NEBRASKA’S WATER MANAGEMENT RESOURCE

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A Simplified and More Efficient Solution for Stream Depletion Analysis in MODFLOW

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Application of a Groundwater Modeling Tool for Managing Hydrologically Connected Area

- The IWM division of NDNR focuses on the management of hydrologically connected groundwater and surface water supplies.
- Understanding the spatial boundaries of fully appropriated areas (i.e., 10-50 area) is one of the research priorities in the field of IWM in Nebraska.
- This delineation helps water managers in different management roles apply focused management strategies to these areas.
Conventional SDA in MODFLOW

- Build the baseline (calibrated) model
- Add new well and rerun the model
- Calculate the SDF term based on the simulation results
- Repeat the iteration at each grid cell for mapping SDF distribution
Issues With the Conventional Method

- Labor intensive to set up the analysis
  - Inputs and outputs
  - SDF calculation
- Prolonged running time
  - 200 rows * 200 columns * 1 layer * 5 minutes = 138 days
- Numerical errors
  - Changes vs. Errors
Efforts at NDNR to Improve the SDA Processes

- **Cycle Well Analysis (CWA) GUI**
  - Automation of input and output processing

- **Cycle Well Analysis Spreadsheet (CWAS)**
  - More flexible specification of model runs
  - Incorporate automatic pumping definition

- **MODFLOW-SDA package (SDA)**
  - Linearization of MODFLOW flow equation
Cycle Well Analysis Software GUI
## Cycle Well Analysis Spreadsheet

The Cycle Well Analysis Spreadsheet contains data related to well analysis, including columns labeled `WellID`, `HBase`, and `HScen1` to `HScen5`. The spreadsheet also includes additional columns such as `Pump` and `zones`.

### Table Preview

<table>
<thead>
<tr>
<th>WellID</th>
<th>HBase</th>
<th>HScen1</th>
<th>HScen2</th>
<th>HScen3</th>
<th>HScen4</th>
<th>HScen5</th>
<th>Pump</th>
<th>zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
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<td>1990.117065</td>
<td>1990.109985</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Development of a stream depletion analysis (SDA) package for MODFLOW

Linearization assumptions

A solution will be obtained herein that considers the effects of streambed clogging and partial stream penetration. A definition sketch for this problem is shown in Figure 3. The calculation of this solution will assume that:

- The ratio of vertical to horizontal velocity components is small (the Dupuit approximation).
- The aquifer is of infinite extent and is homogeneous and isotropic in all horizontal directions.
- Drawdowns are small enough compared with saturated aquifer thicknesses to allow the governing equations to be linearized.
- The streambed cross section has horizontal and vertical dimensions that are small compared to the saturated aquifer thickness, and the stream extends from \( y = -\infty \) to \( y = \infty \) along \( x = 0 \).
- The well flow rate, \( Q_w \), is constant for \( 0 < t < \infty \).
- Changes in water surface elevation in the river created by pumping are small compared with changes created in the water table elevation on the aquifer side of the semipervious layer.
- Seepage flow rates from the river into the aquifer are linearly proportional to the change in piezometric head across the semipervious layer.
Theory of MODFLOW-SDA

- For baseline model
  - $AH = F$
- For scenario model
  - $A'H' = F'$
- Assuming $A' \approx A$
- Thus
  - $A(H' - H) = (F' - F)$
  - $A\Delta H = \Delta F$
Flowchart of MODFLOW-SDA
Results – COHYST model

![Graph showing flow rate over time for Birdwood, comparing Con and New models.](image-url)
Constant pumping at different distance
Changing pumping pattern at different distance
Running time

- Speedup: 20 times faster
  - MODFLOW: 6 minutes
  - MODFLOW-SDA: 20 seconds
- CPU time distribution
Future development of SDA

- Support other MODFLOW versions
  - OHWM – NWT, FMP, UZF, MNW
- Parallelism
  - JUPITER API
- Integration with GWM
Software availability

- Software available upon request
- Future updates:
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