GROUNDWATER MODELING OVERVIEW

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Outline

• Definitions
• Modeling objectives
• The modeling process
• Data requirements
• Model application Process
• Model limitations
• Conclusions
Hydrologic Cycle

Recharge = Rainfall - Evapotranspiration - Runoff

Definitions

• What is a model?
  – Conceptual model: A non-unique representation of reality
  – Numerical model: A computer program representing a conceptual model (e.g., MODFLOW/MODPATH), or data/results manipulation (e.g., GMS)

• Why is it needed?
  – Understanding processes
  – Guiding data collection
  – Predictions
Examples

• Water allocation and sustainable yield assessment
• Risk assessment
• Best cleanup scenario
• Delineation of source protection area

The modeling process

• Site characterization/data collection
• Model development/choice
• Model verification/calibration/validation
• Model application
Groundwater Modeling System (GMS)
## GMS Overview

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### Conceptual Modeling for Groundwater Flow & Transport

**Import Background Data**
- Topo maps and aerial photos
- AutoCAD and GIS data
- Surface elevations

**Define Stratigraphy**
- Import borehole or scatter data
- Interpolate layer boundaries
- Define cross-sections
- Create solids

**Generate & Run Numerical Model**
- Automatically generate grid or mesh
- Map layer data and boundary conditions
- Run model
- Visualize results
- Calibrate model

**Create Conceptual Model**
- Determine model domain
- Define hydraulic material zones and layers
- Define boundary conditions
- Enter source/sinks

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## Example
Factors Affecting Groundwater Flow

Legend
- Silica
- Sand
- Sediments
- Mafic Volcanics
- Micro-Structures
- Basalt
- Tuffs
- Sandstones
- Siltstones
- Conglomerates
- Slate
- Water

Legend
- Hydrology
- Aquifer
- Hydraulic Conductivity
- Water Table Elevation

Sec A-A'
Groundwater Capture Zone Delineations

Data requirements

• Boundary Conditions
  – Flow
    • water levels (rivers, lakes, arbitrary boundary)
    • Flux
      – Flow (spring, arbitrary boundary)
      – No flow (impermeable boundary, arbitrary streamline)
    • Head-dependent flux
  – Chemical transport
    • Concentration value (e.g. at source)
    • Solute flux
      – flux (e.g., from unsaturated zone)
      – No flux boundary
    • Concentration-dependent flux
Data requirements

• Initial conditions
  State of system variables at start of simulation
• Parameters for physical system
  – aquifer geometry
  – aquifer parameters (hydraulic conductivity, storage coefficient, dispersivity, porosity, etc.)
  – location of sources and sinks (wells)
  – fluid conditions (density, viscosity)
  – velocities
  – chemical reactions, decay

• Numerical data
  – Node and grid information
  – Time step sequence
  – Error and stability criteria
• Prediction and optimization analysis
  – Economic information on water supply and demand
  – Legal and administrative rules
  – Environmental factors
  – Other social considerations
Sources of data

- Office work
- Field work

GIS Maps

- extent and boundaries of aquifers and non-water-bearing rocks
- topography, surface water bodies, and land use
- water-table, bedrock-configuration, and saturated-thickness
- parameters
- wells
- recharge
- etc.
Data processing

- Data storage
- Data checking for measurement and transmission errors
- Interpretation of field data
- Storing of processed data
- Model gridding
- Assignment of data to nodes and elements/cells

Model application Process

- Verification: assessing model numerical accuracy
- Calibration: fitting to real life with parameter adjustment
- Validation: fitting without parameter adjustment
Calibration/history matching

• A trial and error procedure matching calculated values with observed data:
  – to refine initial estimates of aquifer properties (parameters)
  – to determine boundaries
  – to determine flow and transport conditions at the boundaries

Calibration data

• Water-level change maps and hydrographs
• Streamflow, including gain and loss measurements
• History of pumping rates and distribution of pumpage
Modeling results

- Check input data for errors
- Check water and mass balance error
- Check computed variables for reasonability (head, drawdown, travel times, velocities, fluxes, concentrations)
- Perform hand calculations
- Check model assumptions for consistency with results
- Rework results for presentation to management
Model uncertainty

• Sources of error
  – natural heterogeneity which cannot be completely described with a limited number of field samples
  – measurement errors
  – differences between real world and the model

Model uncertainty

• Determination of uncertainty in prediction or accuracy in statistical terms
  (e.g., estimate probability that the model’s predictions deviate from reality by more than a specified amount at any given time or location)

• Use sensitivity analysis to study effects of parameter variability (e.g. Monte Carlo Analysis or ad. Hoc approach)
Model limitations

- Data quantity, quality
- In certain areas, models do not exist, or are inadequate
  - lack of scientific understanding
  - inadequate mathematical solution techniques
  - insufficient computer capabilities
- Model accessibility
- Model documentation
- Trained experts
- Model credibility
- Decision-making is not based solely on predictions/screening done with models

Conclusions

- Models do not replace hydrogeologic analysis
- Effectiveness of models depends on quality of input
- Modeling is one of the tools the technical expert has available to assist decision-making
- Best decisions are based on integrated use of resources