Lessons For Life As You Head into Practice: Perspectives on (Groundwater) Modeling

Leslie Smith
Cominco Chair in Minerals and the Environment
University of British Columbia

Presented March 22 2016

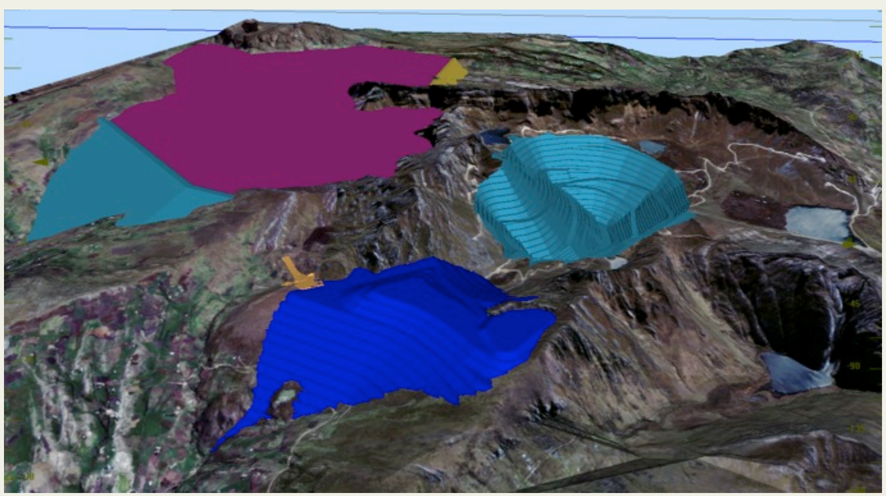
UBC Geological Engineering Distinguished Lecturer
Co-Sponsored by Vancouver Geotechnical Society

Lessons For Life As You Head into Practice: Perspectives on (Groundwater) Modeling

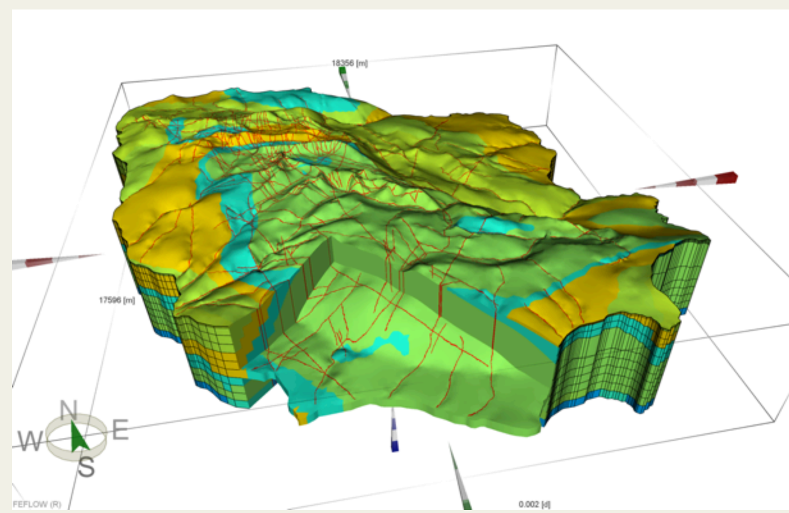
Leslie Smith

Cominco Chair in Minerals and the Environment

University of British Columbia



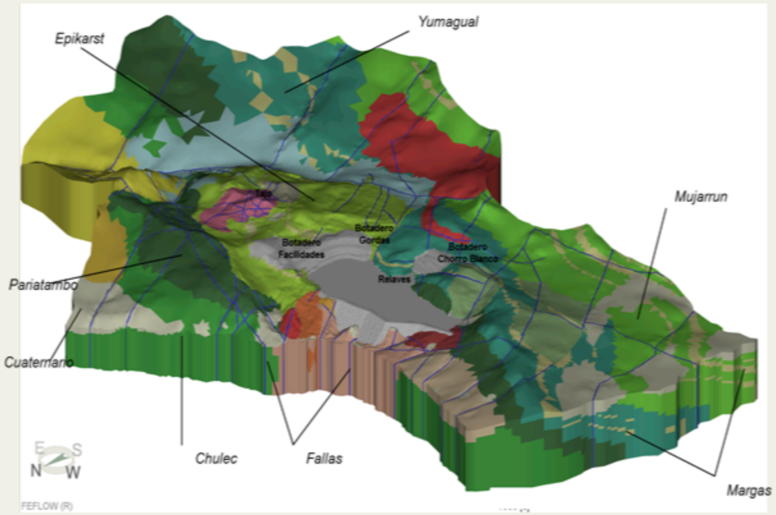
From MWH



Background to this Presentation

Over the past decade there has been a substantial increase in the level of detail commonly included in groundwater models submitted in support of environmental assessments and permitting

- Detailed geologic models
- Millions of nodes



From DHI Peru

A synthesis of recent case histories involving mining projects suggests three concerns:

- Poor choices can still be encountered in defining conceptual models
- Powerful modeling tools can create the illusion of knowledge
- Models are viewed by some as defining the decision rather than as a decision support tool

Outline of Presentation

1. Introductory Comments on Modeling
2. The Prime Directive
3. Lessons To Remember for Life **

** Simple guiding principles to consider when applying groundwater models in an environment of rising expectation

Range of Predictions in Environmental Assessments

Uncertainty Increases

Volume — *Magnitude of effects* - seepage rates from a tailings storage facility

Space — *Zones of impact* - pathway of process water seepage to receiving waters

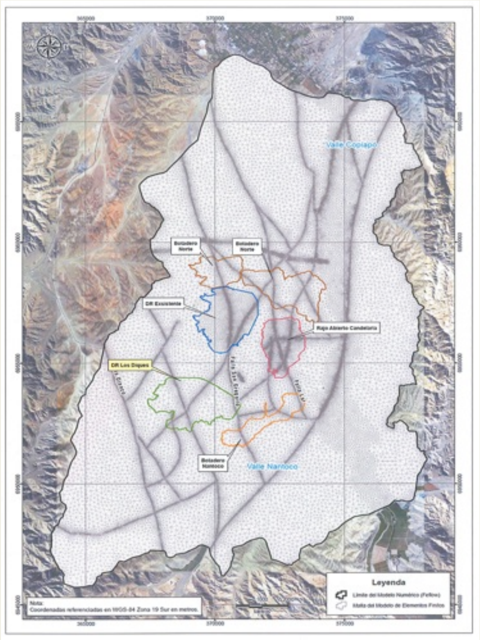
Time — *Timing of effects* - advective transport of solutes to compliance points

Why Use Sophisticated Models?

1. To aid in data interpretation through evaluation of conceptual models and model calibration.

2. To assess the potential impacts of mine plans and evaluate possible mitigation measures, with greater geologic/hydrologic realism embedded in the calculations.

3. It has become the standard of practice in many environmental reviews.



From MWH Peru

Guidelines for Practice

Modeling guidelines are well-established:

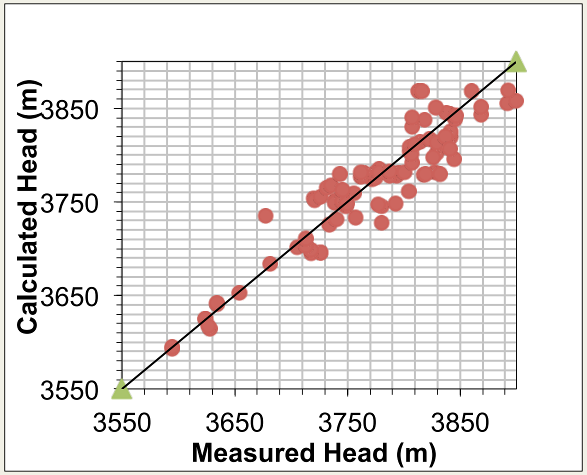
Wels et al. BC MOE (2012) "Guidelines for Groundwater Modeling to Assess Impacts of Proposed Natural Resource Development Activities"

- conceptual models, numerics
- calibration, sensitivity analysis
- verification (benchmark)

Model Acceptance - Metrics

- Replicate large-scale features in the hydraulic head distribution

- Head residuals:
  - unbiased and normally distributed residuals
  - limited spatial clustering of (+/-) residuals
  - % RMSE: global value < 10%
  - % RMSE: local zones of prime interest



- Baseflow estimates for streams

The Prime Directive

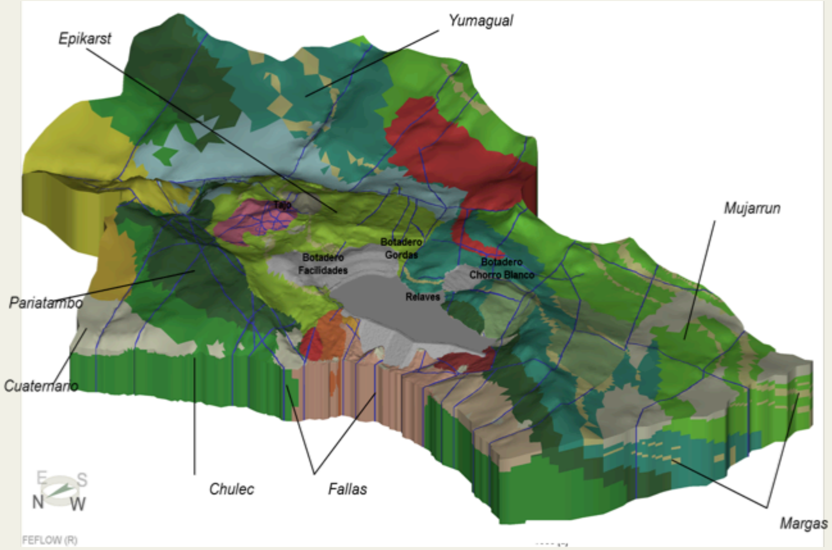
Do not interfere with the internal development of alien civilizations

Acknowledgement - Star Fleet Command

Statement we can always go back to for guidance on the path forward

The Prime Directive in Hydrogeology

A model should be no more complex than needed to reliably answer the questions asked and to support the decision required.



From DHI Peru

Does the analysis of mining impacts in challenging environments necessarily require more complex simulation models?

The Prime Directive would say that this is not the right question – It is the question being asked, and the decision required, that should guide the degree of complexity to be embedded in the groundwater model.

In Sympathy with the Prime Directive: Offer nine lessons for life as you head into practice

The Oracle of Hydrogeology

Lesson 1: The math is easy, thinking is the hard part

Image removed of the conceptual model at a site with a plume originating from a closed tailings impoundment

Defining the conceptual model is the key to success

Analysis used a state of practice automated calibration tool (NSMC) - Null Space Monte Carlo method

Lesson 1: The math is easy, thinking is the hard part

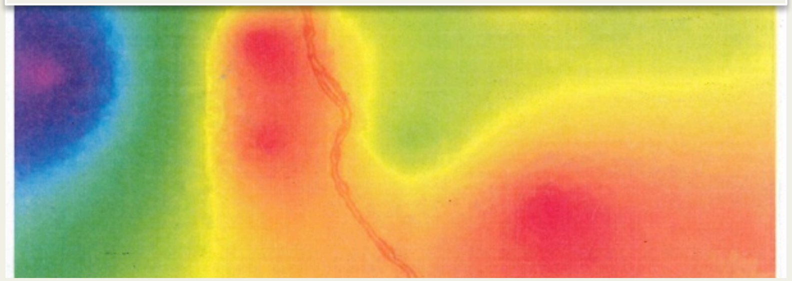
Image removed showing finite difference grid and a major fault zone, likely a key transport pathway, represented by drain cells

Major fault zone was represented by drain cells

Lesson 2: Just because you can does not mean that you should

Powerful modeling tools now allow for the illusion of knowledge with the click of a mouse: use automated calibration, pilot points and geostatistics with caution.

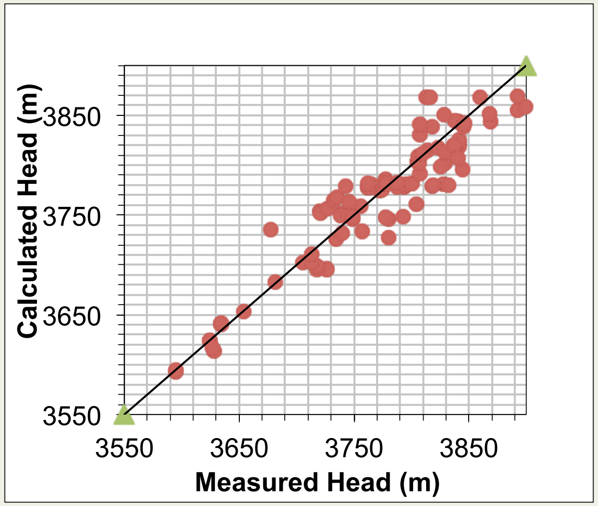
Tool box issue: Calibrated hydraulic conductivity field using automated calibration and geostatistics



Lesson 3: Just because the shoe fits does not mean you should buy it

An incorrect conceptual model may fit the field data well: An accepted calibration is a necessary but not sufficient condition.

Calibration is not verification: Benchmark your model as soon as possible.



Lesson 4: Be sure you play the game fairly

Some argue that groundwater models can always give you the result you are looking for.

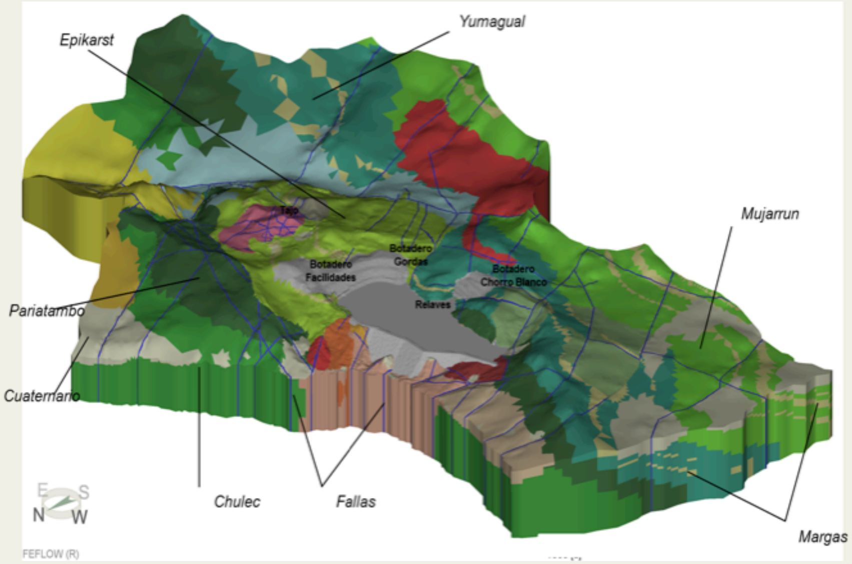
Do not precondition the outcome by your choice of boundary condition.

Image removed of plume moving parallel to an assumed impermeable boundary (flow line)

Lesson 5: Sometimes you just have to bend the rules

Calibration of a transient groundwater model in a system with karstic units could not meet the standard calibration target (<10% RMS error).

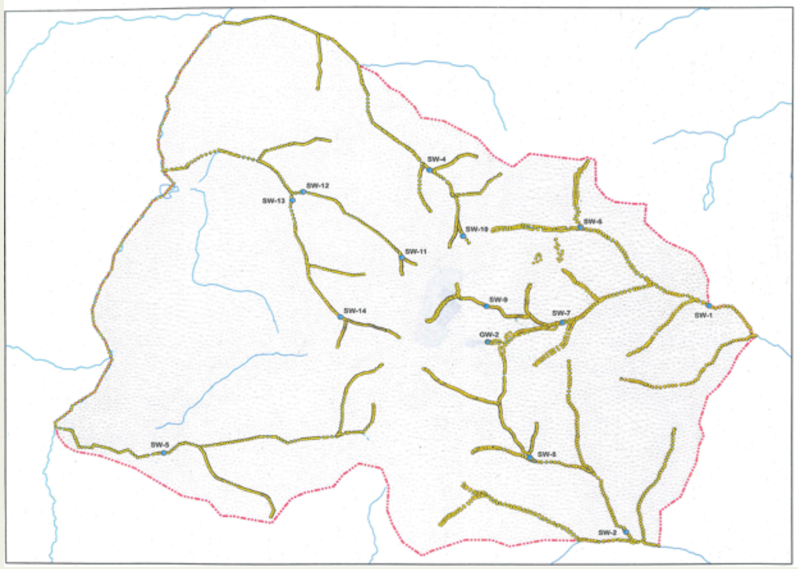
Larger calibration tolerances at the local scale seem appropriate for systems with karstic units or any dual porosity system: high degree of spatial variability in properties, inherent uncertainty in structure.



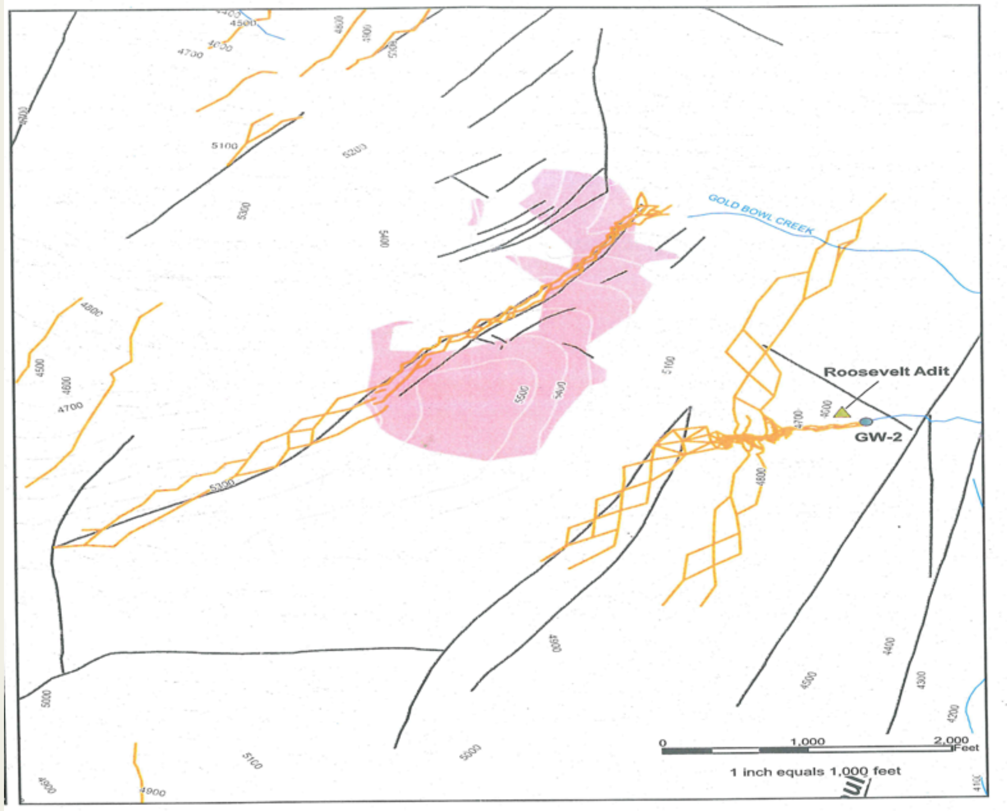
Lesson 6: There are some rules you should never bend

1. Reduce site-wide RMSE misfit and local misfit by adding hydraulic conductivity zones for which there is no sound field evidence.
2. Assign relative weights across the water level data set to artificially improve the calibration metrics.

Lesson 7: Sometimes you just have to bend the “do not bend” rule



Calibration to the head and base flow data suggested an unmapped fault, later confirmed when driving adit



URS - USA

Lesson 8: Acknowledge that sometimes you just can't get your timing right

Simple questions can be very hard to answer reliably:

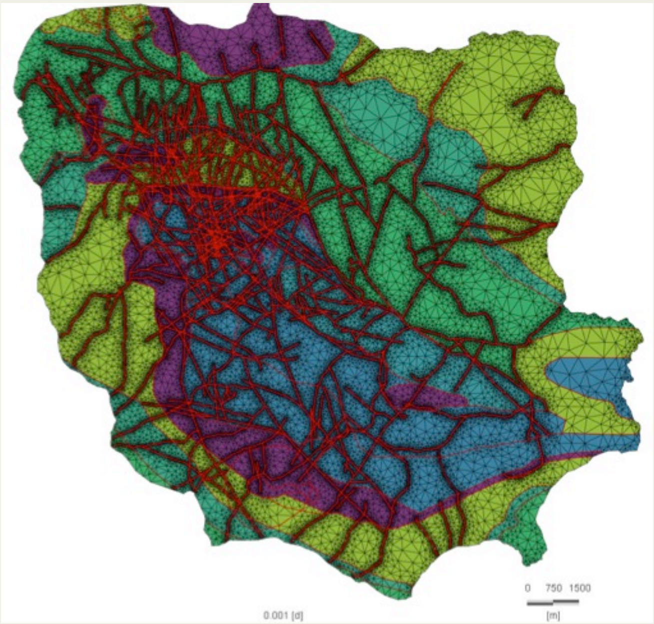
- Timing of stream flow depletion due to groundwater interception during mining operations and timing of stream flow recovery in the closure period.
- Arrival time of solutes at concentrations above background in a fractured bedrock flow system (no calibration data).
- Time at which active water treatment of toe seeps from waste rock may no longer be required in closure, allowing a shift to passive water treatment.

Lesson 9: Faults are many things to many people

Dividend Fault - Bisbee Arizona

Geologic Complexity

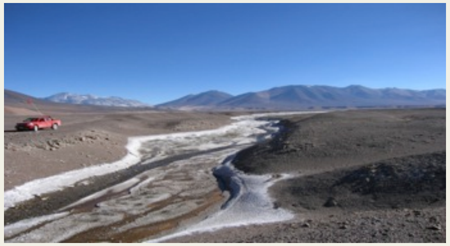
Role of conservative approximation in prediction – all mapped faults assumed to have a hydraulic conductivity higher than the surrounding country rock, unless negated during the calibration process



From MWH

Can we reconcile this approach with the Prime Directive?

Corollary to Prime Directive



A simulation model is a decision support tool: it should not define the decision

EIA Requirement: Compare predicted solute concentrations in receiving waters during operations and in closure period relative to the regulatory standards.

Concern: The calculation becomes the assumed reality.

Recap of the Lessons for Life

1. The math is easy, thinking is the hard part
2. Just because you can does not mean you should
3. Just because the shoe fits does not mean you should buy it
4. Be sure you play the game fairly
5. Sometimes you just have to bend the rules
6. There are some rules you should never bend
7. Sometimes you just have to bend the "do not bend" rule
8. Acknowledge that sometimes you just can't get your timing right
9. Faults are many things to many people

In our world of rising expectations for groundwater models: focus on the conceptual model, add no more complexity than needed, benchmark ASAP, judgment is allowed