GROUND-WATER ELEVATION AND TEMPERATURE ANALYSIS OF LEAKAGE FROM COEUR D'ALENE LAKE, IDAHO

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INTRODUCTION

The Spokane Valley-Rathdrum Prairie (SVRP) aquifer underlies the area of the state line between northern Idaho and eastern Washington. Proper water management requires field data and interpretations of the data. Characterizing leakage from Lake Coeur d'Alene, Idaho near the inlet of the Spokane River is crucial to understanding recharge to SVRP aquifer, leading to enhanced water management decisions.

The purpose of this study was to gain a better understanding of the hydrogeologic controls on leakage at Lake Coeur d'Alene near the inlet of the Spokane River through analysis of water-level and temperature data. This was accomplished by the following objectives:

- Examining water-elevation data
- Examining water-temperature data
- Developing hypothetical water-level and temperature models to assist in the data interpretations
- Discussion of these three components

FIELD METHODS

Water-elevation data and temperature data were obtained for wells near the inlet of the Spokane River and the northwest end of Coeur d'Alene Lake (see Figures 1 and 2 for site location and well information) in northern Idaho. Data for five deep wells with short completion intervals on Blackwell Island were examined; from north to south the wells are MW8D, MW2, MW10D, MW6, MW12D (see Figures 1c and 2). MW6 and MW2 are deeper wells. Data loggers recorded water level and temperature data at the center of screened intervals.

Surface-water elevations and temperatures were recorded from Lake Coeur d'Alene. The depth of Lake Coeur d'Alene south of the wells on Blackwell Island is approximately 60 feet (~19 m). Surface water temperatures were measured in this area near the surface of the lake. Temperature measurements with depth within the lake were collected near Harrison, ID (SE area of lake).

Water elevation data were also collected from two wells at the North Idaho College (NIC) campus, located on the east bank of the Spokane River (Figure 1b). These wells are screened 5 ft from the bottom of each well. AIP-1 has a bottom elevation of 2107 ft and is about 115 ft east of the river. AIP-2 has a bottom elevation of 2100 ft and is located an additional 70 ft to the east.

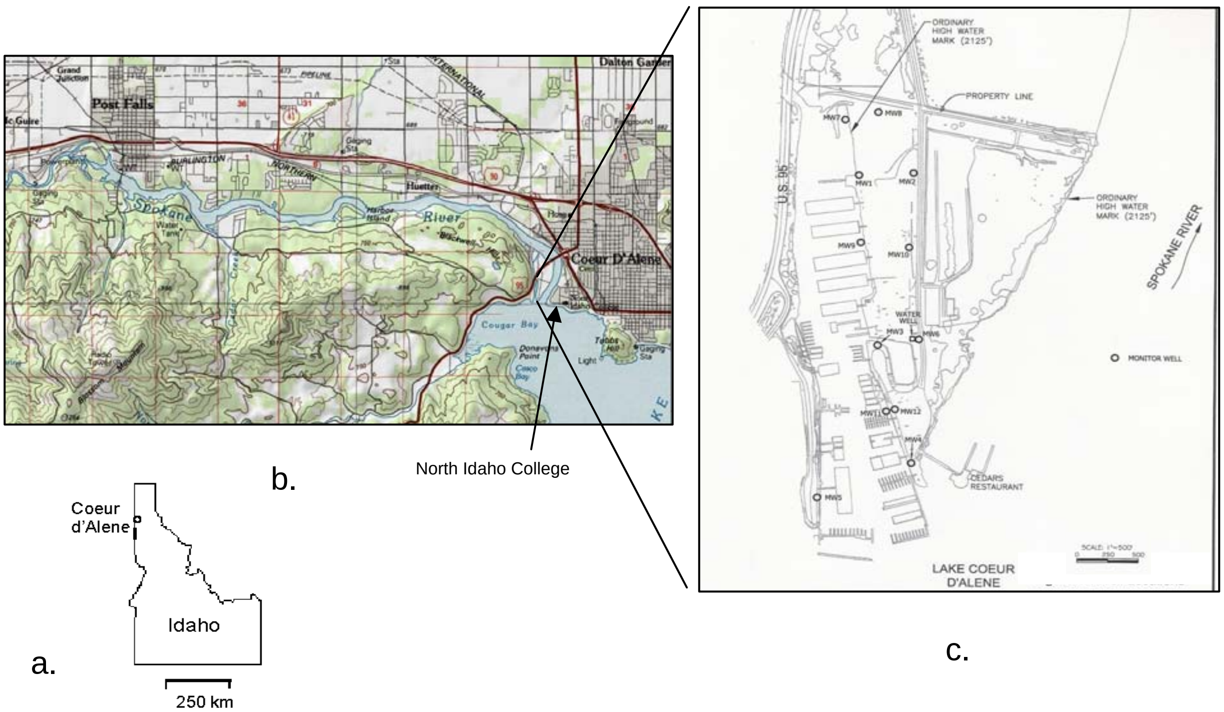

Figure 1. Site maps; a) location map of Coeur d'Alene, Idaho; b) location map of general area (note: boxes with numbers are 1-mile square sections); c) location map of Blackwell Island wells.

WATER ELEVATION DATA

Water elevations for wells on Blackwell Island and nearby surface water are shown in Figure 3. The water table slopes off rapidly to the north away from Lake Coeur d'Alene out into the Spokane Valley/Rathdrum Prairie aquifer. A steep, downward vertical gradient exists in the aquifer under and next to the lake. Wells MW8D, MW10D and MW12D are screened at approximately the same elevations and have similar water-level elevations. MW-2 has a shallower screen completion but has a lower water-level elevation than MW-6. Both wells respond to changes in lake water levels but with less amplitude in MW-2 and a greater time lag.

Ground-water elevations decrease in the NIC wells before lake levels drop in the fall (Figure 4). However, ground-water levels in the Blackwell Island wells (Figure 3) generally following the timing of lake water levels. Reasons for the differences between wells are not known.

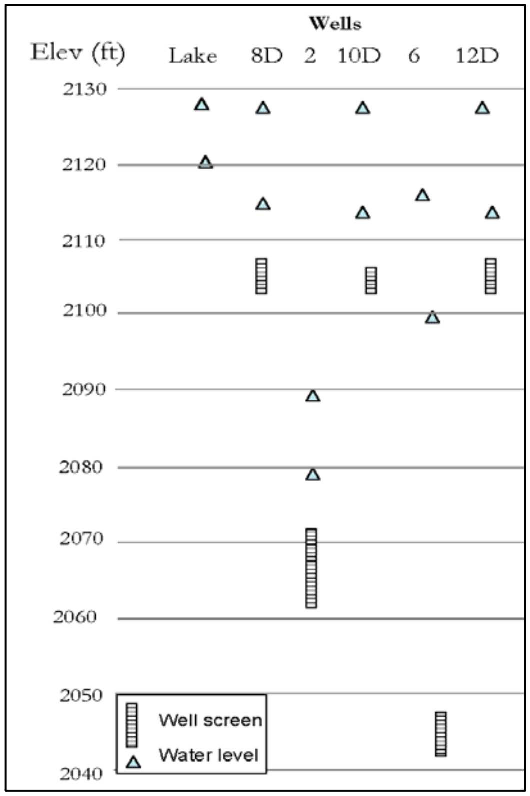

Figure 2. Minimum and maximum water elevations in Lake Coeur d'Alene and in the Blackwell Island wells. Screened elevations are also provided.

TEMPERATURE DATA

Based on patterns of temperature fluctuations in most of the wells, there is a correlation with near-surface lake temperatures (Figure 5). The observed data in the wells have delayed phases compared to the lake data. As expected, the temperature profile for MW12D is quite similar to the near-surface lake profile because the well is located near the marina. MW2 has large delayed temperature response and a much smaller amplitude. This well clearly is not as well connected to the near-surface lake water as the others.

Wells with similar water-level elevations do not all demonstrate this same pattern in their temperature profiles (Figure 5). The temperature profiles are unique for each well. This is somewhat surprising for MW8D and MW10D which are screened at similar elevations and have similar water elevations. The differences are likely caused by mixing along different flow paths, or possibly that leakage is occurring from different depths of the lake.

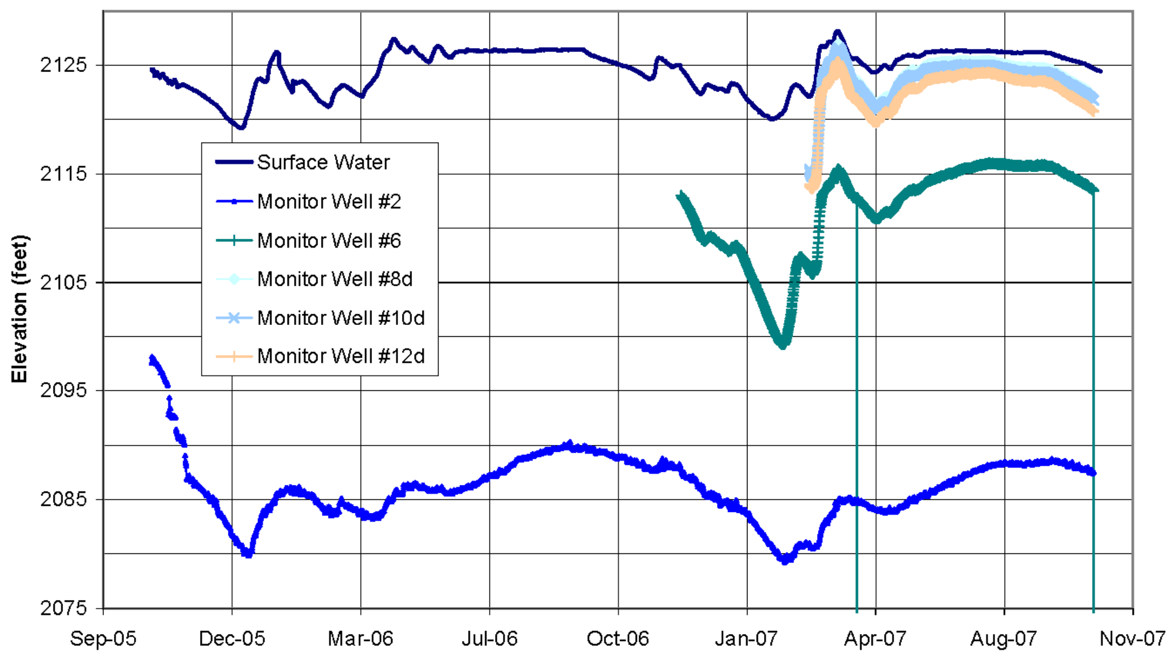

Figure 3. Water elevations in Blackwell Island wells and Lake Coeur d'Alene. (See Figure 1c. for well locations)

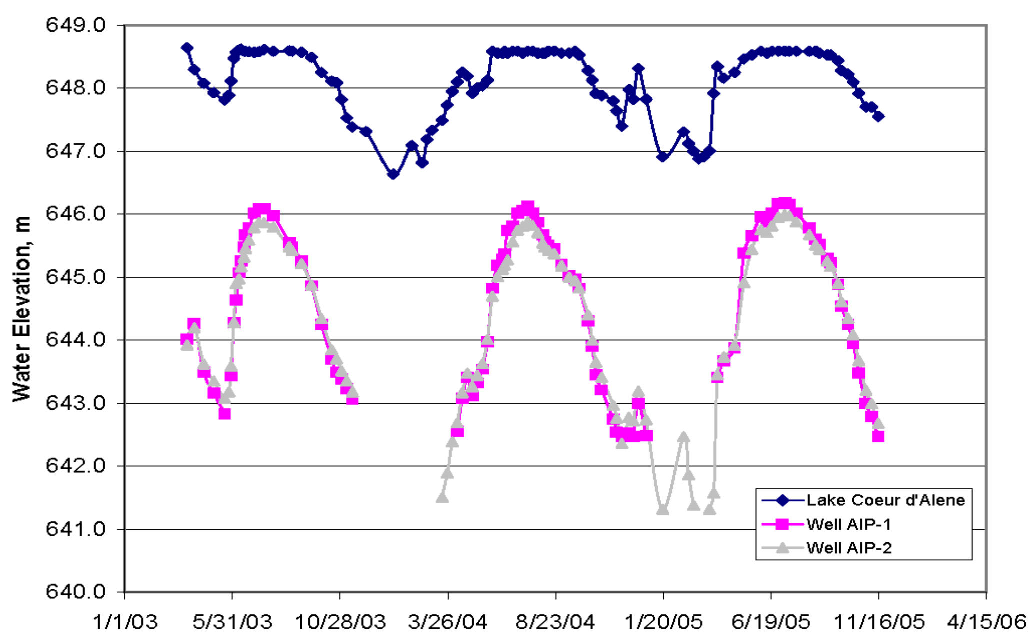

Figure 4. Water elevations in North Idaho College wells and Lake Coeur d'Alene. See Figure 1b for site map (note different scales from Fig 3) (Marcy et al, 2006).

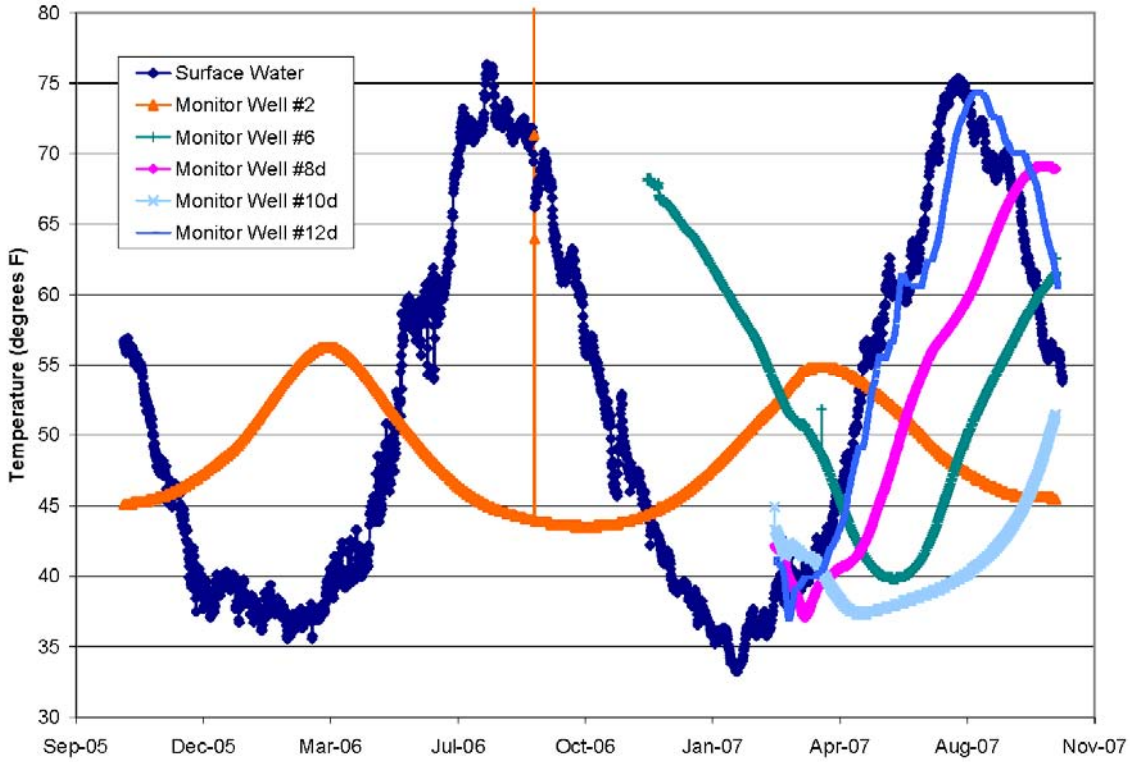

Figure 5. Water temperatures in wells on Blackwell Island and in the near-surface of Coeur d'Alene Lake.

The chart of surface-water elevations and surface-water temperatures exhibit similar timing of the lows, however the timing of the peaks are quite unique (Figure 6). Different wells show different annual fluctuations and different lag times because of varying distances from the shore, depth of screen and hydraulic conductivity differences within the aquifer.

Temperature within the lake varies with depth (Figure 7). At a depth of 3 ft the temperature varied ~42 °F, and at a depth of depth of 62 ft the temperature varied ~15 °F. The temperature low is nearly the same for all depths of the lake during the winter months. Temperature data for MW2 and MW6 is shown on Figure 7 for comparison, demonstrating that horizontal flow out of the deeper section of the lake is not reflected by these profiles.

HYPOTHETICAL TEMPERATURE MODELING

Hypothetical computer modeling of water levels and temperatures in wells and surface water was conducted to better evaluate the effects of hydrogeologic controls on the leakage of surface water to ground water. VS2DHI is a United States

Geological Survey (USGS) computer program used to simulate fluid flow and heat transport in variably saturated porous media in 1D or 2D. The user inputs:

- Model domain
- Hydraulic properties
- Initial and boundary conditions
- Grid spacing
- Other model parameters

In an example study, a 1-D vertical-flow column simulation was conducted. The following include some of the model inputs:

- Column dimensions: 1 m wide by 50 m long, initial temperature T_{ini} =70.34 °F
- Simulated stream with a head of 4 m above the top of the domain, T_{ini} = 63.46 °F
- Two main simulations:
  - Unsaturated: water table 100 m below top of domain
  - Saturated: water table at top of domain
- Duration of simulations: 100 hours
- Hydraulic conductivity (K) = 8.00 x 10^{-6} m/s

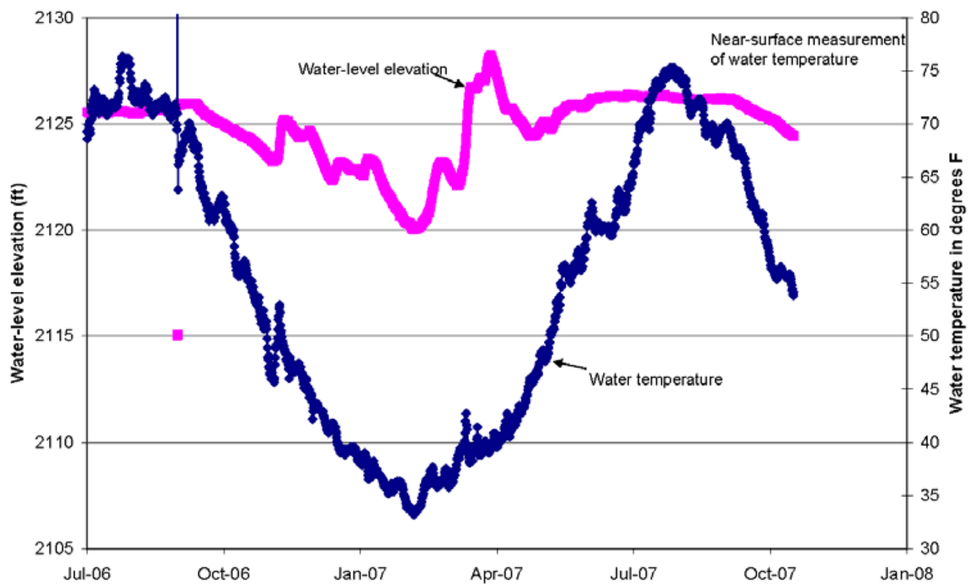

Figure 6. Lake Coeur d'Alene surface elevations and temperatures.

The results of the modeling study provide insight on how heat is transported in a porous medium and model sensitivity for the hydraulic parameters. Figure 8 shows the modeling results of saturated simulations for two different hydraulic conductivities. Figure 9 shows the counterpart for unsaturated simulations. The modeling results indicate that heat travels faster through the column in the unsaturated zone than the saturated zone. Stronestrom and Blasch (2003) state that air has almost no capacity for releasing or storing heat; consequently, heat travels rapidly through air. The system is very sensitive to hydraulic conductivity (K) and is the most sensitive of the input parameters (i.e. dispersivity, porosity, etc).

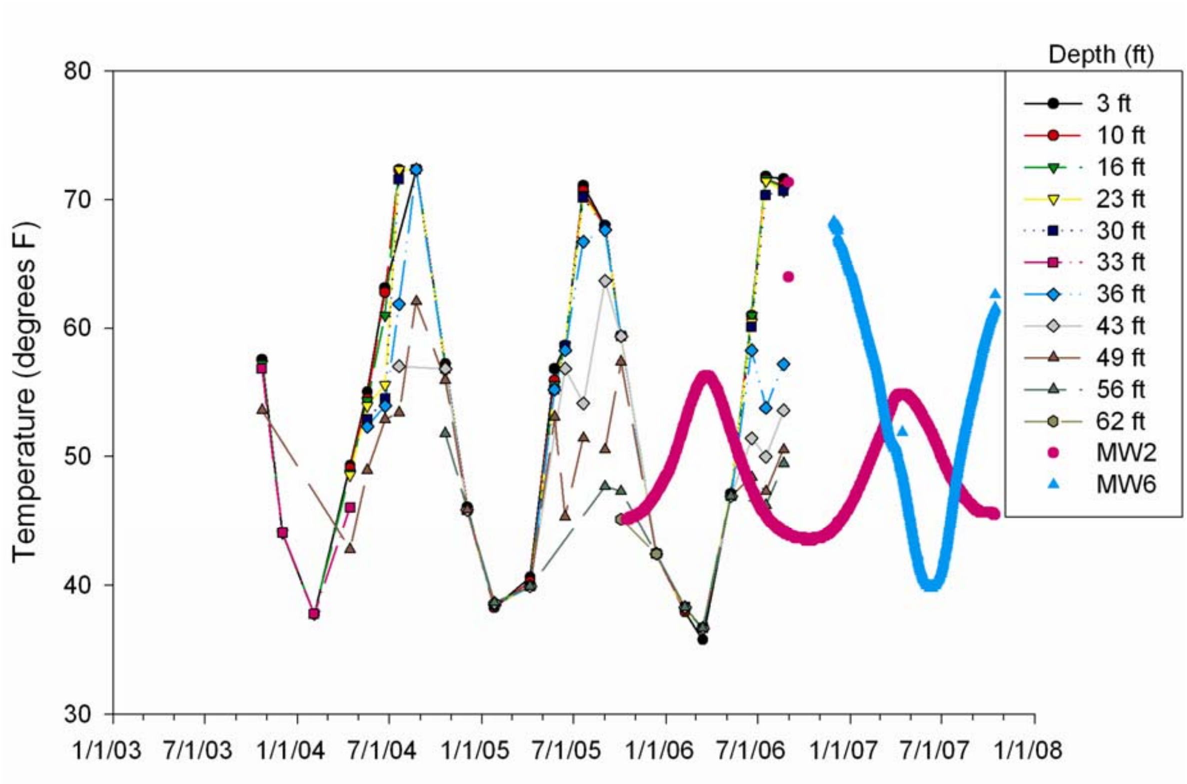

Figure 7. Lake Coeur d'Alene temperatures at different depths, and MW2 & MW6 temperatures

Prudic et al (2003) and Niswonger and Prudic (2003) used VS2DHI to analyze ground-water and surface-water temperatures for the Trout Creek area in Nevada (Figure 10). They found that when the K is high by an order of magnitude the simulated ground water temperature signal has a higher amplitude and a phase that is closer to the measured stream temperatures. When K is an order of magnitude too low the amplitude is nearly flat.

DISCUSSION

Water elevations provide insight into the relative rate of leakage from the lake. As the elevation of the lake increases there is a rapid increase in water elevations in the wells. More leakage occurs at high lake levels due to:

- An increase in lake/sediment contact area
- Sediment along the banks between low and high lake levels may have higher K from grain sorting due to wave action

• More leakage may occur at higher water temperatures, which exist during higher water levels, decreasing the viscosity and increasing K

At low lake levels there is less leakage (less wetted perimeter and possibly lower K per unit area) and ground-water elevations drop rapidly. The zone under the lake is believed to be saturated at high water levels but may go unsaturated at low water levels, based on water elevations in MW6 and vertical gradient calculations.

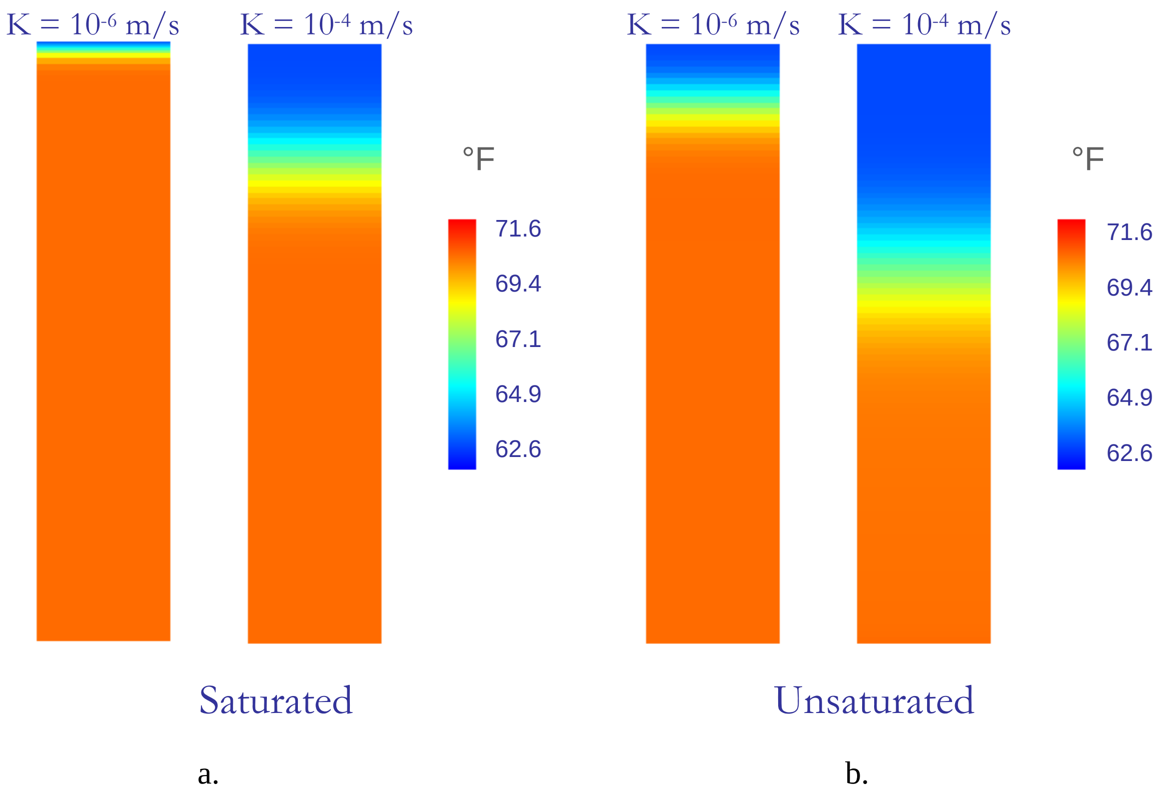

Figure 8. Hypothetical modeling temperature results of two different hydraulic conductivities (two orders of magnitude different) for a) saturated and b) unsaturated.

The timing delay and temperature differences of the well data from lake data are greater at the temperature highs than lows, the opposite for water elevation data. The temperature profiles in the lake with depth are most like the temperatures in the wells at low temperatures (Figure 7). This is because the temperature minimum within the lake is the same at all depths; therefore, the depth at which leakage occurs becomes less significant than at higher temperatures in the lake where the temperature is more stratified.

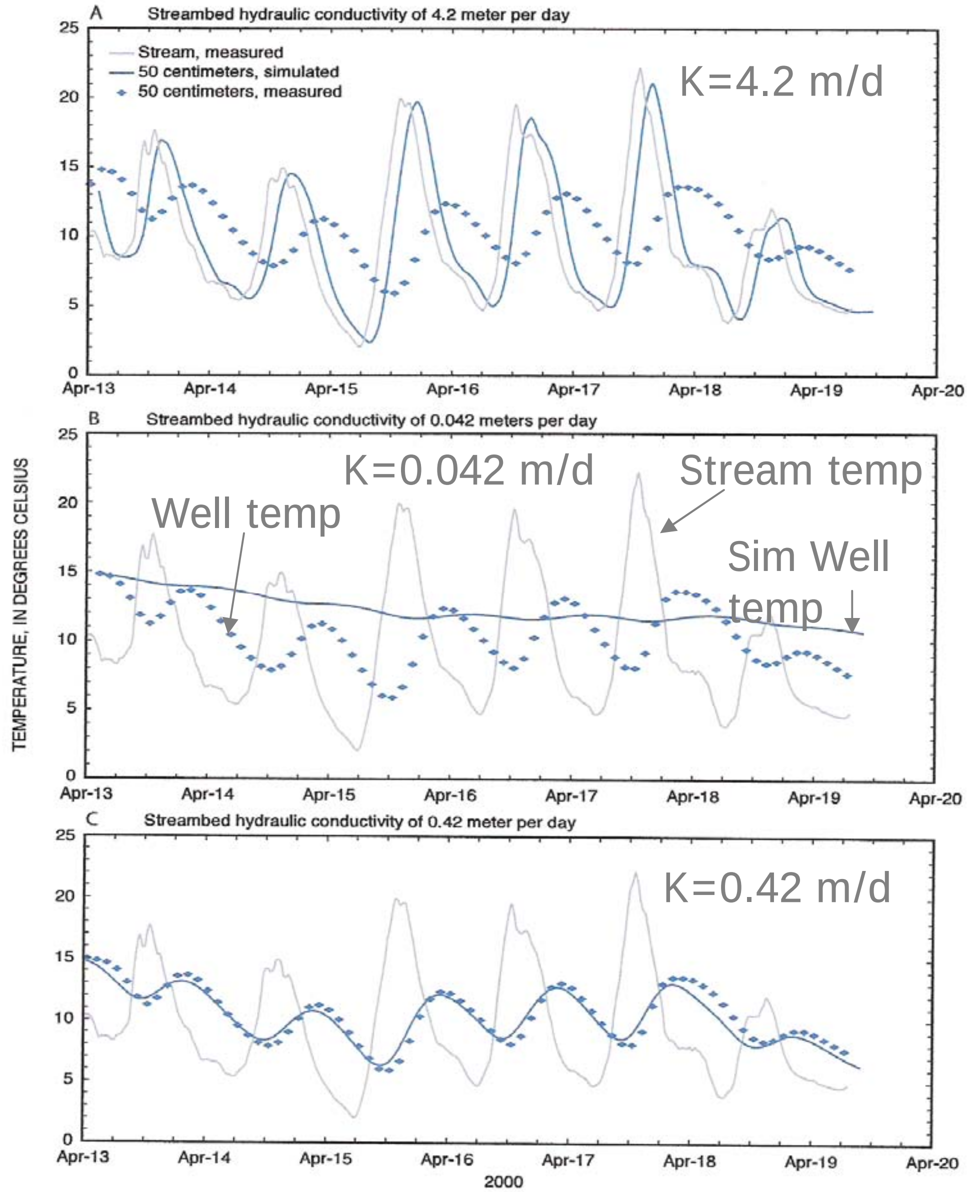

Figure 10. From Niswonger and Prudic (2003), time versus temperature graphs for a well, stream and simulated well-water temperatures (VS2DHI) using different K values.

CONCLUSIONS

Water elevation and temperature data in the wells suggest all of the wells are hydraulically connected to the lake and that more leakage occurs along the shoreline than at greater depths. More leakage from the lake occurs at high lake levels. The lake and Temperature responses in the wells offer supplementary information on the relative hydraulic conductivity of the screened interval, flow paths and saturation. The modeling results suggest that MW2 subdued temperature responses are likely caused by the well being screened in a low K zone. This conclusion is supported by the water-level responses.

Temperature data are an inexpensive but extremely useful tool in understanding leakage. The combination of water elevation and temperature data in wells and surface water provides valuable data for understanding leakage characteristics and hydrologic connections of surface water and ground water.

FUTURE WORK

Additional wells on Blackwell Island and in Lake Coeur d'Alene installed with data loggers collecting water-elevation and temperature data would greatly enhance the understanding of the hydrogeology near the outlet of the lake. Data loggers in Lake Coeur d'Alene set at different depths are desired to collect temperatures with depth. Temperature and water-elevation data from the lake and wells could be modeled using VS2DH1 to begin to quantify the hydraulic conductivity and leakage rates. The additional data and modeling results would be highly beneficial in the spatial characterization of leakage for water management.

ACKNOWLEDGEMENTS

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