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Groundwater Modelling Guidelines for the Alberta Oil Sands: Overview and Discussion

Jon Paul (JP) Jones (AITF & U Waterloo) and Carl Mendoza (U Alberta)

Acknowledgements

The Authors Would Like To Thank

- The Cumulative Environmental Management Association (CEMA)
  - Funders of the Guidelines
  - CEMA GWWG (External Reviews)
- Patrick Delaney, President DHI Canada
  - Internal Reviews

A Bit of Background

- The driving factors for developing the guidelines
  - Recent reports (e.g., RSC 2010) identified a need for a better understanding of groundwater resources in the Oil Sands
    - To date, emphasis is primarily on monitoring… but need to take a more comprehensive view
  - GW modelling plays an integral role in wide array of Oil Sand's activities
  - Currently, there is no guidance available in Alberta regarding standard groundwater modelling practices

Purpose and Objectives

- These guidelines represent a **first step** towards developing standardized modelling practices in the Oil Sands
  - Working towards improving the confidence that stakeholders and decision makers can have in modelling results
  - Living document; the guidelines should be regularly updated and improved upon
- Provide a common starting point for communications between industry, government, academia and the public
- Educate decision-makers on what models are (and are not!), how the results can be used, and the inherent limitations of the modelling process

Purpose and Objectives

- Target Audience for the Guidelines
- Strike a Balance Between Providing Technical Content for Practitioners and Outlining Approaches and Concepts for the Users of the Results
  - Not Meant to be a Recipe Book
  - Emphasis on the Practical over the Theoretical
  - Primarily Concerned with Groundwater Flow Modelling
- Communicate that modelling is a potentially useful but fundamentally imperfect endeavor
- Guidelines in other Jurisdictions

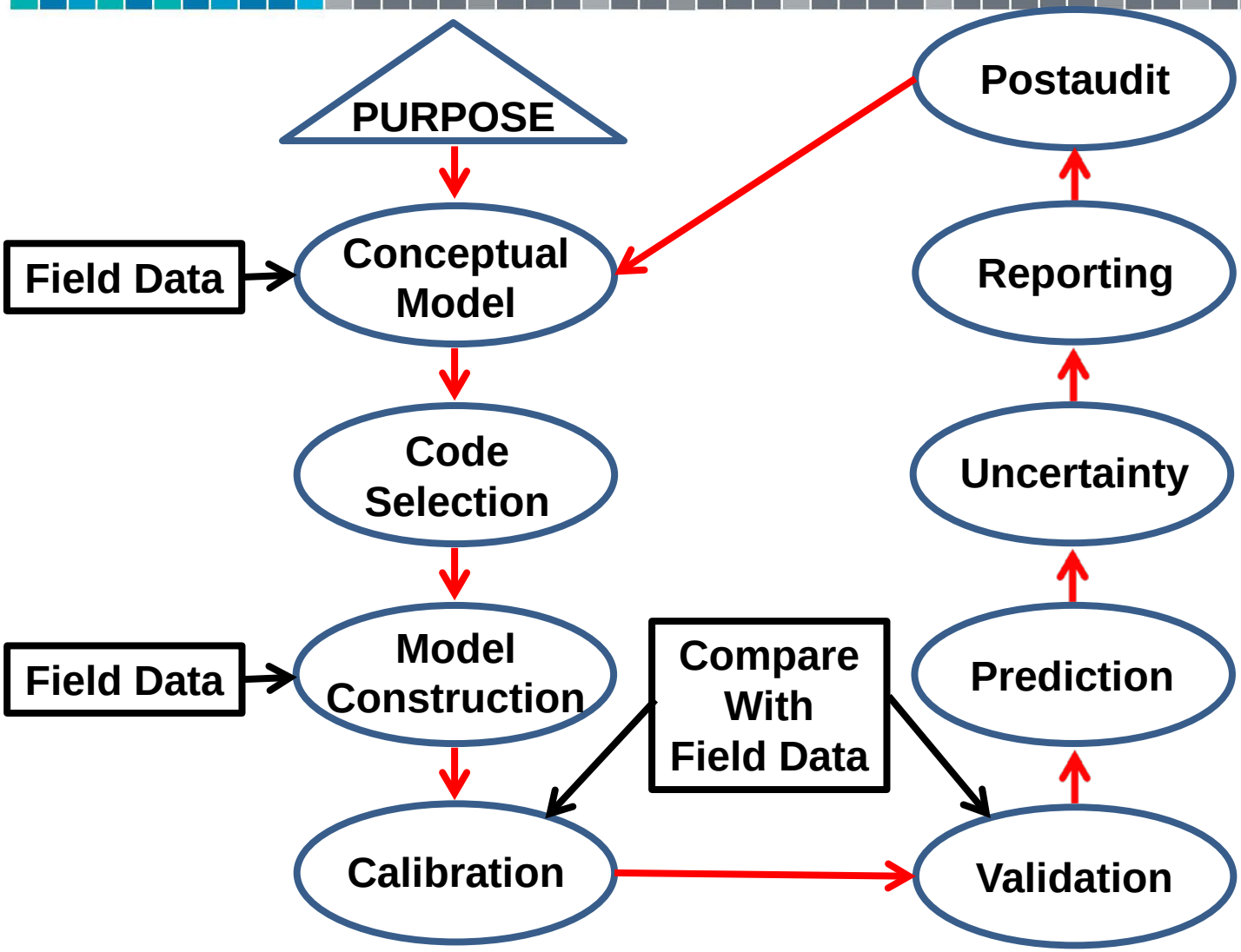
Overview Guidelines Contents

- Basic Modelling Concepts
- Common Groundwater Modelling Tools Used in the Oil Sands
- Model Construction
- Calibration/Validation
- Sensitivity and Uncertainty Analysis
- Reporting

Basic Modelling Concepts

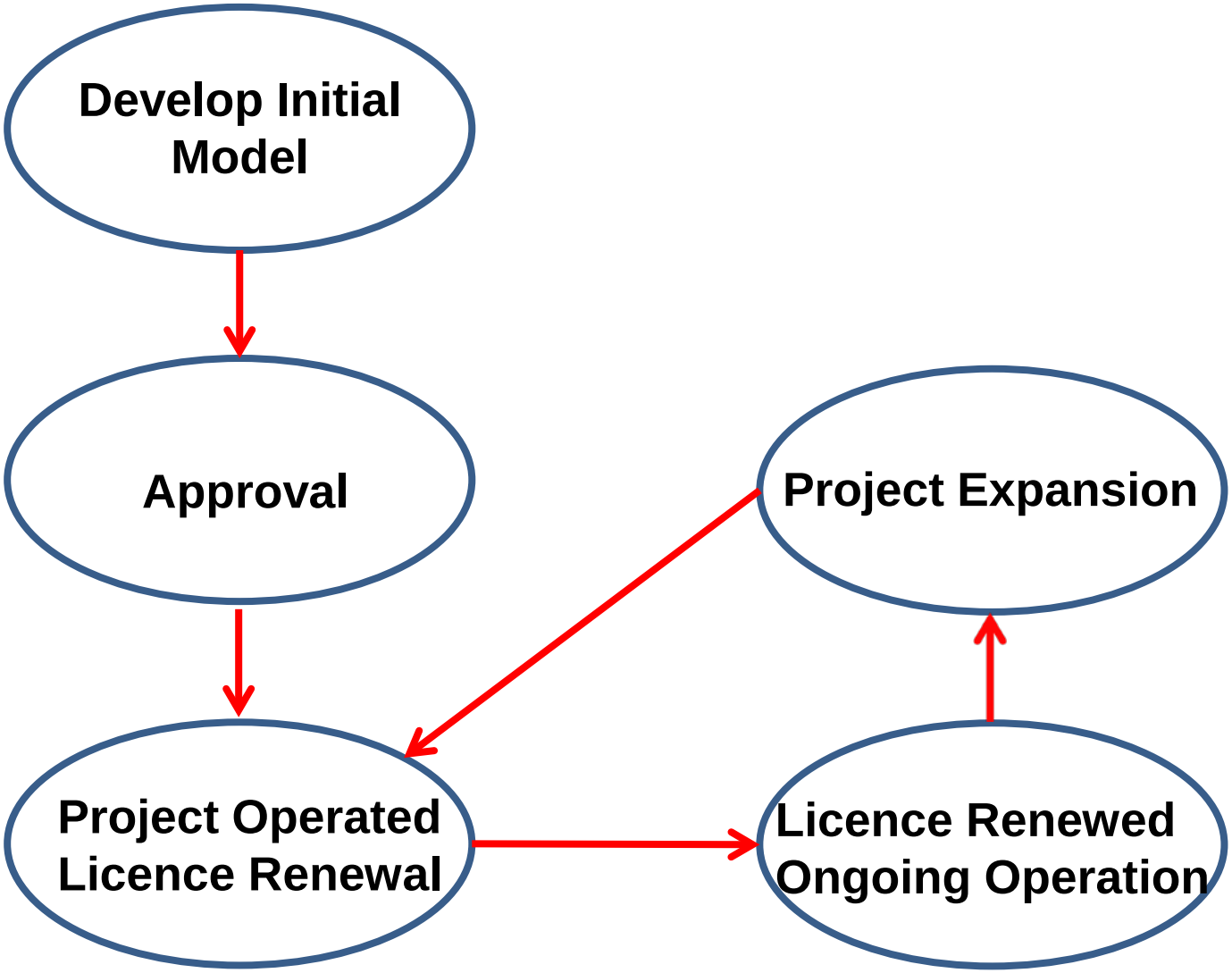
- The Modelling Process
  - ‘Model’ Means Different Things to Different People
- Conceptual Models
  - The Synthesis of What We Know at the Outset
- Categories of Groundwater Models
  - Analytical, Deterministic, Stochastic
- Application of Models
  - Why are We Modelling?

Modelling Study Steps



Adapted from Anderson and Woessner. 1992)

The Evolution of a Typical Oil Sands Groundwater Model



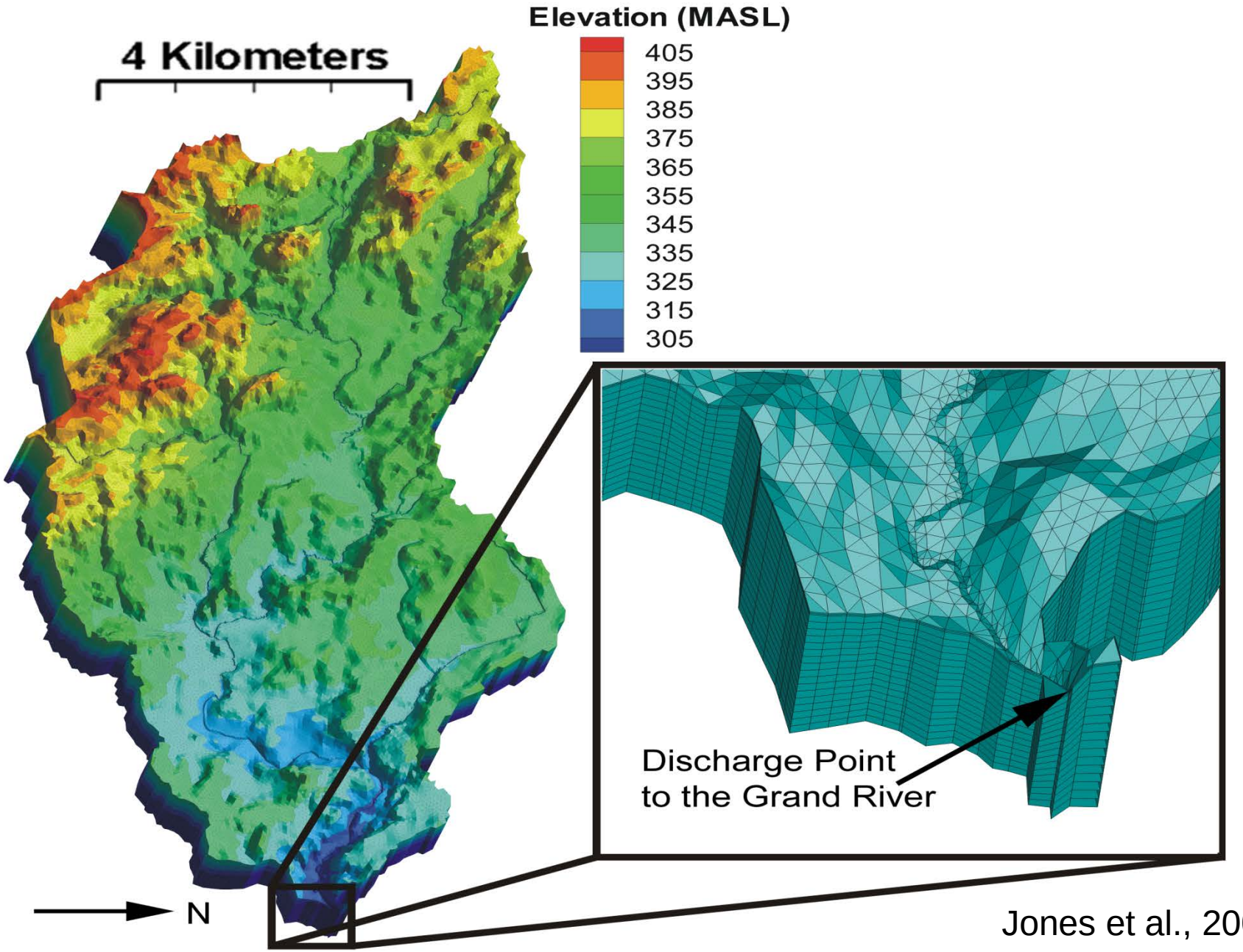
Common GW Modelling Tools Used in the Oil Sands

- MODFLOW
- FEFLOW
- HSPF
  - Not a Groundwater Model per se, but used extensively in Oil Sands work
- Integrated Models
  - A Peak Into the Future of Water Modelling Work in the Oil Sands?
    - MIKE SHE
    - HydroGeoSphere
    - GS-FLOW

Model Construction

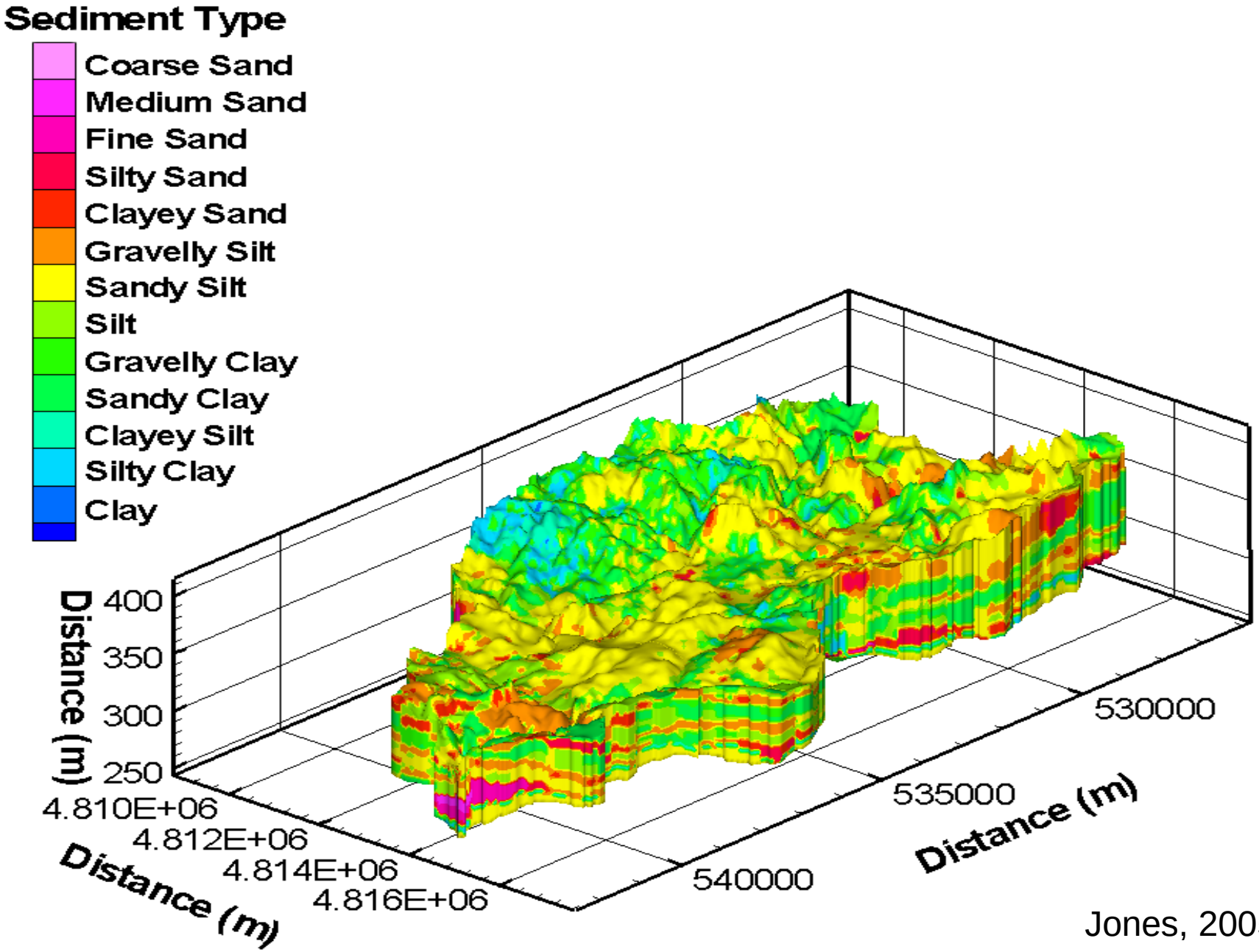
- Preliminary Considerations
  - Processes, Scale, Dimensionality
  - These Considerations Help Dictate the Software Platform Used
- Data
  - Bad Data = Bad Results (GIGO principle)
- Boundary Condition Types
- Defining the Lateral and Vertical Model Domain

Mesh Generation



Jones et al., 2008

Subsurface Hydrostratigraphy

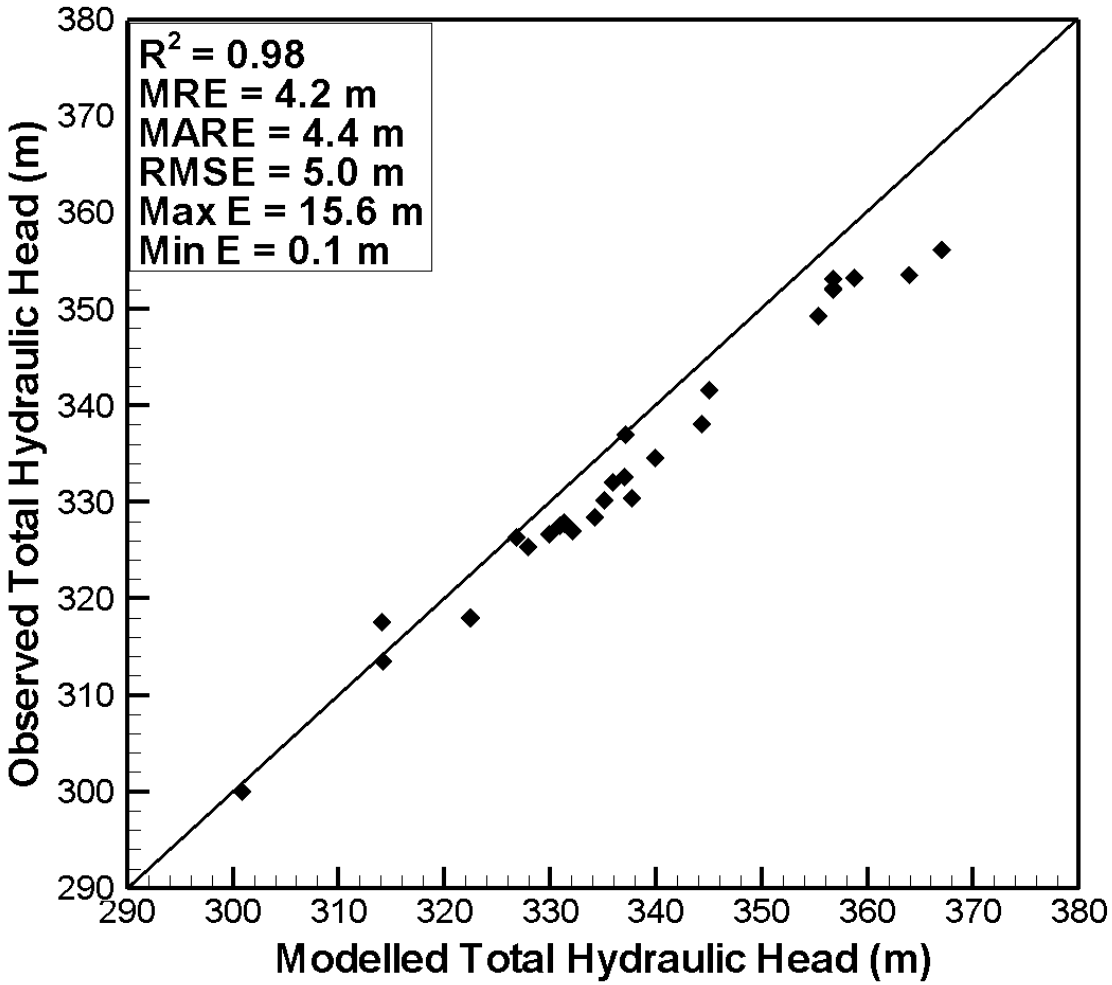


Jones, 2005

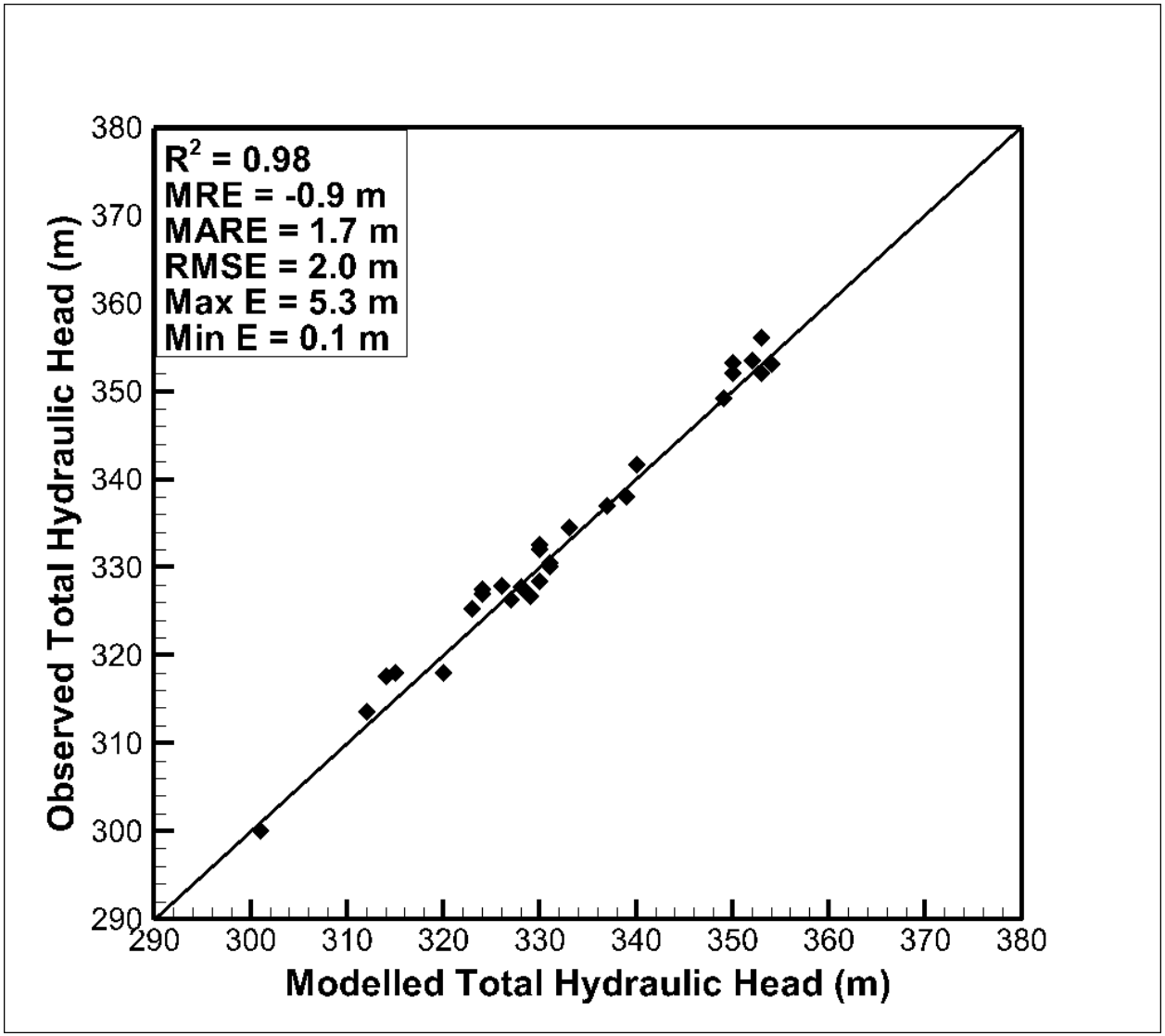
Calibration/Validation

- Calibration Targets
- Steady-State and Transient Procedures
- Evaluating the Results
  - Qualitatively
  - Quantitatively
- Verification/Validation
- Non-uniqueness
- Independent Evaluations and Post-Audits

Diagnostic Scatterplots



Diagnostic Scatterplots



Sensitivity and Uncertainty Analysis

'Not only do we have uncertainty as to the parameter values needed for our design calculations, we even have uncertainty about the very geometry of the system we are trying to analyze. The uncertainties of lithology, stratigraphy, and structure introduce a level of complexity to geotechnical and hydrogeological analysis that is completely unknown in other engineering disciplines.'

- Freeze et al. (1990)

Sensitivity and Uncertainty Analysis

- To Date, Use of These Techniques in the Oil Sands has been Modest at Best

- Rapidly Becoming a ‘Must Have’ Study Feature
  - Often Driven by Regulatory Concerns (e.g., via the SIR & AIR processes for EIA’s)
  - Techniques for Surface Water Modelling are Relatively Established, but Not Necessarily Applicable to Groundwater Studies
  - Need to Balance Between Regulatory Concerns and the Inherent Limitations of Deterministic Groundwater Modelling
    - i.e., Long Model Runtimes

Sensitivity and Uncertainty Analysis: The Guidelines

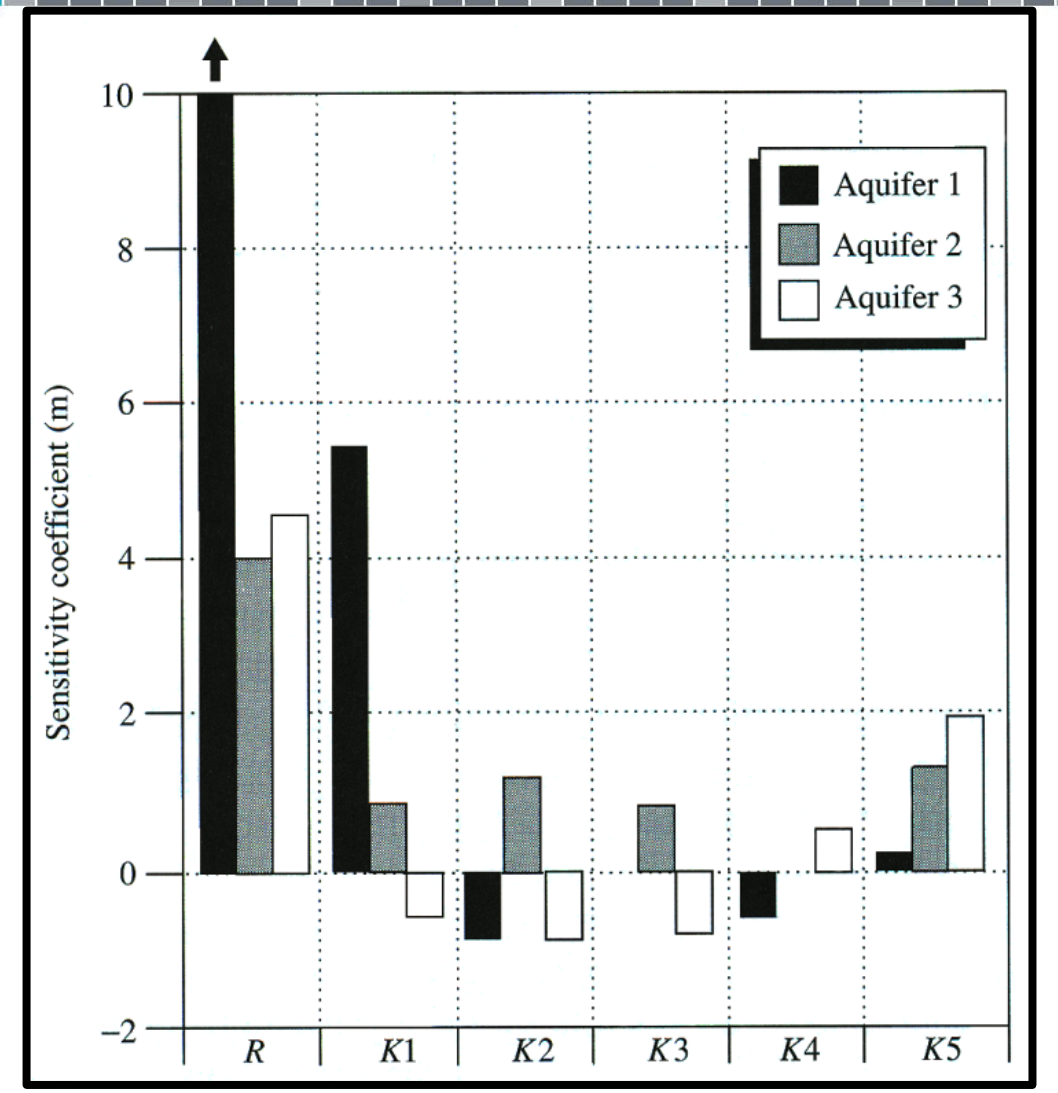
- General Concepts
- Sensitivity Analysis Procedures
- Categories of Uncertainty Analysis and Selected Techniques
  - Screening Tools
  - Differential Analysis
  - Sampling Techniques
  - Variance Techniques

Less Rigorous

More Rigorous

- Uncertainty Quantification via Automated Calibration Tools
  - Promising but Complicated and Computationally Expensive

Sensitivity Analysis: Example



Zheng and Bennet, 2002

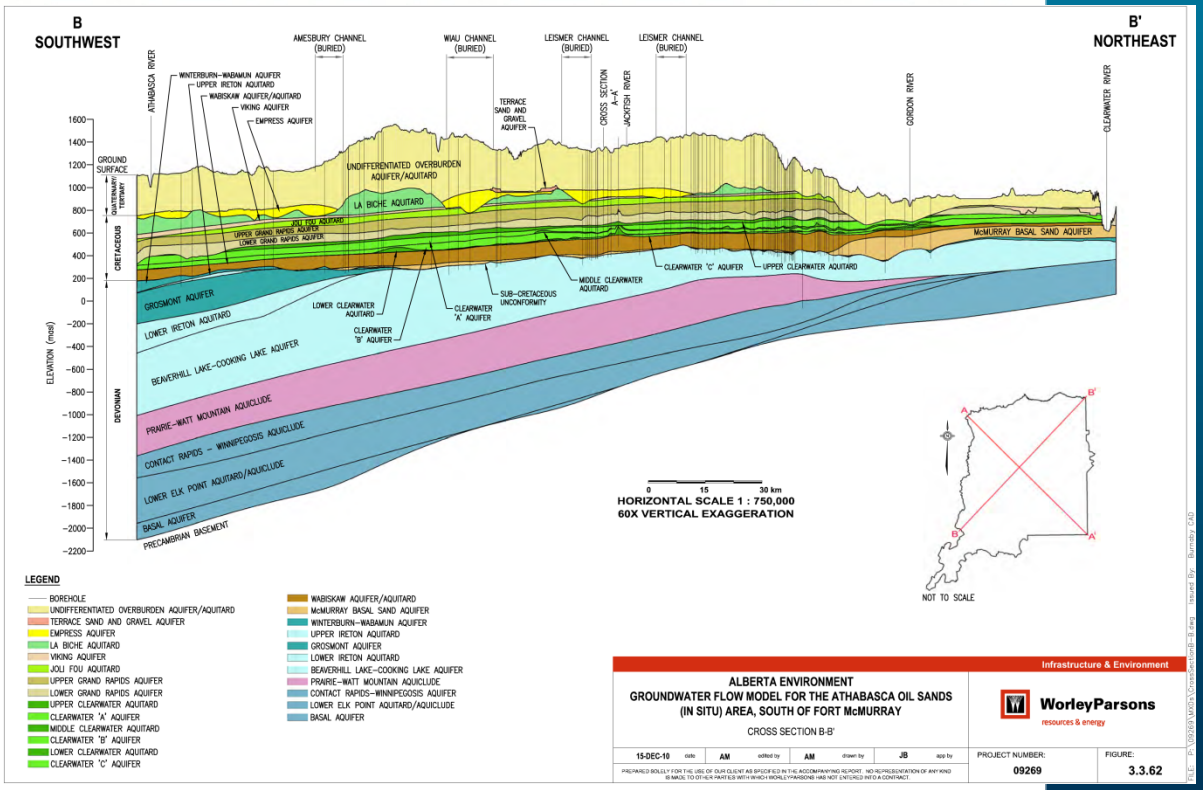
Sensitivity Analysis: Example

	Location of Observation Wells		
Parameter Name	Aquifer 1	Aquifer 2	Aquifer 3
Recharge Rate (R)	1	1	1
Horizontal hydraulic conductivity for AQ 1 (K1)	2	4	5
Horizontal hydraulic conductivity for AQ 2 (K2)	3	3	3
Horizontal hydraulic conductivity for aquifer 3 (K3)	6	5	4
Vertical hydraulic conductivity between AQ 1 and AQ 2 (K4)	4	6	6
Vertical hydraulic conductivity between AQ 2 and AQ 3 (K5)	5	2	2

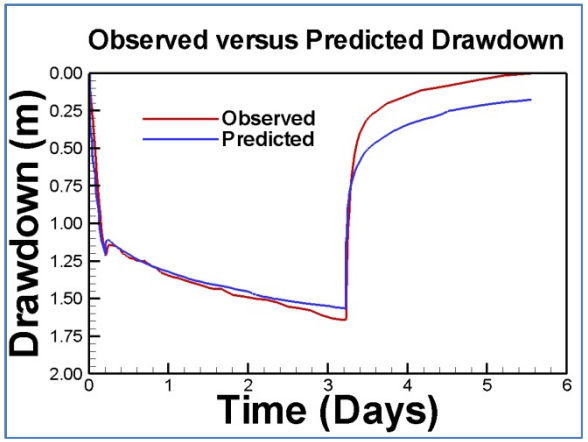
Zheng and Bennet, 2002

Reporting

- Study Logging
- Study Reporting
  - Template
- Study Archiving



ESRD, 2010



Adapted from Harvest Energy, 2010

Questions?

- The Guidelines can be Downloaded at: www.cemaonline.ca

- Please Direct any Guidelines Comments or Suggestions for Future Improvements to: Melanie.Dubois@cemaonline.ca