Interdisciplinary Modeling for Aquatic Ecosystems  
Curriculum Development Workshop

Name: Greg Pohll  
Institution: Desert Research Institute  
Discipline: Groundwater flow and transport modeling  
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Modeling Approaches  
There is a standard modeling approach as defined by the ASTM modeling standards and also reviewed in Anderson and Woessner, 1992:
1. Define the purpose of the modeling exercise.  
2. Develop a conceptual model.  
3. Select an appropriate governing equation and computer code.  
4. Verify the computer code.  
5. Design the numerical model to reflect the conceptual model.  
6. Calibrate the model such that the simulated and observed system behaviors are in agreement.  
7. Verify the model with an independent dataset.  
8. Use the model to make predictions.  
9. Perform a sensitivity and/or uncertainty analysis to quantify potential model errors.  
10. Present the conceptual model, model design and results.  
11. If possible, perform a postaudit to verify the model predictions were accurate.  
12. If the postaudit reveals model flaws then repeat steps 2-11.

References  
Data Input Requirements
Groundwater flow models require numerous data inputs including:

- Defining hydrostratigraphic units
- Fluid sources (e.g. recharge, interbasin flow, etc.)
- Fluid sinks (e.g. ET, pumping)
- Boundary conditions (specified flow, specified head, or head-dependent)
- Model grid geometry
- Time stepping information
- Hydraulic parameters (hydraulic conductivity and storage parameters)
- Initial hydraulic head distribution

Transport models require the following types of input parameters:

- Initial distribution of contaminant concentrations
- Sources and sinks for contaminants
- Dispersion coefficients
- Decay and/or reaction coefficients
- Contaminant loading functions

Model Output
Groundwater flow models typically produce predictions of:

- Hydraulic head values over space and time
- Groundwater fluxes over space and time

Transport models provide information on contaminant migration including:

- Spatial and/or temporal contaminant concentrations
- Contaminant breakthrough curves at specified locations
**Spatial Scales**
Groundwater flow and transport models can simulate at scales ranging from 1 m$^2$ to many thousands of square kilometers. Scale issues always cause problems with hydrogeologic models as field measurements may not be appropriate for model calibration if the model scale is vastly different from the measurement scale.

**Organismal Scales**
Typically groundwater models do not simulate biologic or ecosystem responses, but some investigators have simulated the migration of bacteria and viruses within aquifer systems.

**Temporal Scales**
Groundwater models are typically associated with temporal scales on the order of days to many thousands of years.

**Model Assumptions**
Modeling assumptions are generally aligned with the underlying project objectives. For example, the assumption that an aquifer is homogenous and isotropic may be appropriate for a water supply project, but not for a complex contaminant migration study.

Some typical modeling assumptions include:
- Homogeneous and isotropic hydraulic and transport parameters
- Steady-state flow conditions and associated boundary conditions
- Linear/reversible geochemical reactions
- Simulating a three-dimensional system with a one- or two-dimensional model
- Isothermal fluid properties
- Simulating an unconfined aquifer with confined-type governing equations
- Fickian dispersion
- Most models assume that there is no feedback mechanism between the forcing functions and the internal model solution

**Model Uncertainties**
Groundwater model contain numerous uncertainties including:
- Conceptual model errors
- Lack of information on the spatial and temporal variability
- Errors due to inaccurate boundary condition specification for predictive simulations
- Numerical solvers can impart errors especially for transport solutions
- Parametric uncertainty in model input parameters