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

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Acknowledgements

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  - 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
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

PURPOSE

Field Data

Conceptual Model

Code Selection

Model Construction

Field Data

Compare With Field Data

Calibration

Postaudit

Reporting

Uncertainty

Prediction

Validation

Adapted from Anderson and Woessner. 1992)
The Evolution of a Typical Oil Sands Groundwater Model

- Develop Initial Model
- Approval
- Project Operated Licence Renewal
- Licence Renewed Ongoing Operation
- Project Expansion
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
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

$R^2 = 0.98$
MRE = 4.2 m
MARE = 4.4 m
RMSE = 5.0 m
Max E = 15.6 m
Min E = 0.1 m

Observed Total Hydraulic Head (m)

Modelled Total Hydraulic Head (m)
Diagnostic Scatterplots

R² = 0.98
MRE = -0.9 m
MARE = 1.7 m
RMSE = 2.0 m
Max E = 5.3 m
Min E = 0.1 m

Observed Total Hydraulic Head (m)

Modelled Total Hydraulic Head (m)
‘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

- Uncertainty Quantification via Automated Calibration Tools
  - Promising but Complicated and Computationally Expensive
Sensitivity Analysis: Example

Zheng and Bennet, 2002
# Sensitivity Analysis: Example

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Location of Observation Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aquifer 1</td>
</tr>
<tr>
<td>Recharge Rate (R)</td>
<td>1</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity for AQ 1 (K1)</td>
<td>2</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity for AQ 2 (K2)</td>
<td>3</td>
</tr>
<tr>
<td>Horizontal hydraulic conductivity for aquifer 3 (K3)</td>
<td>6</td>
</tr>
<tr>
<td>Vertical hydraulic conductivity between AQ 1 and AQ 2 (K4)</td>
<td>4</td>
</tr>
<tr>
<td>Vertical hydraulic conductivity between AQ 2 and AQ 3 (K5)</td>
<td>5</td>
</tr>
</tbody>
</table>

Zheng and Bennet, 2002
Reporting

- Study Logging
- Study Reporting
  - Template
- Study Archiving

Adapted from Harvest Energy, 2010
Questions?

- The Guidelines can be Downloaded at: [www.cemaonline.ca](http://www.cemaonline.ca)
- Please Direct any Guidelines Comments or Suggestions for Future Improvements to: Melanie.Dubois@cemaonline.ca