Hydrogeologic Conditions in the Coeur d'Alene Subarea of the Rathdrum Prairie Aquifer, 2007 – 2015

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Overview

1. The Coeur d'Alene Subarea is one of five subareas for the Rathdrum Prairie aquifer. This subarea is located in the southeastern portion of the aquifer.
2. There are nine monitoring wells in the Coeur d'Alene Subarea.
3. Ground water level and water temperature data are collected by manual electric tape measurements and electronic transducers deployed in the wells.
4. Ground water levels in this subarea and throughout the aquifer occur in an annual cycle. The monitoring wells in this subarea exhibit maximum water levels in May through August, and minimum levels in March through April.
5. Ground water level trends from 2007 to 2011 were flat to slightly declining.
6. Ground water levels rose in 2011 and remained at higher-than-normal levels in 2012 due to large snowpacks in 2011 and 2012. Ground water levels returned to normal in 2013 and 2014.
7. Most wells only had increases in their maximum water levels of a couple feet in 2011. However, the maximum water level in Well #23, which is 0.25 miles west of Hayden Lake, rose 28 feet. The water level Well #23 was also much higher than normal in 2012.
8. Water level elevations are much higher in the wells near Hayden Lake and Coeur d'Alene Lake than they are in wells further away from these surface waters. This pattern is probably caused by recharge pathways that are at different elevations and are not hydraulically connected.
9. Ground water temperatures varied with depth, and from well to well.
10. The water temperature profiles from two wells west of Hayden Lake were used to calculate a ground velocity between the wells of 35 feet per day.
11. Water temperature profiles in two wells near the Spokane River and Coeur d'Alene Lake also indicate that there are at least two hydraulically-separate recharge pathways at different elevations.
12. Additional information is needed to determine the flux from Hayden Lake and Coeur d'Alene Lake into the aquifer during different times of the year. This may require expansion of the current monitoring network through more wells and enhanced monitoring in the existing wells.

Detailed Analyses

The Idaho Department of Water Resources (IDWR) has a ground water level and ground water temperature monitoring program for the Rathdrum Prairie aquifer that currently consists of 30 wells. The Coeur d'Alene Subarea, which is one of five subareas for the aquifer, is located in the southeastern part of the Rathdrum Prairie aquifer. There are nine monitoring wells in the Coeur d'Alene subarea. Four monitoring wells are located near Coeur d'Alene Lake, two wells are located near the Spokane River about 1.5 miles northwest of the lake's outlet, one well is located next to Hayden Lake, and two wells are located in the interior of the Rathdrum Prairie at distances over 1.5 miles from any surface water. Figure 1 shows the location of the nine wells and Table 1 provides the attributes of each well.

The aquifer is recharged by Coeur d'Alene Lake, Hayden Lake, and the Spokane River from the Coeur d'Alene Lake outlet to the Idaho state line. The lakes and the monitoring wells have similarities in water level hydrographs; ie, the maximum water level in the aquifer occurs when the lake levels are at their highest, and vice versa. The Hayden Lake area, the Spokane River area, and the Coeur d'Alene Lake Outlet area are discussed in separate sections because of unique hydrologic conditions in each area.

Hayden Lake Area

The Spokane Valley Rathdrum Prairie Aquifer Atlas (2015) attributes the recharge from Hayden Lake to be 45 million gallons per day, which is the second largest recharge rate of the nine lakes surrounding the Rathdrum Prairie aquifer (Coeur d'Alene Lake is first). Water from Hayden Lake spills over the levee on the western end when the lake level is high enough. The spill is uncontrolled and currently unmeasured. The spilled water infiltrates into the ground immediately west of the lake. The USGS monitors the water level in Hayden Lake with a staff gauge that is read monthly. Hayden Lake water levels range from about 2235 feet Above Sea Level (ft ASL) to about 2240 ft ASL, with the minimum values occurring in November through February and the maximum values occurring in April and May.

Well #23 is located about ½ mile west of Hayden Lake, and Well #22 is located about 2.5 miles west of Well #23 (Figure 1). The maximum water level in Well #23 decreased about 15 feet in 2010, and then rose over 28 feet in 2011 (Figure 2). The maximum ground water levels in this well are directly related to the duration of spill from Hayden Lake. In 2010, there was no spill; in 2011, spill occurred for almost six months, which is about twice as long as normal. The spill in 2012 was also longer than normal which resulted in higher-than-normal ground water levels in Well #23 again.

A relationship also exists between the water levels in Hayden Lake and in Well #22. The maximum ground water level in Well #22 in 2010 was about three feet lower than in 2009. The maximum ground water level rose about 12 feet in 2011, and rose another foot in 2012. The maximum ground water has declined since then but as of 2014, the level was still about 3.5 feet higher than it was in 2009. The water level responses in Wells #22 and #23 to the changes in discharge from Hayden Lake indicate that the aquifer is able to easily receive the extra water spilled from Hayden Lake, which is then dispersed quickly to the west. The ground water gradients between Wells #22 and #23 varied in the four year time period from 2009 to 2012. The biggest changes were in 2010 when the gradient decreased about 15% from 2009, and in 2011 when it increased almost 30% from 2010. Lower-than-normal ground water levels in 2010 in Well #23 were followed by a ground mound in 2011. This mound spread out so rapidly that it was gone by 2013, as indicated by the maximum water levels in Well #23, and by the gradient between Wells #22 and #23 which returned to the gradient of 2009.

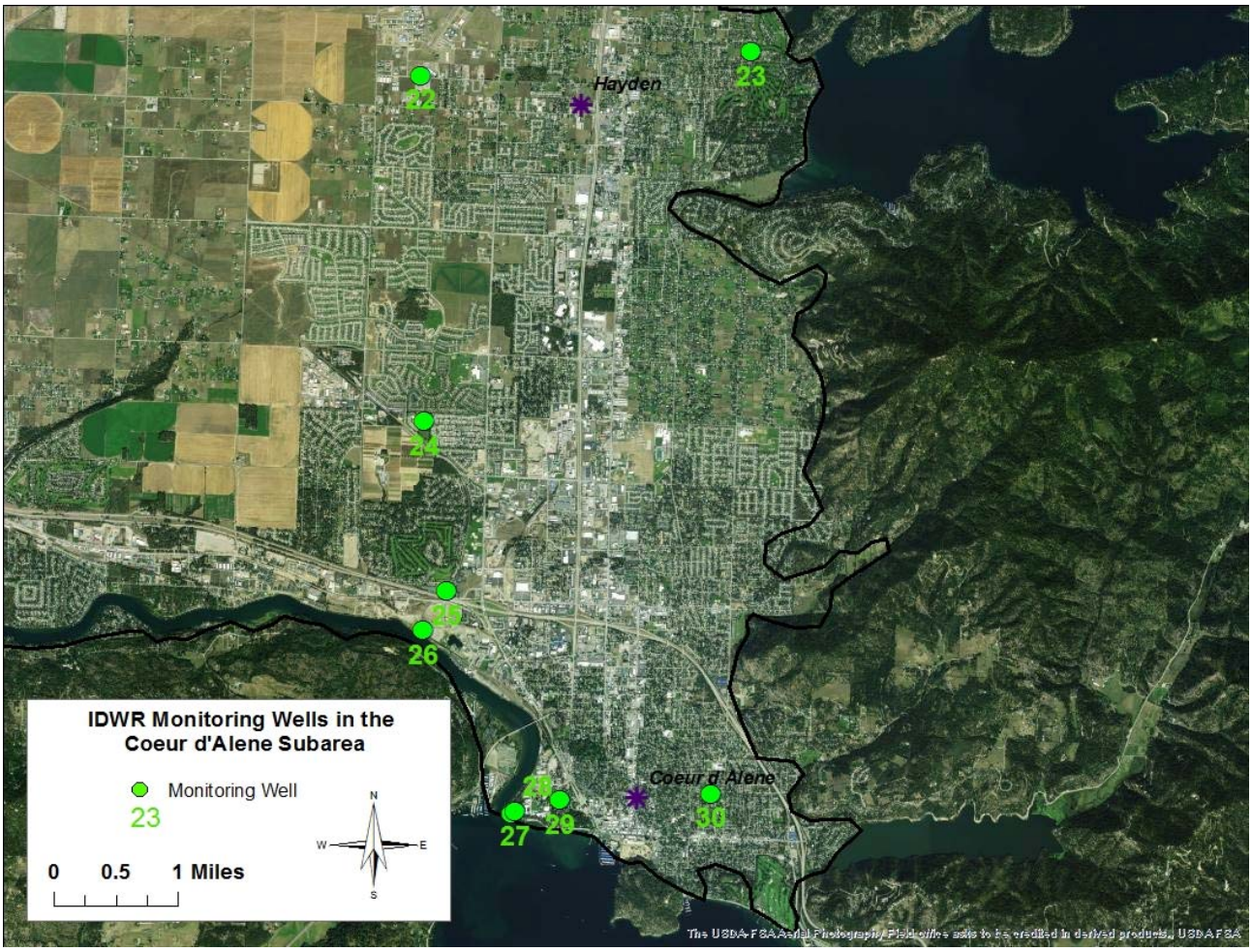

Figure 1. Location of IDWR's nine monitoring wells in the Coeur d'Alene Subarea.

Table 1. List of the Coeur d'Alene monitoring wells.

Well Number	Station Name Common Name	Year Drilled	Well Depth (feet)	Open Interval[1] (feet from top of casing)	Open Interval (feet above Sea Level)	Water Level Elevation[2]	Height of water column (ft)[3]	Period of Monitoring Data
22	51N 04W 15CAC1 CDA Airport	1972	343	323-333 (S)	1976-1966	2015	65	06/2008-current
23	51N 03W 18BCC1 Avondale Golf	1994	310	272-297 (S)	2022-1997	2070	93[4]	05/2008-current
24	51N 04W 34CAA1 Woodland School	2013	264	224-264 (S)	2036-1996	2021	25	10/2013-current
25	50N 04W 03DCD1 Prairie Trail	2010	176	165-170 (S)	2016-2011	2063	60	03/2011-current
26	50N 04W 10ACB1 Centennial Trail	2010	120	115-120 (S)	2027-2022	2056	40	03/2011-current
27	50N 04W 14CDB1 NIC Beachside	1992	24	19-24 (S)	2117-2112	2119	13	07/2009-current
28	50N 04W 14CDB2 NIC Dikeside	1992	34	26-31 (S)	2109-2104	2120	16	04/2010-current
29	50N 04W 14DBA1 Fort Grounds	2007	88	60-70 (S)	2054-2064	2080	34	07/2007-current
30	50N 04W 13DAA1 Pearson's Field	2003	458	245-255 (P) 345-355 (P)	1940-1930 1840-1830	2068	338	09/2006-current

[1] P = Perforations; O = Open Hole; S = Screen. [2] Based on average annual water level. [3] Based on maximum water level. [4] Based on maximum water level, exclusive of 2011 and 2012.

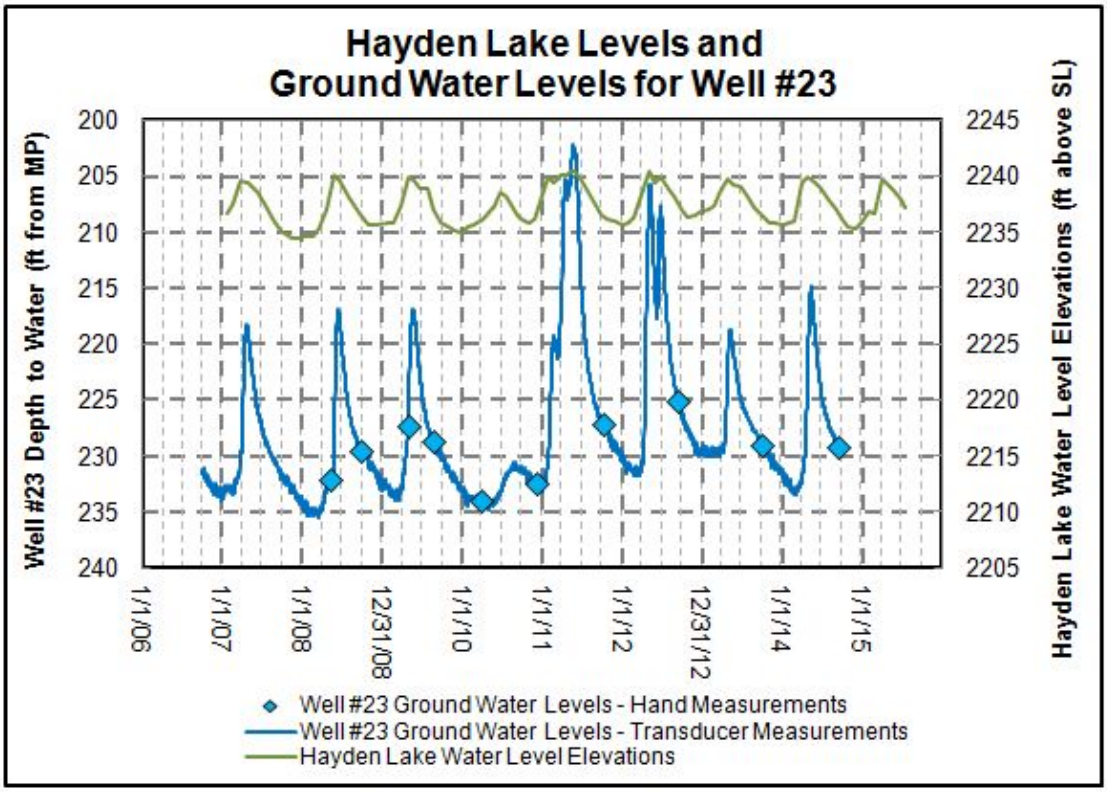

Figure 2. Hayden Lake water levels and ground water levels for IDWR Monitoring Well #23.

The water level gradient between Well #22 and Well #23 is much higher than the water level gradients throughout much of the Rathdrum Prairie aquifer. For example, the gradient between Wells #22 and #23 is 22 feet per mile (ft/mi), while the gradient from Well #22 to Well #21 (which is 6 miles to the southwest) is 1.2 ft/mi.

The water temperature data for Wells #22 and #23 are also very useful for understanding the hydrologic relationships. Changes in the temperature profile in Well #23 in 2010 correlate directly with changes in water levels in Hayden Lake and in Well #23. Water temperatures in Well #23 rose significantly in early 2011 which coincides with the large pulse of recharge water from Hayden Lake. The temperatures stayed above normal in 2012 which was also an above average year for spill from Hayden Lake. Water temperatures declined from 2012 to 2013; then rose again in 2014. Well #22 also exhibited a change in the water temperature profile. However, the change was much less than in Well #23. Water temperatures in Well #22 were essentially flat from 2008 to mid 2011, and they were six to seven degrees warmer than the temperatures in Well #23. In mid 2011, temperatures in Well #22 began increasing and continued to rise for the next 10 months until peaking in June 2012 with a reading that was about 0.5° F higher than in mid 2011. Based on comparing the maximum water temperature in Well #23 in 2011 to the maximum temperature in Well #22 in 2012, it appears that the temperature signature took about one year to travel from Well #23 to Well #22. The temperature travel time over the distance between the wells equates to an average velocity of about 35 feet per day, which is in line with Drost and Seitz (1977), who reported that ground water velocities in the Rathdrum Prairie aquifer can exceed 60 feet per day.

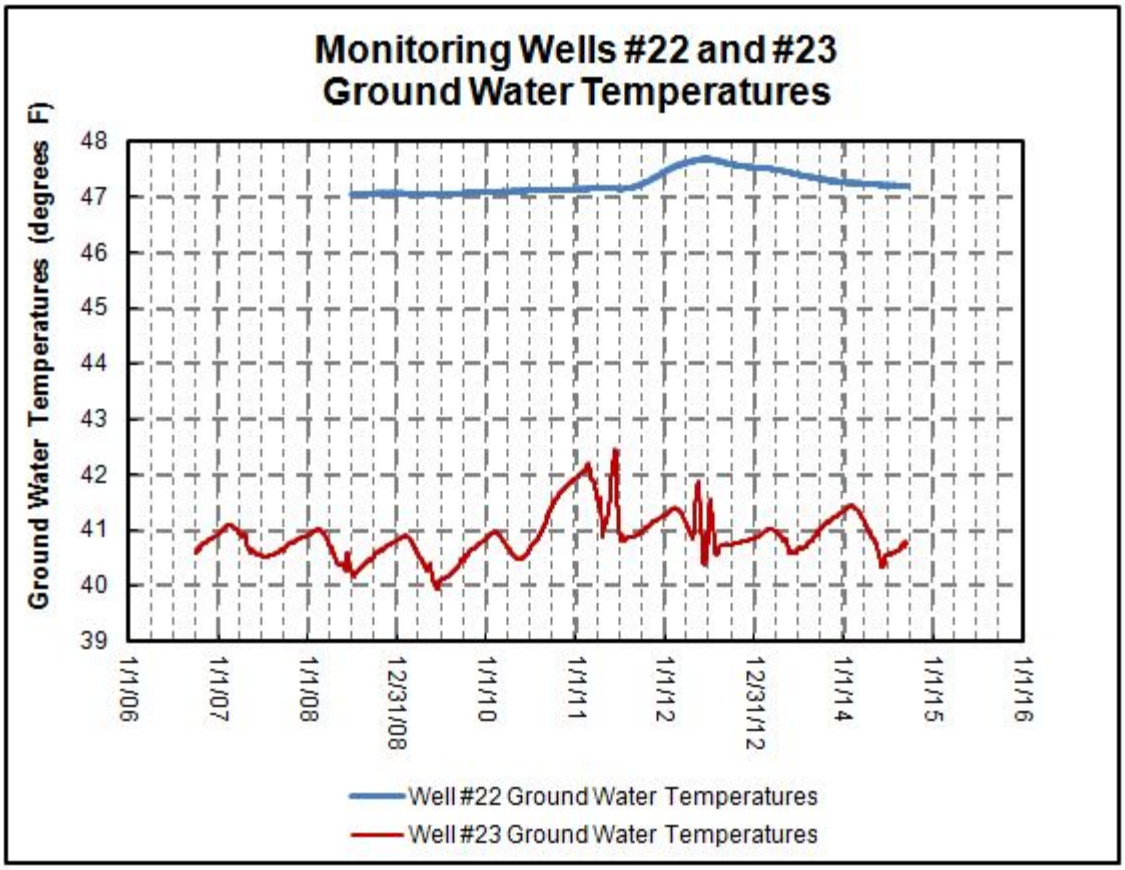

Figure 3. Ground water temperatures for Wells #22 and #23.

<u>Spokane River Area northwest of Coeur d'Alene</u>

Wells #25 and #26 are in the Spokane River Area which is about 1.5 miles northwest of the Coeur d'Alene Lake outlet (Figure 1). Well #25 is about 2200 feet north of the Spokane River; Well #26 is only about 200 feet from the river. Although the wells are only 2000 feet apart, their water level and water temperature profiles are very different.

The hydrographs for Well #25 and Well #29 (which is two miles to the southeast of Well #25) are very similar to each other and to the hydrograph for Coeur d'Alene Lake (Figure 4). The water level gradient from Well #29 to Well #25 is about 8 ft/mi.

The hydrograph for Well #26 is different than the hydrographs for Wells #25 and #29 on five accounts. First, the maximum water level for Well #26 occurs about one to three months before the maximum in Well #25. Second, the water level profile for Well #26, with its double maximum peaks in 2011 and 2012, is significantly different than the profile for Well #25. Third, water level elevations in Well #26 are lower than the elevations in Well #25, despite Well #26 being closer to the river. Fourth, water level cycles in Well #26 appear to lag the cycles for the Spokane River by about six months. Fifth, Well #26 has a tan and orange clay layer from 66 to 76 feet which is atypical of most wells in the area. These unique observations suggest that the clay layer delays the movement of recharge water from the Spokane River downward to the aquifer which was penetrated by Well #26 at 80 feet.

The large range of water temperatures for Well #26 also supports the hypothesis that the well is recharged by the Spokane River (Figure 5). Similar large ranges occur in Wells #27 and #28 to the southeast, which are very close to Coeur d'Alene Lake. However, the profile for Well #26 suggests that it takes some amount of time for the water to reach the aquifer. For example, the temperature range in Well #26 is 20° F less than the ranges in Wells #27 and #28. The water movement from the Spokane River to the aquifer encountered in Well #26 at 80 feet from the land surface must be impeded such that the temperatures are able to partially equilibrate with the ambient earth temperature. Also, it appears that there is an offset of about six months between the temperatures in the river and the temperatures in the well. The highest discharge in the river occurs from March through June. The water in the river in this time period would be the result of the previous winter's runoff, which would have the lowest annual water temperatures. However, the lowest water temperatures in Well #26 don't occur annually until September (Figure 5).

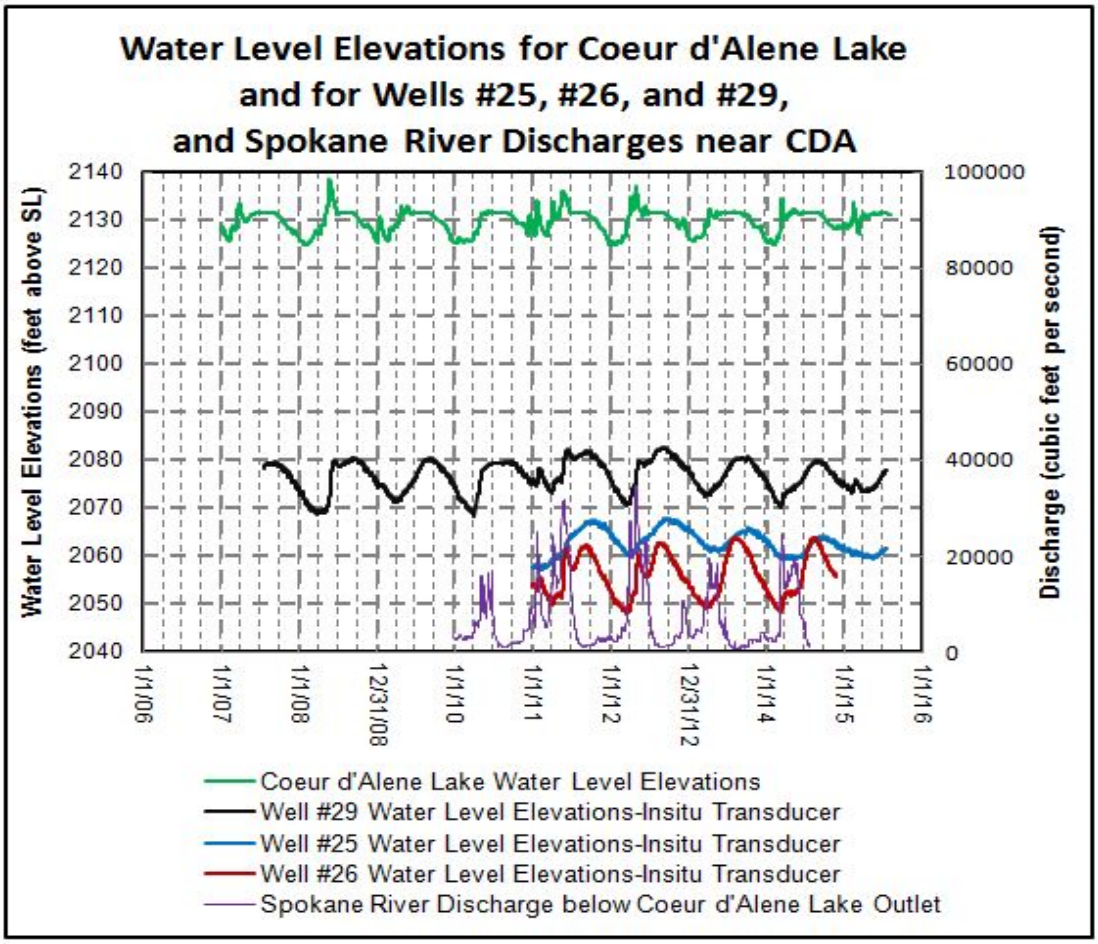

Figure 4. Ground water levels for Monitoring Wells #25, #26, and #29, and discharges for the Spokane River below the Coeur d'Alene Lake outlet.

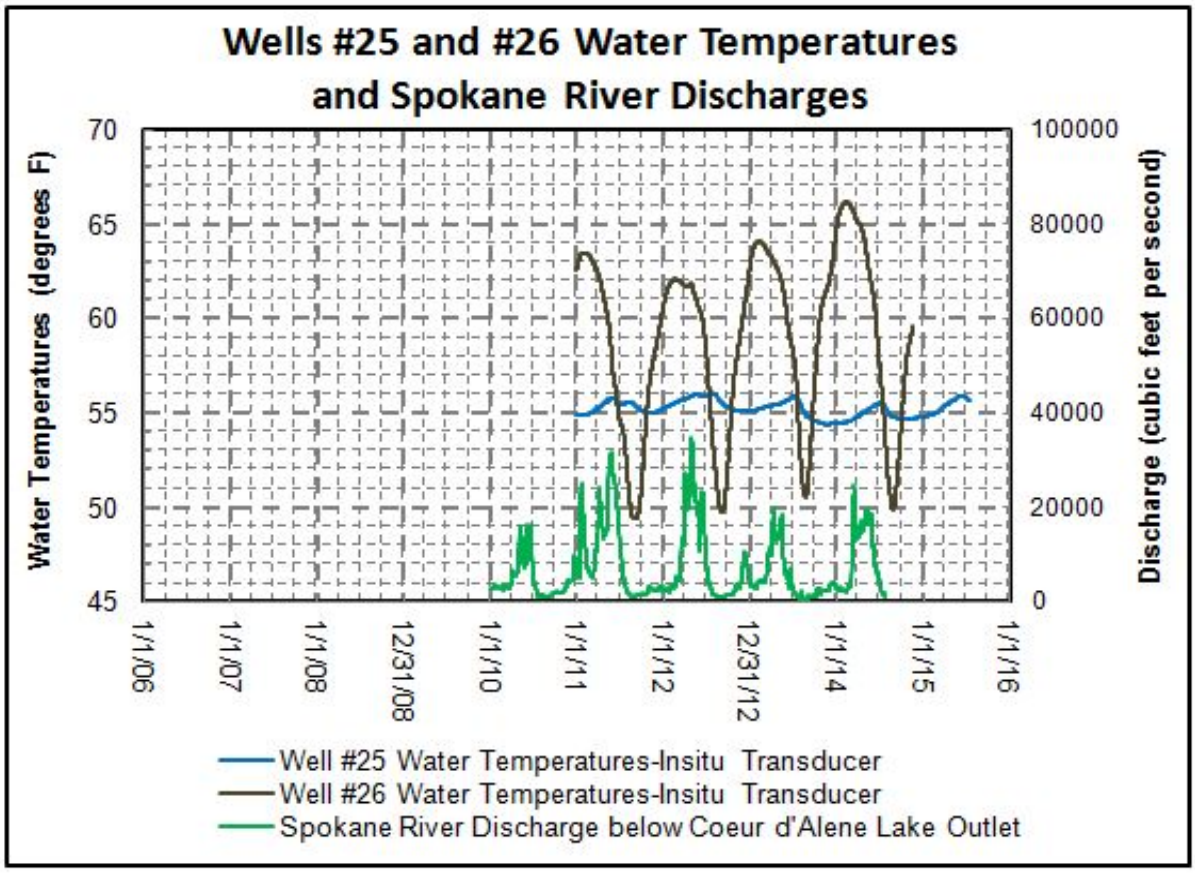

Figure 5. Ground water temperatures for Monitoring Wells #25 and #26, and discharges for the Spokane River below the Coeur d'Alene Lake outlet.

Coeur d'Alene Lake Outlet Area

Wells #27 through #30 are in the Coeur d'Alene Lake Outlet area. Coeur d'Alene Lake has spring and summer water level elevations typically at about 2132 ft ASL, and fall and winter water levels at about 2125 ft ASL. In 2011 and 2012, the spring water level elevations for Coeur d'Alene Lake were higher than 2132 ft ASL for a significant time period because of higher-than-normal snowpack and runoff. All four monitoring wells had water level changes in 2011 and 2012 that trended with the lake with the maximum water levels being higher in those two years than they were before 2011 (Figure 6). Ground water levels were back to normal in 2013 and 2014.

Wells #27 and #28 are only 100 feet and 225 feet from Coeur d'Alene Lake, respectively. Maximum water levels in these two wells are generally only 7 to 12 feet lower than the summer lake levels. The differences between the water levels in the lake and these wells were less in 2011 and 2012 when the lake levels and ground water levels were higher than normal. In 2011, the maximum water level elevation in Well #27 was about 6 feet lower than the lake, and the level in Well #28 was 10 feet lower than the lake. By September, the difference between the elevations in the lake and the wells was 10 feet for Well #27 and 12.8 feet for Well #28. These observations suggest that recharge from the lake peaks in May or June, and is less in late summer and early fall. The observations also suggest that higher lake levels, such as in 2011 and 2012, probably result in more recharge to the aquifer as evident by the smaller differences between lake levels and well water levels (compared to 2010 and 2013).

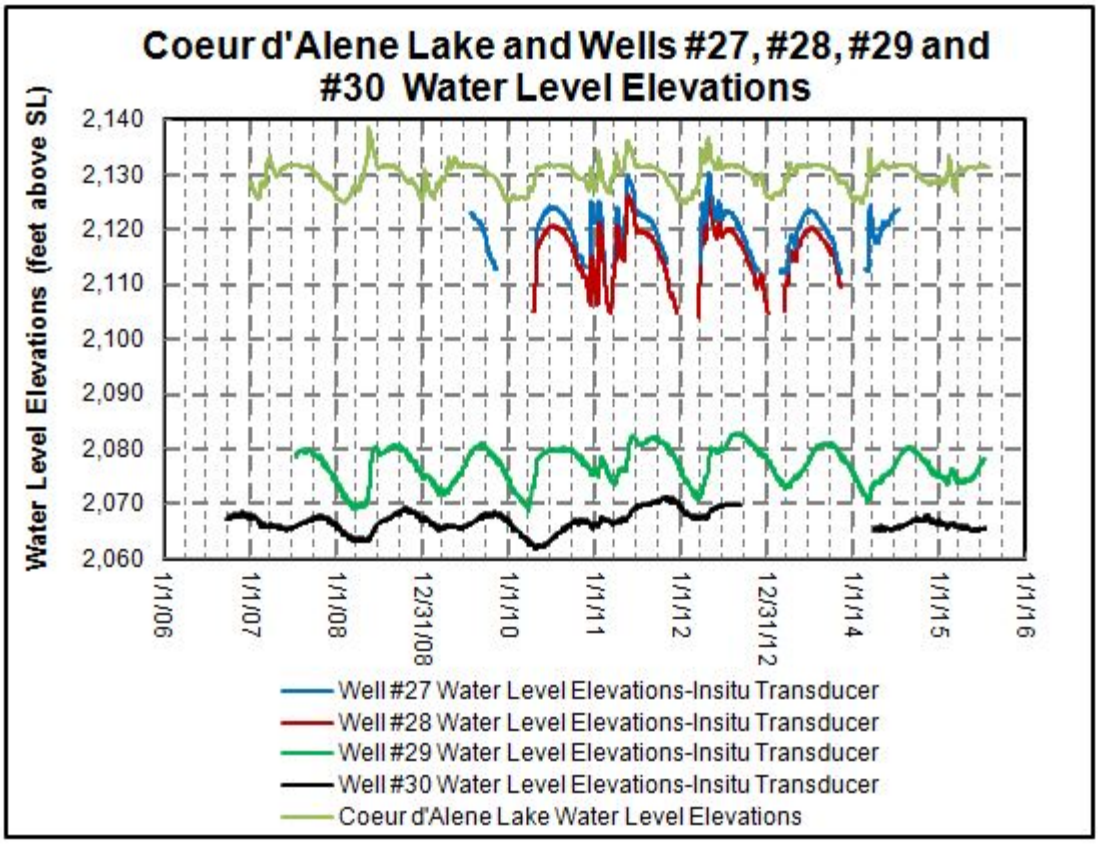

Figure 6. Ground water levels for Monitoring Wells #27 through #30, and for Coeur d'Alene Lake.

Well #29 is 0.25 miles from Coeur d'Alene Lake, and 0.4 miles northeast of Wells #27 and #28. The maximum water level elevation for Well #29 in June 2011 was 43.8 feet lower than the maximum level in Well #28, which occurred in May. This difference equates to a gradient between the two wells of about 110 feet per mile. The gradient from the lake to Well #29 is 203 feet per mile based on the 2011 maximum water levels. These gradients are unreasonably high. The lake is about 80 feet deep near the outlet. It is believed that there are at least two recharge pathways at different elevations by which the lake recharges the aquifer. This would explain why the water level elevations for Well #29 are much less than the water level elevations for Well #28. The water temperature data support this hypothesis. The maximum water temperature for Well #29 is about 10 °F cooler than Well #28 (Figure 7). Also, the water temperature in Well #29 has a range of less than 10 °F, while the range for Well #28 is about 30 °F (Figure 5). These observations indicate that the water in Well #29 originates from a deeper source than the water in Well #29.

Ground water velocities from the lake to Well #29 were calculated based on the differences in the timing of the maximum water levels in 2011. The maximum lake level occurred on May 25, 2011 and the maximum water level in Well #29 occurred on June 14, 2011, a difference of 21 days. Thus, the ground water velocity from the lake to Well #29 was 81 ft/day.

Well #30 is about 1.25 miles east of Well #29. In general, Well #30 has a similar water level hydrograph as Well #29, but the magnitudes of the changes from the maximum to minimum levels are about half as much as Well #29 (Figure 6). Three interesting observations indicate that there are different recharge sources for Wells #29 and #30. First, the water level elevation is 12 feet higher in Well #29 than in Well

#30 (Table 1). Second, the maximum water level was two feet higher in 2011 than in 2010 for Well #29, but four feet higher in Well #30. Third, the water temperature for Well #30 is cooler than Well #29, and the profile shows no distinguishable annual cycles, where as Well #29 has distinct cycles (Figure 7). The current hypothesis is that Well #29 is recharged from Coeur d'Alene Lake to the south while Well #30 is recharged from Fernan Lake to the east.

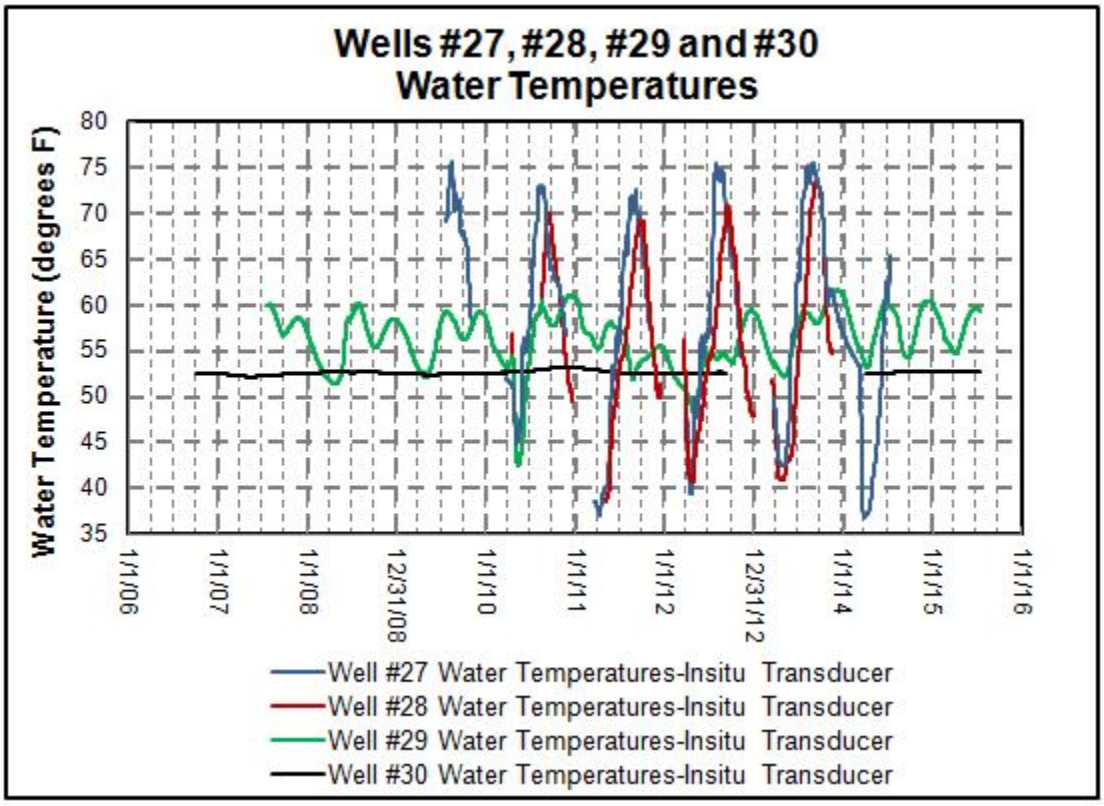

Figure 7. Ground water temperatures for Monitoring Wells #27 through #30.

There are a couple other water temperature observations that are interesting. Water temperatures in Well #27 are consistently warmer than in Well #28 as the water temperatures rise in the spring and summer. Water temperatures rise faster in Well #27 until the maximum temperatures are reached. This creates a significant difference in the timing of the temperature peaks in the two wells. For example, the maximum water temperature in Well #27 in 2010 occurred on August 8, while the maximum water temperature in Well #28 occurred on September 1. This equates to a ground water velocity of only 4 ft/day, which is unusually low for the aquifer.

Minimum water temperatures in Well #29 were about 11°F lower in 2010 than in 2009 (Figure 7). This minimum follows a period of low water elevations in Coeur d'Alene Lake in early 2010 that was longer than previous years. A similar response occurred in this well in early 2012 following a time of lower-than-normal water levels in the lake. The reason for this relationship is unknown. Another unique observation is that Well #29 has double peaks in the maximum values for most years. These peaks occurred in July and December. This pattern did not occur in any other monitoring well.

Nimmer and Ralston (2008) examined temperature signatures in the Coeur d'Alene Lake Outlet Area by analyzing Wells #27 and #28, in conjunction with data from five monitoring wells on Blackwell Island to

the west, and water level and temperature data from Coeur d'Alene Lake. They recognized that the lake's lowest water level in 2007 occurred at the same time that the surface water temperature was at its lowest value (about 33° F). However, the maximum water level and maximum water temperature were offset by about four months (the maximum water level was in April; the maximum water temperature was in August). The results from Nimmer and Ralston (2008) initiated the idea that water temperatures may be useful as a tracer for analyzing surface water and ground water relationships. However, the temperature data from Nimmer and Ralston (2008), and the data from the IDWR monitoring wells, are highly variable, and the relationships between water level elevations, water temperatures and flux from the lake to the aquifer are not yet understood.

Conclusions

The observations show that the hydrogeology in the Coeur d'Alene subarea is complex. Recharge to the aquifer comes from at least three sources: Hayden Lake, Coeur d'Alene Lake, and the Spokane River. Recharge also probably comes from Fernan Lake. Varying water level elevations indicate that there are multiple recharge pathways, most notably in the Coeur d'Alene Lake outlet area. Differences in water temperature profiles indicate that recharge occurs rapidly in some places, and is delayed by stratigraphic constraints in other places. Water temperature profiles have been used to calculate ground water velocities in the Hayden Lake and Coeur d'Alene areas.

Future Plans

1. Continue to monitor all nine wells.
2. Replace the PVC tubing in Well #24 with black poly pipe having a nominal diameter of 1.25 inches. This work will require a pump rig and will cost about $1500.
3. Add two temperature transducers in Well #30 at depths of 250 feet and 350 feet.
4. Establish gages at Hayden Lake for measuring inflow and outflow.

References

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