7. On-Site Wastewater and the Septic Tank Elimination Program

There are several sewer service areas overlying the SVRP aquifer within Spokane County. The major ones include the City of Spokane's sewer service area, served by the Riverside Park Water Reclamation Facility (RPWRF); Spokane County's Spokane Valley sewer service area, served by the Spokane County Regional Water Reclamation Facility (SCRWRF) and RPWRF; Spokane County's North Spokane sewer service area, which is connected to the RPWRF; and the Liberty Lake Sewer and Water District (LLSWD) service area, served by the LLSWD's Water Reclamation Facility (Figure 74). Locations outside of these sewer service areas utilize septic systems to provide on-site wastewater treatment.

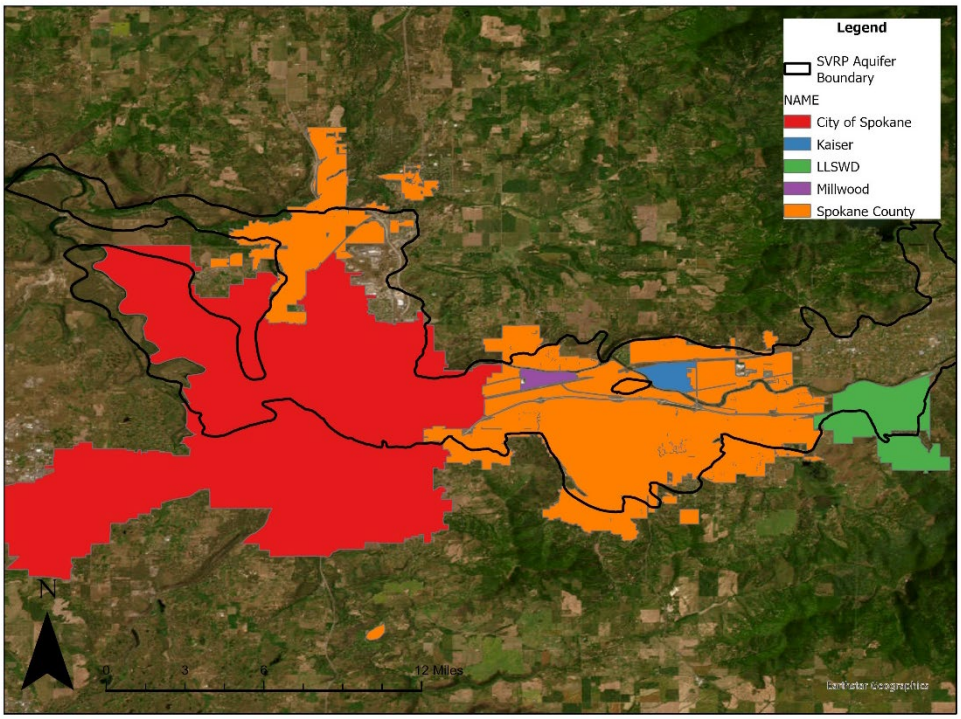

Figure 74. Sewer service areas overlying the Spokane Valley Rathdrum Prairie (SVRP) Aquifer. This shows the extent of sewer service as of 2023; future service areas are not shown. Spokane County's sewer service area is divided between its North Spokane sewer service area (north of the City of Spokane's service area) and its Spokane Valley sewer service area (east of the City of Spokane's service area).

Septic system leachate can degrade groundwater quality. While there is no local data regarding typical concentrations of contaminants in septic tank effluent, data from the U.S. EPA (2002) is presented in Table 8. Indicators of septic leachate impacting groundwater primarily includes elevated levels of nitrate, phosphate, and SRP. Elevated levels of chloride, sulfate, sodium, calcium, and potassium have also been linked to septic leachate. Groundwater below septic systems may also experience lower dissolved oxygen and pH (Katz et al 2011). Volatile organic compounds (VOCs) and synthetic organic compounds (SOCs) in septic tank effluent are likely to be removed in subsoils through gaseous diffusion, volatilization, or biodegradation before reaching groundwater. However, there have been instances of toxic organic contamination from septic infiltration fields.

Table 8. Water quality characteristics of typical domestic septic tank effluent. Summarized from USEPA 2002.

Parameter	**Typical Range**
Temperature (C)	0 – 23
pH	6.4 – 7.8
TDS (mg/L)	354 – 610
Chloride (mg/L)	37 – 110
Total Nitrogen (mg/L)	40 – 100
Total Phosphorus (mg/L)	5 – 17
VOCs	0 – Trace
SOCs	0 – Trace
Heavy Metals	0 – Trace

Spokane County implemented the Septic Tank Elimination Program (STEP) to address concerns identified in the 1978 Spokane Aquifer Cause and Effect Report (Esvelt 1978), which determined that on-site sewage systems were contributing to water quality degradation in the SVRP aquifer. As a result, the 1979 Spokane Aquifer Water Quality Management Plan included the following:

> *The recommendations for handling sanitary wastewater and mitigation of its pollution to the groundwater include the collection of all sewage from urbanized areas and treatment for discharge in such manner that the pollutants cannot enter the aquifer. Central sewer planning within the aquifer sensitive area should result in sewering of areas that have been urbanized or are to be urbanized.*

The update to the Spokane Aquifer Cause and Effect Report (Esvelt and Miller 1983) found increasing trends in nitrate concentrations within the aquifer confirming the need to address on-site sewage disposal. Through the STEP, approximately 75 percent of existing septic systems draining to the SVRP aquifer in Spokane County were converted to sewer. This was done in phases over the course of several decades with much of the sewer installation completed by December 2011 when the SCRWRF came online (Figure 75).

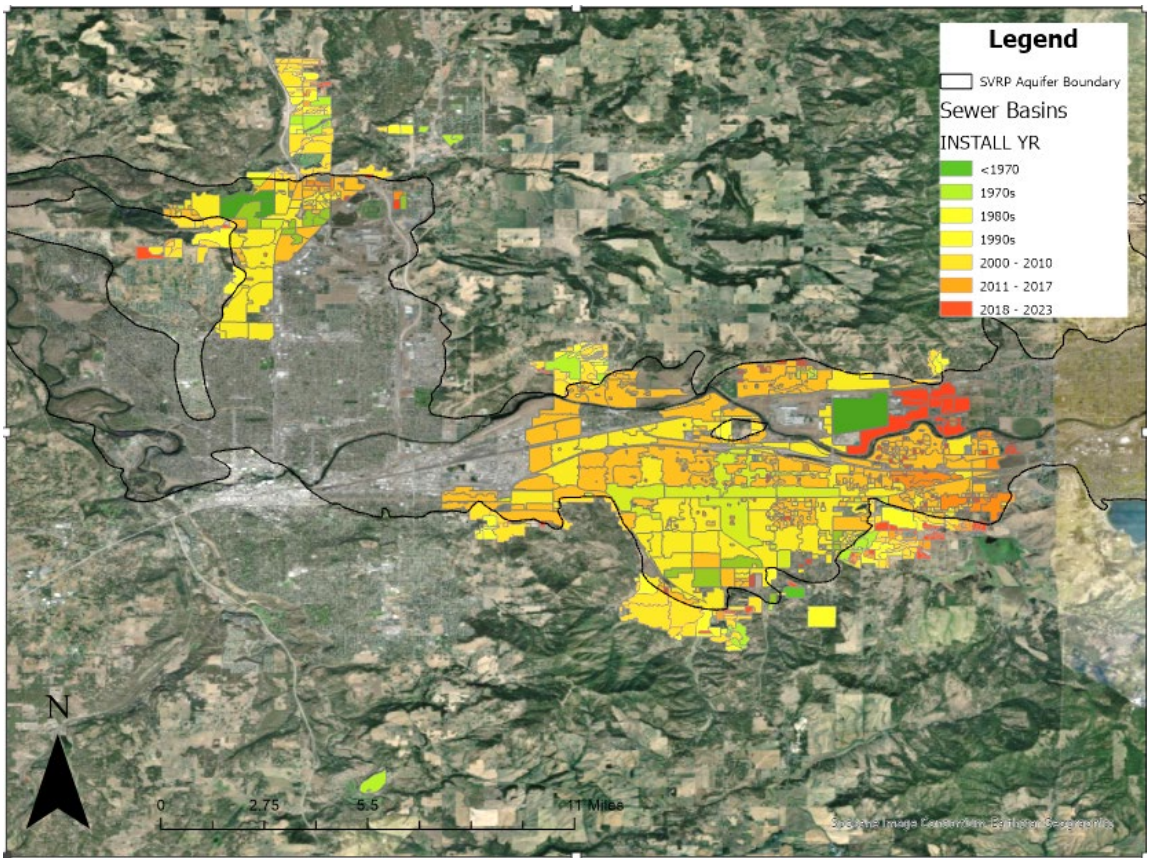

Figure 75. Sewer basins in Spokane County's sewer service area by year installed. Sewer basins are shown overlying the Spokane Valley Rathdrum Prairie (SVRP) Aquifer. This shows the extent of sewer service as of 2023; future service areas are not shown.

This section evaluates the effect of onsite wastewater treatment on groundwater quality and provides an evaluation of the STEP in reducing nitrate concentrations in the aquifer. Because nitrate is a potential health concern and can persist for decades in groundwater with oxic conditions (dissolved oxygen levels >0.5 mg/L), it is important to determine whether the County's STEP has been effective at reducing nitrate levels in the aquifer.

The County's two separate sewer service areas were analyzed individually. Due to the potential persistence of nitrate within the aquifer, and the staggered manner and timespan in which sewer installation occurred, this analysis utilizes data outside of the twenty-year period that is the focus of this study, where available.

Several methods were used to assess the STEP program:

1) Overall trends: Looking at the 20-year (or longer, where data is available) trend in nitrates within the sewer service areas compared to the upgradient, non-sewered wells. Trends can differ depending on the data considered, so data outside the 20-year period may be insightful where available.
2) Before/After analysis: Comparing data from wells within the sewer service areas prior to and after installation of the sewer system. A change in trend provides more evidence that the trend is linked to sewer installation.

7.1. Spokane Valley Sewer Service Area

There are 21 monitoring locations within the County's Spokane Valley sewer service area and seven monitoring locations outside of sewer service along Barker and Idaho Roads that serve as a comparison. Areas along Barker Road north of the river were sewered beginning in 2018 (Figure 75) and, therefore, were not considered as sewered for the purposes of this study. Three monitoring locations on Barker Road (two within the service area and one outside of the service area) are river-influenced wells, which affects the nitrate levels. These monitoring locations are discussed in groups by location and sewer service connection date.

7.1.1. Non-Sewered Area

Seven wells along Idaho and Barker Roads north of the Spokane River are outside of the County's Spokane Valley sewer service area (Figure 76). Nitrate levels measured at the four monitoring locations along Idaho Road are considered the "background" groundwater nitrate levels.

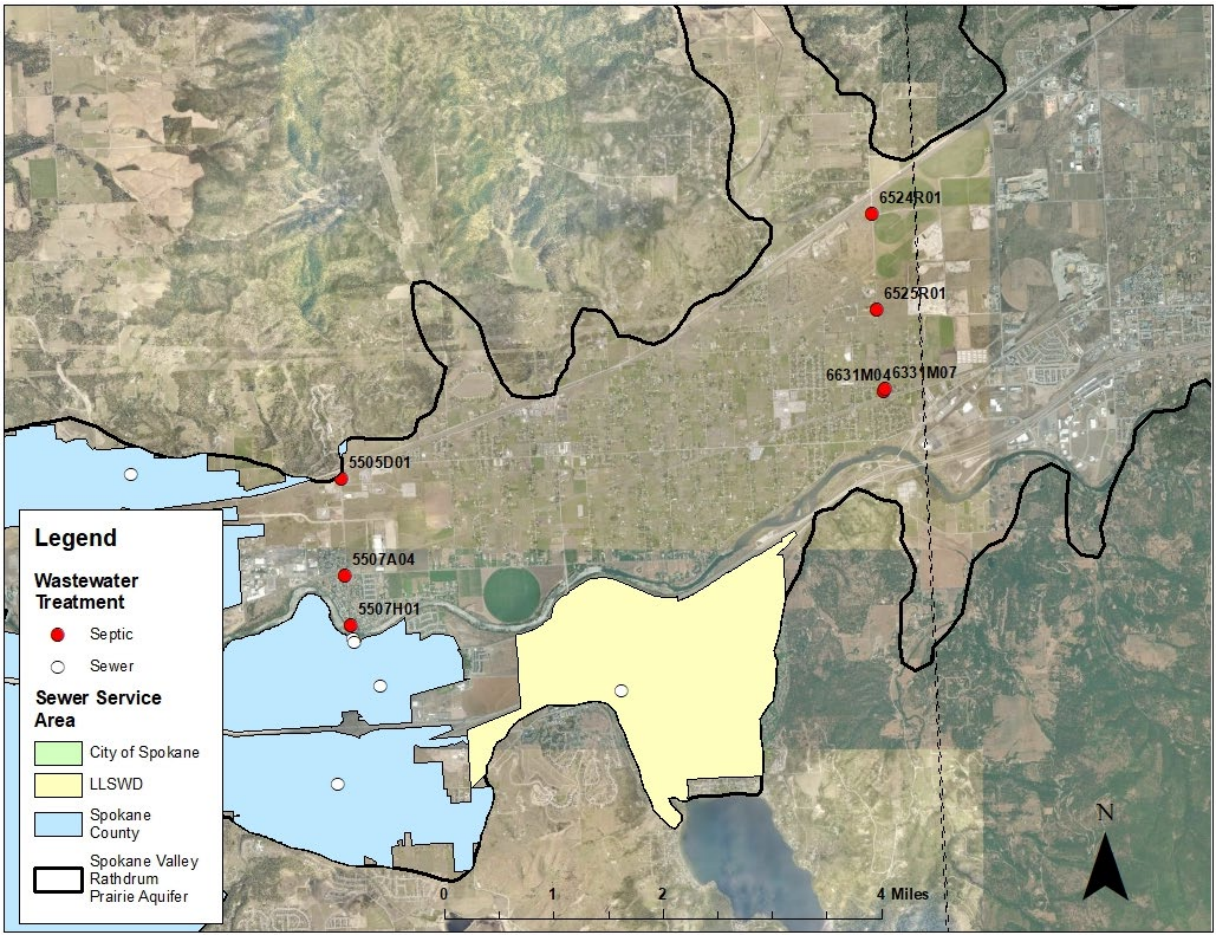

Figure 76. Seven monitoring wells on Idaho and Barker Roads outside of the Spokane County's Spokane Valley sewer service area as of 2017. The seven monitoring locations are 6624R01, 6625R01, 6331M04, 6331M07, 5505D01, 5507A04, and 5507H01.

A plot of nitrate concentrations over time for these seven locations is shown in Figure 77. The monitoring well 6525R01 has the lowest median nitrate levels of the Idaho Road locations at 1.02 mg/L. The

monitoring well to the north, 6524R01, has the highest nitrate concentrations at 2.26 mg/L. The data from these two locations exhibited increasing nitrate concentrations over the 20-year period (Appendix E).

The two southern-most monitoring locations on Idaho Road, the CID East Farms purveyor well (6631M04) and the associated monitoring well (6631M07), have median nitrate concentrations of 1.38 and 1.67 mg/L respectively (Figure 77). The data at these two locations exhibit decreasing nitrate concentrations over the 20-year period. These are the only locations outside of the sewer service area exhibiting a decreasing trend (Appendix E). The County has data dating back to the 1970s for the CID purveyor well (6631M04), and a trend analysis including this additional data indicates stable nitrate levels ($z = -0.76$, $p>0.05$).

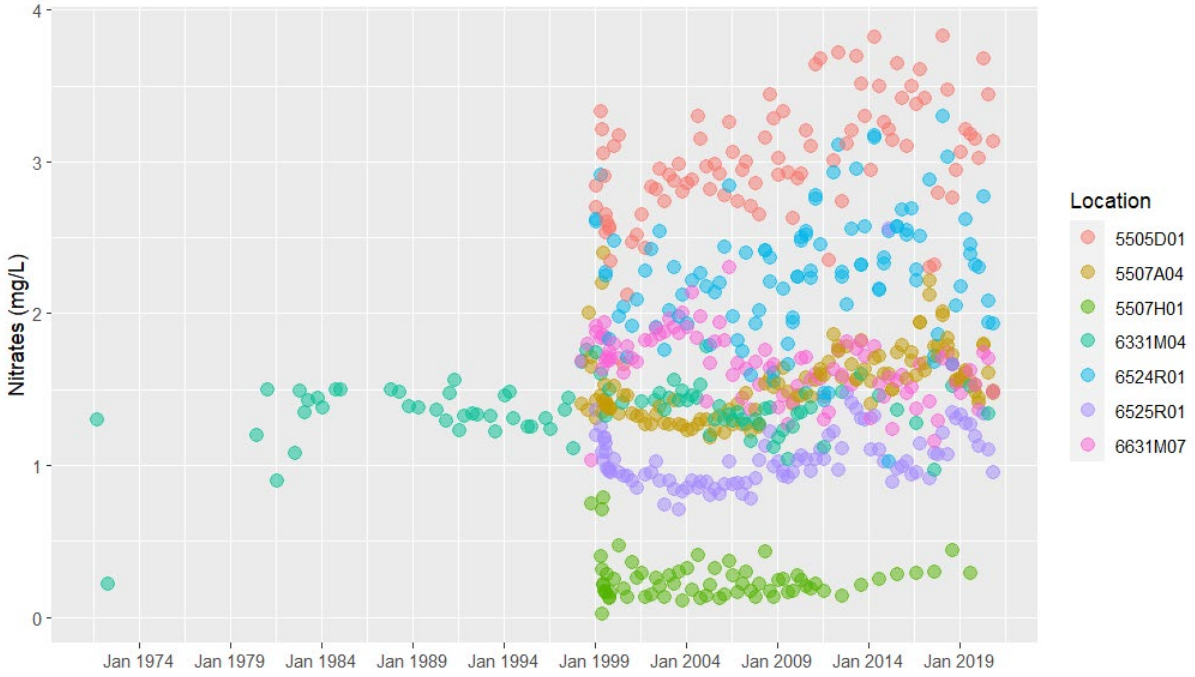

Figure 77. Plot of nitrate concentrations measured over time in samples collected at the seven monitoring locations outside of the sewer service areas along Barker and Idaho Roads.

Of the Barker Road monitoring locations outside of the sewer service area, groundwater from the Trent and Barker well (5505D01) has the highest nitrate levels (median = 2.97 mg/L). The Barker Road North of River well (5507H01) represents river-influenced groundwater and has the lowest nitrate levels (mean = 0.25 mg/L) of the seven monitoring locations outside of the sewer service area. The lower levels are likely due to river dilution (Section 5.1). Trend analysis indicates nitrate levels in samples collected from the Trent and Barker and the Euclid and Barker (5507A04) wells are increasing, while the groundwater sampled at the Barker Road North of River (5507H01) well exhibited stable nitrate levels over the 20-year period (Appendix M).

7.1.2. Barker Road South of River

Neighborhoods along Barker Road south of the river are sewered. There are four monitoring wells along Barker Road in sewered basins: two at the Barker Road Centennial Trail trailhead (5508M01 and

), one at Mission and Barker Road (5517D05), and the CID Site 2A (5518R01) (Figure 78). A plot of nitrate concentrations over time for these locations is shown in Figure 79.

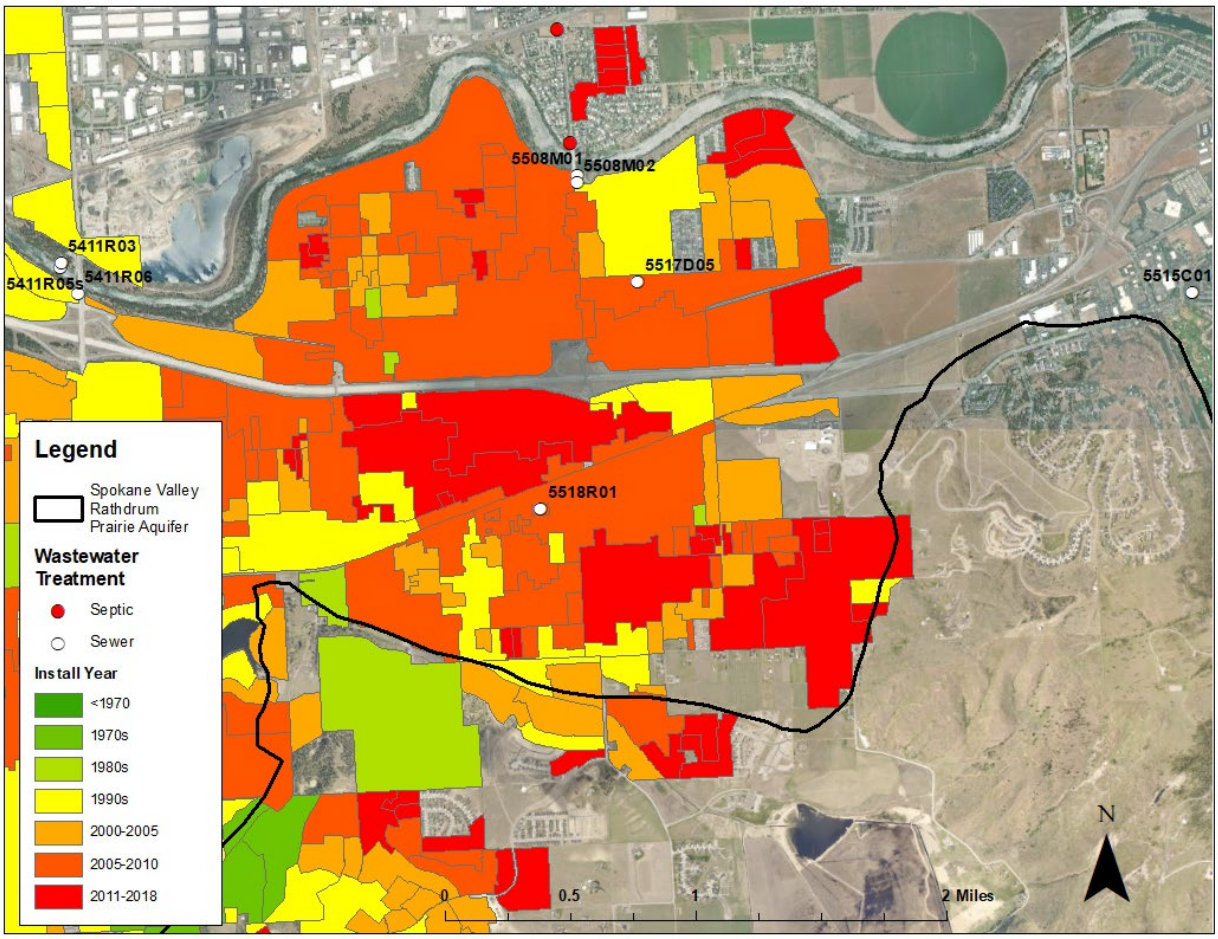

Figure 78. Four monitoring wells located along Barker Roads south of the river within Spokane County's Spokane Valley sewer service area. Sewer basins are colored according to the year installed with basins sewered after 2018 not shown. The four locations are the monitoring wells at the Centennial Trailhead (5508M01 and 5580M02), Mission and Barker Rd. (5517D05), and Consolidated Irrigation District Site 2A (5518R01).

The two monitoring wells at the Centennial Trailhead (5508M01 and 5508M02) are in a neighborhood sewered in 1995 (Figure 78). These also represent river-influenced groundwater, which dilutes nitrate concentrations (see Section 5.1). Periodic low dissolved oxygen (DO<0.5mg/L) at these locations potentially promotes denitrification. The 20-year trend analysis indicates nitrate levels at both wells significantly increased (Appendix E).

Since sampling began in late 1998 for these two wells, this additional data was considered. Trend analysis with this additional data indicates stable levels at both wells (Table 9. Therefore, it is likely that the nitrate levels in these river-influenced wells stabilized since sewer installation. The record does not include data prior to sewering for these locations, so a before-after comparison could not be completed (Table 9).

The other two locations, the Mission and Barker Road monitoring well (5517D05) and the CID Site 2A (5518R01) are further south in neighborhoods that were sewered in 2010 (Figure 78). The 20-year trend analysis indicates nitrate levels decreased at these locations. Though the County has additional data for both sites, including this data in a trend analysis did not change the results; nitrate levels decreased at both locations (Table 9).

A before and after trend analysis using all available data was completed for the Mission and Barker Road monitoring well (5517D05) and the CID Site 2A (5518R01). This shows decreasing nitrate levels prior to sewer installation with nitrate levels stabilizing afterwards at both locations (Table 9, Figure 79). The decreasing trend prior to sewer installation is likely the result of upgradient sewering in the 1990s and early 2000s. This is shown in Figure 79 where nitrate levels recorded at 5518R01 appear to be generally higher before 1995 than afterwards. Any additional reductions following more localized sewer installation may not yet be shown in the data given the recent installation.

Table 9. Results of trend analyses of nitrate concentrations measured in samples collected at monitoring locations in East Spokane. Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation to determine the effects of sewering. The period covered by the data available is shown.

Well ID	Before	After	All data
5508M01			1998-2019
	---	---	Z= 1.79 p>0.05
			Not Trending
5508M02			1998-2019
	---	---	Z= -0.42 p>0.05
			Not Trending
5517D05	2010		
	Z= -4.23 p<0.05	Z= -1.41 P>0.05	Z= -5.47 p<0.05
	Decreasing	Not Trending	Decreasing
5518R01	2010		
	Z= -4.39 p<0.05	Z= -0.23 p>0.05	Z= -3.48 p<0.05
	Decreasing	Not Trending	Decreasing

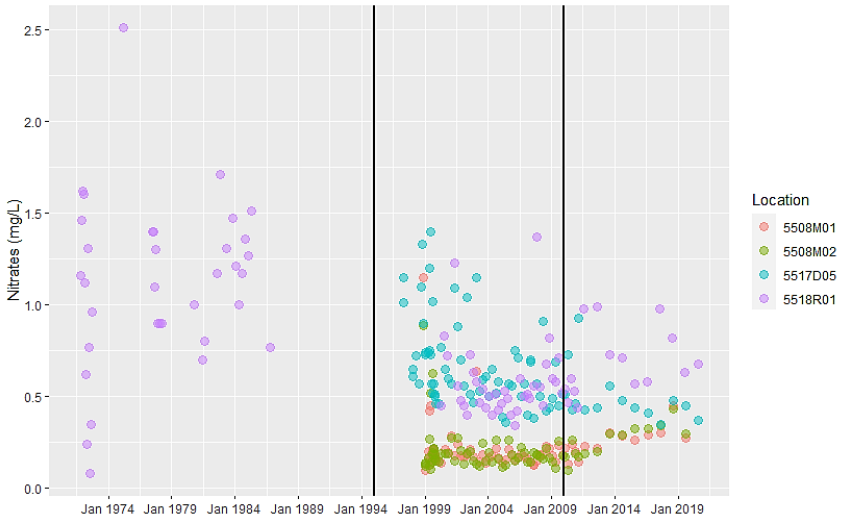

Figure 79. Plot of nitrate concentrations measured in samples collected at four monitoring locations along Barker Road south of the river over time. The four locations are the monitoring wells at the Centennial Trailhead (5508M01 and 5580M02), Mission and Barker Rd. (5517D05), and Consolidated Irrigation District Site 2A (5518R01). The solid lines indicate the date of sewer installation in 1995 (for 5508M01 and 5508M02) and 2010 (for 5517D05 and 5518R01), respectively.

7.1.3. Northern Sullivan Road

Neighborhoods along the northern Sullivan Road corridor to the intersection with Indiana Avenue are sewered. These neighborhoods were generally sewered in the 1990s, with those closer to the Indiana intersection sewered earlier than those near the northern terminus. Four monitoring locations are used to monitor groundwater conditions along the northern Sullivan Road corridor. The northern-most location is a monitoring well at the East Valley High School (EVHS) (6436N01). The remaining locations are at the opposite end of the corridor. These include a well and a natural spring at Sullivan Park (5411R03 and 5411R05s, respectively) just north of the Spokane River and a monitoring well just south of the Spokane River (5411R06) closer to the intersection with Indiana Avenue (Figure 80). A plot of nitrate concentrations over time for these locations is shown in Figure 81.

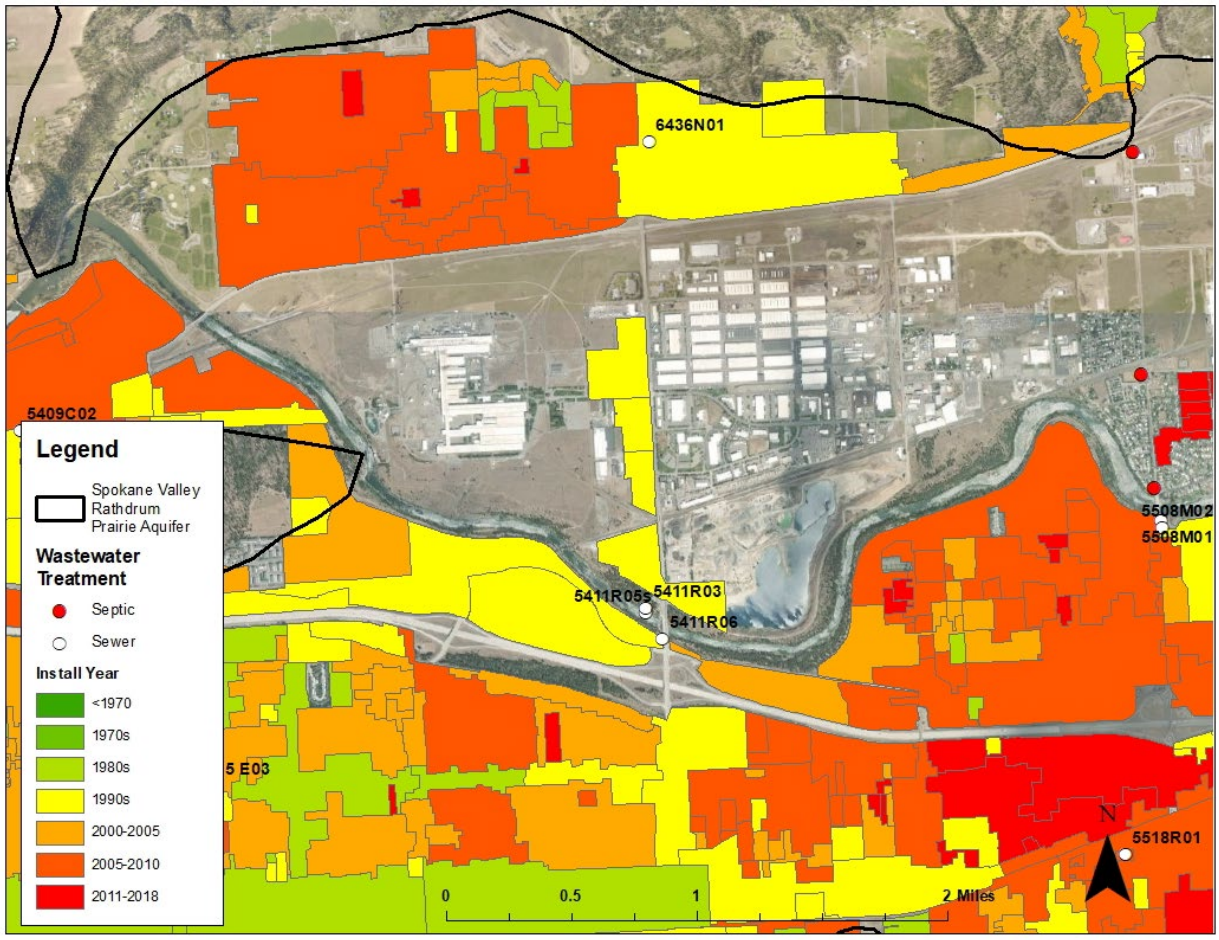

Figure 80. Monitoring wells located along Sullivan Road from its northern terminus to the Indiana Avenue intersection within County's Spokane Valley sewer service area. Sewer basins are colored according to the year installed with basins sewered after 2018 not shown. The four locations are the monitoring well at East Valley High School, (6436N01), a monitoring well and a natural spring at Sullivan Park (5411R03 and 5411R05s, respectively) just north of the Spokane River, and a monitoring well just south of the Spokane River at the intersection with Indiana Avenue (5411R06).

The neighborhood in the vicinity of the monitoring well at the EVHS was sewered in 1999, but sampling began at this location in 2006. Therefore, trends can only be assessed since that time. Nitrate levels in the EVHS monitoring well samples significantly decreased over the 13-year period (Table __, Figure _).

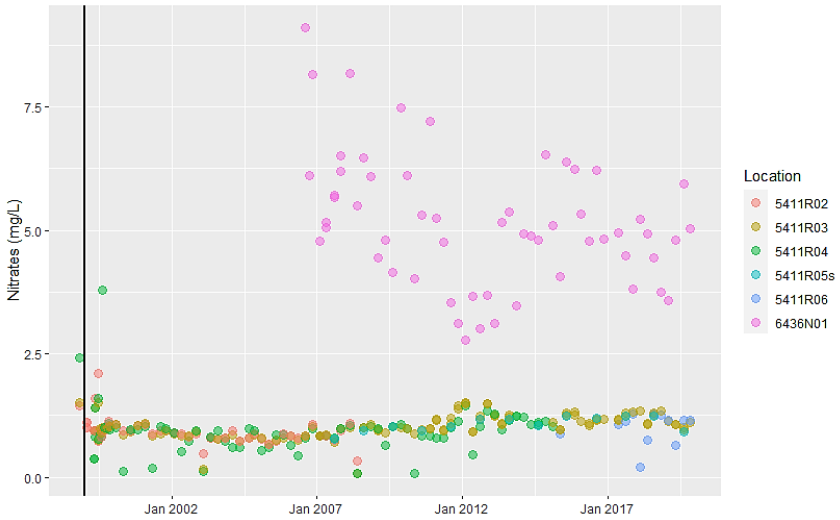

Figure 81. Plot of nitrate concentrations measured in samples collected over time at six monitoring locations along the northern Sullivan Road corridor. The six locations are the monitoring well at East Valley High School (6436N01), Sullivan Park South (5411R03), the natural springs at Sullivan Park (5411R05s), and the Sullivan Rd. Centennial Trail/Krispy Kreme (5411R04/6). The solid line indicates the date of sewer installation in 1999 (for 6436N01). The sewer installation in 1993 for the other locations is not shown since this predates the data record by 5 years.

The 20-year trend analysis indicates nitrate levels at the Sullivan Park monitoring well (5411R03) and the springs (5411R05s) increased. The neighborhoods in the vicinity of Sullivan Park were sewered in 1993. Data for these monitoring locations begins in 1998. A trend analysis including this additional data was completed, but this did not change the results. These locations still exhibited increasing nitrate levels (Table 10). A before and after analysis was not possible given available data.

The original 20-year trend analysis did not detect a trend in samples from the Sullivan Road well (5411R06), but data from this location only dates to May 2015. However, this monitoring well was a replacement for a former well at this location (5411R04), which was abandoned during construction at the Sullivan bridge in 2015. Data from the former well was used to supplement the data from the existing well so that nitrate trends could be determined for a longer period. The supplemental data resulted in an increasing trend in nitrate levels at this location (Table 10). A before and after analysis was not possible given available data.

The differences in both levels and trends in nitrates at the EVHS monitoring well and the other Sullivan Road locations suggest different sources of nitrates. The locations at Sullivan Park and the Indiana Avenue intersection may be impacted by upgradient locations (see Section 7.1.9).

Table 10. Results of trend analyses of nitrate concentrations measured in samples collected over time at four monitoring locations along Sullivan Road. Trends were assessed using all available nitrate data. The period covered by the data available is shown.

Well ID	All data
6436N01	2006 – 2019
	Z= -2.28 p<0.05
	Decreasing
5411R03	1998 – 2019
	Z= 5.54 P<0.05
	Increasing
5411R04/06	1998 – 2019
	Z= 3.02 p<0.05
	Increasing
5411R05s	1998 – 2019
	Z= 2.59 p<0.05
	Increasing

7.1.4. Northern Spokane Valley

For this analysis, northern Spokane Valley is defined as those neighborhoods north of Sprague and south of I-90. Outside of the Sprague and Pines Road corridors, which were sewered in the 1980s, most of the neighborhoods in northern Spokane Valley were sewered in the early 2000s (Figure 82).

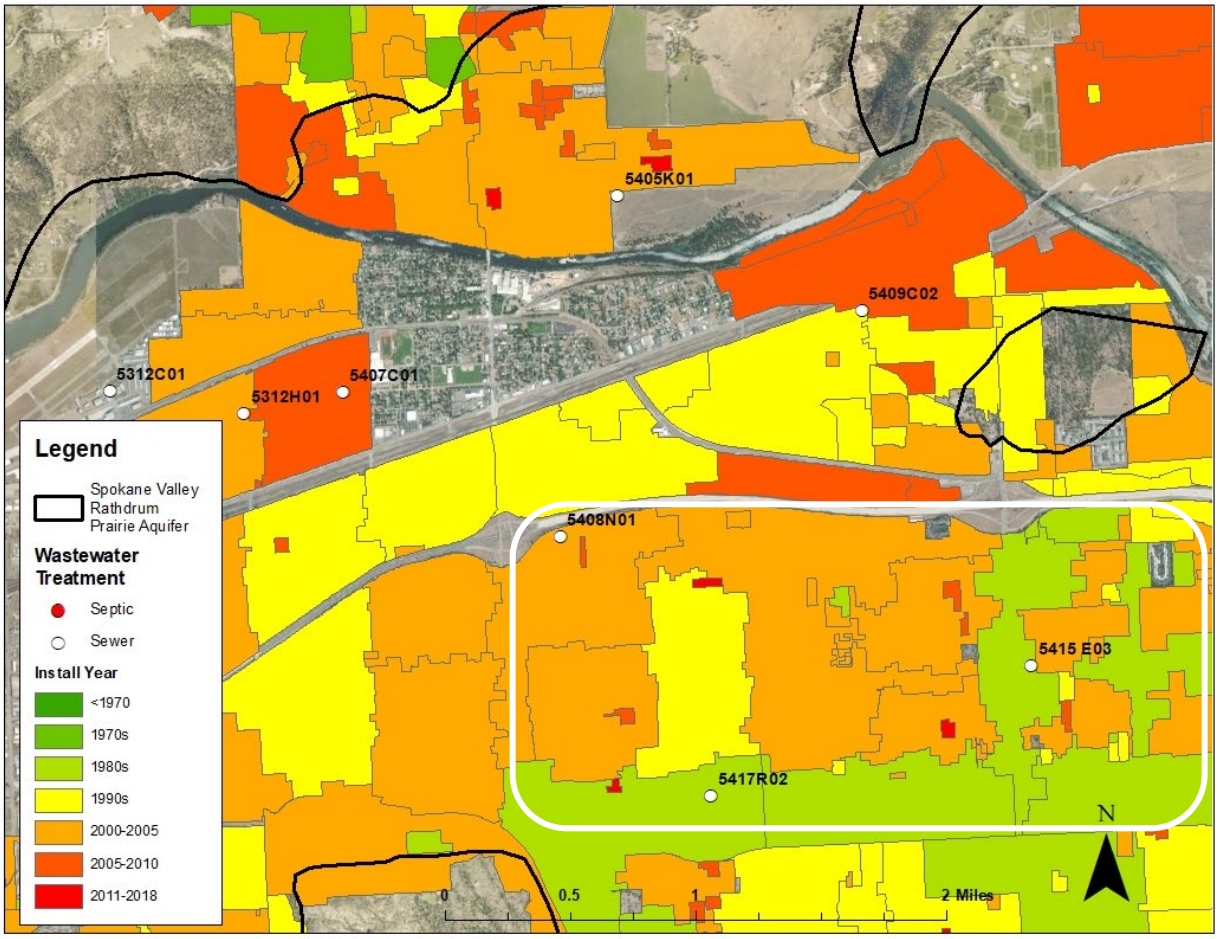

Figure 82. Monitoring wells located within the northern Spokane Valley. Sewer basins are colored according to the year installed with basins sewered after 2018 not shown. The three locations are the Balfour Park monitoring well (5417R02) and the Modern Electric wells at Site 6 and Site 11 (5408N01 and 5415E03, respectively).

There are three monitoring wells in northern Spokane Valley: the Modern Electric wells at Site 6 and Site 11 (5408N01 and 5415E02, respectively), and the Balfour Park monitoring well (5417R02) (Figure 82). A plot of nitrate concentrations over time for these locations is shown in Figure 83.

The 20-year trend analysis indicates nitrate levels in samples from the Balfour Park monitoring well (5417R02) and the Modern Electric Site 6 (5408N01) well decreased, but the nitrate levels in samples from the Modern Electric Site 11 (5415E03) well were not trending.

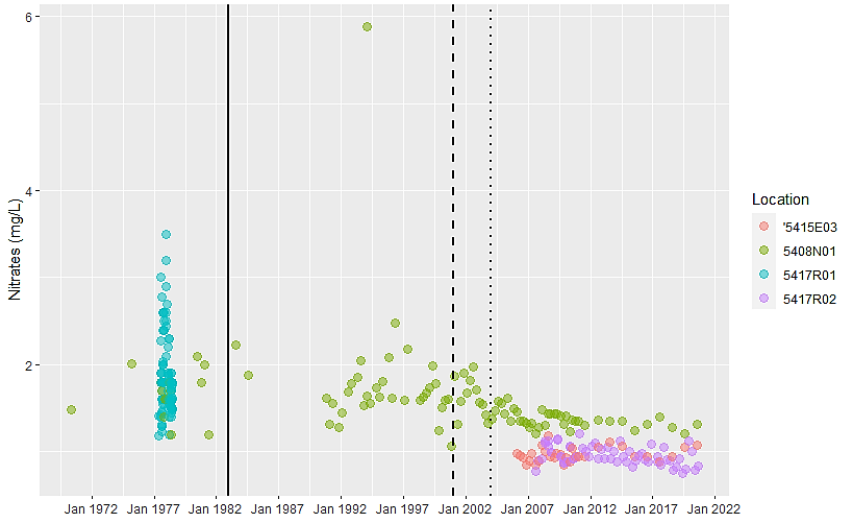

Figure 83. Plot of nitrate concentrations measured in samples collected over time at three monitoring locations within northern Spokane Valley. The three locations are the Balfour Park monitoring well (5417R01 and 5417R02) and the Modern Electric Site 6 and Site 11 wells (5408N01 and 5415E02, respectively). The lines indicate the year of sewer installation for each location as follows: 1983 (solid) for 5417R01/02, 2001 (dashed) for 5408N01, and 2004 (dotted) for 5415E03.

The two Modern Electric wells are in neighborhoods sewered in the early 2000s. The County's record of nitrate data for the Modern Electric Site 11 well (5415E02) begins in 2006, so additional analysis is not possible. The record for the Modern Electric Site 6 well (5408N01) begins in 1970, allowing for trend analysis over a longer period as well as before and after sewer installation. Nitrate levels significantly decreased since the 1970s, which does not differ from the 20-year trend. The before and after trend analysis shows no trend in nitrate levels prior to sewer installation, but a decreasing trend following installation (Table 11).

Table 11. Results of trend analyses of nitrate concentrations measured in samples collected over time at monitoring locations in northern Spokane Valley. Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation to determine the effects of sewering. Year of sewer installation and the period covered by the data assessed is shown for each location.

Well ID	Before	After	All data
5408N01	2001		1970 – 2019
	z= -0.28 p>0.05	Z= -4.91 p<0.05	Z= -6.32 p<0.05
	Not Trending	Decreasing	Decreasing
5415E02	2004		2006 – 2019
	---	---	Z= 0.97 p>0.05
	---	---	Not Trending
5417R01/R02	1983		1977 – 2019
	Z= -0.95 p>0.05	Z= -2.82 p<0.05	Z= -9.99 p<0.05
	Not Trending	Decreasing	Decreasing

The Balfour Park well is within a neighborhood in the Sprague corridor sewered in 1983. The Balfour Park monitoring well (5417R02) replaced a former well (5417R01) at this location. Data from the former well dates from 1977 to 1978. Using this data to supplement data from the existing well allows the long-term trend in nitrate levels to be assessed as well as a before and after analysis. With the additional data, nitrate levels at this location decreased and the decrease followed sewer installation (Table 11). This mirrors the results of the Modern Electric Site 6 well, demonstrating that the groundwater in the vicinity of the northern Spokane Valley responded similarly to sewering.

7.1.5. Southern Spokane Valley

For this analysis, southern Spokane Valley is defined as those neighborhoods south of Sprague, east of the Dishman-Mica Road and west of Sullivan Road. Two purveyor wells (5426L03 and 5427L01) are in southern Spokane Valley. While these wells are in neighborhoods that were sewered in 1991, most neighborhoods in southern Spokane Valley generally had sewer installed from the 1980s through the 1990s (Figure 84). A plot of nitrate concentrations over time for these locations is shown in Figure 85.

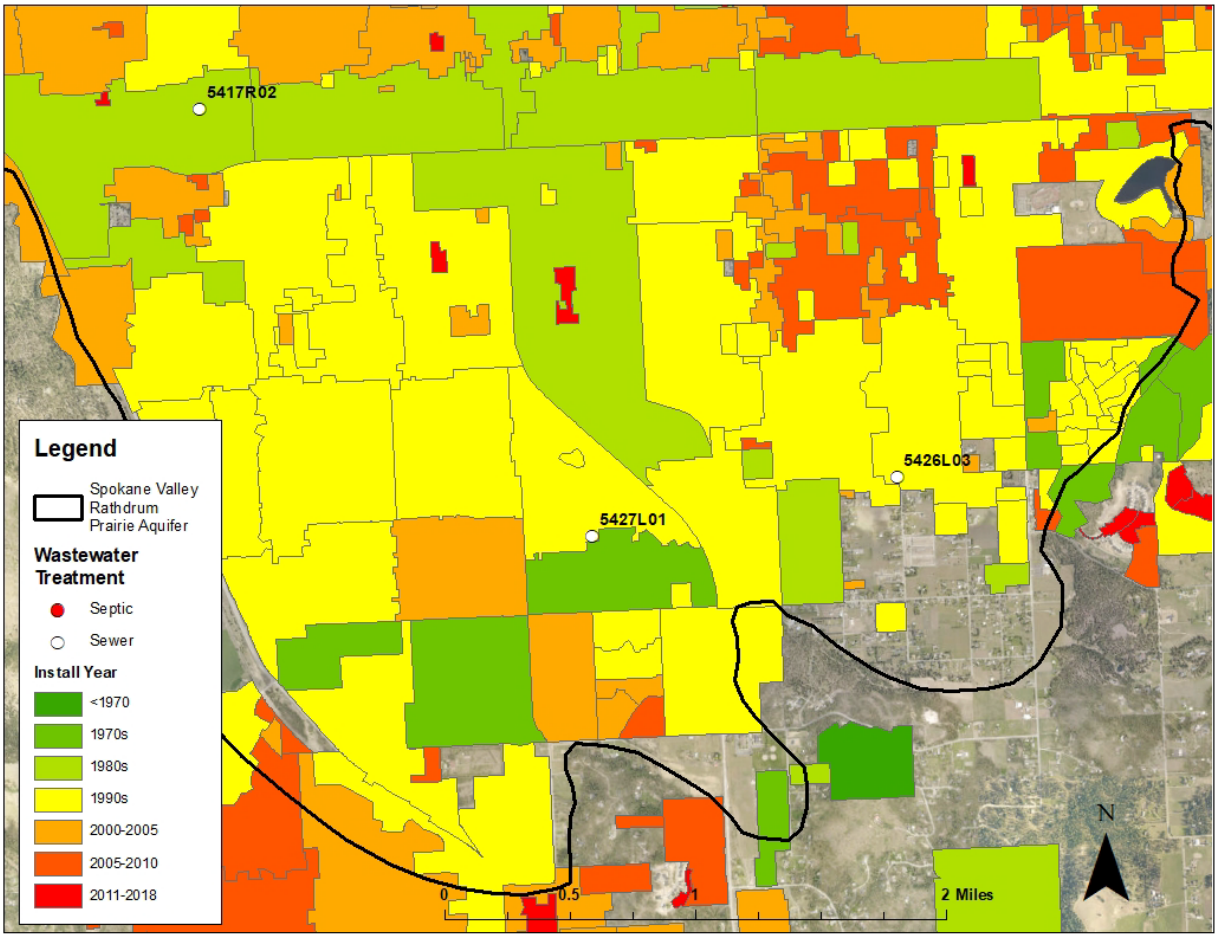

Figure 84. Monitoring wells located within the southern Spokane Valley. Sewer basins are colored according to the year installed with basins sewered after 2018 not shown. The two locations are the Spokane County Water District #3 well at 26th and Vercler (5427L01) and the Vera Water and Power well #4 (5426L03).

The 20-year trend analysis indicates nitrate levels in the Spokane County Water District (SCWD) #3 well (5427L01) were stable while the nitrate levels in the Vera Water and Power well (5426L03) decreased. For the Vera Water and Power well, the County's record starts in 2013, so additional analysis is not possible.

The County has a longer record for the SCWD #3 well (5427L01), including data prior to sewer installation in 1991. This data indicates a different outcome than the 20-year trend.

Analysis of all available data for the SCWD #3 well indicates nitrate levels decreased since 1980. A before and after analysis shows no trend in nitrate levels prior to sewer installation, but a decreasing trend following installation (Table 12). Overall, this suggests nitrate levels in southern Spokane Valley decreased throughout the 1990s during sewer installation but stabilized in the 2000s when sewer installation had finished in most neighborhoods.

Table 12. Results of trend analyses of nitrate concentrations measured in samples collected over time at monitoring locations in southern Spokane Valley. Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation to determine the effects of sewering. Year of sewer installation and the period covered by the data assessed is shown for each location.

Well ID	Before	After	All data
5426L03	1991		2013 – 2019
	---	---	Z= -2.18 p<0.05
	---	---	Decreasing
5427L01	1991		1980 – 2019
	Z= 0.65 p>0.05	Z= -6.21 p<0.05	Z= -7.12 p<0.05
	Not Trending	Decreasing	Decreasing

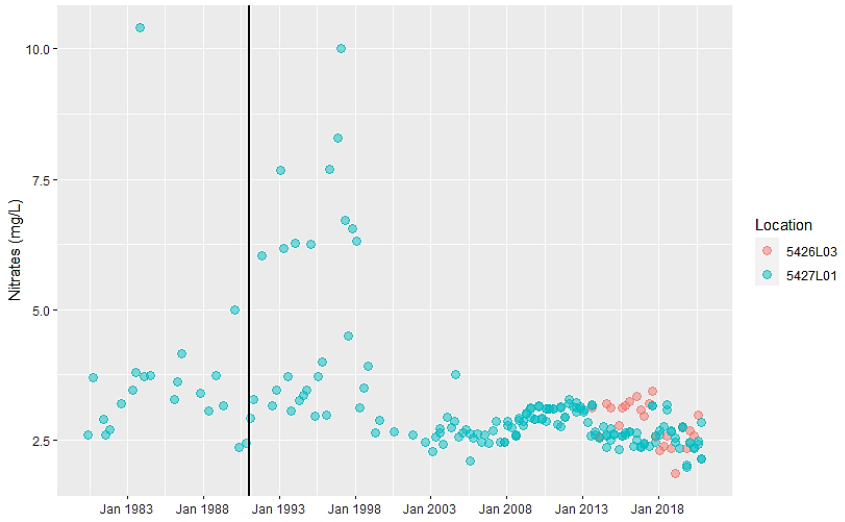

Figure 85. Plot of nitrate concentrations measured in samples collected over time at two monitoring locations within southern Spokane Valley. The two locations are the Spokane County Water District #3 well at 26th and Vercler (5427L01) and the Vera Water and Power well (5426L03). The line indicates the year of sewer installation, 1991, for both wells.

7.1.6. Pasadena Park

Pasadena Park is located north of Millwood and the Spokane River within the Pasadena Park Irrigation District service area. Only the southernmost portion of Pasadena Park overlays the SVRP aquifer and includes a mix of neighborhoods with and without sewer. Sewer was generally installed in the early 2000s (Figure 86). The Irrigation District's well at Site 2 (5405K01) is used to monitor groundwater conditions. A plot of nitrate concentrations over time for this location is shown in Figure 87.

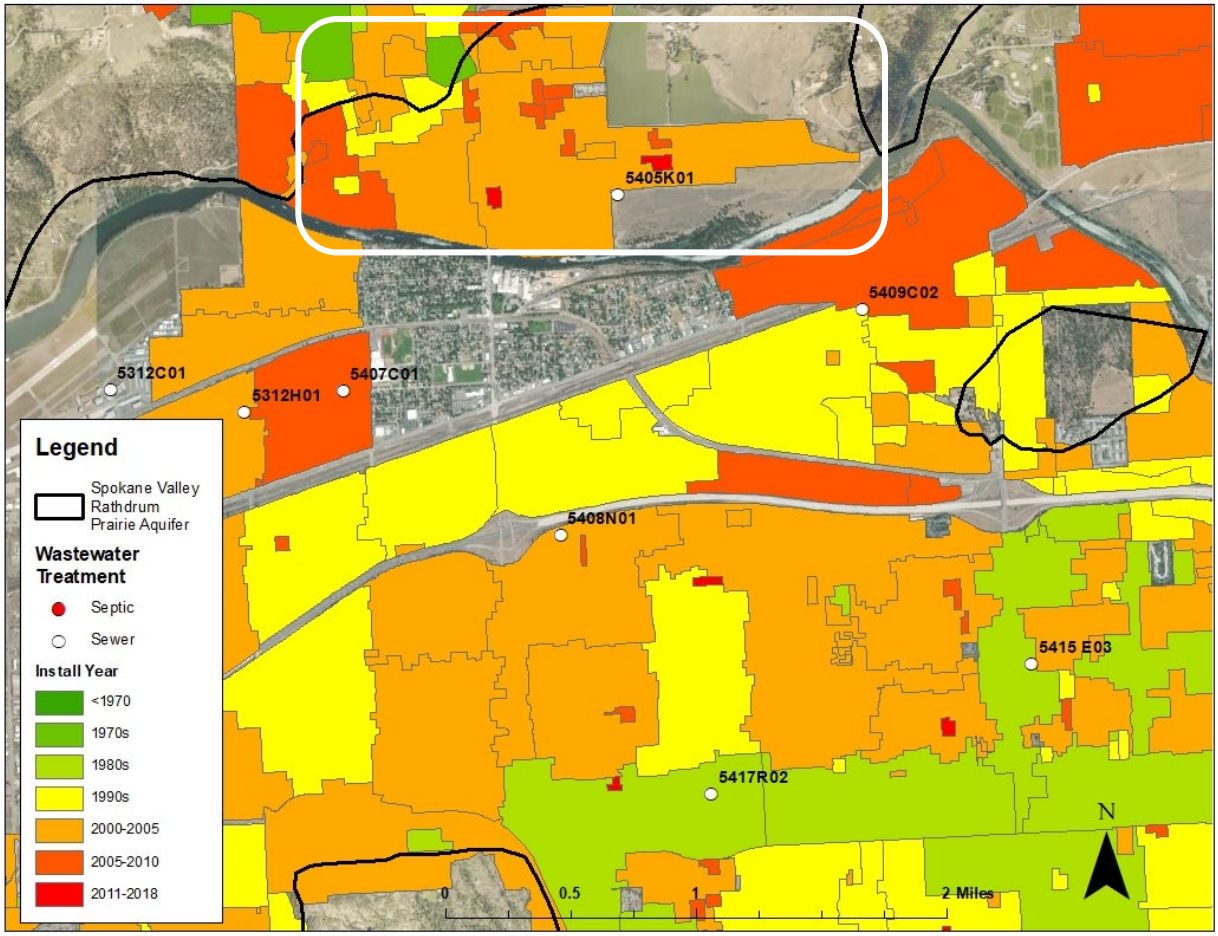

Figure 86. Monitoring location within Pasadena Park in sewered neighborhoods. This is the Pasadena Park Irrigation District Site 2 well (5405K01). Sewer basins are colored according to the year installed with basins sewered after 2018 not shown.

The trend analysis indicates nitrate levels were stable at this location. The County's nitrate data for the Site 2 (5405K01) well dates to 2001, so this is only an 18-year trend. The neighborhood in the vicinity of the well was sewered in 2002, only a year after the start of sampling. Therefore, a trend might not yet be detectable in the data.

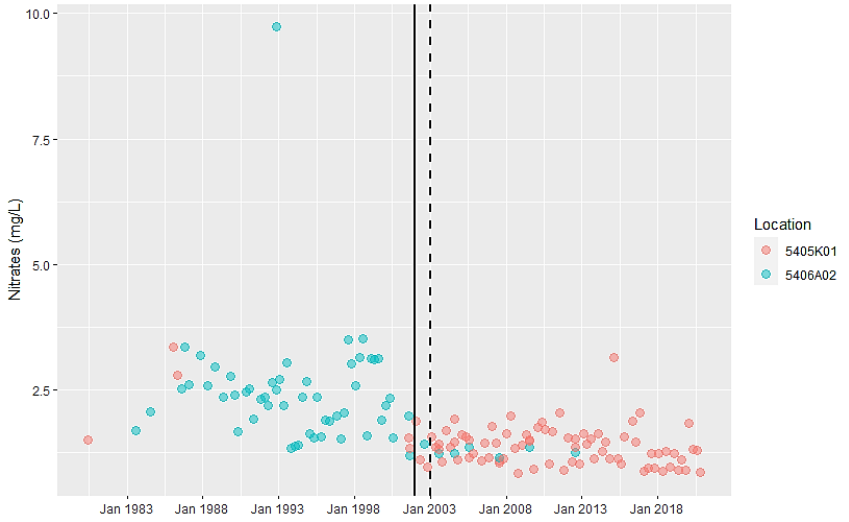

Figure 87. Plot of nitrate concentrations measured in samples collected over time at two monitoring locations within Pasadena Park. The two locations are the Pasadena Irrigation District Site 2 (5405K01) and Site 4 (5406A02). The lines indicate the year of sewer installation for each site as follows: 2002 (solid) for 5405K01 and 2003 (dashed) for 5406A02.

The County sampled other Pasadena Park Irrigation District wells in the past and has a few early records from the 1980s for the currently used well. Of the other wells, the well at Site 4 (5406A02) has the most consistent record with data spanning from 1983 to 2012. The available data appears to be comparable to the data for Site 2 (5405K01) well (Figure 87). In addition, the neighborhood represented by the Site 4 well had sewer installed a year after the Site 2 well in 2003. Therefore, the response to sewering should be comparable. Given this, Site 4 is assumed to be an appropriate surrogate to help assess long term trends within the area.

Table 13. Results of trend analyses of nitrate concentrations measured in samples collected over time at monitoring locations in Pasadena Park. Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation to determine the effects of sewering.

Well ID	Before	After	All data
5405K01	2002		1980 – 2019
	z= -1.86 p>0.05	Z= -2.01 p<0.05	Z= -2.48 p<0.05
	Not Trending	Decreasing	Decreasing
5406A02	2003		1983 – 2012
	Z= -1.82 p>0.05	Z= 0.25 p>0.05	Z= -3.22 p<0.05
	Not Trending	Not Trending	Decreasing
Combined	2003		1983 – 2019
	Z= -4.12 p<0.05	Z= -2.01 p<0.05	Z= -8.17 p<0.05
	Decreasing	Decreasing	Decreasing

A trend analysis was conducted for each site separately using all available data, as well as for their combined data (Table 13). The results of this differed from the original assessment for the Site 2 well (5405K01). In each case, the data exhibited an overall decreasing trend when considering all data. However, the results of the before and after analysis did not agree. It is important to note that Site 2 had minimal data to consider in its "before" period and Site 4 had minimal data to consider for its "after" period. However, taken together with the plotted data, it appears that declines in nitrate levels occurred before and after localized sewer installation.

7.1.7. Orchard Avenue

Orchard Avenue is located immediately west of Millwood and is bound by the Spokane River to the north and Trent Avenue to the south. The neighborhoods within Orchard Avenue were sewered in 2006. This area's drinking water is provided by the Orchard Avenue Irrigation District. The Irrigation District wells at Site 1 and Site 2 (5312H01 and 5407C01, respectively) are used to monitor groundwater quality in this area. An upgradient monitoring well at Frederick and Bowdish (5409C02) is within a neighborhood sewered in 2007, a year following the Orchard Avenue neighborhoods (Figure 88). A plot of nitrate concentrations over time for these locations is shown in Figure 89.

The 20-year trend analysis indicates nitrate levels at the Site 1 well (5312H01) and the upgradient monitoring well (5409C02) increased but levels were stable at the Site 2 well (5407C01) (Appendix E).

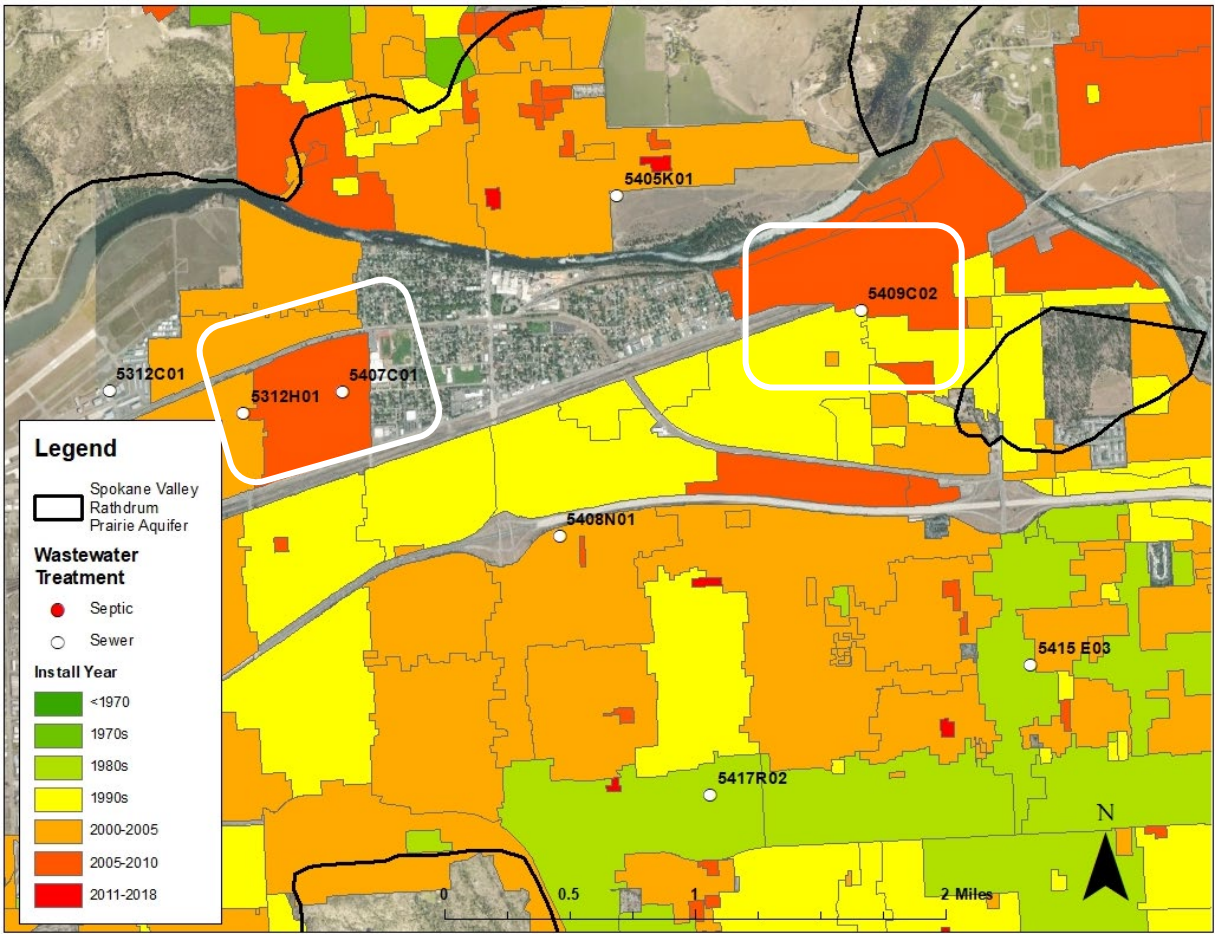

Figure 88. Monitoring locations within Orchard Avenue Irrigation District's service area. This includes Orchard Avenue Irrigation District Site 1 and Site 2 wells (5312H01 and 5407C01, respectively) and an upgradient monitoring well at Frederick and Bowdish (5409C02). Sewer basins are colored according to the year installed with basins sewered after 2018 not shown.

The County has data for the Orchard Avenue Irrigation District wells prior to the 20-year period, allowing for a trend analysis over a longer period as well as a before and after analysis. The Site 1 well (5312H01) has a relatively consistent record dating back to 1970. The Site 2 well (5407C01) has records dating back to 1973, but with a large gap in the record from 1982 to 2000. The upgradient monitoring well at Frederick

and Bowdish (5409C02) only has 17 years of data starting in 2002. While this does not allow for analysis of trends beyond this period, it does allow for a before and after analysis.

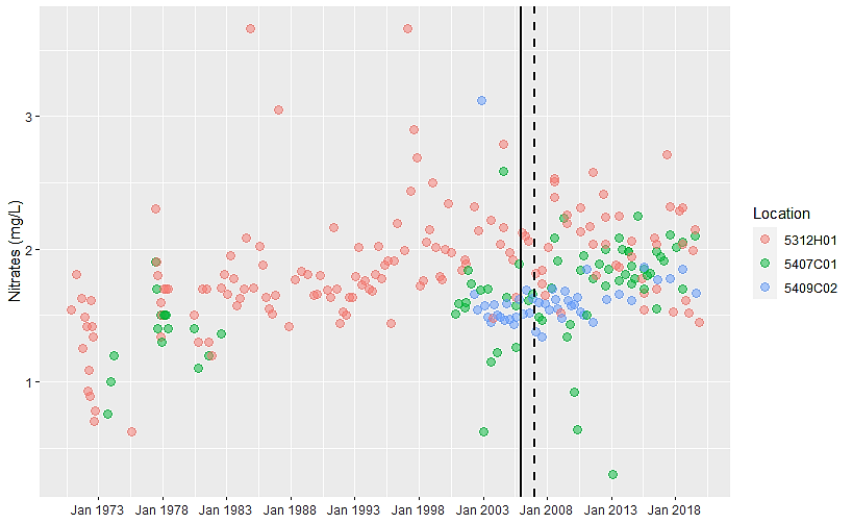

Figure 89. Plot of nitrate concentrations measured in samples collected over time at two monitoring locations within the Orchard Avenue Irrigation District service area. This includes the Irrigation District Site 1 (5312H01) and Site 2 (5407C01) wells, and an upgradient monitoring well at Frederick and Bowdish (5409C02). The lines indicate the year of sewer installation for each site as follows: 2006 (solid) for 5312H01 and 5407C01, and 2007 (dashed) for 5409C02.

The trend analysis of all available data for the three sites indicates nitrate levels increased over time (Table 14). However, the results of the before and after analysis differ among the three sites. This is likely due to the difference in available data. Since Site 1 (5312H01) has the most consistent long-term record, its results are likely more reliable, indicating nitrate levels increased and then stabilized after sewer installation. The lack of a trend after sewering could either be because there is not enough post-sewer data to detect a trend or because any decrease from sewer installation is potentially compromised by nitrate inputs occurring further upgradient (see Section 7.1.9).

Table 14. Results of trend analyses of nitrate concentrations measured in samples collected at monitoring locations in the North Spokane sewer service area. Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation to determine the effects of sewering.

Well ID	Before	After	All data
5312H01	2006		1970 – 2019
	z= 6.84, p<0.05	z= -1.13 p>0.05	z= 6.85 p<0.05
	Increasing	Not Trending	Increasing
5407C01	2006		1973 – 2019
	z= 2.33 p<0.05	z= 2.35 p<0.05	z= 5.41 P<0.05
	Increasing	Increasing	Increasing
5409C02	2007		2002 – 2019
	z= -0.52 p>0.05	z= 1.95 p>0.05	z= 2.80 p<0.05
	Not Trending	Not Trending	Increasing

7.1.8. East Spokane

East Spokane is defined as the neighborhoods on the westside of Dishman Hills and south of Sprague Avenue (Figure 90). Most neighborhoods in this area were sewered in the early 2000s. There are four wells in East Spokane: the East Spokane Irrigation District Site 1 well (5324G01), the two nested monitoring wells at 3rd and Havana (5322A01 and 5322A03), and the 6th and Havana monitoring well

(5323E01). A plot of nitrate concentrations over time for these locations is shown in Figure . The 20-year trend analysis indicates that the nitrate levels at all four wells decreased (Appendix E).

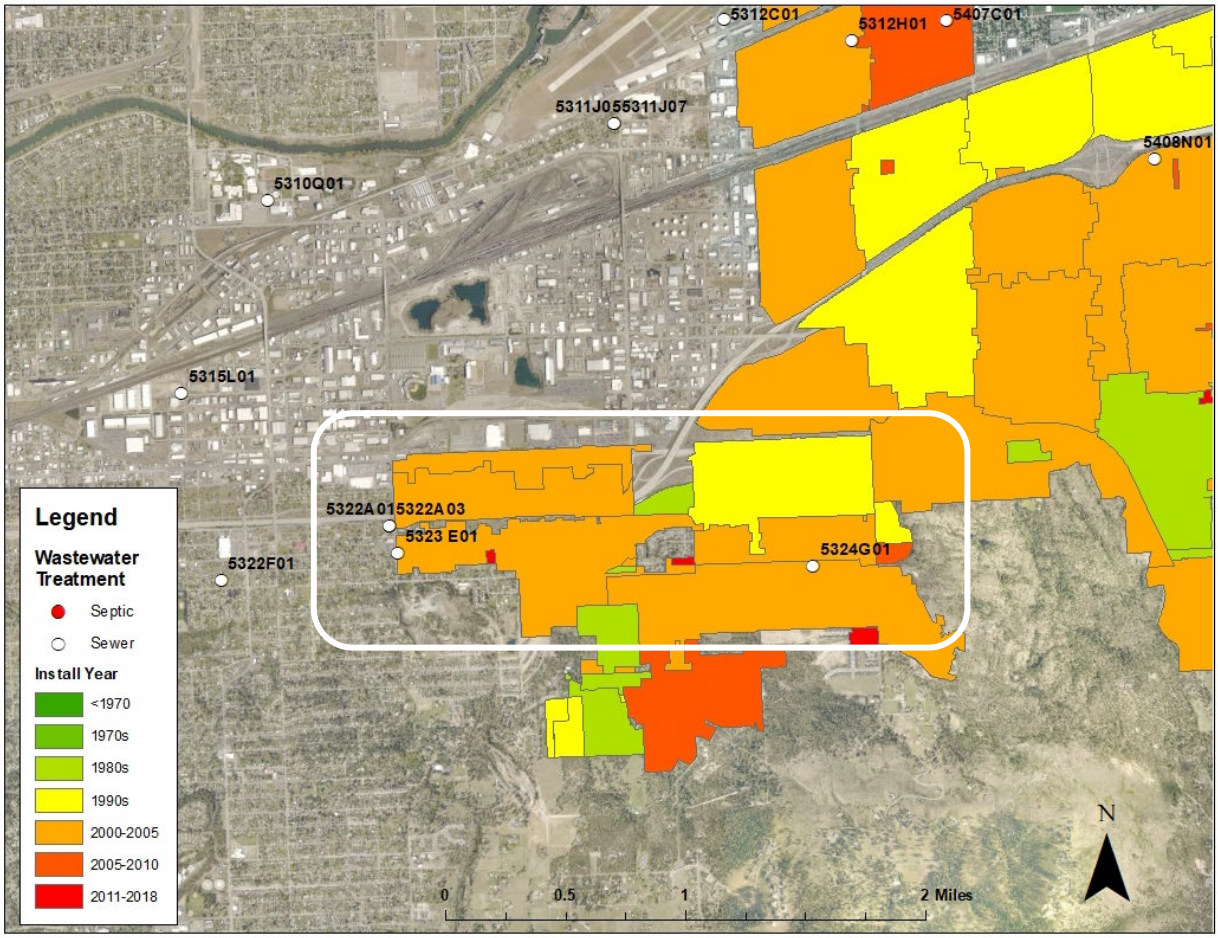

Figure 90. Monitoring locations within east Spokane in sewered neighborhoods. This includes East Spokane Irrigation District Site 1 (5342G01), the nested wells at 3rd and Havana (5322A01 and A03), and the 6th and Havana monitoring well (5323E01). Sewer basins are colored according to the year installed with basins sewered after 2018 not shown.

The neighborhoods in the vicinity of the East Spokane Irrigation District Site 1 well (5324G01) and the Third and Havana nested wells (5322A01 and A03) were sewered in 2002. The County has data dating back to 1970 for the East Spokane Irrigation District well. For the nested wells at 3rd and Havana, the County has data dating to 1995. This allows for a trend analysis over a longer period, as well as a before and after analysis. The trend analysis using all available data indicates nitrate levels decreased over time at all three wells. The before and after trend analysis indicates nitrate levels were stable prior to sewer installation in 2002, but that nitrate levels decreased following sewer installation (Table15).

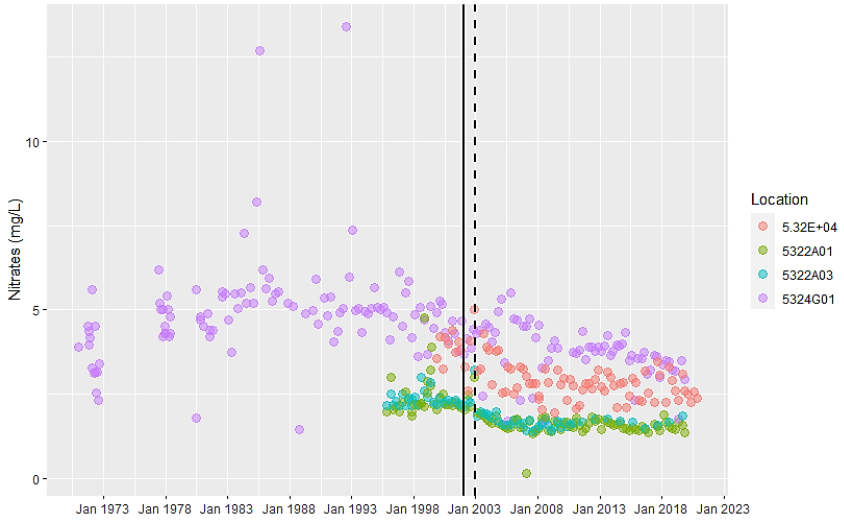

Figure 91. Plot of nitrate concentrations measured in samples collected over time at four monitoring locations within east Spokane Valley. This includes the East Spokane Irrigation District Site 1 (5324G01), the nested monitoring wells at 3rd and Havana (5322A01 and 5322A03), and the 6th and Havana monitoring well (5323E01). The lines indicate the year of sewer installation for each site as follows: 2002 (solid) for 5324G01, 5322A01, and 5322A03; and 2003 (dashed) for 5323E01.

For the 6th and Havana well, the County does not have data prior to the 20-year period considered here. Therefore, a trend analysis over a longer period is not possible. However, since the neighborhood in the vicinity of this well was sewered in 2003, a before and after analysis is possible. The results of this analysis mirror the results of the other wells, with nitrate levels appearing stable prior to sewer installation and then decreasing following installation.

Table 15. Results of trend analyses of nitrate concentrations measured in samples collected at monitoring locations in east Spokane. Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation to determine the effects of sewering.

Well ID	Before	After	All data
5324G01	2002		1970 – 2019
	z= 0.83 p>0.05	Z= -4.54 p<0.05	Z= -6.59 p<0.05
	Not Trending	Decreasing	Decreasing
5322A01	2002		1995 – 2019
	Z= 0.72 p>0.05	Z= -2.68 p<0.05	Z= -8.04 p<0.05
	Not Trending	Decreasing	Decreasing
5322A03	2002		1995 – 2019
	Z= 0.25 p>0.05	Z= -1.72 p>0.05	Z= -6.86 p<0.05
	Not Trending	Not Trending	Decreasing
5323E01	2003		1999 – 2019
	Z= -0.25 p>0.05	Z= -2.22 p<0.05	Z= -5.08 p<0.05
	Not Trending	Decreasing	Decreasing

7.1.9. Impacts from Unsewered Areas

Increasing nitrate levels at several locations within the Spokane Valley sewer service area is a concern because sewering is intended to prevent nitrates from entering groundwater. An assessment of purveyor well capture zones developed by CH2M Hill (1998) demonstrates these locations may be influenced by nitrate inputs occurring further upgradient in unsewered areas. A capture zone defines the area where groundwater flows toward a well within a specified period. The locations where nitrates increased are within the 5-year and 10-year capture zones of the City of Spokane's Electric and Parkwater wells. The 5-year capture zone extends out to Harvard Road and the 10-year capture zone extends beyond the stateline (Figure 92). Given the persistence of nitrates in oxic conditions, it is feasible that nitrate inputs from septic system use outside of the sewer service area is being transported along these capture zones. (5409C02, 5407C01, and 5312H01, see Section 6.1.7).

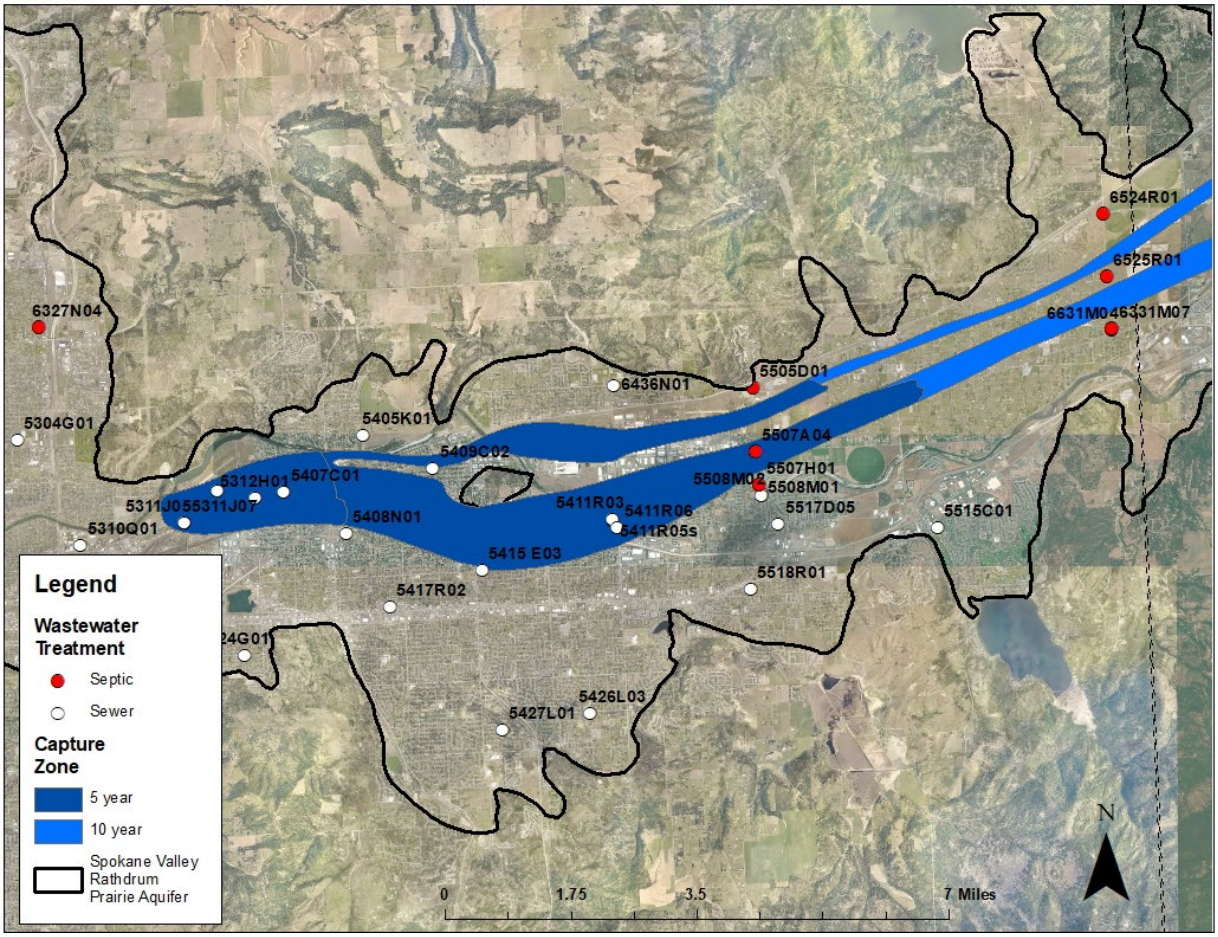

Figure 92. The five and ten-year capture zones for the City of Spokane Electric and Parkwater wells, which potentially convey nitrates from unsewered areas to areas with sewer. Four monitoring locations with increasing 20-year trends in nitrate levels (5311J05, 5409C02, 5407C01, 5411R05s) within the County's sewer service area are along this flow path. The capture zones were developed by CH2M Hill (1998) as part of wellhead protection planning.

7.2. North Spokane Sewer Service Area

There are eight County monitoring locations in North Spokane. Six of these locations are within a sewered neighborhood or influenced by adjacent sewered neighborhoods. Two of these locations are completely outside of the influence of sewer service and are in areas where septic systems are used to treat wastewater. These are discussed in groups by location and sewer service connection date as shown in Figure 93.

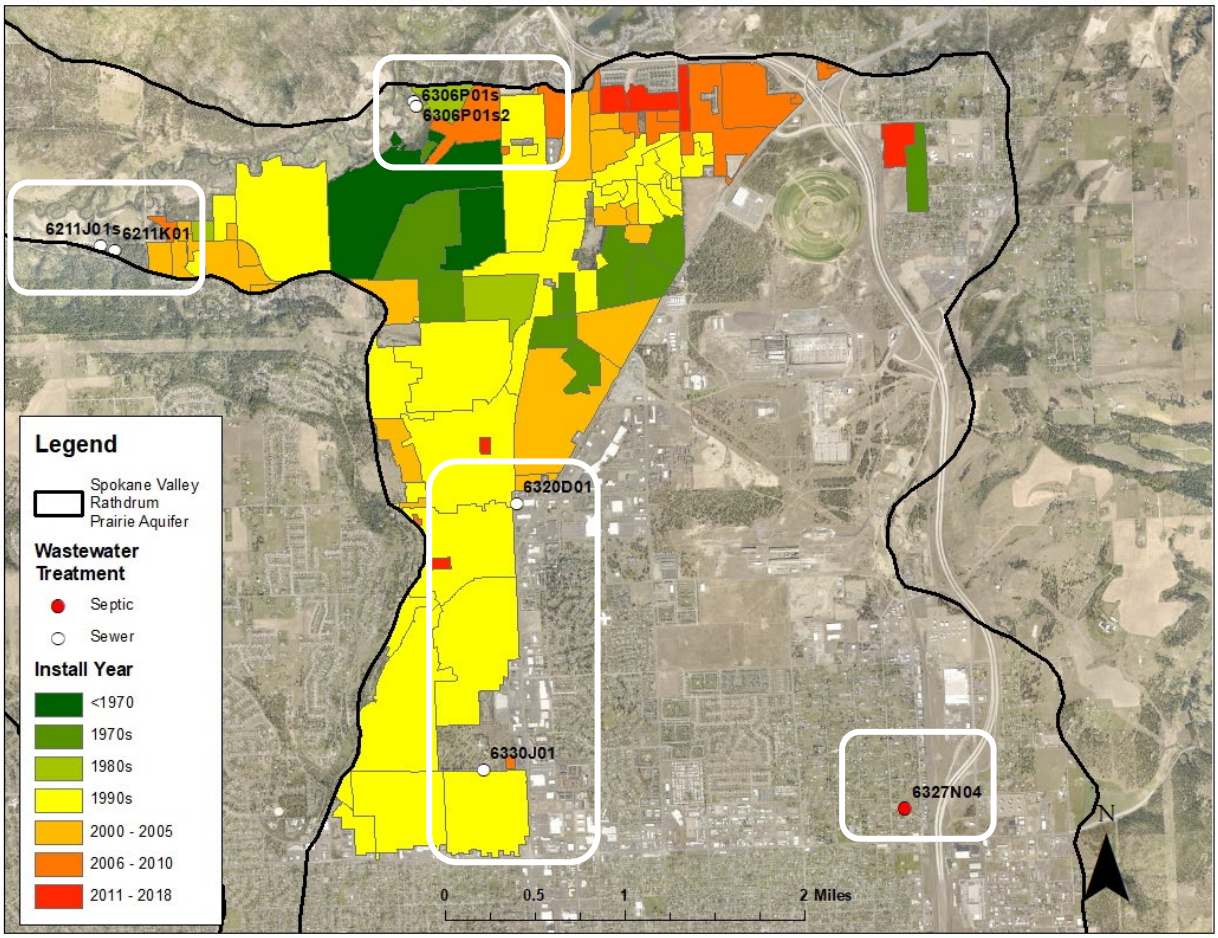

Figure 93. Sewer basins and monitoring locations within the North Spokane sewer service area. Sewer basins are colored according to the year installed with basins sewered after 2018 not shown.

7.2.1. Non-Sewered Area

The North Spokane Irrigation District well (6328H01) and the Fire Station at Houston and Regal well (6327N04) are within the non-sewered area of North Spokane and are outside the influence of the County's and City of Spokane's sewer system (Figure 93). A plot of nitrate concentrations over time for these locations is shown in Figure 94. It should be noted that the North Spokane Irrigation District well is completed in the confined aquifer in the Hillyard Trough, which influences groundwater chemistry at this location (see Section 4.2).

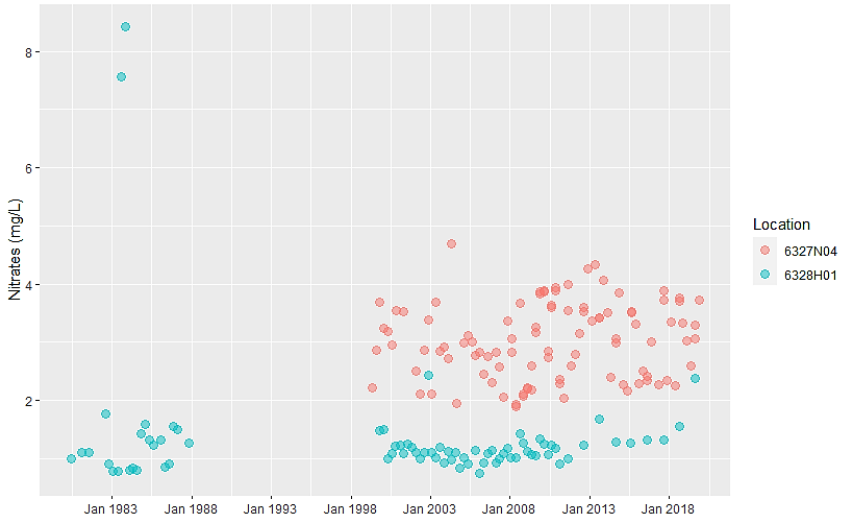

Figure 94. Plot of nitrate concentrations measured in samples collected over time at two monitoring locations in North Spokane outside of sewer service. This includes the North Spokane Irrigation District well (6328H01), which is completed beneath a confining layer, and the monitoring well at the Fire Station at Houston and Regal (6327N04).

The 20-year trend analysis indicates that nitrate concentrations in groundwater samples from the and the Fire Station well (6327N04) were increasing. There is no additional data for this location to conduct further analysis. Nitrate levels from the North Spokane Irrigation District (6328H01) were stable (i.e. not trending) over the 20-year assessment. Including the County's additional data for the North Spokane Irrigation District well (6328H01) did not change the results, indicating nitrate levels in groundwater sampled from this location have been stable since 1980. This is likely the result of the protective qualities of the confining layer.

7.2.2. Whitworth

Neighborhoods in North Spokane in the vicinity of Town and Country, Country Homes, and Whitworth University were connected to sewer between 1998 and 2000. However, these are intermingled with non-sewered neighborhoods. There are two wells in this area: the Whitworth Water District Well 2A (6320D01) and the Holy Cross, Rhoades and Washington monitoring well (6330J01) (Figure 93).

The Whitworth Water District well (6320D01) is near the border between the County's North Spokane sewer service area and the City of Spokane's sewer service area. This well has some data collected prior to sewer installation, but there is a gap from the early 1980s through 1999 during the transition to sewer.

The Holy Cross monitoring well (6330J01) is in an unsewered neighborhood, but near a sewered neighborhood, Spokane Terrace, which was sewered in 1998. All the County's data for the Holy Cross well post-dates sewering in the bordering neighborhood, as monitoring of this location started in 1999.

Given the two monitoring locations do not have data that adequately covers pre- and post-sewering, the County's database was assessed for a past monitoring location that is wholly within a sewered neighborhood in the vicinity and has enough data to help assess trends. The Spokane County Water District (SCWD) Lyons & Normandie Well (6330R02) was identified as an appropriate comparison well. It

is located within the upgradient sewered neighborhood of Spokane Terrace and has data that spans a timeframe (1970s to 2014) prior to and after sewer installation.

A plot of nitrate concentrations over time for these locations is shown in Figure 95. The data from these three wells demonstrates that the two current monitoring locations (6330J01 and 6320D01) have nitrate levels comparable to the upgradient SCWD well (6330R02), so they are likely representing similar conditions as predicted.

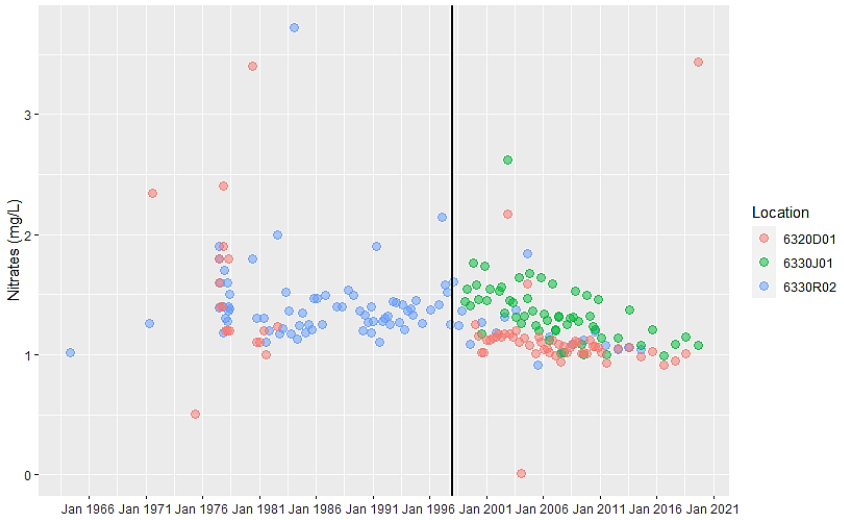

Figure 95. Plot of nitrate concentrations measured in samples collected over time at three monitoring locations within North Spokane sewer service area. This includes the Whitworth Water District well (6320D01), Holy Cross monitoring well (6330J01), and the Spokane County Water District (SCWD) Lyons & Normandie Well (ID 6330R02). The line indicates the year of sewer installation (1998) for these wells.

Trends were assessed before and after 1998, as well as over the entire dataset, for each location (Table 16). Nitrate levels measured in the SCWD well (6330R02) and the Whitworth Water District well (6320D01) did not have a significant trend prior to sewer installation. Following installation, levels significantly decreased at both locations. The Holy Cross well (6330J01), which only has post-1998 data, was also found to have a significant decreasing trend in nitrate concentrations. The general decrease in nitrate concentrations after 1998 indicates that the sewer connection influenced this downward trend at all locations. This demonstrates that the two downgradient wells are influenced by the adjacent, upgradient sewered neighborhoods.

Table 16. Results of trend analyses of nitrate concentrations measured in samples collected at monitoring locations in the North Spokane sewer service area. Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation to determine the effects of sewering.

Well ID	Before 1998	After 1998	All data
6330R02	z = 0.19, p>0.05	z = -1.76 p>0.05	1964 – 2014
			Z= -2.77 P<0.05
	Not Trending	Not Trending	Decreasing
6330J01	---	z = -5.06 p<0.05	1999 – 2019
			-5.06 P<0.05
	---	Decreasing	Decreasing
6320D01	-1.64 p>0.05	z = -3.99 p<0.05	1971 – 2019
			-5.75 P<0.05
	Not Trending	Decreasing	Decreasing

7.2.3. Spokane Hatchery – Griffith Springs

While the Griffith Springs monitoring location is outside of the North Spokane sewer service area, GIS data suggests the headwaters of Griffith Springs surface within the adjacent sewered neighborhoods to the east (Figure 93). Given direction of groundwater flow, the groundwater sampled at the Spokane Hatchery well may also be influenced by these adjacent sewered neighborhoods. These neighborhoods were connected to sewer between 2000 and 2009.

A plot of nitrate concentrations over time for the Spokane Fish Hatchery well (6211K01) and Griffith Springs (6211J01s) is shown in Figure 96. Unfortunately, Griffith Springs lacks data for the period of sewer installation. However, given that nitrate concentrations are comparable to the nearby Hatchery well, it is assumed the groundwater sampled at these two locations would have responded similarly to sewer installation.

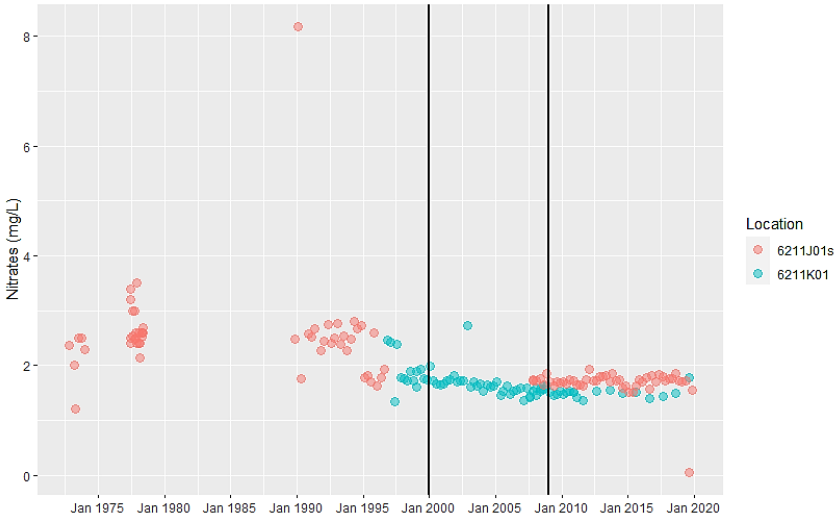

Figure 96. Plot of nitrate concentrations measured in samples collected over time at two monitoring locations near the Spokane Fish Hatchery. This includes Griffith Springs (6211J01s) and the Spokane Hatchery well (6211K01). The lines indicate the years 2000 and 2009, between which sewer installation occurred upgradient of the monitoring locations.

Figure 96 shows that the groundwater at the Hatchery well had a decline in nitrate concentrations during the period when sewer was being connected in adjacent neighborhoods. Although data is missing for Griffith Springs during this period, the available data also suggests a decline in nitrate concentrations from the levels present in the 1990s.

Table 17. Results of trend analyses of nitrate concentrations measured in samples collected at the Spokane Hatchery Well (6211K01) and Griffith Springs (6211J01s). Trends were assessed using all available nitrate data, and nitrate data before and after sewer installation in 2000 and 2009 to determine the effects of sewering.

Well ID	**Before**	**After**	**Before**	**After**	**All data**
6211K01	**2000**		**2009**		**1996 – 2019**
	z=-1.86, p>0.05	Z=-5.10, p<0.05	-6.30, p<0.05	Z = 0, p>0.05	Z= -7.07, P<0.05
	Not Trending	Decreasing	Decreasing	Not Trending	Decreasing
6211J01s	**2000**		**2009**		**1972 – 2019**
	-0.90, p>0.05	-0.01, p>0.05	-3.57, p<0.05	-0.15, p>0.05	Z= -6.97 P<0.05
	Not Trending	Not Trending	Decreasing	Not Trending	Decreasing

Trend analysis was conducted before and after the years 2000 and 2009, as well as over the entire dataset for each location (Table 17). A downward trend in nitrate levels at the Hatchery well occurred after 2000

and before 2009. This suggests that the start of sewer connections in 2000 initiated the downward trend and that nitrate levels stabilized by the last sewer connections in 2009. The analysis for Griffith Springs is influenced by the data gaps between 1978 and 1989, and in 1996 and 2007. It is possible that the post-2000 trend was missed, and nitrate concentrations had relatively stabilized by the time monitoring resumed. However, the before and after 2009 analysis for the springs mirrors that for the well.

7.2.4. Waikiki Springs

Waikiki Springs is on the northern border of the Little Spokane Arm of the SVRP aquifer. The neighborhood upgradient of the Waikiki Springs monitoring locations was sewered in 1987 (Figure 93), although County records indicate this basin was not connected to sewer until 2017. Internal discussions during review of this report confirmed that the area was sewered closer to 1987. Monitoring started at the original Waikiki Springs location (6306P01s) in 2007 and the second location (6306P01s2) in 2016.

A plot of nitrate over time for the two Waikiki Springs monitoring locations is shown in Figure 97. Given the data, it appears nitrate concentrations were affected after 2017 but is unlikely attributable to sewer although coincident with the year the area was thought to be connected. The first monitoring location at Waikiki Springs (6306P01s) has data spanning pre- and post-2017. The second location (6306P01s2) only has a few data points that pre-date 2017.

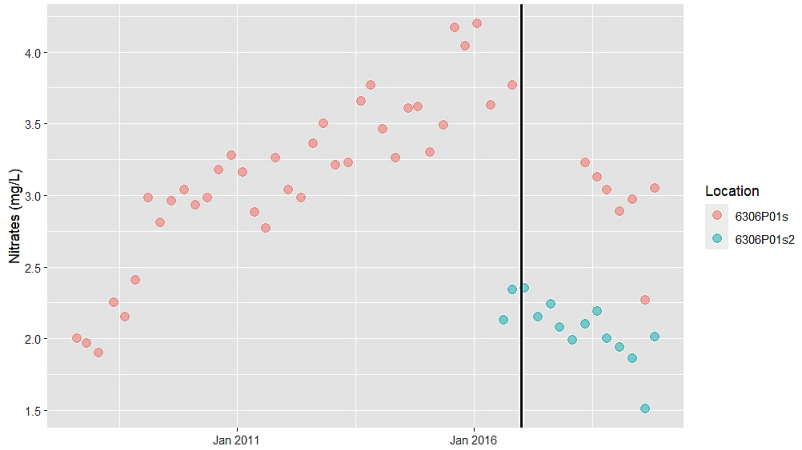

Figure 97. Plot of nitrate concentrations measured in samples collected over time at two monitoring locations at Waikiki Springs. The line indicates the year 2017.

Though nitrate concentrations at 6306P01s appear to increase prior to 2017 and decrease following (Figure 97), the analysis indicates there is no trend post-2017 (Table 18). The overall increasing trend at this location appears to be driven by the increase in concentrations prior to 2017.

Figure 97 shows that nitrate concentrations at the second monitoring location, 6306P01s2, also appears to be decreasing. The second location has a downward trend overall, but when the data is separated into pre- and post-sewer, no trends are detected. It is unclear what drove the nitrate trends in this basin given sewer occurred prior to any data collected.

Table 18. Results of trend analyses of nitrate concentrations measured in samples collected at Waikiki Springs monitoring locations. Trends were assessed using all available nitrate data, and nitrate data before and after 2017.

Well ID	Before 2017	After 2017	All data
6303P01s	z=6.45, p<0.05	Z=6.65, p>0.05	Z= 4.11, P<0.05
	Increasing	Not Trending	Increasing
6303P01s2	-0.38, p>0.05	-1.11, p>0.05	Z=-2.85 P<0.05
	Not Trending	Not Trending	Decreasing