Little Spokane Groundwater Elevation & Stream Flow Monitoring Project

Technical Memorandum – 2011 Project Update

June 30, 2011

Prepared for:
WRIA 55/57 Watershed
Implementation Team

Prepared by:
Spokane County
Water Resources

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TO: **WRIA 55/57 WIT**

FROM: **SPOKANE COUNTY WATER RESOURCES**

SUBJECT: **LITTLE SPOKANE GROUND WATER MONITORING PROJECT 2011 UPDATE**

DATE: **JUNE 30, 2011**

SPOKANE COUNTY
WATER RESOURCES

TECHNICAL MEMORANDUM

Introduction

This technical memorandum describes the work completed and presents data collected for the Little Spokane Ground Water Elevation and Stream Flow Monitoring Project (project) between June 30, 2010 and June 30, 2011. The project is Task 14 of the Water Resource Inventory Area (WRIA) 55-57 Phase 4 Implementation project funded by Washington Department of Ecology (Ecology) Grant G0700149.

The project began on June 30, 2009. The *Little Spokane Ground Water Elevation & Steam Flow Monitoring Project Report* issued on June 30, 2010 describes the selection of monitoring locations and data collection procedures. The work completed between June 30, 2010 and June 30, 2011 includes the following:

- Collection of survey data for wellheads and the base of the river channel adjacent to each well at 5 locations;
- Collection of continuous ground water elevation data at 8 wells;
- Collection of discharge measurements that can be used to estimate the change in river flow for 8 reaches of the Little Spokane River (seepage run).

Figure 1 shows the project location, well monitoring sites, seepage run discharge measurement sites, seepage run river reaches and elevation cross section locations.

Survey Data Collection

Survey data of the wellhead elevation for the following wells was collected:

- Whitworth Water District #2 Rivilla Well
- Spokane County Water District #3 Pine River Park Well
- Whitworth Water District #2 Shady Slope Well
- Spokane County Colbert Landfill North Glen Well
- Spokane County Water District #3 River Estates Well

In addition to the well head elevation, the elevation of the base of the river channel adjacent to each well was collected at three sites (Rivilla, Pine River, River Estates). At the other two locations (Shady Slope, North Glen) the Little Spokane River adjacent to the well at each location was not accessible so alternate locations were surveyed. At the Shady Slope location the elevation of the base of the Little Deep Creek channel was collected, and at the North Glen location the elevation at a bridge 1400 feet upstream of the well location was collected. The elevation of the base of the Little Spokane River channel adjacent to each well in these two locations was estimated based on the elevation data collected and available topographic data. Ideally a stilling well with a data logger would be installed at each site so that the elevation of the river surface could be measured instead of the base of the river channel. Due to budget constraints this was not done.

The purpose of collecting this data was to assess the relationship between ground water elevation data collected at each well and the Little Spokane River elevation. Figures 7 through 11 show an elevation cross section of each location. Table 1 presents the elevation data for each location. Figure 1 shows all survey locations, and Figures 2 through 6 show a detail of each location. The elevation data was collected by Spokane County Engineering and Roads survey staff using survey grade GPS with a vertical accuracy of 0.01 feet.

Table 1-Survey Data

Location	Elevation	Latitude	Longitude
Rivilla Well	1585.444	47ø46'56.45392"N	117ø25'00.63458"W
River Survey Location 1	1576.456	47ø46'56.57804"N	117ø25'00.77459"W
Pine River Park Well	1619.105	47ø47'27.99398"N	117ø23'35.04450"W
River Survey Location 2	1604.253	47ø47'30.76944"N	117ø23'35.73886"W
Shady Slope Well	1638.891	47ø47'45.61923"N	117ø22'38.25855"W
River Survey Location 3	1629.487	47ø47'49.81281"N	117ø22'42.02994"W
North Glen Well	1675.985	47ø51'23.40671"N	117ø21'47.62950"W
River Survey Location 4	1661.374	47ø51'38.46233"N	117ø21'53.73103"W
River Estates Well	1721.887	47ø54'57.59965"N	117ø20'21.26315"W
River Survey Location 5	1697.085	47ø54'56.00677"N	117ø20'10.31856"W

Ground Water Elevation Data

Ground water elevation and temperature data has been collected from September 2009 to the present at eight wells for this project. The well locations are shown in Figure 1. The data is collected on an hourly basis. At the Rivilla, Mt. View and Pine River Park wells conductivity is collected in addition to ground water elevation and temperature. Figures 12 through 22 present the data for each well. The data is also provided in an Excel spreadsheet on the accompanying CD.

Little Spokane River Seepage Run Data

A seepage run consists of making multiple stream flow measurements at various points along the river within a short period of time to determine where the river is gaining or losing water. The seepage run portion of this project was completed by the Spokane Conservation District. Their complete report is provided in Appendix A. The following is a summary of the data collected.

Stream flow discharge measurements were completed on September 30, 2010 at the locations shown in Figure 23. Table 2 presents the discharge data and Table 3 presents the stream flow gains and losses for each river reach.

Table 2-Little Spokane Seepage Run Discharge Measurements

Site	Site Name	2009 Discharge (cfs)	2010 Discharge (cfs)
20	Little Spokane River at Scotia Road	23.6	22.3
19	USGS Elk gage – rated discharge	47.0	40.0
18	Dry Creek at mouth	1.72	1.65
-	Outlet Reflection Lake	5.26	6.15
17	Otter Creek at mouth	6.89	5.72
15	Little Spokane River upstream of West Branch	54.7	54.8
16	West Branch Little Spokane River at mouth	11.5	11.0
14	Little Spokane River at Milan	58.4	59.1
13	Little Spokane River upstream of Bear Creek	69.2	65.6
12	Bear Creek at mouth	3.00	3.12
11	SCC Chattaroy gage – rated discharge	76.0	69.0
10	Deer Creek at mouth	0.767	1.13
9	Dragoon Creek at mouth	20.0	18.7
8	Little Spokane River downstream of Dragoon Creek	99.8	102
0	Colbert landfill discharge	0.890	1.26
7	Little Spokane River upstream of Deadman Creek	114	110
6	Deadman Creek at mouth	9.22	8.25
5	USGS Dartford gage – rated discharge	132	125

Table 3: Little Spokane River Gains and Losses 2009 and 2010

Reach ID	Reach Description	Reach Length (miles)	Change in Flow due to Ground Water Interactions (Δ cfs)		Change in Flow per mile (cfs/mile)	
			2009	2010	2009	2010
1	Scotia to Elk	9.3	23	18	2.5	1.9
2	Elk to West Branch	4.4	-6.2	1.3	-1.4	0.30
3	West Branch to Milan	1.4	-7.8	-6.7	-5.6	-4.8
4	Milan to Bear Creek	2.1	11	6.5	5.1	3.1
5	Bear Creek to Chattaroy	6.6	3.8	0.30	0.58	0.05
6	Chattaroy to Colbert	3.7	3.1	11.9	0.84	3.22
7	Colbert to Deadman Creek	5.9	13	8.0	2.2	1.4
8	Deadman Creek to Dartford	2.4	8.8	6.7	3.7	2.8

Discussion of Results

The primary purpose of this monitoring effort is to collect data that will improve the understanding of the interaction of ground water with the Little Spokane River. The data can be analyzed in several ways to further that understanding including:

- A comparison of ground and surface water elevations;
- A comparison of changes in river stage to changes in groundwater elevation;
- Evaluation of ground water temperature changes; and
- Evaluation of changes in river flow in sections, or reaches, of the river.

The difference between ground water elevation and surface water elevation in a particular location can be used to determine the hydraulic gradient between the two points and provide information on whether ground water is flowing into the surface water body or surface water is flowing into ground water.

If a gradient does exist this only represents the potential for flow between ground and surface water. In some instances the ground water that is measured is from a confined aquifer and the water level is the potentiometric water surface and a pathway between ground and surface water may not exist. Therefore an understanding of the local geology is necessary in addition to the hydraulic gradient to understand the exchange between surface and ground water.

A comparison of changes in ground water elevation and changes in river stage can also show a connection of surface water to ground water. If ground water elevation changes track closely with river stage changes there is a high degree of connection between the ground and surface water. This does not necessarily indicate that there is flow between the ground and surface water. When the river stage changes there is a change in pressure, or pressure wave, that propagates through the ground water. This pressure wave can be a standing wave which means the water moves vertically but not horizontally. The USGS has documented this pressure wave propagation in both hydraulic gradient conditions, toward and away from the river (USGS Scientific Investigations Report 2011-5026).

Evaluation of temperature changes in ground water can also show a relationship between ground and surface water. Surface water temperatures have a seasonal pattern; low temperatures in late December or early January and high temperatures during mid to late August. Ground water that is not in close proximity to surface water and/or at greater depths does not generally show a seasonal pattern. Therefore if ground water does show a seasonal pattern it is often caused by influences from surface water.

Seepage runs are a measurement of the change in river flow between two points taking into account any surface inflow or outflow (i.e. tributary streams) between the two points. The change in river flow is attributed to gains or losses from the river to ground water.

These four analysis tools can be used in combination to further understanding of surface and ground water interaction in the areas that are included in this monitoring program. The following is a discussion of each of the monitoring locations.

Whitworth Water District #2 Rivilla Well –

The geologic setting of this well is a small area of alluvial deposits comprised of sands and gravels approximately ½ mile wide and ½ mile in length between hills comprised of granitic formations.

Groundwater at this site ranged from 1.2 and 4.37 feet above the base of the river channel between September 2009 and June 2011. The range of river depth, which must be added to the elevation of the base of the river channel to determine hydraulic gradient, is within 1.2 and 4.37 feet. Therefore, the gradient between ground and surface water at this location is essentially flat. This is also evident from the elevation cross section shown in Figure 7.

Figure 24 shows a comparison of changes in ground water elevation and changes in river surface elevation at the Dartford gage. Changes in ground water elevation track closely with changes in river surface elevation which indicates that pressure changes caused by changes in river elevation propagate through ground water quickly.

Temperature changes in ground water at this well show a seasonal pattern with the yearly maximum occurring in late August/early September, and the yearly minimum occurring in late January/early February. This is similar to the seasonal temperature pattern of the river which indicates that surface water is flowing into ground water at this location and reaching the well within a short time period.

Spokane County Water District #3 Pine River Park Well –

The geologic setting of this well is alluvial deposits with between 20 and 70 feet of sands and gravels on top of a layer of clay that ranges between 10 and 100 feet thick. Below the clay layer there is another layer of sands and gravels on top of granitic bedrock. The Pine River Park well is completed in the lower sand and gravel layer. The primary aquifer in this area is located in the lower sand and gravel layer; and the ground water elevation measured at this location is a potentiometric water surface, thus this is a confined aquifer. One of six wells in the area indicates water was encountered above the clay layer.

Groundwater at this site ranged from 0 and 20 feet below the base of the river channel between September 2009 and March 2011. This indicates that during this period the gradient is from river to ground water. During spring of 2011 the ground water elevation did extend above the base of the river channel. Between March 2011 and June 2011 the ground water elevation ranged between 0 and 3.22 feet above the base of the river channel. The range of river depth, which must be added to the elevation of the base of the river channel to determine hydraulic gradient, was likely greater than 3.22 feet during the period March 2011 and June 2011. Therefore, the gradient between ground and surface water at this location is from the river toward ground water. This is also evident from the elevation cross section shown in Figure 8.

Figure 25 shows a comparison of changes in ground water elevation and changes in river surface elevation at the Dartford gage. The ground water elevation in this well shows a pronounced seasonal trend. This well is a monitoring well and is located in close proximity to a Spokane County Water District #3 production well. During the summer months there is a drawdown of approximately 15 feet. The well appears to fully recover from the summer draw down by the following February. There are small changes in river surface elevation that correlate with changes in ground water elevation. Those changes, though, are relatively small in comparison to the seasonal trend. During the period March to June 2011 when the ground water elevation is at it highest point during the study period the correlation between ground water and surface water elevation is much stronger. Temperature changes during the study period are relatively minor and show no apparent trend, except that the lowest temperatures occurred between March and June 2011.

This site location is within river reach 8 of the seepage run. Data from 2009 and 2010 indicate that the river gains from ground water within this reach. In 2009 it gained 8.8 cfs and in 2010 it gained 6.7 cfs. This seepage run data is in contrast to the hydraulic gradient at the time of the seepage runs, which was from the river toward groundwater.

A pathway between the lower sand and gravel aquifer and the river does not appear to exist. The contradiction between the seepage run and hydraulic gradient data and the relatively constant ground water temperature support that conclusion. It does appear that pressure changes due to changes in river stage do propagate into the lower sand and gravel confined aquifer to some degree. It also appears that during periods of high river flows propagation of pressure changes is much more pronounced.

It is not known if upstream of this location the lower sand and gravel aquifer connects to ground water that is in connection with the river. The propagation of pressure changes due to changes in river stage suggests that this may be the case. Also, the source of the apparent ground water contributions to the river in river reach 8 is not known.

Whitworth Water District #2 Shady Slope Well –

The Shady Slope well is approximately 1 mile upstream of the Pine River Park well. The geologic setting is similar except the clay layer between the upper and lower sand and gravel layers is only 13 feet thick in contrast to the 100 foot thick clay layer in the Pine River Park well. The Shady slope well is completed in the lower sand and gravel confined aquifer and the measured water level is the potentiometric surface of that aquifer. The Shady Slope well is 1500 feet from the river while the Pine River Park well is only 500 feet from the river.

Ground water at this site ranged from 1 to 20 feet below the base of the river channel between September 2009 and June 2011. Therefore, the gradient between the ground water in the aquifer represented by the Shady Slope well and surface water at this location is from the river toward ground water. This is also evident from the elevation cross section shown in Figure 9.

Temperature changes in ground water at the Shady Slope well show a pattern over the study period. There is a range of 3 degrees Celsius with maximum temperatures occurring in January/February and minimums occurring in April/May. This is in contrast to the temperature pattern of the river where maximums occur in August/September and minimums occur in December/January. This indicates that surface water is potentially recharging the ground water and there is an approximate travel time of 4 months from the location where the surface water enters ground water and the Shady Slope well.

The Shady Slope well is within river reach 8 of the seepage run, the same reach as the Pine River Park well. Data from 2009 and 2010 indicate that the river gains from ground water within this reach. In 2009 it gained 8.8 cfs and in 2010 in gained 6.7 cfs. This seepage run data is in contrast to the hydraulic gradient at the time of the seepage runs, which was from the river toward groundwater.

Spokane County Colbert Landfill North Glen Well –

The geologic setting of the north glen well is an area of alluvial deposits approximately ½ mile wide comprised of sands and gravels with thin layers of finer grained materials. Within the vicinity of the well are wetlands that have standing water until late summer and springs that discharge from the hillside east of the well.

Ground water at this site ranged from 4 to 7 feet above the river surface elevation (Figure 15). This indicates the hydraulic gradient is from ground water to surface water. This is also evident from the cross section shown in Figure 10. In contrast to the other sites the river surface elevation is used instead of the base of the river channel. There was no access to the river adjacent to this well at this location, so the river surface elevation was surveyed from a bridge 1400 feet upstream. That survey data, in conjunction with topographic data, was used to estimate the elevation of the river surface adjacent to the well location.

Figure 27 shows a comparison of changes in ground water elevation and changes in river surface elevation at the Dartford gage. Changes in ground water elevation track closely with changes in river surface elevation which indicates that pressure changes caused by changes in river elevation propagate through ground water quickly.

Temperature changes in ground water at this well have a range of 2.61 degrees Celsius over the study period. The temperature variations show a seasonal pattern, though it is approximately 3 months behind surface water temperature. The maximum temperatures occur in late November/early December and the minimum temperature occurs in late March/early April. This indicates that surface water is potentially recharging the ground water and there is an approximate travel time of 3 months from the location where the surface water enters ground water and the North Glen well.

The North Glen well is within river reach 7 of the seepage run. Data from 2009 and 2010 indicate that the river gains from ground water within this reach. In 2009 it gained 13.31 (cfs) and in 2010 it gained 6.7 cfs. This seepage run data is consistent with the hydraulic gradient at the time of the seepage runs, which was from ground water to the river

Spokane County Water District #3 River Estates Well –

The geologic setting of the River Estates well is similar to that of the North Glen well - alluvial deposits comprised of sand and gravels. The River Estates well is a monitoring well in close proximity to a municipal production well and does exhibit a draw down during the summer, though it is not as significant as the Pine River Park well.

Ground water at this site ranged from 1.6 to 8.5 feet above the base of the river channel at this location (Figure 16). The river depth at this location can fluctuate within that range; therefore the hydraulic gradient at this site is relatively flat and may fluctuate between from ground water to surface water and from surface water to ground water depending on the flow in the river and withdrawals from ground water. Figure 11 shows the elevation cross section for this location.

Figure 28 shows a comparison of changes in ground water elevation and changes in river surface elevation at the Dartford gage. Changes in ground water elevation correlate with changes in surface water elevation which indicates that the pressure change caused by changes in river elevation propagate quickly to ground water.

Temperature changes in ground water at this well have a range of 2.22 degrees Celsius over the study period. The temperature variations show a seasonal pattern, though it is approximately 3 months behind surface water temperature, similar to the North Glen well. The River Estates well does exhibit some excursion from this pattern, most notably in May and June of 2010. This potentially reflects the influence on a changing hydraulic gradient at this location.

The North Glen well is within river reach 5 of the seepage run. Data from 2009 and 2010 indicate that the river gains from ground water within this reach, but the increase is within the margin of error. In 2009 it gained 3.8 (cfs) and in 2010 in gained 0.28 cfs. This seepage run data is consistent with a relatively flat hydraulic gradient that switches directions depending on river stage and the magnitude of ground water withdrawals.

Ecology Deer Park Monitoring Well-

This well is within the Dragoon Creek subbasin, a tributary to the Little Spokane River. The well is approximately 1 mile north of Dragoon Creek and 9 miles northwest of the Little Spokane River. The well is completed in the Columbia River Basalt Group that is present in the Deer Park area.

The ground water elevation in this well (Figures 18 and 31) is not correlated with surface water changes in the Little Spokane River, which was expected. The elevation does follow a seasonal pattern with a summer time draw down between 4 and 8 feet and recovery during the winter months. This pattern is possibly due to the influence of large withdrawals from the basalt aquifer for irrigation. In contrast to the wells near the river, the ground water temperature is nearly constant.

Ecology Chattaroy Monitoring Well-

This well is approximately 2.5 miles from the Little Spokane River. The well is completed in sands and gravels that overlie granitic bedrock.

The ground water elevation in this well varied by approximately 2.5 feet during the study period (Figures 19 and 30). This well demonstrates a seasonal pattern similar to the Deer Park well with the exception of the recovery. The fall/winter recovery is a steady increase from October to May. Similar to the Deer Park well the water level elevation is not correlated with surface water changes in the Little Spokane River and ground water has a constant temperature.

Whitworth Water District #2 North Mt. View Well-

This well is approximately 1.75 miles northwest of the Little Spokane River. The well is completed in sand. The well log provides this description: "*The water in this well flows from a narrow vein of sand between clay layers at the 68 ft. level*." The ground water elevation has varied almost 4 feet over the study period.

In contrast to the Deer Park and Chattaroy wells this well shows some correlation to the water level changes in the river. The changes, though, occur several days after the change in elevation in the river. There are two potential explanations for this correlation: 1) The aquifer this well is completed in may be connected to the river and changes in ground water elevation are the result of a pressure wave propagating through the aquifer, or 2) the well is responding to the same precipitation events that the river is and therefore the changes show a correlation. The ground water temperature does not indicate a surface water influence.

Recommendations

As described previously, the goal of these monitoring and data analysis efforts are to better understand the connection of the ground and surface water in the Little Spokane River Basin, especially as it relates to late summer base flows that are largely derived from ground water.

Recommendations for future work are:

1. Continue existing monitoring program at current locations;
2. Establish additional locations for continuous ground water elevation monitoring;
3. Continue the development of a Little Spokane Basin Hydrogeologic database. A database has been developed under previous WRIA 55/57 Phase IV Implementation projects. The goal of this work would be to refine and add additional data to existing well records and add new wells to the database. Refinement of existing records would include the following:
    - Increase the accuracy of the location data for each well;
    - Refine the stratigraphic framework to include identification of upper sand and gravel units, confining layers, and lower sand and gravel units;
    - Identification of water bearing layers and assignment of wells to a particular aquifer; and
    - Addition of well yield and construction data.

4. Utilize the Little Spokane Hydrogeologic database to conduct the following analyses :
    a. Development of geologic cross sections;
    b. Development of the surface topography and thickness of each stratigraphic unit;

    c. Development of a groundwater level potentiometric surface for each identified aquifer; and

5. Additional seepage runs on the Little Spokane River.
6. Develop a monitoring network suitable for synoptic ground water elevation data collection and monthly data collection;

Figures

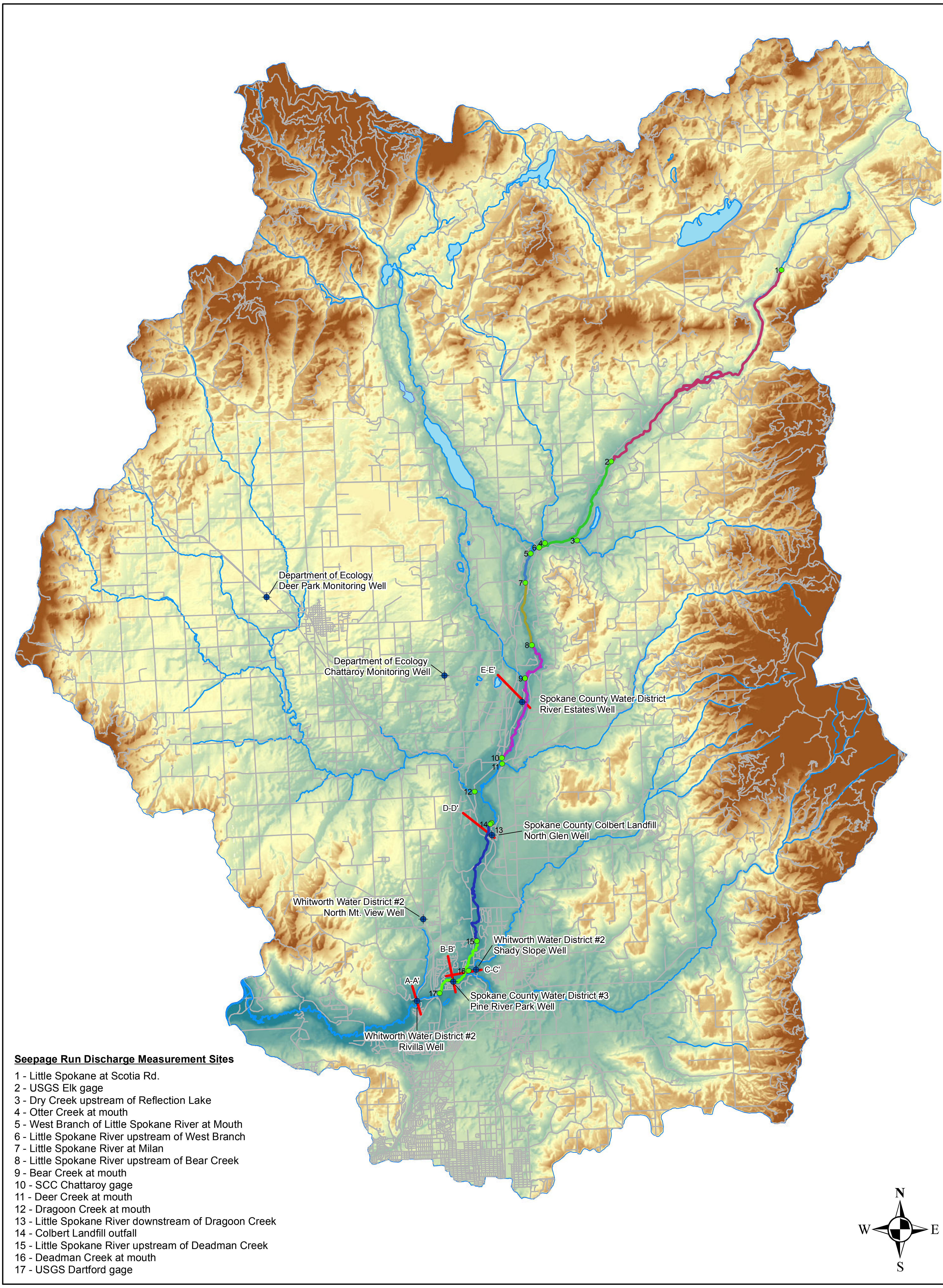

Figure 1 - Little Spokane Ground & Surface Water Monitoring Project

Seepage Run Reaches

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6
- Reach 7
- Reach 8

- Seepage Run Discharge Measurement Sites
- Continuous Groundwater Elevation Monitoring Locations
- Elevation Cross Sections

0 0.5 1 2 3 4 Miles

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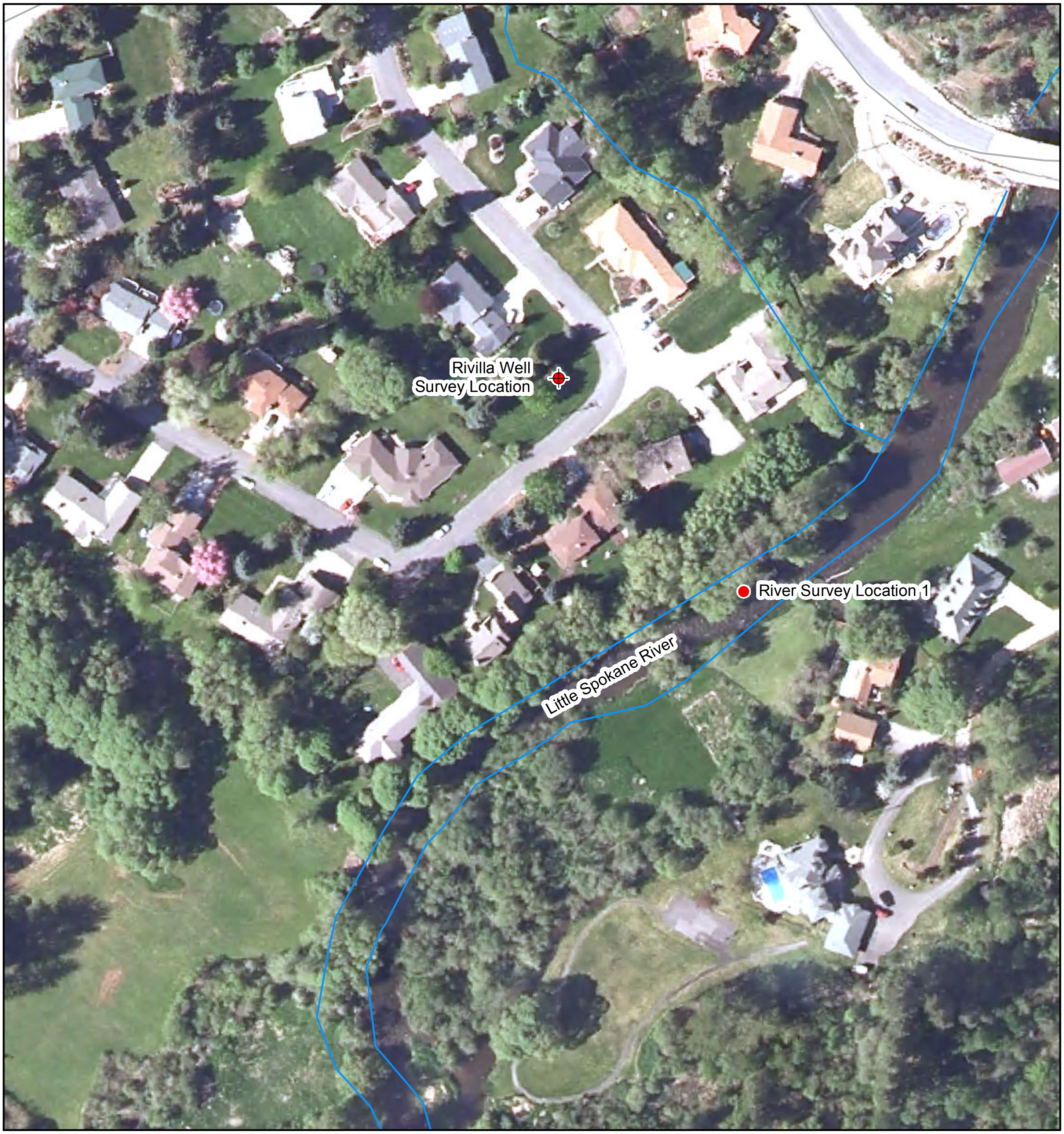

Figure 2 - Rivilla Survey Locations

Aerial photo take in 2009 at 1 ft resolution

Well Survey Location

River Survey Location

N W E S

0 25 50 100 150 200 Feet

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Figure 3 - Pine River Park Survey Locations

Aerial photo take in 2009 at 1 ft resolution

Well Survey Location

River Survey Location

N W E S

0 25 50 100 150 200 Feet

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Figure 4 - Shady Slope Survey Locations

Aerial photo take in 2009 at 1 ft resolution

Well Survey Location

River Survey Location

N W E S

0 25 50 100 150 200 Feet

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Figure 5 - North Glen Survey Locations

Aerial photo take in 2009 at 1 ft resolution

Well Survey Location

River Survey Location

N W E S

0 45 90 180 270 360 Feet

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Figure 6 - River Estates Survey Locations

Aerial photo take in 2009 at 1 ft resolution

Well Survey Location

River Survey Location

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Figure 7— Rivilla Elevation Cross Section & Groundwater Elevation Data

The data presented below shows the groundwater elevation data for the Whitworth Water District #2 Rivilla Well in relation to the Little Spokane River.

Notes:

The well head elevation and Little Spokane River Bottom elevation were surveyed by Spokane County Engineering and Roads staff. Elevation data for the cross section is from a digital elevation model generated from 2ft contour lidar data. Water level graph shown in cross section is referenced to the cross section elevation and shows the water level fluctuations over the study period relative to the land surface.

Lithologic data for the Rivilla well not available

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

Universal Transverse Mercator Projection, Zone 11

All units in feet.

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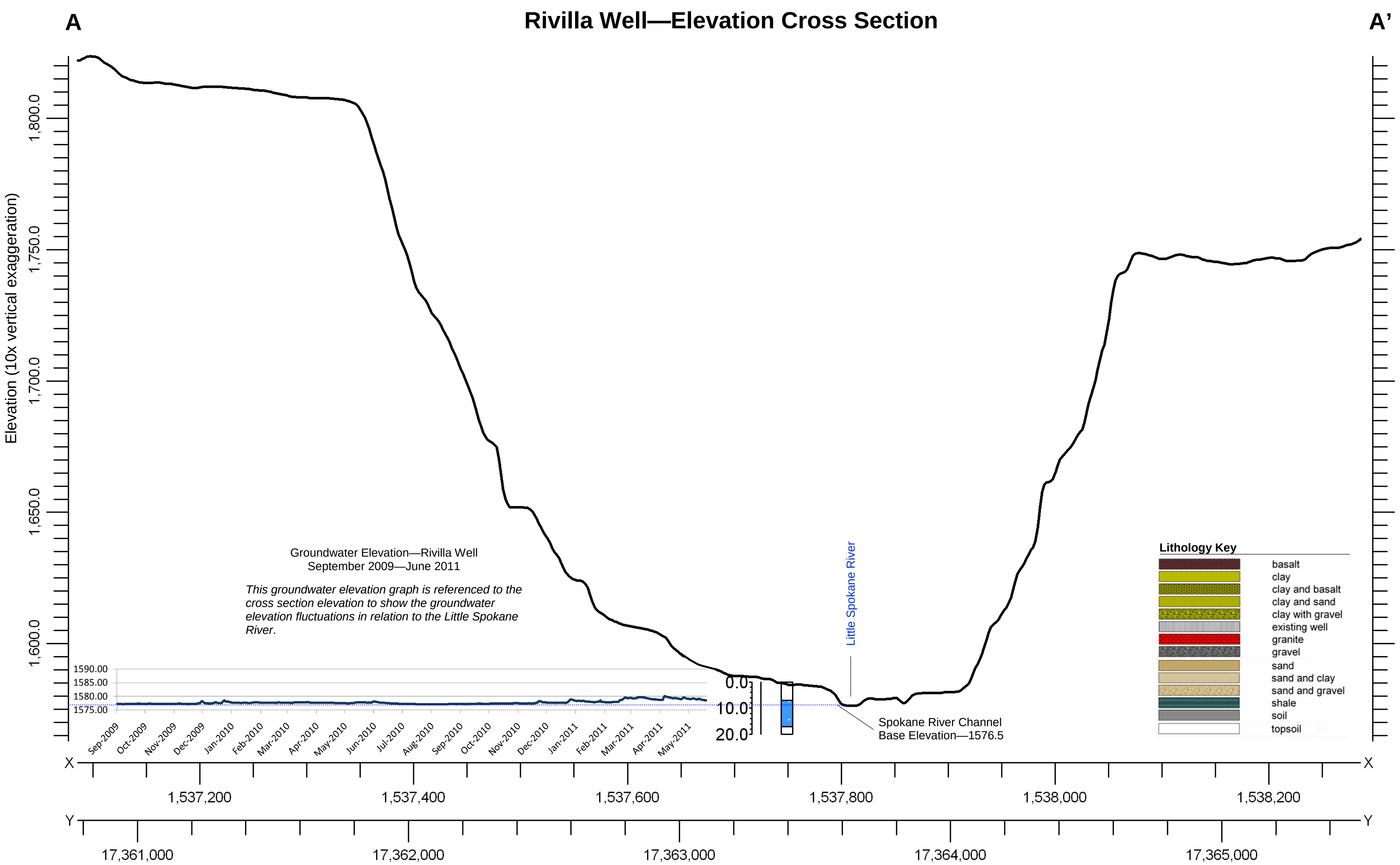

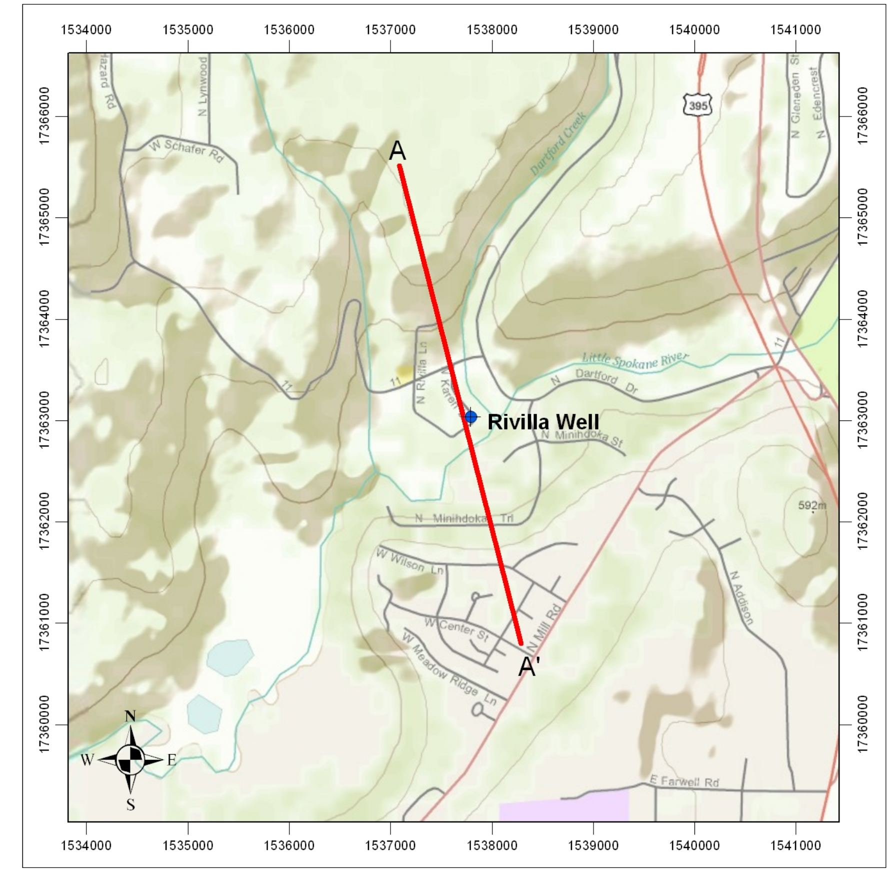

Elevation Cross Section Location Map

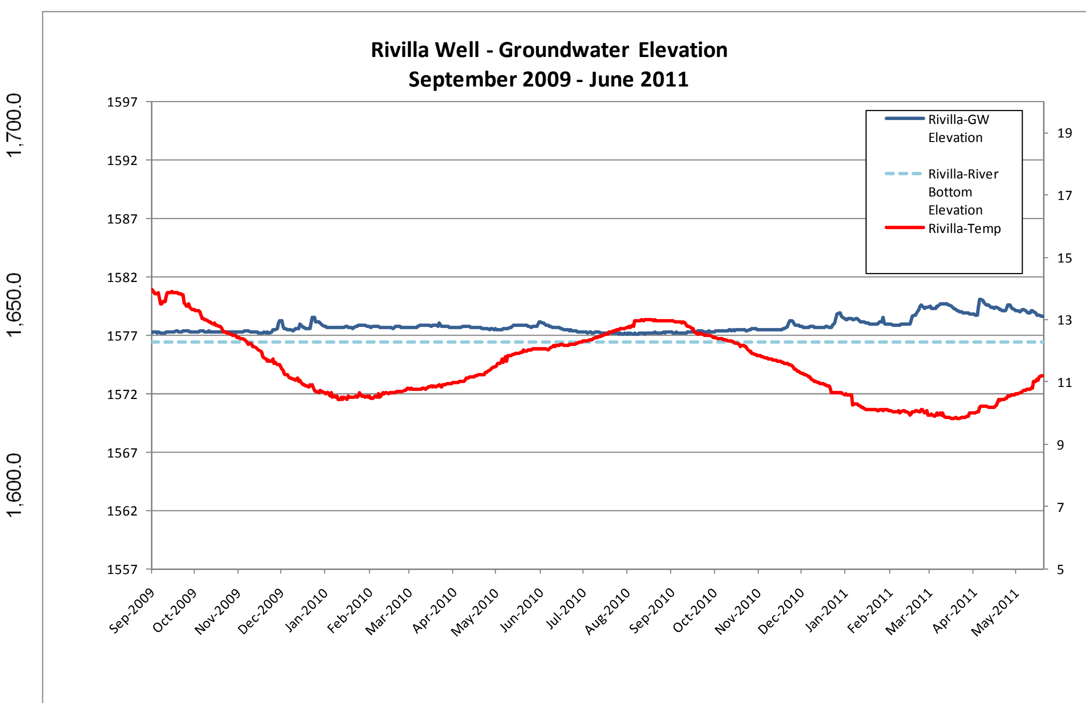

Figure 8— Pine River Park Elevation Cross Section & Groundwater Elevation Data

The data presented below shows the groundwater elevation data for the Spokane County Water District #3 Pine River Park observation well in relation to the Little Spokane River.

Notes:

The well head elevation and Little Spokane River Bottom elevation were surveyed by Spokane County Engineering and Roads staff. Elevation data for the cross section is from a digital elevation model generated from 2ft contour lidar data.

Water level graph shown in cross section is referenced to the cross section elevation and shows the water level fluctuations over the study period relative to the land surface.

Lithologic data interpreted from driller well log

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

Universal Transverse Mercator Projection, Zone 11

All units in feet.

SPOKANE COUNTY WATER RESOURCES

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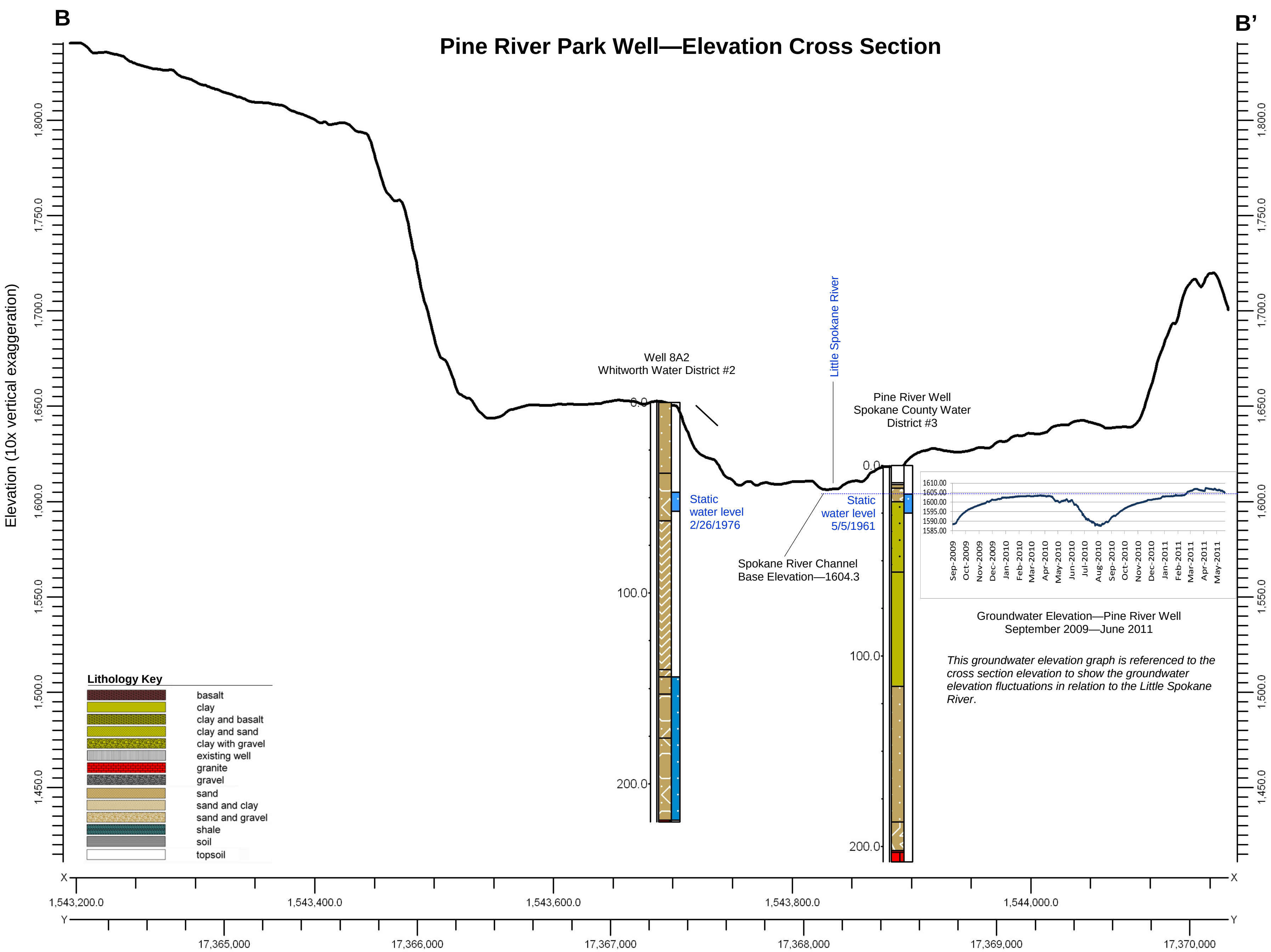

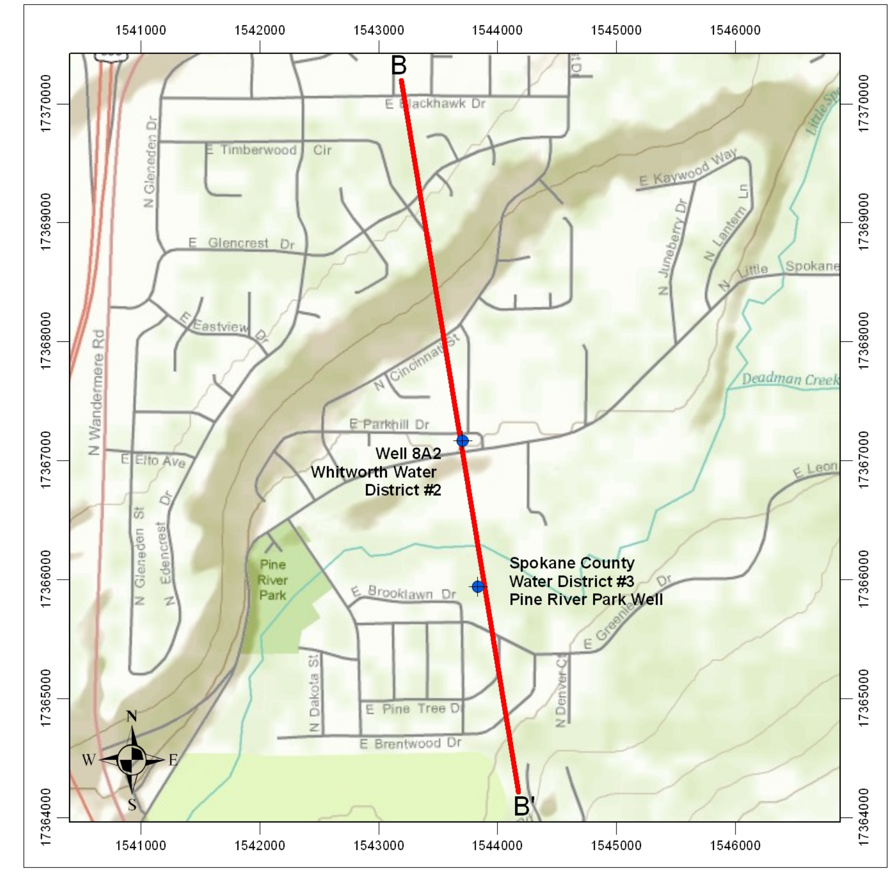

Elevation Cross Section Location Map

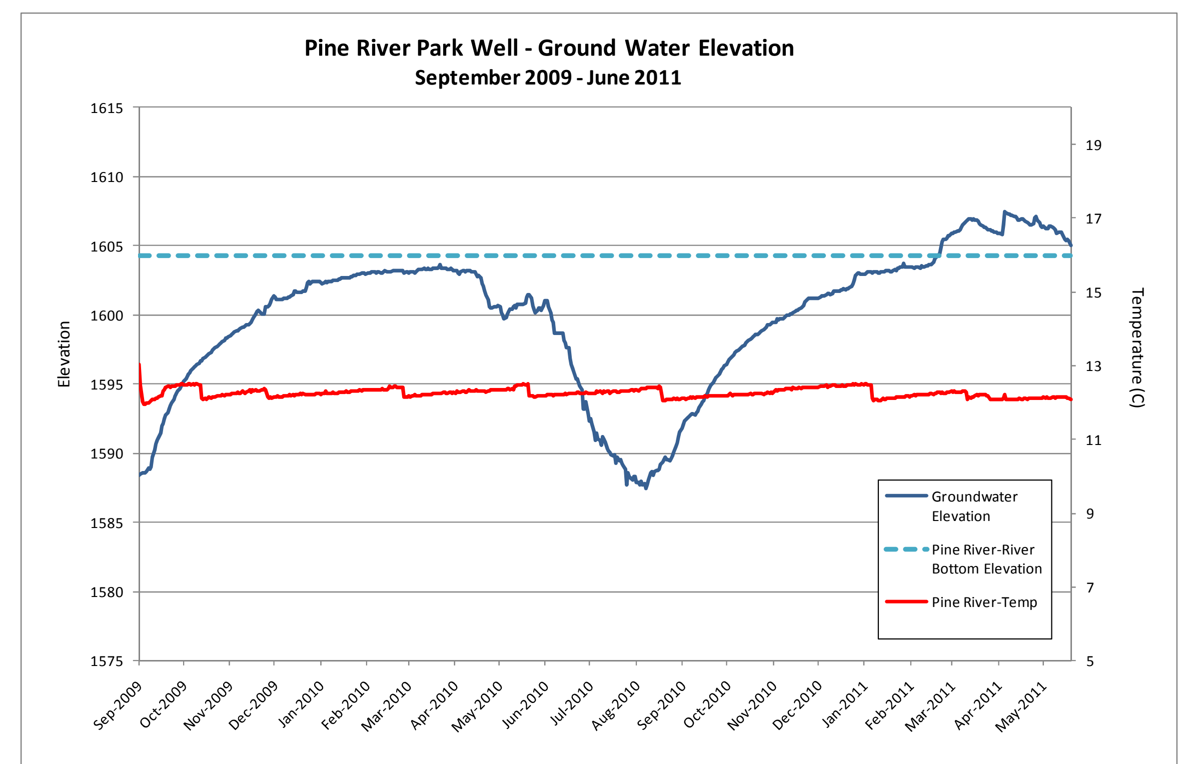

Figure 9— Shady Slope Elevation Cross Section Groundwater Elevation Data

The data presented below shows the groundwater elevation data for the Whitworth Water District #2 Shady Slope observation well in relation to the Little Spokane River and Little Deep Creek.

Notes:

The well head elevation and Little Deep Creek Bottom elevation were surveyed by Spokane County Engineering and Roads staff. Elevation data for the cross section is from a digital elevation model generated from 2ft contour lidar data. Little Spokane River Elevation data is from 2 ft contour lidar data.

Water level graph shown in cross section is referenced to the cross section elevation and shows the water level fluctuations over the study period relative to the land surface.

Lithologic data interpreted from driller well log

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

Universal Transverse Mercator Projection, Zone 11

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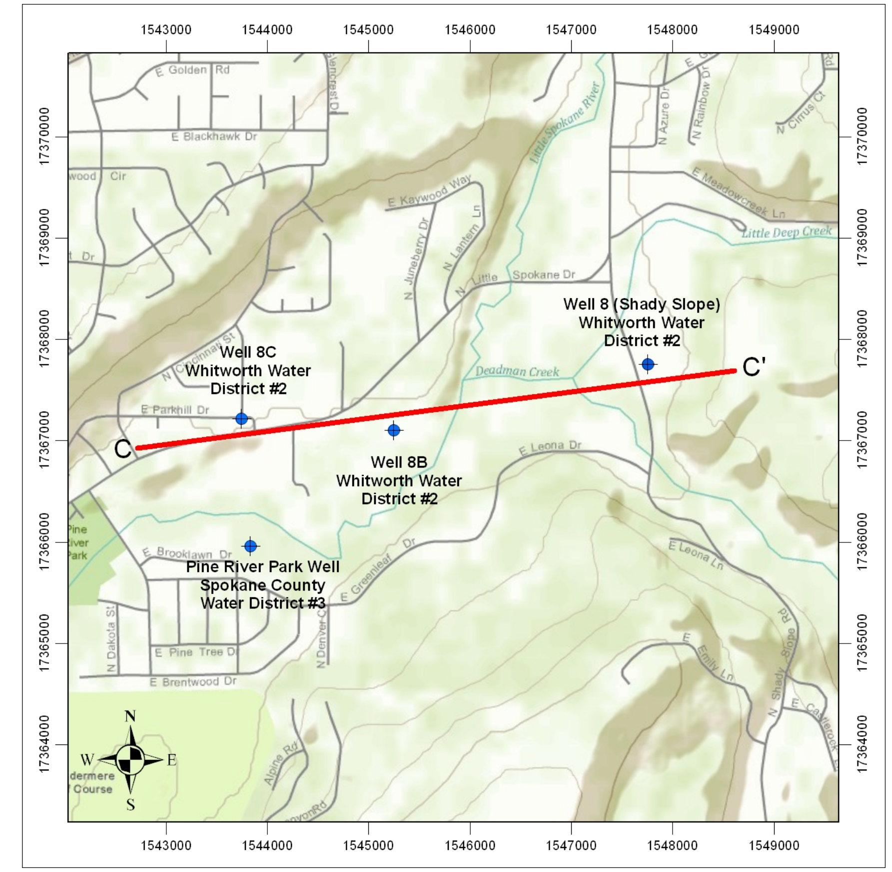
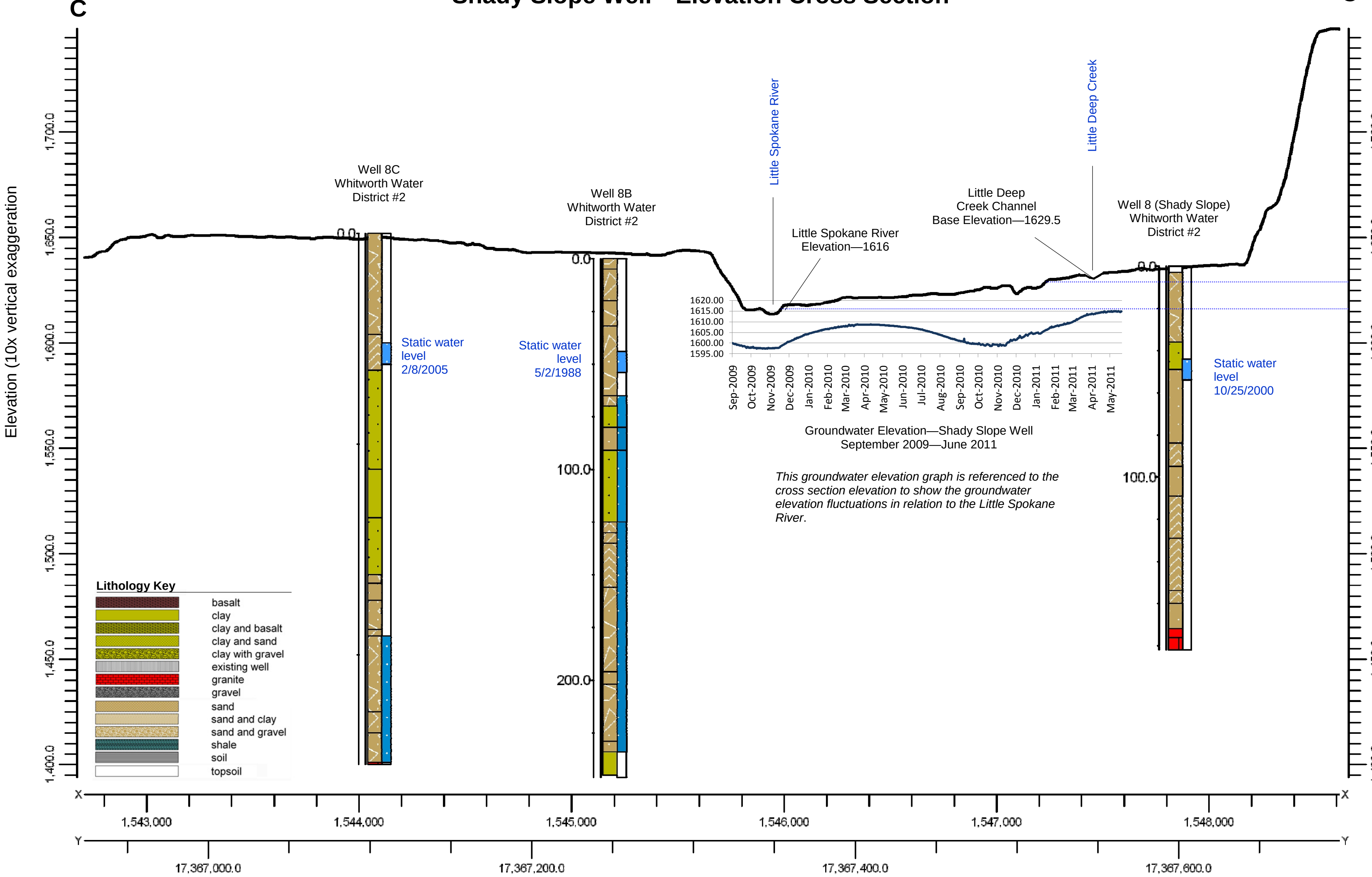


Elevation Cross Section Location Map

Shady Slope Well—Elevation Cross Section



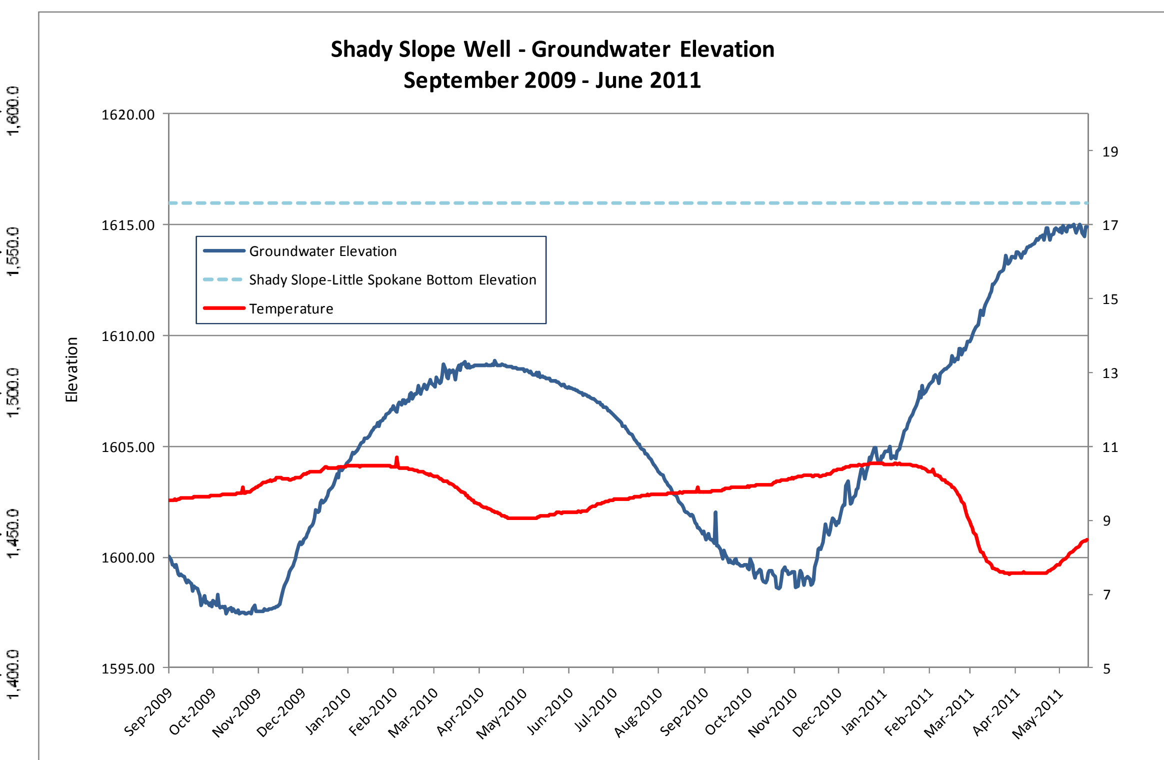


Figure 10— North Glen Elevation Cross Section & Groundwater Elevation Data

The data presented below shows the groundwater elevation data for the Spokane County Colbert Landfill North Glen monitoring well in relation to the Little Spokane River.

Notes:
The well head elevation and Little Spokane River elevation were surveyed by Spokane County Engineering and Roads staff. Elevation data for the cross section is from a USGS digital elevation model.
Water level graph shown in cross section is referenced to the cross section elevation and shows the water level fluctuations over the study period relative to the land surface.
Lithologic data interpreted from driller well log
Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)
Universal Transverse Mercator Projection, Zone 11

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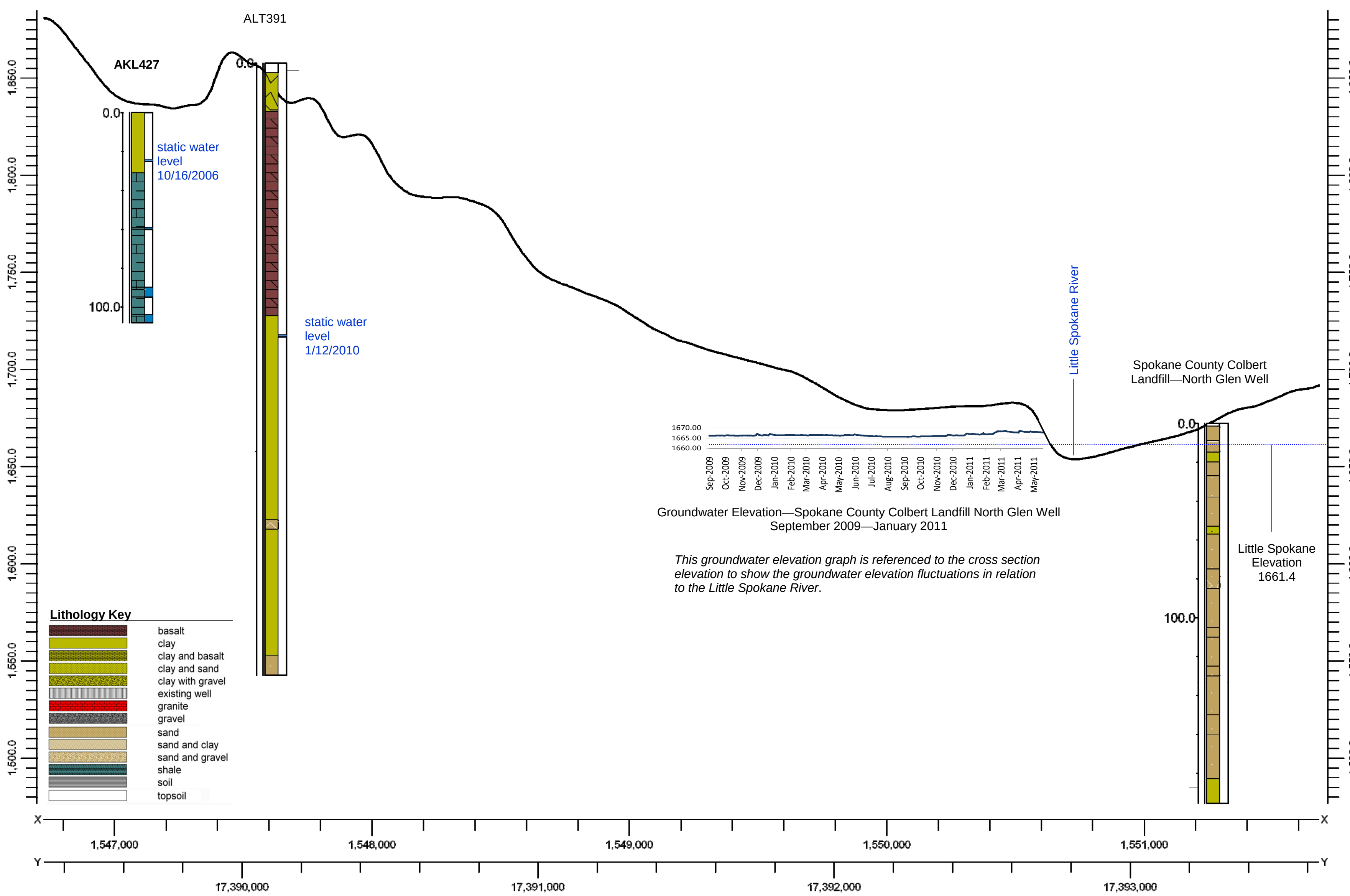
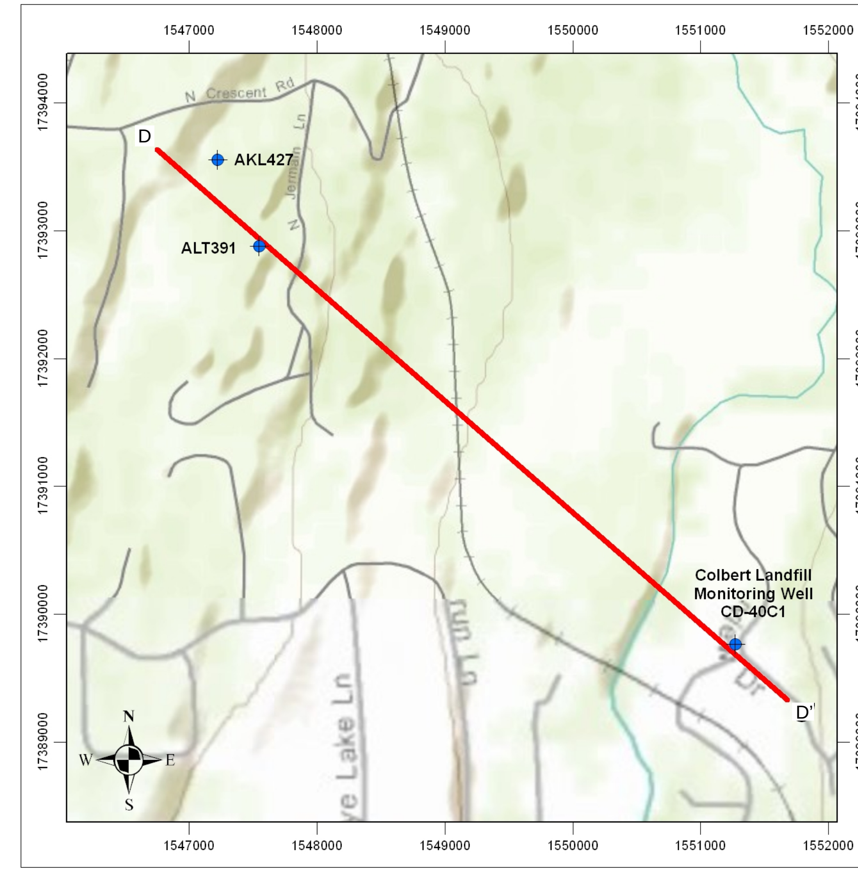
D — North Glen Well—Elevation Cross Section — D'





Elevation Cross Section Location Map

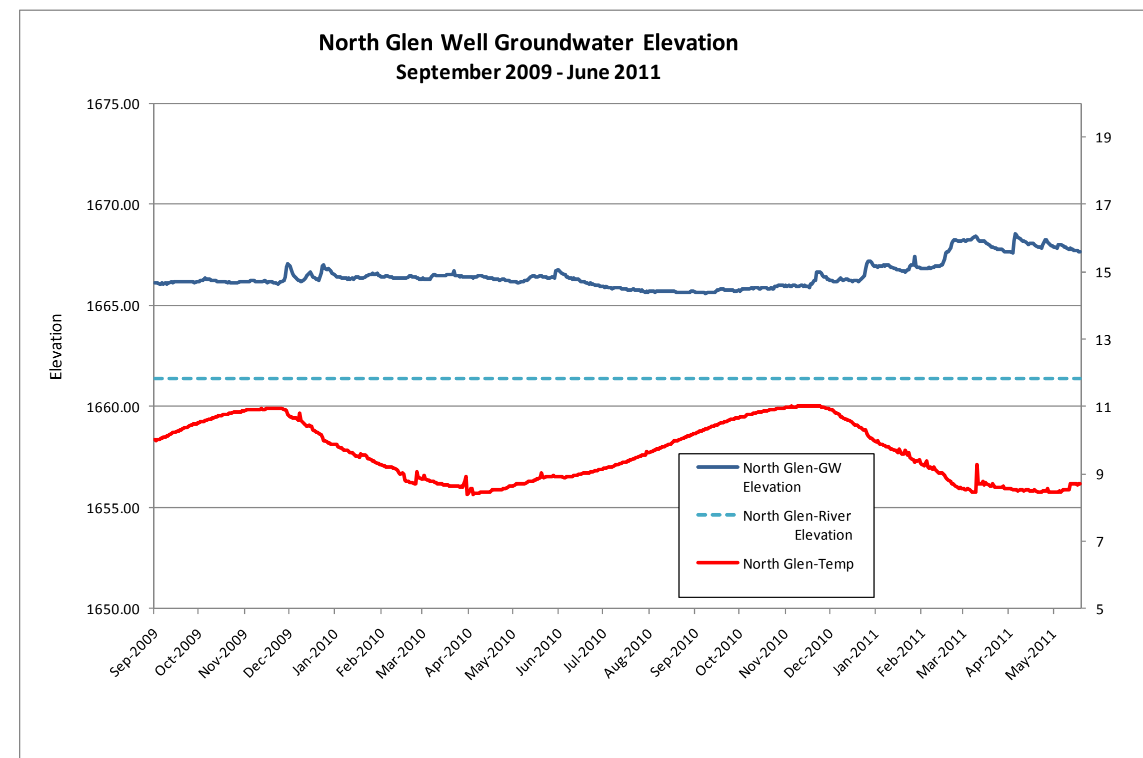


Figure 11— River Estates Elevation Cross Section & Groundwater Elevation Data

The data presented below shows the groundwater elevation data for the Spokane County Water District #3 observation well in relation to the Little Spokane River.

Notes:

The well head elevation and Little Spokane River elevation were surveyed by Spokane County Engineering and Roads staff. Elevation data for the cross section is from a USGS digital elevation model.

Water level graph shown in cross section is referenced to the cross section elevation and shows the water level fluctuations over the study period relative to the land surface. Lithologic data interpreted from driller well log

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

Universal Transverse Mercator Projection, Zone 11

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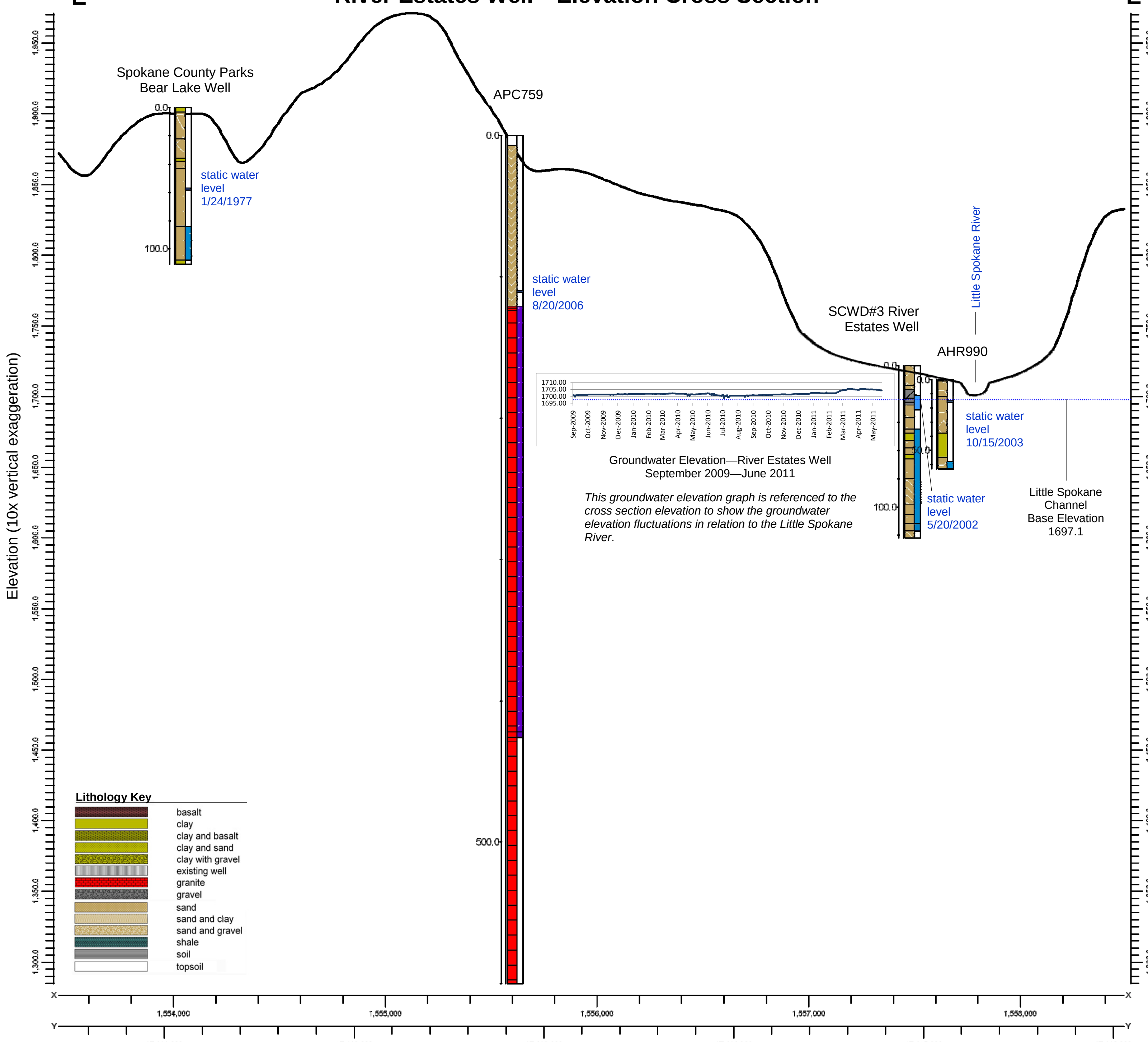
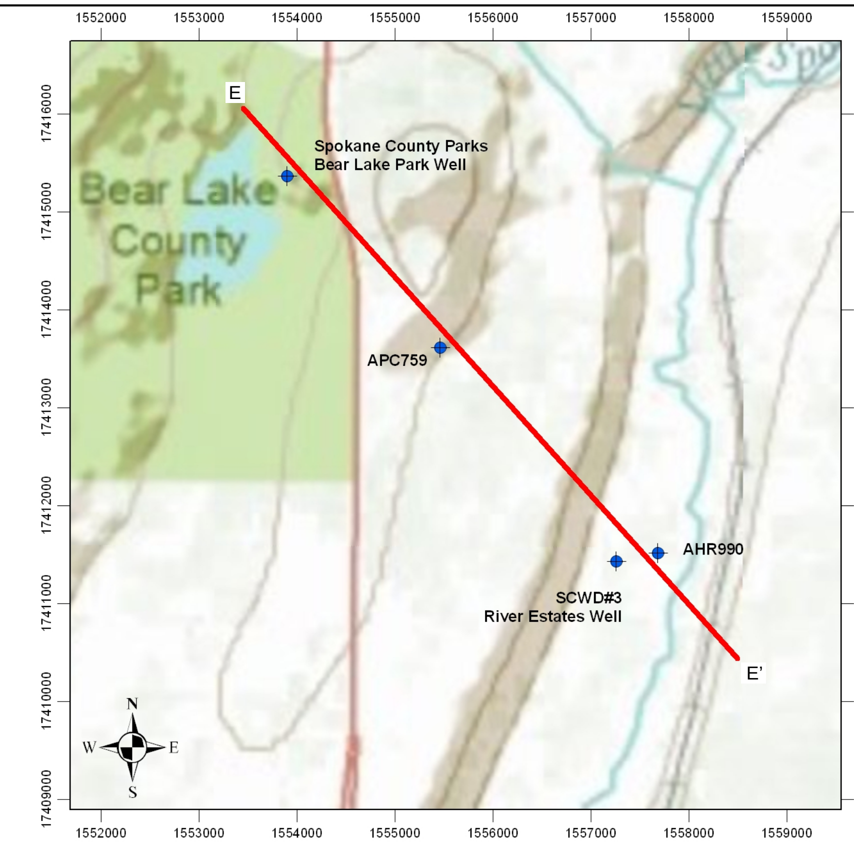
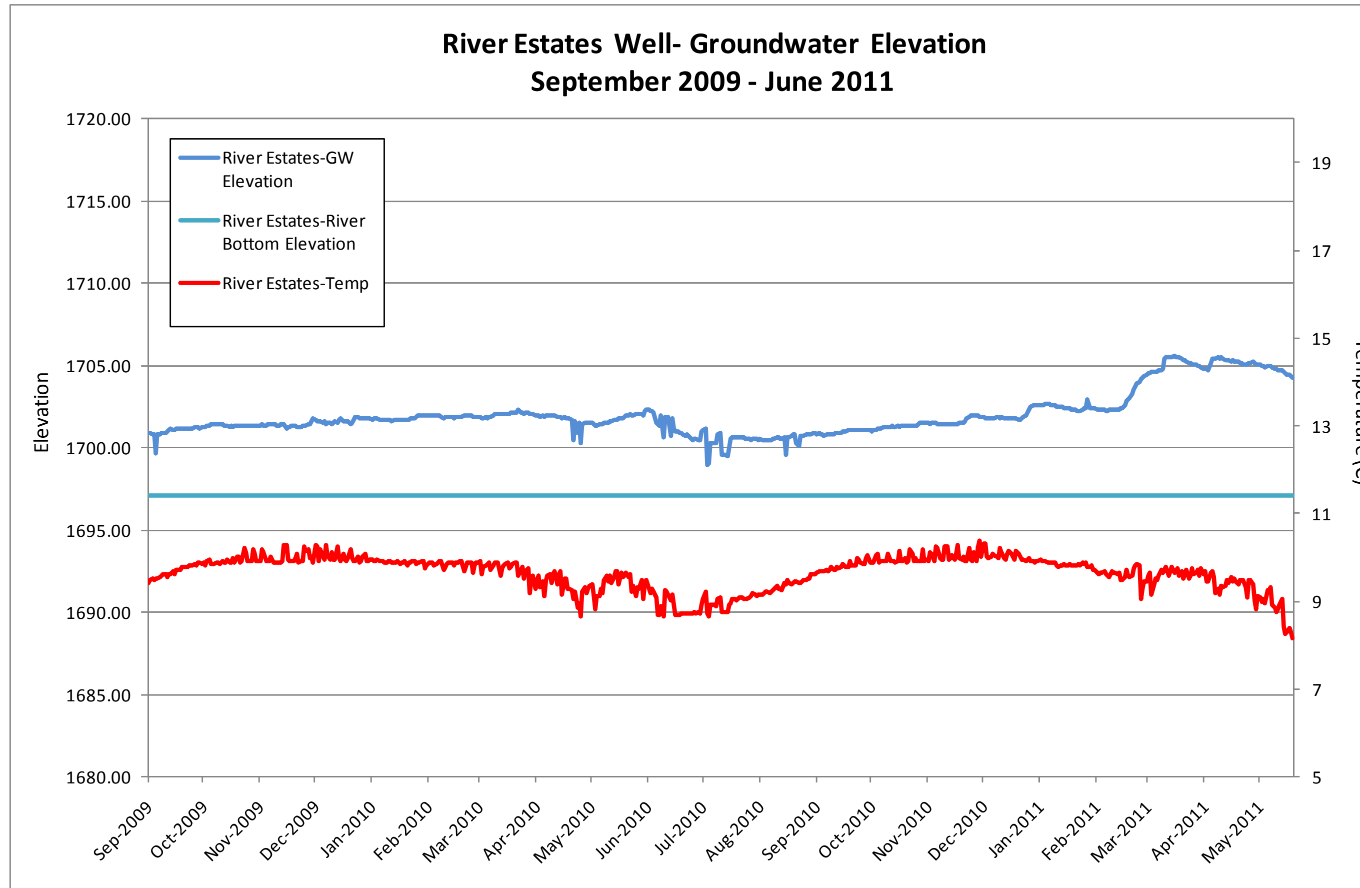




Elevation Cross Section Location Map



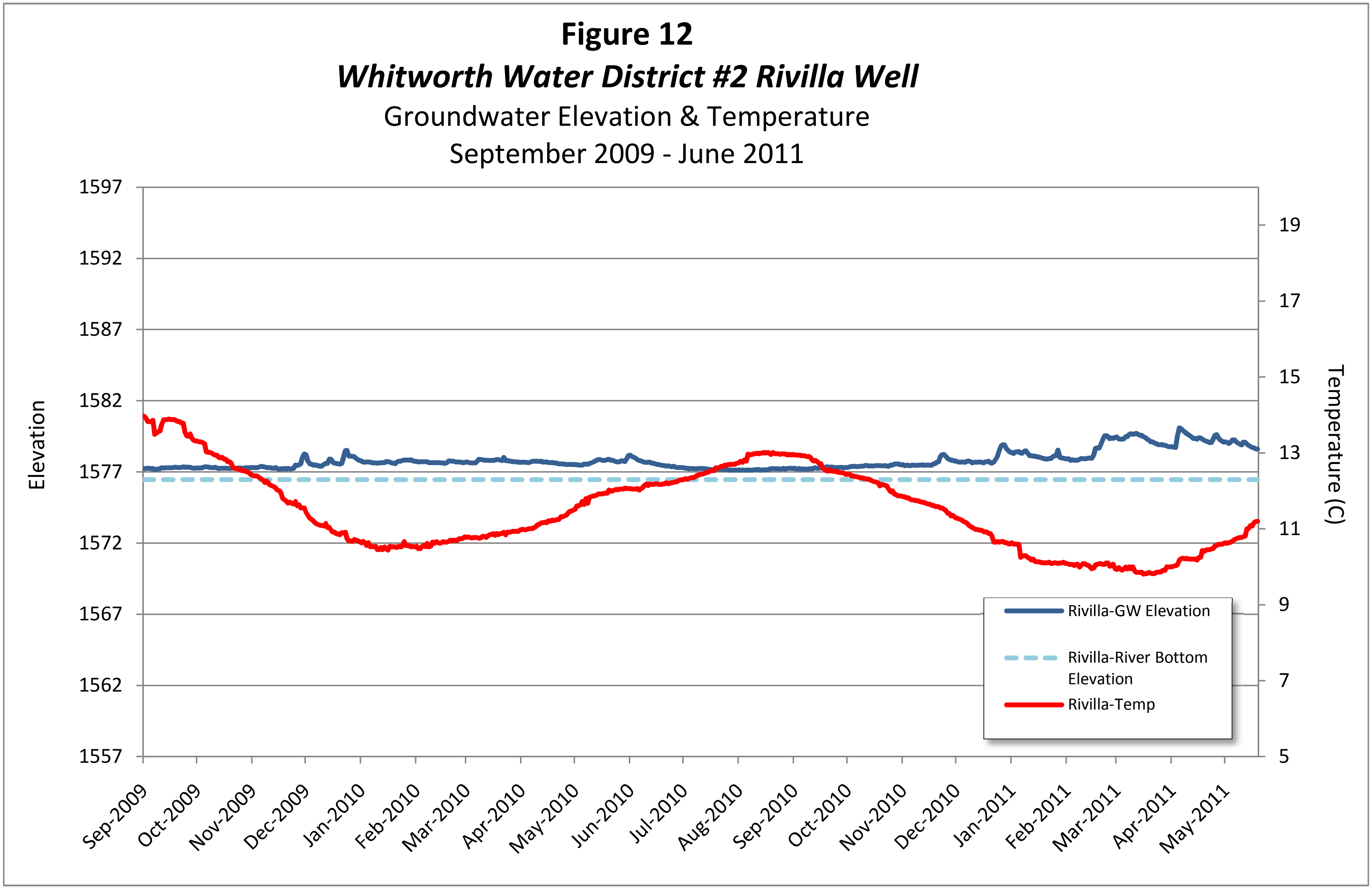


Figure 12
Whitworth Water District #2 Rivilla Well
Groundwater Elevation & Temperature
September 2009 - June 2011
Elevation
Temperature (C)
1597
1592
1587
1582
1577
1572
1567
1562
1557
19
17
15
13
11
9
7
5
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
Rivilla-GW Elevation
Rivilla-River Bottom Elevation
Rivilla-Temp

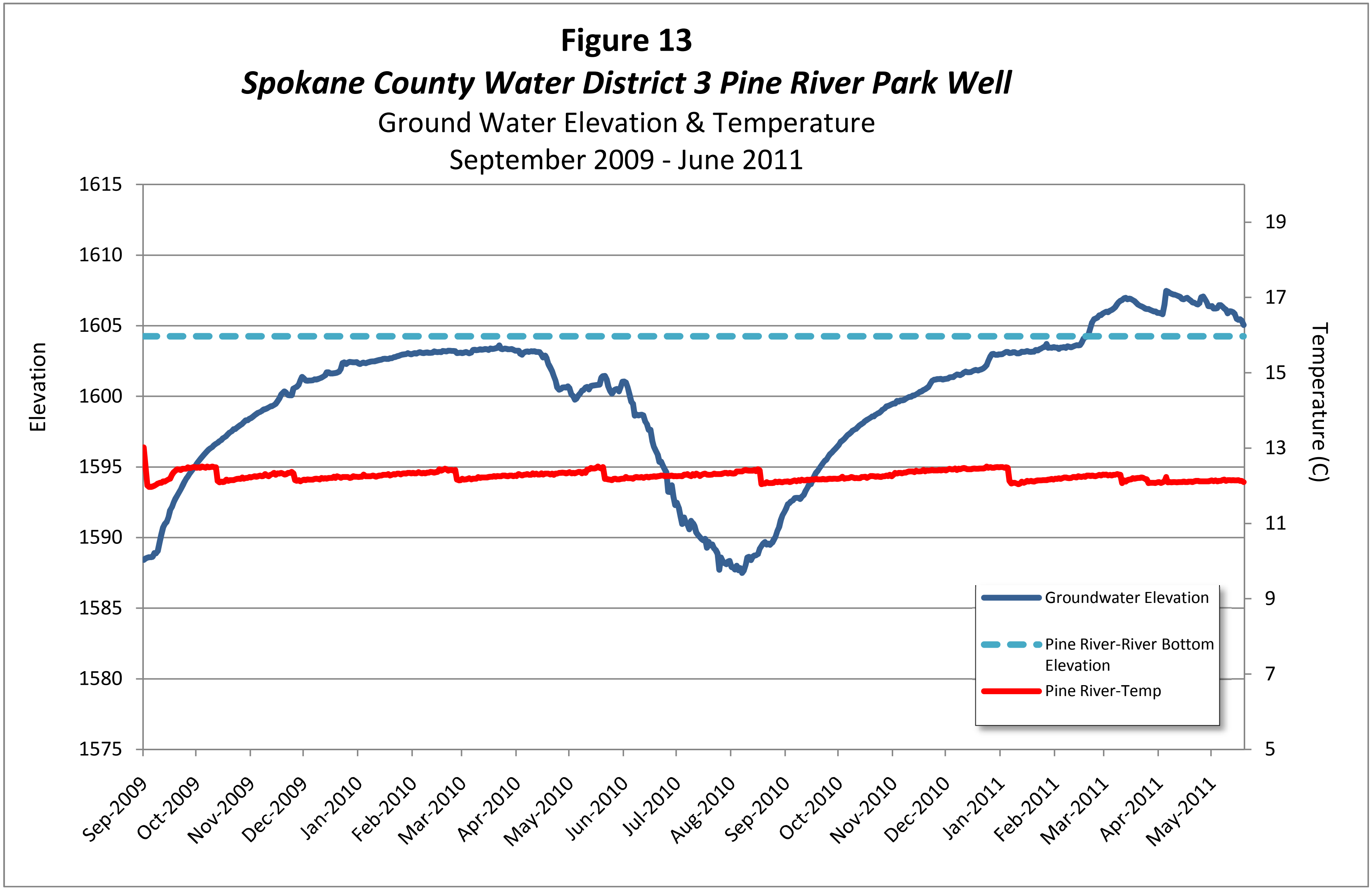


Figure 13
Spokane County Water District 3 Pine River Park Well
Ground Water Elevation & Temperature
September 2009 - June 2011
Elevation
Temperature (C)
1615
1610
1605
1600
1595
1590
1585
1580
1575
19
17
15
13
11
9
7
5
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
Groundwater Elevation
Pine River-River Bottom Elevation
Pine River-Temp

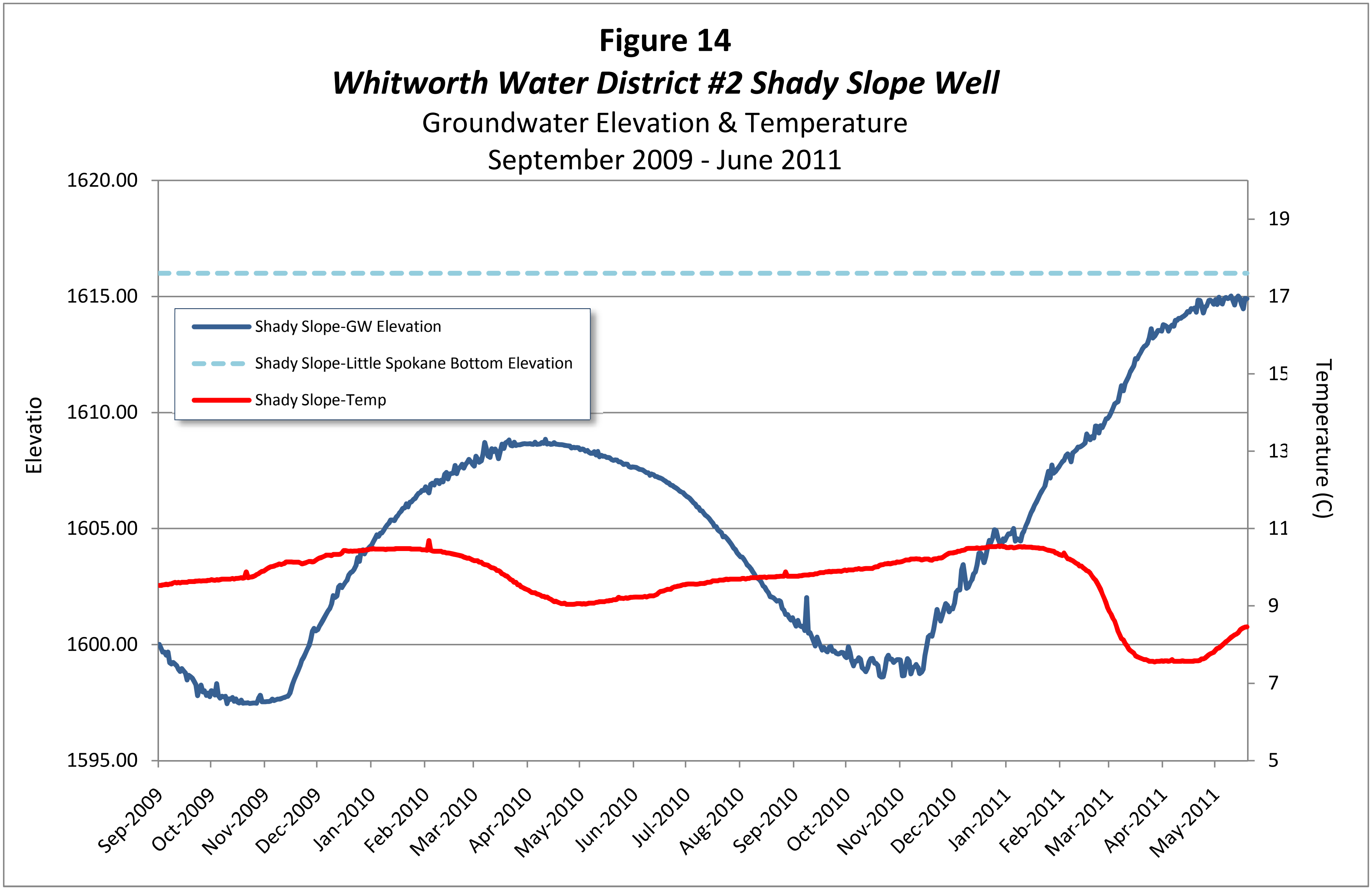


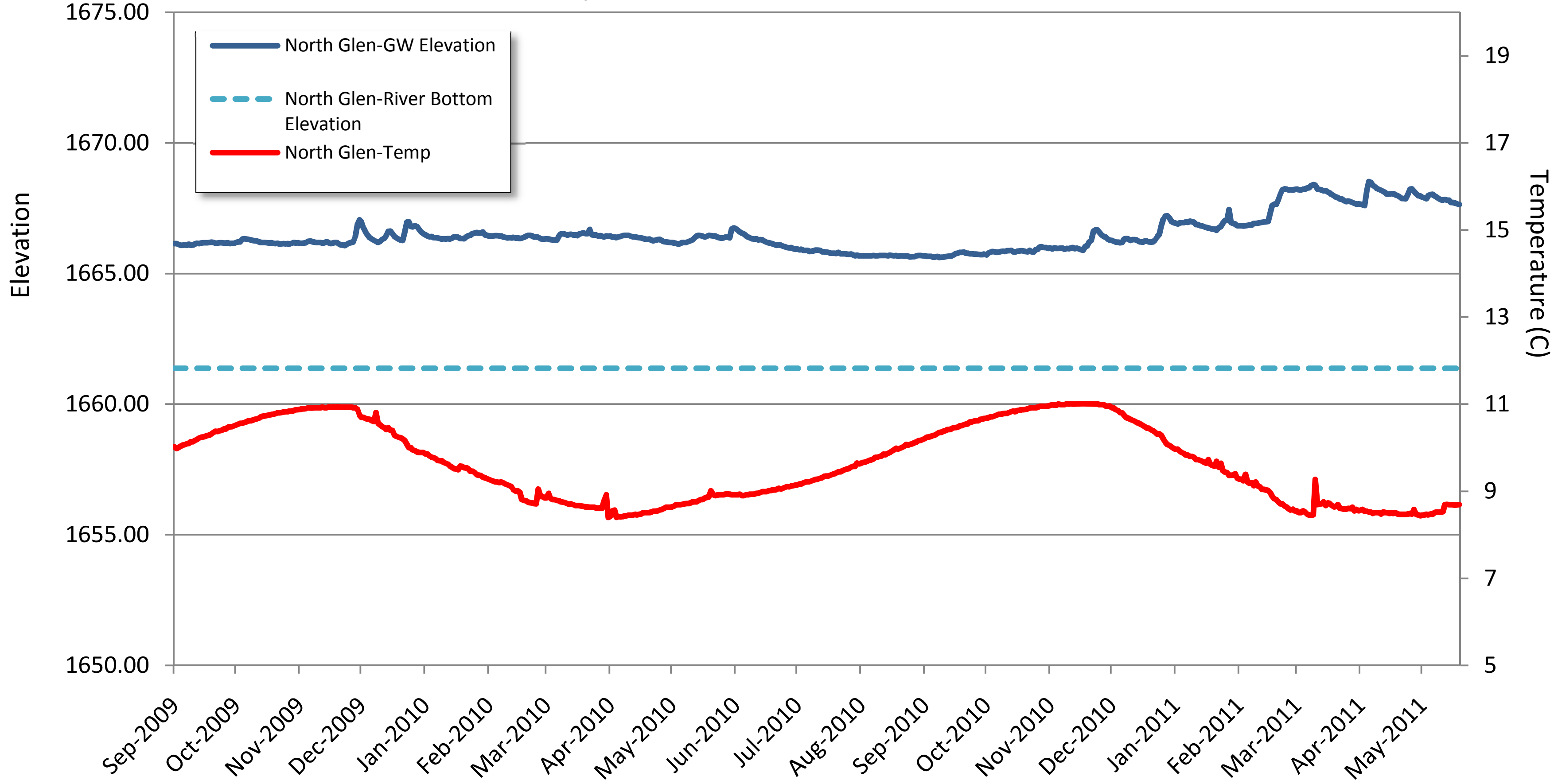
Figure 14
Whitworth Water District #2 Shady Slope Well
Groundwater Elevation & Temperature
September 2009 - June 2011
1620.00
1615.00
1610.00
1605.00
1600.00
1595.00
Elevatio
19
17
15
13
11
9
7
5
Temperature (C)
Shady Slope-GW Elevation
Shady Slope-Little Spokane Bottom Elevation
Shady Slope-Temp
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011

Figure 15

Spokane County Colbert Landfill North Glen Well

Groundwater Elevation & Temperature

September 2009 - June 2011



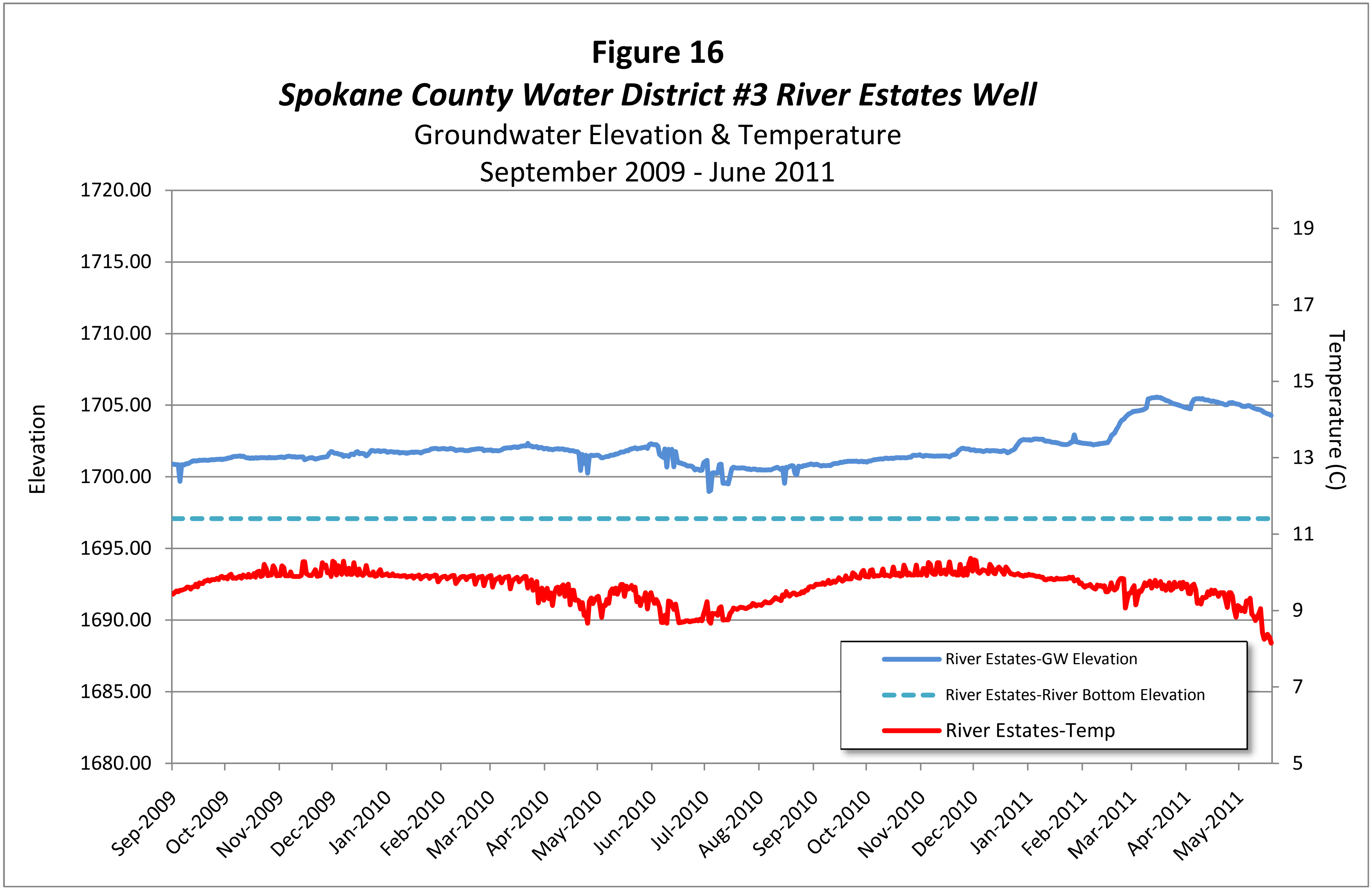
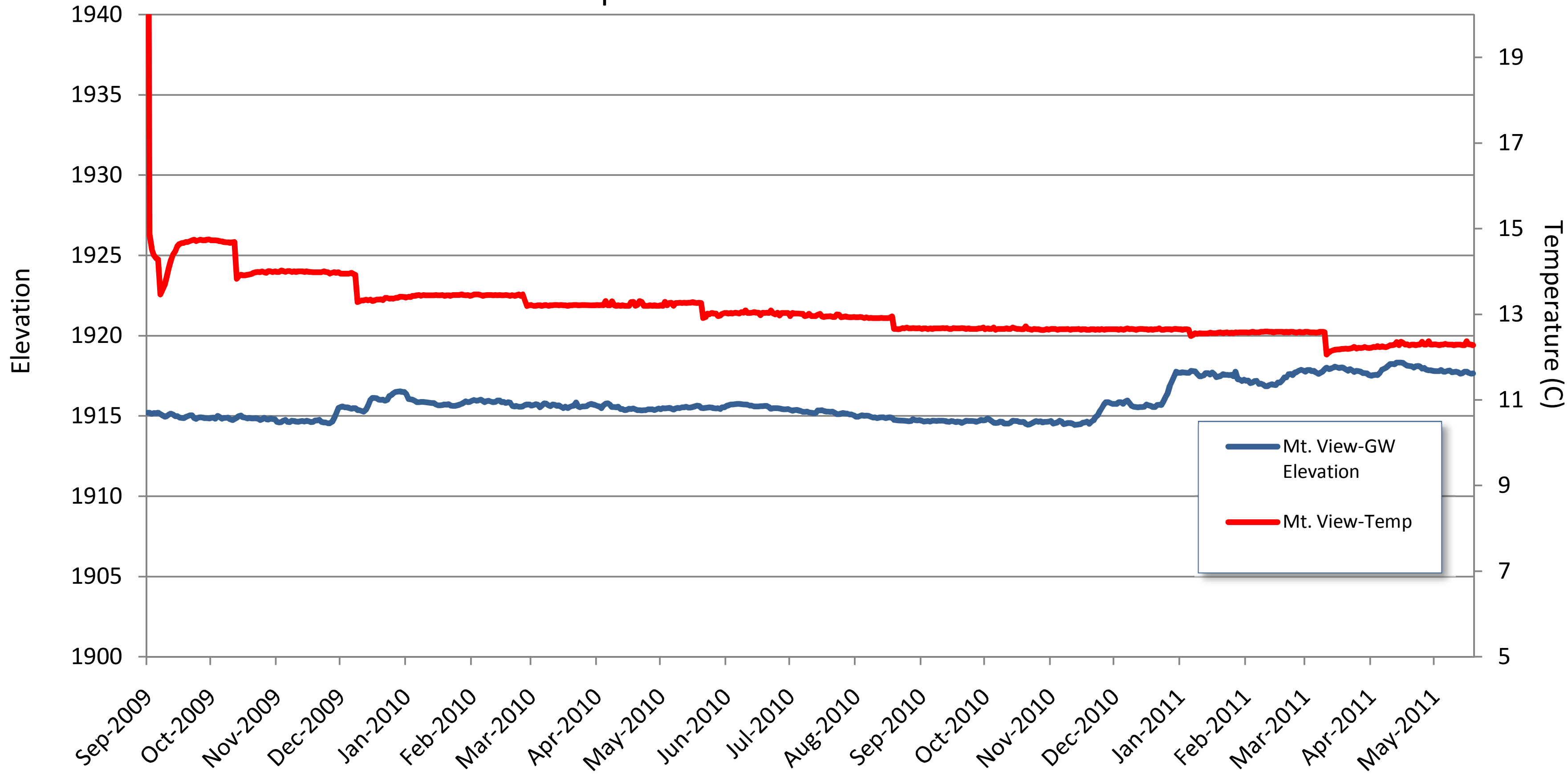


Figure 16
Spokane County Water District #3 River Estates Well
Groundwater Elevation & Temperature
September 2009 - June 2011
Elevation
Temperature (C)
1720.00
1715.00
1710.00
1705.00
1700.00
1695.00
1690.00
1685.00
1680.00
19
17
15
13
11
9
7
5
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
River Estates-GW Elevation
River Estates-River Bottom Elevation
River Estates-Temp

Figure 17

Whitworth Water District #2 North Mt. View Well

Groundwater Elevation & Temperature
September 2009 - June 2011



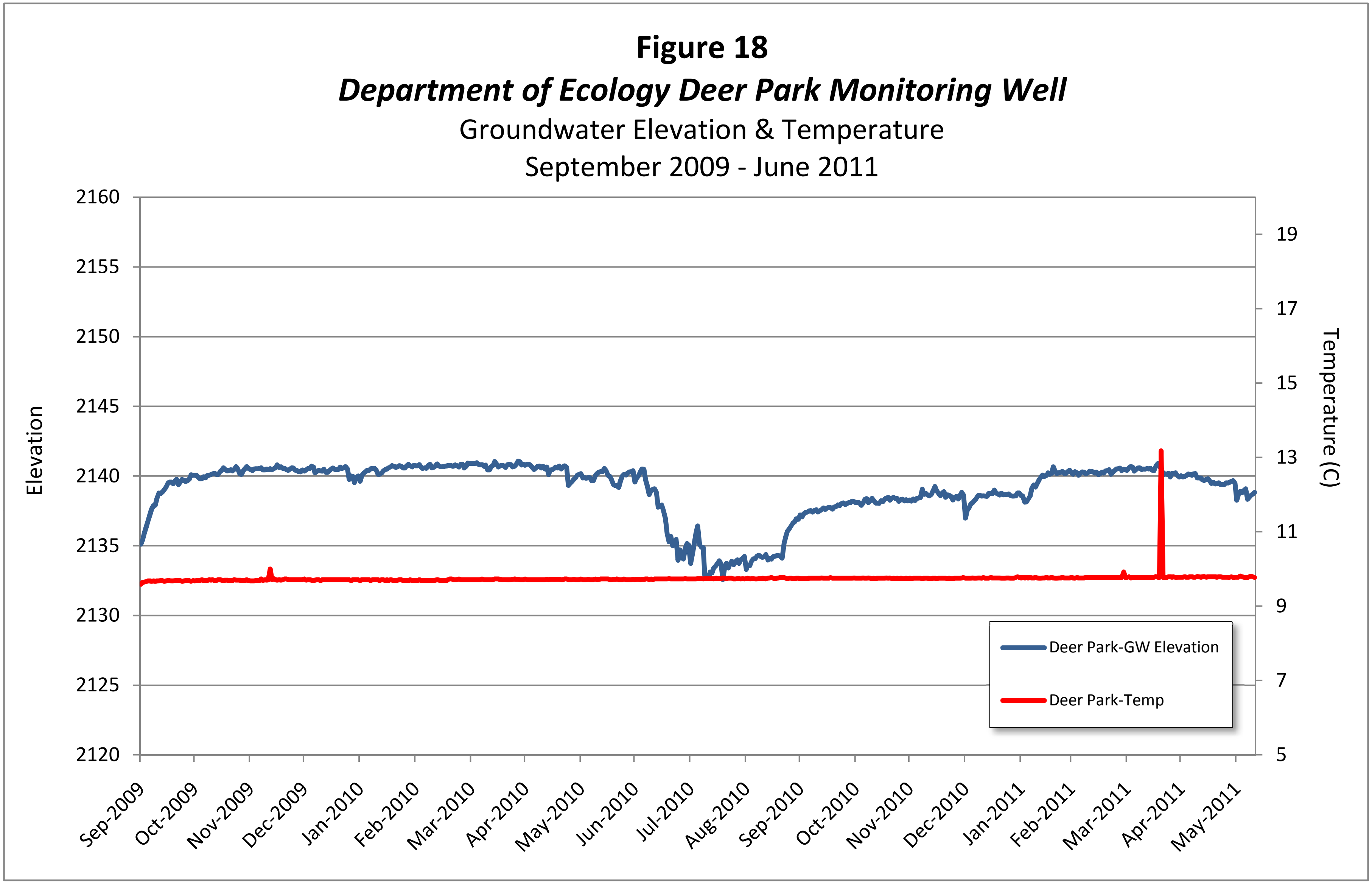


Figure 18
Department of Ecology Deer Park Monitoring Well
Groundwater Elevation & Temperature
September 2009 - June 2011
Elevation
Temperature (C)
2160
2155
2150
2145
2140
2135
2130
2125
2120
19
17
15
13
11
9
7
5
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
Deer Park-GW Elevation
Deer Park-Temp

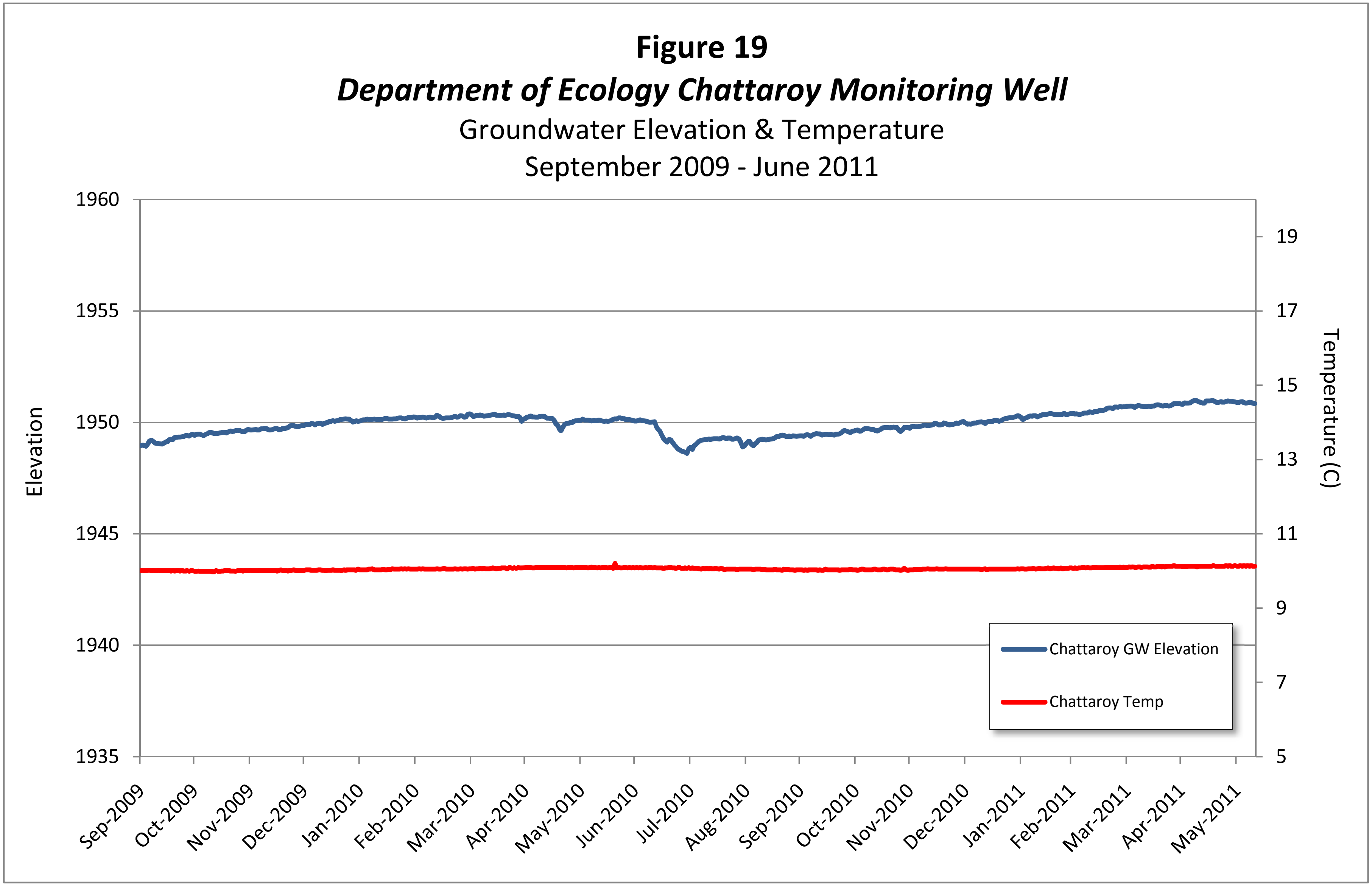


Figure 19
Department of Ecology Chattaroy Monitoring Well
Groundwater Elevation & Temperature
September 2009 - June 2011
Elevation
Temperature (C)
1960
1955
1950
1945
1940
1935
19
17
15
13
11
9
7
5
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
Chattaroy GW Elevation
Chattaroy Temp

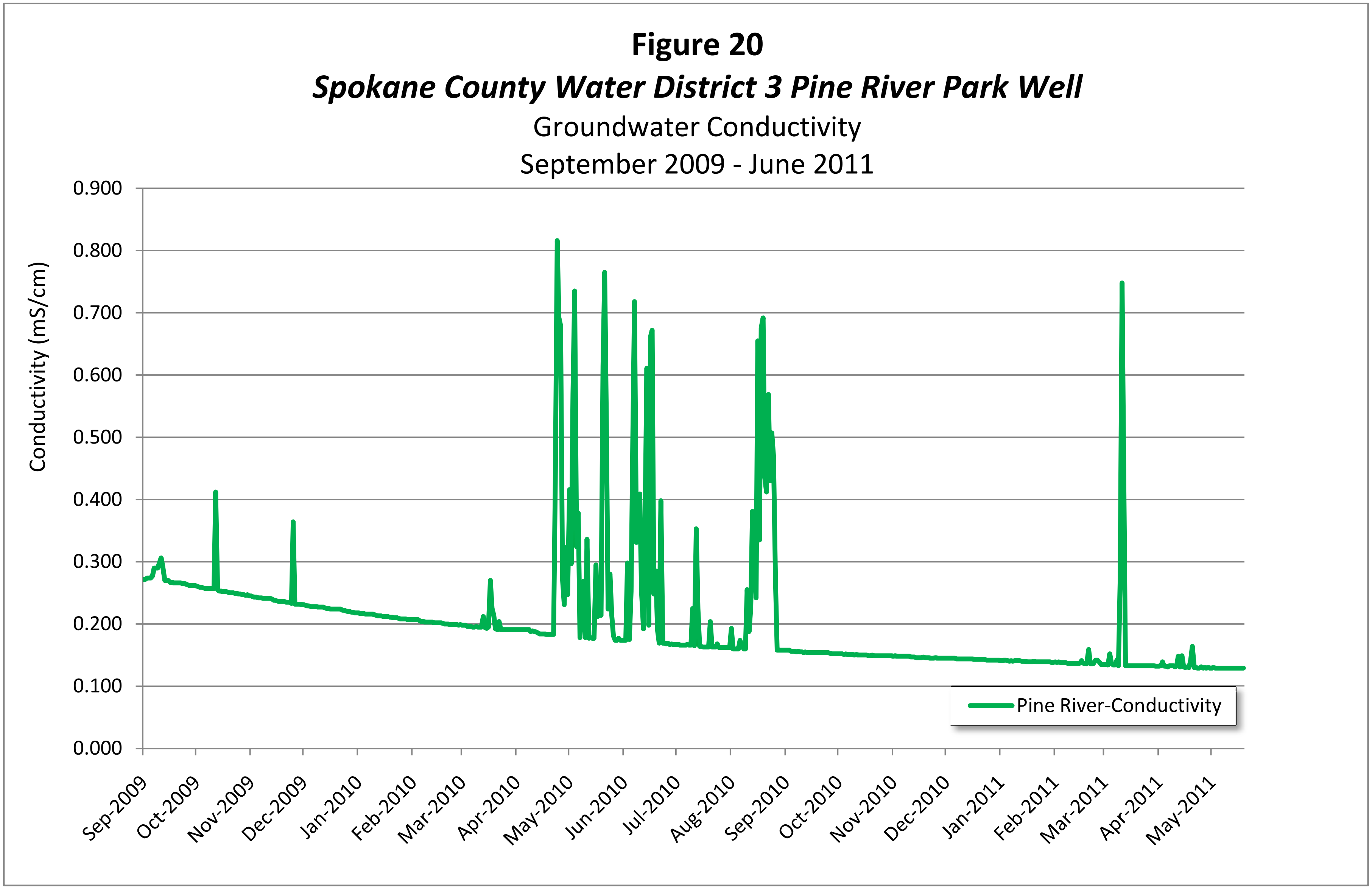


Figure 20
Spokane County Water District 3 Pine River Park Well
Groundwater Conductivity
September 2009 - June 2011
Conductivity (mS/cm)
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Pine River-Conductivity
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011

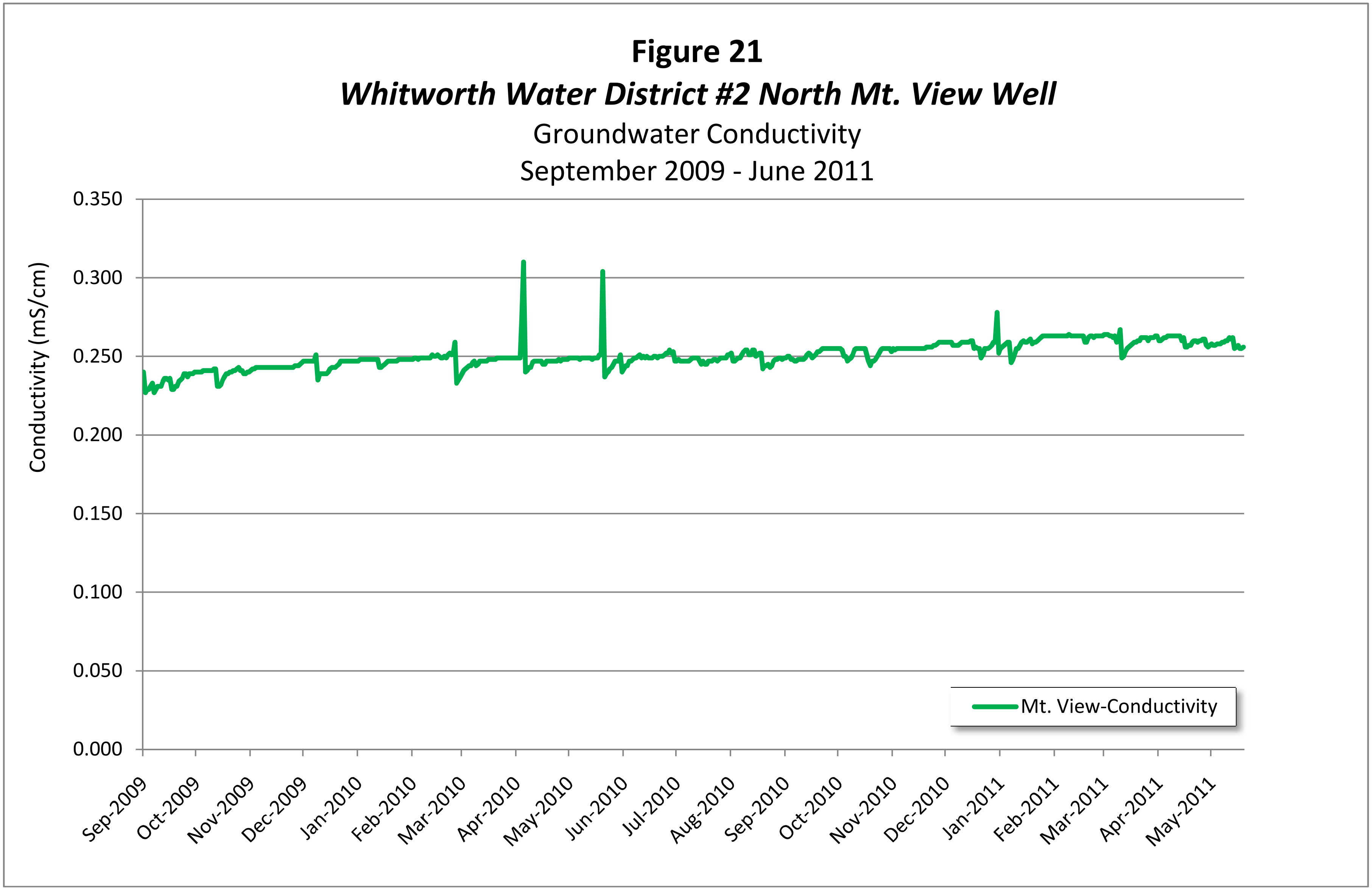


Figure 21
Whitworth Water District #2 North Mt. View Well
Groundwater Conductivity
September 2009 - June 2011
Conductivity (mS/cm)
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
Mt. View-Conductivity

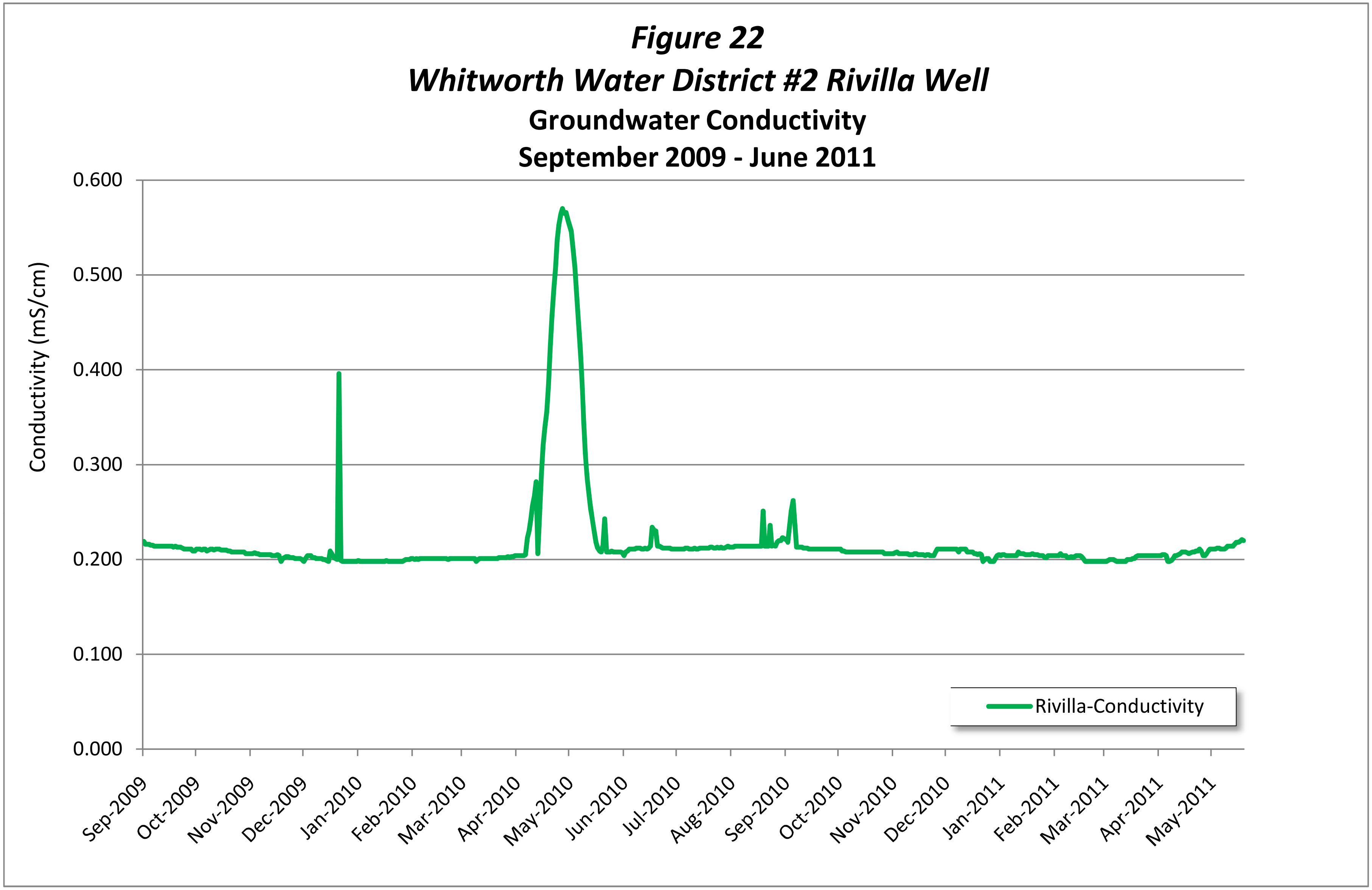


Figure 22
Whitworth Water District #2 Rivilla Well
Groundwater Conductivity
September 2009 - June 2011
Conductivity (mS/cm)
0.600
0.500
0.400
0.300
0.200
0.100
0.000
Sep-2009
Oct-2009
Nov-2009
Dec-2009
Jan-2010
Feb-2010
Mar-2010
Apr-2010
May-2010
Jun-2010
Jul-2010
Aug-2010
Sep-2010
Oct-2010
Nov-2010
Dec-2010
Jan-2011
Feb-2011
Mar-2011
Apr-2011
May-2011
Rivilla-Conductivity

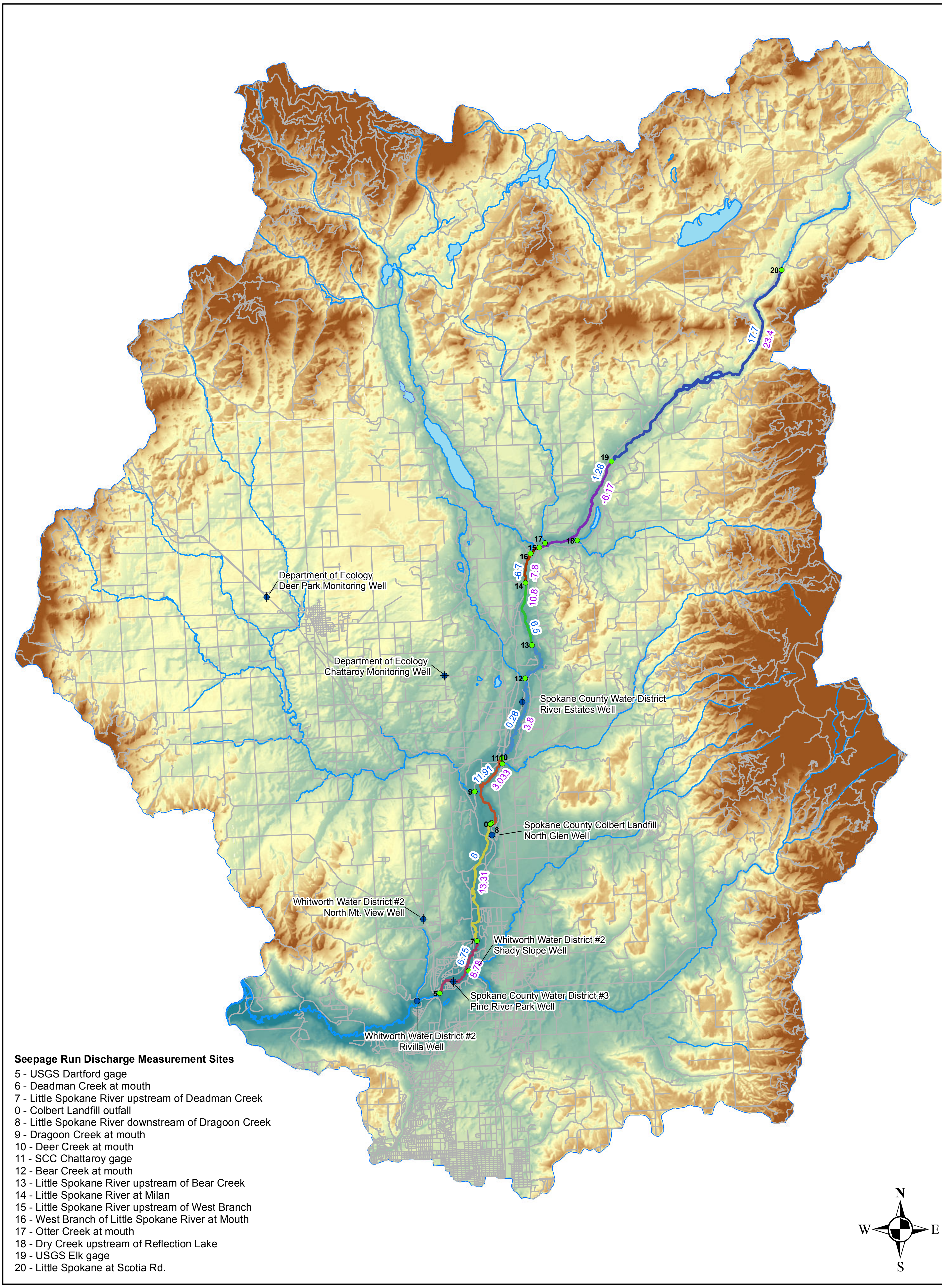


Figure 23 - Little Spokane River Seepage Runs

Little Spokane Seepage Run Reaches

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5
- Reach 6
- Reach 7
- Reach 8

Continuous Groundwater Elevation Monitoring Locations

Seepage Run Discharge Measurement Sites

0 0.5 1 2 3 4 Miles

SPOKANE COUNTY
WATER RESOURCES

Little Spokane Ground & Surface Water Monitoring Project - 2011
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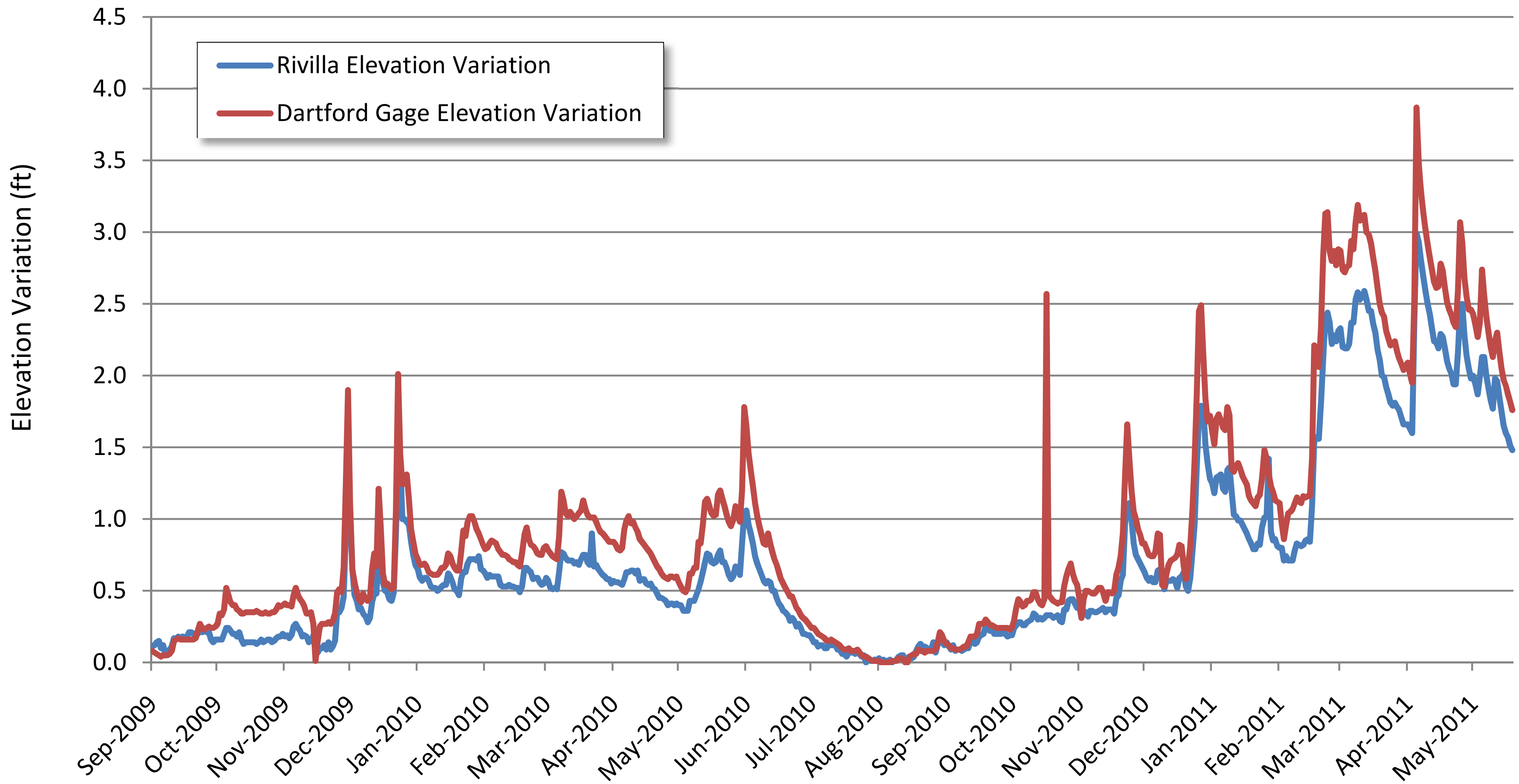
Figure 24

Comparison of Water Level Change: Rivilla Well & Dartford Gage

September 2009 - June 2011

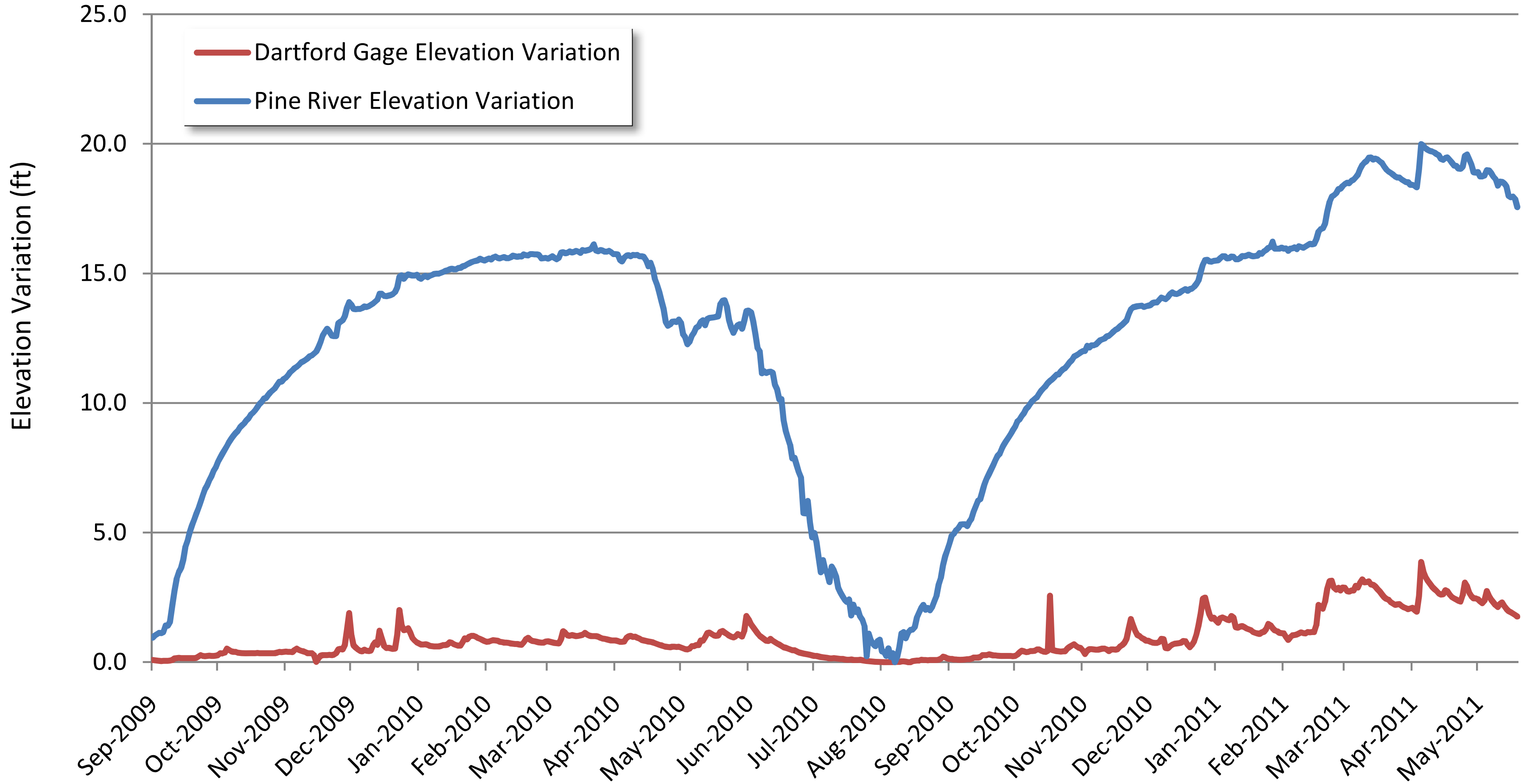


Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Figure 25

Comparison of Water Level Change: Pine River Park & Dartford Gage

September 2009 - June 2011

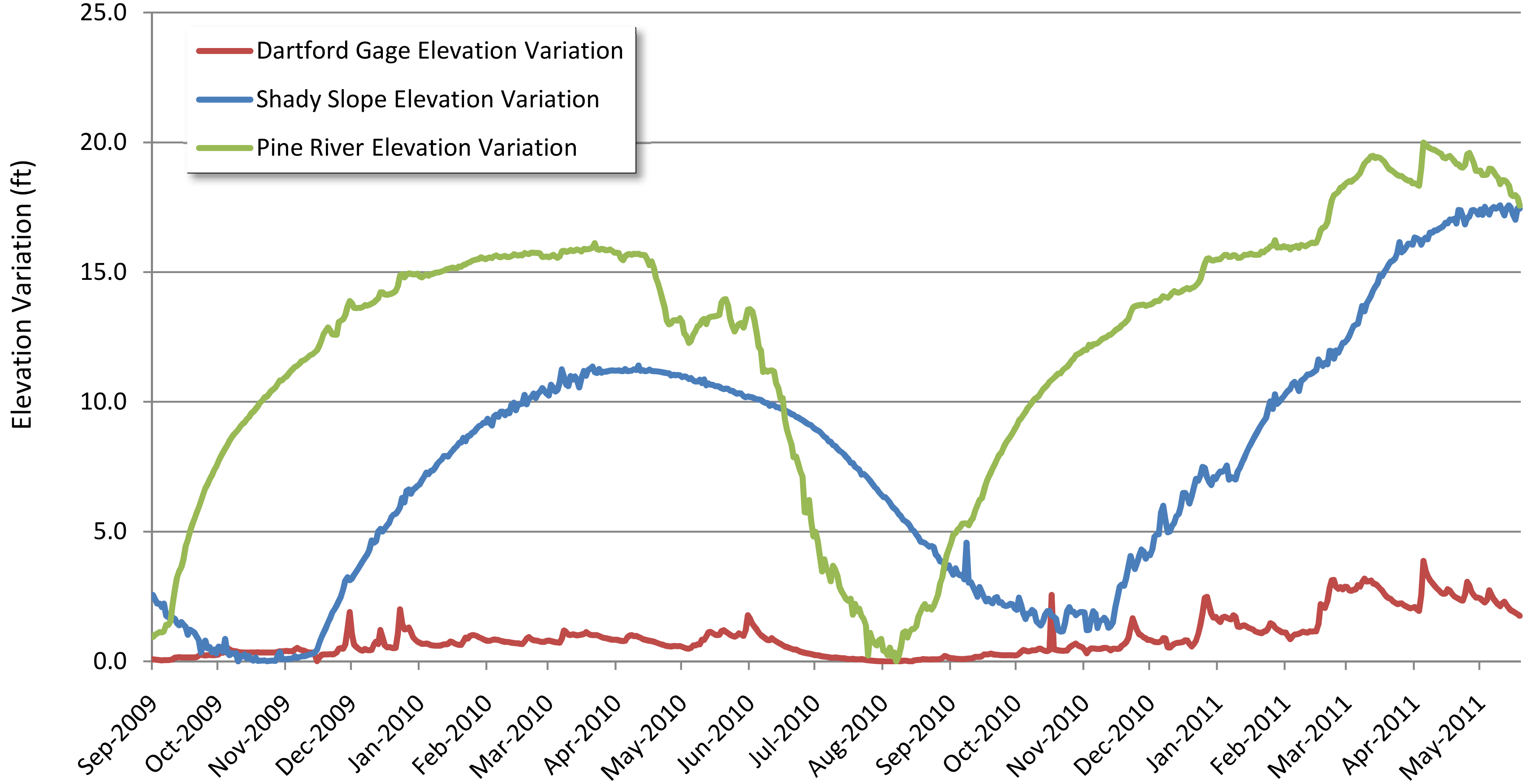


Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Figure 26

Comparison of Water Level Change: Shady Slope, Pine River Park & Dartford Gage

September 2009 - June 2011

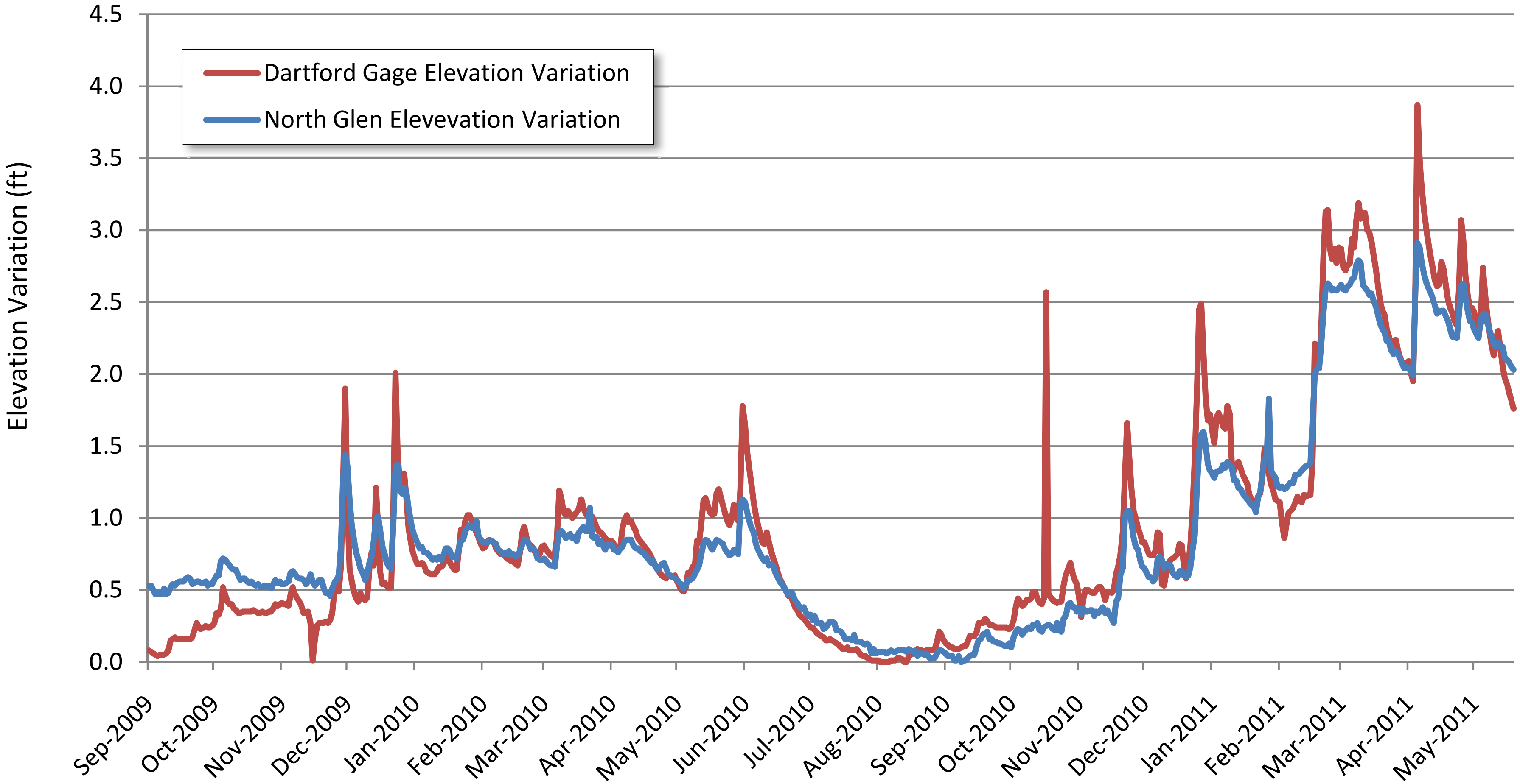


Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Figure 27

Comparison of Water Level Change: North Glen & Dartford Gage

September 2009 - June 2011

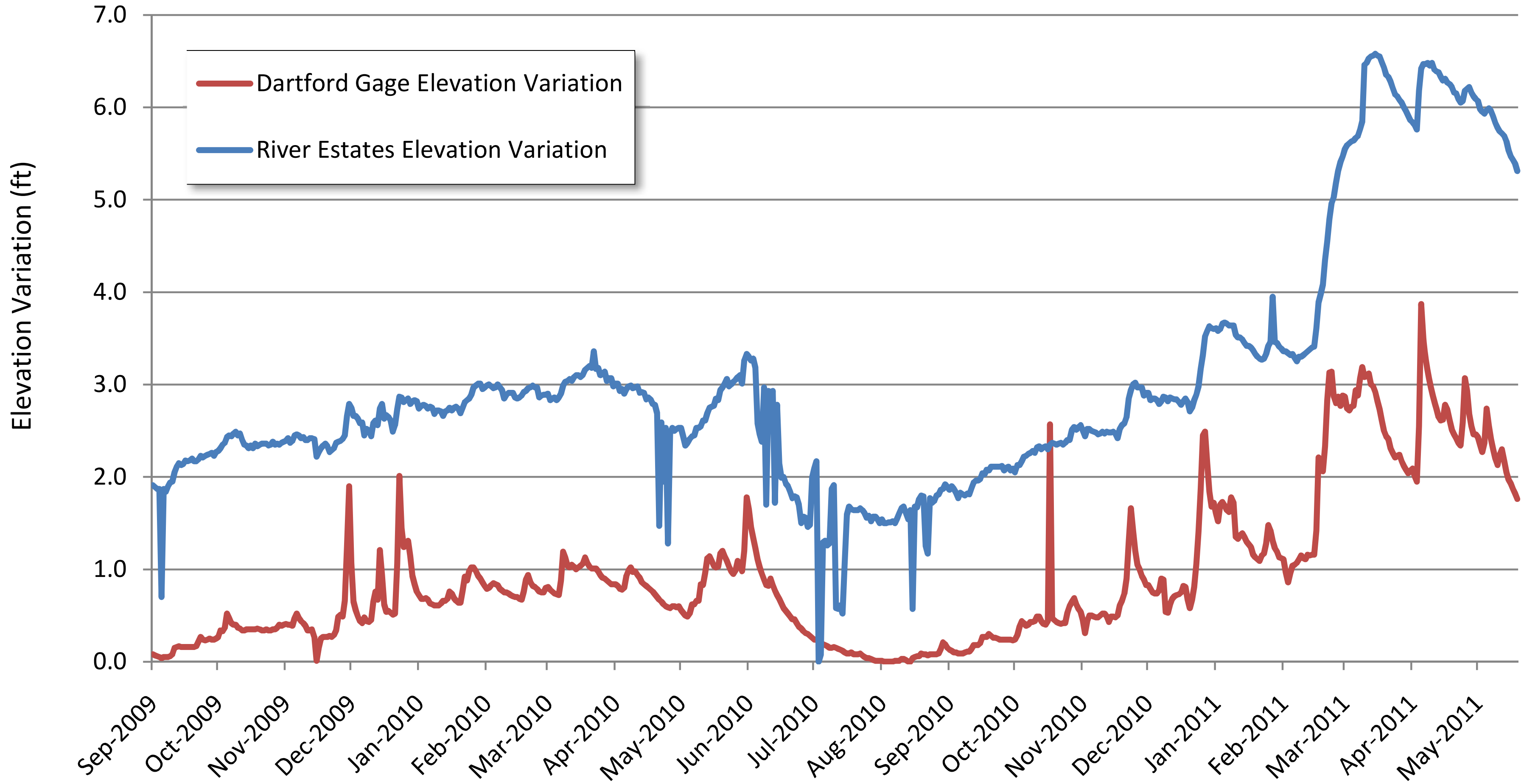


Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Figure 28

Comparison of Water Level Change: River Estates & Dartford Gage

September 2009 - June 2011

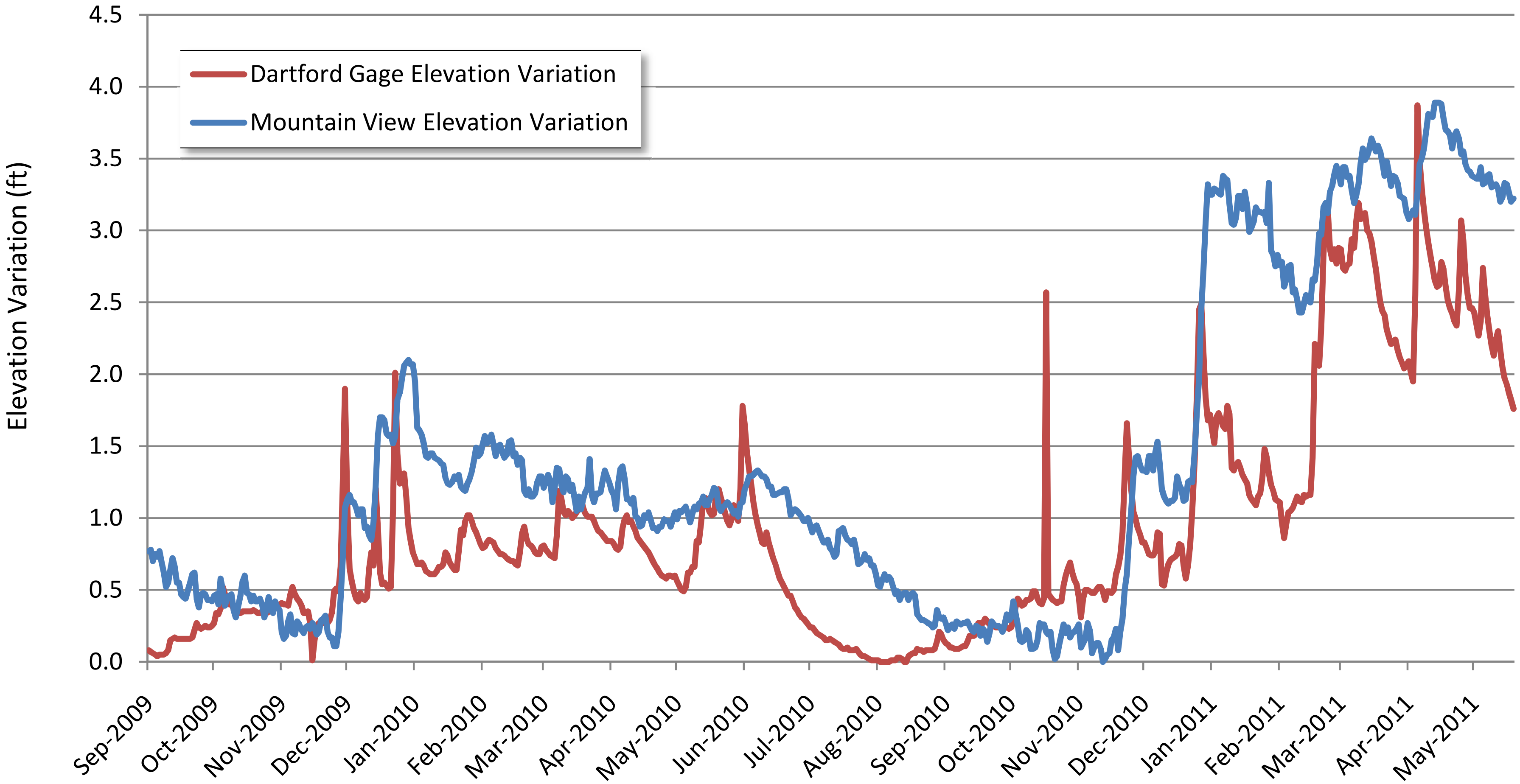


Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Figure 29

Comparison of Water Level Change: North Mt. View & Dartford Gage

September 2009 - June 2011

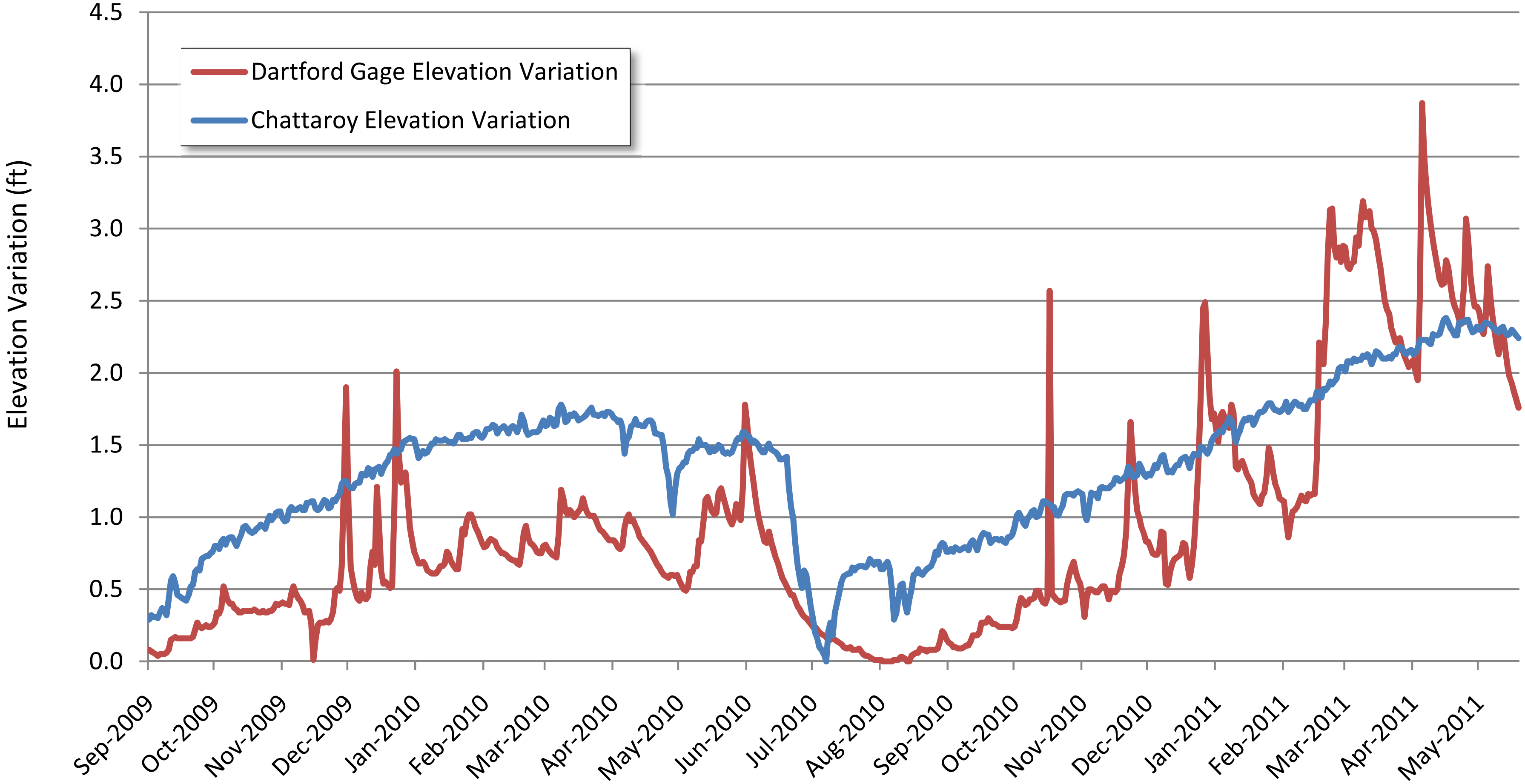


Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Figure 30

Comparison of Water Level Change: Chattaroy & Dartford Gage

September 2009 - June 2011

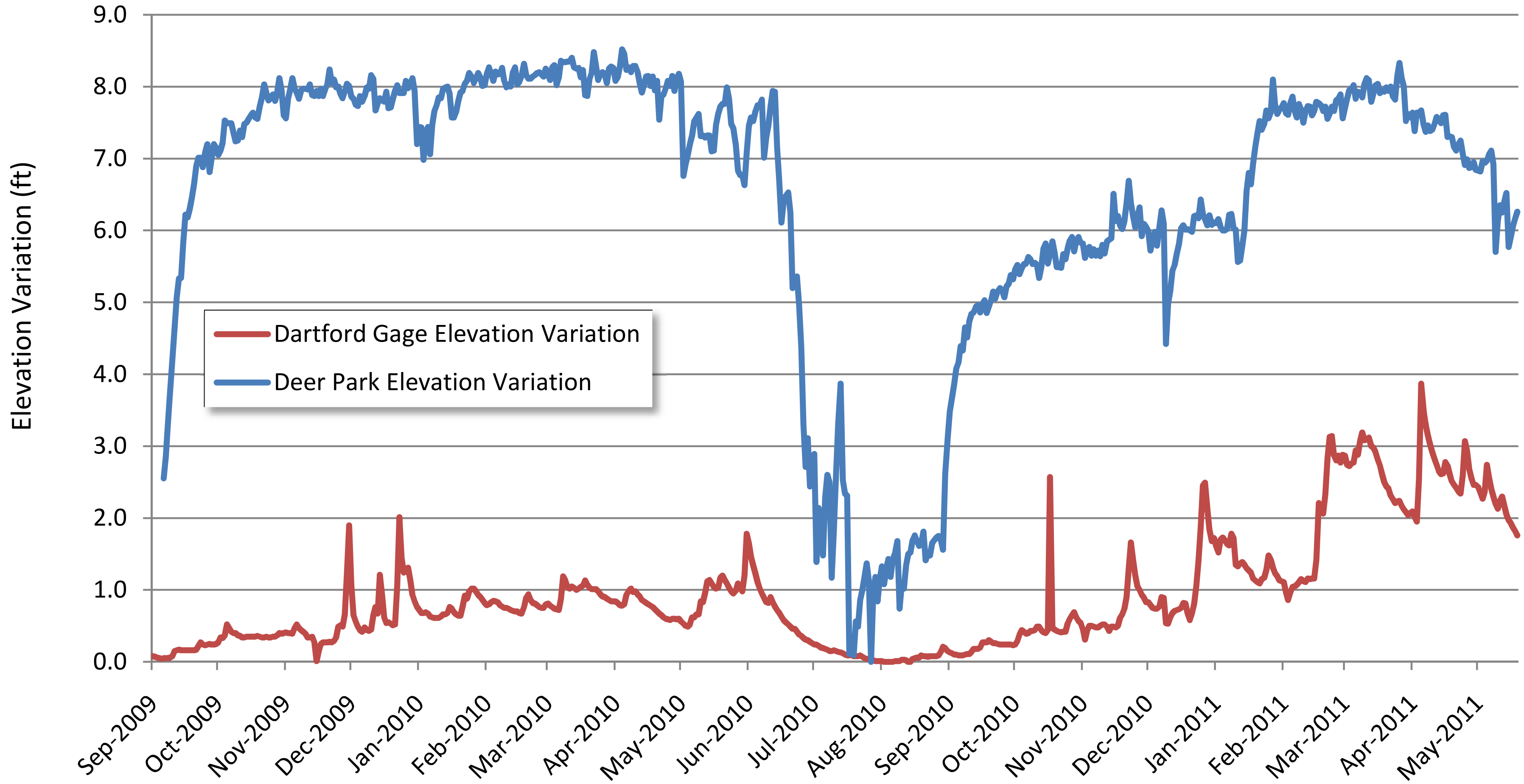


Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Figure 31

Comparison of Water Level Change: Deer Park & Dartford Gage

September 2009 - June 2011



Note: The y axis represents the difference between the daily value and the minimum value recorded over the study period.

Appendix A

Spokane Conservation District
Little Spokane River Seepage Run Summary Report

Little Spokane River Seepage Run Summary Report

In 1976 an instream flow rule (WAC 173-555) established minimum flows for the Little Spokane River. When river flows drop below the minimum flow established in rule, water right holders junior to the rule are ordered to cease withdrawals from the river. In 21 of the last 32 years, stream flow in the Little Spokane River have fallen below the minimum instream flow requirements and junior water right holders have been ordered to cease withdrawals. In that same time frame approximately 8,900 wells, mainly for domestic purposes, have been drilled in the basin. A better understanding of the ground/surface water interactions will improve the understanding of the impacts of ground-water withdrawals on surface water flows and may provide ways to increase surface water flows.

The headwaters of the Little Spokane River are split between the West Branch of the Little Spokane River and the mainstem. Some studies suggest the mainstem may receive baseflow from the Pend Oreille River system in the form of inter-basin underflow. The West Branch of the Little Spokane River heads in the Diamond Lake drainage and flows through several lakes (Sacheen, Fan, Horseshoe, and Eloika) before merging with the main stem at approximately River Mile 33.

Above Dartford, the Little Spokane River flows are a combination of ground water contributions and tributaries flows (such as from Deadman and Dragoon Creeks). In the lower reach between the Dartford gage and the mouth, flow increases significantly as a result of groundwater discharge from the Spokane Valley Rathdrum Prairie Aquifer. The Little Spokane River has few artificial controls and the hydrograph responds to seasonal influences, such as significant rainfall events and snowpack melt.

A seepage run is an important tool in evaluating the connection of ground and surface waters. The WRIA 55 Ground-Water Inventory and Mapping project completed in June 2009 concluded that adequate seepage run data for the Little Spokane above the Dartford gage did not exist and a new data collection effort was started.

When evaluating surface water quantities during the low flow season, the use of seepage runs (multiple stream flow measurements on a single stream or creek) can provide insight into the ground water and surface water interactions. Identifying the different gaining and losing reaches of a stream can provide information for water and project management. Gaining reaches can provide opportunity for plants to reestablish and grow during dry conditions. Areas where streams are losing surface flow to the ground water system may be areas where the ground water resource is over utilized.

The goal of this project was to build on the 2009 seepage run data and improve the understanding of the connection of ground and surface water in the Little Spokane Basin north of the Dartford gage. The objective was to identify reaches that have a net stream flow gain or loss which infers gains or loss to the associated unconfined aquifer system in connection with the river.

Little Spokane River Seepage Run Discharge Measurements

The Spokane County Conservation District completed 13 stream flow measurements (Table 1) along the Little Spokane River mainstem on September 30, 2010 to evaluate ground water/surface water interactions (Figure 1, Sites 5-20). All sites were measured on a single day. Cross-sections were modified to meet the measurement requirements for depth and velocity outlined in Rantz and others. All sites identified in the QAPP (Table 1) were measured, with the following exceptions:

1. The measurement at Site 15, Little Spokane River downstream of West Branch, could not be wadded. The Little Spokane River at Eloika Road immediately upstream of the West Branch confluence was substituted.
2. The outfall from Reflection Lake was added.

Table 1: Measurement Site Types and Locations identified in the Approved QAPP

Site	Type	Location
5	Main Stem	USGS Dartford gage – rated discharge
6	Tributary	Deadman Creek at mouth
7	Main Stem	Little Spokane River upstream of Deadman Creek
8	Main Stem	Little Spokane River downstream of Dragoon Creek
9	Tributary	Dragoon Creek at mouth
10	Tributary	Deer Creek at mouth
11	Main Stem	SCC Chattaroy gage – rated discharge
12	Tributary	Bear Creek at mouth
13	Main Stem	Little Spokane River upstream of Bear Creek
14	Main Stem	Little Spokane River at Milan
15	Main Stem	Little Spokane River downstream of West Branch
16	Tributary	West Branch Little Spokane River at mouth
17	Tributary	Otter Creek at mouth
18	Tributary	Dry Creek at mouth
19	Main Stem	USGS Elk gage – rated discharge
20	Main Stem	Little Spokane River at Scotia Road

Notes:

1. USGS is U. S. Geological Survey.
2. SCC is Spokane Community College.

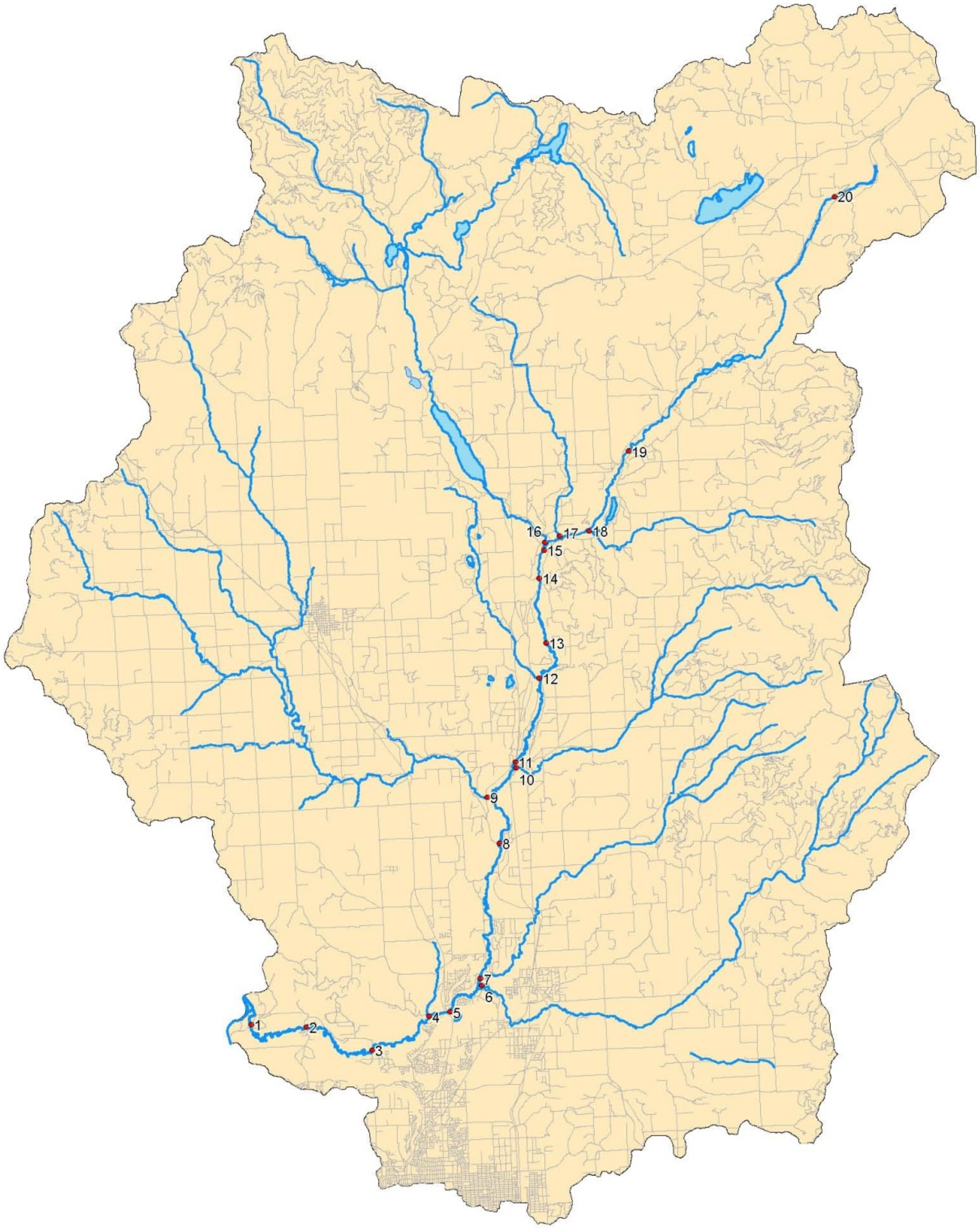


Figure 1: Sample Site Location

The discharge measurements were done during the low flow period. Measurements were made eight days after a small weather system increased the river flow. The measurements were made after the flow stabilized (Figure 2). No large scale irrigation was in operation prior to, or during the measurements. The Colbert landfill treatment discharge to the creek was 1.26 cfs. Along with the flow measurements, the rated flows at three established stream gaging sites were also obtained.

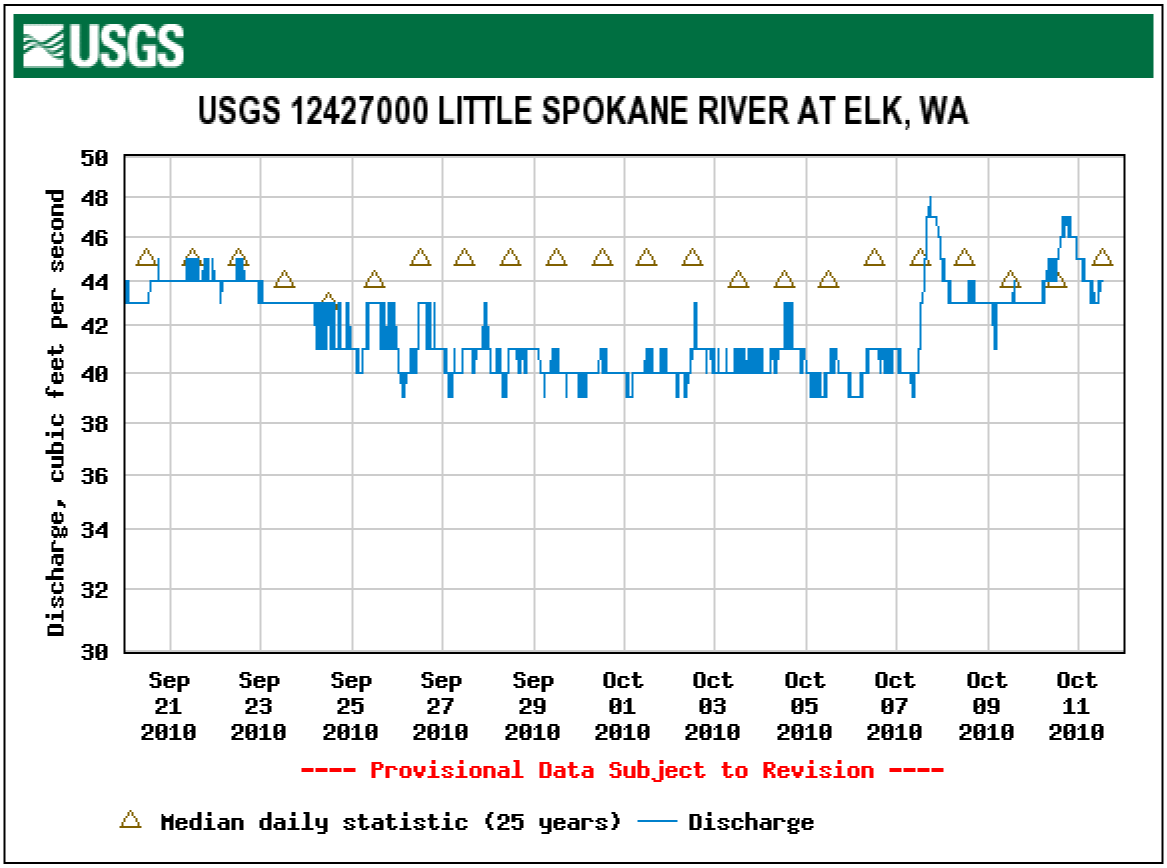


Figure 2: USGS Little Spokane River flows at Elk

Results

Flow measurements along the mainstem of the Little Spokane River increased downstream from the headwaters near Newport, Washington to the confluence with the Spokane River. The seepage run data were collected to differentiate between the contributions to the Little Spokane River from ground water or from tributaries. The groundwater flow measurements completed on September 30, 2010 show significant ground water/surface water interactions, with both gaining and losing reaches (Figure 3), similar to what was seen on the October 7, 2009 seepage run.

For the Little Spokane River, the 2010 flows show significant increases from Scotia to Elk (River Mile 46.9 to 37.6). From Elk to Milan, although the Little Spokane River flow increases

(40.0 cfs to 59.1 cfs), the increase was due to surface water inflow from tributaries (24.5 cfs). The tributary surface flows were 41 percent of the measured flow at Milan. From Elk to Milan, after accounting for the surface water contributions from the tributaries, 5.4 cfs were lost from the Little Spokane River mainstem to groundwater. This is approximately 0.93 cfs per mile. After Milan, the flows due to groundwater slightly increase to Chattaroy with significant increases downstream of Chattaroy Table 3. The 2009 and 2010 streamflow measurements are shown on Figure 4, along with stream bed elevation.

Table 2: Little Spokane River Discharge Measurement Summary

River Mile	Description	2009 Discharge (cfs)	2010 Discharge (cfs)	Elevation (feet)
46.9	Little Spokane River at Scotia Road	23.6	22.3	2130
37.6	USGS Elk gage – rated discharge	47.0	40.0	1870
34.6	Dry Creek at mouth	1.72	1.65	NA
NA	Outlet Reflection Lake	5.26	6.15	NA
33.5	Otter Creek at mouth	6.89	5.72	NA
33.2	Little Spokane River upstream of West Branch	54.7	54.8	1790
32.8	West Branch Little Spokane River at mouth	11.5	11.0	NA
31.8	Little Spokane River at Milan	58.4	59.1	1770
29.7	Little Spokane River upstream of Bear Creek	69.2	65.6	1715
27.8	Bear Creek at mouth	3.00	3.12	NA
23.1	SCC Chattaroy gage – rated discharge	76.0	69.0	1690
23.0	Deer Creek at mouth	0.767	1.13	NA
21.4	Dragoon Creek at mouth	20.0	18.7	NA
19.4	Little Spokane River downstream of Dragoon Creek	99.8	102	1655
19.4	Colbert landfill discharge	0.890	1.26	NA
13.5	Little Spokane River upstream of Deadman Creek	114	110	1615
13.0	Deadman Creek at mouth	9.22	8.25	NA
11.1	USGS Dartford gage – rated discharge	132	125	1585

Notes:

1. River miles are for main stem Little Spokane River only, and are measured from the mouth of the Little Spokane River (RM 0.0) upstream. Measurements are from USGS 7.5 minute topographic maps.
2. The Little Spokane River measured cross-section at River Mile 19.4 was above the Colbert landfill discharge in 2009 and below the Colbert landfill discharge in 2010.
3. No discharge was measured at the USGS or SCC sites, the rated flows were used for the stations at Dartford, at Chattaroy, and at Elk.
4. cfs is cubic feet per second.
5. NA is not applicable.

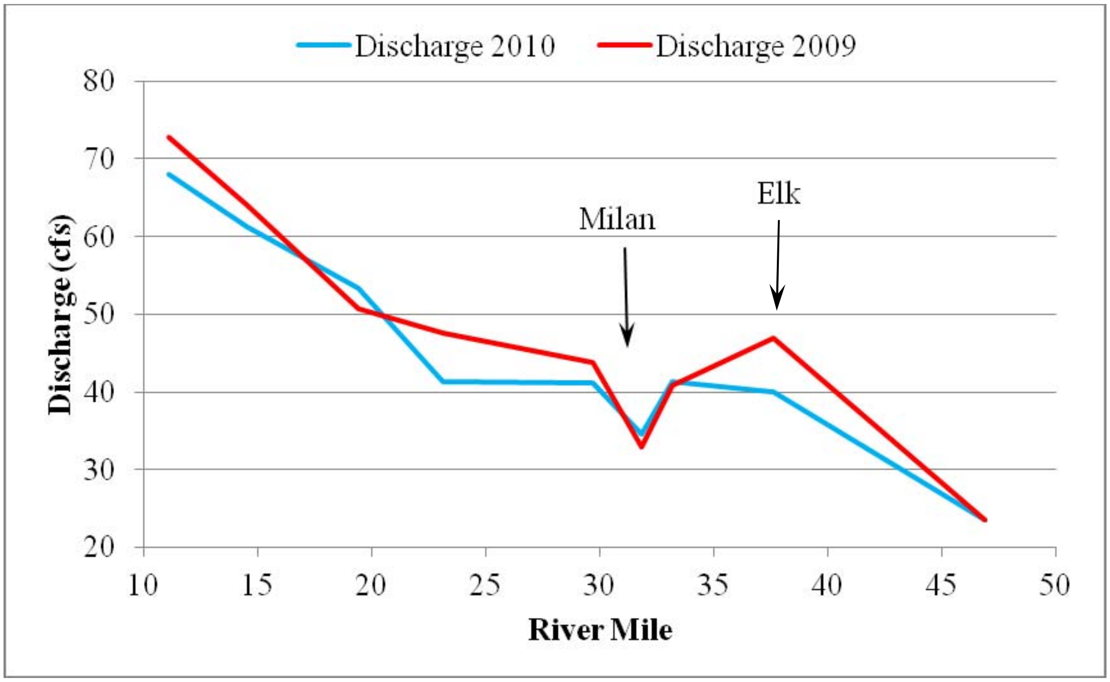


Figure 3: Little Spokane River 2009 and 2010 Groundwater Discharge at Select River Miles

Table 3: Change in Little Spokane River Flow due to Ground Water/Surface Water Interactions

Reach	Reach Length (miles)	Change in Flow due to Ground Water Interactions (Δ cfs)		Change in Flow per mile (cfs/mile)	
		2009	2010	2009	2010
Scotia to Elk	9.3	23	18	2.5	1.9
Elk to West Branch	4.4	-6.2	1.3	-1.4	0.30
West Branch to Milan	1.4	-7.8	-6.7	-5.6	-4.8
Milan to Bear Creek	2.1	11	6.5	5.1	3.1
Bear Creek to Chattaroy	6.6	3.8	0.30	0.58	0.05
Chattaroy to Colbert	3.7	3.1	11.9	0.84	3.22
Colbert to Deadman Creek	5.9	13	8.0	2.2	1.4
Deadman Creek to Dartford	2.4	8.8	6.7	3.7	2.8

Notes:

1. cfs is cubic feet per second.
2. Reach lengths are based on distance between measurements on the Little Spokane River mainstem as listed in Table 2.

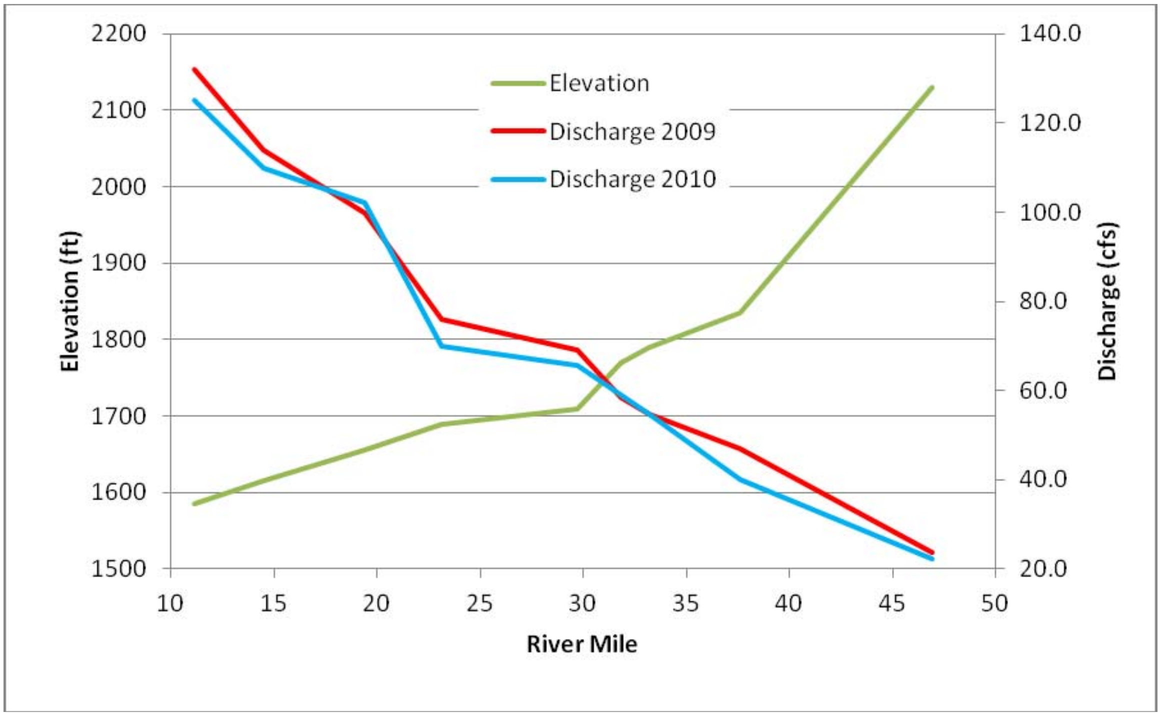


Figure 4: 2009 and 2010 Discharge Measurements at Select River Miles