DEPARTMENT OF NATURAL RESOURCES

Ecological and Water Resources - Groundwater Technical Analysis

Blaine-Ham Lake Area Well Interference Investigation Report

Date: 05/15/2023

To: Claudia Hochstein, Well Interference Coordinator

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From: Amanda Yourd, Groundwater Specialist

Subject: Blaine-Ham Lake Area Well Interference Investigation Report, Anoka County

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PROFESSIONAL GEOLOGIST

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Geologist under the Laws of the State of Minnesota.

License No: 50027 *Signature:* Ellen J Considine Digitally signed by Ellen J Considine Date: 2023.06.14 16:09:41 -05'00'

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This report is accompanied by the following:

Supplemental Information – Complaint Forms and Invoices

Blaine-Ham Lake Area Well Interference Fact Sheet

Executive Summary

In 2022, the Minnesota Department of Natural Resources (DNR) received reports of low water supply or out-of-water situations at 143 private domestic wells in the Blaine-Ham Lake area. DNR was notified of these complaints via phone calls, emails, and DNR well interference complaint forms, but could only investigate complaints where complaint forms were received.

This report investigates a subset of 50 complaints that experienced water supply issues in 2022 and submitted well interference complaint forms before December 31, 2022. Outstanding and future complaints will be investigated in future reports.

Forty-seven of the 50 complaints evaluated in this report were found valid. Permitted and unpermitted pumping by the City of Blaine (1976-6227) was the sole cause of well interference in 45 complaints, and the main cause in two complaints. Two golf course irrigation permits, Majestic Oaks (2000-6108) and TPC Twin Cities (1977-6081), were minor contributors to two complaints.

There is a continued risk to domestic water supply in this area. The following is recommended:

- Domestic well 470557 should be replaced with a new, deeper well as the pump is at the maximum depth in the existing well and the complainant is still experiencing water supply issues.
- Domestic well 679976 should be replaced or rehabilitated (at well driller and complainant discretion) as well work done due to low water levels caused the open hole to partially fill with sand.
- Risk of future water supply issues at domestic wells should be evaluated as part of the permit amendment review for City of Blaine Wells 19, 20, and 21.

Introduction

In August 2022, the Minnesota Department of Natural Resources (DNR) received many reports of low water supply or out-of-water situations from residents with private domestic wells in the Cities of Blaine and Ham Lake in Anoka County, Minnesota (Figure 1). The majority of domestic well water supply issues occurred in 2022, although some residents (referred to as complainants in this report) also experienced issues in 2021. Most of the complainants live in the City of Ham Lake, where there is no municipal water supply and residents rely on private wells for water supply.

As of December 31, 2022, over 140 complainants reported water supply issues to DNR in the Blaine-Ham Lake area. DNR grouped the complaints into three categories:

- **Investigated in this report:** Fifty complainants experienced water supply issues in 2022 and submitted a complete Water Well Information and Complaint Questionnaire (complaint form) to DNR by December 31, 2022 (Figure 1). This report covers the investigation of these 50 complaints.
- **Reimbursed by City of Blaine:** The City of Blaine reimbursed at least 24 complainants for well work completed to restore their water supply. The City of Blaine was pumping five permitted and three unpermitted high-capacity wells within three miles of the complaints. Most of the complainants that the City of Blaine reimbursed were within Blaine city limits. This report will not discuss those complaints further.
- **Not addressed in this report:** The remaining complainants either did not submit complaint forms, submitted inadequate or incomplete complaint forms, submitted complaint forms after December 31, 2022, or experienced water supply issues exclusively in 2021. This report will not discuss those complaints further.

There are 21 permitted groundwater appropriators pumping from 38 high-capacity installations (including three dug pits/holding pond pumps) within three miles of the complaints (Figure 1; referred to as "investigation area" in this report). Three of the 38 installations are unpermitted wells associated with the City of Blaine Water Appropriation permit 1976-6227. The DNR selected the approximately 75-square-mile investigation area to include nearby permitted high-capacity wells which could plausibly have impacted the 50 complaint locations.

This report describes the DNR investigation to determine if nearby high-capacity pumping in the area caused the domestic water supply issues for the 50 complaints. Each complaint is assessed in the context of local geology, aquifer information, well construction information, information from local well professionals, details of the specific problems at each location, high-capacity groundwater use data, and groundwater level data. The report provides conclusions and technical recommendations.

Complaint Information

Detailed information about the complainant wells and nature of the complaints received is shown in Appendix A Table A-1, listed by complainant last name. Supplemental Information includes complaint forms and receipts for each complainant. DNR gathered complaint information from correspondence with complainants and well professionals, completed interference complaint forms, receipts for completed well work, and the Minnesota Well Index (MGS and MDH, 2023).

Though the timing, location, well construction, completed well work, and nature of the complaints varies, there are commonalties between the 50 complaints. The following summarizes the commonalities and other relevant complaint information:

- **Most issues occurred in July and August 2022.** Three water supply issues occurred in either February or April 2022. The remaining water supply issues occurred in July or August 2022. Table A-1 shows the date of first driller visit, which is used as a proxy for when the water supply issues occurred. Two complainants (470557 and 679976) are still experiencing water supply issues.
- **All complaints are located in the City of Ham Lake.** Most of the complaints are in the southern part of Ham Lake near Bunker Lake Boulevard (Figure 1). A much smaller group of complaints is in the northeast corner of Ham Lake.
- **Most wells are deeper than 100 feet.** Deeper wells had more water supply problems than shallow wells in the area. Forty-six complainant wells were over 100 feet deep. The remaining four were 60 to 100 feet deep. Depths of greater than 100 feet correspond with the Deep Confined – Shallow Bedrock aquifer system (see Aquifer Information section below for details).
- **Complainants experienced low water supply:** Low water pressure or out-of-water situations were the chief complaints. One complainant also reported poor water quality.
- **Complainant wells had about 30 feet of drawdown:** The average drop in water level (drawdown) in complainant wells was approximately 30 feet with a range from 7 to 54 feet. DNR subtracted the water level at the time of the complaint from the water level recorded on the complainant's well log at the time of well installation to calculate drawdown. In cases without a water level reading at the time of the complaint, DNR needed to estimate drawdown. DNR assumed that water levels in out-of-water wells were at or below the original pump depth, and so subtracted the original pump depth from the well log static water level. Additional uncertainties in drawdown estimates include differences in initial static water level date for each well, amount of domestic self-pumping drawdown, and cumulative drawdown caused by other nearby domestic wells.
- **Lowering pumps resolved water supply issues.** In 46 wells, lowering the pump resolved water supply issues in 2022. Pumps were lowered from 20 to 80 feet, although most pumps were lowered approximately 40 feet. Over half of wells had original pump depths between 40 and 60 feet below land surface, and final pump depths ranged from 60 to 160 feet. Pumps were also replaced in some of these 46 wells.
- **Four wells did not have pumps lowered.** The pump in well 470557 was not lowered because it was already at the maximum depth the 60-foot well could accommodate. Pumps were not lowered in wells

134330, 423316, and 673579 because other well work was completed (pumps were replaced but not lowered or the pressure tank was replaced).

Setting

Anoka County is located in the east central part of Minnesota in a topographically low-relief area. The City of Blaine has been designated as Suburban Edge (Metropolitan Council, 2020a), while Ham Lake has been designated as Rural Residential with a higher incidence of agricultural land use (Metropolitan Council, 2020b).

Area geology and hydrogeology (aquifer information) has been described in detail in numerous publications: Berg (2016); Greer (2016); Metropolitan Council (2014); Runkel et al. (2006); Runkel et al. (2003); Runkel et al. (2014); Setterholm (2013). Information from these publications relevant to this investigation is summarized below.

Geology

The geology of the area consists of 100- to 350-foot-thick unconsolidated Quaternary glacial materials that were deposited over 10,000 years ago and directly overly Paleozoic sedimentary bedrock (sandstone, limestone, and shale) that was deposited approximately 500 million years ago. The Anoka Sand Plain, an approximately 20- to 80-foot thick, glacially deposited layer of sand and gravel that covers much of Anoka County, is the dominant surficial geologic feature. Buried Quaternary sediments (glacial outwash and till) directly underlie the Anoka Sand Plain.

Aquifer Information

Aquifers are present in the Quaternary deposits and Paleozoic bedrock units (Figure 2). Berg (2016) has identified a Quaternary water table aquifer, six Quaternary confined aquifers, and four Paleozoic bedrock aquifers in the investigation area.

The top of the Paleozoic bedrock was eroded over time which means some of the formations are limited or discontinuous in this area. The erosional bedrock surface (shown in Figures 3 and 4) is significant in this investigation because it is highly fractured in the upper 50 feet (hashed area in Figure 2), which makes it a productive aquifer, regardless of the geologic unit that is present at the erosional surface (Runkel et al. 2003). Overlying buried confined aquifers and leaky tills are in direct contact with this fractured bedrock surface, effectively connecting the Quaternary and Paleozoic aquifer systems. It is thus useful to categorize aquifers into three general flow systems:

1. Water Table – Shallow Semi-Confined system
2. Deep Confined – Shallow Bedrock system
3. Deep Bedrock system

The three aquifer systems are described in more detail below and are based on previous regional work by Runkel et al. (2006) and local aquifer information compiled by Berg (2016).

Water Table – Shallow Semi-Confined System

The Water Table – Shallow Semi-Confined system consists of the water table aquifer (designated as ss unit in Figure 2) and the shallowest confined aquifer (referred to as sl aquifer in Figure 2). The water table is extensive in the investigation area and is commonly found within ten feet of land surface. The top of the shallow confined aquifer usually occurs between 50 and 100 feet below land surface, has thickness of up to approximately 75 feet, and is the most prevalent and extensive of the six confined aquifers in the Blaine area.

There is a high degree of connection between the water table and shallow confined aquifers within the investigation area (indicated by the number 2 on cross sections in Figure 2), such that the shallow confined aquifer is confined in some areas and semi-confined in areas where it is closely connected to the water table aquifer. The shallow confined aquifer is underlain by a relatively continuous confining unit with low (<30%) sand content (Figure 2; Greer, 2016; Berg, 2016). In areas where this uppermost till is thin or absent, or where high-capacity pumping induces leakage, there is greater connection between the shallow confined and the underlying aquifers (indicated by the number 3 on cross sections in Figure 2). Based on age and residence time of water in deep confined aquifers reported by Berg (2016) and shown in Figure 2, the connection between the Water Table – Shallow Semi-Confined system and deeper confined aquifers appears to be generally limited.

Locally, the water table is not relied upon for domestic or high-capacity pumping. The shallow confined aquifer is commonly used for domestic wells but is not used for high-capacity pumping in the area. Of the 13 complainant wells screened in buried confined aquifers, nine are completed in deeper confined aquifers (>100 feet deep), and four are completed in shallower confined aquifers less than 100 feet deep (presumably the shallow confined aquifer).

Deep Confined – Shallow Bedrock System

The Deep Confined – Shallow Bedrock system is the most productive aquifer system in the area. This aquifer system consists of:

- Confined aquifers (sc, se, sx, sr, sp aquifers in Figure 2) that occur at depths greater than 100 feet and range in thickness from 20 to 150 feet, and
- Bedrock units that are within 50 feet of the erosional bedrock surface (referred to as “shallow bedrock”), which include the Jordan Sandstone, St. Lawrence Formation, Tunnel City Group, Wonewoc Sandstone, and Eau Claire Formation (Figures 2 to 4). Since the Jordan Sandstone is the uppermost bedrock in the investigation area and is a highly fractured and productive aquifer throughout (Berg, 2016; Figure 4), it is included in the Deep Confined – Shallow Bedrock system even when it is greater than 50 feet from the bedrock surfact.

The erosional bedrock surface is highly fractured, which increases hydraulic conductivity of bedrock aquifers by orders of magnitude and compromises the integrity of confining layers (Runkel et al., 2003, 2006, 2014). Bedrock units that are typically classified as confining units under deep bedrock conditions act as fractured aquifers when near the bedrock surface (Runkel et al. 2014). The Upper Tunnel City Group is the most wide-spread at the bedrock surface in the investigation area (Figures 3 and 4). Runkel et al. (2006) reported that the Upper Tunnel City has regionally extensive clusters of bedding plane fractures with very high hydraulic conductivity values that would be even higher within 50 feet of the erosional surface. This

results in flow paths and travel time that are less predictable in the shallow bedrock system than in deeper bedrock systems.

Runkel et al. (2006) states that the shallow bedrock system is likely well connected to overlying glacial aquifers, and Greer et al. (2014) found that pumping bedrock aquifers causes a decline in deep confined aquifers. Figure 2 shows that some deep confined aquifers are directly connected to the shallow bedrock aquifer, especially in bedrock valleys in the east and west of the investigation area. In areas where there are tills between deep confined aquifers and shallow bedrock, connection is likely via leakage through tills with high (>60%) sand content (Berg, 2016).

The Deep Confined – Shallow Bedrock system is the most heavily used aquifer in the investigation area, especially for high-capacity pumping. Berg (2016) states that most of the bedrock wells open to the Tunnel City produce water from this uppermost 50-foot enhanced permeability zone, even if the well is open to deeper bedrock aquifers as well (Blum, 2011). In the investigation area, all but one high-capacity bedrock well (discussed below) are open to the enhanced permeability zone within 50 feet of the bedrock surface, and all include the Tunnel City where it is present.

Most of the complainant wells (37 of 50) are completed in the shallow bedrock system, primarily the Tunnel City.

Deep Bedrock System

The Deep Bedrock system is comprised of aquifers that are greater than 50 feet below the erosional bedrock surface. In the investigation area this includes the Tunnel City Group and Wonewoc Sandstone in some areas and Mount Simon Sandstone in all areas (Figures 2 through 4). Runkel et al. (2006) states that the deeper bedrock system in the Twin Cities Metro area is supported by both intergranular and fracture flow, but generally has lower conductivity than the highly-fractured shallow bedrock system.

There are no complainant wells in the investigation area that are open to the Deep Bedrock system. There is one high-capacity well that is open in the Deep Bedrock system. City of Blaine Well 9 (1976-6227; 208618) is open to the lower portion of the Tunnel City and the entire Wonewoc starting at 107 feet below the bedrock surface. This well is in the southwest of the area where the Tunnel City is relatively thick, so the lower portion of the Tunnel City (Lone Rock Formation; Figure 4) is greater than 50 feet below the erosion surface and acts as an aquitard between the deep and shallow bedrock systems. Greer et al. (2014) found that pumping of Well 9 did not cause drawdown in deep confined aquifers, so it can be assumed that City of Blaine Well 9 is not well connected to the Deep Confined – Shallow Bedrock system.

Many other high-capacity wells in the investigation area are open to the Wonewoc and Mount Simon, but always in combination with shallower bedrock systems that are part of the high-permeability shallow bedrock zone. All high-capacity wells are open to the Tunnel City where it exists.

Groundwater Users

High-Capacity Water Use

Groundwater use from high-capacity pumping within the investigation area includes a municipal permit for the City of Blaine, and permits for irrigation (agriculture, golf course, sod farm, athletic field), recreation pool water level maintenance, and private water supply (Appendix B, Table B-1, Figure B-1). The City of Blaine is the largest user in the area and is permitted for a combined 3.337 billion gallons per year, while all

the other permits in the area are permitted for 877 million gallons per year total (Table B-1). There are 38 permitted high-capacity installations associated with 21 permitted groundwater appropriation permits within the investigation area. The 38 installations include three dug pits/holding ponds and three wells (City of Blaine Wells 19, 20, and 21) that are currently not permitted but are part of a permit amendment submitted to DNR on January 18, 2022 (Figure 1).

Public Water Supply

The City of Blaine is the only public water supplier in the investigation area (Figure 5). The City of Blaine uses groundwater for both residential and non-residential use and sources water from the Deep Confined – Shallow Bedrock system (see purple boxes in Figure 2). In 2015, the City reported that approximately 33% of average daily water demand went toward non-residential use, while 67% went toward supplying water to the City's 66,300 residents (City of Blaine, 2020; Metropolitan Council, 2020a). From 2005 to 2015, the City reported that average total per capita water demand water decreased, even as population increased (City of Blaine, 2020).

History of High-Capacity Pumping

The first records of high-capacity pumping in the area are for private water supply in 1965 (1965-1311) and golf course irrigation in 1970 (1970-0791). The City of Blaine began using water in 1976. Agricultural, sod farm and golf course irrigation permits were added throughout the late 1970s through early 2000s. The "Permit Authorization Date" in Table B-1 is the most recent date that each permit was either issued or amended to increase water use, increase pumping rate, or add a new well.

Since 1988, water use records show that water use has increased decade over decade, primarily due to an increase in municipal water use by the City of Blaine (Figure 5). Non-municipal high-capacity use has remained steady over the period of record and was slightly below average over the past 10 years. Total water use in the area is generally inversely correlated with precipitation (more water gets pumped during drier years), but overall water use is increasing independent of precipitation. Unpermitted pumping of City of Blaine Wells 19, 20, and 21 in Blaine began in June 2021 and continued through August 2022, except for Well 21, which pumped an additional 1.2 million gallons in September 2022.

High-Capacity Pumping in 2022

Water use was the highest on record in 2022 (Figure 5; note use from the water table and dug pit/holding ponds are not included because there are no complainant wells completed in the water table). The City of Blaine pumped 85% of all reported water use in 2022. Pumping from City of Blaine Wells 19, 20, and 21 accounted for 23% of total reported water use in 2022 and is the reason for the increase in 2022 water use compared to previous years. Municipal and non-municipal water use, including use from City of Blaine Wells 19, 20, and 21, was highest in July 2022 (Figure 6). Blaine reported to DNR that all pumping from Wells 19, 20 and 21 had stopped by August 15, 2022, due to the large number of well interference complaints received (although as described above, Well 21 pumped in September 2022).

Water use from wells open exclusively to the Tunnel City or Tunnel City-Wonewoc aquifers also increased in 2022 (Figure 7). This increase was due to unpermitted pumping from City of Blaine Well 19 and 21, both of which are open to the Tunnel City-Wonewoc aquifer.

Domestic Water Use

Most residents in the City of Blaine receive water from the City's municipal supply, although there are some residents who continue to rely on private wells. The City of Ham Lake had a population of 16,170 in 2020 (Metropolitan Council, 2020b) and does not have a public water supply system, so all residents source water from domestic wells or private water supply wells.

Groundwater Level Monitoring

DNR and permitted appropriators monitor groundwater levels in dedicated observation wells in the investigation area (shown in Figure 1 and listed in Appendix C, Table C-1). To better understand groundwater fluctuations, DNR also instrumented an unused permitted high-capacity well (563006) and three City of Blaine observation wells (805151, 805152, 805153). Additionally, DNR collected manual measurements from three complainant wells (470557, 705584, 737231) in August 2022. Data from wells shown in Table C-1 is available on the DNR Cooperative Groundwater Monitoring webpage.

All wells shown in Table C-1 are completed in deep confined aquifers (>100 feet deep) or shallow bedrock aquifers (Tunnel City Group), except for the 470557 domestic well, which is completed in a shallow confined aquifer, and City of Blaine observation well 805151, which is open to the deep bedrock system (Wonewoc aquifer starting 160 feet below the erosional bedrock surface).

Observations from water level data shown in Figures 5 and 6 include:

- **Aquifers are connected in the area.** Monitored observation, irrigation, and domestic wells completed in the deep confined aquifers and shallow bedrock aquifers show similar long-term trends in most of the investigation area. The only well in a shallow confined aquifer (domestic well 470557) also shows similar trends to deep confined and bedrock wells (Figure 6).
- **Water levels decline in the summer months in response to increases in high-capacity pumping**. Prior to 2021, there was typically approximately two to four feet of seasonal decline in the Tunnel City shallow bedrock aquifer in Columbus (243000) and three to 10 feet of seasonal decline in the deep confined wells in Lino Lakes (208135) and Blaine (805156).
- **Declines were greatest in the summer of 2022**. In 2022, there was approximately five feet of decline in the Tunnel City shallow bedrock aquifer in Columbus (243000). Declines in deep confined aquifers increased to 12 feet in Lino Lakes (208135), 13 feet in Columbus (243178), and 30 feet in Blaine (805156).
- **Since 2020, there has been four to five feet of year-over-year decline** in deep confined aquifers (208135, 243178) and shallow bedrock aquifers (243000). Blaine Observation Well 6 (805151 – deep confined), located near the unpermitted pumping, has had eight feet of decline between February 2020 and January 2023. Year-over-year decline indicates that water extraction (pumping) is greater than aquifer recharge (precipitation) for these years. It is unknown if this year-over-year decline is occurring in the far western portion of the investigation area because data in that area is limited.

History of Well Interference

DNR has records of a cluster of at least seven well interference complaints submitted in July 1988 in the southeastern portion of the investigation area. The complaints appear to be associated with unpermitted

pumping from 1988-6385 high-capacity well (448834) used to irrigate sod. Well 448834 is completed in the Deep Confined – Shallow Bedrock system (St. Lawrence – Tunnel City). It is unknown how these complaints were resolved.

Analysis and Results

DNR analyzed the available information described in the Complaint Information, Setting, Appendix A to C, and Supplemental Information to assess the validity of each complaint. DNR designated complaints as follows:

- **Valid:** 47 of the 50 complaints where DNR determined that high-capacity pumping from one or more nearby wells caused water supply issues.
- **Not Valid:** Three complaints (unique well numbers 134330, 423316, 673579) where DNR determined that a faulty pump, faulty pressure tank, or reason other than nearby high-capacity pumping caused water supply issues. Not valid complaints are highlighted in gray in Table 1, and described in detail in Appendix D.

The complaints occur across a large geographic area where 38 high-capacity installations are located (Appendix B). DNR evaluated which high-capacity wells contributed to water supply issues at each valid complaint. Some high-capacity wells were excluded early in the investigation, as described in the next section. The remaining high-capacity wells were further evaluated using predictive drawdown simulations (see Appendix E) to determine which wells contributed to the well interferences.

Table 1. Well Interference Investigation Results and Contributors

Complainant Well Unique Number	Complainant Name	Valid or Not Valid	Invoice Dollar Amount	Well Interference Contributors
655273	Albers, Timothy	Valid	$ 3,919.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
786870	Almen, Kerry Debbie	Valid	$ 499.99	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20, 21)
512906	Andersen, Kyle	Valid	$ 1,570.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20, 21)
545856	Anderson, Kellie; Will, Gary	Valid	$ 728.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20)
1000029961	Anderson, Gerry	Valid	$ 1,980.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19) TPC Twin Cities 1977-6081 (Well 1)
827686	Banack, Michelle	Valid	$ 300.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
625108	Barber, Wade	Valid	$ 590.00	Blaine 1976-6227 (Wells 12, 18, 19)
803364	Carlson, Tabithah	Valid	$ 700.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19)
843890	Casper, Erin	Valid	$ 365.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20, 21)
808399	Cole, Jason	Valid	$ 600.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20)
739635	Dallmann, Laurel	Valid	$ 1,330.25	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
786862	Drewlo, Steve	Valid	$ 525.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20)
671882	Gardner, Jill	Valid	$ 2,099.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
849632	Griffin, Kevin	Valid	$ 648.90	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
622317	Hanover, Christopher	Valid	$ 3,679.83	Blaine 1976-6227 (Wells 12, 17, 18, 19)

Complainant Well Unique Number	Complainant Name	Valid or Not Valid	Invoice Dollar Amount	Well Interference Contributors
739667	Hawkins, Kristi & Mike	Valid	$ 550.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
794990	Helmeke, Rob	Valid	$ 598.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
700613	Ingvaldsen, Chris	Valid	$ 1,876.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
690770	Inwards, Jeremiah	Valid	$ 550.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
637084	Jeon, Hilary and Pil	Valid	$ 768.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
630080	Johnson, Dave	Valid	$ 550.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
831168	Kim, Lindsay	Valid	$ 602.50	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20, 21)
827885	Krtnick, Christian	Valid	$ 598.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
731111	Larkin, Alex & Jamie	Valid	$ 1,000.80	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20)
705584	McGuire, Adam	Valid	$ 550.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
679976	Minikus, Dave	Valid	$ 3,900.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
738518	Montminy, Jason	Valid	$ 586.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
562769	Moua, Hueseng	Valid	$ 450.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20, 21)
178112	Niemi, Amy	Valid	$ 6,385.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20, 21)
761499	Novak, David	Valid	$ 653.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
737231	Peterson, Allison	Valid	$ 695.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
820511	Peterson, Brian	Valid	$ 581.20	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
685266	Pikus, Eugene	Valid	$ 389.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19) Majestic Oaks Arcis LLC 2000-6108 (Well 3)
731105	Plocienik, Tim	Valid	$ 300.00	Blaine 1976-6227 (Wells 12, 17, 18, 19, 20, 21)
786218	Pogalz, Bryan	Valid	$ 1,361.66	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
721893	Pratt, Diane Jimmy	Valid	$ 2,173.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
707662	Schaefer, Becky	Valid	$ 850.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19)
836099	Schowalter, Andy	Valid	$ 630.00	Blaine 1976-6227 (Wells 12, 18, 19)
670212	Skamser, Lisa	Valid	$ 766.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19)
623934	Slanga, Thomas	Valid	$ 576.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
602063	Sletten, Sam Susan	Valid	$ 550.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
641235	Sorensen, George	Valid	$ 2,583.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
695616	Trempe, Tom	Valid	$ 565.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
795122	Vanstrom, Dwayne	Valid	$ 655.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19)
609861	VanTrease, Mark	Valid	$ 850.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
470557	Vu, Seng	Valid	$ 300.00	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20, 21)
664739	Wright, Heather	Valid	$ 3,021.36	Blaine 1976-6227 (Wells 12, 13, 17, 18, 19, 20)
134330	Creese, Peter	Not Valid	$ 4,290.23	Not Applicable
673579	Marier, Marcella	Not Valid	$ 1,800.00	Not Applicable
423316	Sondles, Alan	Not Valid	$ 4,804.69	Not Applicable

Excluded High-Capacity Wells

High-capacity pumping records, permit information, and well logs were evaluated to determine which appropriators could have contributed to the well interferences. If the high-capacity wells met any of the criteria listed below they were excluded from this investigation:

- **Source of water is either water table aquifer and dug pits/holding pond, or the Deep Bedrock aquifer system (six wells excluded).** These installations were excluded because no complainant wells were completed in the water table aquifer or Deep Bedrock system. As described above, the Lone Rock Formation acts as an aquitard to flow between the Deep and Shallow Bedrock systems, so pumping from the Deep Bedrock aquifer would not cause drawdown in any of the complainant wells. Dug pit/holding ponds are connected to the water table in this area, and pumping from the water table would not cause drawdown in the complainant wells.
- **No water was used during 2022 (six wells excluded).**
- **Reported water use was less than 0.25 million gallons during 2022 (three wells excluded).** Wells that used than 0.25 million galls did not cause drawdown in any of the complainant wells.
- **Reported 2022 pump rate is less than 100 gallons per minute (two wells excluded).** Wells that pumped at less than 100 gallons per minute did not cause drawdown at any of the complainant wells.
- **Appropriation permit was issued or amended prior to the installation of a complainant well (two wells excluded).** MN Rule 6115.0730 Subpart 3, item A states that "it is the responsibility of the prospective new domestic well owner to ensure that the new domestic well will be constructed at adequate depth so that it will provide an adequate domestic water supply which will not be limited by the permitted appropriation." Item B states that "Holders of valid permits for appropriation of water in areas where adequate water supplies are available shall not be responsible for well interference problems, involving new domestic wells exempt from permit, when such…wells are installed subsequent to authorized appropriation." Authorization of appropriation includes issuing a permit or amending the permit to increase pump rate, volume, or add an additional well. Table B-1 shows the permit authorization date for all high-capacity wells in the investigation area. If a permit with multiple wells was amended, the permit authorization date for all wells would be updated to the most recent amendment date for all wells on the permit.

Using this criteria, 19 high-capacity installations were excluded from further investigation (Table 2). The remaining 19 high-capacity wells were evaluated to determine if their pumping contributed to valid complaints.

Table 2. High-Capacity Wells Excluded from Investigation

Permit Number	Unique Well Number	Reason for Exclusion
1965-1311	228787	Appropriation authorization pre-dates all complainant wells
1965-1311	231873	Appropriation authorization pre-dates all complainant wells
1970-0791	not applicable	Dug Pit/Holding Pond
1970-0791	510541	Zero water use in 2022
1970-0845	231864	Water use less than 0.25 MGY in 2022
1976-6227	208615	Zero water use in 2022
1976-6227	208616	Zero water use in 2022
1976-6227	208618	Deep Bedrock Aquifer System
1977-6393	133213	Pump rate less than 100 gpm in 2022
1989-6155	449127	Zero water use in 2022.

Permit Number	Unique Well Number	Reason for Exclusion
1989-6346	255359	Water Table Aquifer
1989-6468	450537	Water use less than 0.25 MGY in 2022.
2000-6108	not applicable	Dug Pit/Holding Pond
2000-6108	510541	Zero water use in 2022
2000-6108	790641	Zero water use in 2022
2001-6126	not applicable	Dug Pit/Holding Pond
2003-3015	554238	Water Table Aquifer
2009-0034	753655	Pump rate less than 100 gpm in 2022
2015-2536	563009	Water use less than 0.25 MGY in 2022

Valid Complaints

Groundwater level and use data, complainant well data, and predictive drawdown simulations showed that high-capacity pumping caused groundwater levels to fall beyond the reach of the pump in 47 complainant wells; 47 of the 50 complaints were found valid (Table 1; Figure 8). Evidence supporting this includes:

- **Timing of water use, water levels and complaints:**
    - Annual water use was the highest on record in 2022 (Figure 5), and monthly water use was highest on record in July 2022 (Figure 6). The City of Blaine was the largest monthly and annual water user in 2022. Unpermitted pumping from City of Blaine wells 19, 20, and 21 accounted for the increase in 2022 water use and was highest in July 2022.
    - All observation wells that were monitored on August 6, 2022 (Columbus 243000 and 243178; Lino Lakes 208135) show lowest recorded groundwater level on this day (Figures 5 and 6). Water levels from complainant domestic wells (470557, 737231, 705584) all had lowest water levels recorded in early to mid-August.
    - All complainants reported water supply issues in July or August 2022, and 38 of the 47 complainants experienced water supply issues within two weeks of August 6, 2022. Most water supply problems were resolved by lowering pumps in complainant wells. This shows that water supply issues were caused by water levels falling below the reach of the pumps rather than other reasons (i.e., mechanical failure).
    - Water levels in all wells increase in late August and September 2022 as unpermitted pumping stops and water use from other users decreases. Water levels in City of Blaine Observation Well 6 (805156) increased by eight feet within 24 hours of the shut-off of Wells 19 and 20 on August 15, 2022, even though City of Blaine Well 18 was still pumping nearby.
- **Same aquifer system:** Complainant wells are completed in the Deep Confined-Shallow Bedrock system where the most high-capacity pumping occurred in 2022. Manual measurements collected in complainant domestic wells (470557, 737231, 705584) have similar trends to nearby observation wells (Figure 6), showing that the Deep Confined – Shallow Bedrock system is laterally well-connected.
- **Water use increase in the Tunnel City aquifer**: The largest increase in use in the area was from wells that are completed exclusively in the Tunnel City and Tunnel City-Wonewoc aquifer in the Deep

Confined – Shallow Bedrock system (Figure 7). This increase was primarily due to the unpermitted pumping of City of Blaine Wells 19 and 21, both of which are open to the Tunnel City-Wonewoc aquifer. All 47 of the valid complaints are located in the mapped area of the Tunnel City (green shading in Figure 3). Twenty-four of the valid complainant wells are open only to the Tunnel City and an additional 12 are open to the Tunnel City and the overlying St. Lawrence.

- **Modeling:** Analytical modeling described in Appendix E showed the 47 complainant wells are in the radius of influence of at least three high-capacity pumping wells (Figure E-1 and Table E-2). Drawdown was modeled in all 47 valid complainant wells.

High-Capacity Wells that Contributed to Interference

Methods

Well interference contributors were determined by calculating a radius of influence for each of the 19 high-capacity wells included in this investigation (Appendix E, Table E-2). Valid complainant wells that fell within the radius of influence of a high-capacity well were evaluated to determine if the high-capacity permit authorization date pre-dated the complainant well installation date. If this was the case, the high-capacity well could not be considered a contributor to the complainant well installation per MN Rule 6115.0730 Subpart 3. This resulted in some complainant wells falling within the radius of influence of high-capacity wells without the high-capacity well noted as a contributor to well interference. For example, Table E-2 and Figure 8 show that six complainant wells fall within the radius of influence for permit 1977-6081 TPC Twin Cities. However, five of these complainant wells were installed after the 1977-6081 permit authorization, so permit 1977-6081 could not be considered a contributor for those five wells.

Results

Using the methods described above, it was determined that pumping from nine high-capacity wells (including three unpermitted wells) contributed to well interference for the 47 valid complaints. Figure 8 and Table 1 show the complete list of contributors for each of the 47 valid complaints along with the amount of money spent by each of the complainants to restore their water supply (receipts for expenses are shown in Supplemental Information).

Table 3 shows the number of valid complaints associated with 2022 reported pumping from each of the nine contributing high-capacity wells.

Table 3. High-Capacity Well Pumping that Contributed to Valid Well Interference Complaints

Permittee Name (Permit Number)	Well Name (Unique Number)	Number of Valid Complaints Associated with 2022 Reported Pumping
City of Blaine (1976-6227)	Well 12 (127264)	47
City of Blaine (1976-6227)	Well 18 (809699)	47
City of Blaine (1976-6227)	Well 19 (819518) - *unpermitted*	47
City of Blaine (1976-6227)	Well 17 (721815)	45
City of Blaine (1976-6227)	Well 20 (819519) - *unpermitted*	39
City of Blaine (1976-6227)	Well 13 (127270)	33

Permittee Name (Permit Number)	Well Name (Unique Number)	Number of Valid Complaints Associated with 2022 Reported Pumping
City of Blaine (1976-6227)	Well 21 (819520) - *unpermitted*	15
TPC Twin Cities (1977-6081)	Well 3 (114392)	1
Majestic Oaks (2000-6108)	Well 1 (615970)	1

Main findings from the investigation into the high-capacity wells that contributed to valid complaints include:

- **Pumping by the City of Blaine was the main cause of well interference in all 47 valid complaints.**
    - The City of Blaine was the only contributor in 45 of the 47 complaints. Individual modeled drawdown estimates in each of 45 complainant wells are not reported because the City of Blaine well pumping (permitted and unpermitted) was the only contributor and therefore caused the drawdown in each well.
    - Unpermitted pumping by City of Blaine Well 19 contributed to well interference in all 47 complaints. Unpermitted pumping from City of Blaine Wells 20 and 21 contributed to well interference in 40 and 15 complaints, respectively.
- **Pumping by two golf course irrigation wells was a minor cause of well interference in two valid complaints**. TPC Twin Cities Golf Course (1977-6081) well pumping contributed to the well 1000029961 complaint and Majestic Oaks Golf Course (2000-6108) well pumping contributed to the well 685266 complaint. The City of Blaine was also a contributor in these two complaints, so DNR calculated drawdown in domestic wells to determine how much each high-capacity well contributed to interference.
    - Table 4 shows that pumping by six high-capacity installations caused a total modeled drawdown of 28 feet in well 685266, which is two feet more than the observed drawdown of 26 feet (observed drawdown is the difference between water level collected on August 30, 2002, when the well was drilled and 45 feet on August 11, 2022 when the well was out of water and well driller visited to lower the pump). Majestic Oaks Golf Course caused 4% of drawdown in this well while the City of Blaine cause 96%.
    - Table 5 shows that seven high-capacity contributors caused a total modeled drawdown of 24 feet for well 1000029961. Observed water level decline is unknown for well 1000029961 as the initial static water level is unknown. TPC Twin Cities Golf Course caused 4% of drawdown in this well while the City of Blaine cause 96%.
    - Uncertainty in observed drawdown include differences in initial static water level date for each well, amount of domestic self-pumping drawdown, and cumulative drawdown caused by other nearby domestic wells. Uncertainty in predicted drawdown includes heterogeneity in hydraulic properties of aquifer materials, and inexact information about actual pump on-off times.

Table 4. Drawdown Estimates for Complainant Well 685266

Responsible Permittee	Well Name (Unique ID)	Total Modeled Drawdown (feet)	Percentage of Total Drawdown
Blaine 1976-6227	Well 12 (127264)	8	29%
Blaine 1976-6227	Well 17 (721815)	7	25%
Blaine 1976-6227	Well 18 (809699)	5	18%
Blaine 1976-6227	Well 13 (127270)	4	14%
Blaine 1976-6227	Well 19 (819518) - *unpermitted*	3	11%
Majestic Oaks 2000-6108	Well 1 (615970)	1	4%

Table 5. Drawdown Estimates for Complainant Well 1000029961

Responsible permittee	Well name (unique ID)	Total Modeled Drawdown	Percentage of Total Modeled Drawdown
Blaine 1976-6227	Well 12 (127264)	5	21%
Blaine 1976-6227	Well 17 (721815)	5	21%
Blaine 1976-6227	Well 18 (809699)	5	21%
Blaine 1976-6227	Well 13 (127270)	3	13%
Blaine 1976-6227	Well 19 (819518) - *unpermitted*	3	13%
Blaine 1976-6227	Well 20 (819519) - *unpermitted*	2	8%
TPC Twin Cities 1977-6081	Well 1 (114392)	1	4%

High-Capacity Wells that Did Not Contribute to Well Interference

Ten high-capacity wells did not contribute to well interference for any complaints (Table 6). This does not include the 19 wells that were excluded from the investigation (Table 2). The 10 wells that did not contribute were evaluated using the reported 2022 pumping rates and volumes and did not cause more than one foot of drawdown at any of the valid complainant wells (see Table E-2 for radii of influence for each well).

Table 6. High-Capacity Wells that Did Not Contribute to Well Interference

Permit Number	Unique Well Number	Landowner
1970-0791	208594	CF Majestic Oaks Arcis LLC, c/o Arcis Equity Partners, LLC
1970-0845	231866	Bunker Hills Golf Club
1970-0845	500696	Bunker Hills Golf Club
1977-6064	107242	Hogdal, Virgil; Hogdal, John
1980-6263	231862	Robinson Landscaping, Inc
1988-6385	448834	Robinson, Daniel; Robinson, Scott
1989-6190	444820	Hentges, Eldon
1990-6006	208611	Anoka-Hennepin ISD 11
1990-6014	431681	Anoka County Parks And Recreation
1999-6118	624188	Robinson Landscaping, Inc; Robinson, Margie

Risk of Future Water Supply Issues

There is risk of future water supply issues in complainant wells that were determined valid, especially for wells that had pumps lowered by only 20 feet (Appendix A-1). In addition, there are more domestic wells in this area (inside and outside of investigation area) that may be at risk if water use is greater than or equal to 2022 water use in the future. **It is recommended that risk to future domestic water supply be evaluated in detail as part of the permit amendment review for City of Blaine Wells 19, 20, and 21.** Private domestic wells should be evaluated to determine if pumps need to be lowered or wells replaced to accommodate future use.

Valid Complaints Requiring More Work

Two complainant wells with valid complaints are still experiencing water supply issues, and further work is required to resolve the complaint. Pumping from the City of Blaine wells was the sole cause of well interference for these wells (Table 1), so the City of Blaine should work with complainants to restore water supply. Additional information about those two wells is provided below.

Complainant Well 470557

Well 470557 is a 60-foot well screened in a shallow confined aquifer that is still not providing adequate water for the complainant. As per well driller visit on February 9, 2023 (Supplemental Information), the pump cannot be lowered any further in this well. The driller determined that the well, pump, and pressure tank were in good working condition and that the low water supply is due to low water levels in the aquifer. **The driller recommended that well 470557 be replaced with a new, deeper well.**

It is also recommended that DNR further evaluate safe yield of the shallow confined aquifer in this area as part of the City of Blaine permit amendment review. The pump depth (51 feet) is below the top of the aquifer (50 feet), and because the water levels are still regularly falling below the pump, water levels are falling below the top of the aquifer. It is unknown how much of the water level issues can be attributed to a lower yielding (isolated) aquifer or high-capacity pumping. However, other domestic wells in the Shallow Confined aquifer (less than 100 feet deep) are not reporting water supply issues in this area. Safe yield evaluation is outside the scope of this report but will be addressed in the City of Blaine permit amendment review.

Complainant Well 679976

Well 679976 is a 300-foot well completed in the Tunnel City aquifer that developed a compromised open hole after a higher horsepower pump was installed at a greater depth. The well driller who serviced the well reported to DNR on March 24, 2023, that the water level dropped below the pump on August 11, 2022, so the driller lowered the existing pump by 60 feet (Supplemental Information). However, the pump was too damaged from running dry, so it had to be replaced with a more powerful pump on August 22, 2022. When the driller was test pumping the new pump, it started pumping sand, and the driller suspected that this was due to a partial collapse of the open hole due to pumping at a greater depth and with a higher horsepower pump. The driller said this can happen in open holes (i.e., no screen) which are common in this area (see driller notes from 3/24/2023 in Supplemental Information). The complainant has sand in their water since then. In early March 2023, **the driller recommended that the well 679976 be either rehabilitated or completely replaced**.

Conclusions and Recommendations

Forty-seven of the 50 complaints evaluated in this report were found valid. Permitted and unpermitted pumping by the City of Blaine (1976-6227) was the sole cause of well interference in 45 complaints, and the main cause in two complaints. Two golf course irrigation permits, Majestic Oaks (2000-6108) and TPC Twin Cities (1977-6081), contributed to one valid complaint each. These golf course permits caused 4% of the drawdown in the two complaints, while the City of Blaine non-residential use caused 96% (Tables 4 and 5). Table 2 and Figure 8 show the complaints and contributing wells.

There is a continued risk to domestic water supply in this area. The following is recommended:

- Domestic well 470557 should be replaced with a new, deeper well because the pump is at the maximum depth in the existing well and the complainant is still experiencing water supply issues.
- Domestic well 679976 should be replaced or rehabilitated because well work done to mitigate the water supply problems caused the open hole to partially fill with sand.
- Risk to future water supply at area domestic wells should be evaluated as part of the permit amendment review for City of Blaine Wells 19, 20, and 21.
- The DNR should further evaluate the groundwater sustainability (safe yield) of the shallow confined source aquifer of well 470557 as part of the City of Blaine permit amendment review.

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Figures

Figure 1. Well Interference Complaint Locations in Blaine-Ham Lake Area

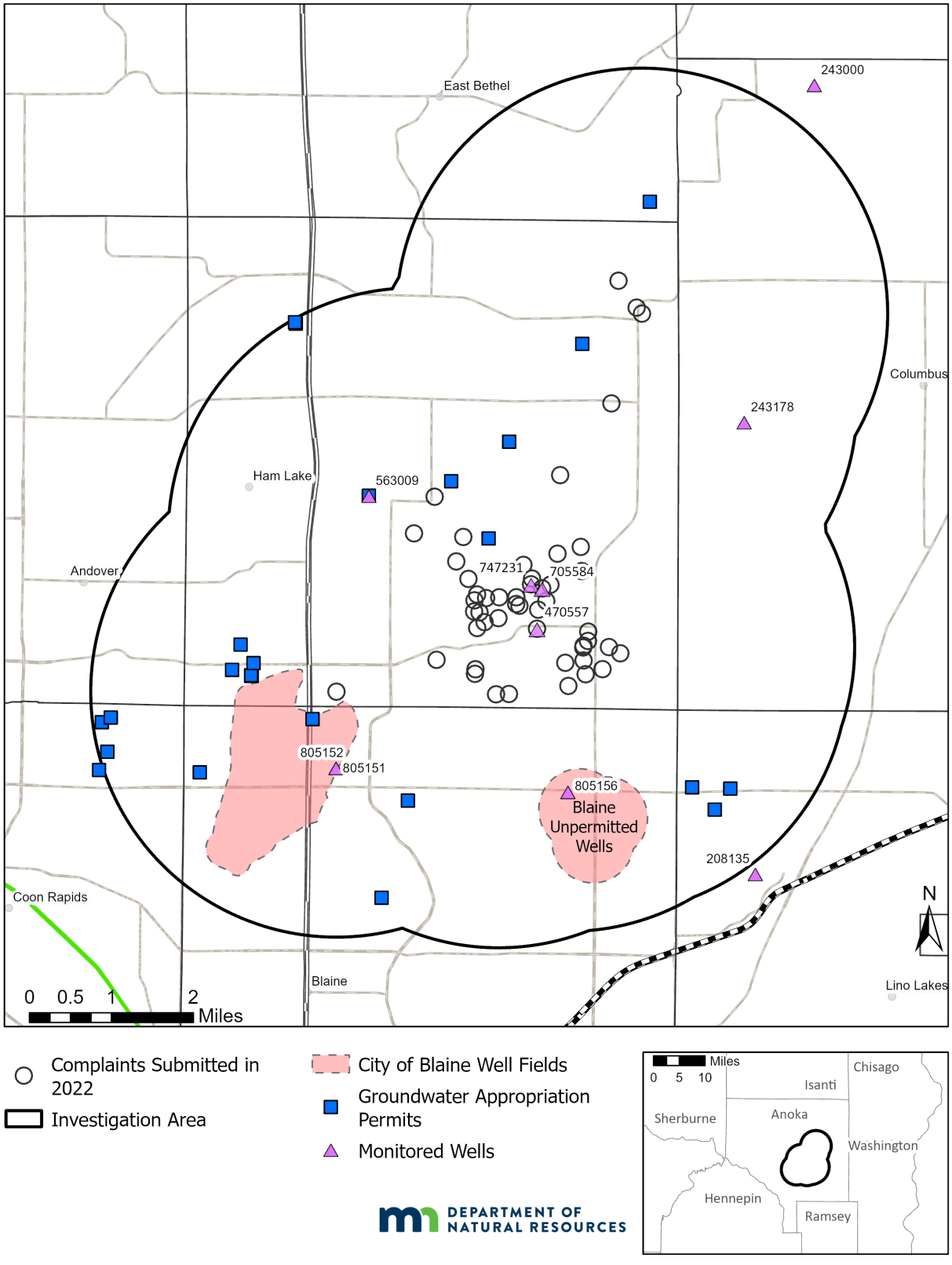
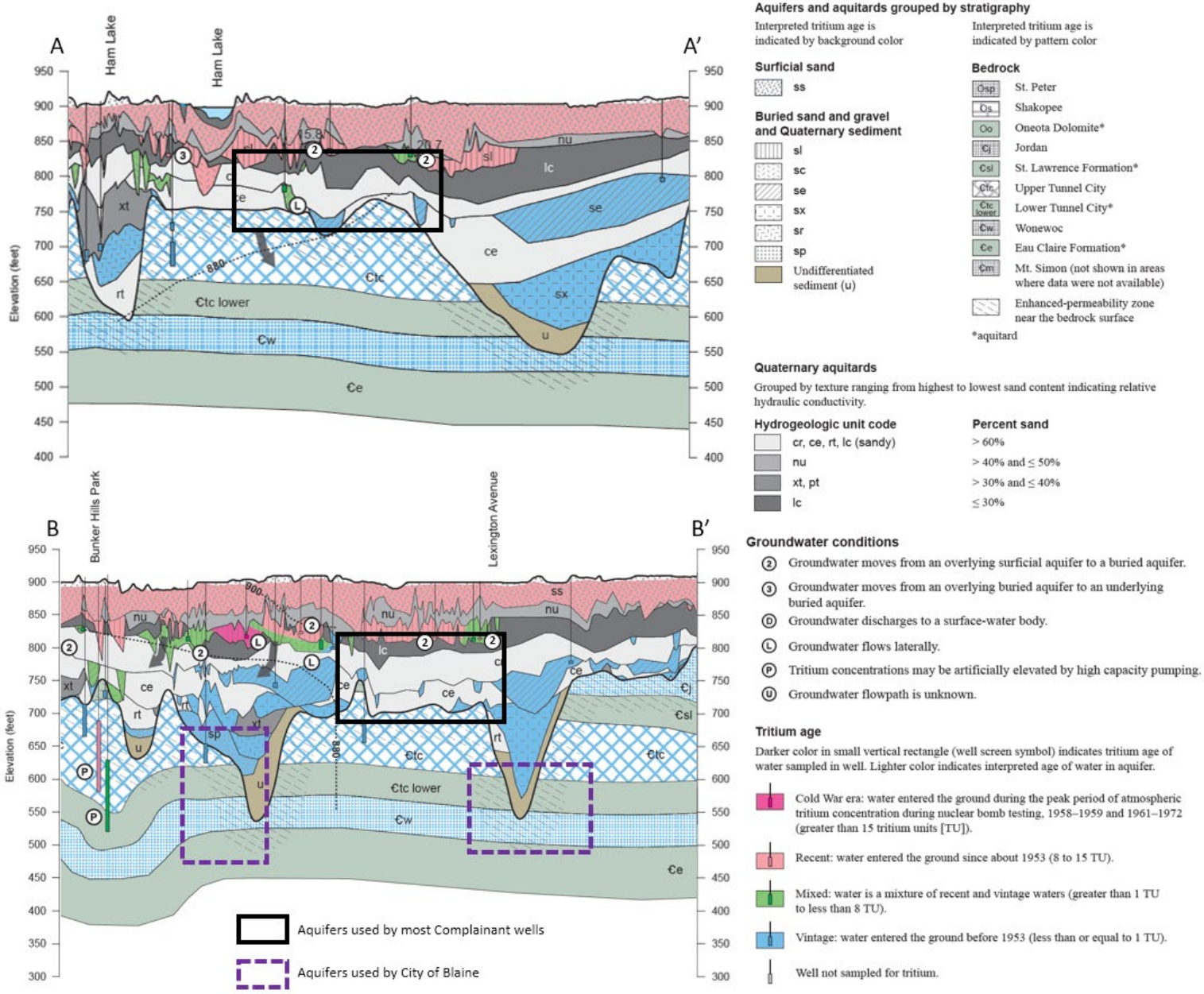


Figure 2. Hydrogeologic Cross Sections (modified after Berg, 2016)



Aquifers and aquitards grouped by stratigraphy

Interpreted tritium age is indicated by background color

Surficial sand

- ss

Buried sand and gravel and Quaternary sediment

- sl
- sc
- se
- sx
- sr
- sp
- Undifferentiated sediment (u)

Interpreted tritium age is indicated by pattern color

Bedrock

- Osp — St. Peter
- Os — Shakopee
- Oo — Oneota Dolomite*
- Cj — Jordan
- Csl — St. Lawrence Formation*
- Ctc — Upper Tunnel City
- Ctc lower — Lower Tunnel City*
- Cw — Wonewoc
- Ce — Eau Claire Formation*
- Cm — Mt. Simon (not shown in areas where data were not available)
- Enhanced-permeability zone near the bedrock surface

*aquitard

Quaternary aquitards

Grouped by texture ranging from highest to lowest sand content indicating relative hydraulic conductivity.

Hydrogeologic unit code	Percent sand
cr, ce, rt, lc (sandy)	> 60%
nu	> 40% and ≤ 50%
xt, pt	> 30% and ≤ 40%
lc	≤ 30%

Groundwater conditions

- (2) Groundwater moves from an overlying surficial aquifer to a buried aquifer.
- (3) Groundwater moves from an overlying buried aquifer to an underlying buried aquifer.
- (D) Groundwater discharges to a surface-water body.
- (L) Groundwater flows laterally.
- (P) Tritium concentrations may be artificially elevated by high capacity pumping.
- (U) Groundwater flowpath is unknown.

Tritium age

Darker color in small vertical rectangle (well screen symbol) indicates tritium age of water sampled in well. Lighter color indicates interpreted age of water in aquifer.

- Cold War era: water entered the ground during the peak period of atmospheric tritium concentration during nuclear bomb testing, 1958–1959 and 1961–1972 (greater than 15 tritium units [TU]).
- Recent: water entered the ground since about 1953 (8 to 15 TU).
- Mixed: water is a mixture of recent and vintage waters (greater than 1 TU to less than 8 TU).
- Vintage: water entered the ground before 1953 (less than or equal to 1 TU).
- Well not sampled for tritium.

Figure 3. Bedrock Surface in Investigation Area

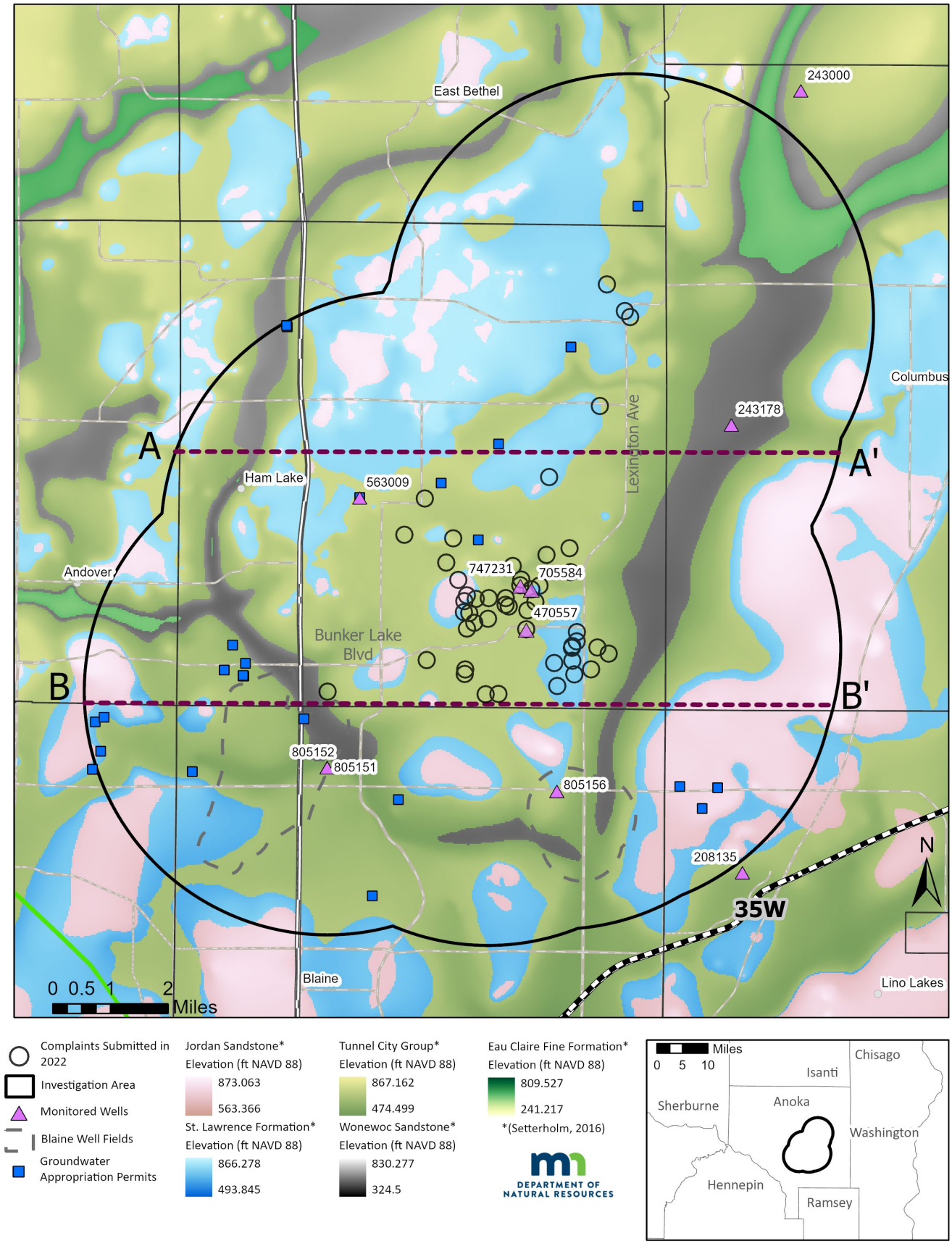


Figure 4. Bedrock Stratigraphy and Hydrostratigraphy in Blaine-Ham Lake Area (modified from Berg, 2016)

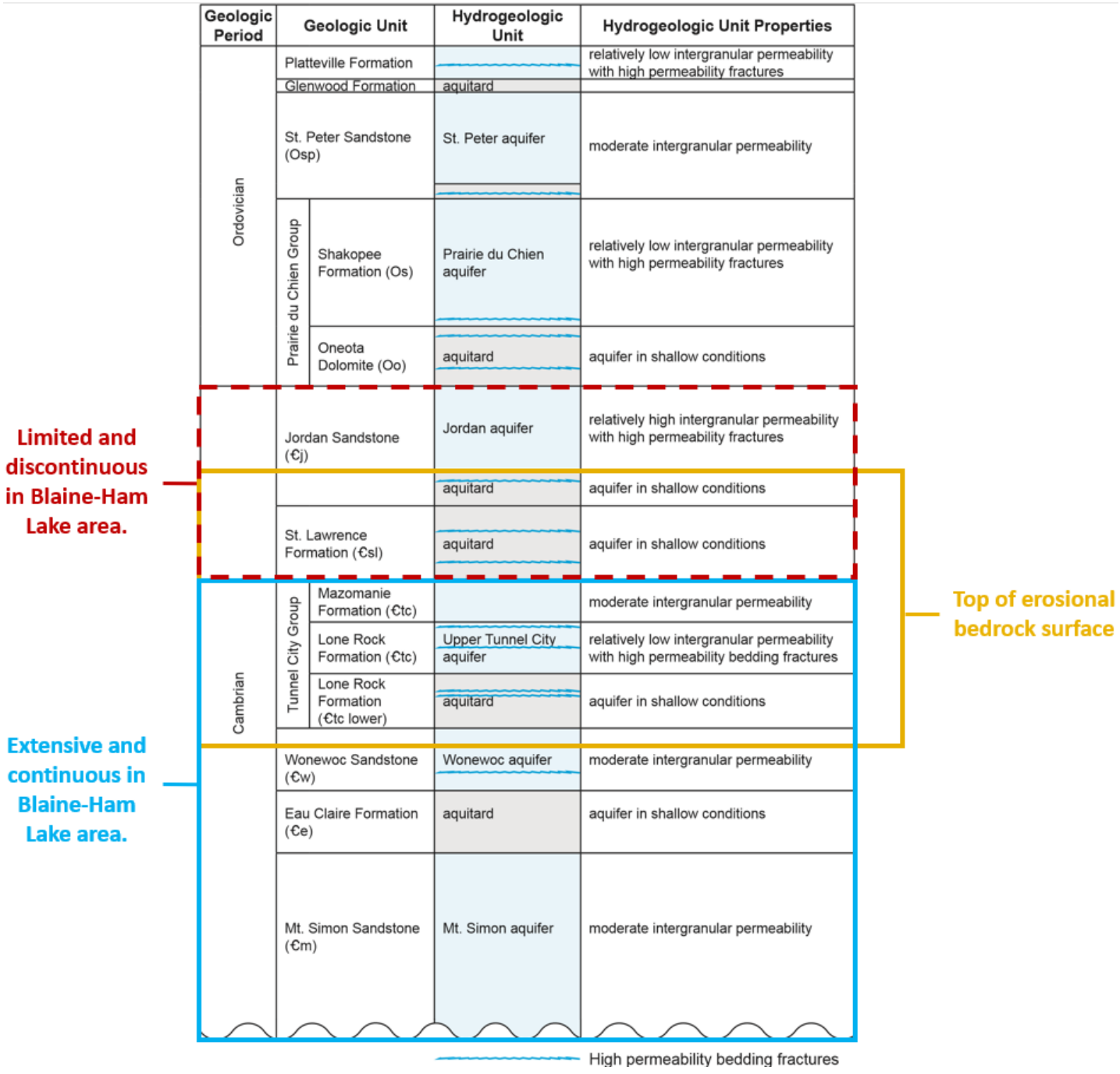


Figure 5. Long-term Water Use, Water Levels, and Precipitation

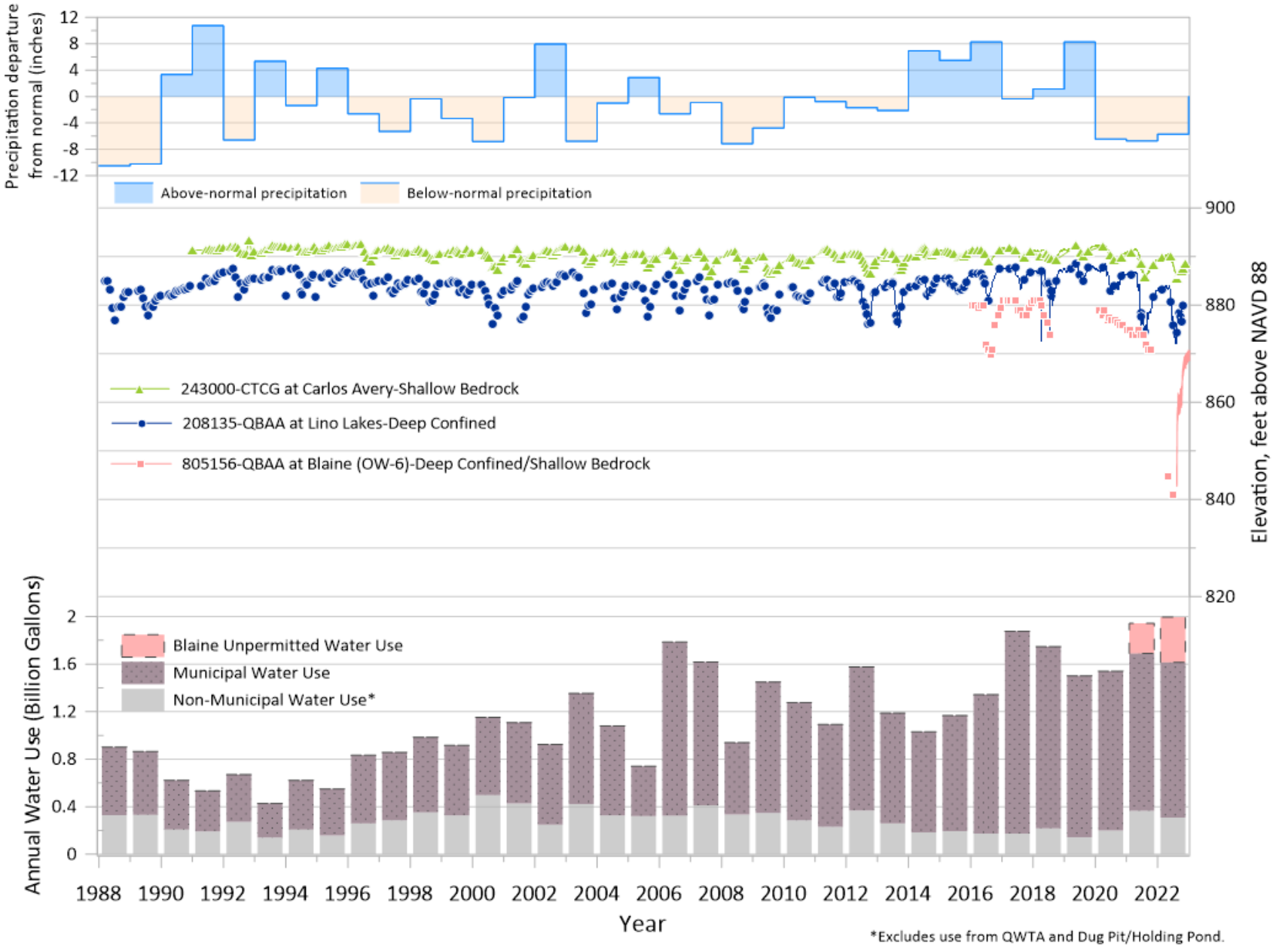


Figure 6. Monthly Water Use and Water Levels

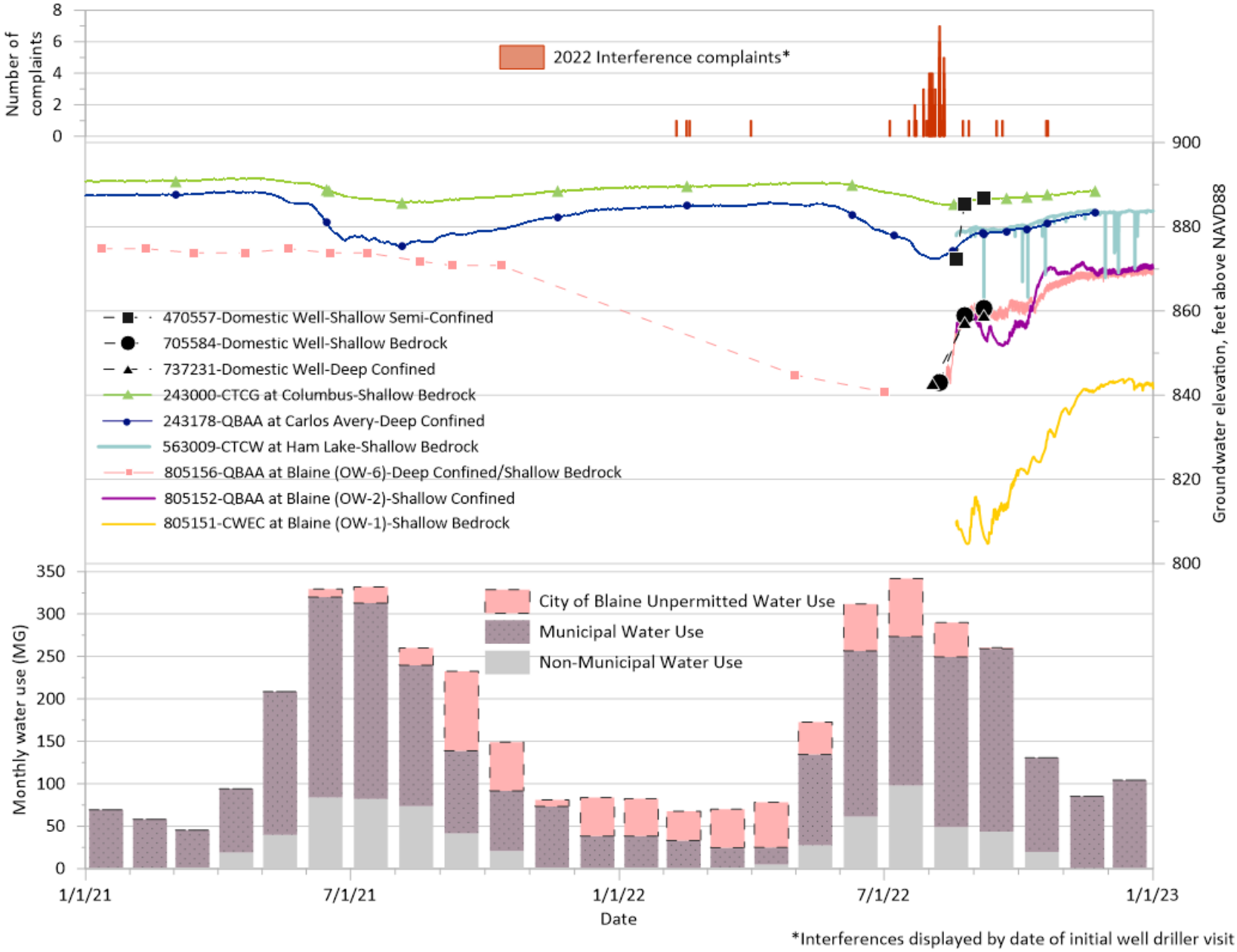


Figure 7. Long-term Water Use by Aquifer

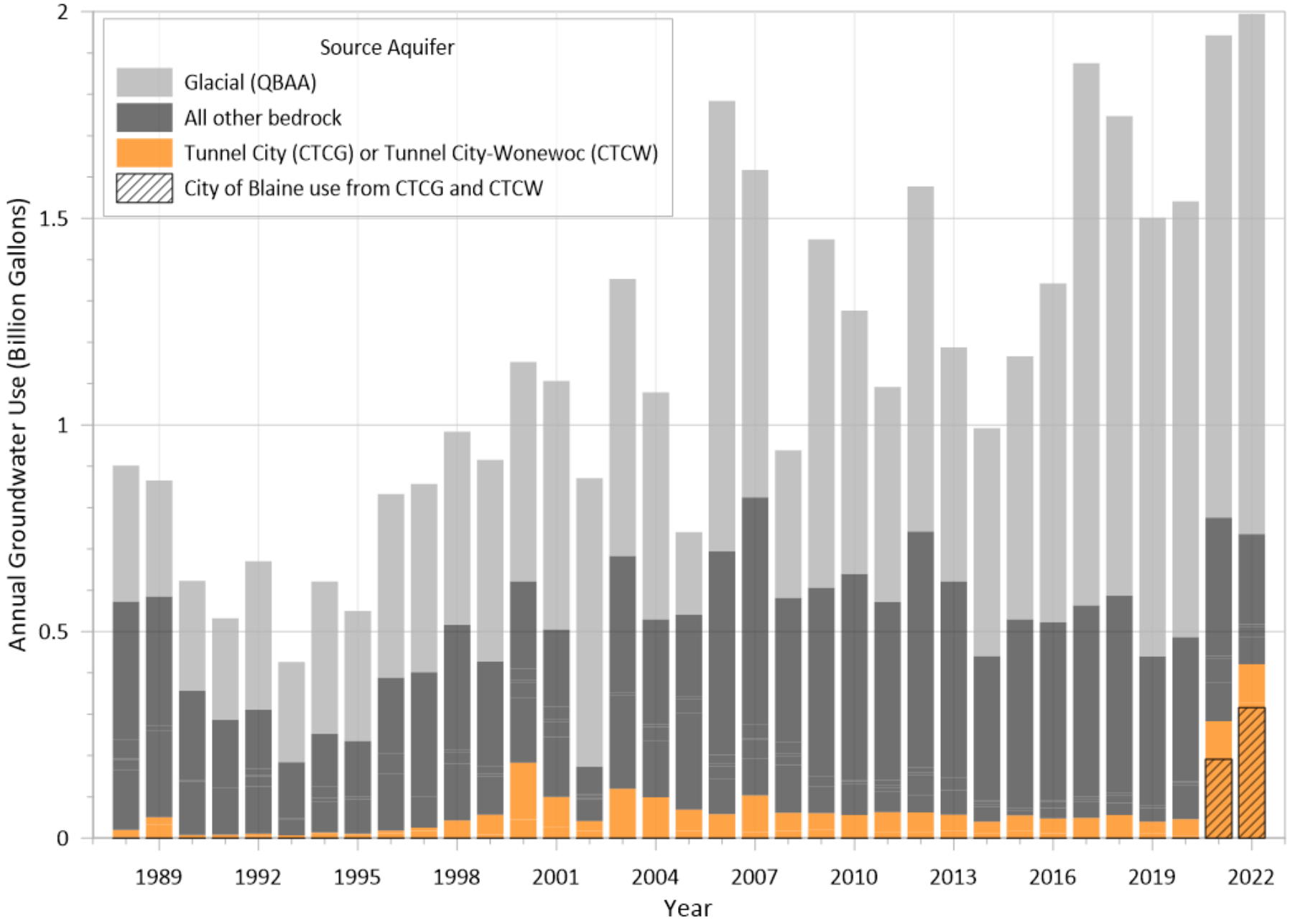


Figure 8. Map of Valid and Not Valid Complaints with Contributing Permits

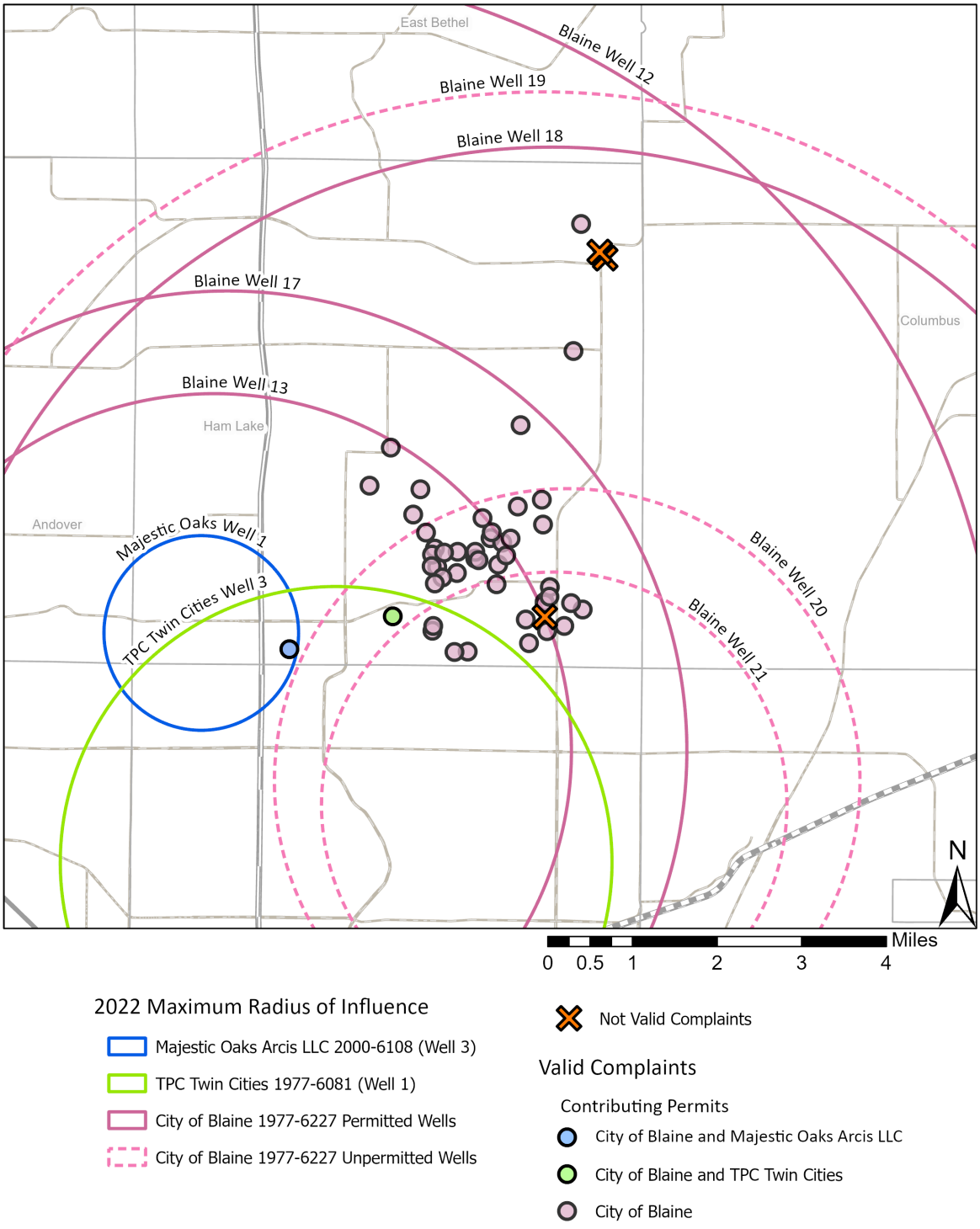


Figure 8 shows the radii of influence for each high-capacity well that contributed to water supply problems at each valid complainant well. Complaints are color-coded to show which permits were found to contribute to drawdown. There is only one complaint that Majestic Oaks contributed to, and only one complaint that TPC Twin Cities contributed to. If a high-capacity well permit authorization was issued prior to complainant well installation, the high-capacity well was excluded from the investigation per MN Rule 6115.0730 Subpart 3. For example, TPC Twin Cities 1977-6081 has a permit authorization date that pre-dates complainant well installation dates for five of the six complainant wells that fall within the well's radius of influence. TPC Twin Cities was therefore only a contributor to well interference for the one complainant well (shown in green) that pre-dated the permit authorization.

Appendix A. Complaint Information

Table A-1. Complaint Information

Unique Well Number	Complainant Name	Date Drilled	Date of First Driller visit	Well Work Completed	UTM E (m)	UTM N (m)	Depth (ft BGS)	Screened /Open Interval (ft BGS)	Static water Level on Well Log (ft BGS)	Water Level At Time of Complaint (ft BGS)	Observed Water Level Decline**	Original Submersible Pump Depth (ft BTOC), Horsepower	New Submersible Pump Depth (ft BTOC), Horsepower	Penetrated Aquifer System (MDH Aquifer Code)
655273	Albers, Timothy	11/1/2000	8/8/2022	Lowered and replaced pump	486616	5007324	201	172-201	35	57	22	60; 0.75 HP	100; 0.75 HP	Deep confined-Shallow Bedrock (CSLT)
786870	Almen, Kerry and Debbie	11/3/2011	7/23/2022	Lowered pump	486967	5007626	220	169-220	25	Unknown	15	40; 0.75 HP	60 Same pump	Deep confined-Shallow Bedrock (CTCG+)
512906	Andersen, Kyle	6/12/1992	7/22/2022	Lowered and replaced pump	486974	5007660	154	149-153	25	60	35	42 0.5 HP	102 0.5 HP	Deep confined-Shallow Bedrock (QBAA)
545856	Anderson, Kellie; Will, Gary	7/27/1999	7/28/2022	Lowered pump	486476	5009472	225	200-225	17	Unknown	23	40 0.75 HP	80 Same pump	Deep confined-Shallow Bedrock (CTCG)
1000029961	Anderson, Gerry and Nancy	00/00/1970^	9/20/2022*	Lowered and replaced pump	484085	5007382	270^	Unknown	Unknown	Unknown	Unknown	60 0.5 HP	80 0.5 HP	Deep confined-Shallow Bedrock (CTCG+)
827686	Banack, Michelle	6/14/2017	8/11/2022	Lowered pump	486241	5008538	220	193-220	33	Unknown	27	60 0.75 HP	80 Same pump	Deep confined-Shallow Bedrock (CTCG+)
625108	Barber, Wade	12/17/1998	7/31/2022	Lowered pump	487521	5012426	217	168-217	10	Unknown	30	40 0.5 HP	80 Same pump	Deep confined-Shallow Bedrock (CTCG)
803364	Carlson, Tabithah	6/24/2015	8/1/2022	Lowered pump	484047	5010590	360	211-360	32	68	36	70 1 HP	112 Same pump	Deep confined-Shallow Bedrock (CTCG+)
843890	Casper, Erin	6/4/2020	7/5/2022	Lowered pump	484844	5008657	184	180-184	28	Unknown	52	80 1 HP	100 Same pump	Deep confined-Shallow Bedrock (CSLT)
808399	Cole, Jason	1/21/2015	8/5/2022	Lowered pump	486323	5008859	169	159-169	10	64	54	60 0.75 HP	120 Same pump	Deep confined-Shallow Bedrock (QBAA+)
134330	Creese, Peter	5/11/1978	1/4/2022	Replaced pressure tank	486974	5007370	94	90-94	14	Unknown	Unknown	Unknown 0.5 HP	No changes	Water table-Shallow semi-confined (QBAA+)
739635	Dallmann, Laurel	5/4/2006	8/8/2022	Lowered pump, sprinkler system inspected	485255	5006704	230	177-230	30	60	30	60 1 HP	100 Same pump	Deep confined-Shallow Bedrock (CSLT)
786862	Drewlo, Steve	10/5/2011	7/28/2022	Lowered pump	486920	5009603	231	211-231	20	Unknown	20	40 0.75 HP	80 Same pump	Deep confined-Shallow Bedrock (CTCG+)

Unique Well Number	Complainant Name	Date Drilled	Date of First Driller visit	Well Work Completed	UTM E (m)	UTM N (m)	Depth (ft BGS)	Screened /Open Interval (ft BGS)	Static water Level on Well Log (ft BGS)	Water Level At Time of Complaint (ft BGS)	Observed Water Level Decline**	Original Submersible Pump Depth (ft BTOC), Horsepower	New Submersible Pump Depth (ft BTOC), Horsepower	Penetrated Aquifer System (MDH Aquifer Code)
671882	Gardner, Jill	12/17/2001	8/4/2022	Lowered and replaced pump	485651	5008480	290	223-290	25	58	33	60 0.5 HP	100 0.75 HP	Deep confined-Shallow Bedrock (CSLT)
849632	Griffin, Kevin	4/15/2021	4/20/2021	Lowered pump	484830	5008570	180	161-180	20	Unknown	40	60 1 HP	100 Same pump	Deep confined-Shallow Bedrock (CTCG+)
622317	Hanover, Christopher	9/3/1999	7/30/2022	Lowered and replaced pump	486515	5011015	200	161-200	15	40	25	40 0.5 HP	60 0.5 HP	Deep confined-Shallow Bedrock (CTCG)
739667	Hawkins, Kristi & Mike	8/15/2006	8/2/2022	Lowered pump	484850	5007197	197	168-197	30	Unknown	30	60 1 HP	100 Same Pump	Deep confined-Shallow Bedrock (CSLT)
794990	Helmeke, Rob	2/28/2013	8/8/2022	Lowered pump	486515	5011015	230	177-230	30	Unknown	30	60 1 HP	100 Same Pump	Deep confined-Shallow Bedrock (CSLT+)
700613	Ingvaldsen, Chris	2/25/2004	8/1/2022	Lowered and replaced pump	485029	5008123	280	214-280	20	60	40	60 0.5 HP	100 0.75 HP	Deep confined-Shallow Bedrock (CTCG)
690770	Inwards, Jeremiah	6/10/2003	8/2/2022	Lowered pump	485064	5008117	260	199-260	20	44	24	40 0.75 HP	80 Same pump	Deep confined-Shallow Bedrock (CTCG)
637084	Jeon, Hilary and Pil	9/28/2000	8/24/2022	Lowered pump	487015	5007099	168	158-168	35	Unknown	20	55 0.5 HP	80 Same pump	Deep confined-Shallow Bedrock (QBAA)
630080	Johnson, Dave	8/15/1999	8/2/2022	Lowered pump	485654	5008614	285	215-285	8	Unknown	52	60 0.5 HP	100 Same pump	Deep confined-Shallow Bedrock (CTCG)
831168	Kim, Lindsay	9/25/2018	7/18/2022	Lowered pump	487316	5007116	160	148-160	19	Unknown	41	60 0.75 HP	100 Same pump	Deep confined-Shallow Bedrock (QBAA+)
827885	Krtnick, Christian	6/13/2017	8/2/2022	Lowered pump	484712	5008974	175	160-175	32	Unknown	28	60 1 HP	100 Same pump	Deep confined-Shallow Bedrock (QBAA+)
731111	Larkin, Alex and Jamie	2/21/2006	8/5/2022	Lowered pump	486938	5009128	238	203-238	18	68	50	40 1 HP	100 Same pump	Deep confined-Shallow Bedrock (CSLT)
673579	Marier, Marcella	1/9/2002	2/18/2022	Replaced pump	488017	5014310	88	78-88	35	Unknown	7	42 0.5 HP	42 0.5 HP	Water table-Shallow semi-confined (QBAA)
705584	McGuire, Adam	7/5/2004	8/8/2022	Lowered pump	486162	5008787	200	188-200	28	60	32	60 1 HP	100 Same pump	Deep confined-Shallow Bedrock (CTCG)
679976	Minikus, Dave	9/10/2002	8/1/2022	Lowered and replaced pump	484930	5008316	300	248-300	20	74	54	80 1 HP	160 1 HP	Deep confined-Shallow Bedrock (CTCG)

Unique Well Number	Complainant Name	Date Drilled	Date of First Driller visit	Well Work Completed	UTM E (m)	UTM N (m)	Depth (ft BGS)	Screened /Open Interval (ft BGS)	Static water Level on Well Log (ft BGS)	Water Level At Time of Complaint (ft BGS)	Observed Water Level Decline**	Original Submersible Pump Depth (ft BTOC), Horsepower	New Submersible Pump Depth (ft BTOC), Horsepower	Penetrated Aquifer System (MDH Aquifer Code)
738518	Montminy, Jason	5/4/2006	8/11/2022	Lowered pump	485962	5008980	258	203-258	28	Unknown	32	60 0.75 HP	100 Same pump	Deep confined-Shallow Bedrock (CTCG)
562769	Moua, Hueseng	7/10/1995	7/22/2022	Lowered pump	487473	5007633	170	160-170	15	Unknown	Unknown	Unknown Unknown HP	+20 Same pump	Deep confined-Shallow Bedrock (QBAA)
178112	Niemi, Amy	1/00/1981	7/27/2022	Lowered and replaced pump	487066	5007938	198	171-198	12	55	43	42 0.75 HP	120 0.75 HP	Deep confined-Shallow Bedrock (CSLT)
761499	Novak, David	10/5/2009	8/3/2022	Lowered pump	485792	5009250	240	187-240	20	60	40	80 1 HP	120 Same pump	Deep confined-Shallow Bedrock (CTCG)
737231	Peterson, Allison	3/3/2006	8/3/2022	Lowered pump	485942	5008867	184	175-185	25	64	39	80 1 HP	120 Same pump	Deep confined-Shallow Bedrock (QBAA)
820511	Peterson, Brian	6/14/2016	7/28/2022	Lowered pump	484712	5008974	244	183-244	30	Unknown	38	68 1 HP	108 Same pump	Deep confined-Shallow Bedrock (CSLT+)
685266	Pikus, Eugene	8/30/2002	8/11/2022	Lowered pump	482119	5006756	109	100-109	19	45	26	60 1 HP	80 Same pump	Deep confined-Shallow Bedrock (QBAA)
731105	Plocienik, Tim	11/3/2005	10/21/2022*	Lowered pump	484712	5008974	213	175-213	18	Unknown	24	42 0.75 HP	62 Same pump	Deep confined-Shallow Bedrock (CSLT)
786218	Pogalz, Bryan	8/27/2012	8/11/2022	Lowered pump	486083	5008369	263	195-263	38	57	19	63 1 HP	105 Same pump	Deep confined-Shallow Bedrock (CTCG)
721893	Pratt, Diane and Jimmy	7/8/2005	8/28/2022	Lowered and replaced pump	484884	5008008	200	161-20	21	50	29	60 0.75 HP	80 0.75 HP	Deep confined-Shallow Bedrock (CJSL)
707662	Schaefer, Becky	8/5/2004	8/8/2022	Lowered pump	484473	5009318	197	178-197	35	61	26	63 0.75 HP	100 Same pump	Deep confined-Shallow Bedrock (QBAA)
836099	Schowalter, Andy	10/30/2019	8/5/2022	Lowered pump	487661	5014838	220	208-220	12	Unknown	28	40 1 HP	80 Same pump	Deep confined-Shallow Bedrock (CTCG+)
670212	Skamser, Lisa	10/11/2001	8/3/2022	Lowered pump	484611	5009798	260	190-260	30	Unknown	33	63 0.75 HP	103 Same pump	Deep confined-Shallow Bedrock (CTCG)
623934	Slanga, Thomas	5/21/1999	8/8/2022	Lowered pump	485317	5008612	260	201-260	25	65	40	60 1 HP	100 Same pump	Deep confined-Shallow Bedrock (CTCG)
602063	Sletten, Sam and Susan	7/28/1997	8/4/2022	Lowered pump	485713	5008446	275	229-275	25	64	39	60	100	Deep confined-Shallow Bedrock (CTCG)

Unique Well Number	Complainant Name	Date Drilled	Date of First Driller visit	Well Work Completed	UTM E (m)	UTM N (m)	Depth (ft BGS)	Screened /Open Interval (ft BGS)	Static water Level on Well Log (ft BGS)	Water Level At Time of Complaint (ft BGS)	Observed Water Level Decline**	Original Submersible Pump Depth (ft BTOC), Horsepower	New Submersible Pump Depth (ft BTOC), Horsepower	Penetrated Aquifer System (MDH Aquifer Code)
423316	Sondles, Alan	12/5/1986	2/9/2022	Replaced pump and water softener	488122	5014191	66	59-66	12	Unknown	Unknown	40 0.5 HP	40 0.5 HP	Water table-Shallow semi-confined (QBAA)
641235	Sorensen, George	6/7/2000	8/9/2022	Lowered and replaced pump	486675	5006868	200	180-200	24	52	28	60 1 HP	100 1 HP	Deep confined-Shallow Bedrock (CSLT)
695616	Trempe, Tom	10/24/2003	Unknown	Lowered pump	485302	5008202	300	189-230	20	68	48	80 0.5 HP	120 Same pump	Deep confined-Shallow Bedrock (CTCG)
795122	Vanstrom, Dwayne	6/14/2013	8/9/2022	Lowered pump	483642	5009869	295	252-295	30	59	29	60 1 HP	100 Same pump	Deep confined-Shallow Bedrock (CTCG+)
609861	VanTrease, Mark	6/2/1998	8/11/2022	Lowered pump	485059	5008597	300	208-300	30	66	36	63 0.5 HP	126 Same pump	Deep confined-Shallow Bedrock (CTCG)
470557	Vu, Seng	11/26/1990	8/1/2022	Inspected and lowered pump***	486059	5007993	60	56-60	22	35	13	40 0.5 HP	51*** Same pump	Water table-Shallow semi-confined (QBAA+)
664739	Wright, Heather	8/7/2001	8/3/2022	Lowered and replaced pump	484882	5008668	202	153-202	35	67	32	67 1 HP	86 1 HP	Water table-Shallow semi-confined (CSLT)

Coordinates are estimates from the Minnesota County Well Index and are in the NAD83 system, Zone 15; BGS=Below ground surface; BTOC=Below top of casing; MDH=Minnesota Department of Health

*These homeowners reported having water level issues in the late summer but didn't have well driller visits until later in the year.

**Drawdown is the static water level from the drilling record subtracted from the water level taken at the time of the complaint. In cases where we didn't have a water level at the time of the complaint the static water level was subtracted from the original pump depth.

***Pump was lowered prior to the complainant purchase of the property (August 2021), but exact date is unknown.

^Estimated by homeowner and well driller.

+Interpreted from well log.

Appendix B. Water Appropriation and Water Use Information

Figure B-1. Groundwater Permit Holder Locations by Use Type

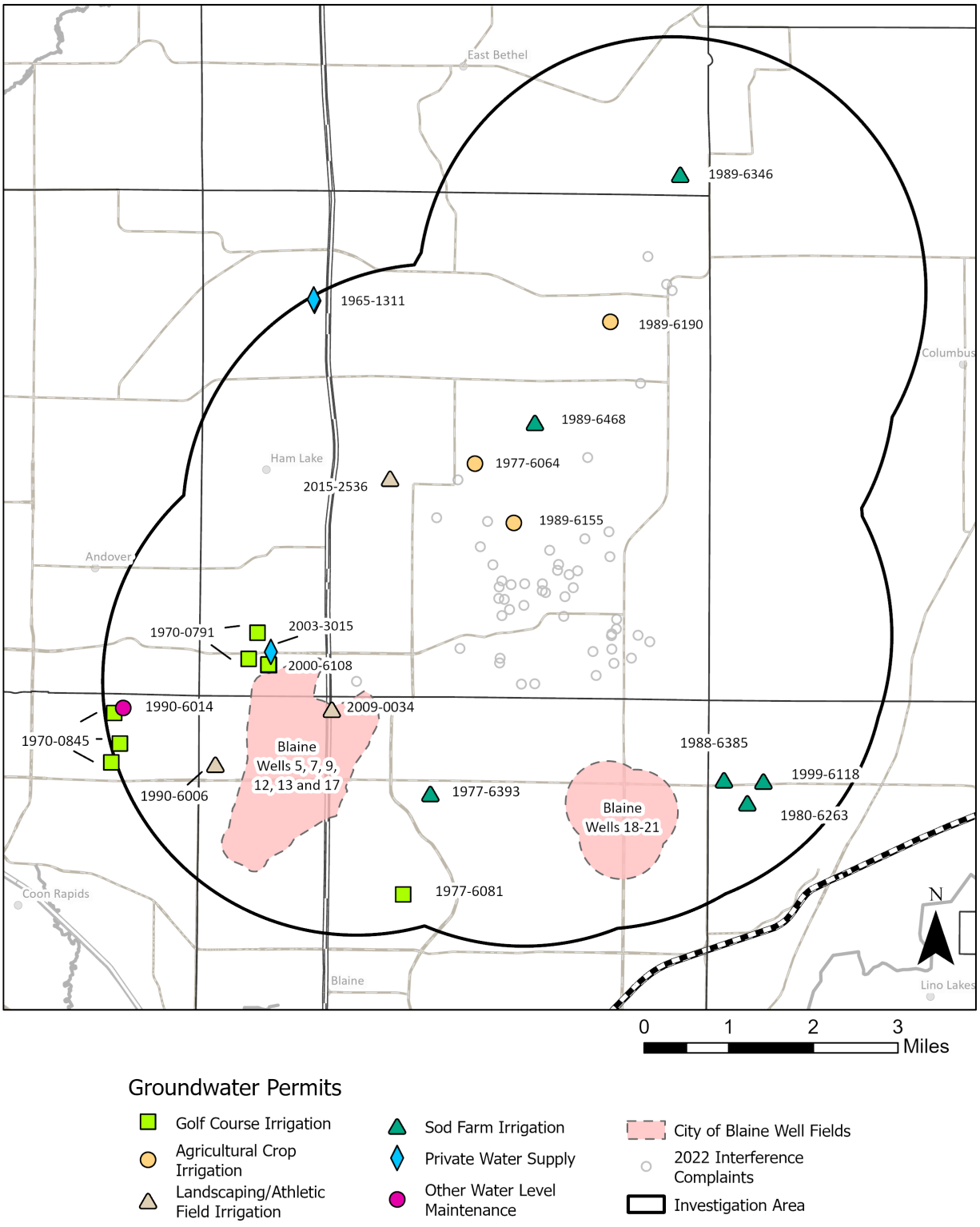


Table B-1. Nearby Permit Information and 2022 Monthly Reported Water Use

Permit Number, Permit Holder Name	Use Type	Combined Permitted Volume (MGY)*	Permit Authorization Date	Unique Number (Well Name)	Well Depth (Feet)	Pumped Aquifer (MGS Aquifer Codes)	Interpreted Flow System	2022 Pumping Rate (gpm)*	January Water Use (MG)*	February Water Use	March Water Use	April Water Use	May Water Use	June Water Use	July Water Use	August Water Use	September Water Use	October Water Use	November Water Use	December Water Use	Total 2022 Water Use (MG)*
1965-1311 Flamingo Terrace	Private Water Supply	17.7	9/25/1968	228787 (Well 2)	390	CTCW	Deep Confined-Shallow Bedrock	370	0.63	0.55	0.59	0.47	0.49	0.50	0.52	0.41	0.36	0.40	0.37	0.43	5.69
1965-1311 Flamingo Terrace	Private Water Supply	17.7	9/25/1968	231873 (Well 1)	395	CWOC	Deep Confined-Shallow Bedrock	370	0.625	0.55	0.59	0.47	0.49	0.5	0.52	0.4075	0.355	0.3955	0.369	0.43	5.69
1970-0791 CF Majestic Oaks Arcis LLC, C/O Arcis Equity Partners, LLC	Golf Course Irrigation	100	4/17/1991	Pond	N/A	Dug Pit/Holding Pond	Dug Pit/Holding Pond	1000	0	0	0	0	0	0	0	0	0	0	0	0	0
1970-0791 CF Majestic Oaks Arcis LLC, C/O Arcis Equity Partners, LLC	Golf Course Irrigation	100	4/17/1991	208594 (Well 1)	594	CTCGCMTS	Deep Confined-Shallow Bedrock	1200	0	0	0	1.46	1.61	10.57	14.20	7.44	10.33	3.51	0	0	49.11
1970-0791 CF Majestic Oaks Arcis LLC, C/O Arcis Equity Partners, LLC	Golf Course Irrigation	100	4/17/1991	510541 (Well 2)	546	CTCGCMTS	Deep Confined-Shallow Bedrock	Inactive	0	0	0	0	0	0	0	0	0	0	0	0	0
1970-0845 Bunker Hill Golf Club	Golf Course Irrigation	195	7/11/1990	231864	191	QBAA	Deep Confined-Shallow Bedrock	400	0	0	0	0.23	0	0	0	0	0	0	0	0	0.23
1970-0845 Bunker Hill Golf Club	Golf Course Irrigation	195	7/11/1990	231866 (Well 2)	236	QBAA	Deep Confined-Shallow Bedrock	1200	0	0	0	0.13	6.63	11.08	8.65	8.25	5.76	3.44	0	0	43.93
1970-0845 Bunker Hill Golf Club	Golf Course Irrigation	195	7/11/1990	500696 (Well 3)	199	QBAA	Deep Confined-Shallow Bedrock	800	0	0	0	0.13	6.63	11.08	8.65	8.25	5.76	3.44	0	0	30.45
1976-6227 City of Blaine	Municipal/Public Water Supply	3337	10/21/2020	127270 (Well 13)	685	CTCGCMTS	Deep Confined-Shallow Bedrock	1000	0	0.063	9.127	8.997	6.579	0	24.192	34.6	32.692	27.97	3.897	7.619	155.74
1976-6227 City of Blaine	Municipal/Public Water Supply	3337	10/21/2020	208615 (Well 5)	686	CTCGCMTS	Deep Confined-Shallow Bedrock	480	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0.03
1976-6227 City of Blaine	Municipal/Public Water Supply	3337	10/21/2020	208616 (Well 7)	487	CTCE	Deep Confined-Shallow Bedrock	1000	0	0	0	0	0	0	0	0	0	0	0	0	0
1976-6227 City of Blaine	Municipal/Public Water Supply	3337	10/21/2020	208618 (Well 9)	480	CTCE	Deep Bedrock	600	0	0	0	0	1.99	13.03	11.91	14.38	12.40	0.47	0	0.25	54.43
1976-6227 City of Blaine	Municipal/Public Water Supply	3337	10/21/2020	127264 (Well 12)	228	QBAA	Deep Confined-Shallow Bedrock	2000	36.96	31.83	10.38	7.38	58.01	71.03	70.56	43.83	49.03	20.52	40.06	52.44	492.04
1976-6227 City of Blaine	Municipal/Public Water Supply	3337	10/21/2020	721815 (Well 17)	244	QBAA	Deep Confined-Shallow Bedrock	2000	0	0	0	0	19.55	48.81	6.57	60.61	73.56	21.55	0	0	230.65

Permit Number, Permit Holder Name	Use Type	Combined Permitted Volume (MGY)*	Permit Authorization Date	Unique Number (Well Name)	Well Depth (Feet)	Pumped Aquifer (MGS Aquifer Codes)	Interpreted Flow System	2022 Pumping Rate (gpm)*	January Water Use (MG)*	February Water Use	March Water Use	April Water Use	May Water Use	June Water Use	July Water Use	August Water Use	September Water Use	October Water Use	November Water Use	December Water Use	Total 2022 Water Use (MG)*
1976-6227 City of Blaine	Municipal/Public Water Supply	3337	10/21/2020	809699 (Well 18)	340	QBAA	Deep Confined-Shallow Bedrock	1700	0	0	4.05	3.59	20.78	62.32	62.21	47.09	47.59	40.46	40.46	43.12	371.69
1976-6227 City of Blaine (unpermitted)	Municipal/Public Water Supply	Under review	10/21/2020	819518 (Well 19)	415	CTCW	Deep Confined-Shallow Bedrock	1200	44.29	27.16	41.17	40.19	27.32	17.02	34.72	23.16	0	0	0	0	255.03
1976-6227 City of Blaine (unpermitted)	Municipal/Public Water Supply	Under review	10/21/2020	819519 (Well 20)	395	QBAA	Deep Confined-Shallow Bedrock	1600	0	0	0.06	0	4.3	17.22	27.64	15.85	0	0	0	0	65.07
1976-6227 City of Blaine (unpermitted)	Municipal/Public Water Supply	Under review	10/21/2020	819520 (Well 21)	414	CTCW	Deep Confined-Shallow Bedrock	800	0	7.50	4.02	13.08	6.62	21.10	5.92	1.51	1.21	0	0	0	60.96
1977-6064 Virgil and John Hogdal	Agricultural Crop Irrigation	80	4/21/1989	107242	555	CTCGCMTS	Deep Confined-Shallow Bedrock	800	0	0	0	0	0.02	0	0.47	2.91	1.39	0	0	0	4.78
1977-6081 TPC Twin Cities	Golf Course Irrigation	52.1	11/7/2001	114392 (Well 1)	400	CTCG	Deep Confined-Shallow Bedrock	500	0	0	0	0	5.40	16.16	25.27	7.04	15.34	7.40	0	0	76.61
1977-6393 Lake Irrigation, LLC	Sod Farm Irrigation	16.3	4/16/1985	133213 (Well 1)	600	CTCGCMTS	Deep Confined-Shallow Bedrock	600	0	0	0	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0	0	4.53
1980-6263 Robinson Landscaping, Inc.	Sod Farm Irrigation	38	9/3/1980	231862 (Well 1)	720	CJDNCMTS	Deep Confined-Shallow Bedrock	800	0	0	0	0	0	0.76	3.24	0	0	0	0	0	4.0
1988-6385 Daniel and Scott Robinson	Sod Farm Irrigation	63.5	12/12/1988	448834 (Well 1)	340	CSLT	Deep Confined-Shallow Bedrock	300	0	0	0	0	2.52	5.41	12.92	0	0	0	0	0	20.85
1989-6155 Warren Hoffman	Agricultural Crop Irrigation	65.2	12/28/1988	449127 (Well 1)	380	CTCW	Deep Confined-Shallow Bedrock	400	0	0	0	0	0	0	0	0	0	0	0	0	0
1989-6190 Eldon Hentges	Agricultural Crop Irrigation	130	1/9/1989	444820 (Well 1)	266	CTCG	Deep Confined-Shallow Bedrock	300	0	0	0	0	0	0	9.9	6	0	0	0	0	15.9
1989-6346 Carlos Avery Turf Nursery	Sod Farm Irrigation	62.7	6/5/1989	255359 (Well 1)	30	QWTA	Water Table – Shallow Semi-Confined	200	0	0	0	0	0	0	0	0	0	0	0	0	0
1989-6468 Glynn Haag	Sod Farm Irrigation	20	4/21/2014	450537 (Well 1)	350	CTCG	Deep Confined-Shallow Bedrock	400	0	0	0	0	0	0.01	0	0	0	0	0	0	0.01
1990-6006 Anoka-Hennepin ISD 11	Landscaping/Athletic Field Irrigation	16	4/29/1991	208611 (Well 1)	480	CTCE	Deep Confined-Shallow Bedrock	275	0	0	0	0	0.97	2.43	3.06	1.99	2.09	1.72	0	0	12.26
1990-6014 Anoka County Parks and Recreation	Other Water Level Maintenance	6.8	6/8/2015	431681 (Well 1)	385	CTCW	Deep Confined-Shallow Bedrock	100	0.01	0.01	0.01	0.01	1.41	1.75	1.6	1.5	0.45	0	0	0	6.73
1999-6118 Robinson Landscaping, Inc.; Margie Robinson	Sod Farm Irrigation	13	2/11/2005	624188 (Well 1)	315	CSLT^	Deep Confined-Shallow Bedrock	300	0	0	0	0	0	0	3.66	0	0	0	0	0	3.66

Permit Number, Permit Holder Name	Use Type	Combined Permitted Volume (MGY)*	Permit Authorization Date	Unique Number (Well Name)	Well Depth (Feet)	Pumped Aquifer (MGS Aquifer Codes)	Interpreted Flow System	2022 Pumping Rate (gpm)*	January Water Use (MG)*	February Water Use	March Water Use	April Water Use	May Water Use	June Water Use	July Water Use	August Water Use	September Water Use	October Water Use	November Water Use	December Water Use	Total 2022 Water Use (MG)*
2000-6108 CF Majestic Oaks Arcis LLC, c/o Arcis Equity Partners, LLC	Golf Course Irrigation	52.5	10/10/2013	Pond	N/A	Dug Pit/Holding Pond	Dug Pit/Holding Pond	800	0	0	0	0	0	0	0	0	0	0	0	0	0
2000-6108 CF Majestic Oaks Arcis LLC, c/o Arcis Equity Partners, LLC	Golf Course Irrigation	52.5	10/10/2013	510541 (Well 2)	546	CTCGCMTS	Deep Confined-Shallow Bedrock	Inactive	0	0	0	0	0	0	0	0	0	0	0	0	0
2000-6108 CF Majestic Oaks Arcis LLC, c/o Arcis Equity Partners, LLC	Golf Course Irrigation	52.5	10/10/2013	615970 (Well 3)	268	QBAA	Deep Confined-Shallow Bedrock	300	0	0	0	0.57	1.57	3.97	5.52	6.52	4.58	0	0	0	22.73
2000-6108 CF Majestic Oaks Arcis LLC, c/o Arcis Equity Partners, LLC	Golf Course Irrigation	52.5	10/10/2013	790641 (Well 4)	278	QBAA	Deep Confined-Shallow Bedrock	300	0	0	0	0	0	0	0	0	0	0	0	0	0.00
2001-6126 TPC Twin Cities	Golf Course Irrigation	52.1	11/7/2001	Pond	N/A	Dug Pit/Holding Pond	Dug Pit/Holding Pond	800	0	0	0	1.33	2.45	6.83	4.69	0.18	0.20	0	0	0	15.67
2003-3015 Majestic Greens, LLC; Kristine Wiemiller	Private Water Supply	3	n/a	554238 (Well 1)	188	QWTA	Water Table – Shallow Semi-Confined	250	0.08	0.18	0.16	0.11	0.15	0.13	0.11	0.11	0	0	0	0	1.02
2009-0034 Wildwood Village and Wildwood Village II	Landscaping/Athletic Field Irrigation	3.7	10/4/2010	753655 (Well 1)	147	QBAA	Deep Confined-Shallow Bedrock	60	0	0	0	0	0.47	0.47	0.47	0.3	0.3	0	0	0	2.02
2015-2536 City of Ham Lake	Landscaping/Athletic Field Irrigation	7.4	12/4/2015	563009 (Fire/Irrigation 1)	334	CTCW	Deep Confined-Shallow Bedrock	200	0	0	0	0	0	0.05	0.04	0.02	0	0	0	0	0.11

*MGY=million gallons per year; gpm=gallons per minute; MG=million gallons; All monthly water use is reported in million gallons (MG) rounded to the nearest 0.01 million gallons

^Aquifer changed from CJDNCSTL to CSLT based on well stratigraphic report and bedrock elevations from Setterholm (2013).

Appendix C. Monitored Wells

Table C-1. Wells Monitored Within Three Miles of the Complainants

Well Name (MGS aquifer*, unique number)	Interpreted Flow System	UTM Easting and Northing (meters)*	Well Depth (ft BGS)*	Aquifer Depth (ft BGS)	Aquifer Elevation (ft NAVD88)	Aquifer Thickness (ft)	Period of Record	Frequency of Measurements
DNR Observation Well 02009 Lino Lakes (QBAA, 208135)	Deep Confined-Shallow Bedrock	490349 E 5003179 N	125	90	808	35	2/4/1971-11/22/2022	Manual: 1x/3 months Logger: 1x/hour
DNR Observation Well 02027 Colombus (CTCG, 243000)	Deep Confined-Shallow Bedrock	491508 E 5018697 N	333	219	576	114	12/27/1990-1/22/2022	Manual: 1x/3 months Logger: 1x/hour
DNR Observation Well 02026 Lino Lakes (QBAA, 243178)	Deep Confined-Shallow Bedrock	490130 E 5012065 N	150	137	766.8	13	7/18/1991-11/22/2022	Manual: 1x/3 months Logger: 1x/hour
Domestic Well (QBAA, 470557)	Shallow Confined	486060 E 5007994 N	60	50	858	10	11/26/1990; 8/19/2022-9/7/2022	Manual: occasional
Ham Lake County Park Irrigation Well (CTCW; 563009)	Deep Confined-Shallow Bedrock	482756 E 5010618 N	334	175	730	135	8/19/2022-1/18/2023	Manual: 1x/3 months Logger: 1x/hour
Domestic Well (CTCG, 705584)	Deep Confined-Shallow Bedrock	186162 E 5008787 N	200	184	715	16	7/5/2004; 8/25/2022-9/7/2022	Manual: occasional
Domestic Well (QBAA, 737231)	Deep Confined-Shallow Bedrock	485942 E 5008883 N	184	170	731	14	3/2/2006; 8/3/2022-9/7/2022	Manual: occasional
City of Blaine OW-1 (CWEC, 805151)	Deep Bedrock	482110 E 5005268 N	430	370	529	60	1/21/2016-7/19/2018; 8/19/2022-1/18/2023	Manual: 1x/month Logger: 1x/hour
City of Blaine OW-2 (QBAA; 805152)	Deep Confined-Shallow Bedrock	482110 E 5005264 N	210	120	779	90	1/21/2016-7/19/2018; 8/19/2022-1/18/2023	Manual: 1x/month Logger: 1x/hour
City of Blaine OW-6 (QBAA, 805156)	Deep Confined-Shallow Bedrock	486667 E 5004793 N	200	120	786	75	1/21/2016-7/19/2018; 8/19/2022-1/18/2023	Manual: 1x/month Logger: 1x/hour

*Aquifers shown using MGS aquifer codes; UTM locations are in NAD83, Zone 15N; elevations are relative to NAVD88; BGS=below ground surface.

Appendix D. Not Valid Complaints

Three of the 50 complaints were found to be not valid because the water supply issues were not caused by high-capacity pumping. The complaints are highlighted in gray in Table 1 and shown with an "X" symbol on Figure 8.

Each complaint is listed by complainant unique well number below along with complaint details and an explanation of why it was found not valid. Complaint details can also be found in the Supplemental Information accompanying this report.

Unique Well Number 134330

The complainant reported low water supply in April 2022 and had a plumber visit the residence. The plumber advised the complainant to replace the pressure tank, and the pressure tank was replaced on April 8, 2022. The complainant reported to DNR on February 1, 2023, that they did not experience any water supply problems after the replacement of the pressure tank in April 2022, and that replacing the pressure tank solved all low water supply problems. Because the complainant well did not have issues during the lowest water periods during the summer of 2022 and replacing the pressure tank restored water supply, it was determined that a faulty pressure tank caused the water supply issues.

Unique Well Number 673579

The complainant reported an out-of-water situation on February 17, 2022. A well driller visited on February 18, 2022, and determined that the pump needed to be replaced. The well driller replaced the pump but did not lower the pump (the original and new pump depth were both 42 feet below land surface). On November 8, 2022, the well driller reported to DNR that the pump was replaced because it was bad, not because it had burned out from a water level issue. On February 1, 2023, the complainant's daughter reported to DNR that they had not experienced any water supply issues since the pump was replaced in February 2022, and that replacing the pump fixed the problem. Since the complainant well did not have issues during the lowest water periods during the summer of 2022 and replacing the pump at the same depth restored water supply, it was determined that a faulty pump caused the water supply issues.

Unique Well Number 423316

The complainant has experienced black sediment and rotten-egg smell to their water since they purchased the property in October 2021. As of March 6, 2023, they are still experiencing the same water quality issues. A timeline of the complaint is outlined below:

- **October 2021:** Complainant purchased the property and began experiencing poor water quality right away. Complainant reported to DNR that the well did not pass inspection when they purchased the property. The property sellers did something to get the well into compliance before the sale was final, but the complainant is not sure what they did.
- **February 9, 2022:** Complainant reported that the pump stopped working, so they hired a well driller to replace the pump. The well driller did not lower the new pump (the original and new pump depth were

both 40 feet below land surface). The complainant reported continuing issues with water quality after the pump was replaced.

- **August 18, 2022:** Complaint replaced their water softener to try to resolve ongoing water quality issues.
- **August 29, 2022:** Complainant reported persisting water quality issues to DNR and that the issues seemed to be worse than before.
- **November 8, 2022:** The well driller who replaced the pump in February 2022 reported to DNR that they could not remember why the pump was replaced. They said that since the pump was only replaced and not lowered, they guessed that the issue was a water quality or bad pump issue rather than a water level issue.
- **March 6, 2023:** Complainant was still reporting issues with black sediment and bad smelling water. They said they have to replace their water filter every three weeks. They report low water pressure when filter starts to get full, but water pressure is restored when they change the filter.

This complaint was determined to be not valid for the following reasons:

- **It is unknown when water quality issues began.** Because the complainant well didn't pass inspection, the water quality issues were present before the sale was finalized in October 2021. However, it is unknown if or how long the issues were present prior to October 2021.
- **Water quality issues not associated with water levels.** Water quality fluctuations at this location do not correlate with fluctuation in water levels. Although complainant reported worst water quality on August 29, 2022, when water levels were near all-time lows, they have not reported large changes in water quality from October 2021 through March 2023. Figure 6 shows that there was wide variation in water levels over this time.
- **Issues resolved in similar well nearby.** Complainant well 673579 (detailed above) is located across the street from this well (423316). Both wells are screened in a shallow confined aquifer; well 673579 is 88 feet deep and well 423316 is 66 feet deep. Submersible pumps were replaced in both wells but not lowered in February of 2022. The pump replacement resolved issues in well 673579 but not well 423316.

The following is recommended for well 423316:

- Consult with a licensed well driller to determine if the water quality issue is caused by a physical well issue (i.e. hole in the casing) or if the well needs to be cleaned due to a chemical or bacterial issue.
- Refer to the Minnesota Department of Health factsheet called, *Why Does My Water Smell Like Rotten Eggs?*, for information on what could be making the water smell.
- Contact the Minnesota Department of Health (Patrick Sarafolean, 651-201-3962) with any questions about water quality.

Appendix E. Analytical Methods

Analytical Modeling

Predictive modeling with groundwater analysis software AQTESOLV (Duffield, 2007) was conducted to determine which permitted users included in the investigation contributed to drawdown at each of the 47 valid complainant domestic wells. Predictive model inputs and methods are described below.

Aquifer System

All high-capacity and complainant wells were assumed to be completed in the Deep Confined – Shallow Bedrock aquifer system. This aquifer system includes all wells that are open to the upper 50 feet of erosional bedrock surface or screened in a Quaternary confined aquifer greater than 100 feet below land surface. As discussed in the Setting section of this report, there are multiple unconsolidated and bedrock aquifers that are part of the Deep Confined – Shallow Bedrock aquifer system. Since AQTESOLV (Duffield, 2007) is unable to simulate pumping from multiple adjacent aquifers, as is likely happening in this area, the Deep Confined – Shallow Bedrock aquifer system was simulated as a single aquifer.

All but two high-capacity wells included in the investigation and 46 of 47 complainant wells determined to be valid met this classification. Complainant well 470557 is completed at a depth of 60 feet below land surface (Shallow Semi-Confined system), but this well was included in the Deep Confined – Shallow Bedrock system because water level data from this well showed that it tracks with the deeper system water levels, indicating hydrologic connection (described in Setting section and shown in Figure 6).

Analytical Solution and Aquifer Parameters

The Theis (1935) solution for non-leaky confined aquifers was used to simulate the pumped aquifer as it represents a conservative approximation of conditions and requires fewer aquifer parameters (i.e. leakage) than other solutions. With variations in geology and the large number of unknowns throughout the investigation area it was determined that a solution requiring fewer parameters would be best.

Aquifer parameters used in the Theis (1935) solution were determined by averaging values from nearby aquifer tests and literature (Table E-1). The parameters shown in Table E-1 fall within literature values expected in this setting.

Drawdown Predictions

The forward modeling function in AQTESOLV (Duffield, 2007) was used with the Theis (1935) solution and the above parameters to simulate drawdown caused by pumping each high-capacity well in July and August 2022. Every high-capacity well included in the investigation was simulated individually using the following method:

- High-capacity wells were pumped continuously at their 2022 reported rate until their monthly reported volume (Table B-1) was used. This resulted in one pumping cycle in July and one cycle in August 2022. Although appropriators within the investigation area do not pump in the way described above, this approach was used because individual pump operation schedules were unknown for most appropriators.

- Distance-drawdown plots were created in AQTESOLV (Duffield, 2007) using maximum predicted drawdown for either July or August 2022, which ever month had the highest drawdown. The distance-drawdown plots were used to visually determine the radius of influence for each high-capacity well.
- For this investigation, radius of influence is defined as the distance at which the high-capacity well causes at least one foot of drawdown (see Figure E-1 for illustration). The radius of influence for each well is shown in Table E-2. If wells used water in July and August 2022, the month with the higher radius of influence was used.
- The area of influence (circle created from the radius of influence) was plotted on a map around each high-capacity well (Figure 8). The radius of influence creates circle areas of influences around each high-capacity well because the simulated aquifer is assumed to be homogenous, isotropic, and without barrier or recharge boundaries. A high-capacity well was determined to be a contributor to the well interference for complainant wells that were located within the one-foot drawdown radius of influence for the high-capacity well. As Table E-2 shows, some valid complainant wells fell within a high-capacity well radius of influence, but were installed after the high-capacity permit authorization date, which resulted in the high-capacity well not being a contributor to well interference for that well.

Tables and Figures.

Table E-1. Aquifer Parameters

Parameter (variable name)	Value	Source and Notes
Transmissivity (T)	11,660 feet^2/day	Arithmetic mean of nearby literature values and values from nearby aquifer tests for the deep confined-shallow bedrock aquifer system. *
Storativity (S)	.0015 (unitless)	Arithmetic mean of nearby literature values and values from nearby aquifer tests for the deep confined-shallow bedrock aquifer system. * This storativity falls within the upper range expected for confined aquifer (Todd, 1980).
Aquifer Thickness (b)	100 feet	Thickness of 100 feet for the deep confined-shallow bedrock system was determined by using a thickness of 50 feet each for the deep confined and shallow bedrock systems as follows: 1. Deep Confined: arithmetic mean thickness of the deepest confined aquifer greater than 100 feet below land surface for each high-capacity well in the investigation area is approximately 50 feet. 2. Shallow Bedrock: Runkel et al. (2006) states that upper 50 feet of bedrock erosional surface is more conductive.
Hydraulic Conductivity (K)	117 feet/day	Calculated from transmissivity and aquifer thickness. Falls within the range of values for coarse sand and fractured to cavernous carbonate rocks according to Heath (1983).
Anisotropy Ratio (K_z/K_r)	1	Aquifer was assumed to be isotropic.

*Sources used in arithmetic mean calculation: Blum (1995); Blum (2011); Djerrari (2007), Greer et al. (2014); Greer (2016); Greer et al. (2016); MDH (1999); MDH (1998); Roberston (2002); Runkel et al. (2003); Runkel et al. (2006); Short Elliott Hendrickson, Inc. (2005); Winter and Pfannkuch (1976).

Table E-2. Radius of Influence for Each Appropriator Included in Investigation

Permit Number	Permittee Name	High-Capacity Well Unique Number	High-Capacity Well Radius of Influence	Number of Valid Complaints within Radius of Influence of High-Capacity Well	Number of Valid Complaints Eliminated due to Permit Authorization Pre-Dating Complainant Well Construction (Unique ID of Complainant Wells)	Total Number Valid Complaints Attributed to High-Capacity Well (Unique ID of Complainant Well)
1976-6227	City of Blaine	224698	9 miles	47	0	47
1976-6227	City of Blaine	819518 (unpermitted)	8 miles	47	0	47
1976-6227	City of Blaine	809699	7 miles	47	0	47
1976-6227	City of Blaine	721815	5 miles	45	0	45
1976-6227	City of Blaine	127270	4 miles	33	0	33
1976-6227	City of Blaine	819519 (unpermitted)	4 miles	39	0	39
1977-6081	TPC Twin Cities	114392	3 miles	6	5 (739635, 739667, 794990, 820511, 685266)	1 (1000029961)
1976-6227	City of Blaine	819520 (unpermitted)	3 miles	15	0	15
1970-0791	CF Majestic Oaks Arcis LLC, c/o Arcis Equity Partners, LLC	208594	2 miles	1	1 (685266)	0
1970-0845	Bunker Hills Golf Club	231866	2 miles	0	0	0
1970-0845	Bunker Hills Golf Club	500696	2 miles	0	0	0
1988-6385	Robinson, Daniel and Scott	448834	2 miles	0	0	0
1989-6190	Hentges, Eldon	444820	1 mile	2	2 (625108, 836099)	0
2000-6108	CF Majestic Oaks Arcis LLC, c/o Arcis Equity Partners, LLC	615970	1 mile	1	0	1 (685266)
1980-6263	Robinson Landscaping, Inc	231862	1 mile	0	0	0
1977-6064	Hogdal, Virgil and John	107242	1 mile	3	3 (803364, 670212, 795122)	0
1999-6118	Robinson Landscaping, Inc; Robinson, Margie	624188	1 mile	0	0	0
1990-6006	Anoka-Hennepin ISD 11	208611	1 mile	0	0	0
1990-6014	Anoka County Parks And Recreation	431681	1700 feet	0	0	0

Figure E-1. Radius of Influence Diagram (modified from Bresciania et al., 2020)