5. Spokane River – SVRP Aquifer Interaction

Water is exchanged between the Spokane River and the SVRP Aquifer for much of the river's length. The Spokane River is the largest source of recharge to the aquifer. There are several reaches where the Spokane River discharges to the aquifer: 1) Coeur d'Alene Lake to Flora Road; 2) Plantes Ferry to Upriver Dam; and 3) Green Street to Monroe Street (Figure 58). These reaches are considered losing reaches (Figure 59). It is estimated that the Spokane River loses 718 cubic feet per second (cfs) of water to the aquifer, representing 49 percent of the aquifer's total mean annual inflow of 1,417 cfs.

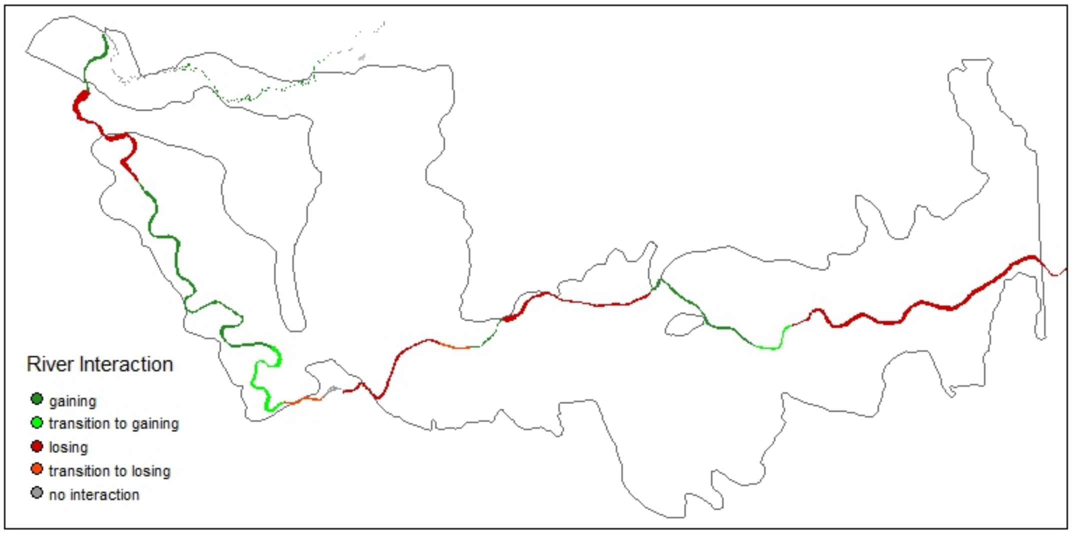

Figure 58. The gaining and losing reaches of the Spokane River and the groundwater source of each well. Groundwater source was determined by using total dissolved solids (TDS) and conductivity as an indicator of groundwater interaction with the Spokane River.

There are also two distinct river reaches where the Spokane River receives water from the aquifer: 1) Flora Road to Trent Road; and 2) The Spokane Gage to Nine Mile Dam. These reaches are considered gaining reaches (Figures 58 and 59). The Spokane River receives an estimated 861 cfs from the aquifer, representing 59 percent of the aquifer's total mean annual outflow of 1,468 cfs (Hsieh, et al 2007).

This section discusses the groundwater – surface water interactions in a losing reach and two gaining reaches of the Spokane River.

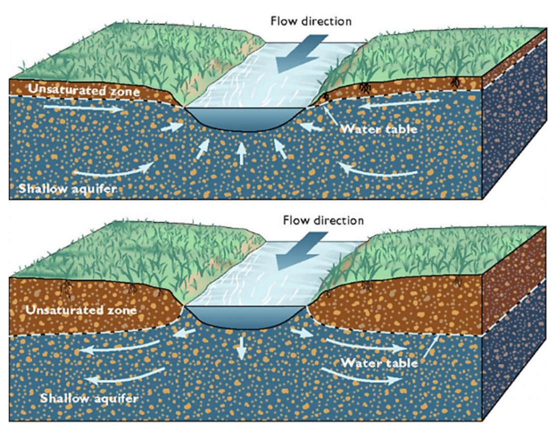

Figure 59. Diagram showing the groundwater-surface water interaction in a gaining reach (top) and losing reach (bottom).

5.1. Losing Reach: Barker Road Cross-Section

At a losing reach, the aquifer's water quality can be influenced by the river's water quality. The Spokane River's influence on groundwater was assessed by examining seven monitoring locations along Barker Road that provide a cross-section of a losing reach of the Spokane River. These sites span from the Trent and Barker Road monitoring well (5505D01) to the CID Site 2A purveyor well (5518R01) (Figure 60) and have been previously used to study the Spokane River – SVRP Aquifer interaction by both Ecology (Marti and Garrigues 2001) and the USGS (Caldwell and Bowers 2003).

Where available, data from Ecology's EIM database for the Spokane River at Barker Road for the same 20-year period was used for comparison with groundwater quality along the cross section. Due to the limited Spokane River data available, all available data was used and not limited to a certain season.

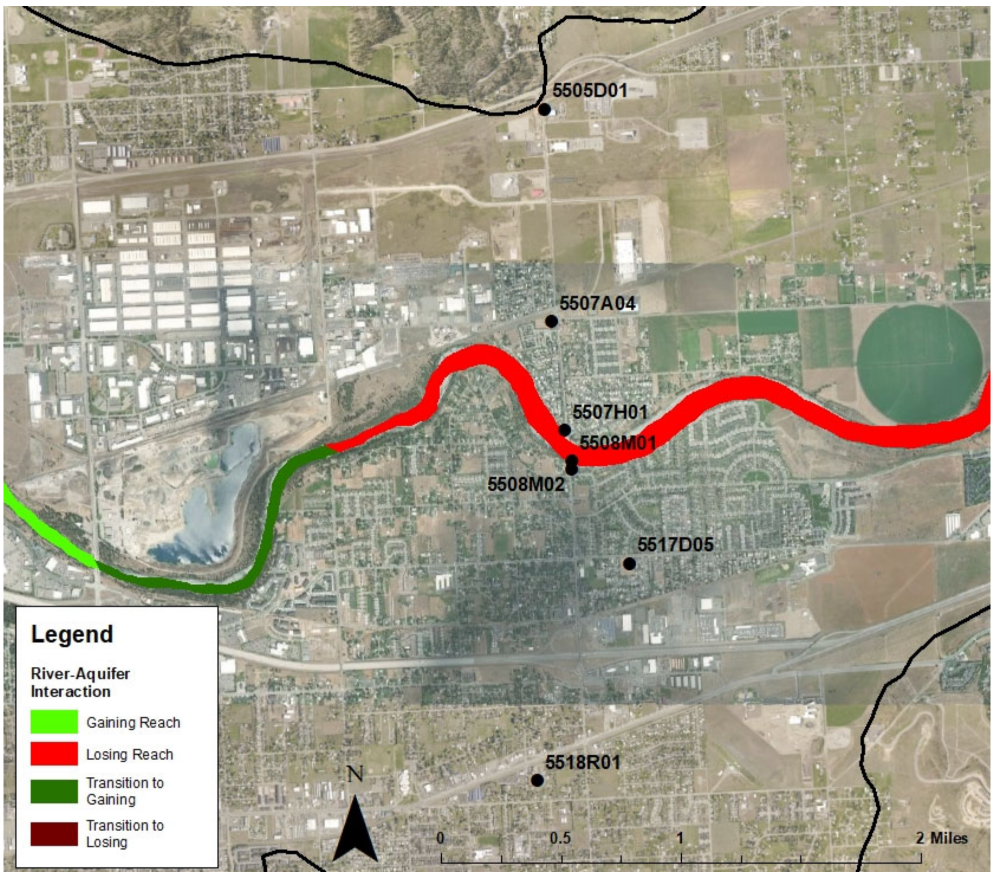

Figure 60. An aerial view of the lower portion of the losing reach of the Spokane River from the stateline to Flora Road, including the seven monitoring locations along Barker Road used to provide a cross-section of groundwater conditions.

This assessment confirms findings presented by Ecology (Marti and Garrigues 2001) and the USGS (Caldwell and Bowers 2003). The groundwater levels along the cross-section range from 10 to 20 feet below the river's bottom elevation at ~1980 feet, indicating the river recharges the groundwater at Barker Road. However, the groundwater gradient along the cross-section suggests the water tends to flow in a southwesterly direction. Therefore, the river provides more recharge and mixing with groundwater to the south. The groundwater from the northern-most wells (5505D01 and 5507A01) is not influenced by the river (Figure 61).

This is confirmed by the water quality data. Groundwater temperature, conductivity, and major ion concentrations are useful indicators of the extent of the Spokane River's influence on the aquifer. Groundwater from the northern-most wells (5505D01 and 5507A01) has relatively stable, cooler temperatures with high conductivity and major ion concentrations indicative of the regional groundwater system. The groundwater immediately adjacent to the river (5507H01, 5508M01 and 5508M02) has highly variable, but generally warmer temperatures with lower conductivity and major ion concentrations like the river.

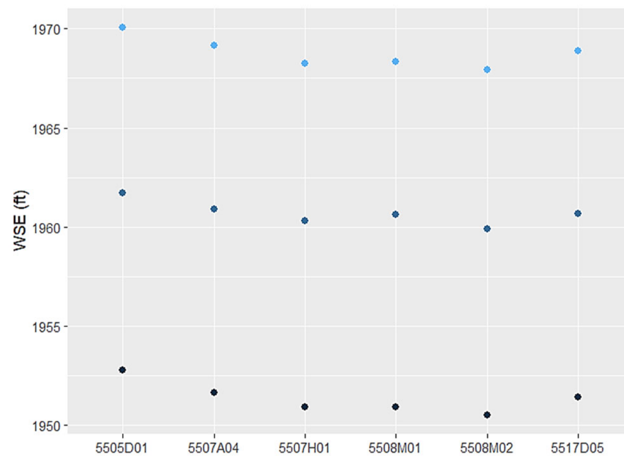

Figure 61. Water surface elevations (WSE, in feet) at six groundwater sites along Barker Road representing a cross-section at a losing reach of the Spokane River. Each set of WSEs were measured during three separate monitoring events occuring at high, medium, and lower groundwater levels. Groundwater moves in the direction from high to low elevations.

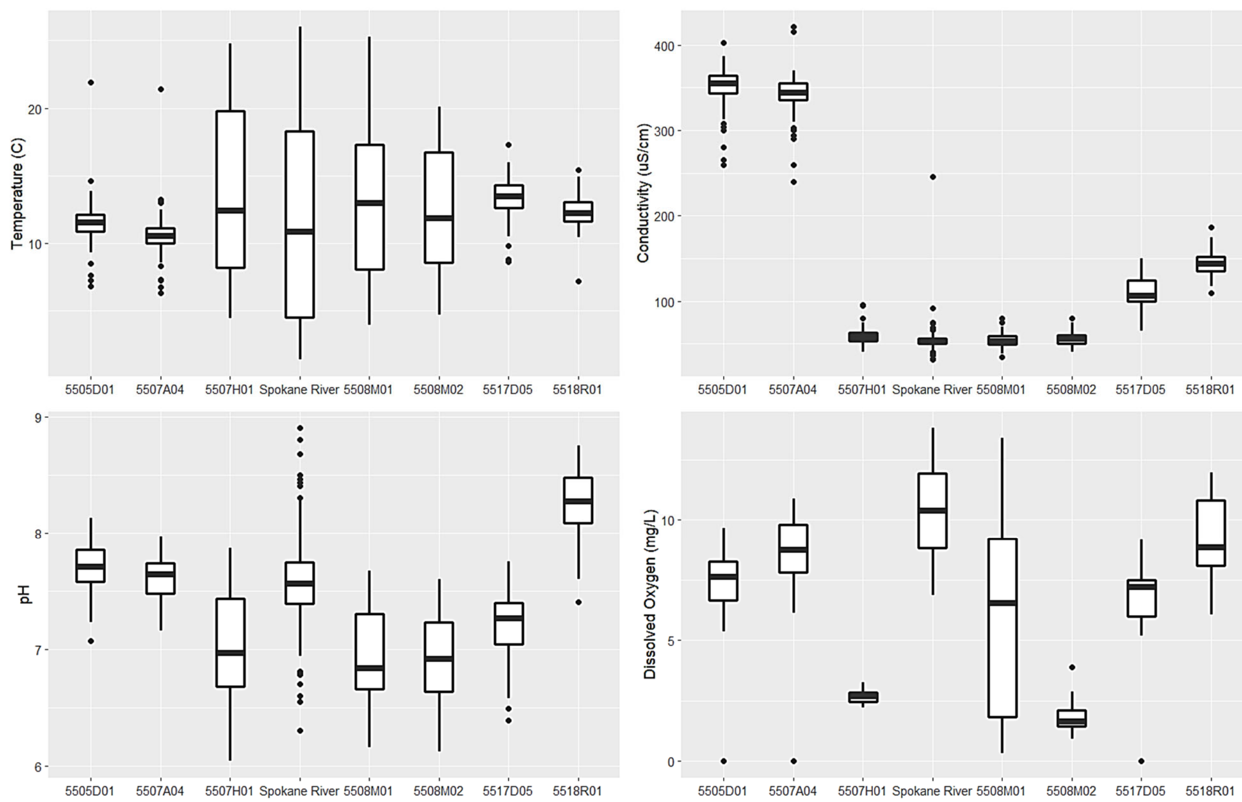

Figure 62. Boxplots comparing temperature (in Celsius), pH, conductivity (in uS/cm), and dissolved oxygen (in mg/L) measurements collected between 1999 and 2019 at seven wells along Barker Road and the Spokane River at Barker Road representing a cross-section at a losing reach of the river. From left to right, the sites are arranged from the northern most site at Trent and Barker monintoring well (5505D01) to the southern most site at the Consolidated Irrigation District Site 2A purveyor well (5518R01). Data for the Spokane River at Barker Road was compiled from Ecology's Environmental Information Management (EIM) database.

Groundwater from the southern-most locations (5517D05 and 5508R01) has slightly higher temperatures, conductivity, and major ion concentrations indicating a potential mixing of river water and groundwater (Figures 62 and 63).

The USGS categorized groundwater into three source water groups based on median total dissolved solids (TDS) concentration (Table 6). According to this scheme, a median TDS less than 50 mg/L indicates that groundwater primarily originates from the Spokane River, a median TDS greater than 100 mg/L indicates that groundwater originates from the regional groundwater system, and a median TDS between 50 and 100 mg/L indicates the groundwater is likely a mixing from the river and the regional system. Median conductivity levels at each location fit the USGS groundwater source classification scheme, given that conductivity can be converted to TDS using equation (EQN) 2:

EQN 2. Conductivity (us/cm) x 0.64 = TDS (mg/L)

Table 6. Groundwater source classification for the losing reach monitoring locations using total dissolved solids (TDS) and conductivity as an indicator of groundwater interaction with the Spokane River based on USGS.

Groundwater Source	TDS (mg/L) Range	Conductivity (uS/cm) Range	Monitoring Locations
River	<50	<78	5507H01, 5508M01 and 5508M02
Transitional	50 – 100	78 – 156.25	5517D05 and 5508R01
Regional	>100	>156.25	5505D01 and 5507A01

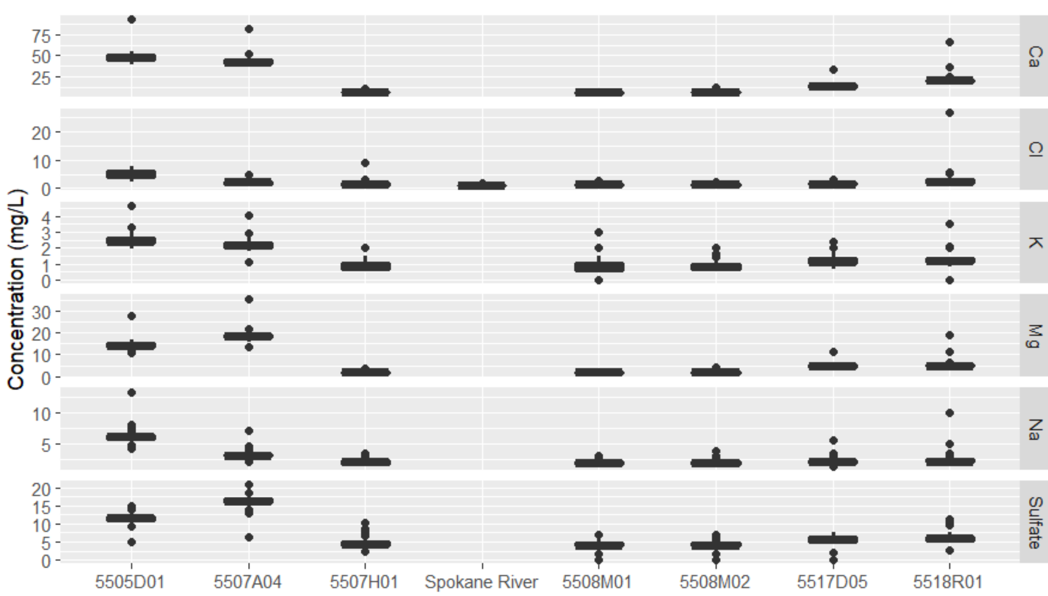

Figure 63. Boxplots comparing major ion concentrations (in mg/L) measured in samples collected between 1999 and 2019 at seven wells along Barker Road and the Spokane River at Barker Road representing a cross-section at a losing reach of the river. From left to right, the sites are arranged from the northern most site at Trent and Barker monintoring well (5505D01) to the southern most site at the Consolidated Irrigation District Site 2A purveyor well (5518R01). Major ions are calcium (Ca), chloride (Cl), potassium (K), magnesium (Mg), sodium (Na), and sulfate. Data for the Spokane River at Barker Road was compiled from Ecology's Environmental Information Management (EIM) database.

Groundwater from the river influenced wells 5507H01 and 5508M02 have lower levels of dissolved oxygen (median DO<3 mg/L) and slightly acidic conditions (median pH<7). While this differs from the river's conditions, the USGS noted that the river transports fine-grained materials that settle into the spaces between the aquifer sediments, reducing permeability. This could be affecting dissolved oxygen and pH levels in the river-influenced aquifer. The difference in the DO and pH levels at each site helps explain differences in nutrient and trace metal concentrations along the cross-section.

Nitrate data reflect a similar pattern displayed in conductivity and major ion concentrations (Figure 64). The lower concentrations of nitrate in the Spokane River with groundwater concentrations increasing with distance from the river suggests a dilution effect from the river. Periodic anoxic conditions occurring in the near river aquifer may promote denitrification (the reduction of nitrate to nitrogen gas), which could also contribute to lower nitrate in the near-river aquifer.

Total phosphorus and SRP data along the losing reach demonstrate that the Spokane River may be contributing phosphorus into the near-river aquifer (Figure 64). This is evidenced by higher median concentrations in samples from wells in proximity to the river and concentrations generally decreasing with distance from the river. While there may be some direct transport, the slightly acidic and periodic anoxic conditions in the near-river aquifer may promote mobilization of phosphate anions, which could contribute to the higher concentrations.

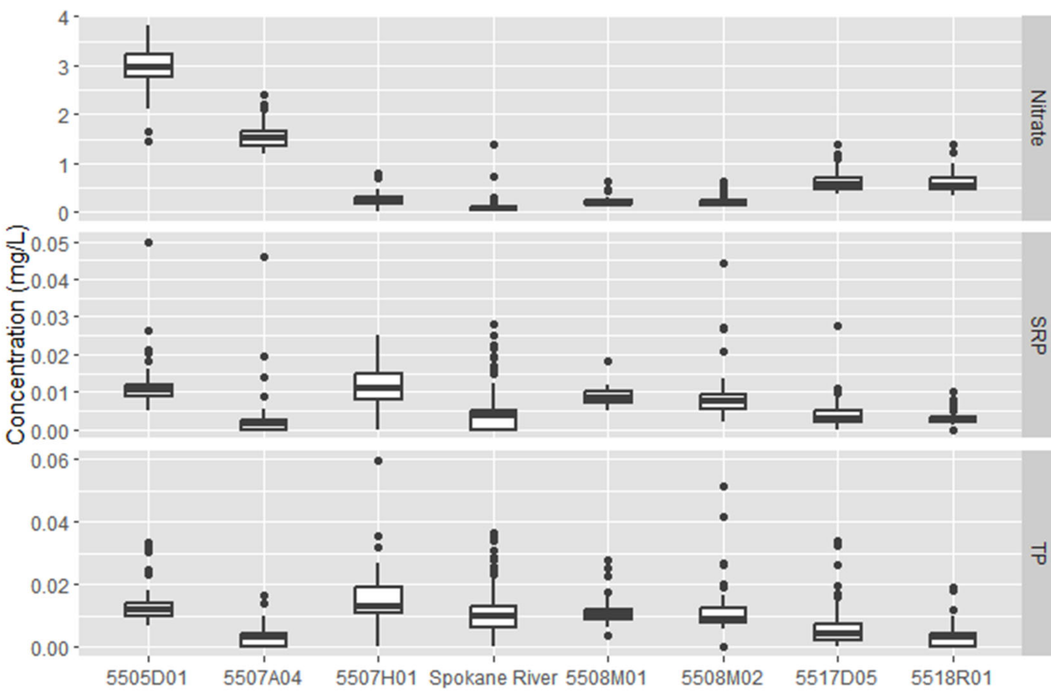

Figure 64. Boxplots comparing nutrient concentrations (in mg/L) measured in samples collected between 1999 and 2019 at seven wells along Barker Road and the Spokane River at Barker Road representing a cross-section at a losing reach of the river. From left to right, the sites are arranged from the northern most site at the Trent and Barker monintoring well (5505D01) to the southern most site at the Consolidated Irrigation District Site 2A purveyor well (5518R01). Nutrients are nitrate, soluble reactive phosphorus (SRP), and total phoshorus (TP). 5518R01 has a TP outlier of 0.43 mg/L not shown here. Data for the Spokane River at Barker Road was compiled from Ecology's Environmental Information Management (EIM) database.

Previous studies indicated the Spokane River is a likely source of cadmium, copper, lead, and zinc in the aquifer, but that these metals are not transported far in the aquifer. Data presented here mostly confirms this. The Spokane River has higher concentrations of these metals than groundwater and they are generally not detectable outside of the river-influenced aquifer (represented by 5507H01, 5508M01 and 5508M02) due to pH-influenced sorption processes (Figure 65). These metals commonly exist as positively charged ions and will sorb onto aquifer sediments as they move further from the river into the more alkaline (pH>7) conditions.

Even so, the metals transported from the Spokane River to the SVRP Aquifer have low detection rates in the river-influenced aquifer. Detection rates for the well immediately north of the river (5507H01) are as follows: cadmium, 20 percent; copper, 40 percent; and lead, 25 percent. For the well immediately south of the river (5508M01), lead is generally not detectable, and cadmium and copper are detectable 30 and 11 percent of the time, respectively.

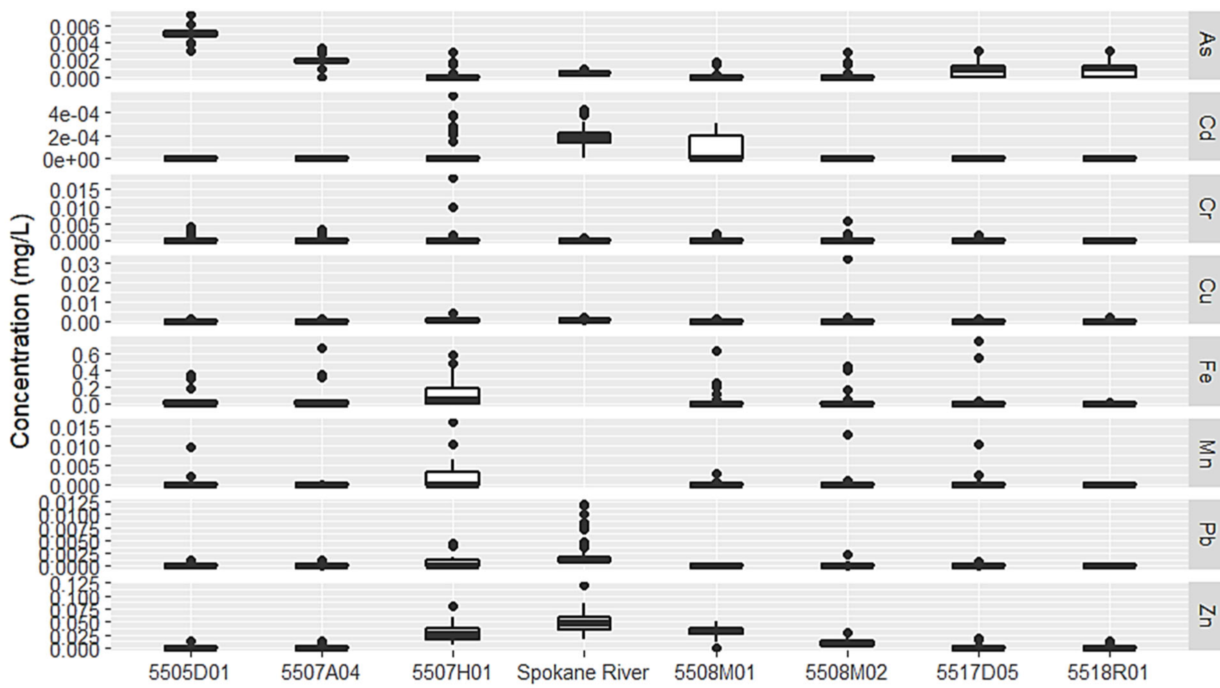

Figure 65. Boxplots comparing concentrations of trace metals (in mg/L) measured in samples collected between 1999 and 2019 at seven wells along Barker Road and the Spokane River at Barker Road representing a cross-section at a losing reach of the river. From left to right, the sites are arranged from the northern most site at Trent and Barker monintoring well (5505D01) to the southern most site at the Consolidated Irrigation District Site 2A purveyor well (5518R01), which is the general direction of groundwater flow (shown by arrow). Trace metals are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), and zinc (Zn). Data for the Spokane River at Barker Road was compiled from Ecology's Environmental Information Management (EIM) database.

Zinc, however, is generally detectable in the river-influenced aquifer. The median groundwater concentration is about 0.03 mg/L immediately north (5507H01) and south (5508M01) of the river, slightly lower than the median river concentration of 0.0383 mg/L. The median groundwater concentration drops to 0.01 mg/L at 5508M02. Zinc is generally non-detectable in groundwater collected from outside of the river-influenced aquifer.

Of the other metals assessed, iron and manganese are detected about half the time in samples collected just north of the river (5507H01) but are generally not detectable at remaining groundwater locations along the cross-section. Due to lack of river data for these parameters, it is unclear if the Spokane River is a potential source, or if the iron and manganese levels are a result of more localized conditions. Chromium is generally not detectable in the Spokane River or the SVRP aquifer along the losing reach.

Arsenic is detectable in the regional and transitional groundwater. Median concentrations at these sites are between 0.002 and 0.005 mg/L. However, arsenic drops to undetectable levels in the river-influenced aquifer where groundwater becomes more acidic. This promotes adsorption of arsenic to the aquifer sediments, reducing the concentration in the river-influenced groundwater.

5.2. Gaining Reach: Sullivan Road to Trent Avenue

A gaining reach is where the aquifer discharges groundwater into the river (Figure 59). Along such reaches, groundwater mixes with river water influencing the river's water chemistry. To look at how the Spokane River's chemistry changes along the gaining reach in response to groundwater inputs, data from the Ecology EIM database was compiled for surface water monitoring locations along the gaining reach that spans from Sullivan Road to Plantes Ferry (Figure 66). For the same 20-year period (1999 – 2019), the EIM Spokane River dataset is limited to temperature, pH, conductivity, chloride, and nutrient (nitrate, phosphorus, and SRP) data for three locations along the gaining reach: Sullivan Road (RM87.8), Trent Street (RM85.3), and Plantes Ferry (RM84). The Spokane River at Barker Road (RM90.4) location is also provided to show river conditions just upstream of the gaining reach. Due to the limited Spokane River data available, all available data was used and not limited to low-flow summer conditions when groundwater influence is the strongest.

This was compared to the County's data for groundwater monitoring locations along the gaining reach. To better relate groundwater data to the Spokane River data, data from monitoring locations were combined to show conditions at each of the river locations (Table 7).

Table 7. Combined data from groundwater monitoring locations representing groundwater conditions at each river location.

River Locations	Groundwater Locations
Barker Rd.	*Groundwater data not used for analysis
Sullivan Rd.	5411R05s, 5411R03, 5411R06
Trent St.	6436N01
Plantes Ferry	(Plantes Ferry/5404A01 not used)

For example, data from the three groundwater monitoring locations at Sullivan Road (5411R05s, 5411R03, 5411R06) were combined to show overall groundwater conditions at Sullivan Road. Data from the East Valley High School monitoring well is used to represent groundwater entering the river in the vicinity of Trent based on flow paths from purveyor well capture zones (CH2M Hill 1998). The groundwater from the Plantes Ferry monitoring well (5404A01) represents a unique condition associated with its proximity to the edge of the aquifer boundary and a confining layer, and it is not used in this assessment since the data suggests that either the confined aquifer is not interacting with the river or the groundwater input from the confined aquifer is low enough to be extremely diluted.

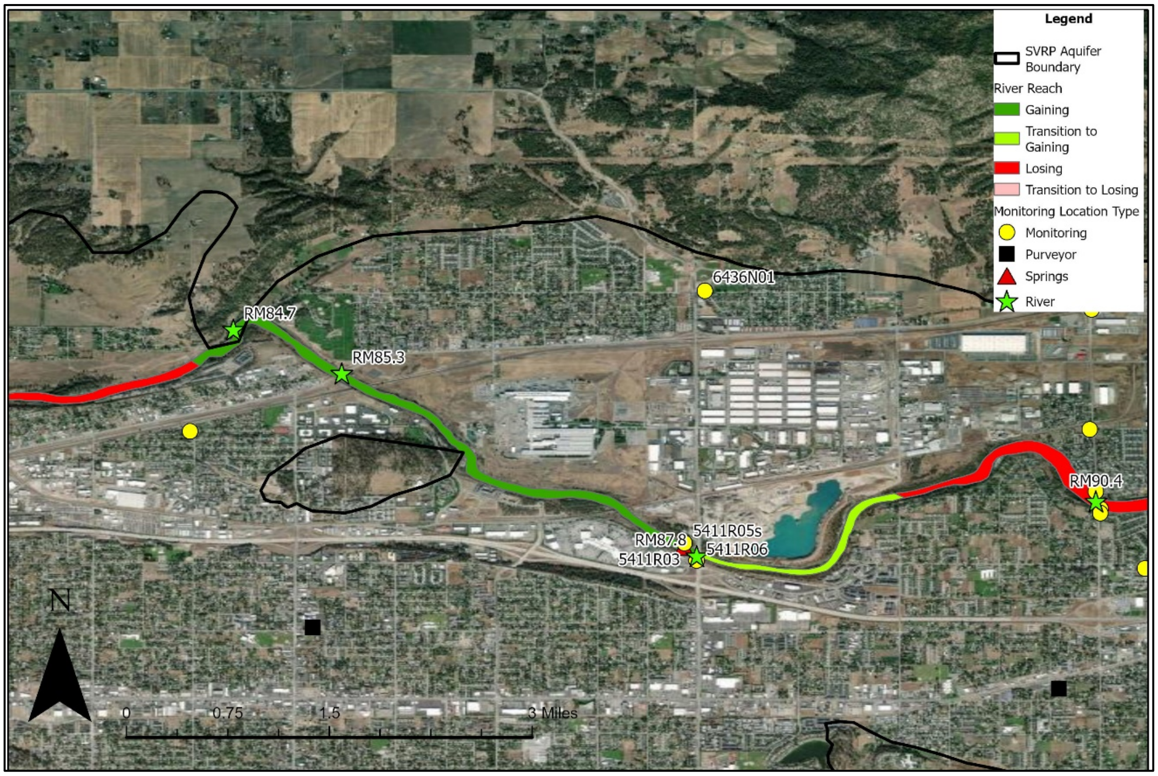

Figure 66. An aerial view highlighting the gaining reach of the Spokane River spanning from Sullivan Road at river mile (RM) 87.8 to Plantes Ferry at RM 84.7. The other monitoring locations used to assess surface water and groundwater conditions along the gaining reach include two monitoring wells at Sullivan Road (5411R03 and 5411R06), the Sullivan Park springs (5411R05s), the East Valley High School monitoring well (6436N01), and the Spokane River at Trent (RM85.3). Groundwater data from several wells were combined to provide groundwater conditions at each of the river locations as indicated in Table 7.

River temperature and conductivity data provide insight to groundwater contributions along a gaining reach. Groundwater influence is usually represented by a decrease in river temperatures and an increase in river conductivity. This generalization is for low-flow summer conditions when groundwater inputs are providing much of the river flow within a gaining reach. Though the data is not limited to low-flow conditions, this pattern can still be seen in the data.

While median river temperature increases from Barker to Trent, the max temperature decreases from 26 to 16 degrees Celsius. This demonstrates the cooling effect of the groundwater inputs along this reach. Median river conductivity increases from Barker (median 53 uS/cm) to Trent (median 205 uS/cm) in response to groundwater as expected (Figure 67).

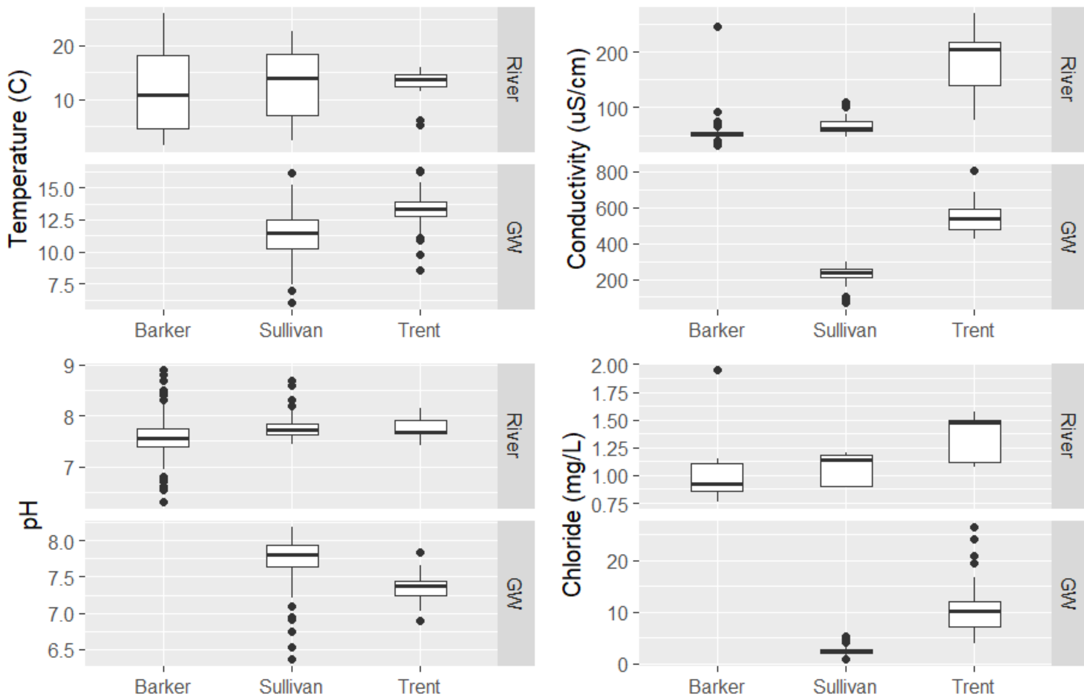

Figure 67. Boxplots comparing river and groundwater (GW) temperature (in Celsius), pH, conductivity (in uS/cm), and chloride concentrations (in mg/L) at locations along a gaining reach of the Spokane River. From left to right, the sites are arranged from east to west, from Barker Road to Trent Avenue, which is the direction of the Spokane River's flow. Spokane River data is from Ecology's Environmental Information Management (EIM) database.

The data suggests that the aquifer may be contributing chloride and nutrients to the river. The groundwater locations generally have higher concentrations of these constituents than their river counterparts, leading to an overall increase in river concentrations in the gaining reach (Figures 67 and 68). Between Barker and Trent, median river levels increase from 0.93 to 1.48 mg/L for chloride, 0.06 to 0.67 mg/L for nitrate, 0.0097 to 0.014 mg/L for total phosphorus, and 0.0036 to 0.005 mg/L for SRP.

In all cases, groundwater entering the river near Trent appears to have the largest impact on river water quality along the gaining reach. The groundwater entering the river at Trent has much higher concentrations of chloride and nutrients than that entering at Sullivan. This may be in part due to the groundwater from Trent traveling along the margins of the aquifer to the north of the river, where chloride and nutrients tend to concentrate. In addition, there may be some influence from non-sewered areas along this flow path (see Section 7.1.9)

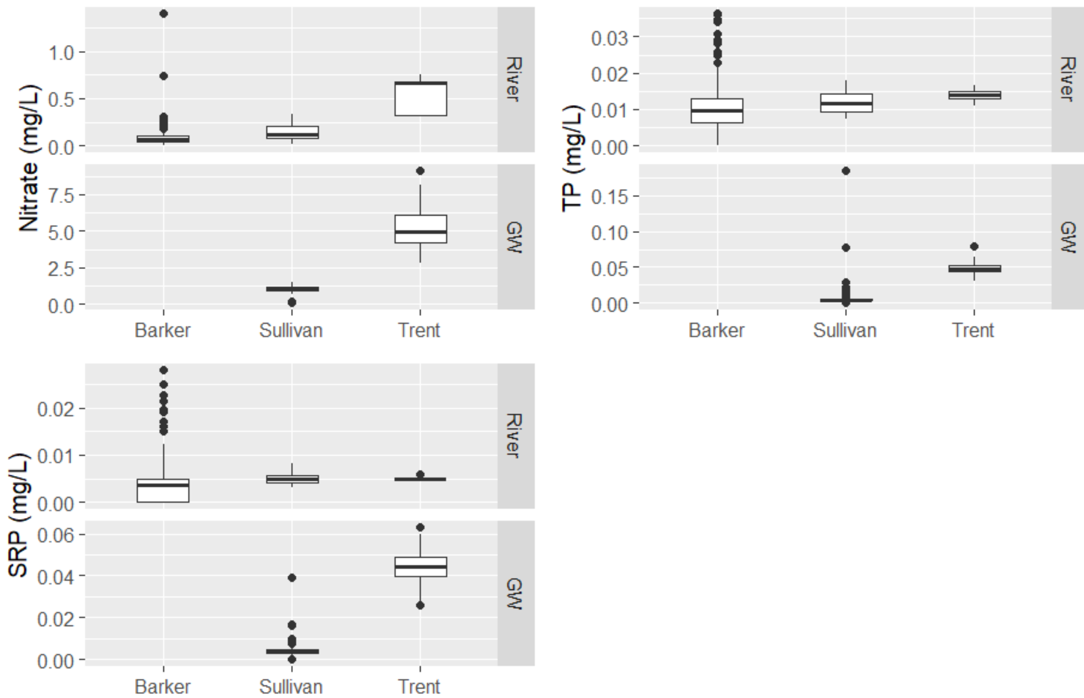

Figure 68. Boxplots comparing river and groundwater (GW) nitrate, soluable reactive phosphorus (SRP), and total phosphorus concentrations (in mg/L) at three locations along a gaining reach of the Spokane River. From left to right, the sites are arranged from east to west, from Barker Road to Trent Avenue, which is the direction of the Spokane River's flow. Spokane River data is compiled from Ecology's Environmental Information Management (EIM) database.

5.3. Three Springs/Western Arm Gaining Reach

Three Springs is a natural spring that enters the Spokane River just upstream of the T.J. Meenach bridge at the start of the gaining reach overlaying the Western Arm of the SVRP aquifer (Figure 69). Three Springs is a relatively small input to the Spokane River. A single flow comparison for the spring and the Spokane River below the T.J. Meenach bridge measured the spring at 1.88 cubic feet per second (cfs) and the river at 1030 cfs in September 2004 (Kimbrough et al, 2005). Three Springs, therefore, is unlikely to significantly influence the chemistry of the Spokane River itself. However, for the purpose of this analysis, Three Springs is considered to represent the general quality of groundwater moving through the Trinity Trough and discharging to the Spokane River at the start of the gaining reach overlaying the Western Arm of the SVRP aquifer.

To examine the possible influence of groundwater on the Spokane River, data from the Ecology EIM database was compiled for the same 20-year period (1999 – 2019) for two surface water monitoring locations up- and down-stream of Three Springs at the Sandifer (RM72.5) and T.J Meenach bridges (RM 69.8), respectfully (Figure 69). The EIM data for these locations are limited to temperature, dissolved oxygen, pH, conductivity, and nutrients (nitrate, phosphorus, and SRP). The County has monitored the water quality at the Three Springs location on a quarterly basis since October 2007.

Figure 69. Aerial and close-up view of Three Springs monitoring location (5212F01s) located on a gaining reach of the Spokane River overlaying the Western Arm of the Spokane Valley Rathdrum Prairie (SVRP) Aquifer between the Sandifer Bridge at River Mile 72.5 (RM72.5) and the T.J. Meenach Bridge (RM69.8).

There are two important items of note regarding this analysis. First, Latah Creek enters the Spokane River just downstream of the Sandifer Bridge (Figure 69). However, since August/September represent low flow conditions when Latah Creek's influence on the Spokane River is small compared to groundwater, the creek's influence is considered negligible. For example, Latah Creek's discharge in September 2004 at 7.43 cfs, which is about 8 percent of the total estimated inflow to the Spokane River along this reach during low flow. Groundwater, including the springs, accounted for the other 91 percent. Second, available data collected between June and September were used to assess groundwater influence since this is when groundwater accounts for most of the inflows.

Groundwater influence along a gaining reach is usually represented by decrease in river temperatures and an increase in river conductivity. The Spokane River between the Sandifer and TJ Meenach bridges, the groundwater (represented by Three Springs) appears to slightly cool the river and increase the conductivity as expected. The river's median temperature decreases from 14.45 to 14.20 degrees Celsius and the river's median conductivity increases from 150 to 313 uS/cm in response to groundwater inputs (Figure 70). Along this reach, the river's median pH and dissolved oxygen levels slightly increase. The pH goes from 8.11 to 8.17 and dissolved oxygen goes from 9.27 to 9.5 mg/L. However, this does not appear to be from groundwater influence.

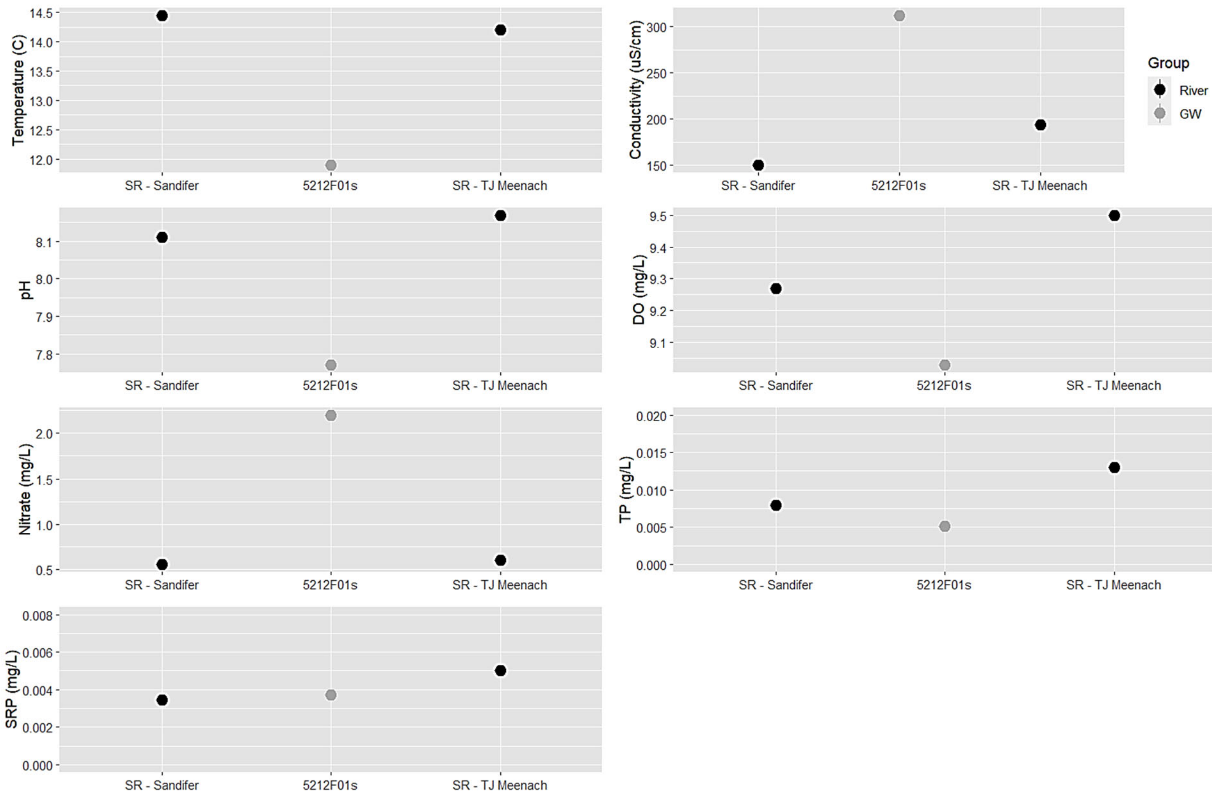

Figure 70. Plots comparing river and groundwater (GW) median temperature (in Celsius), conductivity (in uS/cm), pH, and dissolved oxygen (DO), nitrate, soluable reactive phosphorus (SRP), and total phosphorus (TP) concentrations (in mg/L) along a gaining reach of the Spokane River between the Sandifer and the TJ Meenach bridges in the direction of the Spokane River's flow. Three Springs (5212F01s) enters the river between these two river locations. Data for the Spokane River locations was compiled from Ecology's Environmental Information Management (EIM) database.

Concentrations of nitrate, SRP, and total phosphorus measured in Three Springs compared to the Spokane River at the Sandifer and TJ Meenach bridges are provided in Figure 70. Three Springs has higher median nitrate levels than the Spokane River (median = 2.06). The groundwater input raises the river nitrate levels between the Sandifer Bridge (median = 0.31 mg/L) and the TJ Meenach bridge (median = 0.56 mg/L). Groundwater total phosphorus levels are lower than those in the river upstream at Sandifer Bridge, but the groundwater SRP levels are near that in the river. The median river total phosphorus at Sandifer is 0.0073 mg/L and 0.0043 mg/L in the springs. The median SRP in the river at Sandifer and the springs is 0.0035 and 0.0038 mg/L, respectively. Therefore, the groundwater inputs are likely not a major contribution to the increased levels of total phosphorus and SRP measured in the river at TJ Meenach bridge, where median total phosphorus is 0.014 mg/L and SRP is 0.005 mg/L.