3. Groundwater Quality Summaries

This section summarizes raw data for each water quality parameter for the 20-year period from 1999 through 2019. The parameters are discussed in alphabetical order by analyte group: field parameters, major ions, nutrients, and total metals.

3.1. Field Parameters

3.1.1. Conductivity

Conductivity measures water's ability to conduct electrical current and is directly related to the concentration of ions (charged particles) in the water. Conductivity is important for identifying where the Spokane River influences groundwater quality, as proximity to the river is not necessarily indicative of river influence (see Section 5).

Conductivity data are summarized in Appendix E. Levels in the aquifer range from 72 to 481 uS/cm with an overall median of 275 uS/cm (Figure 6). The spatial distribution of conductivity in relation to aquifer thickness is shown in Figure 7. Median conductivity at individual monitoring locations ranges from 53.50 to 537.40 uS/cm. The lowest conductivity occurs in groundwater at monitoring locations influenced by the Spokane River, which are along Barker Road adjacent to a losing reach of the river.

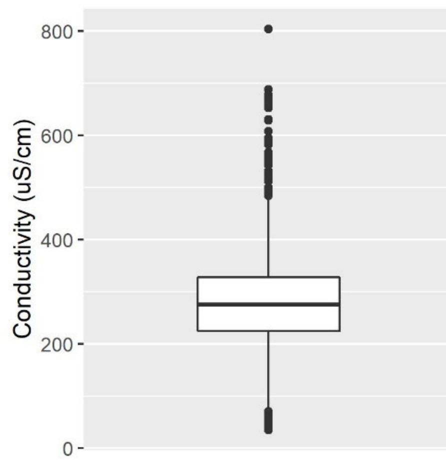

Figure 6. Boxplot showing the statistical distribution of 3,183 conductivity measurements collected at 51 monitoring locations between 1999 and 2019.

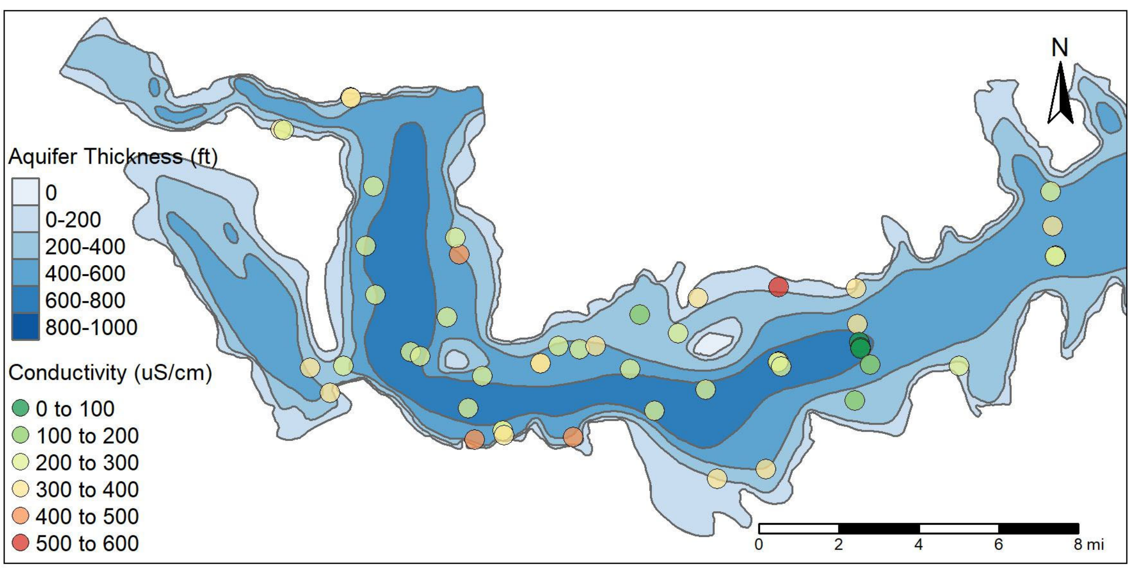

Figure 7. Spatial distribution of median conductivity (uS/cm) within the Spokane Valley Rathdrum Prairie aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007).

Outside of the river-influenced wells, conductivity is generally higher along the margins of the aquifer and lower in the main body of the aquifer, except in a few locations. This demonstrates conductivity is generally related to the amount of groundwater, which influences the concentrations of major ions through dilution.

3.1.2. Dissolved Oxygen

Dissolved oxygen (DO) is important for identifying oxic (DO >0.5mg/L) and anoxic (DO <0.5mg/L) conditions, which affect groundwater quality. DO data are summarized in Appendix E. Levels within the aquifer range from 4.41 to 12.54 mg/L with an overall median of 8.53 mg/L (Figure 8).

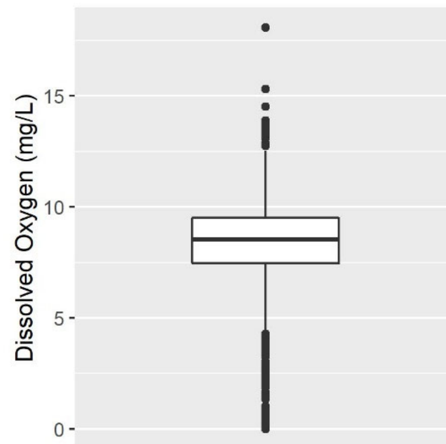

Figure 8. Boxplot showing the statistical distribution of 1,288 dissolved oxygen measurements collected at 51 monitoring locations between 1999 and 2019.

The spatial distribution of DO levels is shown in Figure 9. Groundwater sampled from the Plantes Ferry monitoring well has persistent anoxic conditions (median is 0.29 mg/L) due to a confining layer (see Section 4.2). Otherwise, groundwater in the aquifer has oxic conditions, with median DO ranging from 5.81 to 10.51 mg/L at other sites. Of these, the lowest DO concentrations occur in the Hillyard Trough/North Spokane, the river-influenced wells on Barker Road, and locations between the Stateline/Idaho Road and Barker Road (median concentrations <8.0 mg/L). The natural springs locations have some of the highest DO levels, likely due to exchange with the air.

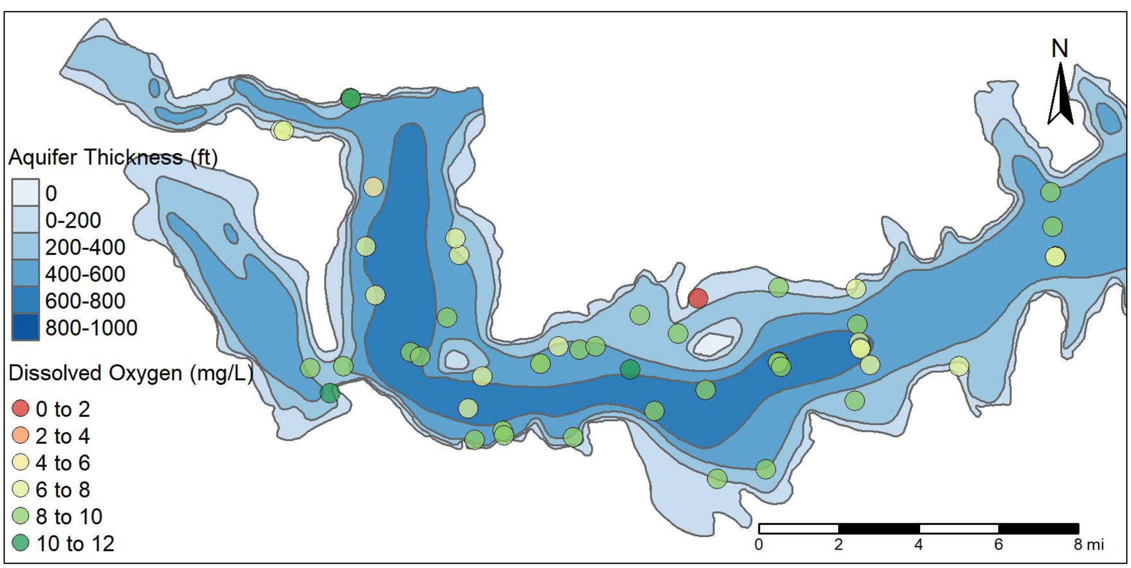

Figure 9. Spatial distribution of median dissolved oxygen (mg/L) within the Spokane Valley Rathdrum Prairie aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007).

3.1.3. pH

pH is important because acidic (pH<7) and alkaline (pH>7) conditions influence groundwater quality. The pH data are summarized in Appendix E. Levels within the aquifer range from 6.74 to 8.60 with an overall median of 7.72 (Figure 10).

The spatial distribution of pH levels is shown in Figure 11. Median pH at individual monitoring locations ranges from 6.84 to 8.27.

Slightly acidic conditions exist in the groundwater sampled from the confined aquifer at Plantes Ferry (median 6.84) and the three river-influenced monitoring wells at Barker Road (medians between 6.84 and 6.97). All other monitoring locations have alkaline conditions. Of these, the lowest pH occurs at the margins of the aquifer where median pH is near neutral.

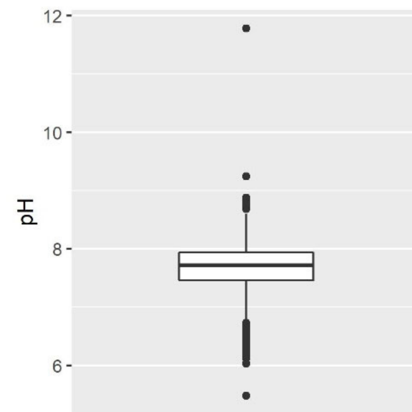

Figure 10. Boxplot showing the statistical distribution of 3,037 pH measurements collected at 51 monitoring locations between 1999 and 2019.

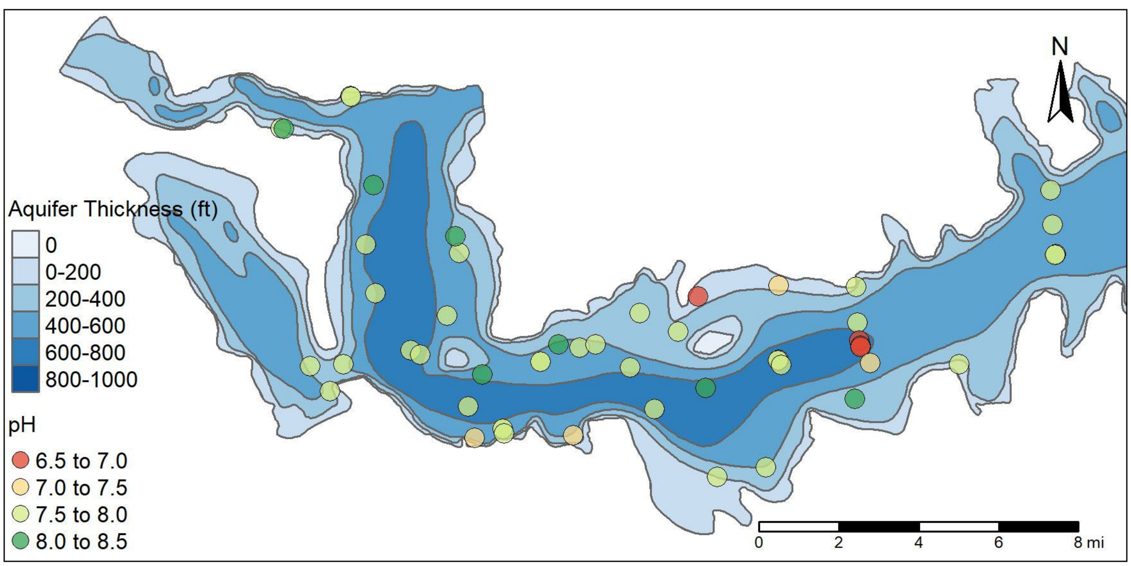

Figure 11. Spatial distribution of median pH within the Spokane Valley Rathdrum Prairie aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007).

3.1.4. Temperature

Groundwater temperature influences other parameters such as dissolved oxygen and pH. Groundwater temperature data is summarized in Appendix E. Temperatures within the aquifer range from 7.37 to 16.80 Celsius (C) with an overall median of 12 C (Figure 12).

The spatial distribution of groundwater temperature in relation to aquifer thickness is shown in Figure 13. Median groundwater temperature at individual monitoring locations ranges from 10.50 C to 13.8 C.

Spatial patterns in groundwater temperature are not easily apparent. However, the river-influenced locations on Barker Road are generally warmer and, outside of a few locations, groundwater generally warms from east to west.

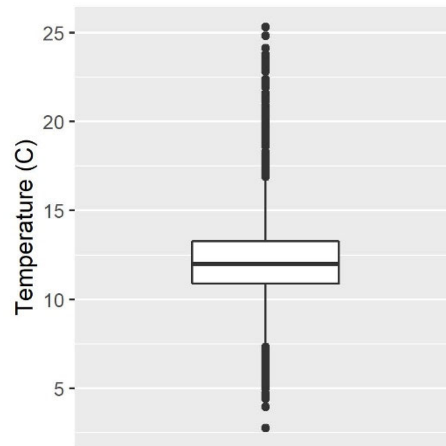

Figure 12. Boxplot showing the statistical distribution of 3,205 groundwater temperature measurements collected at 51 monitoring locations between 1999 and 2019.

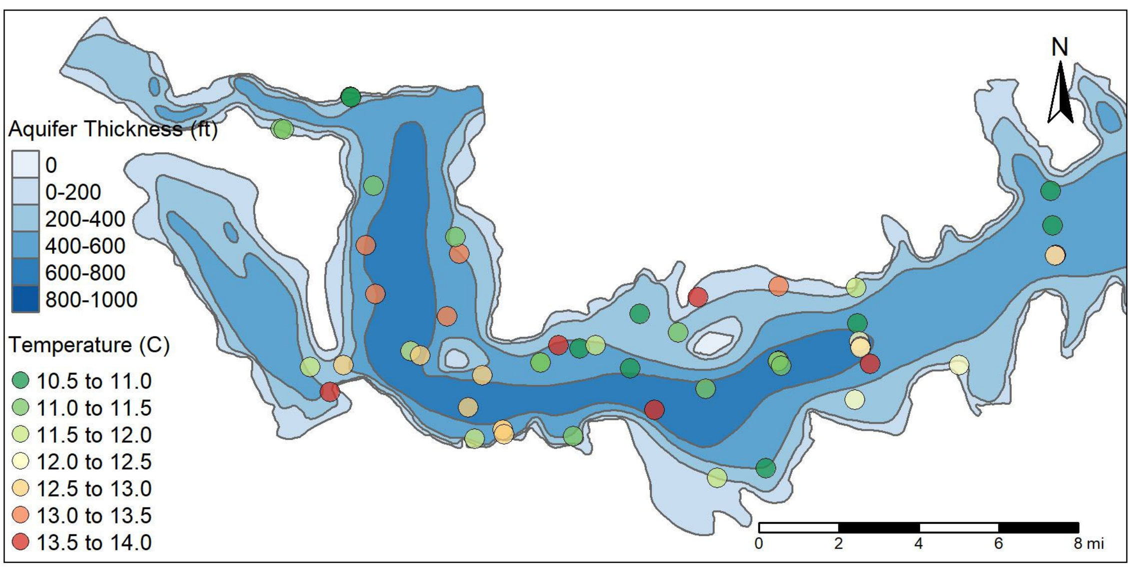

Figure 13. Spatial distribution of median groundwater temperature (Celsius) within the Spokane Valley Rathdrum Prairie aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007).

3.2. Major and Minor Ions

3.2.1. Calcium

Calcium data are summarized in Appendix E. Levels within the aquifer range from 9.89 to 54.5 mg/L with an overall median of 32.4 mg/L (Figure 14). All samples had detectable levels of calcium.

Spatial distribution of calcium levels within the aquifer are shown in Figure 15A. Median concentrations at each monitoring location range from 5.87 to 65.4 mg/L. The lowest concentrations occur in groundwater from river-influenced wells along Barker Road. The highest concentrations occur in groundwater from the East Valley High School (EVHS) monitoring well and other locations along the margins of the aquife

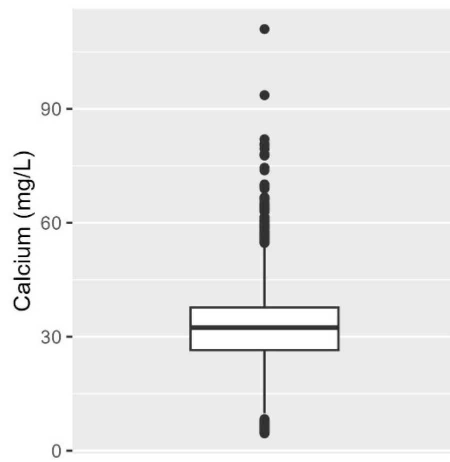

Figure 14. Boxplot showing the statistical distribution of calcium concentrations (mg/L) of 2,445 samples collected at 51 monitoring locations between 1999 and 2019.

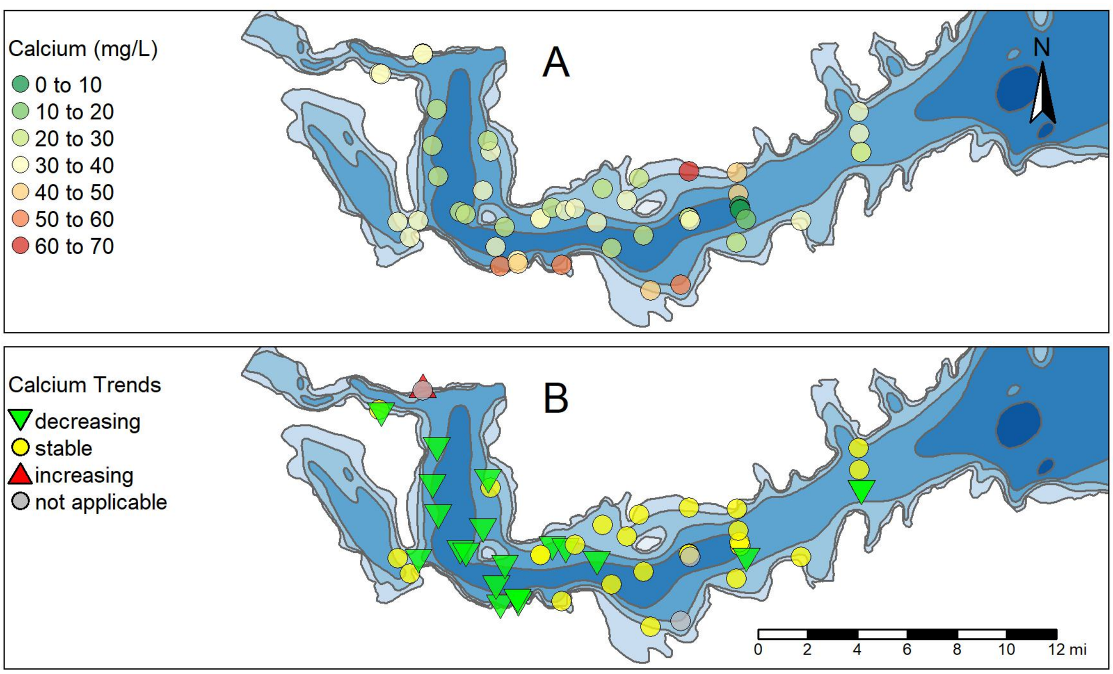

Figure 15. (A) Spatial distribution of median calcium concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in calcium concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

During the 20-year period, calcium levels at most locations were either stable or decreasing (Figure 15B). Decreasing trends occurred in the western portion of the aquifer underlaying the City of Spokane. Levels were stable in the eastern portion from the Spokane Valley to the Stateline. Only Waikiki Springs (6306P01s) had increasing levels. Three sites did not have enough data for a trend analysis.

Calcium in groundwater does not pose a health hazard and does not have applicable drinking water quality standards. However, calcium and magnesium contribute to water hardness.

3.2.2. Chloride

Chloride data are summarized in Appendix E. Levels within the aquifer range from non-detect (below the reporting limit of 0.2 mg/L) to 13.9 mg/L with an overall median of 4.09 mg/L (Figure 16). Less than 1 percent of all samples were non-detect.

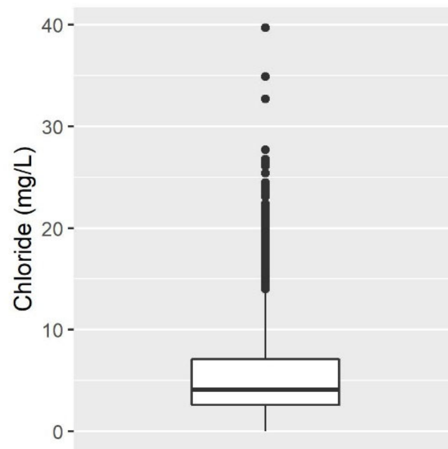

Figure 16. Boxplot showing the statistical distribution of chloride concentrations (mg/L) of 3,038 samples collected at 51 monitoring locations between 1999 and 2019.

The spatial distribution of chloride levels within the aquifer is shown in Figure 17A. Median concentrations at each monitoring location range from 1.26 to 17.55 mg/L. The lowest concentrations occur in groundwater from the river-influenced wells along Barker Road. The highest concentrations occur along the margins of the aquifer.

Trend analysis indicates chloride levels increased at most locations (n = 46) over the 20-year period and were stable at five locations (Figure 17B). Two of the locations with stable concentrations are the North Spokane Irrigation District well and the Plantes Ferry monitoring well, which represent conditions in separate confined aquifers (see Section 4.2). The remaining three stable locations have smaller datasets.

Chloride does not pose a health hazard and does not have an MCL. As an aesthetic contaminant, chloride has a secondary standard of 250 mg/L to maintain palatability and use. However, chloride levels across the aquifer are well below 250 mg/L. There is no State trigger level for chloride.

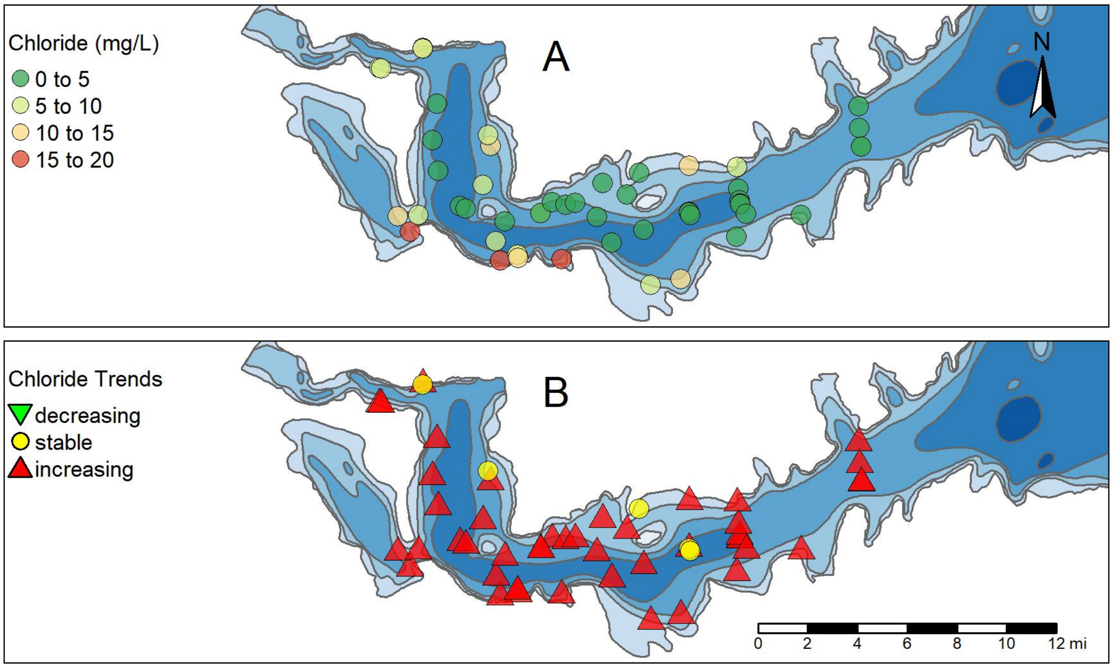

Figure 17. (A) Spatial distribution of median chloride concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in chloride concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

3.2.3. Fluoride

Fluoride data are summarized in Appendix E. Most samples (88 percent) were non-detect. Given this, the statistical distribution of fluoride data is not shown. Fluoride is generally not at detectable levels in the aquifer, except at three locations: the monitoring wells at EVHS (6306N01) and Plantes Ferry (5404A01), and the Vera Water and Power well (5426L03) (Figure 18A). The groundwater at the EVHS and Vera wells has median concentrations near 0.1 mg/L. Samples from the Plantes Ferry had a median concentration of 0.296 mg/L, nearly three times the other two locations. However, this represents unique conditions in a confined aquifer (see Section 4.2). Only the Plantes Ferry monitoring well had enough data to complete a trend analysis, which indicated stable fluoride concentrations over the 20-year period (Figure 18B).

Fluoride has a MCL of 4 mg/L. The secondary standard and State trigger level are both set at 2 mg/L. These levels were never exceeded during the 20-year period. The U.S. Department of Health and Human Services (HHS) recommends fluoride at 0.7 mg/L in drinking water as optimal for dental health, as fluoride helps prevent tooth decay. However, fluoride levels are generally below the HHS recommended levels.

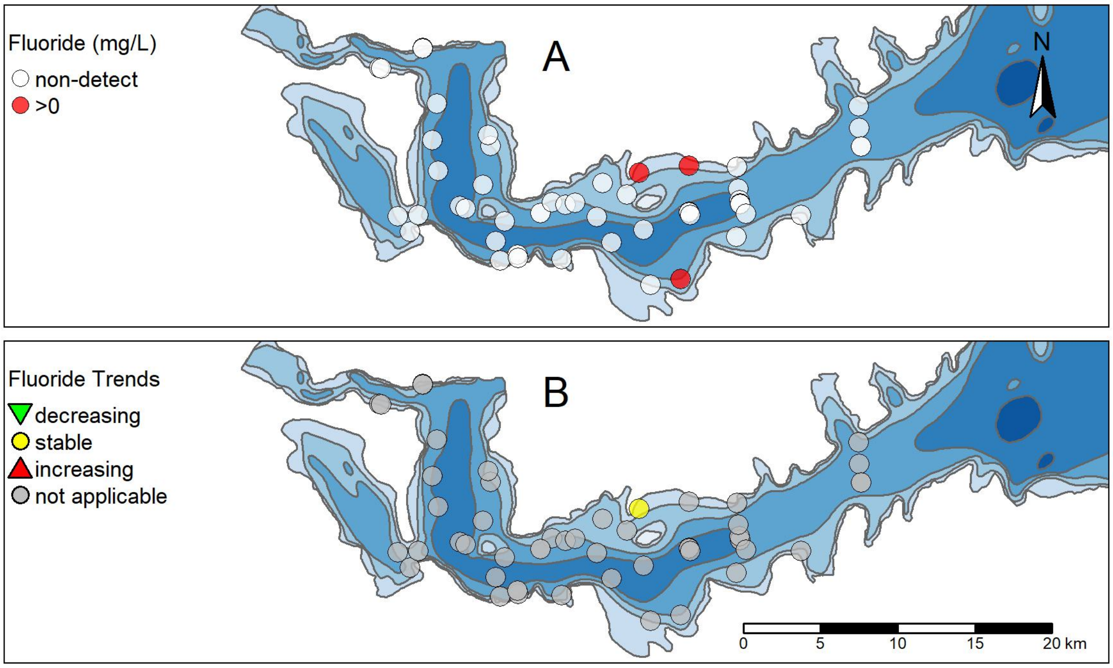

Figure 18. (A) Spatial distribution of median fluoride concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness data layer is modeled from Kahle and Bartolino (2007). (B) Trends in fluoride concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

3.2.4. Magnesium

Magnesium data are summarized in Appendix E. Levels within the aquifer range from 1.35 to 25.55 mg/L with an overall median of 13.20 mg/L (Figure 19). All samples had detectable levels of magnesium.

The spatial distribution of magnesium levels throughout the aquifer is shown in Figure 20A. Median concentrations at each monitoring location ranged from 1.71 to 28.9 mg/L. The lowest concentrations occur in groundwater from the river-influenced wells on Barker Road. The highest concentrations are found along the margin of the aquifer.

During the 20-year period, magnesium levels across the aquifer were primarily stable (n = 21) or decreasing (n = 26). Only Waikiki Springs (6306P01s) had increasing levels. Three locations did not have enough data for a trend analysis (Figure 20B).

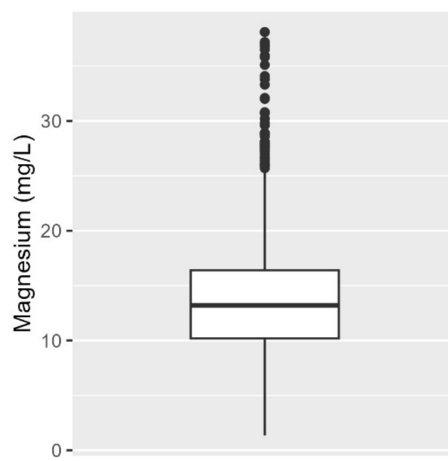

Figure 19. Boxplot showing the statistical distribution of magnesium concentrations (mg/L) of 2,445 samples collected at 51 monitoring locations between 1999 and 2019.

Magnesium in groundwater does not pose a health hazard and does not have applicable drinking water quality standards. However, magnesium in groundwater contributes to water hardness.

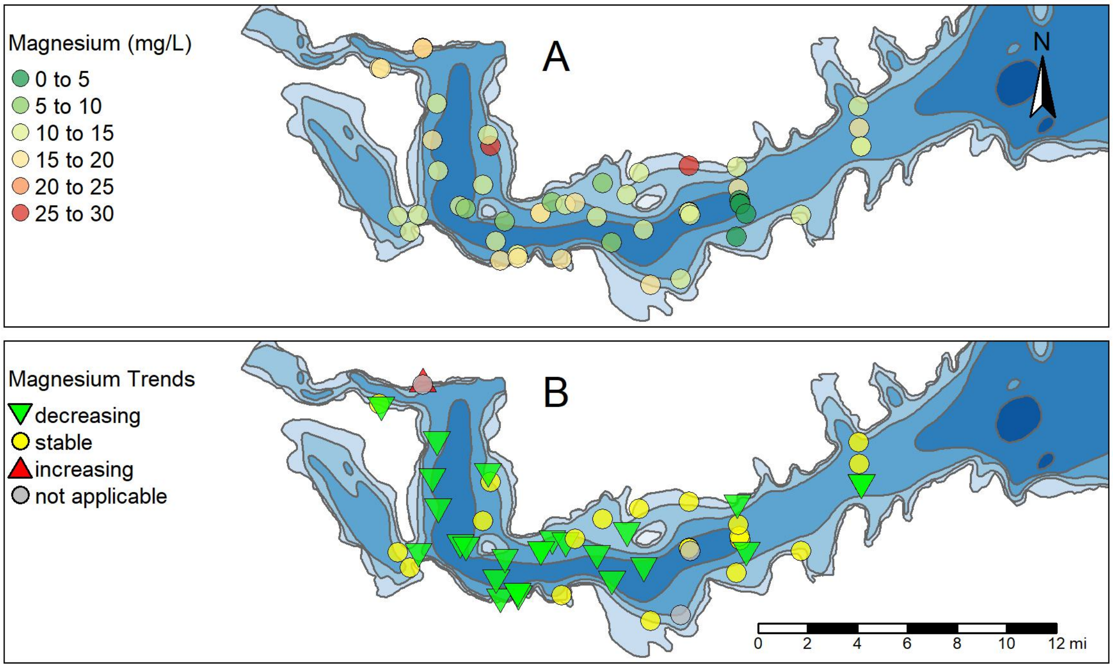

Figure 20. (A) Spatial distribution of median magnesium concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in magnesium concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

3.2.5. Potassium

Potassium data are summarized in Appendix E. Levels within the aquifer range from 0.89 to 3.16 mg/L with an overall median of 2.01 mg/L (Figure 21). Less than 1 percent of all samples were non-detect (below the reporting limit of 0.5 mg/L).

The spatial distribution of potassium levels within the aquifer is shown in Figure 22A. Median concentrations at each monitoring location ranged from 0.84 to 5.34 mg/L. The lowest levels occur in groundwater from the river-influenced wells on Barker Road. The highest concentrations are along the margin of the aquifer.

Trend analysis indicates potassium levels at most monitoring locations (n = 31) were stable over the 20-year period. Of the remaining locations, fourteen had decreasing levels and three had increasing levels. Trend analysis was not conducted for three locations due to small sample size (Figure 22B).

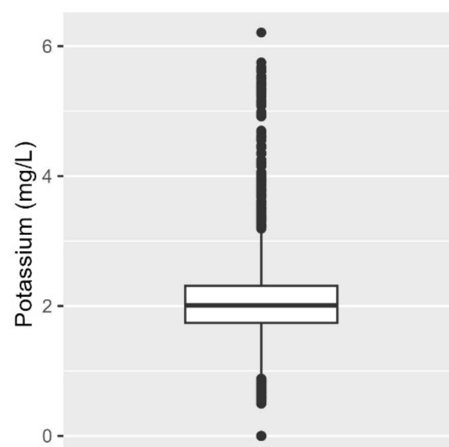

Figure 21. Boxplot showing the statistical distribution of potassium concentrations (mg/L) of 2,403 samples collected at 51 monitoring locations between 1999 and 2019.

Potassium in groundwater does not pose a health hazard and does not have applicable drinking water quality standards.

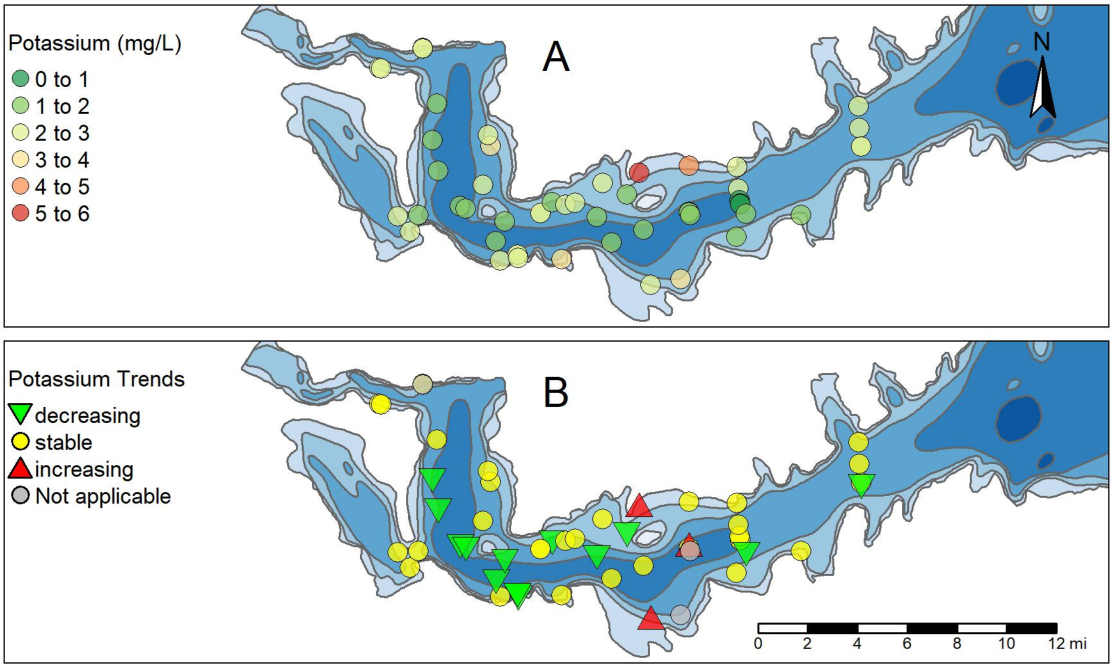

Figure 22. (A) Spatial distribution of median potassium concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in potassium concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

3.2.6. Sodium

Sodium data are summarized in Appendix E. Levels across all samples range from non-detect (below the analytical reporting limit of 0.5 mg/L) to 8.54 mg/L with an overall median of 3.72 mg/L (Figure 23). Less than 1 percent of the samples were non-detect.

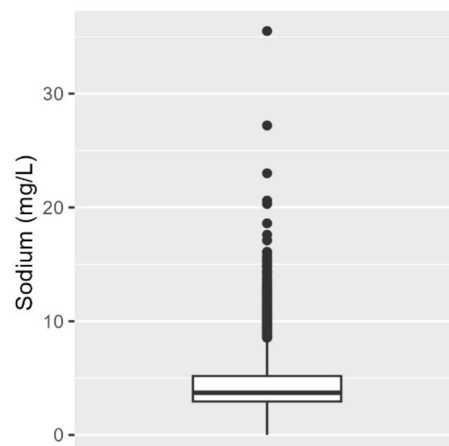

Figure 23. Boxplot showing the statistical distribution of sodium concentrations (mg/L) of 2,447 samples collected at 51 monitoring locations between 1999 and 2019.

The spatial distribution of sodium levels within the aquifer is shown in Figure 24A. Median concentrations at each monitoring location range from 1.87 to 11.80 mg/L. The lowest concentrations occur in groundwater from the river-influenced wells on Barker Road. The highest concentrations are along the margin of the aquifer.

Trend analysis indicates sodium levels were stable at most monitoring locations (n = 30) over the 20-year period. Of the remaining locations, 16 had decreasing levels and two had increasing levels. Trend analysis was not conducted for three locations due to small sample size (Figure 24B).

Sodium in groundwater does not pose a health hazard and does not have applicable drinking water quality standards.

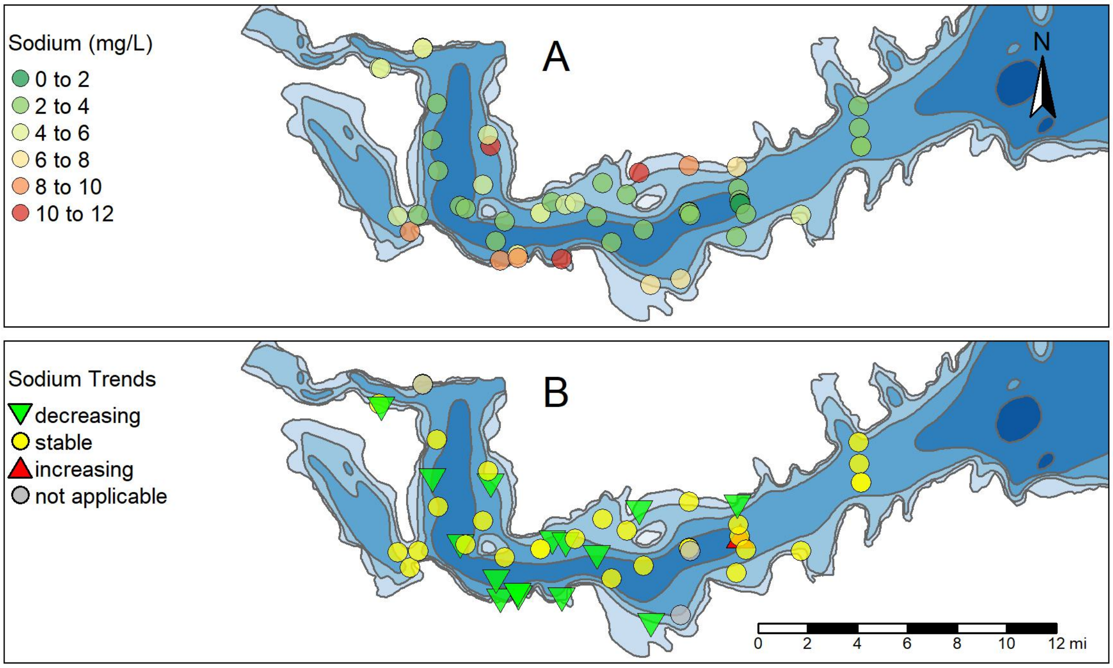

Figure 24. (A) Spatial distribution of median sodium concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness data layer is modeled from Kahle and Bartolino (2007). (B) Trends in sodium concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

3.2.7. Sulfate

Sodium data are summarized in Appendix E. Sulfate analysis was discontinued after February 2011. Three locations do not have sulfate data as they were added to the monitoring network after the analysis was discontinued.

Sulfate levels within the aquifer range from 1.73 to 23 mg/L with an overall median of 11.70 mg/L (Figure 25). Less than 1 percent of the samples (n = 1) were non-detect (below the analytical reporting limit of 0.3 mg/L).

The spatial distribution of sulfate levels throughout the aquifer is shown in Figure 26A. Median concentrations at each monitoring location range from 4.13 to 21.40 mg/L. The lowest concentrations occur in samples collected from the river-influenced wells along Barker Road. The highest median concentration occurred at the Plante’s Ferry monitoring well, which represents unique conditions in a confined aquifer (see Section 4.2).

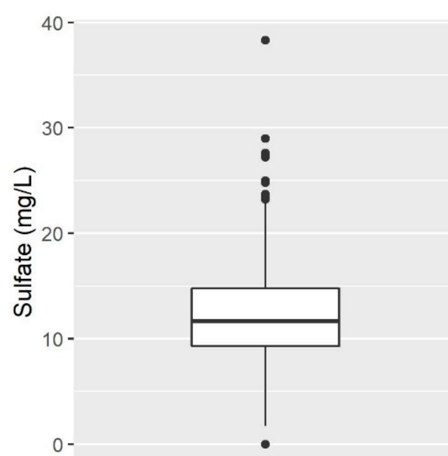

Figure 25. Boxplot showing the statistical distribution of sulfate concentrations (mg/L) of 1,979 samples collected at 51 monitoring locations between 1999 and 2011.

Trend analysis indicates sulfate levels were largely stable (n=23) or decreasing (n=21) over the 20-year period. Only three locations exhibited increasing levels. Four sites did not have enough data to complete a trend analysis (Figure 26B).

Sulfate does not pose a health hazard; it is an aesthetic contaminant with a secondary standard of 250 mg/L to maintain palatability and use. Sulfate levels across the aquifer are well below these levels. There is no State trigger level for sulfate.

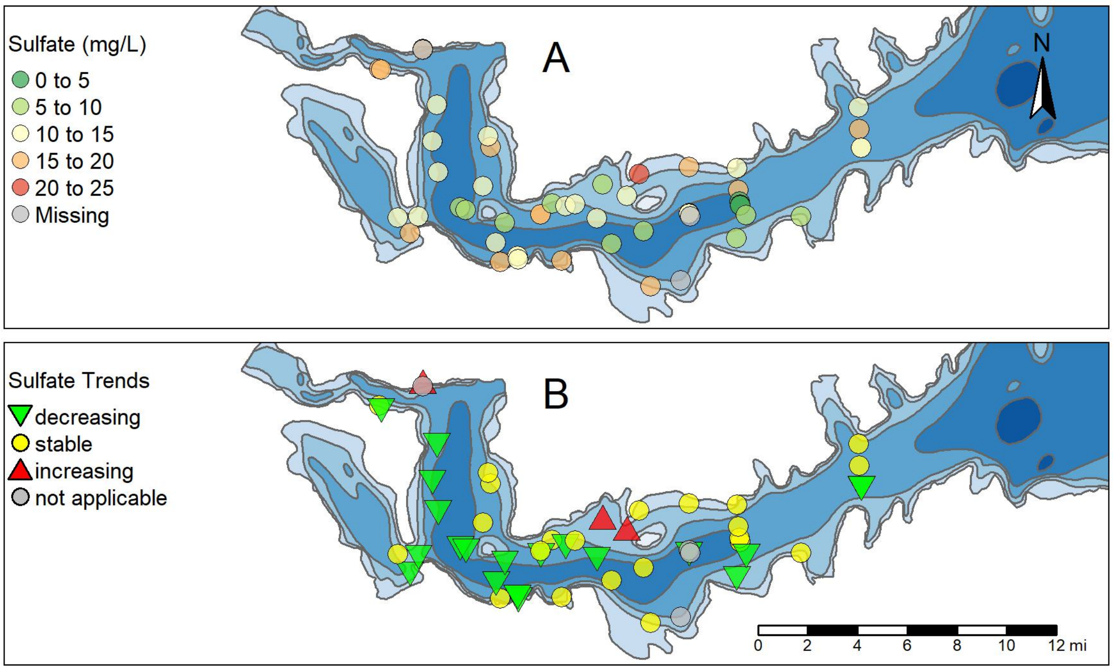

Figure 26. (A) Spatial distribution of median sulfate concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in sulfate concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

3.3. Nutrients

3.3.1. Nitrate

Nitrate data are summarized in Appendix E. Levels across all samples ranged from non-detectable levels (below the reporting limit 0.05 mg/L) to 3.77 mg/L with an overall median of 1.49 mg/L (Figure 27). Less than 1 percent of all samples were non-detect. Most non-detect samples were from the Plantes Ferry monitoring well, which represents conditions in a confined aquifer. These non-detects constitute 70 percent of samples from this location (see Appendix E).

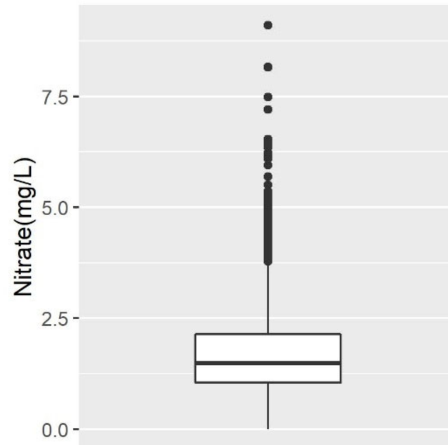

Figure 27. Boxplot showing the statistical distribution of nitrate concentrations (mg/L) of 3,083 samples collected at 51 monitoring locations between 1999 and 2019.

The spatial distribution of nitrate levels within the aquifer is shown in Figure 28A. Median concentrations at each monitoring location range from non-detectable levels to 4.94 mg/L. The highest concentrations occurred in samples from the EVHS monitoring well. Other areas of elevated nitrate levels occur along the margin of the aquifer. The lowest levels are found in river-influenced groundwater along Barker Road.

Trend analysis indicates nitrate levels increased at 13 monitoring locations, decreased at 23 locations, and were stable at 14 locations over the 20-year period (Figure 28B). Locations where nitrate concentrations increased included the 8 locations outside of a sewer service area and 6 locations influenced by nitrate transport from upgradient, non-sewered areas (see Section 7). The Plantes Ferry monitoring well did not have enough data to perform a trend analysis.

Nitrate has a MCL of 10 mg/L and a State reporting level of 5 mg/L. Over the 20-year period, the MCL was never exceeded. However, 33 samples from four monitoring locations had concentrations at or above the State reporting level (Figure 28C). Most of these exceedances (n=26) occurred in samples collected from the EVHS monitoring well. Three of the four sites have not had an exceedance in the last 10 years.

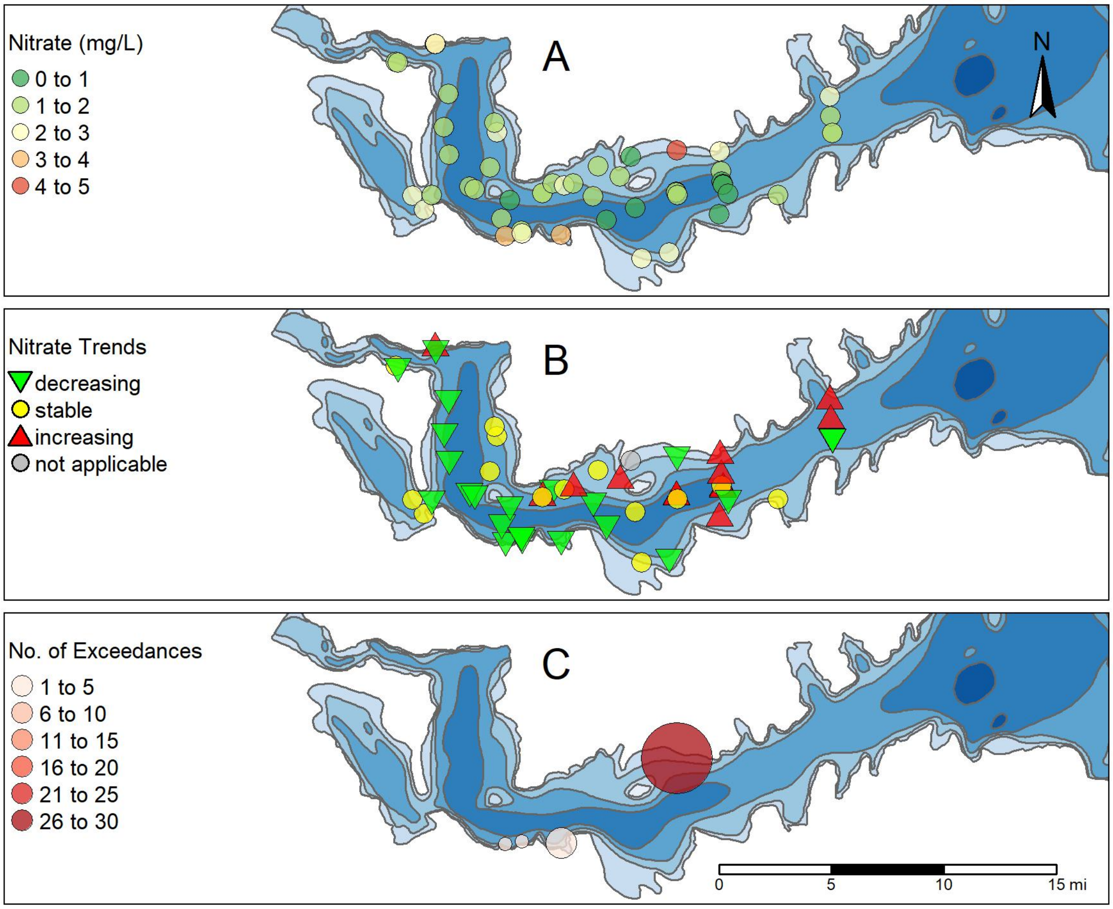

Figure 28. (A) Spatial distribution of median nitrate concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in nitrate concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019. (C) Number of exceedances of the State reporting level for nitrate (5 mg/L) over the 20-year period between 1999 and 2019.

3.3.2. Phosphorus

Total phosphorus data are summarized in Appendix E. Levels within the aquifer range from non-detectable levels (below the reporting limit) to 0.0228 mg/L with an overall median of 0.0060 mg/L (Figure 29). Approximately 9 percent samples were non-detect. Reporting limits changed over the years (Appendix C).

The spatial distribution of phosphorus levels throughout the aquifer is shown in Figure 30A. Groundwater from the Plantes Ferry well, which represents unique conditions in a confined aquifer, has the highest median phosphorus concentration at 0.231 mg/L. This is well above the other locations, which have median concentrations ranging from 0.0025 to 0.05 mg/L.

Trend analysis indicates most locations (n = 33) had stable phosphorus levels over the 20-year period. Of the remaining locations, 16 exhibited decreasing levels and 2 exhibited increasing levels (Figure 30B). There are no drinking water quality standards for total phosphorus.

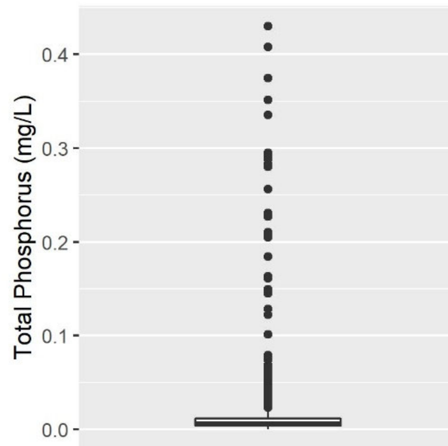

Figure 29. Boxplot showing the statistical distribution of total phosphorus concentrations (mg/L) of 2,465 samples collected at 51 monitoring locations between 1999 and 2019.

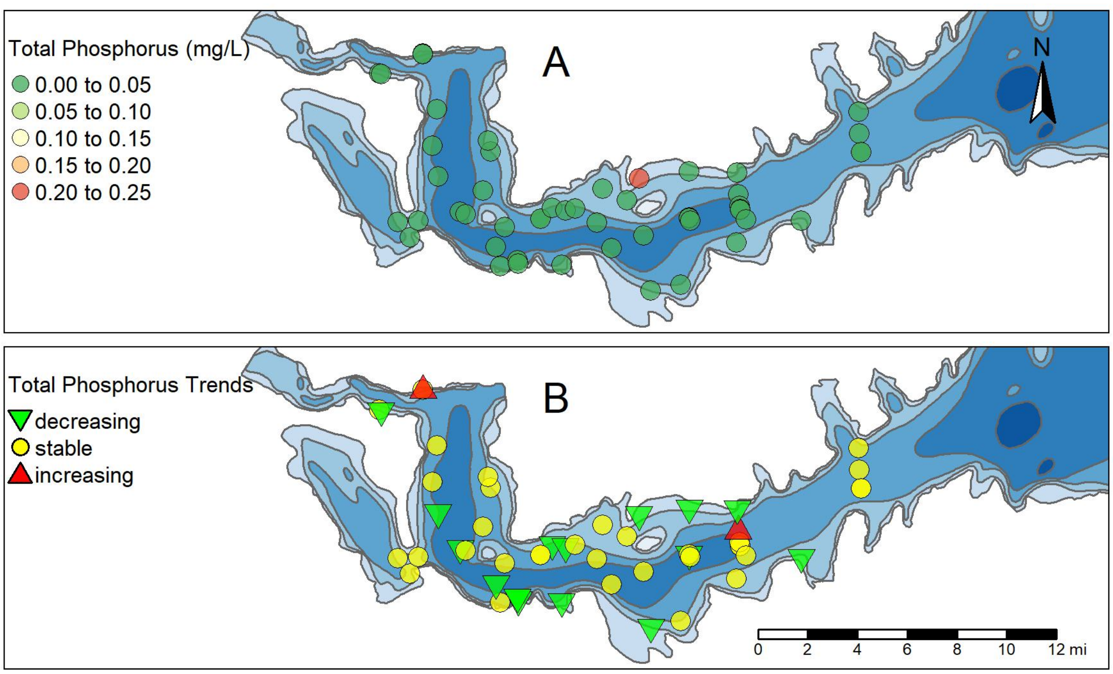

Figure 30. (A) Spatial distribution of median total phosphorus concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in total phosphorus concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

3.3.3. Soluble Reactive Phosphorus

Soluble Reactive Phosphorus (SRP) data are summarized in Appendix E. SRP is that portion of total phosphorus that is available for plant growth. Levels across all samples ranged from non-detectable levels to 0.0184 mg/L (Figure 31). Approximately 6 percent of samples were non-detect.

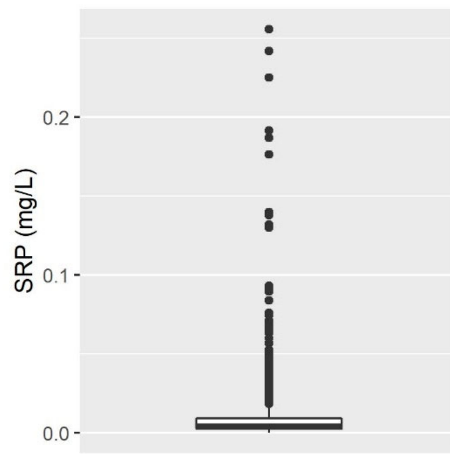

Figure 31. Boxplot showing the statistical distribution of soluble reactive phosphorus (SRP) concentrations (mg/L) of 2,987 samples collected at 51 monitoring locations between 1999 and 2019.

The spatial distribution of SRP concentrations throughout the aquifer is shown in Figure 32A, and it largely mirrors the spatial distribution of total phosphorus (Figure 30A). Median concentrations at individual monitoring locations range from 0.00165 to 0.0589 mg/L. The similarities in spatial patterns and concentrations in SRP and total phosphorus suggests that most of the phosphorus within aquifer is available for plant growth.

However, groundwater in the confined aquifer at Plantes Ferry has a median SRP concentration (0.0589 mg/L) that is about 15 percent of the median total phosphorus concentration (0.28 mg/L).

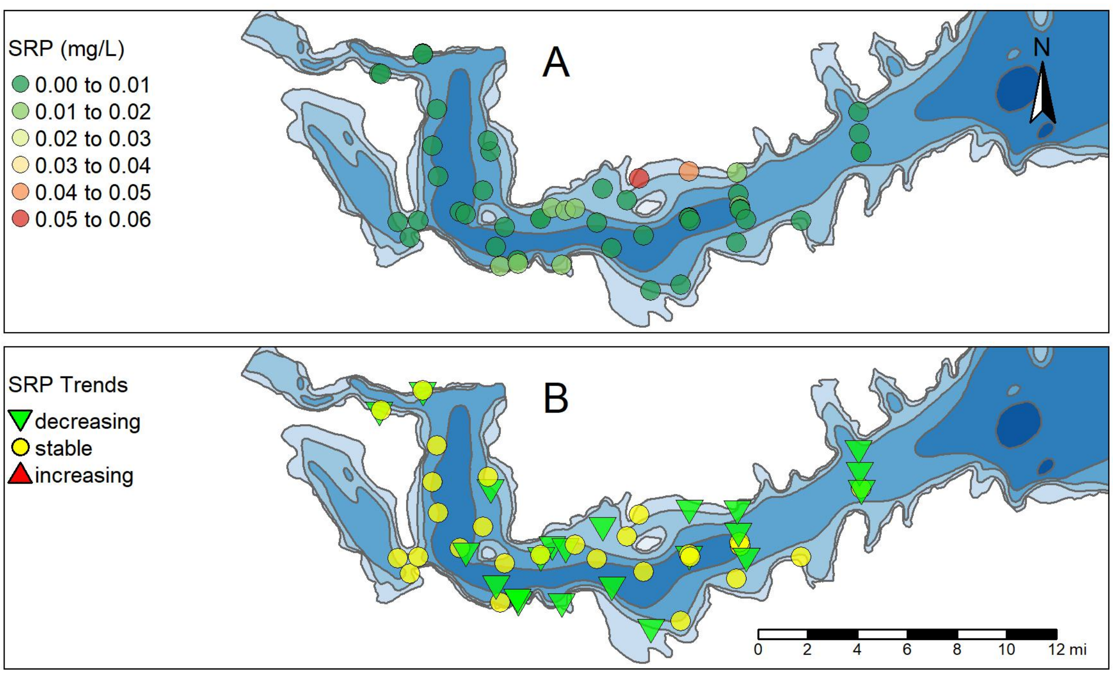

Figure 32. (A) Spatial distribution of median soluble reactive phosphorus (SRP) concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in SRP concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

Trend analysis indicates SRP was either stable (n = 38) or decreasing (n = 23) over 20-year period (Figure 32B). There are no drinking water quality standards for SRP.

3.4. Metals

3.4.1. Arsenic

Arsenic data are summarized in Appendix E. Levels within the aquifer range from non-detect (below the reporting limit of 0.001 mg/L) to 0.0060 mg/L with an overall median is 0.0026 mg/L (Figure 33). About 12 percent of all samples were non-detect.

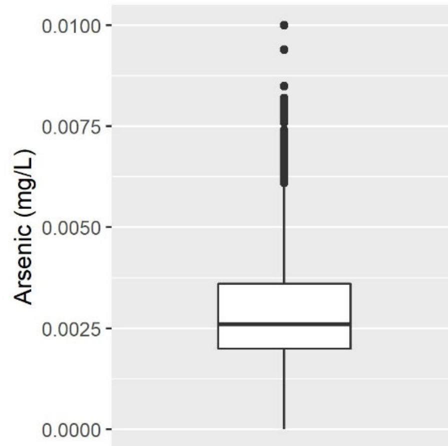

Figure 33. Boxplot showing the statistical distribution of arsenic concentrations (mg/L) of 2,276 samples collected at 51 monitoring locations between 1999 and 2019.

The spatial distribution of arsenic levels throughout the aquifer is shown in Figure 34A. Median concentrations at each monitoring location range from non-detect to 0.0067 mg/L. Samples from the Plantes Ferry monitoring well and the three river-influenced monitoring wells generally have non-detectable levels of arsenic. The highest concentrations are found in the vicinity of Felts Field in northwest Spokane Valley.

Trend analysis indicates arsenic levels at most locations (n = 30) were stable over the 20-year period. Of the remaining locations, nine locations exhibited decreasing levels and five exhibited increasing levels. Seven locations did not have enough data to perform a trend analysis due to a high proportion of non-detects or small sample size (Figure 34B, Appendix E).

Note that while the trend analysis indicated a decreasing trend for the Mission and Barker monitoring well (5517D05), the Sen slope calculated for this site indicates no change over time. This site has close to the threshold of 50 percent non-detectable data that would have excluded it from the trend test; the high percentage of non-detects is because of river influence on arsenic concentrations at this site (see Section 5.1). Therefore, it is likely that a trend does not exist at this location, as with other river-influenced locations.

Arsenic has a MCL of 0.010 mg/L, which is also the State trigger level. Over the 20-year period, this level was reached in one sample collected from the East Spokane Water District well (5324G01) in July 2001 (Figure 34C).

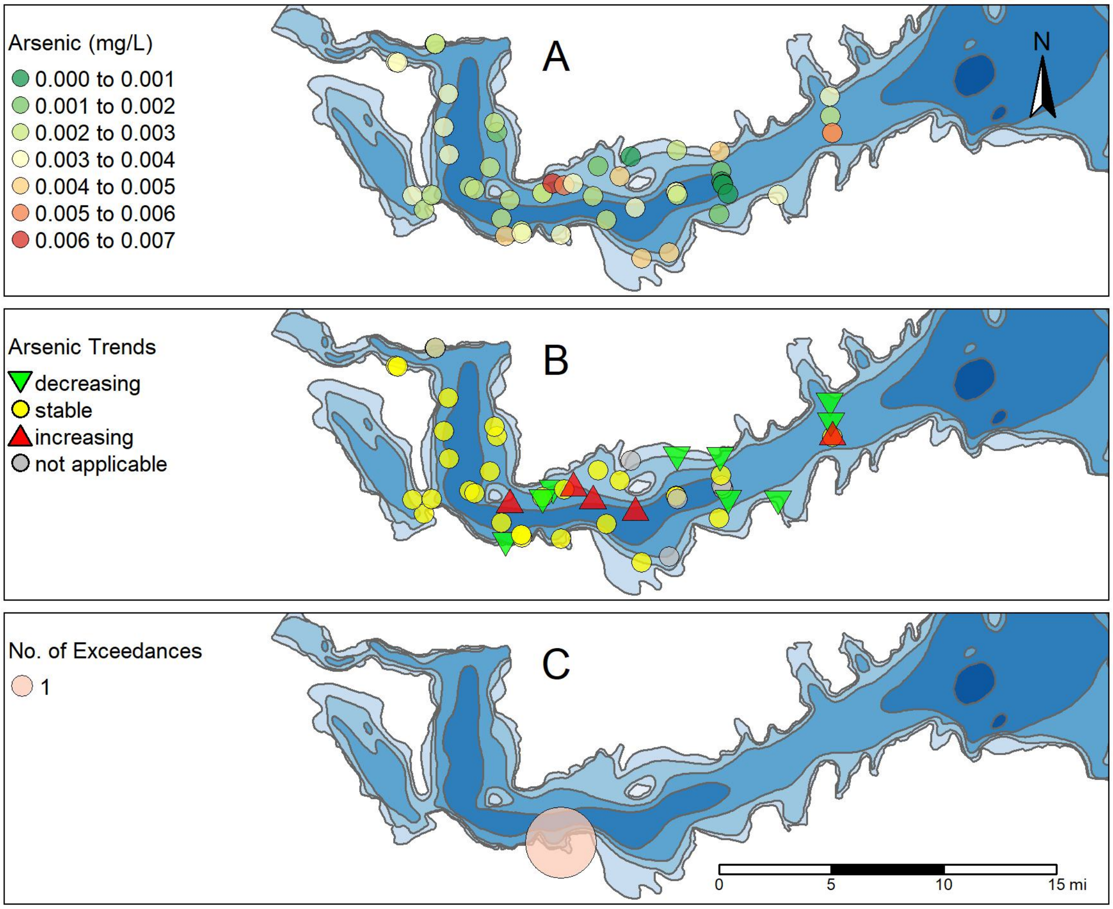

Figure 34. (A) Spatial distribution of median arsenic concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in arsenic concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019. (C) Number of exceedances of the MCL for arsenic (0.01 mg/L) over the 20-year period between 1999 and 2019.

3.4.2. Cadmium

Cadmium data are summarized in Appendix E. Most samples (98 percent) were non-detect for cadmium. Cadmium is generally not detectable at any of the monitoring locations (median = 0 mg/L due to high proportion of non-detects). Given this, statistical and spatial distributions of cadmium data are not shown, and trend analysis was not conducted. Over the 20-year period, reporting limits for cadmium were lowered from 0.001 to 0.0002 mg/L, but this did not affect the ability to detect cadmium. Cadmium has a primary MCL of 0.005 mg/L, which is also the State trigger level. This level was never exceeded.

3.4.3. Chromium

Chromium data are summarized in Appendix E. Most samples (85 percent) were non-detect. Reporting limits for chromium analysis changed over time (Appendix C). Given the prevalence of non-detects, the statistical distribution is not shown.

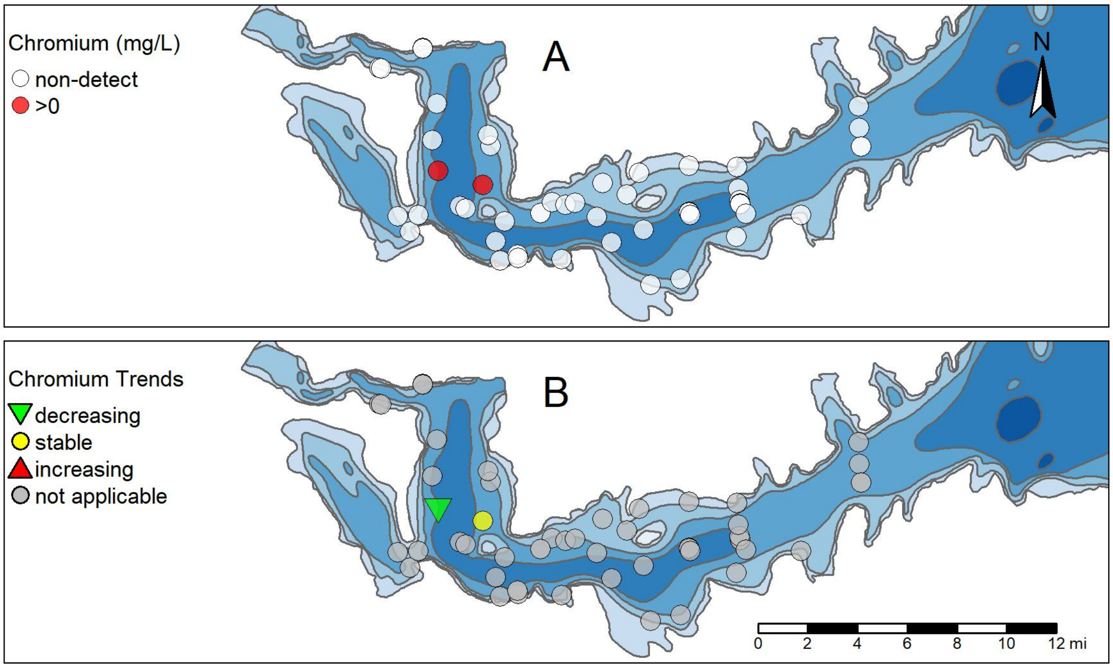

Figure 35. (A) Spatial distribution of median chromium concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in chromium concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

Chromium is generally detectable at two locations: the monitoring wells at Franklin Park (6331J01) and the Northeast Community Center (5304G01) (Figure 35A). Both have median concentrations of 0.0011 mg/L, which is within the analytical reporting limits used over the course of the 20-year period.

Trend analysis of data from these two locations indicate decreasing concentrations at Franklin Park and stable levels at the Northeast Community Center (Figure 35B). Chromium has a MCL of 0.1 mg/L, which is also the State's trigger level. This level was never exceeded during the 20-year period.

3.4.4. Copper

Copper data are summarized in Appendix E. Levels within the aquifer ranged from non-detect (below the reporting limit of 0.001 mg/L) to 0.0027 mg/L. Most samples (69 percent) were non-detect. Given this, the Q1 and median concentrations are zero, but the Q3 concentration is 0.0011 mg/L (Figure 36).

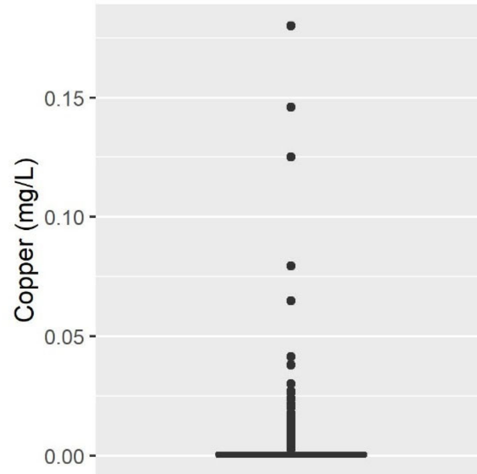

Figure 36. Boxplot showing the statistical distribution of copper concentrations (mg/L) of 2,445 samples collected at 51 monitoring locations between 1999 and 2019.

The spatial distribution of copper levels throughout the aquifer is shown in Figure 37A. Most monitoring locations (n = 41) had non-detectable levels for 50 percent or more of their samples, resulting in median copper concentration of zero. The remaining 11 monitoring locations have median copper levels ranging from 0.00045 to 0.00230 mg/L. It is worth noting that 10 of these monitoring locations are purveyor wells.

These 11 monitoring locations had enough detectable data to perform a trend analysis. Over the 20-year period copper levels were stable at six locations, decreasing at four locations, and increasing at one location (Figure 37B). The location with the increasing trend is the I.E. Cold Storage well (5213B01).

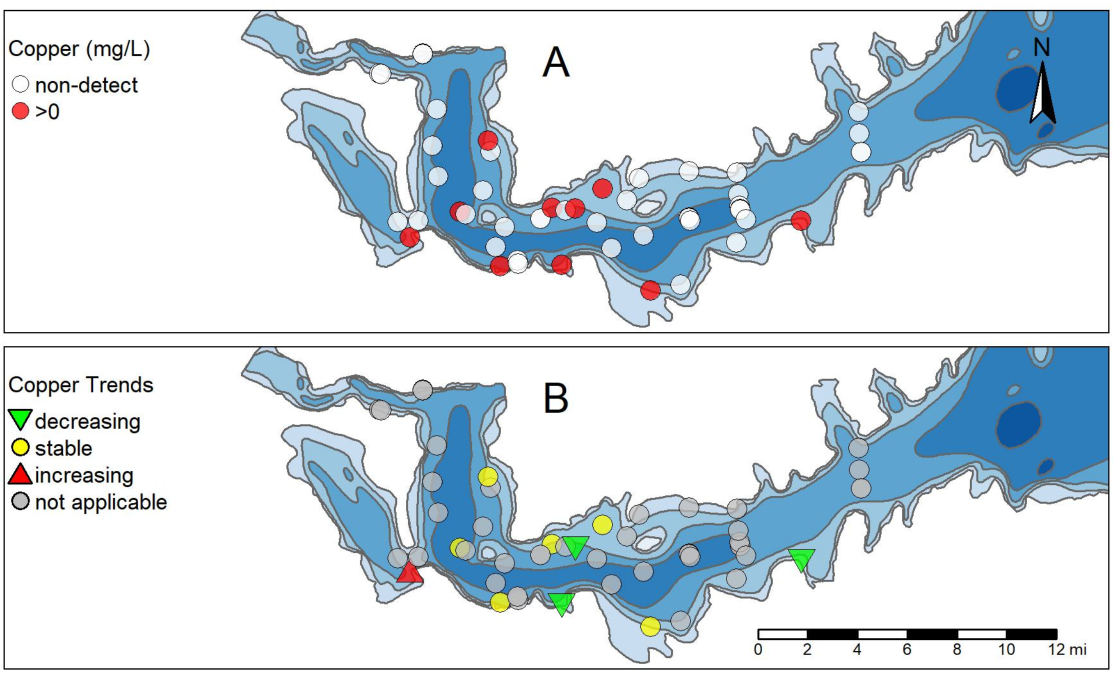

Figure 37. (A) Spatial distribution of median copper concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in copper concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

Copper has an action level (equivalent to an MCL) of 1.3 mg/L and a secondary standard of 1.0 mg/L. Over the 20-year period, these were never exceeded.

3.4.5. Iron

Iron data are summarized in Appendix E. Levels within the aquifer range from non-detect (or below the reporting limit) to 0.0451 mg/L. About 72.2 percent of all samples were non-detect. Given the prevalence of non-detects, the Q1 and median concentrations are zero but the Q3 concentration is 0.0181 mg/L (Figure 38). Reporting limits for iron ranged from 0.01 to 0.15 mg/L (Appendix C), which affected the statistical distribution (e.g., the Q3 is within these levels).

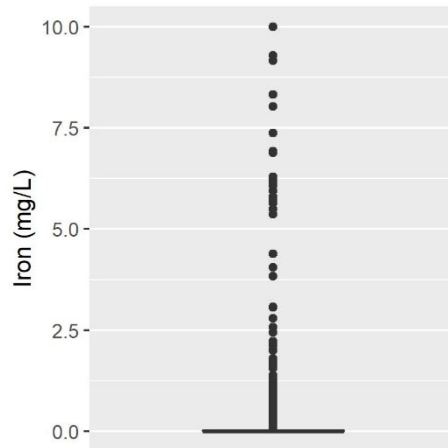

Figure 38. Boxplots showing the statistical distribution of iron concentrations (mg/L) of 1,995 samples collected at 51 monitoring locations between 1999 and 2011.

The spatial distribution of iron levels throughout the aquifer is shown in Figure 39A. Three locations do not have data for iron as they were added to the monitoring network after iron analysis was discontinued following the February 2011 sampling event. Most monitoring locations (n = 42) have median iron concentrations at zero due to 50 percent or more of samples collected having non-detectable levels.

The remaining six monitoring locations have median concentrations above zero (Figure 39A). Five of these locations represent conditions in the upper, unconfined aquifer. These have median iron concentrations ranging from 0.0173 to 0.2385 mg/L. The Plantes Ferry monitoring well (5404A01), which represents unique conditions in a confined aquifer, has a median iron concentration at 6.14 mg/L. This is 25 times higher than the concentrations found in the unconfined aquifer. The unique conditions of this confined aquifer are discussed in Section 4.2.

These six locations had enough data for trend analysis. During the 20-year period, iron levels at half of these locations were stable (SCC, East Spokane, Frederick and Bowdish) and were decreasing at the other half (EVHS, Plantes Ferry, and Barker Rd. North of River) (Figure 39B).

Iron is not a health hazard in drinking water and, therefore, no MCL is established. Iron is an aesthetic contaminant with a secondary water quality standard of 0.3 mg/L. Over the 20-year period, a total of 188 samples from 34 monitoring locations exceeded the secondary standard (Figure 39C).

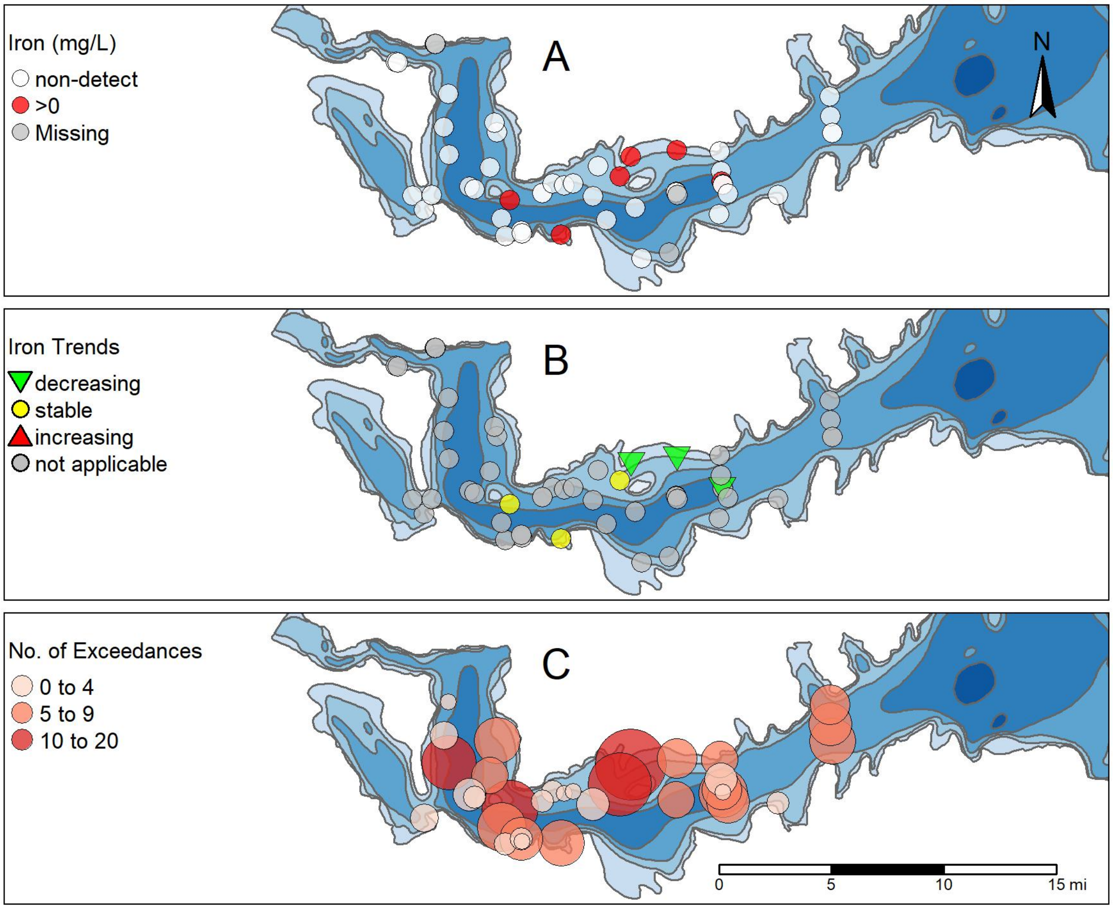

Figure 39. (A) Spatial distribution of median iron concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness data layer is modeled from Kahle and Bartolino (2007). (B) Trends in iron concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019. (C) Number of exceedances of the secondary standard for iron (0.3 mg/L) over the 20-year period between 1999 and 2019.

3.4.6. Lead

Lead data are summarized in Appendix E. Approximately 94 percent of the samples were non-detect. All monitoring locations have median concentrations at zero due to 50 percent or more of the samples collected having non-detectable levels. Given this, the statistical and spatial distribution of lead data is not shown. There is not enough detectable data for site-specific trend analysis. Lead has an action level (equivalent to an MCL) of 0.015 mg/L. Over the 20-year period, there have been four exceedances of the action level, resulting from one-time exceedances at four different monitoring locations (Figure 40). None of these exceedances happened within the last 10 years.

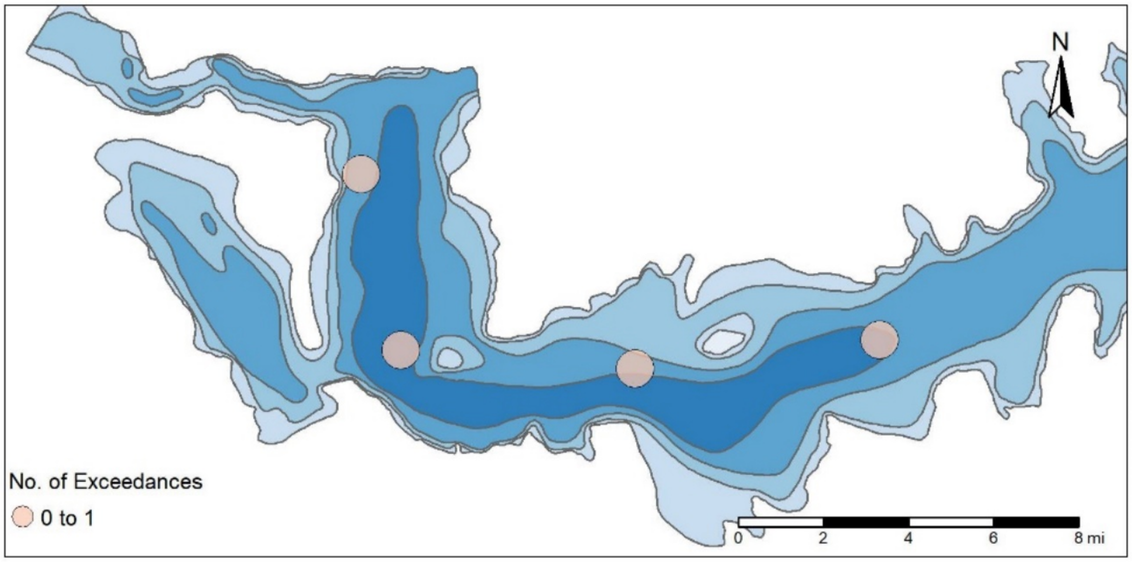

Figure 40. Number of exceedances of the Maximum Contaminant Limit (MCL) for lead (0.015 mg/L) over the 20-year period between 1999 and 2019.

3.4.7. Manganese

Manganese data are summarized in Appendix E. Approximately 88 percent of all samples were non-detect. Given this, the statistical distribution of manganese data is not shown. The spatial distribution of manganese concentrations throughout the aquifer is shown in Figure 41A. Most monitoring locations (n = 47) have median manganese concentrations at zero. Four locations have median concentrations above zero. Three of these locations are in the upper, unconfined aquifer: the monitoring wells at SCC (5310Q01), Frederick and Bowdish (5409C02), and EVHS (6436N01). Their median manganese concentrations range from 0.0019 to 0.01 mg/L. The Plantes Ferry monitoring well (5404A01) represents conditions in a confined aquifer with a median manganese concentration of 0.3590 mg/L. This is over 30 times higher than the other locations.

Site-specific trend analysis at these four locations indicates that over the 20-year period, the manganese levels in groundwater at EVHS were stable, were decreasing at Plantes Ferry, and were increasing at the SCC and Frederick and Bowdish monitoring wells (Figure 41B).

Manganese is not a health hazard in drinking water and, therefore, no MCL is established. Manganese is an aesthetic contaminant with a secondary water quality standard of 0.05 mg/L. The State reporting level is 0.01 mg/L. During the 20-year period, the secondary standard was exceeded in 40 samples from eight sites. Most of these exceedances (70 percent) occurred at the Plantes Ferry monitoring well. The other seven locations had five or less exceedances (Figure 41C). The State reporting level was exceeded in 128 samples from 25 sites. The Plants Ferry confined aquifer accounted for a large portion (22 percent) of these exceedances followed by the Frederick and Bowdish well (18 percent).

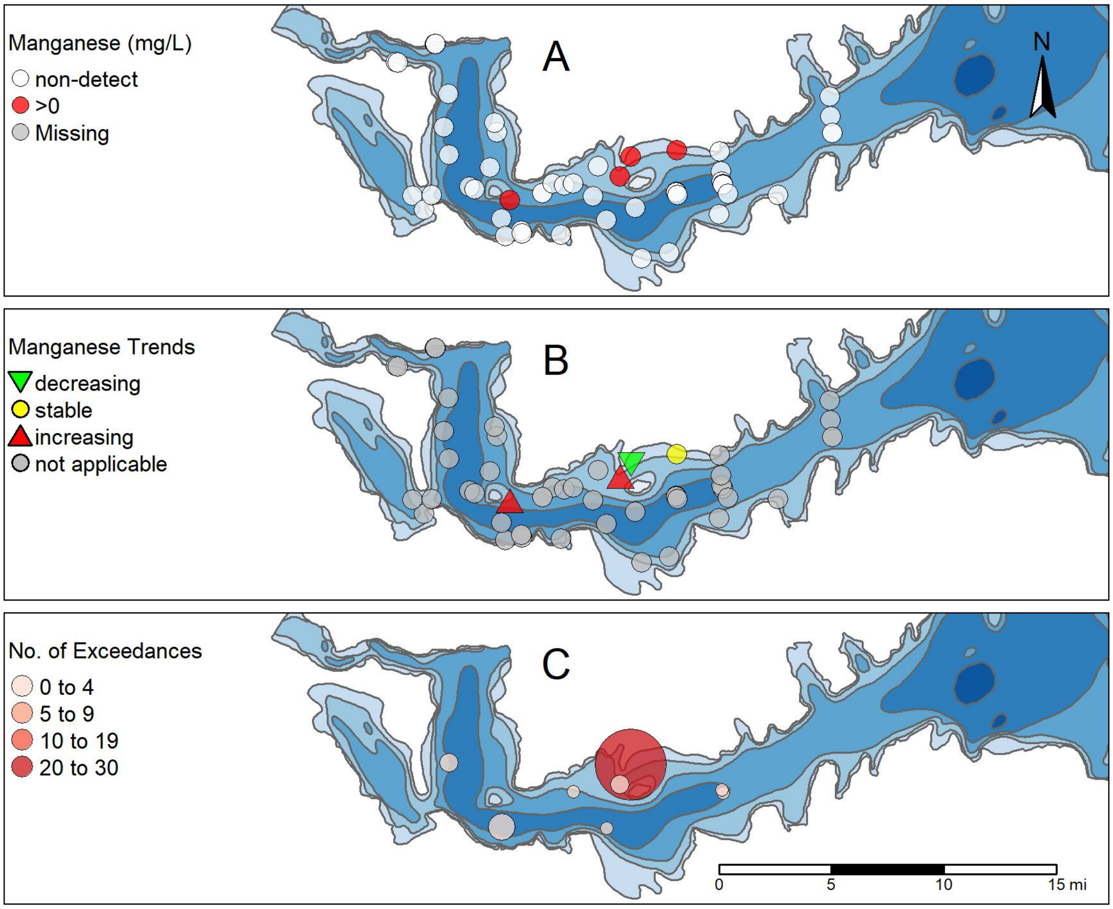

Figure 41. (A) Spatial distribution of median manganese concentrations (mg/L) within the Spokane Valley Rathdrum Prairie aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness data layer is modeled from Kahle and Bartolino (2007). (B) Trends in manganese concentrations (mg/L) within the Spokane Valley Rathdrum Prairie aquifer over the 20-year period between 1999 and 2019. (C) Number of exceedances of the secondary standard for manganese (0.05 mg/L) over the 20-year period between 1999 and 2019.

3.4.8. Mercury

Mercury data are summarized in Appendix E. Most samples (90 percent) were non-detect. Mercury is generally not detectable at any of the monitoring locations (median = 0 mg/L due to high proportion of non-detects). Given this, statistical and spatial distributions of mercury data are not shown, and trend analysis was not conducted. Mercury has a MCL of 0.002 mg/L, which is also the State's trigger level. During the 20-year period, this level was never exceeded.

3.4.9. Zinc

Zinc data are summarized in Appendix E. Most samples (77.5 percent) were non-detect. Given this, the statistical distribution of zinc data is not shown. The spatial distribution of zinc levels throughout the aquifer is shown in Figure 42A. Zinc is generally not detected at most monitoring locations (n = 44). Seven monitoring locations have median concentrations ranging from 0.0097 to 0.031 mg/L. These seven locations are all within the upper, unconfined aquifer. Three of these represent river-influenced groundwater along Barker Road (5508M01, 5508M02, and 5507H01).

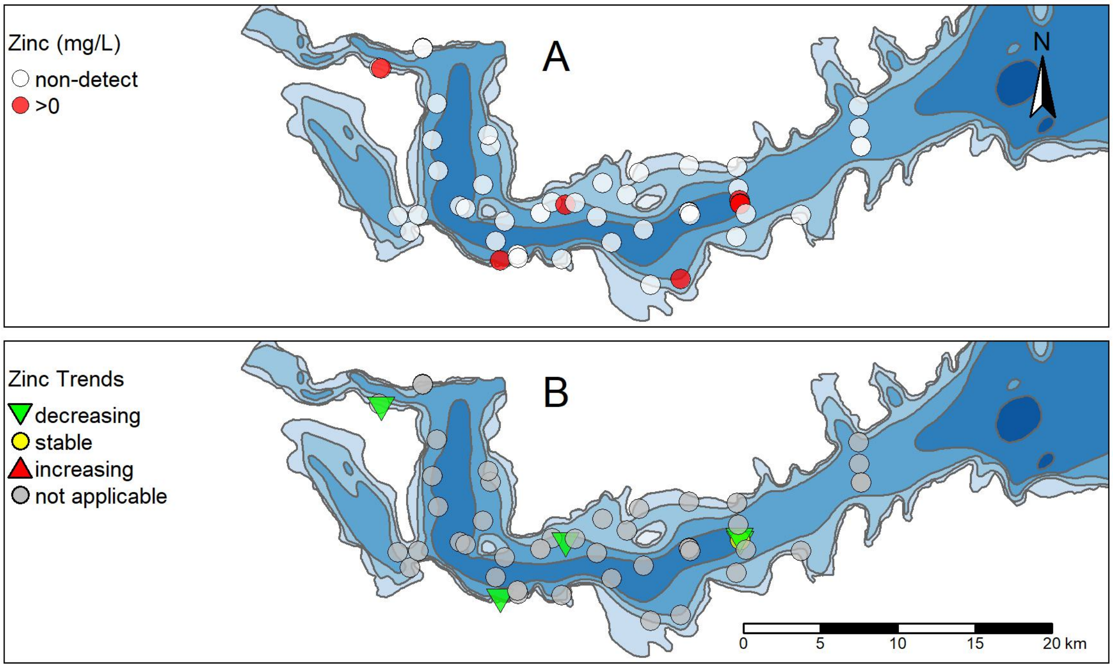

Figure 42. (A) Spatial distribution of median zinc concentrations (mg/L) within the Spokane Valley Rathdrum Prairie (SVRP) aquifer in relation to aquifer thickness (feet), an indicator of the amount of groundwater. Aquifer thickness is modeled from Kahle and Bartolino (2007). (B) Trends in zinc concentrations (mg/L) within the SVRP aquifer over the 20-year period between 1999 and 2019.

Trend analysis was conducted for the seven monitoring locations with detectable data. Zinc concentrations decreased over the 20-year period at five of these locations (6211K01, 5322F01, 6312H01, 5507H01, and 5508M01) and were stable at two of the locations (5508M02 and 5426L01) (Figure 42B).

Zinc does not have an MCL. It has a secondary standard of 5 mg/L and a State reporting level of 0.2 mg/L. The secondary standard was never exceeded. The State reporting level was exceeded three times.

3.5. Water Levels

Groundwater levels are monitored by the County only at the 29 monitoring wells. The static water level is measured in monitoring wells prior to sampling. Due to the infrastructure at purveyor wells, manual water level measurements were not collected at these locations.

Groundwater elevation contours, which indicate direction of groundwater flow from the highest elevation at the Stateline to the lowest at the tips of the Western and Little Spokane Arms, were produced in a previous study (Hsieh et al 2007). Median groundwater surface elevations measured at the monitoring wells fit within values of these groundwater elevation contours (Figure 43).

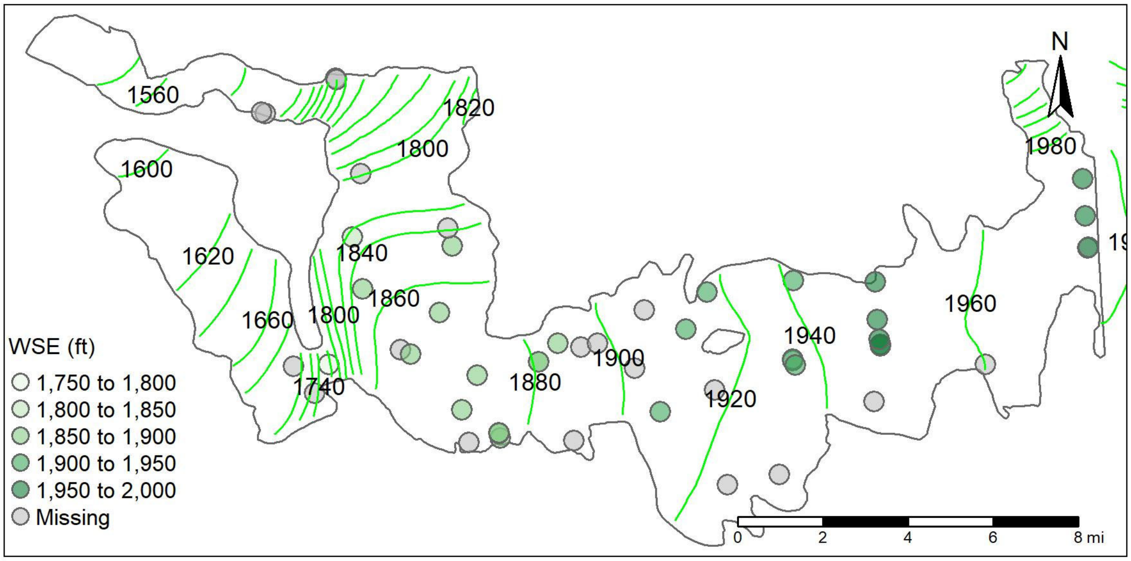

Figure 43. The 20-year (1999 – 2019) median groundwater surface elevations (WSEs) measured in feet at monitoring wells in relation to the groundwater elevation contours (in 20-foot increments) modeled after Hsieh et al (2007). WSEs are not measured at purveyor wells or springs (indicated as "missing").

The groundwater surface elevations measured at each site over time are shown in Figure 44 and WSE data are summarized in Appendix E. This shows the seasonal fluctuation of groundwater levels, which vary between two and six feet depending on the location.

Figure 44. Groundwater surface elevations (WSEs) measured at 28 monitoring wells over the 20-year period between 1999 and 2019.

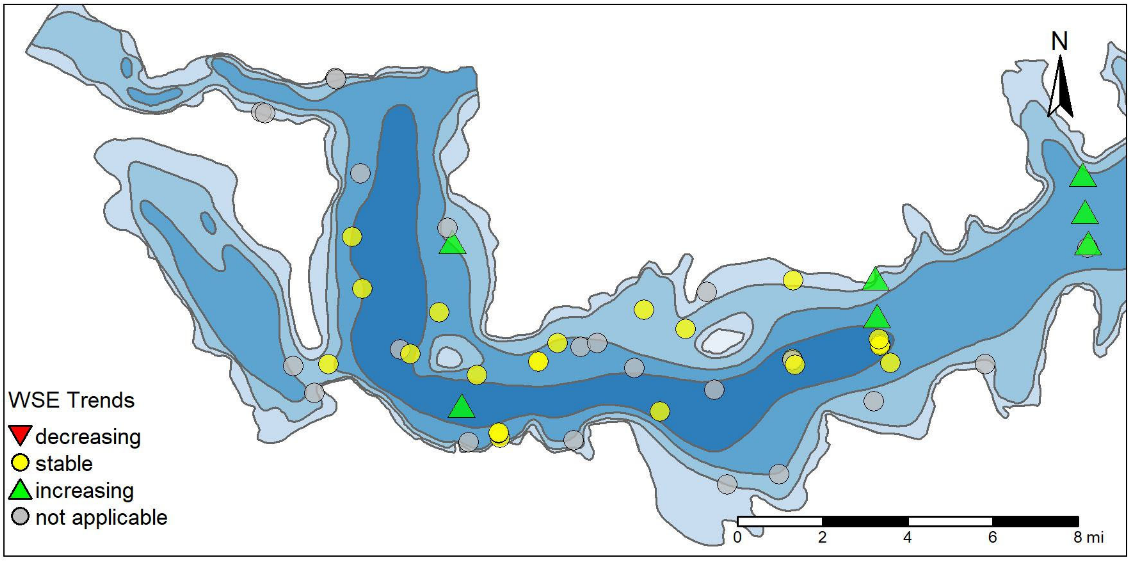

Figure 45. Trends in groundwater surface elevations (WSEs) measured at 28 monitoring wells over the 20-year period between 1999 and 2019. Groundwater surface elevations are not applicable for purveyor wells and natural springs, which are shown in gray.

Trends in WSE data were determined using either the Mann-Kendall or the Seasonal Mann-Kendall test based on seasonality and heterogeneity in the data (see Section 1.6). The Kruskal-Wallis test indicated all but two monitoring wells (6524R01 and 5411R06) exhibited seasonality in groundwater elevations. The van Belle and Hughes (1984) heterogeneity test found evidence of heterogeneity (opposing trends) for one site (5308H01). Therefore, the Mann-Kendall trend test was performed on those three sites, and the Seasonal Mann-Kendall test was performed on the remaining 26 sites.

Groundwater levels were stable at most monitoring wells (n = 21). Seven locations exhibited increasing trends in water levels (Figure 45). Three of these are on Idaho Road, including a monitoring well (6631M07) located adjacent to the CID East Farms well field. The increase was calculated at approximately 0.3 foot per year. The similarities in water level patterns at the Idaho Road wells suggest these locations are influenced by pumping at the CID East Farms well field. However, decreased water usage from the purveyor well field is not necessarily the reason for the increased water levels.

Two monitoring wells located north of the river at the Barker Road intersections with Trent and Euclid Avenues (5505D01 and 5507A04 respectively) also had increasing water levels. Since the Idaho Road locations are upgradient, the increase occurring there may be influencing the two Barker Road locations as more water is moving through the aquifer. However, the rate of increase at these locations was a little less than half that at Idaho Road, between 0.12 and 0.14 foot per year.

The remaining two monitoring wells with increasing trends include one located at the intersection of Olive and Fiske (5315L01) in an industrial/commercial area and another at the fire station on Houston and Regal in North Spokane (6327N04). The increase at these locations happened at a much lower rate than those at Idaho and Barker Roads, at 0.04 foot per year. Other monitoring wells located throughout the Hillyard Trough display similar patterns in water levels, but their data does not indicate any trends.

Spokane area weather data was compiled from the National Weather Service for the same 20-year period. The weather data included the monthly mean air temperature and the monthly mean and monthly total precipitation and snow fall amount. This data was assessed for trends on an annual and monthly basis. The results of this analysis did not account for the increases in groundwater levels. No trends were identified in precipitation or snowfall levels. There was a significant increase in annual temperatures over the 20-year period. However, this weather data is localized while the SVRP Aquifer is a regional aquifer system and, therefore, requires consideration of weather data at a larger spatial scale.

Rather than compiling and analyzing individual weather stations throughout Washington and Idaho to determine correlations, the Pacific Decadal Oscillation (PDO) Index was used as a regional climatic indicator. The PDO is a climatic pattern driven by sea surface temperatures in the North Pacific Ocean. The PDO Index classifies associated climatic patterns into warm (positive index values) or cool (negative index values) phases. In the Pacific Northwest, the PDO's warm phase is associated with warmer, drier winters and the cool phase is associated with cooler, wetter winters. These phases have historically occurred in irregular decadal cycles of 15 to 30 years though, more recently, the cycles have become shorter.

The groundwater levels from four monitoring wells were plotted in relation to the PDO phases over time (Figure 46). From this graphical analysis, the groundwater levels at these locations appear to be influenced by the PDO. Groundwater levels generally decreased from 1999 through 2007 following a 23-year warm phase. The short, 3-year cool phase (1999 to 2002) that occurred during this period was likely not long enough to counter the effects of the longer warm phases that preceded and followed it. Groundwater levels began to rise with the 7-year cool phase starting in 2007, peaking towards the end of this phase before decreasing with the most recent warm phase starting in 2014.

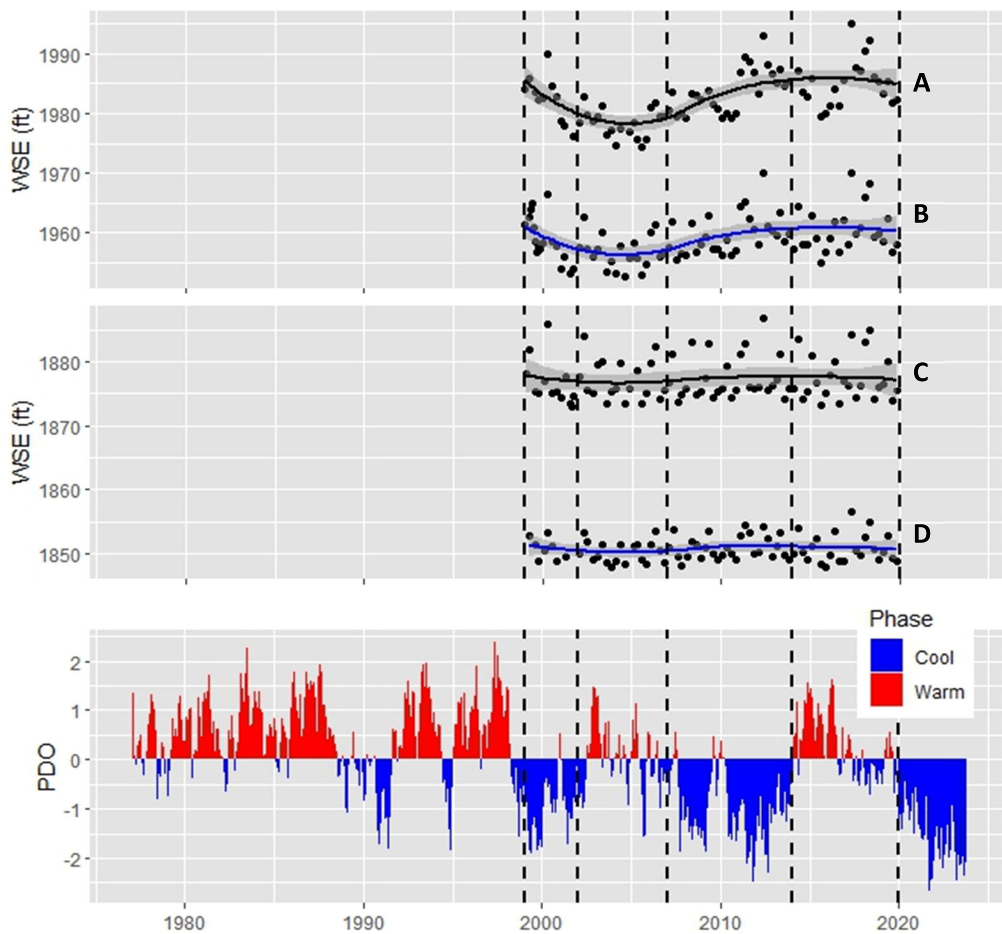

Figure 46. Plot of water surface elevations (WSE) (in feet) measured at four monitoring wells from January 1999 to December 2019 in relation to the Pacific Decadal Oscillation (PDO) Index by phase for the period January 1975 to October 2023. The four monitoring wells are: A) Idaho Road 1000 feet South of Trent (6524R01); B) Trent and Barker (5505D01); C) Olive and Fiske (5315L01); and D) Fire Station at Houston and Regal (6327N04). The dashed lines delineate the generally accepted periods of "warm" and "cool" phases. PDO Index is based on Huang et al 2017 and was downloaded from the NOAA Physical Sciences Laboratory (PSL).

While the graphical analysis shows a relationship between the PDO phase and groundwater levels, an advanced statistical analysis called Singular Spectrum Analysis is needed to confirm that the groundwater level fluctuations are correlated with the PDO. While this analysis is beyond the scope of this report, another study (Velasco et al 2017) utilized Singular Spectrum Analysis on long-term groundwater level data from a USGS monitoring well near Liberty Lake (USGS Site Number 474011117072901). A plot of the long-term data from the USGS well in relation to the PDO Index is shown in Figure 47 for reference. This demonstrates that groundwater levels from the USGS Liberty Lake well generally track with the PDO overtime with relatively lower levels during warm phases and higher levels during cool phases.

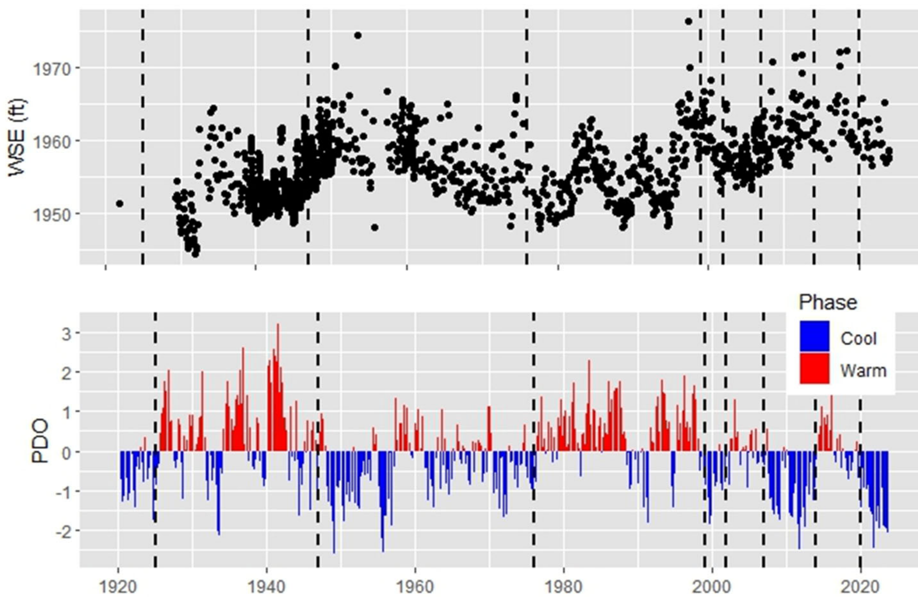

Figure 47. Plot of water surface elevations (WSE) (in feet) measured at a long-term U.S. Geologic Survey (USGS) monitoring well near Liberty Lake, Washington (USGS Site Number 474011117072901 in relation to the Pacific Decadal Oscillation (PDO) Index by phase for the period January 1920 to October 2023. The dashed lines delineate the generally accepted periods of "warm" and "cool" phases. Groundwater data was downloaded from the USGS National Water Information System (NWIS). The PDO Index is based on Huang et al 2017 and was downloaded from the NOAA Physical Sciences Laboratory (PSL).

However, Velasco et al (2017) indicated that the Atlantic Multidecadal Oscillation (AMO), another cyclic climatic pattern, had greater influence over the groundwater levels measured at the USGS Liberty Lake well than the PDO. The AMO is driven by sea surface temperatures in the North Atlantic Ocean and has much longer cycles (50 to 80 years). In the Pacific Northwest, the AMO index's positive phases are associated with increased precipitation and the negative phase with decreased precipitation (note that this is reversed from the PDO index). Due to its longer cycles, assessing correlations with the AMO requires a much longer water level record. The wells in the County's monitoring network do not have sufficient water level records for such an assessment.