Modeling Flow Regimes for a cyclical wetland using Groundwater Temperatures in McLean County, IL

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ABSTRACT

Wetlands act as a sink in reducing excess nutrients through plant uptake and denitrification before entering into lakes, rivers, and streams. Additionally, seepage into the subsurface and the subsequent migration also serves as a sink for nutrients. Variation in the flow regime of the wetland may influence the fate of nutrients in the subsurface. In order to assess water quality of the wetland system, a groundwater model was used to determine fluid flow and the velocity of solutes within the system. The constructed wetland has a flaw, and during the late summer, it goes dry. A bromide tracer test was completed in May 2013 to evaluate the wetland's capacity to retain water. By the sixth day, the Br- concentrations within the wells approached the mean concentration within the wetland, suggesting that the wetland is leaking. The similar concentrations between the water in the wells and in the wetland suggest there is limited dilution by groundwater. Also temperature data indicate different flow regimes associated with a filled wetland and the dry wetland. To assess the role of the conditions within the wetland on the groundwater flow regimes, a model was created using SEAWAT. The observed temperatures are used in SEAWAT. Preliminary data suggests that the presence of water within the wetland alters the local groundwater flow direction. While the underlying groundwater flow direction does not change, the presence of water within the wetland creates an area of recharge from which water appears to radiate in all directions.

INTRODUCTION

- Temperature has the highest potential to explain the complex groundwater characteristics and model groundwater flow (Anderson, 2005; Conant, 2004).
- Heat is transported in the subsurface by conduction and convection via groundwater flow.
- Factors which control groundwater temperature are solar radiation, air temperature, precipitation, and direct inflows.

STUDY SITE

- Durbin wetland, a small reservoir in McLean County, IL.
- Dimensions of Durbin wetland are approximately 250 feet by 150 feet with depth of 6.64 feet and a volume of 218,250 cubic feet. The wetland was constructed with one wetland pond and an overflow wetland. The wetland runs adjacent to a stream channel on the west (FIGURE 1).
- The reservoir was built to sub-irrigate during drought and treat nutrient contamination into surrounding surface water.
- During hot-dry summers, the wetland dries; refilling begins in late fall as seasonal changes, evapotranspiration ends and precipitation increases, occur.

HYPOTHESIS

- How do dry conditions and wet conditions for a wetland influence the thermal regime of a local groundwater system?

METHODS

FIELD COLLECTION

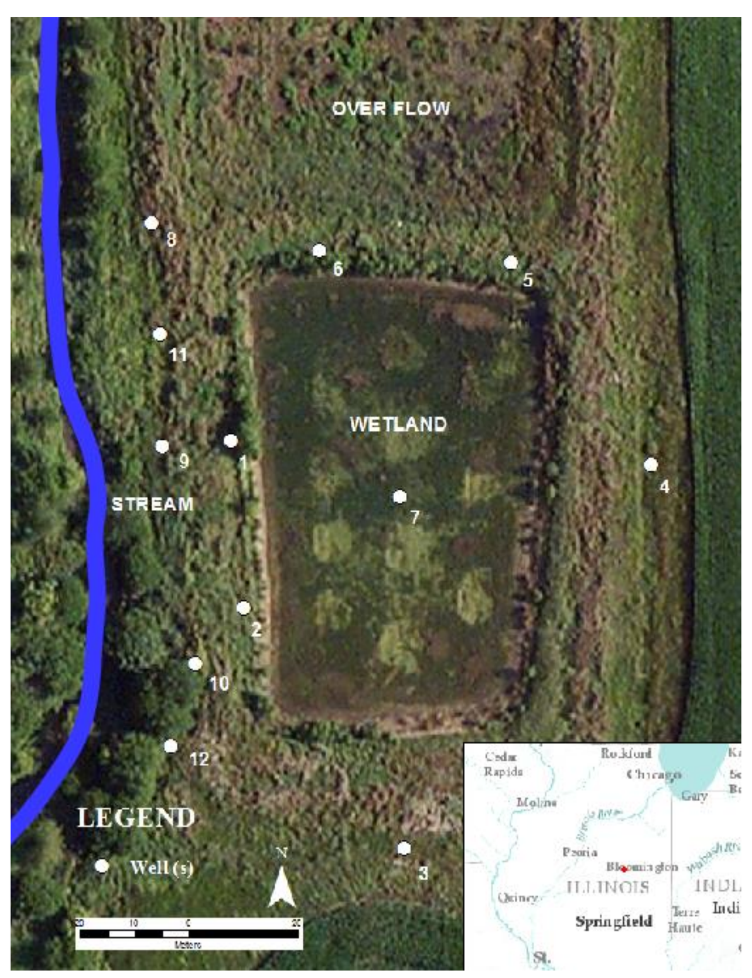

FIGURE 1: Durbin wetland location showing the locations of monitoring wells (modified from Google Maps, 2014).

- The site contains 11 observation wells (FIGURE 1), note well 7 is used solely for water sampling. On the west bank of wetland there is a significantly pronounced berm where well 1 and well 2 reside.
- Hydraulic head and temperature were measured in the field from 9/12/2013 to 10/8/2014.
- Water temperature (°C) was measured using a YSI-85 salinity-conductivity meter.
- Head values were measured with a water level meter and adjusted to surveyed elevations.
- Bromide tracer test was conducted by mixing 48 kg of sodium bromide into the wetland.
- Samples from the wetland, wells, and stream, were collected over 16 days.

MODELING

- GFLOW was used to verify the regional groundwater flow (FIGURE 2).
- Kriging was used to interpolate the water table (hydraulic head) and the thermal gradient within the study area (FIGURE 4 and FIGURE 5 respectively).

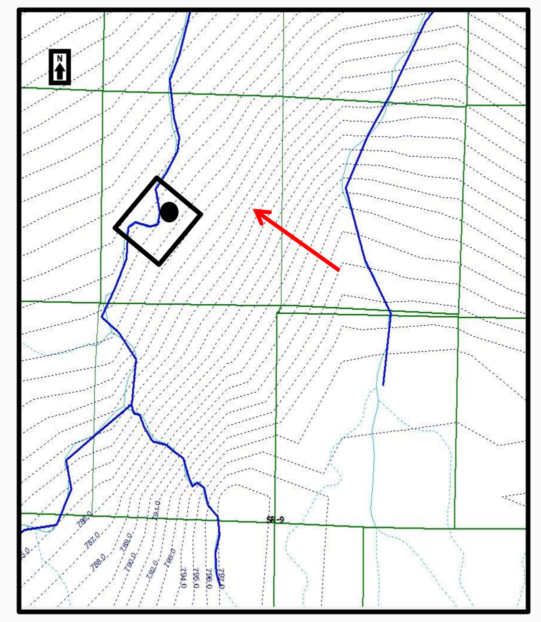

FIGURE 2. Regional groundwater flows from Southeast to northwest. Site location is the black dot. Red arrow represents flow direction. Open square is the boundary for model.

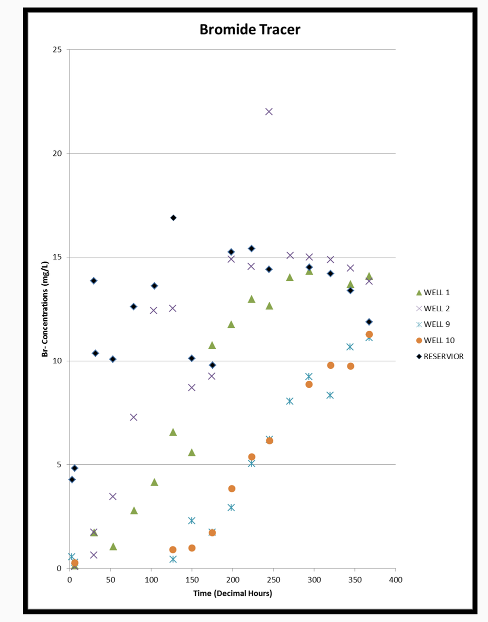

FIGURE 3. Break through curves for tracer tests indicates wetland waters infiltrate into subsurface and travel towards the stream. Concentrations of bromide were seen in the down gradient wells after three days of the initial start of test.

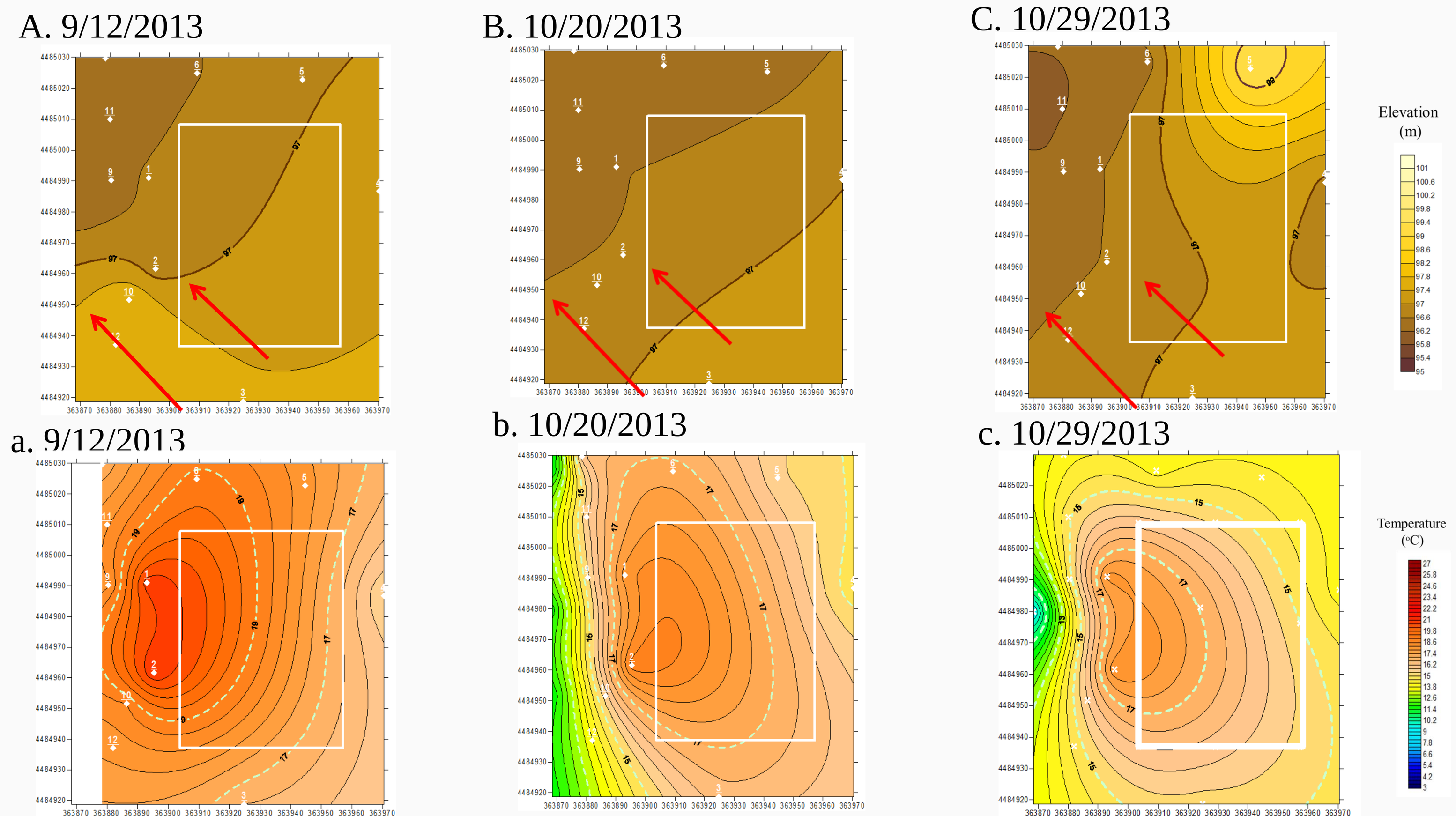

FIGURE 4. At dry conditions, the wetland is absent, the groundwater flow is consistent with the regional flow model in FIGURE 2. (4A- C) Temperature gradient cools through time and toward stream (4a- c). The berm is a thermal source creating a heterogeneous pattern. (White box outlines wetland and red arrows are flow lines.)

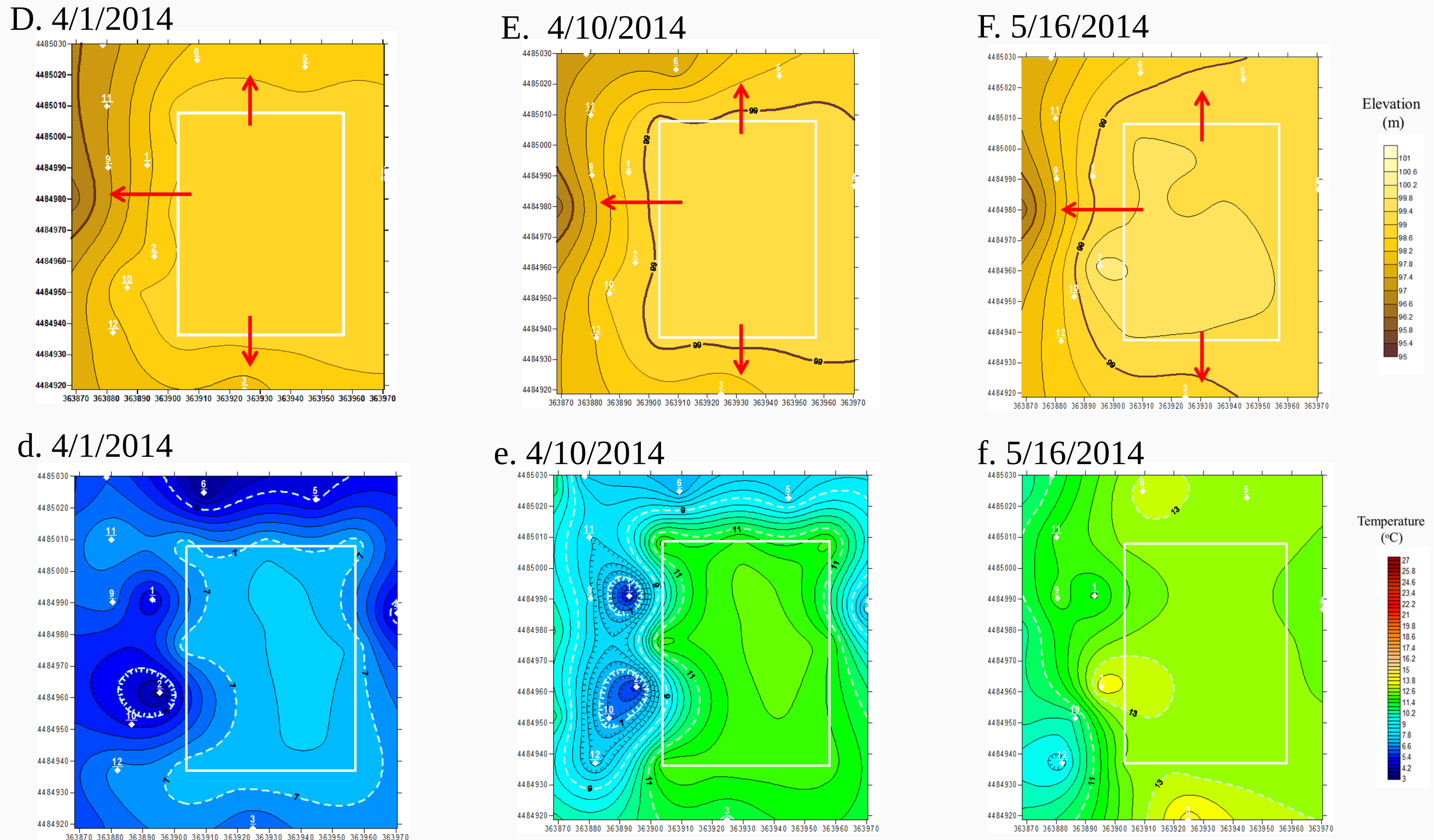

FIGURE 5. In (D- E), the wetland is a zone of recharge and water moves out and away from wetland. Temperature is coldest at wells 1 and 2, but in general the temperature is warmer in wetland and cooler toward stream (d-f). (White box outlines wetland and red arrows are flow lines.)

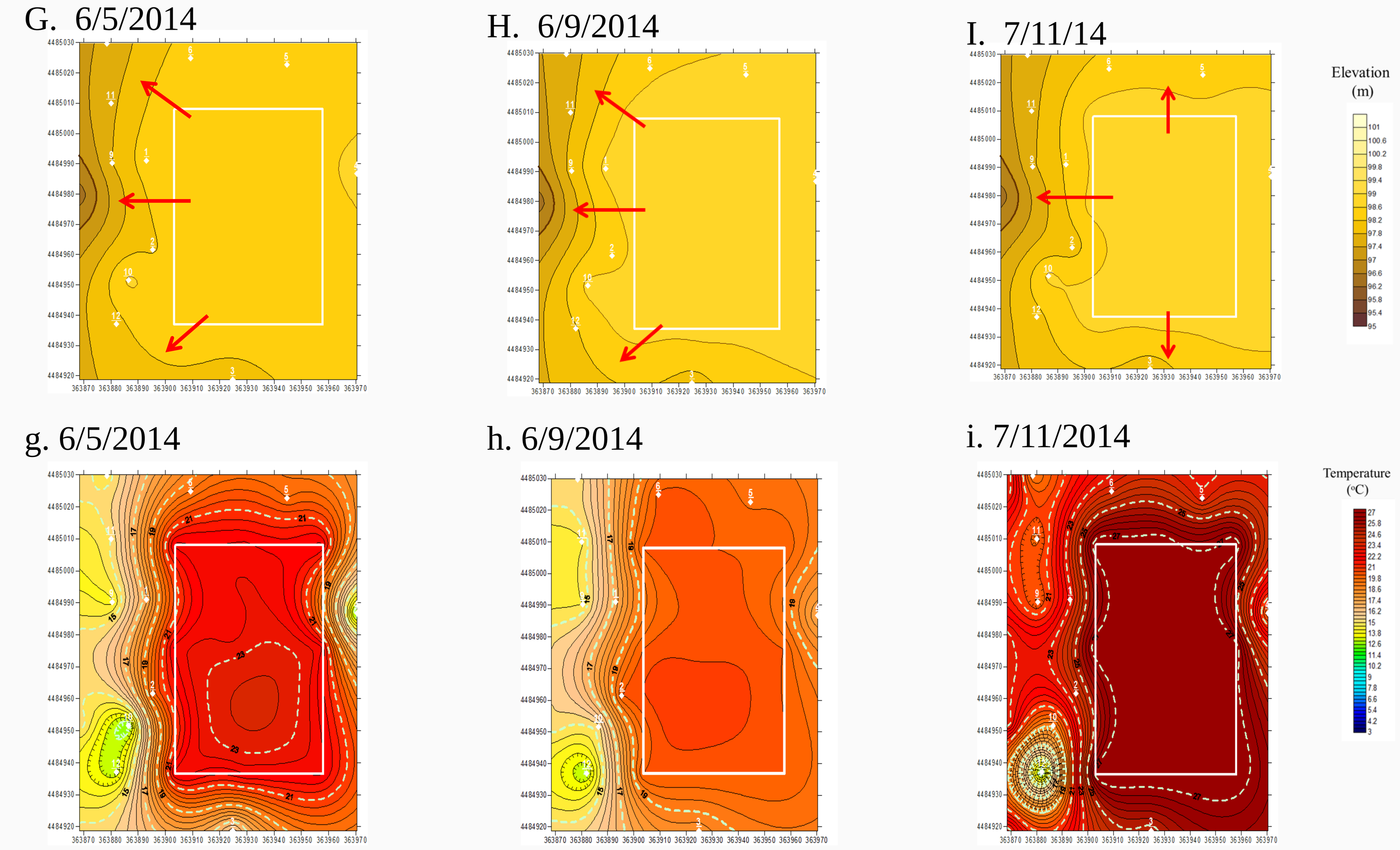

FIGURE 6. The wetland in wet conditions is a zone of recharge and water moves away from wetland (G- I). Thermal gradient is warm in the wetland and cools toward stream. The area around well 12 could be an upwelling from deeper groundwater. (The white box outlines the wetland and the red arrows are flow lines.)

DISCUSSION

- The regional groundwater flow is from southeast to northwest.
- Bromide tracer test indicate connection with wetland and groundwater from observed bromide concentrations within the wells.
- At dry conditions, the wetland becomes absent and groundwater flow is northwest following the regional groundwater flow.
- At wet conditions, the wetland is a zone of recharge and water moves in the north, west, and south direction away from the wetland.
- On the western bank of wetland is a pronounced berm where well 1 and 2 reside. The berm is a thermal source. Temperature highs could be the result of solar radiation and air temperatures.
- The overall temperature gradient is warm in the wetland and cools toward the stream.
- In FIGURE 6 (g-i), well 12 shows possible upwelling zone from deeper groundwater.
- The wet and dry conditions of the wetland does influence the direction of groundwater flow.

Photo of dry (9/22/2013) and wet (4/1/2014) wetland.

REFERENCES
Anderson, M.P., 2005, Heat as a Ground Water Tracer: Ground Water, v.43, no. 6, p. 951-968, doi10.1111/j.1745-6584.2005.00052.x.
Conant Jr. B. 2004, Delineating and Quantifying Ground Water Discharge Zones Using Streambed Temperatures: Ground Water, v.42, no. 2, p. 243-257.