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

MIKE 3
Coastal and inland waters in 3D

MIKE 21
Coastal and inland waters in 2D

MIKE FLOOD
Inundation and mapping

LITPACK
Sediment transport and littoral processes

MIKE SHE
Integrated hydrology

Software for

Water

Environments

MIKE URBAN
Urban water distribution and collection

FEFLOW
Groundwater systems

WEST
Wastewater treatment plants

MIKE 11
Rivers, channels and reservoirs

MIKE BASIN
GIS-based river basin management

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

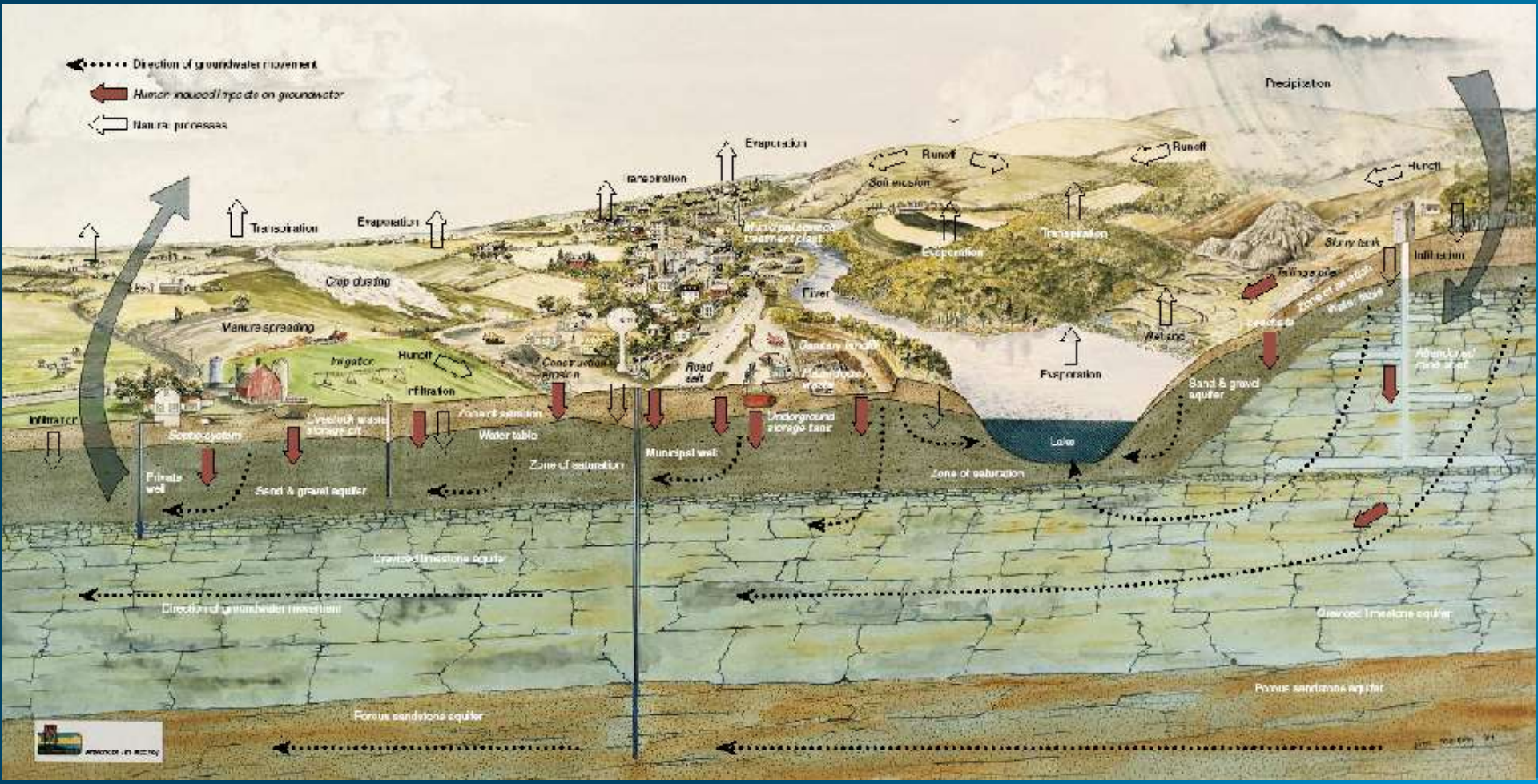
Land

Biodiversity

Environmental Modelling

Water Modelling –> Hydrologic Cycle

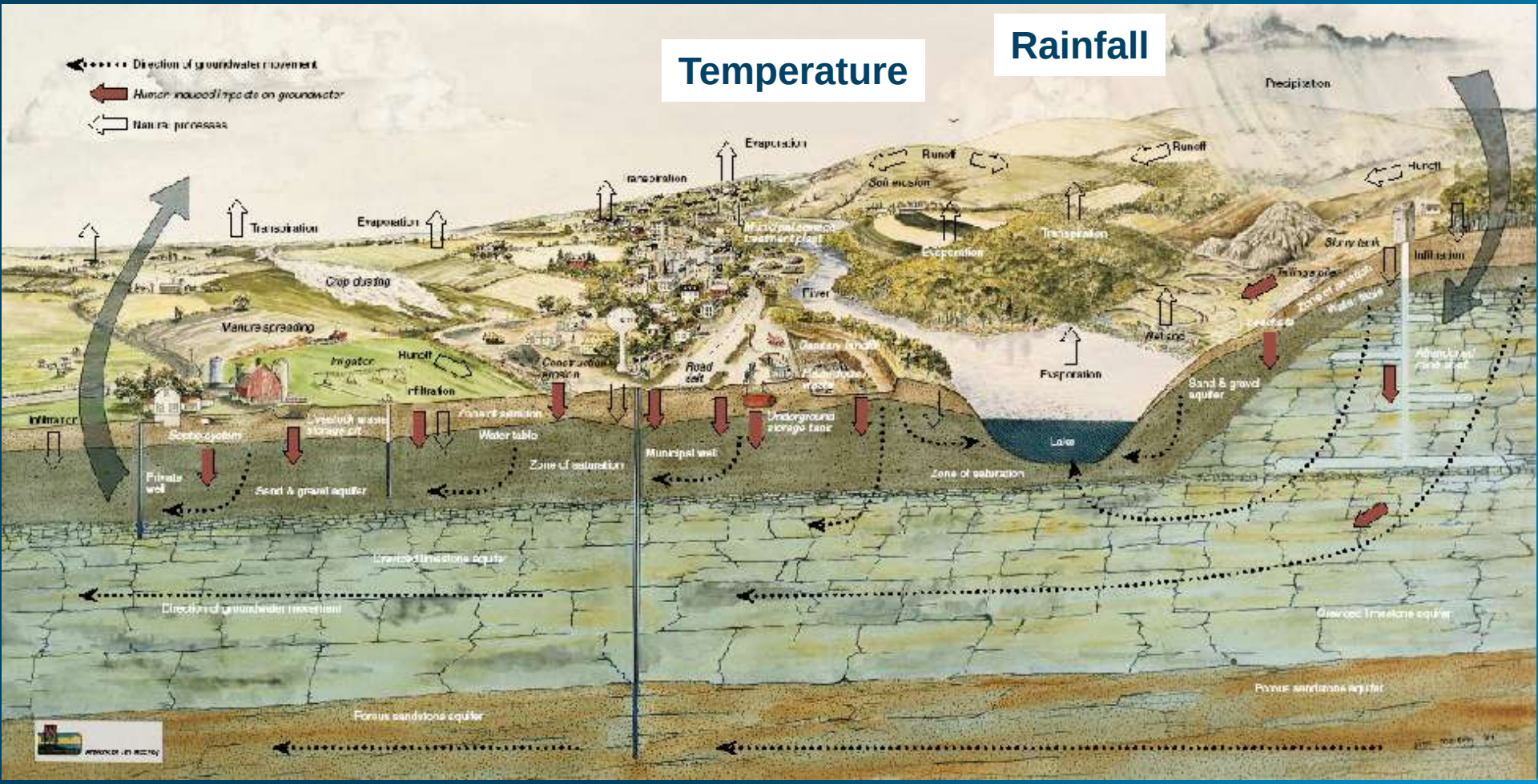
Climate, Surface Runoff, Infiltration, Evapotranspiration, Rivers, Groundwater



Environmental Modelling

Water Modelling –> Hydrologic Cycle

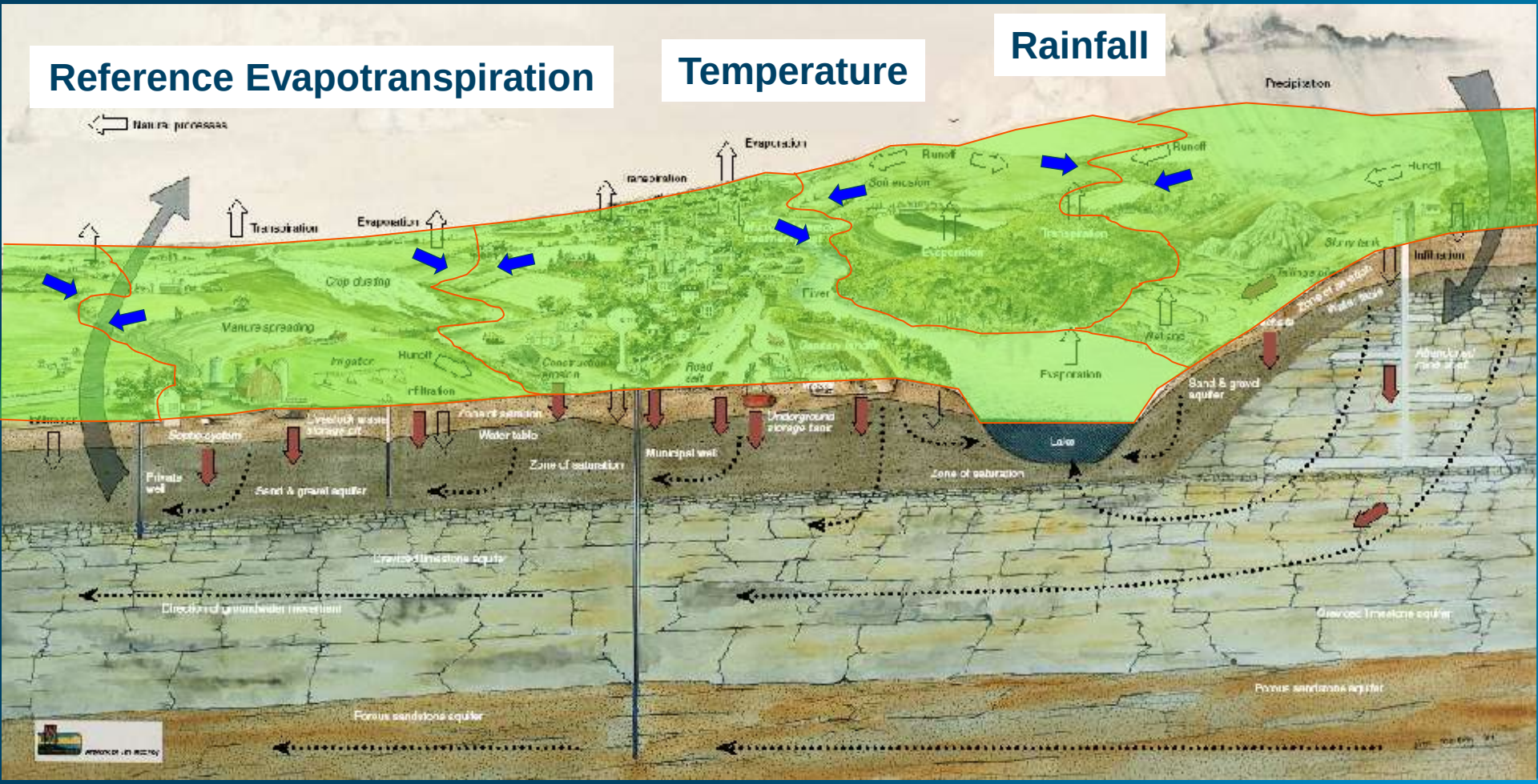
- ✔ Climate modeling - Well established models



Environmental Modelling

Water Modelling –> Hydrologic Cycle

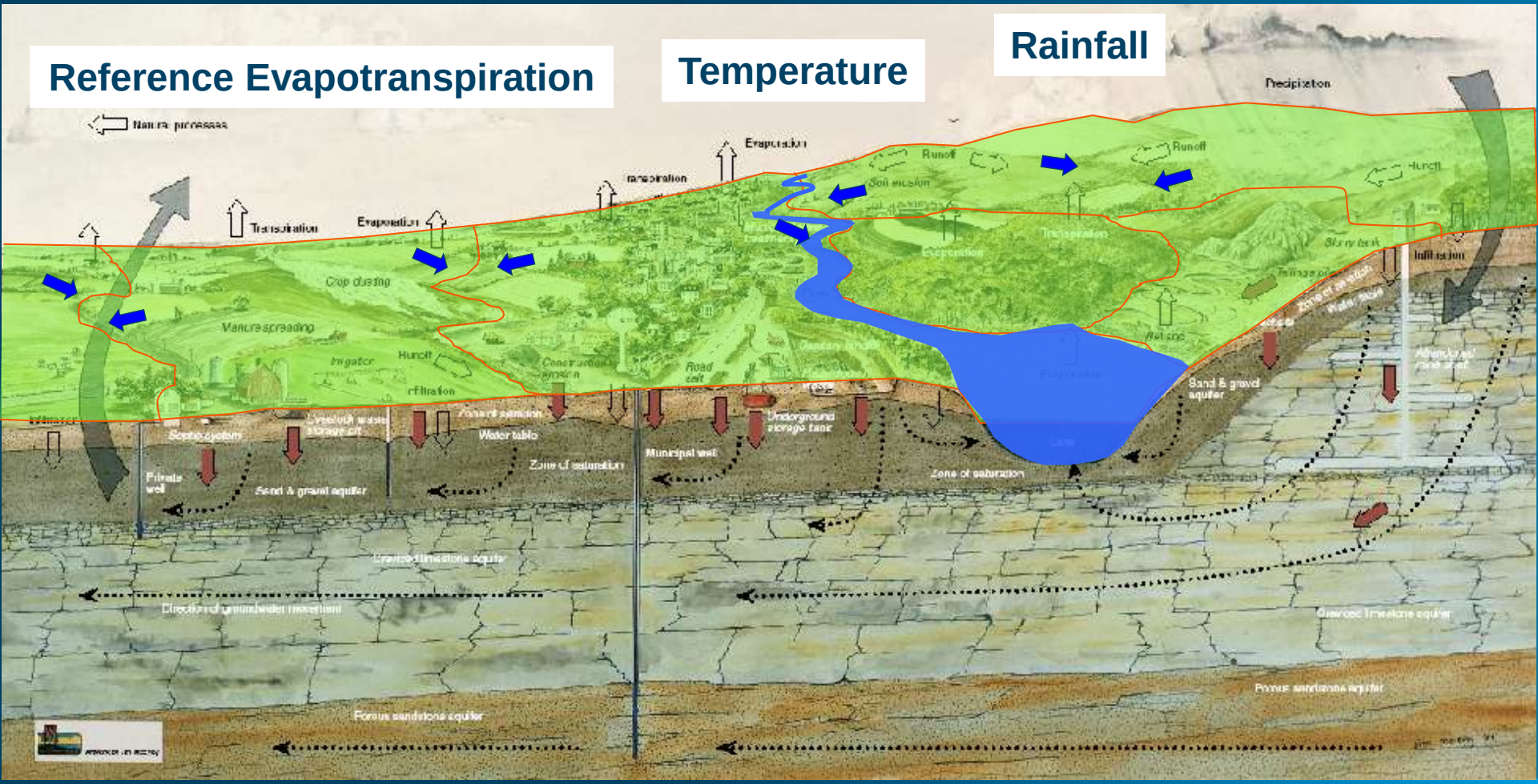
- Surface Runoff , Infiltration, Evapotranspiration - Well established models



Environmental Modelling

Water Modelling –> Hydrologic Cycle

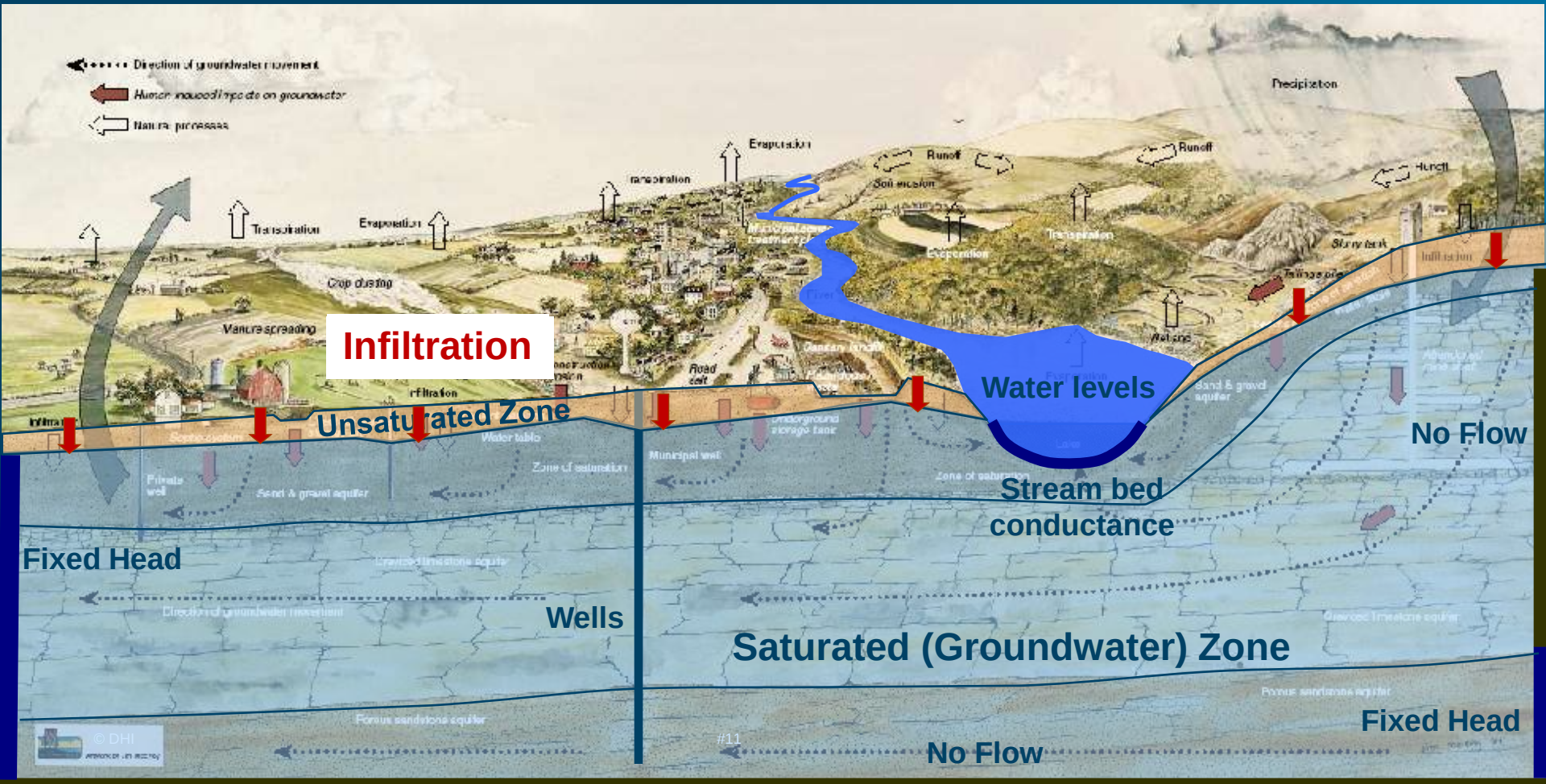
- ✔ Rivers and Lakes - Well established processes and models



Environmental Modelling

Water Modelling –> Hydrologic Cycle

- Groundwater - Well established processes and models

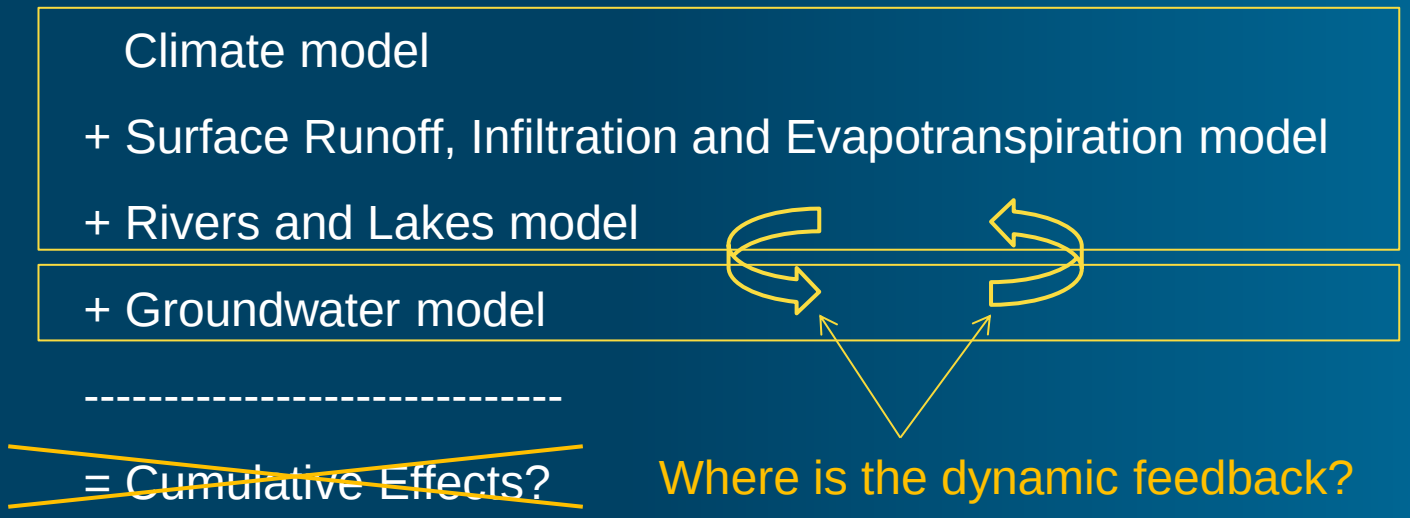


Environmental Modelling

Success! We have all of the water models!

How do you manage Cumulative Effects?

How do you measure Cumulative Effects?



Environmental Modelling

Why is dynamic feedback important?

Urbanization

Deforestation

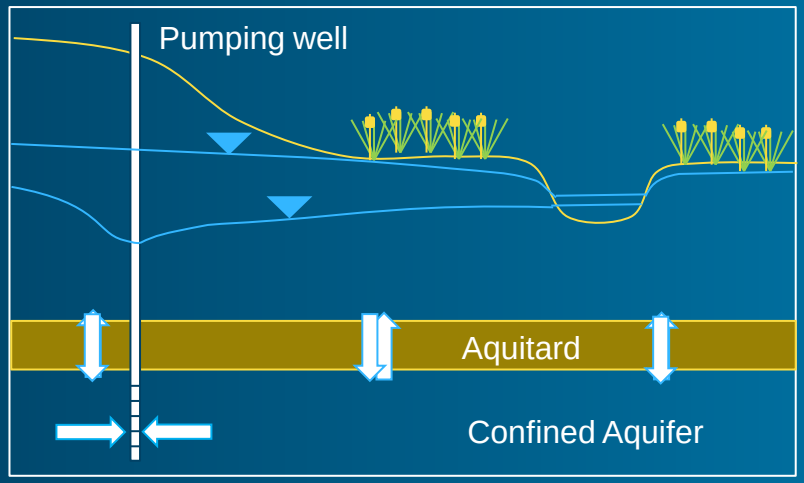
Urbanization

Increased runoff to low area

Wetland formation

Changes to vegetation and wildlife habitat

Groundwater Pumping



Install pumping well

Depressurize confined aquifer

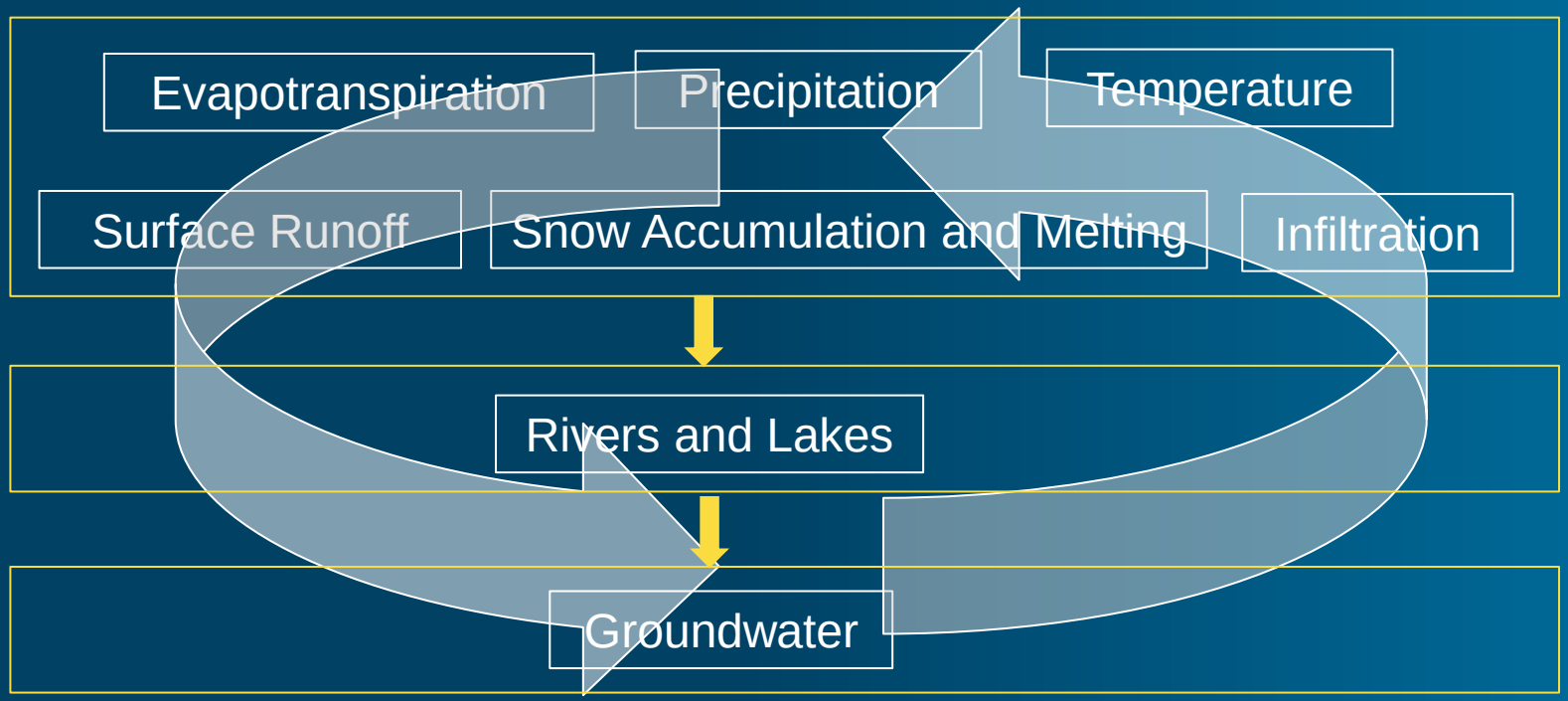
Dewater wetland and reduce baseflows to river

Changes to vegetation and aquatic habitat

Environmental Modelling

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

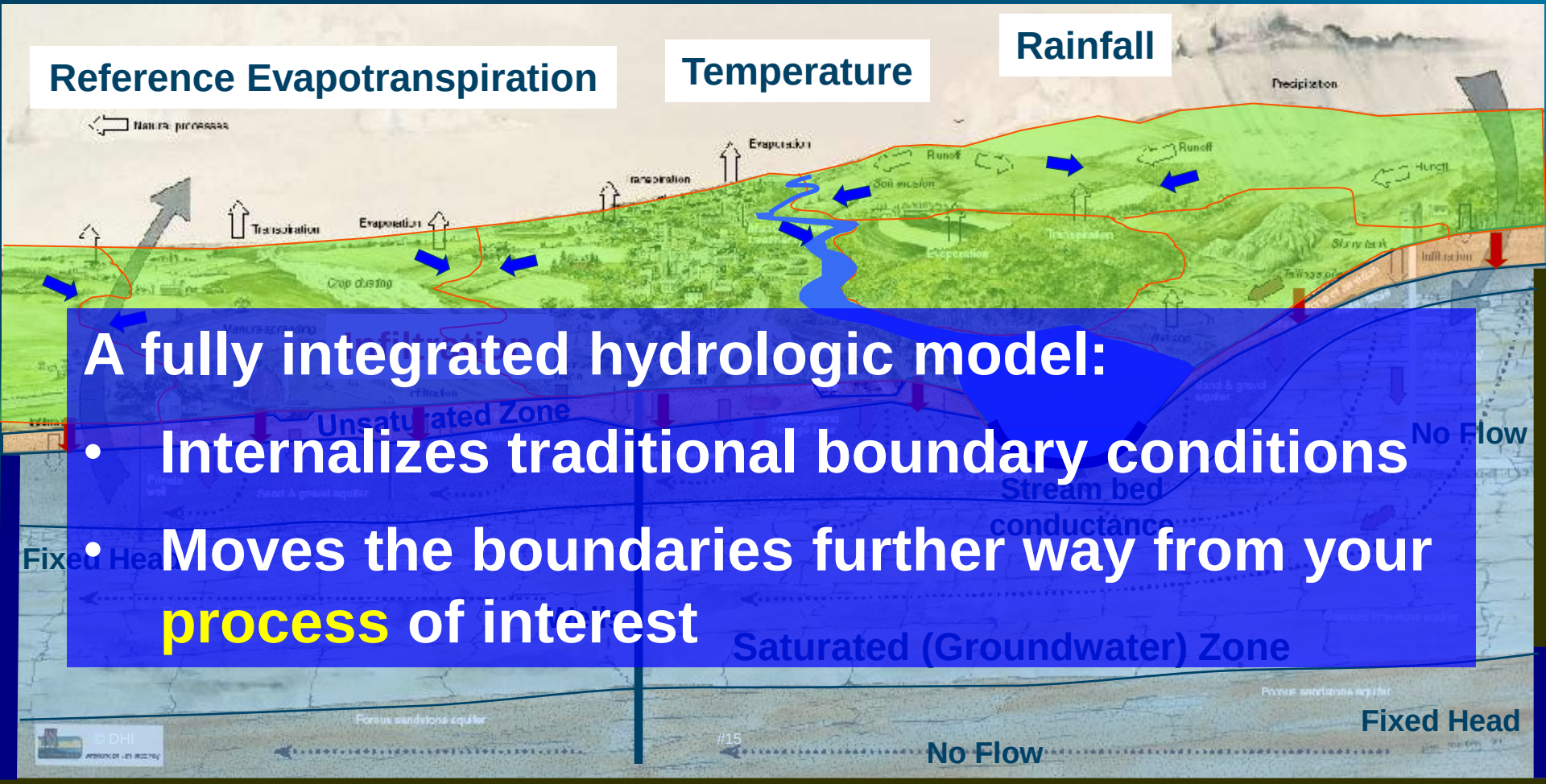
- they should be integrated



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

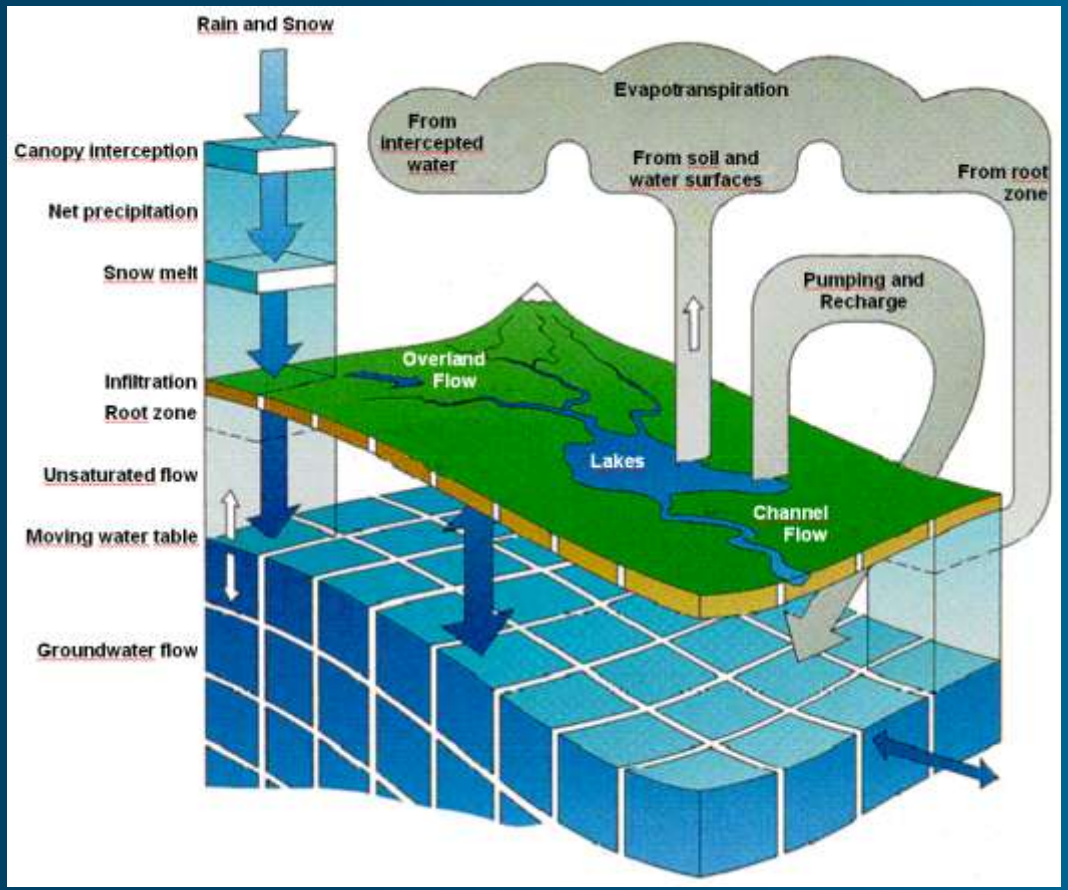
Groundwater and Surface Water
One Water — One Resource — One Model

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)

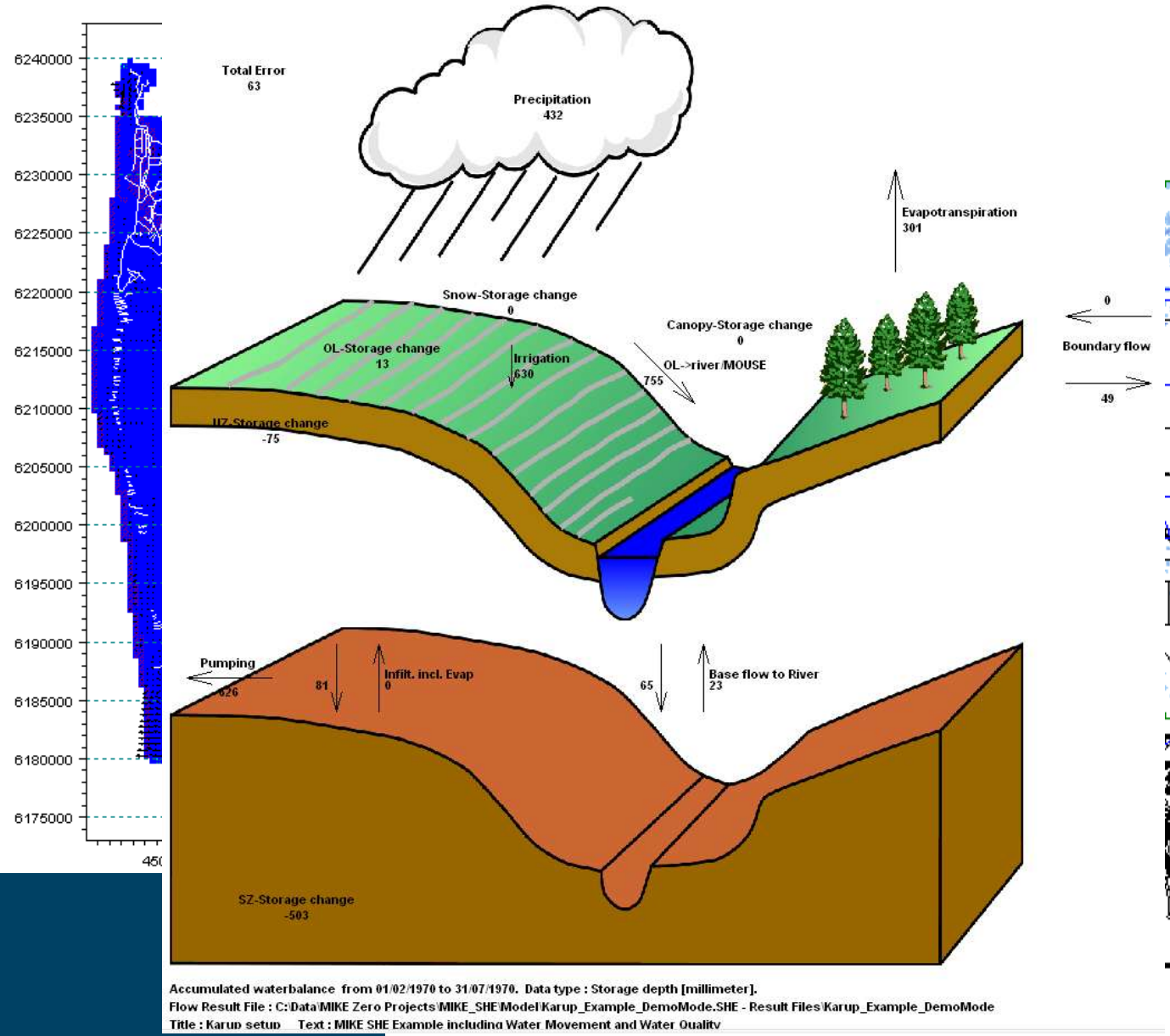
Saturated groundwater flow

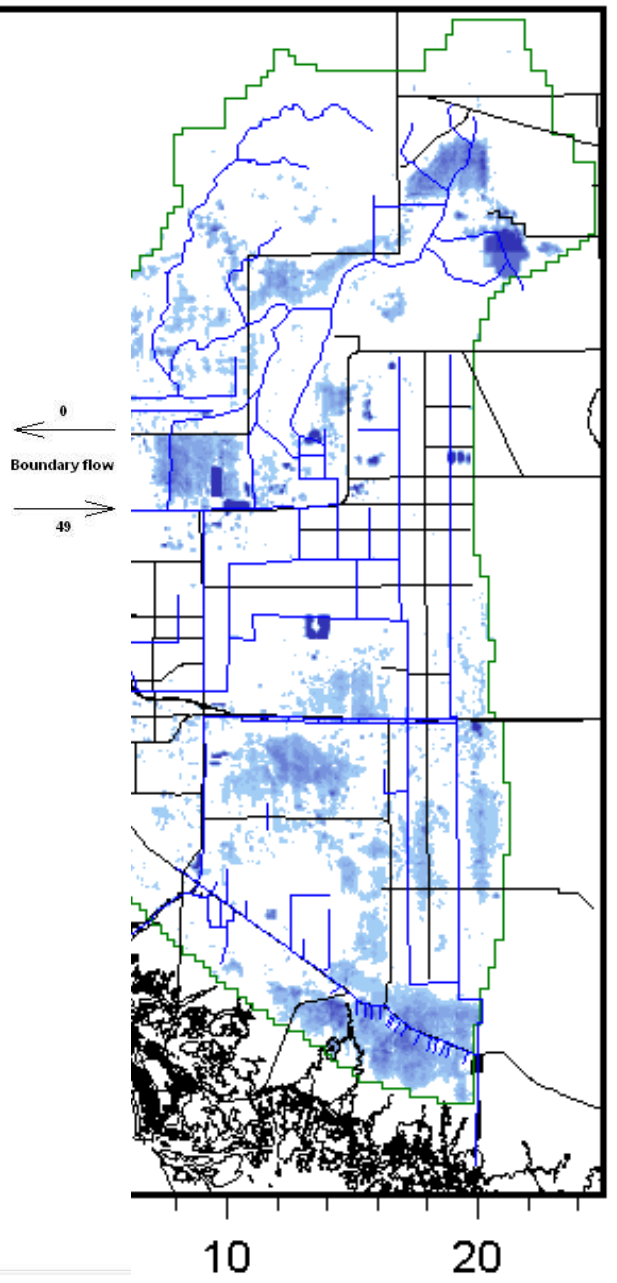
MIKE SHE – Integrated watershed hydrology modelling

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

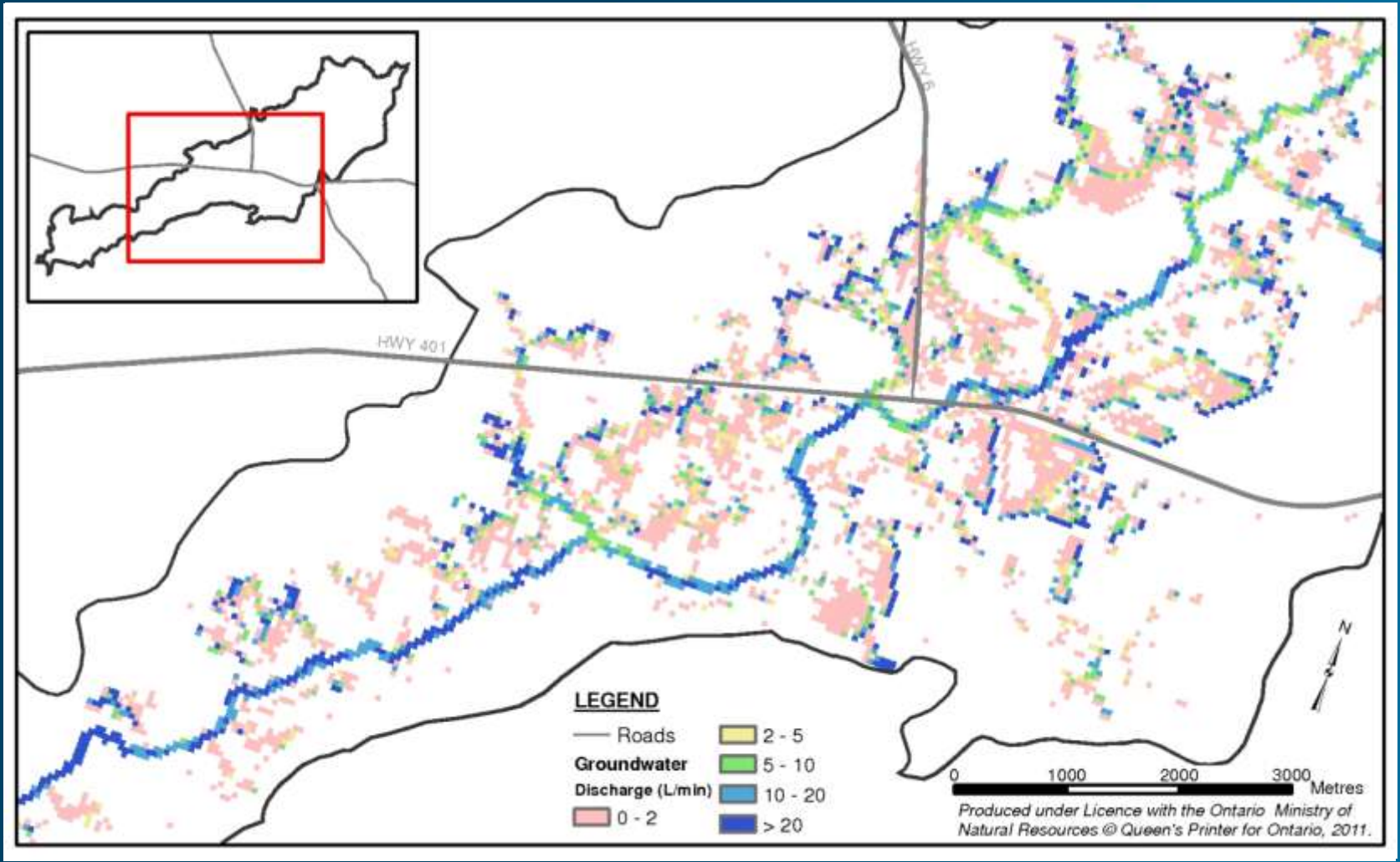
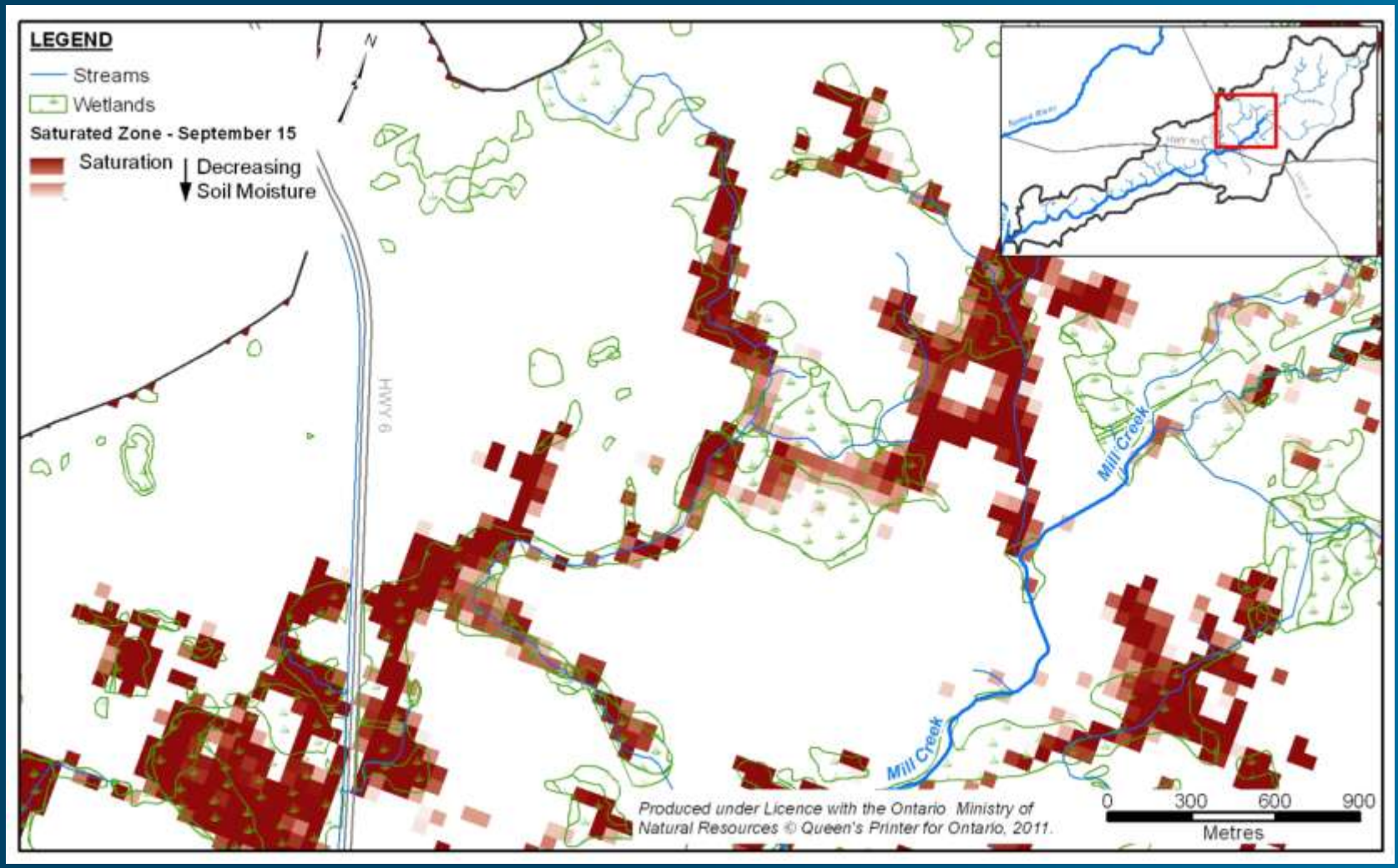


Image is provided courtesy of Matrix Solutions

Seasonal wetland delineation



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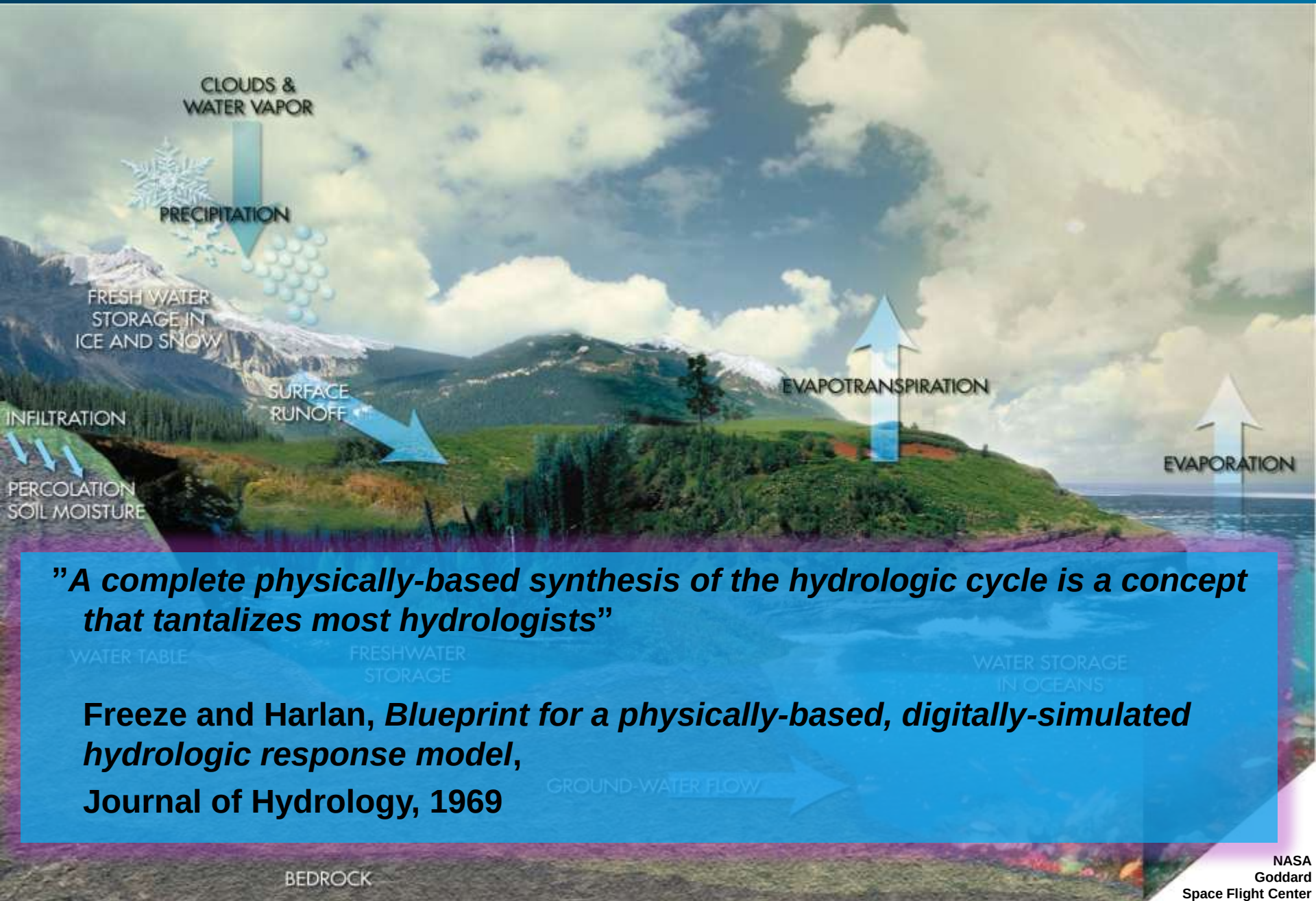
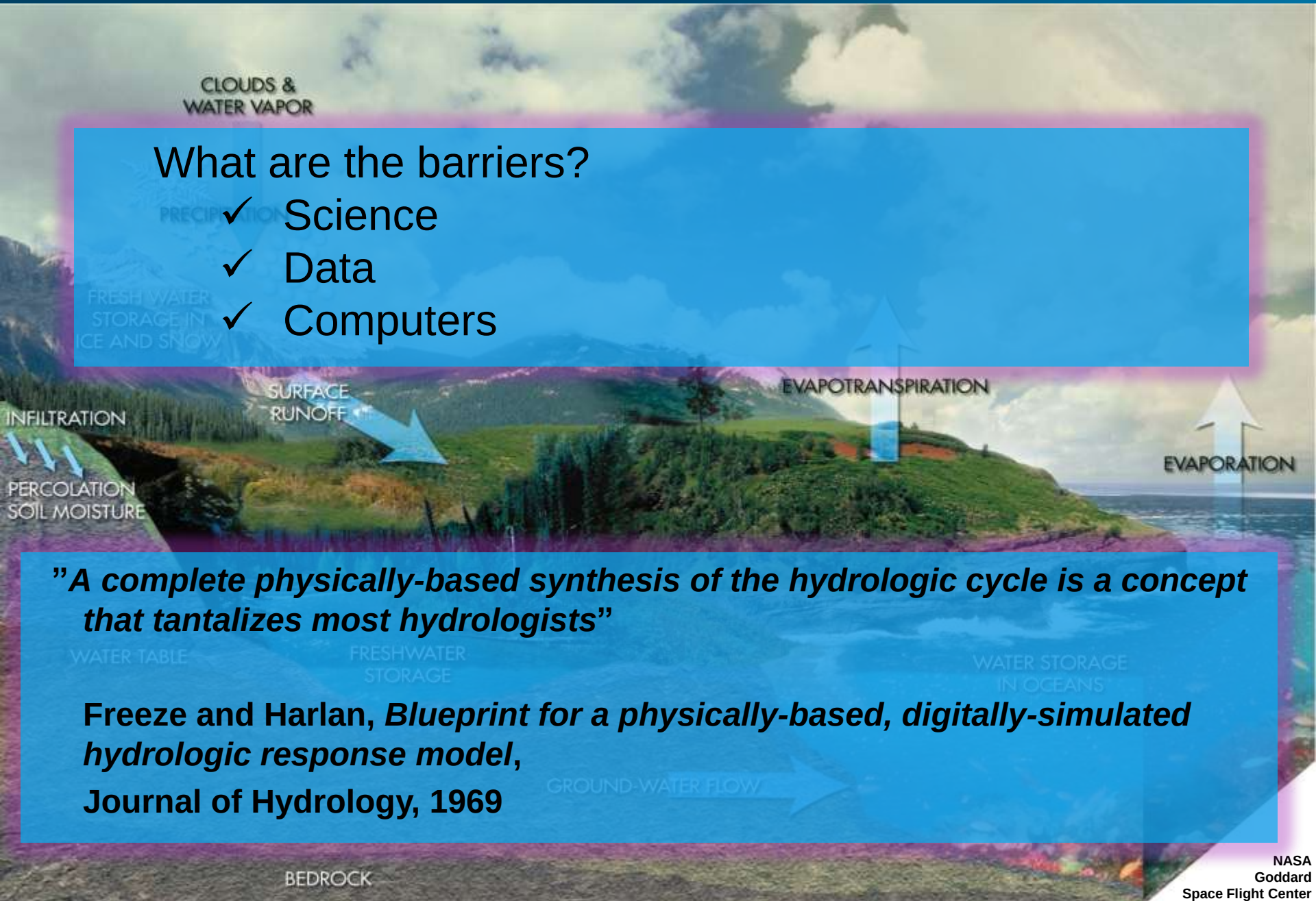


"A complete physically-based synthesis of the hydrologic cycle is a concept that tantalizes most hydrologists"

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

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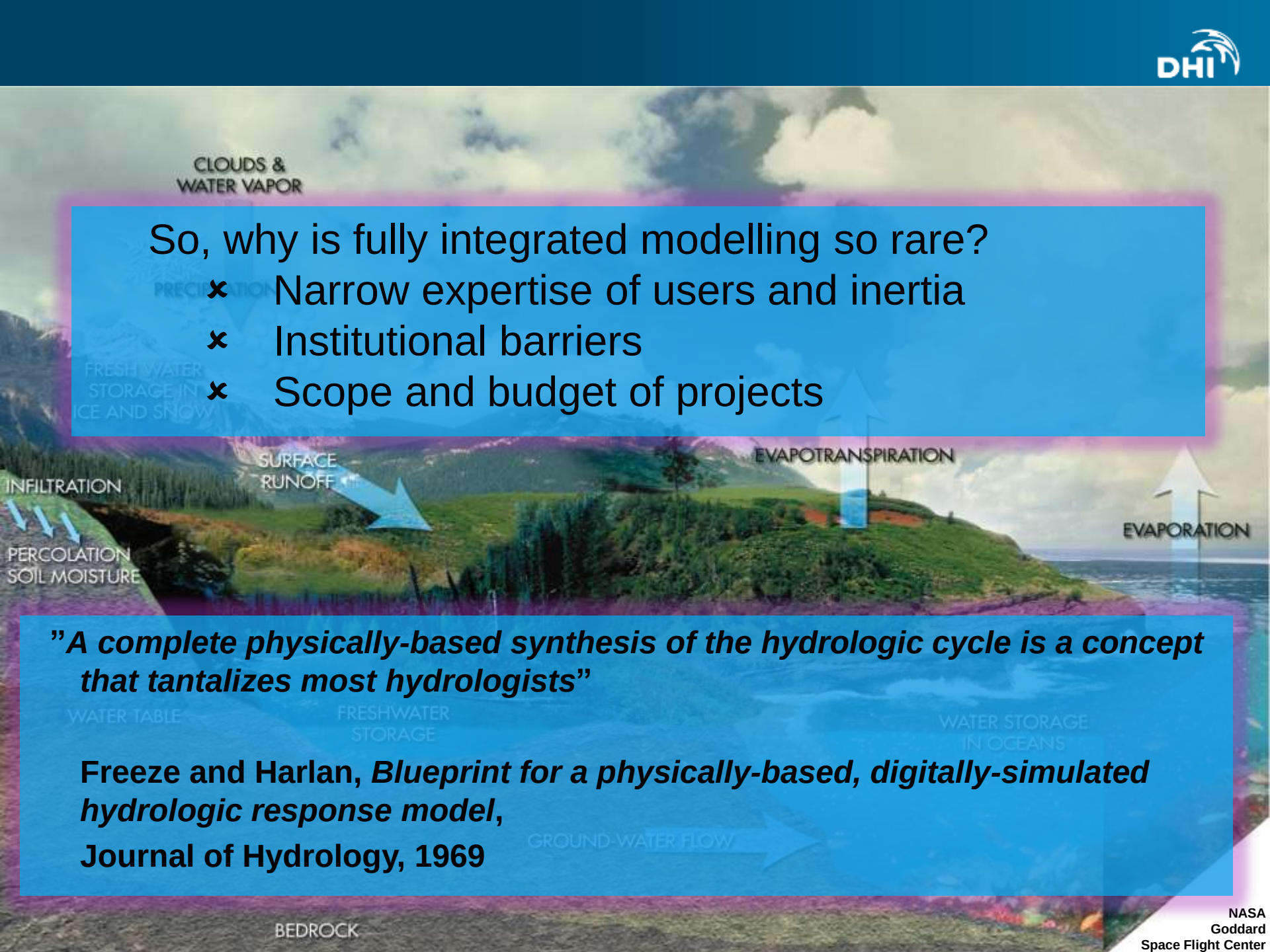

So, why is fully integrated modelling so rare?

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

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Elbow River Watershed Integrated Model

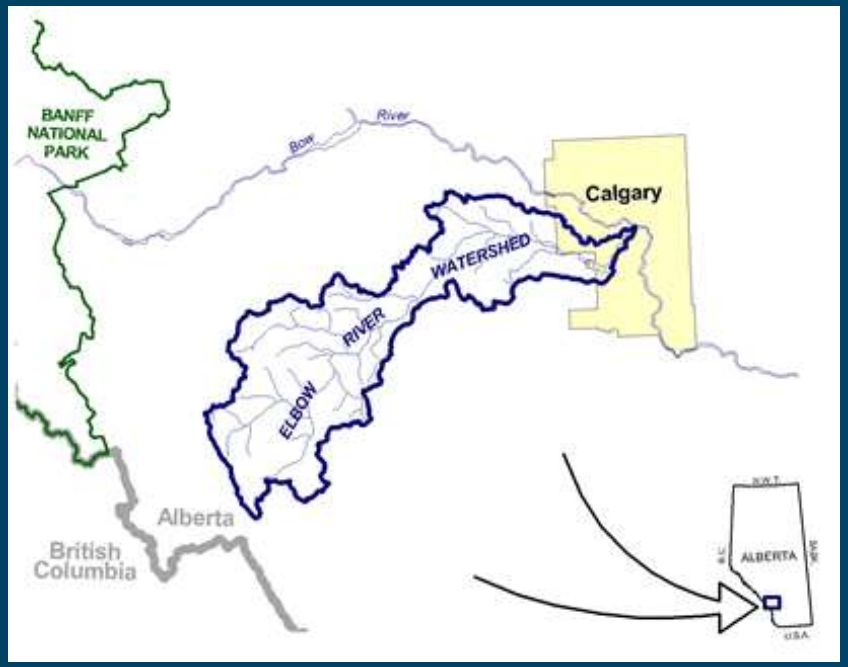
Research collaboration between University of Calgary, Alberta Environment and DHI

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

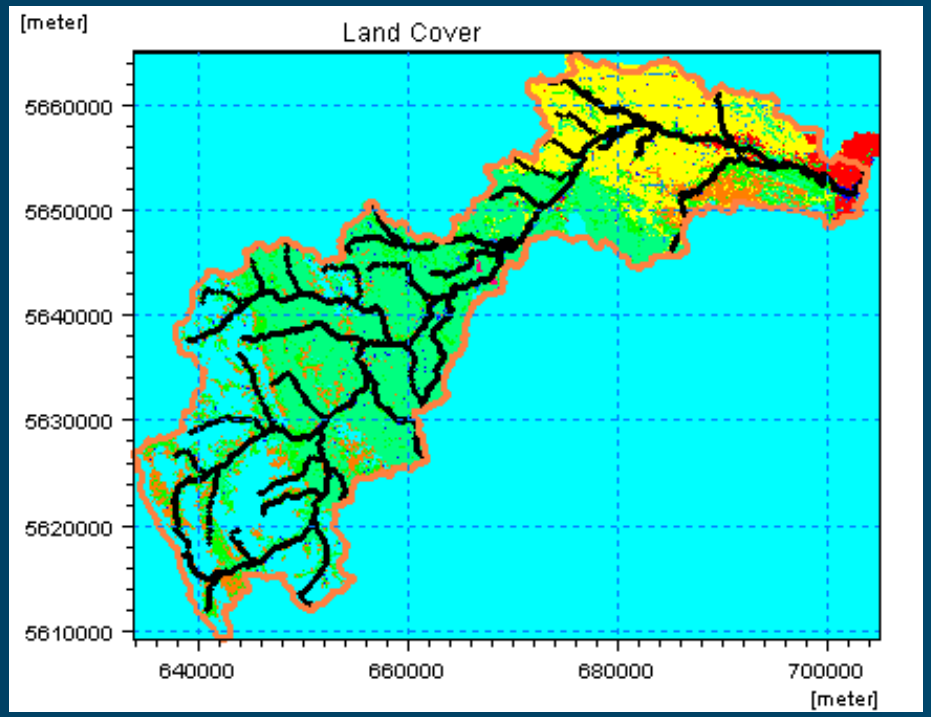
Model Overview



- 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

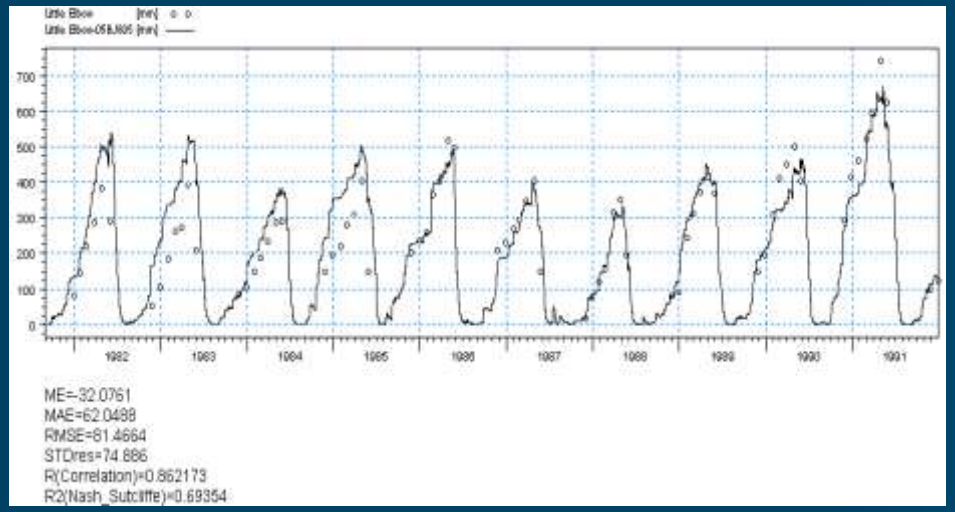
Model Overview

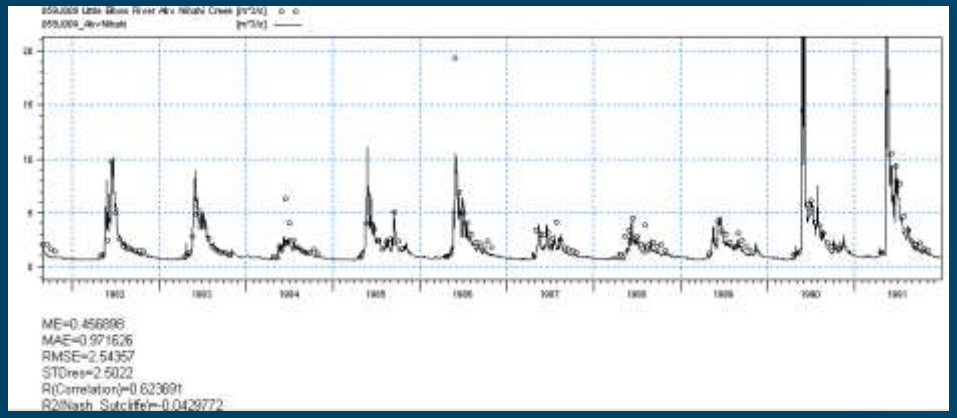


- Snowmelt – modified degree-day method
- Overland flow – 2D finite-difference diffusive wave
- Unsaturated flow and ET – 2-layer water balance approach
- Groundwater flow – 3D finite-difference method
- Channel flow – 1-dimensional hydrodynamic approach

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?

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