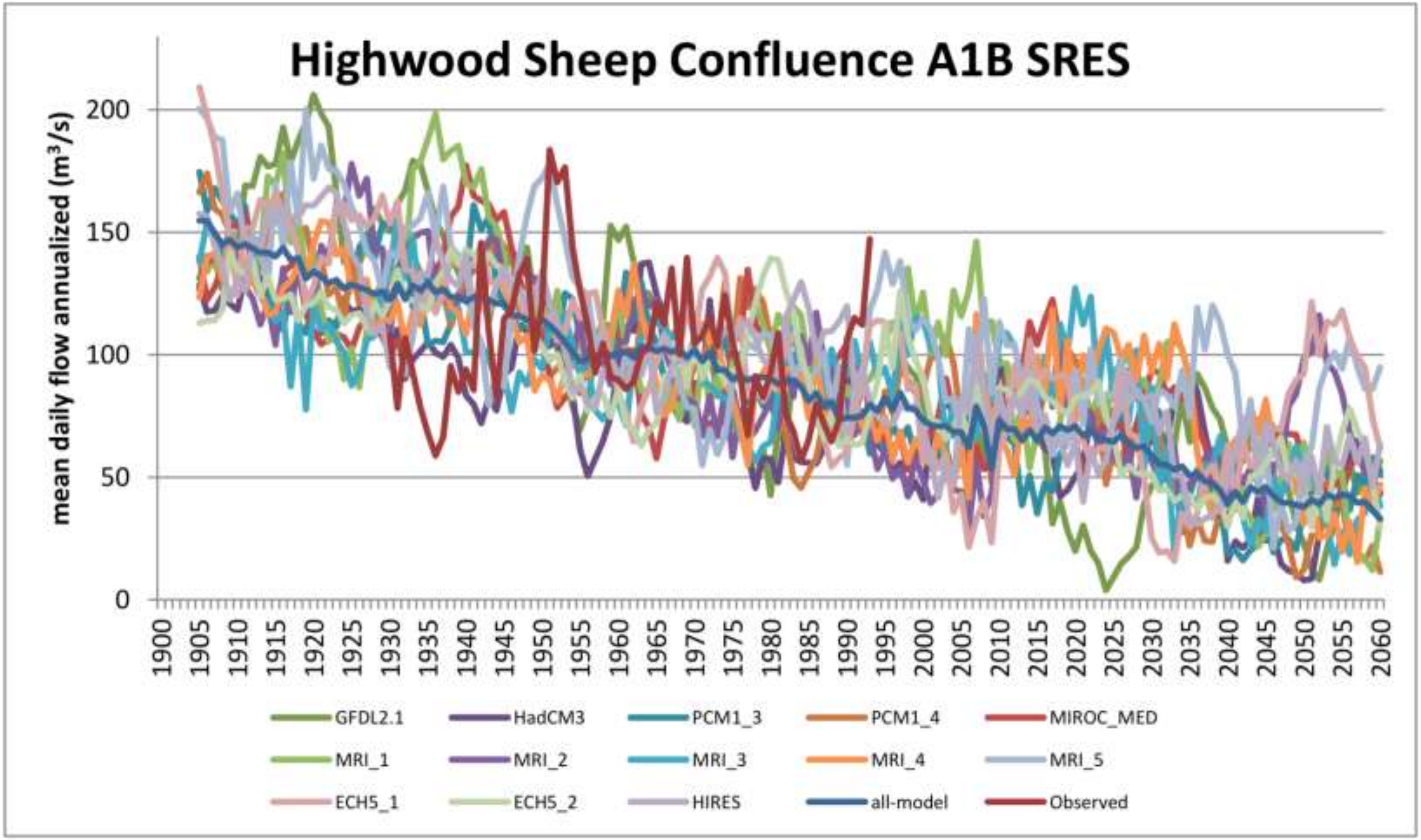
To make cut:
***r* > 0.7**

Streamflow Simulations, 1900-2100



St. Jacques et al. 2012

Ensemble Projection of Annual Flows



Conclusion

- The **standard practice** of running hydrological models with projected climate means is the best approach for assessing impacts of changes on land use and mean climate conditions on **water balances and basin yield**.

- However this approach **fails provide information on shifts in hydrologic extremes** because the variability is inherited from the model calibration; the forcing of interannual to decadal variability is not modeled.

- Considerable time and effort is given to the calibration and validation of environmental models but not to the selection and **validation of climate models**.

- Why are **climate models** not considered **environmental models**?

Day 2 – Session 4

Vinod Mahat – University of Alberta & Foothills Research Institute

BIOGRAPHY

Vinod Mahat received his B.S. in Civil Engineering from Institute of Engineering, Pulchowk Campus, T.U., Nepal in 1997, M.S. in Hydropower Development with a concentration in hydrology from Norwegian University of Science and Technology, Trondheim, Norway in 2006, and Ph.D. in Civil and Environmental Engineering with a concentration in snow hydrology from Utah State University, Logan, UT, USA in 2011. Dr. Mahat has more than 10 years of international academic research and professional experiences in hydrology focusing on snowmelt modelling, watershed modelling and forest disturbances and climate change impacts on watershed hydrology. His academic and professional experiences include assessing data quality, modifying, calibrating and verifying models, conducting hydrologic modelling for flood control purposes and testing and developing of stochastic stream flow model. His academic experience also includes analyzing, preparing and summarizing data and results in reports, and presenting information to team members, clients, students, and peers at professional conferences. Currently, Dr. Mahat works as a Postdoctoral Researcher at the University of Alberta for Forest Research Institute. His current research focuses on potential impacts of climate change and vegetation dynamics on the monthly and annual water balance in southern Alberta's Rocky Mountain watersheds.

Day 2 – Session 4

Vinod Mahat – University of Alberta & Foothills Research Institute

ABSTRACT

Rivers in Southern Alberta are vulnerable to climate change because much of the river water originates as snow in the eastern slopes and Rocky Mountains. Changes to the likelihood of forest disturbance (wildfire, insects, logging, etc.) may also have compounding impacts with climate change. This project is evaluating the impacts of climate change and forest disturbance on streamflow in the upper parts of the Oldman. Here we present the results for future climate change scenarios, which were evaluated with HBV-EC in combination with a stochastic weather generator (LARS-WG) driven by GCM output climate data. Three climate change scenarios (A1B, A2 and B1) were selected to cover the range of possible future climate conditions (2020, 2050, and 2080). GCM projected less than 10 % increase in precipitation in winter and about same amount of precipitation decrease in summer. These small changes in projected precipitation resulted in up to 200% (9.3 mm) increase in winter streamflow in February and up to 63% (31.2 mm) decrease in summer flow in June. This amplification is mostly driven by the projected increase in temperature that melted winter snow earlier in winter and spring, suggesting possible future water scarcity in the snow melt dominated regions during the summer. A “guided” GLUE (generalized likelihood uncertainty estimation) approach was used to obtain best100 parameter sets to produce the ranges of streamflows for uncertainty analysis. The impacts of uncertainty were found to be higher in spring and summer flows compared to winter and fall flows.

Impacts of climate and forest changes to streamflow in Southern Alberta.

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Motivation

- Hydrology of Mountainous regions are most affected by the climate change as precipitation would change from snow to rain in warming climate [IPCC, 2007].
- Rivers in Southern Alberta are snow-fed river, and thus are vulnerable to climate change.
- Forest disturbances (wildfire, insects, logging, etc.) may have compounding impacts with climate change.

Objectives

- To assess the effects of potential future climate and forest change on the high water yielding headwaters of Alberta's Southern Rocky Mountain regions with the application of hydrological model.

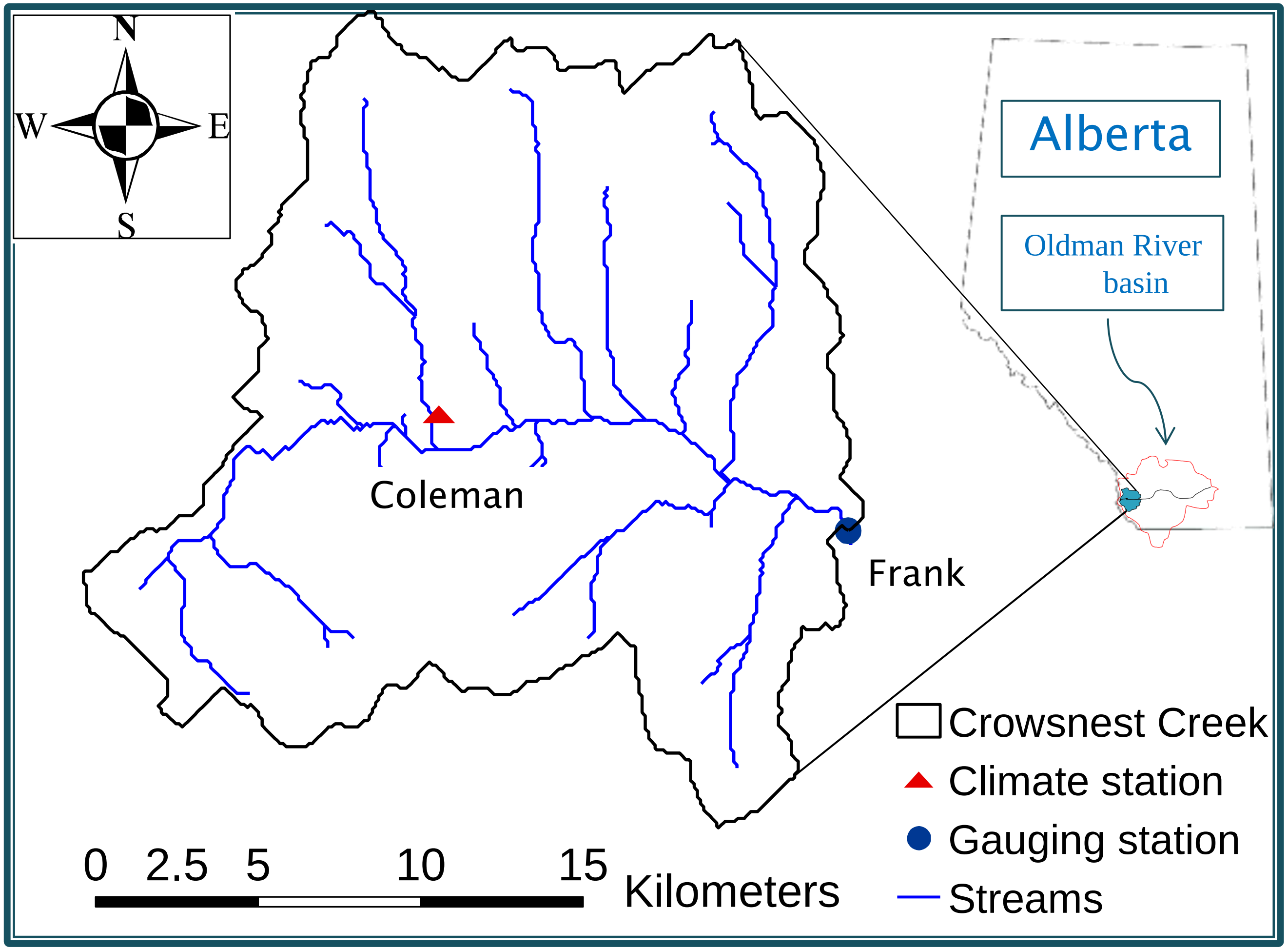
Study watershed

- Crowsnest Creek watershed
- Area:

  (384 km2)
- Elevation:

  (1236 – 2732 m)
- Forest:

  Lodgepole pine, Engelmann spruce, sub-alpile fir with alpine ecozones etc.



Method

The study methodology comprises of

- Estimates of future monthly climate means (precipitation, maximum temperature, T_{max}, and minimum temperature, T_{min}) in relation to observed climates at driver station, Coleman.
- Disaggregation (temporal downscale) of monthly climate means into daily realizations for use with hydrological model.
- Hydrological model calibration, application and parameters sensitivity

Method

Estimates of future monthly climate means in relation to observed climates at driver station

- Changes in monthly climate means observed in GCM outputs for the study watershed are calculated as

$$\Delta T_{max} = (T_{max}{}^{F} + \varepsilon) - (T_{max}{}^{R} + \varepsilon) \quad \ldots\ldots(1)$$

$$\Delta T_{min} = (T_{min}{}^{F} + \varepsilon) - (T_{min}{}^{R} + \varepsilon) \quad \ldots\ldots.(2)$$

$$\Delta P = \frac{\varepsilon\, P^{F}}{\varepsilon\, P^{FR}} \quad \ldots\ldots(3)$$

- Daily observed climate at Coleman station is aggregated to monthly scale and monthly means of these are perturbed with ΔT_{max}, ΔT_{min} and ΔP to obtain the future monthly climate means in relation to driver station, Coleman.

Reference period	Future period			Emission Scenario
1965 - 1996 observed climate at driver station	2011-2040 (2020s)	2041-7200 (2050s)	2071-2100 (2080s)	A1B, A2, B1

Method
Disaggregation

- **Disaggregation** is done based on each month's statistical properties derived from observed daily climate data (1965-1996) at driver station using stochastic weather generator, LARS-WG.
- **LARS-WG**
  - Series of wet and dry day is determined using semi-empirical approach, fitting probability distribution to observed relative frequencies of wet and dry spell lengths [Semenov and Brooks, 1999].
  - Daily T_{max} and T_{min} are modeled separately with daily means and standard deviation conditioned on the wet or dry status of the day [Semenov and Brooks, 1999].
    - Autocorrelation values of observed T_{max} and T_{min} are also used.
    - Seasonal cycles are modeled by finite Fourier series of order 3.
  - Open source: available at Environment Canada website. (http://www.cccsn.ec.gc.ca/index.php?page=lars-wg)

Method

Hydrological model calibration, application and parameters sensitivity

Hydrological model (HBV-EC)

- Three main modules: snow, soil, runoff transfer
- Group Response Unit (GRU):
  - Elevation band , land cover (open, forest, water and glacier), different slope, aspect, elevation etc.
- Inputs: temperature, precipitation, monthly estimates of evapotranspiration
- Outputs: streamflow, SWE, evaporation, soil moisture content etc.
- Open source: available at modeling framework ‘Green Kenue’ developed by National Research Council Canada in collaboration with Environment Canada. (http://www.nrc-cnrc.gc.ca/eng/solutions/advisory/green_kenue/download_green_kenue.html)

Calibration

- Driven by the thirty two years (1965-1996) climate data recorded at driver station, Coleman.
- Simulated streamflow is compared the with observed values at watershed outlet, Frank.

Method

Hydrological model calibration, application and parameters sensitivity

Application

- The model is driven by the LARS-WG aggregated daily realizations to simulate the streamflows for the reference and nine different future periods.
- Climate change impacts assessment is carried out comparing the model simulated streamflows for the reference and these nine future periods.

Parameter sensitivity

- 100 most behavioral parameters giving higher Nash Sutcliffe efficiency are selected using GLUE approach.
- These 100 parameters sets are used with HBV-EC to provide results in terms of a range to capture the model parameters sensitivity.

Results

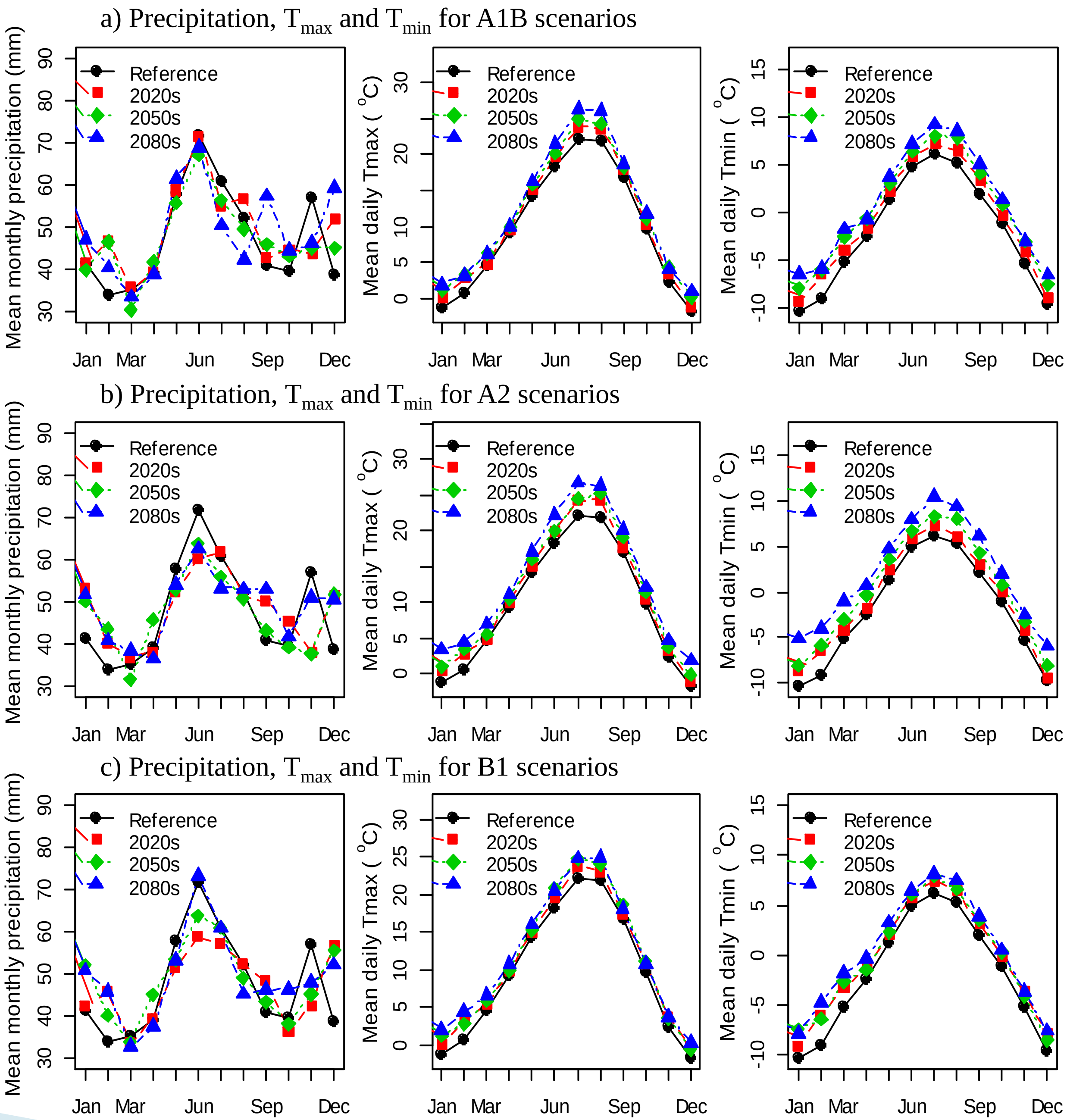
Estimates of relative changes in monthly climate means observed in GCM outputs

Time period	Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Ann mean
Percentage change in mean monthly precipitation															
2011–2040 ("2020s")	A1B	2.6	4.1	−4.3	3.9	−7.3	−5.0	−2.4	−2.8	3.2	−2.7	−7.9	3.6	−1.6	
	A2	3.1	3.8	−4.5	3.5	−7.3	−5.2	−2.3	−3.1	2.7	−2.6	−7.7	3.6	−1.6	−1.7
	B1	2.3	3.6	−4.2	3.9	−7.8	−5.6	−2.6	−3.6	2.8	−3.5	−7.7	3.4	−1.9	
2041–2070 ("2050s")	A1B	4.2	4.7	−2.9	4.9	−6.6	−4.6	−1.6	−1.8	4.3	−1.9	−6.7	4.8	−0.6	
	A2	3.7	4.4	−3.0	5.0	−6.1	−4.5	−1.3	−1.5	4.3	−1.9	−7.0	4.5	−0.6	−0.98
	B1	3.7	2.6	−3.6	3.8	−7.9	−5.2	−2.0	−3.2	3.0	−3.4	−7.5	3.1	−1.7	
2071–2000 ("2080s")	A1B	5.3	4.4	−1.9	4.6	−6.0	−3.8	−0.6	−1.0	4.9	−1.3	−6.4	6.3	0.04	
	A2	6.7	6.8	−1.2	6.1	−5.0	−3.1	0.5	−0.1	6.1	−0.6	−6.0	6.8	1.1	0.002
	B1	3.9	4.5	−2.7	4.5	−6.9	−5.2	−2.0	−2.5	3.5	−3.2	−7.0	4.2	−1.1	
Change in mean monthly daily air temperature															
2011–2040 ("2020s")	A1b	1.6	3.1	0.9	0.7	1.0	1.6	1.5	1.7	1.5	0.8	0.9	0.7	1.3	
	A2	2.0	2.8	0.6	0.4	1.2	1.7	1.8	1.8	1.1	0.9	1.0	0.8	1.3	1.4
	B1	1.7	3.6	1.5	1.0	1.1	1.3	1.6	1.3	1.2	1.2	1.1	1.1	1.5	
2041–2070 ("2050s")	A1B	3.1	3.6	2.2	1.2	1.7	2.0	2.5	2.7	2.2	1.7	2.0	1.8	2.2	
	A2	2.6	3.4	1.8	1.6	2.2	2.0	2.4	3.0	2.6	1.9	1.6	1.6	2.2	2.1
	B1	3.0	2.7	2.0	0.9	0.9	2.4	2.5	1.9	1.9	1.3	1.4	0.8	1.8	
2071–2000 ("2080s")	A1B	3.8	3.2	2.9	1.0	2.4	3.1	3.7	3.5	2.8	2.1	2.4	3.0	2.8	
	A2	5.2	5.3	3.3	2.2	3.4	3.7	4.5	4.6	4.0	2.7	2.8	3.6	3.8	3.0
	B1	3.8	4.3	3.0	1.6	2.1	2.1	2.4	2.7	1.8	1.3	1.8	1.8	2.4	

Results

Future monthly climate means in relation to observed climates at driver station

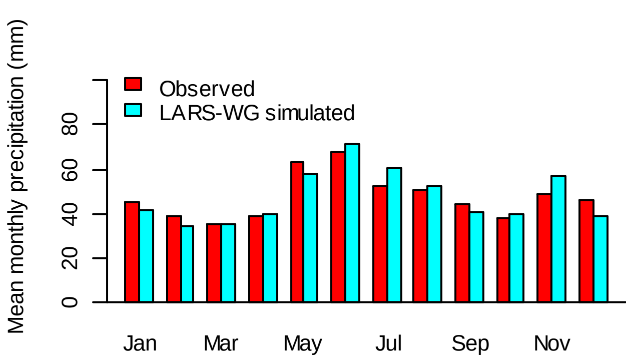
- Increase in precipitation in winter < 10%.
- Decrease in precipitation in summer < 10%.

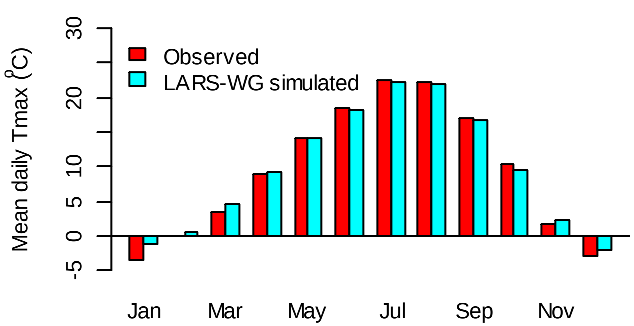


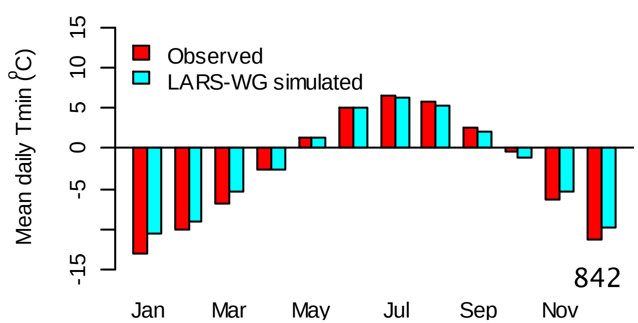
Results

Disaggregation of monthly climate means into daily realizations

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation												
Observed mean	45.10	39.13	34.98	39.03	63.24	67.58	52.56	50.98	44.42	38.19	48.70	45.91
Observed standard deviation	31.80	31.59	21.59	17.63	29.39	26.19	40.22	39.99	26.67	24.34	33.15	30.23
Disaggregated mean	41.36	33.85	35.42	39.34	57.96	71.61	60.82	52.11	41.01	39.62	56.99	38.60
Disaggregated standard deviation	21.67	17.00	20.24	17.64	25.49	25.81	23.65	20.02	22.19	21.19	32.38	22.44
P-values for T-test	0.583	0.406	0.933	0.943	0.442	0.535	0.319	0.887	0.577	0.803	0.315	0.276
P-values for F-test	0.036	0.001	0.720	0.995	0.431	0.936	0.03	0.03	0.309	0.445	0.896	0.102
Tmin												
Observed mean	-13.05	-10.09	-6.87	-2.63	1.35	4.95	6.61	5.86	2.46	-0.46	-6.39	-11.15
Observed standard deviation	4.76	4.06	2.93	1.69	0.95	1.16	1.02	1.20	1.38	1.58	3.16	4.32
Disaggregated mean	-10.41	-9.10	-5.21	-2.51	1.32	4.93	6.15	5.33	2.07	-1.13	-5.30	-9.67
Disaggregated standard deviation	1.82	1.72	1.32	0.83	0.65	0.71	0.49	0.63	0.97	1.21	1.44	1.73
P-values for T-test	0.005	0.208	0.005	0.734	0.914	0.944	0.024	0.031	0.188	0.062	0.080	0.078
Tmax												
Observed mean	-3.51	-0.02	3.55	8.91	14.22	18.38	22.37	22.36	16.90	10.41	1.66	-2.83
Observed standard deviation	4.07	3.14	2.85	2.21	1.85	1.84	2.14	2.55	3.43	2.23	2.91	3.34
Disaggregated mean	-1.25	0.64	4.64	9.21	14.24	18.30	22.12	21.84	16.85	9.66	2.33	-1.86
Disaggregated standard deviation	1.38	1.13	0.83	1.09	1.22	0.93	1.08	1.04	1.38	1.30	1.10	1.19
P-values for T-test	0.006	0.263	0.052	0.499	0.957	0.826	0.558	0.282	0.935	0.106	0.227	0.128







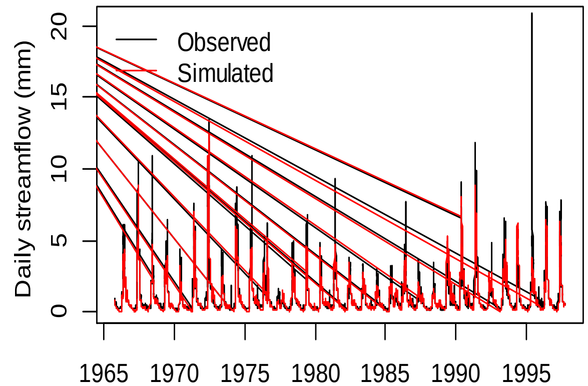
Results

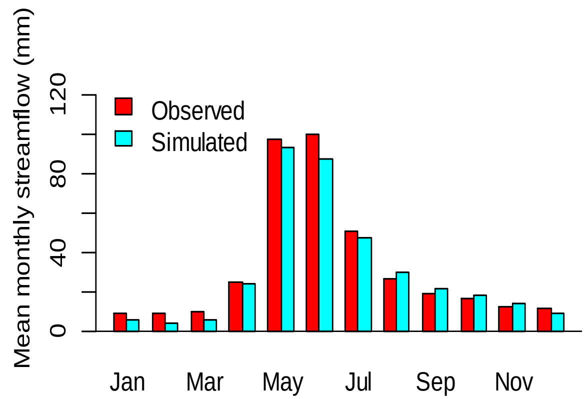
Hydrological model calibration, application and parameters sensitivity

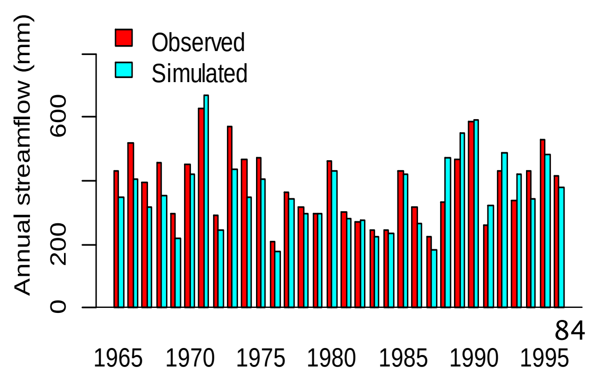
Calibration

HBV-EC is driven by the observed climate at driver station, Coleman, and model simulated streamflow is compared with observed values for calibration.

- HBV-EC reproduces the streamflow with Nash Sutcliffe efficiency 0.82.
- Some peak flows underestimated
- Large difference observed in February which is 50% (5 mm).
- Maximum 12 mm difference was observed in June.
- Difference in annual mean was less than 15% for 80% of time.
- Difference in annual mean was about 6%.







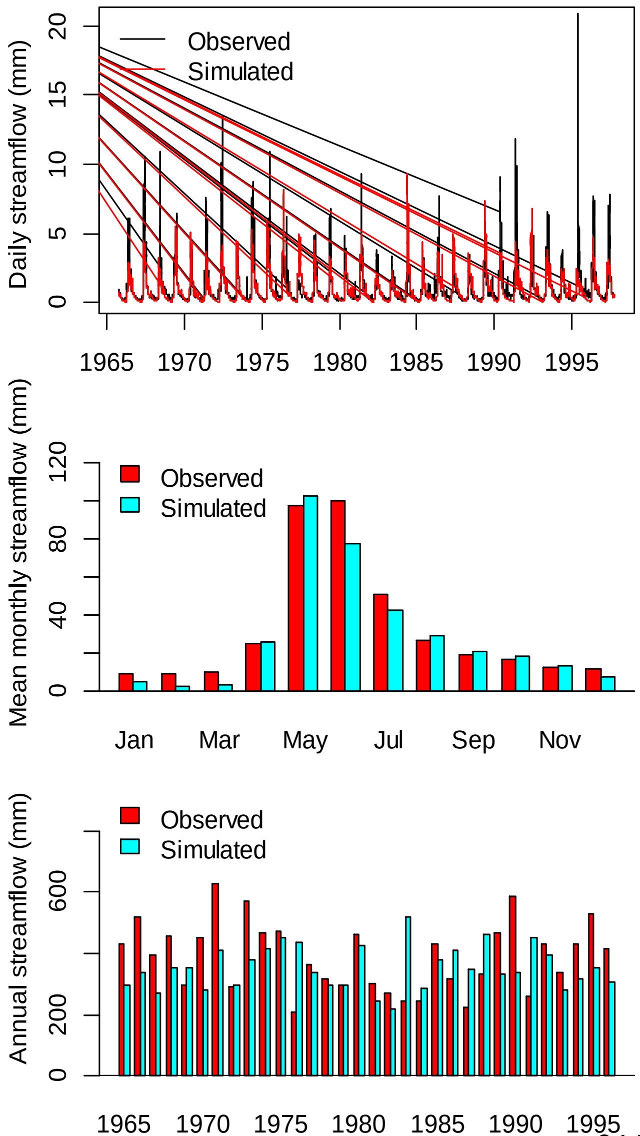
Results

Hydrological model calibration, application and parameters sensitivity

Application

HBV-EC is driven by the disaggregated climate at driver station, Coleman, and model simulated streamflow is compared with observed values.

- Similar result as in calibration was obtained though the input came from different sources.
- Difference in annual mean was about 9%.



Results

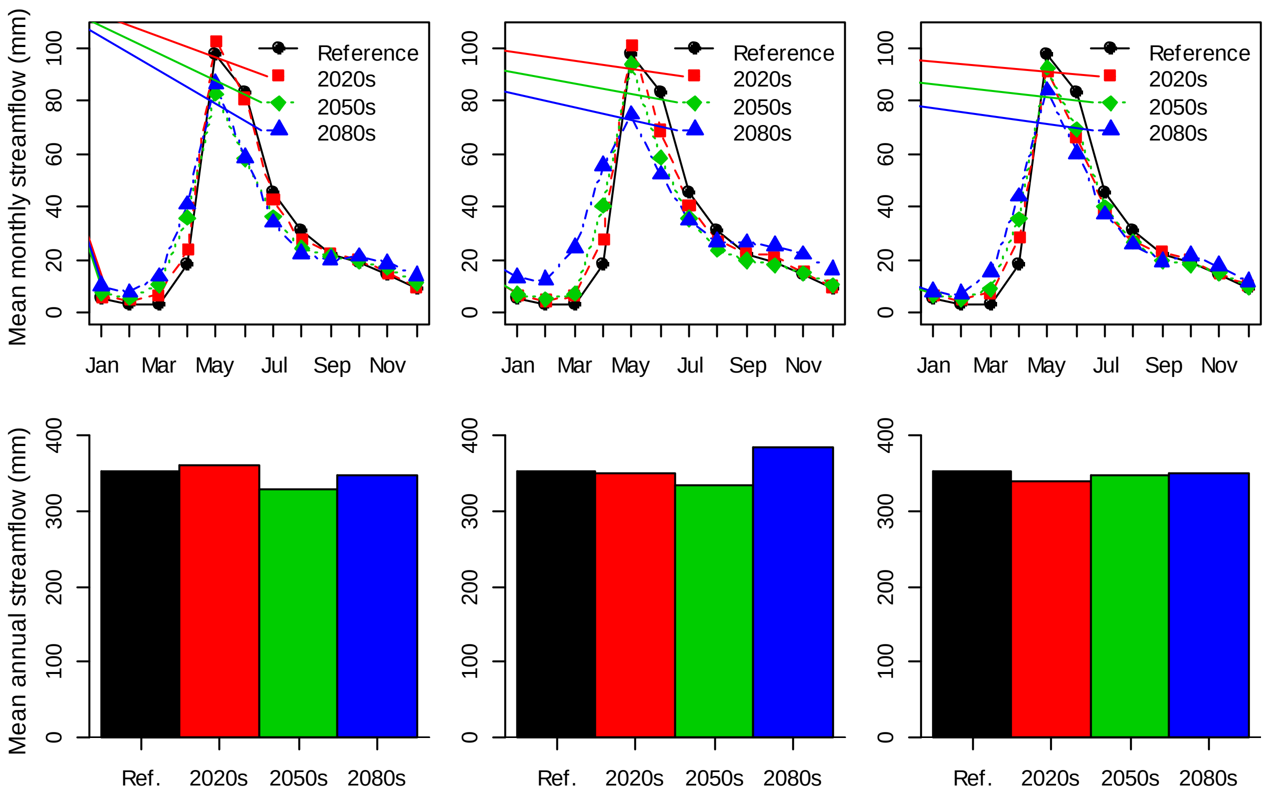
Hydrological model calibration, application and parameters sensitivity

Application

HBV-EC is driven by the disaggregated climate at driver station for reference and nine future periods, and model simulated streamflows, snow water equivalent (SWE) and evapotranspiration are compared.

Streamflow

- Winter low flows increased up to 200% (9.3 mm) in February.
- Summer high flows decreased up to 63% (31.2 mm) in June.
- Fall (September, October and November) flows were least affected and remains almost.
- Not much difference in annual water yield.

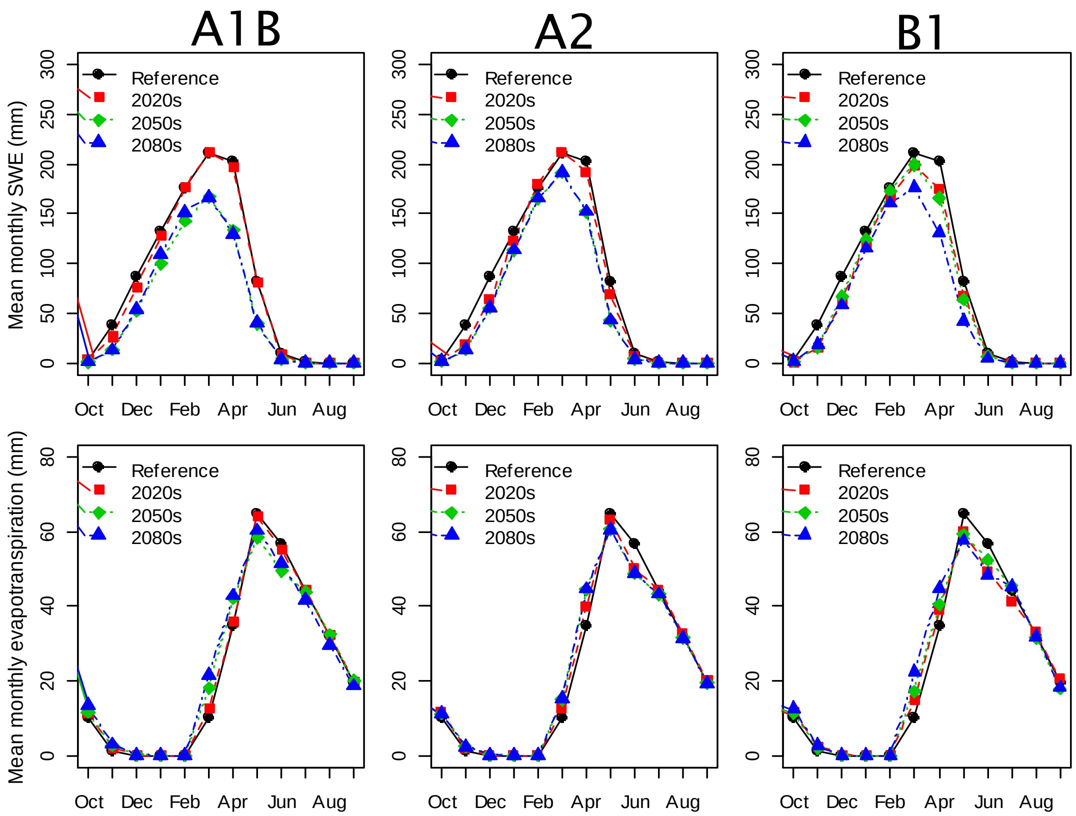


Results

Hydrological model calibration, application and parameters sensitivity

Application

- SWE
  - SWE decreased
- Evapotranspiration
  - Evapotranspiration increased in spring and decreased in summer.
  - Despite increase in temperature throughout the year, decrease in evapotranspiration during summer indicates the water limited evapotranspiration, not the energy limited.

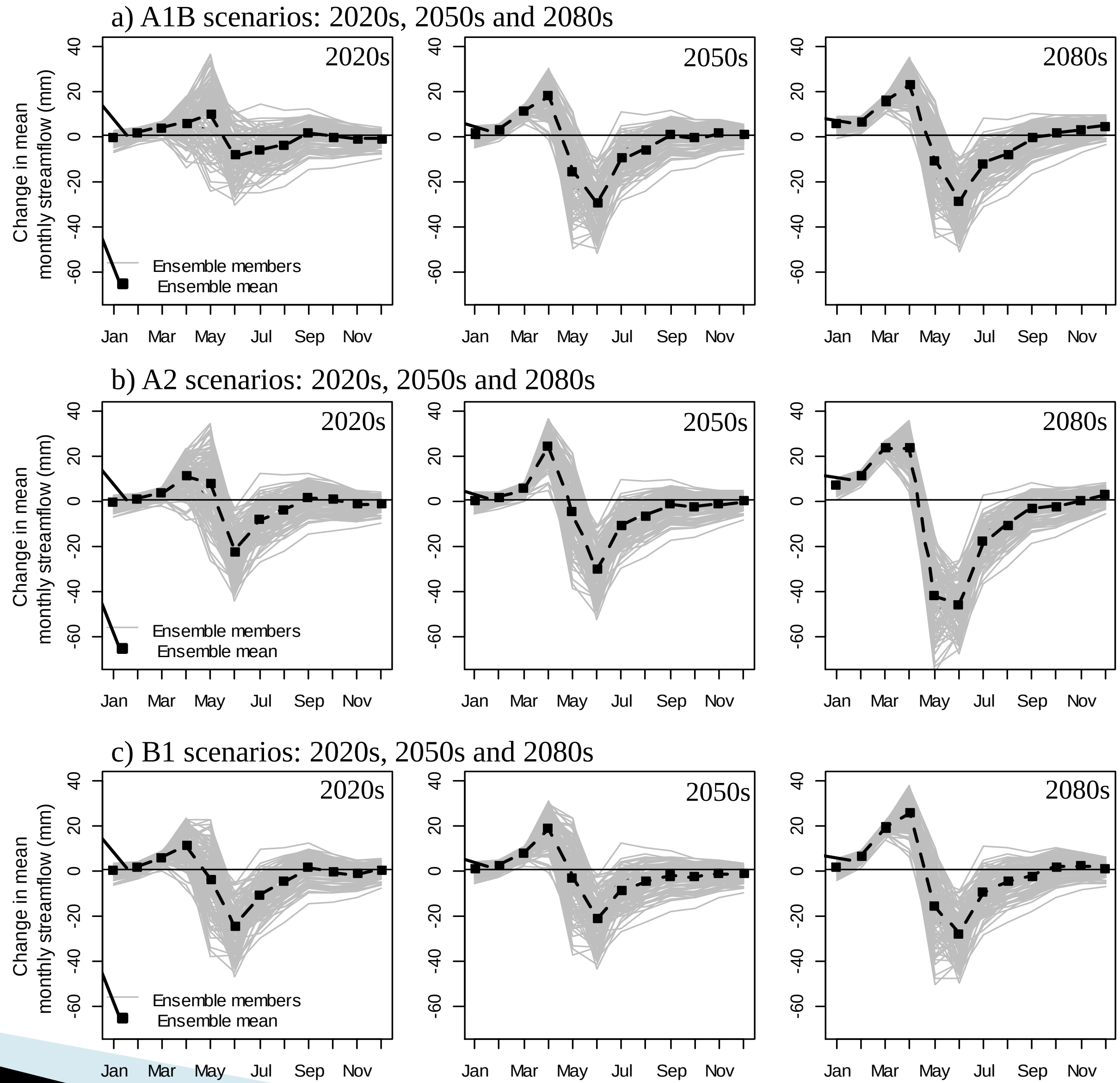


Results

Hydrological model calibration, application and parameters sensitivity

Sensitivity

- The impacts of uncertainty were higher during spring and summer.
- Chances of summer flow dropping is more.



Conclusions

- Less than 10 % increase in precipitation in winter resulted in up to 200% (9.3 mm) increase in winter streamflow.
- Less than 10 % decrease in precipitation in summer resulted in up to 63% (31.2 mm) decrease in summer flow.
- Impacts of climate change on streamflow is relatively higher for A2 scenario and this is reasonable as there is rapid economic growth but the technological changes are fragmented in A2 scenario compared to other two scenarios .
- There is more uncertainty in the prediction of summer flows, so chances of dropping summer flow is higher.

- Forest disturbances (wildfire, insects, logging, etc.) that may have compounding impacts with climate change, remains subject of further analysis.

Questions?