Tackling tough water resource problems in karst aquifers using models

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Karst Aquifers

Highly productive

Susceptible to contamination
Observed Water Levels

Data
Linear trend

Water Level (ft)


Water Level (ft)

Public
Agriculture
Commercial
Self-Supply
Landscape
Thermoelectric

40%
28%
19%
9%
2%
2%
Key Questions

1. Can we reduce nutrient loads to the FAS while maintaining economic sustainability?
2. What role does climate play in groundwater levels?
3. Can we meet that numeric nutrient criteria?

Complex problems. Do we need complex models to solve them?
Study Site

Santa Fe River basin

- Heavy agriculture
- Abundance of data
- Springs
- Confined/unconfined conditions

76 m

Springs
Rivers
SWAT + MODFLOW

Model Selection

Precipitation

Evapotranspiration

Forest growth

Crop growth

Runoff

Aquifer Recharge (to MODFLOW)

Groundwater Table (MODFLOW)

Stream Loss (MODFLOW)

River Stage (to MODFLOW)

Later Flow

Remaining ET (MODFLOW)

Pumping Well (MODFLOW)

Stream Gain (MODFLOW)
**SWAT**
- Partitioned calibration
- SWAT Model only
  - 4 river stations
- SUFI-2 / NSE objective
- Calibration: 2000–2005
- Validation: 2006–2010

**MODFLOW**
- Calibrated
- Steady State → Transient
  - High/Low water years
Model Comparison Hierarchy

FULLY INTEGRATED

COUPLED BUT INDEPENDENT

SWAT
- Tipping bucket groundwater
- Semi-empirical

SWAT-MODFLOW
- Only communication between river cells
- Recharge to MODFLOW via HRU

DisCo
- Runoff and subsurface saturation linked
- Richards Equation

- Curve numbers
- HRU discretization

Darcy's Law (GW)

NLDAS gridded climate data
Results: Water Balances

DisCo

SWAT-MODFLOW

SWAT
May 2000

- Spatial dynamics are good
- Temporal dynamics are stagnant at times

Results: Groundwater

Observed head (m) vs. Simulated head (m) (2000-2005)

\[ R^2 = 0.8897 \]
\[ B = 1.4497 \]
Results: Calibration

![Calibration Results](image)

<table>
<thead>
<tr>
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<th>SWAT</th>
<th>SWAT-MODFLOW</th>
<th>DISCo</th>
<th>OBSERVED</th>
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Results: Calibration

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MODEL 2.0

**Land Cover**

NLDAS ➔ 2017 USDA

- Improved resolution of crops
- Aggregated urban to reduce HRU

**Enhanced surface runoff**

- Previously tied to NFSEG rivers
- Increased river runoff and basin aggregation
- Enhance coupling

**Groundwater Domain**

- Increased groundwater contributing area
- More aligned with DisCo
Conclusions

→ SWAT-MODFLOW performed well for the application it was designed for
→ Other models, fully integrated and more simplistic, did not necessarily provide improved performance
→ For some applications, SWAT could be a reasonable alternative in karst environments
→ All models still have issues reproducing recessions in fluviokarst environments
   → Geologic vs hydraulic controls
   → Significance?