Using Hydrologic Models in the Decision-Making Process

Breanna Clabourne[1], Ty P.A. Ferré[1], Chloé Fandel[1], and J. E. Dickinson[2]

The University of Arizona, Tucson

[1]Department of Hydrology & Atmospheric Sciences

[2]United States Geological Survey

Study Objective

To demonstrate the utility of a hydrologic model in the decision-making process to inform competing interests of stakeholders.

Why It Matters

Groundwater is a precious water resource. Hydrologic models empower scientists and stakeholders to make better decisions about the potential use of such resources.

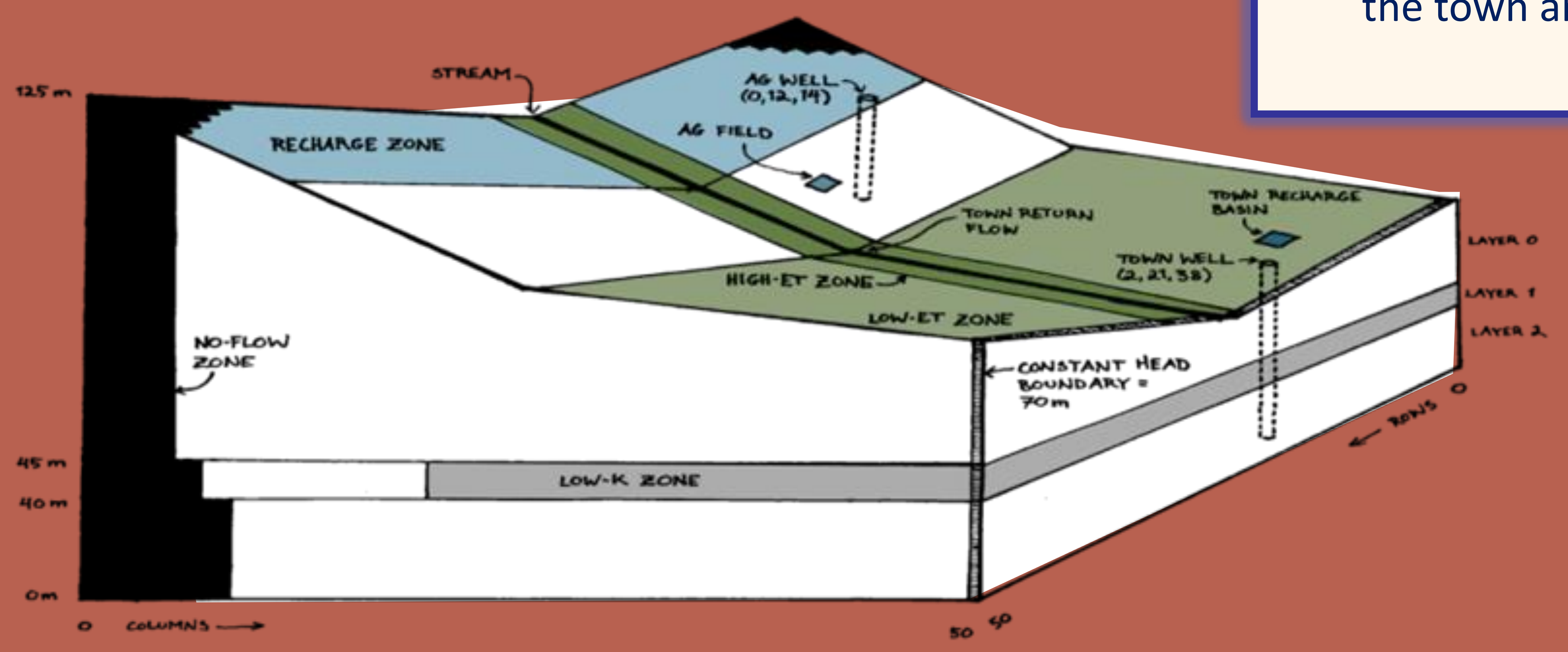

Figure 1 Schematic of the model aquifer. Courtesy of Chloé Fandel.

The Model

- The model aquifer provides water for two hypothetical stakeholders.
- The first hypothetical stakeholder, a town, has an established pumping well.
- The second hypothetical stakeholder, an agricultural developer, wishes to build a 124-acre field and irrigation well for crop production. There are ten potential irrigation well locations and three potential crops of wheat, cotton, and pistachio. Figure 2 shows an areal view of the model aquifer.

Methods

- The locations of the town well and field remained constant.
- 30 model ensembles represent the ten potential irrigation well locations and three crops. Each ensemble has 50 models. Model parameters varied within the values shown in Table 1.
- An additional 5 models were generated to act as "Truth Models" that provide head measurements in the aquifer. Truth Model parameters varied within the values shown in Table 2.
- Likelihoods of the projected head in the town well were weighted based on how well they matched the head measurements in the Truth Models.
- Agricultural (Ag) Net Profit was determined by subtracting pumping and water delivery costs from the profit made from selling each crop for a 10-year period.
- Trade-off plots showing the head in the town well and agricultural net profit were generated to compare the parameters of interest (POIs) of the town and agricultural developer.

Table 1. Ensemble model parameters

Parameter	Values	Unit
$K_x=K_y=K_z$	[5, 10, 25, 50, 100]	m/day
K_z ratio in low K layer	[1e-6, 1e-4, 1e-2, 1e-1, 1]	[-]
S_y	[0.05, 0.075, 0.1, 0.2, 0.3]	[-]
Mountain Front Recharge	[1e-5, 2e-5, 3e-5, 4e-5, 5e-5]	m/day
ET in Valley	[1e-6, 5e-6, 1e-5, 5e-5, 1e-4]	m/day
ET along Stream	[1, 1.5, 2, 2.5, 3]	m/day

Table 2. Truth model parameters

Parameter	Values	Unit
$K_x=K_y=K_z$	[5, 15, 35, 65, 100]	m/day
K_z ratio in low K layer	[1e-6, 1e-3, 1e-2, 1e-1, 1]	[-]
S_y	[0.05, 0.085, 0.15, 0.25, 0.3]	[-]
Mountain Front Recharge	[1e-5, 2e-5, 3e-5, 4e-5, 5e-5]	m/day
ET in Valley	[1e-5, 5e-5, 8e-5, 9e-5, 1e-4]	m/day
ET along Stream	[1, 1.75, 2.25, 2.85, 3]	m/day

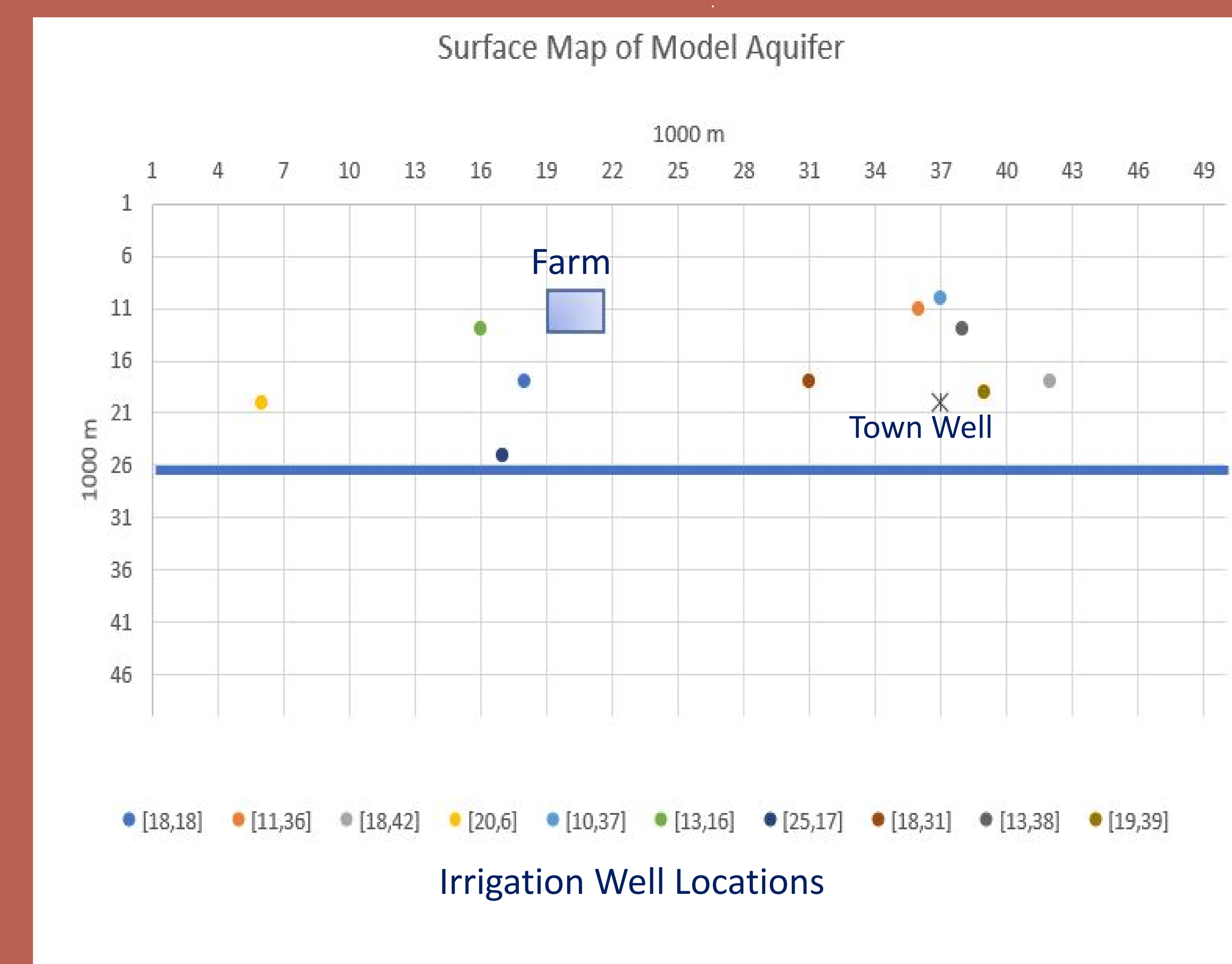

Figure 2. Areal view of model aquifer

Results

- Figure 3 shows the trade-off plot for the POIs of the town and agricultural developer when there are no head measurements in the model aquifer. Without data, each model is weighted equally. All models with cotton resulted in $0 of Ag Net Profit, so those models were eliminated.
- Figure 4 shows the trade-off plot where each design is weighted based on the head measurements in Truth Model 1. The five models that optimize both POIs are circled on the plot.
- Figure 5 shows the optimized models weighted against Truth Models 1-5.

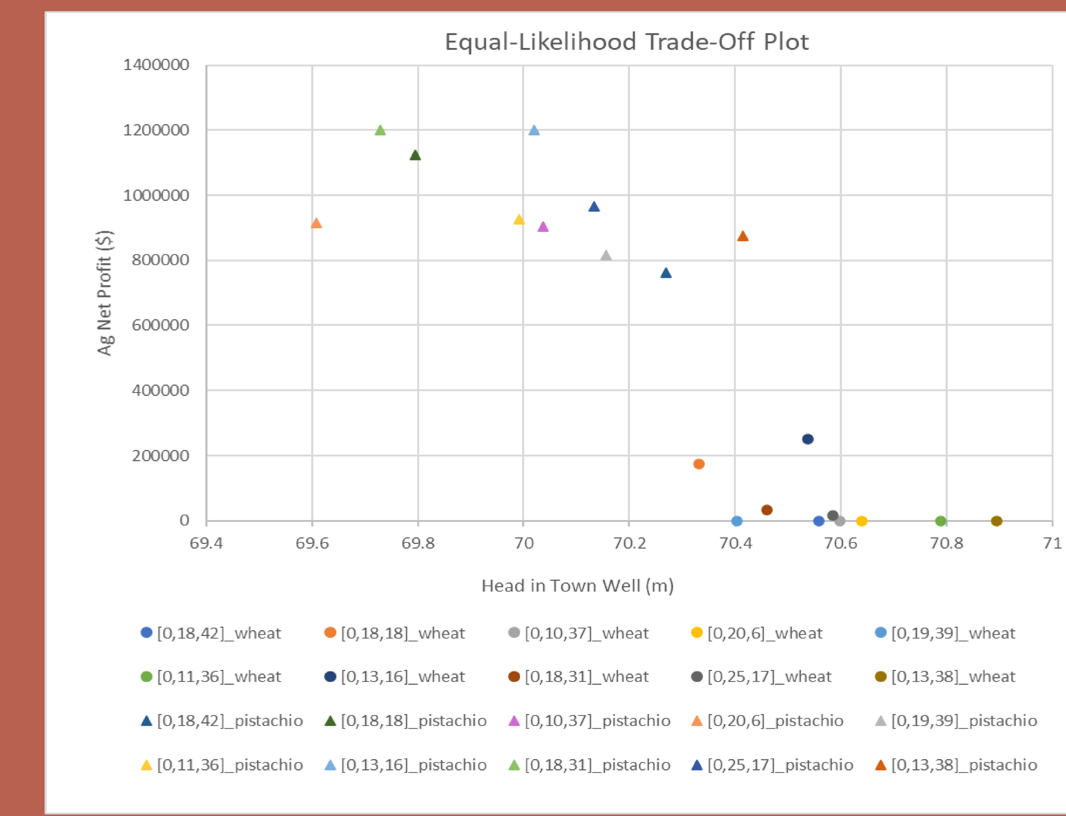

Figure 3. Equal-likelihood trade-off plot.

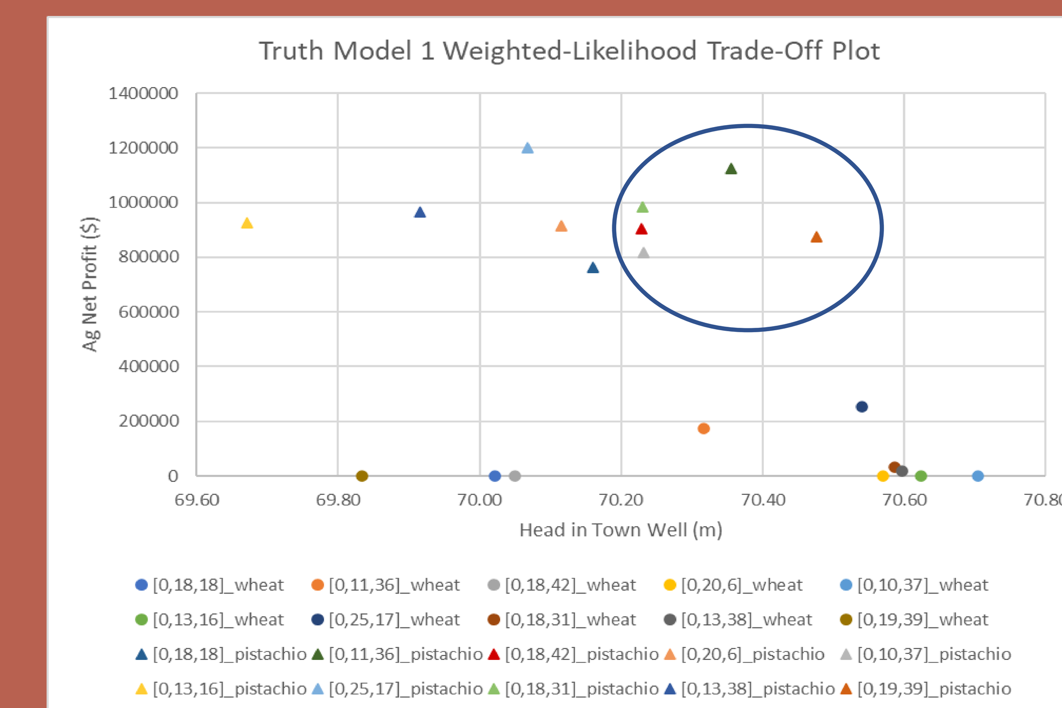

Figure 4. Truth Model 1 Weighted-Likelihood trade-off plot. Optimized models are circled.

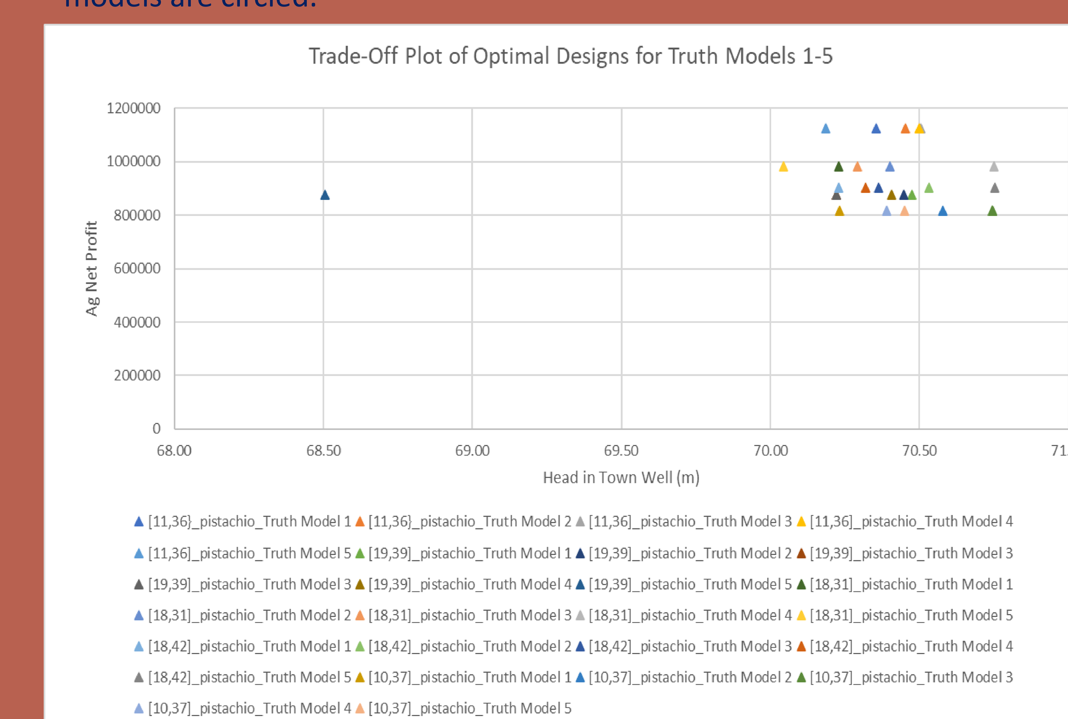

Figure 5. Trade-off plot of optimized models weighted against Truth Models 1-5.

Discussion and Conclusion

This study illustrates the challenges stakeholders experience when finding a compromise for their competing interests. The town aims to maximize the head in their well to have enough water to support their population. On the other hand, the agricultural developer wishes to maximize their net profit. Figure 3 shows the trade-off for each irrigation well location and crop type combination. However, each model outcome is weighted the same since no aquifer head measurements are included in the analysis. A model's results are only as good as its field measurements. Therefore, the results shown in Figure 3 do not accurately represent the "real-world" conditions of the model aquifer. To account for this, model outcomes were weighted based on how well their aquifer head predictions matched the aquifer head measurements simulated in a Truth Model. Figure 4 shows the projected head in the town well after the model outcomes were weighted against Truth Model 1. As different as the stakeholders' interests are, Figure 4 identifies 5 potential models that optimize the outcomes for the town and agricultural developer with Truth Model 1. However, hydrologic parameters can vary by orders of magnitude, making it difficult to identify parameter values with a great degree of certainty. Figure 5 shows as more truth models are incorporated into the analysis, the more difficult it becomes to identify the optimal choice for both stakeholders. This process of incorporating additional aquifer head measurements to account for as many outcomes as possible is necessary. However, it may lead to even more uncertainty when choosing the "right" option for both stakeholders.